County of Los Angeles

Draft
Environmental Impact Report
SCH No. 2005051143
Volume XI
Appendix 4.8 (continued)

MISSION VILLAGE

Prepared for:

Los Angeles County
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NEWHALL RANCH
Newhall Ranch Company

OCTOBER 2010

County of Los Angeles

Draft Environmental Impact Report

SCH No. 2005051143

Volume XI
Appendix 4.8 (continued)

MISSION VILLAGE

Project No.	04-181
Vesting Tentative Tract Map No.	61105
SEA Conditional Use Permit No.	RCUP200500080
Oak Tree Permit No.	ROAK200500032
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Conditional Use Permit (Off-Site Improvements)	RCUP200500081

Substantial Conformance Determinations for Grading and Hillside Management Guidelines

NEWHALL RANCH
Newhall Ranch Company

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OCTOBER 2010

DRAFT
ENVIRONMENTAL IMPACT REPORT
for
MISSION VILLAGE

SCH No. 2005051143

County Project No. 04-181
Vesting Tentative Tract Map No. 61105
SEA Conditional Use Permit No. RCUP200500080
Oak Tree Permit No. ROAK200500032

Oak Tree Permit No. T200500043
Conditional Use Permit RCUP200500081
(Off-Site Improvements)

Volume XI
Appendix 4.8 (continued)

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October 2010

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R.T. Frankian & Associates, Evaluation of Building Setbacks, Airport Mesa (Area E1), Vesting Tentative Tract 61105, Newhall Ranch, Los Angeles County, California. October 14, 2009

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Impact and Response to Perchlorate Contamination, Valencia Water Company Well Q2, Dated April 2005
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DWR Brief in the 41K litigation

California Water Impact Network, et al. v. Castaic Lake Water Agency, Appellate Court 2d Civil No. B177978 (Second District Court of Appeal's unpublished decision)

CalSim II: Simulation of Historical SWP-CVP Operations, Technical Memorandum, DWR Bay-Delta Office, November 2003

CalSimII Benchmark Studies

Musings On A Model: CalSim II In California's Water Community, San Francisco Estuary and Watershed Science, Vol. 3, Issue 1 (March 2005), Article 1, by Inês C. Ferreira, *et al*

DWR letter to Mindy McIntyre, Planning and Conservation League, April 20, 2006

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California Water Impact Network, Inc. v. Castaic Lake Water Agency, Second Appellate District, Division Five, Appellate Case No. B205622

Castaic Lake Water Agency Litigation Settlement Agreement

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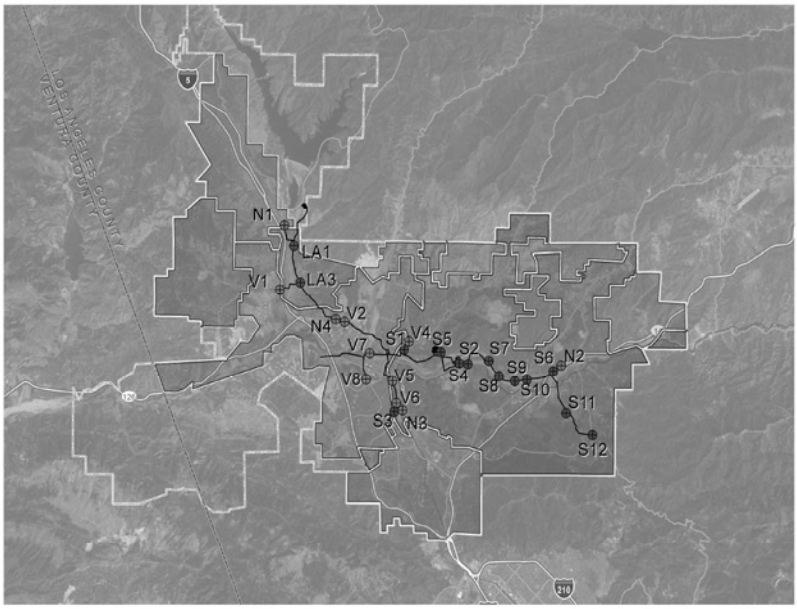

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CLWA Santa Clarita Water Division
Los Angeles County Waterworks District 36
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May, 2007

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Executive Summary

This annual report, which is the ninth in a series that began in 1998, provides current information about the water requirements and water supplies of the Santa Clarita Valley. The report was prepared for the imported water wholesaler, Castaic Lake Water Agency (CLWA), and for the four local retail water Purveyors that serve the Valley: CLWA Santa Clarita Water Division, Los Angeles County Waterworks District 36, Newhall County Water District, and Valencia Water Company. These entities and representatives from the City of Santa Clarita and the County of Los Angeles meet as required to coordinate the management of imported water from the State Water Project (SWP) with local groundwater, now augmented by recycled water, to meet water requirements in the Valley.

This report provides information about local groundwater resources, SWP water supplies, water conservation, and recycled water. The report reviews the sufficiency and reliability of supplies in the context of existing water demand, with focus on actual conditions in 2006, and it provides a short-term outlook of water supply and demand for 2007.

ES.1 2006 Water Requirements and Supplies

In 2006, total water requirements in the Santa Clarita Valley were about 91,400 acre-feet (af), of which about 74,100 af (81 percent) were for municipal use and the remainder (17,300 af) was for agricultural and other (miscellaneous) uses, including individual domestic uses. Total demand in 2006 was about nine percent higher than in 2005, essentially identical to what was estimated in the 2005 Water Report. Water requirements in 2006 were also exactly consistent with projections in the 2005 Urban Water Management Plan (UWMP). The difference from 2005 water requirements is largely attributable to the significantly wet conditions that prevailed in 2005, which resulted in below-average water demand in that year. In other words, water requirements in 2006 reflected a return to near-average demand, consistent with projected demand in the 2005 UWMP, and not an anomalous “increase” that might be interpreted when compared to the immediately preceding year.

Total water requirements in 2006 were met by a combination of about 50,400 af from local groundwater resources (about 33,100 af for municipal and about 17,300 af for agricultural and other uses), about 40,600 af of SWP water, and about 400 af of recycled water.

Of the 50,400 af of total groundwater pumping in the Valley in 2006, about 43,000 af were pumped from the Alluvium and about 7,300 af were pumped from the underlying, deeper Saugus Formation. Alluvial pumping represented about a 5,000 af increase from 2005, and Saugus pumping was slightly higher than in 2005, by about 750 af. Neither pumping volume resulted in any notable overall change in groundwater conditions (water levels, water quality, etc.) in either aquifer system. SWP deliveries to the Purveyors increased by about 2,600 af from the previous year. Water uses and supplies in 2006 are summarized in the following Table ES-1.

Table ES-1
Santa Clarita Valley
Summary of 2006 Water Supplies and Uses
(acre-feet)

Municipal		
State Water Project		40,646
Groundwater (Total)		33,061
Alluvium	*27,189*	
Saugus	*5,872*	
Recycled Water		419
Subtotal		**74,126**
Agriculture/Miscellaneous		
State Water Project		-
Groundwater (Total)		17,312
Alluvium	*15,872*	
Saugus	*1,440*	
Subtotal		**17,312**
Total		***91,438***

In accordance with the California Urban Water Management Planning Act, the Valley-wide UWMP was updated in 2005 to extend projected water demands through 2030, and to describe the combination of local groundwater, imported water supplies from the State Water Project, local recycled water supplies, and other water supplies planned to meet those existing and projected water demands in the Valley. The 2005 UWMP describes the reliability of local groundwater resources and the adequacy of groundwater supplies to meet groundwater demand, including consideration of the impacts of perchlorate contamination on several municipal water

supply wells. The 2005 UWMP also describes the plans and ongoing work for integrated control of perchlorate migration and full restoration of perchlorate-impacted groundwater supply.[1]

Notable details about each component of water supply in the Valley, and about the water supply outlook for 2007, include the following.

ES.2 Alluvial Aquifer

The groundwater operating plan in the 2005 UWMP includes Alluvial pumping in the range of 30,000 to 40,000 acre-feet per year (afy) in average/normal years, and slightly reduced pumping (30,000 to 35,000 afy) in dry years. Pumping from the Alluvium was 43,000 af in 2006, slightly above the overall 2005 UWMP range due to high groundwater levels that allowed higher pumping in the eastern part of the basin.

On a long-term basis, continuing through 2006, there is no evidence of any historic or recent trend toward permanent water level or storage decline. In general, throughout a large part of the basin, Alluvial groundwater levels have generally remained near historic highs during the last 30 years. Higher than average precipitation in late 2004 and 2005 resulted in significant water level recovery in the eastern part of the basin, continuing the overall trend of fluctuating groundwater levels within a generally constant range over the last 30 years. These ongoing data indicate that the Alluvium remains in good operating condition and can continue to support pumping in the operating range included in the 2005 UWMP, or slightly higher, without adverse results (e.g., long-term water level decline or degradation of groundwater quality.)

Based on an integration of water quality records from multiple wells completed in the Alluvium, there have been historical fluctuations in groundwater quality, typically associated with variations in precipitation and streamflow. However, like groundwater levels, there has been no long-term trend toward groundwater quality degradation; groundwater produced from the Alluvial aquifer remains a viable municipal and agricultural water supply.

In 2002, as part of ongoing monitoring of wells for perchlorate contamination, perchlorate was detected in one Alluvial well (the SCWD Stadium Well) located near the former Whittaker-Bermite facility. The detected concentration was slightly below the Notification Level for

[1] The 2005 UWMP was challenged in a lawsuit filed in early 2006 by the California Water Impact Network and the friends of the Santa Clara River, ultimately seeking a mandate that the approval of the UWMP by CLWA and the Purveyors be invalidated. The 2005 UWMP remains valid unless affected by a future judgment or order of the court. CLWA and the Purveyors believe the lawsuit is without merit, and have been vigorously defending the plan in court.

perchlorate (6 ug/l), and the well has been inactivated for municipal water supply since the detection of perchlorate. In early 2005, perchlorate was detected in a second Alluvial well, VWC's Well Q2. Valencia's response plan for Well Q2 was to pursue permitting and installation of wellhead treatment, followed by return of the well to water supply service in October 2005. All other Alluvial wells operated by the Purveyors continue to be used for municipal water supply service; those wells near the Whittaker-Bermite property are sampled in accordance with drinking water regulations and perchlorate has not been detected. As detailed in the 2005 UWMP, the ongoing inactivation of one Alluvial well due to perchlorate contamination does not limit the Purveyors' ability to produce groundwater from the Alluvium in accordance with the groundwater operating plan in the 2005 UWMP.

The ongoing characterization and plan for control and cleanup of perchlorate in the Valley has focused on the Saugus Formation. In addition, however, on-site cleanup and control activities in 2006 included continuation of soil cleanup on one part of the Whittaker-Bermite site, and continuation of pumping and treatment in the Northern Alluvium on the Whittaker-Bermite site. Expanded pumping, with treatment, intended to effect perchlorate containment in the Northern Alluvium, is expected to be operational in 2007.

ES.3 Saugus Formation

The groundwater operating plan in the 2005 UWMP includes pumping from the Saugus in the range of 7,500 to 15,000 afy in average/normal years; it also includes planned dry-year pumping from the Saugus of 21,000 to 35,000 afy for one to three consecutive dry years. The 2005 UWMP recognizes the results of basin yield analyses in 2004 and 2005 which found that such short-term pumping can be recharged during subsequent wet/normal years to allow groundwater levels and storage to recover, as it has in historical periods.

Pumping from the Saugus Formation was about 7,300 af in 2006; on average, Saugus pumping has been about 6,700 afy since 1980. Both rates are near the lower end of the range included in the UWMP. As a result of long-term relatively low pumping from the Saugus Formation, groundwater levels in that aquifer have remained generally constant to slightly increasing over the last 35 to 40 years; those trends continued in 2006.

In 1997, ammonium perchlorate was discovered in four wells completed in the Saugus Formation in the vicinity of the former Whittaker-Bermite facility located generally toward the east, on the south side of the basin. All four of those impacted wells remain out of active supply service. In 2006, a very low level of perchlorate was detected in another Saugus municipal well

(NCWD's Well NC-13). That low level detection has been interpreted to not indicate anything new about the migration of perchlorate; however, it has also prompted additional monitoring well installation and a focused study of the Saugus Formation in that area. Results are expected to be integrated with other groundwater remediation to be submitted by the Whittaker-Bermite site owners and reviewed by the State Department of Toxic Substances Control (DTSC). All other Saugus wells owned and operated by the Purveyors are available for municipal water supply service. As part of regular operation, those wells are sampled in accordance with drinking water regulations and perchlorate has not been detected. Despite the inactivated Saugus wells, the Purveyors still have sufficient pumping capacity in other wells to meet the planned normal range of Saugus pumping in the 2005 UWMP.

Work toward the ultimate remediation of perchlorate contamination, including the restoration of impacted groundwater supply continued to progress in 2006, with focus on permitting of a jointly developed plan to "pump and treat" contaminated water from two wells to stop migration of the contaminant plume, and to deliver treated water to partially replace impacted well capacity. Environmental review of the project had been completed with adoption of a Mitigated Negative Declaration in September 2005. The Final Interim Remedial Action Plan was completed and approved by DTSC in January 2006. Construction of facilities and pipelines necessary to implement the pump and treat program and to also restore inactivated well capacity is now anticipated to be completed in 2008.

ES.4 Imported Water

CLWA's contractual Table A Amount is 95,200 af of water from the SWP. CLWA operates two water filtration and disinfection plants, with a total treatment capacity of 86 million gallons per day of capacity for subsequent distribution to the Purveyors.

CLWA's final allocation of Table A for 2006 was 100 percent, or a full 95,200 af. The total available SWP supply in 2006 was 99,105 af, including 3,905 af of 2005 carryover delivered in early 2006. CLWA deliveries were 40,646 af to the Purveyors and 20,000 af to the Rosedale-Rio Bravo Water Banking and Exchange Program.

CLWA has two groundwater banking agreements with the Semitropic Water Storage District in Kern County. In accordance with those agreements, over a ten-year period (until 2012/13), CLWA can withdraw up to 50,870 af of water that it stored in 2002 and 2003 to meet Valley demands when needed. In addition to the banking in Semitropic, CLWA finalized an agreement with the Rosedale-Rio Bravo Water Storage District in 2005, and has now banked 20,000 afy of

surplus Table A Amount in that District's Water Banking and Exchange Program in both 2005 and 2006. In accordance with the provisions of that agreement, CLWA can withdraw up to a total of 35,600 af of that water, at a rate up to 20,000 afy, to meet Valley water demands when needed. In addition, in early 2007, CLWA finalized a Water Acquisition Agreement with the Buena Vista Water Storage District (Buena Vista) and the Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo). Under this program, Buena Vista's high flow Kern River entitlements (and other acquired waters that may become available) are captured and recharged within the Rosedale-Rio Bravo's service area on an ongoing basis. CLWA will receive 11,000 af of these supplies annually either through exchange of Buena Vista's and Rosedale-Rio Bravo's SWP supplies or through direct delivery of water to the California Aqueduct via the Cross Valley Canal. Additionally, CLWA is entitled to 22,000 af of water that was stored in the Rosedale Rio-Bravo Water Banking and Exchange Program in 2005 and 2006 on CLWA's behalf as part of the Water Acquisition Agreement. With the addition of those supplies, CLWA now has a recoverable total of 57,600 af in the Rosedale Rio-Bravo Water Banking and Exchange Program.

Since SWP water deliveries are subject to reduction when dry conditions occur in Northern California, the UWMP includes programs, like the Semitropic and Rosedale-Rio Bravo programs, for enhancing water supply reliability during such occurrences. A capital improvement program funded by CLWA has been established to provide facilities and additional water supplies needed to firm up SWP water supplies during times of drought.

ES.5 Recycled Water

Recycled water service was initiated in July 2003 in accordance with CLWA's Draft Reclaimed Water System Master Plan (2002). The amount of recycled water used for irrigation purposes, at a golf course and in roadway median strips, was approximately 420 af in 2006. CLWA completed CEQA analysis in early 2007 of the various options for a recycled water system as outlined in the Master Plan.

ES.6 2007 Water Supply Outlook

In 2007, total water demands are expected to be on the order of 99,000 to 102,000 af, consistent with the growth rate and related water demand projections in the 2005 UWMP and reflective of notably dry conditions in early 2007. It is expected that water demands in 2007 will continue to be met with a generally similar mix of water supplies comprised of imported SWP water, local groundwater, and recycled water.

As of April 21, 2007, the allocation of water from the SWP is 60 percent of CLWA's Table A Amount, or 57,120 af. Combined with local groundwater from the two aquifer systems (42,500 af), total Flexible Storage Account (6,060 af), net carryover SWP water from 2006 (2,569 af), annual acquisition through the Buena Vista Water/Rosedale Rio-Bravo Water Acquisition Agreement (11,000 af), and recycled water (500 af), the total available water supplies for 2007 are nearly 120,000 af. As a result, CLWA and the Purveyors anticipate having more than adequate supplies to meet all water demands in 2007.

In October 2006, Watershed Enforcers, a legal project of the California Sportfishing Protection Alliance, filed a lawsuit in Alameda County Superior Court alleging that the California Department of Water Resources (DWR) was not in compliance with the State Endangered Species Act (CESA) and does not have the required State permit to "take" protected fish species in the Sacramento-San Joaquin Delta (Delta) as part of its pumping operations at the Banks Pumping Plant located near the town of Tracy. In April 2007, the court agreed with the plaintiffs and ordered a shutdown of pumping from the Delta if appropriate permits could not be obtained in 60 days. In May 2007, DWR filed an appeal of the lower court's decision, which automatically stayed that decision pending the outcome of the appeal. At the same time, DWR entered into a Memorandum of Understanding with the California Department of Fish and Game (DFG) to jointly work with the appropriate federal agencies to develop a federal biological opinion that complies with CESA. During the preparation of the new biological opinion, DWR committed itself to actions related to protecting species through the adaptive management provisions of the existing biological opinions. Upon completion of this effort, DWR plans to submit a request to DFG for a consistency determination under CESA that would allow for incidental take based on the new federal biological opinion. In terms of short-term water supply availability, CLWA does not anticipate that any of the preceding actions will cause a net reduction in delivery of imported water that would in turn result in a shortage of overall water supply to meet projected 2007 water demands.

In any given year, SWP supplies may be reduced due to dry weather conditions or regulatory factors. During such an occurrence, the remaining water demands are planned to be met by a combination of alternate supplies such as returning water from CLWA's accounts in the Semitropic Groundwater Storage Program and the Rosedale-Rio Bravo Water Banking and Exchange Program, deliveries from CLWA's flexible storage account in Castaic Lake Reservoir, local groundwater pumping, short-term water exchanges, and participation in DWR dry-year water purchase programs in accordance with the 2005 Urban Water Management Plan. CLWA has now banked excess 2002 and 2003 SWP Table A water in the Semitropic Groundwater

Storage Program; it has banked excess 2005 and 2006 SWP Table A water in the Rosedale-Rio Bravo Water Banking and Exchange Program; and it has banked water purchased in 2005 and 2006 through the Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement in the Rosedale-Rio Bravo Water Banking and Exchange Program. CLWA can draw upon its accounts as needed, pursuant to the terms of the banking agreements. The banked excess 2002 and 2003 SWP Table A water in Semitropic now represents nearly 51,000 af of recoverable water for drought water supply. The banked excess 2005 and 2006 SWP Table A water, augmented by water acquired through the Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement in 2005 and 2006, now represent a total of 57,600 af of recoverable water for drought water supply from the Rosedale-Rio Bravo Banking and Exchange Program.

Drought periods may affect available water supplies in any single year and for a duration usually not longer than three consecutive years. It is important to note that hydrologic conditions vary from region to region throughout the state. Dry conditions in Northern California affecting SWP supply may not affect local groundwater and other supplies in Southern California, and the reverse situation can also occur (as it did in 2002 and 2003). For this reason, CLWA and the Purveyors have emphasized developing water supplies that add diversity in water supply options, especially in dry years. Diversity of supply is considered a key element of reliability, giving Valley water Purveyors the ability to draw on multiple sources of supply during dry year conditions.

I. Introduction

1.1 Background

For most residents of the Santa Clarita Valley (Valley), domestic water service is provided by four retail water Purveyors. They are the Castaic Lake Water Agency's (CLWA) Santa Clarita Water Division (SCWD), Los Angeles County Waterworks District 36 (LA36), Newhall County Water District (NCWD), and Valencia Water Company (VWC). Together, the Purveyors provide water to nearly 68,000 service connections. Castaic Lake Water Agency (CLWA) contracts for State Water Project water from Castaic Lake where it is treated, filtered, and disinfected at two treatment plants before distribution to the Purveyors. Staff of these entities meet regularly to coordinate the supply of water in the Valley. Their respective service areas are shown in Figure I-1.

Water supply for a small fraction of Valley residents is provided by individual private water supply wells. The locations, construction details, annual pumpage and other information about these private wells are not currently available. CLWA has been working with private well owners to receive information about their wells for incorporation in future reports and for planning purposes. Pumping as reported herein includes an estimate of groundwater pumped from private wells; it is expected that this estimate will be refined in the future as more information about the private wells is obtained.

In addition to municipal and individual private water uses in the Valley, there remains an agricultural water demand that is predominately dependent on local groundwater for its water supply. Accordingly, ongoing agricultural water requirements and the use of local groundwater to meet those requirements are considered in analyses and reports on water supplies such as this report.

Over the last 20 years, CLWA and the Purveyors have reviewed and reported on the availability of water supplies to meet all water requirements in the Valley. Those reports have also addressed local water resources, most notably groundwater, in the region. Past studies have assessed the condition of local groundwater aquifers, their hydrogeologic characteristics, aquifer storage capacity, operational yield and recharge rate, groundwater quality and contamination, and the ongoing conjunctive use of groundwater and imported water resources.

Other efforts have included developing drought contingency plans, coordinating emergency response procedures and implementing Valley-wide conservation programs. In 1985, the Purveyors prepared the area's first Urban Water Management Plan (UWMP.) Information in the plan was coordinated among CLWA and the Purveyors to provide accurate, comprehensive and consistent water supply and demand information for long term planning purposes. In accordance with the California Urban Water Management Planning Act, the Valley-wide UWMP was most recently updated in 2005 to extend water demand projections through 2030, and to describe the combination of local groundwater, imported water supplies from the State Water Project, local recycled water supplies, and planned other water supplies to meet the existing and projected water demands in the Valley. The 2005 UWMP describes the reliability of local groundwater resources and the adequacy of groundwater supplies to meet that component of overall water supply. The 2005 UWMP also describes the impacts of perchlorate contamination on several municipal water supply wells, and the plans and ongoing work for integrated control of perchlorate migration and full restoration of perchlorate-impacted groundwater supply.[1]

1.2 Purpose and Scope of the Report

The purpose of this report, which is the ninth in a series of annual water reports that began in 1998, is to provide current information about the available water supplies and demands of the Santa Clarita Valley. CLWA and the Purveyors have prepared this series of reports in response to a request made by the Los Angeles County Board of Supervisors in 1998. Over the last few years, this series of reports has also served as an annual summary of groundwater conditions in the Valley in fulfillment of the commitment in the Santa Clarita Valley Groundwater Management Plan, adopted in 2003 to regularly report on implementation of that Plan. This report was prepared for Castaic Lake Water Agency, for CLWA's Santa Clarita Water Division, for Los Angeles County Waterworks District 36, for Newhall County Water District, and for Valencia Water Company. It continues a format for providing information regarding water uses and the availability of water supplies on an annual basis. It is intended to be a helpful resource for use by water planners and local planning agencies. This report is complemented by the more detailed UWMP for the area, which provides longer-term water supply planning over a 25-year period, and by a number of other technical reports, some of which are specifically referenced herein.

[1] The 2005 UWMP was challenged in a lawsuit filed in early 2006 by the California Water Impact Network and the friends of the Santa Clara River, ultimately seeking a mandate that the approval of the UWMP by CLWA and the Purveyors be invalidated. The 2005 UWMP remains valid unless affected by a future judgment or order of the court. CLWA and the Purveyors believe the lawsuit is without merit, and have been vigorously defending the plan in court.

1.3 Santa Clarita Valley Water Purveyors

As introduced above, four retail water Purveyors provide water service to most residents of the Santa Clarita Valley. Brief summary descriptions of those four Purveyors are as follows.

Castaic Lake Water Agency Santa Clarita Water Division has a service area that includes a portion of the City of Santa Clarita and unincorporated portions of Los Angeles County in the communities of Saugus, Canyon Country, and Newhall. Water is supplied from both groundwater and CLWA turnouts to about 27,600 service connections.

Los Angeles County Waterworks District 36 has a service area that encompasses approximately 7,635 acres in the Hasley Canyon area and the unincorporated community of Val Verde. LACWWD 36 has about 1,400 service connections. The District has traditionally obtained its full water supply from a connection to the CLWA's Castaic Conduit. In 2004 and 2005, the District supplemented its surface water supply with groundwater purchased from the Los Angeles County Peter J. Pitchess Detention Center. In 2006, however, the District returned to sole supply from CLWA.

Newhall County Water District's service area includes portions of the City of Santa Clarita and unincorporated portions of Los Angeles County in the communities of Newhall, Canyon Country, Saugus, and Castaic. NCWD supplies water from both groundwater and CLWA turnouts to approximately 9,350 service connections.

Valencia Water Company's service area serves about 29,100 service connections in a portion of the City of Santa Clarita and in the unincorporated communities of Castaic, Newhall, Saugus, Stevenson Ranch, and Valencia. VWC supplies water from both groundwater and CLWA turnouts; VWC also delivers recycled water for a small amount of non-potable use.

1.4 The Upper Santa Clara River Hydrologic Area and East Groundwater Subbasin

The Upper Santa Clara River Hydrologic Area (HA), as defined by the California Department of Water Resources (DWR), is located almost entirely in northwestern Los Angeles County. The area encompasses about 654 square miles comprised of flat valley land (about 6 percent of the total area) and hills and mountains (about 94 percent of the total area) that border the valley area. The mountains include the Santa Susana and San Gabriel Mountains to the south and the Sierra Pelona and Leibre-Sawmill Mountains to the north. Elevations range from about 800 feet on the

valley floor to about 6,500 feet in the San Gabriel Mountains. The headwaters of the Santa Clara River are at an elevation of about 3,200 feet at the divide separating this hydrologic area from the Mojave Desert.

The Santa Clara River and its tributaries flow intermittently from Lang Station westward about 35 miles to Blue Cut, just west of the Los Angeles-Ventura County line, where it forms the outlet for the Upper Santa Clara River Hydrologic Area. The principal tributaries of the River in the Santa Clarita Valley are Castaic Creek, San Francisquito Creek, Bouquet Creek, and the South Fork of the Santa Clara River. In the Santa Clarita Valley, the Santa Clara River receives treated wastewater discharge from the Saugus and Valencia Water Reclamation Plants, which are operated by the Sanitation Districts of Los Angeles County.

The Santa Clara River Valley East Groundwater Subbasin, beneath the Santa Clarita Valley in the Upper Santa Clara River HA, is the source of essentially all local groundwater used for water supply in the Santa Clarita Valley. Below Blue Cut, the Santa Clara River continues westward through Ventura County to its mouth near Oxnard. Along that route, the River traverses all or parts of six groundwater basins in Ventura County (Piru, Fillmore, Santa Paula, Oxnard Forebay, Oxnard Plain and Mound) as shown in Figure I-2.

There are two primary precipitation gages in the Santa Clarita Valley, the Newhall-Soledad 32c gage and the Newhall County Water District gage (Figure I-3). The National Climatic Data Center (NCDC) and Los Angeles County Department of Public Works (LADPW) have maintained records for the Newhall-Soledad 32c gage since 1931. Newhall County Water District has maintained records for the NCWD gage since 1979. The cumulative records from these two gages correlate very closely, with the NCWD gage recording approximately 25 percent more precipitation than the Newhall-Soledad 32c gage. This is likely due to the location of the NCWD gage, which is at the base of the mountains rimming the southern edge of the Santa Clarita Valley.

The Santa Clarita Valley is characterized as having an arid climate. Historically, intermittent periods of less-than-average precipitation have typically been followed by periods of greater-than-average precipitation in a cyclical pattern, with each wetter or drier period typically lasting from one to five years. Long-term precipitation records for the Newhall-Soledad 32c gage are illustrated in Figure I-3. The long-term average precipitation is 18.1 inches (1931-2006). Figure I-3 also shows the yearly departure from mean annual precipitation. In general, periods of less-than-average precipitation have been longer and more moderate than periods of greater-than-average precipitation. Recently, the periods from 1971 to 1976, 1984 to 1991 and 1999 to 2003

have been drier than average; the periods from 1977 to 1983 and 1992 to 1996 have been wetter than average. Wet conditions that began in late 2004 continued into early 2005. Significant storm events in January 2005 produced over 13 inches of measured precipitation, or more than 70 percent of average annual precipitation in the first month of the year. Significant storm events continued in February, resulting in nearly 17 inches of additional measured precipitation, or nearly 100 percent of average annual precipitation in February alone. In total, 2005 had about 37 inches of measured precipitation, or slightly more than 200 percent of long-term average precipitation. Those significantly wet conditions contributed to substantial groundwater recharge and decreased water demand that year. In contrast, total precipitation in 2006 was slightly less than 14 inches, or about 4 inches below the long-term average, resulting in water requirements that can be described as “normal” (as projected in the 2005 UWMP) and no dramatic changes in groundwater conditions, as described herein.

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Figure I-1
CLWA and Purveyor Service Areas

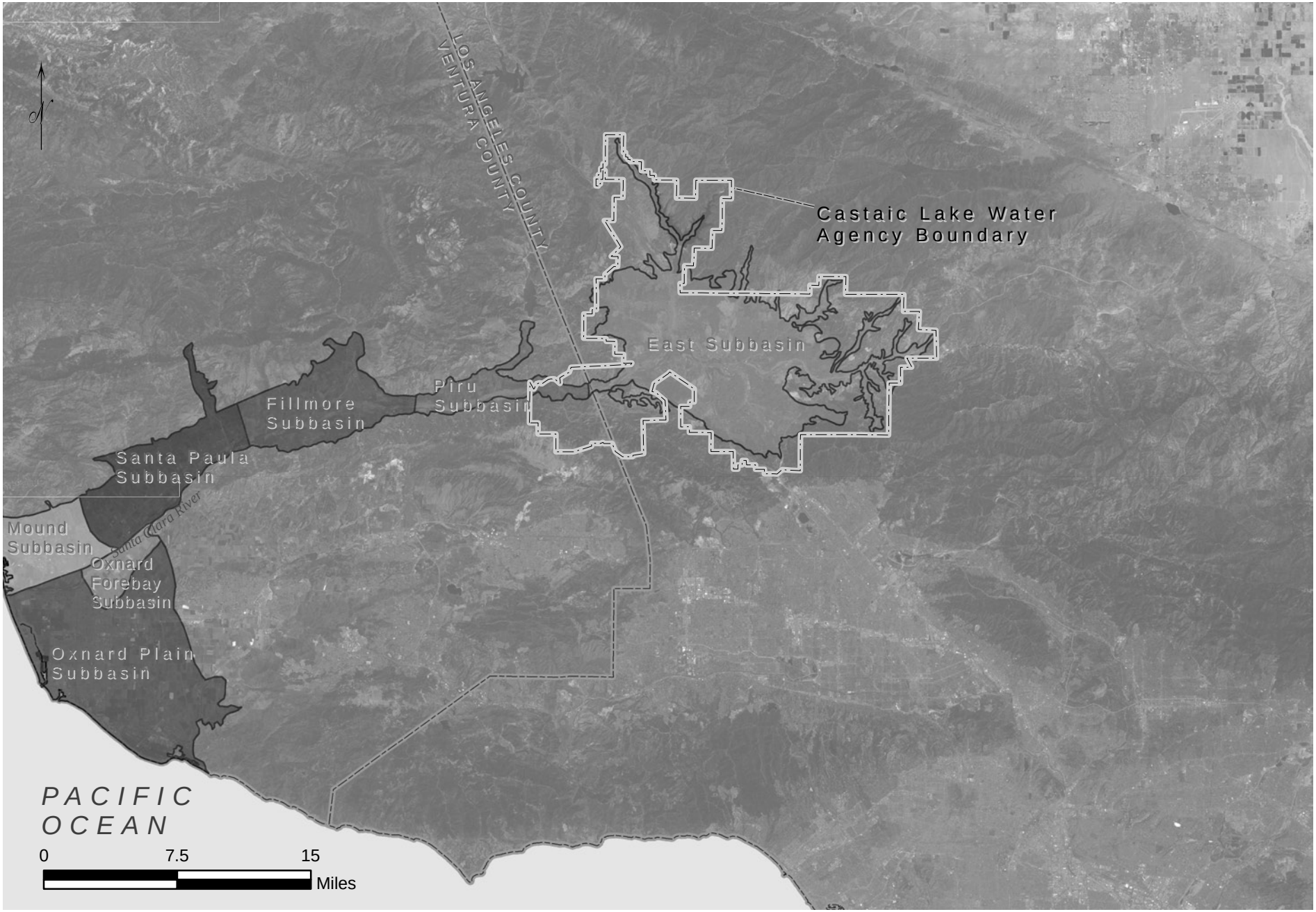

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Figure I-2
Santa Clara River Groundwater Subbasins

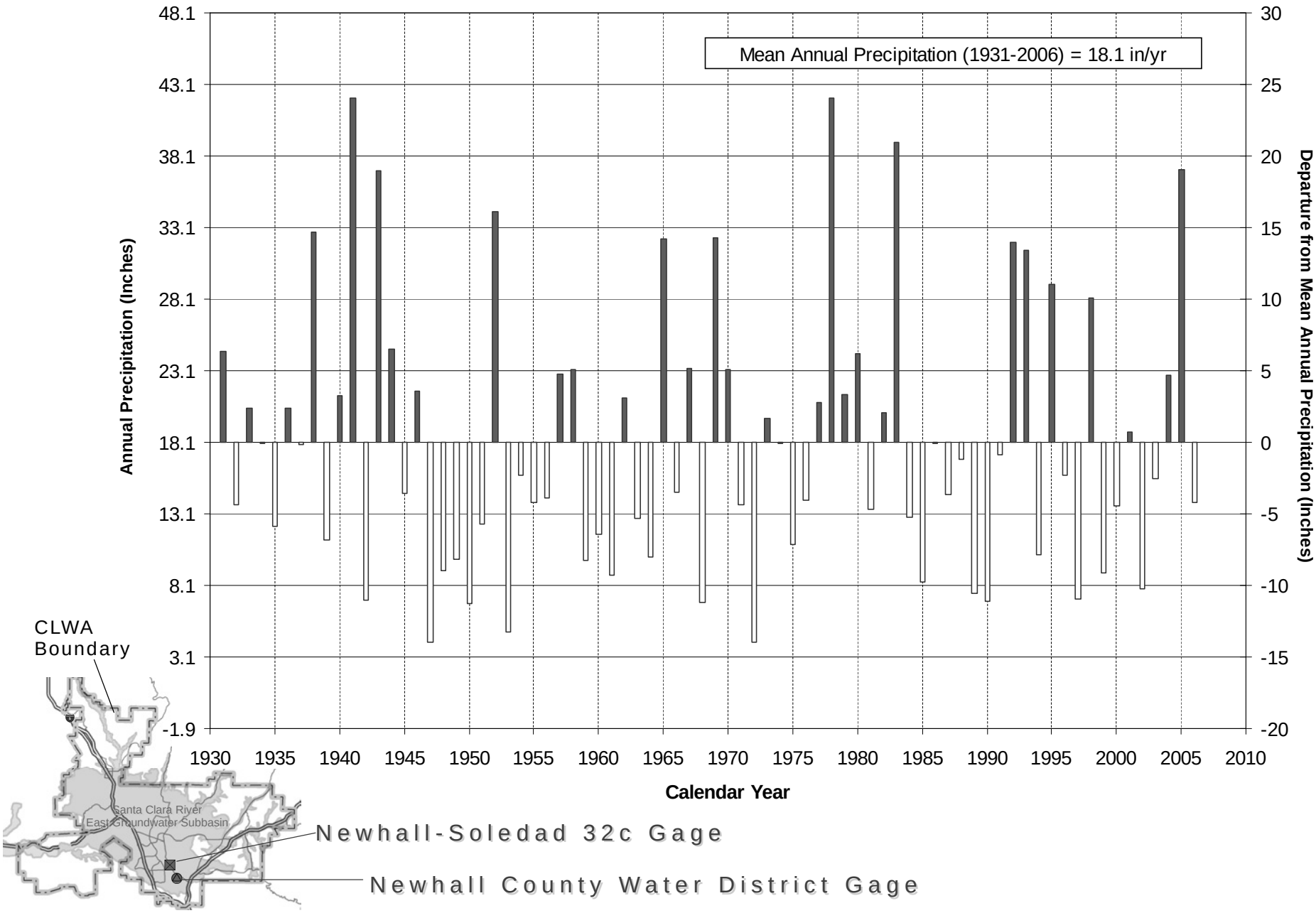

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Figure I-3
Annual Precipitation and Departure from Mean Annual Precipitation
Newhall-Soledad 32c Gage *

II. 2006 Water Requirements and Supplies

In 2006, total water use in the Santa Clarita Valley was 91,400 af, an increase of nearly 7,800 af from the previous year. Of the total water demand, 74,100 af (81 percent) was for municipal use and the remaining 17,300 af (19 percent) was for agricultural and other (miscellaneous) uses, including individual domestic uses. These total water demands were met by a combination of 50,400 af from local groundwater resources (about 33,000 af for municipal supply and about 17,300 af for agricultural and other uses), about 40,600 af of SWP water, and about 400 af of recycled water.

Compared to the previous year, total water demand in the Santa Clarita Valley increased by about nine percent in 2006. Actual water use in 2006 was essentially identical to the short-term projected water requirement of 91,500 acre-feet presented in last year's Water Report. The increase in water use in 2006 is attributed to an increase of about 1,300 municipal service connections, from 66,300 in 2005 to 67,600 in 2006, and a return to a more typical use of water for agricultural irrigation after the notable decrease in 2005 as a result of extremely wet conditions in that year. The magnitude of increased water use in 2006 was consistent with the analysis of weather impacts on water usage in the 2005 Urban Water Management Plan, and is reflected in an overall water requirement that is consistent with the projections in the 2005 UWMP. As summarized in that Plan, examination of historical water use patterns in the Valley since 1980, when State Water Project deliveries began, shows that weather variations have influenced water use by nine to ten percent of normal, or average, use. In hotter, dry years, water demands have been as much as nine percent higher than normal while in cooler, wet years, water demands have been as much as ten percent less than normal. In the immediately preceding year, 2005, extended and significantly wet conditions resulted in a water demand that was about six percent below the average projection in the 2005 UWMP. In 2006, although precipitation was slightly below average, total water requirements for all uses in the Valley were the same as both the average projections in the 2005 UWMP and the short-term projection in the 2005 Water Report.

The uses of local and imported water supplies to meet municipal water requirements since 1980, when the importation of SWP water began, are summarized in Table II-1. Water supply utilization by each individual municipal Purveyor is tabulated in Tables II-2 through II-5 for the same period of time. Notable with regard to municipal water requirements is that, through 2006, total municipal demand (74,100 af) was slightly below (by about 2,000 af) the projections in the 2005 UWMP.

Water supply utilization for all agricultural and other non-municipal uses is summarized in Table II-6 and tabulated by three categories of agricultural and other users in Table II-7. The latter category of Small Private Domestic, Irrigation and Golf Course Uses in Table II-7 includes an estimated 500 af of small private pumping from the Alluvium.

Water supply utilization for all uses in the Santa Clarita Valley, again for the period 1980 to present, is summarized in Table II-8. The trends in utilization of local groundwater and imported SWP water, complemented by the recent addition of recycled water, are graphically illustrated in Figure II-1. As can be seen by inspection of Table II-8 and Figure II-1, total water use in the Valley has nearly linearly increased since the early 1980's, with some weather-related fluctuations in certain years. The resultant increase in total water demand, since the inception of supplemental SWP importation, has been from about 37,000 acre-feet in 1980 to the mid-80,000 acre-feet per year range over the prior four years, to slightly more than 90,000 acre-feet in 2006. As can also be seen by inspection of Table II-8 and Figure II-1, most of that increase in water demand has been met with increasing importation of SWP water. Since the early 1990's, following a decade of decreased groundwater use during the initial period of SWP importation, total groundwater pumping has remained within a fairly narrow range of about 39,000 to 46,000 acre-feet per year through 2005. After the significantly wet conditions in 2005 and the resultant high groundwater levels, total local groundwater pumping increased to slightly more than 50,000 acre-feet in 2006.

Table II-1
Water Supply Utilization by Municipal Purveyors*
(Acre-Feet)

* includes CLWA-SCWD, LACWD 36, NCWD and VWC

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	*Recycled Water*	**Total**
1980	1,125	16,625	4,569	-	**22,319**
1981	5,816	14,056	4,950	-	**24,822**
1982	9,659	8,684	3,569	-	**21,912**
1983	9,185	8,803	3,398	-	**21,386**
1984	10,996	12,581	3,809	-	**27,386**
1985	11,823	12,519	4,140	-	**28,482**
1986	13,759	12,418	4,975	-	**31,152**
1987	16,285	12,630	4,962	-	**33,877**
1988	19,033	12,197	6,404	-	**37,634**
1989	21,618	13,978	7,217	-	**42,813**
1990	21,613	13,151	8,302	-	**43,066**
1991	7,968	17,408	14,417	-	**39,793**
1992	13,911	16,897	10,458	-	**41,266**
1993	13,393	19,808	10,151	-	**43,352**
1994	14,389	20,068	11,531	-	**45,988**
1995	16,996	20,590	8,087	-	**45,673**
1996	18,093	24,681	7,373	-	**50,147**
1997	22,148	25,273	6,752	-	**54,173**
1998	20,254	23,898	4,706	-	**48,858**
1999	27,282	27,240	2,728	-	**57,250**
2000	32,579	25,216	3,193	-	**60,988**
2001	35,369	22,055	3,267	-	**60,691**
2002	41,768	22,097	4,360	-	**68,225**
2003	44,419	19,397	3,581	50	**67,447**
2004	47,205	18,970	5,701	420	**72,296**
2005	38,034	26,368	5,948	418	**70,768**
2006	40,646	27,189	5,872	419	**74,126**

Percent Contribution of Water Supplies

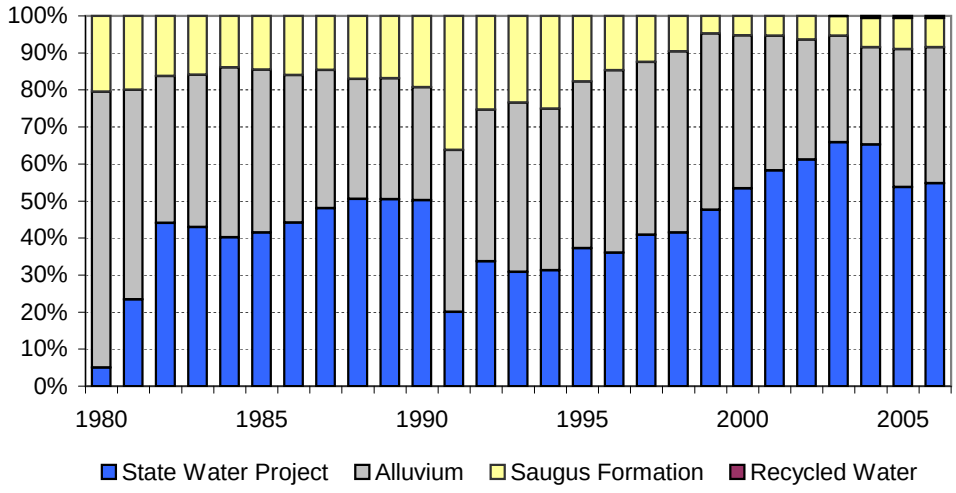


Table II-2
Water Supply Utilization by CLWA Santa Clarita Water Division
(Acre-Feet)

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	**Total**
1980	1,125	9,460	0	**10,585**
1981	4,602	7,109	0	**11,711**
1982	6,454	4,091	0	**10,545**
1983	5,214	4,269	0	**9,483**
1984	6,616	6,057	0	**12,673**
1985	6,910	6,242	0	**13,152**
1986	8,366	5,409	0	**13,775**
1987	9,712	5,582	0	**15,294**
1988	11,430	5,079	63	**16,572**
1989	12,790	5,785	0	**18,575**
1990	12,480	5,983	40	**18,503**
1991	6,158	5,593	4,781	**16,532**
1992	6,350	8,288	2,913	**17,551**
1993	3,429	12,016	2,901	**18,346**
1994	5,052	10,996	3,863	**19,911**
1995	7,955	10,217	1,726	**19,898**
1996	9,385	10,445	2,176	**22,006**
1997	10,120	11,268	1,068	**22,456**
1998	8,893	11,426	0	**20,319**
1999	10,772	13,741	0	**24,513**
2000	13,751	11,529	0	**25,280**
2001	15,648	9,896	0	**25,544**
2002	18,921	9,513	0	**28,434**
2003	20,668	6,424	0	**27,092**
2004	22,045	7,146	0	**29,191**
2005	16,513	12,408	0	**28,921**
2006	17,146	13,156	0	**30,302**

Percent Contribution of Water Supplies

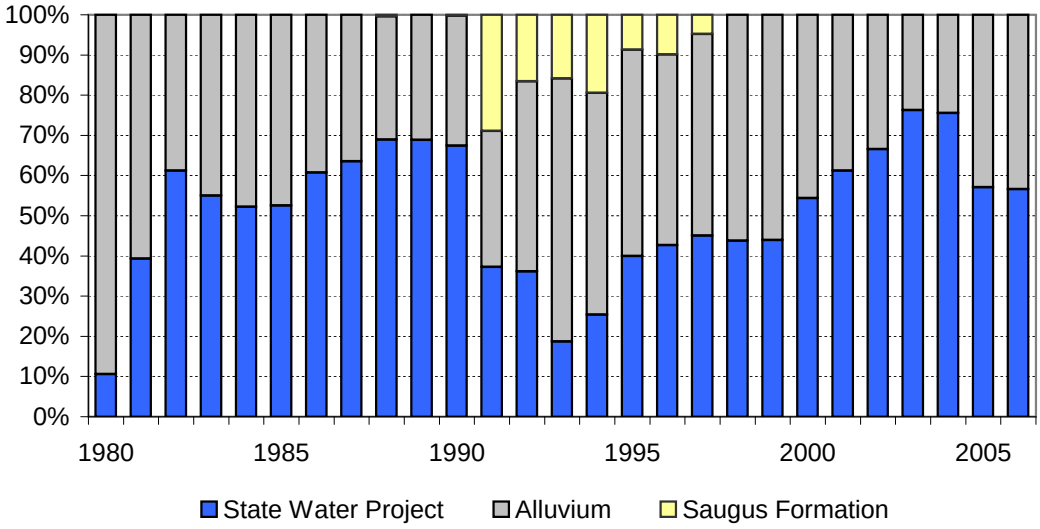


Table II-3
Water Supply Utilization by Los Angeles County Waterworks District 36
(Acre-Feet)

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	**Total**
1980	0	-	-	**0**
1981	0	-	-	**0**
1982	145	-	-	**145**
1983	207	-	-	**207**
1984	240	-	-	**240**
1985	272	-	-	**272**
1986	342	-	-	**342**
1987	361	-	-	**361**
1988	434	-	-	**434**
1989	457	-	-	**457**
1990	513	-	-	**513**
1991	435	-	-	**435**
1992	421	-	-	**421**
1993	465	-	-	**465**
1994	453	-	-	**453**
1995	477	-	-	**477**
1996	533	-	-	**533**
1997	785	-	-	**785**
1998	578	-	-	**578**
1999	654	-	-	**654**
2000	800	-	-	**800**
2001	907	-	-	**907**
2002	1,069	-	-	**1,069**
2003	1,175	-	-	**1,175**
2004	854	380	-	**1,234**
2005	857	343	-	**1,200**
2006	1,289	-	-	**1,289**

Groundwater purchased from Los Angeles County Honor Farm

Percent Contribution of Water Supplies

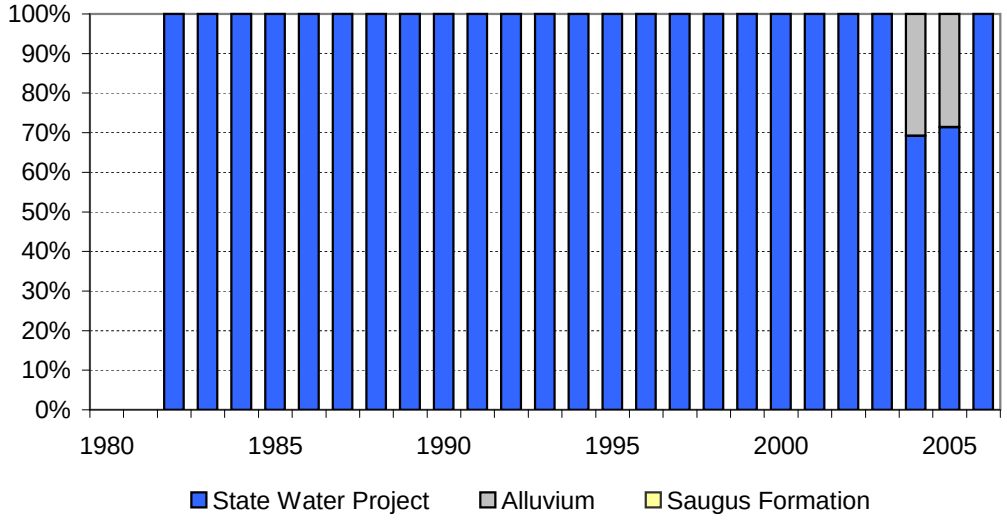


Table II-4
Water Supply Utilization by Newhall County Water District
(Acre-Feet)

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	**Total**
1980	0	1,170	2,363	**3,533**
1981	0	1,350	2,621	**3,971**
1982	0	1,178	2,672	**3,850**
1983	0	1,147	2,787	**3,934**
1984	0	1,549	2,955	**4,504**
1985	0	1,644	3,255	**4,899**
1986	0	1,842	3,548	**5,390**
1987	22	2,127	3,657	**5,806**
1988	142	2,283	4,041	**6,466**
1989	428	2,367	4,688	**7,483**
1990	796	1,936	4,746	**7,478**
1991	675	1,864	4,994	**7,533**
1992	802	1,994	5,160	**7,956**
1993	1,075	1,977	5,068	**8,120**
1994	906	2,225	5,103	**8,234**
1995	1,305	1,675	4,775	**7,755**
1996	1,213	1,803	4,871	**7,887**
1997	1,324	2,309	5,168	**8,801**
1998	1,769	1,761	4,557	**8,087**
1999	5,050	1,676	2,622	**9,348**
2000	6,024	1,508	2,186	**9,718**
2001	5,452	1,641	2,432	**9,525**
2002	5,986	981	3,395	**10,362**
2003	6,572	1,266	2,513	**10,351**
2004	5,896	1,582	3,739	**11,217**
2005	5,932	1,389	3,435	**10,756**
2006	5,898	2,149	3,423	**11,470**

Percent Contribution of Water Supplies

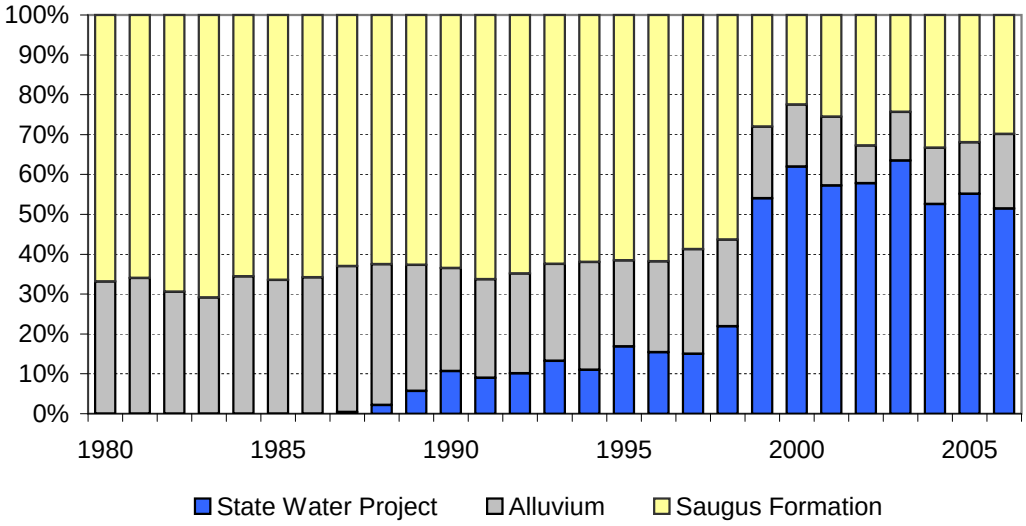


Table II-5
Water Supply Utilization by Valencia Water Company
(Acre-Feet)

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	*Recycled Water*	**Total**
1980	0	5,995	2,206	-	**8,201**
1981	1,214	5,597	2,329	-	**9,140**
1982	3,060	3,415	897	-	**7,372**
1983	3,764	3,387	611	-	**7,762**
1984	4,140	4,975	854	-	**9,969**
1985	4,641	4,633	885	-	**10,159**
1986	5,051	5,167	1,427	-	**11,645**
1987	6,190	4,921	1,305	-	**12,416**
1988	7,027	4,835	2,300	-	**14,162**
1989	7,943	5,826	2,529	-	**16,298**
1990	7,824	5,232	3,516	-	**16,572**
1991	700	9,951	4,642	-	**15,293**
1992	6,338	6,615	2,385	-	**15,338**
1993	8,424	5,815	2,182	-	**16,421**
1994	7,978	6,847	2,565	-	**17,390**
1995	7,259	8,698	1,586	-	**17,543**
1996	6,962	12,433	326	-	**19,721**
1997	9,919	11,696	516	-	**22,131**
1998	9,014	10,711	149	-	**19,874**
1999	10,806	11,823	106	-	**22,735**
2000	12,004	12,179	1,007	-	**25,190**
2001	13,362	10,518	835	-	**24,715**
2002	15,792	11,603	965	-	**28,360**
2003	16,004	11,707	1,068	50	**28,829**
2004	18,410	9,862	1,962	420	**30,654**
2005	14,732	12,228	2,513	418	**29,891**
2006	16,313	11,884	2,449	419	**31,065**

Percent Contribution of Water Supplies

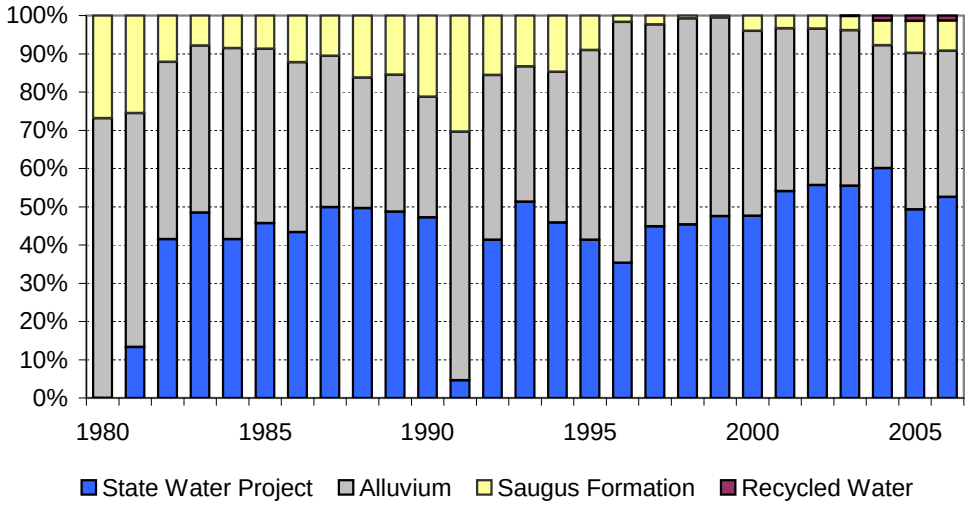


Table II-6
Water Supply Utilization for Agricultural and Other Uses
(Acre-Feet)

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	**Total**
1980	0	14,831	20	**14,851**
1981	0	16,737	20	**16,757**
1982	0	13,184	521	**13,705**
1983	0	11,483	454	**11,937**
1984	0	14,737	640	**15,377**
1985	0	12,828	575	**13,403**
1986	0	11,787	510	**12,297**
1987	0	10,012	599	**10,611**
1988	0	9,451	524	**9,975**
1989	0	9,743	542	**10,285**
1990	0	10,725	559	**11,284**
1991	0	9,779	500	**10,279**
1992	987	10,694	466	**12,147**
1993	443	10,318	459	**11,220**
1994	311	13,065	494	**13,870**
1995	6	13,874	473	**14,353**
1996	780	13,757	813	**15,350**
1997	1,067	14,326	993	**16,386**
1998	12	12,750	849	**13,611**
1999	20	16,166	988	**17,174**
2000	3	14,721	887	**15,611**
2001	0	15,489	873	**16,362**
2002	0	16,179	800	**16,979**
2003	0	14,203	626	**14,829**
2004	0	14,787	803	**15,590**
2005	0	12,280	505	**12,785**
2006	0	15,872	1,440	**17,312**

Percent Contribution of Water Supplies

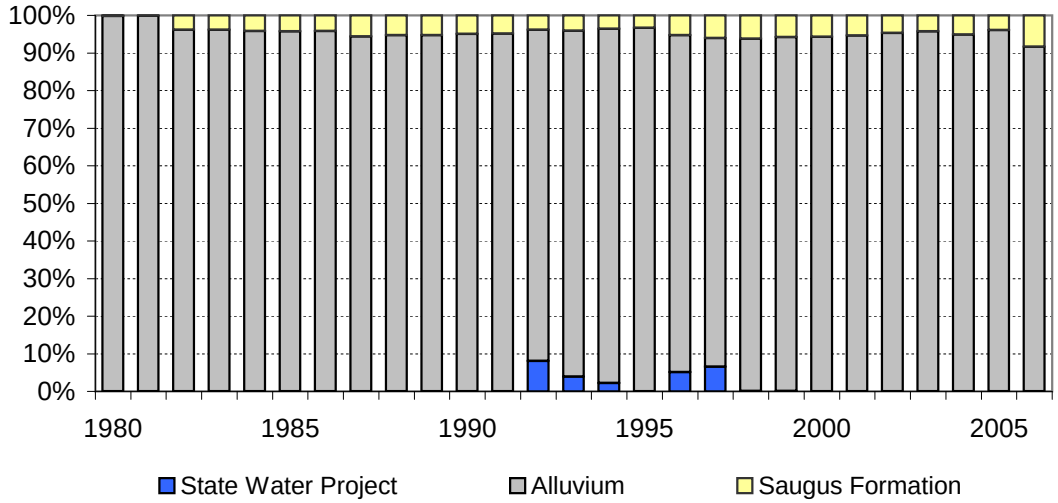


Table II-7
Individual Water Supply Utilization by Agricultural and Other Users
(Acre-Feet)

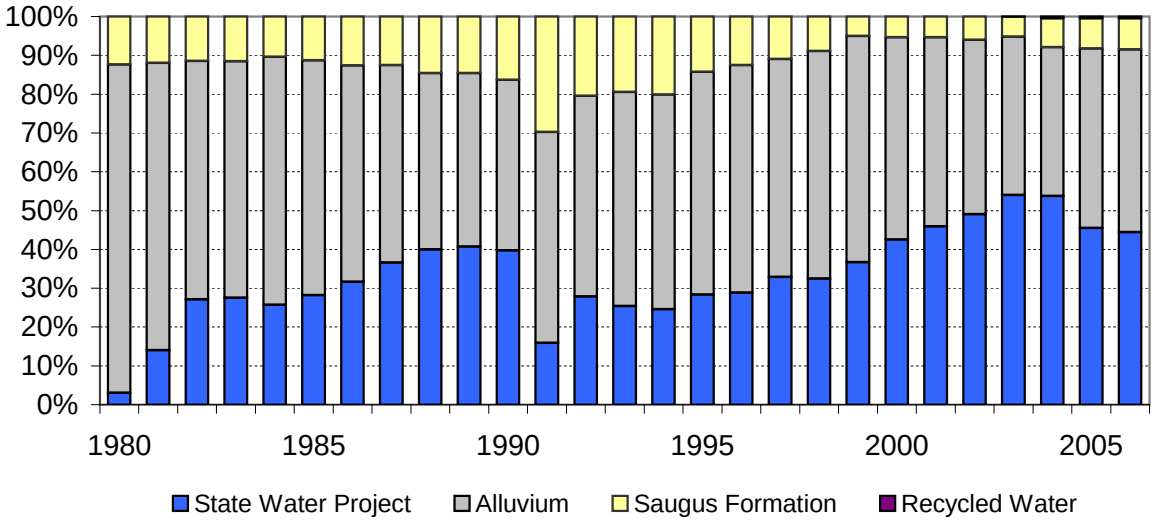
	Newhall Land and Farming			***Los Angeles County Honor Farm***			***Small Private Domestic, Irrigation and Golf Courses Uses***		
Year	*Alluvium*	*Saugus Formation*	**Total**	*Alluvium*	*State Water Project*	**Total**	*Alluvium* [1]	*Saugus Formation* [2]	**Total**
1980	11,331	20	**11,351**	3,000	0	**3,000**	500	0	**500**
1981	13,237	20	**13,257**	3,000	0	**3,000**	500	0	**500**
1982	9,684	20	**9,704**	3,000	0	**3,000**	500	501	**1,001**
1983	7,983	20	**8,003**	3,000	0	**3,000**	500	434	**934**
1984	11,237	20	**11,257**	3,000	0	**3,000**	500	620	**1,120**
1985	9,328	20	**9,348**	3,000	0	**3,000**	500	555	**1,055**
1986	8,287	20	**8,307**	3,000	0	**3,000**	500	490	**990**
1987	6,512	20	**6,532**	3,000	0	**3,000**	500	579	**1,079**
1988	5,951	20	**5,971**	3,000	0	**3,000**	500	504	**1,004**
1989	6,243	20	**6,263**	3,000	0	**3,000**	500	522	**1,022**
1990	8,225	20	**8,245**	2,000	0	**2,000**	500	539	**1,039**
1991	7,039	20	**7,059**	2,240	0	**2,240**	500	480	**980**
1992	8,938	20	**8,958**	1,256	987	**2,243**	500	446	**946**
1993	8,020	20	**8,040**	1,798	443	**2,241**	500	439	**939**
1994	10,606	20	**10,626**	1,959	311	**2,270**	500	474	**974**
1995	11,174	20	**11,194**	2,200	6	**2,206**	500	453	**953**
1996	12,020	266	**12,286**	1,237	780	**2,017**	500	547	**1,047**
1997	12,826	445	**13,271**	1,000	1,067	**2,067**	500	548	**1,048**
1998	10,250	426	**10,676**	2,000	12	**2,012**	500	423	**923**
1999	13,824	479	**14,303**	1,842	20	**1,862**	500	509	**1,009**
2000	11,857	374	**12,231**	1,644	3	**1,647**	1,220	513	**1,733**
2001	12,661	300	**12,961**	1,604	0	**1,604**	1,224	573	**1,797**
2002	13,514	211	**13,725**	1,602	0	**1,602**	1,063	589	**1,652**
2003	10,999	122	**11,121**	2,273	0	**2,273**	931	504	**1,435**
2004	10,991	268	**11,259**	2,725	0	**2,725**	1,071	535	**1,606**
2005	8,648	6	**8,654**	2,499	0	**2,499**	1,133	499	**1,632**
2006	11,477	934	**12,411**	3,026	0	**3,026**	1,369	506	**1,875**

1. Robinson Ranch Golf Course irrigation and estimated private pumping.
2. Valencia Country Club and Vista Valencia Golf Course irrigation.

Table II-8
Total Water Supply Utilization for Municipal, Agricultural and Other Uses
(Acre-Feet)

Year	*State Water Project*	*Alluvium*	*Saugus Formation*	*Recycled Water*	**Total**
1980	1,125	31,456	4,589	-	**37,170**
1981	5,816	30,793	4,970	-	**41,579**
1982	9,659	21,868	4,090	-	**35,617**
1983	9,185	20,286	3,852	-	**33,323**
1984	10,996	27,318	4,449	-	**42,763**
1985	11,823	25,347	4,715	-	**41,885**
1986	13,759	24,205	5,485	-	**43,449**
1987	16,285	22,642	5,561	-	**44,488**
1988	19,033	21,648	6,928	-	**47,609**
1989	21,618	23,721	7,759	-	**53,098**
1990	21,613	23,876	8,861	-	**54,350**
1991	7,968	27,187	14,917	-	**50,072**
1992	14,898	27,591	10,924	-	**53,413**
1993	13,836	30,126	10,610	-	**54,572**
1994	14,700	33,133	12,025	-	**59,858**
1995	17,002	34,464	8,560	-	**60,026**
1996	18,873	38,438	8,186	-	**65,497**
1997	23,215	39,599	7,745	-	**70,559**
1998	20,266	36,648	5,555	-	**62,469**
1999	27,302	43,406	3,716	-	**74,424**
2000	32,582	39,937	4,080	-	**76,599**
2001	35,369	37,544	4,140	-	**77,053**
2002	41,768	38,276	5,160	-	**85,204**
2003	44,419	33,599	4,207	50	**82,276**
2004	47,205	33,757	6,503	420	**87,885**
2005	38,034	38,648	6,453	418	**83,553**
2006	40,646	43,061	7,312	419	**91,438**

Percent Contribution of Water Supplies



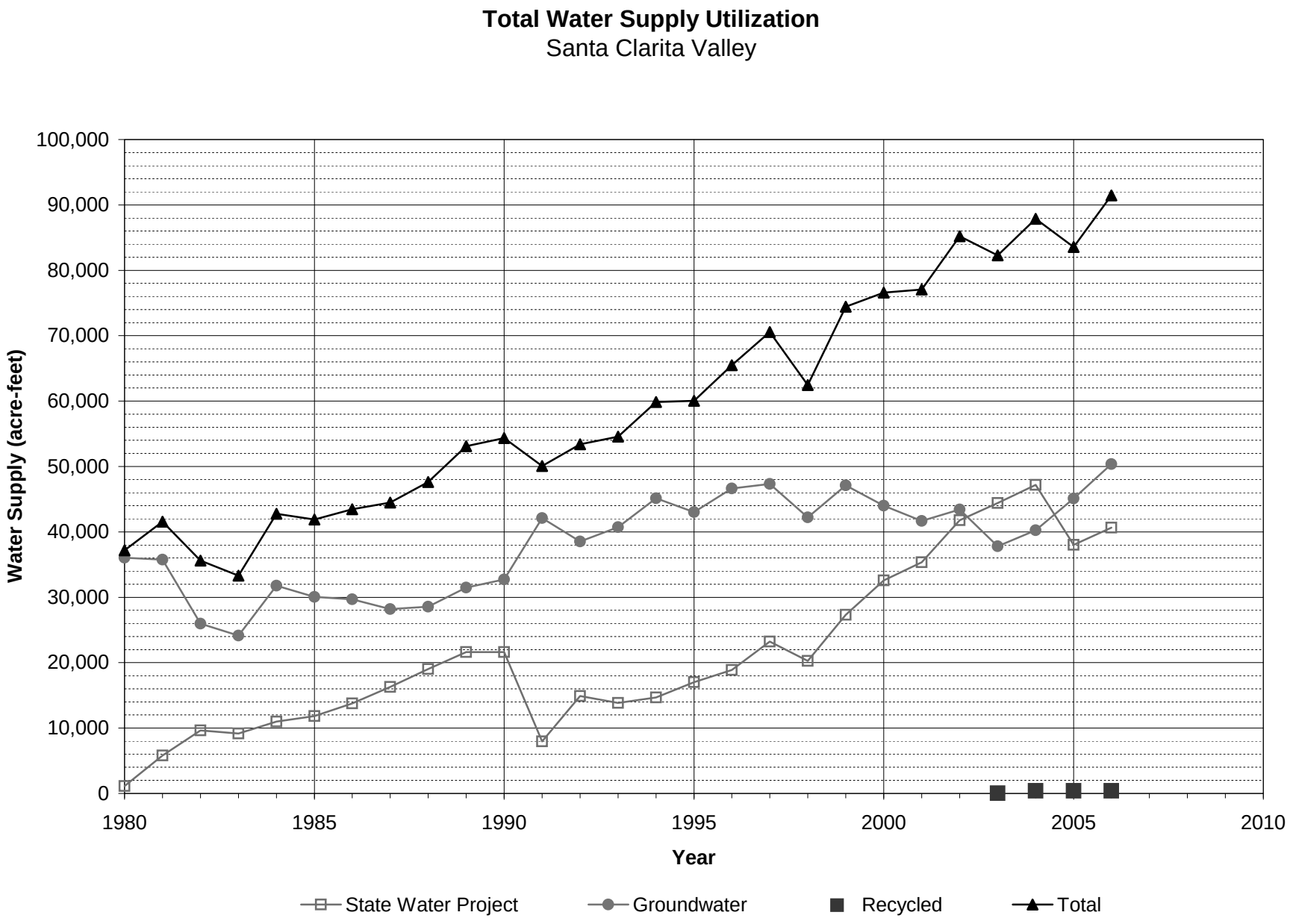

Total Water Supply Utilization
Santa Clarita Valley
Water Supply (acre-feet)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1980
1985
1990
1995
2000
2005
2010
Year
State Water Project
Groundwater
Recycled
Total

Figure II-1

III. Water Supplies

Prior to 1980, local groundwater extracted from the Alluvium and the Saugus Formation was the sole source of water supply in the Santa Clarita Valley. Since 1980, local groundwater supplies have been supplemented with imported SWP water supplies. Those water supplies were further augmented by the initiation of deliveries from CLWA's recycled water program in 2003. This section describes the groundwater resources of the Santa Clarita Valley, SWP water supplies, and CLWA's recycled water program.

3.1 Groundwater Basin Yield

The groundwater basin generally beneath the Santa Clarita Valley, identified in the State Department of Water Resources' Bulletin 118 as the Santa Clara River Valley Groundwater Basin, East Subbasin (Basin No. 4-4.07), is comprised of two aquifer systems. The Alluvium generally underlies the Santa Clara River and its several tributaries, and the Saugus Formation underlies practically the entire Upper Santa Clara River area. The mapped extent of the Santa Clara River Valley East Subbasin in DWR Bulletin 118 and its relationship to the extent of the CLWA service area are illustrated in Figure III-1. The subbasin boundary approximately coincides with the outer extent of the Alluvium and Saugus Formation.

A 2001 Update Report on both the Alluvium and Saugus Formation Aquifers (Slade, 2002), which updated analyses and interpretation of hydrogeologic conditions from earlier reports (Slade, 1986 and 1988), included extensive detail on major aspects of the groundwater basin. Notable parts of the Update Report relative to groundwater supply included:

- Analysis of historical groundwater levels and production indicates that there have been no conditions that would be illustrative of groundwater overdraft;

- Utilization of operational yield (as opposed to perennial yield) as a basis for managing groundwater production would be more applicable in this basin to reflect fluctuating utilization of groundwater in conjunction with imported SWP water;

- Operational yield of the Alluvium would typically be 30,000 to 40,000 afy for wet and normal rainfall years, with an expected reduction into the range of 30,000 to 35,000 afy in dry years;

- Operational yield of the Saugus Formation would typically be in the range of 7,500 to 15,000 afy on a long-term basis, with possible short-term increases during dry periods into a range of 15,000 to 25,000 afy, and to 35,000 afy if dry conditions continue.

Following on the 2001 Update Report, the groundwater component of overall water supply in the Valley derives from a groundwater operating plan to meet water requirements (municipal, agricultural, small domestic) while maintaining the basin in a sustainable condition (i.e., no long-term depletion of groundwater or interrelated surface water). This operating plan also addresses groundwater contamination issues in the basin, all consistent with the adopted Groundwater Management Plan. The groundwater operating plan is based on the concept that pumping can vary from year to year to generally rely on increased groundwater use in dry periods and increased recharge during wet periods, and to collectively assure that the groundwater basin is adequately replenished through various wet/dry cycles.

The groundwater operating plan, summarized in Table III-1, is as follows:

Alluvium – Pumping from the Alluvial Aquifer in a given year is related to local hydrologic conditions in the eastern Santa Clara River watershed. Pumping is expected to typically range between 30,000 and 40,000 afy during normal and above-normal rainfall years. Due to hydrogeologic constraints in the eastern part of the Basin, pumping is expected to be typically reduced to between 30,000 and 35,000 afy during locally dry years.

Saugus Formation – Pumping from the Saugus Formation in a given year is related to the availability of other water supplies, particularly from the SWP. During average-year conditions within the SWP system, Saugus pumping is expected to typically range between 7,500 and 15,000 afy. Planned dry-year pumping from the Saugus Formation is expected to range between 15,000 and 25,000 afy during a drought year and can increase to between 21,000 and 25,000 afy if SWP deliveries are reduced for two consecutive years, and between 21,000 and 35,000 afy if SWP deliveries are reduced for three consecutive years. Such high pumping is expected to typically be followed by periods of reduced (average-year) pumping, at rates between 7,500 and 15,000 afy, to further enhance the effectiveness of natural recharge processes that would recover water levels and groundwater storage volumes after the higher pumping during dry years.

Table III-1
Groundwater Operating Plan for the Santa Clarita Valley

Aquifer	Groundwater Production (af)			
	Normal Years	**Dry Year 1**	**Dry Year 2**	**Dry Year 3**
Alluvium	30,000 to 40,000	30,000 to 35,000	30,000 to 35,000	30,000 to 35,000
Saugus	7,500 to 15,000	15,000 to 25,000	21,000 to 25,000	21,000 to 35,000
Total	**37,500 to 55,000**	**45,000 to 60,000**	**51,000 to 60,000**	**51,000 to 70,000**

In 2004, as part of analyzing the restoration of perchlorate-impacted groundwater supply in the Valley, a numerical groundwater flow model was developed and calibrated for use in analyzing the response of the groundwater basin to long-term operation at the operational yields noted above, with focus on perchlorate extraction and the control of perchlorate migration in the basin. That groundwater flow model was then utilized in 2005 to specifically analyze the sustainability of groundwater supplies in both the Alluvium and the Saugus Formation through a long-term (78 year) hydrologic period that was selected to examine groundwater basin response to variations in pumping in accordance with the operating plan. Resultant projections of groundwater levels, groundwater storage, and surface water flows showed the basin to respond in a long-term sustainable manner, with no chronic depletion of groundwater levels, storage, or stream flows. The analysis of groundwater sustainability was summarized in a Basin Yield Report (CH2M Hill and LSCE, 2005), which included the following findings:

- The groundwater basin has historically been, and continues to be, in good operating condition and not in overdraft conditions, as indicated by historical data.

- The groundwater plan is sustainable over varying hydrologic conditions, because it is feasible to intermittently exceed a long-term average yield for one or more years without creating long-term adverse impacts to the groundwater system and the Santa Clara River.

- The groundwater operating plan for the Alluvium and the Saugus Formation can be used for long-term water supply planning purposes. In particular, although increased pumping from the Saugus Formation during dry periods can be expected to cause short-term declines in groundwater levels, it is not projected to cause permanent declines in groundwater discharges or streamflow. Saugus groundwater levels can be expected to recover to pre-drought conditions when pumping is reduced in subsequent wet to normal years.

- The strategy around which the groundwater operating plan was designed (maximizing the use of Alluvial Aquifer and imported water during years of normal or above-normal availability of these supplies, while limiting the use of the Saugus Formation during these periods, then temporarily increasing Saugus pumping during years when SWP supplies are significantly reduced because of drought conditions) is viable on a long-term basis.

- The historical observations of basin conditions and the model simulations together support the historical and ongoing confidence that groundwater can continue to be a sustainable source of water supply under the groundwater operating plan.

3.2 Alluvium – General

The spatial extent of the aquifers used for groundwater supply in the Valley, the Alluvium and the Saugus Formation, are illustrated in Figure III-1. Geologic descriptions and hydrogeologic details related to both aquifers are included in several technical reports including Slade (1986, 1988 & 2002), CH2M Hill (2005) and LSCE (2005), and in the 2005 Urban Water Management Plan.

Consistent with the 2001 Update Report (Slade), the 2005 Basin Yield Report (CH2M Hill and LSCE), and the 2005 UWMP, the management practice of the Purveyors continues to be to rely on groundwater from the Alluvium for part of the overall municipal water supply, whereby total pumping from the Alluvium (by municipal, agricultural, and small private pumpers) is in accordance with the groundwater operating plan, 30,000 to 40,000 afy in wet and normal years, with possible reduction to 30,000 to 35,000 afy in dry years. Such operation will maximize use of the Alluvium because of the aquifer's ability to store and produce good quality water on a sustainable basis, and because the Alluvium is capable of rapid recovery of groundwater storage in wet periods. As with many groundwater basins, it is possible to intermittently exceed a long-term average yield for one or more years without long-term adverse effects. Higher pumping for short periods may temporarily lower groundwater storage and related water levels, as has been the case in the Alluvium several times since the 1930's. However, subsequent decreases in pumping limit the amount of water level decline. Normal to wet-period recharge results in a rapid return of groundwater levels to historic highs. Historical groundwater data collected from the Alluvium over numerous hydrologic cycles continue to provide assurance that groundwater elevations, if locally lowered during dry periods, recover in subsequent average or wet years. Such water level response to rainfall is a significant characteristic of permeable, porous, alluvial aquifer systems that occur within large watersheds. In light of these historical observations,

complemented by the long-term sustainability analysis using the numerical groundwater flow model, there is ongoing confidence that groundwater will continue to be a sustainable source of water supply at the rates of pumping described in the Basin Yield Report, now incorporated in the 2005 UWMP.

Long-term adverse impacts to the Alluvium could occur if the amount of water extracted from the aquifer were to exceed the amount of water that recharges the aquifer over an extended period. However, the quantity and quality of water in the Alluvium and all significant pumping from the Alluvium are routinely monitored, and no long-term adverse impacts have ever been evident. Ultimately, the Purveyors have identified cooperative measures to be taken, if needed, to ensure sustained use of the aquifer. Such measures include but are not limited to the continuation of conjunctive use of imported SWP surface water with local groundwater, artificial recharge of the aquifer with local runoff or other surface water supplies, financial incentives discouraging extractions above a selected limit, expanded use of other water supplies such as recycled water, and expanded implementation of demand-side management, including conservation.

3.2.1 Alluvium – Historical and Current Conditions

Total pumping from the Alluvium in 2006 was about 43,000 af, an increase of about 4,300 af from the preceding year. Total Alluvium pumping was thus slightly above the groundwater operating plan range. Of the total Alluvial pumpage in 2006, about 27,200 af (63 percent) was for municipal water supply, and the balance, about 15,800 af (37 percent), was for agriculture and other smaller uses, including individual domestic uses. Most of the increased pumping from the Alluvium in 2006, when compared to the preceding year, was attributable to an increase in pumping for agricultural irrigation. In a longer-term context, there has been a change in municipal/agricultural pumping distribution since SWP deliveries began in 1980, toward a slightly higher fraction for municipal water supply (from about 50 percent to more than 60 percent of Alluvial pumpage), which reflects the general land use changes in the area. Ultimately, on a long-term average basis since the importation of SWP water, total Alluvial pumping has been almost 31,500 afy, which is at the lower end of the range of operational yield of the Alluvium. The overall historic record of Alluvial pumping is illustrated in Figure III-2.

Groundwater levels in various parts of the basin have historically exhibited different responses to both pumpage and climatic fluctuations. During the last 20 to 30 years, depending on location, Alluvial groundwater levels have remained nearly constant (generally toward the western end of the basin), or have fluctuated from near the ground surface when the basin is full, to as much as

100 feet lower during intermittent dry periods of reduced recharge (generally toward the eastern end of the basin). For illustration of the various groundwater level conditions, the Alluvial wells have been grouped into areas with similar groundwater level patterns as illustrated in Figure III-3. Figures III-4 and III-5 present historical groundwater levels organized into hydrograph form (groundwater elevation vs. time) for four areas throughout the basin. The other areas shown in Figure III-3 exhibit groundwater level responses that are similar to those illustrated in the four areas.

The ‘Mint Canyon’ area, located at the far eastern end of the groundwater basin, and the nearby ‘Above Saugus WRP’ and ‘Bouquet Canyon’ areas generally exhibit similar groundwater level responses. Those parts of the Alluvium have historically experienced a number of alternating wet and dry hydrologic conditions (Figure III-4) during which groundwater level declines have been followed by returns to historic highs. When water levels are low, well yields and pumping capacities in this area can be impacted. The affected Purveyors typically respond by increasing use of Saugus Formation and imported (SWP) supplies, as shown in Table II-8. The Purveyors also shift a fraction of the Alluvial pumping that would normally be supplied by ‘Mint Canyon’ area wells to areas further west, where well yields and pumping capacities remain fairly constant because of smaller groundwater level fluctuations. As shown in Figure III-6, the Purveyors decreased total Alluvial pumping from the ‘Mint Canyon’ area steadily from 2000 through 2003, and correspondingly increased pumping in the ‘Below Saugus WRP’ and ‘Below Valencia WRP’ areas. In spite of a continued period of below-average precipitation from 1999 to 2003, that progressive decrease in pumping resulted in a cessation of groundwater level decline in the ‘Mint Canyon’ area in 2002 and 2003. Subsequently, wet conditions in late 2004, continuing into 2005, resulted in full recovery of groundwater storage. With such high groundwater levels, pumping in the ‘Mint Canyon’ area was increased in 2005 and further increased in 2006, with no significant change in groundwater levels in 2005 and a slight decrease in 2006.

The ‘Below Saugus WRP’ area (Figure III-4), along the Santa Clara River immediately downstream of the Saugus Water Reclamation Plant, and the ‘San Francisquito Canyon’ area generally exhibit similar groundwater levels. In this middle part of the basin, historical groundwater levels were lower in the 1950's and 60's than current levels. Groundwater levels in this area notably recovered as pumping declined through the 1960's and 1970's. They have subsequently sustained generally high levels for much of the last 30 years, with three dry-period exceptions: mid-1970's, late 1980's to early 1990's, and the late 1990’s to early 2000’s. Recoveries to previous high groundwater levels followed both of the short dry-period declines in the 1970's and 1990's. Most recently, groundwater levels recovered significantly following a

wetter-than-average year in 2004 and significantly wet 2005. In 2006, groundwater levels remained largely unchanged in this area.

The ‘Castaic Valley’ area is located along Castaic Creek below Castaic Lake. In that area, groundwater levels have remained fairly constant, with slight responses to climatic and other fluctuations, since the 1950’s (Figure III-5). Small changes in groundwater levels in 2006 were consistent with other short-term historical fluctuations. The long-term, generally constant trend remained through 2006.

The ‘Below Valencia WRP’ area is located along the Santa Clara River downstream of the Valencia Water Reclamation Plant, where discharges of treated effluent from the Valencia WRP to the Santa Clara River contribute to groundwater recharge. Groundwater levels in this area exhibit slight, if any, response to climatic fluctuations, and have remained fairly constant since the 1950’s despite, over the last 20 years, a notable increase in pumping that continued through 2006 in that area (Figure III-5 and III-6).

In summary, depending on the period of available data, all the history of groundwater levels in the Alluvium shows the same general picture: recent (last 30 years) groundwater levels have exhibited historic highs; in some locations, there are intermittent dry-period declines (resulting from use of some groundwater from storage) followed by wet-period recoveries (and associated refilling of storage space). On a long-term basis, whether over the last 27 years since importation of supplemental SWP water, or over the last 40 to 50 years (since the 1950's - 60's), the Alluvium shows no signs of water level-related overdraft, i.e., no trend toward decreasing water levels and storage. Consequently, pumping from the Alluvium has been and continues to be sustainable, well within the operational yield of that aquifer on a long-term average basis, and also within the operating yield in almost every individual year.

3.3 Saugus Formation – General

Saugus wells operated by the Purveyors are located in the southern portion of the basin south of the Santa Clara River (Figure III-7). Consistent with the 2001 Update Report (Slade) and the 2005 Basin Yield Report (CH2M Hill and LSCE), the management practice of the Purveyors is to utilize the Saugus in accordance with the groundwater operating plan, in the range of 7,500 to 15,000 afy in average/normal years, and planned dry-year pumping of 15,000 to 35,000 afy for one to three consecutive dry years, when shortages to CLWA’s SWP water supplies could occur. Such high pumping would be followed by periods of lower pumping (7,500 to 15,000 afy in average/normal years as noted above) in order to allow recharge to recover water levels and

storage in the Saugus. Maintaining the substantial volume of water in the Saugus Formation is an important strategy to help maintain water supplies in the Santa Clarita Valley during drought periods.

3.3.1 Saugus Formation – Historical and Current Conditions

Total pumping from the Saugus in 2006 was about 7,300 af, or about 750 af more than in the preceding year. Of the total Saugus pumping in 2006, most (nearly 5,900 af) was for municipal water supply, and the balance (1,400 af) was for agricultural and other irrigation uses. Historically, groundwater pumping from the Saugus peaked in the early 1990's and then steadily declined through the remainder of that decade. Since then, Saugus pumping had been in the range of about 4,000 to 6,500 afy, with the increase to about 7,300 af in 2006. On a long-term average basis since the importation of SWP water, total pumping from the Saugus Formation has ranged between a low of about 3,700 afy (in 1999) and a high of nearly 15,000 afy (in 1991); average pumping from 1980 to present has been about 6,700 afy. These pumping rates remain well within, and generally at the lower end of the range of operational yield of the Saugus Formation. The overall historic record of Saugus pumping is illustrated in Figure III-8.

Unlike the Alluvium, which has an abundance of wells with extensive water level records, the water level data for the Saugus Formation are limited by both the distribution of the wells in that Formation and the periods of water level record. The wells that do have water level records extending back to the mid-1960's indicate that groundwater levels in the Saugus Formation were highest in the mid-1980's and are currently higher than they were in the mid-1960's (Figure III-9). Based on these data, there is no evidence of any historic or recent trend toward permanent water level or storage decline.

Consistent with the 2001 Update Report (Slade), the 2005 Basin Yield Report (CH2M Hill and LSCE), and the 2005 UWMP, the management practice of the Purveyors continues to be to maintain groundwater storage and associated water levels in the Saugus Formation so that supply is available during drought periods, when Alluvial pumping might be reduced and SWP supplies also could be decreased. The period of increased pumping during the early 1990's is a good example of this management strategy. Most notably, in 1991, when SWP deliveries were substantially reduced, increased pumping from the Saugus made up almost half of the decrease in SWP deliveries. The increased Saugus pumping over several consecutive dry years (1991-1994) resulted in short-term declining groundwater levels, reflecting the use of water from storage. However, groundwater levels subsequently recovered when pumping declined, reflecting recovery of groundwater storage in the Saugus Formation.

3.4 Imported Water

CLWA obtains water supplies from the State Water Project (SWP), which is owned and operated by the California Department of Water Resources (DWR). CLWA is one of 29 contractors holding long-term SWP contracts with DWR. SWP water originates as rainfall and snowmelt in northern and central California. Runoff is stored in Lake Oroville, which is the project's largest storage facility. The water is then released from Lake Oroville down the Feather River to the Sacramento River and through the Sacramento-San Joaquin Delta. Water is diverted from the Delta into the Clifton Court Forebay, and then pumped into the 444-mile long California Aqueduct. SWP water is temporarily stored in San Luis Reservoir, which is jointly operated by DWR and the U.S. Bureau of Reclamation. Prior to delivery to CLWA, SWP supplies are stored in Castaic Lake, located at the end of the West Branch of the California Aqueduct.

CLWA's service area covers approximately 195 square miles (124,800 acres), including the City of Santa Clarita and surrounding unincorporated communities. CLWA obtains SWP water from a SWP terminal reservoir, Castaic Lake. The water is treated, filtered and disinfected at CLWA's Earl Schmidt Filtration Plant and Rio Vista Water Treatment Plant, which have a combined treatment capacity of 86 million gallons per day. Treated water is delivered from the treatment plants by gravity flow to each of the four Purveyors through a distribution network of pipelines and turnouts. At present, CLWA delivers water to the four Purveyors through 25 turnouts as schematically illustrated in Figure III-10.

In 2006, CLWA fulfilled the following major accomplishments in order to enhance, preserve, and strengthen the quality and reliability of existing and future supplies:

- completed construction of the Sand Canyon Pipeline and Pump Station, and commenced construction on the Sand Canyon Reservoir;
- certified an Environmental Impact Report and initiated design for the Rio Vista Water Treatment Plant expansion;
- delivered 20,000 af of surplus SWP Table A water into the Rosedale-Rio Bravo Water Banking and Exchange Program;
- certified an Environmental Impact Report for acquisition of 11,000 afy of Kern River supplies through the Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement;
- exercised the right to utilize 1,376 af of flexible storage in Castaic Lake through an agreement with Ventura County SWP contractors;

- continued implementation of various water supply programs recommended in the UWMP;
- continued implementation of the AB 3030 Groundwater Management Plan;
- continued implementation of the water conservation Best Management Practices;
- continued cooperative effort with the U.S. Army Corps of Engineers for characterization studies of the former Whittaker-Bermite site and in a task force effort with the City of Santa Clarita, local legislators, and state agencies to effect the cleanup and remediation of all aspects of the former Whittaker-Bermite site, including perchlorate contamination of local groundwater; and
- continued work on the design and construction of facilities for restoration of groundwater supply wells impacted by perchlorate contamination.

3.4.1 State Water Project Table A Supplies

Each SWP contractor has a specified water supply amount shown in Table A of its contract that currently totals approximately 4.1 million af. The term of the CLWA contract is through 2038 and is renewable after that year. Although the SWP has not been fully completed, the SWP can deliver all of the 4.1 million af of Table A Amounts during very wet years.

CLWA has a contractual Table A Amount of 95,200 af per year of water from SWP.[2] CLWA's final allocation of Table A Amount for 2006 was 100 percent. On November 22, 2005, the

[2] 41,000 af of CLWA's 95,200 af Table A Amount was acquired from the Wheeler Ridge-Maricopa Water Storage District by way of a Table A water transfer agreement executed in March 1999. CLWA prepared an environmental impact report (EIR) to address the environmental consequences of the transfer agreement. The environmental review for the project by CLWA was the subject of litigation in Los Angeles Superior Court. CLWA prevailed in the EIR litigation at the trial court; however, the project opponents (Friends of the Santa Clara River) filed an appeal.

In January 2002, the Court of Appeal issued a decision ordering the Superior Court to decertify the EIR for the transfer agreement on the grounds that it had tiered off of another EIR that had been subsequently decertified in other litigation. In doing so, however, the Court of Appeal also examined all of the plantiffs' other arguments, found them to be without merit, and held that, if the tiering problem had not arisen, it would have affirmed the earlier trial court judgment upholding the EIR.

The Court of Appeal did not invalidate any portion of the completed 41,000 afy transfer agreement. Instead, the Court directed the trial court to vacate certification of the EIR, and to retain jurisdiction until CLWA corrects the tiering technicality by preparing a new EIR. In September 2002, the Los Angeles Superior Court refused to prohibit CLWA from using the 41,000 af of Table A water while a new EIR is being prepared. The Superior Court decision on remand was appealed by Friends of the Santa Clara River to the appellate court in January 2003. In December 2003, the appellate court denied any relief to Friends and affirmed the trial court's ruling.

The revised EIR was released for public review and comment in April 2004. It was subsequently certified by the CLWA Board of Directors on December 23, 2004. On January 24, 2005, separate lawsuits challenging the environmental review for this same project were filed by California Water Impact Network and Planning and

initial allocation for 2006 was announced as 55 percent. On December 14, 2005, it was raised to 65 percent. On January 17 and March 23, 2006 the allocation was increased to 70 percent and 80 percent, respectively. On April 18, 2006 the final allocation of 100 percent was announced.

In addition to its Table A Amount, CLWA also has access to 4,684 af of "flexible storage" in Castaic Lake. In addition, during 2005 CLWA negotiated an agreement with the Ventura County SWP contractors to allow CLWA to utilize their flexible storage account of 1,376 af. In combination, this provides total flexible storage of 6,060 af, which is maintained in Castaic Lake for use in a future dry period or an emergency. This amount was available in 2006, but was not utilized due to wet conditions statewide.

As delineated in Table III-2, due to the 100 percent allocation, CLWA had excess SWP water in 2006. As DWR increased the allocation through the year, and due to a net 3,905 af of carryover from 2005, the total available SWP supply in 2006 was 99,105 af. CLWA deliveries were 40,646 af to the Purveyors and 20,000 af to its account in the Rosedale-Rio Bravo Water Banking and Exchange Program, leaving more than 34,484 af of Table A Amount available for carryover to 2007. Portions of the carryover water from 2005 were utilized for local deliveries to the Purveyors, as well as Rosedale-Rio Bravo banking program deliveries.

As described in the 2005 Water Report, CLWA completed an agreement in 2005 to participate in a long-term water banking program with Rosedale-Rio Bravo Water Storage District in Kern County. CLWA delivered 20,000 af of its Table A water into storage in 2005. As noted above, CLWA delivered another 20,000 af into that storage account in 2006. This long-term program will allow the storage of 100,000 af at any one time, and will provide significant dry year reliability for the Santa Clarita Valley.

3.4.2 Other Imported Water Supplies

In early 2007, CLWA finalized a Water Acquisition Agreement with the Buena Vista Water Storage District (Buena Vista) and the Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo) in Kern County. Under this Program, Buena Vista's high flow Kern River entitlements (and other acquired waters that may become available) are captured and recharged within

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Conservation League in the Ventura County Superior Court. On March 19, 2007, the Los Angeles Superior Court ruled that the 2004 EIR was properly prepared except for one defect – it failed to show an adequate analytical basis for the assumed impacts of the Monterey Amendments on the SWP allocations. The court also ruled that the transfer contract should not be set aside but ordered that certification of the EIR should be set aside and corrected to include the analytical basis for the three allocation scenarios in the EIR. CLWA is evaluating the method of correction to the EIR on this limited issue.

Table III-2
2006 CLWA State Water Project Supply and Disposition
(acre-feet)

Supply		
Net 2005 Carryover to 2006 [1]		3,905
CLWA 2006 Final Allocation [2]		95,200
Total 2006 SWP Supply		**99,105**
Disposition		
Purveyor Deliveries (Total)		40,646
CLWA SCWD	*17,146*	
Valencia Water Company	*16,313*	
Newhall County Water District	*5,898*	
Los Angeles County WWD 36	*1,289*	
CLWA/DWR/Purveyor Metering[3]		(25)
Rosedale – Rio Bravo Water Banking and Exchange Program		20,000
2005 Table A Carryover to 2006[4]		38,484
Total 2006 SWP Disposition		**99,105**

1. Amount used by CLWA, based on final DWR delivery accounting; total 2005 carryover was 31,377 af.

2. Final 2006 allocation was 100% of contractual Table A amount of 95,200 acre-feet, which progressed as follows:

Initial allocation, November 22, 2005	55%
Allocation increase, December 14, 2005	65%
Allocation increase, January 17, 2006	70%
Allocation increase, March 23, 2006	80%
Allocation increase, April 18, 2006	100%

Does not include 2,089 af of Article 21 water used at CLWA's Devil's Den Ranch in Kern and Kings Counties.

3. Reflects meter reading differences.

4. Total 2006 Table A carryover to 2007.

*

Rosedale-Rio Bravo's service area on an ongoing basis. CLWA will receive 11,000 af of these supplies annually through either exchange of Buena Vista's and Rosedale-Rio Bravo's SWP supplies or through direct delivery of water to the California Aqueduct via the Cross Valley Canal. Additionally, CLWA is entitled to 22,000 af of water that was stored in the Rosedale-Rio Bravo Water Banking and Exchange Program in 2005 and 2006 on CLWA's behalf as part of the Water Acquisition Agreement.

3.4.3 Imported Water Supply Reliability

In April 2006, the Department of Water Resources updated its State Water Project Delivery Reliability Report. That report is intended to assist SWP contractors in assessing the adequacy of the SWP component of their overall supplies. The report is updated with new information and calculations of delivery reliability every two years. A discussion of the Reliability Report, as well as the most significant opportunities for meeting the future water supply needs of the Santa Clarita Valley, is provided in the 2005 UWMP.

Groundwater banking and conjunctive use offer significant opportunities to improve water supply reliability for CLWA. Groundwater banking is the process of storing available supplies of water in groundwater basins during wet years or when supplemental water is otherwise available. During dry periods, or when normal imported water supplies are not otherwise available, banked water can be recovered from groundwater storage to replace, or firm up, the normal imported water supply.

As described herein, CLWA has entered into two groundwater banking programs and now has, in aggregate, over 100,000 acre-feet of recoverable water in banked groundwater storage outside the local groundwater basin. The first component of overall groundwater banking is the result of two 10-year agreements between CLWA and Semitropic Water Storage District whereby, in dry years, CLWA can withdraw up to 50,870 af of 2002 and 2003 SWP Table A water that it stored in Semitropic to meet Valley demands when needed.[3] More recently, after banking 20,000 acre-feet of its SWP Table A water in each of the last two years in the long-term Rosedale-Rio Bravo Water Banking and Exchange Program in Kern County, augmented by the acquisition of 22,000 acre-feet as part of the Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement, also banked in the Rosedale-Rio Bravo Water Banking and Exchange Program, CLWA now has a recoverable total of 57,600 acre-feet in that groundwater storage bank (i.e. 67,000 af less contractual losses).

[3] Legal challenges to the 2002 banking program with Semitropic were resolved by the appellate court in favor of CLWA on all issues.

Somewhat conceptually similar to groundwater banking, conjunctive use is the purposeful integrated use of surface water and groundwater supplies to maximize water supply from the two sources. CLWA and the Purveyors have been conjunctively utilizing local groundwater and imported (SWP) surface water since the initial importation of SWP water in 1980. The groundwater banking programs described above allow CLWA to firm up the SWP component of conjunctive use in the Valley by storing surplus SWP water, in wet years, in groundwater basins outside the Valley, thus allowing recovery and importation of that water as needed in dry years to maintain a greater overall amount of imported surface water to be used conjunctively with local groundwater, further supporting the sustainable use of local groundwater at the rates in the groundwater operating plan.

3.5 Water Quality – General

Water delivered by the Purveyors consistently meets drinking water standards set by the Environmental Protection Agency (EPA) and the California Department of Health Services (DHS). An annual Consumer Confidence Report is provided to all Santa Clarita Valley residents who receive water from one of the four water retailers. There is detailed information in that report, about the results of quality testing of the groundwater and treated SWP water supplied to the residents of the Santa Clarita Valley during 2006. Several constituents of particular local interest are discussed in more detail below.

Total Trihalomethanes

In 2002, the United States Environmental Protection Agency implemented the new Disinfectants and Disinfection Byproducts Rule. In part, this rule establishes a new MCL of 80 ug/L (based on an annual running average) for Total Trihalomethanes (TTHM). TTHMs are byproducts created when chlorine is used as a means for disinfection. CLWA and the Purveyors implemented an alternative method of disinfection, chloramination, in 2005 to maintain compliance with the new rule and future regulations relating to disinfection byproducts. TTHM concentrations have remained significantly below the MCL since implementation of alternative disinfection.

Perchlorate

Perchlorate has been a water quality concern in the Valley since 1997 when it was originally detected in four Saugus wells operated by the Purveyors in the eastern part of the Saugus Formation, near the former Whittaker-Bermite facility. In late 2002, perchlorate was detected in a fifth municipal well, in this case an Alluvial well (SCWD's Stadium Well) also located near the former Whittaker-Bermite site. In early 2005, perchlorate was detected in a second Alluvial

well (VWC's Well Q2) near the former Whittaker-Bermite site. In 2006, a very low concentration of perchlorate was detected in another Saugus well (NCWD's Well NC-13), near one of the originally impacted wells. However, that detection has been interpreted to not be an indication of continued perchlorate migration in a westerly direction. Subsequent monitoring well installation has been completed and a focused study of the Saugus Formation near this latest detection has been commenced. Results of this study and any subsequent recommended actions will be incorporated into the overall groundwater remediation and removal actions submitted by Whittaker-Bermite and reviewed by the State Department of Toxic Substances Control (DTSC) as discussed below.

Wells with perchlorate concentrations exceeding the then-applicable Action Level (18 ug/l) or, more recently, the Notification Level (6 ug/l) were removed from active water supply service. One of the Alluvial wells was returned to active water supply service, with treatment, in late 2005 as discussed below; the other impacted wells remain out of service. The 2005 UWMP specifically addressed the adequacy of groundwater supply in light of the inactivation of the impacted Alluvial and Saugus wells; and it addressed the plan and schedule for restoration of perchlorate-impacted wells, including the protection of existing non-impacted wells. As summarized in the 2005 UWMP, the inactivation of the impacted wells does not constrain the ability to meet the groundwater component of water supply in the Valley.

In 2000, CLWA and the impacted Purveyors had filed a lawsuit against Whittaker Corporation (the former owner of the contaminated property) and Santa Clarita LLC and Remediation Financial, Inc. (the owners of record at that time). The lawsuit sought to have defendants pay all necessary costs of response, removal of the contaminant, remedial actions, and any liabilities or damages associated with the contamination. An Interim Settlement and Funding Agreement was reached in 2003. Although that Agreement expired in January 2005, the parties, under DTSC oversight, jointly developed a plan to "pump and treat" contaminated water from two of the Purveyors' impacted wells to stop migration of the contaminant plume and to restore the municipal groundwater supply that has been impacted by perchlorate. The parties also continued negotiations intended to achieve a long term settlement to the litigation through 2006, and a final settlement was completed and executed in April 2007.

In 2006, the impacted Purveyors (SCWD, NCWD, and VWC) and CLWA continued working toward implementation of a jointly developed plan that will combine pumping from two of the impacted wells and a water treatment process to restore the impacted pumping capacity and control the migration of contamination in the aquifer. The development and implementation of a cleanup plan for the Whittaker-Bermite site and the impacted groundwater is being coordinated

among CLWA, the impacted Purveyors, the State DTSC, and U.S. Army Corps of Engineers. DTSC is the lead agency responsible for regulatory oversight of the Whittaker-Bermite site. In February 2003, DTSC and the impacted Purveyors entered into a voluntary cleanup agreement entitled *Environmental Oversight Agreement*. Under the Agreement, DTSC is providing review and oversight of the response activities being undertaken by the Purveyors related to the detection of perchlorate in the impacted wells. Under the Agreement's Scope of Work, the impacted Purveyors have prepared a Work Plan for sampling the production wells, prepared a report on the results and findings of the production well sampling, prepared a draft Human Health Risk Assessment, prepared a draft Remedial Action Workplan, completed the evaluation of treatment technologies, and completed an analysis to show the integrated effectiveness of a project to restore impacted pumping capacity, extract perchlorate for treatment, and control the migration of perchlorate in the Saugus Formation. Environmental review of that project was completed in 2005 with adoption of a mitigated Negative Declaration. The Final Interim Remedial Action Plan for containment and extraction of perchlorate was completed and approved by DTSC in January 2006. Design of the treatment facilities and related pipelines is complete. Construction of those facilities and pipelines to implement the pump and treat program and to also restore inactivated well capacity is anticipated to commence in mid-2007 and conclude in mid-2008, with the facilities on line by fall 2008.

On the Whittaker-Bermite site, soil remediation activities in operating unit subareas started in 2005. Groundwater pump and treat operations in the Northern Alluvium, which also started in 2005, continued through 2006. Expanded pumping, intended to effect perchlorate containment in the Northern Alluvium, is expected to be operational in 2007.

As noted above, perchlorate was detected in a second Alluvial well, VWC's Well Q2, in early 2005. In response, Valencia removed the well from active service, and commissioned the preparation of an analysis and report assessing the impact of, and response to, the perchlorate contamination of that well. Valencia's response for Well Q2 was to obtain permitting for installation of wellhead treatment, followed by installation of treatment facilities and returning the well to water supply service in October 2005. Well Q2 continues to be operated, with wellhead perchlorate treatment under permit from DHS, as part of Valencia's regular Alluvial groundwater supply. Ongoing treatment of water from Well Q2 is expected to continue until DHS determines that it is no longer needed. Depending on timing, the Perchlorate Treatment System at Well Q2 is planned to be relocated and integrated with the CLWA containment/restoration program described above after it is no longer needed at Well Q2.

3.5.1 Groundwater Quality – Alluvium

Groundwater quality is, of course, a key factor in assessing the Alluvial aquifer as a municipal and agricultural water supply. Groundwater quality details and long-term conditions, examined by integration of individual records from several wells completed in the same aquifer materials and in close proximity to each other, have been discussed in previous annual Water Reports and in the 2005 UWMP. There were no changes in groundwater quality in 2006 that would change any of the fluctuations, trends, or other groundwater quality conditions as illustrated in Figures III-11 and III-12. In summary, those conditions include: no long-term overall trend and, most notably, no long-term decline in Alluvial groundwater quality; a general groundwater quality "gradient" from east to west, with lowest dissolved mineral content to the east, increasing in a westerly direction; and periodic fluctuations in some parts of the basin, where groundwater quality has inversely varied with precipitation and stream flow. Those variations are typically characterized by increased mineral concentrations through dry, lower stream flow, and lower recharge conditions, followed by lower mineral concentrations through wetter, higher stream flow, higher recharge conditions.

The presence of long-term consistent water quality patterns, although intermittently affected by wet and dry cycles, supports the conclusion that the Alluvial aquifer remains a viable ongoing water supply source in terms of groundwater quality.

3.5.2 Groundwater Quality – Saugus Formation

As discussed above for the Alluvium, groundwater quality is a key factor in also assessing the Saugus Formation as a municipal and agricultural water supply. As with groundwater level data, long-term Saugus groundwater quality data are not sufficiently extensive to permit any sort of basin-wide analysis or assessment of pumping-related impacts on quality. However, integration of individual records from several wells has been used to examine general water quality trends. Based on those records, water quality in the Saugus Formation has not historically exhibited the precipitation-related fluctuations seen in the Alluvium. Based on available data over the last 50 years, groundwater quality in the Saugus has exhibited a slight overall increase in dissolved mineral content as illustrated in Figure III-13. More recently, several wells within the Saugus Formation have exhibited an additional increase in dissolved mineral content, similar to short-term changes in the Alluvium, possibly as a result of recharge to the Saugus Formation from the Alluvium. Dissolved mineral concentrations in the Saugus Formation remain below the Secondary (aesthetic) Upper Maximum Contaminant Level. Groundwater quality within the

Saugus will continue to be monitored to ensure that degradation to the long-term viability of the Saugus as an agricultural or municipal water supply does not occur.

3.5.3 Imported Water Quality

CLWA operates two water treatment plants, the Earl Schmidt Filtration Plant located near Castaic Lake and the Rio Vista Water Treatment Plant located in Saugus. CLWA produces water that meets drinking water standards set by the U.S. EPA and California DHS. SWP water has different aesthetic characteristics than groundwater with lower dissolved mineral concentrations (total dissolved solids) of approximately 280 to 314 mg/L, and lower hardness (as calcium carbonate) of 130 to 170 mg/l.

3.6 Recycled Water

Recycled water is available from two existing water reclamation plants operated by the Sanitation Districts of Los Angeles County. In 1993, CLWA prepared a draft Reclaimed Water System Master Plan that outlined a multi-phase program to deliver recycled water in the Valley. CLWA has completed environmental review on the construction of Phase I of the project, which will deliver 1,700 afy of water. Deliveries of recycled water began in 2003 for irrigation water supply at a golf course and in roadway median strips. In 2006, recycled water deliveries were 419 af.

Surveys conducted by CLWA indicate an interest for recycled water by existing water users as well as future development when it becomes available. In 2002, CLWA produced an updated Draft Recycled Water Master Plan. Overall, the program is expected to ultimately recycle up to 17,400 af of treated (tertiary) wastewater suitable for reuse on golf courses, landscaping and other non-potable uses, as set forth in the UWMP.

CLWA has completed California Environmental Quality Act (CEQA) analysis of the Recycled Water Master Plan (2002). This analysis consisted of a Program Environmental Impact Report (PEIR) covering the various options for a recycled water system as outlined in the Master Plan. The PEIR was certified by the CLWA Board in March 2007.

3.7 Santa Clara River

The Memorandum of Understanding (MOU) between the Santa Clarita Valley Purveyors and the United Water Conservation District, which manages surface and groundwater resources in seven

groundwater basins in the Lower Santa Clara River Valley Area, was a significant accomplishment when it was prepared and executed in 2001. The MOU initiated a collaborative and integrated approach to data collection; database management; groundwater flow modeling; assessment of groundwater basin conditions, including determination of basin yield amounts; and preparation and presentation of reports, including continued annual reports such as this one for current planning and consideration of development proposals, and also including more technically detailed reports on geologic and hydrologic aspects of the overall stream-aquifer system. Meetings of the MOU participants have continued, and integration of the Upper (Santa Clarita Valley) and Lower (United WCD) Santa Clara River databases has been accomplished. As discussed above, a numerical groundwater flow model of the entire Santa Clarita groundwater basin was developed and calibrated in 2002-2004. Subsequent to its initial use in 2004 for assessing the effectiveness of various operating scenarios to restore pumping capacity impacted by perchlorate contamination (by pumping and treating groundwater for water supply while simultaneously controlling the migration of contaminated groundwater), the model was used in 2005 for evaluation of basin yield under varying management actions and hydrologic conditions. The results completed the determination of sustainable operating yield values for both the Alluvium and the Saugus Formation, which are now incorporated in the 2005 UWMP.

On occasion, issues have been raised about whether use and management of groundwater in the Santa Clarita Valley have adversely impacted surface water flows into Ventura County. Part of the groundwater modeling work has addressed the surface water flow question as well as groundwater levels and storage. While the sustainability of groundwater has logically derived primarily from projected long-term stability of groundwater levels and storage, it has also derived in part from modeled simulations of surface water flows and the lack of stream flow depletion by groundwater pumping. In addition, the long-term history of groundwater levels in the western and central part of the basin, as illustrated in Figures III-4 and III-5, supports the modeled analysis and suggests that groundwater has not been lowered in such a way as to induce infiltration from the river and thus impact surface water flows. Finally, long-term stream flow data gauged near the County line show notably higher flows from the Santa Clarita Valley into the uppermost downstream basin, the Piru Basin, over the last 30 to 35 years, as illustrated in Figure III-14.

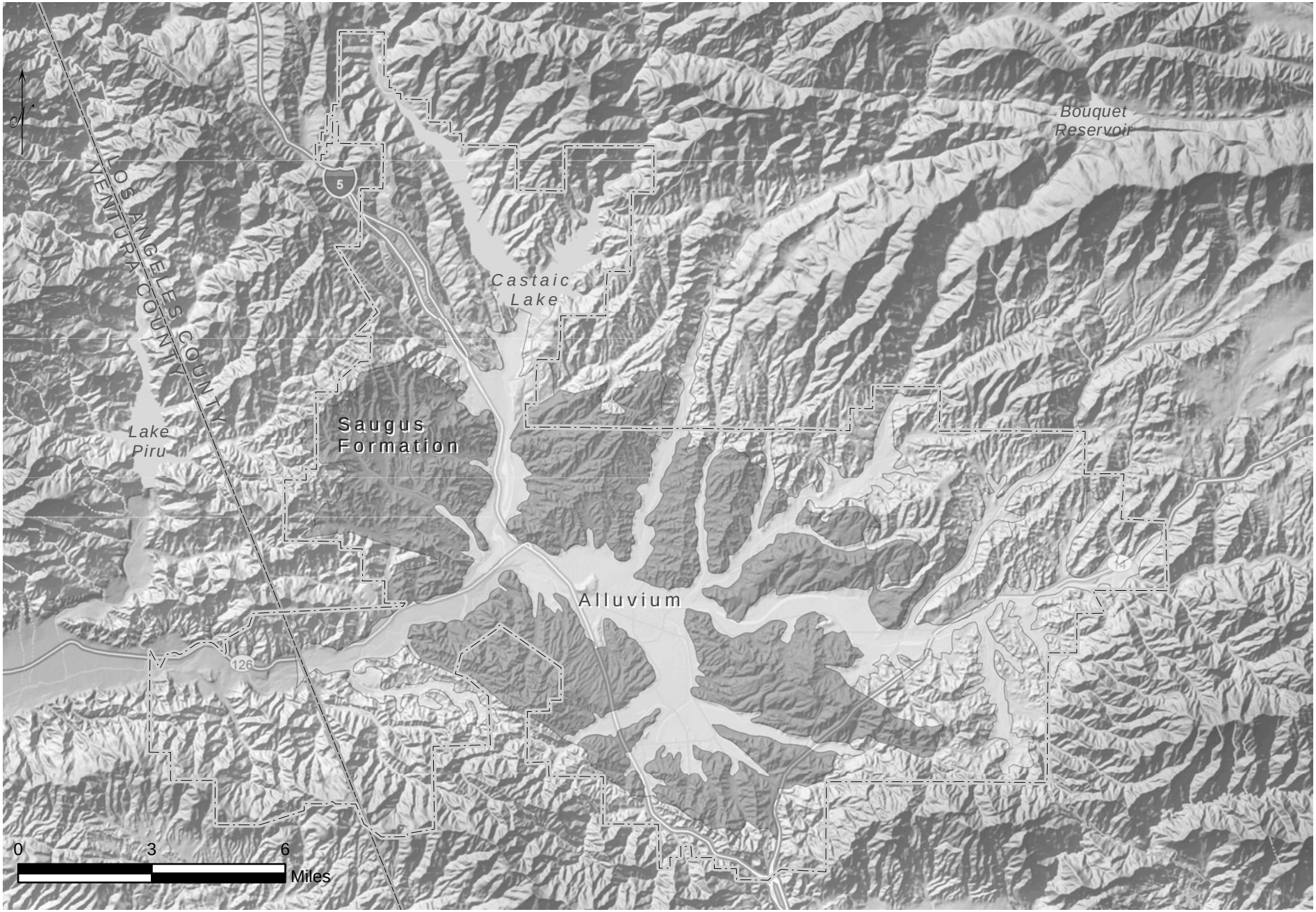

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Figure III-1
Alluvium and Saugus Formation
Santa Clara River Valley, East Groundwater Subbasin

Groundwater Production - Alluvium
Santa Clara River Valley, East Groundwater Subbasin

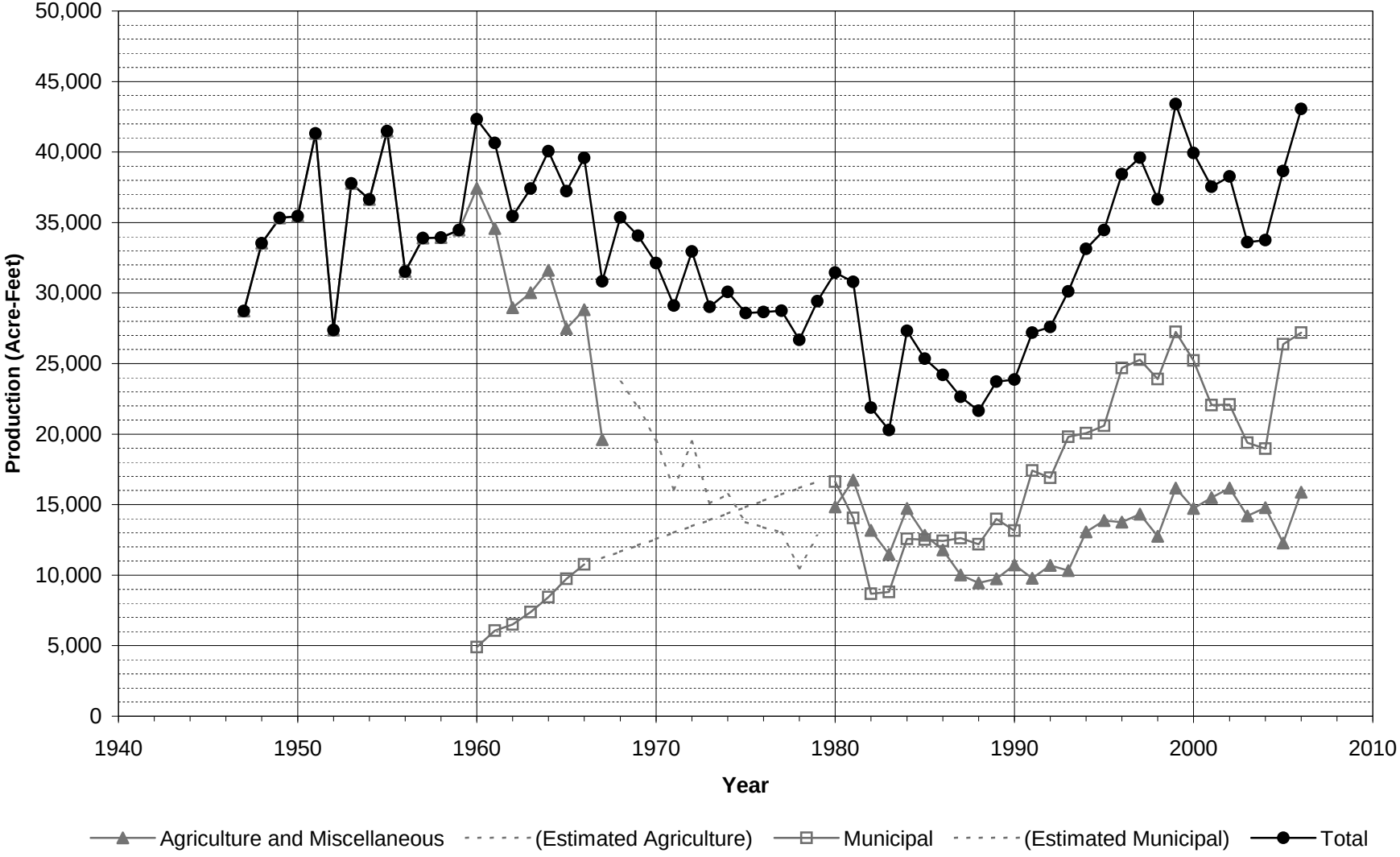

Figure III-2

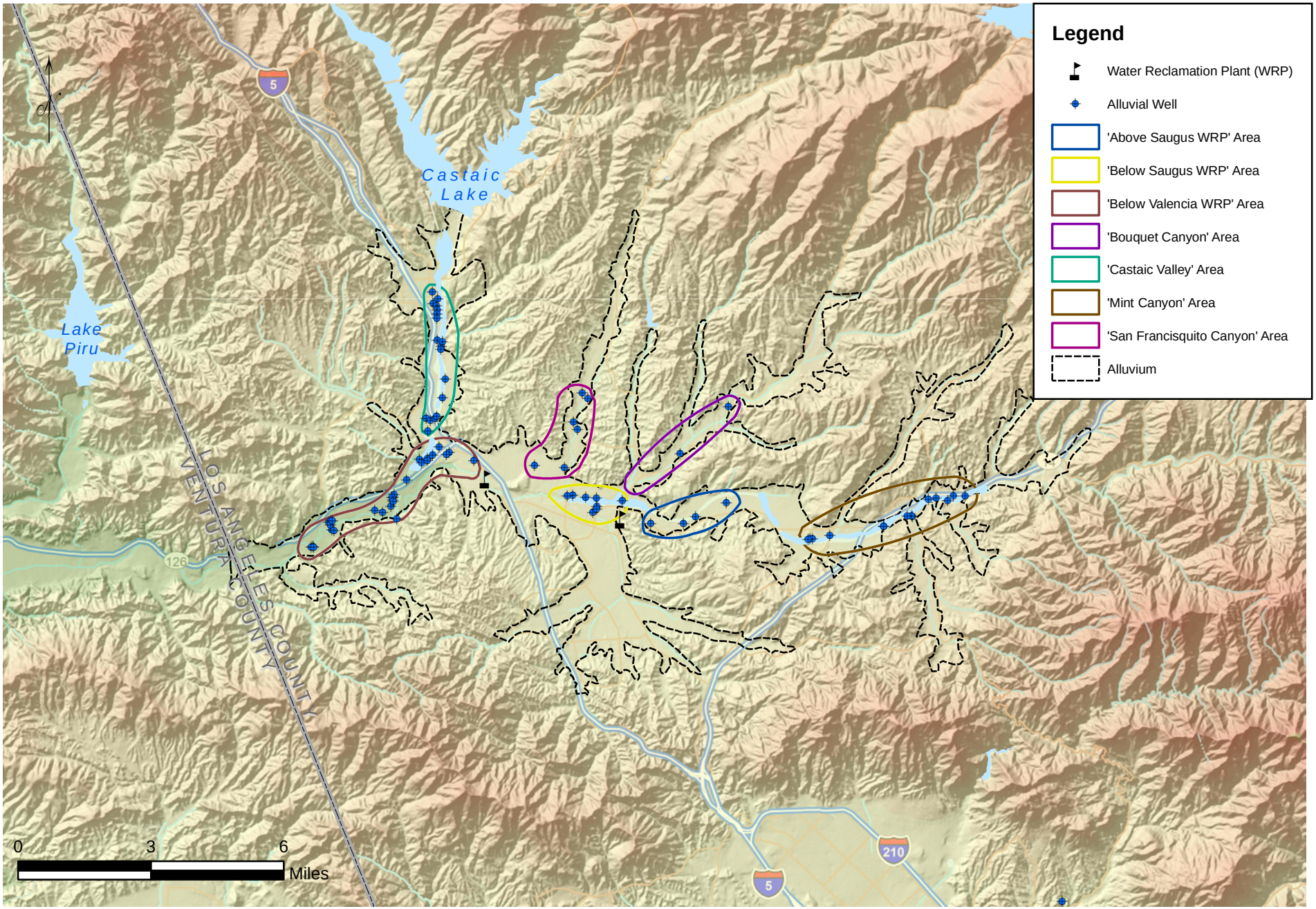

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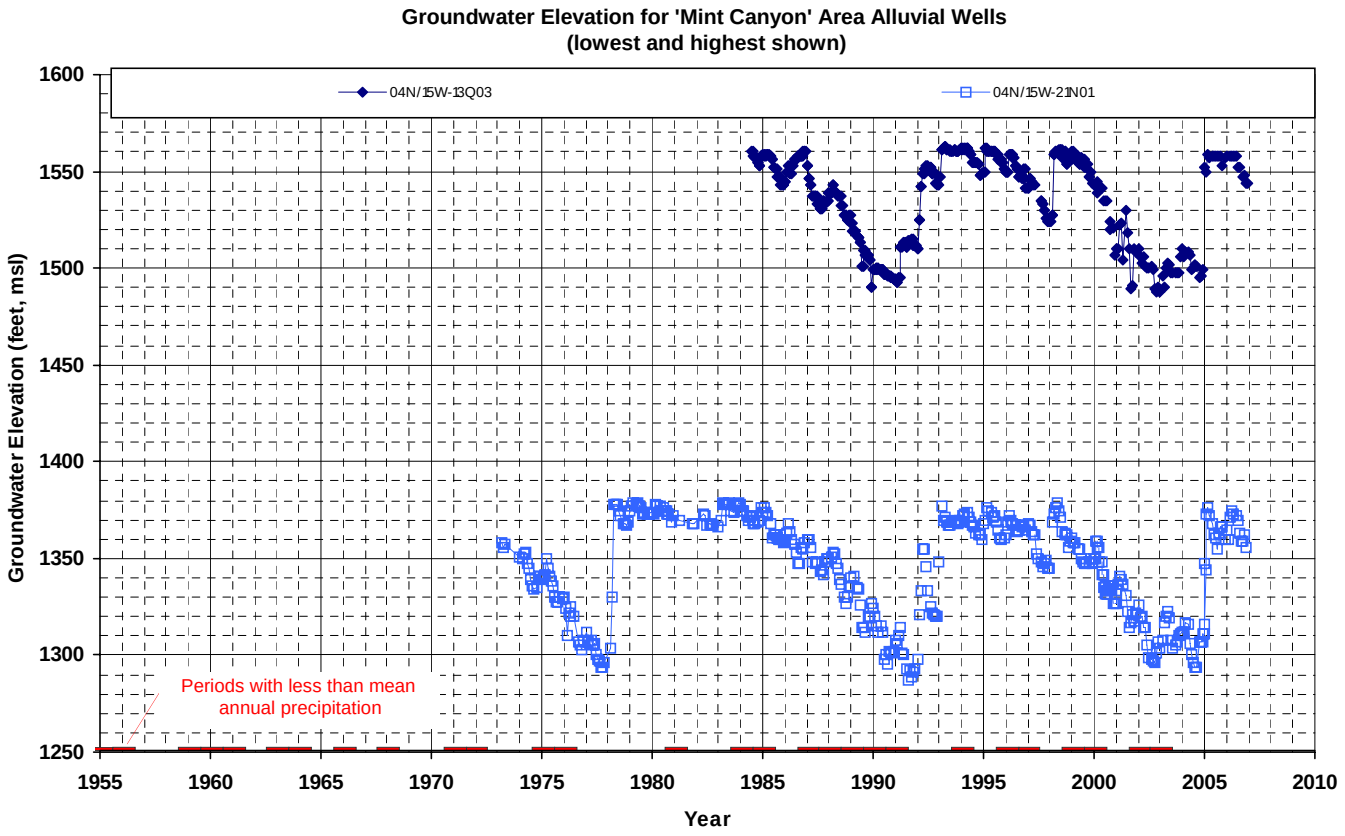
Figure III-3
Alluvial Well Locations By Area
Santa Clara River Valley, East Groundwater Subbasin


Groundwater Elevation for 'Mint Canyon' Area Alluvial Wells
(lowest and highest shown)
04N/15W-13Q03
04N/15W-21N01
Groundwater Elevation (feet, msl)
1600
1550
1500
1450
1400
1350
1300
1250
Periods with less than mean annual precipitation
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

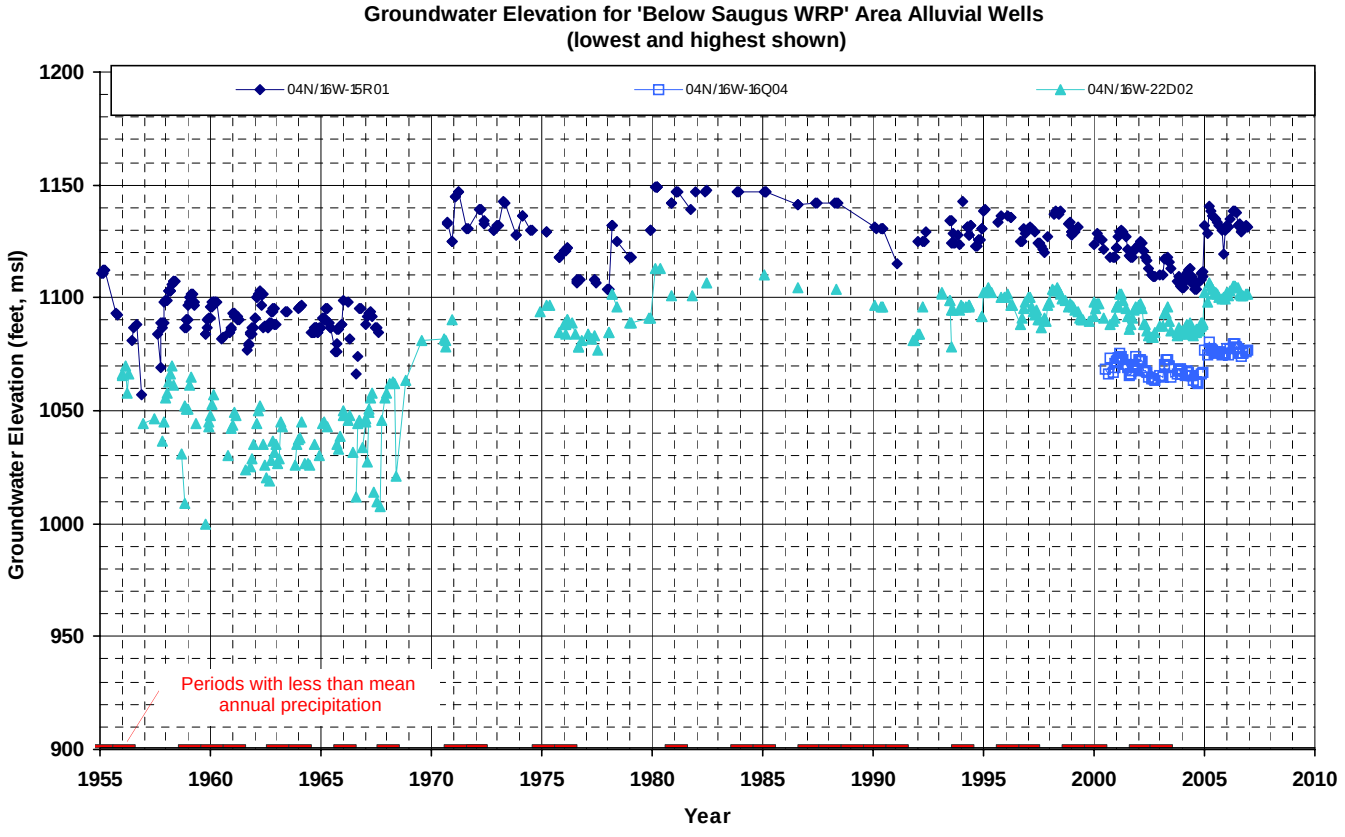
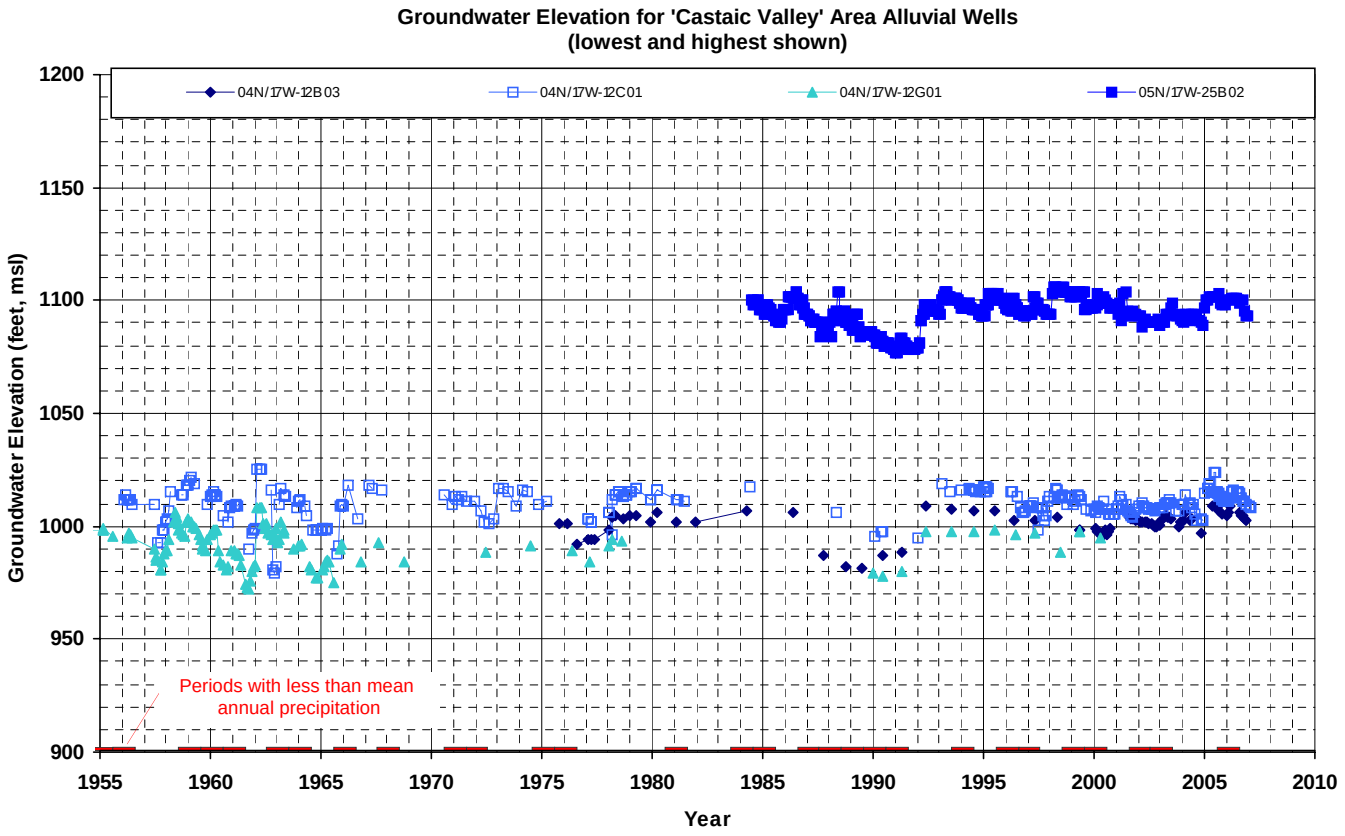

Groundwater Elevation for 'Below Saugus WRP' Area Alluvial Wells
(lowest and highest shown)
04N/16W-15R01
04N/16W-16Q04
04N/16W-22D02
Groundwater Elevation (feet, msl)
1200
1150
1100
1050
1000
950
900
Periods with less than mean annual precipitation
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

Figure III-4


Groundwater Elevation for 'Castaic Valley' Area Alluvial Wells
(lowest and highest shown)
04N/17W-12B03
04N/17W-12C01
04N/17W-12G01
05N/17W-25B02
Groundwater Elevation (feet, msl)
1200
1150
1100
1050
1000
950
900
Periods with less than mean annual precipitation
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

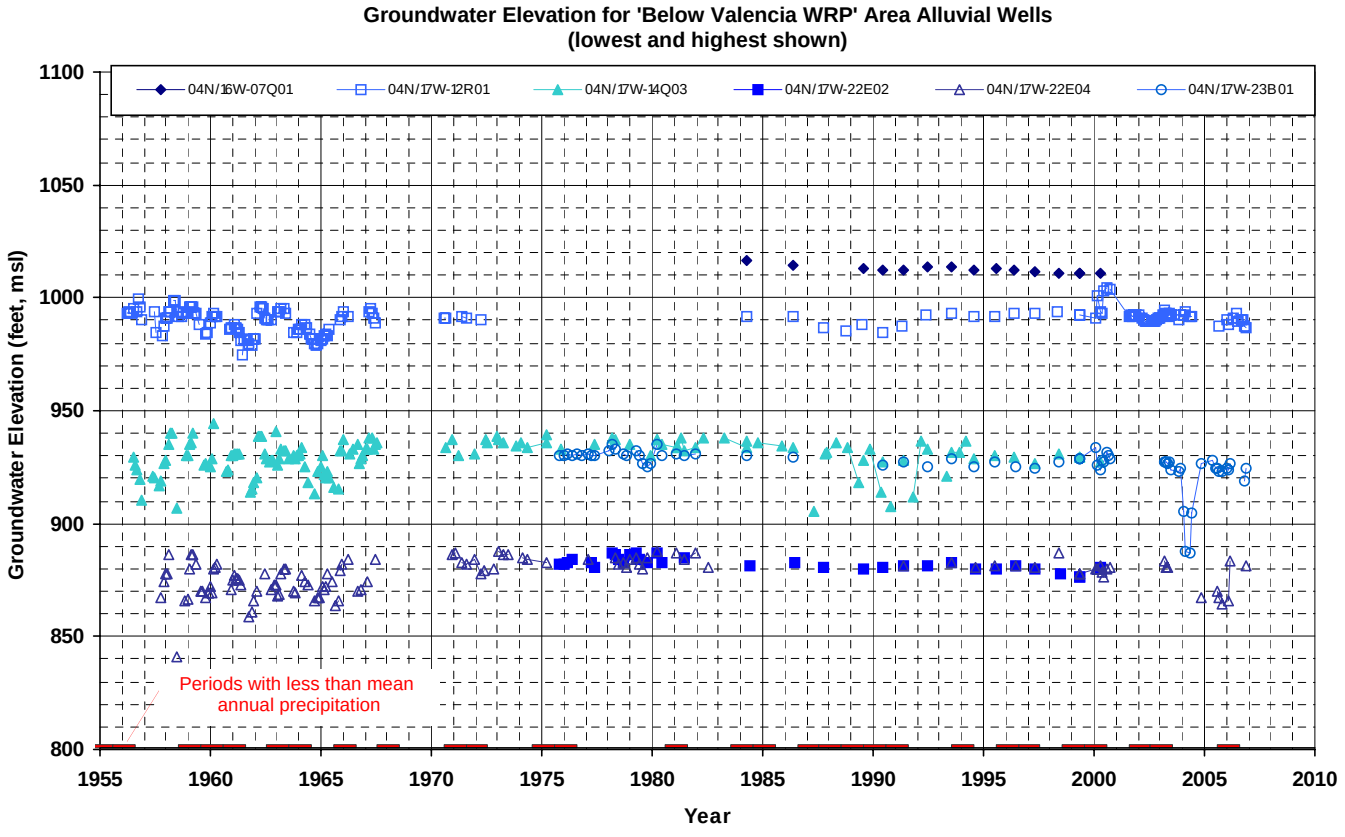

Groundwater Elevation for 'Below Valencia WRP' Area Alluvial Wells
(lowest and highest shown)
04N/16W-07Q01
04N/17W-12R01
04N/17W-14Q03
04N/17W-22E02
04N/17W-22E04
04N/17W-23B01
Groundwater Elevation (feet, msl)
1100
1050
1000
950
900
850
800
Periods with less than mean annual precipitation
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

Figure III-5

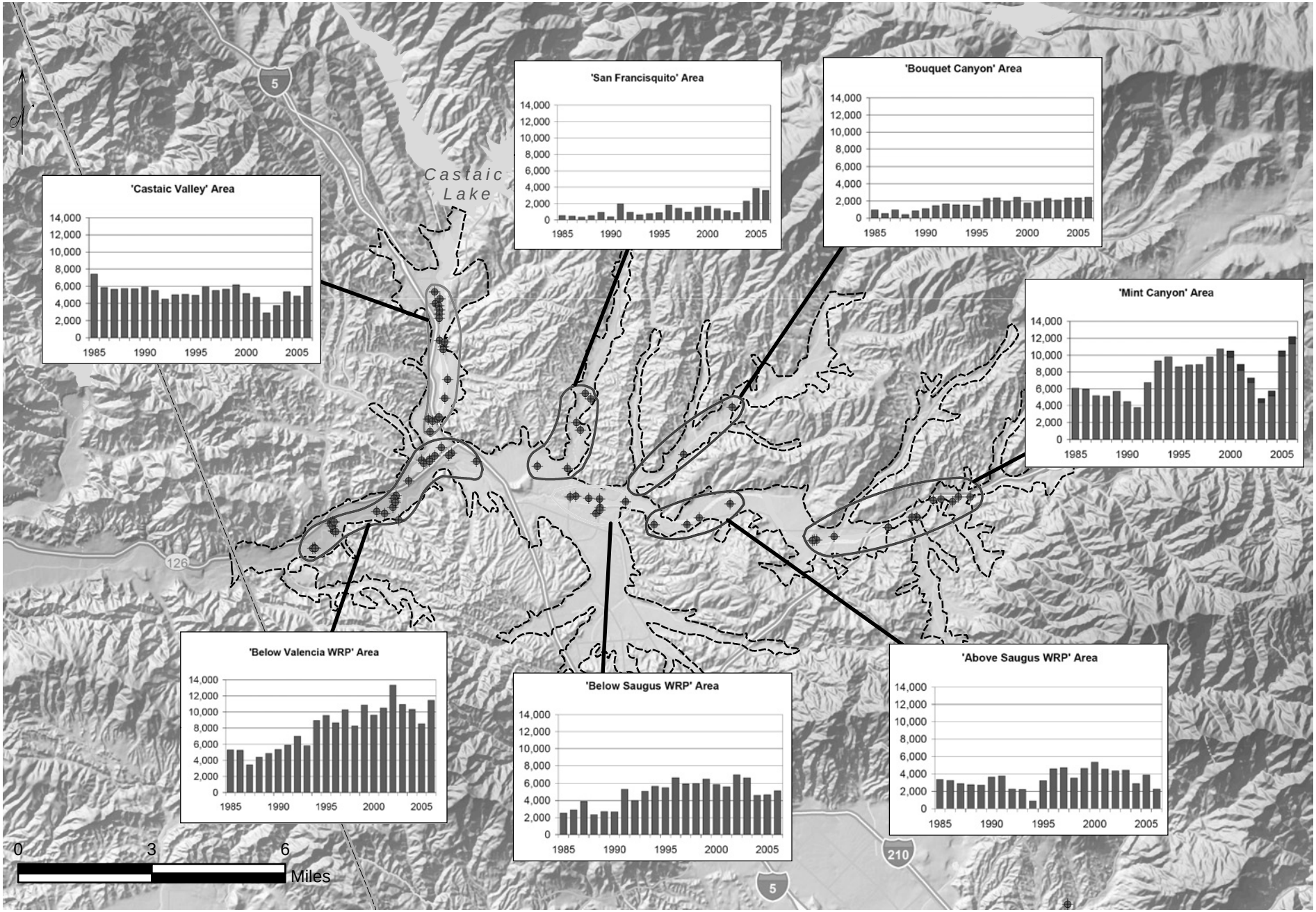


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Figure III-6
Annual Groundwater Production from Alluvium by Area (Acre-feet)
Santa Clara River Valley, East Groundwater Subbasin

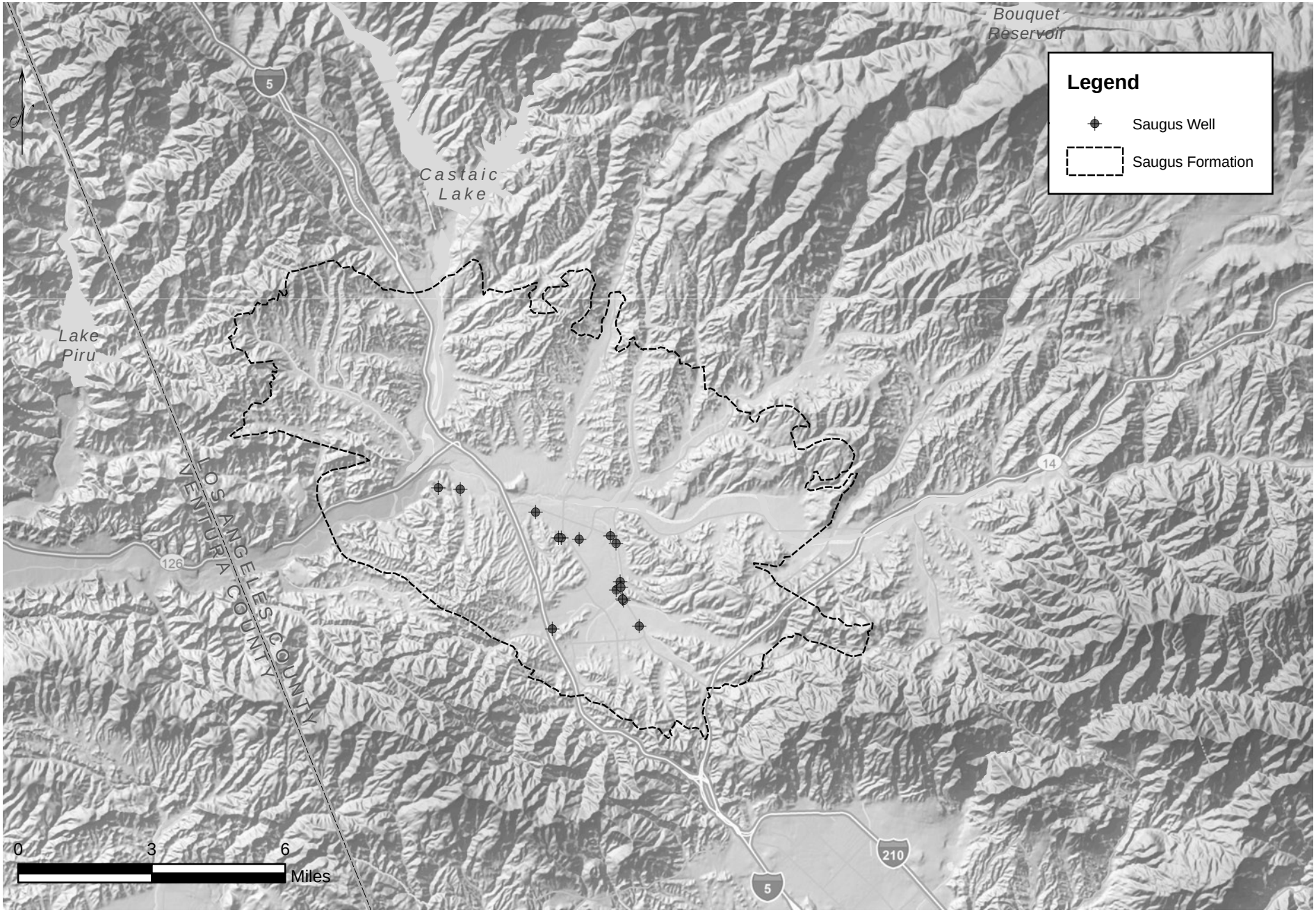

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Figure III-7
Saugus Well Locations
Santa Clara River Valley, East Groundwater Subbasin

Groundwater Production - Saugus Formation
Santa Clara River Valley, East Groundwater Subbasin

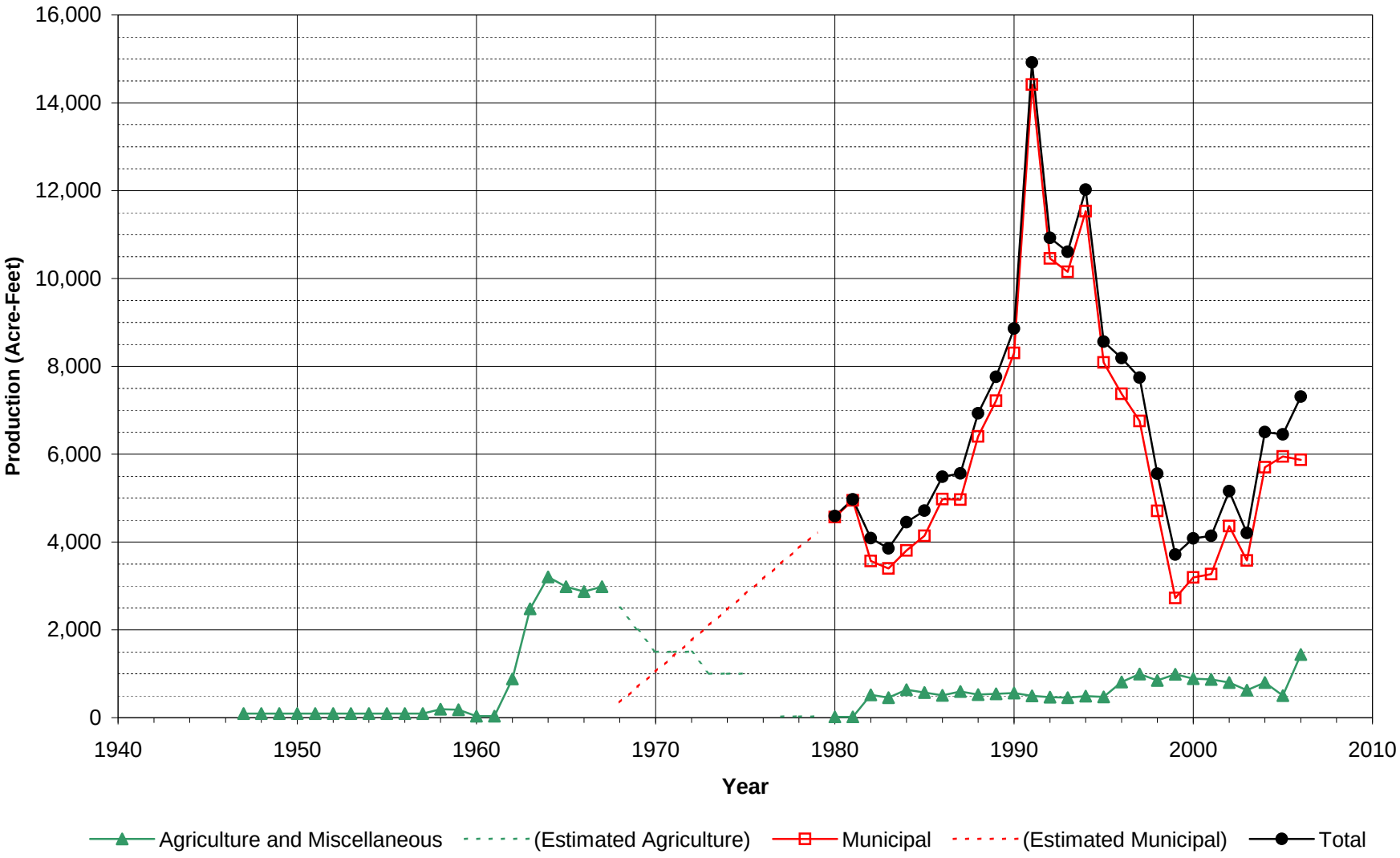
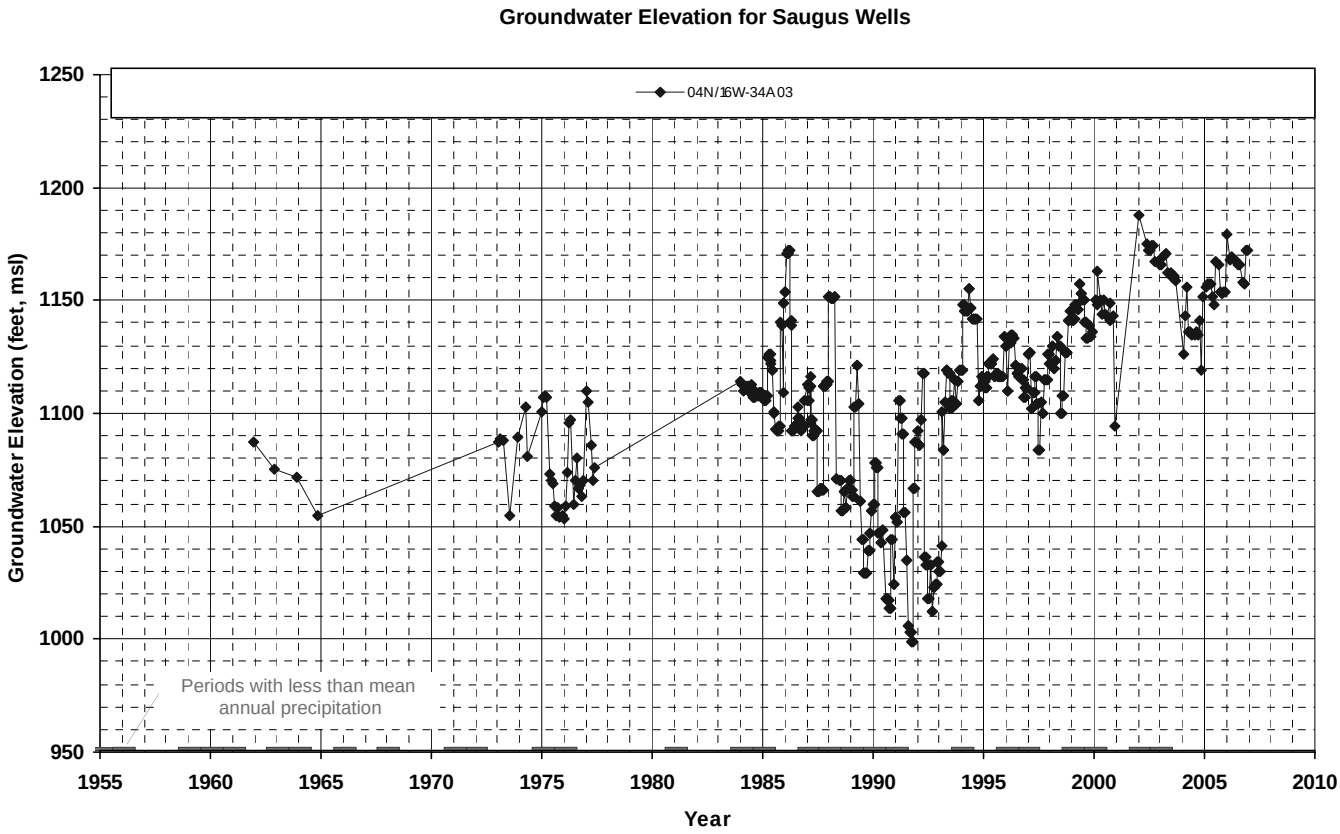


Figure III-8


Groundwater Elevation for Saugus Wells
04N/16W-34A03
Groundwater Elevation (feet, msl)
1250
1200
1150
1100
1050
1000
950
Periods with less than mean annual precipitation
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

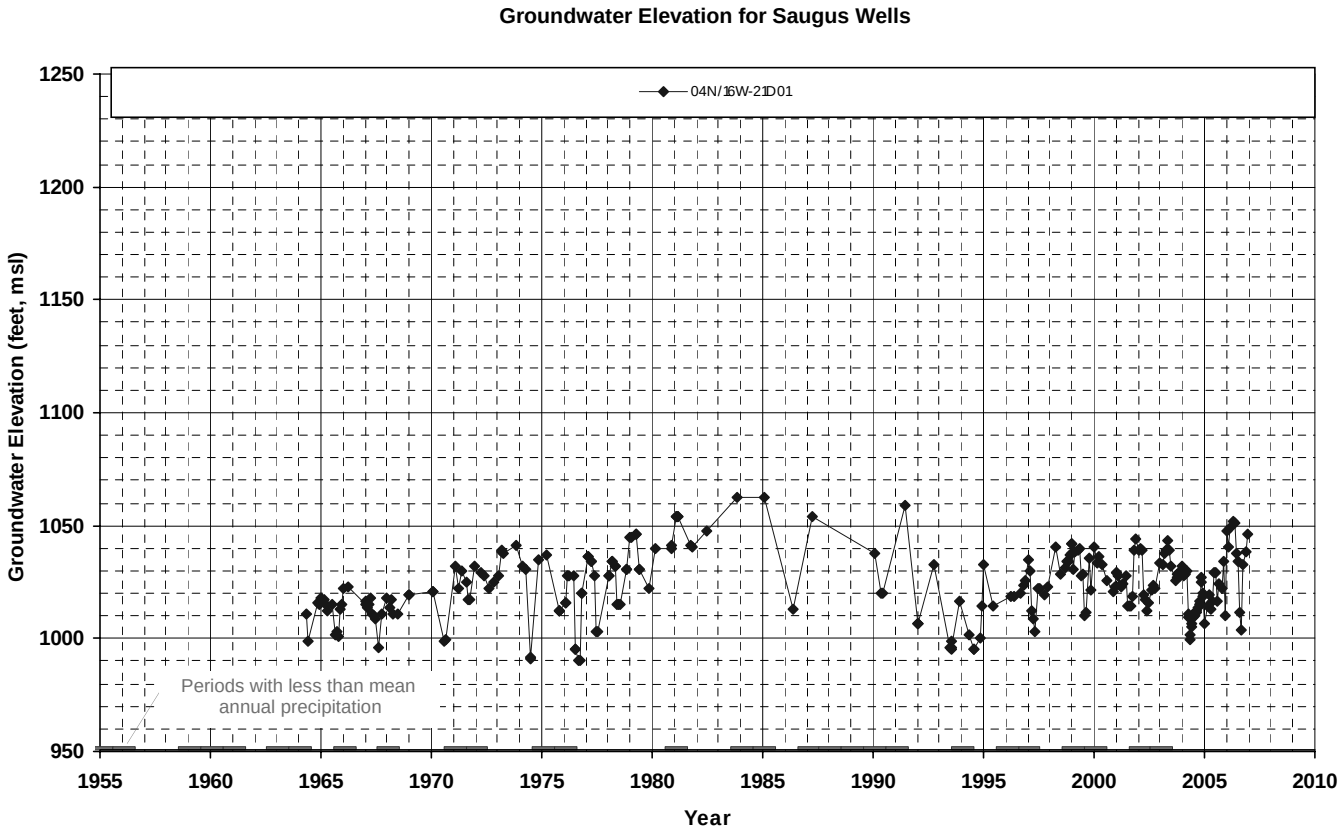

Groundwater Elevation for Saugus Wells
04N/16W-21D01
Groundwater Elevation (feet, msl)
1250
1200
1150
1100
1050
1000
950
Periods with less than mean annual precipitation
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

Figure III-9

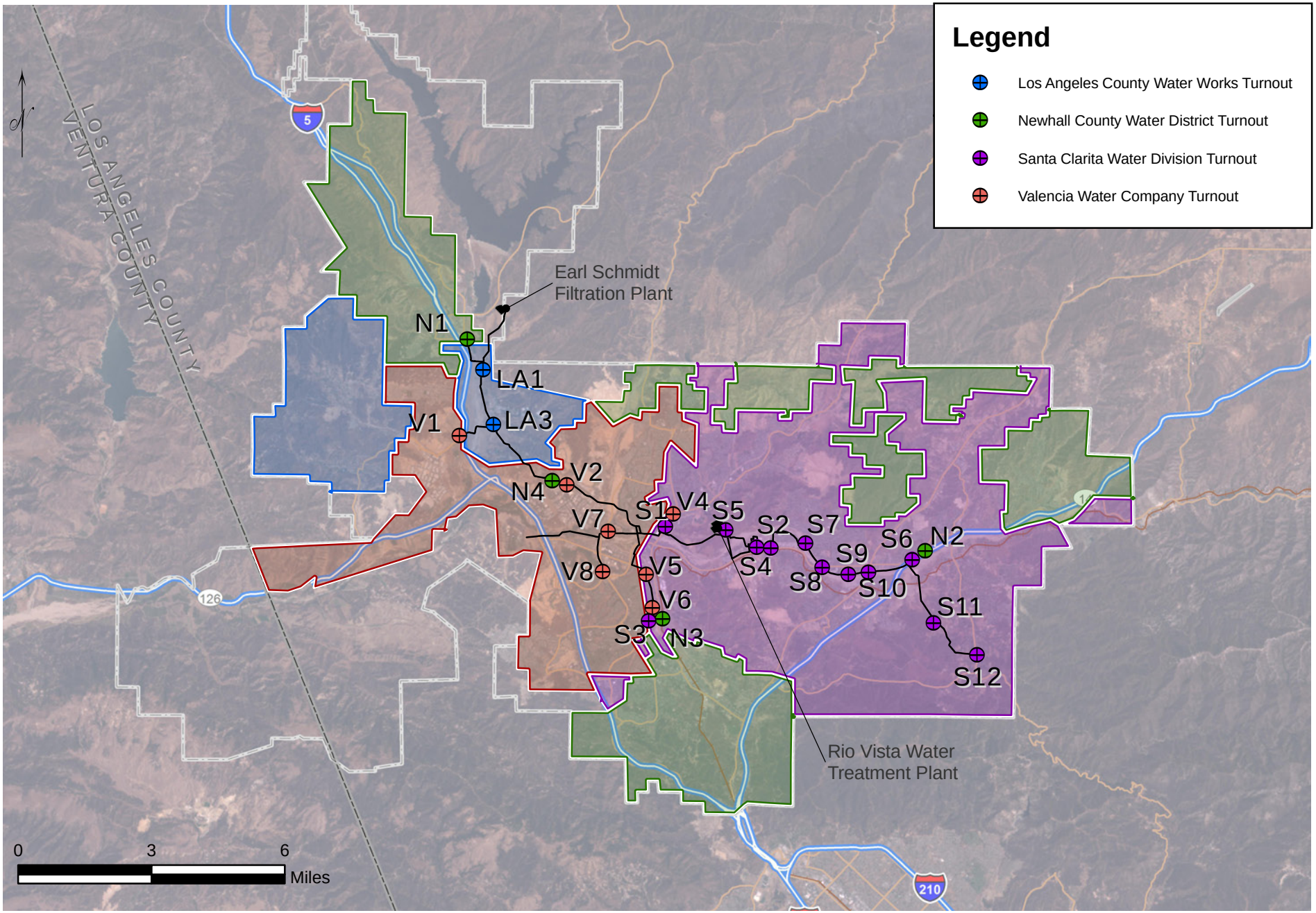


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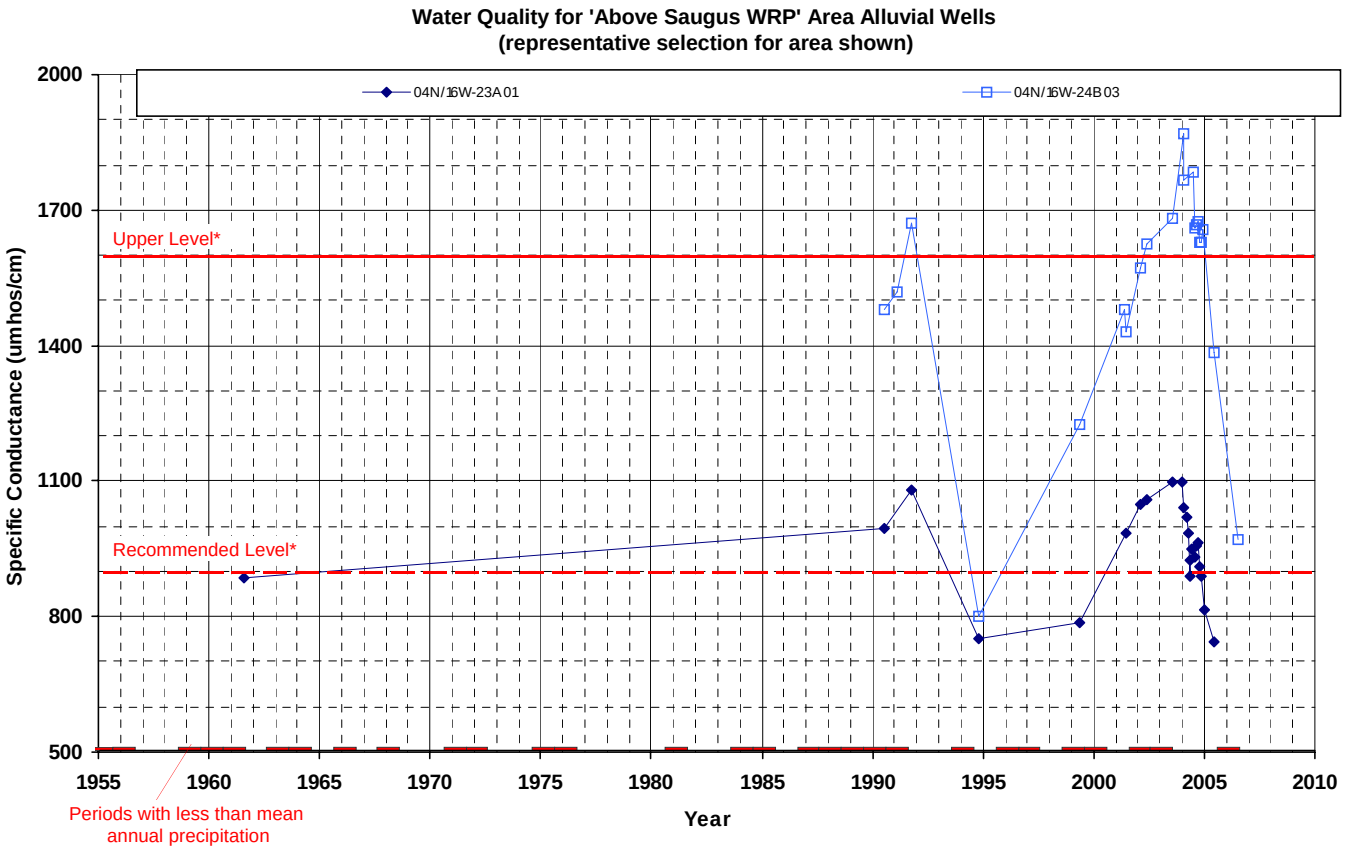
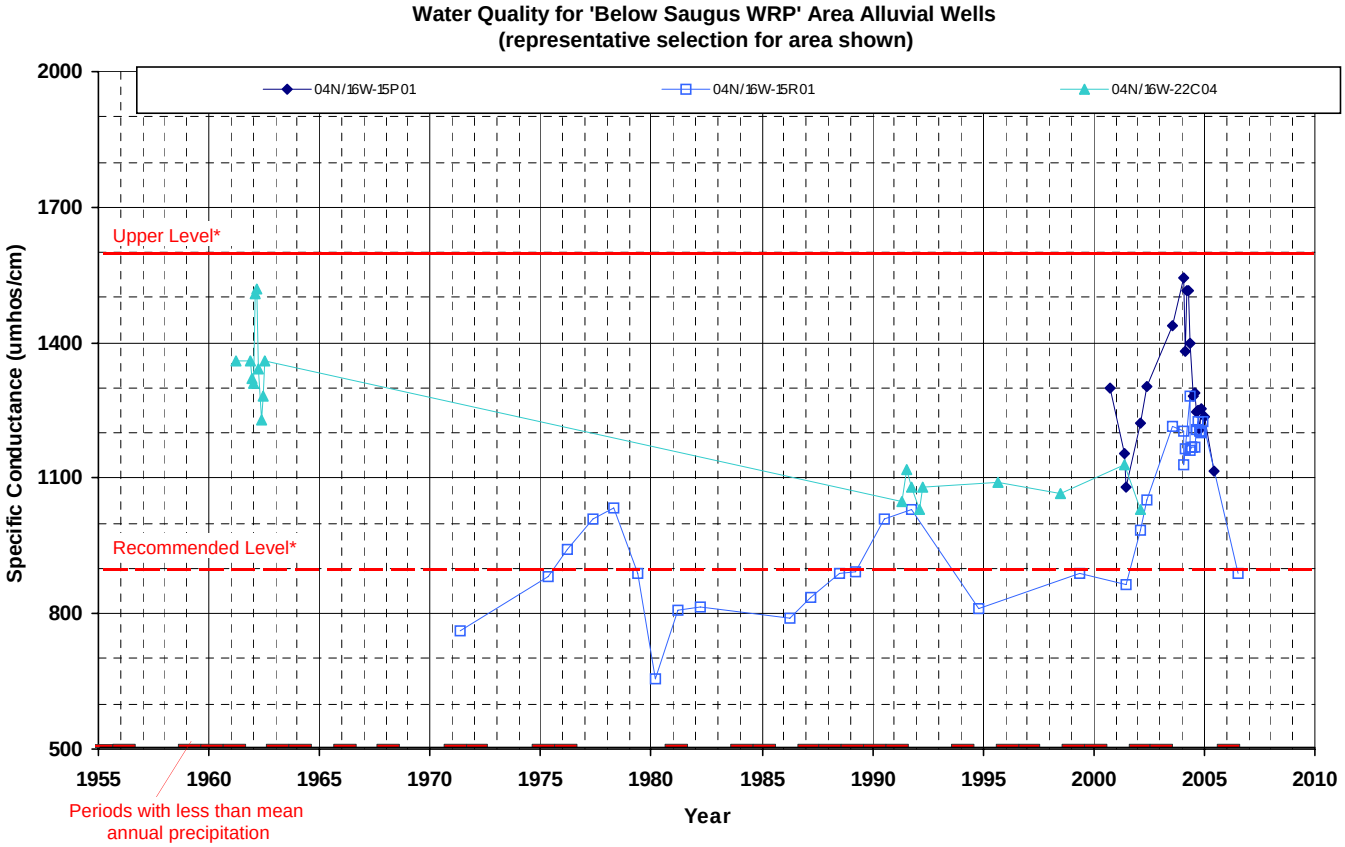
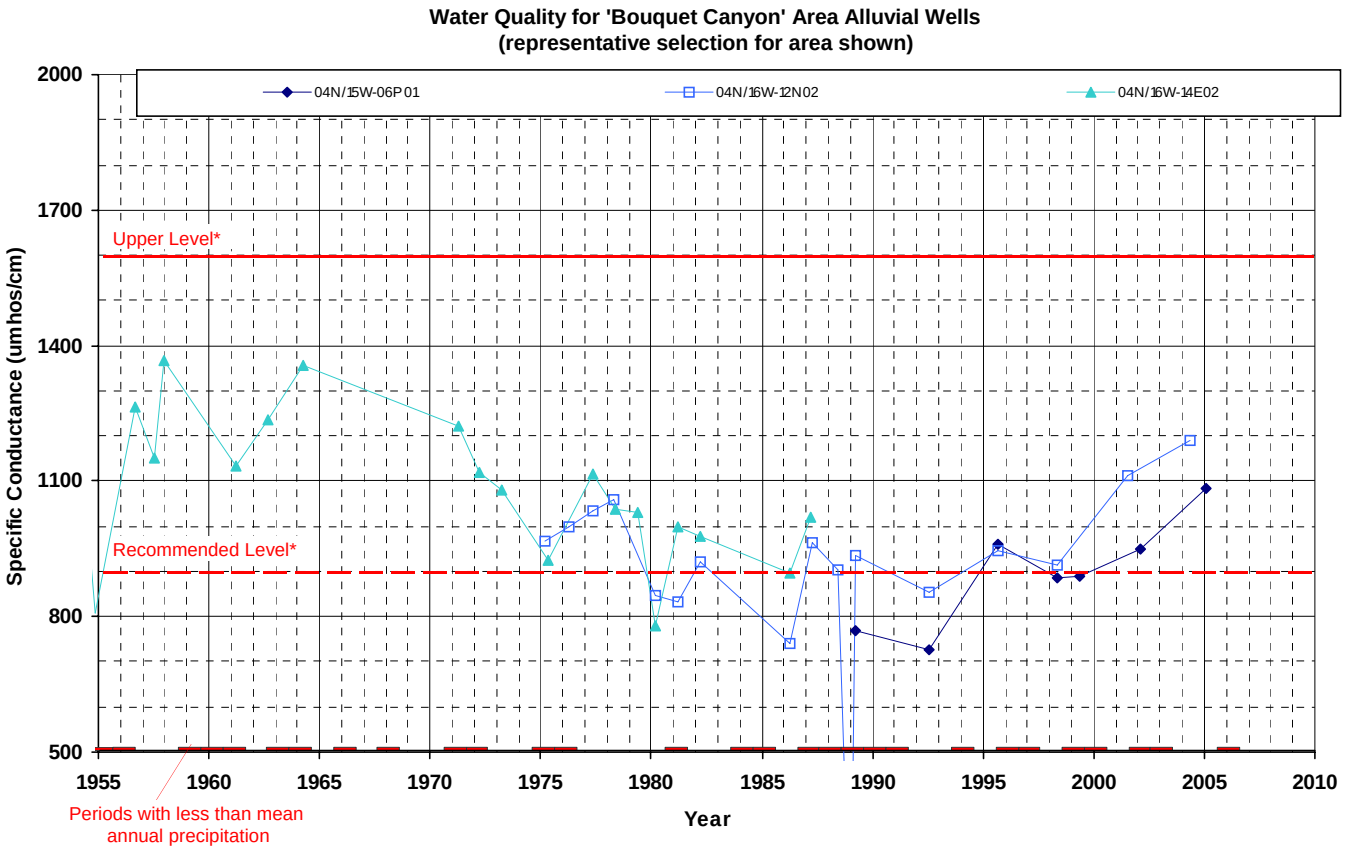
Figure III-10
Treated Water Distribution System
Castaic Lake Water Agency

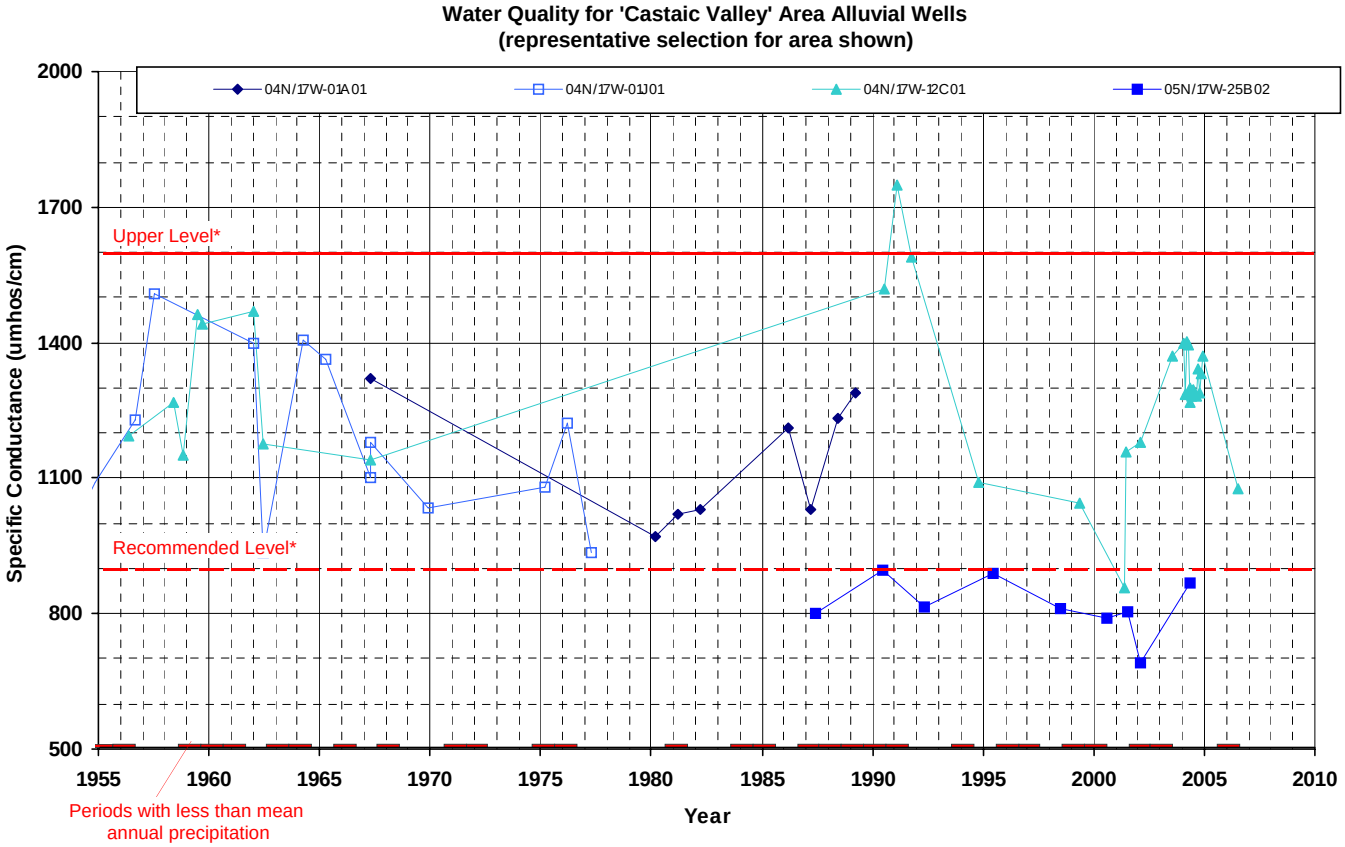




*California Department of Health Services Secondary Maximum Contaminant Level

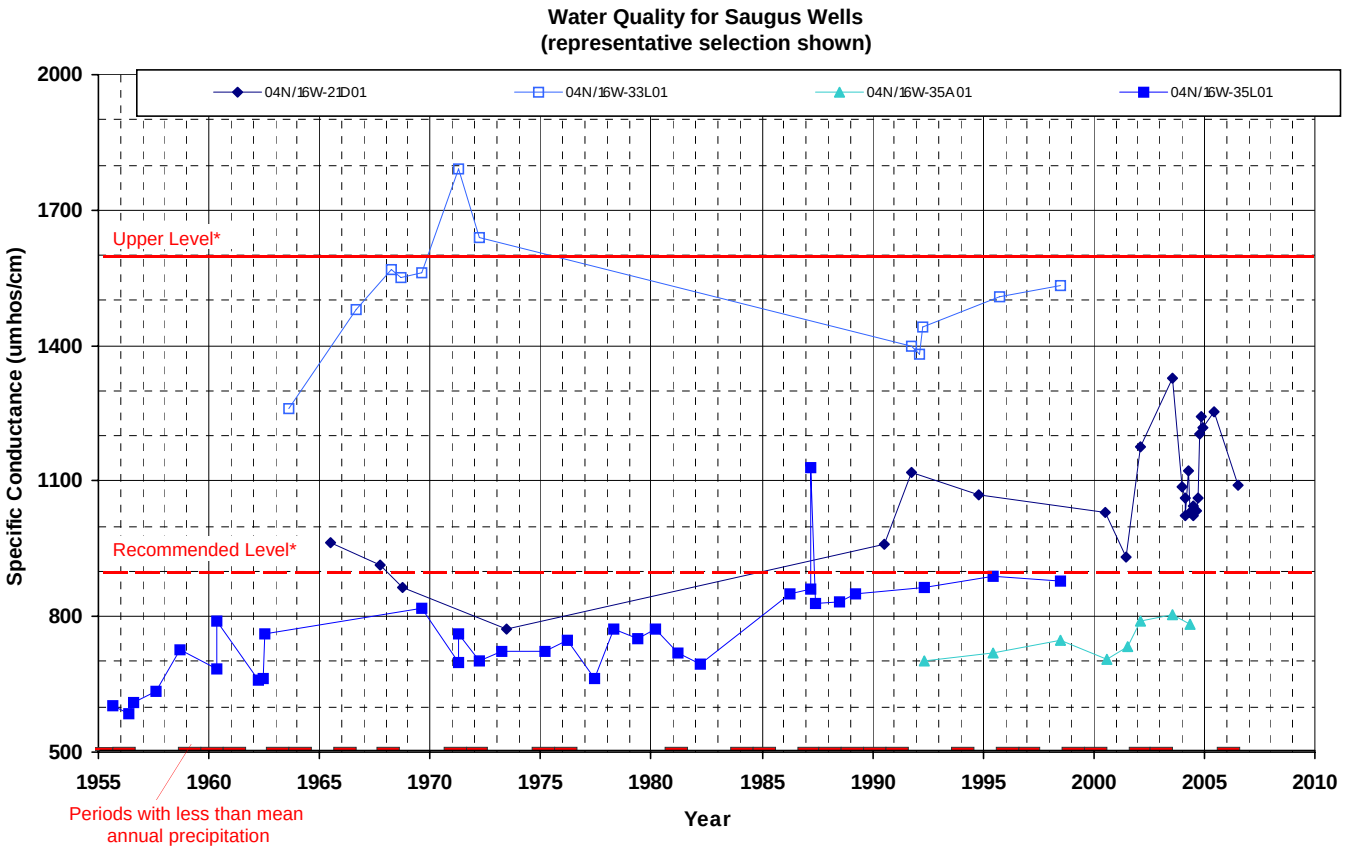
Figure III-11





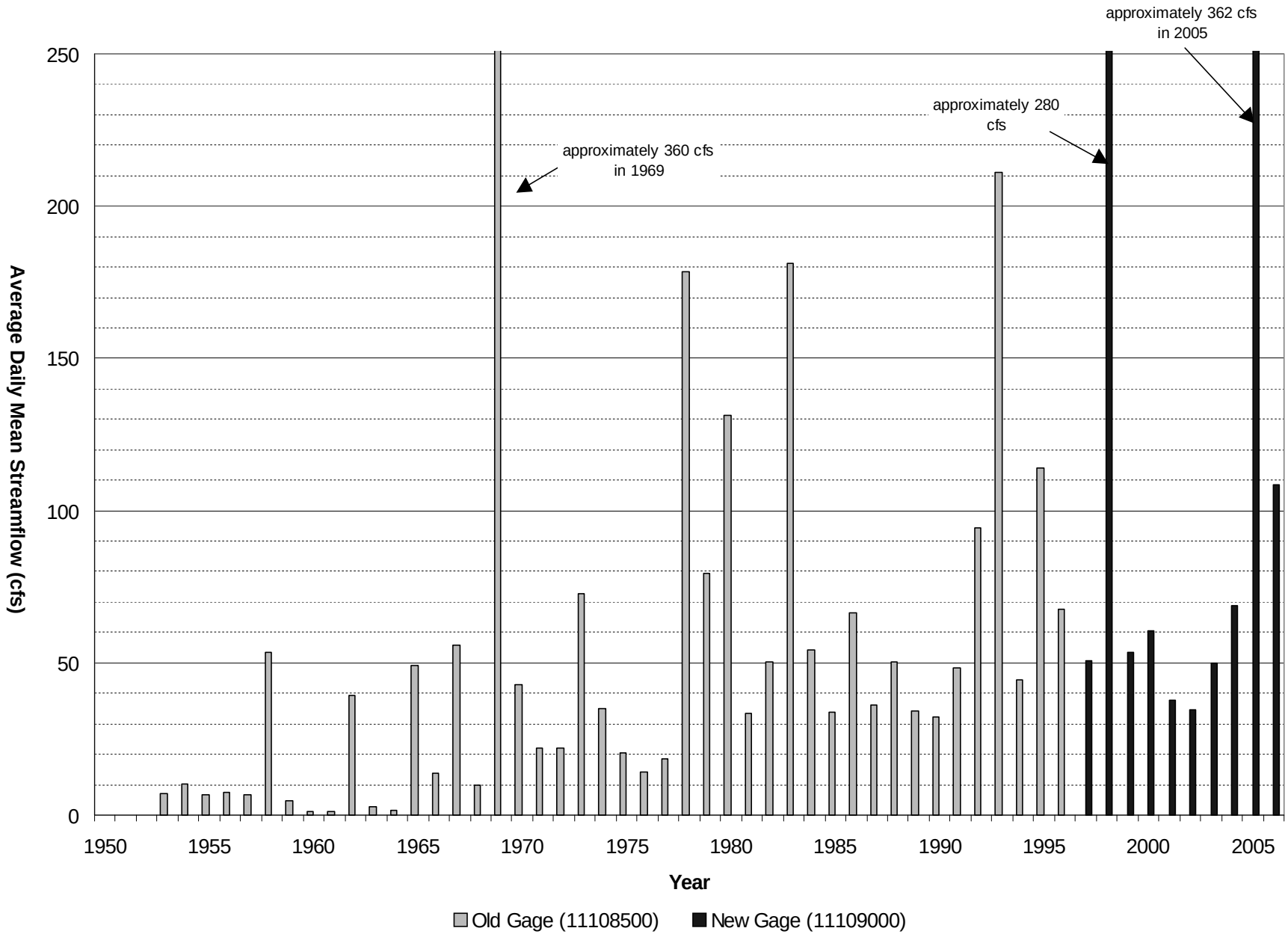
*California Department of Health Services Secondary Maximum Contaminant Level

Figure III-12



*California Department of Health Services Secondary Maximum Contaminant Level

Figure III-13



2006 streamflow average through September 30, 2006.

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Figure III-14
Annual Average of Daily Mean Streamflow
Santa Clara River at Los Angeles - Ventura County Line

IV. Summary of 2006 Water Supply and 2007 Outlook

As discussed above, total water demands in the Santa Clarita Valley were 91,400 af in 2006. This represented an increase of about nine percent from total demand in 2005. Of the total demand in 2006, about 74,100 af was for municipal water supply, and the balance (17,300 af) was for agricultural and other uses, including individual domestic uses. As also discussed herein, the total demand in 2006 was met by a combination of local groundwater and imported SWP water, and by a small amount of recycled water.

The water demand in 2006 was the same as the average projection in the UWMP and the same as the short-term projected demand that was estimated in the 2005 Water Report. For illustration, historical water use from 1980 through 2006 is plotted in Figure IV-1; also shown with that historical record are the projected total water demands in the UWMP through 2030. As discussed in the 2005 UWMP, year-to-year fluctuations in historical water demand have ranged from about ten percent below to about nine percent above the average or "normal" projection that would describe the long-term historical trend in the Valley's total water demand. The primary factor causing the year-to-year fluctuations is weather. In the short term, wetter years have typically resulted in decreased water demand, and drier years have typically resulted in higher water demand. Extended drier periods, however, have resulted in decreases in demand due to conservation and water shortage awareness. The decline in water demand toward the end of the 1987-92 drought is a good example of such reduced demand. A good recent example of wet-year effects on water demand was 2005, where extremely wet conditions resulted in total water requirements about six percent below the average projection in the UWMP.

The average water demand projection in the 2005 UWMP for 2007 is 93,600 acre-feet. For short-term planning, however, recognizing the continuation of growth and below-normal precipitation in early 2007, water demand in 2007 is expected to be greater than the average projection in the 2005 UWMP. Also recognizing that the most recent weather-related impact on water demand was notable (about 6 percent reduction attributable to very wet conditions in 2005) but less than the full range (10 percent) reflected in the 2005 UWMP, it is further expected that water demands in 2007 could be affected by a similar amount (6 percent), up to the upper range in the 2005 UWMP (9 percent), above the average projection. As a result, total water requirements in 2007 are expected to be on the order of 99,000 to 102,000 acre-feet.

It is expected that both municipal and agricultural water demands in 2007 will be met with a generally similar mix of water supplies as in previous years, notably local groundwater and imported SWP water, complemented by recycled water that will continue to supply a small fraction of total water demand.

As of April 20, 2007, the allocation of water from the SWP in 2006 is 60 percent of CLWA's Table A Amount, or 57,120 af. Combined with local groundwater from the two aquifer systems (42,500 af), total Flexible Storage Account water (6,060 af), net carryover SWP water from 2005 (2,569 af), annual acquisition from Buena Vista Water District (11,000 af), and recycled water (500 af), the total available water supplies for 2007 are about 120,000 af. Consequently, CLWA and the Purveyors anticipate having more than adequate supplies to meet all water demands in 2007. Projected 2007 water supplies and demand are summarized in Table IV-1.

In October 2006, Watershed Enforcers, a legal project of the California Sportfishing Protection Alliance, filed a lawsuit in Alameda County Superior Court alleging that the California Department of Water Resources (DWR) was not in compliance with the State Endangered Species Act (CESA) and does not have the required State permit to "take" protected fish species in the Sacramento-San Joaquin Delta (Delta) as part of its pumping operations at the Banks Pumping Plant located near the town of Tracy. In April 2007, the court agreed with the plaintiffs and ordered a shutdown of pumping from the Delta if appropriate permits could not be obtained in 60 days. In May 2007, DWR filed an appeal of the lower court's decision, which automatically stayed that decision pending the outcome of the appeal. At the same time, DWR entered into a Memorandum of Understanding with the California Department of Fish and Game (DFG) to jointly work with the appropriate federal agencies to develop a federal biological opinion that complies with CESA. During the preparation of the new biological opinion, DWR committed itself to actions related to protecting species through the adaptive management provisions of the existing biological opinions. Upon completion of this effort, DWR plans to submit a request to DFG for a consistency determination under CESA that would allow for incidental take based on the new federal biological opinion. In terms of short-term water supply availability, CLWA does not anticipate that any of the preceding actions will cause a net reduction in delivery of imported water that would in turn result in a shortage of overall water supply to meet projected 2007 water demands as summarized in Table IV-1.

In addition to the regular water supplies described above to meet projected demand in 2007, a total of nearly 51,000 af of recoverable water has been stored in the Semitropic Groundwater Storage Bank in Kern County. Another 57,600 af of recoverable water has also been stored in the long-term Rosedale-Rio Bravo Water Banking and Exchange Program, also in Kern County.

Table IV-1
2007 Water Supply and Demand
(acre-feet)

Projected 2007 Demand [1]		**99,000-102,000**
Available 2007 Water Supplies		
Local Groundwater		42,500
Alluvial Aquifer [2]	*35,000*	
Saugus Formation [3]	*7,500*	
Imported Water		76,749
Table A Amount [4]	*57,120*	
Net Carryover from 2005 [5]	*2,569*	
Buena Vista/Rosedale-Rio Bravo[6]	*11,000*	
Flexible Storage Account (CLWA) [7]	*4,684*	
Flexible Storage Account (Ventura County) [7]	*1,376*	
Recycled Water		500
Total Available 2007 Supplies		**119,749**
Additional Dry Year Supplies [8]		
Semitropic Groundwater Storage Bank		50,870
2002 Account[9]	*21,600*	
2003 Account[9]	*29,270*	
Rosedale-Rio Bravo Water Banking and Exchange Program		57,600
2005 Banking of Table A[10]	*17,800*	
2006 Banking of Table A[10]	*17,800*	
2005 and 2006 Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement[11]	*22,000*	
Total Additional Dry Year Supplies		**108,470**

1. Interpolated from 2005 and 2010 projections in 2005 UWMP, *plus estimated 6-9% dry year increase.*

2. The Alluvium represents 30,000 – 40,000 afy of available supply under wet-normal conditions, and 30,000 – 35,000 afy under dry conditions. Available supply in 2007 is shown to be mid-range for average/wet conditions, or upper end of range for dry conditions.

3. The Saugus Formation represents 7,500 – 15,000 afy of available water supply under non-drought conditions, and up to 35,000 afy under increasingly dry conditions. Available supply in 2007 is shown to be limited to wet conditions; no short-term increase in Saugus Formation pumping is required or shown for 2007 water supply.

4. CLWA's SWP Table A amount is 95,200 af. The 2007 allocation, as of April 24, 2007, is 60 percent (57,120 af).

5. Amount used by CLWA in 2007; total carryover was 38,484 af.

6. 2007 annual supply from Buena Vista / Rosedale-Rio Bravo Water Acquisition Agreement.

7. CLWA can directly utilize up to 4,684 af of storage capacity in Castaic Lake. By agreement in 2005, CLWA can also utilize 1,376 af of Ventura County SWP contractors' flexible storage capacity in Castaic Lake.

*

8. Does not include other reliability measures available to CLWA and the retail water Purveyors. These measures include short-term exchanges, participation in DWR's dry-year water purchase programs, local dry-year supply programs and other future groundwater storage programs.

9. Net recoverable water after banking 24,000 af and 32,522 af in 2002 and 2003, respectively.

10. Net recoverable water after banking 20,000 af in each year.

11. Water stored in Rosedale-Rio Bravo Water Banking and Exchange Program pursuant to the Buena Vista / Rosedale-Rio Bravo Water Acquisition Agreement.

Total recoverable water in Kern County storage banks is now more than 108,000 af. That component of overall water supply is separately reflected in Table IV-1 because it is intended for future dry-year supply and will not be used for 2007 water supply.

A significant number of projects are part of an overall program to provide facilities needed to firm up imported water supplies during times of drought. These involve water conservation, surface and groundwater storage, water transfers and exchanges, water recycling, additional short-term pumping from the Saugus Formation, and increasing CLWA's imported supply. This overall strategy is designed to meet increasing water demands while assuring a reasonable degree of supply reliability.

Part of the overall water supply strategy is to provide a blend of groundwater and imported water to area residents to ensure consistent quality and reliability of service. The actual blend of imported water and groundwater in any given year and location in the Valley is an operational decision and varies over time due to source availability and operational capacity of Purveyor and CLWA facilities. The goal is to conjunctively use the available water resources so that the overall reliability of water supply is maximized.

For long-term planning purposes, water supplies and facilities are added on an incremental basis and ahead of need. It would be economically unsound to immediately, or in the short term, acquire all the facilities and water supplies needed for the next twenty to thirty years. This would unfairly burden existing customers with costs that should be borne by future customers. There are many ongoing efforts to produce an adequate and reliable supply of good quality water for Valley residents. Water consumers expect that their needs will continue to be met with a high degree of reliability and quality of service. To that end, CLWA's and the Purveyors' stated reliability goal is to deliver a reliable and high quality water supply for their customers, even during dry periods. Based on conservative water supply and demand assumptions contained in the 2005 UWMP for the next 25 years, in combination with conservation of non-essential demand during certain dry years, CLWA and the Purveyors believe implementing their water plan will successfully achieve this goal.

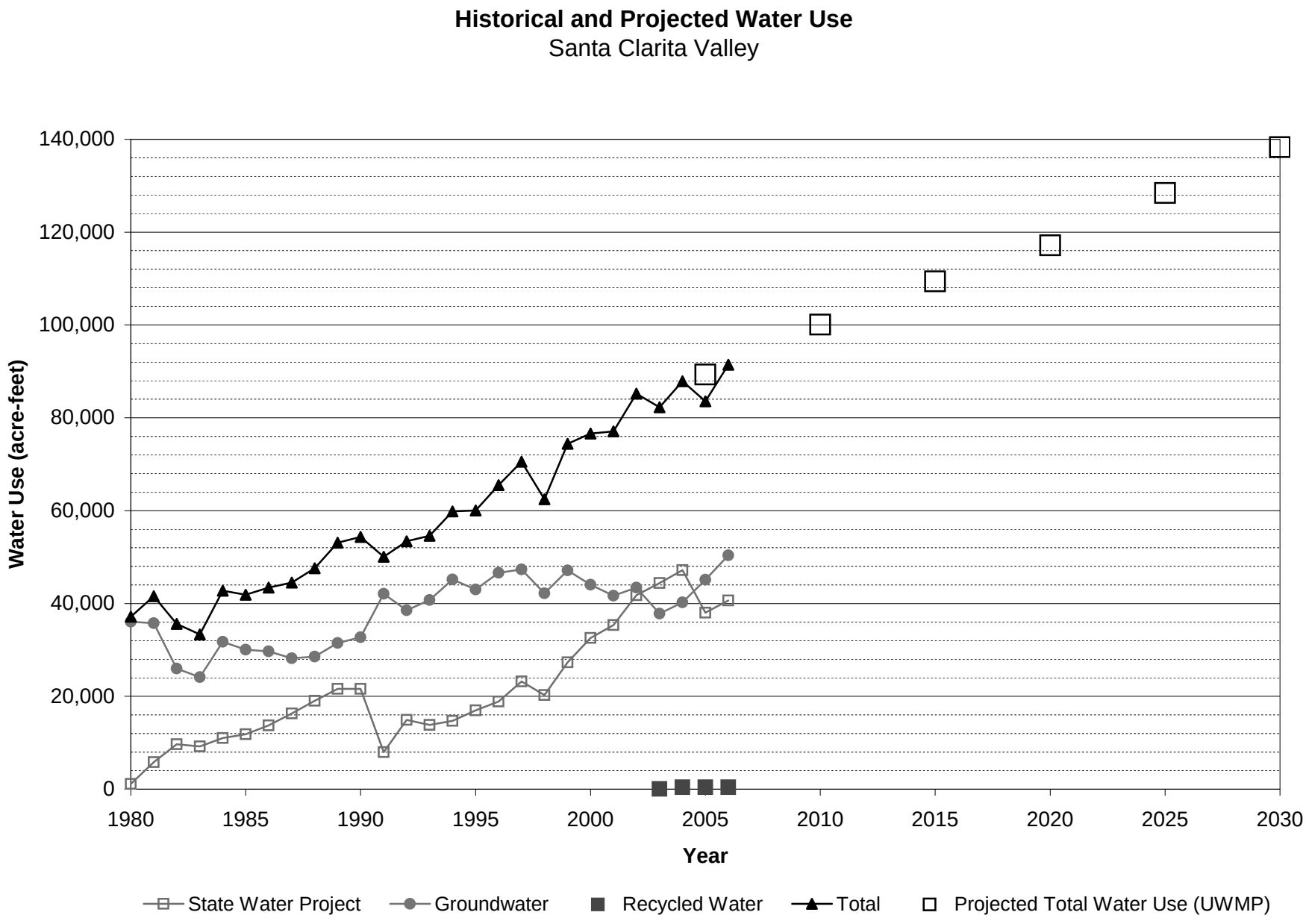
Historical and Projected Water Use
Santa Clarita Valley
Water Use (acre-feet)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
State Water Project
Groundwater
Recycled Water
Total
Projected Total Water Use (UWMP)

Figure IV-1

V. Water Conservation

The California Urban Water Conservation Council (CUWCC) was formed in 1991 through the Memorandum of Understanding (MOU) Regarding Urban Water Conservation in California. The urban water conservation Best Management Practices (BMPs) included in the MOU are intended to reduce California's long-term urban water demands. While the BMPs are currently implemented by the MOU signatories on a voluntary basis, they are specified as part of the Demand Management Measures section of the Urban Water Management Planning Act.

Water conservation can achieve a number of goals, such as:

- Meeting legal mandates
- Reducing average annual potable water demands
- Reducing sewer flows
- Reducing demands during peak seasons
- Meeting drought restrictions

CLWA signed the urban MOU in 2001 on behalf of its wholesale service area, and pledged to implement several BMPs at a wholesale support level (listed below). NCWD signed the MOU in 2002 and VWC signed the MOU in 2006, on behalf of their respective retail service areas. As separate MOU signatories and in their respective roles as retailers, NCWD and VWC are committed to implementing all BMPs that are feasible and applicable in their service areas. Efforts are made to coordinate with CLWA and the other Purveyors wherever possible to maximize efficiency and ensure the cost effectiveness of NCWD's conservation program.

In coordination with the Purveyors, CLWA has been implementing the following BMPs (which pertain to wholesalers) for several years (some prior to signing the MOU in 2001):

BMP 3	System Water Audits, Leak Detection and Repair
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 10	Wholesale Agency Programs
BMP 11	Conservation Pricing
BMP 12	Water Conservation Coordinator

CLWA and the Purveyors have been implementing these BMPs valley-wide. Since 2001, CLWA has also instituted implementation of BMP 2 (Residential Plumbing Retrofits) and BMP 14 (Residential ULFT Replacement Programs) on behalf of the Purveyors.

In addition to these efforts, in September 2006, CLWA installed a weather station at its headquarters adjacent to the Rio Vista Water Treatment Plant. This station became part a network of over 120 automated weather stations in the state of California that make up the California Irrigation Management Information System (CIMIS). The Department of Water Resources (DWR) manages the system which has a primary purpose of making available to the public, free of charge, information useful in estimating crop water use for irrigation scheduling.

NCWD has initiated implementation of the remaining BMPs that are specific to retail water suppliers:

BMP 1	Water survey programs for single-family residential and multi-family residential customers
BMP 3	System water audits, leak detection and repair
BMP 4	Metering with commodity rates for all new connections and retrofit of existing connections
BMP 5	Large landscape conservation programs and incentives
BMP 6	High-efficiency clothes washing machine financial incentive programs
BMP 9	Conservation programs for commercial, industrial, and institutional (CII) accounts
BMP 11	Conservation pricing
BMP 12	Conservation coordinator
BMP 13	Water waste prohibition

Reports to the CUWCC on BMP implementation by CLWA and the Purveyors were included in the 2005 UWMP.

Additional savings are occurring Valley-wide due to state interior plumbing code requirements that have been in effect since 1992, as well as due to changes in lot size and reduction in exterior square footage of new housing and commercial developments. These have begun to impact overall demand in the Valley. The Valley's water suppliers continue to monitor water demand trends through time to assess those factors that are accounting for the reduction, and to attempt to quantify them.

VI. References

California Department of Water Resources, **The California Water Plan Update,** Bulletin 160-05, 2005.

California Department of Water Resources, **Final State Water Project Delivery Reliability Report, 2005**, April 2006.

California Department of Water Resources, **California's Groundwater**, Bulletin 118 – Update 2003, October 2003

Castaic Lake Water Agency, **Groundwater Management Plan, Santa Clara River Valley Groundwater Basin, East Subbasin**, Los Angeles County, California, December 2003.

Castaic Lake Water Agency (CLWA), CLWA Santa Clarita Water Division, Newhall County Water District, and Valencia Water Company, **2005 Urban Water Management Plan**, Los Angeles County Waterworks District No. 36, Cooperating Agency, November 2005.

CH2M Hill, **Evaluation of Historical and Projected Future Flows to Ventura County Resulting From Importation of State Project Water to the Santa Clara River Watershed,** July, 1998.

CH2M Hill **Evaluation of Historical and Projected Future Flows to Ventura County Resulting From Importation of State Project Water to the Santa Clara River Watershed**, Update 2001.

CH2M Hill **Regional Groundwater Flow Model for the Santa Clarita Valley, Model Development and Calibration**, April, 2004.

CH2M Hill, **Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, Santa Clarita,** California, Prepared in support of the 97-005 Permit Application, December 2004.

CH2M Hill, Technical Memorandum, **Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California,** August 2005.

CH2M Hill and Luhdorff & Scalmanini, Consulting Engineers, **Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California**, August 2005.

Kennedy/Jenks Consultants, Draft Report, **Recycled Water Master Plan,** Castaic Lake Water Agency, May 2002.

Luhdorff and Scalmanini, Consulting Engineers, **2005 Santa Clarita Valley Water Report**, prepared for Castaic Lake Water Agency, CLWA Santa Clarita Water Division, Los Angeles

County Waterworks District 36, Newhall County Water District, and Valencia Water Company, April 2006.

Luhdorff and Scalmanini, Consulting Engineers, **Impact and Response to Perchlorate Contamination, Valencia Water Company Well Q2**, prepared for Valencia Water Company, April 2005.

_____, "Memorandum of Understanding Between the Santa Clara River Valley Upper Basin Water Purveyors and United Water Conservation District", August 2001.

Richard C. Slade & Associates, LLC, **2001 Update Report, Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems**, prepared for Santa Clarita Valley Water Purveyors, July 2002.

Slade, R. C., **Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California,** Vols. I and II, prepared for Castaic Lake Water Agency, 1988.

Slade, R. C., **Hydrogeologic Investigation of Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California**, Vols. I and II, prepared for Upper Santa Clara Water Committee, 1986.

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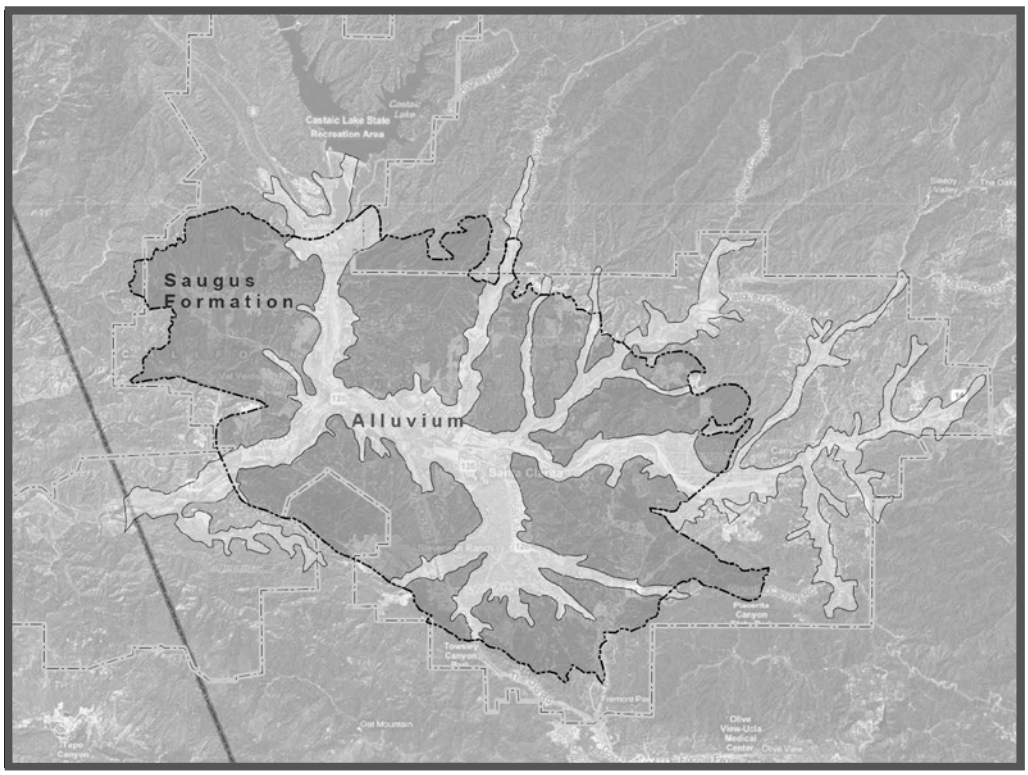

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CLWA Santa Clarita Water Division
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Valencia Water Company
May 2010

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CONSULTING ENGINEERS

2009 Santa Clarita Valley Water Report

prepared for:

Castaic Lake Water Agency (CLWA)
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Executive Summary

This annual report, which is the twelfth in a series that began to describe water supply conditions in 1998, provides current information about the water requirements and water supplies of the Santa Clarita Valley. The report was prepared for the imported water wholesaler, Castaic Lake Water Agency (CLWA), and for the four local retail water Purveyors that serve the Valley: CLWA Santa Clarita Water Division, Los Angeles County Waterworks District 36, Newhall County Water District, and Valencia Water Company. These entities and representatives from the City of Santa Clarita and the County of Los Angeles Department of Regional Planning meet as required to coordinate the management of imported water with local groundwater and recycled water to meet water requirements in the Valley.

This report provides information about local groundwater resources, State Water Project (SWP) and other imported water supplies, water conservation, and recycled water. The report reviews the sufficiency and reliability of supplies in the context of existing water demand, with focus on actual conditions in 2009, and it provides a short-term outlook of water supply and demand for 2010.

ES.1 2009 Water Requirements and Supplies

In 2009, total water requirements in the Santa Clarita Valley were about 86,600 acre-feet (af), of which about 70,000 af (81 percent) were for municipal use and the remainder (16,600 af) was for agricultural and other (miscellaneous) uses, including individual domestic uses. Total demand in 2009 was about 4.5 percent lower than in 2008, less than what was estimated in the 2008 Water Report, and water requirements in 2009 were also lower than the average projection in the 2005 Urban Water Management Plan (UWMP) (but closer to the projection in the 2005 UWMP with conservation). The majority of decreased water demand is attributable to a significant (8%) decrease in municipal water use from 2008. Total water requirements in 2009 were met by a combination of about 47,700 af from local groundwater resources (about 31,100 af for municipal and about 16,600 af for agricultural and other uses), about 38,600 af of SWP and other imported water, and about 300 af of recycled water.

Of the 47,700 af of total groundwater pumping in the Valley in 2009, about 40,000 af were pumped from the Alluvium and about 7,700 af were pumped from the underlying, deeper Saugus Formation. Alluvial pumping represented about a 1,750 af decrease from 2008, and Saugus pumping was slightly higher than in 2008, by about 750 af. Neither pumping volume resulted in any notable overall change in groundwater conditions (water levels, water quality, etc.) in either

aquifer system. Imported water deliveries to the Purveyors decreased by about 3,200 af from the previous year. Water uses and supplies in 2009 are summarized in the following Table ES-1.

Table ES-1
Santa Clarita Valley
Summary of 2009 Water Supplies and Uses
(acre-feet)

Municipal		
SWP and other Imported		38,546
Groundwater (Total)		31,100
Alluvium	*24,396*	
Saugus	*6,704*	
Recycled Water		328
Subtotal		**69,974**
Agriculture/Miscellaneous		
SWP and other Imported		-
Groundwater (Total)		16,564
Alluvium	*15,590*	
Saugus	*974*	
Subtotal		**16,564**
Total		***86,538***

In accordance with the California Urban Water Management Planning Act, the Valley-wide UWMP was updated in 2005 to extend projected water demands through 2030, and to describe the combination of local groundwater, imported water supplies from the State Water Project and other sources, local recycled water supplies, and other water supplies planned to meet those existing and projected water demands in the Valley. The 2005 UWMP describes the reliability of local groundwater resources and the adequacy of groundwater supplies to meet groundwater demand, including consideration of the impacts of perchlorate contamination on several municipal water supply wells. The 2005 UWMP also describes the plans and ongoing work for integrated control of perchlorate migration and full restoration of perchlorate-impacted groundwater supply.

Notable details about each component of water supply in the Valley, and about the water supply outlook for 2010, include the following.

ES.2 Alluvial Aquifer

The groundwater operating plan in the 2005 UWMP includes Alluvial pumping in the range of 30,000 to 40,000 acre-feet per year (afy) following average/normal years, and slightly reduced pumping (30,000 to 35,000 afy) following dry years. An updated review of groundwater basin yield, completed in 2009, includes the same basic range of Alluvial pumping in the 2008 groundwater Operating Plan. Pumping from the Alluvium in 2009 was 40,000 af, which is at the upper end of the operating plan range for the Alluvium and had no adverse effects on groundwater levels and storage in the basin. On average, pumping from the Alluvium has been about 32,000 afy since supplemental imported water became available in 1980. That average rate remains near the lower end of the range of operational yield.

On a long-term basis, continuing through 2009, there is no evidence of any historic or recent trend toward permanent water level or storage decline. In general, throughout a large part of the basin, Alluvial groundwater levels have generally remained near historic highs during the last 30 years. Above average precipitation in late 2004 and 2005 resulted in significant water level recovery in the eastern part of the basin, continuing the overall trend of fluctuating groundwater levels within a generally constant range over the last 30 years. These ongoing data indicate that the Alluvium remains in good operating condition and can continue to support pumping in the operating range included in the 2005 UWMP, or slightly higher, without adverse results (e.g., long-term water level decline or degradation of groundwater quality.)

Based on an integration of water quality records from multiple wells completed in the Alluvium, there have been historical fluctuations in groundwater quality, typically associated with variations in precipitation and streamflow. However, like groundwater levels, there has been no long-term trend toward groundwater quality degradation; groundwater produced from the Alluvial aquifer remains a viable municipal and agricultural water supply.

In 2002, as part of ongoing monitoring of wells for perchlorate contamination, perchlorate was detected in one Alluvial well (the SCWD Stadium Well) located near the former Whittaker-Bermite facility. The detected concentration was slightly below the then-applicable Notification Level for perchlorate (6 µg/l, which was subsequently established as the Maximum Contaminant Level for perchlorate in October 2007), and the well has now been replaced to restore that component of municipal water supply that was impacted by perchlorate. In early 2005, perchlorate was detected in a second Alluvial well, VWC's Well Q2. After an interim period of wellhead treatment, that well has now been returned to regular water supply service. All other Alluvial wells operated by the Purveyors continue to be used for municipal water supply service;

those wells near the Whittaker-Bermite property are sampled in accordance with drinking water regulations and perchlorate has not been detected. As detailed in the 2005 UWMP, the ongoing inactivation of one Alluvial well due to perchlorate contamination does not limit the Purveyors' ability to produce groundwater from the Alluvium in accordance with the groundwater operating plan in the 2005 UWMP or the now updated 2008 groundwater Operating Plan.

The ongoing characterization and plan for control and cleanup of perchlorate in the Valley has focused on the Saugus Formation. In addition, however, on-site cleanup and control activities that began in 2006, and continued through 2009, include continuation of soil cleanup on the Whittaker-Bermite site, and continuation of pumping and treatment in the Northern Alluvium on the Whittaker-Bermite site. Expanded pumping and treatment, intended to effect perchlorate containment in the Northern Alluvium, became operational in October 2007. Under the direction of the State Department of Toxic Substances Control (DTSC), Whittaker has submitted a comprehensive site-wide remediation plan for the contaminants of concern in soil and groundwater detected on the site. A Draft Remedial Action Plan for Operable Units 2 through 6, focused on soil remediation, was submitted to DTSC in 2009. Whittaker has also completed a Draft Feasibility Study for Operable Unit 7 to identify and select treatment technologies for both on-site and off-site groundwater. Final approval of soil and groundwater clean-up plans by DTSC is expected by the end of 2010.

ES.3 Saugus Formation

The groundwater operating plan in the 2005 UWMP includes pumping from the Saugus in the range of 7,500 to 15,000 afy in average/normal years; it also includes planned dry-year pumping from the Saugus of 21,000 to 35,000 afy for one to three consecutive dry years. The 2005 UWMP recognizes the results of basin yield analyses in 2004 and 2005 which found that such short-term pumping can be recharged during subsequent wet/normal years to allow groundwater levels and storage to recover, as it has in historical periods. The 2008 groundwater Operating Plan includes the same broad ranges by Saugus pumping.

Pumping from the Saugus Formation was about 7,700 af in 2009; on average, Saugus pumping has been about 6,800 afy since 1980. Both rates remain near the lower end of the ranges included in the groundwater operating plans and in the UWMP. As a result of long-term relatively low pumping from the Saugus Formation, groundwater levels in that aquifer have remained generally constant to slightly increasing over the last 35 to 40 years; those trends continued in 2009.

In 1997, ammonium perchlorate was discovered in four wells completed in the Saugus Formation in the vicinity of the former Whittaker-Bermite facility located generally toward the east, on the south side of the basin. All four of those impacted wells remain out of active supply service; one of them has been permanently sealed and destroyed. In 2006, a very low level of perchlorate was detected in another Saugus municipal well (NCWD's Well NC-13). That low level detection has been interpreted to not indicate anything new about the migration of perchlorate; however, it has also prompted additional monitoring well installation and a focused study of the Saugus Formation in that area. Results are being integrated with other groundwater remediation efforts and reviewed by the DTSC. All other Saugus wells owned and operated by the Purveyors are available for municipal water supply service. As part of regular operation, those wells are sampled in accordance with drinking water regulations and perchlorate has not been detected. Despite the inactivated Saugus wells, the Purveyors still have sufficient pumping capacity in other wells to meet the planned normal range of Saugus pumping in the 2005 UWMP.

Work toward the ultimate remediation of perchlorate contamination, including the restoration of impacted groundwater supply continued to progress in 2009, with focus on construction of facilities to implement a jointly developed plan to "pump and treat" contaminated water from two of the originally impacted wells to stop migration of the contaminant plume, and to deliver treated water for municipal supply to partially replace impacted well capacity. Environmental review of the project was completed with adoption of a Mitigated Negative Declaration in September 2005. The Final Interim Remedial Action Plan was completed and approved by DTSC in January 2006. Construction of facilities and pipelines necessary to implement the pump and treat program and to also restore inactivated well capacity began in November 2007. Construction was completed in spring 2010, and operational start-up is ongoing as this report is being written.

ES.4 Imported Water

Historically comprised of only its SWP Table A Amount, CLWA's imported water supplies now consist of a combination of SWP water and water acquired from the Buena Vista Water Storage District in Kern County. CLWA's contractual Table A Amount is 95,200 af of water from the SWP. Under the 2007 Water Acquisition Agreement with the Buena Vista Water Storage District (Buena Vista) and the Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo), Buena Vista's high flow Kern River entitlements (and other acquired waters that may become available) are captured and recharged within the Rosedale-Rio Bravo's service area on an ongoing basis. CLWA will receive 11,000 af of these supplies annually through either exchange

of Buena Vista's and Rosedale-Rio Bravo's SWP supplies or through direct delivery of water to the California Aqueduct via the Cross Valley Canal.

CLWA's final allocation of SWP water for 2009 was 40 percent of its Table A Amount, or 38,080 af. The total available imported water supply in 2009 was 67,050 af, comprised of the 38,080 af of Table A supply, 11,000 af purchased from Buena Vista/Rosedale Rio Bravo, 14,610 af of 2008 carryover delivered in 2009, 1,650 af recovered from the Semitropic Water Banking and Exchange Program, 52 af from the 2009 SWP Turnback Pool and 1,658 af through the Yuba Accord. CLWA deliveries to the Purveyors were 38,546 af. Following disposition of available water supplies in 2009, carryover of 28,303 af from 2008 and 2009 is available for 2010 water supply. No additional banking of imported water occurred in 2009.

CLWA has two groundwater banking agreements with the Semitropic Water Storage District in Kern County. In accordance with those agreements, over a ten-year period (until 2012/13), CLWA could withdraw up to 50,870 af of its Table A water that was stored in 2002 and 2003 to meet future Valley demands when needed. Following the withdrawal of 4,950 af in 2009 (1,650 af utilized in 2009 and 3,300 af planned to be utilized in 2010), that balance is 45,920 af. In addition to the banking in Semitropic, CLWA finalized an agreement with the Rosedale-Rio Bravo Water Storage District in 2005 and can now bank up to 100,000 afy of surplus Table A Amount in that District's Water Banking and Exchange Program. In addition to 20,000 af previously banked in both 2005 and 2006, CLWA banked 8,200 af of water in 2007. In accordance with the provisions of that agreement, CLWA can withdraw up to a total of 42,900 af of that water, at a rate up to 20,000 afy, to meet Valley water demands when needed. Additionally, as part of the Buena Vista Water Acquisition Agreement, CLWA is entitled to 22,000 af of water that was stored in the Rosedale Rio-Bravo Water Banking and Exchange Program in 2005 and 2006 on CLWA's behalf. As of 2010, CLWA maintains a recoverable total of 64,900 af in the Rosedale Rio-Bravo Water Banking and Exchange Program.

Since SWP water deliveries are subject to reduction when dry conditions occur in Northern California, the UWMP includes programs, like the Semitropic and Rosedale-Rio Bravo programs, for enhancing water supply reliability during such occurrences. A capital improvement program funded by CLWA has been established to provide facilities and additional water supplies needed to firm up SWP water supplies during times of drought.

ES.5 Recycled Water

Recycled water service was initiated in July 2003 in accordance with CLWA's Draft Reclaimed

Water System Master Plan (2002). The amount of recycled water used for irrigation purposes, at a golf course and in roadway median strips, was approximately 328 af in 2009. CLWA completed programmatic CEQA analysis in early 2007 for full implementation of the recycled water system as outlined in the Master Plan. CLWA is preparing the design of the second phase of the Recycled Water Master Plan that will take water from the Saugus Water Reclamation plant and distribute it to identified users to the north, across the Santa Clara River and then to the west and the east, which will include service to Santa Clarita Central Park. Another new phase of the recycled water system is in design to extend the system south from Magic Mountain Parkway. Collectively, these phases will have design capacity to increase recycled water deliveries by about 1,500 afy.

ES.6 2010 Water Supply Outlook

In 2010, total water demands are expected to be between 82,000-84,000 af, less than actual water use over the last three years, and below the water demand projections in the 2005 UWMP. It is expected that water demands in 2010 will continue to be met with a generally similar mix of water supplies comprised of local groundwater, supplemental SWP and other imported water, and recycled water.

Announced on May 20, 2010, the final allocation of water from the SWP is 45 percent of CLWA's Table A Amount, or 42,840 af. Combined with local groundwater from the two aquifer systems (48,000 af), total Flexible Storage Account (6,060 af), net carryover of SWP Table A allocation from 2008 and 2009 (28,303 af), annual acquisition through the Buena Vista Water/Rosedale Rio-Bravo Water Acquisition Agreement (11,000 af), delivery of water previously recovered but not used from the Semitropic Groundwater Storage Bank (3,300 af), and recycled water (500 af), the total available water supplies for 2010 are 140,000 af. As a result, CLWA and the Purveyors anticipate having more than adequate supplies to meet all water demands in 2010.

In August, 2007, a federal court ruled that certain operational changes were required of the SWP in order to protect the endangered Delta smelt. The court order resulted in the preparation of a new Biological Opinion (BO) requiring DWR to implement mitigation requirements with resultant impacts on SWP water supply reliability. Since then, DWR has prepared two updates to its 2005 Reliability Report, which is issued biennially to assist SWP contractors in assessing the adequacy of the SWP component of their overall supplies under varying hydrologic scenarios, e.g. normal and dry years. The current Draft SWP Delivery Reliability Report 2009 was issued in February, 2010. With the objective of protecting endangered fish such as the Delta

smelt and spring-run salmon, the Draft incorporates restrictions on SWP operations according to the Biological Opinions of the U.S. Fish and Wildlife Service and the National Marine Fishery Service issued on December 15, 2008 and June 4, 2009, respectively. It also considers the impacts on SWP delivery reliability due to climate change, sea level rise, and vulnerability of the Delta's conveyance system and structure due to floods and earthquakes. The current Draft Reliability Report projects long-term reliability of 60 percent during normal year hydrology. CLWA staff has assessed the impact of the current Reliability Report on the CLWA reliability analysis contained in the Agency's 2005 UWMP and concluded that current and anticipated supplies are available to meet anticipated water supply needs.

CLWA, the retail water Purveyors, Los Angeles County and the City of Santa Clarita have formed the Santa Clarita Valley Water Committee. The specific purpose of the committee is to work collaboratively to ensure the progressive implementation of water use efficiency programs and ordinances in the Santa Clarita Valley. In terms of short-term water supply availability, CLWA has determined that, while current operational changes of the SWP are in effect, there are sufficient supplemental water supplies, including SWP water, to augment local groundwater and other water supplies such that overall water supplies will be sufficient to meet projected 2010 water requirements as reflected herein.

In any given year, SWP supplies may be reduced due to dry weather conditions or regulatory factors. During such an occurrence, the remaining water demands are planned to be met by a combination of alternate supplies such as returning water from CLWA's accounts in the Semitropic Groundwater Storage Program and the Rosedale-Rio Bravo Water Banking and Exchange Program, deliveries from CLWA's flexible storage account in Castaic Lake Reservoir, local groundwater pumping, short-term water exchanges, and participation in DWR dry-year water purchase programs in accordance with the 2005 Urban Water Management Plan. Following the recovery of 4,950 af in 2009, the banked excess 2002 and 2003 SWP Table A water in Semitropic represents nearly 46,000 af of recoverable water for drought water supply. In addition, the banked excess SWP Table A water in 2005 and 2006, augmented by banked water acquired through the Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement in 2005, 2006 and 2007, represent a total of 64,900 af of recoverable water for drought water supply from the Rosedale-Rio Bravo Banking and Exchange Program.

Drought periods may affect available water supplies in any single year and for a duration usually not longer than three consecutive years. It is important to note that hydrologic conditions vary from region to region throughout the state. Dry conditions in Northern California affecting SWP supply may not affect local groundwater and other supplies in Southern California, and the

reverse situation can also occur (as it did in 2002 and 2003). For this reason, CLWA and the Purveyors have emphasized developing a water supply portfolio that is diverse, especially in dry years. Diversity of supply is considered a key element of reliability, giving Valley water Purveyors the ability to draw on multiple sources of supply to ensure reliable service during dry years, as well as during normal and wet years.

1. Introduction

1.1 Background

For most residents of the Santa Clarita Valley (Valley), domestic water service is provided by four retail water Purveyors: Castaic Lake Water Agency's Santa Clarita Water Division (SCWD), Los Angeles County Waterworks District 36 (LAWWD36), Newhall County Water District (NCWD), and Valencia Water Company (VWC). Together, the Purveyors provide water to nearly 70,000 service connections. As a State Water Contractor, Castaic Lake Water Agency (CLWA) contracts for State Water Project water delivered from Castaic Lake, after which it is treated, filtered, and disinfected at two CLWA treatment plants before distribution to the Purveyors. Staff of these entities meet regularly to coordinate the supply of water in the Valley. Their respective service areas are shown in Figure 1-1.

While municipal water supply has grown to become the largest category of water use in the Valley, there remains an agricultural and other small private water demand that is predominately dependent on local groundwater for its water supply. Accordingly, ongoing agricultural water requirements and the use of local groundwater to meet those requirements are considered in analyses of water requirements and supplies such as reported herein. In addition to municipal and agricultural water uses in the Valley, water supply for a small fraction of Valley residents is provided by individual private water supply wells. The locations, construction details, annual pumping and other information about these private wells are not currently available. In the absence of detailed information about private wells and associated water use, pumping as reported herein necessarily includes an estimate of groundwater pumped from private wells; it is intended that this estimate will be refined in the future as more information about the private wells is obtained.

For more than 20 years, CLWA and the Purveyors have reviewed and reported on the availability of water supplies to meet all water requirements in the Valley. Those reports have also addressed local water resources, most notably groundwater, in the region. Past studies have assessed the condition of local groundwater aquifers, their hydrogeologic characteristics, aquifer storage capacity, operational yield and recharge rate, groundwater quality and contamination, and the ongoing conjunctive use of groundwater and imported water resources.

Other efforts have included developing drought contingency plans, coordinating emergency response procedures and implementing Valley-wide conservation programs. In 1985, the

Purveyors prepared the area's first Urban Water Management Plan (UWMP.) Information in the plan was coordinated among CLWA and the Purveyors to provide accurate, comprehensive and consistent water supply and demand information for long term planning purposes. In accordance with the California Urban Water Management Planning Act, the Valley-wide UWMP was most recently updated in 2005 to extend water demand projections through 2030, and to describe the combination of local groundwater, imported water supplies from the State Water Project, local recycled water supplies, and planned other water supplies to meet the existing and projected water demands in the Valley. The 2005 UWMP also describes the reliability of local groundwater resources and the adequacy of groundwater supplies to meet that component of overall water supply; and it also describes the impacts of perchlorate contamination on several municipal water supply wells, and the plans and ongoing work for integrated control of perchlorate migration and full restoration of perchlorate-impacted groundwater supply.

In 2009, primarily in preparation for the next update of the UWMP in 2010, an updated analysis of groundwater basin yield was completed to guide the ongoing use of groundwater and the associated distribution of pumping to maintain groundwater use at a sustainable rate while also addressing localized issues such as restoration of groundwater contamination which has impacted local groundwater supplies since 1987. The results of the updated groundwater basin analysis are summarized in this Water Report.

1.2 Purpose and Scope of the Report

The purpose of this report, which is the twelfth in a series of annual water reports that began to describe water supply conditions in 1998, is to provide current information about water requirements and available water supplies to meet those demands in the Santa Clarita Valley. CLWA and the Purveyors began preparation of this series of reports in response to a request made by the Los Angeles County Board of Supervisors in 1998. Over the last few years, this series of reports has also served as an annual summary of groundwater conditions in the Valley in fulfillment of the commitment in the Santa Clarita Valley Groundwater Management Plan, adopted in 2003, to regularly report on implementation of that Plan.

This report was prepared for Castaic Lake Water Agency, for CLWA's Santa Clarita Water Division, and for Los Angeles County Waterworks District 36, Newhall County Water District, and Valencia Water Company. It continues a format for providing information regarding water uses and the availability of water supplies on an annual basis. It is intended to be a helpful resource for use by water planners and local land use planning agencies. This report is complemented by the more detailed Urban Water Management Plan for the area, which provides

longer-term water supply planning over a 25-year period, and by a number of other technical reports, some of which are specifically referenced herein.

1.3 Santa Clarita Valley Water Purveyors

As introduced above, four retail water Purveyors provide water service to most residents of the Santa Clarita Valley. Brief summary descriptions of those four Purveyors are as follows.

Castaic Lake Water Agency Santa Clarita Water Division has a service area that includes a portion of the City of Santa Clarita and unincorporated portions of Los Angeles County in the communities of Saugus, Canyon Country, and Newhall. Water is supplied from both groundwater and CLWA turnouts to about 28,700 service connections.

Los Angeles County Waterworks District 36 has a service area that encompasses approximately 7,635 acres in the Hasley Canyon area and the unincorporated community of Val Verde. LAWWD 36 has nearly 1,400 service connections. The District has traditionally obtained its full water supply from a connection to the CLWA's Castaic Conduit and continued to do so in 2009.

Newhall County Water District's service area includes portions of the City of Santa Clarita and unincorporated portions of Los Angeles County in the communities of Newhall, Canyon Country, Valencia, and Castaic. NCWD supplies water from both groundwater and CLWA turnouts to approximately 9,600 service connections.

Valencia Water Company's service area serves nearly 30,000 service connections in a portion of the City of Santa Clarita and in the unincorporated communities of Castaic, Newhall, Saugus, Stevenson Ranch, and Valencia. VWC supplies water from both groundwater and CLWA turnouts; VWC also delivers recycled water for a small amount of non-potable use.

1.4 The Upper Santa Clara River Hydrologic Area and East Groundwater Subbasin

The Upper Santa Clara River Hydrologic Area (HA), as defined by the California Department of Water Resources (DWR), is located almost entirely in northwestern Los Angeles County. The area encompasses about 654 square miles comprised of flat valley land (about 6 percent of the total area) and hills and mountains (about 94 percent of the total area) that border the valley area. The mountains include the Santa Susana and San Gabriel Mountains to the south, and the Sierra

Pelona and Leibre-Sawmill Mountains to the north. Elevations range from about 800 feet on the valley floor to about 6,500 feet in the San Gabriel Mountains. The headwaters of the Santa Clara River are at an elevation of about 3,200 feet at the divide separating this hydrologic area from the Mojave Desert.

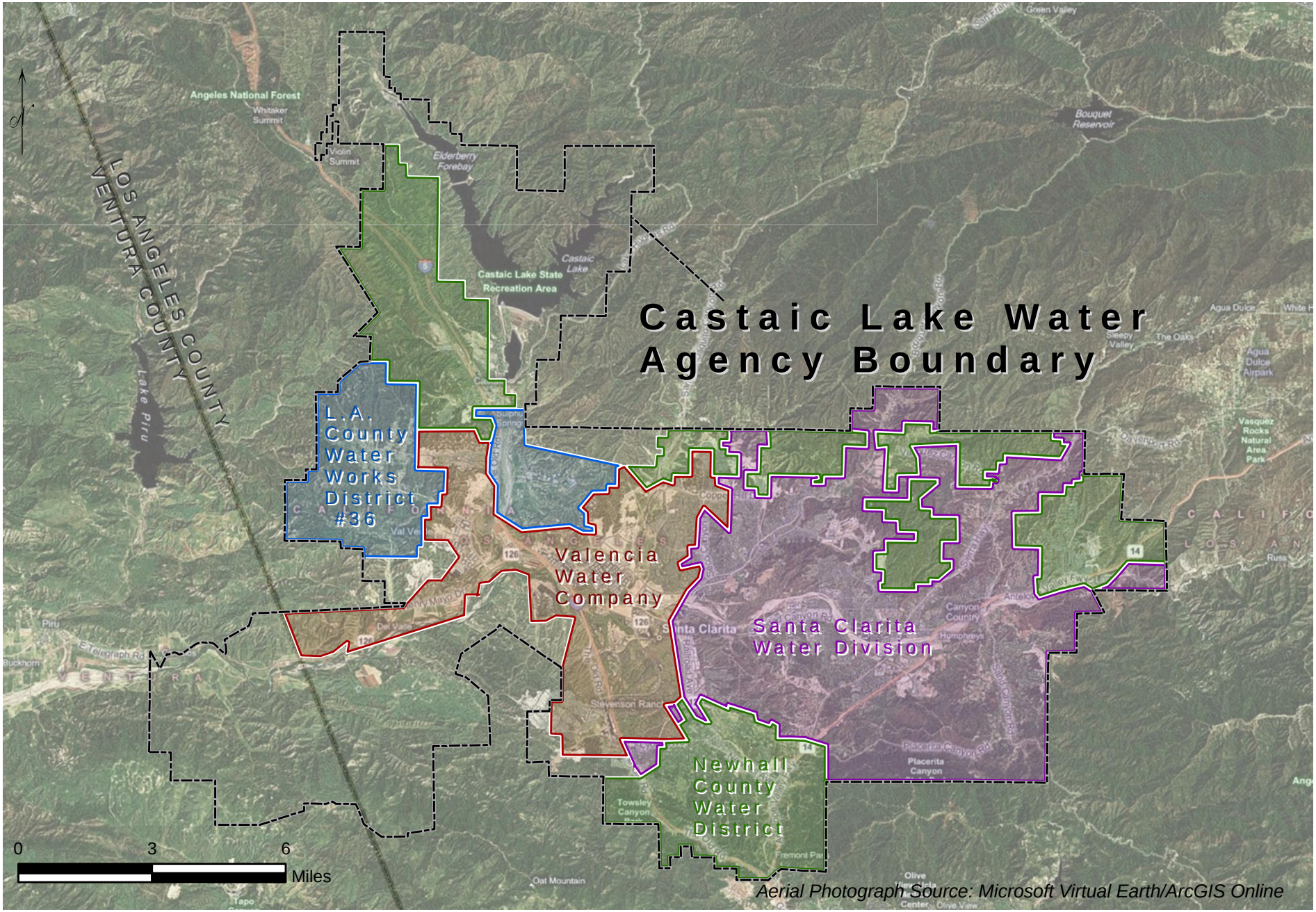
The Santa Clara River and its tributaries flow intermittently from Lang Station westward about 35 miles to Blue Cut, just west of the Los Angeles-Ventura County line, where the River is the outlet from the Upper Santa Clara River Hydrologic Area. The principal tributaries of the River in the Santa Clarita Valley are Castaic Creek, San Francisquito Creek, Bouquet Creek, and the South Fork of the Santa Clara River. In addition to tributary inflow, the Santa Clara River receives treated wastewater discharge from the Saugus and Valencia Water Reclamation Plants, which are operated by the Sanitation Districts of Los Angeles County.

The Santa Clara River Valley East Groundwater Subbasin, beneath the Santa Clarita Valley in the Upper Santa Clara River HA, is the source of essentially all local groundwater used for water supply in the Santa Clarita Valley. Below Blue Cut, the Santa Clara River continues westward through Ventura County to its mouth near Oxnard. Along that route, the River traverses all or parts of six groundwater basins in Ventura County (Piru, Fillmore, Santa Paula, Oxnard Forebay, Oxnard Plain, and Mound) as shown in Figure 1-2.

There are two primary precipitation gages in the Santa Clarita Valley, the Newhall-Soledad 32c gage and the Newhall County Water District gage (Figure 1-3). The National Climatic Data Center (NCDC) and Los Angeles County Department of Public Works (LADPW) have maintained records for the Newhall-Soledad 32c gage since 1931. Newhall County Water District has maintained records for the NCWD gage since 1979. The cumulative records from these two gages correlate very closely, with the NCWD gage recording approximately 25 percent more precipitation than the Newhall-Soledad 32c gage. This is likely due to the location of the NCWD gage, which is at the base of the mountains rimming the southern edge of the Santa Clarita Valley.

The Santa Clarita Valley is characterized as having an arid climate. Historically, intermittent periods of below-average precipitation have typically been followed by periods of above-average precipitation in a cyclical pattern, with each wetter or drier period typically lasting from one to five years. The longer-term precipitation records for the Newhall-Soledad 32c gage are illustrated in Figure 1-3. Long-term average precipitation at that gage is 17.9 inches (1931-2009). Figure 1-3 also shows the cumulative departure from mean annual precipitation. In general, periods of below-average precipitation have been longer and more moderate than

periods of above-average precipitation. Recently, the periods from 1971 to 1976, 1984 to 1991 and 1999 to 2003 have been drier than average; the periods from 1977 to 1983 and 1992 to 1996 have been wetter than average. More recently, wet conditions that began in late 2004, continued into early 2005, ultimately resulting in about 37 inches of measured precipitation, or slightly more than 200 percent of long-term average precipitation, in that year. Those significantly wet conditions contributed to substantial groundwater recharge and decreased water demand that year. Subsequently, total precipitation in 2006 and 2007 was slightly to significantly lower, 14 inches and 6 inches respectively, but water requirements in both years were still close to those projected in the 2005 UWMP, and there were no dramatic changes in groundwater conditions. With the exception of the average annual rainfall total in 2008, the dry conditions that began in 2006 have persisted through 2009. 2009 was a below-average year, with 11.6 inches of precipitation. However, water demand in 2009 was below that projected for average conditions in the 2005 UWMP, and below the short-term projection in the 2008 Water Report. Early year precipitation in 2010 was approximately 13.4 inches through April, or close to long-term average for that part of the year, but water use further decreased from last year for the same period. Combined with other water supply considerations, discussed in Chapter 4, those conditions are expected to result in 2010 water requirements being slightly lower than water use in 2009.



Aerial Photograph Source: Microsoft Virtual Earth/ArcGIS Online

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Figure 1-1
CLWA and Purveyor Service Areas

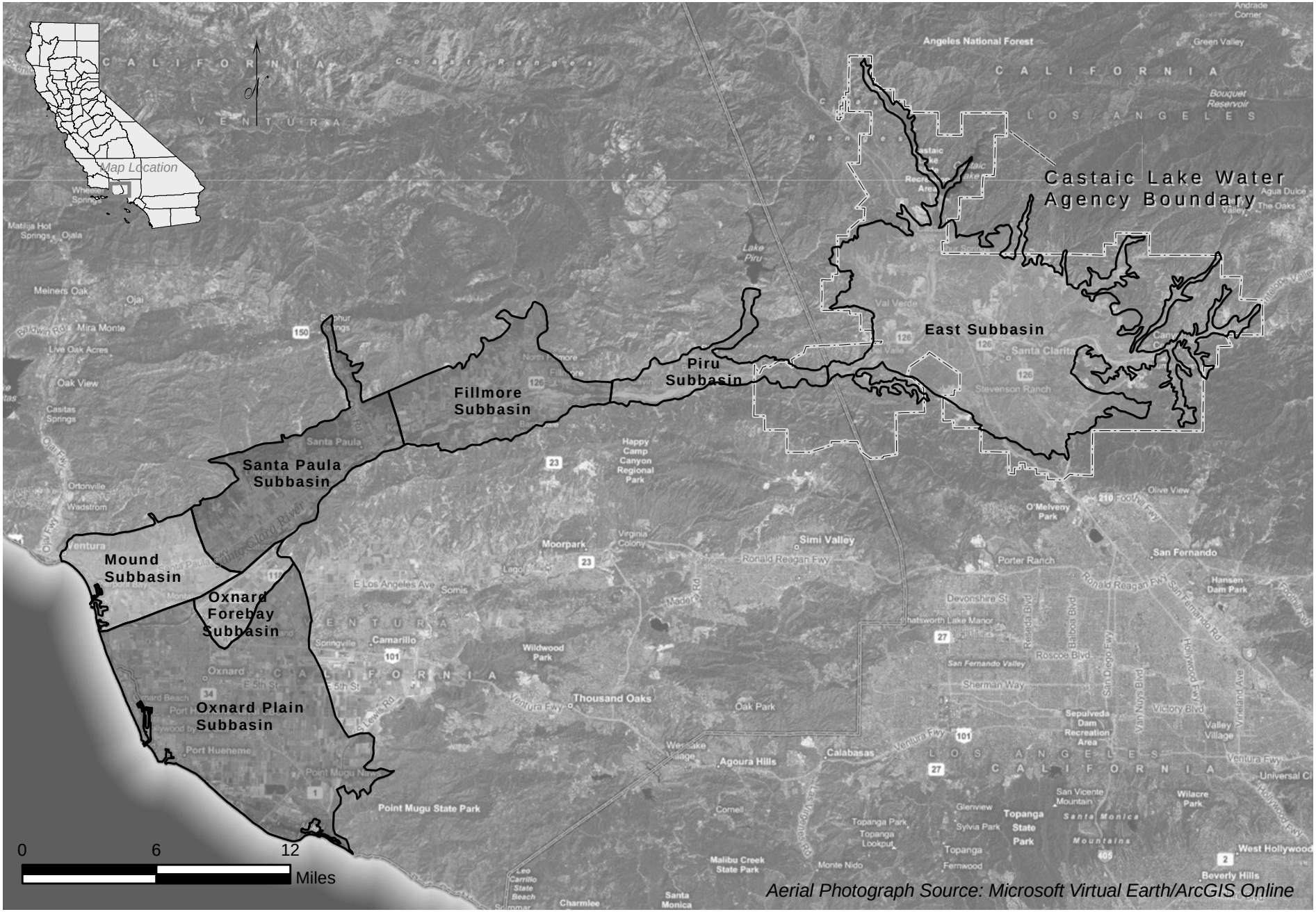

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Figure 1-2
Santa Clara River Groundwater Subbasins

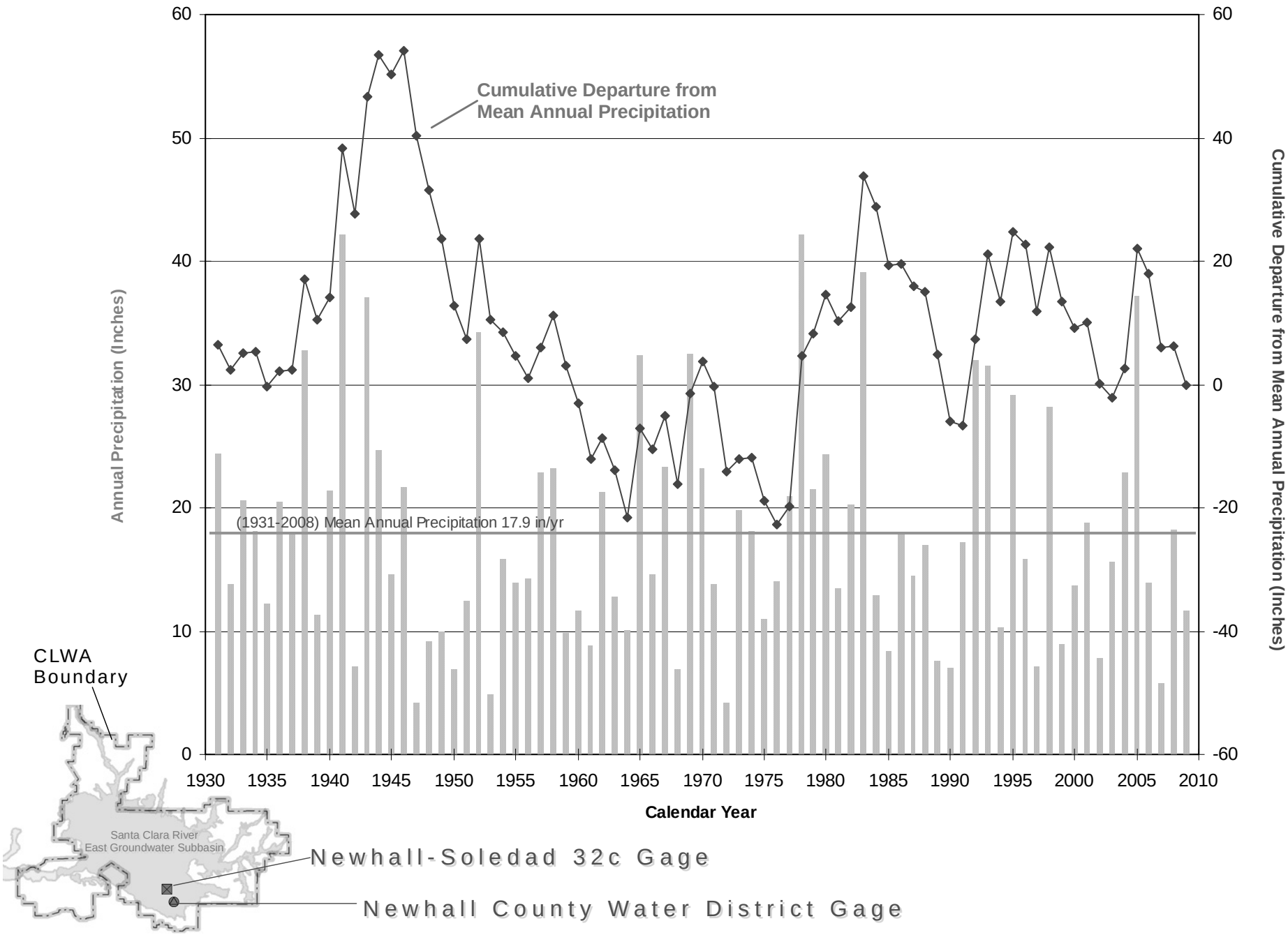

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Figure 1-3
Annual Precipitation and Cumulative Departure from Mean Annual Precipitation at Newhall-Soledad 32c Gage

2. 2009 Water Requirements and Supplies

Total water use in the Santa Clarita Valley was 86,600 af in 2009, a decrease of 4,100 af from the previous year. Of the total water demand, 70,000 af (81 percent) were for municipal use and the remaining 16,600 af (19 percent) were for agricultural and other (miscellaneous) uses, including estimated individual domestic uses. The majority of decreased water demand is attributable to a significant (8%) decrease in municipal water use from 2008. The total water demands were met by a combination of about 47,700 af from local groundwater resources (about 31,100 af for municipal supply and about 16,600 af for agricultural and other uses), about 38,600 af of SWP and other imported water, and about 300 af of recycled water.

Compared to the previous year, total water demand in the Santa Clarita Valley decreased by about 4.5 percent in 2009, and was less than the short-term projected water requirement presented in last year's Water Report. The decrease in water use in 2009 is attributed to ongoing very slow growth in the number of new service connections and continued water conservation awareness as a result of state-wide dry conditions and decreased deliveries of water from the State Water Project. Growth in each Purveyor service area was notably lower than in the preceding two years, with total additions of only about 300 new services connections in 2009, in notable contrast to the growth rate of about 1,000 connections per year over the preceding three years, and in even greater contrast to the predominant growth rate that was three times higher from the late 1990's through 2004. In addition, the Purveyors and the local community continued to be aware of the Governor's Alert in June, 2008 with regard to drought conditions and potential water supply shortages followed by the Governor's Drought Emergency Declaration in February, 2009. The widespread awareness of dry conditions throughout the state and the perceived effects on water supply availability are considered to be prime factors causing total water demand in 2009 to have continued to decline over each of the preceding two years, and to be well below the demand projections in the 2005 UWMP.

The uses of local groundwater, augmented by imported water supplies to meet municipal water requirements since 1980, when the importation of SWP water began, and also slightly augmented by the use of recycled water, are summarized in Table 2-1. Notable with regard to municipal water requirements is that, through 2009, total municipal demand (70,000 af) continues to be below (by about 11,000 af in 2009) the projections in the 2005 UWMP without conservation, and about equal to the projections in the UWMP with conservation.

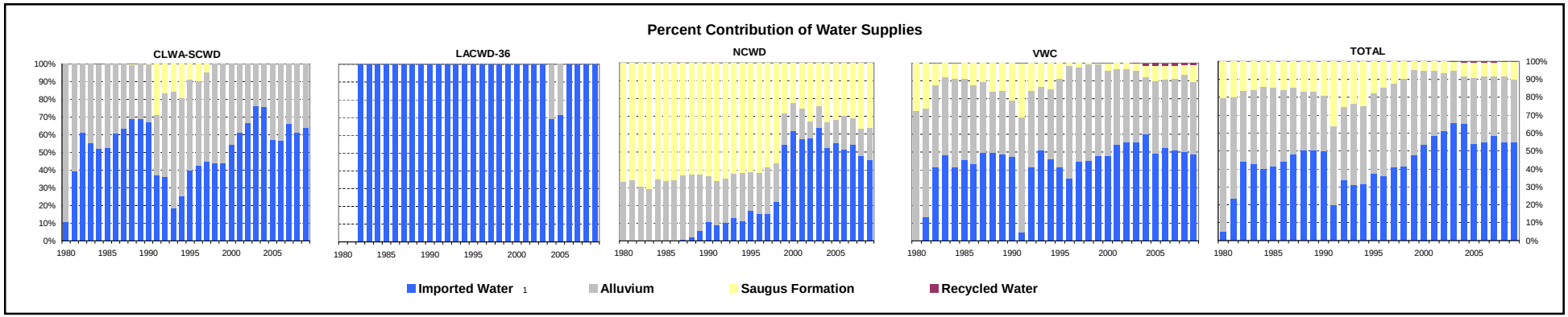
Water supply utilization for all agricultural and other non-municipal uses is summarized in Table 2-2. The category of Small Private Domestic, Irrigation and Golf Course Uses in Table 2-2 includes an estimated 500 af of small private pumping from the Alluvium.

Water supply utilization for all uses in the Santa Clarita Valley, again for the period 1980 to present, is summarized in Table 2-3. The trends in utilization of local groundwater and imported water, complemented by the recent addition of recycled water, are graphically illustrated in Figure 2-1. As can be seen by inspection of Table 2-2 and Figure 2-1, total water use in the Valley was nearly linearly increasing from the early 1980's through 2007, with some weather-related fluctuations in certain years. As discussed above, total water use has declined over the last two years, from a peak slightly above 92,000 af in 2007 to 86,600 af in 2009. Overall, the increase in total water demand since the inception of supplemental SWP importation has been from about 37,000 acre-feet in 1980 to the mid-80,000 acre-feet per year range through 2000-2005, to the short-term peak in the low-90,000 acre-feet per year range in 2006 through 2008.

The decreased demand in 2009 is comparable to the then-increasing demand in 2002. As can also be seen by inspection of Table 2-2 and Figure 2-1, most of the historical increase in water demand has been met with generally increasing importation of SWP water, most recently complemented by other imported water as discussed herein. Since the early 1990's, following a decade of decreased groundwater use during the initial period of SWP importation, total groundwater pumping has fluctuated from year to year, but has remained within a range between about 38,000 and 50,000 acre-feet per year through 2009.

Table 2-1
Water Supply Utilization by Municipal Purveyors
(Acre-Feet)

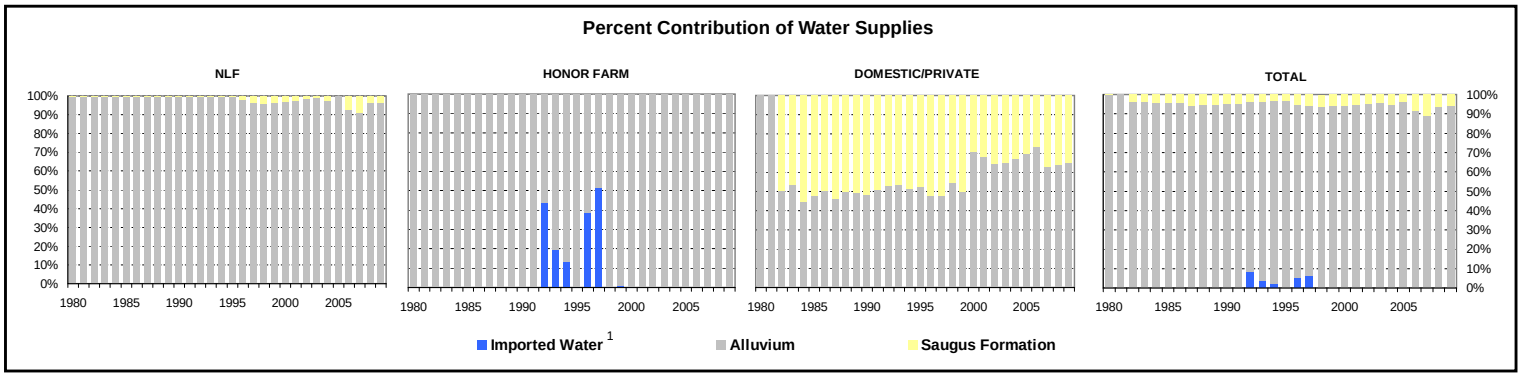
Year	CLWA Santa Clarita Water Division				Los Angeles County Waterworks District 36			Newhall County Water District				Valencia Water Company					All Municipal Purveyors				
	Imported Water [1]	*Alluvium*	*Saugus Formation*	**Total**	*Imported Water* [1]	*Alluvium* [2]	**Total**	*Imported Water* [1]	*Alluvium*	*Saugus Formation*	**Total**	*Imported Water* [1]	*Alluvium*	*Saugus Formation*	*Recycled Water*	**Total**	*Imported Water* [1]	*Alluvium*	*Saugus Formation*	*Recycled Water*	**Total**
1980	1,125	9,460	0	**10,585**	0	-	**0**	0	1,170	2,363	**3,533**	0	5,995	2,206	-	**8,201**	1,125	16,625	4,569	-	**22,319**
1981	4,602	7,109	0	**11,711**	0	-	**0**	0	1,350	2,621	**3,971**	1,214	5,597	2,329	-	**9,140**	5,816	14,056	4,950	-	**24,822**
1982	6,454	4,091	0	**10,545**	145	-	**145**	0	1,178	2,672	**3,850**	3,060	3,415	897	-	**7,372**	9,659	8,684	3,569	-	**21,912**
1983	5,214	4,269	0	**9,483**	207	-	**207**	0	1,147	2,787	**3,934**	3,764	3,387	611	-	**7,762**	9,185	8,803	3,398	-	**21,386**
1984	6,616	6,057	0	**12,673**	240	-	**240**	0	1,549	2,955	**4,504**	4,140	4,975	854	-	**9,969**	10,996	12,581	3,809	-	**27,386**
1985	6,910	6,242	0	**13,152**	272	-	**272**	0	1,644	3,255	**4,899**	4,641	4,633	885	-	**10,159**	11,823	12,519	4,140	-	**28,482**
1986	8,366	5,409	0	**13,775**	342	-	**342**	0	1,842	3,548	**5,390**	5,051	5,167	1,427	-	**11,645**	13,759	12,418	4,975	-	**31,152**
1987	9,712	5,582	0	**15,294**	361	-	**361**	22	2,127	3,657	**5,806**	6,190	4,921	1,305	-	**12,416**	16,285	12,630	4,962	-	**33,877**
1988	11,430	5,079	63	**16,572**	434	-	**434**	142	2,283	4,041	**6,466**	7,027	4,835	2,300	-	**14,162**	19,033	12,197	6,404	-	**37,634**
1989	12,790	5,785	0	**18,575**	457	-	**457**	428	2,367	4,688	**7,483**	7,943	5,826	2,529	-	**16,298**	21,618	13,978	7,217	-	**42,813**
1990	12,480	5,983	40	**18,503**	513	-	**513**	796	1,936	4,746	**7,478**	7,824	5,232	3,516	-	**16,572**	21,613	13,151	8,302	-	**43,066**
1991	6,158	5,593	4,781	**16,532**	435	-	**435**	675	1,864	4,994	**7,533**	700	9,951	4,642	-	**15,293**	7,968	17,408	14,417	-	**39,793**
1992	6,350	8,288	2,913	**17,551**	421	-	**421**	802	1,994	5,160	**7,956**	6,338	6,615	2,385	-	**15,338**	13,911	16,897	10,458	-	**41,266**
1993	3,429	12,016	2,901	**18,346**	465	-	**465**	1,075	1,977	5,068	**8,120**	8,424	5,815	2,182	-	**16,421**	13,393	19,808	10,151	-	**43,352**
1994	5,052	10,996	3,863	**19,911**	453	-	**453**	906	2,225	5,103	**8,234**	7,978	6,847	2,565	-	**17,390**	14,389	20,068	11,531	-	**45,988**
1995	7,955	10,217	1,726	**19,898**	477	-	**477**	1,305	1,675	4,775	**7,755**	7,259	8,698	1,586	-	**17,543**	16,996	20,590	8,087	-	**45,673**
1996	9,385	10,445	2,176	**22,006**	533	-	**533**	1,213	1,803	4,871	**7,887**	6,962	12,433	326	-	**19,721**	18,093	24,681	7,373	-	**50,147**
1997	10,120	11,268	1,068	**22,456**	785	-	**785**	1,324	2,309	5,168	**8,801**	9,919	11,696	516	-	**22,131**	22,148	25,273	6,752	-	**54,173**
1998	8,893	11,426	0	**20,319**	578	-	**578**	1,769	1,761	4,557	**8,087**	9,014	10,711	149	-	**19,874**	20,254	23,898	4,706	-	**48,858**
1999	10,772	13,741	0	**24,513**	654	-	**654**	5,050	1,676	2,622	**9,348**	10,806	11,823	106	-	**22,735**	27,282	27,240	2,728	-	**57,250**
2000	13,751	11,529	0	**25,280**	800	-	**800**	6,024	1,508	2,186	**9,718**	12,004	12,179	1,007	-	**25,190**	32,579	25,216	3,193	-	**60,988**
2001	15,648	9,896	0	**25,544**	907	-	**907**	5,452	1,641	2,432	**9,525**	13,362	10,518	835	-	**24,715**	35,369	22,055	3,267	-	**60,691**
2002	18,921	9,513	0	**28,434**	1,069	-	**1,069**	5,986	981	3,395	**10,362**	15,792	11,603	965	-	**28,360**	41,768	22,097	4,360	-	**68,225**
2003	20,668	6,424	0	**27,092**	1,175	-	**1,175**	6,572	1,266	2,513	**10,351**	16,004	11,707	1,068	50	**28,829**	44,419	19,397	3,581	50	**67,447**
2004	22,045	7,146	0	**29,191**	854	380	**1,234**	5,896	1,582	3,739	**11,217**	18,410	9,862	1,962	420	**30,654**	47,205	18,970	5,701	420	**72,296**
2005	16,513	12,408	0	**28,921**	857	343	**1,200**	5,932	1,389	3,435	**10,756**	14,732	12,228	2,513	418	**29,891**	38,034	26,368	5,948	418	**70,768**
2006	17,146	13,156	0	**30,302**	1,289	-	**1,289**	5,898	2,149	3,423	**11,470**	16,313	11,884	2,449	419	**31,065**	40,646	27,189	5,872	419	**74,126**
2007	20,669	10,686	0	**31,355**	1,406	-	**1,406**	6,478	1,806	3,691	**11,975**	16,779	13,140	2,367	470	**32,756**	45,332	25,632	6,058	470	**77,492**
2008	18,598	11,878	0	**30,476**	1,354	-	**1,354**	5,428	1,717	4,195	**11,340**	16,325	14,324	1,770	311	**32,730**	41,705	27,919	5,965	311	**75,900**
2009	17,739	10,077	0	**27,816**	1,243	-	**1,243**	4,832	1,860	3,868	**10,559**	14,732	12,459	2,836	328	**30,355**	38,546	24,396	6,704	328	**69,974**



1. Reflects State Water Project through 2006; includes imported water from State Water Project and Buena Vista WSD Agreement beginning in 2007.
2.Groundwater purchased from LA County Honor Farm.

Table 2-2
Individual Water Supply Utilization by Agricultural and Other Users
(Acre-Feet)

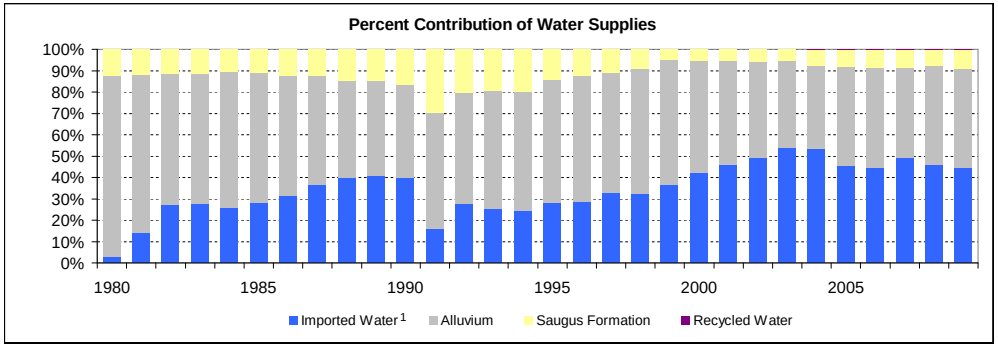
	Newhall Land and Farming			Los Angeles County Honor Farm			Small Private Domestic, Irrigation and Golf Courses Uses			All Agricultural and Other Users			
Year	*Alluvium*	*Saugus Formation*	**Total**	*Alluvium*	*Imported Water* [1]	**Total**	*Alluvium* [2]	*Saugus Formation* [3]	**Total**	*Imported Water* [1]	*Alluvium*	*Saugus Formation*	**Total**
1980	11,331	20	**11,351**	3,000	0	**3,000**	500	0	**500**	0	14,831	20	**14,851**
1981	13,237	20	**13,257**	3,000	0	**3,000**	500	0	**500**	0	16,737	20	**16,757**
1982	9,684	20	**9,704**	3,000	0	**3,000**	500	501	**1,001**	0	13,184	521	**13,705**
1983	7,983	20	**8,003**	3,000	0	**3,000**	500	434	**934**	0	11,483	454	**11,937**
1984	11,237	20	**11,257**	3,000	0	**3,000**	500	620	**1,120**	0	14,737	640	**15,377**
1985	9,328	20	**9,348**	3,000	0	**3,000**	500	555	**1,055**	0	12,828	575	**13,403**
1986	8,287	20	**8,307**	3,000	0	**3,000**	500	490	**990**	0	11,787	510	**12,297**
1987	6,512	20	**6,532**	3,000	0	**3,000**	500	579	**1,079**	0	10,012	599	**10,611**
1988	5,951	20	**5,971**	3,000	0	**3,000**	500	504	**1,004**	0	9,451	524	**9,975**
1989	6,243	20	**6,263**	3,000	0	**3,000**	500	522	**1,022**	0	9,743	542	**10,285**
1990	8,225	20	**8,245**	2,000	0	**2,000**	500	539	**1,039**	0	10,725	559	**11,284**
1991	7,039	20	**7,059**	2,240	0	**2,240**	500	480	**980**	0	9,779	500	**10,279**
1992	8,938	20	**8,958**	1,256	987	**2,243**	500	446	**946**	987	10,694	466	**12,147**
1993	8,020	20	**8,040**	1,798	443	**2,241**	500	439	**939**	443	10,318	459	**11,220**
1994	10,606	20	**10,626**	1,959	311	**2,270**	500	474	**974**	311	13,065	494	**13,870**
1995	11,174	20	**11,194**	2,200	6	**2,206**	500	453	**953**	6	13,874	473	**14,353**
1996	12,020	266	**12,286**	1,237	780	**2,017**	500	547	**1,047**	780	13,757	813	**15,350**
1997	12,826	445	**13,271**	1,000	1,067	**2,067**	500	548	**1,048**	1,067	14,326	993	**16,386**
1998	10,250	426	**10,676**	2,000	12	**2,012**	500	423	**923**	12	12,750	849	**13,611**
1999	13,824	479	**14,303**	1,842	20	**1,862**	500	509	**1,009**	20	16,166	988	**17,174**
2000	11,857	374	**12,231**	1,644	3	**1,647**	1,220	513	**1,733**	3	14,721	887	**15,611**
2001	12,661	300	**12,961**	1,604	0	**1,604**	1,224	573	**1,797**	0	15,489	873	**16,362**
2002	13,514	211	**13,725**	1,602	0	**1,602**	1,063	589	**1,652**	0	16,179	800	**16,979**
2003	10,999	122	**11,121**	2,273	0	**2,273**	931	504	**1,435**	0	14,203	626	**14,829**
2004	10,991	268	**11,259**	2,725	0	**2,725**	1,071	535	**1,606**	0	14,787	803	**15,590**
2005	8,648	6	**8,654**	2,499	0	**2,499**	1,133	499	**1,632**	0	12,280	505	**12,785**
2006	11,477	934	**12,411**	3,026	0	**3,026**	1,369	506	**1,875**	0	15,872	1,440	**17,312**
2007	9,968	971	**10,939**	2,085	0	**2,085**	1,088	656	**1,744**	0	13,141	1,627	**14,768**
2008	9,191	330	**9,521**	3,506	0	**3,506**	1,100	623	**1,723**	0	13,797	953	**14,750**
2009	11,061	379	**11,440**	3,432	0	**3,432**	1,097	595	**1,692**	0	15,590	974	**16,564**



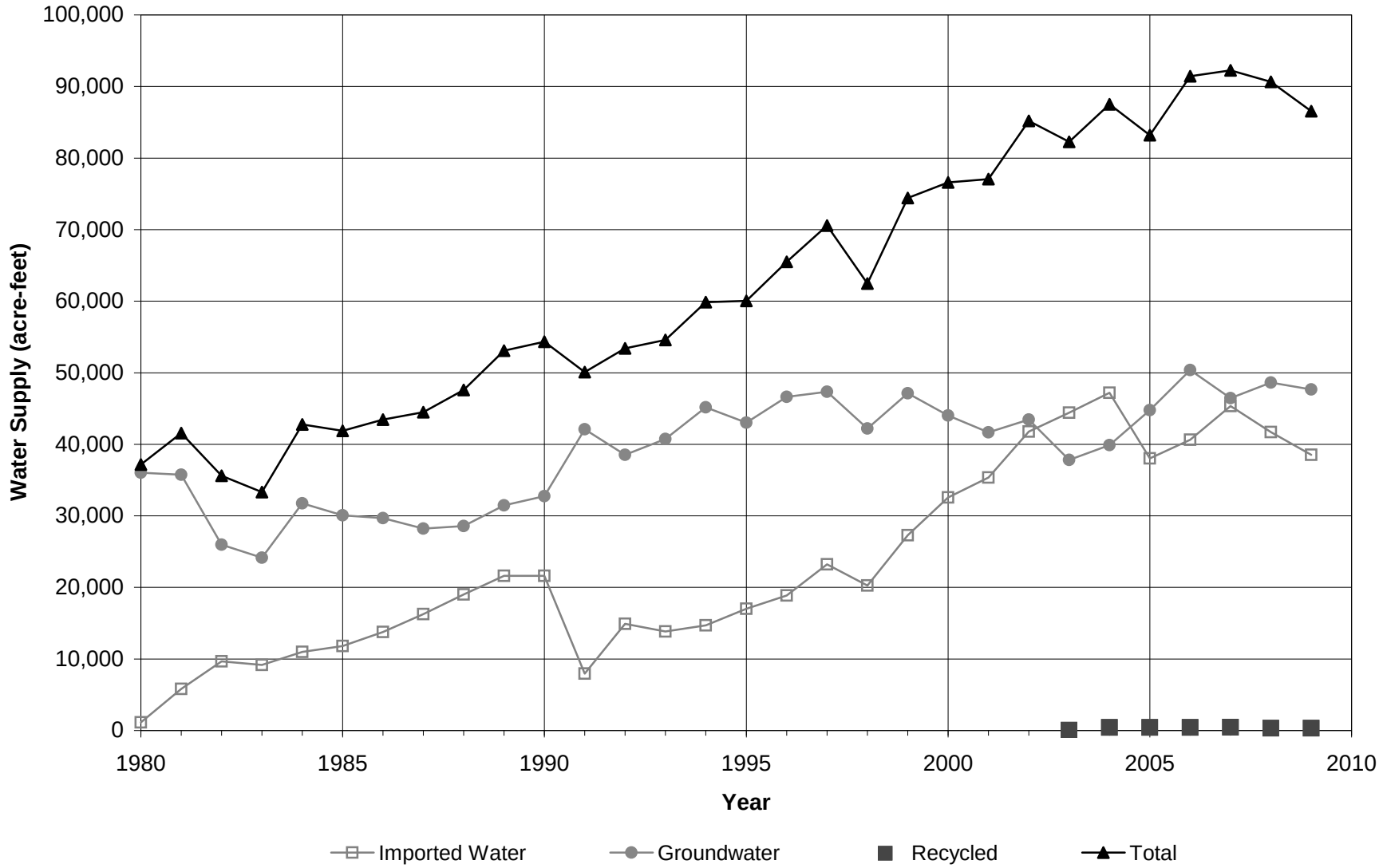
1. *Reflects State Water Project through 2006; includes imported water from State Water Project and Buena Vista WSD Agreement beginning in 2007.*
2. *Robinson Ranch Golf Course irrigation and estimated private pumping.*
3. *Valencia Country Club and Vista Valencia Golf Course irrigation.*

Table 2-3
Total Water Supply Utilization for Municipal, Agricultural and Other Uses
(Acre-Feet)

Year	*Imported Water*[1]	*Alluvium*	*Saugus Formation*	*Recycled Water*	**Total**
1980	1,125	31,456	4,589	-	**37,170**
1981	5,816	30,793	4,970	-	**41,579**
1982	9,659	21,868	4,090	-	**35,617**
1983	9,185	20,286	3,852	-	**33,323**
1984	10,996	27,318	4,449	-	**42,763**
1985	11,823	25,347	4,715	-	**41,885**
1986	13,759	24,205	5,485	-	**43,449**
1987	16,285	22,642	5,561	-	**44,488**
1988	19,033	21,648	6,928	-	**47,609**
1989	21,618	23,721	7,759	-	**53,098**
1990	21,613	23,876	8,861	-	**54,350**
1991	7,968	27,187	14,917	-	**50,072**
1992	14,898	27,591	10,924	-	**53,413**
1993	13,836	30,126	10,610	-	**54,572**
1994	14,700	33,133	12,025	-	**59,858**
1995	17,002	34,464	8,560	-	**60,026**
1996	18,873	38,438	8,186	-	**65,497**
1997	23,215	39,599	7,745	-	**70,559**
1998	20,266	36,648	5,555	-	**62,469**
1999	27,302	43,406	3,716	-	**74,424**
2000	32,582	39,937	4,080	-	**76,599**
2001	35,369	37,544	4,140	-	**77,053**
2002	41,768	38,276	5,160	-	**85,204**
2003	44,419	33,599	4,207	50	**82,276**
2004	47,205	33,757	6,503	420	**87,885**
2005	38,034	38,648	6,453	418	**83,553**
2006	40,646	43,061	7,312	419	**91,438**
2007	45,332	38,773	7,685	470	**92,260**
2008	41,705	41,716	6,918	311	**90,650**
2009	38,546	39,986	7,678	328	**86,538**



1. Reflects State Water Project through 2006; includes imported water from State Water Project and Buena Vista WSD Agreement beginning in 2007.



LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Figure 2-1
Total Water Supply Utilization
Santa Clarita Valley

3. Water Supplies

Prior to 1980, local groundwater extracted from the Alluvium and the Saugus Formation was the sole source of water supply in the Santa Clarita Valley. Since 1980, local groundwater supplies have been supplemented with imported SWP water supplies, augmented in 2007 by acquisition of additional supplemental water from the Buena Vista Water Storage District. Those water supplies have also been slightly augmented by deliveries from CLWA's recycled water program since 2003. This section describes the groundwater resources of the Santa Clarita Valley, SWP and other imported water supplies, and CLWA's recycled water program.

3.1 Groundwater Basin Yield

The groundwater basin generally beneath the Santa Clarita Valley, identified in the State Department of Water Resources' Bulletin 118 as the Santa Clara River Valley Groundwater Basin, East Subbasin (Basin No. 4-4.07), is comprised of two aquifer systems. The Alluvium generally underlies the Santa Clara River and its several tributaries, and the Saugus Formation underlies practically the entire Upper Santa Clara River area. The mapped extent of the Santa Clara River Valley East Subbasin in DWR Bulletin 118 and its relationship to the extent of the CLWA service area are illustrated in Figure 3-1. The mapped Subbasin boundary approximately coincides with the outer extent of the Alluvium and Saugus Formation.

A 2001 Update Report on both the Alluvium and Saugus Formation Aquifers (Slade, 2002), which updated analyses and interpretation of hydrogeologic conditions from earlier reports (Slade, 1986 and 1988), included extensive detail on major aspects of the groundwater basin. Notable parts of the Update Report relative to groundwater supply included findings that:

- Analysis of historical groundwater levels and production indicates that there have been no conditions that would be illustrative of groundwater overdraft.

- Utilization of operational yield (as opposed to perennial yield) as a basis for managing groundwater production would be more applicable in this basin to reflect fluctuating utilization of groundwater in conjunction with imported SWP water.

- Operational yield of the Alluvium would typically be 30,000 to 40,000 afy for wet and normal rainfall years, with an expected reduction into the range of 30,000 to 35,000 afy in dry years.

- Operational yield of the Saugus Formation would typically be in the range of 7,500 to 15,000 afy on a long-term basis, with possible short-term increases during dry periods into a range of 15,000 to 25,000 afy, and to 35,000 afy if dry conditions continue.

Following on the 2001 Update Report, the groundwater component of overall water supply in the Valley derives from a groundwater operating plan to meet water requirements (municipal, agricultural and other non-municipal, and small individual domestic) while maintaining the basin in a sustainable condition (i.e., no long-term depletion of groundwater or interrelated surface water). That operating plan also addresses groundwater contamination issues in the basin, all consistent with the Groundwater Management Plan adopted in 2003. The groundwater operating plan is based on the concept that pumping can vary from year to year to generally rely on increased groundwater use in dry periods and increased recharge during locally wet periods, and to collectively assure that the groundwater basin is adequately replenished through various wet/dry cycles.

The groundwater operating plan, summarized in Table 3-1, is as follows:

Alluvium – Pumping from the Alluvial Aquifer in a given year is related to local hydrologic conditions in the eastern Santa Clara River watershed. Pumping is expected to typically range between 30,000 and 40,000 afy following normal and above-normal rainfall years. Due to hydrogeologic constraints in the eastern part of the basin, pumping is expected to be typically reduced to between 30,000 and 35,000 afy following multiple locally dry years.

Saugus Formation – Pumping from the Saugus Formation in a given year is related to the availability of other water supplies, particularly from the SWP. During average-year conditions within the SWP system, Saugus pumping is expected to typically range between 7,500 and 15,000 afy. Planned dry-year pumping from the Saugus Formation is expected to range between 15,000 and 25,000 afy during a drought year and can increase to between 21,000 and 25,000 afy if SWP deliveries are reduced for two consecutive years, and between 21,000 and 35,000 afy if SWP deliveries are reduced for three consecutive years. Such high pumping is expected to typically be followed by periods of reduced (average-year) pumping, at rates between 7,500 and 15,000 afy, to further enhance the effectiveness of natural recharge processes that would cause groundwater levels and storage volumes to recover after the higher pumping during dry years.

Table 3-1
Groundwater Operating Plan for the Santa Clarita Valley

Aquifer	Groundwater Production (af)			
	Normal Years	**Dry Year 1**	**Dry Year 2**	**Dry Year 3**
Alluvium	30,000 to 40,000	30,000 to 35,000	30,000 to 35,000	30,000 to 35,000
Saugus	7,500 to 15,000	15,000 to 25,000	21,000 to 25,000	21,000 to 35,000
Total	**37,500 to 55,000**	**45,000 to 60,000**	**51,000 to 60,000**	**51,000 to 70,000**

In 2004, as part of analyzing the restoration of perchlorate-impacted groundwater supply in the Valley, a numerical groundwater flow model was developed and calibrated for use in analyzing the response of the groundwater basin to long-term operation at the operational yields noted above, with focus on perchlorate extraction and the control of perchlorate migration in the basin. That groundwater flow model was then utilized in 2005 to specifically analyze the sustainability of groundwater supplies in both the Alluvium and the Saugus Formation through a long-term (78 year) hydrologic period that was selected to examine groundwater basin response to variations in pumping in accordance with the operating plan. Resultant projections of groundwater levels, groundwater storage, and surface water flows showed the basin to respond in a long-term sustainable manner, with no chronic depletion of groundwater levels, storage, or stream flows. The analysis of groundwater sustainability was summarized in a Basin Yield Report (CH2M Hill and LSCE, 2005), which included the following findings:

- The groundwater basin has historically been, and continues to be, in good operating condition and not in overdraft, as indicated by historical data.

- The groundwater plan is sustainable over varying hydrologic conditions, because it is feasible to intermittently exceed a long-term average yield for one or more years without creating long-term adverse impacts to the groundwater system and the Santa Clara River.

- The groundwater operating plan for the Alluvium and the Saugus Formation can be used for long-term water supply planning purposes. In particular, although increased pumping from the Saugus Formation during dry periods can be expected to cause short-term declines in groundwater levels, it is not projected to cause permanent declines in groundwater discharges or streamflow. Saugus groundwater levels can be expected to recover to pre-drought conditions when pumping is reduced in subsequent wet to normal years.

- The strategy around which the groundwater operating plan was designed (maximizing the use of Alluvial Aquifer and imported water during years of normal or above-normal availability of these supplies, while limiting the use of the Saugus Formation during these periods, then temporarily increasing Saugus pumping during years when SWP supplies are significantly reduced because of drought conditions) is viable on a long-term basis.

- Together, the historical observations of basin conditions and the model simulations together support the historical and ongoing confidence that groundwater can continue to be a sustainable source of water supply under the groundwater operating plan.

In 2008, partly in preparation for the next UWMP in 2010, and in part because of recent events that can be expected to impact the future reliability of the supplemental water supply from the State Water Project, the Purveyors initiated an updated analysis to further assess groundwater development potential and possible augmentation of the groundwater operating plan. A further consideration in conducting an updated analysis of the basin was that global climate change could alter local rainfall and associated recharge patterns, thus affecting local groundwater supplies, i.e. the yield of the basin. Finally, the Los Angeles County Flood Control District (LACFCD) is planning a number of small flood control projects in the Santa Clarita Valley; estimated amounts of conservation/groundwater recharge potential were being included for each of the individual projects in the overall LACFCD planning, and the Purveyors had interest in whether that potential could appreciably augment the yield of the basin.

The updated basin yield analysis, completed in August, 2009, concluded the following (LSCE and GSI, 2009).

- The 2008 Operating Plan, with currently envisioned pumping rates and distribution comparable to the Operating Plan described above, will not cause detrimental short- or long-term effects to the groundwater and surface water resources in the Valley and is, therefore, sustainable. Further, local conditions in the Alluvium in the eastern end of the basin can be expected to repeat historical groundwater level declines during dry periods, necessitating a reduction in desired Alluvial aquifer pumping due to decreased well yield and associated actual pumping capacity during those periods. However, those reductions in pumping from the Alluvial aquifer can be made up by an equivalent amount of increased pumping in other parts of the basin without disrupting basin-wide sustainability or local pumping capacity in those other areas. For the Saugus Formation, the modeling analysis indicated that this aquifer can sustain the pumping that is imbedded the 2008 Operating Plan.

- A Potential Operating Plan (Alluvial pumping between 41,500 and 47,500 afy) would result in lower Alluvial groundwater levels, failure of the basin to fully recover (during wet hydrologic cycles) from depressed storage that would occur during dry periods, and generally declining trends in groundwater levels and storage. Long-term lowering of groundwater levels would also occur in the Saugus Formation (pumping between about 16,000 and nearly 40,000 afy) with only partial water level recovery occurring in the Saugus. Thus, the Potential Operating Plan would not be sustainable over a long-term period.

- Several climate change models were examined to estimate the potential impacts on local hydrology in the Santa Clarita Valley. The range of potential climate change impacts extends from a possible wet trend to a possible dry trend over the long term. The trends that range from an approximate continuation of historical average precipitation, to something wetter than that, would appear to result in continued sustainability of the 2008 Operating Plan, again with intermittent constraints on full pumping in the eastern part of the basin. The potential long-term dry trend arising out of climate change would be expected to decrease local recharge to the point that lower and declining groundwater levels would render the 2008 Operating Plan unsustainable. Ultimately it was recognized that a wide range of potential global climate change produces a range of non-unique results with respect to local hydrologic conditions and associated sustainable groundwater supply. Notable in the wide range of possibilities, however, was the output that, over 20 to 25 year planning horizon of the UWMP, the range of relatively wet to relatively dry hydrologic conditions would be expected to produce sustainable groundwater conditions under the 2008 groundwater Operating Plan.

Based on the preceding conclusions, groundwater utilization continues in accordance with the 2008 Operating Plan; and the Potential Operating Plan is not being considered for implementation.

3.2 Alluvium – General

The spatial extent of the aquifers used for groundwater supply in the Valley, the Alluvium and the Saugus Formation, are illustrated in Figure 3-1. Geologic descriptions and hydrogeologic details related to both aquifers are included in several technical reports including Slade (1986, 1988 & 2002), CH2M Hill (2005) and LSCE (2005), and in the 2005 Urban Water Management Plan.

Consistent with the 2001 Update Report (Slade), the 2005 Basin Yield Report (CH2M Hill and LSCE), the 2005 UWMP, and the 2009 Updated Basin Yield Report (LSCE and GSI), the management practice of the Purveyors continues to be to rely on groundwater from the Alluvium for part of the overall municipal water supply, whereby total pumping from the Alluvium (by municipal, agricultural, and small private pumpers) is in accordance with the 2008 groundwater Operating Plan, 30,000 to 40,000 afy following wet and normal years, with possible reduction to 30,000 to 35,000 afy following multiple dry years. Such operation will maximize use of the Alluvium because of the aquifer's ability to store and produce good quality water on a sustainable basis, and because the Alluvium is capable of rapid recovery of groundwater storage in wet periods. As with many groundwater basins, it is possible to intermittently exceed a long-term average yield for one or more years without long-term adverse effects. Higher pumping for short periods may temporarily lower groundwater storage and related water levels, as has been the case in the Alluvium several times since the 1930's. However, subsequent decreases in pumping limit the amount of water level decline. Normal to wet-period recharge results in a rapid return of groundwater levels to historic highs. Historical groundwater data collected from the Alluvium over numerous hydrologic cycles continue to provide assurance that groundwater elevations, if locally lowered during dry periods, recover in subsequent average or wet years. Such water level response to rainfall is a significant characteristic of permeable, porous, alluvial aquifer systems that occur within large watersheds. In light of these historical observations, complemented by the long-term sustainability analysis using the numerical groundwater flow model, there is ongoing confidence that groundwater will continue to be a sustainable source of water supply at the rates of pumping described in the Basin Yield Report, as incorporated in the 2005 UWMP, and as described in the Updated Basin Yield Report, as expected to be incorporated in the 2010 UWMP.

Long-term adverse impacts to the Alluvium could occur if the amount of water extracted from the aquifer were to exceed the amount of water that recharges the aquifer over an extended period. However, the quantity and quality of water in the Alluvium and all significant pumping from the Alluvium are routinely monitored, and no long-term adverse impacts have ever been evident. Ultimately, the Purveyors have identified cooperative measures to be taken, if needed, to ensure sustained use of the aquifer. Such measures include but are not limited to the continuation of conjunctive use of SWP and other imported supplemental water with local groundwater, artificial recharge of the aquifer with local runoff or other surface water supplies, financial incentives discouraging extractions above a selected limit, expanded use of other water supplies such as recycled water, and expanded implementation of demand-side management, including conservation.

3.2.1 Alluvium – Historical and Current Conditions

Total pumping from the Alluvium in 2009 was about 40,000 af, a decrease of 1,750 af from the preceding year. Total Alluvium pumping was at the upper end of the groundwater Operating Plan range. Of the total Alluvial pumping in 2009, about 24,400 af (61 percent) was for municipal water supply, and the balance, about 15,600 af (39 percent), was for agriculture and other smaller uses, including individual domestic uses. In a longer-term context, there has been a change in municipal/agricultural pumping distribution since SWP deliveries began in 1980, toward a higher fraction for municipal water supply (from about 50 percent to more than 65 percent of Alluvial pumpage), which reflects the general land use changes in the area. Ultimately, on a long-term average basis since the beginning of imported water deliveries from the SWP, total Alluvial pumping has been about 32,000 afy, which is at the lower end of the range of operational yield of the Alluvium. That average has been higher over the last decade, about 38,500 afy, which remains within the range of operational yield of the Alluvium. The overall historic record of Alluvial pumping is illustrated in Figure 3-2.

Groundwater levels in various parts of the basin have historically exhibited different responses to both pumpage and climatic fluctuations. During the last 20 to 30 years, depending on location, Alluvial groundwater levels have remained nearly constant (generally toward the western end of the basin), or have fluctuated from near the ground surface when the basin is full, to as much as 100 feet lower during intermittent dry periods of reduced recharge (generally toward the eastern end of the basin). For illustration of the various groundwater level conditions in the basin, the Alluvial wells have been grouped into areas with similar groundwater level patterns, as shown in Figure 3-3. The groundwater level records have been organized into hydrograph form (groundwater elevation vs. time) as illustrated in Figures 3-4 and 3-5. Also shown on these plots is an annual marker indicating whether the year had a below-average amount of rainfall. The wells shown on these plots are representative of the respective areas, showing the range of values (highest to lowest elevation) through each area, and containing a sufficiently long-term record to illustrate trends over time.

Situated along the eastern upstream end of the Santa Clara River Channel, the ‘Mint Canyon’ area, located at the far eastern end of the groundwater basin, and the nearby ‘Above Saugus WRP’ area generally exhibit similar groundwater level responses (Figure 3-4) to hydrologic and pumping conditions. As shown in Figure 3-6, the Purveyors decreased total Alluvial pumping from the ‘Mint Canyon’ area steadily from 2000 through 2003, and correspondingly increased pumping in the ‘Below Saugus WRP’, and ‘Below Valencia WRP’ areas. In spite of a continued period of below-average precipitation from 1999 to 2003, that progressive decrease in pumping resulted in a cessation of groundwater level decline in the ‘Mint Canyon Area’. Subsequent wet

conditions in late 2004, continuing into 2005, resulted in full recovery of groundwater storage. With such high groundwater levels, pumping in the 'Mint Canyon' area was increased in 2005 and 2006, with no significant change in groundwater levels in 2005 and a slight decrease in 2006. Over the last four years, precipitation has been average to below-average. Accordingly, water levels have shown some decline, but this decline has been slowed by the reduction in pumpage in this easternmost part of the basin. Water levels remain within the historic range of levels over similar wet/dry periods. Just below the 'Mint Canyon' area, the 'Above Saugus WRP' has shown a similar decline, despite the steady rate of pumping over the last four years. Here the water levels also remain within the range of historical levels, as expected following a multi-year period without a significant wet year. These parts of the Valley have historically experienced a number of alternating wet and dry hydrologic conditions (Figure 3-4) during which groundwater level declines have been followed by returns to high or mid-range historic levels. This trend has continued over the last four years where below-average hydrologic conditions in 2009 followed three average to below-average years, and groundwater levels remain within mid-range levels.

In the 'Bouquet Canyon' area, pumping has remained relatively constant for the last ten years, and water levels have fluctuated with consecutive wet or dry years. During and since the most recent wet conditions of 2004 and 2005, water levels returned to within historic mid-range levels. During 2009, groundwater level trends either leveled off or showed some increase with the onset of precipitation at the end of the year. This groundwater level response to wet/dry years and pumping is typical for this area of the basin and, for 2009, levels have remained within the range of historical levels. When water levels are low, well yields and pumping capacities in this and other eastern areas can be impacted. The affected Purveyors typically respond by increasing use of Saugus Formation and imported (SWP) supplies, as shown in Table 2-3. The Purveyors also shift a fraction of the Alluvial pumping that would normally be supplied by the eastern areas to areas further west, where well yields and pumping capacities remain fairly constant because of smaller groundwater level fluctuations.

In the western parts and lower elevations of the Alluvium, groundwater levels respond to pumping and precipitation in a similar manner, but to an attenuated or limited extent compared to those situated in the eastern, higher elevation areas. As shown in the western group of hydrographs in Figure 3-5, groundwater level fluctuations become more subtle moving westward and lower in the Valley. The 'Below Saugus WRP' area, along the Santa Clara River immediately downstream of the Saugus Water Reclamation Plant, and the 'San Francisquito Canyon' area generally exhibit similar groundwater level trends. In this middle part of the basin, historical groundwater levels were lower in the 1950's and 60's than current levels. Groundwater levels in this area notably recovered as pumping declined through the 1960's and 1970's. They

have subsequently sustained generally high levels for much of the last 30 years, with three dry-period exceptions: mid-1970's, late 1980's to early 1990's, and the late 1990's to early 2000's. Recoveries to previous high groundwater levels followed both of the short dry-period declines in the 1970's and 1990's. More recently, groundwater levels recovered significantly in both areas, to historic highs, following a wetter-than-average year in 2004 and significantly wet 2005. Since 2005, pumping has been increasing in the 'Below Saugus WRP' area, while 'San Francisquito Canyon' area pumping approximately doubled in 2005, and has since gradually declined and leveled off over the last three years. Despite the current multi-year period of average to below-average precipitation, groundwater levels in these two areas remain in mid-range to high historical range.

The 'Castaic Valley' area is located along Castaic Creek below Castaic Lake. Below that and along the Santa Clara River, downstream of the Valencia Water Reclamation Plant, is the 'Below Valencia WRP' area, where discharges of treated effluent from the Valencia WRP to the Santa Clara River contribute to groundwater recharge. In the 'Castaic Valley' area, groundwater levels continue to remain fairly constant, with slight responses to climatic and other fluctuations, since the 1950's (Figure 3-5). Small changes in groundwater levels over the last four years are consistent with other short-term historical fluctuations. The long-term, generally constant trend remained through 2009. The 'Below Valencia WRP' area groundwater levels exhibit slight, if any, response to climatic fluctuations, and have remained fairly constant since the 1950's despite a notable increase in pumping through the 1990s that has since remained relatively steady over the last seven years, through 2009 (Figure 3-5 and 3-6).

In summary, depending on the period of available data, all the history of groundwater levels in the Alluvium shows the same general picture: recent (last 30 years) groundwater levels have exhibited historic highs; in some locations, there are intermittent dry-period declines (resulting from use of some groundwater from storage) followed by wet-period recoveries (and associated refilling of storage space). On a long-term basis, whether over the last 29 years since importation of supplemental SWP water, or over the last 40 to 50 years (since the 1950's - 60's), the Alluvium shows no chronic trend toward decreasing water levels and storage, and thus shows no symptoms of water level-related overdraft. Consequently, pumping from the Alluvium has been and continues to be sustainable, well within the operational yield of that aquifer on a long-term average basis, and also within the operating yield in almost every individual year.

3.3 Saugus Formation – General

Saugus wells operated by the Purveyors are located in the southern portion of the basin, south of the Santa Clara River (Figure 3-7). Consistent with the 2001 Update Report (Slade), the 2005

Basin Yield Report (CH2M Hill and LSCE), and the 2009 Basin Yield Update Report (LSCE and GSI), the Purveyors have utilized the Saugus in accordance with the original (and the 2008) groundwater Operating Plan, in the range of 7,500 to 15,000 afy in average/normal years, with planned dry-year pumping of 15,000 to 35,000 afy for one to three consecutive dry years, when shortages to CLWA's SWP water supplies could occur. Such high pumping would be followed by periods of lower pumping (7,500 to 15,000 afy in average/normal years as noted above) in order to allow recharge to recover water levels and storage in the Saugus. Maintaining the substantial volume of water in the Saugus Formation is an important strategy to help maintain water supplies in the Santa Clarita Valley during drought periods.

3.3.1 Saugus Formation – Historical and Current Conditions

Total pumping from the Saugus in 2009 was about 7,700 af, or about 750 af more than in the preceding year. Of the total Saugus pumping in 2009, most (about 6,700 af) was for municipal water supply, and the balance (1,000 af) was for agricultural and other irrigation uses. Historically, groundwater pumping from the Saugus peaked in the early 1990's and then steadily declined through the remainder of that decade. Since then, Saugus pumping had been in the range of about 4,000 to 6,500 afy, with the increase to almost 7,700 af in 2007 and again in 2009. Over the last five years, the municipal use of Saugus water has been relatively unchanged; almost all of the relatively small fluctuations from year to year have been related to non-municipal usage. On a long-term average basis since the importation of SWP water, total pumping from the Saugus Formation has ranged between a low of about 3,700 afy (in 1999) and a high of nearly 15,000 afy (in 1991); average pumping from 1980 to present has been about 6,800 afy. These pumping rates remain well within, and generally at the lower end of the range of Operating Yield of the Saugus Formation. The overall historic record of Saugus pumping is illustrated in Figure 3-8.

Unlike the Alluvium, which has an abundance of wells with extensive water level records, the water level data for the Saugus Formation are limited by both the distribution of the wells in that Formation and the periods of water level records. The wells that do have water level records extending back to the mid-1960's indicate that groundwater levels in the Saugus Formation were highest in the mid-1980's and are currently higher than they were in the mid-1960's (Figure 3-9). Based on these data, there is no evidence of any historic or recent trend toward permanent water level or storage decline. There continue to be seasonal fluctuations in groundwater levels but the prevalent longer-term trend is one of general stability.

Consistent with the 2001 Update Report (Slade), the 2005 Basin Yield Report (CH2M Hill and LSCE), the 2005 UWMP, and the 2008 Updated Basin Yield Report (LSCE and GSI, 2009), the

Purveyors continue to maintain groundwater storage and associated water levels in the Saugus Formation so that supply is available during drought periods, when Alluvial pumping might be reduced and/or SWP or other supplemental supplies also decreased. The period of increased pumping during the early 1990's is a good example of this management strategy. Most notably, in 1991, when SWP deliveries were substantially reduced, increased pumping from the Saugus made up almost half of the decrease in SWP deliveries. The increased Saugus pumping over several consecutive dry years (1991-1994) resulted in short-term declining groundwater levels, reflecting the use of water from storage. However, groundwater levels subsequently recovered when pumping declined, reflecting recovery of groundwater storage in the Saugus Formation.

3.4 Imported Water

CLWA obtains the majority of its water supplies from the State Water Project (SWP), which is owned and operated by the California Department of Water Resources (DWR). CLWA is one of 29 contractors holding long-term SWP contracts with DWR. SWP water originates as rainfall and snowmelt in northern and central California. Runoff is stored in Lake Oroville, which is the project's largest storage facility. The water is then released from Lake Oroville down the Feather River to the Sacramento River and through the Sacramento-San Joaquin Delta. Water is diverted from the Delta into the Clifton Court Forebay, and then pumped into the 444-mile long California Aqueduct. SWP water is temporarily stored in San Luis Reservoir, which is jointly operated by DWR and the U.S. Bureau of Reclamation. Prior to delivery to CLWA, SWP supplies are stored in Castaic Lake, a terminal reservoir located at the end of the West Branch of the California Aqueduct.

CLWA's service area covers approximately 195 square miles (124,800 acres), including the City of Santa Clarita and surrounding unincorporated communities. SWP water from Castaic Lake is treated, filtered and disinfected at CLWA's Earl Schmidt Filtration Plant and Rio Vista Water Treatment Plant, which have a combined treatment capacity of 86 million gallons per day. Treated water is delivered from the treatment plants by gravity flow to each of the four Purveyors through a distribution network of pipelines and turnouts. At present, CLWA delivers water to the four Purveyors through 25 potable turnouts as schematically illustrated in Figure 3-10.

In 2009, CLWA fulfilled the following major accomplishments in order to enhance, preserve, and strengthen the quality and reliability of existing and future supplies:

- continued participation in a long-term water banking programs with Rosedale-Rio Bravo Water Storage District and the Semitropic Water Storage District. Water was not

withdrawn from the Rosedale-Rio Bravo Water Storage District, but 1,650 acre-feet was withdrawn from the Semitropic Water Storage District,

- continued implementation of the AB 3030 Groundwater Management Plan,
- continued implementation of the water conservation Best Management Practices,
- reconvened the Santa Clarita Valley Drought Committee, which has now changed its name to the Santa Clarita Valley Water Committee
- continued construction of treatment and distribution facilities for restoration of municipal well capacity impacted by perchlorate contamination,
- continued cooperative effort with the U.S. Army Corps of Engineers for characterization studies of the former Whittaker-Bermite site and in a task force effort with the City of Santa Clarita, local legislators, and state agencies to effect the cleanup and remediation of all aspects of the former Whittaker-Bermite site, including perchlorate contamination of local groundwater,
- began construction of the expansion of the Rio Vista Water Treatment Plant from 30 mgd to 60 mgd, and
- continued recycled water service.

3.4.1 State Water Project Table A Supplies

Each SWP contractor has a specified water supply amount shown in Table A of its contract that currently totals approximately 4.1 million af. The term of the CLWA contract is through 2038 and is renewable after that year. Although the SWP has not been fully completed, the SWP can deliver all 4.1 million af of Table A Amounts during certain wet years.

CLWA has a contractual Table A Amount of 95,200 af per year of water from SWP.[1] On October 30, 2008, the initial allocation for 2009 was announced as 15 percent. The allocation

[1] Of CLWA's 95,200 af annual Table A Amount, 41,000 afy was permanently transferred to CLWA in 1999 by Wheeler Ridge-Maricopa Water Storage District, a member unit of the Kern County Water Agency. CLWA's EIR prepared in connection with the 41,000 afy water transfer was challenged in Friends of the Santa Clara River v. Castaic Lake Water Agency (Los Angeles County Superior Court) ("Friends"). On appeal, the Court of Appeal held that since the 41,000 afy EIR tiered off the Monterey Agreement EIR that was later decertified, CLWA would also have to decertify its EIR as well and prepare a revised EIR. CLWA was not prevented from using any water that is part of the 41,000 afy transfer. Under the jurisdiction of the Los Angeles County Superior Court, CLWA prepared and circulated a revised Draft EIR for the transfer. CLWA approved the revised EIR in late 2004 ("2004 EIR") and lodged the EIR with the Los Angeles Superior Court. Thereafter, the case was dismissed with prejudice (i.e., permanently).

In January 2005, two new challenges to CLWA's 2004 EIR were filed in the Ventura County Superior Court by the Planning and Conservation League ("PCL") and by the California Water Impact Network ("CWIN"); these cases were consolidated and transferred to Los Angeles County Superior Court, Planning and Conservation League v. Castaic Lake Water Agency (Los Angeles County Superior Court,) ("PCL Action"). In May 2007, a final Statement of Decision was filed by the trial court in the PCL Action. It included a determination that the transfer is valid and cannot be terminated or unwound. The trial court did find one defect in the 2004 EIR, requiring Judgment to be entered against CLWA. The defect, however, did not relate to the environmental conclusions reached in the 2004 EIR. Notices of Appeal were filed by PCL and CWIN and the Agency, Kern County Water Agency, and Wheeler Ridge-Maricopa Water Storage District filed notices of cross-appeals. On December 17, 2009, the Court of Appeal issued a published opinion in which it reversed the trial court's Judgment, and found that the 41,000 afy EIR fully complied with CEQA, and remanded the matter to the trial court with directions to issue a new judgment denying PCL's and CWIN's challenges in their entirety. A petition for rehearing was filed by PCL and CWIN on January 4, 2010 but was denied on January 14, 2010. On January 26, 2010, PCL and CWIN filed a petition for review with the California Supreme Court, but the Court denied the petition on March 10, 2010.

was increased to 20 percent on March 18, 2009, and further increased to 30 percent on April 16, 2009; and then to 40 percent on May 20, 2009. The allocation was not subsequently changed. CLWA's final allocation of Table A Amount for 2009 was thus 40 percent, or 38,080 af.

In addition to its Table A Amount, CLWA has access to 4,684 af of "flexible storage" in Castaic Lake. In 2005, CLWA negotiated an agreement with the Ventura County SWP contractors to allow CLWA to utilize their flexible storage account of 1,376 af. In combination, this provides total flexible storage of 6,060 af, which is maintained in Castaic Lake for use in a future dry period or an emergency. This amount was available in 2009, but was not utilized due to other available supplies.

Also in 2005, CLWA completed an agreement to participate in a long-term water banking program with Rosedale-Rio Bravo Water Storage District in Kern County. CLWA delivered 20,000 af of its excess Table A water into storage in both 2005 and 2006. CLWA delivered another 8,200 af into that storage account in 2007 but did not contribute to or withdraw SWP water from the bank in 2008 or 2009. This long-term program will allow the storage up to 100,000 af at any one time, and will provide significant dry year reliability for the Santa Clarita Valley.

The other banking component of CLWA's imported water supply reliability program is comprised of two 10-year agreements with Semitropic Water Storage District whereby CLWA banked surplus Table A water supply in 2002 and 2003. Notable in 2009 was the first recovery of water from the 2002 account; of 4,950 af withdrawn in 2009, 1,650 af were delivered for water supply in the Valley, and the 3,300 af balance is intended to be delivered in 2010.

As delineated in Table 3-2, with the 40 percent Table A allocation and other imported water supplies, including 14,610 af of carryover from 2008, CLWA had total available supply of 67,050 af in 2009, most of which was delivered to the Purveyors (38,546 af), leaving 28,303 af of Table A Amount available for carryover to 2010.

3.4.2 Other Imported Water Supplies

In early 2007, CLWA finalized a Water Acquisition Agreement with the Buena Vista Water Storage District (Buena Vista) and the Rosedale-Rio Bravo Water Storage District (Rosedale-Rio Bravo) in Kern County. Under this Program, Buena Vista's high flow Kern River entitlements (and other acquired waters that may become available) are captured and recharged within

Table 3-2
2009 CLWA Imported Water Supply and Disposition
(acre-feet)

Supply		
Net 2008 SWP Carryover to 2009 [1]		14,610
Buena Vista/Rosedale Rio-Bravo		11,000
Yuba County Accord Water		1,658
2009 SWP Turnback Pool Water		52
Semitropic Water Banking and Exchange Program		1,650
2009 Final SWP Table A Allocation [2]		38,080
Total 2009 Imported Water Supply		**67,050**
Disposition		
Purveyor Deliveries (Total)		38,546
CLWA SCWD	*17,739*	
Valencia Water Company	*14,732*	
Newhall County Water District	*4,832*	
Los Angeles County WWD 36	*1,243*	
CLWA/DWR/Purveyor Metering[3]		201
Rosedale – Rio Bravo Water Banking and Exchange Program		0
2009 Table A Carryover to 2010[4]		28,303
Total 2009 Imported Water Disposition		**67,050**

1. Total 2009 carryover; amount used by CLWA, based on final DWR delivery accounting was 10,107 af.

2. Final 2009 allocation was 40% of contractual Table A amount of 95,200 acre-feet, which progressed as follows:

Initial allocation, October 30, 2008	15%
Allocation increase, March 18, 2009	20%
Allocation increase, April 16, 2009	30%
Final allocation, May 20, 2009	40%

3. Reflects meter reading differences.

4. Total 2009 Table A carryover to 2010.

Rosedale-Rio Bravo's service area on an ongoing basis.[2] CLWA receives 11,000 af of these supplies annually through either exchange of Buena Vista's and Rosedale-Rio Bravo's SWP supplies or through direct delivery of water to the California Aqueduct via the Cross Valley Canal.

In 2008, CLWA entered into the Yuba Accord Agreement, which allows for the purchase of water from the Yuba County Water Agency through the Department of Water Resources to 21 State Water Project contractors (including CLWA) and the San Luis and Delta-Mendota Water Authority. CLWA may purchase up to approximately 1,000 af per year and in 2009 received 1,658 af as part of the Agreement.

3.4.3 Imported Water Supply Reliability

The Department of Water Resources issued its Draft State Water Project Delivery Reliability Report 2009 in February 2010. The report is updated with new information and calculations of delivery reliability every two years and is intended to assist SWP contractors in assessing the adequacy of the SWP component of their overall supplies. The current Draft Reliability Report, with the objective of protecting endangered fish such as the Delta smelt and spring-run salmon, incorporates restrictions on SWP operations according to the Biological Opinions of the U.S. Fish and Wildlife Service and the National Marine Fishery Service issued on December 15, 2008 and June 4, 2009, respectively. It also considers the impacts on SWP delivery reliability due to climate change, sea level rise, and vulnerability of the Delta's conveyance system and structure due to floods and earthquakes. The current Draft Reliability Report projects long-term reliability of 60 percent during normal year hydrology. In 2010, CLWA staff assessed the impact of the current Reliability Report on the CLWA reliability analysis contained in the Agency's 2005 UWMP. It concluded that current and anticipated supplies are available to meet anticipated water supply needs.

Groundwater banking and conjunctive use offer significant opportunities to improve water supply reliability for CLWA. Groundwater banking is the process of storing available supplies of water in groundwater basins during wet years or when supplemental water is otherwise available. During dry periods, or when imported water supply availability is reduced, banked water can be recovered from groundwater storage to replace, or firm up, the imported water supply deliveries.

[2] A CEQA action was filed by California Water Impact Network (CWIN) in November 2006 challenging the adequacy of CLWA's EIR on the acquisition of 11,000 af from the Buena Vista Water Storage District and Rosedale-Rio Bravo Water Storage District. In November 2007, a Los Angeles Superior Court ruled in favor of CLWA on all points. In January 2008, CWIN filed a notice of appeal. The case was argued before the appellate court March 2, 2009. On April 20, 2009, the Court of Appeal issued an opinion affirming the Superior Court's judgement.

As described herein, CLWA has entered into two groundwater banking programs and now has, in aggregate, more than 110,000 af of recoverable water in banked groundwater storage outside the local groundwater basin. The first component of CLWA's overall groundwater banking program is the result of two 10-year agreements between CLWA and Semitropic Water Storage District whereby, over the terms of the two agreements, CLWA can withdraw up to 45,920 af of SWP Table A water that it stored in Semitropic to meet Valley demands when needed in dry years (45,920 af is the net recoverable balance after originally banking 24,000 af in 2002 and 32,522 af in 2003, and withdrawing 4,950 af in 2009). The second component of the program, the long-term Rosedale-Rio Bravo Water Banking and Exchange Program in Kern County, has a recoverable total of 64,900 acre-feet in storage (i.e., 75,200 af originally banked less contractual losses).

Conjunctive use is the purposeful integrated use of surface water and groundwater supplies to maximize water supply from the two sources. CLWA and the Purveyors have been conjunctively utilizing local groundwater and imported surface water since the initial importation of SWP water in 1980. The groundwater banking programs described above allow CLWA to firm up the imported water component of conjunctive use in the Valley by storing surplus SWP and other water, in wet years, in groundwater basins outside the Valley. This allows recovery and importation of that water as needed in dry years to maintain a greater overall amount of imported surface water to be used conjunctively with local groundwater, further supporting the sustainable use of local groundwater at the rates in the groundwater operating plan.

3.5 Water Quality – General

Water delivered by the Purveyors consistently meets drinking water standards set by the Environmental Protection Agency (EPA) and the California Department of Public Health (DPH). An annual Water Quality Report is provided to all Santa Clarita Valley residents who receive water from one of the four water retailers. There is detailed information in that report about the results of quality testing of the groundwater and treated SWP water supplied to the residents of the Santa Clarita Valley during 2008. Several constituents of particular local interest are discussed in more detail below.

Total Trihalomethanes

In 2002, the United States Environmental Protection Agency implemented the new Disinfectants and Disinfection Byproducts Rule. In part, this rule established a new MCL of 80 µg/l (based on an annual running average) for Total Trihalomethanes (TTHM). TTHMs are byproducts created when chlorine is used as a means for disinfection. CLWA and the Purveyors implemented an alternative method of disinfection, chloramination, in 2005 to maintain compliance with the new

rule and future regulations relating to disinfection byproducts. TTHM concentrations have remained significantly below the MCL since implementation of alternative disinfection.

Perchlorate

Perchlorate has been a water quality concern in the Valley since 1997 when it was originally detected in four wells operated by the Purveyors in the eastern part of the Saugus Formation, near the former Whittaker-Bermite facility. In late 2002, perchlorate was detected in a fifth municipal well, in this case an Alluvial well (SCWD's Stadium Well) also located near the former Whittaker-Bermite site. In early 2005, perchlorate was detected in a second Alluvial well (VWC's Well Q2) near the former Whittaker-Bermite site. In 2006, a very low concentration of perchlorate was detected in another Saugus well (NCWD's Well NC-13), near one of the originally impacted wells. However, that detection has been interpreted to not be an indication of continued perchlorate migration in a westerly direction. Subsequent monitoring well installation has been completed and a focused study of the Saugus Formation has ultimately been incorporated into the overall groundwater remediation and removal actions submitted by Whittaker-Bermite and reviewed by the State Department of Toxic Substances Control (DTSC) as discussed below.

Wells with perchlorate concentrations exceeding the then-applicable Action Level (18 μg/l) or, more recently, the then-applicable Notification Level (6 μg/l)[3] were removed from active water supply service. One of the Alluvial wells (VWC's Well Q2) was returned to active water supply service, with treatment, in late 2005 as discussed below. The other impacted wells remain out of service; two wells (VWC's Well 157 and SCWD's Stadium Well) have been sealed and replaced by new wells, and two wells (SCWD's Saugus 1 & 2 Wells) are being returned to service as described below. The 2005 UWMP specifically addressed the adequacy of groundwater supply in light of the inactivation of the impacted Alluvial and Saugus wells; and it addressed the plan and schedule for restoration of perchlorate-impacted wells, including the protection of existing non-impacted wells. As summarized in the 2005 UWMP, the inactivation of the impacted wells does not constrain the ability to meet the groundwater component of total water supply in the Valley.

In 2000, CLWA and the impacted Purveyors filed a lawsuit against Whittaker Corporation (the former owner of the contaminated property) and Santa Clarita LLC and Remediation Financial, Inc. (the owners of record at that time). The lawsuit sought to have defendants pay all necessary costs of response, removal of the contaminant, remedial actions, and any liabilities or damages associated with the contamination. An Interim Settlement and Funding Agreement was reached

[3] The Maximum Contaminant Level (MCL) for perchlorate was set at 6 μg/l by the State Department of Public Health in October 2007.

in 2003. Although that Agreement expired in January 2005, the parties, under DTSC oversight, jointly developed a plan to "pump and treat" contaminated water from two of the Purveyors' impacted wells to stop migration of the contaminant plume and to partially restore the municipal well capacity that has been impacted by perchlorate. The parties also continued negotiations intended to achieve a long term settlement to the litigation through 2006, and a final settlement was completed and executed in April 2007.

Since 2007, the impacted Purveyors (SCWD, NCWD, and VWC) and CLWA continued working toward implementation of a jointly developed plan that will combine pumping from two of the impacted wells and a water treatment process to restore the impacted pumping capacity and control the migration of contamination in the aquifer. The development and implementation of a cleanup plan for the Whittaker-Bermite site and the impacted groundwater is being coordinated among CLWA, the impacted Purveyors, the State DTSC, and U.S. Army Corps of Engineers. DTSC is the lead agency responsible for regulatory oversight of the Whittaker-Bermite site.

In February 2003, DTSC and the impacted Purveyors entered into a voluntary cleanup agreement entitled *Environmental Oversight Agreement*. Under the Agreement, DTSC is providing review and oversight of the response activities being undertaken by the Purveyors related to the detection of perchlorate in the impacted wells. Under the Agreement's Scope of Work, the impacted Purveyors prepared a Work Plan for sampling the production wells, a report on the results and findings of the production well sampling, a draft Human Health Risk Assessment, a draft Remedial Action Workplan, an evaluation of treatment technologies and an analysis showing the integrated effectiveness of a project to restore impacted pumping capacity, extract perchlorate-impacted groundwater from two Saugus wells for treatment, and control the migration of perchlorate in the Saugus Formation. Environmental review of that project was completed in 2005 with adoption of a mitigated Negative Declaration. The Final Interim Remedial Action Plan for containment and extraction of perchlorate was completed and approved by DTSC in January 2006. Design of the treatment facilities and related pipelines is complete. Construction of those facilities and pipelines to implement the pump and treat program and to also restore inactivated municipal well capacity began in November 2007 and was completed, and in operational startup, as this report was being drafted (May, 2010).

Under the direction of DTSC, Whittaker has submitted a comprehensive site-wide remediation plan for the contaminants of concern in soil and groundwater detected on the property. A Draft Remedial Action Plan for Operable Units 2 through 6 that is focused on soil remediation was submitted to DTSC in 2009. The plan contains a number of recommended technologies to remove contaminants from the soil, in addition to a proposed clean-up schedule for the site. Whittaker has also completed a Draft Operable Unit 7 Feasibility Study to identify and select

treatment technologies for both on-site and off-site groundwater. Final approval by DTSC of soil and groundwater clean-up plans is expected by the end of 2010.

As noted above, perchlorate was detected in a second Alluvial well, VWC's Well Q2, in early 2005. In response, Valencia removed the well from active service, and commissioned the preparation of an analysis and report assessing the impact of, and response to, the perchlorate contamination of that well. Valencia's response for Well Q2 was to obtain permitting for installation of wellhead treatment, followed by installation of treatment facilities and returning the well to water supply service in October 2005. After nearly two years of operation with wellhead treatment, including regular monitoring specified by the State Department of Public Health (DPH), all of which resulted in no detection of perchlorate in Well Q2, Valencia requested that DPH allow treatment to be discontinued. DPH approved that request in August 2007, and treatment was subsequently discontinued. DPH-specified monitoring for perchlorate continues at Well Q2; there has been no detection of perchlorate since discontinuation of wellhead treatment.

On the Whittaker-Bermite site, soil remediation activities in operating unit subareas started in 2005. Groundwater "pump and treat" operations in the Northern Alluvium, which also started in 2005, continued through 2009. Expanded pumping, intended to effect perchlorate containment as well as to treat 'hot spots' in the Northern Alluvium, became operational in October 2007. Also on the Whittaker-Bermite site, remediation work in the Saugus Formation is underway. Additional objectives of this project include the reduction of further transport of contaminants to regional groundwater and reduction of the size of the contaminant mass in deep/perched zones.

Hardness

In 2008, the Valencia Water Company began a demonstration project delivering pre-softened groundwater from one of its wells to approximately 420 residents located in the Copperhill Community of Valencia. Hard water is the primary complaint from Valencia customers and it is estimated that more than 50 percent have installed individual water softening units at their homes. In addition to having high operating costs, many of these units are designed to discharge a brine (salt) solution to the sanitary sewer system that is eventually discharged to the Santa Clara River, or is part of the recycled water supply. The environmental impact of such discharges was the subject of a major Chloride Total Maximum Daily Load investigation which concluded with a commitment by the Purveyors to achieve surface water quality goals for in-stream discharge from the basin. Valencia's project is aimed at improving the quality of water for its customers to eliminate the need for home softening devices and to achieve the environmental benefits of reduced chloride discharge to the river.

The demonstration project utilizes softening technology that removes calcium and produces small calcium carbonate pellets which can be reused in a variety of industries. The demonstration project has now been operated for over a year and provides the water company with customer feedback and technical/financial information to assess potential future expansion of treatment to other well sites.

3.5.1 Groundwater Quality – Alluvium

Groundwater quality is, of course, a key factor in assessing the Alluvial aquifer as a municipal and agricultural water supply. Groundwater quality details and long-term conditions, examined by integration of individual records from several wells completed in the same aquifer materials and in close proximity to each other, have been discussed in previous annual Water Reports and in the 2005 UWMP. There were some changes in groundwater quality in 2009 that reflect fluctuations, trends, or other groundwater quality conditions as illustrated in Figures 3-11 and 3-12. These graphs show historical specific conductance values for representative wells in the Valley with the California Department of Public Health Secondary Maximum Levels included for reference. Most of the trends show a significant lowering of the specific conductance values by half following the wet years of 2004-2005. Since then, those trends have returned to 2004 levels but do not exceed historical levels. In summary, those conditions include: no long-term overall trend and, most notably, no long-term decline in Alluvial groundwater quality; a general groundwater quality "gradient" from east to west, with lowest dissolved mineral content to the east, increasing in a westerly direction; and periodic fluctuations in some parts of the basin, where groundwater quality has inversely varied with precipitation and stream flow. Those variations are typically characterized by increased mineral concentrations through dry periods of lower stream flow and lower groundwater recharge, such as is currently occurring, followed by lower mineral concentrations through wetter periods of higher stream flow and higher groundwater recharge.

The presence of long-term consistent water quality patterns, although intermittently affected by wet and dry cycles, supports the conclusion that the Alluvial aquifer remains a viable ongoing water supply source in terms of groundwater quality.

3.5.2 Groundwater Quality – Saugus Formation

As discussed above for the Alluvium, groundwater quality is a key factor in also assessing the Saugus Formation as a municipal and agricultural water supply. As with groundwater level data, long-term Saugus groundwater quality data are not sufficiently extensive to permit any sort of basin-wide analysis or assessment of pumping-related impacts on quality. However, integration

of individual records from several wells has been used to examine general water quality trends. Based on those records, water quality in the Saugus Formation has not historically exhibited the precipitation-related fluctuations seen in the Alluvium. Based on available data over the last 50 years, groundwater quality in the Saugus has exhibited a slight overall increase in dissolved mineral content as illustrated in Figure 3-13. More recently, several wells within the Saugus Formation have exhibited an additional increase in dissolved mineral content, similar to short-term changes in the Alluvium, possibly as a result of recharge to the Saugus Formation from the Alluvium. Since 2005, however, these levels have been steadily dropping or remaining constant. Dissolved mineral concentrations in the Saugus Formation remain below the Secondary (aesthetic) Upper Maximum Contaminant Level. Groundwater quality within the Saugus will continue to be monitored to ensure that degradation to the long-term viability of the Saugus as a component of overall water supply does not occur.

3.5.3 Imported Water Quality

CLWA operates two water treatment plants, the Earl Schmidt Filtration Plant located near Castaic Lake and the Rio Vista Water Treatment Plant located in Saugus. CLWA produces water that meets drinking water standards set by the U.S. EPA and DPH. SWP water has different aesthetic characteristics than groundwater with lower dissolved mineral concentrations (total dissolved solids) of approximately 250 to 360 mg/l, and lower hardness (as calcium carbonate) of about 105 to 135 mg/l.

Historically, the State Water Project (SWP) delivered only surface water from the Sacramento-San Joaquin River Delta. However, CLWA and other SWP users, in anticipation of drought, many years ago began “water banking” programs where SWP water could be stored or exchanged during wet years and withdrawn in dry years. The last three years have seen severe state-wide drought. As a result, water has been withdrawn from the water banking programs and pumped into the SWP system. During the period of 2008 through 2010, a greater portion of water in the SWP has been this “pumped-in” water. The “pumped-in” water has met all water quality standards established by DWR under its anti-degradation policy for the SWP.

3.6 Recycled Water

Recycled water is available from two water reclamation plants operated by the Sanitation Districts of Los Angeles County. In 1993, CLWA prepared a draft Reclaimed Water System Master Plan that outlined a multi-phase program to deliver recycled water in the Valley. CLWA previously completed environmental review on the construction of Phase I of the project, which will ultimately deliver 1,700 afy of recycled water. Deliveries of recycled water began in 2003

for irrigation water supply at a golf course and in roadway median strips. In 2009, recycled water deliveries were 328 af, generally consistent with recycled water deliveries that have ranged between 311 and 470 afy over the past six years.

Surveys conducted by CLWA indicate an interest for recycled water by existing water users as well as by future development as recycled water becomes available. In 2002, CLWA produced an updated Draft Recycled Water Master Plan. Overall, the program is expected to ultimately recycle up to 17,400 af of treated (tertiary) wastewater suitable for reuse on golf courses, landscaping and other non-potable uses, as set forth in the UWMP.

In 2007, CLWA completed California Environmental Quality Act (CEQA) analysis of the Recycled Water Master Plan (2002). This analysis consisted of a Program Environmental Impact Report (PEIR) covering the various options for a recycled water system as outlined in the Master Plan. The PEIR was certified by the CLWA Board in March 2007.

CLWA is preparing the design of the second phase of the Recycled Water Master Plan that will take water from the Saugus Water Reclamation plant and distribute it to identified users to the north, across the Santa Clara River and then to the west and the east, which will include service to Santa Clarita Central Park. There is also a new phase of the of the recycled water system in design that would extend the existing system southward from the intersection of Magic Mountain Parkway and the Old Road to the intersection of Orchard Village Road and Lyons Avenue, serving large irrigation customers along its proposed alignment. Collectively, these phases will have design capacity to increase recycled water deliveries by about 1,500 afy.

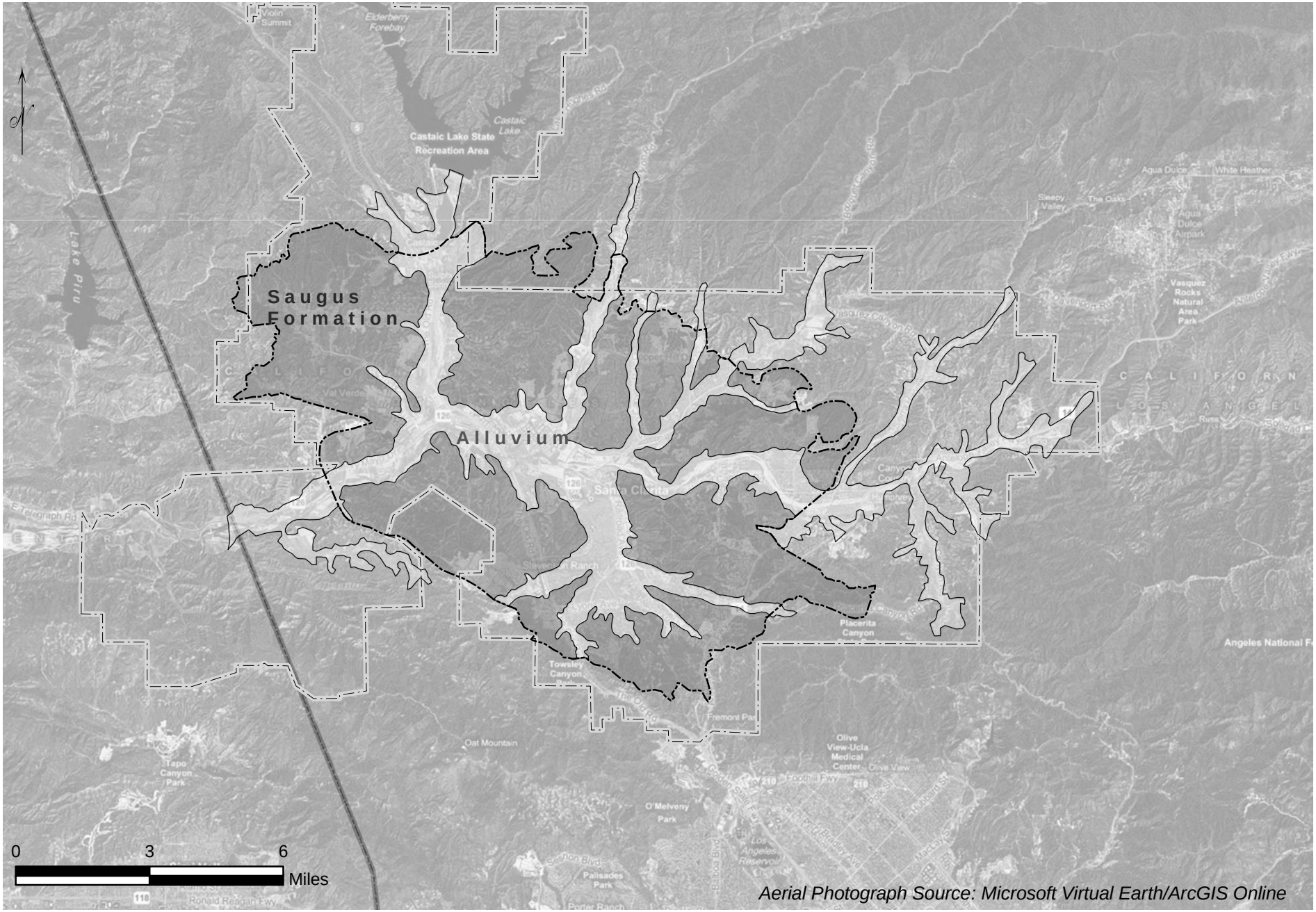
3.7 Santa Clara River

The Memorandum of Understanding (MOU) between the Santa Clarita Valley Purveyors and the United Water Conservation District, which manages surface and groundwater resources in seven groundwater basins in the Lower Santa Clara River Valley Area, was a significant accomplishment when it was prepared and executed in 2001. The MOU initiated a collaborative and integrated approach to data collection; database management; groundwater flow modeling; assessment of groundwater basin conditions, including determination of basin yield amounts; and preparation and presentation of reports, including continued annual reports such as this one for current planning and consideration of development proposals, and also including more technically detailed reports on geologic and hydrologic aspects of the overall stream-aquifer system. Meetings of the MOU participants have continued, and integration of the Upper (Santa Clarita Valley) and Lower (United WCD) Santa Clara River databases has been accomplished. As discussed above, a numerical groundwater flow model of the entire Santa Clarita groundwater

basin was developed and calibrated in 2002-2004. Subsequent to its initial use in 2004 for assessing the effectiveness of various operating scenarios to restore pumping capacity impacted by perchlorate contamination (by pumping and treating groundwater for water supply while simultaneously controlling the migration of contaminated groundwater), the model was used in 2005 for evaluation of basin yield under varying management actions and hydrologic conditions. The results completed the determination of sustainable operating yield values for both the Alluvium and the Saugus Formation, which were incorporated in the 2005 UWMP. The updated analysis of basin yield, completed in 2009, indicates that the 2008 Operating Plan will maintain river flows at higher levels than occurred prior to urbanization of the Valley.

On occasion, issues have been raised about whether use and management of groundwater in the Santa Clarita Valley have adversely impacted surface water flows into Ventura County. Part of the groundwater modeling work has addressed the surface water flow question as well as groundwater levels and storage. While the sustainability of groundwater has logically derived primarily from projected long-term stability of groundwater levels and storage, it has also derived in part from modeled simulations of surface water flows and the lack of streamflow depletion by groundwater pumping. In addition, the long-term history of groundwater levels in the western and central part of the basin, as illustrated in Figures 3-4 and 3-5, supports the modeled analysis and suggests that groundwater has not been lowered in such a way as to induce infiltration from the river and thus impact surface water flows.

Historical annual stream discharge in the Santa Clara River, into and out of the Santa Clarita Valley, is shown on Figure 3-14. The upstream gage at Lang Station was reinstated in 2002 and shows a wide range of average annual inflow over the last seven years. The downstream gage was moved in 1996 to its present location near Piru, about two miles downriver from the former County Line Gage. The combined record (1953-2009) of these two downstream gages indicates an annual stream discharge of about 47,000 afy. These data gaged near the County line show notably higher flows from the Santa Clarita Valley into the uppermost downstream basin, the Piru Basin, over the last 30 to 35 years.



Aerial Photograph Source: Microsoft Virtual Earth/ArcGIS Online

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Figure 3-1
Alluvium and Saugus Formation
Santa Clara River Valley, East Groundwater Subbasin

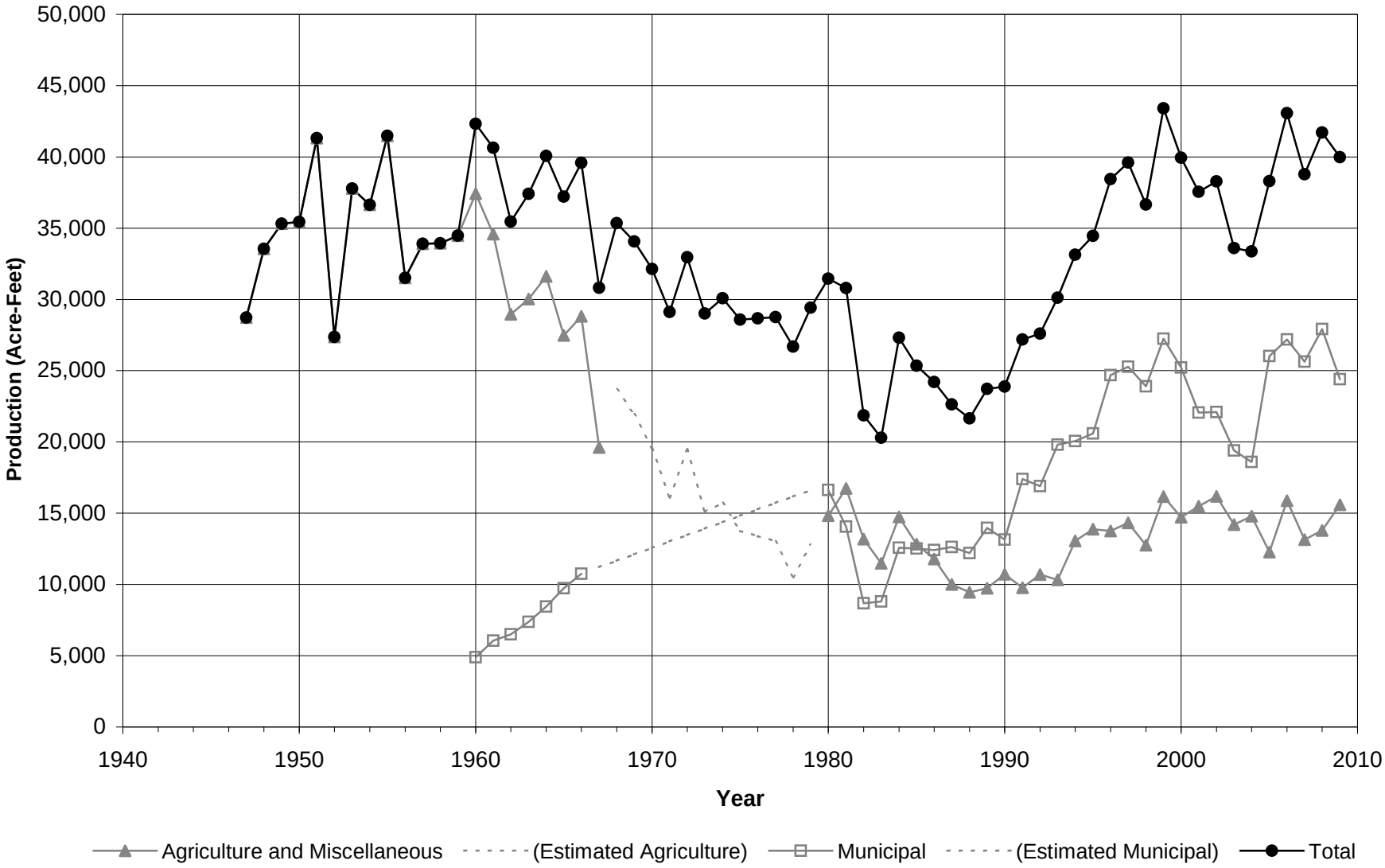

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Figure 3-2
Groundwater Production - Alluvium
Santa Clara River Valley, East Groundwater Subbasin

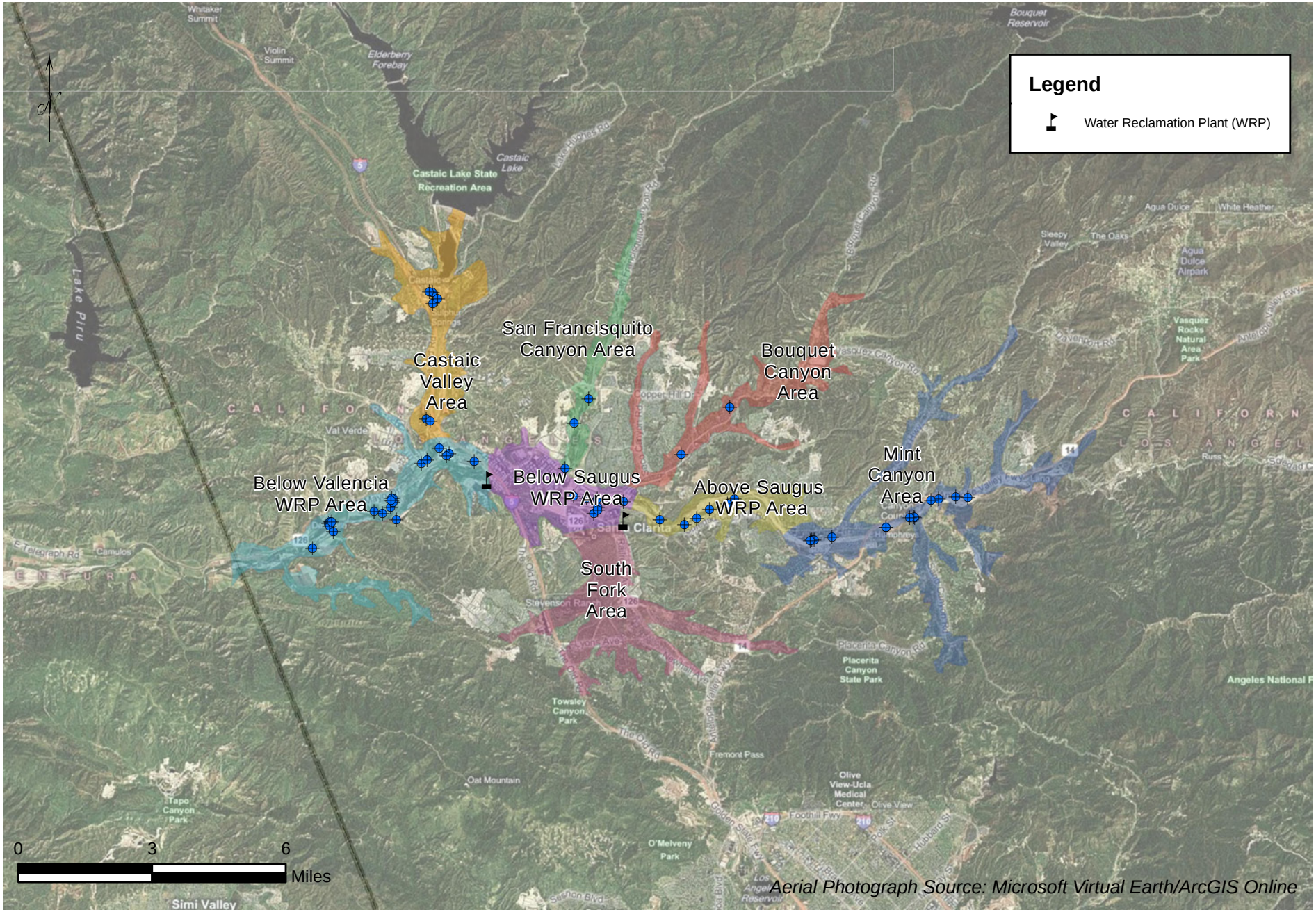

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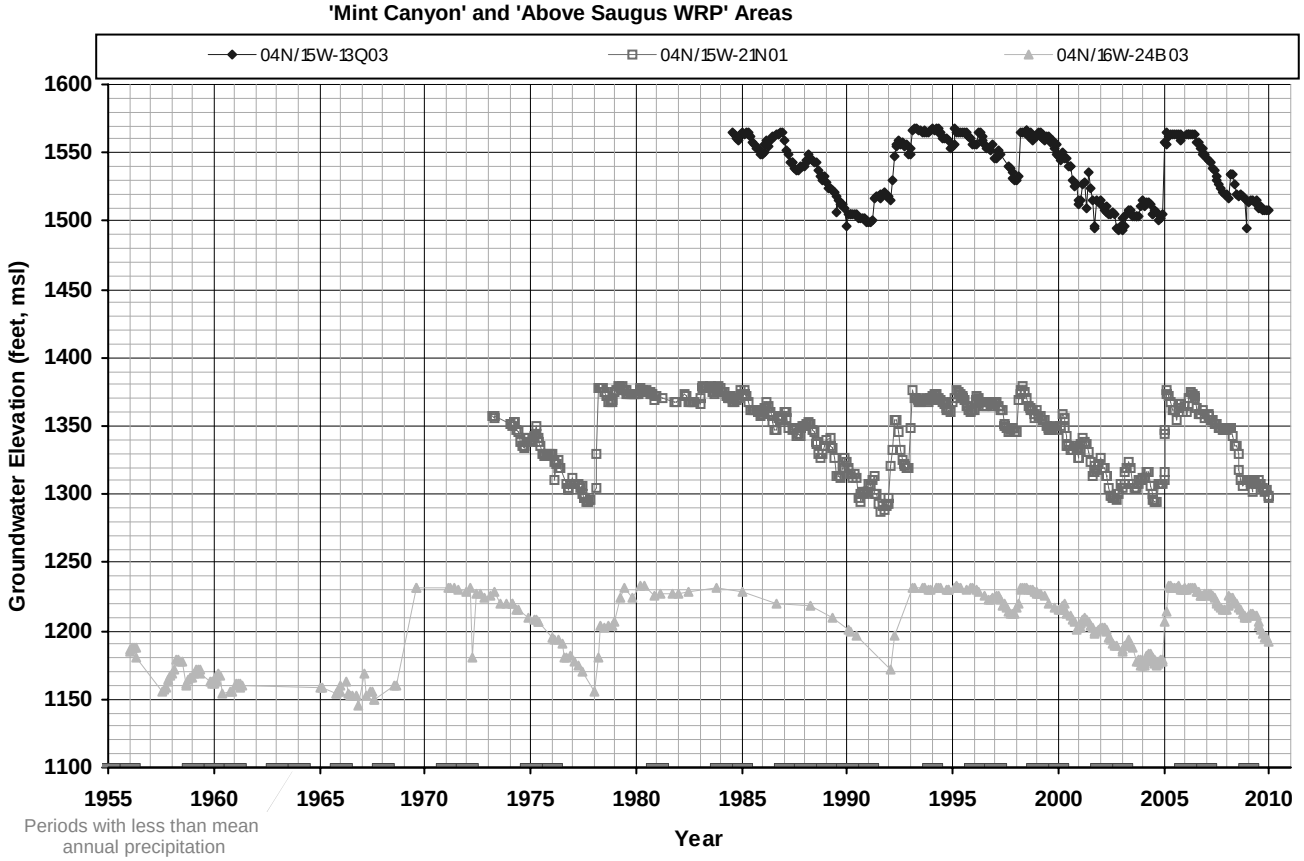
Figure 3-3
Alluvial Well Locations By Area
Santa Clara River Valley, East Groundwater Subbasin



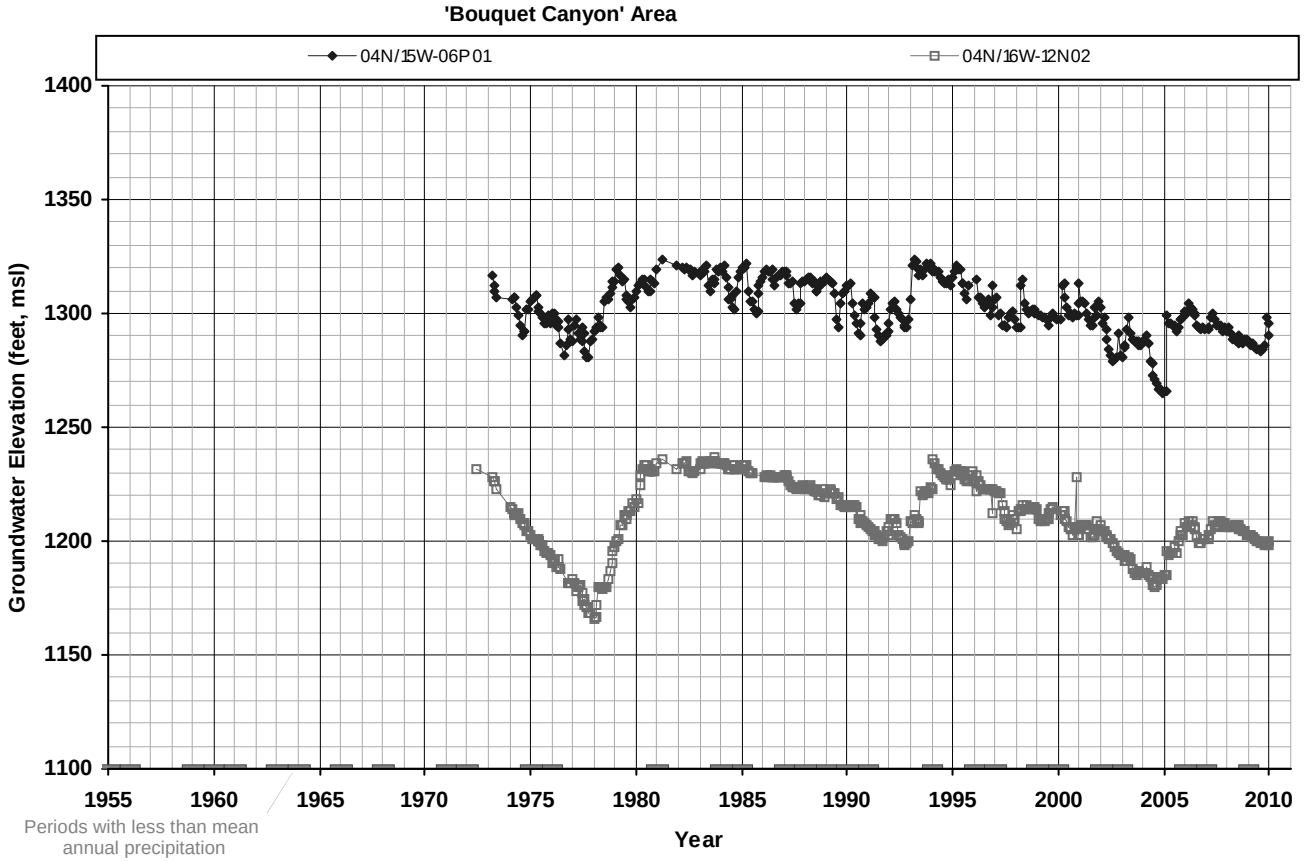


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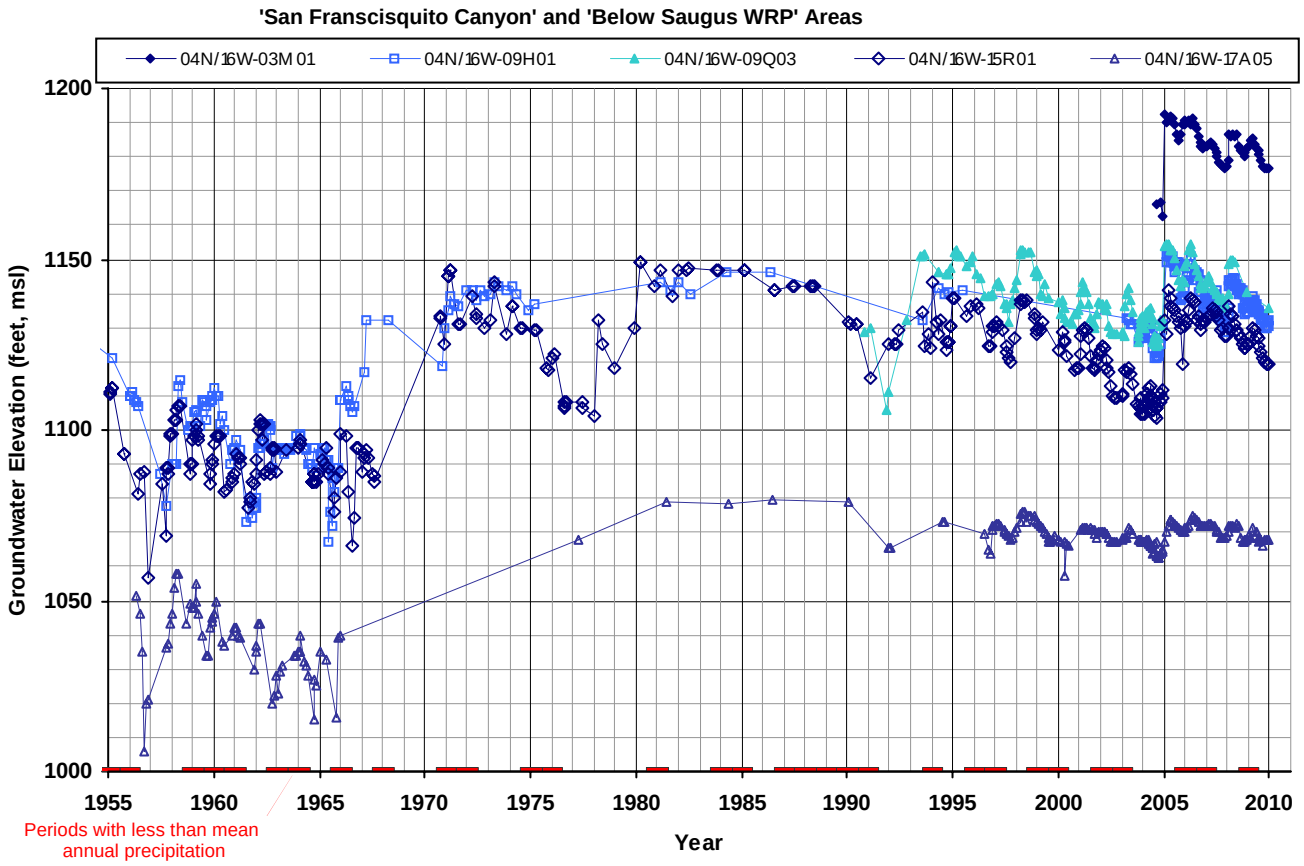
Figure 3-4
Groundwater Elevations in
Eastern Santa Clarita Valley Alluvial Wells



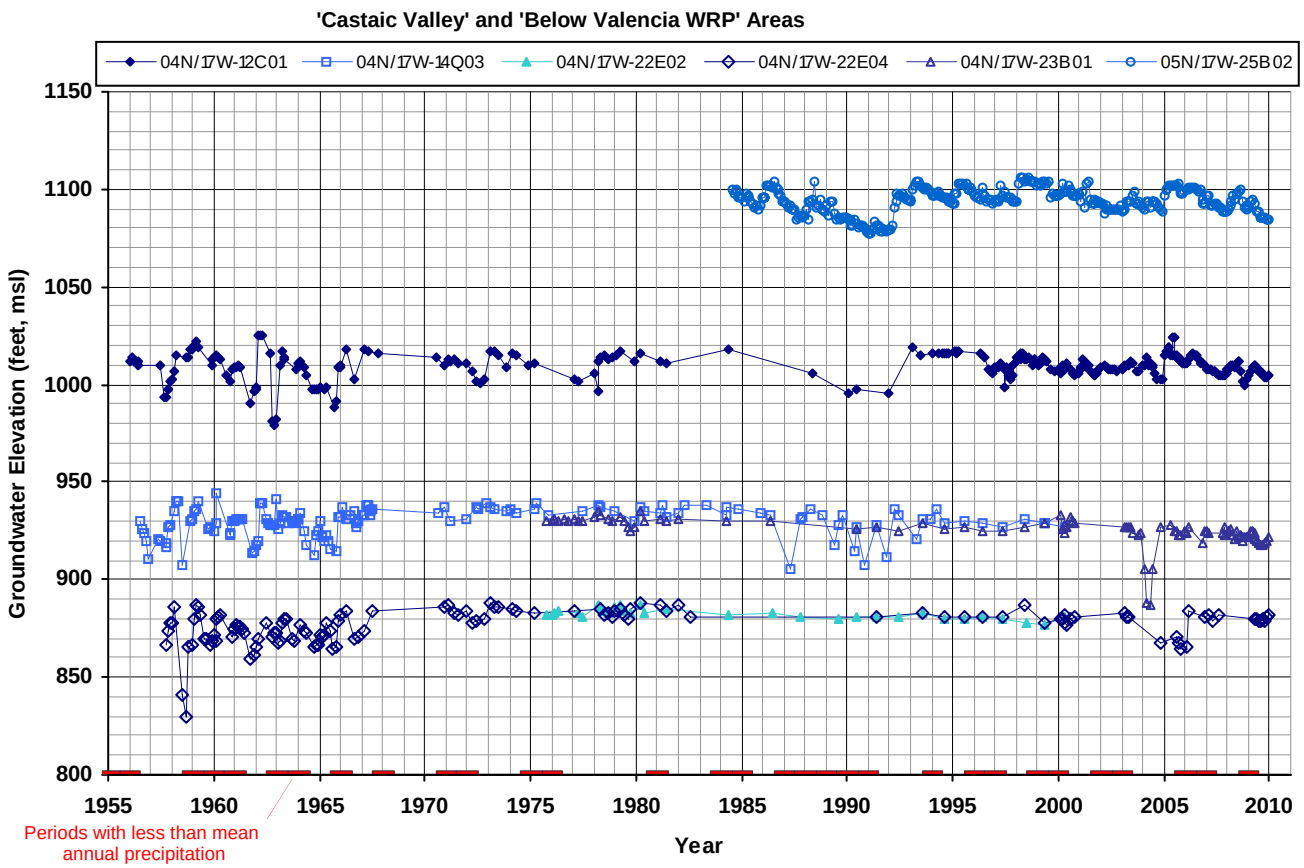


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Figure 3-5
Groundwater Elevations in Western Santa Clarita Valley Alluvial Wells

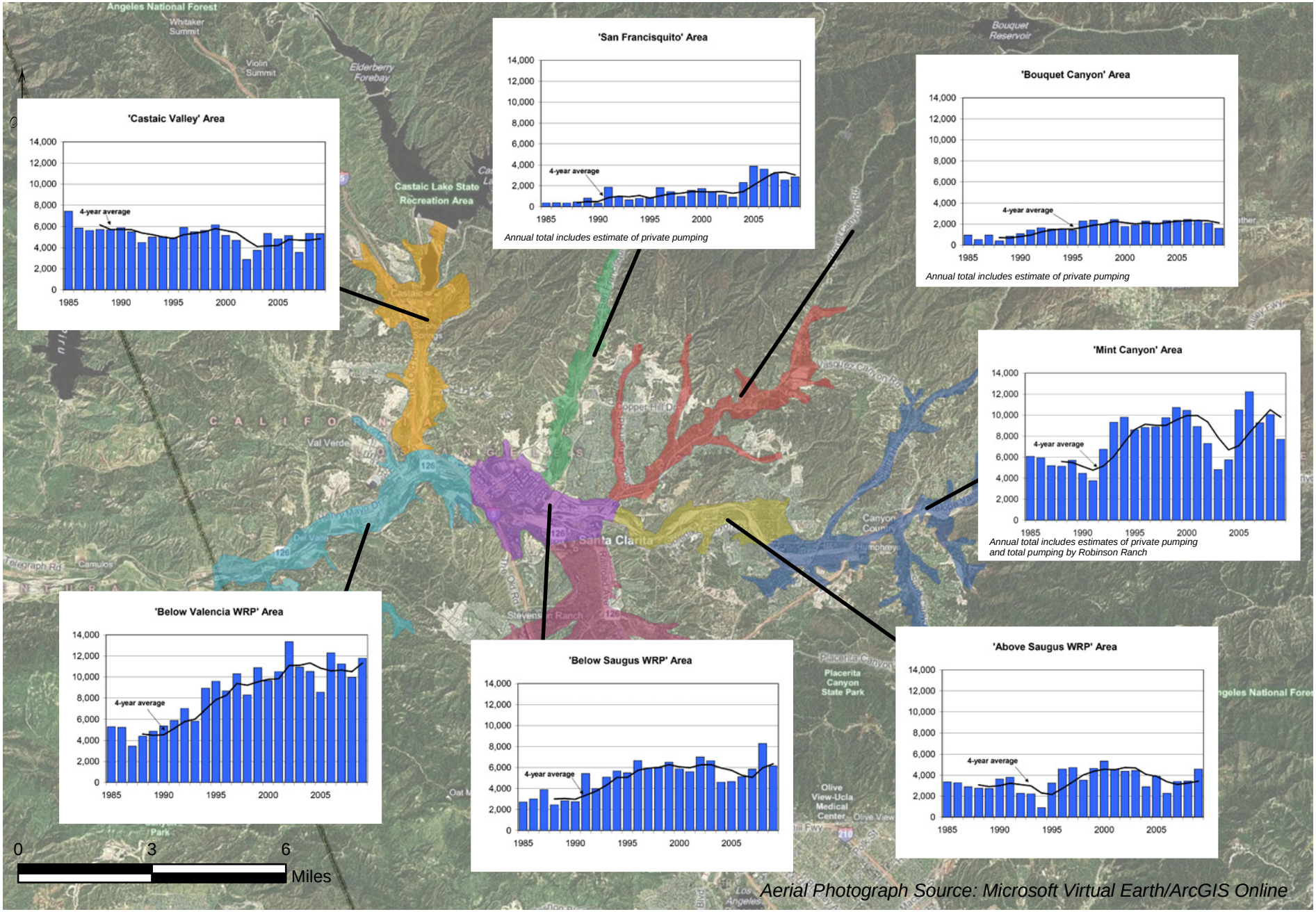

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Figure 3-6
Annual Groundwater Production from Alluvium by Area (Acre-feet)
Santa Clara River Valley, East Groundwater Subbasin

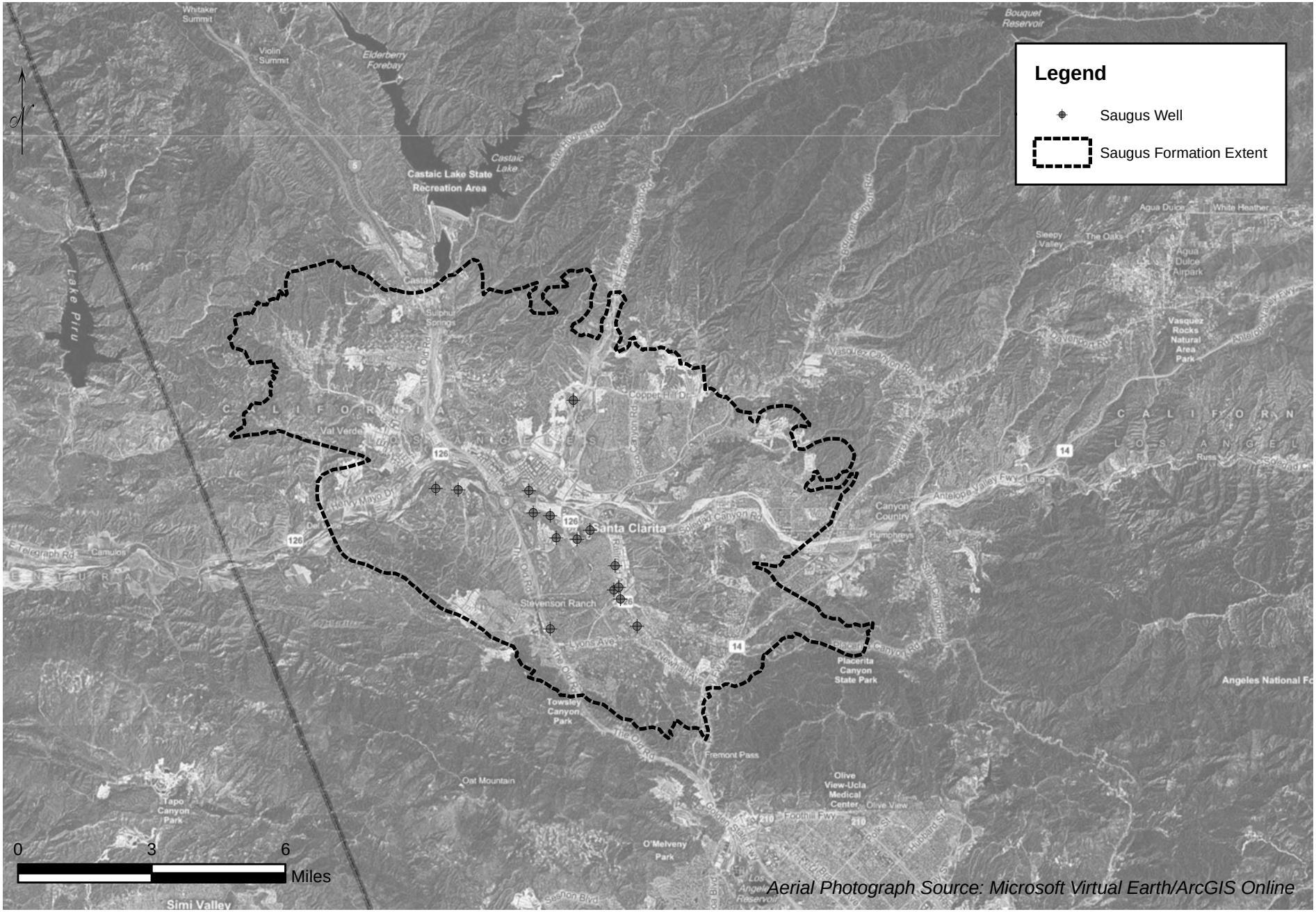

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Figure 3-7
Saugus Well Locations
Santa Clara River Valley, East Groundwater Subbasin

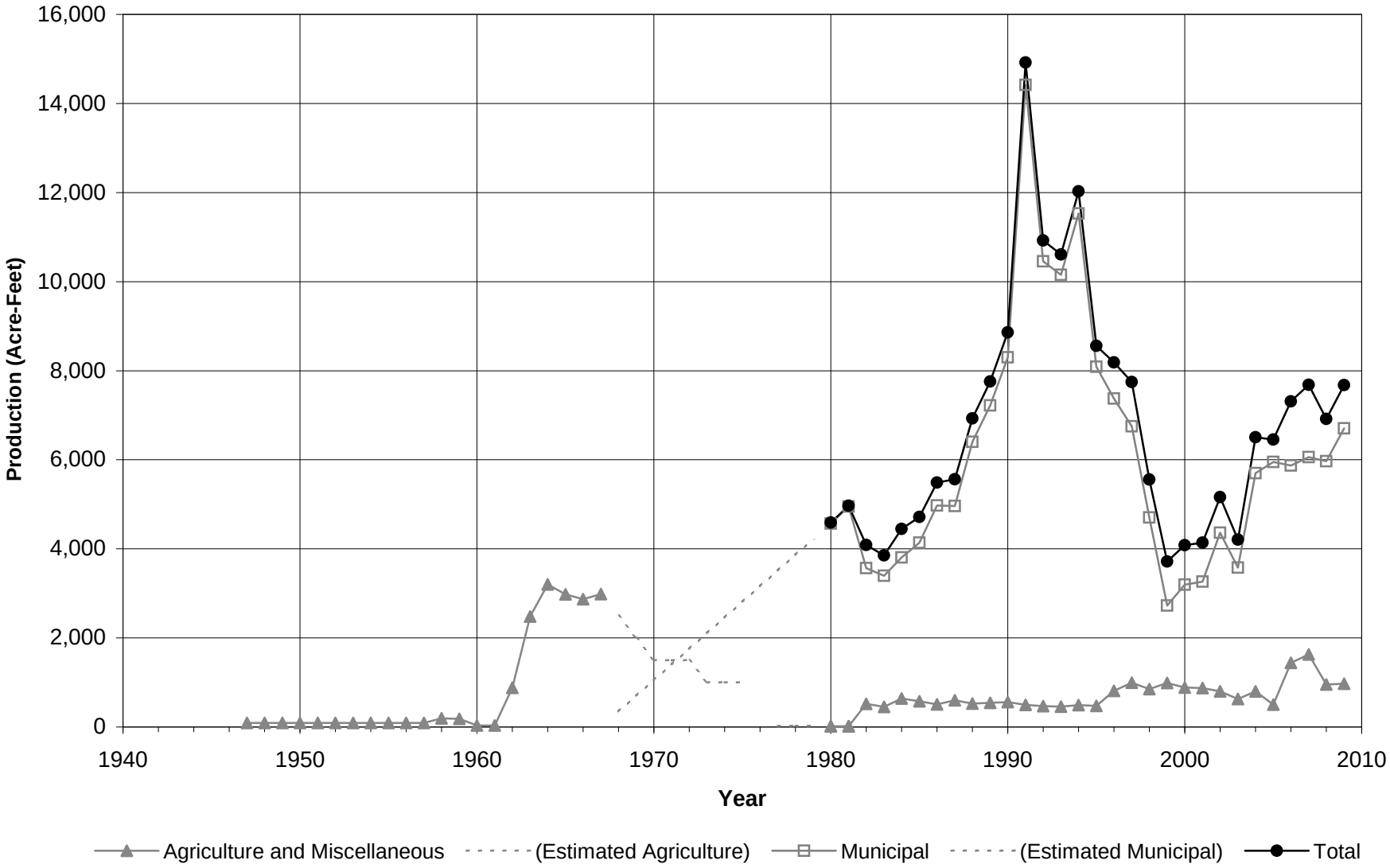

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Figure 3-8
Groundwater Production - Saugus Formation
Santa Clara River Valley, East Groundwater Subbasin

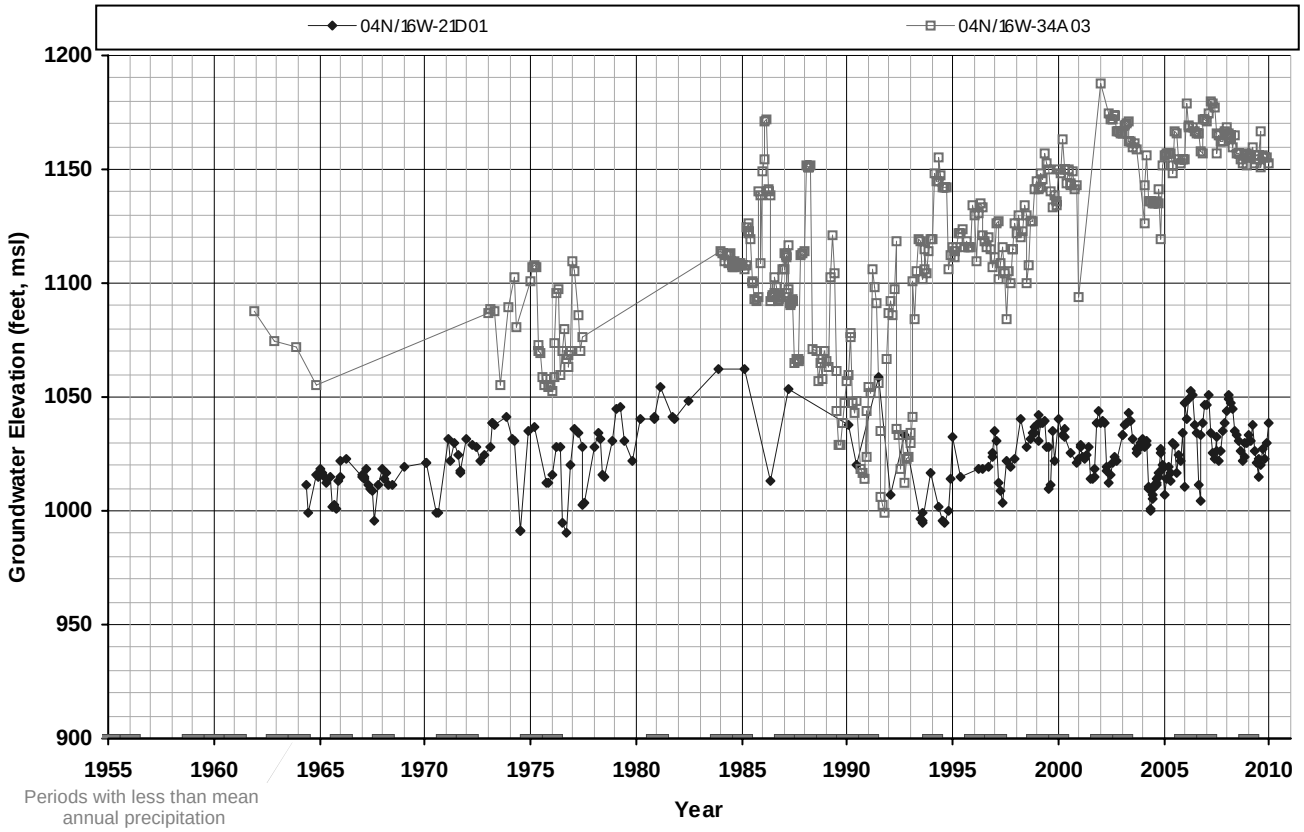

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Figure 3-9
Groundwater Elevations in Saugus Wells

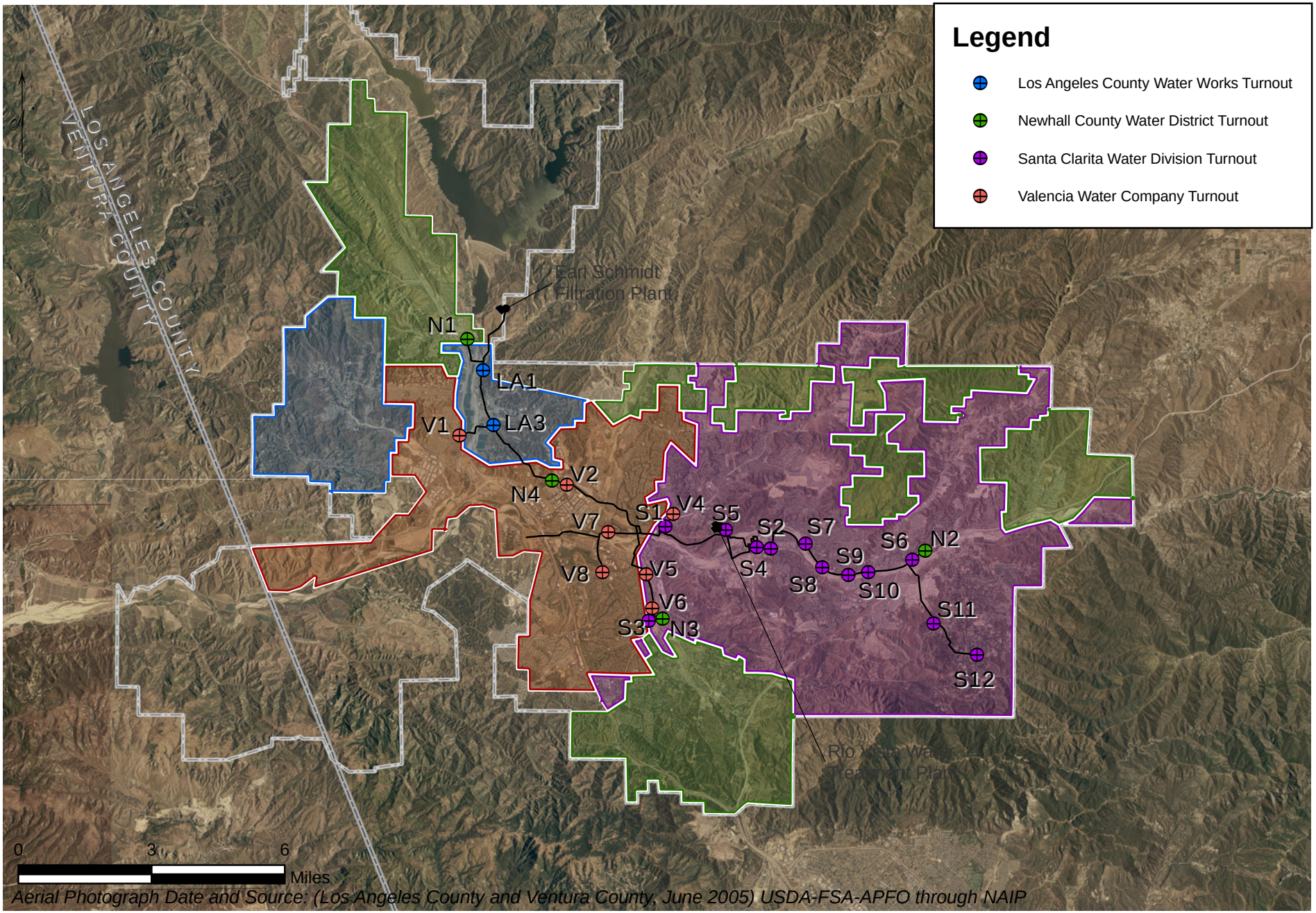

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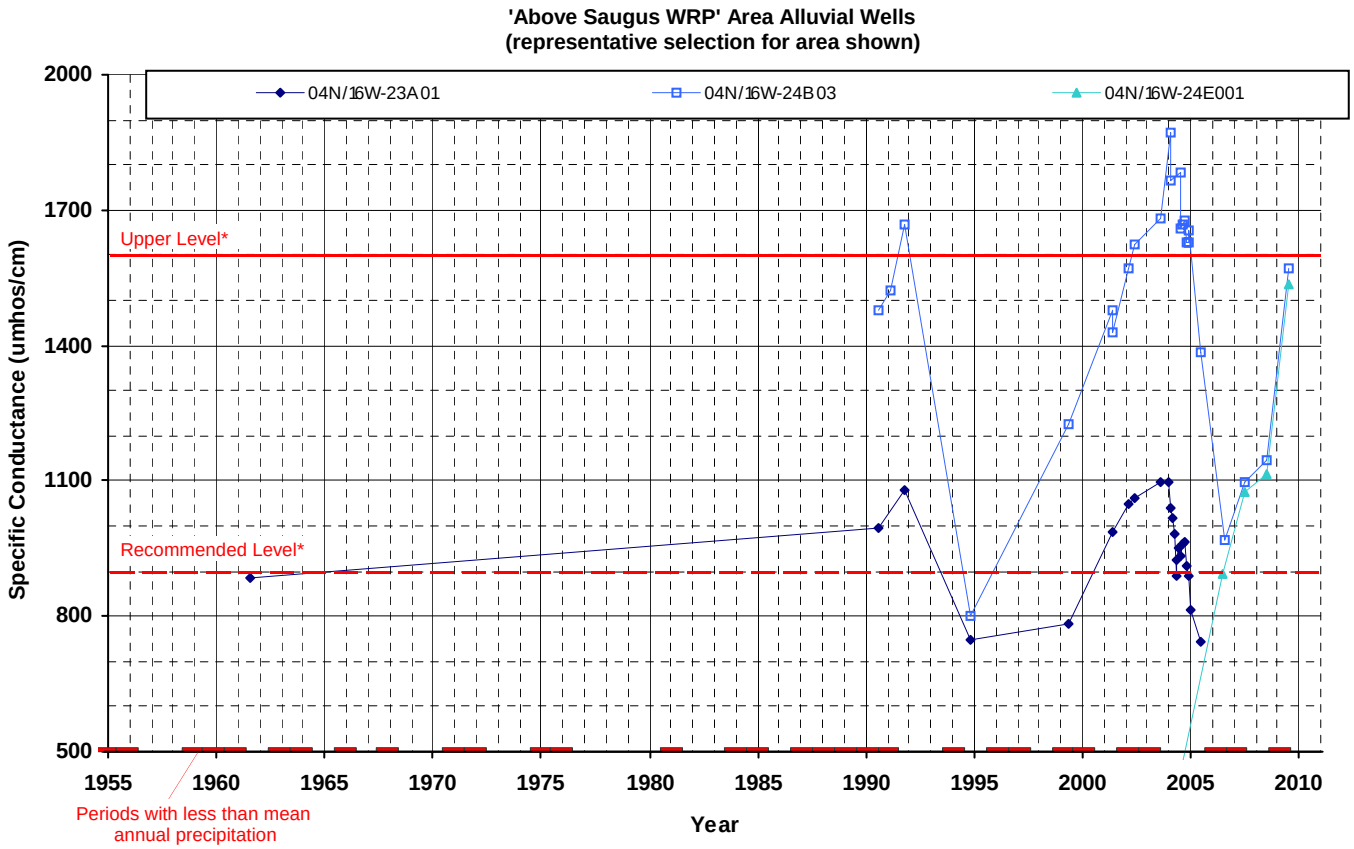
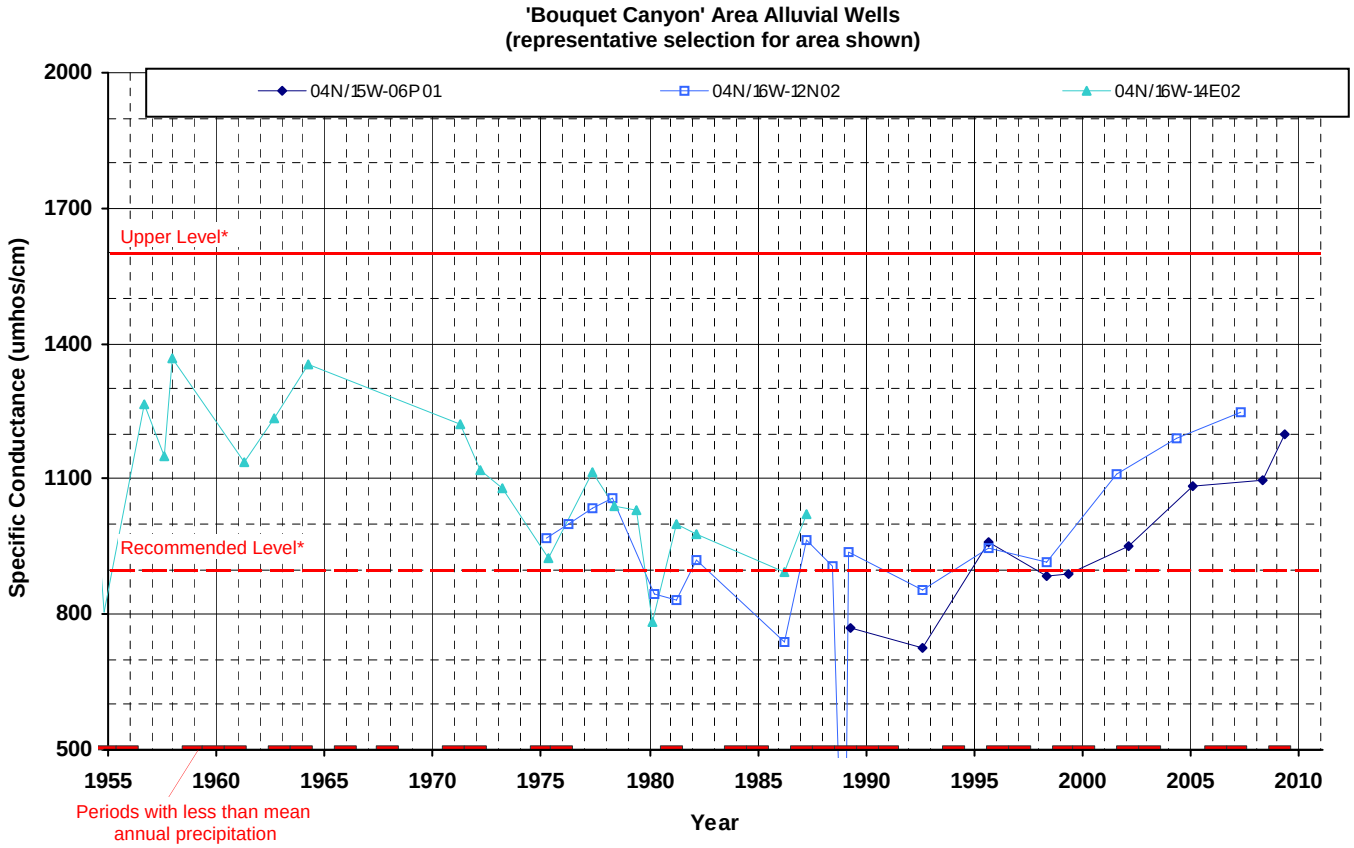
Figure 3-10
Treated Water Distribution System
Castaic Lake Water Agency





*California Department of Public Health Secondary Maximum Contaminant Level

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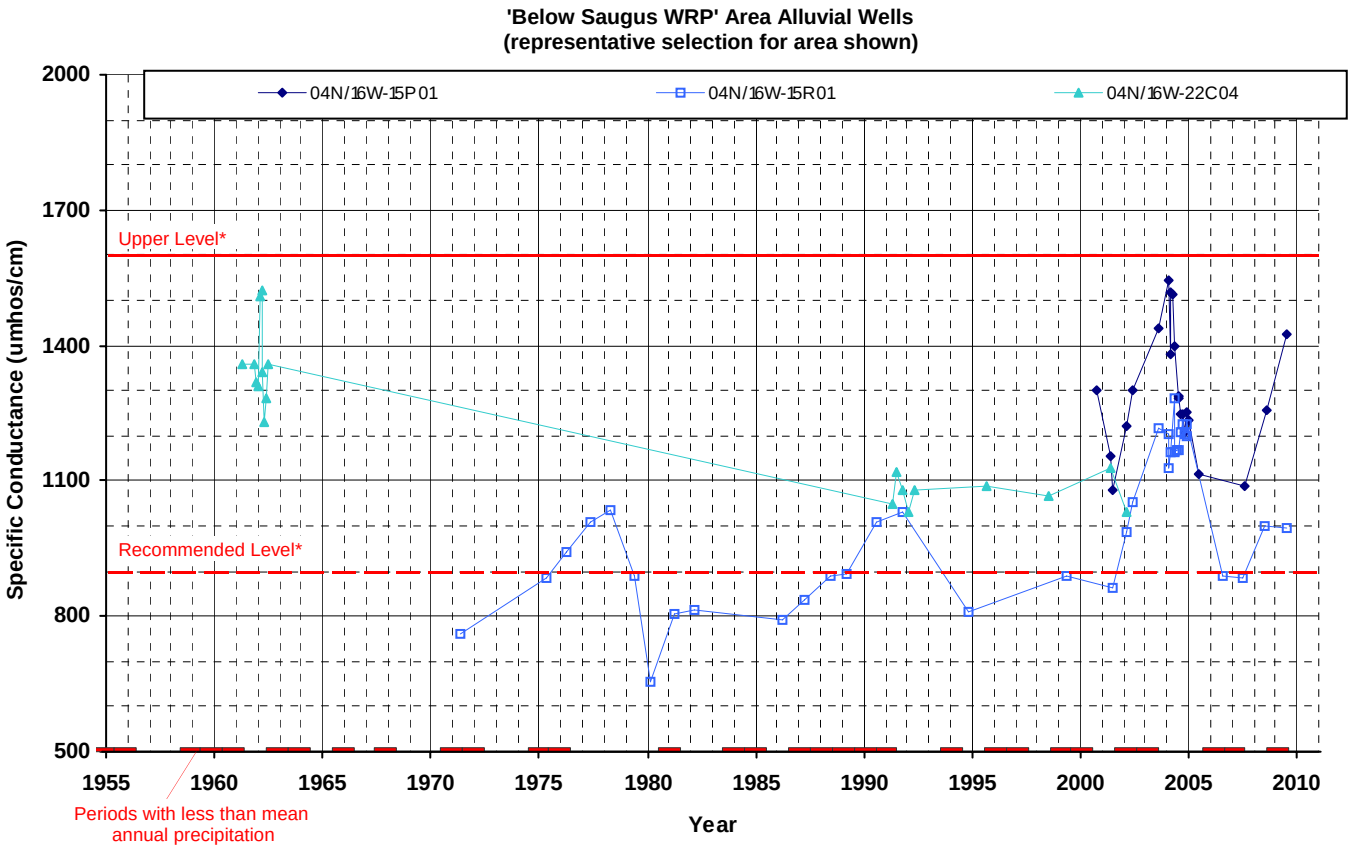
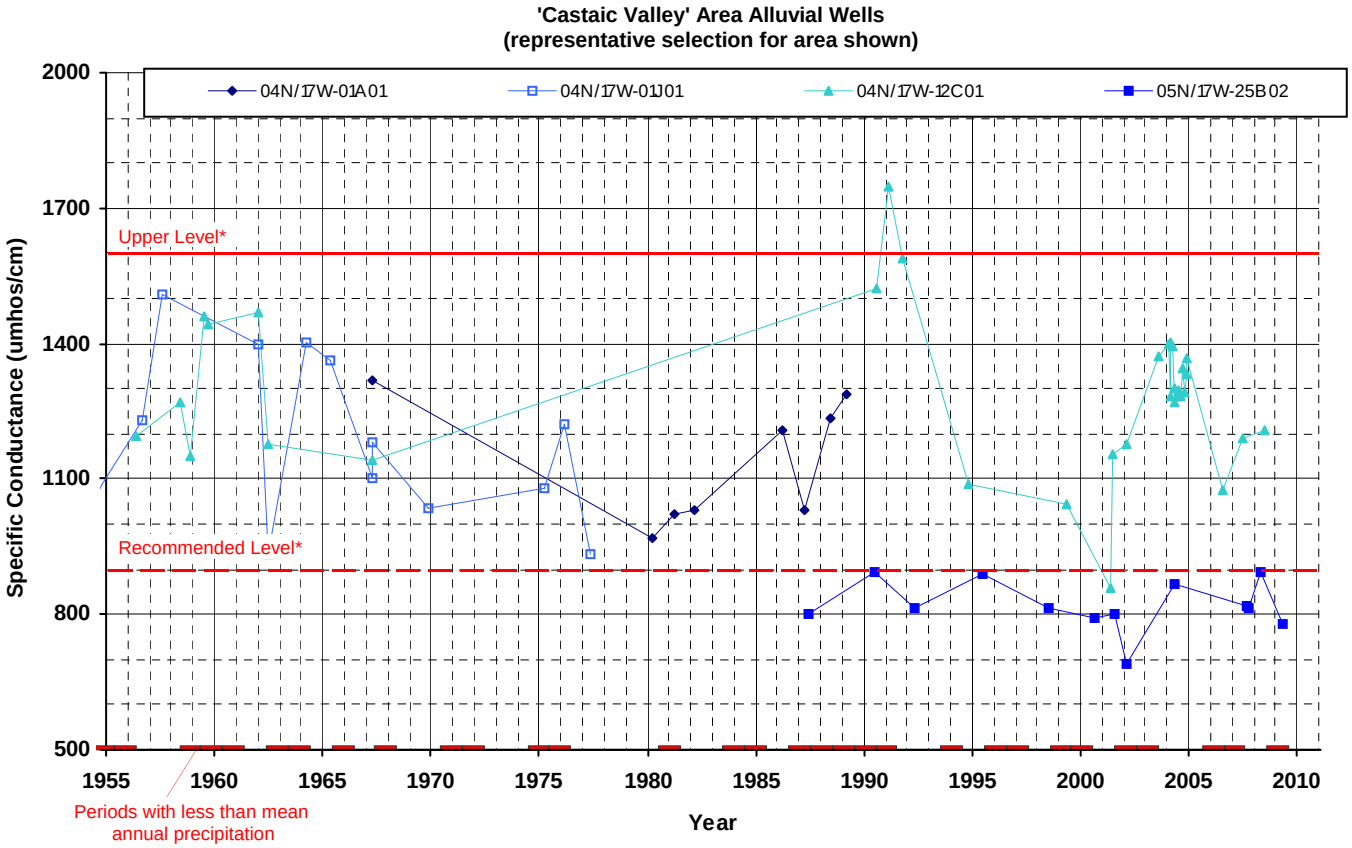
Figure 3-11
Groundwater Quality in
Eastern Santa Clarita Valley Alluvial Wells





*California Department of Public Health Secondary Maximum Contaminant Level

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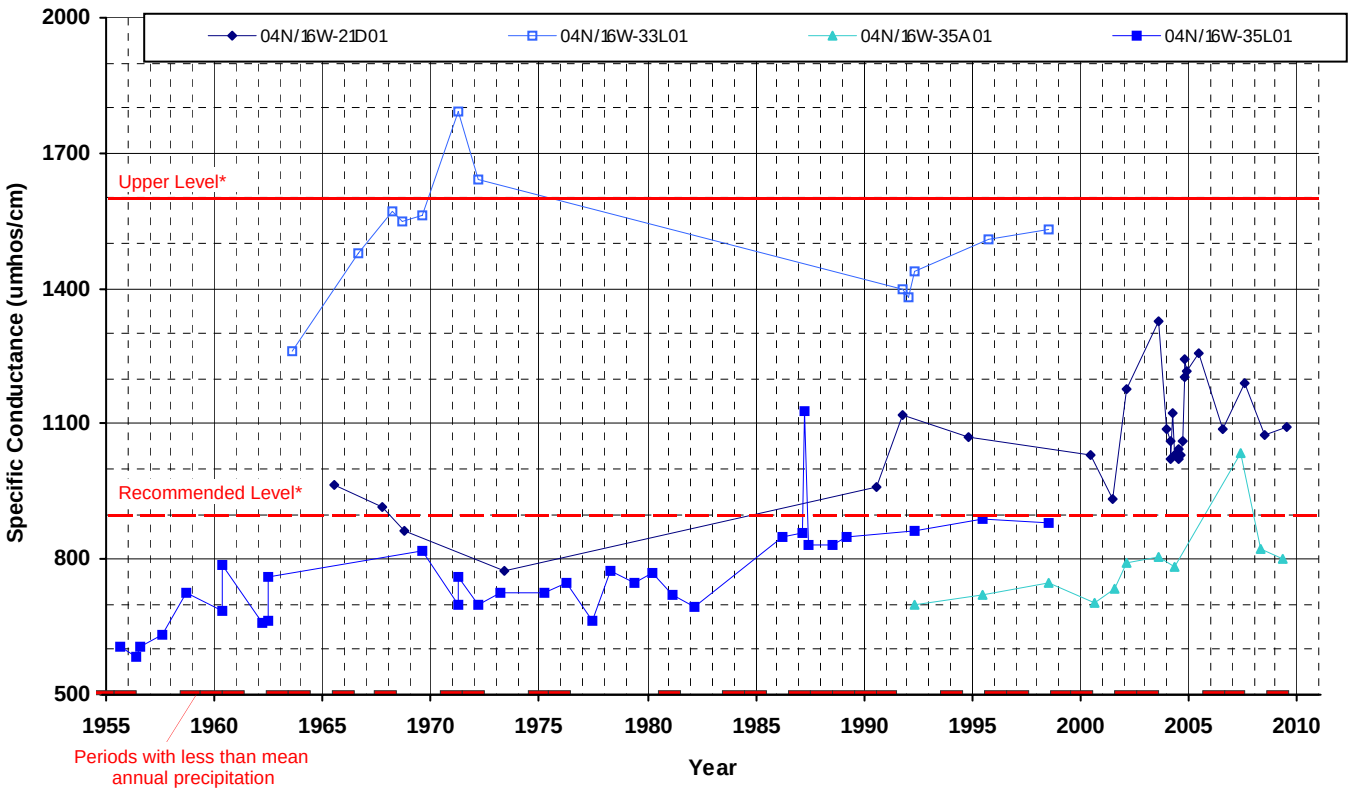
Figure 3-12
Groundwater Quality in
Western Santa Clarita Valley Alluvial Wells



*California Department of Public Health Secondary Maximum Contaminant Level

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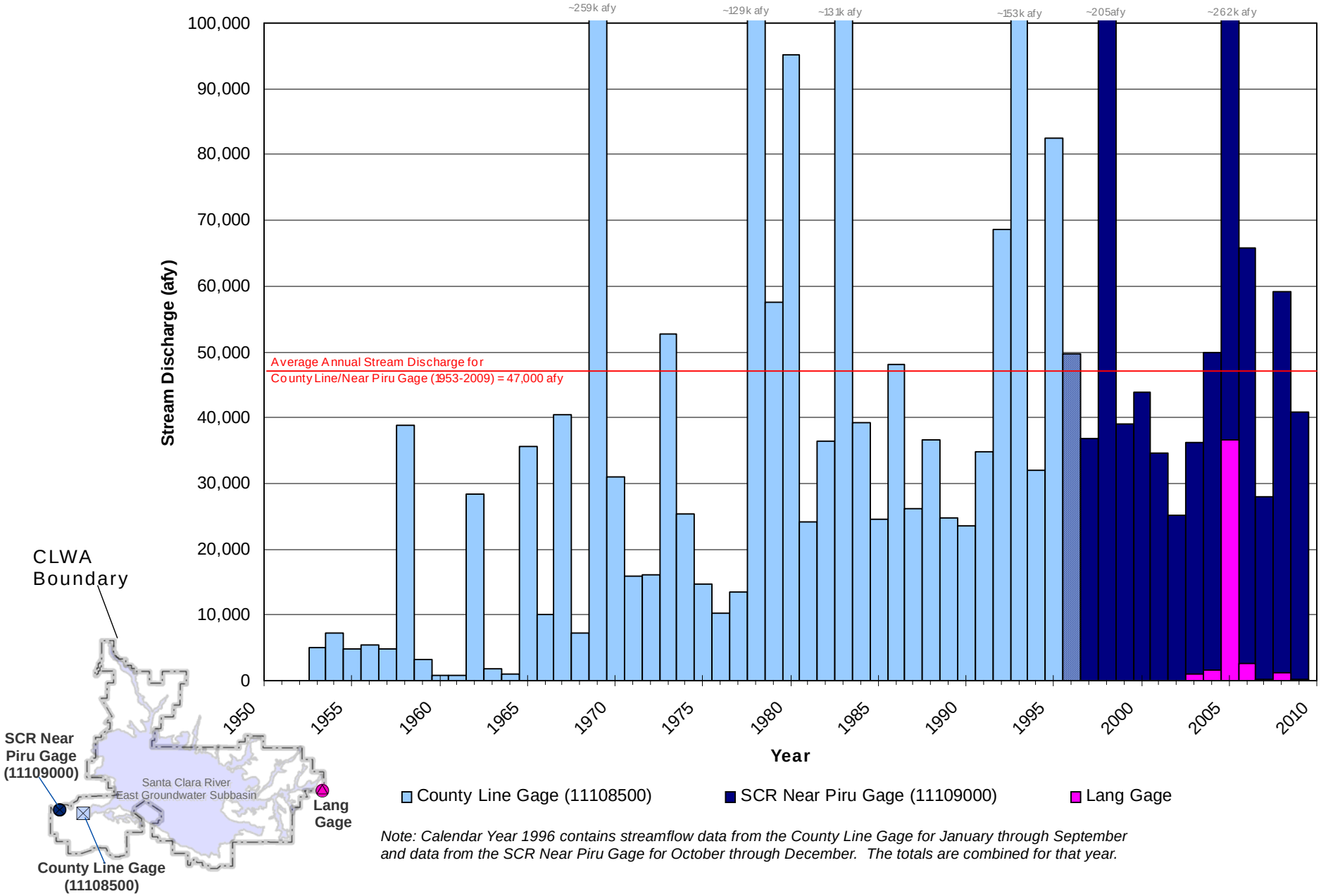
Figure 3-13
Groundwater Quality in Saugus Wells



Note: Calendar Year 1996 contains streamflow data from the County Line Gage for January through September and data from the SCR Near Piru Gage for October through December. The totals are combined for that year.

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Figure 3-14
Annual Stream Discharge
Santa Clara River

4. Summary of 2009 Water Supply and 2010 Outlook

As discussed in the preceding chapters, total water demands in the Santa Clarita Valley were 86,600 af in 2009. This represented a decrease of 4,100 af, or about 4.5 percent, from total demand in 2008 and continues a declining trend in total water demand over the last two years. Of the total demand in 2009, nearly 70,000 af were for municipal water supply, and the balance (16,600 af) was for agricultural and other uses, including estimated individual domestic uses. As detailed in Chapter 2, the total demand in 2009 was met by a combination of local groundwater, SWP and other imported water, and a small amount of recycled water.

The water demand in 2009 was notably lower than the average projection in the 2005 UWMP, (97,900 af), and also lower than the short-term projected demand that was estimated in the 2008 Water Report (91,000 af). For illustration, historical water use from 1980 through 2008 is plotted in Figure 4-1; also shown with that historical record are the projected total water demands in the 2005 UWMP through 2030. As discussed in the 2005 UWMP, year-to-year fluctuations in historical water demand have ranged from about ten percent below to about nine percent above the average or "normal" projection that would describe the long-term historical trend in the Valley's total water demand. The primary factor causing the year-to-year fluctuations is weather. In the short term, wetter years have typically resulted in decreased water demand, and drier years have typically resulted in higher water demand. Extended drier periods, however, have resulted in decreases in demand due to conservation and water shortage awareness. The decline in water demand toward the end of the 1987-92 drought is a good example of such reduced demand. A good recent example of wet-year effects on water demand was 2005, where extremely wet conditions resulted in total water requirements about six percent below the average projection in the 2005 UWMP.

Adding to the types of demand fluctuations described in the 2005 UWMP are the recently-observed effects of broad economic conditions on growth. As reflected by the numbers of service connections in each Purveyor service area, growth in 2009 further slowed, with addition of a total of only about 300 new service connections, in contrast to about 1,000 new connections in each of the preceding two years, and in notable contrast to the predominant growth rate nearly three times higher from the late 1990's through 2004. In addition, the Purveyors were informed by, and have conveyed to the local community, the Governor's Alert in June, 2008 regarding drought conditions and potential water supply shortages, and the Governor's subsequent Drought Emergency Declaration in February, 2009. The widespread awareness of dry conditions throughout the state, aggressive conservation messaging, and the decrease in local growth are

prime factors causing total water demand in 2009 to be notably less than each of the preceding two years, and well below the earlier estimated demand in the 2005 UWMP.

The preceding factors are expected to have a continuing effect in 2010, resulting in estimated total water demand that is again lower than last year. Total municipal water requirements in the first quarter of 2010 were about 16 percent lower than in 2009; that trend continued through April, at the end of which total municipal water requirements were about 19 percent lower than through the first four months of 2009. If municipal demand through the balance of the year tracks average or below average use over the same period through the last two years, and with agricultural and other water requirements comparable to previous years, total water demand in 2010 will be around 82,000 to 84,000 af. That range continues to be substantially below the 100,000 af demand projected for 2010 in the 2005 UWMP.

It is expected that both municipal and agricultural water demands in 2010 will continue to be met with a mix of water supplies as in previous years, notably local groundwater and imported SWP and other supplemental water, complemented by recycled water that will continue to supply a small fraction of total water demand.

On May 20, 2010, the final allocation of water from the SWP in 2010 was announced to be 45 percent; for CLWA, that equates to 42,840 af of its total Table A Amount, of 95,200 af. Combined with local groundwater from the two aquifer systems (48,000 af), total Flexible Storage Account water (6,060 af), net carryover SWP water from 2008 and 2009 (28,303 af), annual acquisition from Buena Vista Water/Rosedale-Rio Bravo Water Storage Districts (11,000 af), unused water previously withdrawn from the Semitropic Groundwater Storage Bank (3,300 af), and recycled water (500 af), the total available water supplies for 2010 are about 140,000 af. Consequently, CLWA and the Purveyors anticipate having more than adequate supplies to meet all water demands in 2010. Projected 2010 water supplies and demand are summarized in Table 4-1.

In August, 2007, a federal court ruled that certain operational changes were required of the SWP in order to protect the endangered Delta smelt. The court order resulted in the preparation of a new Biological Opinion (BO) requiring DWR to implement mitigation requirements with resultant impacts on SWP water supply reliability. Since then, DWR has prepared two updates to its 2005 Reliability Report, which is issued biennially to assist SWP contractors in assessing the adequacy of the SWP component of their overall supplies under varying hydrologic scenarios, e.g. normal and dry years. The current Draft SWP Delivery Reliability Report 2009 was issued in February, 2010. With the objective of protecting endangered fish such as the Delta

Table 4-1
2010 Water Supply and Demand
(acre-feet)

Projected 2010 Demand [1]		**82,000-84,000**
Available 2010 Water Supplies		
Local Groundwater		48,000
Alluvium [2]	*39,000*	
Saugus Formation [3]	*9,000*	
Imported Water		91,503
Table A Amount [4]	*42,840*	
Net Carryover from 2009 [5]	*28,303*	
Buena Vista/Rosedale-Rio Bravo[6]	*11,000*	
Flexible Storage Account (CLWA) [7]	*4,684*	
Flexible Storage Account (Ventura County) [7]	*1,376*	
Yuba Accord[8]	*0*	
Recovery of Banked Water		
Unused Semitropic 2002 Account withdrawal in 2009	*3,300*	
Recycled Water		500
Total Available 2010 Supplies		**140,003**
Additional Dry Year Supplies [9]		
Semitropic Groundwater Storage Bank		45,920
2002 Account[10]	*16,650*	
2003 Account[10]	*29,270*	
Rosedale-Rio Bravo Water Banking and Exchange Program		64,898
2005 and 2006 Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement[11]	*22,000*	
2005 Banking of Table A[12]	*17,800*	
2006 Banking of Table A[12]	*17,800*	
2007 Rosedale Rio-Bravo Banking[12]	*7,298*	
Total Additional Dry Year Supplies		**110,818**

1. Decreased from 2005 UWMP projections to reflect recent early 2010 actual water use, recent three-year trend, and economy-driven decrease in growth.

2. The Alluvium represents 30,000 – 40,000 afy of available supply under local wet-normal conditions, and 30,000 – 35,000 afy under local dry conditions. Available supply in 2010 is shown to be upper-range for average/wet conditions based on actual Alluvium conditions.

3. The Saugus Formation represents 7,500 – 15,000 afy of available water supply under non-drought conditions, and up to 35,000 afy under increasingly dry conditions. Available supply in 2010 is shown to be below mid-range for average/wet conditions, but above recent Saugus pumping in anticipation of perchlorate containment and cleanup pumping in the second half of 2010.

4. CLWA's SWP Table A amount is 95,200 af. The initial 2010 allocation was 15 percent (14,820 af). On March 17, 2010, the allocation was increased to 20 percent (19,040 af). On April 15, 2010 the allocation

was increased to 30 percent (28,560 af). On May 4, 2010 the allocation was increased to 40 percent (38,080 af). On May 20, 2010 the final allocation was increased to 45 percent (42,840 af).

5. Net amount available to CLWA in 2010; total carryover was 28,303 af.

6. 2010 annual supply from Buena Vista / Rosedale-Rio Bravo Water Acquisition Agreement.

7. CLWA can directly utilize up to 4,684 af of storage capacity in Castaic Lake. By agreement in 2005, CLWA can also utilize 1,376 af of Ventura County SWP contractors' flexible storage capacity in Castaic Lake.

8. Up to 850 af of non-SWP water supply is available to CLWA in critically dry years as a result of agreements among DWR, Yuba County Water Agency, and the U.S. Bureau of Reclamation regarding settlement of water rights issues on the Lower Yuba River (Yuba Accord). CLWA opted to not take any Yuba water in 2010.

9. Does not include other reliability measures available to CLWA and the retail water Purveyors. These measures include short-term exchanges, participation in DWR's dry-year water purchase programs, local dry-year supply programs and other future groundwater storage programs.

10. Net recoverable water after banking 24,000 af and 32,522 af in 2002 and 2003, respectively and recovering 4,950 af in 2009.

11. Water stored in Rosedale-Rio Bravo Water Banking and Exchange Program pursuant to the Buena Vista/Rosedale-Rio Bravo Water Acquisition Agreement.

12. Net recoverable water after banking 20,000 af in both 2005 and 2006, and banking 8,200 af in 2007.

smelt and spring-run salmon, the Draft incorporates restrictions on SWP operations according to the Biological Opinions of the U.S. Fish and Wildlife Service and the National Marine Fishery Service issued on December 15, 2008 and June 4, 2009, respectively. It also considers the impacts on SWP delivery reliability due to climate change, sea level rise, and vulnerability of the Delta's conveyance system and structure due to floods and earthquakes. The current Draft Reliability Report projects long-term reliability of 60 percent during normal year hydrology. CLWA staff has assessed the impact of the current Reliability Report on the CLWA reliability analysis contained in the Agency's 2005 UWMP and concluded that current and anticipated supplies are available to meet anticipated water supply needs. However, the preceding discussion of SWP supply should be considered by noting that, while the SWP Reliability Report represents a reasonable scenario with respect to long term reliability, recent reductions in supply reduce the difference between available supply and demand in the future, thereby making the CLWA service area more subject to shortages in certain dry years. Accordingly, the reduction in SWP supply reinforces the need to continue diligent efforts to conserve potable water and increase the use of recycled water, both to meet the goals in the 2005 UWMP and to maximize utilization of potable water supplies.

As discussed in Chapter 5, CLWA and the retail water purveyors have worked with Los Angeles County and the City of Santa Clarita in preparing a water conservation ordinance and the enforcement mechanisms to aggressively implement water conservation in the CLWA service area. In terms of short-term water supply availability, however, CLWA and the Purveyors have determined that, while current operational changes of the SWP are in effect, there are sufficient supplemental water supplies, including SWP water, to augment local groundwater and other water supplies such that overall water supplies will be sufficient to meet projected water requirements, as reflected herein, without the need for mandatory rationing though the summer of 2010. CLWA, the retail water Purveyors, Los Angeles County and the City of Santa Clarita have formed the Santa Clarita Valley Water Committee. The specific purpose of the committee is to work collaboratively to ensure the progressive implementation of water use efficiency programs and ordinances in the Santa Clarita Valley.

In addition to the regular and previously banked water supplies described above to meet projected demand in 2010, a residual of nearly 46,000 af of recoverable water remains stored in the Semitropic Groundwater Storage Bank in Kern County. Nearly 64,900 af of recoverable water are also stored in the long-term Rosedale-Rio Bravo Water Banking and Exchange Program, also in Kern County. After recovery of 4,950 af of banked water in 2009, 1,650 af of which were used in 2009 and 3,300 af of which are intended to be used in 2010, remaining recoverable water in all the Kern County storage banks slightly exceeds 110,000 af. That

component of overall water supply is separately reflected in Table 4-1 because it is intended for future dry-year supply and will not be used for 2010 water supply.

CLWA and the Purveyors have implemented a number of projects that are part of an overall program to provide facilities needed to firm up imported water supplies during times of drought. These involve water conservation, surface and groundwater storage, water transfers and exchanges, water recycling, additional short-term pumping from the Saugus Formation, and increasing CLWA's imported supply. This overall strategy is designed to meet increasing water demands while assuring a reasonable degree of supply reliability.

Part of the overall water supply strategy is to provide a blend of groundwater and imported water to area residents to ensure consistent quality and reliability of service. The actual blend of imported water and groundwater in any given year and location in the Valley is an operational decision and varies over time due to source availability and operational capacity of Purveyor and CLWA facilities. The goal is to conjunctively use the available water resources so that the overall reliability of water supply is maximized while utilizing local groundwater at a sustainable rate.

For long-term planning purposes, water supplies and facilities are added on an incremental basis and ahead of need. It would be economically unsound to immediately, or in the short term, acquire all the facilities and water supplies needed for the next twenty to thirty years. This would unfairly burden existing customers with costs that should be borne by future customers. There are numerous ongoing efforts to produce an adequate and reliable supply of good quality water for Valley residents. Water consumers expect that their needs will continue to be met with a high degree of reliability and quality of service. To that end, CLWA's and the Purveyors' stated reliability goal is to deliver a reliable and high quality water supply for their customers, even during dry periods. Based on conservative water supply and demand assumptions contained in the 2005 UWMP for a planning horizon over the next 25 years, in combination with conservation of non-essential demand during certain dry years, CLWA and the Purveyors believe implementing their water plan will successfully achieve this goal.

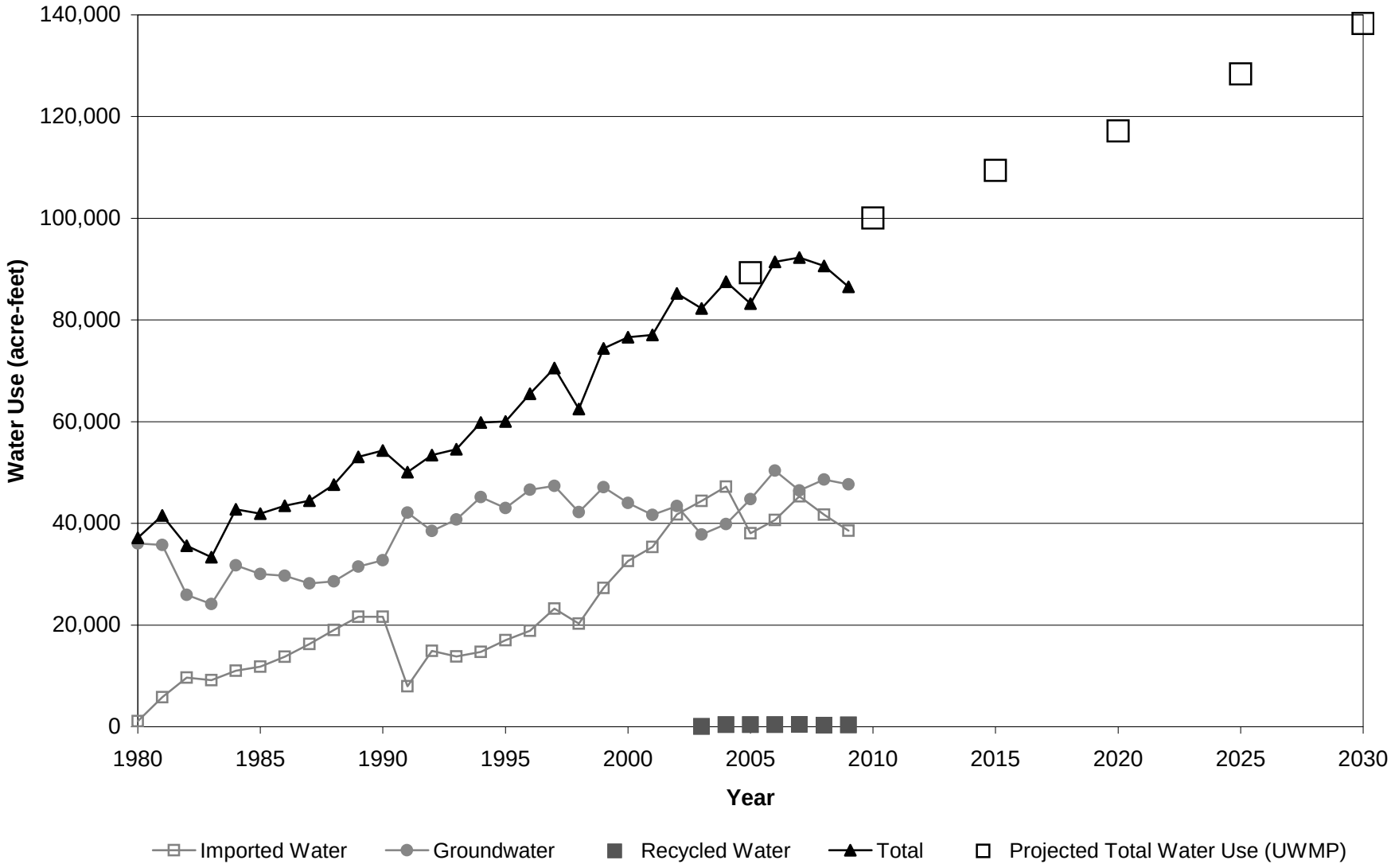

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Figure 4-1
Historical and Projected Water Use
Santa Clarita Valley

5. Water Conservation

The California Urban Water Conservation Council (CUWCC) was formed in 1991 through the Memorandum of Understanding (MOU) Regarding Urban Water Conservation in California. The urban water conservation Best Management Practices (BMPs) included in the MOU are intended to reduce California's long-term urban water demands. While the BMPs are currently implemented by the MOU signatories on a voluntary basis, they are specified as part of the Demand Management Measures section of the Urban Water Management Planning Act. Water conservation can achieve a number of goals, such as:

- meeting legal mandates
- reducing average annual potable water demands
- reducing sewer flows
- reducing demands during peak seasons
- meeting drought restrictions
- reducing carbon footprint, waste water flows and urban runoff.

CLWA signed the urban MOU in 2001 on behalf of its wholesale service area, and pledged to implement several BMPs at a wholesale support level (listed below). NCWD signed the MOU in 2002 and VWC signed the MOU in 2006, both on behalf of their respective retail service areas. As separate MOU signatories and in their respective roles as retailers, NCWD and VWC are committed to implementing all BMPs that are feasible and applicable in their service areas. Efforts are made to coordinate with CLWA and the other Purveyors wherever possible to maximize efficiency and ensure the cost effectiveness of NCWD's and VWC's conservation program.

In coordination with the Purveyors, CLWA has been implementing the following BMPs (which pertain to wholesalers) for several years (some prior to signing the MOU in 2001):

BMP 3	System Water Audits, Leak Detection and Repair
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 10	Wholesale Agency Programs
BMP 12	Water Conservation Coordinator

CLWA and the Purveyors have been implementing these BMPs valley-wide. Since 2001,

CLWA has also instituted implementation of BMP 2 (Residential Plumbing Retrofits) and BMP 14 (Residential Ultra Low Flush Toilet (ULFT) and High Efficiency Toilet (HET) Replacement Programs) on behalf of the Purveyors.

In addition to these efforts, in September 2006 CLWA installed a weather station at its headquarters adjacent to the Rio Vista Water Treatment Plant. This station became part a network of over 120 automated weather stations in the state of California that make up the California Irrigation Management Information System (CIMIS). The Department of Water Resources (DWR) manages the system which has a primary purpose of making available to the public, free of charge, information useful in estimating crop water use for irrigation scheduling.

NCWD, SCWD and VWC have initiated implementation of the remaining BMPs that are specific to retail water suppliers:

BMP 1	Water survey programs for single-family residential and multi-family residential customers
BMP 2	Residential plumbing retrofits (including Weather Based Irrigation Controllers)
BMP 3	System water audits, leak detection and repair
BMP 4	Metering with commodity rates for all new connections and retrofit of existing connections
BMP 5	Large landscape conservation programs and incentives
BMP 6	High-efficiency clothes washing machine financial incentive programs
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 9	Conservation programs for commercial, industrial, and institutional (CII) accounts
BMP 11	Conservation pricing
BMP 12	Conservation coordinator
BMP 13	Water waste prohibition
BMP 14	Residential High Efficiency Toilet (HET) Replacement Program

Reports to the CUWCC on BMP implementation by CLWA and the Purveyors were included in the 2005 UWMP and have been reported annually to the CUWCC since 2007.

Additional savings are occurring Valley-wide due to state interior plumbing code requirements that have been in effect since 1992, as well as due to changes in lot size and reduction in exterior square footage of new housing and commercial developments. The City of Santa Clarita and

County of Los Angeles have also taken a more active conservation role and have begun implementing water efficient devices and practices on the properties they own and manage. All of these efforts have begun to impact overall demand in the Valley, as can be seen in the significant decline in total water demand over the last two years and extending into early 2010. The Valley's water suppliers continue to monitor water demand trends through time to assess those factors that are accounting for the reduction, and to attempt to quantify them.

Most recently with regard to water conservation, CLWA and the retail water Purveyors entered into an MOU in 2007 to prepare a Santa Clarita Valley Water Use Efficiency Strategic Plan (the Plan). The purpose of the plan is to prepare a comprehensive long-term conservation plan for the Santa Clarita Valley by adopting objectives, policies and programs designed to promote proven and cost effective conservation practices. The Plan provides a detailed study of existing residential and commercial water use and recommends programs designed to reduce the overall Valley-Wide water demand by 10 percent by 2030. The programs are designed to provide Valley residents with the tools and education to use water more efficiently. The six programs identified in the Plan are:

- High Efficiency Toilet Rebate Program
- CII Audits & Customized Incentive Program
- Large Landscape Audits & Customized Incentive Program
- Landscape Contractor Certification and Weather Based Irrigation Controller Program
- High Efficiency Washer Rebate Program
- Public Information and Education Programs

In addition to the six programs designed for existing customers, the Plan also identifies three other key factors that will help reduce the valley's overall water demand; passive conservation, inflation, and new more water-efficient building ordinances.

Finally, the Plan includes an Appendix with more aggressive water use efficiency measures designed to meet a potential 20 percent reduction in water use by 2020. This includes funding more active conservation programs, retrofit on resale legislation, water rate reform, water budget based rates, and a more aggressive recycled water program.

Implementation of the majority of the programs identified in the Plan are beginning in 2010 through funding by CLWA on behalf of all the Purveyors.

In addition to this effort, the water Purveyors are working with City and County agencies to develop a landscape irrigation ordinance for the Santa Clarita Valley. This ordinance will focus primarily on new construction aimed at reducing overall water demands by requiring efficient landscape design and delivery systems. Implementation of the ordinance is expected in 2010, depending on review and adoption by the City and County.

Finally, in 2008, Governor Schwarzenegger issued a proclamation for all Californians to reduce their per capita water consumption by 20 percent by the year 2020. In November 2009, the Governor and California's legislature reached an historic agreement over ensuring long term water supply reliability for California, as well as restoring and protecting the Sacramento-San Joaquin Delta and other ecologically sensitive areas. The agreement is comprised of four policy bills and an $11.4 billion bond measure. One of the policy bills (SB 7X7) identifies reporting criteria and guidelines for water utilities to track and measure progress toward achieving the 20 percent per capita demand reduction goal. Water utilities are required to implement strategies and report progress in their Urban Water Management Plans. In 2010, DWR is expected to provide guidance and criteria for implementing the provisions of this new law; that guidance is expected to provide clarification regarding individual (per-capita) and broader (Valley-wide) conservation goals, which will be utilized in the preparation of the 2010 update of the UWMP for the Santa Clarita Valley.

6. References

California Department of Water Resources, **California's Groundwater**, Bulletin 118 – Update 2003, October 2003.

California Department of Water Resources, **The California Water Plan Update,** Bulletin 160-05, 2005.

California Department of Water Resources, **The State Water Project Delivery Reliability Report 2007, Final,** August 2008.

Castaic Lake Water Agency, **Groundwater Management Plan, Santa Clara River Valley Groundwater Basin, East Subbasin**, Los Angeles County, California, December 2003.

Castaic Lake Water Agency (CLWA), CLWA Santa Clarita Water Division, Newhall County Water District, and Valencia Water Company, **2005 Urban Water Management Plan**, Los Angeles County Waterworks District No. 36, Cooperating Agency, November 2005.

CH2M Hill, **Evaluation of Historical and Projected Future Flows to Ventura County Resulting From Importation of State Project Water to the Santa Clara River Watershed,** July, 1998.

CH2M Hill **Evaluation of Historical and Projected Future Flows to Ventura County Resulting From Importation of State Project Water to the Santa Clara River Watershed**, Update 2001.

CH2M Hill **Regional Groundwater Flow Model for the Santa Clarita Valley, Model Development and Calibration**, April, 2004.

CH2M Hill, **Analysis of Perchlorate Containment in Groundwater Near the Whittaker-Bermite Property, Santa Clarita,** California, Prepared in support of the 97-005 Permit Application, December 2004.

CH2M Hill, Technical Memorandum, **Calibration Update of the Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California,** August 2005.

CH2M Hill and Luhdorff & Scalmanini, Consulting Engineers, **Analysis of Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin, Los Angeles County, California**, prepared for Upper Basin Water Purveyors, August 2005.

Kennedy/Jenks Consultants, Draft Report, **Recycled Water Master Plan,** Castaic Lake Water Agency, May 2002.

Luhdorff and Scalmanini, Consulting Engineers, **Impact and Response to Perchlorate Contamination, Valencia Water Company Well Q2**, prepared for Valencia Water Company, April 2005.

Luhdorff and Scalmanini, Consulting Engineers, **2008 Santa Clarita Valley Water Report**, prepared for Castaic Lake Water Agency, CLWA Santa Clarita Water Division, Los Angeles County Waterworks District 36, Newhall County Water District, and Valencia Water Company, April 2009.

Luhdorff and Scalmanini, Consulting Engineers and GSI Water Solutions, **Analysis of Groundwater Supplies and Groundwater Basin Yield, Upper Santa Clara River Groundwater Basin, East Subbasin**, prepared for Santa Clarita Valley Municipal Water Purveyors, August 2009.

Masnada, Dan, General Manager, Castaic Lake Water Agency, Letter to Bruce W. McClenden, Director of Planning, Los Angeles County Department of Regional Planning, *Availability of Future Water Supply in the Santa Clarita Valley*, February 5, 2008.

Memorandum of Understanding Between the Santa Clara River Valley Upper Basin Water Purveyors and United Water Conservation District, August 2001.

Richard C. Slade & Associates, LLC, **2001 Update Report, Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems**, prepared for Santa Clarita Valley Water Purveyors, July 2002.

Slade, R. C., **Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California,** Vols. I and II, prepared for Castaic Lake Water Agency, 1988.

Slade, R. C., **Hydrogeologic Investigation of Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California**, Vols. I and II, prepared for Upper Santa Clara Water Committee, 1986.

Statement of Decision, ***California Water Network v. Castaic Lake Water Agency*****, Los Angeles County Superior Court No. BS098724, filed April 2, 2007 ("Chalfant Decision")**

California Water Impact Network v. Castaic Lake Water Agency
BS 098724

Statement of Decision on Petition for Writ of Mandate

ORIGINAL FILED
APR 02 2007
LOS ANGELES SUPERIOR COURT

Petitioners California Water Impact Network ("CWIN") and Planning and Conservation League ("PCL") petition for writ of mandate under California Environmental Quality Act ("CEQA"). The court has read and considered the moving papers, oppositions, and reply, heard oral argument, and renders the following decision.

A. Statement of the Case

Petitioner CWIN commenced its petition for writ of mandate in Ventura County Superior Court on January 24, 2005. The petition alleges that on December 23, 2004, the Castaic Lake Water Agency ("Castaic"), a public water agency and water wholesaler that treats and delivers water to water retailers in Los Angeles and Ventura Counties, approved the permanent transfer of 41,000 acre feet per year from Real Party in Interest Kern County Water Agency ("Kern") and its member unit in Kern County, Wheeler Ridge-Maricopa Water Storage District ("Wheeler Ridge"), to Castaic (the "Kern water transfer," the "Kern transfer," or the "transfer"). Castaic also purported to certify the Environmental Impact Report ("EIR") for the project (the "2004 EIR" or the "EIR"). Petitioner claims the Kern water transfer "threatens to promote large-scale urban sprawl in Ventura and Los Angeles Counties, while diverting water from important environmental and agricultural uses in Kern County forever." Petitioner alleges that the 2004 EIR is premature, and fails to comply with CEQA.

The petition alleges a cause of action for violation of CEQA in that Real Party in Interest California Department of Water Resources ("DWR"), not Castaic, should have been the lead agency for the 2004 EIR, which does not adequately describe the background on which the project is based, fails to disclose a reliance on an invalid Urban Water Management Plan, fails to adequately describe alternatives to the project, including a "no project" alternative, fails to discuss growth inducement, and inaccurately states the availability of water availability.[1]

On January 24, 2005, PCL filed its own petition for writ of mandate against Castaic in Ventura County Superior Court. The PCL petition alleges a violation by Castaic in recording a Notice of Determination on December 23, 2004, certifying the 2004 EIR and rendering its approval of the Kern water transfer. The petition purports to allege five "causes of action" for violation of CEQA in the 2004 EIR based on Castaic stealing DWR's duty to be the lead agency for the EIR, certification of a defective EIR, approval of inadequate findings, erroneous presentation of the project as already complete, and "prejudicial abuse of discretion."

On June 22, 2005, upon motion by Castaic, the Ventura County Superior Court (the Honorable Frederick H. Bysshe, Jr.) ordered the transfer of both petitions, which had been consolidated, to Los Angeles. On March 27, 2006, the case was reassigned to this court.

On June 27, 2006, the court heard the demurrers of Castaic and Real Party in Interest Kern to the consolidated petitions. The court ruled that the petitions were timely filed and were

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[1]On CWIN's oral motion, the petition's second and third causes of action have been dismissed. As a result, CWIN's petition solely concerns Castaic's compliance with CEQA in the 2004 EIR.

not barred under the doctrine of *res judicata*. The court noted that the Kern water transfer agreements are valid. While principles of *collateral estoppel* barred Petitioners from re-raising issues resolved by the Second District with respect to the 1999 EIR, this conclusion did not foreclose the petitions and the demurrers were overruled.

On July 16, 2006, the court denied Castaic's motion for a legal determination under principles of *collateral estoppel* and party admission that Castaic is the proper lead agency for preparation of the EIR for the Kern water transfer. However, Petitioners are bound by their concession that Castaic may act as the lead agency at some point for an EIR on the Kern water transfer.

B. Preliminary Issues

1. Standing and Timeliness

Petitioner PCL alleges that it is a non-profit corporation devoted to environmental protection. PCL Pet. at ¶6-7. Some of PCL's members live in the area affected by the Kern water transfer. PCL Pet. at ¶8. Petitioner CWIN alleges that it is a nonprofit public benefit corporation the purpose of which is to protect California's environment. CWIN contends that it is impacted by the Kern water transfer because its members reside in and use the Santa Clara River watershed, which is impaired by the water transfer. CWIN Pet. at ¶9. Thus, Petitioners contend that they are impacted by the project and have standing to raise the issues herein. Respondents do not contest Petitioners' standing. *See* Waste Management of Alameda County, Inc. v. County of Alameda, (2000) 79 Cal.App.4th 1223, 1233-34.

The actions are timely on CEQA issues, each having been filed on January 24, 2005, within 30 days of Castaic's Notice of Determination that the 2004 EIR had been certified, filed in various counties between December 23 and December 27, 2004. *See* Pub. Res. Code §21167(c).

2. The Administrative Record

Castaic has certified the administrative record. Pub. Res. Code §21167.6; LASC 9.24(e). The record was received in evidence at trial.

Castaic and Kern, and DWR separately ask the court to judicially notice various records. Judicial notice is the acceptance by a court without formal proof of the existence of a matter of law or fact that is relevant to an issue in the case. People v. Rowland, (1992) 4 Cal.4th 238, 268, n.6. Certain documents are subject to judicial notice. Ev. Code §451, 452. Even where subject to judicial notice, however, a document must be relevant. Id.

The California Supreme Court decision in Western States Petroleum Assn. v. Superior Court, ("Western States") (1995) 9 Cal.4th 559, 573, n.4, provides that extrinsic evidence is generally not admissible for a traditional mandamus challenging a quasi-legislative agency action. The exclusion of extrinsic evidence in a traditional mandamus action is essentially the exclusion of irrelevant evidence. Extrinsic evidence is generally not admissible for a traditional mandamus challenging a quasi-legislative agency action. Id. Such evidence may be admissible in a narrowly construed exception in which (1) the evidence in question existed before the agency made the decision, and (2) the evidence could not have been presented to the agency in the first instance in the exercise of reasonable diligence. Id. at 578. The purpose of limiting extra-record evidence is that the free use of such evidence would invade the deference to which the legislative

branch is entitled under the constitutional separation of powers. If the courts freely considered extra-record evidence in mandamus cases, the highly deferential substantial evidence standard would be turned into a *de novo* standard where the courts in effect would decide not whether an administrative decision was supported by the evidence before the agency but instead whether it was the wisest and best decision according to the courts. Id. at 572.

Castaic asks the court to judicially notice: (1) the unpublished appellate decision in Friends of the Santa Clara River v. Castaic Lake Water Agency, 2003 Cal.App. Unpub. LEXIS 11239, dated December 1, 2003 ("Friends II"), and (2) the unpublished appellate decision in California Water Network v. Castaic Lake Water Agency, 2006 Cal.App. Unpub. LEXIS 2452, dated March 23, 2003.[2] The existence of these court decisions is subject to judicial notice. Ev. Code §452(d).[3]

DWR asks the court to judicially notice (1) Amendment No. 19 to the Water Supply Contract between it and Castaic dated May 28, 2003, and (2) Notice of Preparation of EIR for the Monterey Amendment dated January 24, 2003. DWR contends that these documents are official acts of a California agency subject to judicial notice under Ev. Code section 452(c) and (d). The Notice of Preparation is an official act of DWR and is judicially noticed. However, Amendment No. 19 is not. Official acts should be limited to regulations, public announcements, and other actions the existence of which is beyond dispute. A well informed person has no way of knowing whether Amendment No. 19 is authentic and valid. Nor is it a court record under section 452(d). DWR's request for judicial notice of Amendment No. 19 is denied.

C. Statement of Facts

1. SWP

In 1951, the Legislature authorized construction of a state water storage and delivery system. Planning & Conservation League v. Department of Water Resources, (2000) 83 Cal.App.4th 892, 898. The Legislature subsequently authorized the State Water Project ("SWP"), a complex system of 28 reservoirs and dams, 26 power and pumping plants, and 600 miles of canals and aqueducts to deliver 4.23 million acre-feet of water annually to Central and Southern California. The primary source for the SWP is the drainage of the Feather River, a tributary of the Sacramento River in Northern California (hereinafter, the "Delta").

DWR is the state agency charged with the statutory responsibility to build, manage, and operate the SWP. Essentially, DWR is the wholesale provider of water to middlemen agencies. In 1961, DWR entered into individual contracts with various agricultural and urban water suppliers in the State, referred to as State Water Contractors. *See* Water Code §12937. There are 29 agencies or districts that currently are State Water Contractors.

The SWP water contracts entitled the contractors to receive an annual amount of SWP

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[2]Castaic also supplied the court with copies of its decisions on demurrer and motion for legal determination in this case, which need not be judicially noticed.

[3]Real Party Wheeler purports to join in Castaic's request for judicial notice. In its ruling on the demurrers, the court informed Wheeler of the futility of a joinder as merely a cheerleading effort. No further discussion of the purported joinder is necessary.

water in exchange for a proportionate share of financing and maintaining the SWP facilities. Each water contract contains provisions for both allocation of the amount of water available each year and costs among the contractors. Each contract identifies a Table A amount, the annual maximum amount of water which DWR agrees to deliver, if available for delivery, to each SWP contractor on an annual basis. Delivery of the Table A amount is not assured, but rather provides the basis for proportional allocation of available water among contractors. The Table A amount is specified as either agricultural or urban (M&I). Each contract also includes Article 40, which permits water transfers between contractors, and Article 41, which requires DWR approval of any transfer subject to reasonable terms and conditions. AR 2356.

Each contractor annually submits a request to DWR for water delivery in the following year, up to the amount in Table A. In a year when DWR is unable to deliver the total of contractor requests, deliveries to all contractors will be reduced. The current Table A totals are 4.17 million acre-feet per year.[4] In fact, given existing facilities and contractor demands, the SWP can only deliver an average of 2.96 million acre-feet per year.

2. The Monterey Agreement

Historically, the delivery of less than Table A totals was not a significant problem because contractor demand was less than the Table A amounts. However, in the late 1980's and early 1990's, a drought led to SWP deliveries in amounts below that requested by contractors. Articles 18(a) and (b) of the SWP water contracts addressed DWR's temporary and permanent inability to deliver the water allocations listed in Table A of the contracts by requiring agricultural contractors to accept a reduction in water first before any remaining reduction was shared by urban contractors. In 1990, agricultural contractors received only half their requested water and none in 1991. Because contractors pay their proportionate share of fixed costs regardless of how much water is delivered, the agricultural contractors were paying for water they were not receiving and they were displeased. As a result, urban and agricultural water contractors clashed over DWR's delivery obligations and the proper interpretation of Article 18. AR 45-46.

In December 1994, five State Water Contractors and and DWR reached agreement on a broad set of fourteen principles (the "Monterey Agreement"). Among other things, the Monterey Agreement changed the allocation between agricultural and urban contractors of entitlements to SWP water. The Monterey Agreement eliminated Article 18 and specified that all SWP water was to be allocated in proportion to Table A amounts. Paragraph 24 of the Monterey Agreement provides for the permanent transfer of 130,000 acre-feet from certain willing agricultural contractors, including KWCA, to urban contractors, as implemented by individual agreement. AR 2515. It also provides that individual contractors may transfer entitlements among themselves beyond the 130,000 acre feet proposed, with DWR expeditiously executing any necessary documents and approving all such contracts. Other provisions of the Monterey Agreement include a revision of water allocations during shortages, eliminating the "agriculture first" provision, and retirement of 45,000 other acre-feet of entitlement by agricultural contractors.

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[4]An "acre-foot" is the amount of water that would cover one acre one foot deep.

The Monterey Agreement provides that individual SWP contracts could be amended to conform to it. Over the next two years, 27 of the 29 Water Contractors amended their SWP contracts to implement the principles of the Monterey Agreement (collectively, the "Monterey Amendments").

In 1995, a State Water Contractor, Central Coast Water Authority ("Central"), acted as lead agency and certified a program EIR analyzing the environmental impacts of the Monterey Agreement. This program EIR also addressed Paragraph 24 (Article 53 in the Monterey Amendments) water transfers, including the Kern water transfer. In late 1995, PCL filed a lawsuit in Sacramento Superior Court challenging the program EIR, Planning & Conservation League v. Department of Water Resources, ("PCL").

3. The Kern Water Transfer Agreement

Castaic is a State Water Contractor created by the California Legislature. Its mandate is to purchase and deliver sufficient supplies of water to serve the needs of the Santa Clarita Valley. *See* Swanson v. Marin Municipal Water District, (1976) 56 Cal.App.3d 512, 524 (water district has obligation to augment available water to meet increasing demands). Castaic diverts its SWP water from the West Branch of the California Aqueduct. Castaic is one of the Water Contractors entering into the Monterey Amendments (Amendment 17 to Castaic's SWP contract).

Kern County Water Agency ("KCWA") is a special district formed by the Legislature in 1961. Wheeler Ridge is a special district formed in 1959 to provide supplemental water to agricultural lands in Kern County and is located immediately north and east of Castaic. KCWA has contracts with Wheeler Ridge and other member agencies, for KCWA's SWP water.[5]

In March 1999, Castaic entered into an agreement to purchase from Wheeler Ridge, subject to KCWA's consent, 41,000 acre-feet per year of SWP water (the Kern water transfer). The price for the transfer was $47 million in debt instruments purchased by private investors. The purpose of the transfer is to permit Castaic to serve the water demands of existing users, as well as meet a portion of future water demand from anticipated growth within the Castaic service area. AR 16. The Kern water transfer is the largest transfer under Article 53 of the Monterey Amendments, and it counts towards the 130,000 acre-feet limit. In their transfer agreement, both sides warranted that there was no pending or threatened litigation other than PCL that could affect the 41,000 acre feet SWP entitlement. AR 2562-63.[6]

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[5]In 1998, another KCWA member, Belridge Water Storage District, certified an EIR on the environmental effects of transferring 130,000 acre-feet of SWP water to unidentified purchasers. This EIR was not challenged.

[6]Castaic has been planning since 1987 to increase the supply of water to Santa Clarita Valley. At that time, Los Angeles County General Plan forecast substantial population growth in the Santa Clarita Valley. In 1988, Castaic adopted a Capital Program and Water Plan (the "Capital Program") to address the purchases, construction, and improvements necessary to meet the anticipated water demand. The Capital Program called for the purchase of SWP water from districts willing to sell, including Wheeler Ridge, and the storage of water for later use during drought conditions at Semitropic Groundwater Storage District's ("Semitropic") basins. AR

DWR's approval of the Kern water transfer was required under Articles, 15, 41, and 56 of the SWP contracts. On March 31, 1999, DWR approved the transfer by entering into Amendment 18 of Castaic's SWP contract. Amendment 18 adds Article 53(j), which provides that "in accordance with Article 53(a)" of the Monterey Amendments, Castaic's Table A annual entitlements were increased by 41,000 acre-feet. AR 2545-47. DWR and KCWA, which consented to the transfer of its water, also entered into Amendment 28 to KCWA's SWP contract, an amendment which reduced KCWA's entitlement by 41,000 acre-feet. Based on these amendments, DWR has allocated SWP water to Castaic since 1999 based on a total Table A amount of 95,000 acre-feet -- Castaic's original Table A 54,000 acre-feet plus the 41,000 acre-feet from the Kern water transfer.

On March 29, 1999, Castaic, acting as lead agency, certified an EIR for the Kern water transfer. This 1999 EIR tiered off the 1995 Monterey Amendment program EIR, the Belridge EIR, and Castaic's own 1988 EIR for the Capital Program. In April 1999, Castaic's EIR for the Kern water transfer was challenged in Friends of the Santa Clara River v. Cataic Lake Water Agency, BS056954 ("Friends"). On August 16, 2000, the trial court entered judgment, denying the petition in its entirety.

4. The PCL and Friends Decisions

In September 2000, the Third Appellate District in PCL found that DWR was the only entity with the "statewide perspective and expertise" to serve as lead agency for the Monterey Agreement program EIR. Because "the allocation of water to one part of the state has potential implications for distribution throughout the system," the court recognized DWR's principal responsibility to "facilitate the water transfers allowed under the Monterey Agreement." 83 Cal.App.4th at 907. The use of Central as lead agency for the Monterey Agreement program EIR was inappropriate. Id. at 907.

This lead agency error was not harmless because the EIR also was defective. Perhaps as a consequence of Central's lack of statewide expertise, the EIR failed to properly discuss a "no project" alternative, including the environmental impact of implementing the pre-Monterey Agreement Article 18(b)'s permanent water shortage provision. Id. at 918. This was particularly important because local land use planners rely on the "paper water" entitlements in Table A

41845.

Pursuant to the Capital Program, Castaic permanently acquired 12,700 acre-feet of SWP Table A water in 1991 from Devil's Den Water District, a SWP contractor immediately north of Castaic. This transfer was subject to DWR approval, which per Article 41 of the SWP contracts could not be unreasonably withheld. DWR approved the transfer, noting that the transferred water remained labeled for "agricultural purposes" for purposes of delivery shortages.

Also pursuant to the Capital Program, in 2002 Castaic entered into a groundwater storage or "banking" agreement with Semitropic. This action was challenged under CEQA on the basis that the Monterey Agreement required DWR to conduct an environmental review. The challenge was rejected by the appellate court, which held that DWR had no jurisdiction over Castaic's management of water; DWR merely schedules SWP water delivery to Castaic. Cal. Water Network v. Castaic Lake Water Agency, (2006) 206 Cal.App. Unpub. LEXIS 2452, 9.

rather than real, deliverable water. The question was what impacts were reasonably foreseeable from eliminating Article 18(b)'s solution to permanent water shortage? Id. at 914-15. The PCL court held that the EIR, which lacked simulation models and projections relating to land use planning and demand for water, did not adequately address this issue. Id. at 919. It directed the Sacramento Superior Court to retain jurisdiction over the action until a new EIR was prepared and certified.

Based on the Third District's PCL decision, on January 10, 2002, the Second Appellate District reversed the judgment in Friends and directed the trial court to issue a writ of mandate compelling Castaic to set aside certification of its EIR. Friends, (2002) 95 Cal.App.4th 1373. The reversal was based solely on the fact that Castaic's EIR had been tiered upon the now inadequate Monterey Agreement program EIR. The Second District rejected all of the other challenges to Castaic's EIR, finding them to be without merit. The appellate court noted that Castaic may be able to cure the defect by waiting for DWR to comply with the Third District's directive in PCL by preparing a new program EIR. Castaic could issue a subsequent EIR, a supplement to EIR, or addendum to EIR, tiering upon the new Monterey Agreement EIR.

The Friends appellate decision concluded as follows: "The judgment is reversed. The trial court shall issue a writ of mandate vacating the certification of the EIR, shall retain jurisdiction until Respondent certifies an EIR complying with CEQA consistent with the views expressed in this opinion, and shall consider such orders it deems appropriate under [Pub. Resources Code] section 21168.9."

On October 25, 2002, after remand from the court of appeal, the Friends trial court issued a Peremptory Writ of Mandate and Judgment on Remand, retaining jurisdiction until Castaic certifies an EIR that complies with CEQA and is consistent with the views expressed by the Second District. The trial court did not direct Castaic to set aside its approval of the Kern water transfer and denied the petitioner's request to enjoin Castaic from using any of the 41,000 acre feet of additional water allotted to it by the Kern water transfer. The trial court did state that the injunction request could be renewed upon a showing that the water was actually used for an improper purpose (irreversible new development).

5. Monterey Plus

On June 6, 2003, the Sacramento Superior Court approved a settlement between the parties in PCL. That settlement, known as "Monterey Plus," provides that the Monterey Agreement can proceed on an interim basis. In exchange, DWR agreed, among other things,[7] to prepare a new program EIR for implementation of the Monterey Agreement. This new EIR would include (1) information on water deliveries during the drought and recent historical period, (2) an analysis of a no project alternative, including the environmental impact of Article 18's water shortage provisions, (3) analysis of environmental impacts from changes in SWP operations and deliveries resulting from implementation of the Monterey Agreement, (4) analysis

[7]Some of the other provisions include biennial reports on project reliability, land use restrictions on the Kern Water Bank, new guidelines for permanent water transfers, new procedures for public involvement in contract changes, and funding for watershed restoration and new technical studies. AR 45048-49.

of environmental impacts of seven already completed water transfers from KWCA and member units totaling 70,000 acre-feet (Attachment E), which the parties recognized were "final," and of the Kern water transfer, which the parties acknowledged was being challenged in the pending Friends litigation in Los Angeles Superior Court, and (5) analysis of the environmental impacts from implementation of Monterey Plus. AR 48557-59. With respect to the Kern water transfer, the Monterey Plus parties agreed that "jurisdiction with respect to [Friends] should remain in that court and that nothing in this Settlement Agreement is intended to predispose the remedies or other actions that may occur in that pending litigation." The Monterey Plus did not require DWR to re-approve or disapprove any transfer.

6. The Friends II Decision

The Second District upheld the Friends trial court's decision not to grant injunctive relief for the Kern water transfer on December 1, 2003, in unpublished case no. B164027 ("Friends II"). PCL had filed an *amicus* brief supporting the petitioner in Friends II, pointing out that the Monterey Plus settlement now existed and arguing that the Friends decision required the trial court to rely on the status of PCL litigation, including the new Monterey Agreement program EIR DWR was to prepare, in deciding injunctive relief. The Friends II appellate court stated that PCL was wrong; it merely had suggested, not required, that the trial court could determine and rely on the status of the PCL case in deciding injunctive relief.

7. The 2004 EIR

After Friends, Castaic decided to prepare a revised EIR prior to DWR's preparation of a Monterey Amendment EIR. Castaic was driven by a concern that the Friends petitioner and others would use the decertification of its 1999 EIR to cloud its right to the transferred water, as well as Castaic's duty to its customers to complete the environmental documentation and finalize the Kern water transfer.

In June 2004, Castaic prepared and circulated a draft EIR that tiered only on Castaic's 1988 Capital Program EIR. Castaic concluded that it was the lead agency because it has the principal responsiblility for carrying out and implementing the project. Because the transfer is between neighboring SWP contractors, involving the withdrawal of water from a single branch of the Aqueduct, Castaic concluded that the transfer has no significant impacts on SWP operations or the water diverted from the Delta. *See* AR 13-14.

PCL served comments to the draft EIR on August 16, 2004. These comments criticized the use of Castaic as lead agency, arguing that Castaic's review was "premature" and "likely to operate at cross-purposes with DWR's statewide review." AR 1959. PCL contended that DWR, not Castaic, was required to be the lead agency under the PCL decision. Only DWR's expertise could analyze the changes in the amount of supplies available, the location and timing of deliveries, and changes in the SWP's conveyance and storage facilities for all of the proposed transfers, including the Kern water transfer. AR 1962. CWIN also timely expressed concern about Castaic's lack of authority to act as lead agency, and the potential for conflict with DWR's role. AR 578-580.

DWR, acting as a responsible agency under CEQA, commented on the draft EIR. It stated that the "document adequately and thoroughly discusses the proposed project and its

impacts. The [draft]EIR discusses the effects of the project on the environment and State Water Project (SW) and uses baseline conditions consistent with those being considered for inclusion in [DWR's EIR]. The draft also "adequately discusses the reliability of the SWP, pre- and post-Monterey Amendment conditions, future conditions, and SWP operations." DWR acknowledged that Castaic's EIR uses a model, DWRSIM, to assess the potential impact associated with the Kern transfer and that DWR's EIR will use a newer model, CALSIM II. DWR indicated that the use of a different computer model may cause slight changes in results, which may lead DWR to different conclusions than those made by Castaic in its EIR. Despite this fact, DWR concluded that the draft EIR adequately discusses the reliability of SWP, pre- and post- Monterey Amendments conditions, future conditions, and SWP operations. AR 564-65.

Castaic rejected Petitioners' concerns, and relied on DWR's comments to refute objections that its draft EIR will be inconsistent with the yet to be prepared DWR program EIR. AR 961-4. Castaic adopted findings, a mitigation monitoring program and statement of overriding considerations and certified a final EIR (the 2004 EIR).[8] The 2004 EIR describes Castaic's water program for the future needs of Santa Clarita Valley, the procedural history of the project (including the 1999 EIR), and the fact that the Kern water transfer has been implemented and ongoing since 1999. It uses two separate baselines for the project setting and evaluates environmental impacts of the Kern water transfer on the SWP, Castaic, and Wheeler Ridge. In discussing these impacts, the 2004 EIR considers three SWP scenarios: (a) with the Monterey Agreement, (b) without the Monterey Agreement, and (c) without the Monterey Agreement and with Article 18(b) permanent shortages. The EIR uses the DWRSIM model and concludes no significant direct environmental impacts will occur as a result of the project. There would, however, be indirect growth impacts as a result of water provided by the project.

8. The Petitioners Take Over from the Friends Petitioner

On January 24, 2005, CWIN and PCL filed separate petitions for writ of mandate in Ventura County concerning Castaic's compliance with CEQA in the 2004 EIR, and other issues.

On February 1, 2005, the Friends petitioner dismissed the action with prejudice. On February 7, 2005, the trial court in Friends held a hearing on Castaic's *ex parte* application to vacate the dismissal with prejudice and to discharge the writ of mandate. Castaic argued that, by dismissing, the petitioner was attempting to get the clerk, through ministerial act, to divest the court of its continuing jurisdiction over the 2004 EIR prepared in response to the court's peremptory writ of mandate. Instead, the Friends petitioner was passing the baton to CWIN and PCL for a challenge to the 2004 EIR. The trial court declined to set aside the dismissal, stating that whether the Ventura proceedings were a continuation of the Friends lawsuit was an issue of fact for the Ventura (now this) court.

On March 5, 2005, Castaic petitioned the Second Appellate District for a writ of mandate with respect to the trial court's refusal to vacate the dismissal, arguing that the trial court violated Pub. Resources Code section 21168.9 (stating that the trial court shall maintain jurisdiction over the agency's proceedings until the court has determined that the agency has complied with

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[8]On December 30, 2004, Castaic filed its return to the peremptory writ of mandate in Friends.

CEQA) because it had not yet determined that the 2004 EIR complied with CEQA Yet, under CEQA, a trial court that orders preparation of a new EIR must retain jurisdiction for a final determination of the EIR's validity.

On April 14, 2005, the Second Appellate District denied Castaic's petition for "failure to demonstrate that the 'retain jurisdiction' provision of Public Resources Code section 21168.9, subdivision (b), abrogates the entitlement to voluntary dismissal conferred by Code of Civil Procedure section 581, subdivision (b)(1)."[9]

D. CEQA

1. Standard of Review

A party may seek to set aside an agency decision for failure to comply with CEQA by petitioning for either a writ of administrative mandamus (CCP §1094.5) or of traditional mandamus. CCP §1085. A petition for administrative mandamus is appropriate when the party seeks review of a "determination, finding, or decision of a public agency, made as a result of a proceeding in which by law a hearing is required to be given, evidence is required to be taken and discretion in the determination of facts is vested in a public agency, on the grounds of noncompliance with [CEQA]." Pub. Res. Code §21168. This is generally referred to as an "adjudicatory" or "quasi-judicial" decision. Western States Petroleum Assn. v. Superior Court, ("Western States") (1995) 9 Cal.4th 559, 566-67. A petition for traditional mandamus is appropriate in all other actions "to attack, review, set aside, void or annul a determination, finding, or decision of a public agency on the grounds of noncompliance with [CEQA]." Where an agency is exercising a quasi-legislative function, such as by adopting a rule or entering into a contract, it is properly viewed as a petition for traditional mandamus. Id. at 567; Pub. Res. Code §21168.5.

At issue here is a CEQA challenge to a quasi-legislative action recorded by Castaic in a December 23, 2004 Notice of Determination approving the project, certifying the 2004 EIR, and adopting findings, a mitigation monitoring program, and a statement of overriding considerations. This procedural setting, where no administrative hearing was held or required, is governed by traditional mandamus. In determining whether to grant a petition for traditional mandamus in a CEQA case, the court may consider only whether there was a prejudicial abuse of discretion. Public entities abuse their discretion under CEQA if the agency has not proceeded in a manner required by law or if its determination or decision is not supported by substantial evidence. Western States, 9 Cal.4th at 568; Pub. Res. Code §21168.5.[10]

This requires "scrutiny of the alleged defect" depending on whether the claim is predominately "improper procedure or dispute over the facts." Vineyard Area Citizens for

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[9]The Second District later dismissed Castaic's appeal from the Friends dismissal, finding that the voluntary dismissal was not appealable. *See* H.D. Arnaiz, Ltd. v. County of San Joaquin, (2002) 96 Cal.App.4th 1357, 1364-67.

[10]The standard of review for traditional mandamus in a non-CEQA case is governed by an "arbitrary and capricious" standard, not a "prejudicial abuse of discretion" standard. The CEQA standard is the more stringent inquiry. Western States, 9 Cal.4th at 574.

Responsible Growth v. City of Rancho Cordova, ("Vineyard") (2007) 40 Cal.4th 412, 435. Whether Castaic is the proper lead agency is an procedural issue of law for the court. PCL, 83 Cal.App.4th at 905-06. Similarly, as Petitioners argue (Pet. Supp. Resp. Br. at 5), whether Castaic's 2004 EIR failed to provide certain required information and, as a result, presents uncertainties about the finality of the Kern water transfer is failing "to proceed in a manner required by CEQA" and an issue of law. Vineyard, 40 Cal.4th at 435. These issues require "a critical consideration, in a factual context, of legal principles and their underlying values." Harustak v. Wilkins, (2000) 84 Cal.App.4th 208, 212.

On the other hand, whether Castaic abused its discretion in the 2004 EIR's findings must be answered with reference to the evidence in the administrative record. This standard requires deference to the agency's factual and environmental conclusions based on conflicting evidence, but not to issues of law. Laurel Heights Improvement Assn. v. Regents of University of California, ("Laurel Heights") (1988) 47 Cal.3d 376, 393, 409. Argument, speculation, and unsubstantiated opinion or narrative will not suffice.[11] Guidelines, 15384(a), (b). The findings must be supported by "substantial evidence," defined as "enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached. CEQA Guidelines §15384(a). The question whether substantial evidence exists is a question of law. *See* California School Employees Association v. DMV, (1988) 203 Cal.App.3d 634, 644.

2. CEQA

The purpose of CEQA (Pub. Res. Code §21000 *et seq.*) is to maintain a quality environment for the people of California both now and in the future. Pub. Res. Code §21000(a). "[T]he overriding purpose of CEQA is to ensure that agencies regulating activities that may affect the quality of the environment give primary consideration to preventing environmental damage." Save Our Peninsula Committee v. Montery County Board of Supervisors, (2001) 87 Cal.App.4th 99, 117. CEQA must be interpreted "so as to afford the fullest, broadest protection to the environment within reasonable scope of the statutory language." Friends of Mammoth v. Board of Supervisors, (1972) 8 Cal.3d 247, 259. Public agencies must regulate both public and private projects so that "major consideration is given to preventing environmental damage, while providing a decent home and satisfying living environment for every Californian." Pub. Res. Code §21000(g).

The Legislature chose to accomplish its environmental goals through public environmental review processes designed to assist agencies in identifying and disclosing both environmental effects and feasible alternatives and mitigations. Pub. Res. Code §21002.

Under CEQA, a "project" is defined as any activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment (1) undertaken directly by any public agency, (2) supported through contracts, grants, subsidies, loans or other public assistance, or (3) involving the issuance of a lease, permit,

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[11]As an aid to carrying out the statute, the State Resources Agency has issued regulations called "Guidelines for the California Environmental Quality Act ("Guidelines"), contained in Code of Regulations, Title 14, Division 6, Chapter 3, beginning at section 15000.

license, certificate, or other entitlement for use by a public agency. Pub. Res. Code §21065. The word "may" in this context means a reasonable possibility. Citizen Action to Serve All Students v. Thornley, (1990) 222 Cal.App.3d 748, 753. "Environment" means the physical conditions which exist within the area which will be affected by a proposed project, including land, air, water, minerals, flora, fauna, noise, objects of historic or aesthetic significance. Guidelines, §21060.5.

The "project" is the whole of the action, not simply its constituent parts, which has the potential for resulting in either direct or reasonably foreseeable indirect physical change in the environment. Guidelines §15378. An indirect physical change must be considered if that change is a reasonably foreseeable impact which may be caused by the project. On the other hand, a change that is "speculative or unlikely to occur is not reasonably foreseeable." Guidelines §15064(d)(3). The term "project" may include several discretionary approvals by government agencies; it does not mean each separate government approval. Guidelines §15378(c).

The EIR is the "heart" of CEQA, providing agencies with in-depth review of projects with potentially significant environmental effects. Laurel Heights, 6 Cal.4th at 1123. An EIR describes the project and its environmental setting, identifies the potential environmental impacts of the project, and identifies and analyzes mitigation measures and alternatives that may reduce significant environmental impacts. Id. Using the EIR's objective analysis, agencies "shall mitigate or avoid the significant effects on the environment... whenever it is feasible to do so. Pub. Res. Code §21002.1. The EIR serves to "demonstrate to an apprehensive citizenry that the agency has in fact analyzed and considered the ecological implications of its actions." No Oil, Inc. v. City of Los Angeles, (1974) 13 Cal.3d 68, 86. It is not required to be perfect, merely that it be a good faith effort at full disclosure. Kings County Farm Bureau v. City of hanford, (1990) 221 Cal.App.3d 692, 711-12. A reviewing court passes only on its sufficiency as an informational document and not the correctness of its environmental conclusions. Laurel Heights, 47 Cal.3d at 392. An EIR will be upheld if it suffices as an informational document; mandate will issue only if it fails to include relevant information which precludes informed decision-making and informed public participation.

"Choosing the precise time for CEQA compliance involves a balancing of factors. EIRs... should be prepared as early as feasible in the planning process to enable environmental considerations to influence project program and design and yet late enough to provide meaningful information for environmental assessment." Guidelines, §15004(b). As a general rule, public agencies shall not undertake actions concerning a proposed project that would have a significant adverse effect or limit the choice of alternatives or mitigation measures before completion of CEQA compliance. Guidelines, §15004(b)(2). "[I]n order to achieve the salutary objectives of CEQA the determination of the earliest feasible time to [prepare the CEQA document] is to be made initially by the agency itself, which decision must be respected in the absence of manifest abuse." Mount Sutro Defense Committee v. Regents of University of California, (1978) 77 Cal.App.3d 20, 36, 40.

E. Analysis

CWIN and PCL argue that DWR is required to be the lead agency for the Monterey Amendments project EIR, which will examine all water transfers on a program level. The Kern

water transfer is part of the Monterey Amendments project. Therefore, DWR is the correct lead agency to conduct the environmental review of the Kern water transfer. According to Petitioners, while Castaic may not serve as the lead agency for "first-level" environmental review of the water transfer, it may serve as lead agency for a project level EIR for the Kern water transfer.

1. Validity of the Transfer

At the outset, the court must make clear an issue greatly discussed at hearing. Petitioners contend, and Castaic and Wheeler Ridge strongly dispute, that DWR may "invalidate" the Kern water transfer when it performs the program EIR.

Under contract and validation law, the Kern water transfer contract, entered into in 1999, is valid, has been approved by DWR, and Castaic has paid Wheeler Ridge for it. Neither the parties nor DWR can terminate the Kern transfer contract. Nothing in CEQA permits a public agency to void a contract.

In Kenneth Mebane Rranches v. Superior Court, (1992) 10 Cal.App.4th 276, a flood control district sought to condemn land outside its territory in order to mitigate the environmental impact of a project within its boundaries. The appellate court held that CEQA only requires mitigation of environmental impacts where it is feasible to do so. Where mitigation is infeasible, an agency can always approve a project notwithstanding environmental impacts if it issues a statement of overriding interests. But it cannot take actions that are not legal, and hence infeasible. 10 Cal.App. at 291-92.

Thus, in evaluating the environmental effects of the Monterey Agreement, DWR may impose mitigations that are legal. But it cannot invalidate the Kern transfer. The imposition of illegal mitigations would be infeasible. *See also* Pub. Res. Code §21004 (in mitigating significant environmental impact, agency may only employ powers provided by law).[12]

This does not mean that DWR's Monterey Amendments EIR cannot affect the Kern water transfer. DWR's EIR will consider the environmental impacts of the Kern water transfer in conjunction with the Attachment E transfers which the parties in Monterey Plus agreed were completed and final. DWR conceivably could conclude that these transfers have significant environmental impacts. As a consequence, DWR might have to impose feasible mitigation measures, adopt alternatives, or make a finding of infeasibility and adopt a statement of overriding considerations.[13] If mitigations/alternatives are adopted, they could significantly impact Castaic and Wheeler Ridge. As DWR states, "the contract amendments that effectuated the transfers under the Monterey Amendment[s] do not preclude DWR in its choice of

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[12]The parties disagree on whether the Monterey Amendments are valid and final. That is, they disagree on whether the amendments can be challenged in a reverse validation action separate and apart from CEQA. Resolution of this issue is unnecessary to the court's decision.

[13]At hearing, Petitioners' counsel stated that the parties to Monterey Agreement entered into a joint statement of the possible impacts from the Amendments, citing AR 48628-29. The joint statement at those pages of the record does not discuss possible mitigations; it merely summarizes the terms of Monterey Plus.

alternatives in the Monterey Amendment[s] EIR or mitigation measures that may need to be imposed to reduce significant impacts to less than significant." DWR Br. at 20. DWR gives an example of reducing the amount of SWP water to protect water quality standards for fish in the Delta. Id. at 20. These mitigations could undermine the Kern water transfer.[14] But DWR will not be considering whether the Kern water transfer is valid; it simply does not have the authority to void that transfer. *See* Kenneth Mebane Ranches v. Superior Court, (1994) 10 Cal.App.4th 276, 292.

2. Lead Agency Law

The lead agency under CEQA is the agency that carries out a project or has primary authority for approving a project. Pub. Res. Code 121067; Guidelines §15051; *see* PCL, 83 Cal.App.4th at 904 (DWR, not Central (a State Water Contractor), had principal responsibility for carrying out the Monterey Agreement and should have been lead agency for program EIR). The role and responsibility of the lead agency is "fundamental to the CEQA process as a whole." Guidelines §15050. The identification of the proper lead agency plays a "crucial role" in the division of responsibilities among public agencies reviewing a project. PCL, 83 Cal.App.4th at 903. When determining the appropriate lead agency, the courts look to determine which agency has principal responsibility for the core project activity. Friends of Cuyamaca Valley v. Lake Cuyamaca, (1994) 28 Cal.App.4th 419, 427. The lead agency responsibility is placed upon the agency with power to approve or disapprove the project. Lexington Hills v. State of California, (1988) 200 Cal.App.3d 415, 433. Though one agency has substantial responsibility for a project, it cannot act as lead agency if another agency bears final responsibility. *See* Fullerton Joint Union High School District v. Board of Education, (1982) 32 Cal.3d 779, 795, n.15 (State Board of Education, not county, had final responsibility for school district plan). Where the project is local, such as land use decisions, the agency that has general governmental power over a project is almost always the lead agency. Where two or more agencies are involved in a project, the agency that will carry out the project shall be the lead agency. Guidelines §15051(a).

3. The Impact of the PCL Decision

Petitioners contend that the PCL decision left no doubt that DWR is the appropriate lead agency for a program-level environmental review of the water transfers in the Monterey Agreement, contrasting DWR's statewide expertise with CCWA's "provincial experience." The Monterey Amendments restructure water distribution throughout the state, and the "allocation of water to one part of the state has potential implications for distribution throughout the system." Only DWR has principal responsibility for implementation of the Monterey Amendments. Op. Br. at 11-12; *see* PCL, 83 Cal.App.4th at 904, 908. Since the Kern water transfer is part of the Monterey Amendments, DWR must perform any EIR concerning the Kern water transfer.

Petitioners' argument is a *non-sequitur*. Nothing in PCL requires DWR to perform the environmental review for the Kern water transfer. Certainly, the PCL decision requires that DWR prepare the program EIR for the Monterey Amendments, now Monterey Plus. The

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[14]The close cooperation between DWR and Castaic on the 2004 EIR reduces, but does not eliminate, the prospect that DWR will impose alternatives or mitigations.

appellate court's reason for committing this task to DWR is that CEQA requires the lead agency to be the agency with principal responsibility for the project, the project is the environmental review of the Monterey Agreement, and DWR, not CCWA, has principal responsibility for implementing the Monterey Agreement. The decision pointed out that DWR manages the SWP, and has the statewide expertise and perspective to conduct the environmental review of the Monterey Agreement, which statewide project. While CCWA may have had a substantial stake in seeing the Monterey Agreement implemented, it did not have principal responsibility for it. DWR did, and DWR is required to perform the EIR for the Monterey Agreement. 83 Cal.App.4th at 906.

However, the PCL decision does not commit DWR to conduct the EIR for the Kern water transfer, or for any site specific project conducted pursuant to the Monterey Amendments. The PCL decision plainly requires DWR to prepare the program EIR for the Monterey Amendments, and its permanent transfer of 130,000 acre feet of SWP water. But it does not even mention the Kern water transfer, which is a local water transfer of Wheeler Ridge water to a point 60 miles further south in Santa Clarita Valley. The local nature of the project makes Castaic the logical choice to act as lead agency of this transfer, and nothing in PCL requires Castaic to wait for DWR's program EIR. The Kern water transfer is simply a different project from the Monterey Amendments.

Petitioners' concession that at some point Castaic can and should act as the lead agency for the Kern water transfer EIR undermines their argument that PCL committed this task to DWR. The concession shows that Petitioners really are concerned about the timing of this project specific EIR, and not whether it was committed to DWR in the PCL decision. Petitioners contend that Castaic must wait for DWR's Monterey Amendments program EIR and tier off of it for the Kern water transfer EIR. This argument is, as Castaic describes it, that Castaic "jumped the gun" by preparing the 2004 EIR. But the argument implicitly concedes that PCL did not commit the transfer EIR to DWR.

4. The Agency with Principal Responsibility

Even if PCL did not commit environmental review of the Kern water transfer to DWR, Petitioners argue that the Kern water transfer is an integral part of the Monterey Amendments project. This is shown by Monterey Plus, which excludes the Kern water transfer from the list of transfers designated as "final" and recognizes DWR's responsibility to assess its environmental impacts as part of the programmatic review. The Kern water transfer contract itself expressly relies on the Monterey Amendments, using its provisions as authority to accomplish the Kern water transfer. Even Wheeler Ridge's amendment to its SWP contract identifies the outcome of PCL as a factor that could impact the Kern water transfer's effectiveness. All of these facts, Petitioners argue, mean that the transfer is part of the Monterey Amendments environmental review.

Petitioners further argue that the nature of a program EIR supports their position. This purpose "is to document a series of actions so related they can be characterized as one project." Friends, 95 Cal.App.4th at 1377. The Monterey Amendments, including its transfer provisions, qualify as a "series of actions so related that they can be characterized as one project." An integrated review of the entire program may provide occasion for a more exhaustive

consideration of effects and alternatives than would be practical in an EIR on an individual action, ensure consideration of cumulative actions that might be slighted on a case-by-case analysis, avoid duplicative reconsideration of basic policy considerations, and allow the lead agency to consider broad policy alternatives and program-wide mitigation measures at an early time when the agency has greater flexibility to deal with basis problems or cumulative impacts. Id. at 1377. These factors are all borne out by the 2004 EIR, which presents a series of issues (the amount of supplies available to several water agencies, the location and timing of SWP deliveries, and use of SWP conveyance and storage facilities) on which DWR has superior expertise and greater accountability than Castaic. DWR may not delegate to Castaic its responsibility to prepare the environmental review for the Kern water transfer.

Under lead agency law, Castaic may act as lead agency and prepare an EIR for the Kern water transfer. The Kern water transfer is a project separate in time from the Monterey Amendments, now Monterey Plus. The core of the project is a local transfer of water between Castaic and Wheeler Ridge. Castiac alone had the responsibility to determine the water needs of its service area and to obtain the necessary water for those needs. Castaic negotiated and entered into the transfer contract with Wheeler Ridge. Castaic performed the contract by obtaining private investors who paid $47 million to Wheeler Ridge's water, and by taking delivery from DWR. The transfer is valid and cannot be challenged. Thus, Castaic has the general governmental power over the transfer, and is presumptively the lead agency for its own project. Bakman v. Dept. of Transportation, (1979) 99 Cal.App.3d 665, 678-79. Indeed, the environmental review of water transfers is generally performed by a local, not state, agency. County of Amador v. El Dorado County Water Agency, (1999) 76 Cal.App.4th 931 (local agency's analysis of water transfer project); Save Our Carmel River v. Monterey Peninsula Water Management District, (2006) 141 Cal.App.4th 677, 701 (city was lead agency as recipient of water transfer); Friends of the Eel River v. Sonoma County Water Agency, (2003) 108 Cal.Appp.4th 859 (local agency's EIR for plan to increase diversions of water from river); Sierra Club v. West Side Irrigation District, (2005) 128 Cal.App.4th 690 (local agency's environmental review of two projects to transfer water rights).[15]

It is true that DWR has an overall interest in promoting effective water management on a statewide basis. Pursuant to this interest, DWR had the right to approve the Kern water transfer, and it did so. This does not equate to principal responsibility, however. DWR is required by statute to "facilitate" the voluntary transfer of water between local agencies. Water Code §109.

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[15]The Friends court implicitly decided that Castaic may act as lead agency for the Kern water transfer. The Friends court acknowledged that it was required to address all deficiencies in the EIR unless it made a finding of improper lead agency. Pub. Res. Code §21005(c). If Castaic was the improper lead agency for the 1999 EIR, the appellate court was obligated to say so. The Friends court concluded that the 1999 EIR's only deficiency was that it tiered from the defective Monterey Agreement program EIR. Thus, the decision necessarily implied that Castaic was the proper lead agency for the 1999 EIR.

Of course, this case concerns the 2004 EIR, not the 1999 EIR, and the court previously held that Petitioners were not bound by the Friends court's implied determination. But the project is the same, and the implicit appellate determination is entitled to weight.

Per the SWP contracts, DWR's approval of the Kern water transfer could not be unreasonably withheld. Thus, DWR's involvement in the transfer is to facilitate the transfer by approving it and providing the SWP schedule delivery. Moreover, the SWP is intended as a supplement, not the exclusive supply, of water. Water supply decisions must be made by local Water Contractors, who obtain water both from SWP and other sources.[16]

Given that the decision to enter into the Kern water transfer belonged solely to Castaic and Wheeler-Ridge, and that DWR's approval is necessary merely to facilitate the transfer, Casataic had principal responsibility for the transfer.[17]

5. Project Definition

Petitioners contend for the first time in their Supplemental Vineyard Reply and at oral argument that the correct project definition is not the Kern water transfer, but is really the Monterey Amendments, citing the court's earlier ruling on Castaic's motion for legal determination that the key issue is whether the Amendments are a "series of actions (including the Kern water transfer) so related that they should be characterized as a single project." Pet. Supp. Reply at 5.

The correct definition of the project -- whether it is the Monterey Amendments or the Kern water transfer -- is a different issue than whether Castaic can act as lead agency for the project. Although the court did allude to project definition in ruling on the earlier motion, Petitioners never raised this issue in their opening brief or reply. Instead, they raise it for the first time in a reply brief on the application of Vineyard to this case. On appeal, an issue raised without analysis or authority lacks foundation and need not be addressed. City of Arcadia v. State Water Resources Control Board, ("Arcadia") (2006) 135 Cal.App.4th 1392, 1429, 1431. Similarly, an issue raised for the first time in supplemental reply deprives the opposing party of an opportunity to analyzing the issue and defend their position. Petitioners have waived the correct project definition as an issue by not raising it earlier.

Assuming *arguendo* that the issue has not been waived, a project under CEQA includes an activity directly undertaken by a public agency which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment. Pub. Res. Code §21065(a). The "project" must be broadly defined, so as to ensure against avoiding environmental review by "chopping a larger project into little ones" or "piecemealing." Bozung v. Local Agency Formation Commission, (1975) 13 Cal.3d 263, 283-84. The project includes "the whole of an action" that has a potential for resulting in a direct or indirect physical change in the environment. Guidelines §15378. An accurate project description is necessary for an intelligent evaluation of the potential environmental effects of a

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[16]As Wheeler Ridge points out, DWR was not the lead agency for the 1991 Devils Den transfer or any of the Attachment E transfers listed in the Monterey Agreement.

[17]Given that DWR's approval may not be unreasonably withheld, cases holding that a state agency should prepare the EIR where it has final authority to approve a project are simply inapposite. *See* Fullerton v. State Board of Education, (1982) 32 Cal.3d 779, 795, n.15 (State Board of Education had final authority to submit plan to voters for new unified school district).

proposed activity. Mcqueen v. Board of Directors, (1988) 202 cal.App.3d 1136, 1143. The agency must avoid "piecemealing" or splitting a project into two or more segments. Otherwise, the cumulative environmental impacts of each piece may not be fairly analyzed. Burbank-Glendale-Pasadena Airport Authority v Hensler, (1991) 233 Cal.App.3d 577, 592. On the other hand, CEQA was not intended to and cannot reasonably be construed to make a project of every activity of a public agency, regardless of the nature and objective of such activity...." Simi Valley Recreation & Park District v. Local Agency Formation Commission, (1975) 51 Cal.App.3d 648, 663.

In San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus, (1994) 27 Cal.App.4th 713, 731-32, the court held that the project description in an EIR was improperly restricted to a 633 single family residential units, a 40,500 square foot commercial center, and a 14 acre park, failing to include sewer expansion which the EIR acknowledged would be required as part of the development. Although a separate EIR was prepared for the sewer expansion, neither it nor the development project EIR referred to the growth-inducing effects of the two projects considered together. This failure to address cumulative impacts was a separate failure of the development EIR. 27 Cal.App.4h at 733. "[t]he danger of filing separate environmental documents for the same project is that considration of the cumulative impact on the environment of the two halves of the project may not occur. This danger was here realized." Id. at 734 (citation omitted). Because the EIR did not "adequately apprise all interested parties of the true scope of the project for intelligent weighing of the environmental consequences of the project" informed decision-making was precluded, the EIR was inadequate. Id.

The lesson from San Joaquin and other project definition cases is that the project should be defined broadly to ensure a complete analysis of impacts resulting from future expansion or continuation of other phases of the project.

In this case, DWR is the lead agency for the Monterey Amendments program EIR. DWR's description of its project is to improve the management of SWP supplies and operations through the Monterey Amendments. Thus, the Monterey Amendments EIR is broad in scope. The EIR will look at changing the allocation of all SWP water supplies (including deletion of agriculture first shortage provisions), retiring 45,000 acre feet of agricultural water, and establishing more efficient use of SWP facilities. As part of the analysis, it will analyze the potential impacts from permanently transferring 130,000 acre feet of water from agricultural to urban contractors per the Monterey Agreement. This analysis will look at the individual transfers, including the Kern water transfer, as they fit the entire Monterey Amendments. But DWR does not intend to consider each transfer individually; it intends to evaluate the impact of all the Attachment E transfers and the Kern water transfer as a whole. DWR Br. at 17.

Castaic's 2004 EIR project description concerns the impacts of the Kern water transfer alone. Castaic's EIR does look at cumulative impacts of the project with other projects, including the Monterey Amendments, but does not purport to assess the environmental impacts of the Monterey Amendments independent of the Kern water transfer. AR 141-42.

Castaic relies on the independent utility test to argue that the Kern water transfer is a separate project the environmental impact of which may be separately analyzed from the Monterey Amendments. The "independent utility" test has been developed in NEPA cases to determine whether multiple actions are connected so as to require an agency to consider them in

a single environmental review. Wetlands Action Network v. United Sates Army Corps. Engineers, (9th Cir. 2000) 222 F.3d 1105, 1118.[18] Pursuant to the independent utility test, where each of two projects would have taken place with or without the other, each has "independent utility" and the two are not considered so connected that an agency must consider them in a single environmental review. Native Ecosystems Council v. Dombeck, (9th Cir. 2002) 304 F.3d 886, 894. *See also* DelMar Terrace Conservancy, Inc. v. City Council of the City of San Diego, (1992) 10 Cal.App.4th 712 (freeway segment was separate project serving a viable purpose even if long-term, multi-segment plan to expand freeway never occurred, and had independent utility under CEQA).

Castaic argues that it has contemplated the Kern water transfer since 1988, when it included a transfer with Kern in its 1988 Capital Program for the Santa Clarita Valley's future water needs. For economic reasons, Wheeler Ridge, too, sought to transfer its SWP water rights since approximately 1985. Castaic concludes that the Kern water transfer would have occurred with or without the Monterey Amendments. Articles 40 and 41 of the SWP contract permitted transfers between Water Contractors, subject to DWR approval. Article 53, added to the SWP contracts by the Monterey Amendments and concerning the transfer of 130,000 acre-feet, did not "enlarge, restrict, or otherwise impact" Castaic's right to acquire water from Wheeler Ridge under Articles 40 and 41. Instead, it was merely a blanket approval of certain contemplated transfers. Castaic Op. Br. at 21. The Kern water transfer was completed, paid for, and operating since 1999. Nothing about it is tied to the outcome of the Monterey Amendments. Thus, while the transfer is part of a larger scheme (the Monterey Amendments), it is a long-planned site specific project with independent utility from the Monterey Amendments.

The court cannot conclude that the Kern water transfer would have taken place without the Monterey Amendments. True, Castaic has wanted Wheeler Ridge's SWP allocation of water since the late 1980's, and Wheeler Ridge was willing to provide it. Yet, it did not happen until after the Monterey Amendments. The contract between Castaic and Wheeler Ridge states that the transfer was taking place "in accordance with" Article 53 of the Monterey Amendments, and those Amendments change the way SWP water is allocated in California. It does not say that the transfer is being made under Article 41. Petitioners contend, and the court agrees, that only through conjecture can one conclude that Castaic and Wheeler Ridge would have entered into the transfer without the Monterey Amendments, and with Article 18's agriculture first provisions in place.[19]

Though the court cannot conclude that the Kern water transfer would have occurred without the Monterey Amendments, it can conclude that the transfer will remain in effect even if the Monterey Amendments are not approved or otherwise are mitigated under CEQA. The court

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[18]Since CEQA was modeled on the federal NEPA statute, federal decisions on NEPA are persuasive authority on CEQA issues. No Oil, Inc. v. Los Angeles, (1974) 13 Cal.3d 68, 86.

[19]When Petitioners commented on the draft EIR that any pre-Monterey Amendments transfer would be subject to Article 18's agriculture first provisions, Castaic did not say that the Kern transfer would have occurred without the Monterey Amendments. It merely responded that the transfer "could occur" either pre- or post- Monterey Amendments. AR 993.

already has indicated that the Kern water transfer is final. The parties to the transfer stated at hearing that they have no intention of rescinding it even if the Monterey Amendments are mitigated and Article 18's agriculture first provisions are in effect. This position is supported by the fact that the 2004 EIR evaluates the water supply impacts of just such a pre-Monterey Amendment Article 18 scenario. AR 186. As such, it is compelling evidence that the transfer will stand.[20]

Plainly, then, the Kern water transfer is final and will remain in place whatever happens to the Monterey Amendments. As such, the transfer has "independent utility" for purposes of environmental review. It is not so connected to the larger Monterey Amendments that the two must must be considered in a single environmental review. *See* Native Ecosystems Council v. Dombeck, 304 F.3d at 894.

6. EIR Timing

Petitioners' real argument seems to be that, whenever a program EIR is anticipated, the agency preparing an EIR for a specific project must wait for the program EIR.

This is not the law. Nothing in CEQA requires Castaic to wait for DWR's program EIR. Indeed, as a general proposition, the environmental review process should be undertaken early enough in the planning process to impact planning decisions, with the timing committed to the agency's discretion. City of Vernon v. Board of Harbor, (1988) 63 Cal.App.4th 677, 690-91. The Kern water transfer occurred almost eight years ago. It has been paid for and operating for a number of years. Castaic tried to conduct a timely environmental review, but that EIR was set aside in Friends. It is not an abuse of discretion for Castaic to want to complete the environmental review and obtain finality for the transfer without waiting for DWR's program EIR of the Monterey Amendments, now Monterey Plus.

Nor does this decision frustrate the law concerning program EIRs and tiering. The purpose of a program EIR is to document a series of actions so related that they can be characterized as one project. Friends, 95 Cal.App.4th at 1377. If the program EIR is sufficiently comprehensive, the lead agency may dispense with further environmental review for later activities within the program that are adequately covered in the program EIR. Guidelines §15618(c). Thus, the program EIR may be used to focus or simplify later environmental review, or as the basis of a tiered EIR. "Tiering" means the coverage of general matters and environmental effects in an EIR prepared for a policy, plan, program or ordinance, followed by narrower or site-specific EIRs which incorporate by reference the discussion in the prior report. *See* Pub. Resources Code §§ 21068.5, 21093 and Guideline §§ 15152, 15385. Tiering is favored "whenever feasible, as determined by the lead agency." Pub. Resources Code §21093(b). It is required where a prior EIR has been prepared and certified for a program, plan, or ordinance. Pub. Resources Code §21094(a). However, tiering is only required "where a prior environmental report has been prepared and certified for a program." Friends, 95 Cal.App.4th at 1383. It is not required, and in fact is prohibited, where the program EIR has yet to be prepared. Vineyard Area Citizens for Responsible Growth v. City of Rancho Cordova, ("Vineyard") (2007) 40 Cal.4th 412

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[20]Petitioners think so too, for their principal argument is premised on the 2004 EIR's assumption that the transfer is final for all purposes.

EIR cannot tier off of *future* environmental document).

7. Vineyard

In Vineyard, the Supreme Court addressed a county prepared EIR for a large land use development project known as "Sunrise Douglas." The principal issue was the availability of long-term water supply for the project, and the environmental impacts and mitigation for such supply. The Supreme Court analyzed the various water supply cases and distilled several principles. First, the EIR for a land use project must present sufficient facts to evaluate the pros and cons of supplying the amount of water the project will need, and not simply ignore or assume a water supply solution will be found for a development project. Second, an adequate EIR for a large project must show water supply for the entire project. It is not enough to show available water for early stages. While the agency may tier and defer analysis of certain details of later phases of long-term or complex projects, deferring analysis through tiering is appropriate when the impacts or mitigation measures are not determined by the first-tier approval and are specific to later phases. Third, the future water supplies identified and analyzed must bear a likelihood of actually being available. Finally, where there is some uncertainty about availability, CEQA requires some discussion of possible replacement sources or alternatives, and their environmental consequences.

Of particular use herein, the Supreme Court discussed the EIR's reliance on an anticipated local Water Board's master plan update, which would discuss the availability of long-term water supplies to the area and their environmental impact. The Court held that the county's EIR cannot tier from a *future* environmental document. If the environmental analysis from the Water Board's anticipated master plan update was important to understanding the long-term water supply for Sunrise Douglas, it should have been performed in the Sunrise Douglas EIR even though that might result in subsequent duplication by the Water Board's master plan update. Or, the county could have deferred analysis and approval of Sunrise Douglas until the Water Board's master plan update, then tiered the Sunrise Douglas EIR from the programmatic analysis performed by the Water Board.

The Vineyard decision shows that the timing of Castaic's project specific EIR in relation to DWR's program EIR is up to Castaic. It may either wait for DWR's program EIR and tier off of it, or prepare its own EIR for the Kern water transfer first. If it chooses the latter, Castaic may not tier off an environmental document that does not yet exist. Instead, Castaic must analyze all necessary environmental impacts and mitigations. If analysis of some portion of the Monterey Amendments is important to understanding the environmental impacts of the Kern water transfer, then analysis of that issue must be included in Castaic's EIR. But if Castaic's EIR does so, it is irrelevant that the document duplicates some of what DWR would do, or even that it may be inconsistent with DWR's analysis.[21] As DWR contends, CEQA's goal is to ensure sufficient information; it contains no prohibition against too much information. DWR Br. at 21. The timing of Castaic's EIR for the Kern water transfer is up to Castaic and Castaic alone.

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[21]As previously stated, the prospect of inconsistencies between Castaic's EIR and DWR's program EIR is diminished by Castaic's use of DWR modeling, DWR's comments and input into the 2004 EIR, and the general cooperation and coordination between the two agencies.

F. Contents of the 2004 EIR

Apart from the proper lead agency, Petitioners argue that the 2004 EIR is inadequate. Initially, the court believed that Castaic could have real problems on this issue. It is one thing for Castaic to act as lead agency on a water transfer before the program EIR is prepared; Vineyard and other case law say that Castaic may do so. But the EIR must be adequate and complete. Vineyard teaches that if analysis of some portion of the Monterey Amendments is important to understanding the environmental impacts of the Kern water transfer, then that analysis must be included in Castaic's EIR. PCL held that the "no project" alternative was particularly important for the Monterey Amendments, and the public was entitled to know what would happen if the Amendments were not approved and Article 18 was implemented in the event of water shortage. Commentators particularly wanted to know whether imposition of Article 18 might eliminate the "paper water" entitlements in the water contracts, reduce land planning decisions based on that paper water, and ultimately reduce growth and construction of additional SWP facilities. PCL, 83 Cal.App.4th at 892-3.

The court wondered whether Castaic would have the expertise to perform any analysis of the Monterey Amendments or the "no project" alternative that would be required in the 2004 EIR. However, the parties' briefs, and oral argument at hearing, have demonstrated that, with one exception, the 2004 EIR's contents are sufficiently presented. Indeed, Petitioners barely criticize the 2004 EIR's adequacy, except as it impacts the lead agency issue.

1. "Deception"

Petitioners' principal argument about content is that the 2004 EIR is deceptive in failing to make clear that the Kern water transfer is not "final." They contend that the 2004 EIR's project definition treats the Kern water transfer as an immutable *fait accompli* which fails to disclose that the "final status" of the transfer depends on the DWR's forthcoming review. According to Petitioners, the EIR improperly relies on the interim availability of the water to predict that DWR will "leave it in place," a point which the court in California Oak Foundation v. City of Santa Clarita, ("California Oak") (2005) 133 Cal.App.4th 1219, 1238, n.16 had no trouble dispatching, and also improperly states that it would be unnecessary and speculative to consider what the DWR might do to change the transfer (*See* AR 994). Pet. Op. Br. at 19-20. This false assumption that the transfer is immutable may result in land use decision-makers approving projects based on water availability "worth little more than a wish and a prayer." Id. at 20-21.

The court has determined that the transfer is final as a matter of law. Therefore, the EIR is not wrong in saying so. What Petitioners really contend is that the Kern water transfer, though final, can be affected by the DWR's program EIR through mitigations and imposition of alternatives. Yet, the EIR proceeds as if the transfer cannot be altered. As counsel described the issue at hearing, the 2004 EIR "talks about risk, but never directly informed the public about the fact that the transfer may be unwound through the Monterey Amendment EIR process." Thus, the EIR refers to the transfer as of an "*existing* 41,000 " acre feet of SWP Table A water (AR 15, 35) and states that "no permits or *other approvals* would be required other than" certification of the

EIR. AR 16.[22]

The EIR is the method for disclosure of environmental issues. Rural landowners Assn. V City Council, 43 Cal.App.3d 1013, 1020. CEQA's purpose is to compel agencies to make decisions with environmental consequences in mind, but CEQA does not and cannot guarantee that these decisions will always favor environmental concerns. Laurel Heights, 47 Cal.3d at 393. The EIR should provide sufficient analysis to allow decision-makers to make intelligent judgments about environmental consequences. Guidelines §15151. The evaluation of environmental effects need not be exhaustive, but the EIR's sufficiency is reviewed in the light of what is reasonably foreseeable. Id. Perfection is not required, but adequacy, completeness, and a good faith effort at full disclosure is. Id.

In California Oak, the court addressed the proposed development of a 584 acre industrial park project in the Santa Clarita. The City's EIR relied on the Kern water transfer for water supply, and the appellate court held that it did not adequately address the uncertainty in that water delivery. 133 Cal.App.4th at 1236. The City's comments "did little more than dismiss project opponents' concerns about water supply" and the EIR failed to discuss the adequacy and availability of water supply absent the Kern water transfer. Appendix K to the EIR did acknowledge uncertainty in the Kern water transfer, but this was insufficient in part because inforamtion "scattered here and there in EIR appendices" or a report "buried in an appendix" is not a substitute for good faith reasoned analysis. Id. at 1239 (citation omitted). Moreover, Appendix K contained no facts and analysis about the likelihood of deficit or alternative sources of supply, and was misleading about the fact that Castaic had an SWP "entitlement" without explaining that the entitlement consisted in part of "paper water." Id. at 1239-40. Hence the EIR failed as an informational document on water supply issues.

Castaic contends, and the other Respondents agree, that the 2004 EIR fully addresses the uncertainty of what DWR will do. At hearing, they contended that Petitioners really are arguing that the 2004 EIR is misleading because it does not anticipate Petitioners' argument.[23]

The EIR explains that planning for water supply to meet demands requires consideration of reliability of SWP supplies, because historical and statistical analysis show that the full Table A amount will not be available in some years. AR 41. The EIR explains that Castaic's Table A amount is the maximum SWP amount, and the amount of SWP water actually available to it varies from year to year. Id. The EIR acknowledges that DWR's allocations are based on that year's hydrological conditions, the amount of water stored in the SWP system, and contractor requests for water. AR 16. The EIR discusses the Monterey Agreement (AR 46-47), PCL and Monterey Plus. AR 17-18, 47. The EIR cautions land use planners who might rely on the EIR to predict future water supplies, that while Castaic will implement all feasible measures to obtain water "past water deliveries are not a guarantee of future delivery rates." AR 13.

The EIR considers the environmental impact of the project based on water allocation

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[22]At trial, Petitioners' counsel made plain that this issue of deception is distinct from the reliability of water delivery by DWR.

[23]Respondents' contention sounds like an argument that Petitioners failed to exhaust their administrative remedies. However, no failure to exhaust claim was made in their briefs.

scenarios of pre-Monterey Amendments without Article 18 cutbacks, pre-Monterey Amendments with Article 18 cutbacks, and post-Monterey Amendments. AR 56. The EIR argues that the project could have been authorized under Article 41, but instead was implemented under Article 53 of the Monterey Agreement. It adds that DWR is preparing a new EIR for the Monterey Amendment.

Since the Monterey Amendments change the way in which SWP water is allocated among contractors, the 2004 EIR provides three separate analyses of the project's impacts to water supply. AR 186-89. The EIR goes to great lengths to discuss the uncertainties in the Article 18 allocations. AR 187-89. For each scenario, the EIR estimates reliability based on wet, dry, and extended dry year conditions. AR 183-91. The EIR addresses direct impacts to water supply and water quality under the three water allocation scenarios. AR 202-05. It discusses indirect impacts from the growth-inducing effect of the project, and mitigations of these impacts through implementation of existing agency policies. AR 207-224. It discusses the cumulative impact of the project and other projects inside and outside the project area. AR 278-89. Finally, it addresses alternatives to the project, including a no project alternative. AR 293-300.

The EIR clearly demonstrates the variability of SWP deliveries, and covers what could happen as a result of the Monterey Amendments EIR. But Petitioners are correct that the EIR has a hole in it. The EIR does not directly explain that the project may be impacted by the outcome of the Monterey Amendments EIR. Instead, the 2004 EIR assumes there are three possible water delivery scenarios without any discussion of why or how they would occur: "Since the Monterey Amendments change the way in which SWP water is allocated among contractors, the 2004 EIR provides three separate analyses of the project's impacts to water supply." The reader is left to interpret how these allocations could come about, and must conclude on his or her own that they are three possible outcomes of challenges to the Monterey Amendments. Nor does the EIR explain how such challenges could cause these allocations to occur.

An EIR is an informational document which is supposed to provide the reader with the "analytic route the...agency traveled from evidence to action."Citizens of Goleta Valley v. Board of Supervisors, ("Goleta") (1990) 52 Cal.3d 553, 568. This means that the EIR must contain facts and analysis, not just the agency's bare conclusions or opinions. Castaic is not required to predict the outcome of litigation, and may not be able to discuss the likelihood of each of the three allocations. However, it should have at least explained why the three scenarios are relevant and how they would occur.[24] The failure to do so leaves the reader wondering why they are pertinent. Consequently, the 2004 EIR fails to provide the analytic route by which the three alternatives are relevant.

Non-compliance with the disclosure requirements of CEQA may constitute a prejudicial abuse of discretion regardless of whether the agency would have taken the same action had it complied with CEQA. Pub. Res. Code §21005(a). Still, CEQA is subject to the established principle that there is no presumption of prejudicial error. Pub. Res. Code §21005(b). Only if the manner in which the agency failed to follow the law is prejudicial must the decision be set aside. Sierra Club v. State Board of Forestry, (1994) 7 Cal.4th 1215, 1236.

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[24]For example, the court has no idea how a pre-Monterey Amendments without Article 18 cutbacks would occur.

The issue is whether Castaic's failure to supply the analytical route for its consideration of the three allocations is prejudicial. Prejudice depends on whether the failure to include this information makes "any meaningful assessment" of the project's environmental effects impossible, in which case prejudice is presumed. Sierra Club v. State Board of Forestry, (1994) 7 Cal.4th 1215, 1236 (agency approved timber harvesting plans without requiring necessary environmental information in them).[25] Even under this standard, not every CEQA failure is prejudicial. An EIR will be upheld if the error *de minimus* or clerical in nature (Save San Francisco Bay Association v. San Francisco Bay Conservation and Development Commission (1992) 10 Cal.App.4th 908, 935), the EIR analysis is comprehensive, if not perfect, despite the error (Schaeffer Land Trust v. San Jose City Council, (1989) 215 Cal.App.3d 612, 627-28), and information which should have been included to make the EIR accurate nonetheless has no material effect on informed decision-making or informed public participation (Al Larson Boat Shop, Inc. v. Board of Harbor Commissioners, (1993) 18 Cal.App.4th 729, 747-50).

The Vineyard court reiterated that the reviewing court must focus on the nature of the defect, depending on whether the claim is predominantly one of improper procedure or a dispute over facts. Where the agency has employed the correct procedures, greater deference is given to the agency's factual conclusions, which are reviewed for substantial evidence. 40 Cal.4th at 435.

The 2004 EIR's non-compliance concerns its analytic route – why and how the three allocations are pertinent. This is not a fact issue to be supported by substantial evidence. Instead, it is a failure affecting the public's ability to make a "meaningful assessment" of the project's environmental effects. As such, it is prejudicial. *See also* Rural Land Owners Assn. v. Lodi City Council, (1983) 143 Cal.App.3d 1013, 1023 (whenever failure to comply with CEQA results in a subversion of its purposes by omitting information from the environmental review process, the error is prejudicial).[26]

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[25]One appellate court, Resource Defense Fund v. Local Agency Formation Commission, (1987) 191 Cal.App.3d 886, 897-98 has stated that "[f]ailure to comply with CEQA is necessarily prejudicial." This does not appear to be the consensus approach. *See* Dusek v. Anaheim Redevelopment Agency, (1985) 173 Cal.App.3d 1029, 1040-42 ("a minor CEQA sin or two" constituting technical defects where the public had not been misled or defrauded is not enough for prejudice).

[26]Petitioners also argue that the 2004 EIR finesses the non-final nature of the project by jumping the gun and analyzing pre-Monterey Amendments. According to Petitioners, Castaic performed a "mini-programmatic review" at AR 155-06 and App. D (AR 468-550). The charts at AR 184 and 506 show this. According to Petitioners, this is not just factual overlap; this is usurpation of DWR's responsibilities.

DWR correctly points out that Petitioners are complaining about too much information, something that CEQA does not proscribe. Petitioners have no complaint about the content of the mini-program review. To the extent that Castaic performed a task that DWR is obligated to perform, DWR may either use Castaic's analysis or perform a new one. The cooperation of DWR and Castaiac suggests that the overlapping environmental analysis will be consistent. Even if inconsistent, DWR's analysis will control for the Monterey Amendments. There is no

2. Modeling

Petitioners contend that Castaic used an obsolete DWR model, DWRSIM, for making predictions about the amount of SWP water that could be available as a result of the Kern water transfer. DWR has used CALSIM II for modeling SWP deliveries since 2000. While the EIR uses CALSIM II to look at the environmental setting, it only uses DWRSIM to look at environmental impacts. According to Petitioners, Castaic's rationale for doing so -- that DWRSIM should be used for the 1998 environmental setting -- makes no sense. Modeling is for future results, not historical analysis.

Petitioners argue that Castaic's use of an old model prejudicially overstates the reliability of SWP water delivery. App.D, Table 2-2 compares the projected 2020 deliveries based on the two different models. AR 493. The graph shows a discrepancy between the two models, particularly in the 50-70% supply range, and most glaringly in the range of drought conditions. Although the EIR does not quantify these differences, Castaic's responses to public comments presents a table that does. The table shows that the two models can differ by as much as 5000 acre-feet. Pet. Op. Br. at 23. According to Petitioners, this is not the "slight discrepancy" DWR states it is.

When a challenge is brought to studies on which an EIR is based, "the issue is not whether the studies are irrefutable or whether they could have been better. The relevant issue is only whether the studies are sufficient credible to be considered as part of the total evidence that supports the" agency's decision. Laurel Heights, 47 Cal.3d at 409 (lead agency entitled to choose and rely on expert opinion even though others may disagree). Expert testimony constitutes substantial evidence and an agency is entitled to rely on it. Uhler v. City of Encinitas, (1991) 227 Cal.App.3d 795, 805. Even where experts disagree, the agency is entitled to choose one expert's opinion over another. Laurel Heights, 47 Cal.3d at 409. The party challenging the EIR bears the burden of demonstrating that the studies on which the EIR is based "are clearly inadequate or unsupported." State Water Resources Control Board Cases, (2006) 136 Cal.App.4th 674, 795.

CEQA requires Castaic to reasonably inform the reader about the amount of water available. The EIR states that all environmental impacts from the project are driven by the amount of water delivered and the timing of delivery. AR 55. Castaic analyzed the amount of SWP water available for delivery through hydrologic modeling with computer simulations that predict the amount of water available under various hydrologic conditions. To do so, the EIR, like all EIR's had to have an environmental setting for the project. This environmental setting describes the conditions of the project as they exist at the time the Notice of Preparation is published or, if there is none, at the time the environmental analysis is commenced. This setting will normally constitute the baseline physical conditions by which an agency determines whether an impact is significant. Guidelines §15125(a).

The 2004 EIR states that its baseline 1998 environmental setting used DWRSIM, which is a model simulating the operations of the SWP, "because this is the modeling tool that was available during 1998." AR 55. DWR had used DWRSIM in 2000 to conduct a reliability study for another project. The 2004 EIR does use CALSIM II for the current environmental setting of

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usurpation of responsibility.

the project. CALSIM II was available because DWR performed a SWP Delivery Reliability Report in 2003 using CALSIM II as its model. AR 56. Although the modeling tools are different, the criteria used to input into the computer simulation has not changed significantly. Id.

The question raised by Petitioners is why use an older computer simulation model (DWRSIM) for the 1998 baseline when a newer model (CALSIM II) was available? Appendix D of the 2004 EIR, entitled "Technical Data for Hydrologic Analysis," explains that Castaic had to do so because it did not perform any model analysis of its own. Instead, Castaic relied upon DWR's expertise, and its existing model studies. *See* AR 491. DWR used DWRSIM in its 2000 study and CALSIM II in its 2003 study; Castaic relied upon those same studies and same models.

Castaic's reliance on DWR's existing studies and its expertise is an explanation, but the issue becomes whether it is an adequate one.

The answer is in Appendix D, which explains that DWRSIM has a database of monthly runoff based on historic hydrologic data for a 73 year period from 1922-74. DWRSIM takes this data and, depending on the input variables of operating constraints and water contractor demand, estimates the amount of water SWP can deliver each month over that 75 year period. Assuming that hydrologic conditions repeat, the operator can predict the amount of water available under that particular hydrologic condition and with a particular demand and operating condition. AR 491.

Appendix D then shows that DWRSIM and CALSIM II predict similar outcomes, and that the differences in their predictions can be explained. In Figures 2-1 and 2-2 of Appendix D, Castaic compares the two models' prediction of SWP water deliveries at existing demand and at predicted 2020 demand levels. AR 493. The "existing demand" for the DWRSIM model is 1998 demand. The "existing demand" for the CALSIM II model is 2001 estimated demand. The 2001 demand is higher than the 2000 demand. Consistent with reality, the model will only show delivery up to the amount of demand; SWP will not deliver more water than is asked for even if it is available. This difference in demand explains why CALSIM II shows more delivery in wet years than DWRSIM; the lower demand in 1998 limits the amount of delivery.

The difference in demand also explains in part why CALSIM II predicts a higher delivery in extremely dry conditions; 1998's lower demand means more water is left in storage from the preceding year and is available for delivery in a dry year. Appendix D says that the proof is in the pudding: comparison of DWRSIM and CALSIM II in Figure 2-2, for the year 2020 with the same level of demand for each model, shows very close prediction of SWP delivery for both models. AR 492-93.

Castaic concludes that the two models predict "generally comparable" results and their differences are minimal. AR 491, 1003. Castaic argues that, if anything, the slightly higher supplies predicted by the DWRSIM model provide a worst case scenario for purposes of growth inducing impacts; the more water the more developers will grow the Santa Clarita Valley. AR 1003-04, 1009.

Contrary to Petitioners' argument, the use of DWRSIM and not CALSIM II in the 1998 baseline study does not affect the conclusion that the study constitutes substantial evidence. Petitioners do not present expert opinion that the use of DWRSIM results in any error. They merely rely on the differences in Figures 2-1 and 2-2 of Appendix D, and Appendix D explains

the reason for the differences. As Castaic points out, Petitioners cannot point to any environmental significance to the use of DWRSIM and not CALSIM II. Therefore, Petitioners have not met their burden of demonstrating that use of DWRSIM for the 1998 baseline in the 2004 EIR was "clearly inadequate or unsupported."[27]

3. Cumulative Impacts

Petitioners contend that the 2004 EIR attempts to assess the project's impacts on the SWP without discussion why Castaic is competent to do so. As an example, the EIR rejects any significant project impact on the Delta, even though it acknowledges that differences in timing in the use of water for urban (Castaic) rather than agricultural (Wheeler Ridge) purposes would change the timing of deliveries. AR 192. Petitioners argue that the Delta is "in crisis" and there is great potential for conflict between Castaic's and DWR's respective environmental analysis. Pet. Op. Br. at 23-4.

An EIR must contain a cumulative impacts analysis of the project's environmental impact when considered in conjunction with other projects (Guidelines §15130) in order to ensure that "the entire relevant environmental picture" has been adequately considered. Laupheimer v. State of California, (1988) 200 Cal.App.3d 440, 462. A cumulative impact consists of an impact which is created as a result of the combination of the project evaluated in the EIR together with other projects causing related impacts. Guidelines §15130(a)(1). The EIR should not discuss impacts which do not result at least in part from the project being evaluated. Id. The analysis should reflect the severity and likelihood of occurrence of the impact. Guidelines §15130(b). In every case, there should be at least a preliminary search for potential cumulative environmental effects and a preliminary assessment of their significance. Laupheimer, 200 Cal.App.3d at 462-63. The detail required in a cumulative impacts discussion need not be as great as provided for the environmental impacts attributable to the project alone. Guidelines §15130(b). Generally, the EIR should list the projects producing cumulative impacts or provide a summary of projections contained in a prior certified or adopted environmental document which describe the regional conditions contributing to the cumulative impact. Guidelines §15130(b)(1). The 2004 EIR uses the list approach to discuss cumulative impacts of the project's environmental impact when considered in conjunction with other projects. AR 241-289.

Castaic argues that everything that happens with respect to the Kern water transfer happens south of the Delta, and the EIR thoroughly discusses that, including the impact of the timing of deliveries. AR 193-06. Thus, the EIR's conclusion that the project will have no direct

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[27]Castaic does not have statewide expertise on SWP reliability, but its consultants and DWR do. In commenting on Castaic's draft EIR, DWR stated that the differences between CALSIM II and DWRSIM "may cause slight changes in results, which may lead DWR to different conclusions....[in DWR's Monterey Amendments EIR]" AR 564. However, DWR also found that the draft EIR adequately and thoroughly discussed the project and its impacts, including the effects of the project on the environment and the SWP, using appropriate baseline conditions, and had a good discussion of the relationship between the Kern water transfer and Monterey Plus. DWR concluded that the draft EIR a "adequately discusses the reliability of the SWP, pre- and post- Monterey Amendment conditions, and SWP operations." AR 564-65.

significant impact on the SWP or related facilities is fully supported. Castaic contends that Petitioners really are attacking its ability to act as lead agent for a local project if the project has the potential for statewide impact. According to Castaic, this argument goes to the lead agency issue, and is incorrect as a matter of law. Castaic is qualified and required by CEQA to assess impacts that occur outside of its borders in evaluating the Kern water transfer. Citizens of Goleta Valley v. Board of Supervisors, (1990) 52 Cal.3d 553, 573.

The court does not know whether Petitioners really are attacking Castaic's expertise or the adequacy of its assessment of SWP impacts from the Kern transfer. The reason is that Petitioners' arguments are conclusionary and unsupported by analysis, authority, or many facts. Petitioners' obligation was to point out what is wrong with the analysis, or what has been omitted that was required. An issue raised without analysis or authority lacks foundation and need not be addressed. Arcadia, 135 Cal.App.4th at 1429, 1431. The court has no obligation to search the EIR's cumulative analysis section to look for defects. Their general objection requires only a general response that Castaic's cumulative impacts analysis is adequate.

4. The "No Project" Alternative

Petitioners argue that the 2004 EIR fails to address the "no project" alternative, an issue particularly important because it was the principal defect in the PCL Monterey Agreement EIR. As the PCL court stated, a "no project" alternative must discuss "existing conditions" and "what would reasonably be expected to occur in the foreseeable future if the project were not approved, based on current plans and consistent with available infrastructure and community services." 83 Cal.App.4th at 912. The Monterey Agreement EIR did not discuss the projections related to land planning, demand for water, and other impacts of reducing entitlements pursuant to Article 18(b). Id. at 919. Petitioners contend that the 2004 EIR does discuss the water supply reliability impacts of invoking Article 18(b), but not the statewide impacts the PCL court found so crucial.

The short answer to Petitioners contention is that 2004 EIR addresses a different project than the Monterey Amendments. The "no project" alternative for any EIR requires a comparison of the impacts of approving the project with the effect of not doing so. Guidelines §15126.6.(e)(1); Mira Mar Mobile Community v. City of Oceanside, (2004) 119 Cal.App.4th 477, 488-89. The only "no project alternative" that Castaic is obligated to consider is the alternative of "no Kern water transfer." Castaic has addressed this alternative by discussing groundwater sources of water and a possible moratorium. AR 291-4. Petitioners do not quibble with this analysis. But Castaic had no obligation to consider "no Monterey Amendments" as a no project alternative.[28] Indeed, it would make no sense to evaluate "no Monterey Amendments" as an alternative to the Kern water transfer.[29]

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[28]Of course, the 2004 EIR is obligated to consider invocation of Article 18(b) as a reasonably foreseeable environmental impact, and the adequacy of it doing so has been discussed.

[29]For a similar reason, Castaic need not analyze alternative uses of the SWP water in a "no project" alternative. CEQA does not require consideration of alternatives that do not meet the project objective; *i.e.*, delivery of water to Castaic's customers. *See* Guidelines §15126.6(c).

5. Post-Hoc Rationalization

Petitioners also suggest that the 2004 EIR is a post-hoc rationalization for "a decision already made." Pet. Op. Br. at 18. Pre-judging environmental decisions in order to accomplish a project is prohibited under CEQA. An agency may not commit to a project before CEQA review is completed because a fundamental purpose of an EIR is to provide decision-makers with information they can use in deciding whether to approve a project. Therefore, post-approval environmental review has been condemned. Laurel Heights, 47 Cal.3d at 394. *See* Residents Ad Hoc Stadium Com. v. Board of Trustees, (1979) 89 Cal.App.4th 274, 285. Of course, an agency contemplating a project may be presumed to favor the project, and CEQA assumes this to be inevitable. Therefore, it builds in procedural protections to insure that the decision-maker does not fail to note the facts and arguments by opponents to the EIR. Id. at 285.

Castaic had completed the transfer and performed under it for several years prior to preparing the 2004 EIR. Plainly, it desires to keep the transfer and not change it. When the 1999 was found deficient, Castaic was required under CEQA to perform a "fresh look" at the transfer's environmental impacts. With the exception of the analytical hole discussed above, it has done so. *See* City of Vernon v. Board of Harbor, (1998) 63 Cal.App.4th 677, 1523 (adequacy of EIR overcomes contention that it was a post-hoc rationalization).

G. Conclusion

Castaic may act as the lead agency for the Kern water transfer. The 2004 EIR was properly prepared except for one defect – it fails to show the analytic route as to how and why the three allocations of pre-Monterey Amendments, pre-Monterey Amendments without Article 18, and post-Monterey Amendments are relevant and would occur. The court offers no opinion on whether this failure must be rectified by addendum (Guidelines §15164), a subsequent EIR, a supplement to EIR, or a new EIR. That determination is Castaic's to make in the first instance.

The Petition for Writ of Mandate is granted in part. A writ shall issue commanding Castaic to set aside its approval of the 2004 EIR and comply with CEQA, either through the preparation of a new EIR or other environmental documentation, such as an addendum, addressing the analytic route of the three water allocations. Castaic is not directed to set aside the Kern water transfer. Judgment shall be entered in favor of Petitioners solely on this issue.

This shall serve as the court's proposed statement of decision in compliance with CRC 232(c). If there are no written objections filed, the statement shall be final. As Respondents have prevailed on all but one issue, Castaic's council is ordered to prepare a writ of mandate and judgment consistent with this decision, and serve it on all other counsel for approval as to form. After 10 days, Castaic may file the proposed writ and judgment with the court, along with a declaration stating the nature and extent of any objections received. An OSC re: judgment shall be set for April 23, 2007.

Dated: April 2, 2007

/s/ JAMES C. CHALFANT
Superior Court Judge

JAMES C. CHALFANT

Filed 4/20/09 California Water Impact Networkv. Castaic Lake Water Agency CA2/5

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California Rules of Court, rule 8.1115(a), prohibits courts and parties from citing or relying on opinions not certified for publication or ordered published, except as specified by rule 8.1115(b). This opinion has not been certified for publication or ordered published for purposes of rule 8.1115.

IN THE COURT OF APPEAL OF THE STATE OF CALIFORNIA

SECOND APPELLATE DISTRICT

DIVISION FIVE

CALIFORNIA WATER IMPACT NETWORK, INC. et al., Plaintiffs and Appellants, v. CASTAIC LAKE WATER AGENCY, Defendant and Respondent.	B205622 (Los Angeles County Super. Ct. No. BS106546)

APPEAL from an order of the Superior Court of Los Angeles County, Dzintra I. Janavs, Judge. Affirmed.

Law Offices of Babak Naficy and Babak Naficy for Plaintiffs and Appellants.

Hortvitz & Levy, Barry R. Levy and Felix Shafir; McCormick, Kidman & Behrens, Russell G. Behrens and David Boyer for Defendant and Respondent.

I. INTRODUCTION

Plaintiffs, California Water Impact Network and the Friends of the Santa Clara River, appeal from a judgment denying their amended mandate petition which sought to set aside the certification of an environmental impact report and approval for a 2006 Water Acquisition Project ("the project") by defendant, Castaic Lake Water Agency. The 2006 project consists of a plan by defendant to purchase a minimum of 11,000 acre feet per year of water from the Buena Vista Water Storage District ("Buena Vista district") and the Rosedale-Rio Bravo Water Storage District ("Rosedale-Rio Bravo district"). The two districts operate the Buena Vista Water Storage District/Rosedale-Rio Bravo Water Storage District Water Banking and Recovery Program ("Buena Vista/Rosedale-Rio Bravo water banking program"). The Buena Vista/Rosedale-Rio Bravo water banking program, which was subject to full environmental review in 2002, sells water to third parties such as defendant. Defendant's 2006 project also allows for the additional purchase of 9,000 acre feet per year of water that may be available from time to time depending upon hydrologic and operational conditions affecting the Buena Vista/Rosedale-Rio Bravo water banking program.

Plaintiffs argue defendant's 2006 environmental impact report does not comply with the environmental review requirements of the California Environmental Quality Act. (Pub. Resources Code,[1] § 21000 et seq.) Plaintiffs argue the 2006 environmental impact report: does not properly describe the project; does not adequately analyze the growth inducing impacts of the 2006 project; was not prepared by the proper lead agency; and calls for the acquisition of water supplies for developments that are inconsistent with and unaccounted for in the Los Angeles County General Plan. We disagree the asserted grounds provide a basis for setting aside defendant's certification of the 2006

[1] All further statutory references are to the Public Resources Code unless otherwise indicated.

environmental impact report and affirm the judgment denying the amended mandate petition.

II. FACTUAL AND PROCEDURAL MATTERS

A. The 2002 Environmental Impact Report And Buena Vista/Rosedale-Rio Bravo Water Banking Program

The Buena Vista and Rosedale-Rio Bravo districts are adjacent water districts that jointly serve approximately 92,000 acres of primarily agricultural land in southern San Joaquin Valley, west of the City of Bakersfield. The Buena Vista district, which was organized in 1924, has a gross area of approximately 49,000 acres. The Rosedale-Rio Bravo district, which was formed in 1959, has a gross area of approximately 44,000 acres of land developed primarily for irrigated agriculture and urban users. Both water districts are engaged in groundwater recharge, banking, and recovery programs. Both are member units of the Kern County Water Agency ("Kern County agency") which is a water wholesaler. The Kern County agency was created in 1961 by the Legislature to secure and supply adequate water to its local member units in Kern County. Both the districts have rights to Kern River waters. Both the Buena Vista and Rosedale-Rio Bravo districts also have rights to a water supply from the State Water Project through the Kern County agency.

Water Code section 43001 allows a water district to "sell, distribute, or otherwise dispose" of water and water rights.[2] In September 2002, the Buena Vista and Rosedale-Rio Bravo districts certified an environmental impact report which evaluated the impacts of operating their water banking and recovery program including the sale of water to third-party users such as defendant. The 2002 environmental impact report expressly

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[2] Water Code section 43001 states in its entirety, "The board may sell, distribute, or otherwise dispose of water and water rights not necessary for the uses and purposes of the district."

states that third party customers such as defendant will be required to conduct appropriate environmental review as a condition of any sales. The Buena Vista/Rosedale-Rio Bravo water banking and recovery program environmental impact report was certified on October 11, 2002.

The 2002 Buena Vista/Rosedale-Rio Bravo water banking environmental impact report states that approximately 25 percent of groundwater banking would be accomplished using existing accounts in the Buena Vista district. An additional 75 percent of water banking will be accomplished by using accounts to be developed primarily through recharge of Buena Vista Kern River high flow water within the Rosedale-Rio Bravo district. Defendant's 2006 environmental impact report defines "groundwater recharge" as follows, "Refers to the addition to the water within the earth that occurs naturally from infiltration of rainfall and from water flowing over the earth materials that allow water to infiltrate below the land surface." According to the 2002 Buena Vista/Rosedale-Rio Bravo water banking program environmental impact report, recovery from the groundwater banking accounts will be accomplished by: using direct and in-lieu methods; via groundwater pumping; and exchanges of State Water Project supplies. The Buena Vista and Rosedale-Rio Bravo districts were to jointly recover the groundwater. The groundwater was to be recovered by means of accounts to be developed through recharge within the Rosedale-Rio Bravo district. More than 80,000 acre feet of Buena Vista Kern River wet year water were to be captured and recharged within the Rosedale-Rio Bravo district service area in a given year. The recharged waters were to be included in the groundwater bank account. Also, the account would include groundwater which had been previously recharged within the Kern River area by the Buena Vista district. The Buena Vista district committed to the program 150,000 acre feet of previously recharged exportable groundwater which it currently stored. It was estimated that more than 20,000 acre feet of banked water could be recovered or withdrawn from the groundwater bank account in order to supply water demands created by the Buena Vista/Rosedale-Rio Bravo water banking program. The water recovered under the Buena Vista/Rosedale-Rio Bravo water banking program could be delivered to

third-party buyers such as defendant. The primary method of recovery or delivery would be through an "in-lieu" exchange of State Water Project Table A supplies. (Table A, an attachment to long-term water contracts, will be fully discussed later in this opinion.) When the Table A supplies were insufficient for an "in-lieu" exchange, the banked groundwater will be pumped into the California Aqueduct of the State Water Project for delivery to a buyer such as defendant. The 2002 Buena Vista/Rosedale-Rio Bravo water banking program "in-lieu" exchange process was approved by the Department of Water Resources prior to its implementation. The Department of Water Resources monitors all exchanges and deliveries.

B. The 2006 Project

The California Department of Water Resources is responsible for overall water planning for the State of California. Defendant is located in Los Angeles and Ventura Counties and was created by the Legislature in 1962. (Stats.1962, 1st Ex. Sess., ch. 28, p. 208, § 1. Amended by Stats.1970, ch. 443, p. 873, § 1; Wat. Code App. § 103-1.) Defendant is 1 of 29 State Water Project Contractors who enter into agreements with the Department of Water Resources. The 29 contractors have long-term water supply contracts for water service from the State Water Project. The 29 contractors obtain deliveries from the Department of Water Resources in accordance with the long-term contracts. The acre feet of water that may be delivered under an individual contractor's agreement with the Department of Water Resources is set forth in an attachment to the long-term contract. The attachment which sets forth the acre feet of water is referred to as Table A. The Table A attachment establishes the total amount of State Water Project that a contractor may request and potentially receive each year under the terms of the long-term water supply contract. In exchange, the contractors pay the Department of Water Resources any fees and costs related to the operation and maintenance of the State Water Project. The yearly fees are calculated by reference to the Table A amount. The Department of Water Resources is not always able to deliver the quantity of requested

water because of certain factors such as hydrologic conditions, current reservoir storage, and total water contractor requests.

Defendant's service area is approximately 195 square miles (124,800 acres) in incorporated and unincorporated areas in, or adjacent to, the Santa Clarita Valley. Defendant's purpose, at its formation, was to contract through the Department of Water Resources to acquire and distribute State Water Project water to four local purveyors. Defendant's purpose was subsequently expanded by legislation to: acquisition of water from the Department of Water Resources; distribution of water wholesale; water reclamation; retail water sale; and exercise of other related powers. Defendant has a fundamental duty to plan for and procure a reliable water supply. (Cal. Wat. Code-App. § 103-15.) Defendant principally obtains its water supply from the State Water Project.

In February 1984, the Los Angeles County Board of Supervisors adopted the Santa Clarita Valley Areawide General Plan. The 1984 general plan projected that 165,000 residents would inhabit defendant's area by the year 2000. In August 1987, the Los Angeles County Department of Regional Planning prepared a draft amendment to the 1984 general plan forecasting that the population would be 210,000 rather than 165,000 by the year 2000. The 1987 document forecast a population of 270,000 by 2010 in defendant's area. To address water supply and demand forecasts, defendant completed the Capital Program and Water Plan in 1988. The 1988 Capital Program involves a long-term plan for financing purchases, construction, and improvements to meet future needs. The 1988 plan is currently being implemented. In 2003, defendant issued a Water Supply Reliability Plan for the Santa Clarita Valley. The purpose of the 2003 plan is to develop a protocol to evaluate the technical, environmental, and economic issues surrounding a water supply reliability project. The goal is to have in the future only the most effective and cost-efficient projects.

The California Urban Water Planning Act (Wat. Code, § 10631 et seq.) requires contractors, such as defendant, to assess water supply reliability that compares total projected usage with the expected supply over a 20-year period in 5-year increments. (Wat. Code, § 10621, subd. (a), 10631, subd. (a); see *Friends of Santa Clara River v.*

Castaic Lake Water Agency (2004) 123 Cal.App.4th 1, 8.) In accordance with statutory requirements, defendant adopted the 2005 Urban Water Management Plan. However, defendant's 2005 Urban Water Management Plan exceeds the minimum 20-year period and covers a 25-year period. Defendant's 2005 Urban Water Management Plan built upon its 2000 Urban Water Management Plan, as amended. Defendant evaluated the long-term water needs within its service area and compared these requirements against existing potential water supplies. The United States Census indicates defendant's service area had a population of approximately 190,000 with 63,000 households. Defendant projects a population growth from 249,343 in 2005 to 428,209 in 2030. The 2005 Urban Water Management Plant was identified as a potential source to meet future demands for water.

On January 31, 2006, pursuant to section 21092, subdivision (a) defendant issued a notice of preparation of the draft environmental impact report for the 2006 project. The 2006 project consists of the contractual right to annually purchase water from the Buena Vista/Rosedale-Rio Bravo water banking program in the amount of 11,000 acre feet through the year 2035. Defendant further has the right to extend the contract with the Buena Vista and Rosedale-Rio Bravo districts subject to compliance with applicable law. The 2006 project environmental impact report states the 11,000 acre feet of water per year purchase from the Buena Vista/Rosedale-Rio Bravo water banking program "is to be used primarily for annexations" to defendant's service area. But until "any such annexations are likely approved," the supply would be available to meet existing demands. Defendant also has the right to purchase an additional 9,000 acre feet in any given year from the Buena Vista/Rosedale-Rio Bravo water banking program. The Buena Vista/Rosedale-Rio Bravo water banking program delivers water to customers such as defendant in two ways. The first way is the so-called "in lieu" exchange. Under the in lieu exchange method, the Buena Vista and Rosedale-Rio Bravo districts, rather than use their banked groundwater, transfers water to which they have rights under their contracts with the State Water Project. The groundwater could be sold to local customers or it can remain in the ground. In other words, in lieu of pumping groundwater, the

Buena Vista and Rosedale-Rio Bravo districts could ship other water to which they have rights to customers such as defendant. Hence, the terminology in lieu exchange describes this first method of delivering water to defendant under the 2006 project. The second way to deliver the contracted for water is to pump it out of the ground in the Buena Vista and Rosedale-Rio Bravo districts and deliver it via the California Aqueduct to defendant. The principal method of recovery and delivery would be from State Water Project water delivered to the Buena Vista and Rosedale-Rio Bravo districts for recharging or irrigation purposes. Resort to groundwater pumping would occur only in years when the State Water Project undergoes shortages—1 to 5 years in every 35-year period. Under either delivery system, all deliveries were required to comply with State Water Project standards.

Defendant determined its projected demands required supplemental water sources beyond the amounts specified in Table A attached to its long-term water contract with the Department of Water Resources. In addition, banking was needed to improve water supply especially in drought years. In some years, the full amount of contracted water due from the State Water Project may not be available for delivery to its long-term contractors due to: hydrology; the amount of water in storage; the operational constraints and environmental regulations; the amounts of water requested by other contractors; climatic conditions; and other factors. The 2006 environmental impact report states the project consists of an action by defendant to augment its supply to meet the demands of its service area. Further, the 2006 environmental impact report states defendant desired to augment its water supply to meet future demands in the event its service area is enlarged by reason of annexation; or transfer of water from the Buena Vista/Rosedale-Rio Bravo water banking program. Defendant's purchase of water from the Buena Vista/Rosedale-Rio Bravo water banking program guaranteed a firm water supply which is not subject to the variations in the State Water Project supply. The 2006 project is also identified in defendant's 2005 Urban Water Management Program as a source to meet projected demand in the Santa Clarita Valley.

The 2006 environmental impact report indicates that there were no significant direct impacts from the project. The 2006 environmental impact report states that less significant impacts included increased electrical power demand and air emissions from moving water to defendant's service area. This impact removed obstacles to growth in defendant's service area. As a result, defendant identified population growth or development as potential indirect impacts. However, defendant notes that its responsibility is to provide water in the service area and not to approve locations of any new development. To the extent that there were visual or aesthetic effects caused by water purchase programs, the 2006 environmental impact report states that such impact could be mitigated by the county and city agencies approving such developments in the project-specific environmental review process. The 2006 environmental impact report identifies three alternatives to the project: reduced water supply; purchase of desalinated water; and no project. The 2006 environmental impact report concludes the project was the environmentally superior alternative. This is because, under the reduced water supply and no project alternatives, defendant would be required to obtain additional water supplies to meet the projected needs of the service area. The 2006 environmental impact report notes that the desalination project could actually cause more direct impacts to the environment than the project. This is because the construction and operation of new desalination facilities would be required. These activities would have significant impacts on: air quality; aesthetic and visual resources; agricultural resources; biological resources; marine resources; geology and soils; hydrology and water quality; land use and planning; noise levels; and recreation.

The 2006 environmental impact report identifies five possible annexation sites within the service area. The 2006 environmental impact report states that whether the sites were actually annexed was not within the defendant's authority but that water availability was a factor in the annexation process. The potential annexations would result in a 4,375 acre feet of water per year increase in demand for water. The 2006 environmental impact report states that 11,000 acre feet of water per year of water would

be able to serve between approximately 11,340 and 11,830 households, which translates into approximately 36,290 and 37,850 persons.

Pursuant to section 21092, subdivisions (a) and (b)(i) and California Code of Regulations, title 14, section 15087, subdivision (c)(2),[3] the public was provided with the opportunity to comment on the draft 2006 environmental report. Among the issues raised during the comment period was whether the 2006 environmental impact report adequately disclosed whether the project was being pursued under the so-called Monterey Amendment to State Water Project long-term contracts. In the 1990's, disagreements arose between contractors and others with the Department of Water Resources concerning the distribution of State Water Project supplies. State Water Project contractors and the Department of Water Resources negotiated a settlement which provided for an overhaul of long term water contracts and a new approach to managing State Water Project supplies. The dispute arose under article 18 of the long-term contracts. The principles developed as part of the 1994 settlement are known as the "Monterey Agreement." The 1994 "Monterey Agreement" amended water contracts and those changes are known as the "Monterey Amendment." The Monterey Amendment was approved in 1995 and went into effect in August 1996. (See *Friends of Santa Clara River v. Castaic Lake Water Agency* (2002) 95 Cal.App.4th 1373, 1375; *Planning & Conservation League v. Department of Water Resources* (2000) 83 Cal.App.4th 892, 897-902.) One principle of the Monterey Amendment called for the transfer of about 130,000 acre feet of water per year from agriculture to urban users. (*Friends of the Santa Clara River v. Castaic Lake Water Agency*, *supra*, 95 Cal.App.4th at pp. 1376-1377; *Planning & Conservation League v. Department of Water Resources*, *supra*, 83 Cal.App.4th at pp. 901-902.)

The comments to the 2006 draft environmental impact report state: it did not fully disclose whether the transfers were permanent; a permanent transfer implicated the

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[3] All future reference to the Guidelines are to the provisions of California Code of Regulations, title 14.

Monterey Amendment; and the project was the "functional equivalent" of a permanent transfer of water requiring the Department of Water Resources prepare an environmental impact report as the lead agency under the standards set forth in *Planning & Conservation League v. Department of Water Resources*, *supra*, 83 Cal.App.4 at page 920. Defendant responded to the comments by noting the water purchased from the Buena Vista Rosedale-Rio Bravo districts under the 2006 project did not involve the State Water Project Table A supplies. According to defendant, the Monterey Agreement applied to two types of water transfers—permanent transfers of Table A amounts and annual transfers of allocated Table A supplies. Defendant further stated that the Monterey Agreement did not address transfers of non-State Water Project supplies. Citing section 2.4 of the draft environmental impact report, defendant explained no purchase of water subject to Table A had occurred. Instead, defendant pointed out: the Table A supplies for it, as well as Buena Vista and Rosedale-Rio Bravo districts, would remain the same under the 2006 project; the purchased water originated from local and other supplies that will be recharged and banked in groundwater basins; and the supplies included Kern River wet year water and other acquired waters. Defendant also noted that all of the information about the program water supplies was set forth in the 2002 Buena Vista/Rosedale-Rio Bravo water banking environmental impact report.

Defendant denied that there was a functional equivalent of a permanent transfer of Table A waters subject to the Monterey Agreement. Defendant stated the State Water Project Table A supplies attributed to the long-term contract with the Department of Water Recovery constitute but one mechanism for the purchased water to be delivered to defendant through an in-lieu exchange. Thus, defendant argued the Department of Water Resources did not have to be the lead agency. The only role of the Department of Water Resources in the project is to approve the change in place of use and point of delivery of exchange water delivered from to another State Water Project long-term contractor and for the direct delivery of groundwater into the California Aqueduct.

Defendant's Board of Directors adopted Resolution No. 2492 on October 25, 2006, certifying the final 2006 environmental impact report for the project and adopting:

findings; a mitigation monitoring and reporting program; and a statement of overriding considerations. Resolution No. 2492 approved the project. The board determined: the 2006 project's benefits outweighed any significant and unavoidable environmental impacts; substantially all of the 2006 project's indirect impacts consist of growth inducement which is outside of its jurisdiction and control; the 2006 project will bring substantial benefits to the defendant's service area by improving the its ability to meet the present and projected water demands; and the 2006 project will bring substantial benefit to defendant's service area by preparing for projected growth.

C. The Amended Mandate Petition And Its Denial

On November 26, 2006, plaintiffs filed their mandate petition. The first amended petition alleged that plaintiffs are non-profit organizations. Plaintiffs sought to set aside the certification of the 2006 environmental impact report for the project and a declaration defendant's actions were unlawful. The amended petition further alleged: the 2006 environmental impact report fails to clearly identify and describe the likely source of water that will be acquired by defendant because it does not accurately describe the "in-lieu" method; the method employed by the 2006 project is really a transfer of State Water Project Table A water; the 2006 environmental impact report fails to forecast the project's potential impacts on marine life including some sensitive species which would be caused by additional winter pumping; defendant was not the proper lead agency to conduct environmental review of the 2006 project; and the 2006 environmental impact report fails to properly evaluate the use of State Water Project facilities to deliver the exchange of water to the service area which must be done by the Department of Water Resources. Plaintiffs requested issuance of alternative and peremptory writs of mandate commanding defendant to set aside, invalidate, and void the certification of the 2006 environmental impact report. Plaintiffs also requested declaratory and injunctive relief. The trial court denied the first amended petition after briefing and a hearing. Judgment

was entered on all of plaintiffs' causes of action in favor of defendant. This timely appeal followed.

III. DISCUSSION

A. Standard of Review

Our Supreme Court in *Citizens of Goleta Valley* v. *Board of Supervisors* (1990) 52 Cal.3d 553, 563-564, summarized the purposes of the California Environmental Quality Act: "As we recently observed in *Laurel Heights Improvement Assn.* v. *Regents of University of California* (1988) 47 Cal.3d 376, (*Laurel Heights*): 'The foremost principle under [the California Environmental Quality Act] is that the Legislature intended the act "to be interpreted in such manner as to afford the fullest possible protection to the environment within the reasonable scope of the statutory language."' [Citation.] [¶] The EIR has been aptly described as the 'heart of CEQA.' (Guidelines, § 15003, subd. (a); *Laurel Heights, supra,* 47 Cal.3d at p. 392; *County of Inyo* v. *Yorty* (1973) 32 Cal.App.3d 795, 810.) Its purpose is to inform the public and its responsible officials of the environmental consequences of their decisions *before* they are made. Thus, the EIR 'protects not only the environment but also informed self-government.' (*Laurel Heights, supra*, 47 Cal.3d at p. 392.) [Fn. omitted.]"

Whether defendant's certification of the 2006 environmental impact report complies with the relevant provisions of law is reviewed for a prejudicial abuse of discretion. (§ 21168.5; *In re Bay-Delta Programmatic Environmental Impact Report Coordinated Proceedings* (2008) 43 Cal.4th 1143, 1161; *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 435; *Citizens of Goleta Valley* v. *Board of Supervisors, supra,* 52 Cal.3d at pp. 563-564.) Section 21168.5 states, ". . . Abuse of discretion is established if the agency has not proceeded in a manner required by law or if the determination or decision is not supported by substantial evidence." In deciding whether a prejudicial abuse of discretion has occurred

our Supreme Court has stated: "As a result of this standard, 'The court does not pass upon the correctness of the EIR's environmental conclusions, but only upon its sufficiency as an informative document.' [Citation.] [¶] . . . [¶] A court may not set aside an agency's approval of an EIR on the ground that an opposite conclusion would have been equally or more reasonable. [Citation.] A court's task is not to weigh conflicting evidence and determine who has the better argument when the dispute is whether adverse effects have been mitigated or could be better mitigated. We have neither the resources nor scientific expertise to engage in such analysis, even if the statutorily prescribed standard of review permitted us to do so. Our limited function is consistent with the principle that 'The purpose of CEQA is not to generate paper, but to compel government at all levels to make decisions with environmental consequences in mind. . . . ' [Citation.]" (*Laurel Heights Improvement Assn. v. Regents of University of California, supra,* 47 Cal.3d at pp. 392-393; see also *Western States Petroleum Assn. v. Superior Court* (1995) 9 Cal.4th 559, 573-574; *Citizens of Goleta Valley v. Board of Supervisors, supra,* 52 Cal.3d at p. 564.) We review defendant's actions de novo determining whether the administrative record demonstrates any legal error and it contains substantial evidence to support the factual determinations. (*Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova, supra,* 40 Cal.4th at p. 427; *Citizens of Goleta Valley* v. *Board of Supervisors, supra,* 52 Cal.3d at pp. 563-564.)

B. Compliance With The California Environmental Quality Act

1. The environmental impact report adequately describes the project.

There is no merit to plaintiff's argument the 2006 project environmental impact report fails to include an adequate and consistent description of the water source. The absence of information from an environmental impact report does not establish a

violation of Guidelines, section 15124,[4] the controlling provision, as a matter of law. (*Berkeley Keep Jets Over the Bay Committee v. Board of Port Comrs.* (2001) 91 Cal.App.4th 1344, 1355; *Al Larson Boat Shop, Inc. v. Board of Harbor Commissioners* (1993) 18 Cal.App.4th 729, 749.) Rather, judicial review under the prejudicial abuse of discretion standard set forth in section 21168.5 focuses on the sufficiency of the environmental impact report as an informative document. (*Laurel Heights Improvement Assn. v. Regents of University of California, supra,* 47 Cal.3d at p. 392; accord *Vineyard Area Citizens for Responsible Growth v. City of Rancho Cordova, supra,* 40 Cal.4th at p. 445; *Western States Petroleum Assn. v. Superior Court, supra,* 9 Cal.4th at pp. 573-574.) A prejudicial abuse of discretion occurs when the failure to include information in the environmental impact report prevents informed decisions and public participation, which thwarts the goals of the evaluative process. (*Anderson First Coalition v. City of*

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[4] Guidelines, section 15124 states: "The description of the project shall contain the following information but should not supply extensive detail beyond that needed for evaluation and review of the environmental impact. [¶] (a) The precise location and boundaries of the proposed project shall be shown on a detailed map, preferably topographic. The location of the project shall also appear on a regional map. [¶] (b) A statement of the objectives sought by the proposed project. A clearly written statement of objectives will help the lead agency develop a reasonable range of alternatives to evaluate in the EIR and will aid the decision makers in preparing findings or a statement of overriding considerations, if necessary. The statement of objectives should include the underlying purpose of the project. [¶] (c) A general description of the project's technical, economic, and environmental characteristics, considering the principal engineering proposals if any and supporting public service facilities. [¶] (d) A statement briefly describing the intended uses of the EIR. [¶] (1) This statement shall include, to the extent that the information is known to the lead agency, [¶] (A) A list of the agencies that are expected to use the EIR in their decision-making, and [¶] (B) A list of permits and other approvals required to implement the project. [¶] (C) A list of related environmental review and consultation requirements required by federal, state, or local laws, regulations, or policies. To the fullest extent possible, the lead agency should integrate CEQA review with these related environmental review and consultation requirements. [¶] (2) If a public agency must make more than one decision on a project, all its decisions subject to CEQA should be listed, preferably in the order in which they will occur. On request, the Office of Planning and Research will provide assistance in identifying state permits for a project."

Anderson (2005) 130 Cal.App.4th 1173, 1178; *Galante Vineyards v. Monterey Peninsula Water Management Dist.* (1997) 60 Cal.App.4th 1109, 1117.) Guidelines section 15151 provides: "An EIR should be prepared with a sufficient degree of analysis to provide decisionmakers with information which enables them to make a decision which intelligently takes account of environmental consequences. An evaluation of the environmental effects of a proposed project need not be exhaustive, but the sufficiency of an EIR is to be reviewed in the light of what is reasonably feasible. . . . The courts have looked not for perfection but for adequacy, completeness, and a good faith effort at full disclosure." (See *Anderson First Coalition v. City of Anderson*, *supra*, 130 Cal.App.4th at p. 1178; *Berkeley Keep Jets Over the Bay Committee v. Board of Port Comrs.*, *supra*, 91 Cal.App.4th at p. 1355; *Rio Vista Farm Bureau Center v. County of Solana* (1992) 5 Cal.App.4th 351, 368.)

Plaintiffs argue the 2006 environmental impact report omits or mischaracterizes information about the sources for the water supply. To the extent plaintiffs are criticizing the ambiguity of the Buena Vista/Rosedale-Rio Bravo water banking program, they cannot raise that contention. The 2002 environmental impact report is conclusively presumed valid and it is not subject to challenge in this action. (§ 21167.2; *Laurel Heights Improvement Assn. v. Regents of University of California* (1993) 6 Cal.4th 1112, 1130.) Thus, plaintiffs cannot challenge the Buena Vista/Rosedale-Rio Bravo water banking and recovery program under the guise of litigating the 2006 environmental impact report. This action must be limited to whether the 2006 environmental impact report sufficiently informs the decisionmakers and the public about impacts from the project. Plaintiffs may not litigate the impact of the Buena Vista/Rosedale Rio Bravo water banking program. The aforementioned conclusive 2002 environmental impact report repeatedly states that the primary method of delivery will be through "in-lieu" exchange of State Water Project supplies. The 2002 environmental impact report sets forth: the environmental effects of operating the program which included the sale of water to third-parties; discussions of delivery through banked underground water; and analysis of delivery through "in-lieu" exchange of Table A supplies. The 2002 program

environmental impact report fully disclosed that the primary method of delivery would be "in-lieu" exchange but that in some years the delivery might vary depending upon State Water Project supplies.

In any event, the 2006 environmental impact report adequately describes the project. The 2006 environmental report: identifies the sources of the water that will be delivered; describes the growth related effects of the purchase in defendants' service area; and identifies the effects of additional water pumping. The 2006 environmental impact report explains that the primary source of water provided by the Buena Vista/Rosedale-Rio water banking program will be water provided to them by the State Water Project. There is no merit to plaintiffs' contention the discussion in that regard is incomplete or misleading.

Furthermore, we disagree with plaintiffs the "in-lieu" exchange delivery amounts to a permanent transfer of Table A water or the functional equivalent thereof. Before proceeding to a discussion of the merits of plaintiffs' environmental analysis, it bears emphasis that the Buena Vista and Rosedale-Rio Bravo Districts have the statutory authority to sell their water and water rights pursuant to Water Code section 43001. (See fn. 2, *infra*.) At oral argument, plaintiffs' counsel admitted there is no statutory bar to the sale of water rights by the Buena Vista and Rosedale-Rio Bravo Districts. Rather, as fleshed out at oral argument, plaintiffs argue that the proposed transfer of waters violate attachment C to the Monterey Agreement which are Department of Water Resources guidelines for review of proposed permanent transfers of Table A waters. The attachment C guidelines are in furtherance of the state policy favoring voluntary water transfers which includes a preference for use of water for non-irrigation purposes; i.e., for the sustenance of human beings, household conveniences, and the care of livestock. (Wat. Code, § 106; *Prather v. Hoberg* (1944) 24 Cal.2d 549, 562.) Further, paragraph 3 of attachment C states, "These guidelines are not intended to change or augment existing law."

In any event, as discussed above, all information concerning the environmental impacts from the two delivery methods was discussed and analyzed in the *conclusive*

2002 environmental impact report. Nevertheless, there is no merit to the contention that there is a permanent transfer of Table A amounts. Both the Buena Vista and Rosedale-Rio Bravo districts have contractual rights with the State Water Project which allow them to receive a maximum amount of water supply in a given year. The water supply from the State Water Project varies depending on the conditions such as: hydrologic conditions; current reservoir storage; and total water contractor requests. However, the actual amount of water delivered under the 2006 project is not contingent upon Table A supplies distributed by the State Water Project to the Buena Vista and Rosedale-Rio Bravo districts. It is undisputed that the Table A supplies can vary yearly. Rather, under the program, defendant has a contractual right to receive 11,000 acre feet of water per year regardless of whether the Buena Vista and Rosedale-Rio Bravo districts receive Table A supplies. Thus, use of Table A water is neither the actual nor the functional equivalent of a permanent transfer because it may not occur. The "in-lieu" exchange is simply one method to meet the contractual obligation to deliver 11,000 acre feet of water to defendant. It is not a permanent transfer of Table A supplies. And even if the project were such a transfer, it is sufficiently described along with its effects in the 2006 environmental impact report. The 2006 environmental impact report expressly states that the water purchased would come from two sources. The first source is the Buena Vista and Rosedale-Rio Bravo Districts State Water Project waters. The second source is the banked groundwater whose rights are owned by Buena Vista and Rosedale-Rio Bravo Districts. In an unusually dry year, groundwater supplies may be the sole source of waters sold to third parties such as defendant. And the 2006 environmental impact report states that 2006 project does not involve the purchase of Table A amounts. Contrary to plaintiffs' counsel's assertion at oral argument, the 2006 environmental impact report does not mask the source of the waters.

2. The 2006 environmental impact report adequately reviewed growth inducing impacts.

Plaintiffs contend that the 2006 environmental impact report fails to adequately review the growth inducing impacts generated by the purchase of the water. We disagree. In *Muzzy Ranch Co. v. Solano County Airport Land Use Com.* (2007) 41 Cal.4th 372, 388-389, our Supreme Court articulated an agency's responsibility to analyze growth inducing impacts as follows: "Under CEQA, a public agency is not always 'required to make a *detailed* analysis of the impacts of a project on [future] housing and growth.' [Citation.] 'Nothing in the [CEQA] Guidelines, or in the cases, requires more than a general analysis of projected growth. The detail required in any particular case necessarily depends on a multitude of factors, including, but not limited to, the nature of the project, the directness or indirectness of the contemplated impact and the ability to forecast the actual effects the project will have on the physical environment.' [Citation.] [¶] 'In addition, it is relevant, although by no means determinative, that future effects will themselves require analysis under CEQA.' [Citation.] And '[t]hat the effects will be felt outside of the project area . . . is one of the factors that determines the amount of detail required in any discussion. Less detail, for example, would be required where those effects are more indirect than effects felt within the project area, or where it [would] be difficult to predict them with any accuracy.' [Citations].) Most significantly, the CEQA Guidelines provide for streamlined review of projects that are consistent with existing general plans and zoning. [Citation.] When approving a project that is consistent with a community plan, general plan, or zoning ordinance for which an environmental impact report already has been certified, a public agency need examine only those environmental effects that are peculiar to the project and were not analyzed or were insufficiently analyzed in the prior environmental impact report. [Citation.]" (See also *Napa Citizens for Honest Government v. Napa County Bd. of Supervisors* (2001) 91 Cal.App.4th 342, 369.)

The 2006 environmental impact report complies with the statutorily imposed informational requirements. Chapter 4.0 of the 2006 environmental impact report discusses growth inducing impacts and potential indirect impacts on resources from growth. Furthermore, there is no evidence the additional water will induce any growth that is unaccounted for in the general plan of the area. Rather, chapter 5.0 of the 2006 environmental impact report contains a discussion of the project's consistency with general and regional plans. The 2006 environmental impact report assumes that the entire 11,000 acre feet of water per year would be for new growth. The project also assumes that approximately 37,850 people would be served by the water supply from the project. The growth potential was within the general plan forecasts of 270,000 by 2010 and 428,209 by 2030 for the Santa Clarita Valley. Moreover, the 2006 project is a part of a process to meet defendant's obligation to provide water to its service area in accordance with projected population increases. Thus, the 2006 environmental impact report contains a detailed analysis of growth inducing impacts. The 2006 project is also consistent with existent general and community plans projecting growth increases in the service area. The 2006 environmental impact report adequately discusses growth related issues. (*Muzzy Ranch Co. v. Solano County Airport Land Use Com.*, *supra*, 41 Cal.4th at pp. 388-389; *Napa Citizens for Honest Government v. Napa County Bd. of Supervisors*, *supra*, 91 Cal.App.4th at p. 369; see also Guidelines, § 15126.2, subd. (d); *Sierra Club v. West Side Irrigation Dist.* (2005) 128 Cal.App.4th 690, 702-703.)

Finally, we disagree with plaintiffs that there was something amiss in the 2006 environmental impact report because defendant included five proposed annexation sites in the discussion. Plaintiffs interpret defendant's inclusion of the five potential sites identified in chapter 3.0 as evidence of a plan to grow the area. Because of the pending applications, defendant was required to include the sites in the environmental impact report. (Guidelines, § 15125; *Muzzy Ranch Co. v. Solano County Airport Land Use Com.*, *supra*, 41 Cal.4th at pp. 387-388 [§ 21060.5 obligates an defendant to consider environmental impact of project outside the project area when it will have effect on geographically distant area].)

3. Defendant is the correct lead agency.

Plaintiffs assert that defendant's imprecise discussion is an attempt to mask what is the "functional equivalent" of a permanent transfer of surplus Table A supplies belonging to the Buena Vista and Rosedale-Rio Bravo districts. Relying on *Planning & Conservation League v. Department of Water Resources*, *supra*, 83 Cal.App.4th at pages 903-907, plaintiffs argue the proper lead agency should have been the Department of Water Resources. The *Planning & Conservation League* decision held the Department of Water Resources was the proper lead agency for conducting environmental review of the Monterey Agreement. (*Ibid*.; see *Santa Clarita Organization for Planning the Environment v. County of Los Angeles* (2007) 157 Cal.App.4th 149, 153.) The *Planning & Conservation League* decision had statewide implications and involved a number of urban and agricultural contractors. The issues also involved rights under the long-term water supply contracts which governed the entire State of California.

In this case, defendant is the correct lead agency. Section 21067 defines a lead agency, '"Lead agency' means the public agency which has the principal responsibility for carrying out or approving a project which may have a significant effect upon the environment." Defendant argues it is the proper lead agency because: it is the lead proponent of the water acquisition plan; a substantial portion of the 2006 project occurs within its geographic area; and it alone decides whether to accept any water. We agree. Defendant has the principal responsibility for approving and carrying out a project to acquire a water supply for its service area. (§§ 21005, 21080, subd. (c), 21165; Guidelines, §§ 15051-15053.) The 2006 project also affects defendant's duties and obligations to provide water to its service area. In addition, the 2006 project occurs within defendant's jurisdiction. The transfer of water applies to only three agencies, albeit that the transfer will take place within State Water Project facilities. The three agencies are the primary ones affected by the 2006 project. Thus, defendant was the proper lead agency. In any event, plaintiffs conceded in the trial court in their reply brief, and at hearing on the petition that its lead agency analysis rests on the conclusion the

2006 project is in effect a Table A transfer. We have concluded no disguised permanent nor functional equivalent transfer of Table A water has occurred. As a result, the Department of Water Resources was not required to be the lead agency such that it should have prepared the environmental impact report. (*Eller Media Co. v. Community Redevelopment Agency* (2003) 108 Cal.App.4th 25, 46; *Friends of Cuyamaca Valley v. Lake Cuyamaca Recreation & Park Dist*. (1994) 28 Cal.App.4th 419, 426-428; *City of Sacramento v. State Water Resources Control Bd*. (1992) 2 Cal.App.4th 960, 970-973; *City of Redding v. Shasta County Local Agency Formation Com.* (1989) 209 Cal.App.3d 1169, 1173-1177.)

4. The project does not impermissively rely on a draft of general plan.

Relying on *County of Amador v. El Dorado County Water Agency* (1999) 76 Cal.App.4th 931, 941-951, plaintiffs argue the 2006 project improperly appropriated water supplies for development that had not already been included in the Los Angeles County General Plan. In *County of Amador*, the environmental impact report was based on population projections contained in a draft general plan prepared by El Dorado County. (*Id*. at pp. 941, 947.) The *County of Amador* opinion concluded, "We hold only that, in this case, an [environmental impact report] predicated on a draft general plan is fundamentally flawed and cannot pass CEQA muster." (*Id.* at p. 951.)

The *County of Amador* decision is not controlling. Here, there is no draft general plan at issue. In other words, defendant did not predicate the project on a draft general plan which has been judicially determined to be inadequate. Rather, the water planning in this case for the project was based on projections from a number of sources including: the United States Census; defendant's 2005 Urban Water Management Plan; and the existing Santa Clarita Valley Area Plan of the County of Los Angeles General Plan. The existing Los Angeles County General Plan had projections of a population growth of 270,000 by the year 2010. The 2005 Urban Water Management Plan predicted the future need for water to meet the demand for population growth that had been projected by Los

Angeles County and the City of Santa Clarita. Defendant has a duty to plan for long term needs in the service area. The California Urban Water Planning Act (Wat. Code, § 10631 et seq.) requires water contractors, such as defendant, to assess water supply reliability that compares total projected water use with the expected water supply over a 20-year period in 5-year increments. (See *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova, supra,* 40 Cal.4th at pp. 434-435; *Friends of Santa Clara River v. Castaic Lake Water Agency, supra,* 123 Cal.App.4th at p. 8.) The proposed water purchase from the Buena Vista and Rosedale-Rio Bravo districts is one of several measures taken by defendant in order to meet the forecasts of population growth contained in county, city, and federal documents. The *County of Amador* opinion does not require reversal.

IV. DISPOSITION

The judgment is affirmed. Defendant, Castaic Lake Water Agency, is to recover its costs on appeal from plaintiffs, California Water Impact Network and Friends of the Santa Clara River.

NOT TO BE PUBLISHED IN THE OFFICIAL REPORTS

TURNER, P. J.

We concur:

MOSK, J. KRIEGLER, J.

Castaic Lake Water Agency Litigation Settlement Agreement

CASTAIC LAKE WATER AGENCY LITIGATION

SETTLEMENT AGREEMENT

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CASTAIC LAKE WATER AGENCY LITIGATION

SETTLEMENT AGREEMENT

This Castaic Lake Water Agency Litigation Settlement Agreement (the **"Agreement")** is dated as of April 6, 2007 **("Agreement Date"),** by and between the Castaic Lake Water Agency (**"CLWA"**), Santa Clarita Water Company (**"SCWC"**), Newhall County Water District (**"NCWD"**) and Valencia Water Company (**"VWC"**) (collectively, **"Plaintiffs"**), on the one hand, and Whittaker Corporation (**"Whittaker"**), Santa Clarita L.L.C. (**"SCLLC"**), Remediation Financial, Inc. (**"RFI"**), and American International Specialty Lines Insurance Company (**"AISLIC"**), on the other hand. Hereinafter, Whittaker, SCLLC and RFI are collectively referred to as **"Defendants,"** the Plaintiffs and Defendants and AISLIC are collectively referred to as the **"Parties,"** each Plaintiff, each Defendant, and AISLIC is individually referred to as a **"Party,"** and SCLLC and RFI are collectively referred to as the **"RFI Parties"** or **"Debtors."**

RECITALS

A. SCLLC is the owner of approximately 964.79 acres of real property located in the City of Santa Clarita, County of Los Angeles, State of California, described more fully in Exhibit A hereto (the "**SCLLC Property**"). Bermite Recovery, LLC ("**BRLLC**") is the owner of approximately 23.6 acres of real property located in the City of Santa Clarita, County of Los Angeles, State of California, described more fully in Exhibit B hereto (the "**BRLLC Property**"). The SCLLC Property and the BRLLC Property are hereinafter referred to collectively as the "**Site**."

B. SCWC is the operator of water wells commonly designated as Saugus 1, Saugus 2 and the Stadium Well. NCWD is the owner and operator of water wells commonly designated as NC11 and NC13. VWC is the owner and operator of water wells commonly designated as V157 and Q2. Saugus 1, Saugus 2, the Stadium Well, NC11, V157 and Q2 are collectively referred to at all times as the "**Subject Wells**". As set forth in Section 9.1.7 hereof, NC13 shall be deemed a "Subject Well" in the event and only in the event it is treated as a Project Modification pursuant to Section 9.1.7 and only prospectively from that date it is so treated.

C. Plaintiffs and Defendants are parties to a civil action pending in the United States District Court for the Central District of California, Case No. CV 00-12613 AHM (RZx) (the "**Underlying Action**"). In the Underlying Action, Plaintiffs allege, among other things, that (1) groundwater in the vicinity of the Site has been contaminated by perchlorate and other hazardous materials and that such contamination is continuing with releases to the groundwater; (2) perchlorate has been found in the Subject Wells, and Plaintiffs have incurred and will continue to incur costs in responding to the contamination; and (3) Defendants caused and/or permitted (and are continuing to cause and/or permit) the contamination found on, above, under, or released to the environment at and near the Site and in the Subject Wells. Plaintiffs further allege that they have incurred "response costs" in addressing this contamination, including the costs of engaging consultants to undertake environmental assessment, water treatment studies, groundwater analysis and characterization work in connection with the alleged perchlorate contamination. Plaintiffs are seeking recovery of their alleged response costs and other damages, as well as injunctive and declaratory relief. Defendants deny Plaintiffs' allegations and, further, contend in their Counter-Claims that Plaintiffs are liable, in whole or in part, for Plaintiffs' alleged costs and damages **("the Counter-Claims").**

D. Plaintiffs have entered into that certain Environmental Oversight Agreement ("**EOA**") with the California Environmental Protection Agency, Department of Toxic Substances Control ("**DTSC**"). Plaintiffs are designated as "Proponents" under the EOA.

E. Whittaker and DTSC are parties to that certain 1994 Consent Order, Docket HAS 94/95-012 (the "**Consent Order**"), and the DTSC issued to Whittaker that certain Imminent and Substantial Endangerment Determination and Order and Remedial Action Order (the "**Order**") in 2002. SCLLC and DTSC are parties to that certain 2001 Enforceable Agreement (the "**Enforceable Agreement**").

F. Plaintiffs and Defendants entered into that certain Interim Settlement and Funding Agreement dated as of July 28, 2003 (the "**Interim Agreement**") and that certain First Amendment to Interim Settlement and Funding Agreement dated as of October 11, 2004 (the "**First Amendment**") which, among other things, extended the term of the Interim Agreement through January 2005.

G. Plaintiffs and Defendants mutually agree on the "Project and Associated Facilities" (as hereinafter defined) that shall be implemented by the Plaintiffs. The Project and Associated Facilities are intended to provide containment of perchlorate in off-site groundwater in portions of the Saugus Formation and to restore Plaintiffs' groundwater production capacity diminished by perchlorate contamination in the Subject Wells.

H. The Project fulfills some of Defendants' obligations under and resolves some of Defendants' alleged liabilities to DTSC under the Consent Order, the Order, and the Enforceable Agreement with respect to the remediation of groundwater, and Defendants' remaining responsibility for addressing groundwater remediation will be determined in compliance with the lawful requirements of the regulatory agencies.

I. This Agreement provides for certain funds to be available rapidly to address any future perchlorate contamination of Plaintiffs' presently existing **"Threatened Wells"** (as defined herein) during the period defined herein without prejudice to other rights and remedies of the Plaintiffs or the defenses of the Defendants. This Agreement also provides for arbitration to be available to Plaintiffs to resolve certain future disputes, if any, between or among the Parties involving possible future perchlorate contamination of Plaintiffs' **"Presently Existing Saugus Production Wells and Alluvial Production Wells"**, other than the Subject Wells, as hereinafter defined.

J. This Agreement contemplates that the Defendants (or any **"Buyer"** (as defined below) of the Site that assumes certain liabilities of Defendants) will be in compliance with their remediation responsibilities under law with respect to the Site and the associated groundwater, as reflected in the applicable requirements of the Consent Order, Order and the Enforceable Agreement, and that Defendants will conduct their remediation activities in a reasonably expedient, efficient and cost-effective manner as reasonably determined by Defendants and the regulatory authorities. In particular, the Defendants' (and/or any Buyer of the Site that assumes certain liabilities of Defendants) remedial activities within the Site are important to addressing the contamination within the Saugus and **"Alluvial Aquifers"** (as defined below). The Parties acknowledge that payments and expenditures under this Agreement are deemed reasonable and necessary for addressing offsite groundwater contamination emanating from the Site and are consistent with the National Contingency Plan, and are deemed **"Response Costs"** (as defined below) as that term is used and contemplated in CERCLA.

K. VWC reported detecting perchlorate in its alluvial well Q2 in connection with its regular monitoring of active municipal supply wells operating near the site in April 2005

(although a more recent sampling did not detect perchlorate above the current California Department of Health Services ("DHS") limit for reporting perchlorate). VWC temporarily removed the well from active service and installed wellhead treatment to remove perchlorate. The Q2 treatment system started operating in October 2005. The Defendants have funded five hundred thousand dollars ($500,000) for reasonable and necessary and approved capital costs and two hundred twenty three thousand and two hundred ten dollars ($223,210) for reasonable and necessary and approved operations and maintenance costs of the Q2 Treatment System in a Q2 Escrow Account. The Defendants have agreed to pay certain additional reasonable and necessary operating and maintenance costs of that system in accordance with the terms of this Agreement.

L. On July 7, 2004, SCLLC, and RFI filed voluntary Chapter 11 bankruptcy petitions, and the cases thereby commenced are pending in the United States Bankruptcy Court for the District of Arizona ("**Bankruptcy Court**"), denominated Cases Nos. 2-04-BK-11910 CGC, and 2-04-BK-11911 CGC. BRLLC filed a voluntary Chapter 11 bankruptcy petition on September 30, 2004, denominated Case No. 2-04-BK-17294 CGC, also pending in the Bankruptcy Court. Case Nos. 2-04-BK-11910 CGC, 2-04-BK 11911 CGC and 2-04-BK-17294 CGC are hereinafter referred to collectively as the "**Bankruptcy Cases.**" RFI Realty, Inc. filed a voluntary Chapter 11 bankruptcy petition on June 15, 2004 denominated as Case No. 2-04-BK-10486 CGC; the Bankruptcy Cases are jointly administered with RFI Realty, Inc.'s bankruptcy case under Case No. 2-04-BK-10486 CGC. SCLLC and BRLLC have filed a motion seeking Bankruptcy Court Approvals to sell the Site. The term "**Buyer**," as used herein, means the entity to which title to the Site is conveyed after Bankruptcy Court approval; provided, however, that if either the Bankruptcy Court does not approve a sale or a sale approved by the Bankruptcy Court

in the Bankruptcy Cases does not close pursuant to Bankruptcy Court approval, and consequently there is no Buyer, then this Agreement shall not be impacted in any way whatsoever.

M. Plaintiffs have prepared and submitted to DTSC for approval and DTSC has approved a Remedial Investigation ("RI") consisting of a technical memorandum prepared on behalf of the United States Army Corps of Engineers, a Feasibility Study ("FS") and an Interim Remedial Action Plan ("IRAP") for a containment and treatment system for perchlorate contamination in portions of the Saugus Formation. Such containment and treatment system is consistent with the discussions and understandings between the Plaintiffs and Defendants.

N. The Parties are entering into this Agreement in order to effectuate a settlement of the Underlying Action and to resolve certain disputes between Plaintiffs and Defendants that have arisen between them, as well as to provide the Parties with expedited alternative dispute resolution mechanisms for resolving certain disputes which may arise between Plaintiffs and Defendants in the future, to the extent provided and in accordance with the terms and conditions set forth in this Agreement. The Plaintiffs and Defendants have reached a separate settlement concerning the Defendants' Counter-Claims which will be the subject of a separate settlement agreement to be executed by certain of the Parties simultaneously with the execution of this Agreement, (the "Related Settlement") and which is part of the consideration for and a condition precedent to this Agreement.

O. Certain funds from the **"Steadfast PLC Policy"** (defined below), in accordance with and subject to the Coverage and Claims Settlement Agreement and the Bankruptcy Court's December 22, 2005 Order approving same, and the Joint Escrow 1 Agreement and Instructions, are being made available to settle the matters described and released herein. AISLIC shall

request the SF Escrow 1 Account Escrow Agent (Wells Fargo Bank or any successor) to release funds from the SF Escrow 1 Account to satisfy certain of Defendants' payment obligations and obligations to fund escrow accounts hereunder.

P. The Defendants and AISLIC represent that this Agreement is a settlement in the CLWA Case that meets all "Approved CLWA Settlement Parameters" set forth in Exhibit 16 to the Coverage and Claims Settlement Agreement.

Q. The Defendants and AISLIC represent that the payment obligations pursuant to this Agreement will be funded on behalf of Defendants as provided by Section VIII ("Funding Settlement of CLWA Case") of the Coverage and Claims Settlement Agreement and as provided herein.

R. Nothing in this Agreement is intended to alter any rights or obligations existing under the Coverage and Claims Settlement Agreement.

NOW, THEREFORE, in consideration of the execution of this Agreement and for other good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, the Parties hereby agree as follows:

AGREEMENT

ARTICLE 1. DEFINITIONS

In addition to terms defined elsewhere in this Agreement, the following terms shall have the following meanings:

1.1 "**Administrator**" means AISLIC or such successor entity designated as the Administrator of the "SF Escrow 1" in the "Coverage and Claims Settlement Agreement."

1.2 **"Agreement"** means this "Castaic Lake Water Agency Litigation Settlement Agreement."

1.3 **"Agreement Date"** means April 6, 2007.

1.4 "**AISLIC**" means American International Specialty Lines Insurance Company, which issued Pollution Legal Liability Select/Cleanup Cost Cap, policy no. PLS 267-9186 (the "AISLIC Policy") to Defendant Whittaker Corporation and is the entity presently designated as the Administrator of the "SF Escrow 1" in the "Coverage and Claims Settlement Agreement."

1.5 "**AISLIC Future Perchlorate Determination of Coverage**" means a coverage determination by AISLIC satisfactory to Whittaker, at its discretion exercised in good faith, agreeing to provide coverage with respect to a "**Non-Subject Well Future Perchlorate Circumstance"** in response to the demand for coverage delivered by Whittaker as set forth in Section 10.1.1 below.

1.6 **"Allowed Claim"** has the meaning set forth in Section 12.1.5, below.

1.7 **"Alluvial Aquifer**" means the shallow (typically, 50 to 200 feet of saturated thickness), generally unconfined aquifer consisting of unconsolidated fluvial sand and gravel within the valleys and canyons of the Santa Clarita Valley. The Alluvial Aquifer unconformably overlies the Saugus Formation.

1.8 **"Annual Project O&M Deposit"** has the meaning set forth in Section 5.2.1.

1.9 **"Approved Capital Costs"** has the meaning set forth in Section 6.2.1, below.

1.10 **"Approved O&M Costs"** has the meaning set forth in Section 6.4.1, below.

1.11 **"Approved Q2 O&M Costs"** has the meaning set forth in Section 6.3.1, below.

1.12 **"Associated Facilities"** means the "Distribution Pipelines" and the "Replacement Wells & Associated Pipelines" (as defined below).

1.13 **"Bankruptcy Court"** has the meaning described in Recital L.

1.14 **"Bankruptcy Court Determinations"** has the meaning set forth in Section 2.4, below.

1.15 **"Bankruptcy Cases"** has the meaning described in Recital L.

1.16 **"BRLLC"** means Bermite Recovery, LLC the owner of approximately 23.6 acres of real property located in the City of Santa Clarita, County of Los Angeles, State of California and as more fully described in Exhibit B.

1.17 **"BRLLC Property"** has the meaning fully described in Exhibit B.

1.18 **"Buyer"** has the meaning fully described in Recital L.

1.19 **"CGL Policy"** has the meaning set forth in Section 11.1.1.

1.20 **"CLWA"** means Castaic Lake Water Agency.

1.21 **"Commencement of Operations"** means commencement of the operation to purvey water to the public from the Project or **"Q2 Treatment System" (as defined below)**, as the case may be. The Parties agree that Commencement of Operations for the Q2 Treatment System was October 12, 2005 ("Q2 Commencement Date").

1.22 **"Consent Order"** has the meaning fully described in Recital E.

1.23 **"Counter-Claims"** has the meaning fully described in Recital C

1.24 **"Coverage and Claims Settlement Agreement"** means the Settlement Agreement by and between the "RFI Parties", the "Zurich Companies", the "AISLIC Parties", and "Whittaker" (as those terms are defined in the Coverage and Claims Settlement Agreement) that provides for certain funding for this Agreement, and that was filed in the Bankruptcy Cases on November 15, 2005 and approved as modified by the Bankruptcy Court's Order Approving Coverage and Claims Settlement Agreement dated December 22, 2005 (the "Coverage Order").

1.25 **"Day"** or **"day"** means a calendar day unless expressly stated to be a Working Day.

1.26 **"Debtors"** means SCLLC and RFI.

1.27 **"Defendants"** means Whittaker, SCLLC and RFI, collectively.

1.28 **"Distribution Pipelines"** means construction of certain new distribution pipelines as described in Exhibit C.

1.29 **"DTSC"** means the California Environmental Protection Agency, Department of Toxic Substances Control as referred to in Recital D.

1.30 **"Earthquake Policy"** has the meaning set forth in Section 11.1.1.

1.31 **"EIL Policy"** has the meaning set forth in Section 11.1.1.

1.32 **"Effective Date"** has the meaning set forth in Section 2.1

1.33 **"Enforceable Agreement"** refers to that certain 2001 Enforceable Agreement made by SCLLC and DTSC, as described in Recital E, above.

1.34 **"EOA"** means the Environmental Oversight Agreement as referred to in Recital D.

1.35 "**Escrow Accounts**" means the "Project Capital Costs Escrow Account", the "Project O&M Escrow Account", the "Replacement Wells/Distribution Pipelines Escrow Account", and the "Q2 Escrow Account," (all as hereinafter defined.)

1.36 **"Final Approval Order"** has the meaning set forth in Section 2.1.

1.37 **"First Amendment"** has the meaning described in Recital F.

1.38 **"Good Faith Certifications"** has the meaning set forth in Section 2.1.1.

1.39 **"Initial Project Capital Costs Deposit"** has the meaning set forth in Section 4.4.

1.40 **"Interim Agreement"** has the meaning described in Recital F.

1.41 **"JAMS"** means Judicial Arbitration and Mediation Service.

1.42 **"Lump Sum Determination"** has the meaning set forth in Section 5.2.6.

1.43 **"MCL"** means Maximum Contaminant Level as set forth in Section 9.1.1.

1.44 **"NCWD"** means Newhall County Water District.

1.45 **"Order"** refers to that certain Imminent and Substantial Endangerment Determination and Order and Remedial Action Order described in Recital E.

1.46 **"Parties"** means Plaintiffs and Defendants and AISLIC, collectively.

1.47 **"Plaintiffs"** means Castaic Lake Water Agency ("CLWA"), Santa Clarita Water Company ("SCWC"), Newhall County Water District ("NCWD") and Valencia Water Company ("VWC"), collectively.

1.48 **"Plaintiffs' Past Environmental Claims"** means any claim for costs, including response costs, damages, attorneys and consultant fees, replacement water costs, and costs for remedial investigations, monitoring and litigation incurred by Plaintiffs prior to the Effective Date of this Agreement due to contamination of the Subject Wells or contamination of or threatened releases to groundwater at and in the vicinity of the Site; provided, however, that certain costs associated with Saugus 1 & 2 Treatment System, Replacement Wells and Associated Pipelines, and Distribution Pipelines, incurred prior to February 1, 2007, as set forth in Exhibit E to this Agreement (**"Plaintiffs' Past Design Costs"**) or incurred after January 31, 2007 and included within Project Capital Costs pursuant to Section 1.54, are excluded from Plaintiffs' Past Environmental Claims.

1.49 **"Plaintiffs' Past Design Costs"** means certain costs associated with Saugus 1 & 2 Treatment System, Replacement Wells and Associated Pipelines, and Distribution Pipelines, incurred by Plaintiffs prior to February 1, 2007, as set forth in Exhibit E to this Agreement.

1.50 **"Presently Existing Saugus Production and Alluvial Production Wells"** means the wells identified in Exhibit U, including wells replaced in the normal course of system operations in the immediate vicinity of the respective Presently Existing Saugus Production and Alluvial Wells.

1.51 **"Pro Forma Estimate of Project O&M"** has the meaning as set forth in Section 5.1.1 and is attached hereto as Exhibit D. **"Joint Estimate of Project O & M"** has the meaning as set forth in Section 5.2.1.

1.52 **"Project"** means:

1.52.1 The planning, development, design, permitting, construction, operation and maintenance of a system to be installed at the existing Rio Vista Intake Pump Station site for treatment of (i.e., removal of perchlorate from) water pumped from Saugus 1 and 2, so that the water will be available for potable purposes; any necessary operational modifications at the Saugus 1 and 2 Wells; any necessary "Sentry Wells" (as defined below) and/or monitoring wells, to the extent not paid for by other sources and to the extent consistent with applicable regulatory requirements; associated piping at the pump station; and the pipeline from Saugus 1 to Saugus 2 to the treatment plant, described more fully in Exhibit F hereto (the "Saugus 1 & 2 Treatment System"). The Parties through the monthly technical meetings will determine what Sentry Wells and/or monitoring wells may be required, provided that if the technical committee is unable to reach agreement on the number of or need for such wells, and if additional wells are required by DHS or other regulators, the number of and/or need for such wells will be determined by the Cost Consultant in accordance with Article 7.

1.52.2 The **"Q2 Treatment System"** (as defined below), when it has been relocated and incorporated into the Project pursuant to a Q2 Treatment System Relocation as provided in Section 4.2.1 herein.

1.53 **"Project Modification Notice"** has the meaning set forth in Section 9.1.2.

1.54 "**Project Capital Costs**" means the reasonable and necessary costs associated with the planning, development, design, permitting, construction, installation and/or closure of the Project, including such costs incurred after January 31, 2007, but prior to the Effective Date.

1.55 **"Estimate of Project Capital Costs"** means the estimate of the capital costs for the Project as set forth in Exhibit G.

1.56 **"Project Capital Costs Escrow Account"** means the escrow account into which Defendants shall deposit or cause to be deposited the initial amount of five million dollars ($5,000,000), to be used for the purposes described in Section 1.52 of this Agreement. Additional deposits by Defendants into the Project Capital Costs Escrow, up to a maximum additional amount of five million dollars ($5,000,000), may be required as described in Section 4.4 of this Agreement for the purposes set forth in Section 1.52 of this Agreement. Within thirty (30) days after Bankruptcy Court approval of this Agreement, Whittaker, on behalf of all Defendants shall open the "Project Capital Costs Escrow Account" by signing and delivering to City National Bank or other agreed bank escrow instructions substantially in the form of Exhibit H-1 hereto, and depositing the amount of five million dollars ($5,000,000) into said account as described above.

1.57 "**Project Costs**" means Project Capital Costs and Project O&M Costs, including costs arising from a Project Modification, to the extent provided in this Agreement.

1.58 **"Project Modification"** has the meaning set forth in Article 9.

1.59 "**Project O&M Costs**" means the identifiable reasonable and necessary costs actually incurred in operating and maintaining the Project to perform its intended function of providing containment of perchlorate as defined in Section 9.1 of this Agreement and restoring impacted groundwater production capacity, which shall be estimated in an annual estimate to be prepared

by CLWA and agreed to by Whittaker and AISLIC or confirmed by the Cost Consultant, unless and until all Lump Sum determinations are made pursuant to Sections 5.2.6 and 9.1.7 or the applicable regulatory authorities determine that treatment is no longer necessary. Costs of operations and maintenance of the Project incurred by Plaintiffs, limited to such reasonable and necessary additional costs directly related to the perchlorate contamination, shall include (based upon the Project as currently contemplated):

Saugus 1 and 2 Treatment Plant Operations and Maintenance

- Vendor Resin Service Contract(s) – (Replacement Resin, Labor, Transportation, Disposal, Disposal Certification, Insurance)-to be negotiated with Vendor jointly by Plaintiffs, Defendants, and AISLIC

- Power – Treatment Plant Operations, including the costs to pump water from Saugus 1 and 2 and, if applicable, Q2 (after relocation) through the treatment system, but excluding the power costs to pump water to the ground surface and the power costs to pump treated water into the CLWA's or VWC's water system. These power costs shall be based on an allocation calculated by CLWA and approved by Whittaker and AISLIC, and subject to Cost Consultant determination in the event that agreement cannot be reached.

- Materials/Supplies
  - Disinfection (Ammonia) and acid
  - Filters
  - Miscellaneous

- Spare Parts
  - Treatment Equipment
  - Pumping and Piping Systems at Treatment Plant
  - Miscellaneous

- Plaintiffs' Labor, if not performed by outside contractor – salary plus actual benefit load (but not-to-exceed 42%) imposition above his/her normal salary:
  - District Employee, Operations Monitoring/Sampling
  - District Employee, Treatment Equipment Maintenance

- Expenses
  - Water Testing (Directly Related to 97-005 Compliance or process monitoring at Purveyor's Rate Schedule)
  - DHS and POTW Fees
  - Miscellaneous Directly Related to Treatment System Maintenance

- Outside Consultants
  - Permits/Renewals
  - Services in addition to those of the Plaintiffs' employee(s) required to meet obligations under Section 8.3.1.1, 8.3.2.3, 8.3.2.4, and 8.4.1, to the extent such employee(s) are not able to meet such obligations
  - Reports/Compliance
  - Engineering
  - Modeling (Directly Related to 97-005 Compliance)
  - Legal (Directly Related to 97-005 Compliance and Plant Operations), limited to the services provided by law firm(s) employed by Plaintiffs for such DHS compliance and plant operations matters, and at the rates such firm(s) normally charge for such work.
  - Insurance – (Insurance as provided in Article 11)

- Arbitrator (per Section 13.2) and Cost Consultant Costs and Fees (per Article 7)
- Project O&M Escrow Costs and Fees

Project O&M costs shall also include an annual flat payment of twenty thousand dollars ($20,000) (to be adjusted after five years as necessary to account for inflation) in lieu of the following activities and costs: Plaintiffs' Employee(s) to provide services under Sections 8.3.1.1, 8.3.2.3, 8.3.2.4, and 8.4.1; any wages or salaries related to the perchlorate contamination plus all benefit load imposition above his/her normal salary; any additional costs for such employee(s) associated with the monitoring, reporting and record-keeping activities described in Section 8.3.1.1, 8.3.2.3, and 8.3.2.4 of this Agreement that are related to the perchlorate contamination; and any Plaintiffs' Employee(s) costs incurred by Plaintiffs in connection with the Monthly Technical Meetings described in Section 8.4.1 of this Agreement.

Project O&M Costs shall also include the identifiable reasonable and necessary costs of operating and maintaining the Q2 Treatment System when it is relocated from Well Q2 and incorporated into the Project as provided for in Section 4.2.1, monitoring and laboratory services for necessary Sentry Wells and monitoring wells encompassed within the Project to the extent not paid for by other sources and to the extent consistent with applicable regulatory requirements**,** and Project Modification O&M costs, including any costs of evaluating containment for purposes of determining whether a Project Modification is appropriate. The costs and approach of evaluating containment shall be discussed and agreed upon by representatives of Plaintiffs, Whittaker and AISLIC at the monthly Technical Meetings, or determined by Cost Consultant. Prior to determination of the Lump Sum pursuant to Section 5.2.6, Project O&M Costs will also include the reasonable and necessary outside fees and costs

incurred by Plaintiffs and Whittaker that are directly related to the perchlorate contamination and to obtaining funding from Public Funding Sources, subject to an annual cap of two hundred thousand dollars ($200,000) on Plaintiffs' outside fees and costs and one hundred thousand dollars ($100,000) on Whittaker's outside fees and costs, subject to such other restrictions as are found in Section 14.2, below. Fees and costs incurred by Plaintiffs or to be incurred by Plaintiffs in the future that are associated with obtaining funding from **"Public Funding Sources"** (as defined below) will not be considered in the determination of the Lump Sum pursuant to Section 5.2.6 and 9.1.7.

1.60 **"Project O&M Escrow Account"** means the escrow account established and funded by Defendants for payment of Project O&M Costs as described in Section 6.4 of this Agreement.

1.61 **"Property Policy"** has the meaning set forth in Section 11.1.1.

1.62 **"Proofs of Claim"** has the meaning set forth in Section 12.1.5.

1.63 **"Public Funding Sources"** has the meaning set forth in Article 15.

1.64 **"Q2 Capital Costs"** means the costs set forth in Exhibit I which were incurred by VWC for the design and installation of the Q2 Treatment System, all of which have been approved and reimbursed by Defendants.

1.65 **"Q2 Escrow Account"** has the meaning set forth in Section 4.1.

1.66 **"Q2 Escrow Account Instructions**" means the Escrow Instructions for the Q2 Capital Costs Escrow Account attached as Exhibit J hereto, as amended as reflected in Exhibits K-1 and K-2.

1.67 **"Q2 O&M Costs"** means the reasonable and necessary costs actually incurred in operating and maintaining the Q2 Treatment System prior to relocation and incorporation into the Project as provided in Section 4.2.1, as set forth in the Estimate of Q2 O&M Costs, and not

to exceed nine thousand and three hundred dollars ($9,300) on average per month for the first 2 years following Commencement of Operations, except in the event of a **"Q2 Resin Exchange,"** (as defined below). Costs of operation and maintenance of the Q2 Treatment System shall include, but not be limited to, equipment rental, service fees, chemicals, monitoring, laboratory services, and resin replacement related to the treatment of perchlorate and flow rates currently permitted by DHS for the Q2 Treatment System.

1.68 "**Estimate of Q2 O&M Costs**" means the approved monthly operations and maintenance estimate for Q2 O&M Costs for the first two years after Commencement of Operations prior to relocation and incorporation into the Project, set forth in Exhibit L.

1.69 **"Q2 Resin Exchange"** means the removal of ion exchange resin which VWC determines is no longer capable of performing its intended function from the ion exchange vessels and replacement with new resin, and includes but is not limited to, transportation of the spent and new resin, and proper destruction of the spent resin in accordance with applicable regulations.

1.70 **"Q2 Semi-Annual O&M Statement"** has the meaning set forth in Section 6.3.2.

1.71 **"Q2 Treatment System**" means the construction, operation and maintenance of a system installed in October 2005 for treatment of (i.e., removal of perchlorate from) water pumped from Valencia's well Q2.

1.72 **"Q2 Treatment System Relocation"** means the relocation of the Q2 Treatment System as described in Section 4.2.1.

1.73 **"Rapid Response Funds"** means the funds, limited to ten million dollars ($10,000,000), available to Plaintiffs for the period of time set forth in Section 11.2.1 of this Agreement, which the Defendants shall cause to be paid to Plaintiffs on a demand basis in accordance with Section

11.2 of this Agreement, as a result of specified perchlorate impacts to “Threatened Wells” (as defined herein).

1.74 **“Related Settlement”** has the meaning set forth in Recital N.

1.75 **“Remedial Action Plan”** means a technical report prepared in accordance with Section 25356.1 of the California Health and Safety Code and which, at a minimum, addresses the remedial investigation, risk assessment, and evaluation of remedial alternatives and proposes a remedial alternative.

1.76 **“Remedy Stoppage”** means a cessation of Project operations under circumstances requiring a Project Modification.

1.77 **“Replacement Wells & Associated Pipelines”** means:

1.77.1 Two new wells capable of producing water at the combined rate of 4200 gpm (**“Replacement Wells**”) and associated pipeline to convey the water pumped from the Replacement Wells to a nearby reservoir and associated disinfection facility (**“Associated Pipelines”**). As currently contemplated, the Replacement Wells will be constructed in the vicinity of Magic Mountain Amusement Park and the Associated Pipelines will consist of approximately 1000 feet of a 12 inch pipeline and 2500 feet of 18 inch pipeline, as described more fully in Exhibit M hereto (the **“Magic Mountain Wells”)**;

1.77.2 Potential closure and abandonment of the Stadium Well, in SCWC’s reasonable discretion, and NC11, in NCWD’s reasonable discretion, described more fully in Exhibit N hereto (the "Well Closures");

1.77.3 Construction of a new alluvial well (the **"Stadium Replacement Well"**), to be located northeast of the Site in an alluvial area where perchlorate is not present in groundwater, and associated pipeline(s), described more fully in Exhibit O hereto.

1.78 **"Replacement Wells/Distribution Pipelines Capital Costs Escrow Account**" means the escrow account into which Defendants shall make an initial deposit of four million seven hundred and fifty thousand dollars ($4,750,000), to be used for the purposes described in Section 4.3 of this Agreement. Additional deposits by Defendants into the Replacement Wells/Distribution Pipelines Capital Costs Escrow Account may be required for Replacement Wells/Distribution Pipelines Capital Cost additional costs as described in Section 4.3 of this Agreement and for the purposes set forth therein. These additional deposit(s) shall be paid as described in Section 4.3.3. Within thirty (30) business days after Bankruptcy Court approval of this Agreement, Whittaker, on behalf of all Defendants, shall open the "Replacement Wells/Distribution Pipelines Capital Costs Escrow Account" by signing and delivering to City National Bank or other agreed bank escrow instructions substantially in the form of Exhibit P hereto, and depositing the amount of $4,750,000 into said account as described above.

1.79 **"Response Costs"** means "response costs" as defined under CERCLA.

1.80 **"RFI"** means Remediation Financial, Inc.

1.81 **"RFI Parties"** means Santa Clarita L.L.C. ("SCLLC") and Remediation Financial, Inc. ("RFI"), collectively.

1.82 **"Saugus Formation"** means the generally deeper (up to 8,500 feet thick) formation of aquifers consisting of semi-consolidated sandstone, siltstone and conglomerate of Pleistocene age and occurs under confined, semi-confined and unconfined conditions.

1.83 **"SCLLC"** means Santa Clarita L.L.C.

1.84 **"SCLLC Property"** has the meaning described in Exhibit A.

1.85 **"SCWC"** means Santa Clarita Water Company.

1.86 **"Sentry Wells"** means groundwater monitoring wells located upgradient of the Subject Wells.

1.87 **"Site"** means the SCLLC Property and the BRLLC Property collectively

1.88 **"Steadfast PLC Policy"** means the Property Transfer Liability Policy Number PLC 3598792-00 issued by Steadfast Insurance Company ("Steadfast") to the Defendants.

1.89 **"Subject Wells"** has the meaning referred to in Recital B of this Agreement.

1.90 The "**SF Escrow 1 Account**" and the "SF Escrow 1" means the "SF Escrow 1" or "SF Escrow 1 Account" as defined in, established, and governed by the Coverage and Claims Settlement Agreement and the "Joint Escrow 1 Agreement and Instructions (Steadfast Escrow 1 Account)" filed in the Bankruptcy Cases on March 31, 2006.

1.91 The "**SF Escrow 2 Account**" means the "SF Escrow 2" or "SF Escrow 2 Account" as defined in, established, and governed by the Coverage and Claims Settlement Agreement and the "Joint Escrow 2 Agreement and Instructions (Steadfast Escrow 2 Account)" filed in the Bankruptcy Cases on March 31, 2006.

1.92 **"Steadfast"** means Steadfast Insurance Company.

1.93 **"SSCH"** means Steadfast Santa Clarita Holdings, LLC.

1.94 **"Estimate of Supplemental Project O&M"** has the meaning set forth in Section 5.2.3.

1.95 **"Third Party Claims"** has the meaning set forth in Section 12.1.1.

1.96 **"Threatened Wells"** has the meaning set forth in Section 11.2.1.

1.97 **"Underlying Action"** has the meaning referred to in Recital C of this Agreement.

1.98 "**V-206 Replacement Well"** means construction and installation of VWC's well V206 and associated pipelines, and permanent closure and abandonment of VWC's well V157 as described in Exhibit Q.

1.99 **"VWC"** means Valencia Water Company.

1.100 **"Whittaker"** means Whittaker Corporation.

1.101 "**Working Day**" means a day other than a Saturday, Sunday, or federal or California state holiday.

ARTICLE 2. COURT APPROVALS AND RELATED SETTLEMENTS

2.1 Final Bankruptcy Court Approval Order and Good Faith Certifications Required

Except for this Section which is effective upon execution of this Agreement by all Parties, this Agreement, including the Parties' promises, obligations, releases, representations and warranties under this Agreement, shall take effect on the later of the date of the Final Approval Order (as defined below) or the date of the "Good Faith Certifications" (as defined below) ("the **Effective Date**") and is absolutely contingent upon the entry of an order of the Bankruptcy Court that approves this Agreement in its entirety without any modifications and contains the Bankruptcy Court Determinations referenced below, and that has become effective and as to which no stay pending appeal has been issued ("**Final Approval Order**") and such order not being subject to any stay.

2.1.1 This Agreement, and the settlement of claims reflected herein, is absolutely contingent upon (i) court certification that such settlement is made in good faith, and (ii) a settlement of, or the dismissal with prejudice of, all of the claims asserted in the Counter-Claims (the "**Related Settlement**") and court certification of the Related Settlement as being made in good faith (collectively, the "**Good Faith Certifications**"). The court's order(s) setting forth the Good Faith Certifications shall at a minimum provide that "any and all claims against the settling Defendants and the settling counter-defendants, arising out of the matters addressed in the Underlying Action or addressed in the Related Settlement, regardless of when asserted or by whom, are barred; such claims are barred regardless of whether they are brought pursuant to

CERCLA, or pursuant to common law or other federal or state laws," or language substantially to the same effect.

2.1.2 This Agreement shall be null and void *ab initio*, and the Parties shall be returned to their respective positions in all aspects, if either (a) the Related Settlement, Good Faith Certifications and Final Approval Order have not all been obtained before October 31, 2007 for any reason; or (b) the Bankruptcy Court denies a motion to approve this Agreement as written or (c) a court denies a motion for good faith certification of either this Agreement, the Related Settlement or both, as written. RFI Parties, at their sole cost and expense, shall prepare and file a motion with the Bankruptcy Court in a form satisfactory to all Parties seeking the Final Approval Order promptly after the Agreement's execution by all Parties. RFI Parties' motion for a Final Approval Order shall include a request that the Bankruptcy Court in its Final Approval Order make the Bankruptcy Court Determinations in accordance with the requirements set forth in Section 2.4 of this Agreement.

2.1.3 All other Parties shall support the entry of the Final Approval Order and shall cooperate with RFI Parties in presenting the motion seeking approval. The Parties shall cooperate in preparing and filing motions with the District Court seeking the Good Faith Certifications. To the extent required under CERCLA or applicable federal law, the Parties agree to cooperate in obtaining approval of a United States District Court having appropriate jurisdiction (the "**District Court**") as necessary to ensure enforceability of the terms and intent of this Agreement (including but not limited to asking the Bankruptcy Court to certify its findings and/or conclusions regarding certain issues to such District Court).

2.2 Plaintiffs' Reservation of Rights Against Buyer

Plaintiffs specifically reserve all rights against Buyer with regard to Buyer's compliance with all environmental laws and performance of any applicable remediation obligations, subject only to the terms of Section 12.1 hereof.

2.3 Plan Filed by Debtors

If a Final Approval Order is entered by the Bankruptcy Court in the Bankruptcy Cases, then any plan filed by the Debtors in the Bankruptcy Cases ("**Plan**") shall not be materially inconsistent with the terms of this Agreement and the Final Approval Order.

2.4 Final Approval Order Provisions

Debtors and all other Parties hereto acknowledge and agree, and the Final Approval Order shall provide that (a) funds in SF Escrow 1 Account were, pursuant to the Coverage Order, already earmarked for the purposes of satisfying Defendants' obligations pursuant to this Agreement; (b) the requirement that the funds in SF Escrow 1 Account be used exclusively for the purposes for which they are agreed to be used pursuant to the Coverage and Claims Settlement Agreement as modified by the Coverage Order (which are consistent with the purposes for which those funds are to be used pursuant to this Agreement) is res judicata in the Debtors' Bankruptcy Cases; (c) payment of obligations under this Agreement, upon entry of the Final Approval Order, constitutes the permitted use of SF Escrow 1 funds to "fund settlement or a stipulated judgment pursuant to a settlement in the CLWA Case" that meets all of the "Approved CLWA Settlement Parameters" as provided in paragraph IV.F.5.a.(i) of the Coverage and Claims Settlement Agreement as modified by the Coverage Order and as described in Exhibit 16 thereto and such payments pursuant to this Agreement shall constitute, and shall be deemed to be consistent with the requirements for the administration of the SF Escrow 1 funds

by AISLIC pursuant to Section IV.F.5.d. of the Coverage and Claims Settlement Agreement as modified by the Coverage Order; (d) any payment or transfers of funds to or for the benefit of Plaintiffs from SF Escrow 1 Account that are consistent with this Agreement are free and clear of all other adverse claims, rights, title, interest, liens or encumbrances of any kind whatsoever that could be asserted against any property or interest of the Debtors; and (e) the Agreement is a complex agreement resolving numerous disputes and pending legal proceedings among numerous parties and that following the Effective Date, it will be practically and legally impossible to unwind this Agreement or restore the parties to their status quo based upon any reversal or modification on appeal or rehearing or other review; (f) upon entry of the Final Approval Order, the Defendants' payment obligations under this Agreement including any sum awarded pursuant to arbitration hereunder, may be made from the SF Escrow 1 Account; and (g) either i) the terms of the Agreement and Related Settlement are fully consistent with the terms of the SunCal Purchase and Sale Agreement and Joint Escrow Instructions dated July 6, 2006, or ii) that the Buyer consents to the Agreement and the Related Settlement to the extent there is any inconsistency. (Subparagraphs (a) through (g) above required to be included in the Final Approval Order are referred to herein as the "Bankruptcy Court Determinations.") The Final Approval Order shall also provide that the Order applies to any successor Administrator of the "SF Escrow 1" in the "Coverage and Claims Settlement Agreement."

2.5 Plaintiffs' Recourse Against Debtors

Plaintiffs' recourse to (i) enforce all of Debtors' obligations under this Agreement and (ii) for any and all actions, causes of action, claims, demands, liabilities, damages, penalties, debts, losses, costs, expenses and fees (including, without limitation, litigation costs and attorney and consultant fees) of every kind and nature whatsoever, past or future, in law and in equity against

the Debtors and BRLLC arising from or in any way related to releases or threatened releases, or other environmental conditions, past or future, at or around the Site is expressly and completely limited to Debtors' rights to use, and title and interest in, the SF Escrow 1 Account established pursuant to the Coverage and Claims Settlement Agreement and the "Joint Escrow 1 Agreement and Instructions (Steadfast Escrow 1 Account)". Plaintiffs' rights against Debtors are not waived in the Bankruptcy Cases to the extent of Debtors' rights, title and interest in the SF Escrow 1 Account.

ARTICLE 3. PAYMENTS DIRECTLY TO PLAINTIFFS

3.1 Payment for Plaintiffs' Past Environmental Claims

Within thirty (30) Days after the Effective Date, Defendants shall pay the amount of ten million dollars ($10,000,000) by payment of the amount of two million five hundred thousand dollars ($2,500,000) to each of the four Plaintiffs. The obligation to make such payments shall be joint and several, subject to Section 2.5. This payment is in full and complete satisfaction and resolution of Plaintiffs' Past Environmental Claims.

3.2 Payment for Plaintiffs' Past Design Costs

Within thirty (30) Days after the Effective Date, Defendants shall pay the amount of one million seven hundred fifty three thousand one hundred fourteen dollars and fifty-eight cents ($1,753,114.58) to CLWA. The obligation to make such payment shall be joint and several, subject to Section 2.5. This payment is in full and complete satisfaction and resolution of Plaintiffs' Past Design Costs, as set forth in Exhibit E to this Agreement.

3.3 Payment to VWC

Within thirty (30) Days after the Effective Date, Defendants shall pay to VWC one million dollars ($1,000,000). The obligation to make such payment shall be joint and several, subject to Section 2.5. This payment is in full and complete satisfaction and resolution of

Plaintiffs' claims in the Underlying Action for V-206 Replacement Well, including, but not limited to, construction and installation of VWC's well V206 and associated pipelines, and permanent closure and abandonment of VWC's well V157, as described in Exhibit Q.

ARTICLE 4. FUNDING OF Q2 COSTS, REPLACEMENT WELL/DISTRIBUTION PIPELINE CAPITAL COSTS AND PROJECT CAPITAL COSTS

4.1 Funding of Q2 Capital Costs and Q2 O&M Costs

Plaintiffs acknowledge that Defendants previously have caused to be deposited into the "**Q2 Escrow Account**" five hundred thousand dollars ($500,000) for reasonable and necessary and approved Q2 Capital Costs. This payment is in full and complete satisfaction and resolution of Plaintiffs' claims for the capital costs associated with the Q2 Treatment System. Plaintiffs acknowledge that Defendants previously have caused to be deposited into the "Q2 Escrow Account" two hundred twenty three thousand and two hundred ten dollars ($223,210) for certain reasonable and necessary and approved Q2 O&M Costs. This payment is in partial satisfaction and resolution of Plaintiffs' claims for the operations and maintenance costs associated with the Q2 Treatment System. Construction of the Q2 Treatment System has been completed and all Q2 Capital Costs associated with the Q2 Treatment System have been approved and paid by or on behalf of Defendants as of the Effective Date.

A copy of the Q2 Escrow Account Instructions is attached hereto as Exhibit J and incorporated herein by this reference. Copies of Amendments No. 1 and No. 2 to the Q2 Escrow Account Instructions are attached hereto as Exhibit K-1 and Exhibit K-2, respectively and incorporated herein by this reference. Any amounts, including interest, remaining in the Q2 Escrow Account as of the Effective Date shall be used by Plaintiffs for Q2 O&M Costs, and credited against Defendants' obligations for funding Q2 O&M Costs as set forth in Section 4.1.1 below.

4.1.1 The Q2 Treatment System commenced operations on October 12, 2005 ("Q2 Commencement Date"), and VWC has been incurring Q2 O&M Costs for the Q2 Treatment System since that date.

4.1.1.1 During the period prior to October 12, 2007, VWC's withdrawal of funds for Q2 O&M Costs shall not exceed nine thousand and three hundred dollars ($9300) on average per month except in the event of a Q2 Resin Exchange and except for reimbursement of any Q2 O&M Costs that have been incurred prior to the Effective Date and not previously paid out of the Q2 Escrow Account.

4.1.1.2 In the event Commencement of Operation of the Project has not occurred as of October 12, 2007, and the Q2 Treatment System must still be operated pursuant to applicable regulatory requirements, Defendants shall pay or cause to be paid an additional deposit of one hundred eleven thousand and six hundred dollars ($111,600) on or before October 12, 2007, to be used for Q2 O&M Costs. In the event Commencement of Operation of the Project has not occurred as of October 12, 2007, and the Q2 Treatment System must still be operated pursuant to applicable regulatory requirements, Defendants shall pay or cause to be paid additional reasonable and necessary Q2 O&M Costs until the Q2 Treatment System is relocated as provided in Section 4.2.1. After October 12, 2007, VWC may withdraw funds on a monthly basis as is reasonably necessary.

4.1.1.3 Defendants shall pay or cause to be paid into the existing Q2 Escrow Account an additional amount of one hundred sixty seven thousand and five hundred dollars ($167,500), or such other amount as may be agreed by the Defendants or determined by the Cost Consultant in accordance with Article 7, in the event a determination is made by VWC in accordance with its operating permit and upon agreement by Whittaker and AISLIC, that

replacement of the treatment resins used in the Q2 Treatment System is necessary. Such deposit shall be made within 10 days after VWC's written notice of determination and request for funding has been delivered to Defendants. Any dispute regarding such determination by VWC shall be resolved by the Cost Consultant in accordance with Article 7.

4.1.2 Defendants' obligations hereunder for deposits required to be made into the Q2 Escrow Account shall be on a joint and several basis subject to Section 2.5.

4.1.3 Any amounts, including interest, remaining in the Q2 Escrow Account upon Q2 Treatment System Relocation to the location of the Project shall be refunded into the SF Escrow 1 Account (as defined in the Coverage and Claims Settlement Agreement.).

4.1.4 Payments from the Q2 Escrow Account shall be made on a monthly basis in accordance with the procedures set forth in Article 6 and the applicable Q2 Escrow Account instructions.

4.1.5 Defendants and AISLIC shall not be entitled to withdraw any funds from the Q2 Escrow Account or to direct or control the payment of such funds, and shall have no rights with respect to such funds, except as provided in this Agreement.

4.1.6 Payments for Q2 O&M Costs shall continue until the date that VWC and CLWA are required to relocate and integrate the Q2 Treatment System into the Project pursuant to Section 4.2.1 or until treatment of Well Q2 is no longer required by DHS, whichever occurs first. The Q2 Escrow Account shall terminate following written notification from Plaintiffs that the Q2 Treatment System has been integrated into the Project or written notification from Plaintiffs or Cost Consultant or arbitrator determination that treatment of Well Q2 is no longer required by DHS, provided that payment has been made for all Q2 Capital Costs and Q2 O&M

Costs permitted to paid from the Q2 Escrow Account in accordance with the procedures set forth in this Agreement.

4.2 Termination of the Q2 Treatment System Operations

4.2.1 VWC shall undertake to terminate operation of the Q2 Treatment System as soon as reasonably feasible, in accordance with requirements of the California Department of Health Services (DHS). In connection with the construction of the Project, Plaintiffs shall incorporate the Q2 Well and the Q2 Treatment System into the Project, notwithstanding any prior determination that the treatment at Q2 Well is no longer required, so as to enable the Saugus 1&2 Treatment System to treat Q2 water in case the Q2 Well subsequently becomes recontaminated. In connection with the construction of the Project, VWC and CLWA shall incorporate the Q2 Well and the Q2 Treatment System into the operation of the Project not later than (i) two (2) years after the Q2 Commencement Date or (ii) the Commencement of Operations of the Project, whichever is later. Upon relocating operation of the Q2 Treatment System, VWC and CLWA shall transfer the treatment vessels used as part of the Q2 Treatment System to the location of the Project and incorporate the use of those vessels into that system. Upon terminating or relocating operation of the Q2 Treatment System, VWC and CLWA shall transfer the remaining resin used as part of the Q2 Treatment System to the location of the Project and incorporate the unused resin into that system.

4.2.2 The obligation to pay Q2 O&M Costs for the Q2 Treatment System pursuant to Section 4.1.1 of this Agreement shall cease either (i) upon written notification from Plaintiffs or Cost Consultant or arbitrator determination that treatment of Well Q2 is no longer required by DHS; or (ii) upon written notification from Plaintiffs that the Q2 Treatment System has been integrated with the Project and that the Q2 O&M Costs will be included in the Project

O&M Costs and handled in accordance with Article 5, which notice shall not occur later than (i) two (2) years after the Q2 Commencement Date or (ii) the Commencement of Operations of the Project, whichever occurs later. If, after a determination that treatment at well Q2 is no longer required, well Q2 becomes re-contaminated so as to require treatment, said treatment will be handled by means of the Project, and the costs thereof shall be Project O&M Costs.

4.2.3 Any dispute as to whether treatment of water pumped from Q2 can be discontinued or should be recommenced shall be resolved through binding Cost Consultant arbitration, as provided in Article 7 of this Agreement, provided that the arbitration decision must be consistent with the requirements of all regulatory agencies with jurisdiction regarding perchlorate.

4.3 Replacement Wells/Distribution Pipeline Capital Costs Escrow Account

Defendants shall be jointly and severally obligated subject to Section 2.5 to pay for their proportional share of the capital costs associated with the installation of new Distribution Pipelines and Replacement Wells & Associated Pipelines pursuant to this Section 4.3. CLWA, on behalf of all Plaintiffs, and Whittaker, on behalf of all Defendants, concurrently with execution of this Agreement, shall execute and, thereafter, promptly deliver to City National Bank or other agreed bank instructions for an escrow (the "**Replacement Wells/Distribution Pipeline Capital Costs Escrow Account**") substantially in the form of Exhibit P hereto. Within thirty (30) Days after the Effective Date, Defendants shall make an initial deposit into the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account of four million seven hundred and fifty thousand dollars ($4,750,000) to be used for Distribution Pipelines, and Replacement Wells & Associated Pipelines. The Replacement Wells & Associated Pipelines will provide new Saugus Formation production capacity to replace lost well capacity not

provided by the Project or V-206. The Distribution Pipelines will be connected to various turnouts within the Plaintiffs' system.

4.3.1 The Defendants' initial proportional share of the capital costs associated with the Distribution Pipelines and the Replacement Wells & Associated Pipelines will be based on the Percentage Cost Allocation for Distribution Pipelines and Replacement Wells & Associated Pipelines set forth in Exhibit R and the bid items submitted by the bidder selected through a competitive bidding process in accordance with CLWA bid procedures and applicable law. Whittaker's and AISLIC's technical representatives shall be provided reasonable opportunity to advise and consult on design, engineering, location of well replacement and other technical aspects of the contractor selection and construction process. For bid items that do not have specific cost allocations, the weighted cost allocation of the other bid items shall be applied. During construction, the Plaintiffs and Defendants shall provide the funds necessary to pay the selected contractors in the proportion provided for by the determination of the initial proportional share. Upon completion and Plaintiffs' acceptance of the construction, a true-up of the cost allocation shall be performed. To the extent feasible, the true-up shall apply the cost allocation of Distribution Pipelines and Replacement Wells presented in Exhibit R to the actual costs of the Distribution Pipelines and Replacement Wells, including approved change orders.

4.3.2 The Parties acknowledge that construction of the Replacement Wells and Associated Pipelines, except the drilling of the Replacement Wells, will be deferred until the construction of the extension of Magic Mountain Parkway is initiated.

4.3.3 In the event Defendants' proportional share of capital costs associated with Distribution Pipelines and Replacement Wells & Associated Pipelines exceeds four million and seven hundred fifty thousand dollars ($4,750,000), including all costs of redrilling

Replacement Wells that are not capable of producing water at the required rate, Defendants shall be obligated, on a joint and several basis subject to Section 2.5, to deposit in the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account additional funds sufficient to cover such excess, as reasonably determined by Plaintiffs, subject to approval by Whittaker and AISLIC or determination by the Cost Consultant. Such deposits shall be made by Defendants in a timely manner. The Estimate of Replacement Wells/Distribution Pipeline Capital Costs attached hereto as Exhibit S reflects that Defendants' proportional share of the Replacement Wells/Distribution Pipeline Capital Costs exceeds $4,750,000. However, in the event that cost savings are achieved such that Defendants' proportional share of capital costs associated with Distribution Pipelines and Replacement Wells & Associated Pipelines is less than the amounts deposited by Defendants into the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account, any amounts remaining in the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account shall be refunded into the SF Escrow 1 Account (as defined in the Coverage and Claims Settlement Agreement).

4.3.4 Any dispute regarding the reasonableness, timing or necessity of Replacement Wells/Distribution Pipeline Capital Costs, the selection of the lowest responsive and responsible bid in the competitive bidding process, or the Defendants' appropriate proportional share shall be resolved through Cost Consultant arbitration in accordance with Article 7.

4.4 Project Capital Costs Escrow Account

CLWA, on behalf of all Plaintiffs, and Whittaker, on behalf of all Defendants, concurrently with execution of this Agreement, shall execute and, thereafter, promptly deliver to City National Bank or other agreed bank instructions for an escrow (the **"Project Capital Costs**

Escrow Account") substantially in the form of Exhibit H-1 hereto. Within thirty (30) Days after the Effective Date, Defendants shall, jointly and severally, be obligated to make a deposit into the Project Capital Costs Escrow Account of five million dollars ($5,000,000) (**"Initial Project Capital Costs Deposit"**) to pay Project Capital Costs.

4.4.1 In the event Project Capital Costs exceed the amount of the Initial Project Capital Costs Deposit, Defendants shall deposit in the Project Capital Costs Escrow Account additional funds sufficient to cover such excess, as determined by Plaintiffs, subject to AISLIC and Whittaker approval or determination by the Cost Consultant; but such total additional funds shall not exceed five million dollars ($5,000,000). Defendants shall deposit the additional funds in a timely manner after approval by AISLIC and Whittaker or by the Cost Consultant. The Estimate of Project Capital Costs attached hereto as Exhibit G reflects that Project Capital Costs are projected to exceed five million ($5,000,000). However, in the event that cost savings are achieved such that Project Capital Costs are less than the amounts deposited by Defendants into the Project Capital Costs Escrow Account, any amounts remaining in the Project Capital Costs Escrow Account shall be refunded into the SF Escrow 1 Account (as defined in the Coverage and Claims Settlement Agreement.).

4.4.2 Any dispute regarding the reasonableness, timing or necessity of Project Capital Costs shall be resolved through arbitration in accordance with Article 7.

ARTICLE 5. PAYMENT OF PROJECT O&M COSTS

5.1 Project O&M Escrow Account

5.1.1 Defendants shall be jointly and severally obligated subject to Section 2.5 to pay Project O&M Costs in accordance with the terms of this Agreement. The "*pro forma*" Estimate of Project O&M ("**Pro Forma Estimate of Project O&M**") as of the date of execution of this Agreement is attached hereto as Exhibit D.

5.1.2 CLWA, on behalf of all Plaintiffs, and Whittaker, on behalf of all Defendants, and AISLIC shall, within thirty (30) days after Whittaker and AISLIC's receipt of Plaintiffs' written notice of anticipated commencement of Project operations execute and thereafter, promptly deliver to City National Bank or other agreed bank instructions for an escrow for funds to be used for payment of Project O&M Costs substantially in the form of Exhibit H-2 hereto.

5.1.3 Payments from the Project O&M Escrow Account shall be made on a monthly basis in accordance with the procedures set forth in this Article 5, Article 6, and the applicable escrow instructions, which instructions are subject to approval by Plaintiffs, Whittaker, and AISLIC and shall be consistent with the terms of this Agreement.

5.1.4 Upon termination of the Project O&M Escrow Account in accordance with this Agreement, any balance in that account shall be refunded into the SF Escrow 1 Account. The Project O&M Escrow Account shall terminate upon termination of this Agreement or earlier payment of all Lump Sum awards, provided that payment has been made for all Project O&M Costs in accordance with the procedures set forth in this Agreement.

5.2 Project O&M Costs

5.2.1 Defendants shall fund Project O&M Costs by depositing annually in the Project O&M Escrow Account the annual O&M amounts reasonably estimated by CLWA and modified as reasonably estimated by Defendants and AISLIC, or modified as determined by the Cost Consultant, and reflected in the Joint Estimate of Project O&M jointly prepared by the Parties (which may include determinations of the Cost Consultant). The first annual deposit ("**Initial Project O&M Deposit**") shall be due thirty (30) days after Whittaker's, and AISLIC's receipt of Plaintiffs' written notice of anticipated commencement of Project operations and a

Joint Estimate of Project O&M has been agreed between the Parties or determined by the Cost Consultant for the first year of operations. The initial "Joint Estimate of Project O&M" shall be based upon the Pro Forma Estimate of Project O&M attached as Exhibit D hereto, as modified by CLWA and approved by Defendants and AISLIC or determined by the Cost Consultant. ("**Joint Estimate of Project O&M**") Defendants will reasonably consider and respond to CLWA's proposed modifications to the attached Pro Forma Estimate of Project O&M as provided in this Article 5. The Parties will meet and confer concerning any disputes in preparing the initial Joint Estimate of Project O&M . Subsequent annual O&M deposits (each an **"Annual Project O&M Deposit"**) in the amount of the Joint Estimate of Project O&M for the upcoming year (each a "Joint Estimate of Project O&M") as agreed between the Parties or determined by the Cost Consultant, shall be due on or before the anniversary of the Initial Project O&M Deposit. CLWA will provide Whittaker, AISLIC, and Steadfast with a copy of each of Plaintiffs' proposed Joint Estimate of Annual Project O&M at least seventy-five (75) days prior to the anniversary date of the prior year's Annual Project O&M Deposit.

5.2.2 In the event of Defendants' or AISLIC's objection to any item included or excluded on any of the Plaintiffs' proposed Joint Estimates of Project O&M, Defendants or AISLIC shall notify Plaintiffs of their objection in writing within thirty (30) days after receipt of the proposed estimate, stating the reasons for its objection, and the Parties shall exercise their best efforts to resolve the disputed item(s). In the event that the disputed item is not resolved within fifteen (15) days after Defendants' or AISLIC's notice of objection, the disputed item(s) shall be submitted to the Cost Consultant, for expedited resolution in accordance with Article 7, below. Following meet and confer and any determinations of the Cost Consultant, the Parties

shall jointly prepare the Joint Estimate of Project O&M as agreed among the Parties or determined by the Cost Consultant.

5.2.3 In the event that CLWA determines it will be necessary to supplement the Project O&M Escrow Account in any given year to pay for Project O&M Costs, CLWA shall notify Defendants, AISLIC and Steadfast of its determination and provide an itemized statement, using the same format as the then-current Joint Estimate of Project O&M, of the amount of the supplemental funding **("Estimate of Supplemental Project O&M"**) required to cover the additional Project O&M Costs. In the event of Defendants' or AISLIC's objection to any item included in the Plaintiffs' proposed Estimate of Supplemental Project O&M, Defendants or AISLIC shall notify Plaintiffs of their objection in writing within fifteen (15) days after receipt of the proposed Estimate of Supplemental Project O&M, stating the reasons for its objection, and the Parties shall exercise their best efforts to resolve the disputed item(s). In the event that the disputed item is not resolved within fifteen (15) days after Defendants' or AISLIC's notice of objection, the disputed item(s) shall be submitted to the Cost Consultant for expedited resolution in accordance with Article 7. Defendants shall deposit into the Project O&M Escrow Account the amount of the Estimate of Supplemental Project O&M within ten (10) days after determination of the amount of the Estimate of Supplemental Project O&M by agreement of the Parties or determination of the Cost Consultant.

5.2.4 Subject to the provisions of Section 9.1.7 below, the obligation to pay Project O&M Costs pursuant to this Article 5 shall cease the earlier of (i) the California Department of Health Services (DHS), and any other agency that has asserted jurisdiction and whose agreement is required, agrees that treatment of water pumped from Saugus 1 & 2 can be discontinued; or (ii) thirty (30) years after Commencement of Operations of the Project.

5.2.5 Any dispute regarding the reasonableness, applicability or necessity of Project O&M Costs, except for the issue of whether treatment of water pumped from Saugus 1 & 2 can be discontinued, shall be resolved through binding arbitration, as provided in Article 7 of this Agreement, provided that the arbitration decision must be consistent with the requirements of all regulatory agencies with jurisdiction, and prior to determination of the Lump Sum as described in Section 5.2.6. Any dispute regarding whether treatment of water pumped from Saugus 1 & 2 can be discontinued, shall be resolved through binding arbitration, as provided in Sections 13.1 and 13.2 of this Agreement (unless all Parties agree that the issue may be resolved as provided in Article 7 of this Agreement), provided that the arbitration decision must be consistent with the requirements of all regulatory agencies with jurisdiction, and prior to determination of the Lump Sum as described in Section 5.2.6.

5.2.6 Subject to the provisions of Section 9.1.7 below, beginning five years after Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage), CLWA, Whittaker, or AISLIC may demand binding arbitration, as provided in Article 13 of this Agreement, for purposes of obtaining a determination of a lump sum for payment in lieu of the Project O&M Costs that would otherwise be due and payable during the remainder of the up-to thirty-year period (the "Lump Sum") based on the following criteria:

5.2.6.1 The Lump Sum will be calculated on a net present value basis using appropriate assumptions and techniques, including consideration of risk, activities and costs anticipated to occur after payment of the Lump Sum, and any other factors introduced by the Parties at arbitration and determined to be relevant by the arbitrator, but the Lump Sum shall be calculated on the assumption that the Defendants' obligation to pay for the Project O&M shall

cease not later than thirty years after Commencement of Operations of the Project, except as provided in Section 9.1.7. The Lump Sum determination shall also be based, in part, on consideration of the actual Project O&M Costs experienced prior to arbitration, but excluding any such Project O&M Costs as may have been associated with start-up of the system or otherwise not indicative of future Project O&M Costs. The Lump Sum amount will not include any capital costs, including but not limited to, capital costs of Project Modifications implemented pursuant to Article 9 of this Agreement or any projected or potential capital costs for Project Modifications which become or may become necessary after the first three years following Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage). The Lump Sum amount will not include any lobbying costs or legal fees or costs associated with obtaining funding from Public Funding Sources. With respect to the activities and costs subject to the annual flat fee payment of twenty thousand dollars ($20,000), described in Section 1.59, the Lump Sum will be calculated based on an assumption that the $20,000 annual flat fee will be escalated based on CPI. For purposes of this Agreement, CPI means the Consumer Price Index for All Urban Consumers (CPI-U) in the Los Angeles-Riverside-Orange County Consolidated Metropolitan Statistical Area, All Items, as published by the United States Department of Labor, Bureau of Labor Statistics, for which the base year is 1982-84 = 100, or if such publication ceases to be in existence, a comparable index agreed by the Parties.

5.2.7 In the event a Lump Sum determination is made in accordance with Section 5.2.6, the amount of the Lump Sum shall be paid by Defendants, jointly and severally, and subject to Section 2.5, to Plaintiffs within thirty (30) Working Days after the arbitrator's decision is issued and any petition filed prior to that time to vacate or correct the arbitrator’s

decision, pursuant to Cal. Code of Civil Procedure Section 1286.2 (Grounds for Vacation of Award) or Section 1286.6 (Grounds for Correction of Award), is finally adjudicated. Plaintiffs agree to use the Lump Sum amount solely for Project O&M Costs until such Lump Sum amount is exhausted, or until Plaintiffs' obligation to operate the Project, as set forth in Section 8.3.1, ceases.

ARTICLE 6. PAYMENTS FROM THE ESCROW ACCOUNTS

6.1 General

6.1.1 Payments from the Q2 Escrow Account, the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account, the Project Capital Costs Escrow Account, and the Project O&M Escrow Account (the "**Escrow Accounts**") shall be made in accordance with the procedures set forth in this Section and each Escrow Account's instructions, which instructions shall be jointly approved by Plaintiffs, Whittaker, and AISLIC, and shall be consistent with the terms of this Agreement. The Parties acknowledge and agree that funding of the Escrow Accounts is based on the cost estimates contained in the Exhibits to this Agreement, which estimates were prepared by Plaintiffs' consultants and reviewed but not independently verified by Defendants' and AISLIC's consultants, and that the actual costs and expenses incurred will control all corresponding future payments from the Escrow Accounts. The Parties acknowledge and agree that payments from the Escrow Accounts are to be made solely for reasonable and necessary costs and expenses actually incurred and not paid or reimbursed by other sources, even if less than the sums set forth in any estimate. The Parties shall cooperate in minimizing all costs incurred and paid pursuant to this Agreement. The Parties acknowledge and agree that payments from the Escrow Accounts are to be made only for reasonable capital or operations and maintenance costs for the Project, the Replacement Wells and Associated

Pipelines, Q2 Treatment System, and Distribution Pipelines pursuant to this Agreement, and only to the extent such costs are necessary.

6.1.2 Except as provided in this Agreement, Defendants and AISLIC shall not be entitled to withdraw any funds from the Escrow Accounts or to direct or control the payment of such funds, and shall have no rights with respect to such funds, other than approval rights expressly provided in this Agreement. Reporting and payment of taxes owed on income earned with respect to the escrows shall be the responsibility of Plaintiffs.

6.1.3 Upon termination of the Escrow Accounts in accordance with this Agreement, any balance in the Escrow Accounts shall be refunded to the SF Escrow 1 Account. The Q2 Escrow Account shall terminate as set forth in Section 4.1.6. The Project Capital Costs Escrow Account shall terminate upon completion of the construction of the Project, provided that payment has been made for all Project Capital Costs in accordance with the procedures set forth in this Agreement. The Project O&M Costs Escrow Account shall terminate as set forth in Section 5.1.4. The Replacement Wells/Distribution Pipelines Escrow Account shall terminate upon completion of the construction of the Replacement Wells & Associated Pipelines and Distribution Pipelines, provided that payment has been made for all Replacement Wells & Associated Pipelines and Distribution Pipelines in accordance with the procedures set forth in this Agreement. The term "completion" as used in this Section 6.1.3 shall mean satisfactory completion of construction, startup and testing, and formal acceptance by the applicable Plaintiff.

6.2 <u>Payment of Capital Costs</u>

6.2.1 Costs incurred for activities and within the aggregate approved amounts set forth in Exhibit G, with respect to the Project, and Exhibit S, with respect to the Replacement Wells/Distribution Pipelines, following resolution of disputed costs pursuant to Article 7, shall

constitute **"Approved Capital Costs."** Costs incurred for activities or items that are not contained in Exhibits G and S for the applicable Escrow Account, or are in excess of the aggregate amount set forth therein, shall be subject to the approval of Whittaker and AISLIC or confirmation by the Cost Consultant in accordance with Article 7, below, and upon such approval or confirmation, such costs shall also constitute "Approved Capital Costs".

6.2.2 Plaintiffs shall prepare (1) a monthly statement setting forth capital costs incurred by Plaintiffs for the prior period for the Project (the "**Project Monthly Capital Costs Statement**") and paid by Plaintiffs from the Project Capital Costs Escrow Account, (2) a monthly statement setting forth capital costs incurred by Plaintiffs for the prior period for the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account (the "**Replacement Wells/Distribution Pipeline Capital Costs Statement**") and paid by Plaintiffs from the Replacement Wells/Distribution Pipeline Capital Costs Escrow Account, in each case accompanied by copies of relevant underlying invoices and other supporting documentation for such costs. Copies of the Project Monthly Capital Costs Statement, the Replacement Wells/Distribution Pipeline Capital Costs Statement (together, the **"Monthly Capital Costs Statements"**) shall be provided to Whittaker, AISLIC and Steadfast for review at least ten (10) days prior to each monthly Technical Meeting described in Section 8.4, below, and the Parties shall exercise their best efforts to resolve any disputes concerning the invoices included in the Monthly Capital Costs Statements at or prior to the Technical Meeting.

6.2.3 In the event of a dispute concerning items on any invoice, if such dispute is not resolved at or prior to the Technical Meeting, Whittaker or AISLIC shall provide Plaintiffs with written notice of the reason it disputes the invoice within ten (10) days after the Technical Meeting, and the disputed item(s) shall be resolved by the Cost Consultant in accordance with

Article 7, below. Notwithstanding any pending dispute regarding Whittaker or AISLIC's disapproval of an invoice for payment, Plaintiffs may withdraw funds on a monthly basis from the Escrow Accounts to pay for Project Capital Costs, and Replacement Wells/Distribution Pipelines Capital Costs, subject to the provisions of Article 7 of this Agreement, and to pay Escrow Agent's fees, and any fees incurred for the Cost Consultant in accordance with Article 7 below or for arbitrator's fees in accordance with Article 13, Section 13.2 below. Any appropriate adjustment resulting from the determination of the Cost Consultant shall be reconciled in the following Monthly Capital Costs Statement.

6.2.4 Plaintiffs shall provide the tax identification number required to open any Escrow and shall be responsible for fulfilling tax payment, reporting and filing requirements. Interest that accrues on the balances in the Escrow Accounts shall be retained in those Accounts and available for use by Plaintiffs pursuant to the respective agreed uses of each Account until Termination, and credited against Defendants' funding obligations as to the applicable Account.

6.3 Payment of Q2 O&M Costs

6.3.1 Costs incurred for activities and within the approved Q2 Monthly O&M Costs amount shall constitute **"Approved Q2 O&M Costs."**

6.3.2 VWC shall, within ten (10) Working Days after the end of each semi-annual period after Commencement of Operations for the Q2 Treatment System, deliver to Whittaker and AISLIC a statement of invoices for Q2 O&M Costs incurred by VWC during the preceding semi-annual period **("Q2 Semi-Annual O&M Statement"**), accompanied by copies of all of the underlying invoices and other supporting documentation. Copies of the Q2 Semi-Annual O&M Statements shall be provided to Whittaker, AISLIC and Steadfast for review at least twenty (20) days prior to the Technical Meeting following the end of each semi-annual

period. Plaintiffs, Whittaker and AISLIC shall exercise their best efforts to resolve any disputes concerning the invoices included in the Q2 Semi-Annual O&M Statement at or prior to the Technical Meeting; provided, however, that Approved O&M Costs shall not be subject to review or approval.

6.3.3 In the event of a dispute concerning items other than Approved O&M Costs on any invoice, if such dispute is not resolved at or prior to the Technical Meeting, Whittaker or AISLIC shall provide Plaintiffs with written notice of the reason it disputes the invoice within ten (10) days after the Technical Meeting, and the disputed item(s) shall be resolved by the Cost Consultant in accordance with Article 7, below.

6.3.4 Notwithstanding any pending dispute regarding Whittaker's or AISLIC's disapproval of an invoice for payment, Plaintiffs may withdraw funds on a monthly basis from the Q2 Escrow Account to pay Q2 O&M Costs for the Q2 Treatment System, subject to the provisions of Article 7 of this Agreement, and to pay Escrow Agent's fees, and any fees incurred by Plaintiffs for the Cost Consultant in accordance with Article 7, below, or for arbitrator's fees in accordance with Article 13, Section 13.2 below. Any appropriate adjustment resulting from the determination of the Cost Consultant shall be reconciled in the following Q2 Semi-Annual O&M Statement.

6.3.5 Upon request, Plaintiffs shall additionally provide to SCLLC and RFI, or Buyer if the sale has closed, the statement of invoices with copies of the underlying invoices and supporting documentation.

6.4 <u>Payment of Project O&M Costs</u>

6.4.1 Costs incurred for Project O&M activities and within the aggregate amount set forth in the applicable Joint Estimate of Annual Project O&M or Estimate of

Supplemental Project O&M following resolution of any disputed items pursuant to Article 7, shall constitute "**Approved O&M Costs**." Costs incurred for activities or items that are not Approved O&M Costs or are in excess of the aggregate amount set forth in the applicable Joint Estimate of Annual Project O&M or Estimate of Supplemental Project O&M shall be subject to the approval of Whittaker and AISLIC or confirmation by the Cost Consultant in accordance with Article 7, below, and upon such approval or confirmation, such costs shall also constitute "Approved O&M Costs."

6.4.2 Plaintiffs shall, within ten (10) Working Days after the end of each quarterly period following the Commencement of Operations, deliver to Whittaker, AISLIC and Steadfast a statement of invoices for Project O&M Costs incurred and paid by Plaintiffs from the Project O&M Escrow Account during the preceding quarterly period (**"Quarterly Project O&M Statements"**), accompanied by copies of all of the underlying invoices and other supporting documentation. Copies of the Quarterly Project O&M Statements shall be provided to Whittaker and AISLIC for review at least ten (10) days prior to the Technical Meeting following the end of each quarter, and the Parties shall exercise their best efforts to resolve any disputes concerning the invoices included in the Quarterly Project O&M Statement at or prior to the Technical Meeting.

6.4.3 Upon request, Plaintiffs shall additionally provide to SCLLC and RFI, or Buyer if the sale has closed, the Quarterly Project O&M Statements with copies of the underlying invoices and supporting documentation.

6.4.4 In the event of a dispute concerning items on any invoice, if such dispute is not resolved at or prior to the Technical Meeting, Whittaker and/or AISLIC shall provide Plaintiffs with written notice of the reason it disputes the invoice within ten (10) days after the

Technical Meeting, and the disputed item(s) shall be resolved by the Cost Consultant in accordance with Article 7, below.

6.4.5 Notwithstanding any pending dispute regarding Whittaker or AISLIC's disapproval of an invoice for payment, Plaintiffs may withdraw funds on a monthly basis from the Project O&M Escrow Account to pay actual Project O&M Costs, subject to the provisions of Article 7 of this Agreement, and to pay Escrow Agent's fees, and any fees incurred for the Cost Consultant in accordance with Article 7 below or for arbitrator's fees in accordance with Article 13, Section 13.2 below. Any appropriate adjustment resulting from the determination of the Cost Consultant shall be reconciled in the following Quarterly Project O&M Statement.

ARTICLE 7. COST CONSULTANT ARBITRATION

7.1 Cost Consultant

7.1.1 Appointment of Cost Consultant. Michael Kavanaugh shall act as Cost Consultant and perform the functions of Cost Consultant set forth in this Agreement. If Mr. Kavanaugh, any replacement Cost Consultant, or all parties to a disputed issue, determine that the Cost Consultant lacks expertise as to a specific disputed issue, the Cost Consultant (after consultation with the parties to the dispute) shall retain an expert to assist him or her in reaching a determination of that particular dispute.

7.1.2 Functions of Cost Consultant

7.1.2.1 The Cost Consultant, and any replacement Cost Consultant, shall not act as an agent or representative for any Party, and shall exercise independent, neutral judgment in the performance of the Cost Consultant's responsibilities under this Agreement.

7.1.2.2 In the event of a timely demand for arbitration pursuant to Sections 4.1, 4.2, 4.3, 4.4, 5.2 (except as otherwise provided in Sections 5.2.5 and 5.2.6), 6.2,

6.3, 6.4, 8.2, 8.3, 8.4.2, and 9.1 of this Agreement, the Cost Consultant shall resolve the dispute in accordance with this Article 7.

7.1.3 Cost Consultant Fees: The Cost Consultant's fees and costs shall be included in Project O&M Costs.

7.1.4 Replacement of Cost Consultant: The Cost Consultant may only be replaced by mutual agreement of the Plaintiffs, Whittaker and AISLIC or for good cause established to the satisfaction of the arbitrator designated pursuant to Article 13, Section 13.2 of this Agreement. In the event of the resignation, replacement for good cause, or unavailability of the Cost Consultant, Plaintiffs and Whittaker and AISLIC shall jointly retain a replacement Cost Consultant. If the Parties are unable to agree on a replacement, a replacement shall be chosen by the arbitrator designated pursuant to Article 13, Section 13.2 of this Agreement.

7.2 Cost Consultant Dispute Resolution

In the event that the Parties are unable to resolve a dispute arising under the sections listed in Section 7.1.2.2, Plaintiffs, Whittaker and/or AISLIC may, within the time period provided by the applicable section of this Agreement, demand expedited arbitration of the dispute. If no time period is specified in the applicable section, then the demand for expedited arbitration must be made within ten (10) days after the Technical Meeting at which such dispute was addressed and not resolved. Any such demand, accompanied by all materials that Plaintiffs, Whittaker and/or AISLIC consider necessary for resolution of the dispute, shall be served on the other Parties. By the end of the tenth day after their receipt of such a demand for arbitration, the receiving Party may submit to the Cost Consultant and, if so, shall serve upon the other Parties all materials that the receiving Party consider necessary for resolution of the dispute. The Cost Consultant may request further information from the Parties or schedule an arbitration hearing

date (in-person or by telephone conference) and shall render a decision within twenty (20) days after delivery of the demand for arbitration or, if an arbitration hearing is conducted, within ten (10) days of the conclusion of the arbitration hearing, or at such later time as may be agreed by the parties to the dispute and the Cost Consultant. If a Party does not timely demand arbitration, its disapproval shall be deemed waived.

ARTICLE 8. OWNERSHIP, CONSTRUCTION, OPERATION AND MANAGEMENT OF FACILITIES

8.1 Ownership of Facilities

Plaintiffs shall own or lease all Project facilities, all Replacement Wells and Associated Pipelines, all Distribution Pipelines, and the Q2 Treatment System. Plaintiffs represent and warrant that they have reached separate agreement as to their respective ownership of Project facilities, and this Agreement shall remain in full force and effect regardless of any dispute or disagreement that may exist or arise relating to their ownership of Project facilities, all Replacement Wells and Associated Pipelines, all Distribution Pipelines, and the Q2 Treatment System.

8.2 Plaintiffs' Responsibilities

8.2.1 Plaintiffs will be responsible for the planning, development, design, permitting, construction, installation, operation and maintenance of the Project, Q2 Treatment System, and Replacement Wells & Associated Pipelines and Distribution Pipelines consistent with generally accepted industry standards and practices, and subject to review of Project Capital Costs and Project O&M Costs as provided in Articles 4 and 5 of this Agreement, review of Q2 Treatment System as provided in Article 4 of this Agreement, and review of Replacement Wells & Associated Pipelines and Distribution Pipelines as provided in Article 4 of this Agreement, and resolution of disputed items or costs as provided in Articles 6 and 7 of this Agreement.

Subject to dispute resolution by the Cost Consultant in accordance with Article 7, Plaintiffs shall conduct such planning, development, design, permitting, construction and installation of the Project and the Q2 Treatment System through one or more contracts with design professionals and licensed contractors approved by Whittaker and AISLIC, such approval not to be unreasonably withheld.

8.2.2 Whittaker and AISLIC have previously approved of U.S. Filter as the initial Resin Service Contract Vendor for the Project, and the Q2 Treatment System which has already commenced operations. Whittaker and AISLIC shall participate with Plaintiffs in the negotiation of the initial Resin Service Contract with U.S. Filter for the Project, and shall be participants in Plaintiffs' negotiation of any renewal or substitute Resin Service Contract(s) for the Project prior to payment of the Lump Sum. Prior to an arbitration determination of the Lump Sum, all Plaintiff/Whittaker/AISLIC negotiations on Resin Service Contract(s) will include consideration and negotiation of insurance that the Vendor is able to obtain for Plaintiffs and Defendants and obtaining Vendor Labor in connection with operations, monitoring, sampling and maintenance of the Project, and comparison with alternative options of Plaintiffs' costs for substantially same Labor and insurance, liability exposure considerations, and all associated costs. The Parties agree that Plaintiffs will have the option of performing all or certain of the operations, monitoring, sampling and maintenance of the Project and to secure their own insurance policies in accordance with Article 11 "Project Insurance", provided, however, that Defendants' Project O&M payment obligations for such labor and insurance costs will be limited to the cost of reasonably comparable, efficient and effective alternatives available by means of a bid for a resin service contract selected through a competitive bidding process in accordance with CLWA bid procedures and applicable law.

8.2.3 The Project shall be designed, constructed and installed in accordance with Exhibit F (subject to Project Modification pursuant to Article 9 of this Agreement) and all applicable state, federal and local government laws, regulations, ordinances and other applicable legal requirements.

8.3 Operation, Maintenance and Management of Project

8.3.1 Plaintiffs shall, in consultation with each other, operate, maintain and manage the Project (a) in accordance with all applicable state, federal and local government laws, regulations, ordinances, other applicable legal requirements (including the DTSC-approved IRAP), and generally accepted industry standards and practices, and (b) to perform its intended function of providing containment of perchlorate as defined in Section 9.1 of this Agreement, until exhaustion of any Lump Sum determined and paid pursuant to Section 5.2.6 of this Agreement; provided, however, that if there is no Lump Sum determination and payment, Plaintiffs shall operate, maintain, and manage the Project until Defendants cease funding Project O&M Costs pursuant to Section 5.2.4 of this Agreement or any other reason. In fulfilling their obligations hereunder, Plaintiffs shall not be required to fund any Project Modification.

8.3.1.1 Plaintiffs shall provide accounting services necessary for accurately tracking Project Capital and O&M Costs, invoice payments, budget process, deposits to and disbursements from the Escrow Accounts, and credits for funds received from Public Funding Sources.

8.3.2 Monitoring and Reporting

8.3.2.1 As contemplated by the DTSC approved IRAP, Plaintiffs shall arrange for and supervise the required groundwater monitoring and promptly after receipt

provide sampling data to Whittaker, AISLIC, and upon request, to SCLLC, RFI, or if the sale has closed, the Buyer.

8.3.2.2 Plaintiffs shall ensure timely, complete, and satisfactory preparation and submission of any reports and other deliverables that may be required by any state, federal or local government law, regulation, ordinance or other applicable legal requirement, including the DTSC-approved IRAP, and provide copies of such reports to Whittaker and AISLIC. Copies of such reports shall, upon request, be made available to SCLLC, RFI, or if the sale has closed, the Buyer. This obligation can be met by an electronic posting of the requested materials.

8.3.2.3 Plaintiffs shall maintain any and all books, records, accounts and supporting documentation **("Records")** either required by or necessary to document (i) compliance with all applicable state, federal and local government laws, regulations, ordinances and other applicable legal requirements; and (ii) responsible financial management of the Project. Financial Records shall be maintained in accordance with generally accepted accounting principles and shall be retained until the later of (a) five (5) years from the "as of" date or period applicable to the financial Record; or (b) the Internal Revenue Service retention period for such Records. All other Records shall be retained for a minimum of ten (10) years after the record was created. All Records shall be subject to audit pursuant to Section 8.5 of this Agreement.

8.3.2.4 Plaintiffs shall provide Whittaker, AISLIC, and Steadfast on a semi-annual basis, copies of the Plaintiffs' cost estimates for the Project, the Replacement Wells/Distribution Pipelines and the Q2 Treatment System, showing expenditures against such budgets, and shall provide copies of any reports, contracts or other materials to be considered at

the Technical Meeting, in accordance with Section 8.4, below. Plaintiffs shall make available such reports to SCLLC, RFI, or if the sale has closed, the Buyer, upon request.

8.4 Monthly Technical Meetings

8.4.1 Plaintiffs shall hold monthly meetings to consider technical, financial and other issues related to the planning, development, design, permitting, construction, installation, operation and management of the Project, the Q2 Treatment System, and the Replacement Wells/Distribution Pipelines ("Technical Meetings").

8.4.2 Participation in Technical Meetings

8.4.2.1 Each Plaintiff and Whittaker and AISLIC shall designate one or more representative(s) to participate in Technical Meetings in furtherance of planning, development, design, permitting, construction, installation, operation and management of the Project and the Q2 Treatment System, and the planning, development, design, permitting, construction, and installation of the Distribution Pipelines and Replacement Wells & Associated Pipelines. Such meetings shall be held monthly, or more or less frequently if agreed to by all Plaintiffs and Whittaker and AISLIC, upon no less than ten (10) days written notice from Plaintiffs. After Defendants' payment of the Lump Sum as described in Section 5.2.6 and installation of the Distribution Pipelines and Replacement Wells & Associated Pipelines, such meetings will no longer be held, unless otherwise requested by Whittaker and/or AISLIC, with reasonable compensation payable to Plaintiffs as agreed by the Parties.

8.4.2.2 Except for those contracts, proposals, and/or solicitation materials listed in Exhibit T attached to this Agreement, no contract, request for proposal, solicitation of bid package or other solicitation for planning, development, design, permitting, construction or installation of the Project, the Q2 Treatment System or the Distribution Pipelines

and Replacement Wells & Associated Pipelines shall be made by any Plaintiff unless approved by Whittaker and AISLIC, or -- if disapproved by Whittaker and/or AISLIC-- approved by the Cost Consultant. Copies of any contract, request for proposal, solicitation of bid package, report or other document to be considered at any Technical Meeting held pursuant to Section 8.4.2.1 of this Agreement shall be provided to each designated representative at least ten (10) days before the meeting, unless such document or report was then not available, in which event the document or report shall be distributed as long in advance of the meeting as possible. Whittaker and AISLIC shall notify Plaintiffs as soon as possible, but in any event within ten (10) Working Days after receipt, whether they respectively approve each contract, request for proposal, solicitation of bid package or other solicitation for planning, development, design, permitting, construction or installation of the Project, the Q2 Treatment System, or the Distribution Pipelines and Replacement Wells & Associated Pipelines. Absent such timely notice, approval shall be presumed. If Whittaker and/or AISLIC gives timely notice of disapproval of any such contract, request for proposal, solicitation of bid package or other solicitation for planning, development, design, permitting, construction or installation, such notice must be accompanied by a written explanation of the reason for disapproval and, if possible, a proposed revision that is approved.

8.4.2.3 Whittaker's and/or AISLIC's disapproval of any contract, request for proposal, solicitation of bid package or other solicitation for planning, development, design, permitting, construction or installation of the Project, the Q2 Treatment System, or the Distribution Pipelines and Replacement Wells & Associated Pipelines will be subject to binding arbitration, pursuant to Article 7 of this Agreement. The arbitration shall be conducted by the Cost Consultant. Within fifteen (15) Days after Whittaker and/or AISLIC's timely notice of disapproval of any contract, request for proposal, solicitation of bid package or other solicitation

for planning, development, design, permitting, construction or installation of the Project, the Q2 Treatment System, or the Distribution Pipelines and Replacement Wells & Associated Pipelines, Whittaker and/or AISLIC may demand such expedited arbitration. Any such demand, accompanied by all materials that Whittaker and/or AISLIC considers necessary for resolution of the dispute, shall be served on Plaintiffs within that fifteen (15) day period. By the end of the tenth day after their receipt of such a demand for arbitration, Plaintiffs may submit to the Cost Consultant and, if so, shall serve upon Whittaker and AISLIC, all materials that Plaintiffs consider necessary for resolution of the dispute. The Cost Consultant may request further information from the Parties and AISLIC or schedule an arbitration hearing date (in-person or by telephone conference) and shall render a decision within twenty (20) days after delivery of the demand for arbitration or, if an arbitration hearing is conducted, within ten (10) days of the conclusion of the arbitration hearing, or at such later time as may be agreed by the parties to the dispute and the Cost Consultant. If Whittaker and/or AISLIC does not timely demand arbitration, its disapproval shall be deemed waived.

8.4.2.4 Plaintiffs shall make available to Whittaker, AISLIC and Steadfast (i) copies of all notices, documents and other written communications (including, without limitation, drafts and revisions) concerning planning, development, design, permitting, construction or installation of the Project or the Q2 Treatment System sent by Plaintiffs or their consultants to DTSC, DHS, Regional Water Quality Control Board ("**RWQCB**"), California Public Utilities Commission ("**CPUC**"), U.S. Environmental Protection Agency ("**EPA**") and/or any other regulatory agency with jurisdiction at the same time and by the same manner of delivery by which such notices, documents or other written communications are sent; and (ii) promptly following receipt, all notices, documents and other written communications concerning

planning, development, design, permitting, construction or installation of the Project or the Q2 Treatment System received by Plaintiffs or their consultants from DTSC, DHS, RWQCB, CPUC, EPA and/or any other regulatory agency with jurisdiction. Plaintiffs shall additionally make all of such information available upon request to SCLLC, RFI, or if the sale has closed, to the Buyer.

8.4.2.5 Whittaker shall make available to Plaintiffs, AISLIC and Steadfast copies of all public or non-public and non-confidential notices, reports, documents and other written communications to or from Whittaker and DTSC, DHS, RWQCB, EPA and the Buyer (with the Buyer's consent) concerning the Site and groundwater remediation activities and obligations, at the same time and by the same manner of delivery by which such notices, documents or other written communications are sent, or promptly upon receipt by Whittaker.

8.5 Audits

Whittaker and/ or AISLIC may, upon reasonable notice and no more frequently than once a year, audit Plaintiffs' Records, including all invoices and supporting documentation for Project expenditures. The costs of any such audit shall be paid by the requesting party. Any dispute arising from an audit shall be resolved by the arbitrator designated pursuant to Section 13.2.2. Whittaker and/or AISLIC may demand arbitration of such a dispute within thirty (30) Days after receipt of the audit report triggering the dispute. Failure to demand arbitration within that time period shall be a waiver of any dispute triggered by the audit report.

ARTICLE 9. PROJECT MODIFICATION

9.1 Project Modification

9.1.1 The Parties acknowledge that the effectiveness of the remedy contemplated by the Project is not guaranteed by the Plaintiffs, although the Parties believe that the implementation of the Project represents a reasonable approach to providing containment of

perchlorate as defined below and restoring water production. In the event that within the first three (3) years after Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage), a modification of the Project relating to perchlorate remediation is required (1) because of any regulatory requirement or directive or court order; (2) because of a change in water quality standards or regulations; (3) because of an increase in concentration levels of perchlorate in the Subject Wells; (4) to achieve containment of downgradient perchlorate migration; (5) to restore the contemplated capability of the Project to provide water for potable purposes; or (6) to improve Project efficiency or cost effectiveness, Plaintiffs, Whittaker, and/or AISLIC may develop and implement the necessary modification of the Project ("**Project Modification**") in accordance with this Article 9. Any Project Modification will be funded separately from and is not included in the amounts deposited into the Project Capital Costs Escrow Account as described in Section 1.56. For the purposes of this Agreement, containment is achieved when groundwater monitoring and modeling demonstrates (subject to agreement by representatives of Plaintiffs, Whittaker and AISLIC at the monthly Technical Meetings or there is a determination by the Cost Consultant) that hydraulic control of Saugus Formation groundwater in the vicinity of Saugus 1 and 2 is such that future perchlorate migration from the Site in the Saugus Formation will not result in impacts to existing Saugus Formation production wells identified in Exhibit U above an applicable Notification Level or Maximum Contaminant Level ("MCL"). The groundwater modeling and evaluation of containment will also consider other contaminant mass removal and contaminant containment measures implemented on and in the vicinity of the Site.

9.1.2 Promptly upon the occurrence of any of the circumstances described in Section 9.1.1, above, Plaintiffs may provide Whittaker, AISLIC and Steadfast with written

notification of the need for a Project Modification (**"Project Modification Notice"**), with a proposal for the required modification and/or a procedure for developing, implementing and funding such a modification, and the Plaintiffs, Whittaker and AISLIC shall exercise their best efforts to develop an appropriate and mutually acceptable Project Modification. Any proposed Project Modification shall incorporate the use of best available, cost efficient and effective technology upon consultation with the technical representatives of Whittaker and AISLIC. If, within 60 days after the receipt of the Project Modification Notice, the Plaintiffs, Whittaker and AISLIC are unable to agree upon a Project Modification, Plaintiffs may demand arbitration. In that event, the matter will be resolved by the Cost Consultant in accordance with Article 7.

9.1.3 In addition to the foregoing, within the first three (3) years after Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage), Whittaker or AISLIC may propose a Project Modification based upon the occurrence of any of the circumstances described in Section 9.1.1 above, and deliver the proposal, including all appropriate documentation, to the other Parties for consideration at the next Technical Meeting. If the Plaintiffs, Whittaker and AISLIC are unable to agree on the proposed Project Modification within 60 days after delivery of the proposal and documentation, the proposing party may demand arbitration. In that event, the matter will be resolved by the Cost Consultant in accordance with Article 7.

9.1.4 Following the first three (3) years after Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of remedy stoppage requiring Project Modification), and prior to determination of a Lump Sum pursuant to Section 5.2.6, Whittaker or AISLIC may propose a Project Modification and deliver the proposal, including all appropriate documentation, to the other Parties for consideration at the

next Technical Meeting, if Whittaker or AISLIC are willing to pay for the capital costs and O&M costs associated with such Project Modification. If the Parties are unable to agree on the proposed Project Modification within 60 days after delivery of the proposal and documentation, the matter will be resolved by arbitration in accordance with Article 7.

9.1.5 Following the first three (3) years after Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage, and prior to determination of a Lump Sum pursuant to Section 5.2.6, Plaintiffs may propose a Project Modification and deliver the proposal, including all appropriate documentation, to the other Parties for consideration at the next Technical Meeting, if Plaintiffs are willing to pay for the capital costs associated with such Project Modification. Defendants, subject to Section 2.5, will retain the obligation to pay Project O&M Costs, including any increase in such costs resulting from the Project Modification. If the Parties are unable to agree on the proposed Project Modification within 60 days after delivery of the proposal and documentation, the matter will be resolved by arbitration in accordance with Article 7.

9.1.6 Funding By Defendants

Once a Project Modification has been agreed upon or resolved by arbitration, the Project Modification shall become incorporated in the Project, and shall be handled in all respects as a part of the Project, with Defendants obligated on a joint and several basis subject to Section 2.5 to pay for all reasonable and necessary Project Capital Costs and Project O&M Costs associated with the Project Modification, including costs of replacement water in the event of a Remedy Stoppage within the first three years after Commencement of Operation of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage). This Project Modification funding obligation for Project Capital Costs is in addition to the obligation

for funding Project Capital Costs as defined in Section 1.5.4, for which an amount of ten million dollars ($10,000,000) has been allocated. In the event that a modification of the Project is required or desired after the first three (3) years following Commencement of Operations of the Project (which time period will be tolled during any period in excess of one week of Remedy Stoppage), Plaintiffs will bear all Project Capital Costs associated with the Project Modification, except for Project Modifications proposed by Whittaker or AISLIC pursuant to Section 9.1.4. Any increase in O&M costs resulting from such Project Modification will be included in Project O&M Costs required to be paid by Defendants pursuant to the applicable provisions of this Agreement.

9.1.7 Newhall County Well NC13

9.1.7.1 Notwithstanding any other provisions of this Agreement, the provisions of this Section shall govern matters relating to Newhall County Well NC13 in the event of any conflict.

9.1.7.2 The Parties recognize that perchlorate contamination reportedly found in Newhall County Well NC13 may require well-head or equivalent treatment, or well replacement, in the future. If NCWD reasonably believes that well-head or equivalent treatment or replacement of Newhall County Well NC13 is in fact required, then such proposed measures may, in NCWD's sole discretion, be treated as a request for a Project Modification subject to the provisions of Section 9.1.2, even if the proposal is not made until later than three (3) years after Commencement of Operations of the Project; provided, however, that Whittaker and AISLIC retain expressly all rights under the Project Modification provisions of Article 9, including the right to object based on the cost-ineffectiveness of the proposal or on other grounds, and provided that the proposal shall not be treated as a Project Modification unless it is made no later

than July 1, 2017. The funding by Defendants of a Project Modification pursuant to this Section shall include capital costs even if it does not occur until later than three (3) years after Commencement of Operations of the Project.

9.1.7.3 If NCWD seeks and obtains a Project Modification with respect to NC13, then NC13 shall be treated as a Subject Well; however, unless and until NCWD obtains a Project Modification with respect to NC13, it shall not be deemed a Subject Well and there shall be no release of any liability in connection therewith.

9.1.7.4 Any Lump Sum Arbitration conducted at a time when NC13 is not part of a Project Modification shall have no impact on the obligations created in this Section. If NC13 is a Project Modification and is undergoing well head or equivalent treatment at the time a Lump Sum Arbitration for Saugus 1 and 2 Treatment Plant Operations and Maintenance is conducted, the Lump Sum Arbitration shall also determine a separate lump sum for the operation and maintenance of NC13 for the remainder of the up to thirty (30) year period after the commencement of well-head or equivalent treatment at NC13, deducting that portion of the Lump Sum determined for Saugus 1 and 2 Treatment Plant Operations and Maintenance costs allocable to NC13 from such separate lump sum to the extent NC13 is being treated through the Saugus 1 and 2 Treatment Plant.

9.1.7.5 In the event that NC13 becomes a Project Modification after a Lump Sum Arbitration for Saugus 1 and 2 Treatment Plant Operations and Maintenance costs has occurred, the obligation to pay for Project Modification costs shall continue for a period of up to thirty (30) years after the commencement of well-head or equivalent treatment at NC13, unless, beginning three (3) years after such Project Modification, Plaintiffs, Whittaker, or AISLIC, demand binding arbitration as provided in Article 13 of this Agreement and consistent

with this Section, to determine a lump sum payment of NC13 operation and maintenance costs for the remainder of the up to thirty (30) year period.

9.1.7.6 Prior to NC13 becoming a Project Modification, Plaintiffs' rights under the Rapid Response Fund will not be impaired.

ARTICLE 10. DISPUTES REGARDING POSSIBLE FUTURE PERCHLORATE CONTAMINATION

10.1 Process for Addressing Possible Future Perchlorate Contamination

The Parties acknowledge that the remedy contemplated by the Project and Distribution Pipelines, the Q2 Treatment System, and the Replacement Wells and Associated Pipelines does not specifically address possible future impacts of perchlorate on wells other than the Subject Wells.

10.1.1 In the event that there is detection of perchlorate contamination confirmed by subsequent sample above the Notification Level or MCL that affects water production from Presently Existing Saugus Production Wells or Alluvial Wells, other than one of the Subject Wells (hereinafter referred to as a "**Non-Subject Well Future Perchlorate Circumstance**" or "**Circumstance**"), one or more of the affected Plaintiffs shall provide written notice to all other Parties that a Non-Subject Well Future Perchlorate Circumstance exists. Such written notice shall include the facts relevant to such Circumstance, as well as documents relevant to such Circumstance, and shall specify whether any action, payment, or relief is being demanded. The sender of the Notice shall provide such other and further information and documentation, and updates regarding the Circumstance, as may be reasonably appropriate. In the event that an action, payment, or other relief is being demanded of Whittaker, Whittaker shall, within fifteen (15) days of receipt of the Notice, forward such Notice to AISLIC seeking a determination of coverage with respect to such demand, if Whittaker believes that coverage exists for such

demand. In its letter to AISLIC requesting a determination of coverage, and thereafter, Whittaker shall provide to AISLIC all information and documents relating to the Circumstance as have been provided to Whittaker, and Whittaker shall request that AISLIC provide a determination of coverage as soon as possible, and AISLIC shall respond no later than sixty (60) days following AISLIC's receipt of information and documents reasonably necessary to make a coverage determination. In the event that an action, payment, or other relief is being requested, the sender of the Notice shall meet and confer in good faith with such Party that is a subject of the Notice and, as appropriate, its insurers, to attempt to negotiate a resolution of the issues presented by the Circumstance. In the event that after 90 days from the date of receipt of the Notice (the "**Notice Period**"), the issues presented in the Notice are not resolved through such meeting or meetings, then any Plaintiff may elect to initiate the arbitration process for Future Perchlorate Contamination Disputes under Section 13.3.2.1 of this Agreement, provided that the AISLIC Future Perchlorate Determination of Coverage has been received by Whittaker, and Whittaker satisfies itself, at its discretion exercised in good faith, that AISLIC's determination of coverage is acceptable to allow the arbitration to go forward. Whittaker shall notify such Party and AISLIC in writing of Whittaker's decision within 15 days of receiving AISLIC's determination of coverage. If Whittaker provides such notice indicating that AISLIC's determination of coverage is not acceptable to Whittaker, or if AISLIC fails to provide any determination of coverage within the requisite sixty (60) period, then no Plaintiff may elect to initiate the arbitration process.. Where arbitration may be initiated hereunder and a Plaintiff elects to initiate the arbitration process, said Future Perchlorate Contamination Dispute will be resolved through the procedures for Future Perchlorate Contamination Disputes set forth in Section 13.3 of this Agreement.

10.1.2 Unless arbitration may be initiated pursuant to Section 10.1.1 above, and a Plaintiff elects in its sole discretion to initiate the arbitration process pursuant to Section 13.3.2.1 with respect to a Future Perchlorate Contamination Dispute, such dispute will not be subject to the procedures set forth in Section 13.3 and may instead be heard in its entirety by a court of competent jurisdiction.

10.1.3 Except as provided herein, each Party agrees that execution of this Agreement shall constitute their respective consents to jurisdiction of the Federal District Court, Central District of California, or the Superior Court of the County of Los Angeles with regard to Future Perchlorate Contamination Disputes. Notwithstanding the foregoing, the venue for any action against the Debtors, or the reorganized Debtors pursuant to a plan of reorganization approved by the Bankruptcy Court, shall be the Bankruptcy Court to the fullest extent that the Bankruptcy Court has subject matter jurisdiction over such action.

10.1.4 Notwithstanding the foregoing, in the event that Plaintiffs have obtained funds from the Rapid Response Fund pursuant to Section 11.2 to address a Circumstance as defined herein, any disputes over the use of the Rapid Response Fund for the Circumstance for which arbitration is initiated under Section 10.1.1 will be handled in accordance with Section 13.3.

ARTICLE 11. PROJECT INSURANCE; RAPID RESPONSE FUND

11.1 Project Insurance

11.1.1 Plaintiffs shall obtain and maintain in force the following policies of insurance for the Project or obtain additional insured status on policies offered by the Resin Service Contract Vendor throughout the first thirty years of operation of the Project (including any renewals with same or substantially similar coverage):

- a comprehensive general liability policy of insurance, including contractual liability, in substantially the form of Exhibit V to this Agreement (the "**CGL Policy**");
- an Environmental Impairment Liability policy in substantially the form of Exhibit W to this Agreement (the "**EIL Policy**") if obtainable for a commercially reasonable premium as agreed by the Parties and AISLIC or determined by the Cost Consultant;
- an earthquake policy of insurance in substantially the form of Exhibit X to this Agreement (the "**Earthquake Policy**")
- a First-Party Property Insurance policy in substantially the form of Exhibit Y to this Agreement (the **"Property Policy"**).

The CGL Policy, the EIL Policy, the Earthquake Policy and the Property Policy must be obtained by Plaintiffs with Plaintiffs and, other than the Earthquake and Property Policies, Defendants and the Buyer, identified as named insureds or additional insureds, and with coverages, policy limits, and deductibles or self-insured retentions as set forth on Exhibits V, W, X, and Y or as provided on substantially similar coverage, or alternatively, as provided on less expensive similar insurance offered through the Resin Service Contract Vendor. In the event that the Resin Service Contract Vendor is retained to provide operations and maintenance Labor for the Project, no cost of EIL coverage shall be paid by Defendants as Project O&M Costs or otherwise, so long as EIL coverage substantially similar to Exhibit W is provided to Plaintiffs by the Resin Service Contract Vendor.

11.1.2 Incremental costs of the Project Insurance coverage, in excess of the Plaintiffs' non-Project costs of such coverage, will constitute Project O&M Costs.

11.1.3 Duties of Named Insureds

11.1.3.1 Each Party that is named as an insured or additional insured under the CGL Policy, the EIL Policy, or substitute insurance obtained through Resin Service Contract Vendor, Earthquake Policy and Property Policy, shall perform its duties as an insured as set forth in each such policy of insurance.

11.1.3.2 No Party that is named as an insured or additional insured under the CGL Policy or EIL Policy shall act on behalf of any other Party also insured under said insurance policies with respect to (a) giving or receiving of notice of cancellation; or (b) receipt or acceptance of any endorsement issued to or for a part of any of said insurance policies. No Party insured under the CGL Policy or EIL Policy shall cancel, or assign the right to cancel, any of said policies without first obtaining the written consent of all other Parties, which shall not be unreasonably withheld.

11.1.4 The Parties agree not to make a claim against Plaintiffs, Whittaker, AISLIC, the Buyer, Debtors, Steadfast, or SF Escrow 1 or SF Escrow 2 for any sums paid by any insurance policy referenced in this Article 11. The insurance obtained pursuant to this Article 11 shall contain a waiver of subrogation against Plaintiffs, Whittaker, AISLIC, the Buyer, Debtors, Steadfast, and SF Escrow 1 and SF Escrow 2.

11.2 Rapid Response Fund

11.2.1 The Parties acknowledge that the remedy contemplated by the Project and Q2 Treatment System may not effectively contain downgradient movement immediately of perchlorate contamination in the Alluvial Aquifer or portions of the Saugus Formation. Accordingly, Plaintiffs may submit to AISLIC and AISLIC shall process and pay, as soon as practicable from the SF Escrow 1 Account in accordance with this Section 11.2 and the

Coverage and Claims Settlement Agreement, costs incurred to respond on an expedited basis to perchlorate contamination that is confirmed to be present by subsequent sampling, with split samples to be provided to Defendants, in concentrations exceeding the applicable Notification Level or MCL, in VWC wells N, N-7, N-8, S6, S7, S8, 201, and 205, and NCWD wells NC-10, NC-12 and/or NC-13 (the **"Threatened Wells"**) up to a total amount of ten million dollars ($10,000,000) (the **"Rapid Response Fund"**). Plaintiffs shall be entitled to seek such payment and/or reimbursement only for the period ending July 1, 2017.

11.2.2 Pending agreement between Plaintiffs, Whittaker and AISLIC, or a final determination of the appropriate remedy and amounts payable, allowable uses of the Rapid Response Fund by Plaintiffs include, (a) the additional costs of providing consumers with water from alternative water sources ("**Replacement Water**"), if and to the extent that Replacement Water is necessary and not otherwise available, from existing sources without negative impact to Plaintiffs or any of them, and (b) any costs for rental equipment and resin, including the costs of operating and maintaining leased treatment equipment, or for associated site acquisition, preparation and installation costs. Capital Costs for purchase of capital equipment or permanent capital improvements, and operations and maintenance costs associated with purchased capital equipment or permanent capital improvements, are not allowable uses of the Rapid Response Funds absent later agreement by both AISLIC and Whittaker on a case by case basis.

11.2.3 The Rapid Response Fund obligation will be paid from the funds maintained in the SF Escrow 1 Account. The Defendants and AISLIC agree, and the Defendants represent and warrant that they have obtained the agreement of the "Zurich Parties" and the "AISLIC Parties" (as defined in the Coverage and Claims Settlement Agreement) that

the funding of the Rapid Response Fund from the SF Escrow 1 Account falls within the Uses of SF Escrow 1 Funds, Section IV.F.5.a.(i) of the Coverage and Claims Settlement Agreement.

11.2.4 To obtain payment and/or reimbursement from the Rapid Response Fund, Plaintiffs must directly tender their written request(s) for payment for a ninety day period of time, along with a sworn statement describing the need for specified funds due to confirmed perchlorate contamination in concentrations exceeding the applicable Notification Level or MCL in one or more of the Threatened Wells, and identifying the last date, if any, that the Well for which funding is sought may have been disinfected and the product or solution that may have been used, to AISLIC, with courtesy copies to Defendants. All written requests for payment shall state the need for said specified funds within a ninety day period. Any request for additional ninety day funding shall require a new written request for payment accompanied by a new supporting statement as described above and supporting cost documentation. Within fifteen (15) days of receipt of such written request and sworn statement, AISLIC will instruct Wells Fargo Bank or other agreed bank to make payment of the required Rapid Response Funds to Plaintiffs from the SF Escrow 1 Account.

11.2.5 In the event that the SF Escrow 1 Account Terminates (as defined in Section 5 of the SF Escrow 1 Instructions) prior to the expiration of the time period described in Section 11.2.1 above and in the further event that the $10,000,000 Rapid Response Funds have not been fully paid, the AISLIC Policy Coverages A-F, to the extent that limits remain thereunder, will be available to Whittaker to provide Plaintiffs with a rapid response for the remainder of the time period described in Section 11.2.1 above for the remaining unpaid amount of the agreed $10,000,000 in Rapid Response Funds. In the aforementioned circumstances, Plaintiffs must directly submit their written request(s) for payment for a ninety day period of

time, along with a sworn statement describing the need for specified funds due to confirmed perchlorate contamination in concentrations exceeding the applicable Notification Level or MCL in one or more of the Threatened Wells as described in Section 11.2.4, to Whittaker, with courtesy copies to AISLIC. Within seven (7) Working Days of receipt of such written request and sworn statement, Whittaker, in turn, shall submit a claim pursuant to this Agreement to AISLIC under Coverages A-F for the aforementioned Rapid Response Funds, and Whittaker's payment shall be due within twenty-eight (28) Working Days of receipt of Plaintiff's written request to the extent that limits remain under AISLIC Policy Coverages A-F. Upon receipt of said claim from Whittaker ("Whittaker Rapid Response Claim") and provided that the CLWA Plaintiffs have provided a written request and sworn statement to Whittaker pursuant to and in accordance with Section 11.2 "Rapid Response Fund" of this Agreement, AISLIC shall: (1) treat any Whittaker Rapid Response Claim as a covered claim under AISLIC Policy Coverages A, B, C, D, E, or F, and respond to said claim pursuant to the terms of the AISLIC Policy Coverages A-F and without reservation of coverage rights to the extent that limits remain under AISLIC Policy Coverages A-F, but with reservation of AISLIC's rights, to the full extent of the rights set forth herein (a) to assert disputes, claims or controversies under this Agreement and (b) to assert all of Whittaker's substantive defenses to payment of Rapid Response Funds as provided in this Agreement and (2) make payment on Whittaker's Rapid Response Claim to CLWA Plaintiffs on behalf of Whittaker within twenty one (21) Working Days of AISLIC's receipt of a Whittaker Rapid Response Claim that is fully compliant with Section 11.2 of the Castaic Lake Water Agency Litigation Settlement to the extent that limits remain under AISLIC Policy Coverages A-F. Nothing in this Section 11.2.5 of this Agreement is intended or shall be construed to be agreement as to which Coverage(s) (i.e., A, B, C, D, E, or F) apply to Whittaker's Rapid

Response Claim(s). This Section 11.2.5 is unique and specific to Whittaker's Rapid Response obligation and nothing in this Section 11.2.5 is intended to be or shall be of precedential value or construed to be agreement as to treatment or handling of any other current or future claims that Whittaker may assert under or Plaintiffs may assert with respect to the AISLIC Policy.

11.2.6 Any dispute, claim or controversy concerning payment of costs or losses under this Section, including any disputes as to the reasonableness and necessity of said costs, will be resolved by expedited binding arbitration in accordance with Section 13.2 or Section 13.3, as appropriate.

11.2.7 This Rapid Response Fund remedy is in addition to any remedy otherwise available to Plaintiffs at law or in equity, or pursuant to this Agreement, provided that Plaintiffs will not seek duplicate recovery from Defendants or their insurers or AISLIC or SF Escrow 1 for any losses, costs, expenses, or damages paid by the Rapid Response Funds. Defendants and their insurers reserve all defenses they may have with respect to payment of Rapid Response Funds, including but not limited to the defense that Plaintiffs' disinfection or other operation and maintenance procedures carried out after the Effective Date hereof have contributed to or caused the perchlorate detection and the defense that Defendants are not otherwise legally or factually responsible or liable for the perchlorate contamination. In the event that Rapid Response Funds are determined by binding arbitration to have been improperly requested by or paid to Plaintiffs in whole or in part based upon defenses the Defendants or their insurers or AISLIC may have with respect to payment of Rapid Response Funds, Plaintiffs shall be required to reimburse those funds in whole or in part to the SF Escrow 1 or the AISLIC Coverages A-F limits, as appropriate, which Escrow and/or Policy shall be replenished to the extent of the reimbursement.

ARTICLE 12. RELEASES AND DISMISSAL OF UNDERLYING ACTION

12.1 Plaintiffs' Releases

12.1.1 In consideration of Defendants' payments, promises, and covenants herein, including funding provided by or on behalf of Defendants pursuant to the Coverage and Claims Settlement Agreement and the Related Settlement, each Plaintiff, on behalf of itself and its predecessors, successors and assigns, hereby forever releases, acquits and forever discharges Whittaker and its insurers (including but not limited to AISLIC, The Insurance Company of the State of Pennsylvania ("ISOP"), and Steadfast), SCLLC, RFI, RFI Realty, BRLLC, the Buyer, and Steadfast Santa Clarita Holdings, LLC (**"SSCH"**), and their respective officers, directors, shareholders, members, employees, agents, representatives, contractors, reinsurers, consultants, subsidiaries, affiliates, predecessors, successors and assigns from any and all actions, causes of action, claims, demands, liabilities, damages, penalties, fines, debts, losses, costs, expenses and fees (including, without limitation, litigation costs and attorney and consultant fees) of every kind and nature whatsoever, in law and in equity, whether known or unknown, suspected or unsuspected, foreseen or unforeseen, arising out of or relating to the past, present or future detection of perchlorate in the Subject Wells, (except for claims addressed in Section 12.1.2 and Section 12.1.3 which are not released in this Section 12.1.1) including (without limitation) all claims for past and future purchase of replacement water as a result of the detection of perchlorate in the Subject Wells (except for the costs of providing consumers with water from alternative water sources during the first three years after Project operations commence if there is a Remedy Stoppage during said time period), all Plaintiffs' Past Environmental Claims, all Plaintiffs' Past Design Costs Claims, all Plaintiffs' claims relating to the V-206 Replacement Well, including, but not limited to, construction and installation of VWC's well V-206 and associated pipelines, and permanent closure and abandonment of VWC's well V-157, all claims

with respect to the Capital Costs for Q2, and all claims for past or future response costs and other costs incurred as a result of perchlorate detection in the Subject Wells, including attorneys' and consultants' fees and costs. However, excluded from the release provided in this section are any claims or causes of action arising out of or relating to any future claims, causes of action, suits, legal or administrative proceedings by third parties (or by Defendants where the proceeding is initiated by a third party) against Plaintiffs for actual bodily injury, property damage or response costs allegedly suffered or incurred by such third-parties, including but not limited to any and all third party claims, causes of action, suits, legal or administrative proceedings against Plaintiffs and any resulting damages, losses, penalties, fines or liabilities , after the Effective Date arising out of or related to alleged exposure to or release of perchlorate or other chemicals caused by Plaintiffs' operation of the Project, (collectively, **"Third Party Claims"**) but not excluding any Third Party Claims resulting from the Plaintiffs' negligence or willful misconduct in operation of the Project. Plaintiffs represent and warrant that, as of the Effective Date of this Agreement, they are not aware of any Third Party Claims brought against any of them. The releases provided in this Section 12.1.1 shall be effective upon payment of all funds required to be paid within thirty (30) days after the Effective Date of this Agreement..

12.1.2 Release For Costs Applied Against Escrows. Upon each payment from the Escrow Accounts for Project Capital and O&M Costs, Q2 O&M Costs, and Replacement Wells/Distribution Pipeline Capital Costs (and following any adjustment for a disputed item), and upon each payment of Rapid Response Funds from the SF Escrow 1 Account or the AISLIC Policy, as applicable, each Plaintiff, on behalf of itself and its predecessors, successors and assigns, hereby forever releases, acquits and forever discharges Whittaker and its insurers (including but not limited to AISLIC, ISOP and Steadfast), SCLLC, RFI, RFI Realty, BRLLC,

the Buyer, and SSCH, and their respective officers, directors, shareholders, members, employees, agents, representatives, contractors, reinsurers, consultants, subsidiaries, affiliates, predecessors, successors and assigns from any and all actions, causes of action, claims, demands, liabilities, damages, penalties, debts, losses, costs, expenses and fees (including, without limitation, litigation costs and attorney and consultant fees) of every kind and nature whatsoever, in law and in equity, in connection with the Project, the Q2 Treatment System, the Replacement Wells and the Distribution Pipelines, and the Rapid Response Funds, but only to the extent of such payment.

12.1.3 As to Project O&M Costs, and subject to Section 9.1.7 hereof, upon the sooner of payment by Defendants of a Lump Sum determined by arbitration pursuant to Section 5.2.6 hereinabove or of payment of all Project O&M pursuant to Article 5, each Plaintiff, on behalf of itself and its predecessors, successors and assigns, hereby forever releases, acquits and forever discharges Whittaker and its insurers (including but not limited to AISLIC, ISOP and Steadfast), SCLLC, RFI, RFI Realty, BRLLC, the Buyer, and SSCH and their respective officers, directors, shareholders, employees, agents, representatives, contractors, reinsurers consultants, subsidiaries, affiliates, predecessors, successors and assigns from any and all actions, causes of action, claims, demands, liabilities, damages, penalties, debts, losses, costs, expenses and fees (including, without limitation, litigation costs and attorney and consultant fees) of every kind and nature whatsoever, in law and in equity, in connection with the Project. The releases provided in this Section 12.1.3 exclude any Third Party Claims arising after the Effective Date related to alleged exposure to or release of perchlorate or other chemicals caused by Plaintiffs' operation of the Project, other than Third Party Claims resulting from the Plaintiffs' negligence or willful misconduct in operation of the Project.

12.1.4 Plaintiffs agree that the Steadfast PLC policy no. PLC 3598792-00 issued by Steadfast to Defendants has been exhausted by Steadfast's deposit into the SF Escrow 1 Account and the SF Escrow 2 Account of the remaining limits of this pollution liability coverage (**"Steadfast PLC Policy"**) insurance policy, with Plaintiffs waiving any and all purported rights and claims they have or may have against such PLC Policy. Plaintiffs waive and release any and all purported rights and claims they have or may have against the Steadfast EOC policy no. 3554336.

12.1.5 Each of the Plaintiffs has filed a proof of claim in each of the Bankruptcy Cases in which RFI and SCLLC are the debtors asserting the liquidated and unliquidated claims alleged by them against RFI and SCLLC in the Underlying Action (**"Proofs of Claim"**). In place of the Proofs of Claim, Plaintiffs shall have a single allowed claim against the Debtors, and each of them, in the Bankruptcy Cases in an amount equal to the obligations of Debtors pursuant to this Agreement (**"Allowed Claim"**) and the Final Approval Order shall so provide. Except to the extent that certain funds in SF Escrow 1 will be paid on behalf of Defendants to Plaintiffs and to fund escrow accounts for the benefit of Plaintiffs pursuant to this Agreement, and the Coverage and Claims Settlement Agreement, Plaintiffs waive any right to any payment or distribution of assets, property or funds of the estates of the Debtors in the Bankruptcy Cases by reason of their Allowed Claim and such Proofs of Claim shall be deemed satisfied by the consideration furnished by Debtors pursuant to this Agreement. Plaintiffs further agree that, notwithstanding any other provision of this Agreement, their sole recourse against the Debtors and any reorganized Debtors pursuant to a plan of reorganization approved by the Bankruptcy Court, for any and all actions, causes of action, claims, demands, liabilities, damages, penalties, debts, losses, costs, expenses and fees (including, without limitation, litigation costs and attorney

and consultant fees) of every kind and nature whatsoever, in law and in equity against the Debtors shall be the SF Escrow 1 Account.

12.1.6 Plaintiffs agree that this Settlement does not compromise, release, diminish or adversely affect the rights of Debtors or their successors in interest to enforce obligations, if any, of SCWC and/or NCWD to provide water to the Property pursuant to the documents attached collectively as Exhibit Z.

12.1.7 Plaintiffs agree that: (i) the Steadfast PLC Policy is released by all such Plaintiffs such that no Plaintiff can assert any claim against the Steadfast PLC Policy; and (ii) the Steadfast EOC Policy is released by all such Plaintiffs such that no Plaintiff can assert any claim against the Steadfast EOC Policy.

12.2 Bankruptcy Releases.

Debtors, acting on behalf of themselves and on behalf of each of their bankruptcy estates, shall release the Plaintiffs from any and all claims, obligations, causes of action and liabilities (i) under any of sections 542, 544, 545, 547, 548, 549, or 553 of the Bankruptcy Code to avoid any alleged transfer to or seek turnover from a Plaintiff, (ii) under section 550 of the Bankruptcy Code to recovery any such alleged transfer, (iii) under section 510(c) of the Bankruptcy Code to subordinate any claim of a Plaintiff, and (iv) under Section 502(d) or 502(j) of the Bankruptcy Code.

12.3 Civil Code Section 1542

12.3.1 The Parties to this Agreement have read and fully understand the statutory language of Section 1542 of the Civil Code of State of California ("Section 1542"), which reads as follows: "A general release does not extend to claims which the creditor does not know or

suspect to exist in his favor at the time of executing the release, which if known by him must have materially affected his settlement with the debtor."

12.3.2 As to the releases given in Section 12.1 and 12.2, each Party hereto acknowledges that it may hereafter discover facts different from, or in addition to, the facts which it now knows or believes to be true with respect to the perchlorate groundwater contamination in the area of the Site or Subject Wells, and that it is each Party's intention to specifically waive and relinquish any and all protections, privileges, rights and benefits under Section 1542 as to the claims to be specifically released under Sections 12.1 and 12.2.

12.4 Dismissal of Underlying Action

Within forty-five (45) Days after the Effective Date, and provided that the Defendants have paid to Plaintiffs the full amount required to be paid within thirty (30) days after the Effective Date of this Agreement, the Plaintiffs shall file a request for dismissal, with prejudice to the extent expressly released herein and otherwise without prejudice, of the claims asserted in the Underlying Action and, thereafter, shall do whatever is required to effectuate such dismissal.

12.4.1 With respect to any claims dismissed without prejudice, the Parties agree not to assert any statute of limitation or equitable defense based on the passage of any period of time prior to, at a minimum, one year after the Effective Date of this Agreement (the "Tolled Period"). The Tolled Period will be extended automatically for an additional three years (the "Extended Period") unless a Party determines to terminate the Tolled Period at that Party's sole discretion, and provides written notice at any time within the Extended Period, of a specific date, set no earlier than ten days from the date of such written notice. Any applicable statutes of limitation or equitable defense based on the passage of time shall begin to run after four years have elapsed from the Effective Date, or after an earlier date that may be set in accordance with

the foregoing termination of the Extended Period. Notwithstanding anything in this Section, and unless the Extended Period is terminated by a Party, the Parties agree to meet and confer before the expiration of the Extended Period to consider renewal of the tolling period for up to an additional four years in accordance with California Code of Civil Procedure Section 360.5.

12.4.2 With respect to any claims Plaintiffs may allege to have with respect to or arising out of the presence of perchlorate or other hazardous substances, wastes or materials in the groundwater, soil or surface water at or in the vicinity of the Site, Plaintiffs agree to forebear from bringing any action in any court based on such claims for the Tolled Period of one year after the Effective Date of this Agreement and for any additional period of time that the Extended Period is in effect in accordance with subsection 12.4.1 (the "Forbearance Period"). The Forbearance Period shall run concurrently with the Tolling Period and any Extended Period, and the Parties may, by mutual agreement, renew the Tolling and/or Extended Periods in accordance with subsection 12.4.1. Subsections 12.4.1 and 12.4.2 expressly do not apply to any claims that may be asserted in accordance with the provisions of Section 11.2 (Rapid Response Fund), above, and any defenses thereto.

12.5 Notification Regarding Use of Well Disinfectant

Prior to performing any disinfection of any of the Subject Wells or Threatened Wells, Plaintiffs agree to provide Whittaker and AISLIC with 10 days written notice. Prior to applying any disinfecting product or solution down-hole, one water sample will be collected from the Well and analyzed for perchlorate. After all down-hole operations are completed, and prior to putting the Well back into service, one water sample will be collected and analyzed for perchlorate. In addition, one sample of the product or solution to be used for down-hole disinfection will be collected and analyzed for perchlorate. Plaintiffs further agree that in all

other respects, they will follow the American Water Works Association's "AWWA Standard For Disinfection Of Wells", dated November 1, 2003, attached hereto as Exhibit CC, and that Plaintiffs will timely provide Whittaker and AISLIC with the analytic results of the above-referenced three samplings, as well as copies of a completed Worksheet containing the information called for in the AWWA's sample Worksheet that is attached hereto as part of Exhibit CC. All three (3) samples will be tested for perchlorate using the approved United States Environmental Protection Agency (EPA) and DHS Method 314.0 and report the results using a detection limit for reporting (DLR) of 4 ppb. Plaintiffs agree to use the most current perchlorate test method and DLR approved by DHS for drinking water in the event Method 314 is revised in the future.

ARTICLE 13. DISPUTE RESOLUTION

13.1 Disputes Governed by Article 13

All disputes between Parties to this Agreement arising out of or related to this Agreement, including the interpretation, enforcement or breach of this Agreement, (excluding disputes to be decided by the Cost Consultant, which are to be resolved pursuant to Article 7), are subject to the dispute resolution procedures contained in this Article 13.

13.1.1 Procedures Applicable To All Disputes Governed by Article 13

13.1.1.1 Additional Procedural Requirements. The procedural rules of the arbitration herein shall be supplemented by any non-conflicting arbitration procedures of the Judicial Arbitration and Mediation Service (**"JAMS"**) Comprehensive Arbitration Rules & Procedures, or such other alternative dispute resolution provider as may be agreed upon by the parties to the dispute in writing, applicable to commercial arbitration and may be modified by agreement of the parties to the dispute (the "Rules"). If any provision of this Agreement conflicts with the Rules, then this Agreement shall govern.

13.1.1.2 Retention of Consultants. The arbitrator may seek the approval of the parties to the dispute to retain a consultant. The arbitrator shall provide to all parties to the dispute an explanation for the need for the consultant, the consultant's identity, hourly rate, and the estimated costs of the service. All parties to the dispute must approve the retention of the consultant and, if retention of the consultant is approved, the parties to the dispute shall share equally the costs of the consultant. The consultant's cost shall not exceed ten thousand ($10,000) without the prior written consent of the parties to the dispute.

13.2 Expedited Arbitration Procedures

13.2.1 Notice of Dispute; Good Faith Meeting; Demand for Arbitration

Any Party who perceives that a dispute has arisen which is subject to the dispute resolution procedures contained in this Article 13, other than Future Perchlorate Contamination Arbitration or Lump Sum Arbitration governed by Section 13.3 below, may give written notice of such dispute to all other Parties. The Parties shall meet to resolve the dispute within seven (7) Working Days after receipt of such written notice by the last Party to receive it. If the Parties are unable to resolve the dispute in good faith within fifteen (15) Days after receipt of such written notice by the last party to receive it, the Party that gave written notice of the dispute may initiate the arbitration procedure described below by delivery of a Demand for Arbitration to all other Parties (excluding any that no longer legally exist) no later than thirty (30) Days after receipt of the written notice of such dispute by the last party to receive it.

13.2.2 Approved Arbitrators

Disputes subject to the expedited arbitration procedure set forth in this section 13.2 shall be decided by one impartial arbitrator qualified to serve as an arbitrator. The list in Exhibit AA consists of five (5) approved arbitrators; however, on or about the third

anniversary of the effective date of this agreement, the parties shall meet and agree to a list of five arbitrators for the next three year period, and the same process shall take place on each third anniversary thereafter. The list of arbitrators may be supplemented by mutual agreement of the Parties in writing. An arbitrator shall be chosen by agreement of the parties involved in the dispute. If the parties involved in the dispute are unable to reach agreement, the one arbitrator shall be selected by each side (Defendants and AISLIC being considered one side for purposes of such strikes) striking one arbitrator from the list in succession (beginning with Plaintiffs) until only one arbitrator remains. Plaintiffs shall strike one arbitrator within two (2) Working Days of notice of the arbitration. Each successive strike shall take place within two (2) Working Days thereafter. Notice shall be given pursuant to the provisions of Section 15.4 hereof. If the list of five (5) approved arbitrators needs to be supplemented in order to assure a complete list of five (5) available arbitrators before such a selection, the parties to the dispute shall supplement the list by mutual agreement, or in the absence of such agreement, the list shall be supplemented by the Judicial Arbitration and Mediation Service ("JAMS") in Los Angeles (or a mutually agreeable substitute). If the method described above does not identify a person available to act as arbitrator for any particular dispute, the parties involved in the dispute shall use their best efforts to select an arbitrator by mutual agreement. If the parties to the dispute are unable to reach agreement, the listing process set forth by JAMS Rule 15 shall govern.

13.2.3 Expedited Arbitration

Plaintiffs and Defendants and AISLIC shall, within fifteen (15) Working Days after receipt of a Demand for Arbitration pursuant to Section 13.2.1, above, provide written statements of position to the arbitrator, with copies to the other Parties, setting forth their respective positions. Within ten (10) Working Days after receipt of such a written statement of

position, any party may provide a rebuttal to the arbitrator, with copies to the other Parties. Evidentiary hearing and oral argument of the disputed matter shall be held no earlier than fifteen (15) Working Days after delivery of the rebuttal summaries, and should be scheduled at the earliest available convenient time for the parties to the dispute and the arbitrator. The arbitrator shall render a binding written opinion, including detailed findings of fact and conclusions of law, within ten (10) Working Days after the conclusion of the evidentiary hearing and oral argument.

In any such arbitration in which the written opinion is rendered by the arbitrator prior to the arbitrator's determination of the Lump Sum pursuant to Section 5.2.6 and 13.3, the arbitrator's fees shall be a Project O&M Cost. The award by the arbitrator may include the award of reasonable attorney's fees to the prevailing party, if the arbitrator finds that there is a "prevailing" party. The arbitrator will inter alia be empowered to award response costs or damages. The arbitrator will not be empowered to award injunctive or declaratory relief or award punitive damages or determine coverage issues under the AISLIC Policy. In awarding damages resulting from a breach of the Agreement, the arbitrator may take into consideration, among other things, any disruption to the Project, lost production capacity in the Subject Wells, and costs of replacement water resulting from Defendants' breach of their funding obligations hereunder. Any arbitration award against the Debtors is subject to Section 2.5 herein. The Parties acknowledge and agree that each of the Plaintiffs, in its sole discretion, reserves the right to seek declaratory and/or injunctive relief in a state or federal court action against Defendants, notwithstanding the initiation or resolution of any arbitration proceeding under this Article 13. The Plaintiffs agree that they will refrain from pursuing any claim or lawsuit for injunctive or declaratory relief against Defendants based on the same factual circumstances, pending receipt of the arbitrator's determination. The Parties understand and agree that the record from any

arbitration will be admissible in any future claim or lawsuit by Plaintiffs against Defendants or AISLIC, or by Defendants or AISLIC against Plaintiffs, for injunctive or declaratory relief based on the same factual circumstances.

13.3 Procedures Applicable To Arbitration of Future Perchlorate Contamination Disputes And Arbitration of Lump Sum

13.3.1 Panel of Arbitrators. Future Perchlorate Contamination Disputes pursuant to Article 10 hereof and Arbitration of Lump Sum pursuant to Section 5.2.6 and 9.1.7 hereof shall be decided by a panel of three impartial arbitrators qualified to serve as arbitrators. The list in Exhibit "BB" consists of eleven (11) approved arbitrators. The list of arbitrators may be supplemented or amended by mutual agreement of the Parties in writing. An arbitration panel of three (3) shall be chosen by agreement of the parties involved in the dispute. If the parties involved in the dispute are unable to reach agreement, the panel of three (3) arbitrators shall be selected by each side striking one arbitrator from the list in succession (beginning with Plaintiffs) until only a panel of three arbitrators remains. Plaintiffs shall strike one arbitrator within five (5) Working Days of notice of the arbitration. (Defendants and AISLIC being considered one side for purposes of such strikes.) Each successive strike shall take place within two (2) Working Days thereafter. Notice shall be given pursuant to the provisions of Section 15.4 hereof. If the list of eleven (11) approved arbitrators needs to be supplemented in order to assure a complete list of eleven (11) available arbitrators before such a selection, the parties to the dispute shall supplement the list by mutual agreement, or in the absence of such agreement, the list shall be supplemented by the Judicial Arbitration and Mediation Service ("JAMS") in Los Angeles (or a mutually agreeable substitute). If the method described above, does not identify a person available to act as arbitrator for any particular dispute, the parties involved in the dispute shall

use their best efforts to select an arbitrator by mutual agreement. If the parties to the dispute are unable to reach agreement, the listing process set forth by JAMS Rule 15 shall govern.

13.3.2 Election to Arbitrate.

13.3.2.1 Future Perchlorate Contamination Disputes

If there is a dispute with respect to Future Perchlorate Contamination pursuant to Article 10 hereof, any Plaintiff may elect, in its sole discretion, to arbitrate said Future Perchlorate Contamination dispute in accordance with the provisions of Article 10 and this Section 13.3.2. A Plaintiff electing to arbitrate shall initiate the arbitration procedure described below by delivery of a Demand for Arbitration to all other Parties (excluding any that no longer legally exist) no later than thirty (30) Days either (i) after receipt of Whittaker's decision regarding an acceptable AISLIC Future Perchlorate Determination of Coverage as required by Section 10.1.1, or (ii) the expiration of the Notice Period under Section 10.1.1, whichever is later. Within fifteen (15) days of the selection or determination of the panel of arbitrators pursuant to Article 13.2.1 hereof, each party to the dispute shall submit to the arbitrators, and serve on all parties to the arbitration, a short statement of the dispute, their respective positions, and a proposed discovery and hearing schedule. The arbitrators shall be empowered to resolve all issues of law and fact relating to the dispute, including without limitation any issues relating to liability, compensatory damages, response costs and/or the nature and scope of the remedy associated with the presence of perchlorate, but shall not be empowered to award injunctive or declaratory relief. However, the arbitrators designated for any Future Perchlorate Contamination Dispute, may retain continuing jurisdiction after they render a final, binding decision to resolve any additional response cost and damage claims thereafter arising from the same, continuous or related pollution conditions that are involved in the dispute

for which they originally were designated. The Parties acknowledge and agree that each of the Plaintiffs, in its sole discretion, reserves the right to seek declaratory and/or injunctive relief in a state or federal court action against Defendants respecting any Future Perchlorate Contamination Dispute, notwithstanding the initiation or resolution of any arbitration proceeding under this Article 13. The Plaintiffs agree that they will refrain from pursuing any claim or lawsuit for injunctive or declaratory relief against Defendants based on the same factual circumstances, pending receipt of the arbitrator's determination.

13.3.2.2 Lump Sum Arbitration

If Plaintiffs, Whittaker, or AISLIC desire to initiate Lump Sum Arbitration pursuant to Section 5.2.6 and/or 9.1.7, the requesting party shall give written notice to all other Parties. The Parties shall meet and confer to resolve the dispute within fifteen (15) days after receipt of such written notice by the last Party to receive it. If the Parties are unable to resolve the dispute in good faith, the party that gave written notice of the dispute may initiate the arbitration procedure described below by delivery of a Demand for Arbitration to all other Parties (excluding any that no longer legally exist) no later than fifty (50) Days after receipt of the written notice of such dispute by the last party to receive it. Within fifteen (15) days after the selection or determination of the panel of arbitrators pursuant to Article 13.3.1 hereof, Plaintiffs, Whittaker and AISLIC shall submit to the arbitrators and serve on all parties to the arbitration a short statement of the dispute, their respective positions, and a proposed discovery and hearing schedule. The arbitrators shall be empowered to resolve all issues of fact and law relating to said Lump Sum Arbitration.

13.3.3 Preliminary Hearing. Within thirty (30) days after selection or determination of the panel of arbitrators, the arbitrators shall schedule a preliminary hearing. At

the preliminary hearing, the arbitrators shall decide any discovery and briefing issues and set dates, including a hearing date. In resolving discovery issues, the arbitrators shall consider expedition, cost effectiveness, fairness, and the needs of the Parties for adequate information with respect to the dispute.

13.3.4 Commencement of Arbitration. The arbitration hearing shall be scheduled no later than ninety (90) days after the initial preliminary hearing, unless the parties to the dispute mutually agree in writing to extend the date or the arbitrators extend the date.

13.3.5 Decision of Panel Of Arbitrators Final. The arbitrators shall make a written decision, specifying the reasons for the decision, including detailed findings of fact and conclusions of law, within sixty (60) days after the hearing. The decision of at least two (2) of the three (3) panel members shall be binding and final, and there shall be no right to appeal the decision; provided, however, any party to the dispute may seek vacation or correction of the Panel's decision pursuant to California Code of Civil Procedure Section 1286.2 (Grounds for vacation of award) or Section 1286.6 (Grounds for correction of award). Plaintiffs and Defendants, each collectively, shall equally share the expense of the three arbitrators and the arbitration proceeding. The arbitrators will be empowered *inter alia* to award response costs and damages. The arbitrators will not be empowered to award injunctive or declaratory relief or award punitive damages or determine coverage issues under the AISLIC Policy. Any arbitration award against the Debtors is subject to Section 2.5 herein. The Parties understand and agree that the record from any arbitration will be admissible in any future claim or lawsuit by Plaintiffs against Defendants for injunctive or declaratory relief based on the same factual circumstances.

13.3.6 Time Period to Complete Arbitration. The arbitration shall be completed within one hundred fifty (150) days of the preliminary hearing, unless the parties to the dispute mutually agree in writing to extend the date or the arbitrators extend the date.

13.4 Entry of Judgment.

Judgment on the award rendered by the arbitrator(s) may be entered in and enforced by any court of competent jurisdiction.

13.5 Location.

Arbitration proceedings, including hearings, good faith meetings and settlement conferences, shall take place in Los Angeles, California, unless otherwise agreed to by the parties in writing. The Parties shall have the right to participate in any of the arbitration proceedings by telephone.

13.6 Governing Law.

The arbitration, including any proceedings to enforce, confirm, modify or vacate an award, and any proceedings to enforce the terms of this Agreement, shall be governed by the laws of the State of California and applicable federal law.

ARTICLE 14. INSURANCE ISSUES RELATED TO THE AISLIC POLICY

14.1 Condition M of AISLIC Policy

The Parties acknowledge and agree that Condition M of the AISLIC Policy provides as follows:

> Action Against Company – No action shall lie against the Company, unless as a condition precedent thereto, there shall have been full compliance with all of the terms of this Policy, nor until the amount of the Insured's obligation to pay shall have been finally determined either by judgment against the Insured after actual trial or by written agreement of the Insured, the claimant and the Company.
>
> Any person or organization or the legal representative thereof who has secured such judgment or written agreement shall thereafter be entitled to recover under this Policy to the extent of the insurance afforded by the Policy. No person or organization

shall have any right under this Policy to join the Company as a party to any action against the Insured to determine the Insured's liability, nor shall the Company be impleaded by the Insured or his legal representative. Bankruptcy or insolvency of the Insured or of the Insured's estate shall not relieve the Company of its obligations hereunder.

14.2 Effect of This Agreement Under Condition M

Solely to resolve the effect of this Agreement under Condition M of the AISLIC Policy, and not to apply to or affect any other provision of the AISLIC Policy, or affect the terms of the Coverage and Claims Settlement Agreement, nor to affect any other claims for coverage by Whittaker, the Parties agree as set forth in this Section 14.2 as follows. Provided that an arbitration award or Cost Consultant determination is issued pursuant to and in accordance with this Agreement, including but not limited to Articles 7 and 13, and that (a) the time for filing a petition to vacate or correct the arbitrator's or Cost Consultant's decision has expired or such filing has been waived by agreement or (b) any petition filed to vacate or correct the arbitrator's or Cost Consultant's decision, pursuant to Cal. Code of Civil Procedure Section 1286.2 (Grounds for vacation of award) or Section 1286.6 (Grounds for correction of award), is finally adjudicated or dismissed (hereinafter referred to as "Final Arbitration Awards"), AISLIC and Whittaker agree as follows:

i) a Final Arbitration Award issued in favor of Plaintiffs and against Whittaker pursuant to and in accordance with this Agreement shall be deemed to be "a judgment against Insured [Whittaker] after actual trial"; and

ii) any written settlement agreement executed by Plaintiffs, Whittaker, and AISLIC or executed by Plaintiffs and Whittaker (with written consent of AISLIC) on issues or disputes presented to or which could properly be presented to an arbitrator(s) or Cost Consultant pursuant to this Agreement shall be deemed to be

"written agreement of the Insured [Whittaker], the claimant [Plaintiffs] and the Company [AISLIC]", as those quoted phrases are used in Condition M “Action Against Company” of the AISLIC Policy**.**

14.3 Written Agreement

This Agreement shall be deemed to be "written agreement of the Insured [Whittaker], the claimant [Plaintiffs] and the Company [AISLIC]" as that quoted phrase is used in Condition M “Action Against Company” of the AISLIC Policy.

14.4 Full Compliance

AISLIC agrees that, as of the date that AISLIC executes this Agreement, Whittaker’s actions have been in “full compliance with all of the terms of [the AISLIC] Policy” with respect to this Agreement, as said quoted phrase is used in Condition M “Action Against Company” of the AISLIC Policy.

14.5 Covered Claims

Except with respect to the negotiation, arbitration, or litigation of a Non-Subject Well Future Perchlorate Circumstance, AISLIC agrees that (1) all costs, expenses, and obligations incurred by Whittaker pursuant to this Agreement shall be treated as a covered claim under AISLIC Policy Coverages A, B, C, D, E, or F, without reservation of coverage rights to the extent that limits remain under AISLIC Policy Coverages A-F and (2) all costs, expenses, and obligations incurred by Whittaker pursuant to this Agreement shall be paid from either SF Escrow 1, from SF Escrow 2 (under Section IV.F.6.a(iii) of the Coverage and Claims Settlement Agreement), or from any remaining applicable limits of the AISLIC Policy under Coverages A, B, C, D, E, or F, as provided in the Coverage and Claims Settlement Agreement.

14.6 Proceedings Under Article 10

With respect to the negotiation, arbitration, or litigation of a Non-Subject Well Future Perchlorate Circumstance pursuant to Article 10 of this Agreement, AISLIC affirms that it agrees to abide by the obligations set forth in that Article 10. In the event that AISLIC makes a determination of coverage and Whittaker notifies of its satisfaction with such determination pursuant to Article 10 of this Agreement, then the agreements, rights and obligations set forth in Section 14.2 of this Article 14 shall apply with respect to the arbitration of such Non-Subject Well Future Perchlorate Circumstance.

14.7 AISLIC Reservation of Rights

AISLIC reserves all rights of subrogation or contribution pursuant to the AISLIC policy and law with respect to any payments made hereunder, except any claims of subrogation or contribution against the Plaintiffs.

14.8 No Amendment or Waiver

Without limiting the obligations of Whittaker and AISLIC as set forth in this Article 14 of this Agreement, nothing herein shall constitute an amendment of any terms or conditions of the Coverage and Claims Settlement Agreement (including but not limited to, those terms related to funding of settlement of the Underlying Action), or a waiver or amendment of any duties, obligations, reservations, or rights, if any, of AISLIC or Whittaker under the Coverage and Claims Settlement Agreement. In particular, but not by way of limitation, AISLIC and Whittaker disagree over whether Section VI.C.3 of the Coverage and Claims Settlement Agreement independently obligates AISLIC to cover future perchlorate claims without reservation of rights and whether and to what extent, if any, AISLIC has reserved its defenses to

coverage. Nothing in this Article 14, is intended to affect, or shall affect, the resolution of that dispute.

14.9 Coverages K and L

Reference in this Article 14 to Coverages A-F shall not under any circumstances be deemed to affect any duties, obligations, reservations, or rights, if any, of AISLIC or Whittaker with respect to Coverages K and L. In particular, but not by way of limitation, the Parties agree that Coverages K and L are under all circumstances limits of liability that are "inapplicable" to Loss sustained for Clean-up Costs incurred after the Termination Date of the AISLIC Policy.

14.10 Additional Clarifications Regarding AISLIC Policy and Other Agreements

14.10.1 Nothing in this Agreement confers the status of an insured or additional insured or the rights of an insured or additional insured with respect to the AISLIC Policy on any person or entity.

14.10.2 Except as expressly set forth in this Article 14, this Agreement does not alter the rights, duties and obligations between Whittaker and AISLIC under (a) the AISLIC Policy or (b) any other agreements, including but not limited to the Coverage and Claims Settlement Agreement.

14.10.3 The parties agree that nothing in this Agreement shall under any circumstances require AISLIC to make any payment or fulfill any duty or obligation after its applicable limit of liability is exhausted.

14.10.4 Nothing herein shall be deemed or interpreted to alter or amend, nor waive or affect, the terms of Condition C of Section VII, Conditions of the AISLIC Policy.

14.10.5 Nothing herein shall be construed to affect any rights of Whittaker against any of its insurers other than AISLIC or under any of its insurance policies other than the AISLIC Policy.

ARTICLE 15. PUBLIC AND OTHER FUNDING SOURCES

15.1 Background of Intent of the Parties

In entering into this Agreement, the Parties are aware that federal and state Public Funding Sources may be or become available to assist in implementing the Project as well as remedial and/or source control activities to be conducted at or in the vicinity of the Site respecting perchlorate contamination. Federal funds may be available by virtue of the United States Department of Defense involvement and activities conducted at or in the vicinity of the Site. State funds may be available to assist in evaluating and implementing an investigatory/remedial program that may be regionally based, including but not limited to the restoration/containment work contemplated under this Agreement and remedial source control activities to be conducted at the Site.

15.2 Obtaining Funds from Public Funding Sources

The Plaintiffs shall use good faith efforts, in a manner consistent with each of the Plaintiffs' and their representatives' individual and unique obligations under applicable law, to obtain funds from Public Funding Sources so as to provide for reasonable and necessary: (1) costs associated with the Project, including costs to implement the Project, Project Modification, and cost overruns, as identified by Plaintiffs; (2) continued off-Site groundwater monitoring with respect to perchlorate contamination; (3) off-Site response activities in the alluvium and Saugus Formation that address perchlorate contamination; and (4) on-Site source removal activities with respect to perchlorate contamination. To the extent permissible under all applicable laws and the requirements of specific funding authorizations, funding from Public Funding Sources shall

be allocated, credited, and utilized to cover any of the aforementioned categories of reasonable and necessary costs in the above order of priority. The Parties shall comply with all applicable laws, rules and regulations regarding lobbying disclosures in their efforts to obtain funding from Public Funding sources. Whittaker shall cooperate in seeking such funds.

Prior to determination of the Lump Sum pursuant to Section 5.2.6, the reasonable and necessary outside consultant lobbying costs incurred by Plaintiffs and Whittaker that are directly related to the perchlorate contamination and seeking of funding under this Article, shall be Project O&M Costs, and will be included in the Estimate of Project O&M, subject to an annual cap of two hundred thousand dollars ($200,000) on Plaintiffs' outside fees and costs and one hundred thousand dollars ($100,000) on Whittaker's outside fees and costs. In no event shall such "outside fees and costs" include campaign donations or similar donations. Upon request of any Party, a full accounting of such costs shall be provided. The obligation to reimburse lobbying costs shall cease in the year 2011, but such costs may be requested thereafter upon a showing of both good cause and positive results, but in no event later than January 1, 2019.

15.3 Administration of Funds from Public Funding Sources

Plaintiffs shall document, account for, and administer all Public Funding Sources funds received by them in conformity with all applicable laws and all requirements of the administrators of Public Funding Sources.

15.4 Conformity with Public Funding Sources Requirements

Plaintiffs shall design, build, operate and maintain their respective restoration/containment work projects contemplated under this Agreement in conformity with all applicable requirements of the Public Funding Sources from which funds have been secured. If Public Funding Sources have requirements which conflict with this Agreement, the Parties shall

meet and negotiate in good faith to amend this Agreement to conform to the requirements of the Public Funding Sources in a manner that preserves the purposes for the use of such funds as much as possible in a manner consistent with the Parties' intent as contemplated in this Agreement. Notwithstanding any of the provisions of this Article 15 or any other provision of this Agreement, nothing in this Agreement is intended to waive or otherwise effectuate a release, nor shall any Party provide a release of the United States Department of Defense or any other agency or instrumentality of the United States in connection with any alleged liability same may have under federal or state law arising out of or relating to any involvement in operations, waste disposal, or other activities at or in the vicinity of the Site.

ARTICLE 16. MISCELLANEOUS

16.1 Governing Law

This Agreement shall be construed and enforced in accordance with the substantive laws of the State of California, without reference to choice of law rules.

16.2 Waiver

No waiver by a Party of any provision of this Agreement shall be valid unless in writing and signed by an authorized representative of such Party. The waiver by any Party of any failure on the part of another Party to perform any of its obligations under this Agreement shall not be construed as a waiver of any future or continuing failure or failures.

16.3 Amendment of the Agreement

No amendment of this Agreement shall be binding upon the Parties unless it is in writing and executed by all of the Parties (excluding any that no longer legally exist or that do not respond to communications directed to the address for that Party specified below or to such other address as has been designated in accordance with Section 16.4). This Agreement and the

exhibits attached hereto set forth all of the covenants, provisions, agreements, conditions and understandings with respect to the matters addressed in this Agreement and constitute a complete integration.

16.4 Notices

All notices and communications required or permitted to be delivered to the Parties, Steadfast and any Buyer pursuant to this Agreement shall be in writing and (a) delivered personally or (b) sent by a recognized overnight mail or courier service, with delivery receipt requested, or (c) sent by facsimile communication with receipt confirmed by telephone, to the following addresses (or to such other address as may from time to time be specified in writing by the addressee):

Castaic Lake Water Agency
27234 Bouquet Canyon Road
Santa Clarita, CA 91350-2173
Attn: Dan Masnada, General Manager
Telephone: (661) 297-1600
Facsimile: (661) 297-1610
E-mail: dmasnada@clwa.org

Valencia Water Company
24631 Rockefeller Ave.
P. O. Box 5904
Valencia, CA 91385-5904
Attn: Robert J. DiPrimio, President
Telephone: (661) 294-1150
Facsimile: (661) 294-3806
E-mail: rdiprimio@valencia.com

Newhall County Water District
23780 North Pine St.
P. O. Box 220970
Santa Clarita, CA 91321-0970
Attn: Stephen L. Cole, General Manager
Telephone: (661) 259-3610
Facsimile: (661) 259-9673
E-mail: scole@ncwd.org

Santa Clarita Water Company
22722 West Soledad Canyon Road
P. O. Box 903
Santa Clarita, CA 91380-9003
Attn: William J. Manetta, President
Telephone: (661) 259-2737
Facsimile: (661) 286-4333
E-mail: wmanetta@scwater.org

with a copy for all of the above to:

Nossaman, Guthner, Knox & Elliott LLP
445 South Figueroa Street, 31st Floor
Los Angeles, CA 90071-1602
Attn: Frederic A. Fudacz, Esq.
Telephone: (213) 612-7823
Facsimile: (213) 612-7801
E-mail: ffudacz@nossaman.com

Whittaker Corporation
Eric Lardiere, Esq.
Vice-President, Secretary and General Counsel
Whittaker Corporation
1955 N. Surveyor Ave.
Simi Valley, CA 93063-3349
E-mail: elardiere@wkr.com

with copies for Whittaker Corporation to:

Reynold L. Siemens, Esq.
Heller Ehrman LLP
333 S. Hope Street
Suite 3900
Los Angeles, CA 90071-3043
Fax: 213-614-1868
Email: rsiemens@hewm.com

and

Richard A. Dongell, Esq.
Dongell Lawrence Finney Claypool LLP
707 Wilshire Boulevard, 45th Floor
Los Angeles, CA 90017
213-943-6100 telephone
213-943-6101 facsimile

American International Specialty Lines Insurance Company as Administrator of SF Escrow 1:

Stacy Parker, Complex Claim Director
AIG Domestic Claims, Inc.
Pollution Insurance Products High Profile Unit
175 Water Street, 12th Floor
New York, New York 10038
Telephone: (212) 458-2910
Fax: (866) 261-3935

with a copy to:

Richard W. Bryan, Esq.
Erin N. McGonagle, Esq.
Jackson & Campbell, P.C.
1120 20th Street, N.W.
Washington, DC 20036-3437
Telephone: (202) 457-1600
Fax: (202) 457-1678

Santa Clarita, L.L.C.
Remediation Financial, Inc.
Remediation Financial, Inc., Managing Member
Great American Tower
3200 N. Central Avenue, Suite 1570
Phoenix, Arizona 85296
Attn: Myla D. Bobrow, Pres. & CEO
Remediation Financial, Inc.

with a copy for Santa Clarita, L.L.C.
and Remediation Financial, Inc. to:

Lawrence J. Hilton, Esq./William E. Halle, Esq.
Hewitt & O'Neil LLP
19900 MacArthur Boulevard, Suite 1050
Irvine, California 92612

Bermite Recovery LLC
Remediation Financial, Inc., Managing Member
Great American Tower
3200 N. Central Avenue, Suite 1570
Phoenix, Arizona 85296
Attn: Myla D. Bobrow, Pres. & CEO
Remediation Financial, Inc.

with a copy for Santa Clarita, L.L.C., Remediation Financial, Inc., and Bermite Recovery LLC to:

Avion Holdings, Inc.
Re: Remediation Financial Inc.
Suite B-204
15290 N. 78th Way
Scottsdale, AZ 85260
Fax: 480-905-0469

and

Alisa C. Lacey, Esq.
Stinson Morrison Hecker, LLP
1850 N. Central Avenue, Suite 2100
Phoenix, AZ 85004-6925
Telephone: (602) 212-8628
Facsimile: (602) 586-5237
E-Mail: alacey@stinson.com

American International Specialty Lines Insurance Company

Stacy B. Parker, Complex Claim Director
AIG Domestic Claims, Inc.
P & C Severity Claims
Pollution Insurance Products High Profile Unit
175 Water Street, 12th Floor
New York, NY 10038
Telephone: (212) 458-6364
Facsimile: (866) 253-0395

with a copy to:

Richard W. Bryan, Esq.
Erin N. McGonagle, Esq.
Jackson & Campbell, P.C.
1120 20th Street, N.W.
Washington, DC 20036-3437
Telephone: (202) 457-1600
Facsimile: (202) 457-1678
E-mail: rbryan@jackscamp.com
emcgonagle@jackscamp.com

Steadfast Insurance Company

Zurich North America
1400 American Lane
Schaumberg, IL 60196
Attn: General Counsel
E claim # 912-0038512

with a copy for Steadfast to:

Terry D. Avchen, Esq.
Christensen, Miller, Fink, Jacobs, Glaser, Weil & Shapiro
10250 Constellation Boulevard, 19th Floor
Los Angeles, California 90067
Telephone: (310) 556-2920
Fax: (310) 556-2920

and

Neil Selman, Esq.
Selman Breitman, LLP
11766 Wilshire Blvd
6th Floor
Los Angeles, California 90025-6538
Telephone: (310) 689-7070
Fax: (310) 473-2525

Buyer:

SunCal Santa Clarita LLC
c/o SunCal Companies
21900 Burbank Blvd.
Woodland Hills, CA 12367
Attn: Frank Faye
Telephone: (818) 444-1600
Fax: (818) 444-5501

with copies to:

SunCal Companies
2392 Morse Avenue
Irvine, CA 92614
Attn: Mr. Bruce Elieff
Bruce V. Cook, Esq.
Telephone: (949) 777-4000
Facsimile: (949) 7774280

Cherokee Santa Clarita, LLC
c/o Cherokee Investment Partners
4600 Ulster Street
Suite 500
Denver, Colorado 80237
Attn: Mr. Dwight Stenseth
Mr. Guy Arnold
Telephone: (303) 689-1460
Facsimile: 303-689-1461

16.5 Computation of Time

In computing any period of time under this Agreement, where the last day would fall on a Saturday, Sunday, or federal or California state holiday, the period shall run until 5 p.m. Pacific Time on the next Working Day.

16.6 Counterparts

This Agreement will be executed in counterparts, each of which shall be deemed an original, and all of which, taken together, shall constitute one and the same instrument.

16.7 Assignment

No Party shall assign or otherwise transfer its rights or obligations hereunder without the other Parties' prior written consent, which shall not be unreasonably withheld. This Agreement shall be binding upon and inure to the benefit of the respective successors and permitted assigns of the Parties.

16.8 Cooperation

Each Party agrees to execute and deliver such further documents and to perform such further acts as may be reasonable and necessary to carry out the provisions of this Agreement or to effectuate its intent.

16.9 Joint Drafting and Negotiation/Legal Counsel

This Agreement has been jointly negotiated and drafted. The language of this Agreement shall be construed as a whole according to its fair meaning and without regard to or aid of Civil Code Section 1654 and similar judicial rules of construction. Each Party has been advised in connection herewith by counsel of its own choosing.

16.10 Article and Section Headings and Captions

Article and Section headings and captions used in this Agreement are for reference only and shall not be considered in any way in connection with the interpretation or enforcement of this Agreement.

16.11 No Third Party Beneficiaries

No third party shall be entitled to claim or enforce any rights hereunder except (1) Buyer and BRLLC, but only to the extent expressly provided in this Agreement, and (2) persons specifically released in Section 12.1 are entitled to claim the benefit of and enforce such releases.

16.12 Severability

In the event that any provision of this Agreement is determined by a court to be invalid, the court shall reform the provision in a manner that is both consistent with the intent of the Parties and legally valid. The remainder of this Agreement shall not be affected thereby.

16.13 Successors and Assigns

All covenants and agreements contained in this Agreement by or on behalf of any of the Parties hereto shall bind and inure to the benefit of their respective successors and permitted assigns, whether so expressed or not, including any Trustee appointed in the Bankruptcy Cases or a subsequently converted Chapter 7 case or cases.

16.14 Organization/Authorization

Each of the Parties to this Agreement hereby respectively represents and warrants to the others that each of them is a duly organized or constituted entity, with all requisite power to carry out its obligations under this Agreement, and that the execution, delivery and performance of this Agreement have been duly authorized by all necessary action of the board of directors or other governing body of such Party, and will not result in a violation of such Party's organizational documents. RFI and SCLLC represent and warrant that, upon the Effective Date, this Agreement will have received any and all approvals required by the Bankruptcy Court in their respective bankruptcy cases to make this Agreement enforceable as against them.

16.15 No Assignment of Claims

Other than the assignment provided in Section VII of the Coverage and Claims Settlement Agreement and the assignment provided in the Purchase & Sales Agreement between RFI Parties and Whittaker, there has been no assignment of claims.

16.16 No Admission /Not Insurance

This Agreement effectuates settlement of claims that are disputed, contested and denied. Neither this Agreement nor any Party's performance under this Agreement is intended to be or shall be asserted by any other Party to be an admission of any kind or character whatsoever, nor

shall it be deemed to have precedential effect in any other dealings between or among the Parties in any other context. Nothing herein shall be deemed to constitute an insurance policy.

16.17 No Prejudice to Buyer

Nothing in this Agreement shall be construed to prejudice any rights, claims, or defenses, that a Buyer, as defined herein, of the Site may have under applicable federal or state law, or to impose any monetary obligations or liability on the Buyer.

16.18 Entire Agreement

Except as expressly provided herein, this Agreement is the entire agreement between the Parties with respect to the subject matter hereof and supersedes all prior agreements between the Parties with respect thereto. In the event of any conflict between the terms of this Agreement and the Interim Agreement or the First Amendment, the terms of this Agreement shall control.

16.19 Survival

Except as expressly set forth herein, each and all of the releases, representations, warranties, covenants, and agreements in this Agreement and in the Interim Agreement shall survive the execution and delivery of this Agreement.

IN WITNESS WHEREOF, this Agreement has been executed by the undersigned, effective as of the date first written above.

CASTAIC LAKE WATER AGENCY

_____

By:_____
Its: _____

NEWHALL COUNTY WATER DISTRICT

_____

By:_____
Its: _____

SANTA CLARITA WATER COMPANY

_____

By:_____
Its: _____

VALENCIA WATER COMPANY

_____

By:_____
Its: _____

WHITTAKER CORPORATION

_____

By:_____
Its: _____

SANTA CLARITA L.L.C.
By: Remediation Financial, Inc.,
Its: Managing Member

_____
By: Myla D. Bobrow
Its: President & CEO

REMEDIATION FINANCIAL, INC.

_____
By: Myla D. Bobrow
Its: President & CEO

AIG DOMESTIC CLAIMS, INC., the duly authorized claims handling agent of:

AMERICAN INTERNATIONAL SPECIALTY LINES INSURANCE COMPANY, in its capacity as "Administrator" of "SF Escrow 1 Account" and as insurer of Whittaker

_____
By:_____
Its: _____

REVIEWED AND APPROVED:

AVION HOLDINGS, LLC, in its limited capacity as designated representative for the Bankruptcy Estates.

_____

By: G. Neil Elsey
Its: Managing Member

LIST OF EXHIBITS

Exhibit A	Description of SCLLC Property
Exhibit B	Description of BRLLC Property
Exhibit C	Description of Distribution Pipelines
Exhibit D	Pro-Forma Joint Estimate of Project O&M Costs
Exhibit E	Past Design Costs
Exhibit F	Project Description
Exhibit G	Estimate of Project Capital Costs
Exhibit H-1	Project Capital Costs Escrow Instructions
Exhibit H-2	Project O&M Costs Escrow Instructions
Exhibit I	Estimate of Q2 Capital Costs
Exhibit J	Q2 Capital Costs Joint Escrow Agreement and Instructions
Exhibit K-1	Amendment No. 1 to Joint Q2 Escrow Agreement and Instructions
Exhibit K-2	Amendment No. 2 to Joint Q2 Escrow Agreement and Instructions
Exhibit L	Estimate of Q2 O&M Costs
Exhibit M	Description of Magic Mountain Wells
Exhibit N	Description of Well Closure
Exhibit O	Description of Stadium Replacement Well
Exhibit P	Replacement Well/Distribution Pipeline Capital Costs Escrow Instructions
Exhibit Q	Description of V-206 Replacement Well and Closure of V157 Well
Exhibit R	Cost Allocation for Distribution Pipelines and Replacement Wells & Associated Pipelines
Exhibit S	Estimate of Distribution Pipelines and Replacement Wells Capital Costs
Exhibit T	List of Approved Contracts
Exhibit U	Identification of Presently Existing Saugus and Alluvial Production Wells
Exhibit V	Form of CGL Policy

Exhibit W	Form of EIL Policy
Exhibit X	Form of Earthquake Policy
Exhibit Y	Form of First Party Property Insurance Policy
Exhibit Z	Section 12.1.6 Documents
Exhibit AA	List of Approved Arbitrators
Exhibit BB	List of Approved Arbitrators for Future Perchlorate Contamination Disputes and Lump Sum Arbitration
Exhibit CC	AWWA Standard for Disinfection of Wells and Sample Worksheet

Order Granting Joint Motion for Court Approval, Good Faith Settlement Determination and Entry of Consent Order, July 13, 2007

FREDERIC A. FUDACZ (SBN 050546)
ALFRED E. SMITH (SBN 186257)
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Attorneys for Plaintiffs and Counter-Defendants
Castaic Lake Water Agency; Newhall County Water District;
Santa Clarita Water Company; and Valencia Water Company

FILED
CLERK, U.S. DISTRICT COURT
JUL 13 2007
CENTRAL DISTRICT OF CALIFORNIA
BY DEPUTY

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UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

CASTAIC LAKE WATER AGENCY; NEWHALL COUNTY WATER DISTRICT; SANTA CLARITA WATER COMPANY; and VALENCIA WATER COMPANY,

Plaintiffs,

vs.

WHITTAKER CORPORATION; SANTA CLARITA LLC; REMEDIATION FINANCIAL, INC.; and DOES 1-10, Inclusive,

Defendants.

AND RELATED ACTIONS

Case No.: CV 00-12613 AHM(RZx)

PROPOSED ORDER GRANTING JOINT MOTION FOR COURT APPROVAL, GOOD FAITH SETTLEMENT DETERMINATION AND ENTRY OF CONSENT ORDER

Hearing Date: **July 16, 2007**
Time: **10:00 a.m.**
Place: **Courtroom 14**
Hon. A. Howard Matz

The motion of Plaintiffs and Counter-Defendants Castaic Lake Water Agency, Newhall County Water District, Santa Clarita Water Company and Valencia Water Company (collectively, "Plaintiffs" or "Counter-Defendants"), Defendants and Counter Claimants Whittaker Corporation ("Whittaker") and Santa Clarita LLC ("SCLLC"), and Defendant Remediation Financial, Inc. ("RFI") (collectively, "Defendants"), (the foregoing Plaintiffs, Defendants collectively referred to herein as the "Parties"), for approval of the settlement agreement of Plaintiffs' claims ("Claims Settlement") and the settlement agreement of Defendants' counterclaims ("Counterclaim Settlement") and a determination that the settlements were in good faith came before this Court regularly for possible hearing after notice to all counsel. No hearing was necessary nor was a hearing held, in part because no opposition was filed. ATM

Having considered the papers submitted by the Parties, the proposed settlement agreements, and good cause appearing, the Court enters the following findings of fact:

1. The Claims Settlement and Counterclaim Settlement (collectively, the "Settlements") were reached by counsel experienced in similar litigation;
2. The Settlements were reached through the oversight of the Court appointed mediator, the Honorable (ret.) Eugene Lynch;
3. The Settlements were reached through arm's length negotiations without fraud or collusion;
4. Investigation and discovery were and are sufficient to allow counsel, the mediator and the Court to act intelligently; ATM
5. The amounts being paid by the Parties and other consideration being exchanged are fair and reasonable in order to end significant litigation costs and avoid the litigation risks by all Parties in having the unresolved issues determined at trial; ATM

Based on these findings of fact, IT IS HEREBY ORDERED that:

1. The proposed Claims Settlement and Counterclaims Settlement are hereby approved by this Court; and

2. The Claims Settlement and Counterclaims Settlement are in good faith and any and all claims against the settling Defendants and the settling Counter-Defendants that are addressed in the Claims Settlement and the Counterclaims Settlement, and the releases of the claims therein, regardless of when asserted or by whom, are barred; such claims are barred regardless of whether they are brought pursuant to CERCLA, or pursuant to common law or other federal or state laws.

3. The Court commends counsel for their exemplary professionalism.

DATED: July 13, 2007

The Honorable Howard A. Matz
United States District Court Judge

Stipulation to Dismiss Plaintiffs' Claims and Defendants' Counterclaim, August 20, 2007

FREDERIC A. FUDACZ (SBN 050546)
ALFRED E. SMITH (SBN 186257)
BYRON P. GEE (SBN 190919)
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Attorneys for Plaintiffs and Counter-Defendants Castaic Lake Water Agency; Newhall County Water District; Santa Clarita Water Company; and Valencia Water Company

FILED
CLERK, U.S. DISTRICT COURT
AUG 20 2007
CENTRAL DISTRICT OF CALIFORNIA
BY DEPUTY

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UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

CASTAIC LAKE WATER AGENCY; NEWHALL COUNTY WATER DISTRICT; SANTA CLARITA WATER COMPANY; and VALENCIA WATER COMPANY, Plaintiffs, vs. WHITTAKER CORPORATION; SANTA CLARITA LLC; REMEDIATION FINANCIAL, INC.; and DOES 1-10, Inclusive, Defendants. AND RELATED ACTIONS.	Case No.: 00-12613AHM(RZx) **STIPULATION TO DISMISS PLAINTIFFS' CLAIMS AND DEFENDANTS' COUNTERCLAIMS** **Hearing Date:** N/A **Time:** N/A **Place:** Courtroom 14 Hon. A. Howard Matz

ENTERED
CLERK, U.S. DISTRICT COURT
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CENTRAL DISTRICT OF CALIFORNIA
BY DEPUTY

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This Stipulation to dismiss plaintiffs' claims and defendants' counterclaims, entered into by and among Plaintiffs and Counter Defendants Castaic Lake Water Agency, Newhall County Water District, Santa Clarita Water Company and Valencia Water Company (collectively, "Plaintiffs"), Defendants and Counter Claimants Whittaker Corporation ("Whittaker") and Santa Clarita LLC ("SCLLC") and Defendant Remediation Financial, Inc. ("RFI") (collectively, "Defendants"), (the foregoing Plaintiffs, and Defendants are collectively referred to herein as the "Parties"), is made with reference to the following facts and recitals:

RECITALS

1. **WHEREAS,** Whittaker is the former owner of approximately 960 acres of real property located in the City of Santa Clarita, County of Los Angeles, California, (the "Site"). The Site is currently owned by SCLLC.

2. **WHEREAS,** Plaintiff Santa Clarita Water Company is the operator of wells commonly designated as Saugus 1, Saugus 2, and the Stadium Well. Plaintiff Newhall County Water District is the owner and operator of a water well commonly designated as NC11. Plaintiff Valencia Water Company is the owner and operator of water wells commonly designated as V157 and Q2. Saugus 1, Saugus 2, the Stadium Well, NC11, V157 and Q2 are collectively referred to at all times herein the "Subject Wells."

3. **WHEREAS,** on or about November 29, 2000, a civil action was brought in the United States District Court for the Central District of California ("Court"), Case No. CV 00-12613 AHM (RZx) by Plaintiffs (the "CLWA action"). Whittaker, SCLLC and RFI were named as defendants in the CLWA action. In the CLWA action, Plaintiffs vdldsflkdsfkl;alleged, among other things, that 1) the groundwater in and around the Site has been contaminated by perchlorate and other hazardous materials; 2) perchlorate contamination has been found in Subject Wells owned by Plaintiffs; and 3) Whittaker, SCLLC, and RFI caused and/or permitted the contamination. Plaintiffs further alleged that they have incurred "response costs" in addressing this contamination, including the costs of engaging consultants to undertake environmental assessment, water treatment

studies, groundwater analysis and characterization work in connection with the alleged perchlorate contamination.

4. **WHEREAS,** on or about January 19, 2001, Whittaker answered the allegations of Plaintiffs and filed its affirmative defenses in support thereof, and filed its own counter-claims against Plaintiffs alleging, among other things, that Plaintiffs were responsible for the release or threatened release of hazardous substances in and around the Site and as a result Whittaker was entitled to a Declaratory Judgment pursuant to the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA") §113(g)(2), contribution pursuant to CERCLA §113(f), and response costs pursuant to the Hazardous Substances Account Act ("HSAA"). The action commenced by Whittaker's filing of its counter-claims is hereinafter referred to as the "Whittaker Action." On or about January 18, 2001, SCLLC answered the allegations of Plaintiffs and filed its affirmative defenses in support thereof, and SCLLC filed a counter-claim against Plaintiffs (the "SCLLC Action") alleging substantially identical facts as the Whittaker Action and seeking declaratory relief under CERCLA §§ 107(a), contribution under CERCLA §113(f), and recovery of response costs under the HSAA.

5. **WHEREAS,** Whittaker, SCLLC and RFI, and Plaintiffs have entered into the Interim Settlement and Funding Agreement dated as of July 28, 2003 (the "Interim Agreement") and the First Amendment to the Interim Settlement and Funding Agreement dated October 11, 2004, which, among other things, extended the term of the Interim Agreement through January 2005.

6. **WHEREAS,** in or around July, 2004, SCLLC and two of its affiliates filed voluntary Chapter 11 bankruptcy petitions, and the cases thereby commenced are pending in the United States Bankruptcy Court for the District of Arizona (the "Arizona Bankruptcy Court"), denominated Cases Nos. 2-04-BK-11910 CGC, 2-04-BK 11911 CGC and 2-04-BK-17294 CGC, respectively, which cases are jointly administered with a bankruptcy case previously commenced by a petition filed by a third affiliate of SCLLC, RFI, and denominated as Case No. 2-04-BK-10486 CGC. Case Nos. 2-04-BK-11910

CGC, 2-04-BK 11911 CGC, 2-04-BK-17294 CGC and 2-04-BK-10486 are jointly administered under Case No. 2-04-BK-10486 CGC and are collectively referred to as the "Bankruptcy Cases."

7. **WHEREAS,** on April 6, 2007, Plaintiffs and Defendants entered into two settlement agreements that resolve Plaintiffs' claims and Defendants' counterclaims. The settlement agreements require that a joint stipulation to dismiss the claims and counterclaims be filed with the court after the settlement agreements are funded. The claims settlement agreement was funded on or about August 9, 2007 and the counterclaim settlement was funded on or about August 10, 2007.

NOW, THEREFORE, the parties hereby stipulate to dismiss Plaintiffs' claims against Defendants in accordance with the "Castaic Lake Water Agency Litigation Settlement Agreement," (previously filed as Exhibit 1 to the Parties' June 18, 2007 Joint Motion for Court Approval of Settlement Agreements and Good Faith Settlement Determination) with prejudice to the extent expressly released therein, and otherwise without prejudice, as to the claims asserted in the underlying complaint.

The Parties further stipulate to dismiss defendants Whittaker Corporation's and Santa Clarita, LLC's counterclaims against Plaintiffs in accordance with the Counterclaim Settlement Agreement and Release (previously filed as Exhibit 2 to the Parties' June 18, 2007 Joint Motion for Court Approval of Settlement Agreements and Good Faith Settlement Determination) with prejudice to the extent expressly released therein, and otherwise without prejudice, as to the claims asserted in the underlying counter-complaints.

Dated: August 17, 2007

FREDERIC A. FUDACZ
ALFRED E. SMITH
BYRON P. GEE
NOSSAMAN, GUTHNER, KNOX & ELLIOTT, LLP

By: _____
Attorneys for Plaintiffs and Counter-Defendants Castaic Lake Water Agency; Newhall County Water District; Santa Clarita Water Company; and Valencia Water Company

IT IS SO ORDERED
Dated August 20, 2007

_____
United States District Judge

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Dated: August 16, 2007

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PROOF OF SERVICE

The undersigned declares:

I am employed in the County of , State of California. I am over the age of 18 and am not a party to the within action; my business address is c/o Nossaman, Guthner, Knox & Elliott, LLP, 445 S. Figueroa Street, 31st Floor Los Angeles, California 90071-1602.

On August 17, 2007, I served the foregoing

STIPULATION TO DISMISS PLAINTIFFS' CLAIMS AND DEFENDANTS' COUNTERCLAIMS

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Executed on August 17, 2007.

( ) (STATE) I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

(XX) (FEDERAL) I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Mina Munoz

SERVICE LIST

CASTAIC LAKE WATER AGENCY, et al. v. WHITTAKER CORPORATION, et al.
USDC Case No. CV 00-12613 AHM (RZx)

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Castaic Lake Water Agency

Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer

TECHNICAL MEMORANDUM NO. 3
BENCH AND PILOT TEST RESULTS

February 2004

28968

CASTAIC LAKE WATER AGENCY

TREATMENT OF PERCHLORATE CONTAMINATED GROUNDWATER FROM THE SAUGUS AQUIFER

TECHNICAL MEMORANDUM NO. 3

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1.0 EXECUTIVE SUMMARY

1.1 Background

A 6-month study was performed to evaluate the effectiveness of ion exchange (IX) and biological processes for treating perchlorate-contaminated water from the Saugus aquifer. Three single-pass perchlorate-selective IX resins were evaluated at the bench-scale while fixed-bed biological reactors (FXBs) and fluidized-bed biological reactors (FBRs) were tested at the pilot-scale. These processes were chosen due to their ability to remove perchlorate from groundwater without generating a perchlorate-laden waste stream or brine that needs to be discharged.

1.2 Ion Exchange

Breakthrough of most anions from the IX resins occurred in the first 24 hours of run time. No chromatographic peaking was observed for any of the critical anions. Chloride breakthrough decreased from 325 mg/L to background concentrations (~35 mg/L) after 280 bed volumes. Perchlorate breakthrough (i.e., greater than 1 μg/L) occurred at 25,000 to 76,000 bed volumes (26 to 79 days). This translates to treated water volumes of 187,000 to 569,000 gal/cu-ft resin.

Contacting IX effluent with free and combined chlorine for 2- and 24-hour incubation periods produced no detectable (i.e., < 2 ng/L) N-nitrosdimethylamine (NDMA) concentrations for all three resins tested, indicating that NDMA precursors did not leach from the resins. When 2 mg/L of free chlorine was dosed to the IX feed water, effluent NDMA concentrations were below or just over the detection limit. To evaluate the NDMA precursor leaching potential of the resins, 100 mL batches of fresh resin were incubated for four hours in deionized water and groundwater. NDMA was detected in only one sample, which measured at less than half the 10 ng/L Action Level.

A California Total Threshold Limit Concentration (TTLC) analysis showed that metals were mostly non-detect in all three spent resins. Chromium, vanadium, and zinc were detected in two of the spent resins at levels significantly below the regulatory TTLC threshold concentrations. Uranium levels in the spent resin leachate were significantly below the Title 22 MCL of 20 pCi/L. To investigate whether the spent resins would be classified as hazardous for transportation to an incineration facility, a mass balance of the uranium adsorbed and desorbed from the resin up to 50 percent perchlorate breakthrough was performed. The amount of uranium accumulated on the spent resins is far below the lowest permissible reporting quantity and A-value of the California Department of Transportation.

1.3 Biological Filtration

Consistent perchlorate removal to below detection was achieved in the FXB filter using only organisms indigenous to the Saugus aquifer. With influent DO and nitrate concentrations of 7 and 15 mg/L, respectively, the lowest EBCT and acetic acid concentration that allowed consistent perchlorate removal to below detection was 15 minutes and 7.8 mg/L as carbon, respectively. Run times ranged from 24 hours to several days. Effluent from the FXB filter was biologically stable and contained no fecal coliforms. Challenge tests demonstrated that the FXB filter was robust with respect to backwashing episodes, changes in feed water quality, system shut-downs, and electron donor addition failures. Large step increases in feed nitrate concentration (e.g., 23 mg/L) required a period of bio-acclimation before perchlorate removal to below detection could be reestablished in the FXB filter.

Demonstration testing showed that a submerged membrane bioreactor (SMBR) can meet several post-FXB treatment objectives in a single step: 1) aeration, 2) biomass separation, 3) residual organic carbon removal, and 4) hydrogen sulfide removal.

The FBR did not achieve perchlorate removal to below detection over a period greater than 8 days, in spite of numerous mechanical and operational adjustments made to the system. However, testing did demonstrate that biological perchlorate removal can be achieved using indigenous microorganisms, a feature that had not yet been demonstrated for the FBR system. Because the FBR was not optimized, challenge testing was not performed.

Disinfection by-product formation potential (DBPFP) tests were performed using effluent from the FXB, FBR, and SMBR reactors. After 7 days of incubation with an excess chlorine residual, DBPs were formed in all three streams, though only the FBR stream produced DBPs exceeding the current MCLs of 80 μg/L total trihalomethanes (TTHMs) and 60 μg/L HAA5s. It should be noted that the FBR was not optimized prior to the DBPFP tests. Because the FBR feed acetic acid concentrations were higher than ultimately required, the FBR DBPFP tests are considered conservative. DBPs formed in all three streams consisted primarily of haloacetic acids (HAAs). Seven-day incubation of process effluents with combined chlorine produced only low levels of THMs and HAAs. A follow-up 72-hour simulated distribution system (SDS) DBP formation test was conducted on the FBR effluent. The SDS-THM4 and SDS-HAA5 concentrations were 40 μg/L and 23 μg/L, respectively.

To simulate DBP formation potential of FXB effluent that is post-treated at the Rio Vista Water Treatment Plant (WTP), a blend of 90 percent State Project Water (SPW) and 10 percent FXB effluent was ozonated and contacted with free or combined chlorine. Bromate was formed at concentrations ranging from 1.8 to 8.7 μg/L due to high bromide concentrations (200 μg/L) in the blended water. Aldehydes were formed at moderate levels, even in one sample that was spiked with 7.5 mg/L of acetic acid carbon prior to ozonation. High levels of THMs and HAAs were measured in the ozonated samples following a 7-day incubation with free chlorine. However, residual chlorine concentrations were excessive

during incubation and, more importantly, a large fraction of DBP precursors would likely be removed downstream of ozonation, prior to chlorination at the Rio Vista WTP. Seven-day incubation of ozonated water with combined chlorine generated only 23 μg/L TTHM4 and 12 μg/L HAA5.

2.0 INTRODUCTION

2.1 Overview

Castaic Lake Water Agency (CLWA) retained Carollo Engineers (Carollo) to screen available perchlorate treatment alternatives applicable to Saugus Aquifer water, test the most promising alternatives, and select a process train for predesign to treat perchlorate-impacted wells.

Carollo identified the following processes as potential treatment approaches for perchlorate:

- Conventional regenerable IX.
- "Throw-away" perchlorate selective IX.
- FBR biological filtration.
- FXB biological filtration.
- High-pressure membrane separation.

A desktop study was conducted to narrow the treatment alternatives. The benefits and issues related to each one of these approaches were presented at a workshop held at CLWA on February 3, 2003. During the workshop, participants from CLWA, member agencies (Newhall County Water District (NCWD), Valencia Water Company, and Santa Clarita Water Company), Carollo, and Kennedy/Jenks performed a process selection based on the following criteria:

- Effectiveness in treating other potential contaminants such as NDMA, HMX, RDX, TNT, etc.
- DHS approval (fast track implementation).
- O&M costs.
- Capital costs.
- Architectural, siting, and permitting issues.
- Robustness of the process.
- TDS and hardness removal ability.

Workshop participants performed a pair-wise comparison analysis to weight the relative importance of each criterion, and assigned criteria scores to each process. The following alternatives were recommended by the participants for bench and/or pilot testing.

- "Throw-away" perchlorate selective IX.
- FBR biological filtration.
- FXB biological filtration.

These alternatives were selected because they can treat perchlorate with minimal production of perchlorate-laden liquid waste or brine that needs to be discharged.

2.2 Project Objectives

The overall goal of bench and pilot testing at the CLWA was to develop design parameters for a treatment facility that is capable of removing perchlorate to below the action level (AL) at affected Santa Clarita Valley wells. The AL in the State of California is currently 4 µg/L. The method detection limit (MDL) used by the CLWA lab was 1 to 4 μg/L and the minimum reporting limit (MRL) for the standard analytical method (EPA 314.0) is currently 4 μg/L.

The specific objectives of this work were to:

1. Compare the perchlorate removal performance of three commercially available and NSF certified perchlorate-selective IX resins using water from the Saugus Aquifer under identical operational conditions by running a parallel bench-scale flow-through column test.
2. Determine the NDMA formation potential of the three IX resins when subject to pre- or post-chlorination at the bench-scale.
3. Determine characteristics of the spent IX resins.
4. Demonstrate the efficacy of FBR and FXB treatment for perchlorate removal from Saugus aquifer water (i.e., show consistent removal of perchlorate to below the MRL of 4 µg/L).
5. Verify that sufficient perchlorate-reducing biological activity can be developed in the pilot-scale reactors using microorganisms indigenous to the Saugus Aquifer.
6. Using pilot-scale FBRs and FXBs, develop full-scale design criteria for empty-bed contact time (EBCT), backwashing procedures, electron donor (acetic acid) addition, and nutrient addition.
7. Evaluate the robustness of the fluidized- and FXB biological process with respect to system upsets, such as electron donor feed failure, process shutdowns, and changes in the feedwater oxidant concentrations.

8. Compare overall process performance between a FXB and FBR configuration.

9. Demonstrate the efficacy and robustness of the FBR's on-line perchlorate analyzer in comparison to other laboratories.

10. Prepare planning-level capital and O&M cost analyses for biological- and IX-based treatment facilities to be incorporated in the pre-design report.

11. Determine post-treatment requirements for the IX, FBR, and FXB perchlorate removal processes (i.e., characterize process effluent quality and disinfection by-product formation potential).

3.0 BACKGROUND AND TEST SITING

3.1 Test Approach and Siting

The preliminary test program included two main testing protocols:

- Bench-scale IX testing using three perchlorate selective resins.
- Pilot-scale biological testing using two system configurations.

The perchlorate selective resins have a high capacity for perchlorate adsorption and depending on the influent perchlorate and sulfate concentrations, may experience extensive run-times to reach perchlorate breakthrough (i.e., perchlorate > 4 µg/L). To simplify testing logistics, IX testing was conducted at the bench-scale. The test was carried out in the chemical building at the Rio Vista WTP. This site also served as the pilot-scale testing site. Bench-sale IX data are readily scaleable. Factors considered in scaling-up the bench test are water quality, bed volumes until perchlorate breakthrough, EBCT, and separation factors specific to the selected resin. The controlling factor of the contaminants' diffusion into the resin matrix is the selectivity of the resin's positively charged quaternary amine functional group for a specific anion relative to the chloride anion. The order of elution of ions from the resin is determined solely by the selectivity sequence. The species exit the column in reverse preferential order, with the less preferred ions (smallest separation factors) emerging first. Other factors include charge of ion, valence of ion (mono- or divalent), and other resin-specific physical factors.

While the effectiveness of treating perchlorate using biological processes has been demonstrated extensively at the bench-scale, the scalability of these processes is not well established. This project evaluated the removal of perchlorate from Saugus Aquifer water using two pilot-scale biological system configurations (FXB and FBR).

3.2 Feed Water

Perchlorate-contaminated wells were not used for testing due to the complications and costs associated with the discharge requirements and the need for an extensive analysis of influent and effluent waters. Instead, a perchlorate-free operational well (NC-12) located near one of the perchlorate contaminated wells (NC-11) was used as feed water for both bench- and pilot-scale systems. Perchlorate was spiked to achieve a final target concentration of 50 µg/L for most of the study. NC-11 and NC-12 draw water from the Saugus Aquifer and have comparable raw water quality (chemistry). Sulfate was spiked to the feed of the ion-exchange unit to achieve a final target concentration of 300 mg/L. This mimics the highest average sulfate concentration measured in Saugus wells. Sulfate is a critical parameter in the ion-exchange process since it competes with the perchlorate ion. NC-11 and NC-12 were sampled and characterized in February and March 2003, respectively (Table 3.1). NC-12 well water was transferred to four 6,500-gallon storage tanks located outside the chemical building at the Rio Vista WTP via a 6,000-gallon stainless steel tanker truck which was filled at the well site and transferred to the pilot site. The tanker used for transferring the raw feed water was washed with hot water or a caustic solution and then rinsed prior to use, to ensure no impact on the raw water quality. The water stored in the baker tanks at the site was delivered to the test equipment via Schedule 80 PVC. To maintain a consistent water temperature, feed flows were routed through an ITT Standard heat exchanger, Model SX200. The water was used at a rate varying from 2,900 to 5,800 gallons per day (2 to 4 gpm).

Table 3.1 Water Quality Parameters in the Groundwater at Newhall 11 and 12 Wells Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

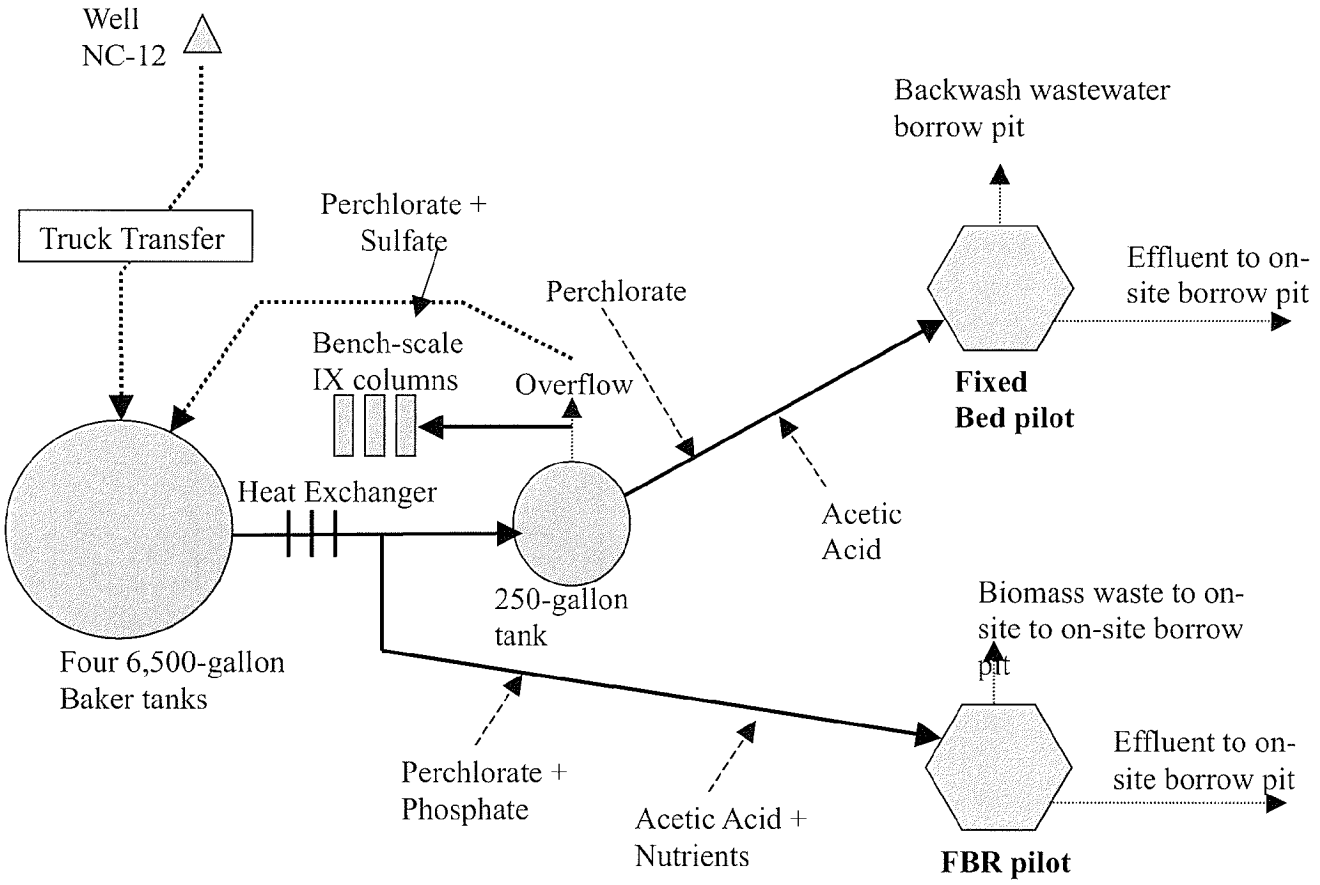
Parameter	Units	NC-12 (March 2003)	NC-11 (Feb 2003)	NC-11 (Historic)
Perchlorate	µg/L	ND[1]	17-20	13-23
Nitrate-NO_3^-	mg/L	14.6	18-20	14-30
Sulfate	mg/L	131	309-330	255-443
Bicarbonate	mg/L	199	220	232-235
Chloride	mg/L	38	28	29-38
Alkalinity	mg/L as $CaCO_3$	163	180	182-280
pH	–	7.5	7.4	7.5-7.7
Conductivity	µhom/cm	846	1,120-1,138	980-1,116
Temperature	degrees C	19	16	
Uranium	pCi/L	0.679	2.887-4.368	NA

Table 3.1	Water Quality Parameters in the Groundwater at Newhall 11 and 12 Wells Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
Parameter	**Units**	**NC-12 (March 2003)**	**NC-11 (Feb 2003)**	**NC-11 (Historic)**
Arsenic	μg/L	1.3	<1.0-1.0	<2.0-2.0
TOC(2)	mg/L	<0.7	2.0(3)	N/A(4)

Notes:
(1) Not detected.
(2) Total Organic Carbon.
(3) After approximately three hours of flushing.
(4) Not available.

A process flow schematic for bench- and pilot-testing is provided in Figure 3.1. The water was pumped from the four 6,500-gal tanks to a 250-gallon tank inside the building. The flow was then split two ways into the FXB and the FBR pilots. Schedule 80 PVC was used to hard pipe the baker tank to the feed pump of each biological pilot skid. Perchlorate stock solution was prepared as necessary by spiking reagent grade sodium perchlorate (Fischer Scientific, Hanover Park, Illinois) to 1 liter of deionized, distilled water from the CLWA laboratory. Peristaltic pumps (Ismatec, Northbrook, Illinois) dosed the perchlorate stock solution near the front end of each pilot feed line for adequate mixing. Perchlorate was dosed independently to each pilot skid to maintain flexibility in the pilot testing protocol. For example, using this configuration, perchlorate spiking tests were applied to one pilot without having to be applied to the other. Technical-grade acetic acid (Eastman Chemical Company, Kingsport, Tennessee) was used as the stock electron donor solution and dosed to the pilot feed lines just before entry to the biological reactors using a peristaltic pump. This acetic acid is undergoing ANSI/NSF 60 certification, which should be completed by the mid-2004. ANSI/NSF 60 - certified, food-grade phosphoric acid (Prayon, Inc., Augusta, Georgia) was also dosed to the pilot feed lines using peristaltic pumps. For the FBR system, a micronutrient mixture was added to the phosphoric acid solution for selected tests. The micronutrient mixture contained trace amounts of iron, copper, magnesium, manganese, zinc, boron, sulfur, molybdenum, and cobalt. The main PVC feed pipes were fitted with a static mixer downstream of the chemical injection points.

For the bench-scale IX tests, water was collected from the pilot feed tank in two 55-gallon tanks (approximately 1 week's supply). The tanks were filled from the overflow line of the 250-gallon tank. A 1,000-mg/L perchlorate stock solution was prepared by adding reagent-grade sodium perchlorate salt to distilled deionized water obtained from the CLWA laboratory. This solution was spiked directly into the containers to result in a final concentration of 50 μg/L. Additional sulfate was also added to the containers by dissolving reagent sodium sulfate (Na_2SO_4) in distilled-deionized water to reach a final sulfate concentration of 300 mg/L.



PROCESS FLOW SCHEMATIC FOR BENCH- AND PILOT-SCALE TESTING

FIGURE 3.1

3.3 Discharge Streams

All process effluents (i.e., bench-scale effluent, pilot-scale effluents, and backwash wastewater) were pumped to a borrow pit on the Rio Vista plant site. The discharge waters were first directed to off-site GAC drums to remove any residual perchlorate prior to ultimate disposal in the borrow pit. The backwash water from the pilot-scale systems was first directed to a 100-gallon drum to allow for settling, and the decant wastewater was then directed to the feed of the GAC drums. The effluent stream from the GAC drums was analyzed for perchlorate once per week. Additional tanks with approximately 300 pounds of Virgin GAC were installed before the discharge point to treat any perchlorate that may be present in the effluents. If perchlorate was detected in the GAC effluent, the spent GAC was removed and replaced with virgin GAC. The borrow pit has no surface discharge and allows negligible percolation due to the presence of a heavy clay soil lining. There was no discharge to the sewer system or Santa Clara River. Spent resins were sent to a certified laboratory for further characterization and disposal.

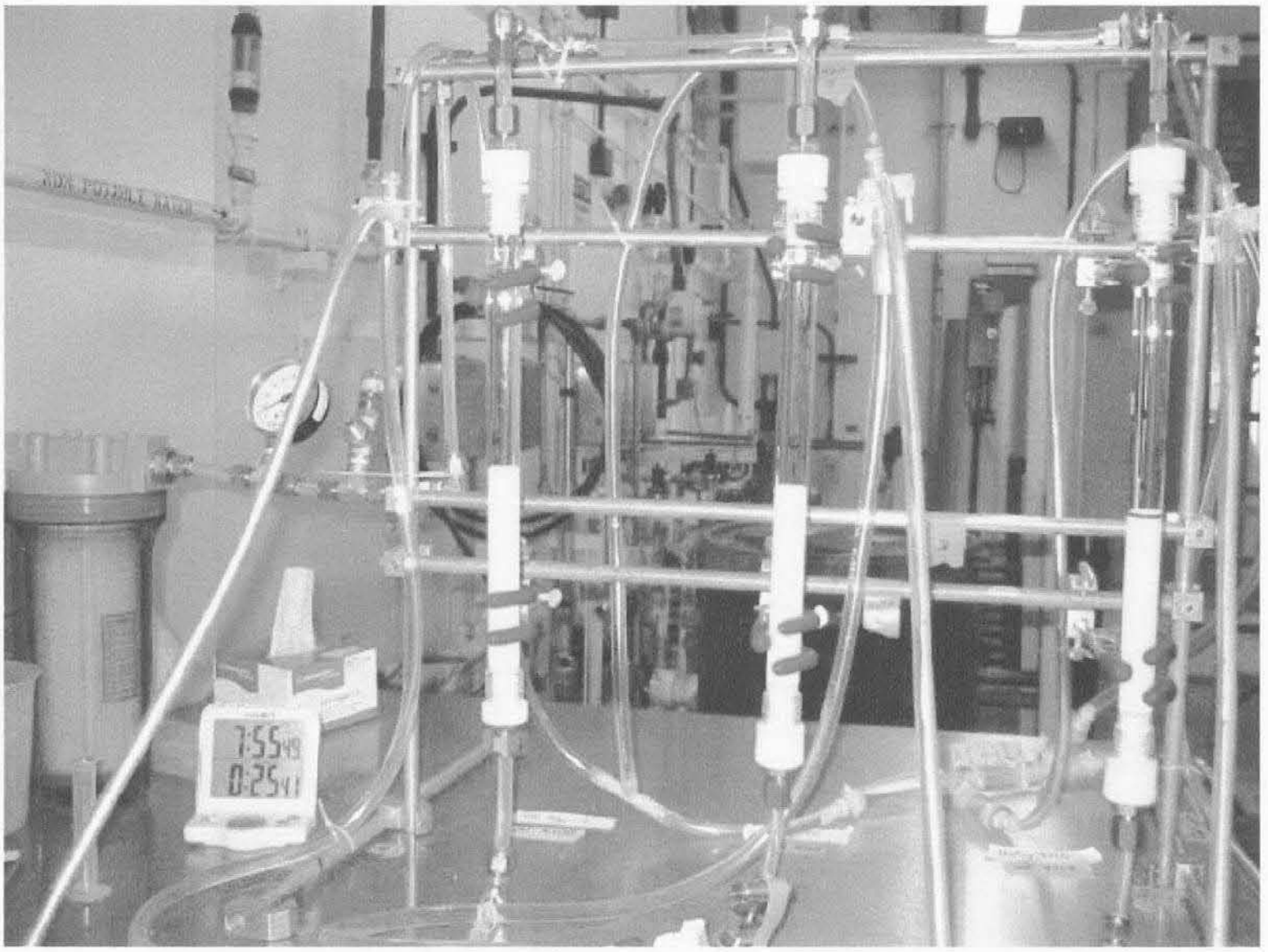
4.0 EQUIPMENT DESCRIPTION AND CAPABILITIES

4.1 Ion Exchange

4.1.1 Bench-Scale Flow-Through Column Testing Unit

A bench-scale flow-through column apparatus was used to evaluate the removal of perchlorate and other anions by IX (Figures 3.2 and 3.2(a)). This equipment was used to determine performance and cost data for three commercially-available perchlorate-selective, IX resins.

Three glass columns were set up to run in parallel, each with a different resin. The columns are 15 mm in diameter, 30 cm in length, and were filled to a depth of 12.7 cm with resin media (22.5 mL of resin). The media was supported with stainless steel screens. Each column was first half-filled with distilled water. Resin was then added from the top and allowed to settle to the bottom of the column. Resin was added until the settled resin level reached the 12.7-cm mark. Resin was added with excess water in the column to prevent the formation of air-gaps in the packed resin. Once the full amount of resin was added, the column was filled with distilled water. An in-line pre-filter (9.824-inch Osmonics Flotrex-GF pleated 3.0 μm absolute Model FGF031AAS) was installed after the feed pump to remove suspended material from the feed water. To monitor headloss, pressure gauges were installed upstream and downstream of the filter housing unit, and pressure relief valves were used to prevent pressure build-up. A three-way valve was also installed in the effluent line to provide a location for manual sampling.



BENCH-SCALE FLOW-THROUGH ION EXCHANGE EQUIPMENT

FIGURE 3.2

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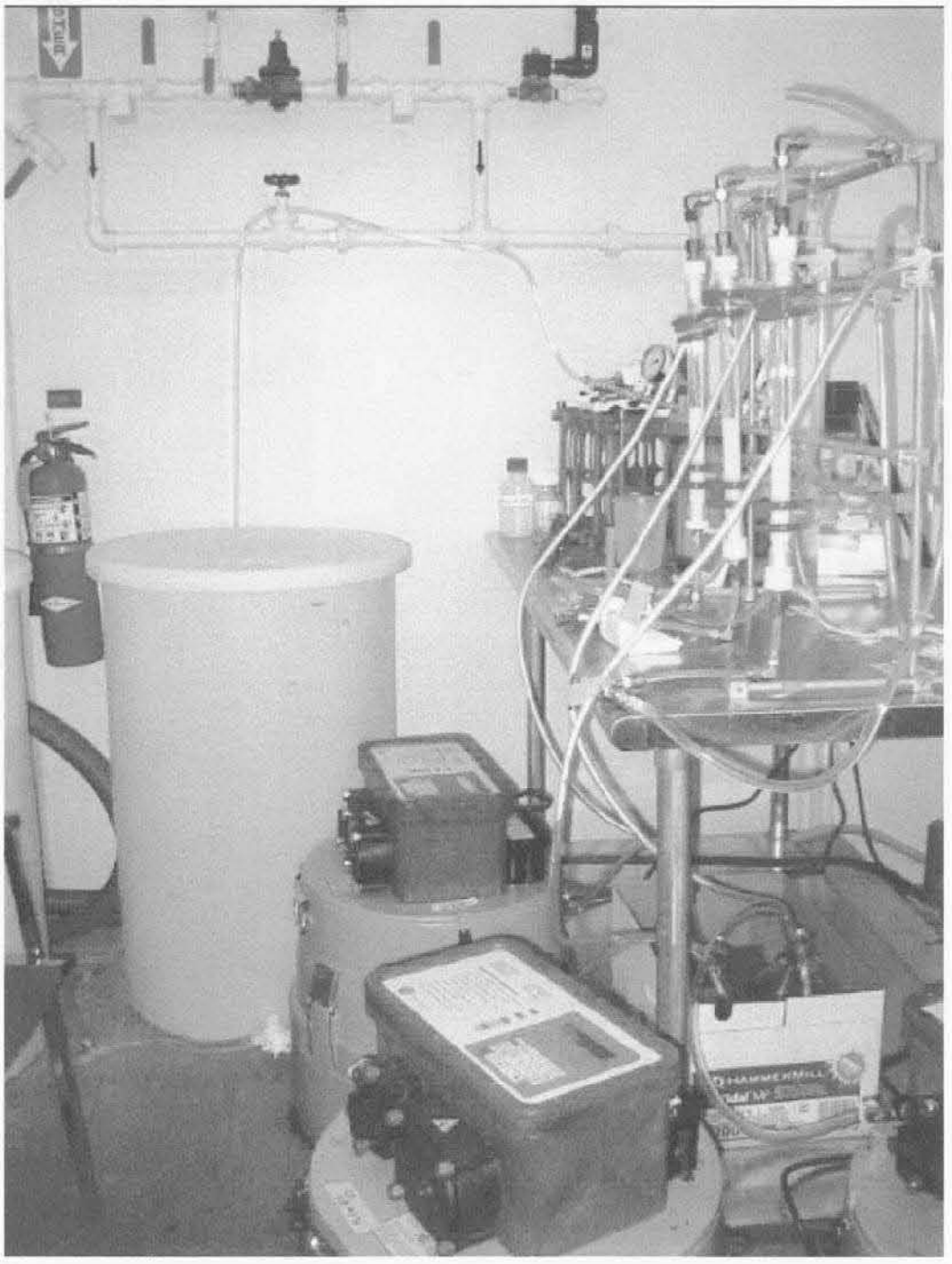

BENCH-SCALE COLUMN SETUP AND AUTOSAMPLERS

FIGURE 3.2(a)

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The columns were set up to run in parallel such that perchlorate spiked water was delivered from the two 55-gallon storage tanks to the head of the columns using an LMI model QG 400 piston lab pump. Flow-rates from each column were measured using a stopwatch and a 5-mL graduated cylinder. Volumetric measurements were taken on a daily basis. The flow was adjusted as necessary using a needle valve located at the effluent of each column. Timed effluent water samples were collected by autosamplers (leased from ISCO, Lincoln, Nebraska) during the first week of testing. The autosamplers were used to collect a one-hour composite batch from each column over a period of 24 hours. This process was repeated over the entire first week. The sampling intervals were determined from modeling results provided by the resin suppliers and/or generated by IX Pro Software using the Saugus water quality and separation factors associated with a perchlorate-selective resin as inputs.

4.1.2 Resins

There are several commercial resin manufacturers/suppliers. Based on the raw water quality in the Saugus Aquifer (i.e., perchlorate, sulfate, nitrate, TDS) and the lack of a dedicated line for disposing spent brine produced from conventional ion-exchange systems, perchlorate-selective, throw-away ion-exchange resins were selected for further evaluation using bench-scale testing. The following three resins were tested in parallel based on the availability for use in packaged systems, vendor recommendations and applicability to treating Saugus groundwater based on modeling results:

- US Filter K-9710 (US Filter Corporation, Rockford, Illinois): USF K-9710 is a strong base quarternary amine macroporous anion resin consisting of a styrene divinylbenzene matrix. The resin was tested at the Edwards Air Force Base. This resin, which received on NSF-61 certification in July 2003, can be supplied directly through a system manufacturer (e.g., US Filter, Calgon Carbon). A full-scale system using this resin is operational in the City of Rialto, California. The resin has a unique dual functionality exhibiting very high selectivity for oxy anions, such as perchlorate and pertechnate, that allows for efficient removal in a relatively high TDS background. US Filter recommends the use of this resin for single pass applications.

- Calgon Carbon Cal Resin 2 Resin 2100 Series (Calgon Carbon Corporation, Pittsburgh, Pennsylvania): This resin consists of a trimethylamine functionalized, chloromethylated copolymer of styrene and divinylbenzene in the chloride form. DHS approved packaged treatment systems are located at the City of Riverside and at California Domestic Water Company. Cal 2100 Series resins are NSF certified (NSF/ANSI Standard 61) through WQA.

- US Filter K-9708 resin (US Filter Corporation, Rockford, Illinois): USF K-9708 is a strong base quarternary amine macroporous anion resin consisting of a styrene divinylbenzene matrix. The resin has a special functionality which exhibits high

selectivity for perchlorates and nitrates over sulfates. This selectivity allows the resin to remove perchlorates and nitrates preferentially over sulfates with no potential for perchlorate or nitrate dumping. The resin is initially in the chloride form. USF K-9708 is an NSF-certified resin.

4.1.3 Autosamplers

During the first week of testing, sample collection from each column was automated using 3700 Portable Isco autosamplers (Isco, Inc., Lincoln, NE). Effluent samples were drawn every hour from 2-L glass Erlenmeyer flasks into the custom-fit polypropylene bottles located within the autosampler. Selected samples were stored at 4 degrees C in amber glass bottles until they were analyzed by CLWA or MWH laboratories. Samples were preserved by laboratory personnel with the exception of TOC/DOC samples for which 8 drops of 50 percent HCl were added on site to reduce the pH to less than 2.

During the remainder of the weeks, samples were manually collected by allowing the effluent to flow directly into the sampling bottles using three-way valves.

4.1.4 NDMA Formation Potential Testing

Bench-scale NDMA formation potential tests were conducted during the later phases of the ion-exchange testing. Post-chlorination testing with free and combined chlorine was conducted on each column effluent, as well as pre-chlorination testing with free chlorine. In addition, resin leaching testing in groundwater and DI water without the addition of chlorine was conducted for baseline comparison.

4.1.4.1 Post-Chlorination Testing with Free Chlorine

A 2,000 mg/L free chlorine stock solution was prepared from a 17,000 mg/L hypochlorite solution provided by CLWA. Two 1-L samples were collected from each column effluent. A 1-mL volume of chlorine stock solution was added to each of the bottles, resulting in a 2 mg/L free chlorine dose. The bottles were incubated for 24 hours in the dark under ambient room temperature. Free chlorine residuals were measured after 2 hours of incubation and after 24 hours of incubation. Samples were sent to MWH Laboratories for NDMA analysis. All chlorine stock solutions, doses, and residuals were measured on-site using a Hach DPD field test kit.

4.1.4.2 Post-Chlorination Testing with Chloramines

An ammonium chloride stock solution was prepared by dissolving 1.9 g of reagent-grade anhydrous NH_4Cl (also provided by CLWA laboratory) in 500 mL water. A chlorine:ammonia-N ratio of 4.0 on a weight basis was used (i.e., 2 mg/L chlorine and 0.5 mg/L ammonia-nitrogen) and 2-hour and 24-hour incubation periods were used as described above. Free and total chlorine residuals were measured in the bottles at the end of the incubation period. Bottles were sent to MWH Laboratories for NDMA analysis.

4.1.4.3 Pre-Chlorination Testing with Free Chlorine

Toward the end of the study, a 2 mg/L free chlorine dose was added to the 55-gallon drum, which fed the IX columns. Two samples were collected over a 4-day time period from each column effluent for NDMA analysis. Free chlorine residuals were measured in the bottles.

4.1.4.4 Fresh Resin Batch Testing

To evaluate the leaching potential of fresh resin, approximately 100 mL of fresh resin was added to 1 L of DI water and 1 L of feed groundwater. Bottles were allowed to incubate for a period of 4 hours. Samples were shipped to MWH Laboratories for NDMA analysis.

4.1.5 Spent Resin Characterization

TTLC and Soluble Threshold Limit Concentration (STLC) are used when determining the hazardous waste characterization of a substance under California State regulations as outlined in Title 26 of the California Code of Regulations (CCR). The three spent resins were shipped to MWH Laboratories (TTLC analyses were subcontracted to Columbia Labs in Canoga Park, California) for the following characterizations:

- TTLC Analysis for CAM 17 Metals (in California): This analysis determines the total concentration of each target analyte in a sample. Resin samples were homogenized and 5 grams of each sample were digested and analyzed for the TTLC metals according to standardized EPA methods (EPA Methods 6020 for most metals, 6010B for cooper, lead, and zinc, and 7471A for mercury). When any target analyte exceeds the TTLC limits (Table 3.19 in the Results Section), the waste is classified as hazardous and its waste code is determined by the compound(s) that failed TTLC. The results of this analysis can be used to determine if analysis for STLC level is necessary by comparing 10 times the STLC limit to the TTLC results. A factor of ten is necessary to compensate for a 1:10 dilution factor that is present in one analysis but not the other. If the TTLC results do not exceed 10 times the STLC limit, then normally no further STLC analysis is required.

- STLC Analysis for Perchlorate, Nitrate, and Uranium: This analysis determines the amount of each analyte that is soluble in the "Waste Extraction Test" (WET) leachate. This WET leachate procedure is used for solid samples or for samples containing more than 0.5 percent solids. The sample is tumbled in 10 times its weight of a 0.2 M sodium citrate buffer for 48 hours.

- Approximately 100 mL of STLC extract was obtained from each resin sample. These extracts were returned to MWH Labs for analysis of perchlorate, nitrate, and radioactive uranium.

4.2 Biological Fixed-Bed Filter

4.2.1 Pilot Skid

A photo of the FXB granular media filtration skid is provided in Figure 3.3. Important process components are identified.

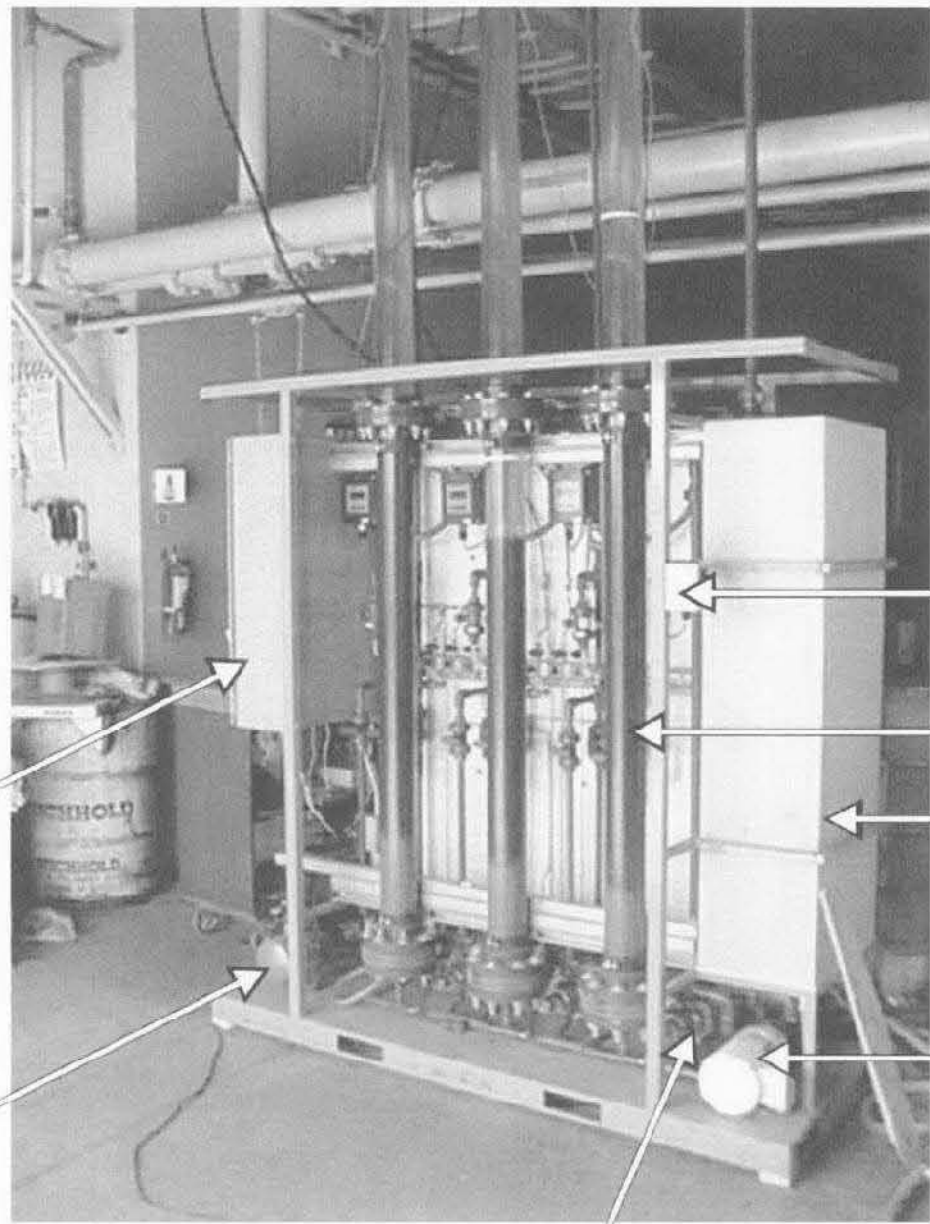
Design criteria and technical specifications for the FXB biological filtration skid are provided in Tables 3.2 and 3.3, respectively.

Table 3.2 Fixed-Bed Filter Design Criteria
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Value/Description
Filter dimensions	4" diameter, 14' tall
Number of filters per skid	3
Number of independent feed pumps	3
Maximum flow per filter	1.5 gpm
Hydraulic loading rate	2-17 gpm/ft^2
Media support mechanism	Retention plate
Backwash type	Air and/or water
Air supply	On-board compressor (with 5 μm filter)
Backwash water tank volume	20 gallons
Parameters measured by in-line meters	Flow Effluent turbidity Effluent particle counts Headloss across the filters

Table 3.3 Fixed-Bed Filter Technical Specifications
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Value/Description
Skid weight	750 lbs
Skid dimensions (LxWxH)	6'6"x2'6"x14'
Electrical requirements	3-phase, 30A, 208-Volt, AC power (Y connection)
Influent, effluent, overflow connections	1" Cam Lock



FIXED-BED BIOLOGICAL FILTRATION PILOT PLANT

FIGURE 3.3

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A schematic of the FXB pilot is shown in Figure 3.4. The FXB skid is configured for down-flow operation. Initially, all three columns on the skid were utilized for pilot testing.

However, because sampling and other daily pilot tasks required for three columns were too onerous for a single operator, two of the columns were shut down one month into the piloting period. Stock perchlorate and (temporarily) phosphate solutions were added upstream of an in-line static mixer using an Ismatec ISM 832B two-channel eight-roller peristaltic pump together with Pharmed 0.020-inch ID peristaltic pump tubing. A second head was added to the peristaltic pump to add acetic acid to the system. Initially, acetic acid was also added at the same location as the perchlorate stock solution. However, excessive growth in the feed lines prompted a relocation of the acetic acid feed to the top of the column one month into the piloting period. Filter effluent turbidity and particle counts were monitored continuously by dedicated turbidimeters and particle counters. A pressure transducer mounted on the pilot skid monitored head loss development across the filter; backwashes, which could include air scour, were initiated manually. The pilot skid is equipped with a data acquisition and control (DAC) system, which stores and manages data. For each filter column, the DAC continuously logs date/time, flow, headloss, effluent turbidity, and effluent particle counts. The skid includes a touch screen interface to monitor and control pilot operations.

4.2.2 Media

The columns were filled to a depth of 7 feet (approximately 0.6 ft^3) with virgin Calgon F-400 granular activated carbon (GAC). This allowed for bed expansion up to 50 percent. F-400 is a bituminous-based carbon commonly used in the United States. The GAC was stored overnight in 5-gallon buckets to wet the surface and internal pores. The filter columns were filled with NC-12 well water and the GAC was dosed slowly into the columns until the 7-foot depth was reached. Once the columns were packed with GAC, they were backwashed for a period of 24 hours at a 45 percent bed expansion to remove carbon fines from the GAC bed.

4.2.3 Stock Solutions

For the biological pilot systems, an intermediate stock perchlorate solution of 136.17 g/L ClO_4^- was made using reagent grade sodium perchlorate salt and distilled deionized water. Individual stock solutions were made as necessary in 2-L glass bottles using the intermediate stock solution. During periods where phosphorus was added to the feed stream, 75 percent pure food-grade phosphoric acid was added directly to the perchlorate stock solution. For the acetic acid stock solutions, technical-grade acetic acid (Eastman Chemical Company, Kingsport, Tennessee) was used. Stock solutions were stored in 2-L glass bottles that were flame sterilized using ethanol.

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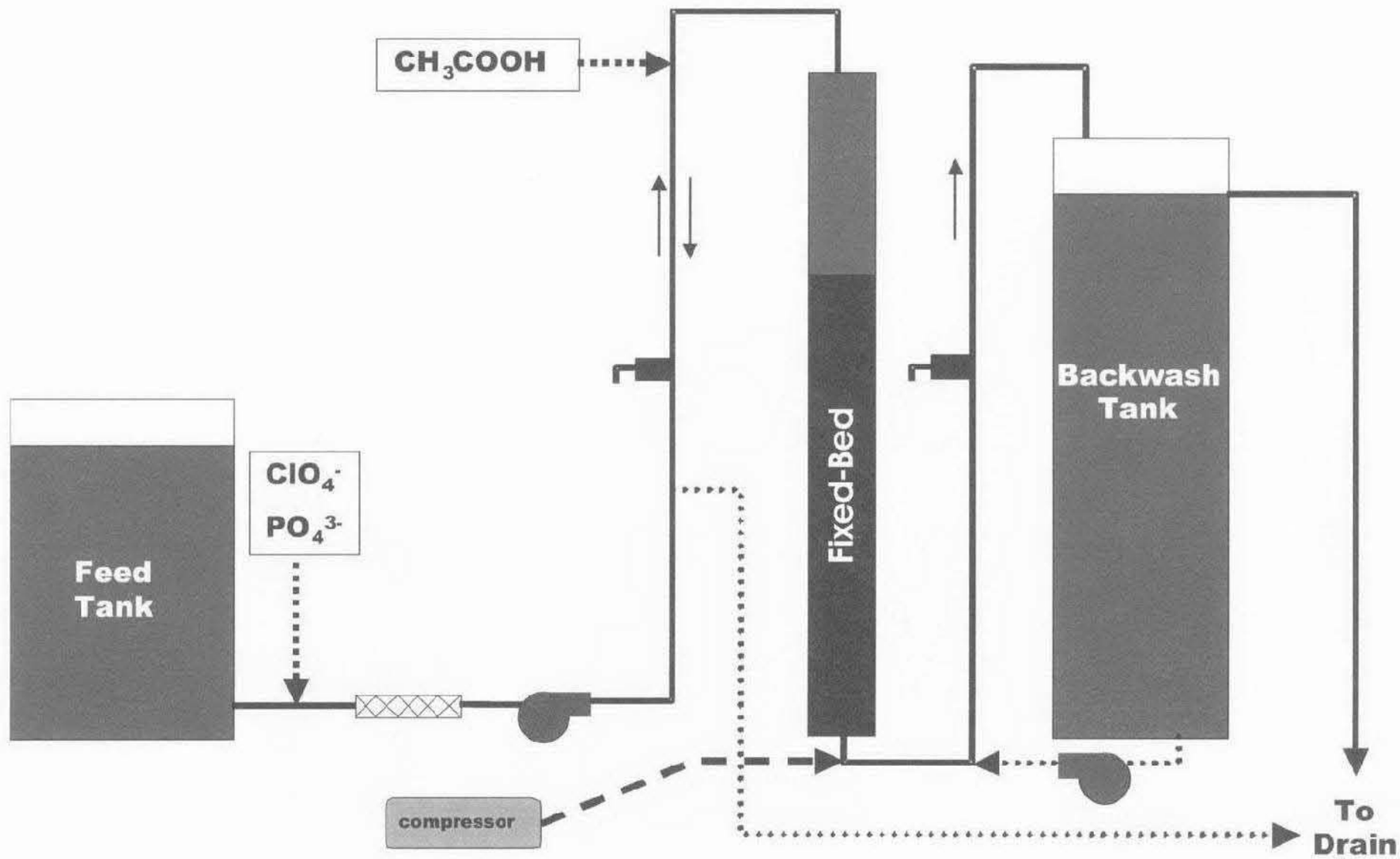

FIXED-BED BIOLOGICAL FILTRATION PILOT SCHEMATIC (NOT TO SCALE)

FIGURE 3.4

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4.3 Biological Fluidized-Bed Reactor

4.3.1 Pilot Skid

The basic components of the pilot FBR system included the bioreactor, bed height control component (when required), biomass separator, a fluid distribution system at the bottom of the reactor, a feed pump, and chemical feed systems (Figure 3.5). The bed of GAC media is hydraulically fluidized to reduce its resistance to flow and to improve substrate/biomass contact by directing liquid flow upward into the bed. The fluidization rate is controlled to maintain a 25 to 30 percent bed expansion over the resting bed height. Feed flow is supplemented with recycle flow to provide the appropriate up-flow velocity for fluidization. When biofilm growth occurs on the GAC media, the particle diameter increases and the effective density of the particle decreases, which causes further expansion of the bed. It is necessary to manage film thickness to control or prevent bed carryover. In full-scale FBR systems, bed height is managed in the top portion of the bed by mechanically shearing the biomass from the GAC through a valve. The "cleaned" GAC particles settle back into the bed, ready to support more biofilm growth, and the sloughed biomass is discharged. In the pilot test unit, mechanical mixing or pump shear was used to perform this task.

Perchlorate and phosphorous stock solutions were added directly to the feed line upstream of the recycle line connection using a diaphragm metering pump. A second diaphragm metering pump was used to add acetic acid stock solution to the feed line. Initially, the acetic acid was injected just prior to the feed pump, but was later moved closer to the bioreactor to minimize biofouling in the feed lines.

4.3.2 Media

The FBR bioreactor uses a proprietary coconut shell based carbon that meets Shaw Environmental-Envirogen specifications for hardness, apparent density, effective size, iodine number, and uniformity coefficient.

4.3.3 Stock Solutions

For the biological pilot systems, an intermediate stock perchlorate solution of 136.17 g/L ClO_4^- was made using reagent grade sodium perchlorate salt and distilled deionized water. Individual stock solutions were made as necessary in 2-L glass bottles using the intermediate stock solution. Food-grade phosphoric acid (Prayon, Inc., Augusta, Georgia) was added directly to the perchlorate stock solution. Acetic acid stock solutions were prepared using technical-grade acetic acid (Eastman Chemical Company, Kingsport, Tennessee) and were stored in a 10-L polypropylene carboy. Before stock solutions were prepared, these carboys were rinsed with rubbing alcohol for sterilization. For selected tests, a micronutrient mixture (GrowMore, Gardena, California) was added directly to the acetic acid stock solution. The micronutrient mixture contained trace amounts of iron, copper, magnesium, manganese, zinc, boron, sulfur, molybdenum, and cobalt.

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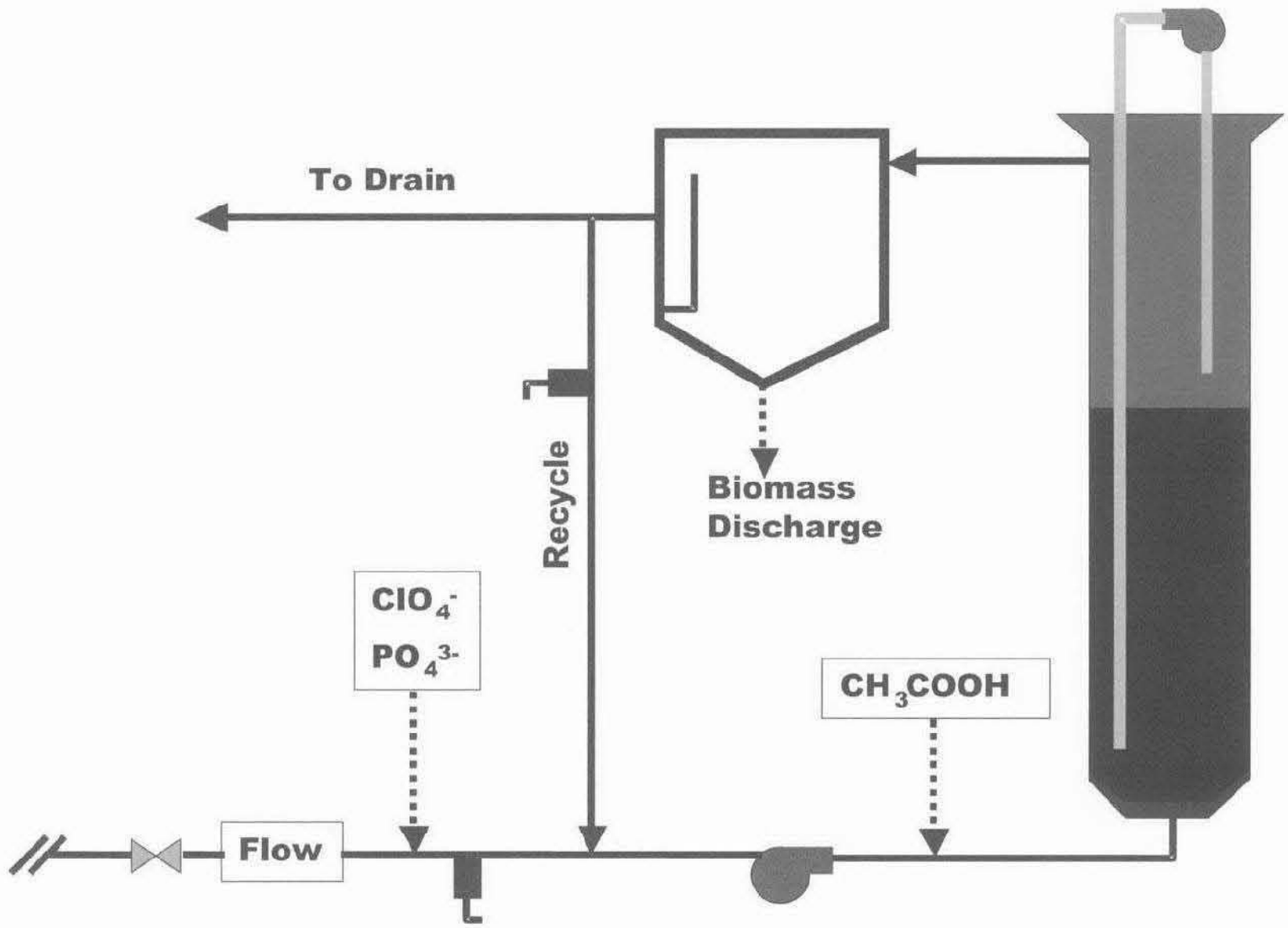

FLUIDIZED-BED BIOLOGICAL FILTRATION PROCESS SCHEMATIC (NOT TO SCALE)

FIGURE 3.5

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4.4 Submerged Membrane Bioreactor

4.4.1 Objectives

Zenon Zeeweed® membranes, operating in an SMBR configuration, were evaluated as an alternative combined treatment step for post-treatment of effluent from the biological filtration process. The post-treatment process must achieve four treatment goals:

1. Aeration: Since biological perchlorate reduction requires anaerobic conditions, DO must be supplied during the post-treatment process.

2. Residual Organic Carbon Removal: Organic substrate is added to the FXB to achieve perchlorate reduction. Therefore, to prevent regrowth problems and to minimize the formation of DBPs, the effluent water must be stabilized biologically.

3. Sulfide Removal: Under anaerobic conditions, sulfate can be reduced to sulfide, which generates a rotten-egg odor. Therefore, the post-treatment process must be able to remove sulfide, which can be accomplished via biological oxidation or air stripping.

4. Biomass Separation: The post-treatment process must provide a barrier for removal of biological matter (HPC bacteria) that sloughs from the biological filters.

4.4.2 System Description

The ZeeWeed® water treatment process is a proprietary ZENON process technology that involves the production of treated water by drawing water through ZeeWeed® "outside-in" hollow fiber membranes that are immersed in the feed water. The ZeeWeed® ultrafiltration membranes have nominal and absolute pore sizes of 0.04 and 0.10 mm, respectively. The membranes act as a physical barrier that prohibits particulate matter exceeding 0.1 μm in size, including *Giardia* cysts and *Cryptosporidium* oocysts, from entering the treated water supply. The small pore size ensures the removal of a high percentage of impurities, including some viruses (typically 2 to 4.5 log reduction), which are removed by a combination of adsorption onto the solids in the process tank and membrane filtration.

The ZeeWeed® membrane filtration system operates under a low-pressure vacuum that is induced within the hollow membrane fibers by a connection to the inlet (suction) side of a centrifugal permeate pump. The treated water is drawn through the membrane by vacuum, enters the hollow fibers and is pumped out to distribution by the permeate pumps. Airflow is introduced at the bottom of the membrane module to create turbulence that scrubs and cleans the outside of the membrane fibers. This reduces the solids accumulation on the membrane surface, thereby allowing the membrane to operate for extended periods at high permeate fluxes. The air also has the beneficial side effect of oxidizing iron and other organic compounds that may be present. It also provides mixing within the process tank to maintain solids in suspension. The membranes are periodically backwashed which consists

of passing permeate through the membranes in the reverse direction to dislodge solids from the membrane surface.

The ZeeWeed® Ultrafiltration system provides a single step process, effectively replacing both the clarification and granular media type (sand) filtration processes found in conventional water treatment plants. The membrane pore size is extremely small and effectively provides a physical barrier to solids present in the water. Therefore, there is no need to create flocculated particles that are large enough to settle in clarifiers or large enough to be captured by granular media filters. Also, as the membranes are immersed directly in the process tank and under only low vacuum, high levels of suspended solids do not foul the membrane.

The ZeeWeed® membranes, operating in an MBR configuration, were considered in this case as an alternative combined treatment step for post-treatment of the effluent from the biological filtration processes. Post-treatment has three main purposes:

- To provide biological oxidation of excess substrate (acetic acid) fed to the filters;
- To re-oxygenate the water; and
- To provide a barrier for removal of biological matter (HPC bacteria) present in effluent from the biological filters.

A flow schematic for the ZeeWeed®-based post biological FXB filtration process is presented in Figure 3.6.

4.4.3 System Components and Specifications

The unit is equipped with:

- Coagulant Feed Pump and Chemical Tank.
- Cleaning Chemicals.
- Process Tank (hydraulic retention time is 3 to 5 hours).
- Membrane Air Scour Blower.
- Dual head, variable speed, reversible, metering pump for permeate and reject.
- One ZeeWeed®-10 Ultrafiltration Membrane.
- Backpulse Tank.
- Instrumentation and Control Panel.

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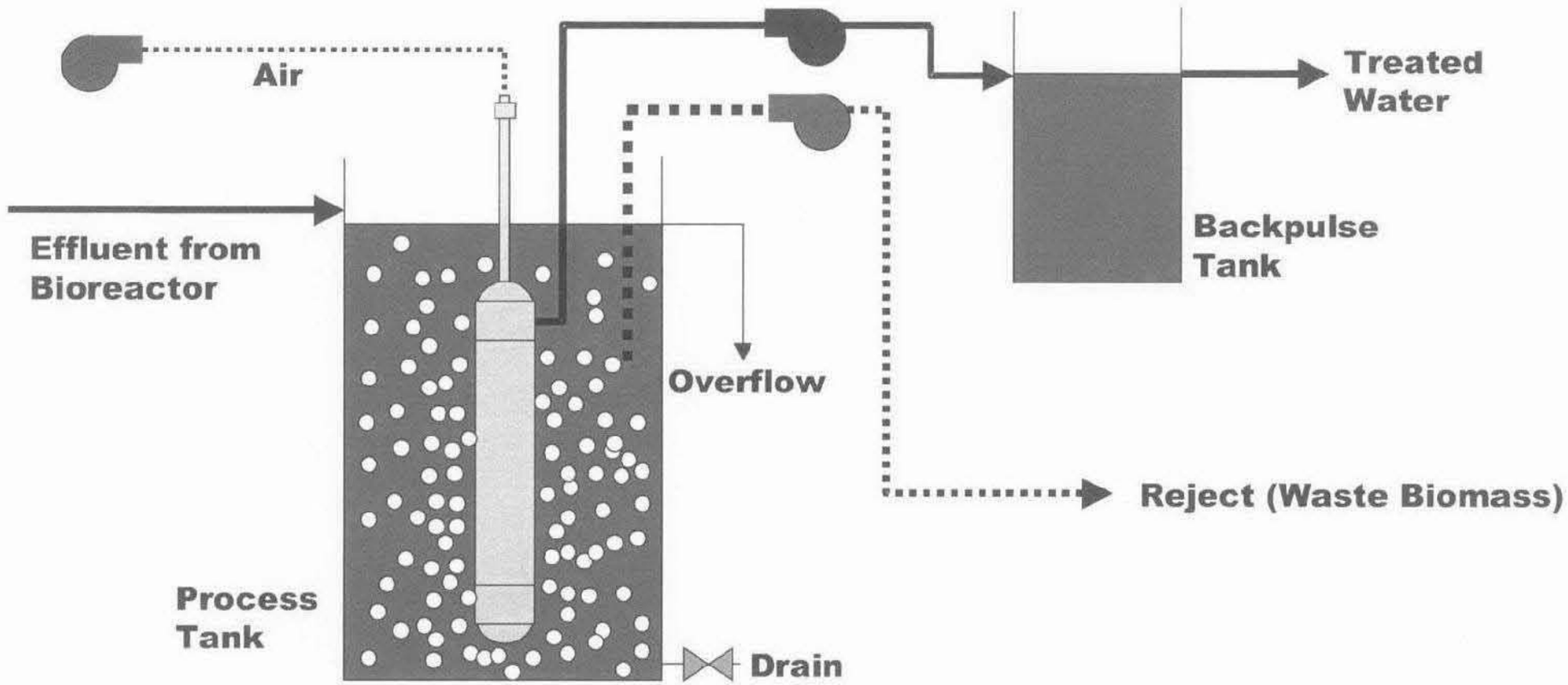

POST-FXB TREATMENT MBR SCHEMATIC (NOT TO SCALE)

FIGURE 3.6

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ZW-10 module and system specifications are listed in Tables 3.4 and 3.5, respectively. Table 3.6 lists system operating limits.

Table 3.4	**SMBR ZW-10 Module Specifications Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency**
Model	ZW-10, Submersible Module
Configuration	Outside/In Hollow Fiber
Dimensions (length x width x height)	6'x4'x5'
Nominal Membrane Surface Area	0.93 m^2 (10 ft^2)
Absolute Pore Size	0.1 micron
Weight of Module (Drained)	1.9 kg (4.2 lb)
Weight of Module (Wet)	2.1 kg (4.6 lb)
Permeate (Fiber Side) Hold-up Volume	0.13 liters (0.033 gal)

Table 3.5	**SMBR ZW-10 System Specifications Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency**
Designation	ZW-10 Bench Test Unit
Electrical service required	115 V, 60 Hz, 2A
Process tank total volume	220 L (58 usg)
Process tank working volume, nominal	190 L (50 usg)
Backpulse tank total volume	20 L (5 usg)
Backpulse tank working volume	15 L (4 usg)
Shipping weight	75 kg (160 lb)
Operating weight	300 kg (660 lb)
Process tank size (with backpulse tank)	75 cm Ø x 160 cm H (30"Ø x 60" H)
Process pump size	40 cm x 15 cm x 15 cm (16" x 6" x 6")
Blower size	40 cm x 25 cm x 25 cm (16" x 10" x 10")
Control panel size	38 cm x 38 cm x 20 cm (15" x 15" x 8")

Table 3.6 SMBR ZW-10 System Operating Limits Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency	
Maximum pump capacity	2 liters/minute (0.53 gpm)
Maximum Transmembrane Pressure	62 kPa (9.0 psig) @ 40°C (104°F)
Typical Operating TMP	10-50 kPa (1.0-7.0 psi) @ 40°C (104°F)
Maximum Operating Temperature	40°C (104°F)
Operating pH range	5-9
Maximum Cleaning Temperature	40°C (104°F)
Cleaning pH Range	2-10.5
Maximum OCl^- Exposure(1)	1,000 mg/L
Maximum TMP Back Wash Pressure	55 kPa (8.0 psi)
Maximum Aeration Flow per Module	3.6 m^3/h (2 scfm)

Notes:
(1) Higher OCl^- concentrations can occasionally be used.

4.5 DBP Formation Potential Testing

4.5.1 Source Waters

DBPFP is defined as the difference between the TTHM or HAA concentration after 7 days of incubation with excess free or combined chlorine residual and the initial TTHM or HAA concentration. Free chlorine and combined chlorine DBPFP tests were conducted using the following source waters:

- FXB and FBR Effluent: This test served as a worst-case scenario test (i.e., no post-treatment downstream to remove excess electron donor).
- SMBR Effluent: This test simulated on-site post-treatment with an aerated SMBR.
- Ozonated FXB and FBR Effluent: This test simulated post-treatment at the Rio Vista WTP.

4.5.2 Formation Potential Method

Test waters were subjected to formation potential evaluation of trihalomethanes and haloacetic acids. The trihalomethane formation potential method (THMFP) is described in the 20th Edition of Standard Methods (Method 5710B). All samples for DBP formation potentials were subjected to the standard methodology for THM formation potential:

"Under standard conditions, samples are buffered at pH 7.0 ±0.2, chlorinated with an excess of free chlorine, and stored at 25 ± 2 degrees C for 7 days to allow the reaction to approach completion. As a minimum, pH is buffered at a defined value and a free chlorine residual of 3 to 5 mg/L exists at the end of the reaction time and THMFP = TTHM at day 7-TTHM at day 0."

In the same manner, HAAFP = THAA at day 7 – THAA at day 0. The same conditions were be used for THMFP and HAAFP with combined chlorine (w:w, chlorine:ammonia = 4).

4.5.3 DBPFP Yield

The THMFP and HAAFP TOXFP yields are a measure of DBP formation potential per mg dissolved organic carbon and are defined as the following:

THMFP yield = THMFP/DOC, where DOC = dissolved organic carbon;

HAAFP yield = HAAFP/DOC and TOXFP yield = TOXFP/DOC.

The yield is a way to estimate the fraction of natural organic matter that is a precursor to formation of halogenated disinfection by-products. It was determined as part of this test.

4.5.4 Chlorine Demand

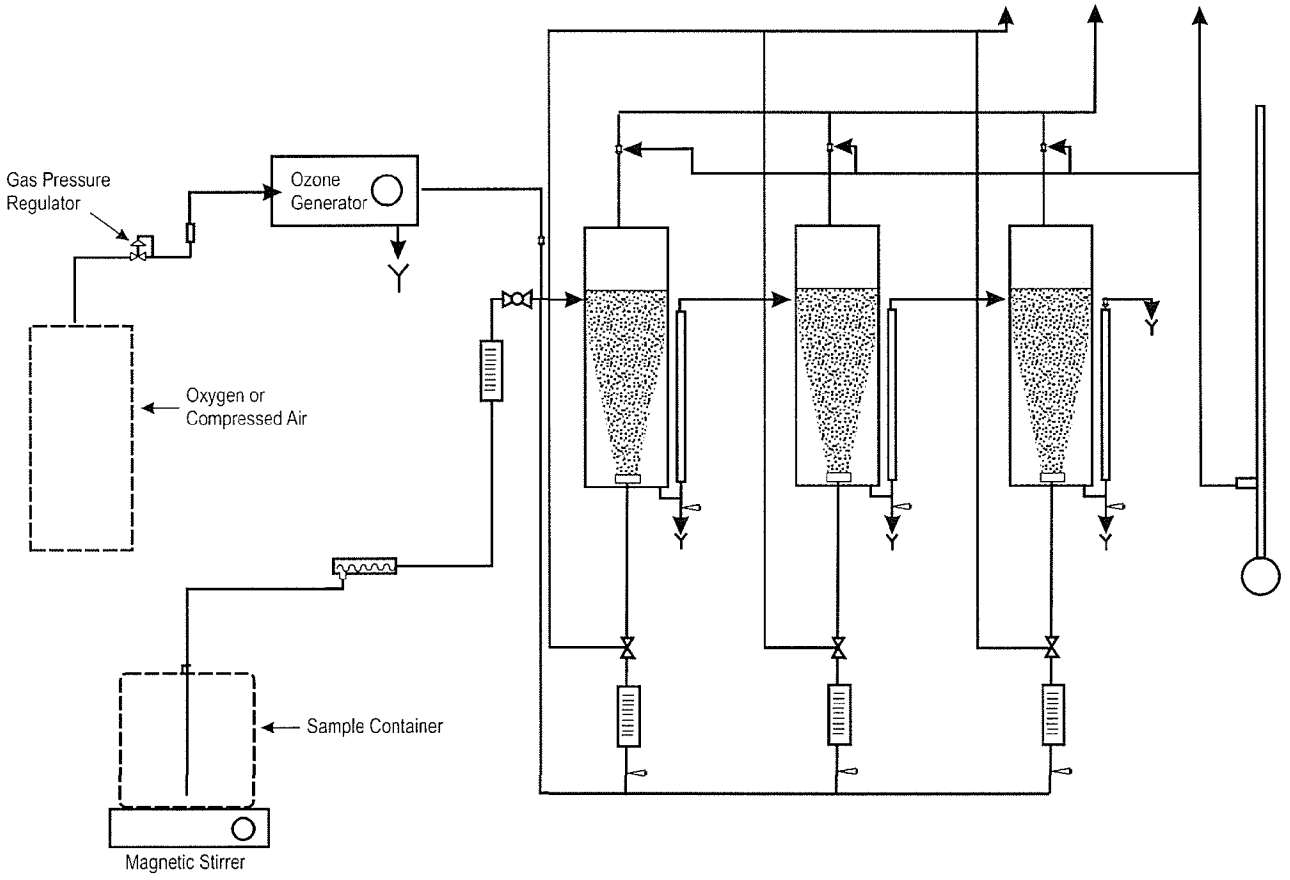
The 7-day chlorine demand was determined by the following procedure:

- Upon receipt of the samples, each sample was analyzed for ammonia, total and free chlorine, and TOC/DOC. The one-hour chlorine demand was measured at day 0. A chlorine:DOC ratio ranging from 2.5 to 5 was used. The results of this preliminary evaluation were used to estimate the required chlorine dose to achieve a 3 to 5 mg/L free chlorine residual at the end of the 7-day incubation period. It was assumed that once the instantaneous free chlorine demand is satisfied, the free chlorine decay would be much slower over the 7-day incubation period.

  A total chlorine residual of 3 to 5 mg/L after the 7-day incubation period was targeted. A chlorine:ammonia ratio of 4 was used.

4.5.5 Ozone Testing

An ozone demand test was conducted on two blended water samples that simulated the feed of the biological effluent to the Rio Vista Surface Water Treatment Plant: 90 percent SPW with 10 percent fixed bed reactor effluent and 90 percent SPW with 10 percent fixed bed effluent spiked with acetic acid. Carollo's bench-scale, continuous-flow, three-chamber ozone contactor was used (Figure 3.7). The hydraulic retention time in the bench-scale contactor was set at 6 minutes, and the test was conducted at ambient water temperature and ambient pH. The applied ozone dose (1.5 mg/L) was equally split between the three chambers. Ozone residuals were measured at the effluent of the third chamber. The



CAROLLO'S CONTINUOUS BENCH-SCALE OZONE REACTOR (NOT TO SCALE)

FIGURE 3.7

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effluent of the third ozone chamber was sampled for parameters listed in Table 3.7. Effluent samples were taken after a minimum of three nominal hydraulic retention times (HRTs) were achieved. The ozonated waters were then subjected to chlorine and chloramines for formation potential testing.

Table 3.7 DBPFP Analytical Matrix
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	FXB and FBR BIO Effluent	MBR Effluent	Ozonated Effluent	Lab
TOC/DOC	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
BDOC	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	MWH
AOC	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	MWH
TTHM	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
HAA5	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
	7-day Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
Free/Total Chlorine				On-site
	After Cl_2/NH_2Cl (time 0 and time 7 day)	After Cl_2/NH_2Cl (time 0 and time 7 day)	After Cl_2/NH_2Cl (time 0 and time 7 day)	
Ammonia	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	On-site
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
pH	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	On-site
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
UV_{254} Absorbance	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
Alkalinity	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
Bromide	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	Before Cl_2/NH_2Cl	CLWA
	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	After Cl_2/NH_2Cl	
Bromate			Before Cl_2/NH_2Cl	CLWA/MWH
Aldehydes			Before Cl_2/NH_2Cl	MWH

4.5.6 Water Quality Analysis

Each sample was analyzed according to the matrix presented in Table 3.7 for full characterization before the addition of disinfectant and 7 days after addition. Ozonated waters were analyzed for bromate and aldehydes. On day 7 of the test following application of chlorine or chloramines, samples were analyzed for free and total chlorine residual, THM4, HAA5, pH, and bromide.

4.6 Simulated Distribution System Test

A follow-up SDS test was conducted on the FBR effluent with free chlorine to confirm the high THM4 and HAA5 levels measured in the FBR effluent during the DBPFP test. Free chlorine was added to the FBR effluent to satisfy the initial demand (approximately 8 mg/L) and to result in a free chlorine residual of 0.3 to 0.5 mg/L after an incubation period of 72 hours. This free chlorine residual and incubation period mimic the free chlorine residuals and maximum hydraulic residence time in the distribution system served by Newhall County Water District wells. The SDS test was conducted at ambient room temperature.

5.0 ANALYTICAL METHODS

Water quality data were measured on-site using bench-top equipment, on-line instruments, and laboratory analyses. The CLWA lab performed the majority of the laboratory analyses. Initial samples for nitrate, sulfate, chloride and bicarbonate were sent to MWH Laboratories in Monrovia, California, in addition to routine analysis for BDOC, sulfide, AOC, VSS, COD, NDMA, uranium, HAAs, TTHMs, and split perchlorate samples. For laboratory analyses, samples were collected in amber glass or polypropylene bottles. Samples sent to MHW labs were placed in bottles supplied by the laboratory and stored at 4 degrees C until analyzed.

5.1 pH

pH was measured on-site using Standard Method 4500-H + B. The pH meter was an Oakton 300 series with a single junction pH electrode. A 2-point calibration of the pH meter was performed daily.

5.2 Temperature

Temperature was measured in accordance with Standard Method 2550 B. This was done daily to check in-line temperature transmitters on the pilot plants. Temperature measurements were made daily using an Oakton 300 series pH/Conductivity meter with a built-in automatic temperature compensation ATC element.

5.3 Turbidity

Feed and permeate water in-line turbidity measurements were logged continuously on the pilot plant using Hach 1720 D low range process turbidimeters. The feed and permeate turbidimeters were calibrated after each run using primary calibration standards purchased from the manufacturer. Turbidimeter sensor lenses were cleaned every two weeks according to the manufacturer's instructions. Turbidimeter flow rates were checked daily to insure that they were within the range required by the manufacturer. Daily bench-top turbidity analyses were performed using a Hach 2100 P field turbidimeter. The instrument was calibrated before measurements using primary turbidity standards (0, 20, 100, 800 NTU).

5.4 Perchlorate

Perchlorate was measured by the CLWA laboratory using EPA method 3.14.0 with a minimum reporting limit of 4 µg/L.

5.5 Common Anions

Analysis for nitrate, nitrite, sulfate, bicarbonate, chloride, and phosphate were provided by CLWA using EPA method 300.0A.

5.6 Dissolved Oxygen

On-site DO measurements were taken using a YSI 5500 portable dissolved oxygen (DO) meter that was calibrated daily.

5.7 Metals

Calcium, magnesium, iron, chromium, and manganese measurements were analyzed using EPA method 200.7 by the CLWA laboratory.

5.8 Sulfide

Total sulfide measurements were made by MWH laboratories using EPA method 376.2.

5.9 NDMA

Analysis for NDMA was made using EPA method 1625 at MWH laboratory.

5.10 Uranium

Uranium analysis was performed by MWH using EPA method 908.1.

5.11 Total Suspended Solids

Total suspended solids (TSS) were measured at CLWA laboratory according to Standard Method 2540 D.

5.12 Total Alkalinity

Total alkalinity was measured at CLWA laboratory according to Standard Method 2320 B.

5.13 Total Hardness

Total hardness was measured at CLWA laboratory according to EPA Method 200.7 and Standard Method 2340 B.

5.14 Organic Carbon

Total organic carbon (TOC) and dissolved organic carbon (DOC) were measured at CLWA laboratory according to EPA Method 415.1. CLWA uses a Shimadzu TOC-5050 Total Organic Carbon Analyzer. The minimum reporting level was 0.7 mg/L. Biodegradable DOC was measured by MWH using the Servais method.

5.15 UV_{254} Absorbance

UV_{254} absorbance was measured at CLWA laboratory according to Standard Method 5910 B. The instrument used for measurements was a Shumadzu UV-1201 UV-VIS Spectrophotometer.

5.16 Total and Free Chlorine

Total and free chlorine concentrations were measured using an on-site, HACH DR 890 field spectrophotometer. High range measurements (0 to 5 mg/L) for total and free chlorine were made in accordance with HACH methods 10070 and 10069, respectively (adapted from Standard Methods). Measurements for total and free chlorine concentrations from 0 to 2.00 mg/L were made using HACH methods 8167 and 8021, respectively (equivalent to Standard Method 4500-Cl G).

5.17 Microbial Parameters

Heterotrophic plates counts (HPCs) and total and fecal coliform counts were measured according to Standard Methods 9215B and 9221 D, respectively by CLWA and MWH laboratories.

5.18 Particle Counts

FXB in-line particle count measurements of the effluent water were logged continuously using a Hach 2200 PCX particle counter. Continuous maintenance of the particle counter (cleaning and flow adjustment) ensured accurate readings.

5.19 Disinfection By-Products

TTHMs and HAAs were measured by MWH laboratories according to EPA Methods 502.2 and 552.2, respectively.

5.20 Ozone Residual

Ozone residual was measured according to the Indigo Blue Method (Standard Method 4500-O3 B). Hach accuvacs were used that withdraw 10 mL of samples directly reacting with the Indigo Powder in the ampule.

5.21 COD

Chemical oxygen demand (COD) analysis was performed at MWH laboratories using EPA method 410.4.

6.0 OPERATING PROTOCOL

6.1 Ion-Exchange Columns

6.1.1 Experimental Design

The bench-scale IX study was conducted by Carollo. There were four objectives for this work:

1. Evaluate the efficiency of three ion-exchange resins for perchlorate removal under the identical feed water, flow rate, and EBCT.
2. Establish the perchlorate breakthrough curves for Saugus Aquifer water using three perchlorate-selective, throw-away resins.
3. Determine the NDMA formation potential of treating Saugus Aquifer water with these resins.
4. Determine characteristics of the spent resin.

- Phase 1 (Perchlorate Breakthrough: Approximately 2 to 4 Months): The columns were fed at a constant flow rate with perchlorate- and sulfate-spiked groundwater and sufficient influent and effluent samples were taken to establish a complete breakthrough curve for each anion. The columns were shut off once perchlorate breakthrough in all columns reached approximately 20 percent of the feed concentration. This translates into an effluent perchlorate concentration of 10 µg/L.

  The operating conditions for each ion-exchange column are listed in Table 3.8. The columns were operated at a service loading rate of 5 gpm/ft^3. With a resin volume of 22.5 mL in each column, the flow rate to each column was approximately 15 mL/min, which equates to an EBCT of 1.5 minutes.

Table 3.8	Breakthrough of Anions Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Parameter	**Value**
EBCT	1.5 min
Service Flow Rate	15 mL/min
Service Loading Rate	5 gpm/ft^3
Surface Loading Rate	2.1gpm/ft^2
Run Length- from Preliminary Modeling	> 20,000 BVs
Batch Feedwater Volume per Column	40 gal/week
Total Batch Feedwater Volume	119 gal/week

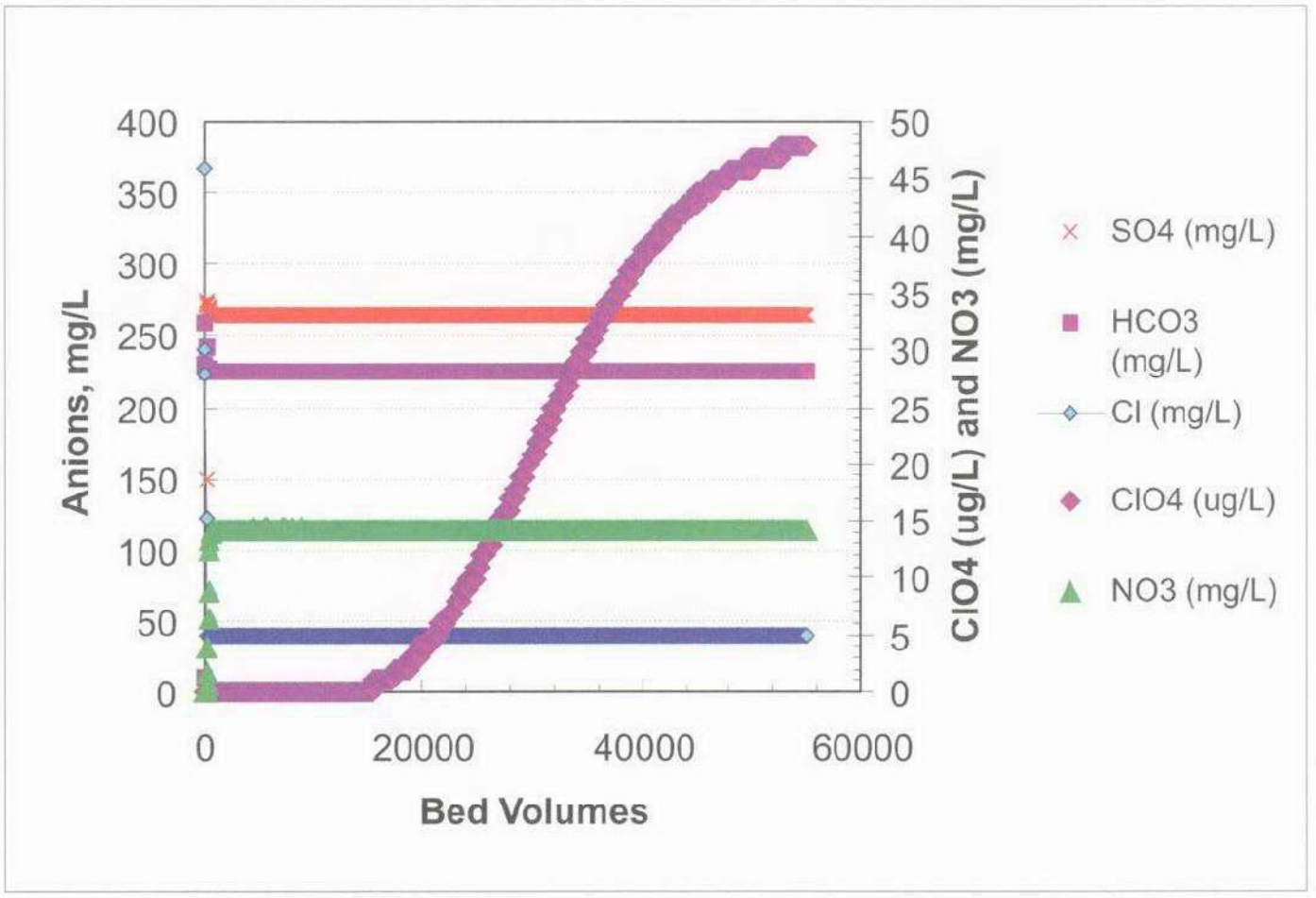
The breakthrough profiles of the various anions depend on the resins selected. Breakthrough modeling data (IX Pro Software) for a generic perchlorate selective resin are tabulated and plotted in Table 3.9 and Figure 3.8, respectively. The anticipated anionic breakthrough order was as follows: bicarbonate, sulfate, nitrate, perchlorate. The inputs to the modeling program were: component concentration, component separation factor (or selectivity coefficient); resin capacity; number of plates; and run length. The separation factors were based on the research conducted by Tripp et al. (2003).

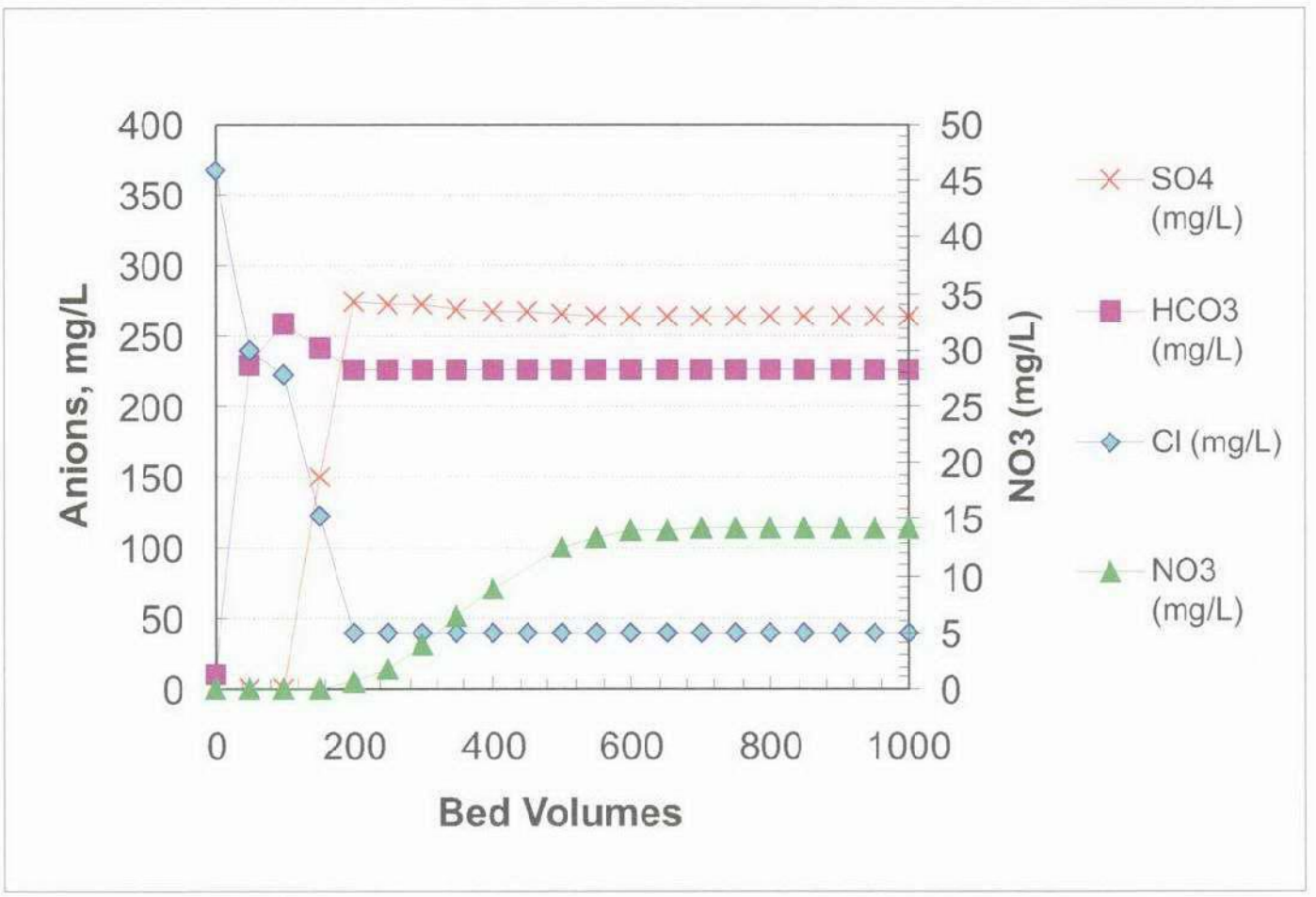
Table 3.9	Breakthrough of Anions for a Generic Perchlorate Selective Resin Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency	
Anions	**Bed Volumes (BVs)**	**Equivalent Time (EBCTxBVs)**
Bicarbonate	40 BVs for complete breakthrough	1 hr
Sulfate	200 BVs for complete breakthrough	5 hours
Nitrate	600 BVs for complete breakthrough	15 hours
Perchlorate	>20,000 BVs for breakthrough up to 4 μg/L	21 days

6.1.2 Sampling

Carollo staff was responsible for day-to-day operation and sampling of the bench-scale IX columns during regular weekdays (excluding holidays). CLWA staff checked on the columns during the weekend and holidays. To address emergencies during off-hours, CLWA staff contacted the lead Carollo operator. Operator log sheets were used daily to record flow rates and sample collection times.

Perchlorate-spiked raw water was analyzed once per week for perchlorate, nitrate, sulfate, bicarbonate, chloride, pH, and conductivity.





20-CLWA204F3.8-6625A10.CDR

ANITICIPATED BREAKTHROUGH CURVES FOR KEY ANIONS

FIGURE 3.8

carollo engineers

CASTAIC LAKE WATER AGENCY

Sampling frequencies for column effluents were established so that breakthrough profiles for sulfate, bicarbonate, chloride, nitrate, and perchlorate were captured. Sampling frequencies were as follows:

- First 48 hours: One sample per hour. Analyzed 12 (every 3 to 4 hours) samples for nitrate, sulfate, chloride, and bicarbonate. Perchlorate was analyzed three times per week.
- After the first two days of operation, sample frequencies were decreased to six samples per day, depending on whether the parameter has broken through. Perchlorate was analyzed three per week.

Table 3.10 lists the sampling frequencies and locations from Day 3 until 20 percent perchlorate breakthrough occurred. This sampling schedule was adequate to capture breakthrough of all anions for all three types of resins. During the first week of operation (i.e., the time-sensitive breakthrough period for bicarbonate, chloride, sulfate, and nitrate), samples were collected with a timed autosampler. Subsequently, all samples were collected manually at the frequencies describe in Table 3.10.

Table 3.10 Testing Matrix for Bench-Scale Ion Exchange Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Chemical Parameter	Lab	Sampling Frequency from Each Column Effluent		
		Day 3-Day 7	Weeks 2-5	Weeks 6-10
pH[1]	-	1/day	1/day	1/day
Temperature[1]	-	1/day	1/day	1/day
Conductivity[1]	-	1/day	1/day	1/day
Perchlorate	CLWA & MWH	2/week	3/week	1/day
Nitrate	CLWA	6/day	3/week	1/week
Sulfate	CLWA	6/day	3/week	1/week
Bicarbonate	CLWA	6/day	3/week	1/week
Chloride	CLWA	6/day	3/week	1/week
Alkalinity	CLWA	2/week	1/week	1/week
Hardness	CLWA	1/week	1/week	1/week
Iron	CLWA	1/week	1/week	1/week
Manganese	CLWA	1/week	1/week	1/week
Calcium	CLWA	1/week	1/week	1/week
Magnesium	CLWA	1/week	1/week	1/week

Table 3.10	Testing Matrix for Bench-Scale Ion Exchange Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
Chemical Parameter	**Lab**	**Sampling Frequency from Each Column Effluent**		
		Day 3-Day 7	**Weeks 2-5**	**Weeks 6-10**
Turbidity	CLWA	1/week	1/week	1/week
TOC	CLWA	1/week	1/week	1/week
Chromium	CLWA	As needed	As needed	As needed
NDMA	MWH	As needed	As needed	As needed
Bromide	CLWA	As needed	As needed	As needed
Arsenic	CLWA	As needed	As needed	As needed
Uranium	MWH	As needed	As needed	As needed

Note:
(1) Measured on-site.

Table 3.10 also identifies the laboratory that was responsible for analyzing each parameter. The majority of parameters were analyzed at CLWA, while perchlorate checks, NDMA, and uranium were measured at MWH laboratories. All samples not analyzed immediately were stored at 4 degrees C for no more than the recommended holding time before analysis.

6.2 Biological Fixed-Bed Filter

6.2.1 Experimental Design

A 6-month biological FXB filtration pilot study was conducted. The overall objective of this study was to demonstrate the efficacy of biological FXB filtration for perchlorate removal from Saugus aquifer water. A more specific objective was to determine whether biologically acclimating the GAC with indigenous microorganisms would be sufficient to achieve efficient perchlorate reduction in the filter. Once these objectives were achieved, a testing protocol was employed to determine requirements for EBCT, backwashing protocol, and acetic acid addition. A series of short-term experiments were also performed to evaluate the robustness of the process with respect to system upsets.

During the first 2 weeks of pilot-testing, acetic acid was fed to each filter at a concentration twice that required to stoichiometrically reduce all influent DO and nitrate (($O_2 \Rightarrow H_2O$, $NO_3^- \Rightarrow N_2$; for calculation purposes, it was assumed that no electron donor is used for cell synthesis). This ensured that electron donor was not limiting. EBCT and acetic acid feed were optimized during Phase 2 of the FXB pilot study. Perchlorate was spiked to the influent at 50 μg/L except during the perchlorate spiking tests (see Phase 3 of this section). Phosphoric acid was added for a two-month portion of the pilot study. No other chemicals were added to the process system during the pilot study.

- Phase 1 (Biological Acclimation): The purpose of this phase was to determine whether or not efficient perchlorate-reducing biological activity could be developed in the GAC filters using microorganisms indigenous to the Saugus Aquifer. Once the filtration skid was mobilized, the filters began treating Saugus Aquifer water from Well NC-12 spiked with perchlorate. Technical-grade acetic acid (electron donor) was added to the feed water. An EBCT of 15 minutes was used during the first few weeks of the acclimation phase to allow for the rapid saturation of sorption sites on the surface of the GAC and to promote rapid growth of the microbial community in the biological FXB filter.

- Phase 2 (EBCT and Acetic Acid Optimization): The purpose of this phase was to determine the minimum EBCT required to achieve perchlorate removal to below the 4 μg/L reporting limit ($EBCT_{critical}$). Acetic acid was initially added at 100 percent excess relative to the emperical stoichiometric influent DO and nitrate demand (based on an influent DO concentration of 7.0 mg/L and an influent nitrate concentration of 15 mg/L). EBCT was incrementally lowered until perchlorate breakthrough was observed. Once $EBCT_{critical}$ was found, the feed acetic acid concentration was incrementally lowered until perchlorate breakthrough was observed ($AC_{critical}$).

- Phase 3 (Robustness Characterization): The purpose of this phase was to determine how the FXB system responds to various process up-sets. The $EBCT_{critical}$ and $AC_{critical}$ were set as operating parameters throughout this phase of testing. Five process upsets were tested: 1) backwashing, 2) perchlorate spiking, 3) nitrate spiking, 4) electron donor feed failure simulation, and 5) a total system shutdown.
  - Backwashing: These tests were designed to evaluate perchlorate removal performance immediately after backwash episodes. Because backwashes remove perchlorate-reducing biomass from the filter, it is possible that perchlorate breakthrough would occur after backwashes until the biological community in the filter had sufficient time to regrow. This test was performed twice, one-month apart. Samples were taken a 0, 15, 30, 45, and 60 minutes after the filter was put into production following a backwash.
  - Perchlorate Spiking: These tests were designed to evaluate perchlorate removal performance during periods of transient perchlorate loading episodes. Perchlorate was spiked to the feed at 100 μg/L for a 48-hour period and effluent perchlorate concentrations were monitored. Influent perchlorate concentration was then readjusted to 50 μg/L and the system was allowed to stabilize (i.e., reestablish pre-spiking, perchlorate removal performance), if necessary. A 48-hour spiking test was then performed using 300 μg/L perchlorate, followed by a 5 mg/L perchlorate spiking test. The 5 μg/L perchlorate spiking test was designed to: 1) demonstrate perchlorate removal performance at a low-end feed perchlorate concentration, 2) initiate the desorption of perchlorate from the carbon surface (if any) as the bed equilibrated with a lowered feed perchlorate concentration. Along

with the regular daily samples, samples were taken at 0, 15, 30, 45, and 60 minutes after the filter was put into production following a change in feed perchlorate concentration.

- Nitrate Spiking: This test was designed to evaluate perchlorate removal performance during periods of transient nitrate loading episodes. Over a 48-hour period, nitrate was spiked to the feed to reach a final influent concentration of 30 mg/L (the historical Saugus aquifer maximum concentration) and effluent perchlorate concentrations were monitored. During the first part of the test, EBCT and acetic acid concentration were not adjusted to account for the increased nitrate in the feed. A second nitrate spiking test was performed during which the EBCT and acetic acid were both adjusted to achieve perchlorate removal to below detection. Along with the regular daily samples, samples were taken at 0, 15, 30, 45, and 60 minutes after the filter was put into production following a change in feed nitrate concentration.
- Electron Donor Feed Failure Simulation: This test was designed to evaluate perchlorate removal performance during a period of simulated electron donor feed system failure. The acetic acid feed was shut off for 48 hours and effluent perchlorate concentrations were monitored. The acetic acid feed was then restarted and the time required to reestablish efficient perchlorate reduction was evaluated. Along with the regular daily samples, samples were taken at 0, 15, 30, 45, 60, 120, 180, 240, and 630 minutes after the filter was put into production following a change in feed perchlorate concentration.
- System Shutdown: This test was designed to evaluate perchlorate removal performance after the system has been shut down for 1-day, 2-day, and 2-week periods. The time required to reestablish efficient perchlorate reduction in the filters was evaluated.

- Backwashing Protocol: Backwashes were performed using effluent water stored in the pilot backwash tank (see Figure 2.4). Backwashes were performed approximately every 48 hours. If run times did not reach 48 hours due to rapid headloss build-up, operating parameters were adjusted (i.e., EBCT and acetic acid concentration). Backwashes consisted of a 10-minute air scour period using ~0.1-0.2 scfm, followed by a 20-minute backwash at 0.8 gpm (9 gpm/ft^2), which resulted in a 45 percent bed expansion.

6.2.2 Sampling

Table 3.11 lists the various water quality parameters that were measured, sampling location and frequency, and the associated laboratory responsible for the analysis. Increased perchlorate sampling frequencies during the challenge tests are described above.

Table 3.11 Sampling Schedule for Fixed-Bed Biological Pilot Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
ClO_4^-	Feed	Once per 2 days	CLWA and occasional checks with MWH
	Effluent	Daily	
	Backwash	As Needed	
NO_3^-	Feed	2/week	CLWA
	Effluent	3/week	
DO	Feed	Daily	On-site
	Effluent	Daily	
NO_2^-	Feed	1/week	CLWA
	Effluent	1/week	
PO_4^{3-}	Feed	1/week	CLWA
	Effluent	1/week	
SO_4^{2-}	Feed	1/week	CLWA
	Effluent	1/week	
NH_3	Feed	1/week	CLWA
	Effluent	2/week	
H_2S	Feed	1/week	MWH
	Effluent	1/week	
TOC/DOC	Feed	3/week	CLWA
	Effluent	3/week	
BDOC	Feed	2/week	MWH
	Effluent	2/week	
HPC	Feed	2/week	CLWA
	Effluent	2/week	
Total coliforms	Feed	1/week	CLWA & MWH
	Effluent	1/week	
	Backwash	1/backwash	
Fecal coliforms	Feed	1/week	CLWA & MWH
	Effluent	1/week	
	Backwash	1/backwash	
Turbidity	Feed	3/wk	Dedicated in-line HACH 1720D turbidimeters and Bench-top turbidimeter
	Effluent	Continuous	
Total particle counts	Effluent	Continuous	In-line particle counter

Table 3.11	Sampling Schedule for Fixed-Bed Biological Pilot Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency		
Parameter	**Sampling Location**	**Sampling Frequency**	**Lab**
pH	Feed	Daily	On-site
	Effluent	Daily	
Headloss	Across FXB	Continuous	In-line pressure transducer
Backwash volatile suspended solids (VSS)	Backwash water	Once per backwash	CLWA
Assimilable Organic Carbon	Backwash water	Once per backwash	MWH
Chemical Oxygen Demand	Backwash water	Once per backwash	MWH
Total Suspended Solids	Backwash water	Once per backwash	MWH

Given that adjustments to process operation were made based on perchlorate removal performance in the filters, it was important to maintain a short turn-around time for perchlorate samples throughout pilot testing. Therefore, perchlorate samples was taken for analysis at the CLWA laboratory to expedite the acquisition of perchlorate data. However, since the CLWA laboratory has partial certification for perchlorate analysis, duplicate samples were set weekly to MWH for analysis. Bacterial samples, TOC/DOC, and anions were transported to the laboratory every Tuesday. Additional anion samples were transported to the lab every 3 days (i.e., Monday, Wednesday, and Friday) due to the short holding time of nitrate (48 hours).

The on-line ion chromatography perchlorate analyzer (DX-800 Process Analyzer), which was generally used to continuously monitor FBR effluent perchlorate concentrations, was configured to accept manual injections of FXB samples. Thus, near real-time perchlorate removal performance was monitored during the majority of FXB pilot testing.

6.3 Biological Fluidized-Bed Reactor

6.3.1 Experimental Design

A 6-month biological FBR pilot study was conducted using Shaw Environmental-Envirogen/US Filter/Envirex Products' low-flow FBR. The overall objective of this study was to demonstrate the efficacy of an FBR biological process for perchlorate removal from Saugus aquifer water. A more specific objective was to determine whether biologically acclimating the GAC with indigenous microorganisms is sufficient to achieve efficient perchlorate reduction in the FBR. The testing protocol was also designed to optimize HRT and acetic acid addition, and to test the robustness of the process during system upsets.

However, establishing consistent perchlorate removal to below detection required the entire length of the pilot testing period.

The FBR system was monitored using a Dionex On-Line Ion Chromatography Perchlorate analyzer (DX-800 Process Analyzer). The use of the DX-800 analyzer provided a better understanding of the instrument's capabilities in a field setting. The testing of this system also allowed for immediate operational responses based on FBR performance.

- Phase 1 (Biological Acclimation): During start-up, the FBR system was filled with NC-12 groundwater. Carbon was added to provide a desired settled bed height of approximately 5 feet. The system was then started in recycle and the carbon hydraulically fluidized 1.25 to 1.30 times the settled bed height. The feed and recycle rates required to meet this bed expansion were documented and utilized as a baseline for future bed growth measurements. Following this procedure, nutrients and electron donor were added to the reactor in batch mode to allow the microbial consortium to develop over a period of two days. The system was then put into continuous operation mode at a feed flow of 1 gpm and a recycle flow of 8 to 9 gpm. The feed flow was set between 1 and 3 gpm throughout pilot testing and the recycle flow was typically set so that total flow was approximately 10 gpm.

- Phase 2 (Continuous Operation): This phase was initially intended to determine optimal feed and recycle flow rates as well as optimal feed phosphorous and acetic acid concentrations. During the bulk of this phase, Carollo worked with Shaw Environmental (formerly Envirogen) staff to make mechanical and operational changes designed to improve the perchlorate removal performance of the FBR.

- Phase 3 (Robustness Characterization): FBR robustness characterization testing did not occur for the FBR as stable performance was not achieved during the 6-month period.

6.3.2 Sampling

Table 3.12 lists the various water quality parameters that were measured once start-up was completed, the sampling location and frequency, and the associated laboratory responsible for the analysis.

Table 3.12 Fluidized-Bed Sampling Matrix
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
Perchlorate	Feed	Once per 2 days	CLWA and occasional checks with MWH + on-line ion chromatograph
	Effluent	Daily	

Table 3.12 Fluidized-Bed Sampling Matrix
Treatment of Perchlorate Contaminated Groundwater
from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
Nitrate	Feed	3/week	CLWA
	Effluent	3/week	
Nitrite	Feed	1/week	CLWA
	Effluent	1/week	
Phosphate	Feed	1/week	CLWA
	Effluent	1/week	
Sulfate	Feed	-	CLWA
	Effluent	-	
DO	Influent	Daily	On-site analysis
	Effluent	Daily	
H_2S	Influent	1/week	MWH
	Effluent	1/week	
BDOC	Feed	2/week	MWH
	Effluent	2/week	
HPC	Feed	1/week	CLWA
	Effluent	1/week	
Total Coliforms	Feed	1/week	CLWA
	Effluent	1/week	
Fecal Coliforms	Feed	1/week	CLWA
	Effluent	1/week	
TOC	Feed	-	CLWA
	Effluent	2/week	
TSS	Feed	-	CLWA
	Effluent	-	
Ammonia	Feed	1/week	CLWA
	Effluent	1/week	
Total phosphorous	Feed	1/week	CLWA
	Effluent	2/week	

6.4 Submerged Membrane Bioreactor

6.4.1 Experimental Design

Due to the short SMBR testing period, the experimental design focused only on demonstration, not optimization, of the SMBR process. Operational settings for the SMBR are listed in Table 3.13.

Table 3.13 SMBR ZW-10 System Operating Parameters Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	Value
Q_{FEED} (mL/min)	300-680
$Q_{PERMEATE}$ (mL/min)	300-680
Recovery (%)	80-99
HRT (hours)	4.7-10.6
Aeration rate (scfm)	1-2

For the majority of SMBR testing, the biological FXB filter was operated using $EBCT_{critical}$ and $AC_{critical}$. SMBR backpulses were initiated every 15 minutes, for a duration of 15 seconds. The system was operated continuously and monitored regularly for two months to determine whether each of the four post-treatment objectives was being met. A three-week acetic acid spiking test was performed after it was observed that biological FXB filter effluent contained non-detect concentrations of TOC. During this test, 3.5 mg/L of acetic acid carbon was continuously spiked to the SMBR process tank using a peristaltic pump to validate residual organic removal efficiency.

6.4.2 Sampling

Table 3.14 lists the various water quality parameters that were measured, sampling location and frequency, and the associated laboratory responsible for the analysis.

Table 3.14 SMBR Sampling Matrix Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Parameter	Sampling Location	Sampling Frequency	Lab
DO	Feed	Daily	On-site
	Effluent	Daily	
H_2S	Feed	1/week	CLWA & qualitative (i.e., by nose)
	Effluent	1/week	

Table 3.14 SMBR Sampling Matrix Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
Parameter	**Sampling Location**	**Sampling Frequency**	**Lab**
TOC/DOC	Feed	3/week	CLWA
	Effluent	3/week	
BDOC	Feed	2/week	MWH
	Effluent	2/week	
HPCs	Feed	2/week	CLWA
	Effluent	2/week	
Total coliforms	Feed	1/week	CLWA
	Effluent	1/week	
Fecal coliforms	Feed	1/week	CLWA
	Effluent	1/week	
Turbidity	Feed	3/week	Bench-top turbidimeter
	Effluent	3/week	
pH	Feed	2/week	On-site probe
	Effluent	2/week	
Process tank volatile suspended solids	Process tank	2/week	CLWA

7.0 TEST RESULTS

7.1 Ion-Exchange Testing Results

7.1.1 Feed Water Quality

The range of constituent concentrations in the feed water to the ion-exchange columns is presented in Table 3.15. The feed water is characterized as low in organic matter, moderately hard and buffered, and moderate in iron and bromide. It should be noted that during the month of October 2003 the NC-12 groundwater quality was observed to slowly change over a 4-week period before returning to its steady-state quality at the end of the bench-scale study. The nitrate concentration decreased from 3.3 mg/L as N to 1.7 mg/L as N, sulfate increased from 290 mg/L to 373 mg/L (after sulfate spike), and the chloride concentration increased from 35 mg/L to 45 mg/L.

Table 3.15	Range of Constituent Concentration in Feedwater to the IX System Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Chemical Parameter	**Unit**	**Count**	**Average**	**Min**	**Max**
Perchlorate	μg/L	18	45.5	42.6	52.9
Nitrate-N	mg/L	18	3.0	1.7	3.4
Sulfate	mg/L	18	301	276	373
Bicarbonate	mg/L	18	199	171	221
Chloride	mg/L	18	37	32	45
pH	—	18	8.1	7.9	8.4
Alkalinity	mg/L as $CaCO_3$	18	165	152	181
TOC	mg/L			<0.7	<0.7
DOC	mg/L			<0.7	<0.7
Arsenic	μg/L			ND	ND
Iron	μg/L	9	15.3	7	27
Manganese	μg/L	9		<1	<1
Hardness	mg/L as $CaCO_3$	2		282	315
Calcium	mg/L	3	84	77	94
Magnesium	mg/L	3	17.7	17	18
Uranium	pCi/L			ND	1.03
NDMA	ng/L			ND	ND
Vanadium	μg/L	3	10.7	2.0	15.0
Bromide	mg/L	2		0.22	0.24
Turbidity	NTU	12	0.337	0.180	0.580
Conductivity	μmhos/cm	15	1043	1003	1158

7.1.2 Operational Data

Two operational parameters were recorded on a daily basis for the ion-exchange setup: flowrate through the columns (Figure 3.9) and pressure buildup. The pump setting and/or the needle valves connected downstream of the columns were adjusted when the measured flow rate deviated by more than 10 percent from the target flow rate of 15 mL/min. The flow rate ranged from 13.5 to 16.5 mL/min during the course of the study, which resulted in an EBCT range of 1.4 to 1.6 minutes. The pressure drop remained constant at 5 psi throughout most of the project duration, and increased to 7 psi during the last two weeks of testing. The level of water in the 55-gal feed tanks was monitored daily. The experimental apparatus was monitored for the presence of air bubbles and leaks.

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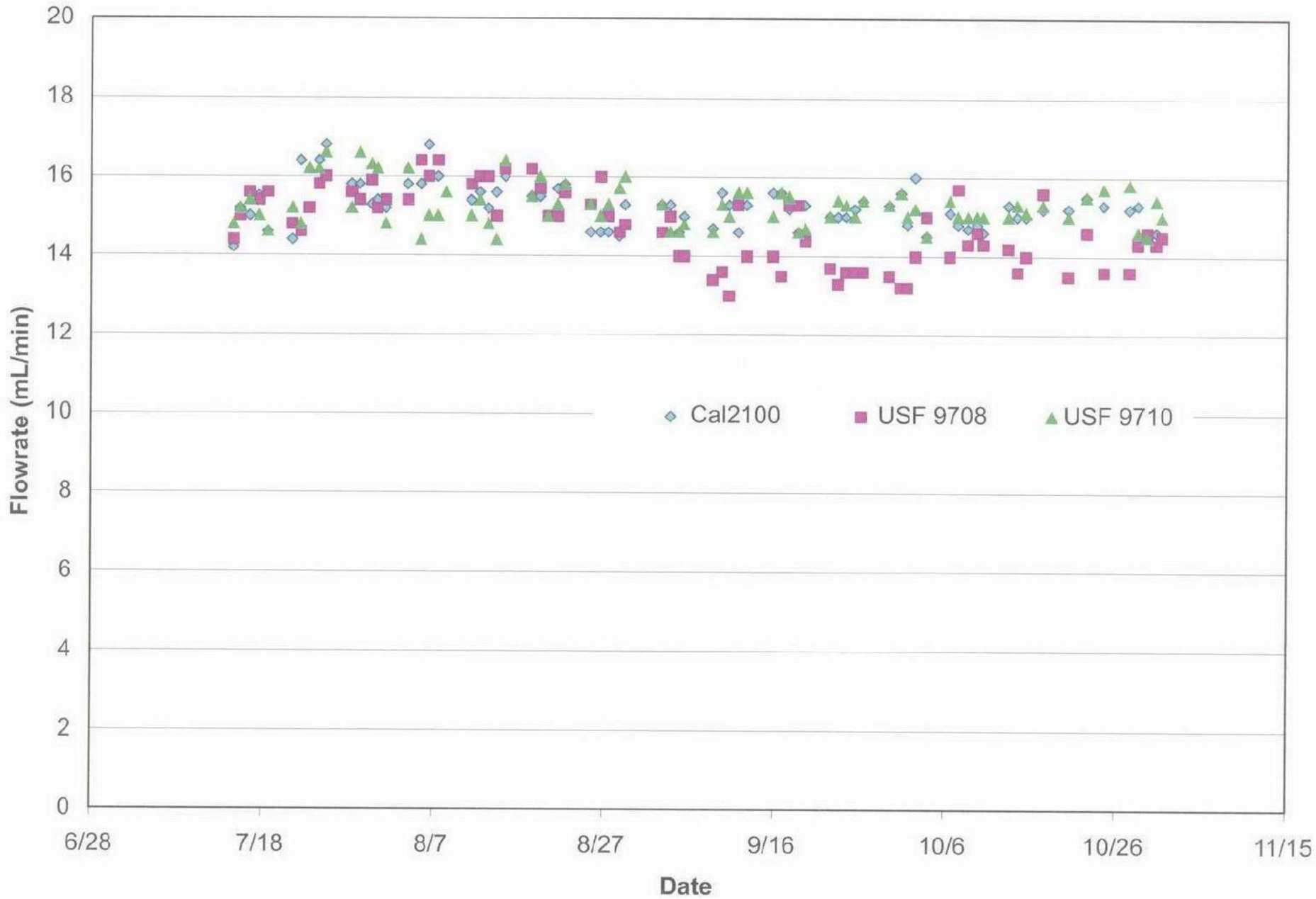

FLOW RATES MEASURED THROUGH THE THREE ION-EXCHANGE COLUMNS

FIGURE 3.9

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7.1.3 Temperature

The temperature, which was measured in the effluent of the three columns over the course of the study, ranged from 32 degrees C (89 degrees F) in the summer months to 16 degrees C (61 degrees F) in the fall (Figure 3.10).

7.1.4 pH Values

pH was measured in the feed and effluent of the three columns, and both ranged from 7.6 to 8.4 (Figure 3.11), indicating only minor impact on pH by the resins.

7.1.5 Breakthrough Curves

Breakthrough curves of key anions were developed for the ion-exchange resins under identical conditions of water quality, flowrate, and EBCT. The three columns were operated in parallel using one feed pump. The columns ran continuously with minimal shut-down periods. A 45-hour shut-down period was simulated at the end of the study to investigate its potential effect on breakthrough.

7.1.5.1 High-Resolution Breakthrough Curves of Key Anions

As predicted by the IXPro Model, the breakthrough of most anions (with the exception of perchlorate) was very fast and occurred in the first 24 hours of operation. This breakthrough sequence was similar for the three resins tested, as illustrated in Figures 3.12 through 3.14. The figures are plotted for the first 2,000 bed volumes of run time.Bicarbonate was the first anion to break through reaching its background value of 220 mg/L after 80 to120 bed volumes. Sulfate was next to breakthrough after 80 bed volumes and reached its steady-state concentration of 300 mg/L after 280 to 310 bed volumes. The nitrate breakthrough rate was somewhat different for the three columns. Nitrate broke through after 280 bed volumes, 440 bed volumes, and 600 bed volumes from USF 9708, USF 9710, and Cal 2100 resins, respectively. Steady-state concentrations were reached after 1,000 bed volumes for all three tested resins. No chromatographic peaking was observed for any of the critical anions within the test conditions.

Chloride concentration dropped from a high of approximately 325 mg/L to background levels of approximately 35 mg/L after 280 bed volumes. The highest measured chloride levels in the first 280 bed volumes did not exceed the Title 22 Secondary Maximum Contaminant Level of 500 mg/L. However, they did exceed the Los Angeles County Sanitation District (LACSD) maximum acceptable chloride level of 100 mg/L in the Santa Clara Valley Basin.

In a full-scale application, following a resin change-out, the new resin may need to be flushed over a few days to meet DHS requirements. This flushed water, which will contain higher concentrations of chloride during the first few hours of flushing (as illustrated in Figures 3.12 to 3.14), will need to be dealt with by discharge to a sewer, for example. The flushed water will be free of perchlorate.

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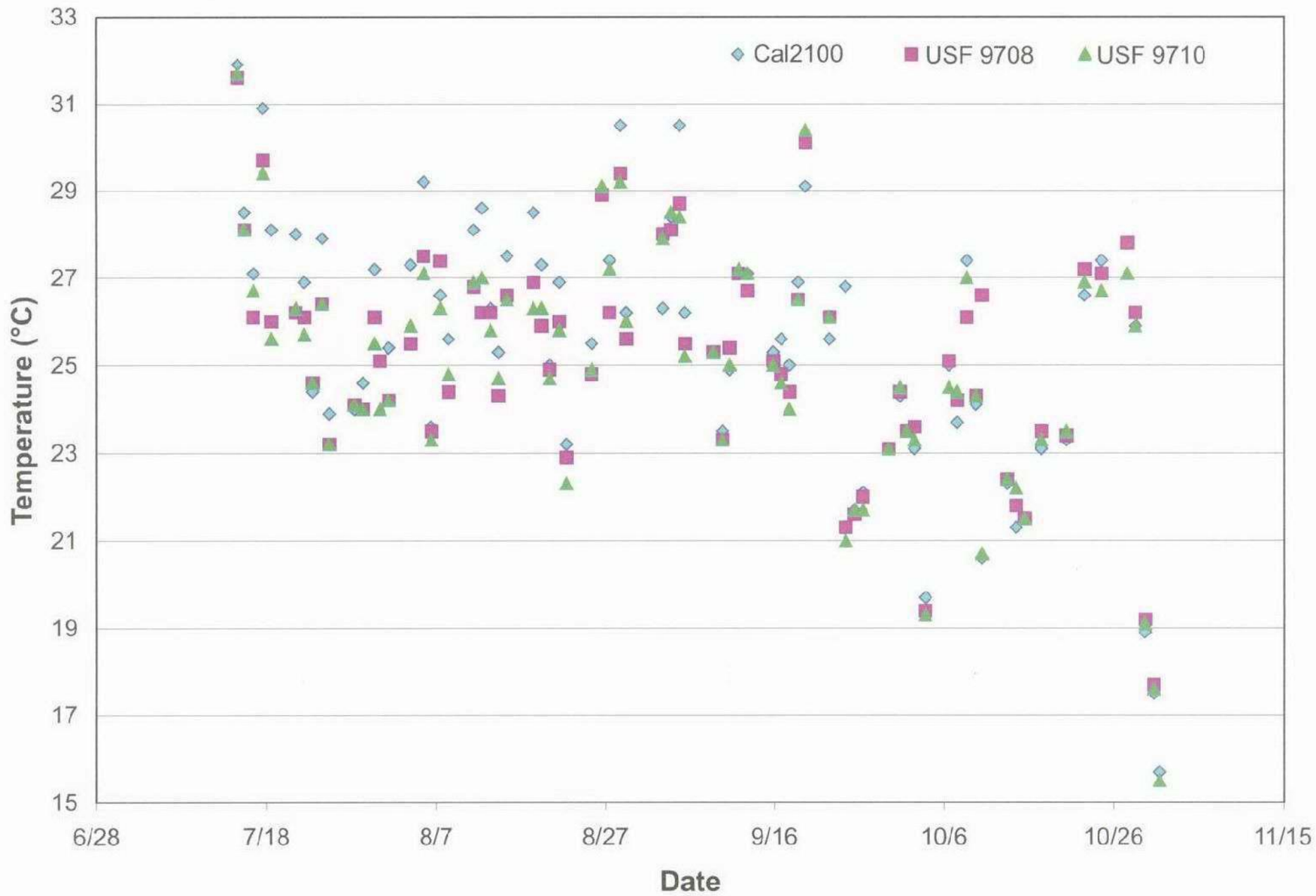

COLUMN EFFLUENT TEMPERATURE MEASURED OVER THE COURSE OF THE STUDY

FIGURE 3.10

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pH VALUES MEASURED IN THE FEED AND IX COLUMN EFFLUENT

FIGURE 3.11

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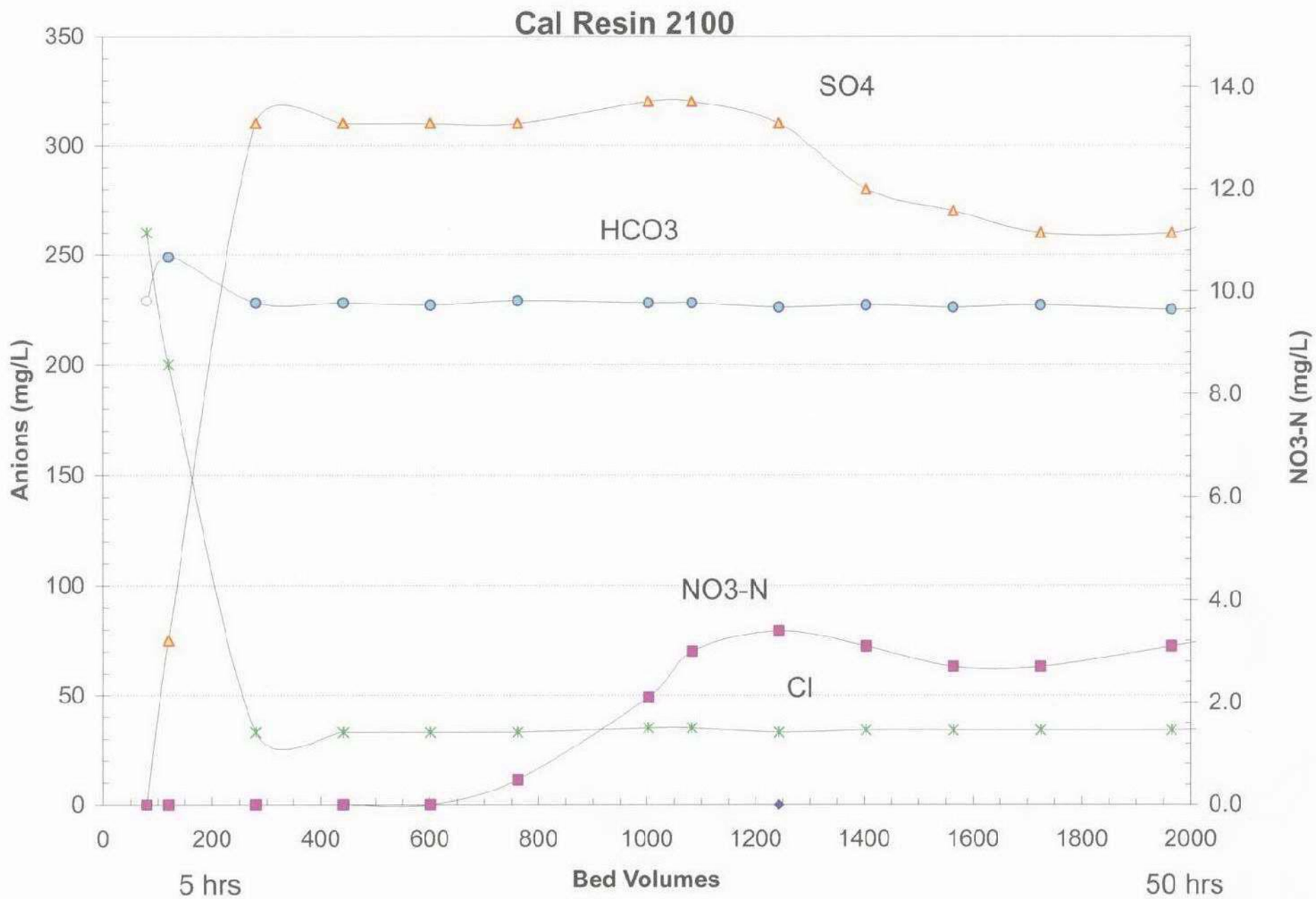

BREAKTHROUGH OF MAJOR ANIONS FROM CAL 2100 SERIES RESIN IN THE FIRST 2000 BVs

FIGURE 3.12

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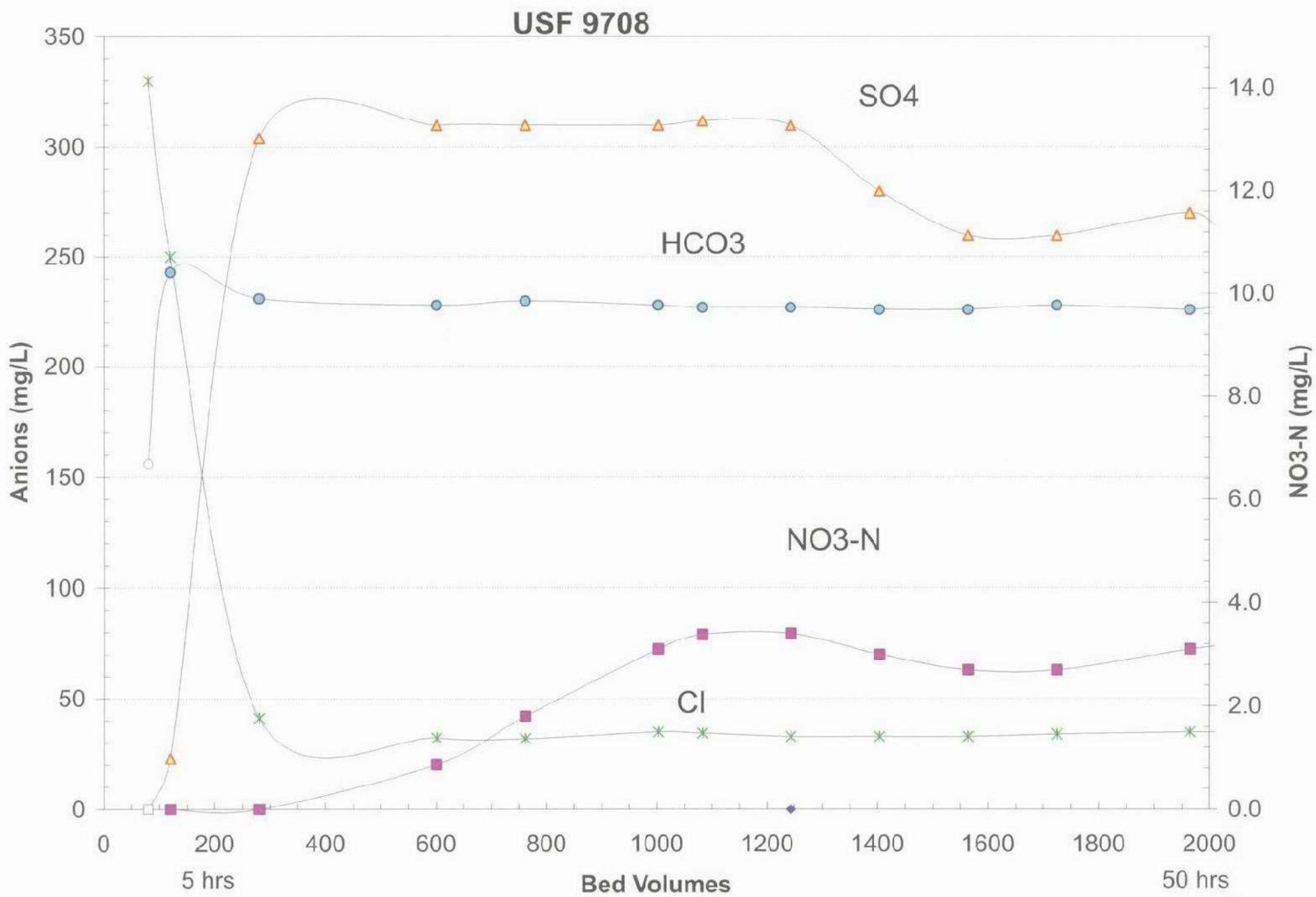

BREAKTHROUGH OF MAJOR ANIONS FROM 9708 RESIN IN THE FIRST 2000 BVs

FIGURE 3.13

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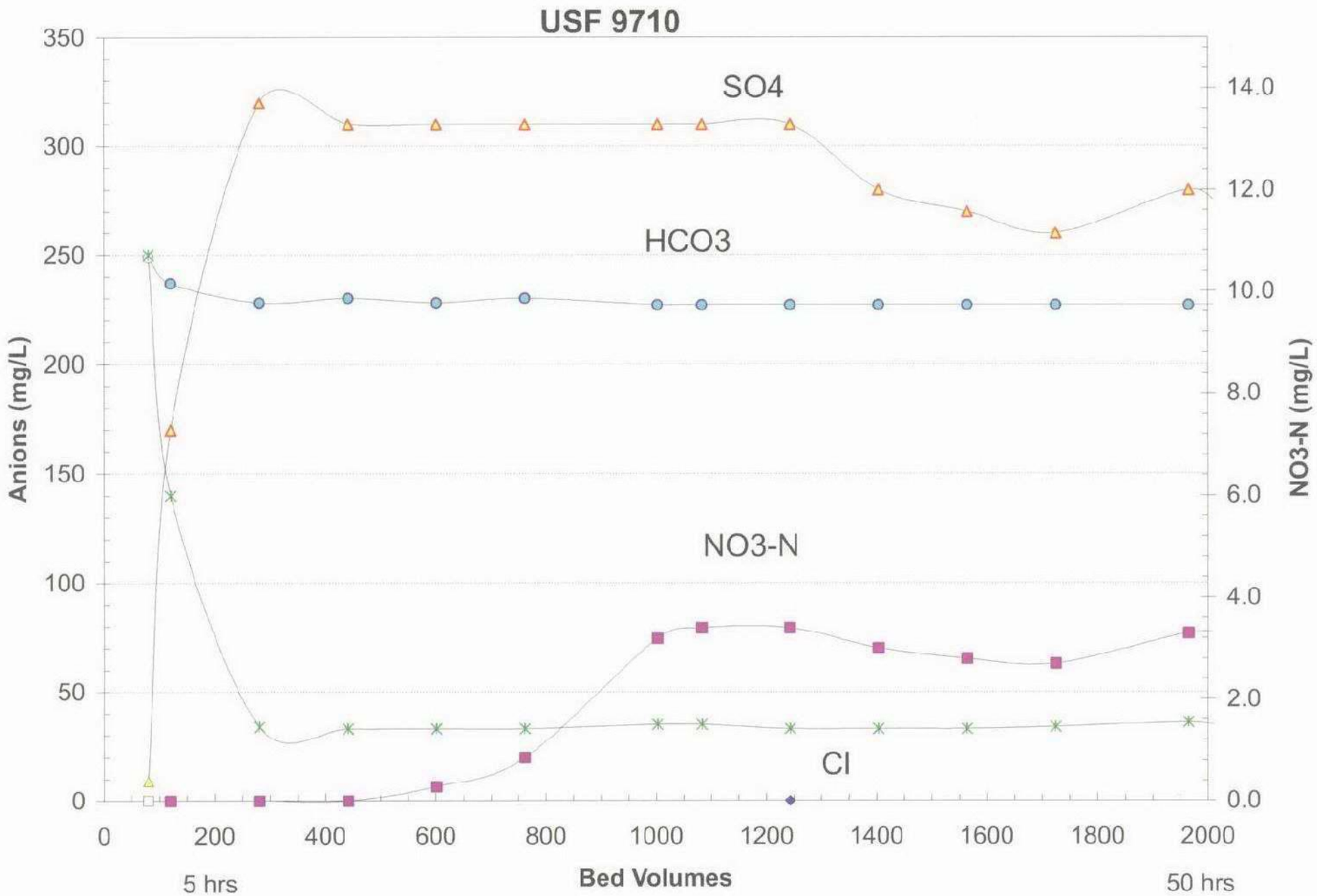

BREAKTHROUGH OF MAJOR ANIONS FROM 9710 RESIN IN THE FIRST 2000 BVs

FIGURE 3.14

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7.1.5.2 Breakthrough Curves of Perchlorate and Other Anions

Perchlorate breakthrough curves for the three ion-exchange resins are illustrated in Figure 3.15. As expected, perchlorate breakthrough did not occur until several thousand bed volumes had been treated by the resin. Actual run lengths were longer than those predicted by the IX-Pro Model. Bed volumes to perchlorate breakthrough (greater than 1 μg/L) were 25,000 bed volumes (26 days), 72,000 bed volumes (75 days), and 76,000 bed volumes (79 days) for USF 9708 resin, USF 9710 resin, and CalResin 2100, respectively. The details of run lengths until perchlorate breakthrough are presented in Table 3.16.

Table 3.16 Run Lengths Until Perchlorate Breakthrough (1 μg/L) Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Resin	Bed Volumes	Treated Water Volumes (gal)	Treated Volume gal/cu-ft resin
USF 9708	25,000	145.3	187,045
USF 9710	72,000	418.5	538,735
CalResin 2100	76,000	441.7	568,600

A temporal change in raw well water quality occurred between 85,000 and 100,000 bed volumes. However, this did not seem to impact the breakthrough of anions, with the possible exception of the USF 9708 perchlorate breakthrough curve, for which a noticeable drop in perchlorate concentration was measured in the effluent during that period.

At the end of the study, a 45-hour shutdown period was simulated by shutting off the feed pump. During this period, the resins were allowed to sit in the columns containing the groundwater. Critical anions were measured immediately after the shut-down period and breakthrough curves were developed for all key anions after restarting the columns. Breakthrough curves of all major anions for USF 9710 are illustrated in Figure 3.16. An increase in chloride concentration (45 to 72 mg/L) was observed upon column restart. Similar trends were observed for USF 9708 and CalResin 2100, indicating leaching from the IX resins.

7.2 NDMA Formation Potential Testing

7.2.1 Post-Chlorination Testing

The results from the post-chlorination testing with free chlorine are plotted in Figure 3.17. Free chlorine residuals ranged from 1.8 to 1.9 mg/L after 24 hours of incubation. The 2- and 24-hour NDMA concentrations in all three ion-exchange column effluents were below the 2 ng/L detection limit. Therefore, precursors did not leach from the resin to form NDMA upon post-chlorination with free chlorine.

The results from the post-chlorination testing with combined chlorine are plotted in Figure 3.18. Total chlorine residuals ranged from 1.6 to 2.2 mg/L after 24 hours of

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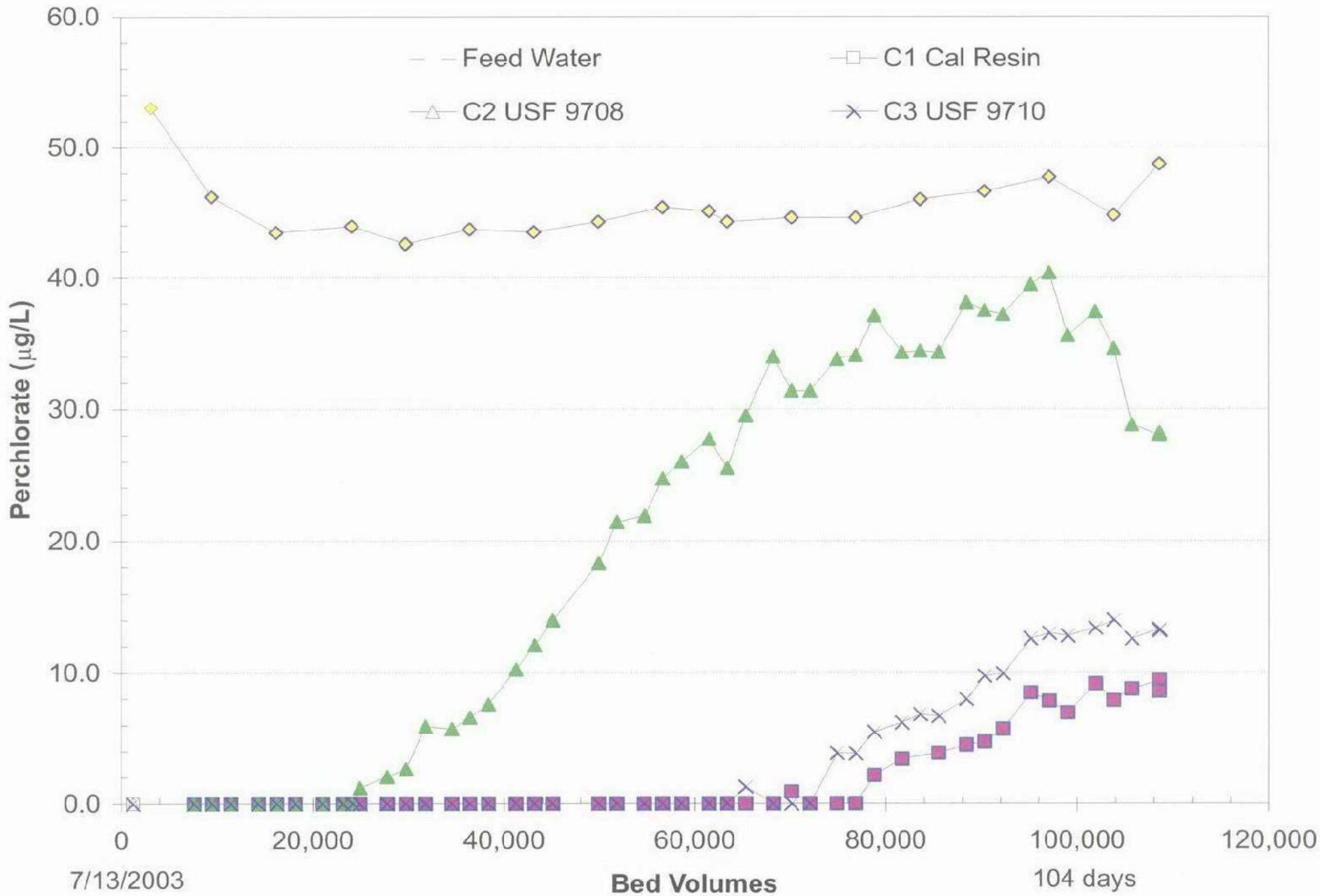

COMPARISON OF PERCHLORATE BREAKTHROUGH CURVES

FIGURE 3.15

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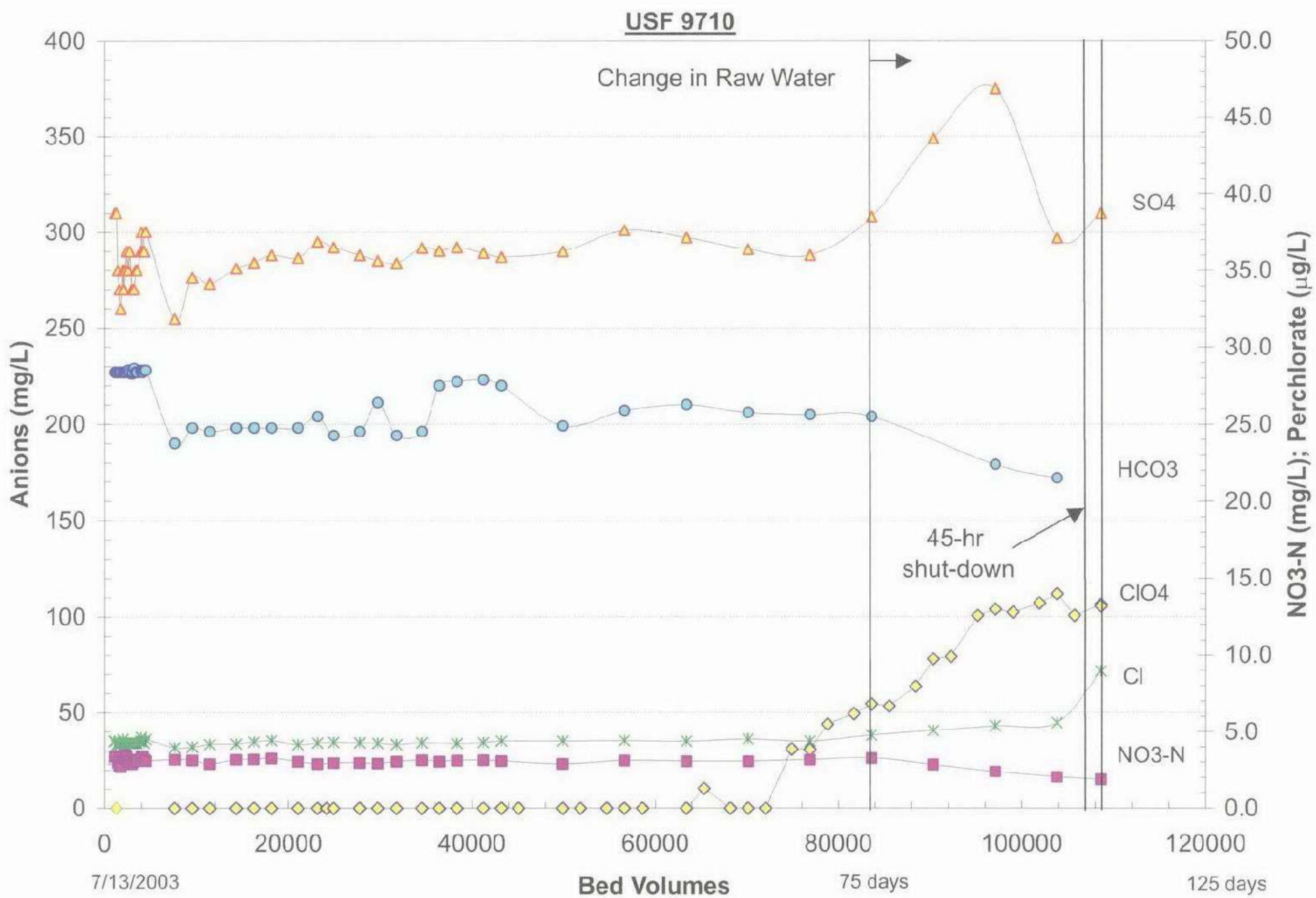

BREAKTHROUGH OF CRITICAL ANIONS FROM USF 9710

FIGURE 3.16

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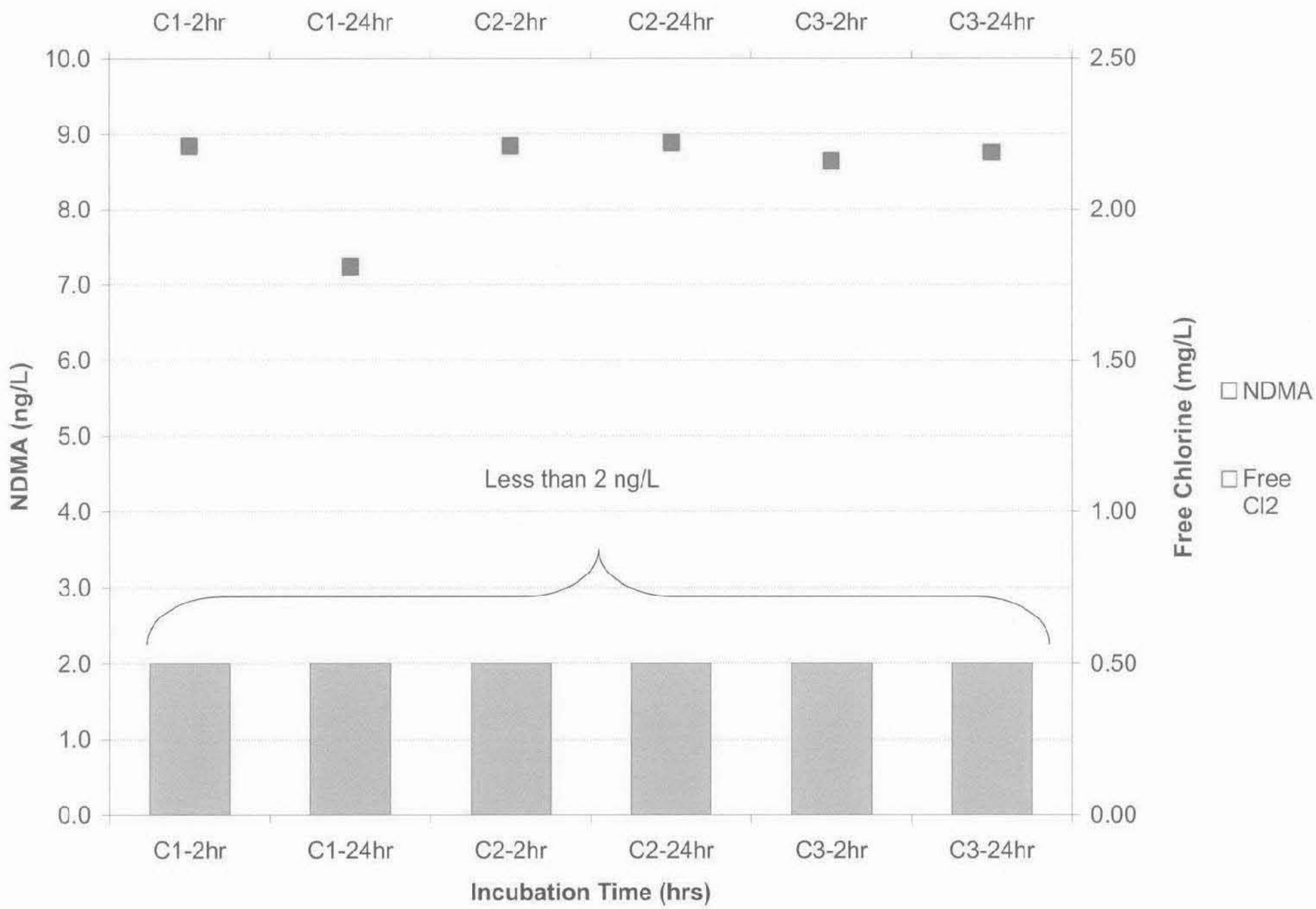

POST-CHLORINATION TESTING WITH FREE CHLORINE NDMA RESULTS

FIGURE 3.17

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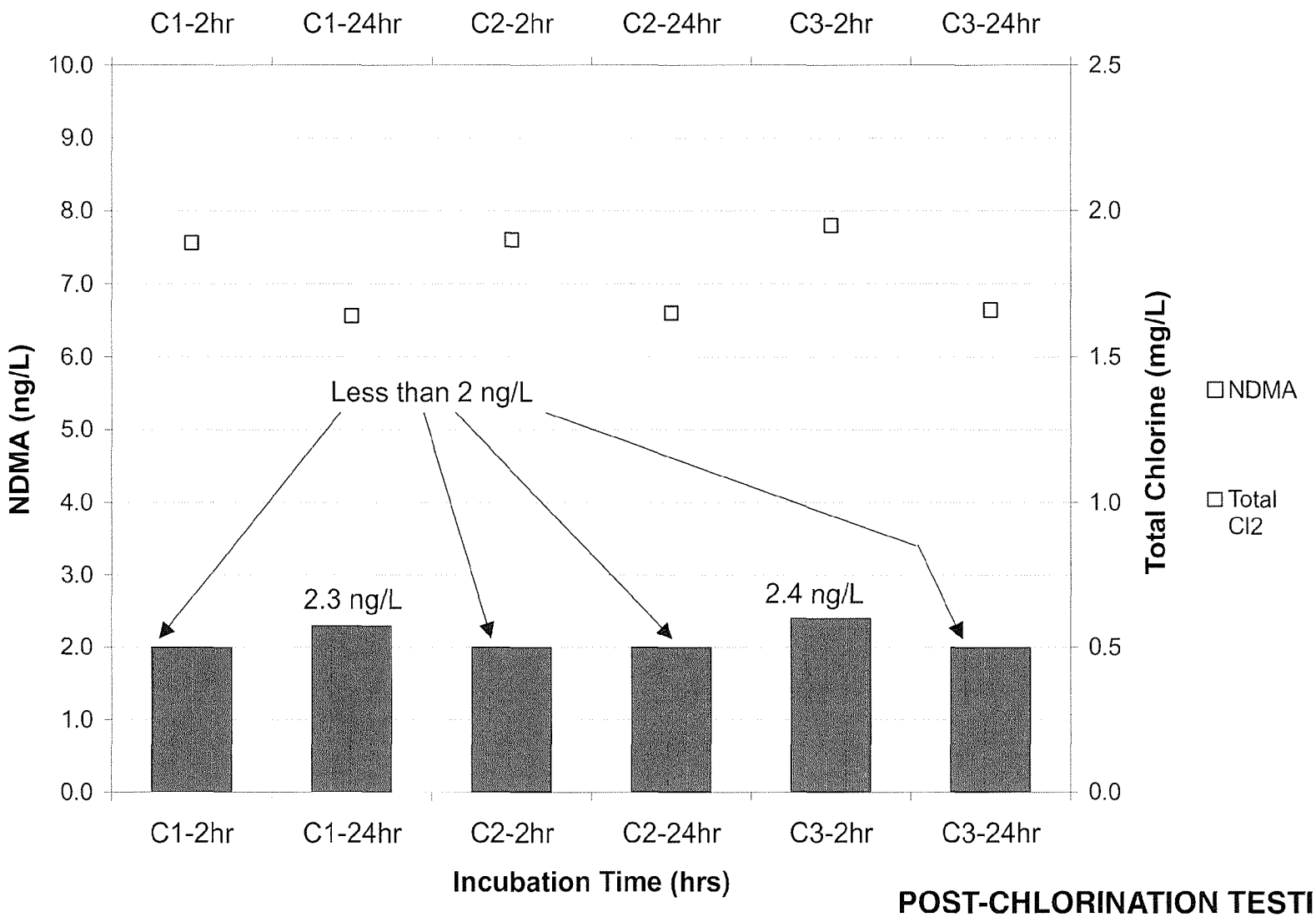

POST-CHLORINATION TESTING WITH COMBINED CHLORINE NDMA RESULTS

FIGURE 3.18

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incubation. The 2- and 24-hour NDMA concentrations in all three ion-exchange column effluents were below or just above the detection limit of 2 ng/L.

7.2.2 Pre-Chlorination Testing

To test the effect of prechlorinated water on the resins, chlorinated feedwater was allowed to run through the columns for a period of 2 hours. After that time, samples were collected and analyzed for NDMA. No detectable free chlorine residual was measured at the column effluents. This experiment was repeated four days later by adding a second 2 mg/L dose of free chlorine (duplicate samples). NDMA results are plotted in Figure 3.19. Measured levels were below or just over the detectable limit of 2 ng/L. The NDMA concentration in the feedwater (control sample) was non-detect.

7.2.3 Fresh Resin Batch Testing

Each resin was tested to determine if leaching of NDMA occurred from precursors in the resin functional sites. These results are plotted in Figure 3.20. Although NDMA was detected in one sample (CalResin), the result was less than half the current Action Level of 10 ng/L.

7.3 Spent Resin Characterization

7.3.1 Lab Results

Table 3.17 presents the Federal Toxicity Characteristic Leaching Procedure (TCLP) toxicity limits, TTLC, and STLC threshold values defined in the California Code of Regulations, Title 22, Chapter 11, Article 3, Section 66261.24, as well as the results from the actual TTLC metal concentrations measured in the three ion-exchange spent resins. TTLC results indicate the total bulk amount of each constituent per unit mass of solid waste. If the TTLC (or bulk) content is low, then the solid waste when subjected to leaching tests (STLC, TCLP) does not produce significant amounts of contaminants in the leachate. Since TTLC results are very low, there would not be any problem with the STLC or TCLP. These soluble limits, however, are listed in the table for comparison.

Most values for the TTLC analysis were non-detect. Chromium, vanadium, and zinc were detected in USF 9708 and USF 9710 spent resins at levels just above minimum reporting limits, but these values are several orders of magnitude below the regulatory TTLC threshold concentrations. Given that the TTLC metal concentrations were 10 times lower than the STLC limits, no further metals analysis for STLC was needed.

Due to the limited quantity of resin samples, TTLC for uranium, which required separate analysis, was not performed by the lab. However, projected total amount of uranium was calculated to be well below the regulatory limit (see Table 3.21). The leachate from spent resins was further analyzed for perchlorate, nitrate, and uranium (Table 3.18). Uranium

levels in the spent resin leachate were significantly below the drinking water Title 22 maximum contaminant limit of 20 pCi/L.

Table 3.17 Comparison of TTLC Metals in Spent Resins to Federal and State Toxicity Limits
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

	Actual TTLC Metals Concentrations Measured in Spent Resins (mg/kg)			Federal and State Regulatory Limits		
Contaminant	**Cal 2100 Series**	**USF 9708**	**USF 9710**	**TTLC Threshold Concentration (mg/kg)**	**STLC Threshold Concentration (mg/L)**	**TCLP Regulatory Level (mg/L)**
Antimony	<4	<4	<4	500	15	
Arsenic	<0.5	<0.5	<0.5	500	5.0	5.0
Barium	<0.3	<0.3	<0.3	10,000	100	100.0
Beryllium	<0.2	<0.2	<0.2	75	0.75	
Cadmium	<0.2	<0.2	<0.2	100	1.0	1.0
Chromium	<0.3	**0.4**	<0.3	2,500	5	5.0
Chromium VI				500	5	
Cobalt	<1	<1	<1	8,000	80	
Copper	<4	<4	<4	2,500	25	
Lead	<10	<10	<10	1,000	5.0	5.0
Mercury	<0.05	<0.05	<0.05	20	0.2	0.2
Molybdenum	<2	<2	<2	3,500	350	
Nickel	<2	<2	<2	2,000	20	
Selenium	<3	<3	<3	100	1.0	1.0
Thallium	<0.2	<0.2	<0.2	700	7.0	
Vanadium	<0.5	**0.6**	<0.5	2,400	24	
Zinc	<4	<4	**7.8**	5,000	250	

Table 3.18	Comparison of Perchlorate, Nitrate and Uranium in Spent Resins Leachates Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Contaminant	**Cal 2100 Series**	**USF 9708**	**USF 9710**	**CA-T22 MCL**	**DHS Action Level**
Perchlorate (μg/L)	< 4,000	< 4,000	< 4,000	—	4
Nitrate-N (mg/L)	21	19	22	10	—
Uranium (pCi/L)	3.0 ± 0.307	7.35 ± 0.752	4.06 ± 0.419	20	—

Table 3.19	Radionuclides Reportable Quantities (Table 2 of Appendix A under CERCLA) Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency	
Radionuclide	**Atomic Number**	**RQ (Ci)**
Uranium 230	92	1
Uranium 231	92	1,000
Uranium 232	92	0.01
Uranium 233	92	0.1
Uranium 234	92	0.1
Uranium 235	92	0.1
Uranium 236	92	0.1
Uranium 237	92	100
Uranium 238	92	0.1
Uranium 239	92	1000
Uranium 240	92	1000

7.3.2 Uranium Accumulation

To further assess any challenges of transporting spent resins from the treatment plant to an incineration facility, a mass balance was performed to calculate the amount of uranium accumulated on the resins for comparison to the Department of Transportation's (DOT's) reportable quantities (which define whether or not a substance is hazardous) and A-Values (values used during shipping of hazardous substances).

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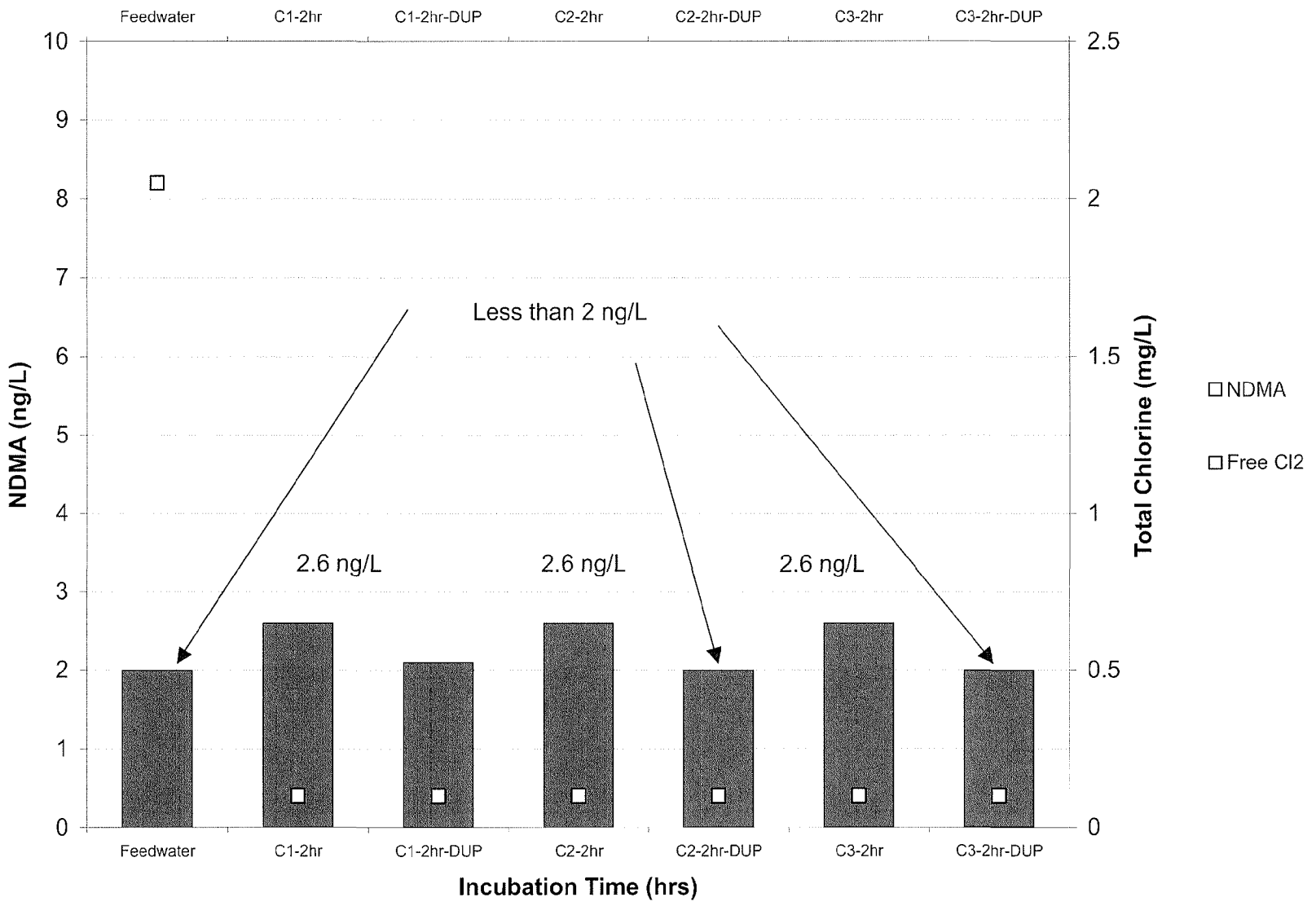

POST-CHLORINATION TESTING NDMA RESULTS

FIGURE 3.19

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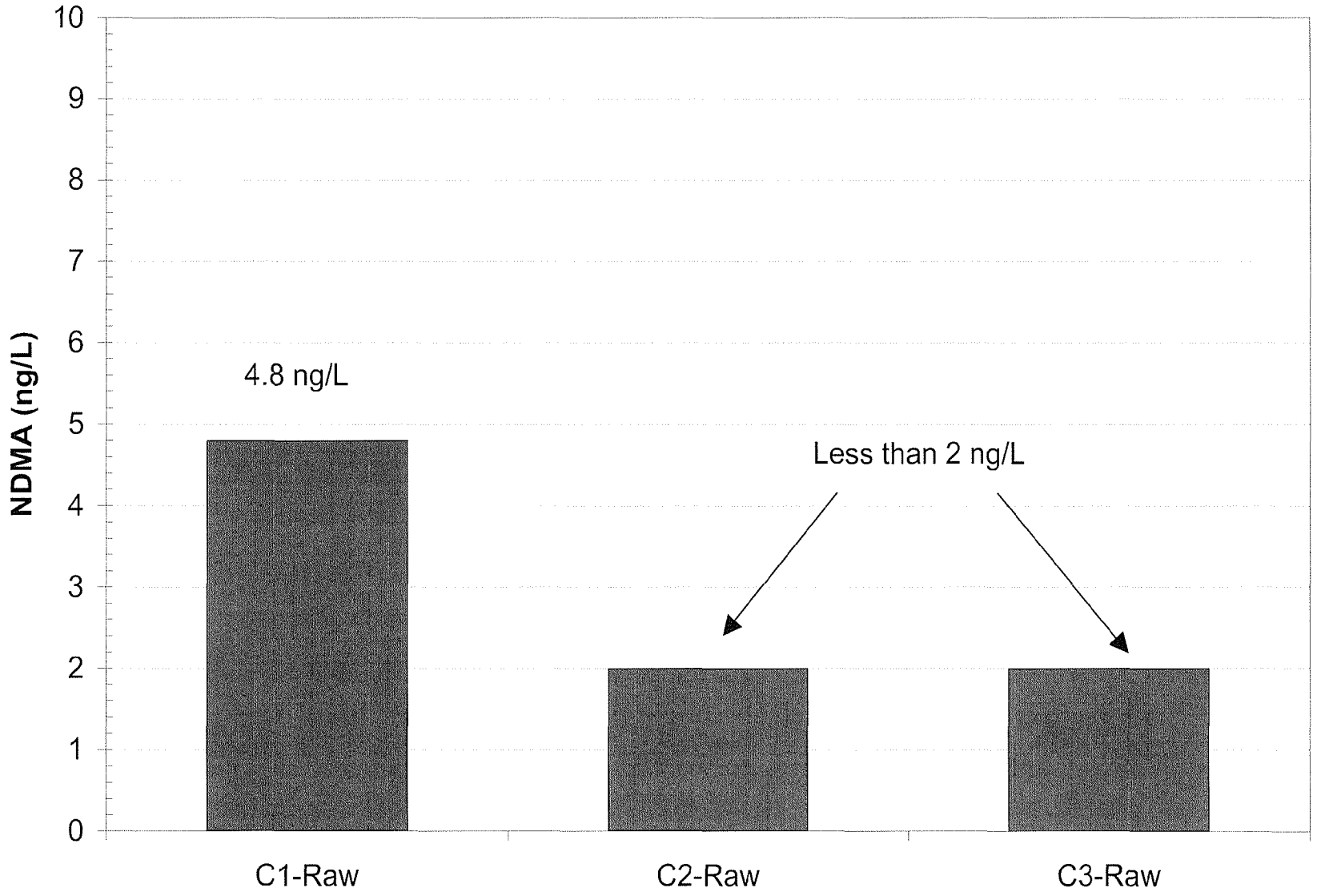

RESIN LEACH TEST RESULTS

FIGURE 3.20

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According to DOT's Hazardous Materials Regulations, 49 Code of Regulation SubChapter C (Hazardous Materials Regulations), subpart §171.8 (Definitions), a hazardous substance means a material, including its mixtures and solutions, that:

1. Is listed in the Appendix A to subpart §172.101 of the subchapter (Purpose and use of hazardous materials table).

2. Is in a quantity, in one package, which equals or exceeds the reportable quantity (RQ) listed in the Appendix A to §172.101 of the subchapter.

Appendix A lists materials and their corresponding RQs that are listed or designated as "hazardous substances" under section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. 9601(14) (CERCLA; 42 U.S.C. 9601 et seq). Table 2 of Appendix A lists radionuclides that are hazardous substances and their corresponding RQs. The RQs in Table 2 for radionuclides are expressed in units of curies, and are shown in Table 3.20.

Table 3.20 A1 and A2 Values for Radionuclides- Shipments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Radionuclide	Atomic Number	A1 (Ci)	A2 (Ci)	Specific Activity (Ci/g)
Uranium 230	92	1,080	0.270	27,000
Uranium 232	92	81.1	0.00811	22
Uranium 233	92	270	0.027	9,700
Uranium 234	92	270	0.027	6,200
Uranium 235	92	Unlimited	Unlimited	0.0000022
Uranium 236	92	270	0.027	0.000065
Uranium 238	92	Unlimited	Unlimited	0.00000034
Uranium Natural	92	Unlimited	Unlimited	0.00000071

As far as transportation of hazardous substances, in Part 173 (Shippers- General Requirements for Shipments and Packaging), Subpart § 173.435, the values of A1 and A2 for radionuclides are defined. A1 means the maximum activity of special form Class 7 (radioactive) material permitted in a Type A package. A2 means the maximum activity of Class 7 (radioactive) material, other than special form, Low-Specific Activity (LSA) or Surface Contaminated Object (SCO), permitted in a Type A package, see Table 3.21.

Table 3.21 Calculated Accumulated Amount of Uranium on the Spent Resins Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Resin	Days Until 50% ClO_4^- Breakthrough	Projected Uranium Accumulation (Ci)	Lowest RQ (Ci)	Lowest A Value (Ci)
Cal Resin	146(1)	1.6E-09	0.01	0.027
USF 9708	60	3.1E-09	0.01	0.027
USF 9710	138(1)	1.2E-09	0.01	0.027

Note:
(1) Extrapolated from perchlorate breakthrough plots

A mass balance of the uranium adsorbed and desorbed from each of the three resins up to 50 percent perchlorate breakthrough was performed based on an influent concentration range of 1.0 to 3.9 pCi/L and measured effluent uranium concentrations from each of the columns. The amount of uranium accumulated on the resins through 50 percent perchlorate breakthrough was calculated and is presented in Table 3.21. Accumulated uranium is far below the lowest permissible reporting quantity and A-value. The resins are thus not classified as hazardous and their transportation and disposal to an incineration facility should not pose a challenge to CLWA.

7.4 Summary of Ion-Exchange Testing Results

7.4.1 Feed Water Quality

The feed water is low in organic matter, has moderate hardness and alkalinity, and contains moderate levels of iron and bromide. The raw water quality was stable over the testing period with the exception of the month of October 2003, during which period pumping rates at the NC-12 well were temporarily reduced, causing a decrease in nitrate concentration, and increases in sulfate and chloride concentrations.

7.4.2 Operational Data

The flow rate ranged from 13.5 to16.5 mg/L during the course of the study, which resulted in EBCTs of 1.4 to 1.6 minutes (the target was 1.5 min).The pressure drop across the column remained constant at 5 psi during most of the project. The water temperature ranged from 32 degrees C (89 degrees F) in the summer months to 16 degrees C (61 degrees F) in the fall. pH ranged from 7.6 to 8.4.

7.4.3 Focused Breakthrough Curves of Nitrate, Sulfate, Chloride, and Bicarbonate

The breakthrough of most anions (with the exception of perchlorate) occurred in the first 24 hours of run time. Bicarbonate broke through immediately, followed by sulfate at 80 bed volumes. Nitrate broke through after 280 bed volumes, 440 bed volumes, and 600 bed

volumes from USF 9708, USF 9710, and Cal 2100 resins, respectively. No chromatographic peaking was observed for any of the critical anions. Chloride level dropped from a high of approximately 325 mg/L to background concentrations (~35 mg/L) after 280 bed volumes.

7.4.4 Long-Term Breakthrough Curves of Perchlorate and Other Anions

Bed volumes to reach perchlorate breakthrough (greater than 1 μg/L) were 25,000 (26 days), 72,000 (75 days), and 76,000 (79 days) for USF 9708 resin, USF 9710 resin, and CalResin 2100, respectively. This translates in treated water volumes of 187,000 gal/ft^3, 540, 000 gal/ft^3, and 569,000 gal/ft^3, respectively. A small increase in chloride concentration was observed after a simulated 45-hour shutdown period, likely due to leaching from the resin.

7.4.5 NDMA Results

The results from the post-chlorination testing with free chlorine (residual of 1.8 to 2.2 mg/L after 24 hours) and with combined chlorine (residual of 1.6 to 1.9 mg/L after 24 hrs) showed that NDMA concentrations in all three ion-exchange column effluents after 2- and 24-hour incubation times were below the detection limit of 2 ng/L. Therefore NDMA precursors did not leach from the resin .

To investigate the formation potential of NDMA upon the reaction of chlorine with DBP precursors in the water or leaching from the resin, a 2-mg/L free chlorine dose was added directly to the feed water. Measured NDMA levels were below or just over the detectable limit of 2 ng/L.

To evaluate the NDMA precursor leaching potential of the resins, 100 mL batches of fresh resin were incubated for four hours in deionized water and groundwater. NDMA was detected in only one sample, which measured at less than half the 10 ng/L Action Level.

7.4.6 Spent Resin Characterization

The California TTLC metal concentration values were mostly non-detect in all three spent resins. Chromium, vanadium, and zinc were detected in USF 9708 and USF 9710 spent resins at levels significantly below the regulatory TTLC threshold concentrations. Uranium levels in the spent resin leachate were significantly below the Title 22 MCL of 20 pCi/L. To investigate whether the spent resins would be classified as hazardous for transportation to an incineration facility, a mass balance of the uranium adsorbed and desorbed from the resin up to 50 percent perchlorate breakthrough was performed. The amount of uranium accumulated on the spent resins is far below the lowest permissible reporting quantity and A-value of the California DOT.

7.5 Fixed-Bed Filter

7.5.1 Biological Acclimation

Figure 3.21 shows FXB perchlorate removal performance during the biological acclimation and optimization phases[1]. Perchlorate was initially removed by adsorption onto the virgin GAC, and began to break through after 12 days as the carbon's adsorption capacity diminished. These data are consistent with other perchlorate/GAC breakthrough curves reported in the literature (Na et al., 2002, Brown et.al, 2002). During the subsequent month of biological acclimation, run times were less than 24 hours due to rapid headloss development in the filter. The pilot feed lines were experiencing heavy biological growth, and the biofilm from the feedlines would occasionally detach and clog the bed. The acetic acid feed concentration was lowered during the acclimation phase (Figure 3.22) to minimize growth. However, excessive biogrowth in the feed lines continued to generate rapid headloss build-up. Phosphoric acid was added at 0.2 mg/L PO_4-P to select away from filamentous organisms suspected of causing the overgrowth and clogging problems. Simultaneously, the electron donor feed was repositioned so that acetic acid was fed directly to the top of the filter column instead of upstream of the static mixer, thus minimizing biofilm growth in the feed line. Consequently, biogrowth was isolated to the filter bed, headloss development rates decreased, and 48-hour run times were achieved. Within 10 days of adding phosphoric acid and repositioning the acetic acid feed, steady perchlorate removal to below detection was achieved in the filter. The phosphoric acid feed was removed during the optimization tests without affecting perchlorate removal performance, indicating that phosphorous in the natural water did not limit biological activity in the filter. Therefore, repositioning the acetic acid feed was likely the key to effectively acclimating the FXB filter for biological perchlorate removal. If this electron donor feed configuration had been used from time zero, it is estimated that steady-state biological perchlorate removal to below detection would have required 3 to 4 weeks of operation.

7.5.2 Optimization

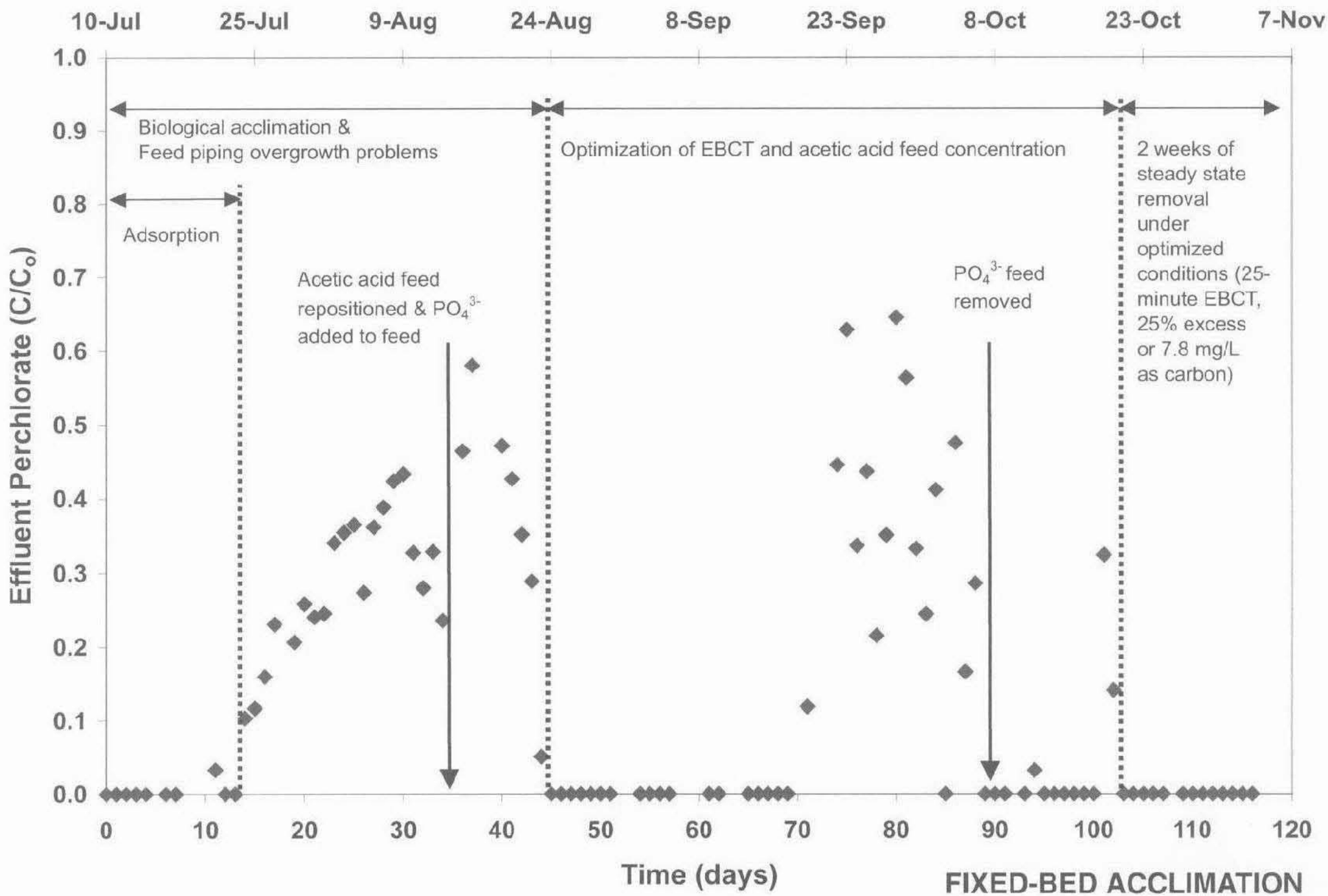
During the two months of piloting after the acclimation period, EBCT and acetic acid feed concentrations were optimized (Figures 3.21 and 3.22). The minimal acetic acid concentration that still allowed removal of perchlorate to below detection was 7.8 mg/L as carbon (25% excess).[2] EBCTs as low as 15 minutes allowed for the consistent, complete removal of perchlorate to below detection, although only 24-hour run times were achieved. To lengthen run times, the EBCT was increased to 20 minutes. However, short-circuiting of the filter was observed throughout this period, resulting in perchlorate breakthroughs from 20 to 65 percent. While the 15-minute EBCT operation resulted in rapid headloss development (i.e., < 24-hour run times) but no perchlorate breakthrough, the 20-minute EBCT resulted in short-circuiting and variable perchlorate breakthrough. It appears that the

---

[1] All perchlorate detections (even those lower than the 4 μg/L MRL) are shown in the FXB and FBR figures.

[2] Assumes complete reduction of 7.0 mg/L of feed DO and 15 mg/L of feed nitrate.

20-CLWA204F3.21-6625A10.CDR



FIXED-BED ACCLIMATION AND OPTIMIZATION

FIGURE 3.21

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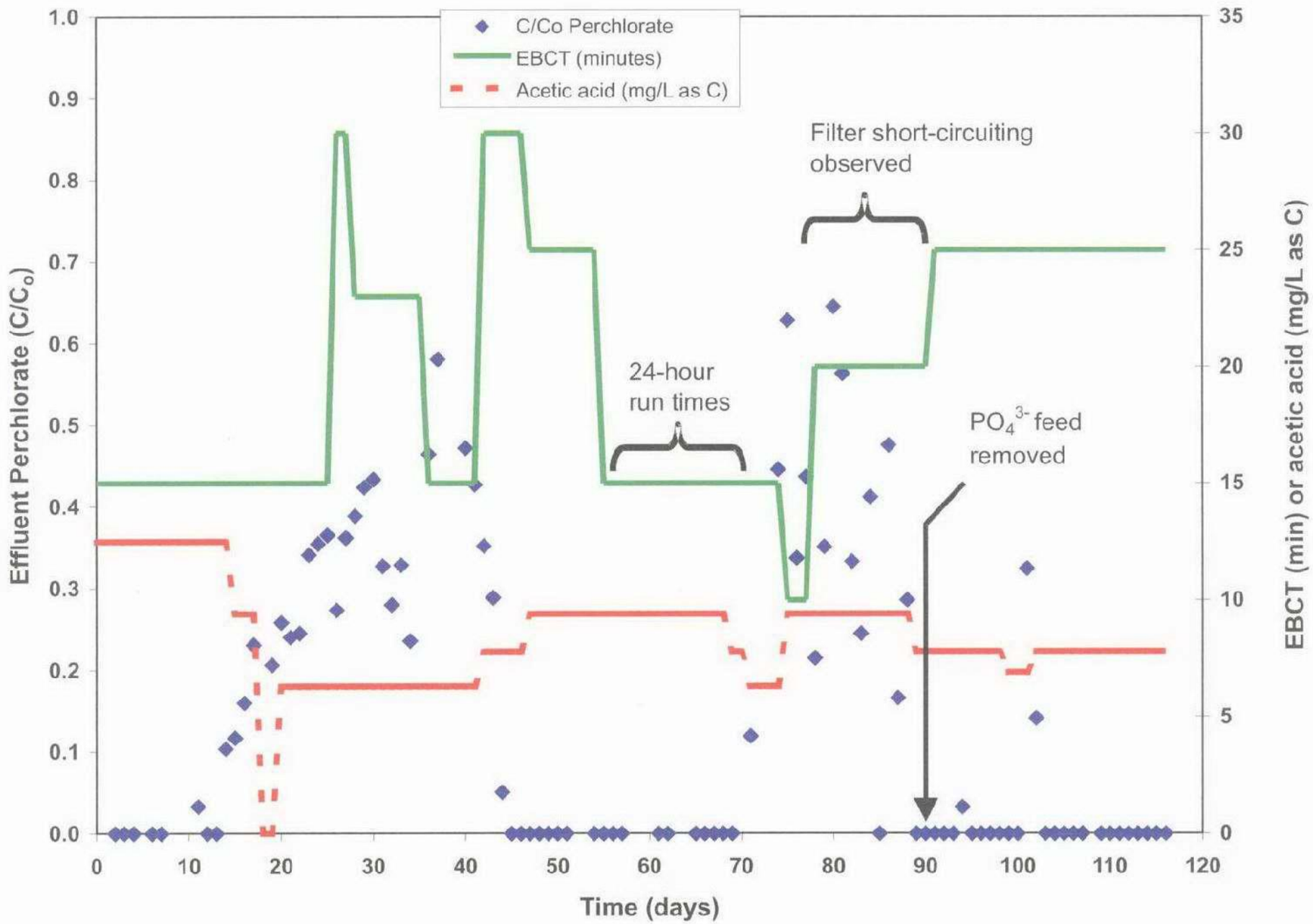
20-CLWA204F3.22-6625A10.CDR



FIXED-BED EBCT AND ACETIC ACID SET-POINTS

FIGURE 3.22

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29040

higher flow rate promoted more uniform hydraulic loading in the filter, which distributed growth evenly across the bed. Instead of passing through the filter evenly, feedwater pumped at lower flow rates followed preferential paths that produced the observed channeling. The shortest EBCT that allowed ≥ 48-hour run times while consistently removing perchlorate to below detection was 25 minutes. Though some channeling was observed under 25-minute EBCT conditions, it was less extensive than that observed during 20-minute EBCT operation. After the optimization period, the filter was run for two weeks using a 25-minute EBCT and 7.8 mg/L acetic acid carbon. Removal of perchlorate to below detection was observed throughout this period as well.

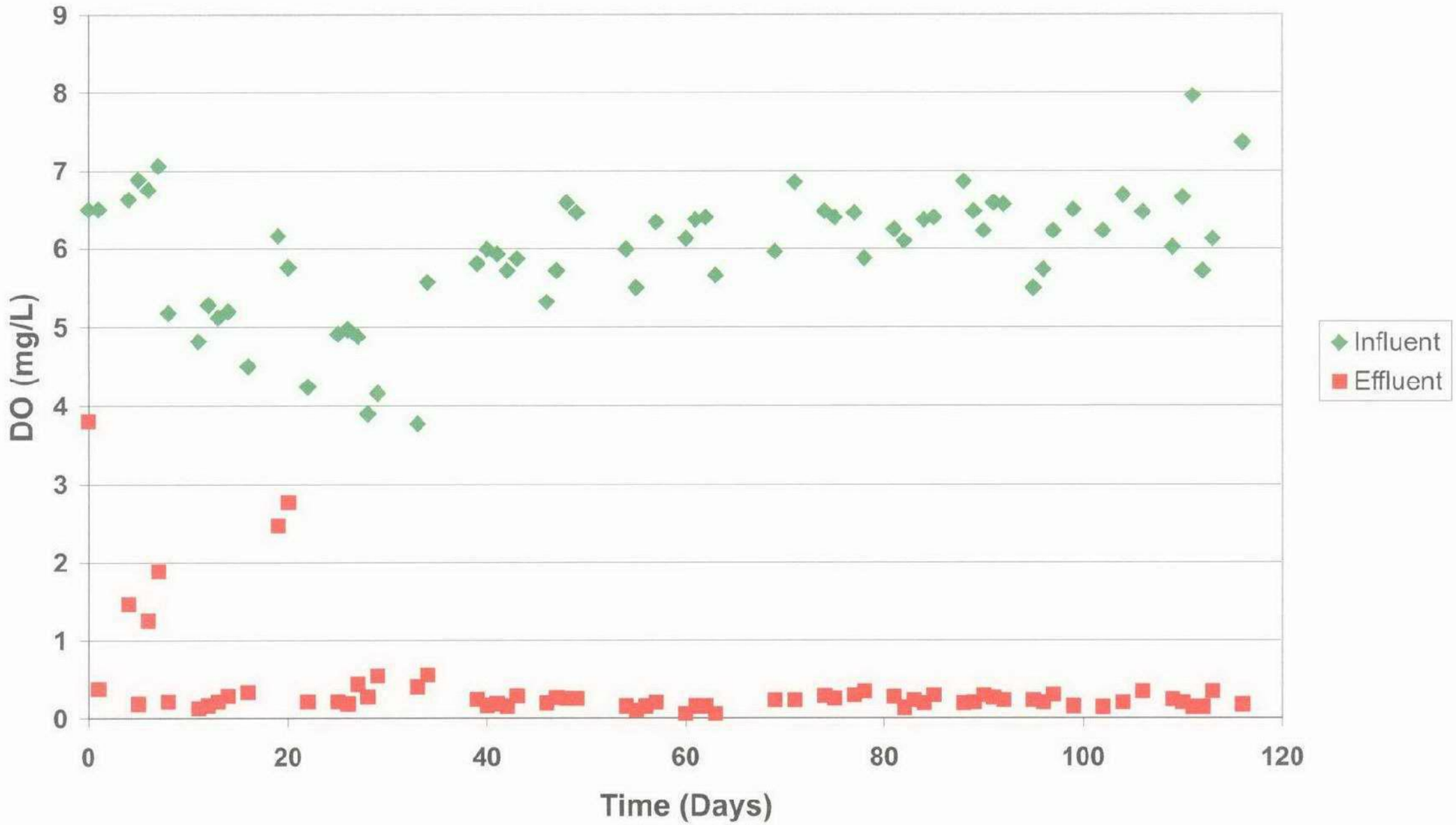
7.5.3 Dissolved Oxygen and Nitrate

All perchlorate-reducing bacteria described in the literature are facultative aerobes or microaerophiles. Thus, oxygen can inhibit biological perchlorate reduction by acting as a competing electron acceptor. Similar to oxygen, nitrate has a high redox potential that allows it to compete with perchlorate for use as an electron acceptor. Research has confirmed the occurrence of this competitive inhibition by demonstrating that DO and nitrate concentrations must be very low to achieve efficient perchlorate reduction in biological reactors (Brown et al., 2001, Herman and Frankenberger, 1999). Therefore, influent and effluent DO and nitrate concentrations were monitored closely during pilot testing.

Effluent DO concentrations were generally low during the acclimation phase (Figure 3.23). DO was likely reacting with the surface of the GAC initially, and was being reduced biologically as bacteria colonized the bed. Influent DO concentrations ranged from 4 to 8 mg/L and were reduced to 0.2 percent 0.3 mg/L throughout most of the pilot testing period. While effluent DO concentrations were steady, Figure 3.24 shows that effluent nitrate concentrations were variable. It was also observed that when effluent nitrate concentrations were detected, effluent perchlorate concentrations were also detected. These data: 1) indicate that DO was preferentially reduced over nitrate, and 2) confirm that DO and nitrate inhibit biological perchlorate reduction, as has been widely reported in the literature.

Figure 3.24 also reveals that feed nitrate concentrations gradually declined to approximately 7 mg/L as NO_3 after operating for 80 days at 15 mg/L as NO_3. The decline in feed nitrate concentrations coincided with a change in the NC-12 pumping schedule. After Day 80 of pilot operation, NC-12 was no longer pumped continuously for production, but rather was turned on periodically only to produce water for pilot plant operation. The resultant decrease in NC-12 production may have caused the variable background nitrate as well as sulfate (Figure 3.27).

20-CLWA204F3.23-6625A10.CDR



FIXED-BED DISSOLVED OXYGEN

FIGURE 3.23

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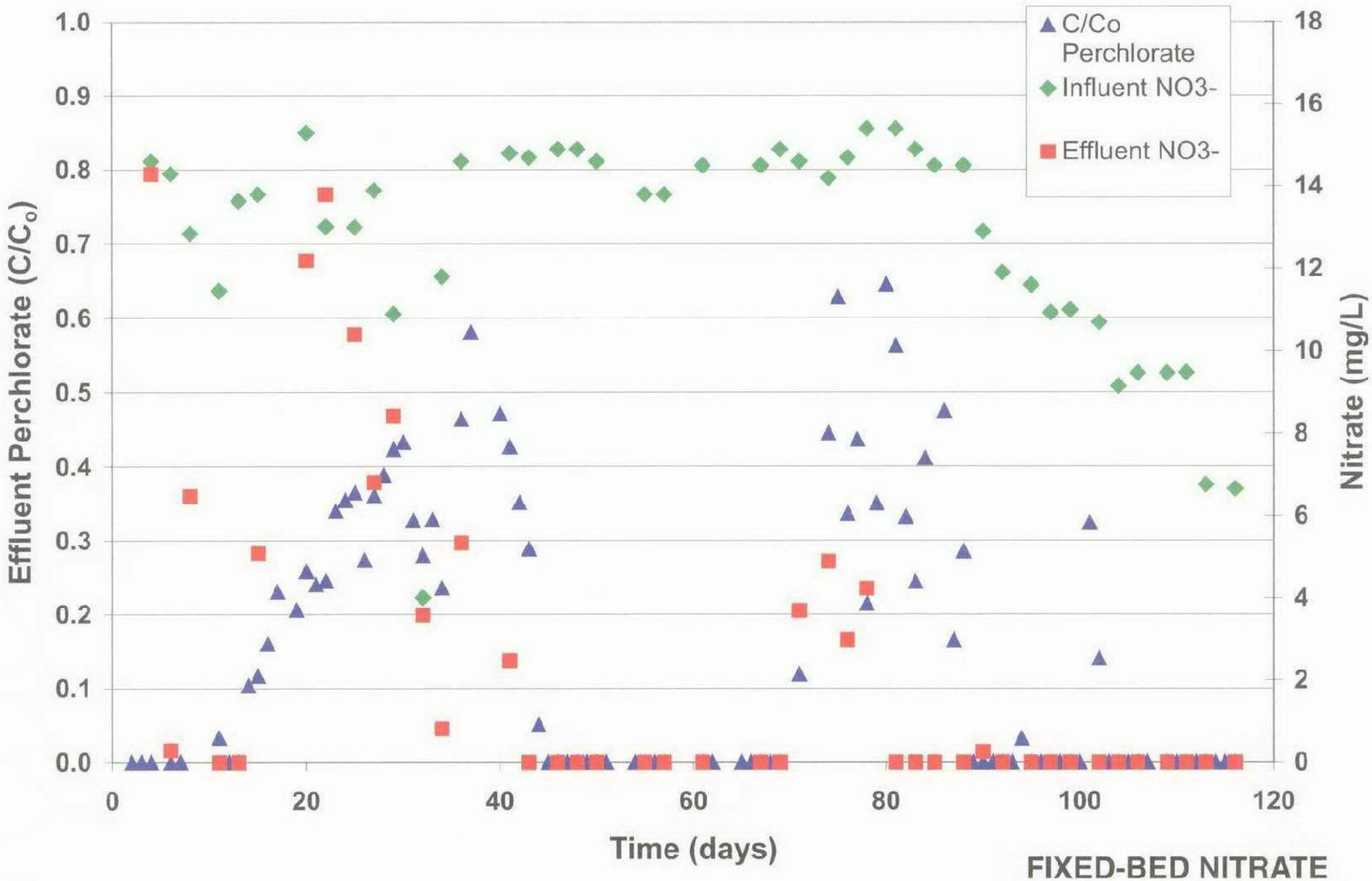
29042

20-CLWA204F3.24-6625A10.CDR



FIXED-BED NITRATE AND PERCHLORATE

FIGURE 3.24

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29043

7.5.4 Other Parameters

The following water quality observations were made during acclimation and optimization phases of FXB piloting:

- Effluent TOC concentrations were very low (Figure 3.25); generally non-detect (i.e, ≤ 0.7 mg/L). Effluent BDOC concentrations were non-detect (Figure 3.26). These data indicate that effluent from the FXB filter is biologically stable, and suggest that the post-treatment steps may be somewhat simplified to aeration and disinfection.
- Sulfate concentrations and pH were not significantly impacted across the filter (Figures 3.27 and 3.28, respectively). However, sulfide was occasionally detectable by smell.
- HPCs increased across the filter, resulting in counts between 70,000 and 650,000/mL (Figure 3.29).
- With the exception of two data points, total coliforms were not detected in the feed or effluent of the filter (Figure 3.30). The two detections indicated that coliforms in the feed water were partially removed across the filter. No fecal coliforms were detected.
- Average feed water turbidities were approximately 0.5 NTU. Average effluent turbidities were approximately 0.6 NTU (Figure 3.31). Average effluent particle count (>2 µm) was 99 counts/mL (Figure 3.31). The particle counter malfunctioned after 80 days of operation.
- Headloss across the filter ranged from < 2 feet to 30 feet (Figure 3.32). Under optimal operating EBCT and acetic acid conditions, headloss peaked at 25 feet, but was typically between 5 and10 feet.

7.5.5 Robustness Characterization

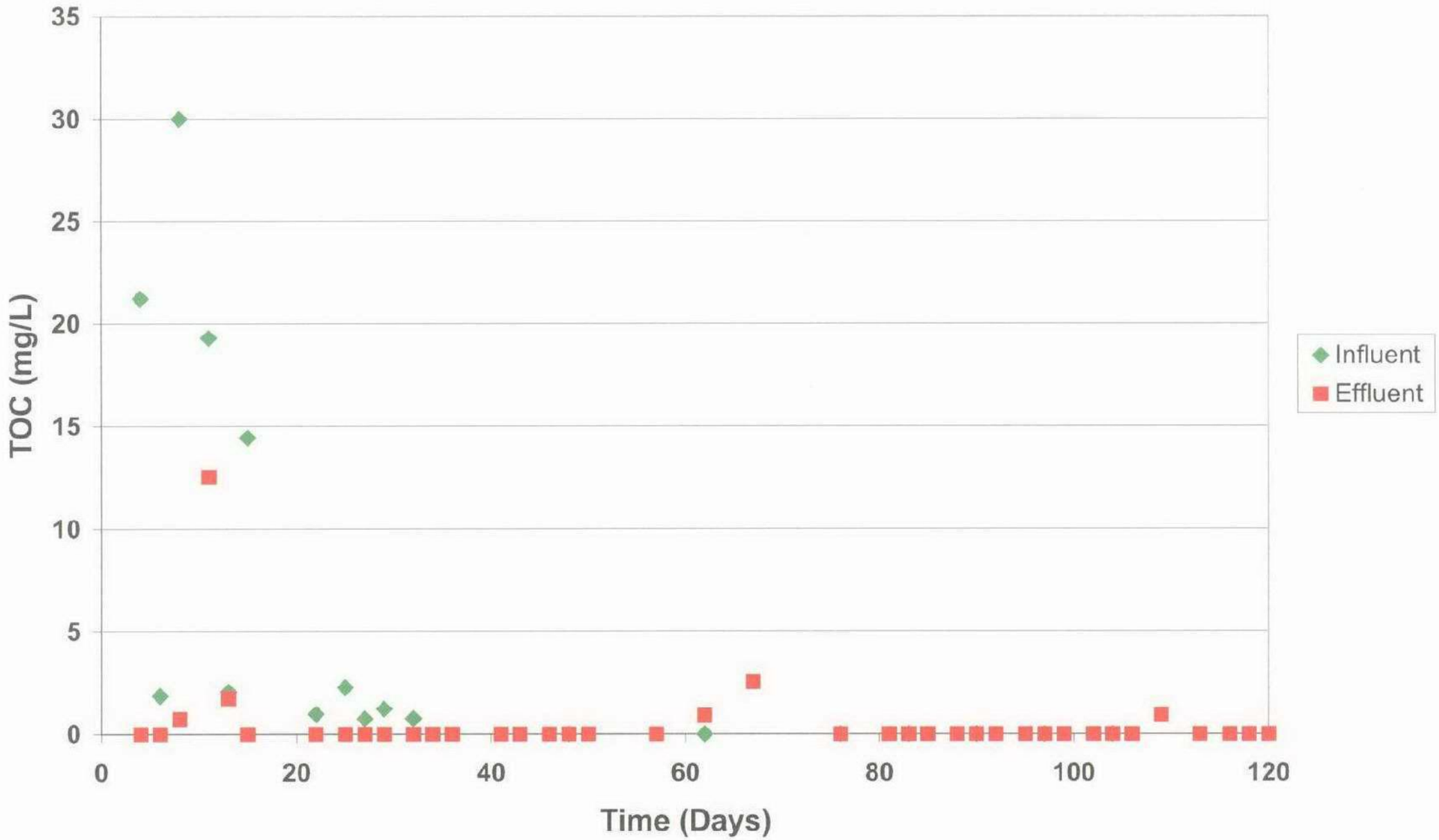
7.5.5.1 Backwashing

The results of the backwash challenge tests are shown in Figure 3.33. After the filter was put back into production following a backwash event, samples were taken every 15 minutes for an hour. No perchlorate was detected. This experiment was repeated one month after the first backwash challenge test with the same result.

7.5.5.2 Perchlorate Spiking

Transient perchlorate loading episodes did not impact perchlorate removal performance in the FXB filter (Figure 3.34). The feed perchlorate concentration was varied from 50 μg/L to 100 μg/L to 50 μg/L to 300 μg/L to 5 μg/L while EBCT and feed acetic acid concentration were maintained at 25 minutes and 7.8 mg/L as carbon, respectively. No perchlorate was detected in the effluent, even for the high resolution samples (i.e., samples taken at 0, 15, 30, 45, and 60 minutes) taken immediately after the influent perchlorate concentration was changed.

20-CLWA204F3.25-6625A10.CDR



FIXED-BED TOTAL ORGANIC CARBON

FIGURE 3.25

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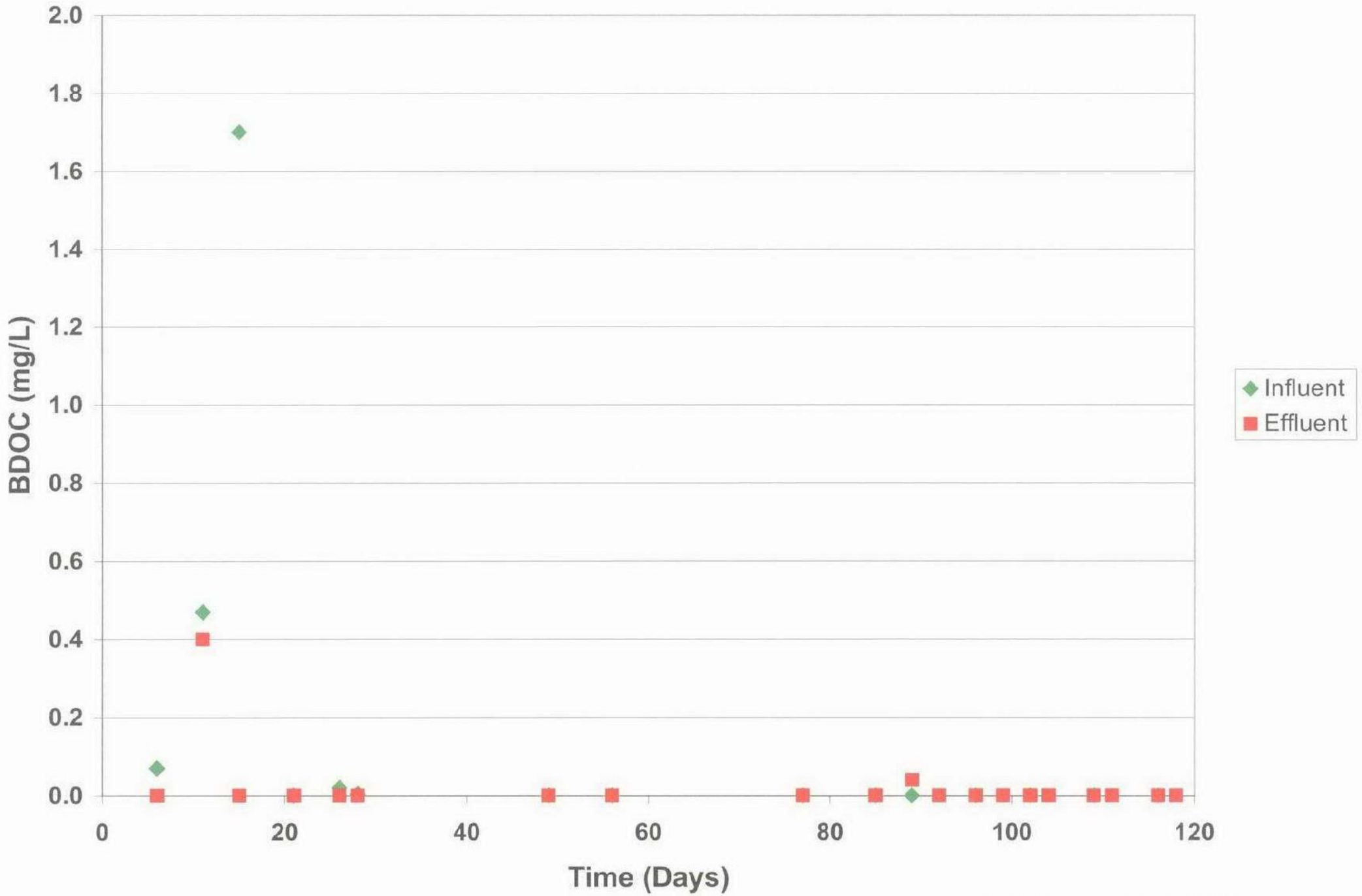
20-CLWA204F3.26-6625A10.CDR



FIXED-BED BDOC

FIGURE 3.26

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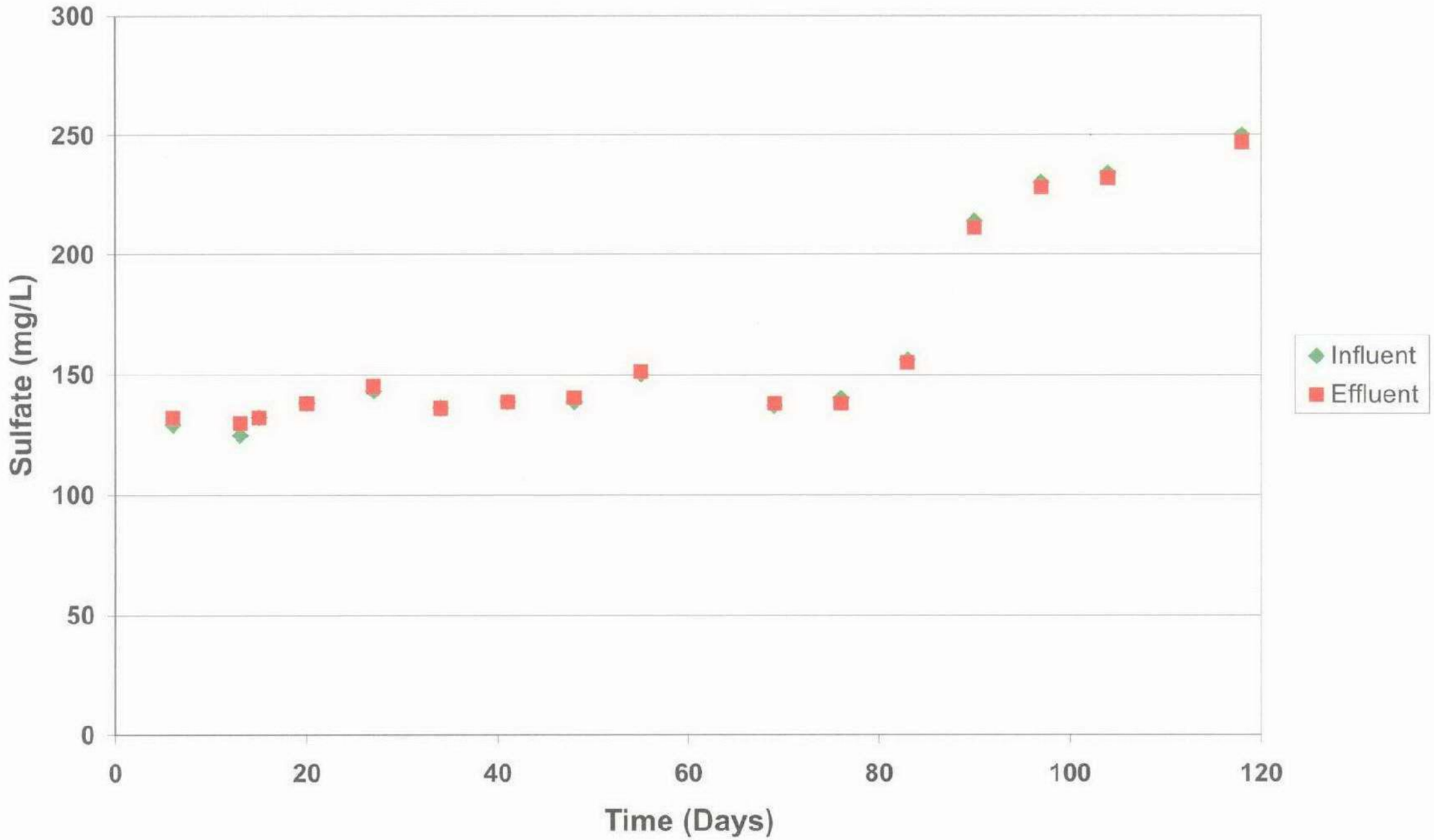
20-CLWA204F3.27-6625A10.CDR



FIXED-BED SULFATE

FIGURE 3.27

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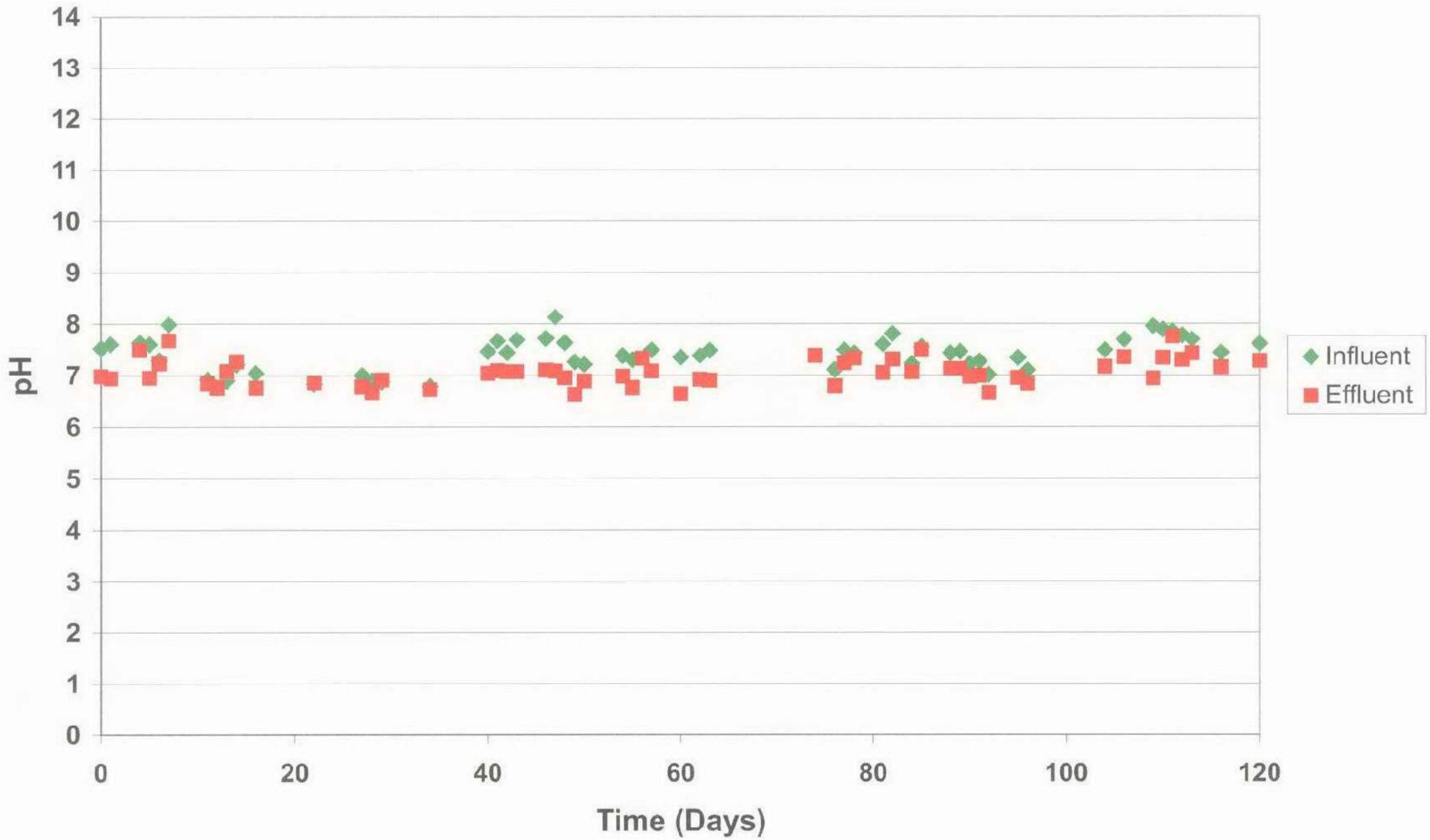
29047

20-CLWA204F3.28-6625A10.CDR



FIXED-BED pH

FIGURE 3.28

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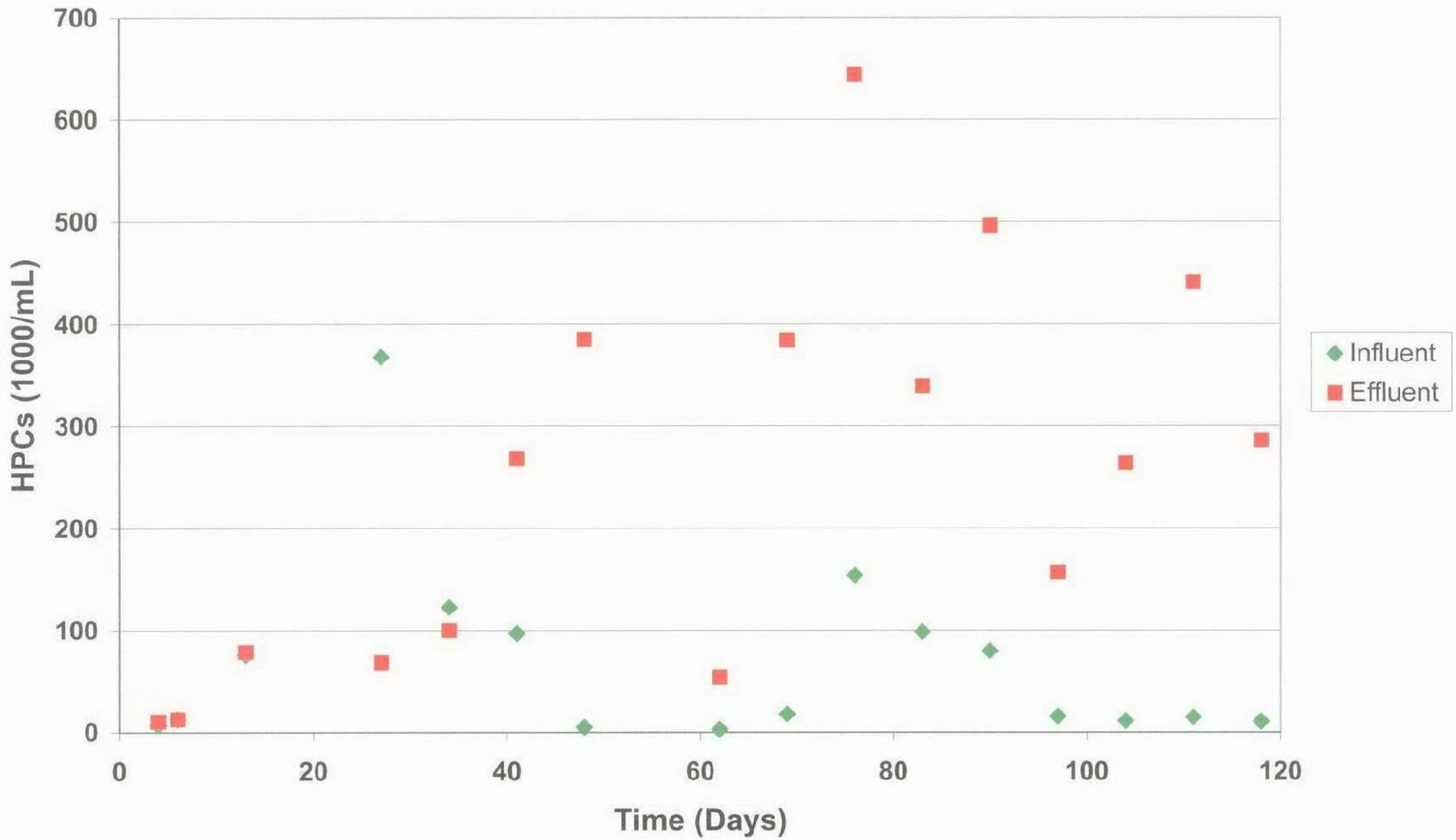
29048

20-CLWA204F3.29-6625A10.CDR



FIXED-BED HETEROTROPHIC PLATE COUNTS

FIGURE 3.29

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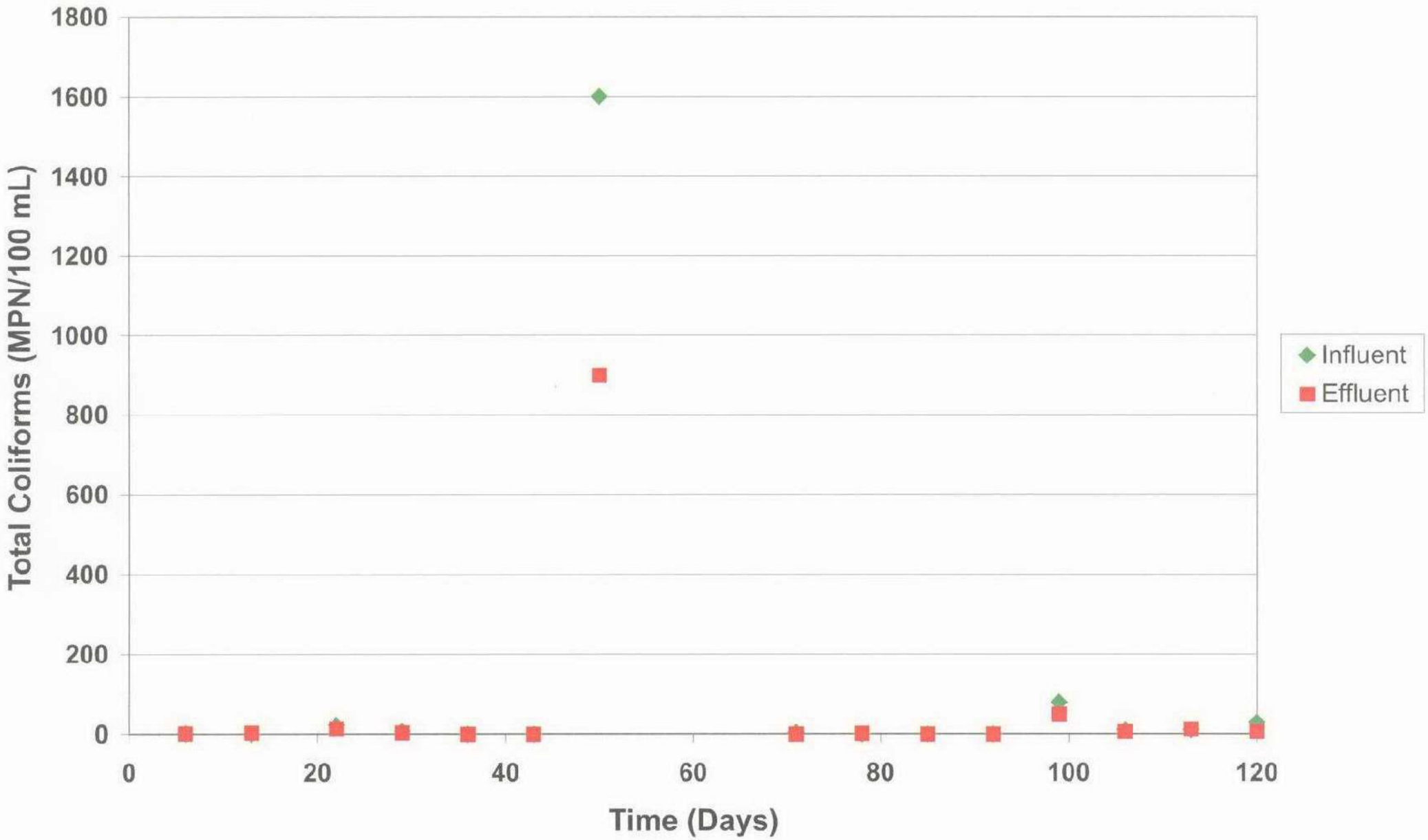
29049

20-CLWA204F3.30-6625A10.CDR



FIXED-BED TOTAL COLIFORMS

FIGURE 3.30

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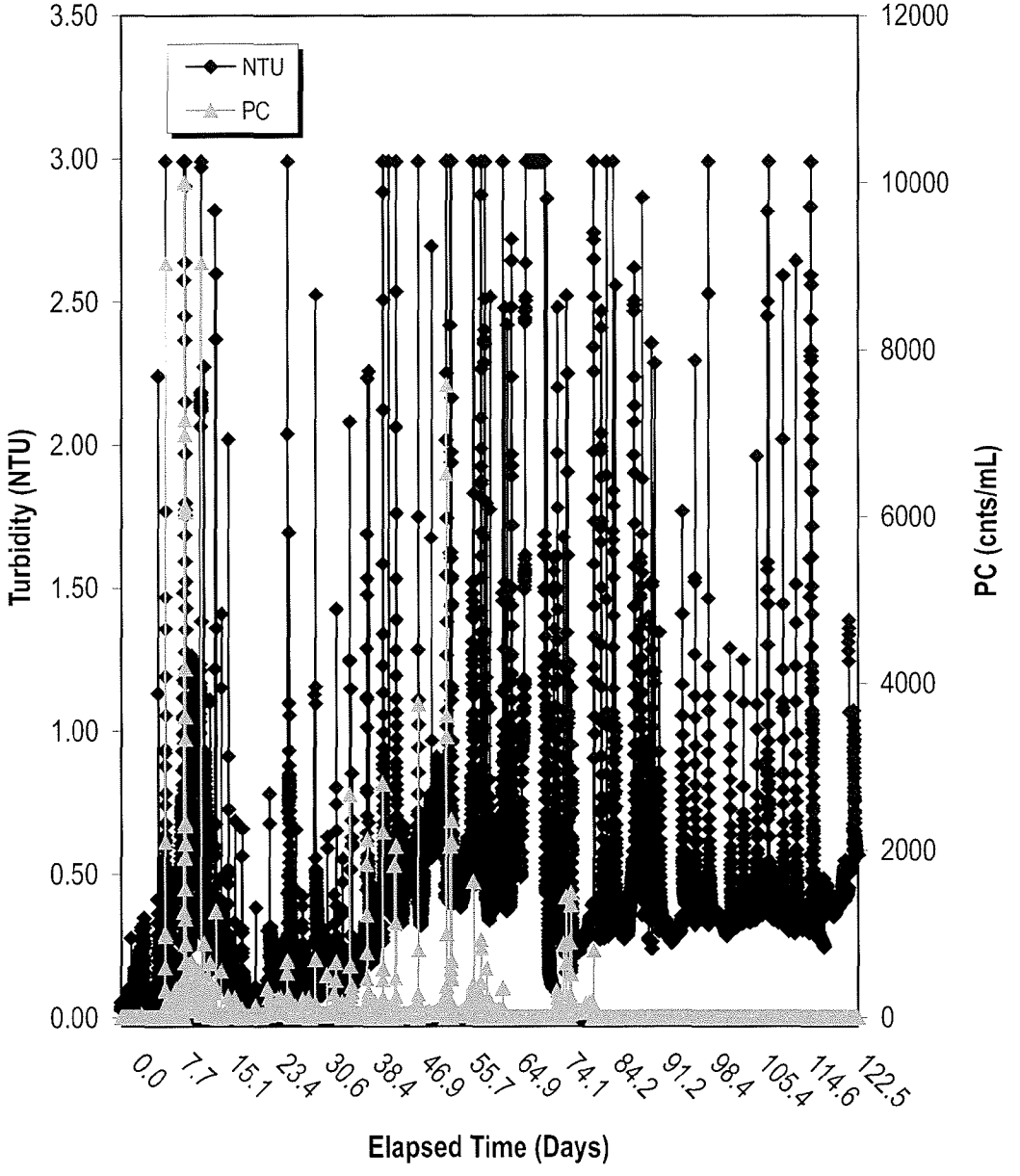
29050



FIXED-BED EFFLUENT TURBIDITY AND PARTICLE COUNTS

FIGURE 3.31

20-CLWA204F3.31-6625A10.CDR

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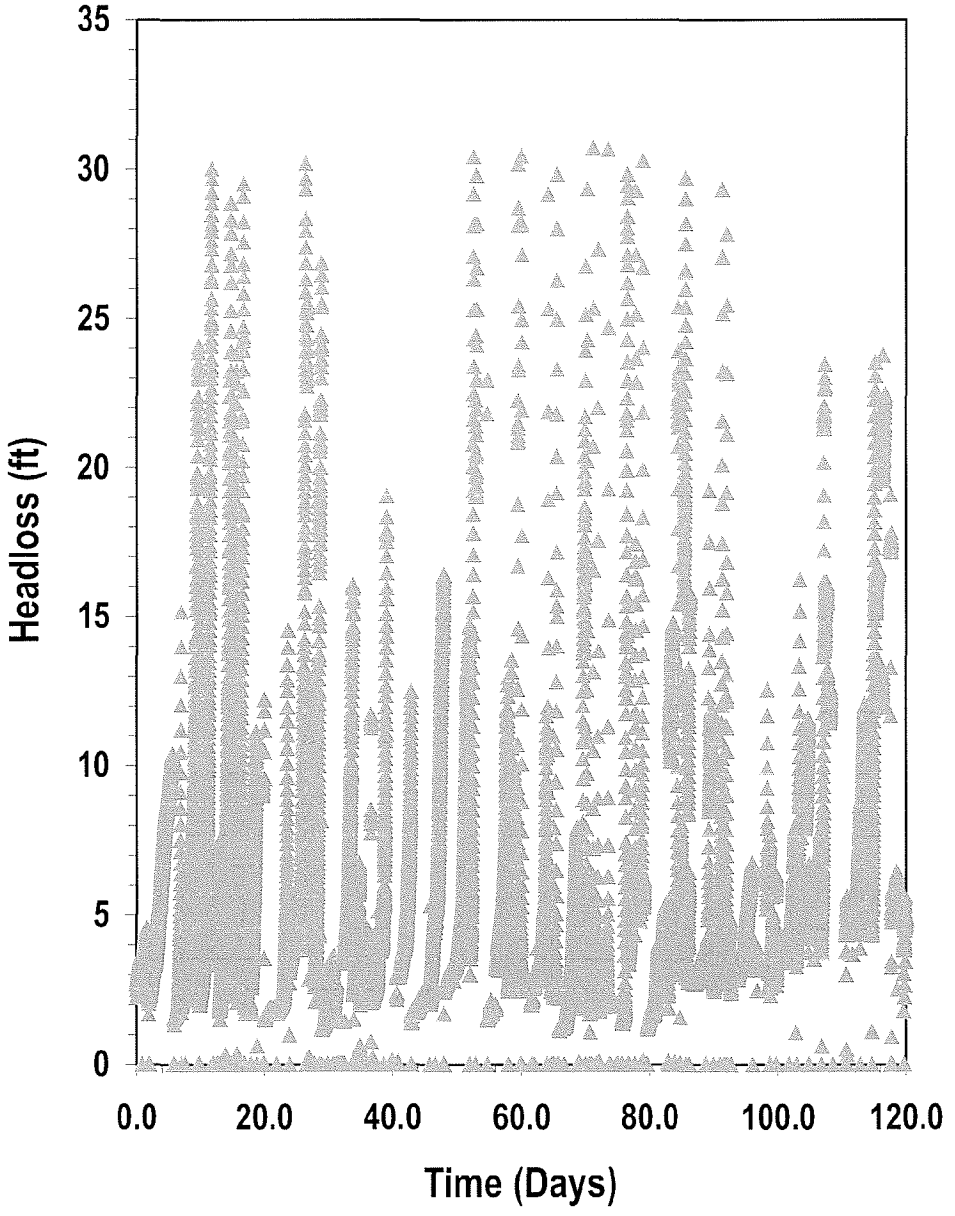
29051



FIXED-BED HEADLOSS

FIGURE 3.32

20-CLWA204F3.32-6625A10.CDR

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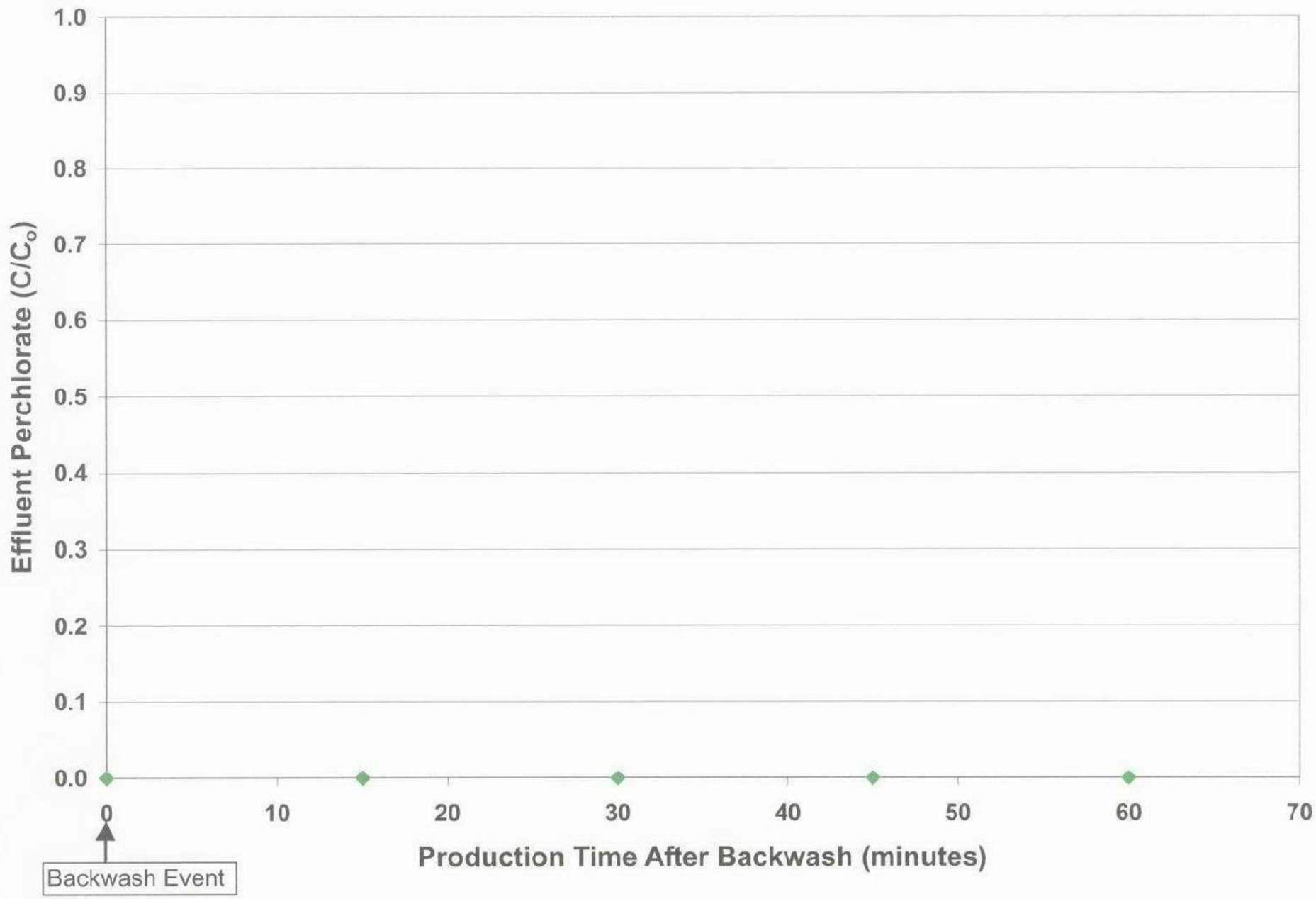
20-CLWA204F3.33-6625A10.CDR



FIXED-BED BACKWASH CHALLENGE TEST

FIGURE 3.33

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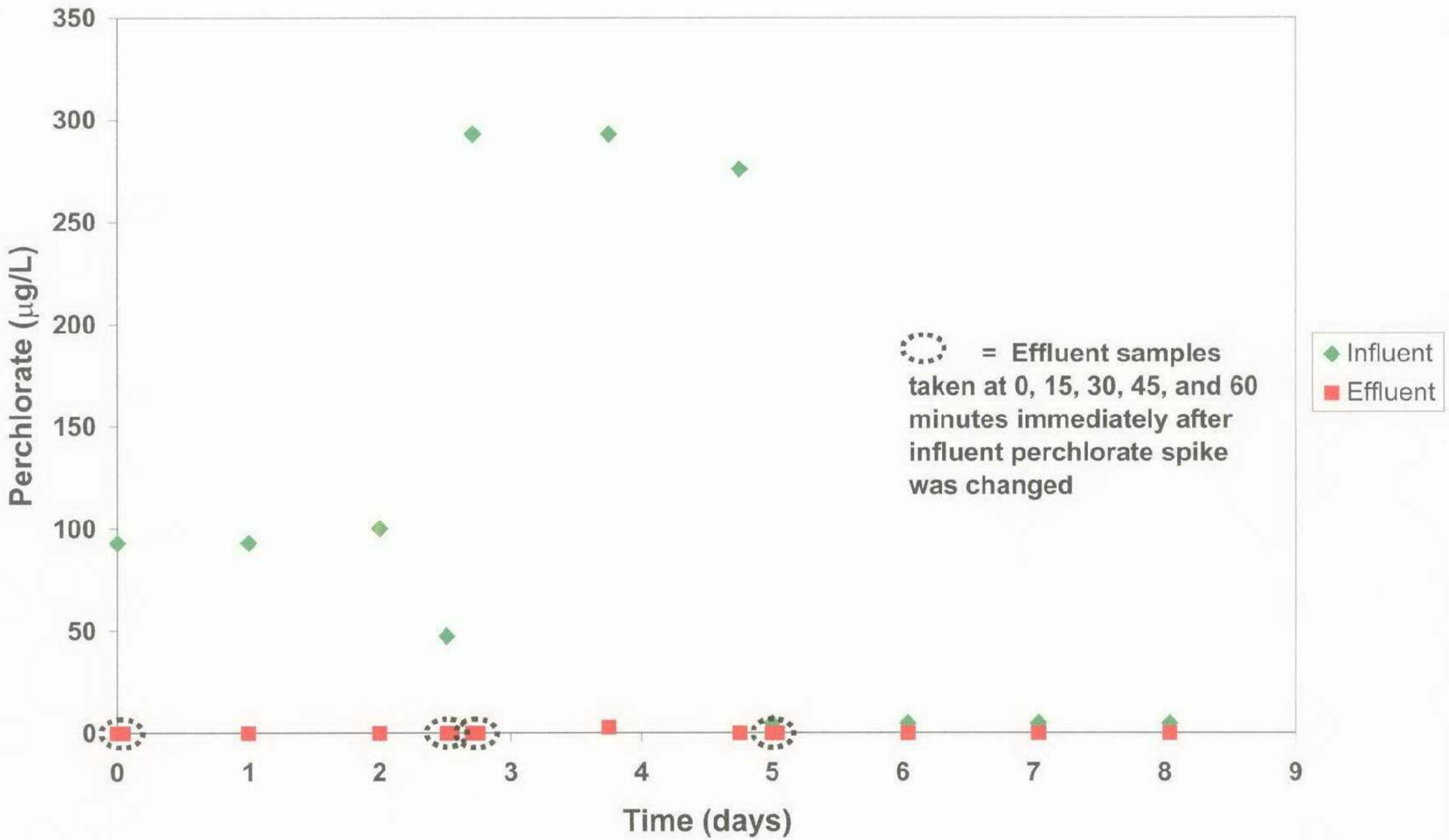
29053

20-CLWA204F3.34-6625A10.CDR



FIXED-BED PERCHLORATE SPIKE CHALLENGE TEST

FIGURE 3.34

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29054

7.5.5.3 Nitrate Spiking

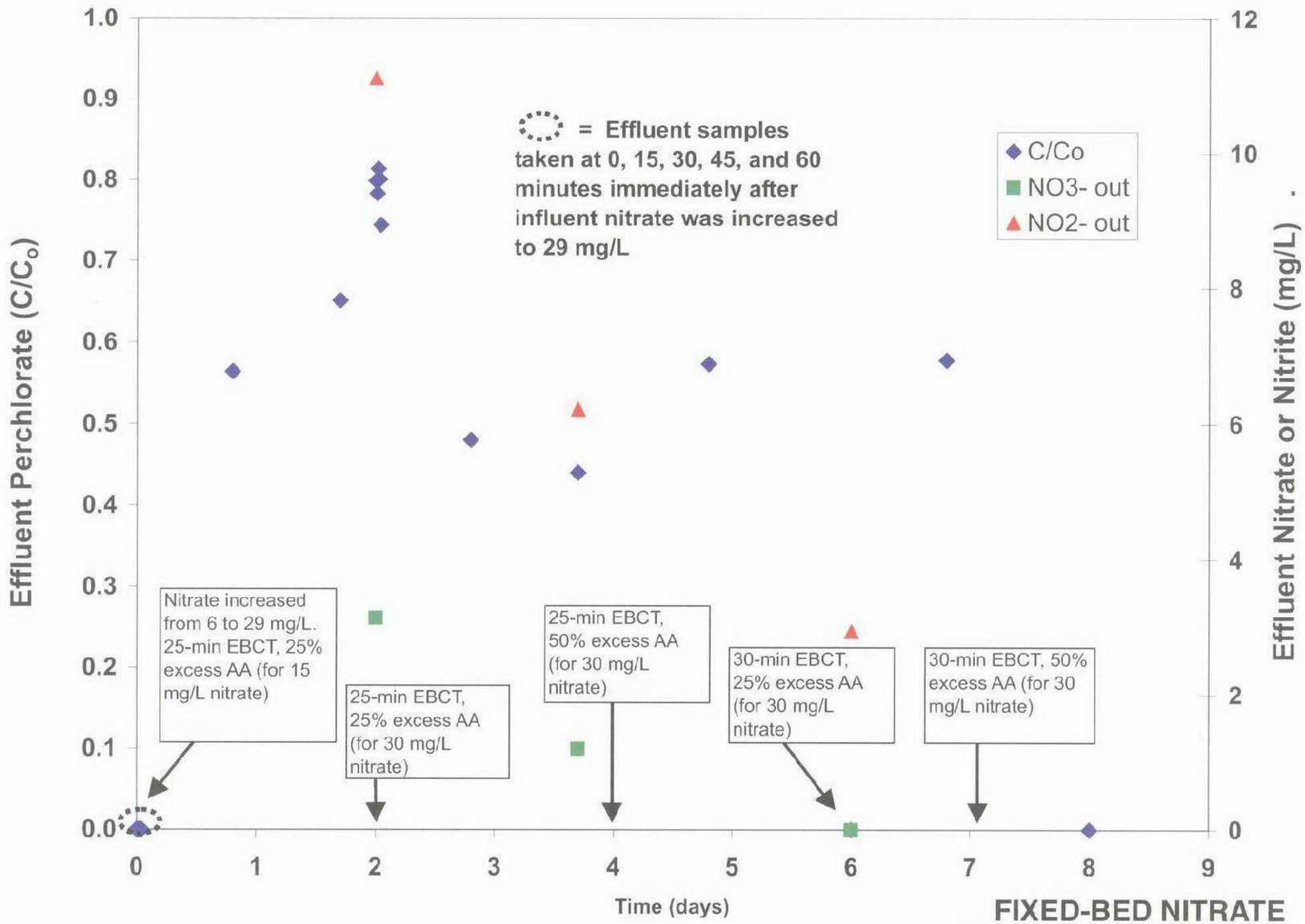
When the feed nitrate concentration was increased stepwise from 6 mg/L as NO_3 to 29 mg/L as NO_3, perchlorate was not detected in the high resolution samples taken up to an hour after the event (Figure 3.35). However, samples taken ≥ 24 hours after the step increase showed perchlorate, nitrate, and nitrite breakthrough. Increasing the acetic acid feed concentration and EBCT did not immediately recover perchlorate removal performance to below detection. Eight days after the feed nitrate concentration was increased by 23 mg/L as NO_3^-, complete removal of nitrate, nitrite, and perchlorate was again observed in the FXB. These data suggest two important phenomena:

1. When large step increases in feed oxidant concentrations occur, the biological FXB requires a period of bioacclimation before perchlorate removal to below detection can be reestablished and maintained. In other words, the bacterial mass in the FXB, which was equilibrated to a feed nitrate concentration of 6 mg/L as NO_3^-, was insufficient to handle a sudden increase in feed nitrate concentration of 23 mg/L as NO_3^-. The bacterial community had to grow and equilibrate with a much higher nitrate concentration before it could produce the redox conditions necessary for complete perchlorate removal.

2. Via adsorption, GAC provides a safety factor with respect to perchlorate removal in the FXB. This is supported by the lack of perchlorate detections immediately following the step nitrate increase. The primary perchlorate removal mechanism in the biological FXB is biological reduction. However, if the microbial activity in the filter is insufficient to remove perchlorate, the GAC can adsorb perchlorate for a period of time to prevent breakthrough. If perchlorate diffusion through the biofilm is fast, adsorption could be occurring near the top of the GAC bed, where the biological activity is highest. If perchlorate diffusion through the biofilm is slow, adsorption could be occurring in the lower portions of the GAC bed, where there is little biological activity. Sorption sites may be biologically regenerated when perchlorate reducing conditions return to the FXB. This may be the case even for adsorption sites in the lower portions of the bed, as GAC tends to migrate toward the top of the column during a backwash event, positioning it at depths of increased biological activity. This hypothesis explains why there might be perchlorate adsorption capacity available on the GAC after five months of pilot testing.

Large step changes in nitrate concentration, like the one tested during this experiment, are not typical for a groundwater system. Unintentional, gradual nitrate fluctuations were observed throughout pilot testing and did not impact perchlorate removal performance in the FXB.

20-CLWA204F3.35-6625A10.CDR



FIXED-BED NITRATE SPIKE CHALLENGE TEST

FIGURE 3.35

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29056

7.5.5.4 System Shut-Down

Figure 3.36 shows the results of the 24- and 48-hour shut-down tests. The pilot plant was turned off for 24 hours and then restarted using a 25-minute EBCT and 7.8 mg/L acetic acid carbon. No backwash was performed prior to restarting the FXB. Samples taken at 0, 15, 30, 45, and 60 minutes and 24 hours after the pilot was restarted showed no perchlorate breakthrough. However, 26 percent and 40 percent breakthrough occurred 48 and 72 hours after the pilot was put back into production. After the 72-hour sample, the pilot was turned off for a period of 48-hours and then restarted without a backwash. Samples taken at 0, 15, 30, 45, and 60 minutes, 24 hours, and 48 hours after the pilot was restarted showed no perchlorate breakthrough. The 72-hour sample showed 24 percent breakthrough and the 96-hour sample again showed perchlorate removal to below detection.

The 24-hour shut-down experiment was repeated, but included a backwash prior to restarting the system. As Figure 3.36 indicates, no perchlorate was detected in the effluent in the high resolution samples or in subsequent samples taken daily for five days. A review of previous data also revealed four periods over which the biological FXB pilot system was shut down unintentionally. These periods ranged from 12 to 62 hours, the biological FXB was backwashed prior to restarting after each period, and production EBCTs were 15 or 25 minutes. No effluent perchlorate was detected following the shut down periods (Figure 3.37).

The biological FXB was also shut down for a two-week period in December 2003. It was backwashed and restarted at a 25-minute EBCT. Consistent perchlorate removal was immediately observed and sustained; no effluent perchlorate was detected.

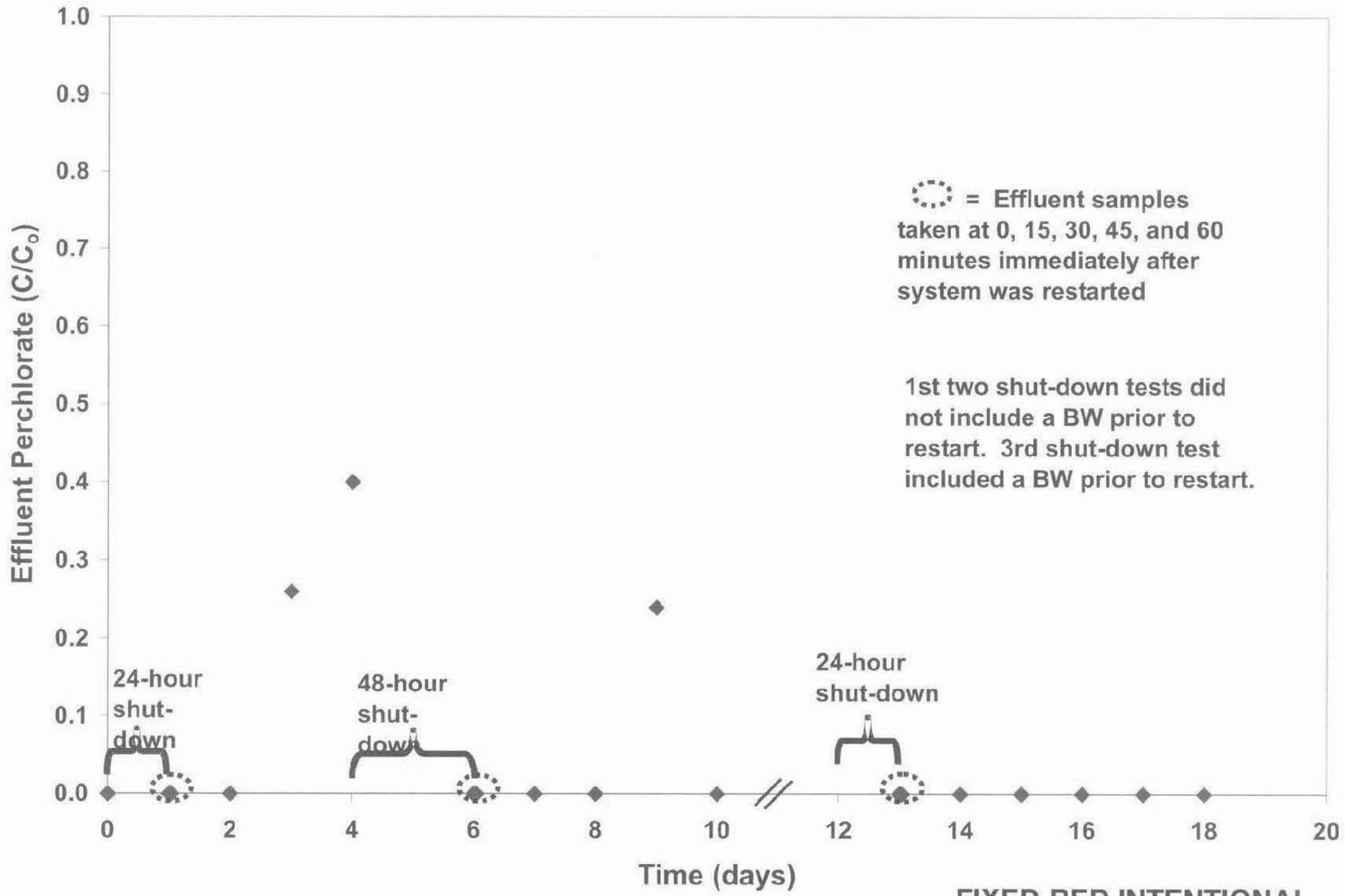
7.5.5.5 Electron Donor Feed Failure Simulation

To investigate the impact of the future of the electron donor addition on perchlorate removal performance in the FXB, the acetic acid feed was shut off and effluent perchlorate concentrations were monitored. Samples taken at 0, 15, 30, 45, and 60 minutes and 2, 3, 5 and 24-hours after the acetic acid pump was turned off showed no perchlorate breakthrough (Figure 3.38). The acetic acid pump was then restarted and perchlorate continued to be removed to below detection. The following hypothesis may account for the exceptional perchlorate removal performance in the biological FXB while no exogenous electron donor was being added to the system:

1. The bacterial community in the biological FXB was respiring endogenously. That is, bacteria were metabolizing their own cells for use as an electron donor. This often occurs when food sources are scarce.

2. Via adsorption, GAC was providing a safety factor with respect to perchlorate removal in the FXB. When the acetic acid pump was turned off, biologically reductive activity likely slowed in the filter, allowing adsorption to become a more active mechanism for perchlorate removal.

20-CLWA204F3.36-6625A10.CDR



FIXED-BED INTENTIONAL SHUT-DOWN CHALLENGE TEST

FIGURE 3.36

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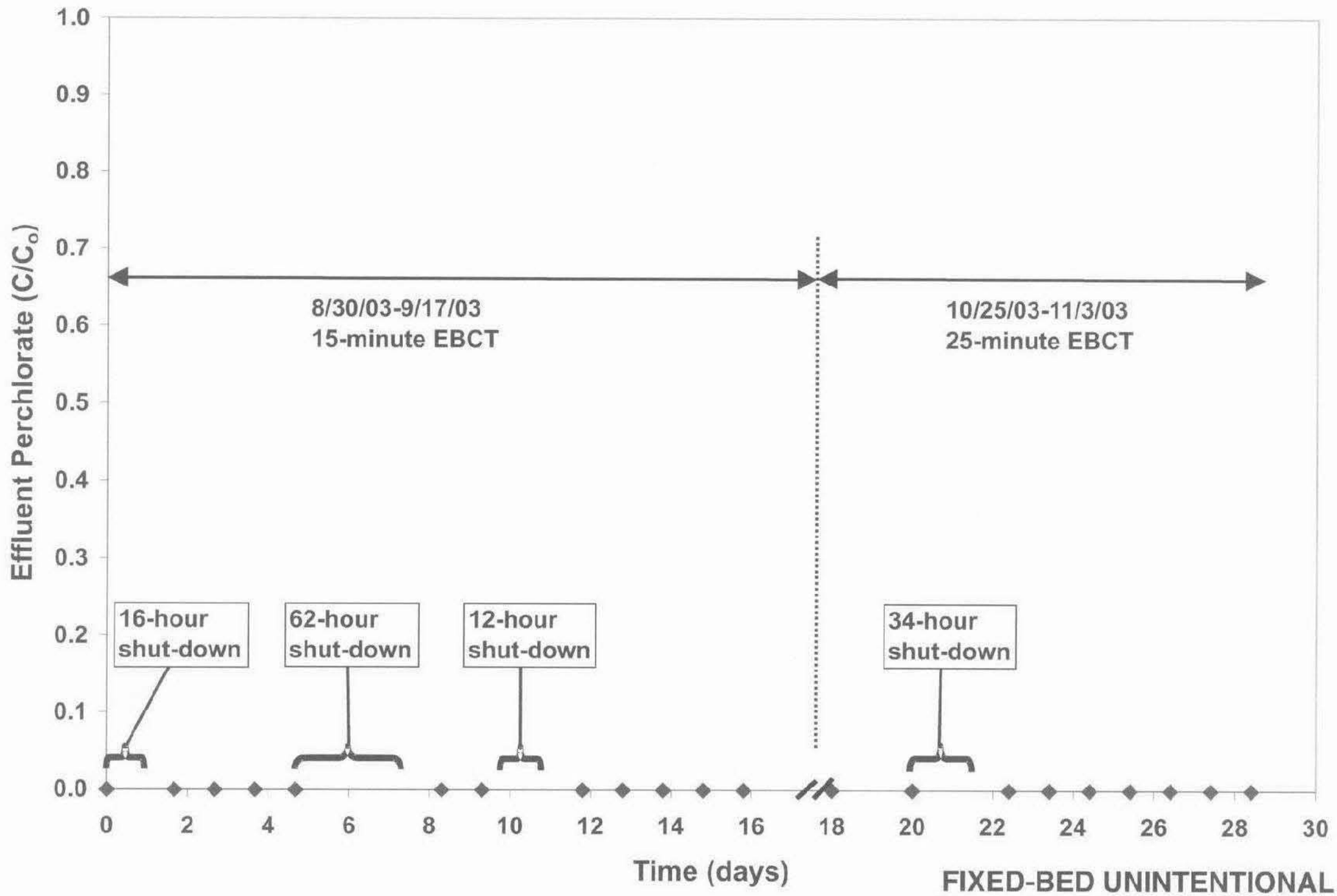
29058

20-CLWA204F3.37-6625A10.CDR



FIXED-BED UNINTENTIONAL SHUT-DOWN PERFORMANCE

FIGURE 3.37

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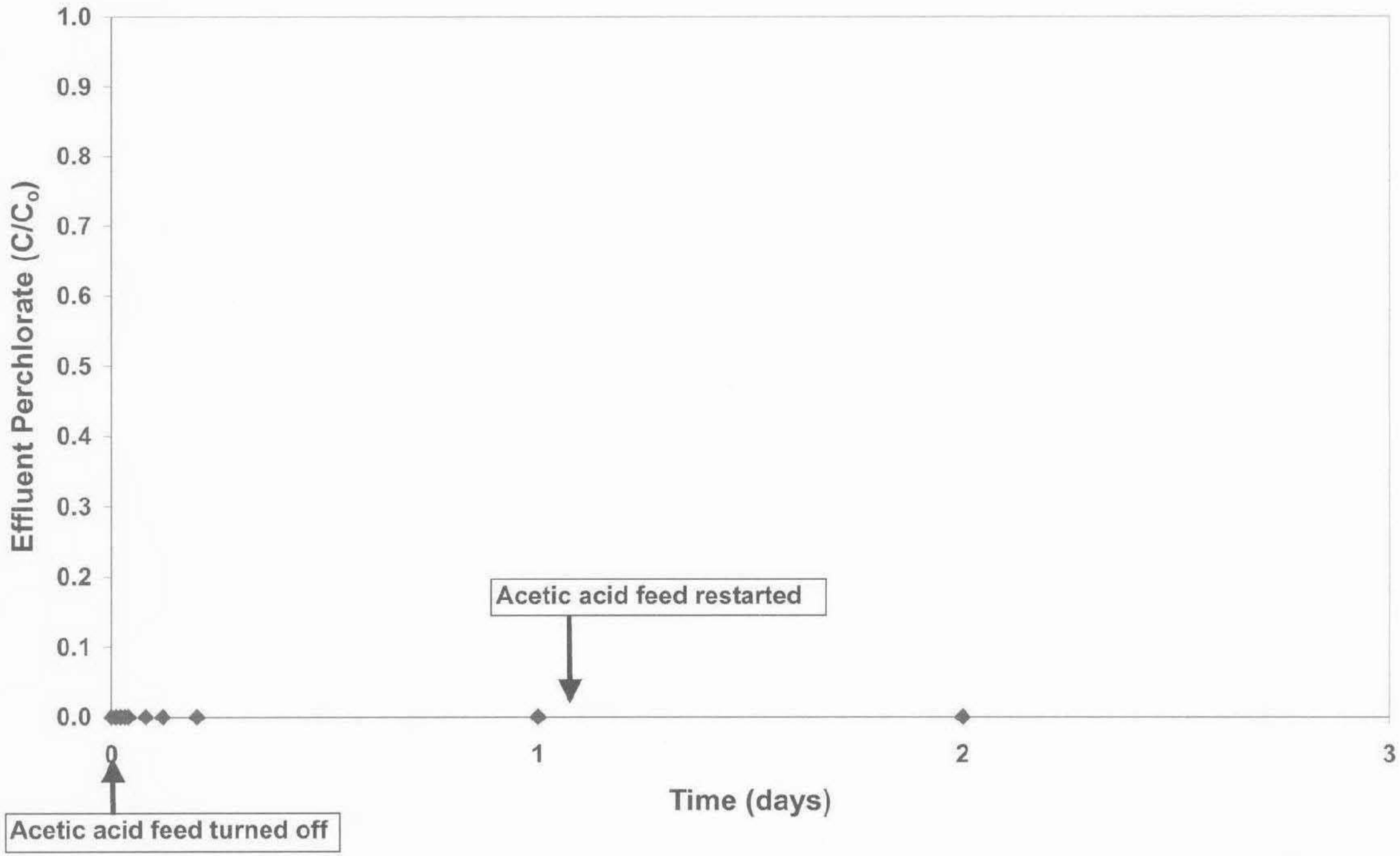
29059

20-CLWA204F3.38-6625A10.CDR



FIXED-BED ACETIC ACID FEED FAILURE CHALLENGE TEST

FIGURE 3.38

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29060

It is possible that both of the above phenomena contributed to the 24-hour removal of perchlorate to below detection in the biological FXB while the acetic acid feed was shut off, though no experiments were performed to confirm this.

7.5.6 Backwash Water Quality

Table 3.22 lists backwash water quality data, as determined using composite samples of backwash water.

Table 3.22 Backwash Water Quality
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Parameter	Range
Perchlorate (µg/L)	ND (two points)
AOC (mg/L)	1.0-2.5
COD (mg/L)	63-250
VSS (mg/L)	41-140
TSS (mg/L)	39
Total coliforms (MPN/100 mL)	4-110
Fecal coliforms (MPN/100 mL)	ND - 4

The level of perchlorate in the backwash water (ND) is below the Los Angeles County Sanitation District (LACSD) Phase I limit of 4 ppb. The values for COD and TSS are used in obtaining discharge permits for the disposal of the backwash water if the water is being discharged into LACSD lines.

7.5.7 Summary

Consistent perchlorate removal to below detection was achieved in the FXB filter using only organisms indigenous to the Saugus aquifer. With influent DO and nitrate concentrations of 7 and 15 mg/L, respectively, the lowest EBCT and acetic acid concentration that allowed consistent perchlorate removal to below detection was 15 minutes and 7.8 mg/L as carbon, respectively. Run times ranged from 24 hours to several days. Effluent from the FXB filter was biologically stable and contained no fecal coliforms. Challenge tests demonstrated that the FXB filter was robust with respect to backwashing episodes, changes in feed water quality, system shutdowns, and electron donor addition failures. Large step increases in feed nitrate concentration (e.g., 15 mg/L) required a period of bio-acclimation before perchlorate removal to below detection could be reestablished in the FXB filter.

7.6 Fluidized Bed Reactor

7.6.1 Perchlorate Removal Performance

Over the course of pilot testing, the FBR achieved perchlorate removal to below detection for periods of up to 8 days. However, perchlorate removal performance generally fluctuated and sustained (i.e., ≥ 2 weeks) removal to below detection was not achieved (Figure 3.39).

7.6.1.1 Mechanical & Operational Adjustments

Numerous mechanical and operational adjustments were made throughout pilot testing to establish sustained perchlorate removal to below detection. A detailed list of these adjustments is provided in Table 3.23 followed by a description of the main mechanical and operational changes, reasons for their implementation, and their impact on perchlorate removal performance. Throughout the course of the study, changes made to the system were done under the direction of representatives from Shaw Environmental.

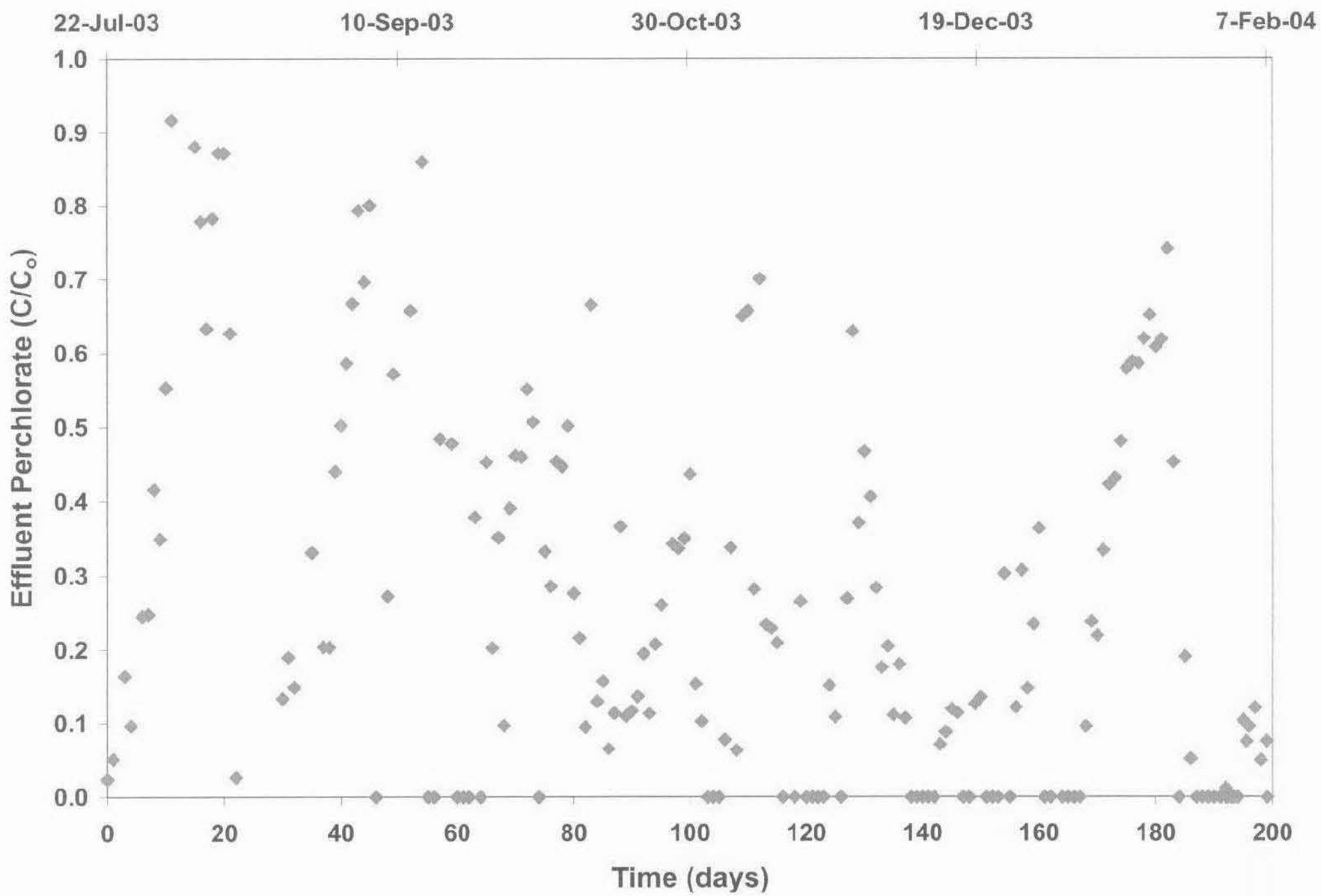
Table 3.23 FBR Mechanical and Operational Adjustments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Date (Day of operation)	Event
7/21/03 (0)	System started. 3 gpm.
8/2/03 (11)	Power outage at pilot caused system shutdown
8/4/03 (13)	System restarted, causing carbon to blow out top of reactor.
8/6/03 (15)	Phosphorous added to feed at 0.2 PO_4–P
8/11/03 (20)	Carbon ball-like mass observed in reactor.
8/13/03 (22)	Mechanical mixer observed to be missing
8/14/03 (24)	System put in recycle to scour carbon.
8/19/03 (29)	Carbon manually cleaned with PVC pole and air scour. Carbon/biomass mats broken up and biomass removed.
8/26/03 (36)	Biomass separator installed with 3/8" SS. Top of reactor removed to insert tubing. Designed to operate continuously by drawing carbon from the bottom of the reactor and place carbon back to top of bed.
8/28/03 (38)	Biomass separator clogged, shut down.
8/29/03 (39)	Biomass separator system changed to 3/4" PVC. Configuration changed to draw from top and put carbon back to bottom.
9/1/03 (41)	Solids recovery tank overflowed. Lowered flow to 1 gpm. Large mat of biomass observed in tank, possibly due to aerobic growth. Large amounts of growth in pump.
9/2/03 (42)	Feed and recycle lines and pump cleaned of biomass.
9/9/03 (49)	Nitrogen blanket added to the top of the reactor to minimize re-entrainment

Table 3.23	FBR Mechanical and Operational Adjustments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Date (Day of operation)	**Event**
	of oxygen.
9/16/03 (56)	Reconfigured system piping to bypass oxygenation vessel. Moved acetic acid injection point closer to bioreactor vessel. Biomass separator system to be operated for 1 hour per day.
9/17/03 (59)	Solids recovery tank overflowing, system shut down for 1 hour (recycle).
9/18/03 (58)	Acetic acid pump replaced. It had lost prime several times.
9/24/03 (64)	Phosphorous feed concentration increased to 3 mg/L PO_4-P
9/25/03 (65)	Excessive biogrowth in effluent line causing back-up of the solids recovery tank. Effluent line cleaned out.
9/26/03 (66)	Flow decreased to 2 gpm
9/29/03 (69)	Flow increased to 3 gpm. Large amounts of biomass floating on water surface in solids recovery tank. Mat removed from tank.
10/1/03 (71)	Water observed in nitrogen line. Water removed and nitrogen restarted. Flow decreased to 2.5 gpm.
10/3/03 (73)	Phosphorous feed concentration increased to 3.5 mg/L PO_4-P.
10/6/03 (76)	Small carbon ball mass observed in reactor. Ball broken up manually and with biomass separator.
10/8/03 (78)	Feed flow reduced to 1.5 gpm.
10/17/03 (87)	Feed flow reduced to 1.0 gpm.
10/21/03 (91)	Feed flow reduced to 0.8 gpm.
10/23/03 (93)	Samples sent to Shaw lab for analysis. Results corroborate results seen from CLWA lab.
10/24/03 (94)	Biomass separator to remain off to promote bed expansion.
10/30/03 (100)	Carbon removed from reactor and bottom of bioreactor removed to check for distribution header clogging. No clogging observed. Added 2 feet of carbon to the reactor for settled bed of 72" and expanded of 92". Flow changed to 2 gpm.
10/31/03 (101)	Flow increased to 3 gpm.
11/3/03 (104)	More carbon added to reactor for settled bed of 82" and expanded of 106".
11/5/03 (106)	Phosphorous feed concentration decreased to 2.5 mg/L PO_4-P
11/13/03 (114)	Micronutrients added to the feed water through electron donor feed.
11/26/03 (127)	Second dose of micronutrient added to system
11/28/03 (129)	Third dose of micronutrient added to system
12/3/03 (134)	Flow decreased to 1.5 gpm and mircronutrient eliminated from feed.

Table 3.23	FBR Mechanical and Operational Adjustments Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency
Date (Day of operation)	**Event**
12/5/03 (136)	Flow increased to 3 gpm and acetic acid feed concentration lowered to 13.9 mg/L as C (15% dilution)
12/10/03 (141)	Plant shutdown for 3 hours. Electron donor decreased (94 grams/day).
12/15/03 (146)	Acetic acid feed concentration increased to 20% dilution (125 grams/day)
12/19/03 (150)	Acetic acid feed concentration increased to 30% dilution (185 grams/day)
12/22/03 (153)	Rapid bed expansion noticed in reactor.
12/23/03 (154)	Biomass separator pump turned on for 1 hour due to rapid bed expansion
12/27/03 (158)	Biomass separator pump turned on for 2 hours
12/30/03 (161)	Biomass separator pump turned on for ½ hour
12/31/03 (162)	System placed in recycle due to rapid bed expansion
1/2/04 (164)	System restarted at 3 gpm.
1/7/04 (169)	Acetic acid feed solution decreased to 20% dilution (125 grams/day)
1/9/04 (171)	Suspended biomass removed from top of the reactor
	Phosphate addition reduced by 50% to 1.25 mg/L PO_4-P
1/12/04 (174)	Acetic acid feed solution increased to 25% dilution (155 grams/day)
1/16/04 (178)	Due to phosphoric acid supply limitations, phosphate addition was reduced to 25 mL in 1 L total volume.
1/19/04 (181)	Flow decreased to 2 gpm w/ current donor addition remaining the same (25% dilution at 1 mL/min).
1/20/04 (182)	System reconfigured to bypass solids recovery tank due to high DO in recycle. New perchlorate stock solution mixed incorrectly, causing influent concentrations to be 20-25 ug/L. Increase of phosphate concentrations back to previous levels (>2 mg/L).
1/21/04 (183)	Flow increased to 3 gpm (1 mL/min 25% dilution for donor) and increased ClO4 back to 50 ug/L. Increased flow of donor to 7 strokes/min from 6 (160 grams/day).
1/24/04 (186)	Increased electron donor to 33% dilution. (210 grams/day)
2/2/04 (195)	Increased flow of donor to 8 strokes/min from 7 (225 grams/day).
2/3/04 (196)	Added micronutrient (~50 mL to 8 L)
2/4/04 (197)	Reduced flow of donor to 5 strokes /min from 8 (180 grams/day).
2/5/04 (198)	Reduced flow to 2 gpm.
2/6/04 (199)	System shutdown (recycle).

20-CLWA204F3.39-6625A10.CDR



FLUIDIZED-BED PERCHLORATE

FIGURE 3.39

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Mechanical Adjustments:

- Concern: Excessive clumpy biogrowth was observed in the FBR, potentially causing clogging or short-circuiting. The mechanical mixer, which was designed to control overgrowth in the system, did not function properly.

  Adjustment: A biomass separator system was installed (Day 35) and used intermittently throughout pilot testing.

  Impact: The biomass separator was effective at controlling bed expansion and overgrowth. However, perchlorate removal performance did not appear to improve by the installation of the biomass separator system.

- Concern: Excessive biogrowth was observed across the entire FBR system, which was clogging pumps and piping and may have been causing short-circuiting in the reactor.

  Adjustments: On Day 29, the GAC was manually scoured using a PVC pipe and aeration. Piping and pumps were cleaned out on Days 42 and 65. Biomass clumps were removed from the solids recovery tank (Day 69) and from the reactor (Day 171). The acetic acid feed point was moved closer to the base of the reactor on Day 56.

  Impact: These adjustments were effective at controlling excessive biogrowth, though they did not appear to positively impact perchlorate removal performance.

- Concern: DO was being entrained between the top of the reactor and the recycle line. This could cause aerobic growth in the system and inhibit perchlorate reduction by increasing the redox potential.

  Adjustments: A nitrogen blanket was added to the top of the reactor on Day 49. The effluent/recycle piping was reconfigured to completely bypass the solids recovery tank on Day 182.

  Impact: Adding the nitrogen blanket and bypassing the oxygenation vessel lowered DO entrainment, and perchlorate removal performance improved slightly with each adjustment. Bypassing the solids recovery tank eliminated DO entrainment and appeared to improve perchlorate removal performance substantially. Four days after the system was reconfigured, perchlorate removal to below detection was achieved and sustained for eight days. However, electron donor was also being adjusted during this period and, after eight days of removal to below detection, perchlorate breakthrough was observed. Therefore, though controlling DO entrainment did appear to improve perchlorate removal performance in the FBR, it did not completely eliminate perchlorate breakthrough.

- Concern: The turbulent zone near the base of the FBR is essentially abiotic due to the high shear stresses generated by the feed jets. If this abiotic zone is a significant

fraction of the overall bed depth, then the depth of the anaerobic zone within the carbon bed might be insufficient to allow for the removal of perchlorate to below detection.

- Adjustment: Two feet of carbon were added to the top of the GAC bed on Day 100. An additional 10 inches of carbon were added to the top of the GAC bed on Day 104.

  Impact: Perchlorate removal performance appeared to improve for about a week after the carbon was added to the bed, though this may have been due to adsorption. Regardless, this improvement in perchlorate removal performance was not sustained beyond one week.

Operational Adjustments:

- Concern: Low phosphorous concentrations may be limiting biological activity in the FBR.

  Adjustment: Phosphorous was added to the feed at 0.2 mg/L PO_4-P beginning on Day 15. Phosphorous addition was increased to 3.0 mg/L PO_4-P on Day 64. Phosphorous addition was increased to 3.5 mg/L PO_4-P on Day 73 (Figure 3.40).

  Impact: Adjusting the concentration of phosphorous being added to the feed did not appear to impact perchlorate removal performance in the FBR. Feed PO_4-P was later reduced to 2.5 mg/L and then 1.25 mg/L for short periods of operation, without impacting perchlorate removal performance.

- Concern: The contact time may be insufficient to allow for sustained perchlorate removal to below detection.

  Adjustment: The feed flow was reduced gradually from 3.0 gpm to 0.8 gpm over a four-week period (Days 71 through 99).

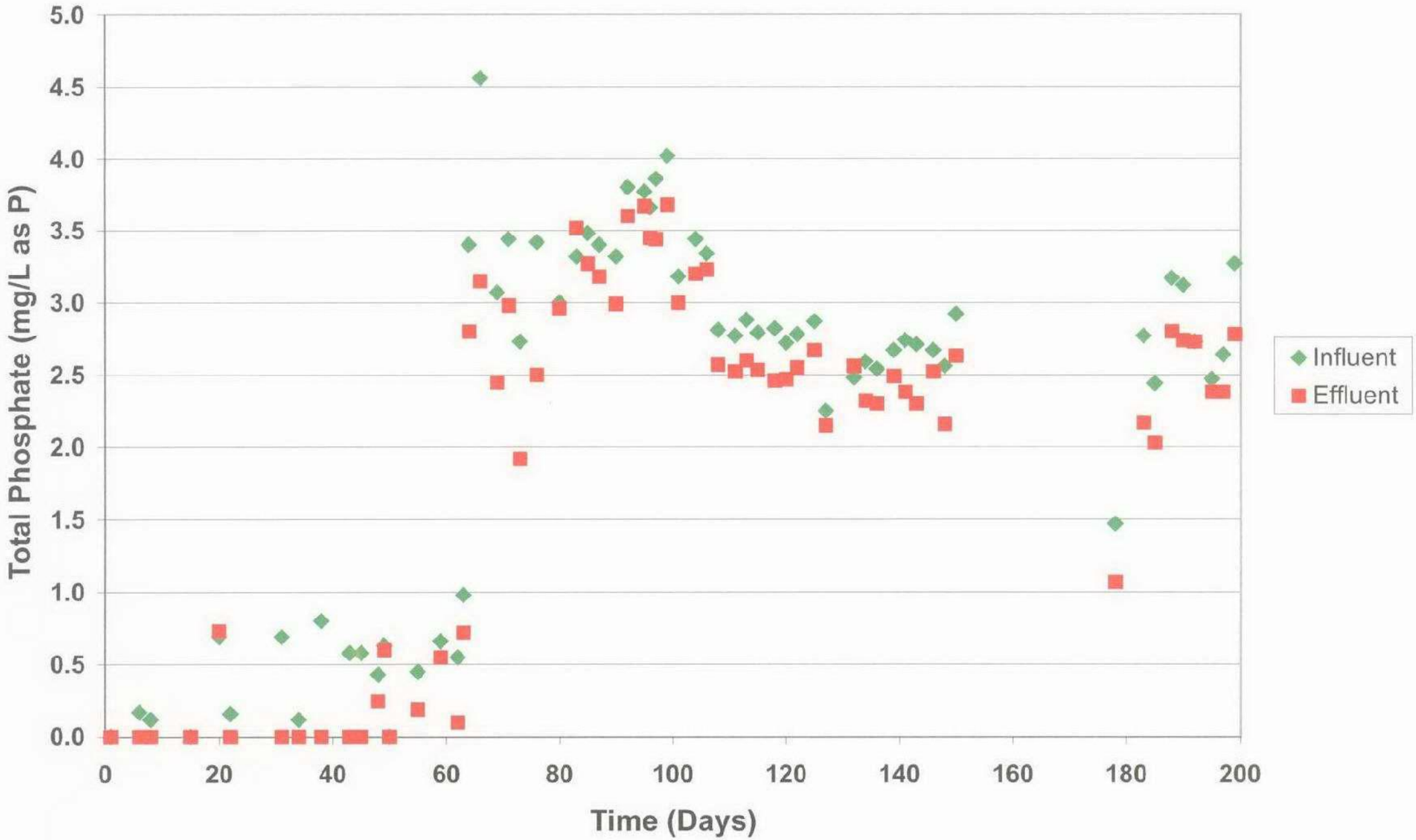
  Impact: While increasing the HRT did appear to improve perchlorate removal performance initially, it did not effect perchlorate removal to below detection, and, eventually, perchlorate removal performance declined at the lower feed flow rates.

- Concern: Low concentrations of micronutrients may be limiting biological activity in the FBR.

  Adjustment: A micronutrient solution was added to the feed from Day 114 to Day 134. It was again added on Day 196 through the end of pilot testing. The micronutrient contained low concentrations of iron, copper, magnesium, manganese, zinc, boron, sulfur, molybdenum, and cobalt.

  Impact: The addition of the micronutrient feed might have caused improved perchlorate removal performance initially, though the impact was confounded due to the nearly simultaneous addition of fresh carbon to the bed. Regardless, perchlorate removal performance eventually declined in spite of the micronutrient feed.

20-CLWA204F3.40-6625A10.CDR



FLUIDIZED-BED PHOSPHOROUS

FIGURE 3.40

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- Concern: Over-excess acetic acid concentrations in the feed may have been selecting away from perchlorate-reducing bacteria and toward sulfate-reducing bacteria. As the feed nitrate concentration decreased during the pilot test period, the acetic acid concentration was not adjusted to account for the decreased oxidant demand in the system. It was theorized that this could help explain why only partial perchlorate removal was observed in spite of very low redox conditions (down to –200 mV). In other words, though complete DO and nitrate reduction and partial sulfate reduction was occurring in the reactor, only partial perchlorate reduction was observed (Figures 3.41 and 3.42), suggesting that the perchlorate-reducing community in the reactor was being depressed.

  Adjustment: Feed acetic acid concentration was lowered on Day 136.

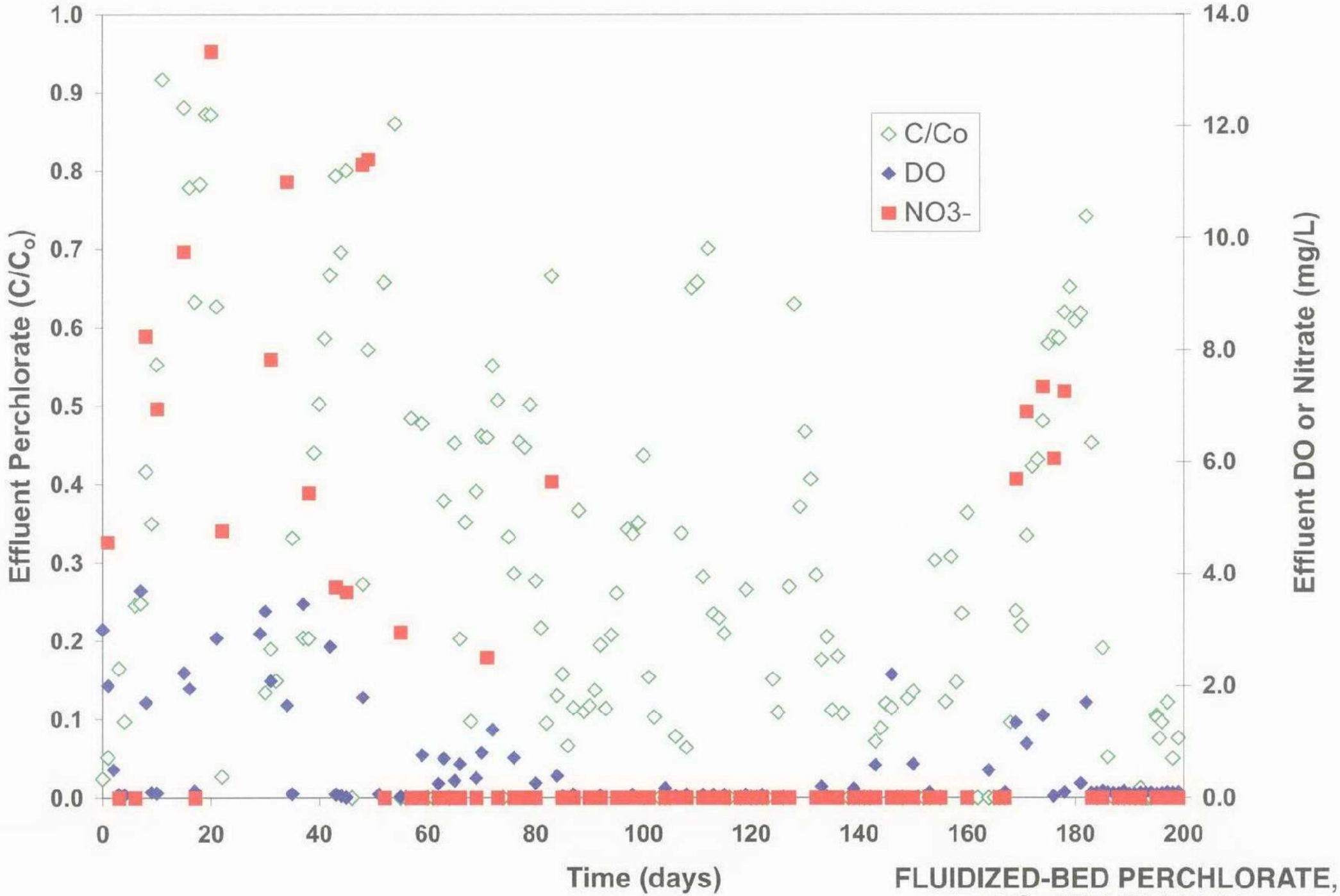
  Impact: Perchlorate was removed to below detection for about a week after the acetic acid feed concentration was lowered. Subsequently, feed acetic acid concentrations were adjusted up and down as feed nitrate concentrations fluctuated. Though perchlorate removal was generally ≥ 90% during this period, sustained perchlorate removal to below detection was not achieved.

7.6.2 Other Parameters

The following non-anionic water quality observations were made during the course of FBR piloting:

- Effluent TOC concentrations were typically 1 to 9 mg/L (Figure 3.43).
- Effluent BDOC concentrations ranged from non-detect to 1.3 mg/L (Figure 3.44).
- On average, pH decreased by 0.5 units across the FBR bed (Figure 3.45). This was likely due to the addition of CO_2 to the water as acetic acid was oxidized.
- HPCs increased across the filter, resulting in counts between 50,000 and 870,000/mL (Figure 3.46).
- Total effluent coliforms ranged from non-detect to 900 MPN/100 mL, but were typically 300 MPN/100 mL or less (Figure 3.47). No fecal coliforms were detected.
- Average feed water turbidities were approximately 0.5 NTU. Effluent turbidities ranged from 2 to 70 NTU (Figure 3.48).

20-CLWA204F3.41-6625A10.CDR



FLUIDIZED-BED PERCHLORATE, DO, AND NITRATE

FIGURE 3.41

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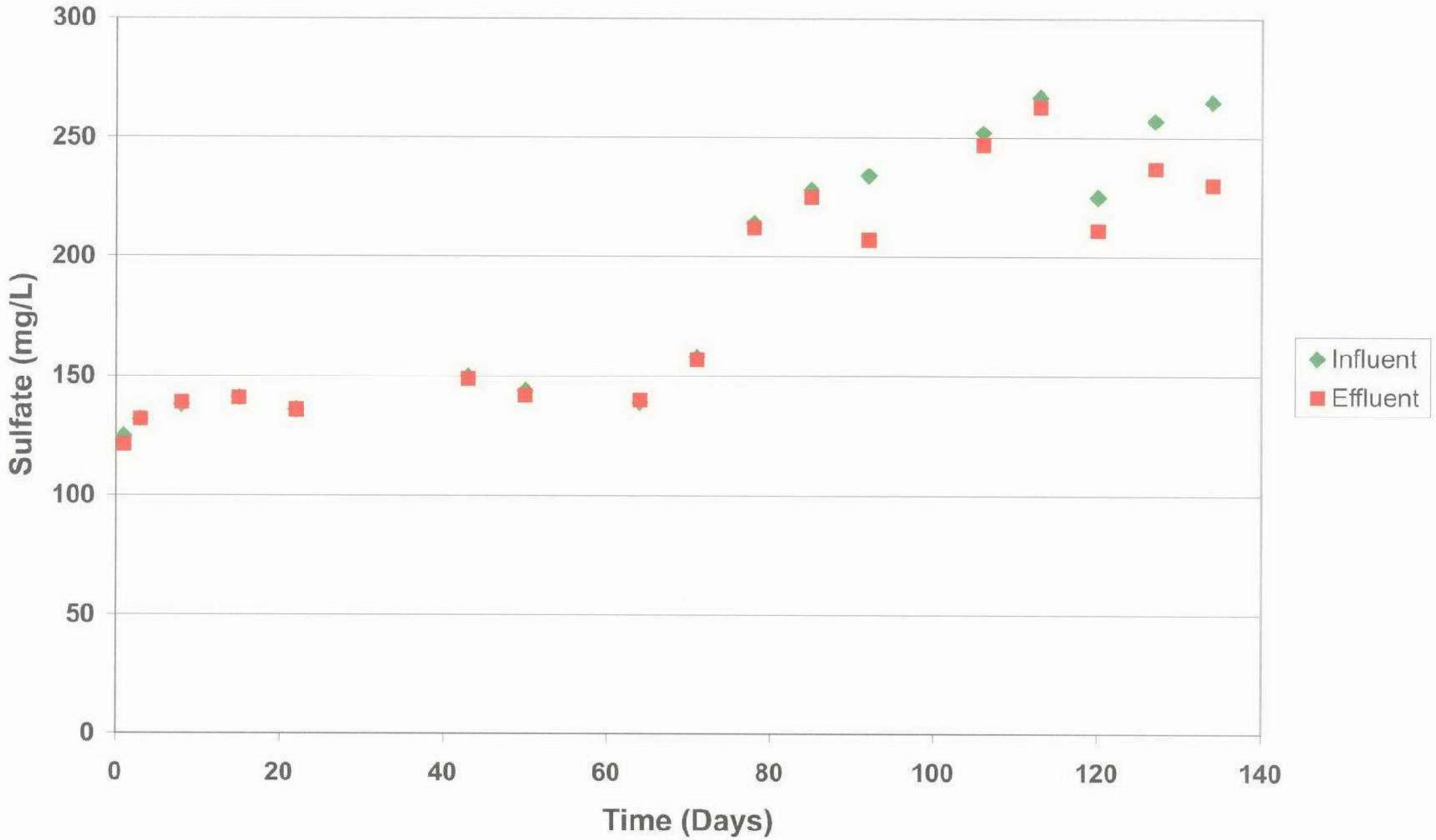
20-CLWA204F3.42-6625A10.CDR



FLUIDIZED-BED SULFATE

FIGURE 3.42

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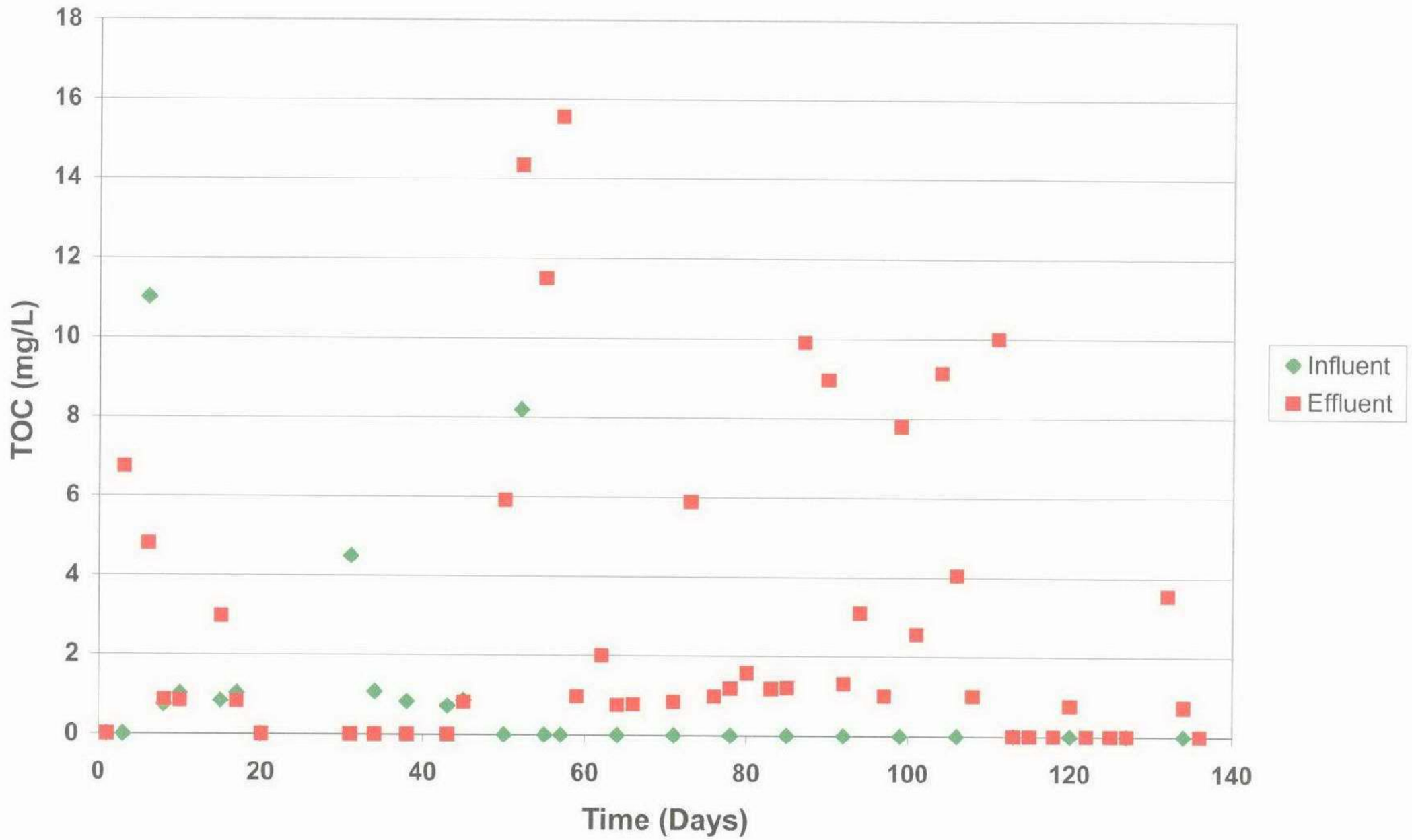
20-CLWA204F3.43-6625A10.CDR



FLUIDIZED-BED TOC

FIGURE 3.43

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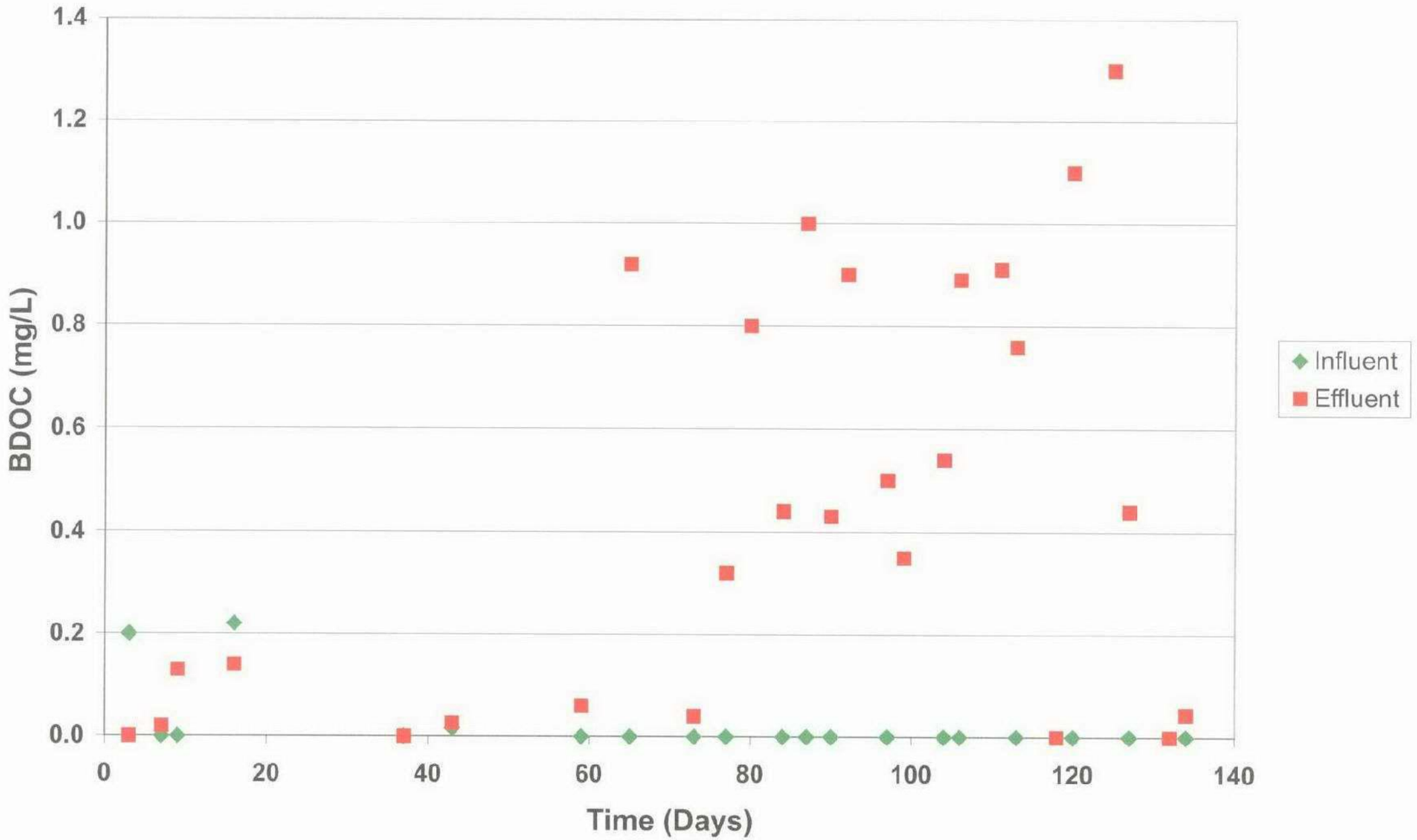
20-CLWA204F3.44-6625A10.CDR



FLUIDIZED-BED BDOC

FIGURE 3.44

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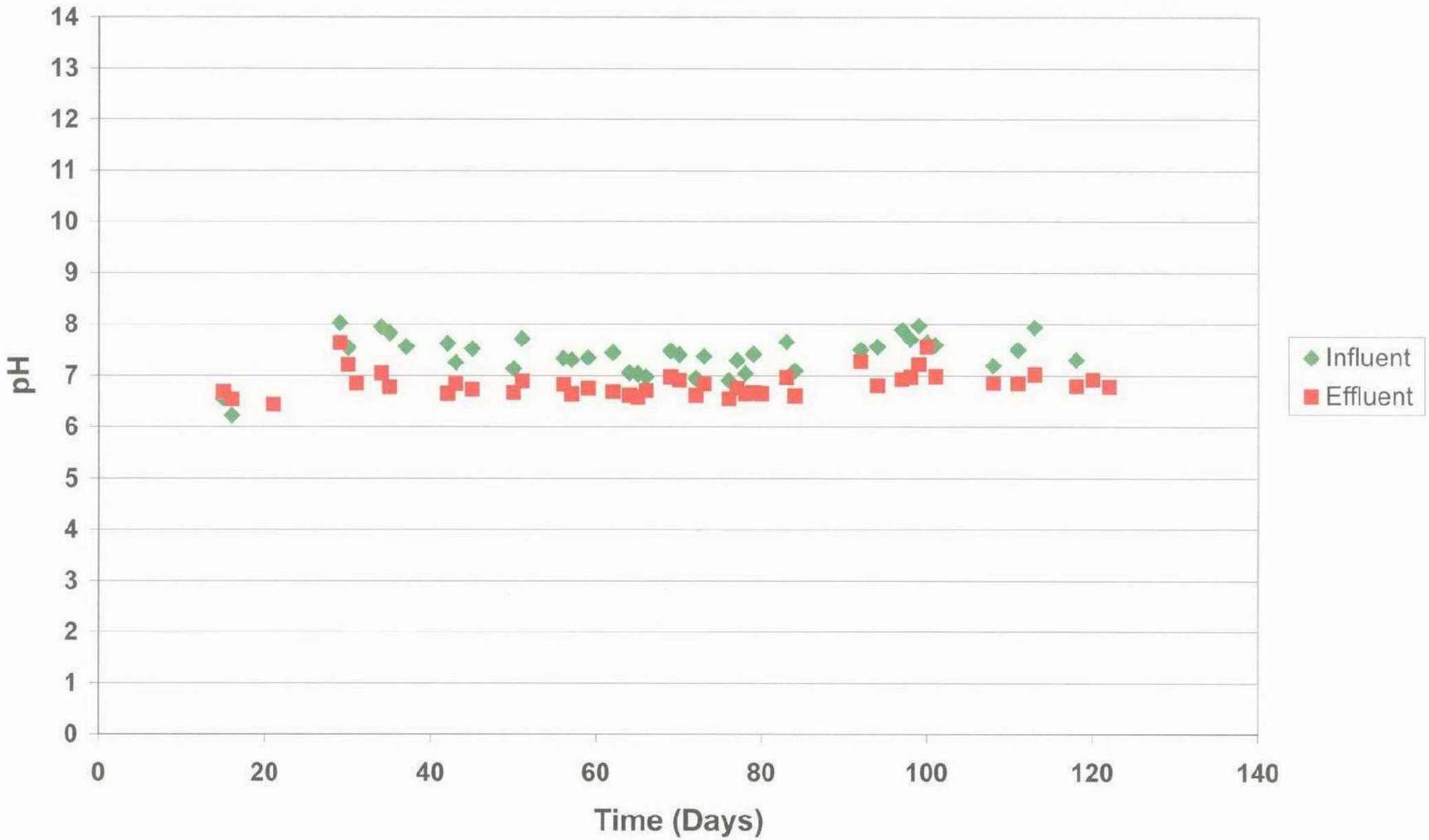
20-CLWA204F3.45-6625A10.CDR



FLUIDIZED-BED pH

FIGURE 3.45

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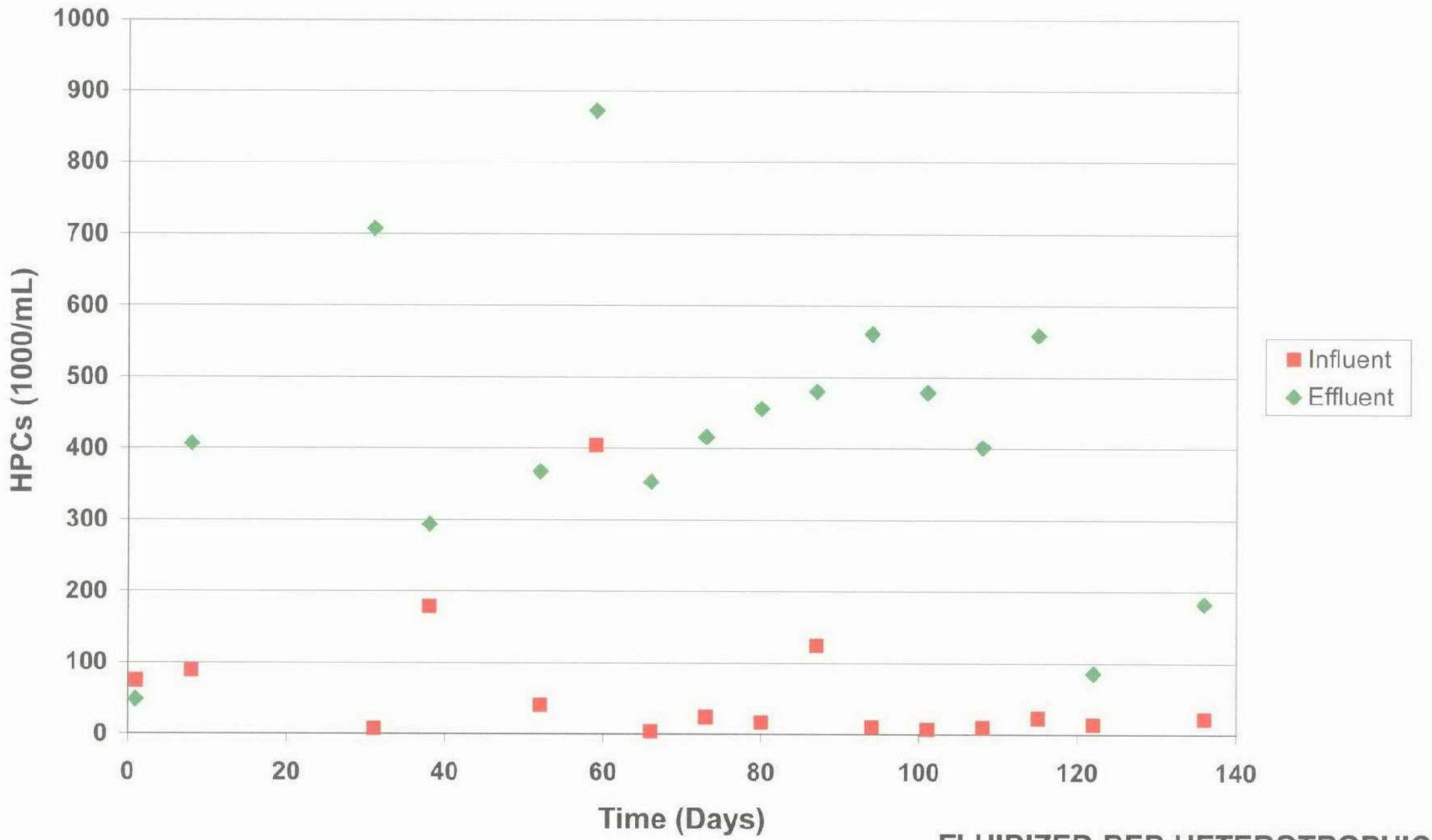
20-CLWA204F3.46-6625A10.CDR



FLUIDIZED-BED HETEROTROPHIC PLATE COUNTS

FIGURE 3.46

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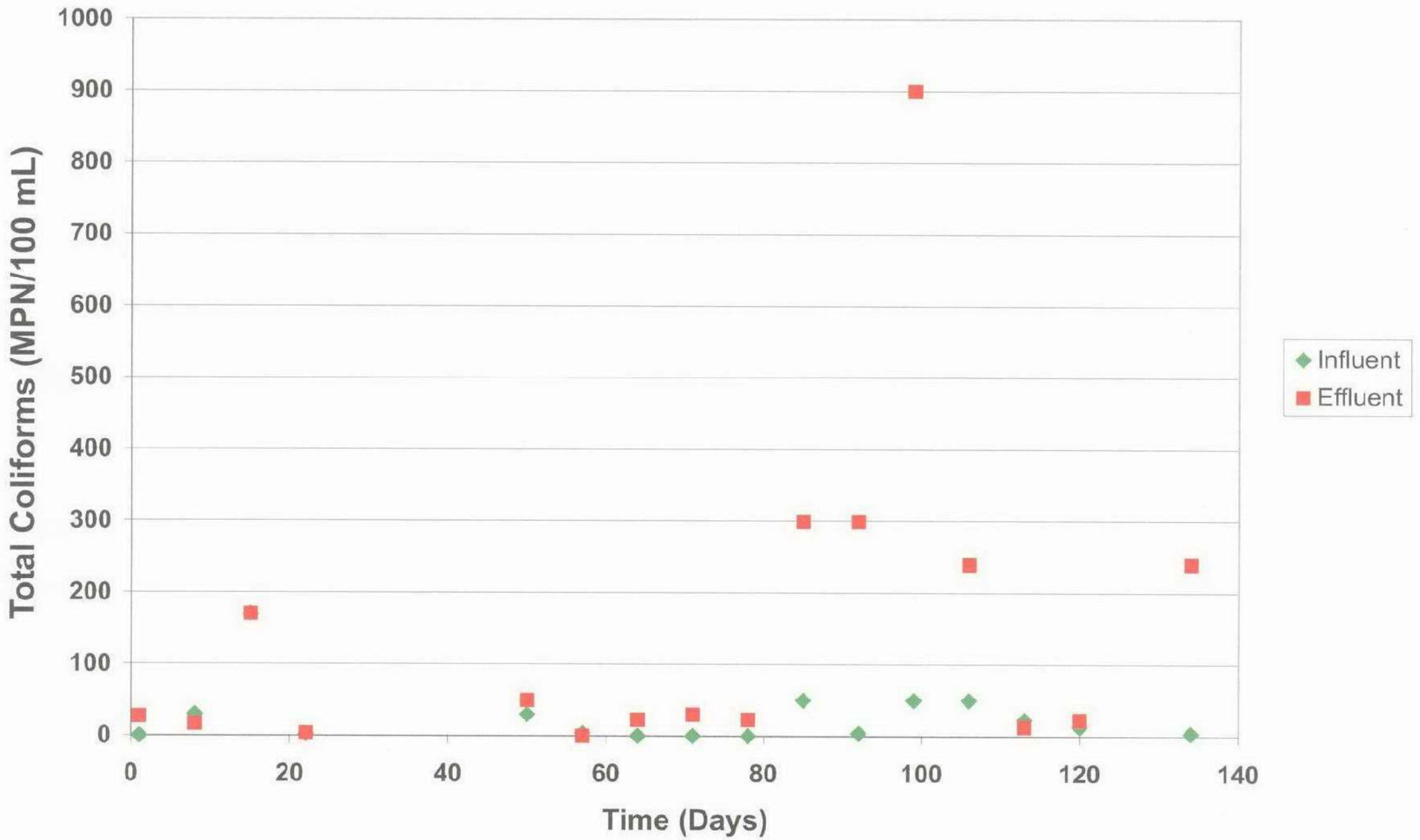
20-CLWA204F3.47-6625A10.CDR



FLUIDIZED-BED TOTAL COLIFORMS

FIGURE 3.47

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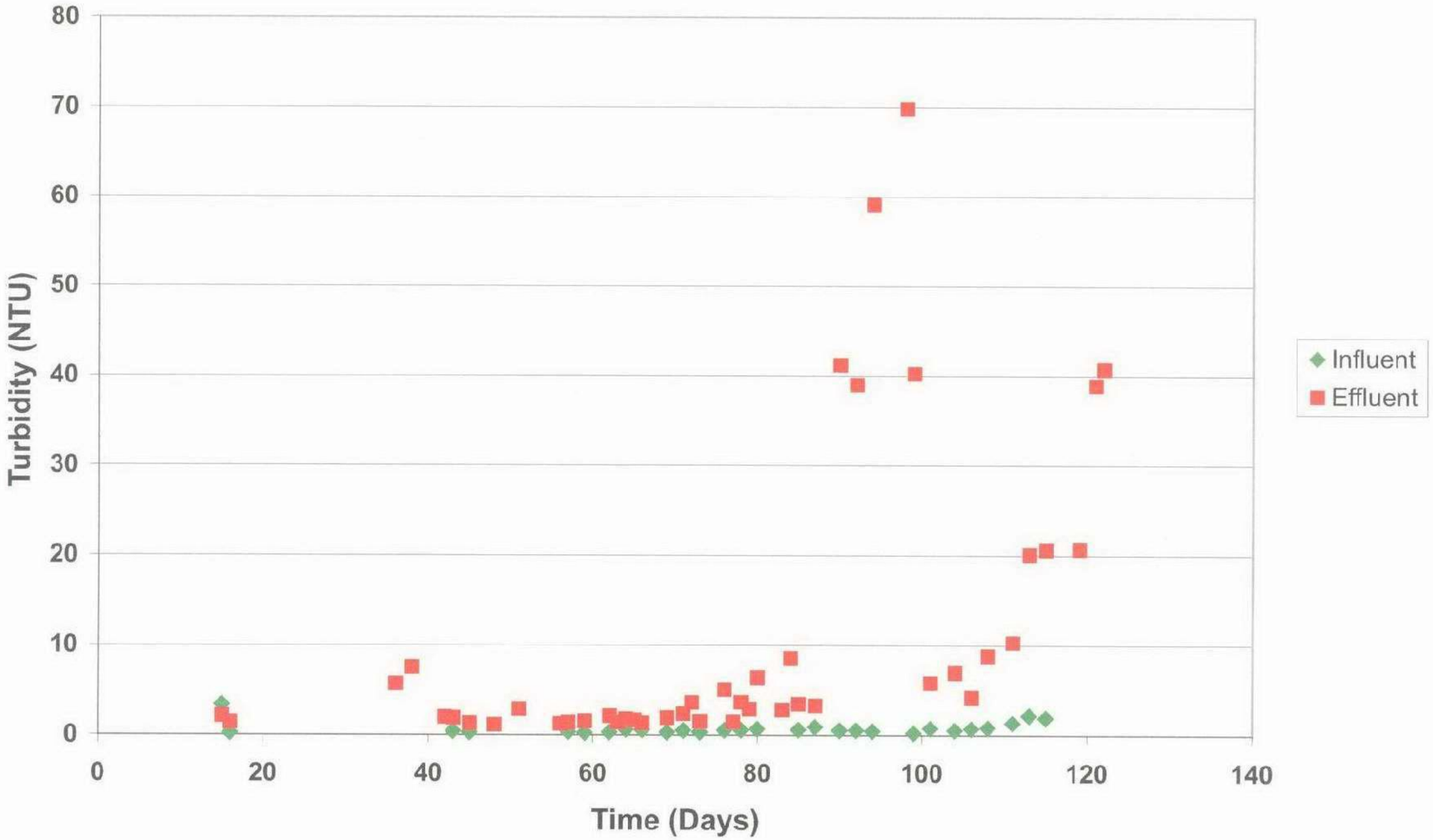
20-CLWA204F3.48-6625A10.CDR



FLUIDIZED-BED TURBIDITY

FIGURE 3.48

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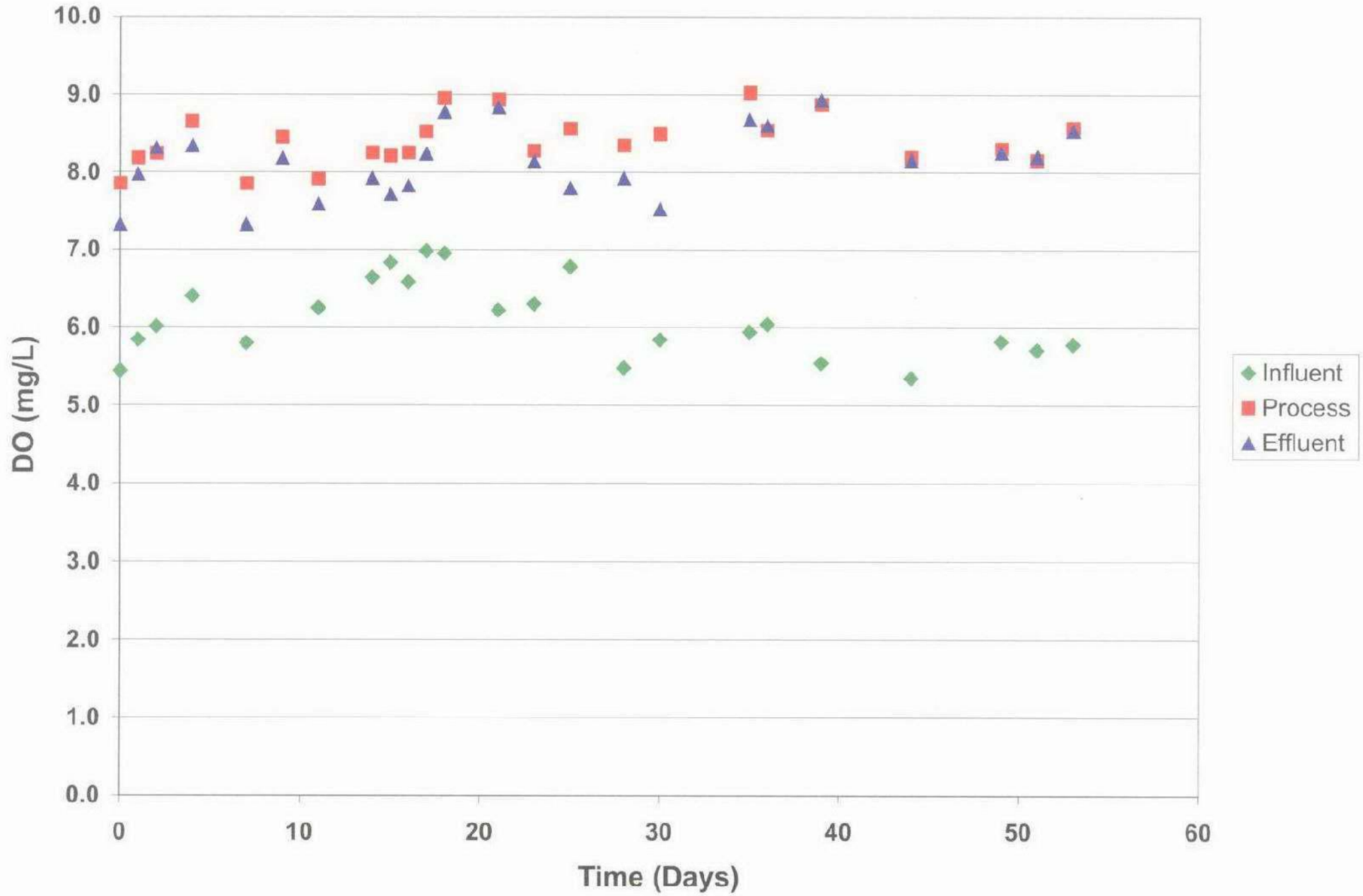
20-CLWA204F3.49-6625A10.CDR



SMBR DISSOLVED OXYGEN

FIGURE 3.49

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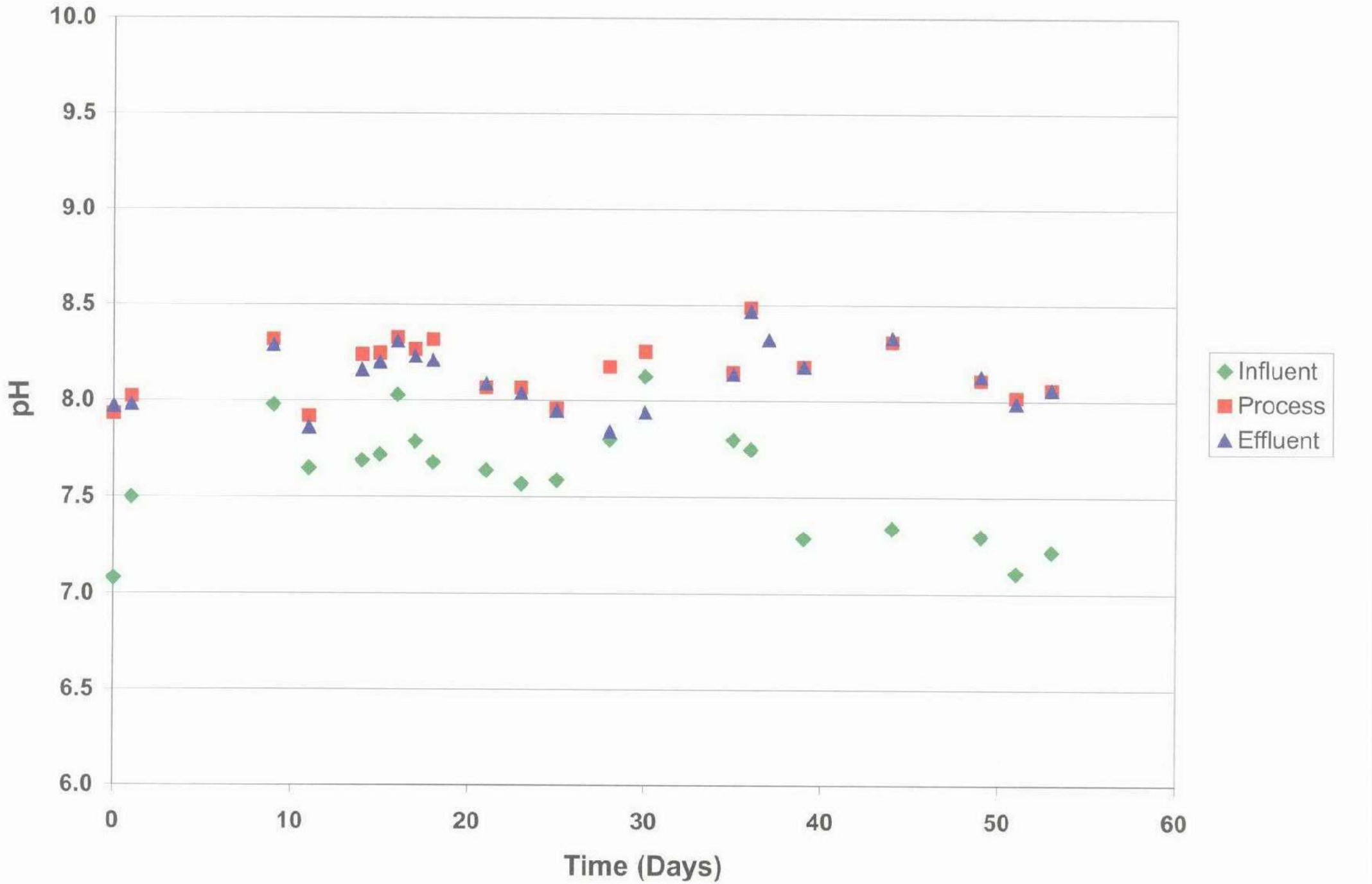
20-CLWA204F3.50-6625A10.CDR



SMBR pH

FIGURE 3.50

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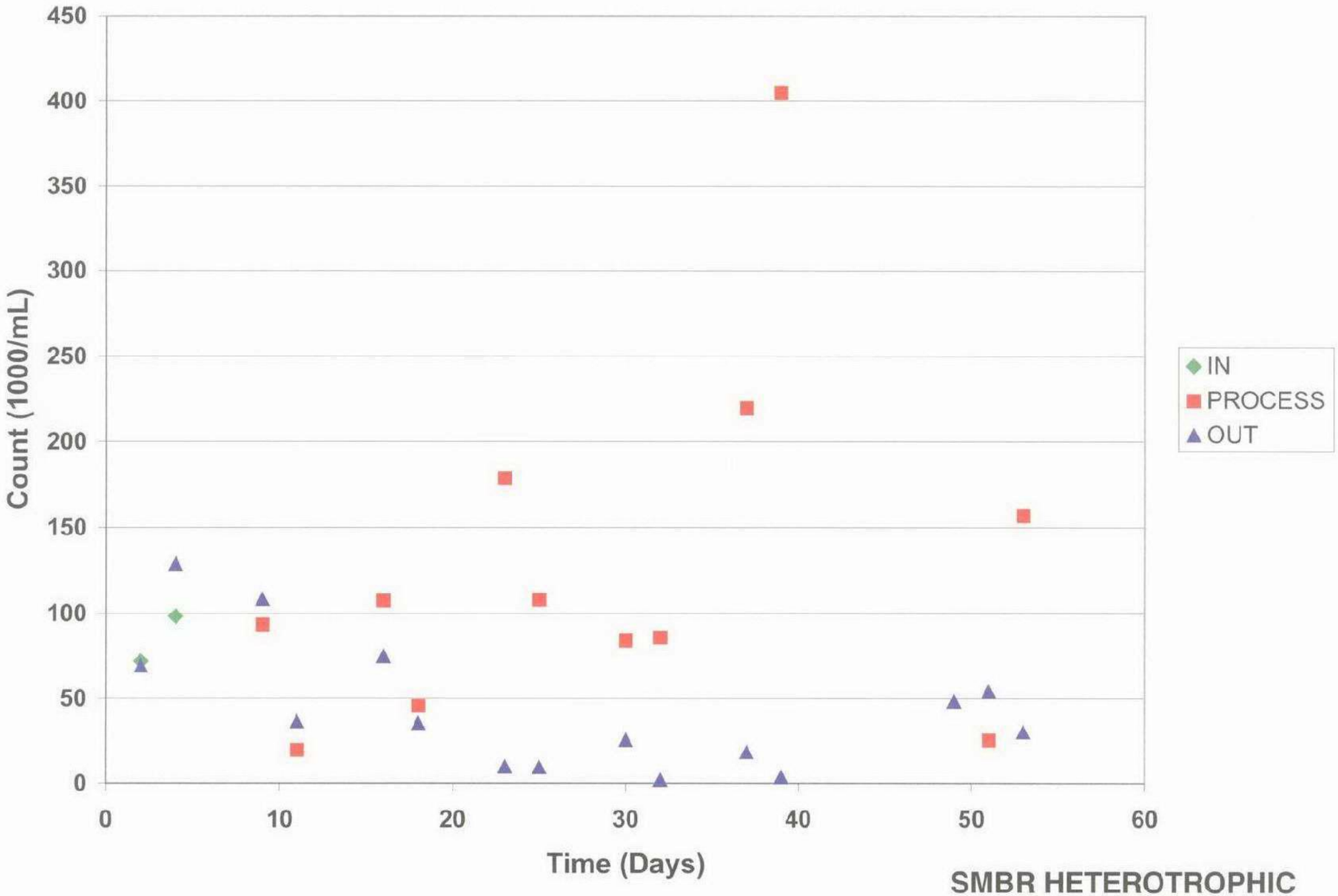
20-CLWA204F3.51-6625A10.CDR



SMBR HETEROTROPHIC PLATE COUNTS

FIGURE 3.51

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7.6.3 Summary

The fluidized-bed reactor did not achieve perchlorate removal to below detection over a period greater than 8 days, in spite of numerous mechanical and operational adjustments made to the system. However, testing did demonstrate that biological perchlorate removal can be achieved using indigenous microorganisms, a feature that had not yet been demonstrated for the FBR system. Because the FBR was not optimized, challenge testing was not performed.

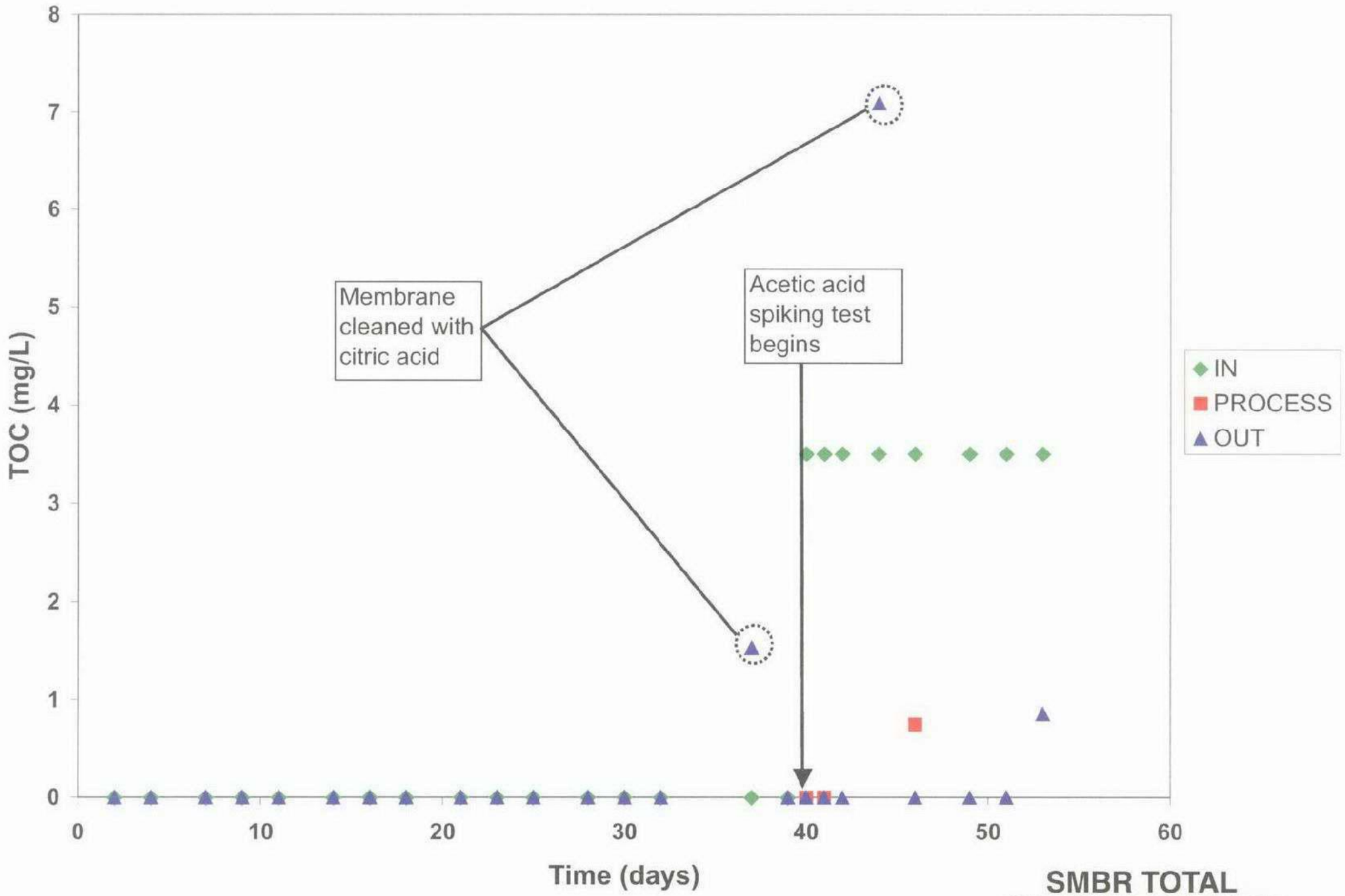
7.7 Submerged Membrane Bioreactor (Post-Treatment of FXB Effluent)

The SMBR was set up to provide post-treatment for the FXB effluent, as required by DHS, i.e., aeration, filtration, and biological degradation of excess BDOC. The SMBR was fed with effluent from the FXB biological filter, which was already partially reaerated due to exposure to atmospheric conditions in the backwash tank. As expected, DO concentrations further increased in the SMBR process tank (Figure 3.49). pH also increased during the post-treatment process (Figure 3.50). The water entering the process tank is likely supersaturated with CO_2, produced by the oxidation of acetic acid in the FXB. Aeration within the process tank volatilizes supersaturated CO_2, thus bringing the water into equilibrium with atmospheric conditions and increasing the pH. Figure 3.51 shows that HPCs were being reduced across the ultrafiltration membrane. The effluent HPC concentrations are typically lower than the values observed in the raw well water. (See Figure 3.29.) Additional removal of heterotrophic bacteria can be achieved through disinfection following the SMBR. Batch experiments were performed to assess chlorine demand and HPC reduction using SMBR effluent. The chlorine demand of SMBR effluent was < 1 mg/L in all but one case, and only low doses of chlorine were required to reduce HPCs below 500 counts/mL (Table 3.24).

Table 3.24 Testing Matrix for Bench-Scale Chlorination of SMBR Effluent Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Chlorine Dose (mg/L)	12/1/03		12/3/03		12/5/03	
	Residual (mg/L)	HPCs (counts/mL)	Residual (mg/L)	HPCs (counts/mL)	Residual (mg/L)	HPCs (counts/mL)
0	0	48,450	0	54,150	0	30,400
0.5	0	69,250	0.15	250	0.08	4
1.0	0.17	271	0.31	100	0.60	52
2.0	0.88	10	1.15	450	1.58	2

20-CLWA204F3.52-6625A10.CDR



SMBR TOTAL ORGANIC CARBON

FIGURE 3.52

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Organic carbon concentrations in the effluent of the biological FXB were typically below detection throughout pilot testing. Therefore, 3.5 mg/L of acetic acid carbon was spiked to the SMBR process tank to evaluate the ability of the SMBR system to remove residual organic carbon. Figure 3.52 shows that in all but one instance, TOC concentrations were below detection in the SMBR effluent. Though some of the acetic acid may have volatilized, the lack of acetic acid smell in the vicinity of the process tank suggests that biological oxidation was the dominant mechanism of organic carbon removal in the SMBR.

Hydrogen sulfide odor was rarely detected in the feed to the SMBR and was never detected in the SMBR effluent. Analytical measurements resulted in no detectable sulfide (MRL = 0.1 mg/L). Any observed removal may have been due to volatilization. However, given a $pK_{a,1} = 7.1$ and an average process tank pH of 8.2, approximately 92 percent of the sulfide was in the HS^- form, thus minimizing the contribution of volatilization to sulfide removal. It is also possible that sulfide oxidation was occurring in the reactor, either spontaneously or via microbial catalysis. No effort was made to isolate the sulfide removal mechanism.

7.7.1 Summary

Demonstration testing showed that a submerged membrane bioreactor can meet several post-FXB treatment objectives in a single step: 1) aeration, 2) biomass separation, 3) residual organic carbon removal, and 4) hydrogen sulfide removal.

7.8 In-Line Ion Chromatographic Analysis

In addition to perchlorate analyses performed by CLWA and MWH labs, an in-line perchlorate analyzer was installed to provide real time perchlorate data. A Dionex DX-800 in-line ion chromatograph was used that can sample, analyze, and store data from up to 21 process streams. The system uses a 2 x 250 mm IonPac® AS16 analytical column (Dionex P/N 055378) with a 2 x 50 mm AG16 guard column. The sample volume was 1,000-mL with a flow rate of 0.4 mL/min. The effluent was an EG50-generated 50 mM potassium hydroxide (KOH) solution with a back pressure of approximately 2,500 psi. A 2-mm AMMS III suppressor operated in the chemical suppression mode and a CD20-PA Conductivity Detector was used for detection. The system was controlled by a CC81 controller. Run times for the samples were 30 minutes.

The instrument was initially connected directly to the FBR with samples being continuously drawn into the analyzer every 30 min for analysis. This created a problem due to the high amount of biomass being sloughed from the system. A rough prefilter was installed to complement the 20-µm pre-sample loop filter. This provided some removal of biomass but clogging continued to occur in the instrument, thus causing high excessive pressure build-up in the system. As a result, the system was configured to analyze only occasional grab samples for remainder of the project. This was beneficial in that the results were obtained in 30 minutes rather than 2 or 3 day for the CLWA lab or up to 1 month for MWH labs.

To test the accuracy of the instrument, split samples of raw water, spiked raw water, and effluents from each of the treatment alternatives were analyzed using the instrument. These samples were also sent to the CLWA lab and two different DHS labs. The results from the tests are provided in Table 3.25.

Table 3.25 Comparison of Perchlorate Results (μg/L) (<MRL indicates less than method reporting limit of 4 μg/L) Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Sample	CLWA	DHS-LA	DHS-Berkley	In-Line Instrument
Raw water	<MRL	<MRL	<MRL	<MRL
IX-Spike	45.1	54.4	47.5	48.5
IX-C1	<MRL	<MRL	<MRL	<MRL
IX-C2	27.7	32.8	29.1	27.3
IX-C3	<MRL	<MRL	<MRL	<MRL
FXB-Spike	42.1	48.6	44.5	38.9
FXB-Out	<MRL	<MRL	<MRL	<MRL
FBR-Spike	41.8	50.2	43.2	42.4
FBR-Out	<MRL	34.2	26.8	<MRL

The results for the Dionex DX-800 were acceptable in most cases and correlated well with results from the other 3 labs. One sample, FBR out, read 27 and 34 mg/L from the two DHS labs, where the CLWA lab and the in-line monitor read below the reporting limit. This may be due to the lack of sample preservation of samples from the FBR. These samples were not preserved, therefore perchlorate degradation could have been an issue. In general, the Dionex instrument showed good correlation with measurements from other laboratories.

7.9 DBP Formation Potential Testing

7.9.1 Experimental Matrix

7.9.1.1 DBPFP Testing on FXB, FBR, and MBR Effluents

Conditions applied during the DBPFP testing conducted on the FXB effluent, the FBR effluent, and the MBR effluent are presented in Table 3.26. For each experiment, three samples were dosed with a range of free and combined chlorine concentrations in order to reach the target free and combined chlorine residual of 3 to 5 mg/L after an incubation period of 7 days. At the end of the incubation period, the sample with the chlorine residual closest to the target was used for DBP analysis and the other two samples were discarded.

Table 3.26	Conditions Applied during DBPFP testing Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Free Chlorine Testing					
Stream	**Free Cl_2 Dose (mg/L)**	**$[Cl_2]_{Free,0}$ (mg/L)**	**Initial Demand (mg/L)**	**$[Cl_2]_{Free,7}$ (mg/L)**	**7-day Demand (mg/L)**
FXB Effluent	10	7.4	2.6	8.6	0
FBR Effluent	24	15.5	8.5	8.0	7.5
MBR Effluent	12	7.4	4.6	7.6	0
Combined Chlorine Testing					
Stream	**Free Cl_2 Dose (mg/L)**	**NH_3-N Dose (mg/L)**	**$[Cl_2]_{Total,0}$ (mg/L)**	**$[Cl_2]_{Total,7}$ (mg/L)**	**7-day Demand (mg/L)**
FXB Effluent	8	2.0	6.3	3.0	3.3
FBR Effluent	12	3.0	5.1	3.1	2.0
MBR Effluent	6	1.5	6.4	3.2	3.2

Free chlorine demand was slightly overestimated, resulting in free chlorine residuals ranging from 7.6 to 8.6 mg/L after 7 days of incubation, which was considerably higher than expected. Instantaneous free chlorine demands ranged from 2.6 mg/L in the FXB effluent to 8.5 mg/L in the FBR effluent. This was expected, since the FBR effluent contained higher levels of organic matter relative to the FXB effluent. The free chlorine demand in the FXB effluent and the MBR effluent was satisfied immediately and no decay of free chlorine was measured thereafter. In the case where the initial free chlorine concentration for the fixed bed effluent was lower than after 7-days of incubation, this was most likely due to the error in the measurements. Sample above 5 mg/L free chlorine had to be diluted to fall within the linear range of the method. In contrast to the other systems, free chlorine continued to decay over the 7-day incubation period in the FBR effluent.

As expected, combined chlorine residuals were more stable, measuring at 3 mg/L after 7 days of incubation in all three streams. The initial combined chloramine demand was greater in the FBR effluent relative to the other two streams.

7.9.1.2 DBPFP Testing on Ozonated FXB Effluent

The ozone test was conducted on a blend of 90 percent SPW and 10 percent FXB effluent to simulate the feed of the biological reactor effluent into the Rio Vista WTP. Conditions applied during ozone testing are presented in Table 3.27. Ozone demand ranged from 1.2 to 1.4 mg/L.

Table 3.27	Conditions Applied During Ozonation Testing Perchlorate Treatment from Saugus Aquifer Castaic Lake Water Agency		
Stream	**Transferred Ozone Dose (mg/L)**	**Ozone Residual (mg/L)**	**HRT (min)**
FXB Effluent	1.76	0.37	5.4
FXB Effluent + Acetic Acid (AA)	1.72	0.54	5.3

Ozonated streams were further analyzed for critical parameters and subjected to DBPFP testing with free and combined chlorine. DBPFP conditions applied during ozone testing are presented in Table 3.28. Seven-day free chlorine residuals were higher than the target residual of 5 mg/L. Due to the limited availability of ozonated water, multiple bottles could not be incubated. Therefore, the DBP formation potential results are conservative. The free chlorine residual at time zero was not measured. Combined chlorine residuals ranged from 3.4 to 4.3 mg/L, falling within the target range of 3 to 5 mg/L.

Table 3.28 Conditions Applied During DBPFP Testing of Ozonated Waters Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Free Chlorine Testing					
Stream	**Free Cl_2 Dose (mg/L)**	**$[Cl_2]_{Free,0}$ (mg/L)**	**Initial Demand (mg/L)**	**$[Cl_2]_{Free,7}$ (mg/L)**	**7-day Demand (mg/L)**
Ozonated FXB Effluent	16	NA	NA	11.4	NA
Ozonated FXB Effluent+ AA	16	NA	NA	10.4	NA
Combined Chlorine Testing					
Stream	**Free Cl_2 Dose (mg/L)**	**NH_3-N Dose (mg/L)**	**$[Cl_2]_{Total,0}$ (mg/L)**	**$[Cl_2]_{Total,7}$ (mg/L)**	**7-day Demand (mg/L)**
Ozonated FXB Effluent	8	2	NA	4.3	NA
Ozonated FXB Effluent+ AA	8	2	NA	3.4	NA

7.9.2 Analytical Results

7.9.2.1 DBPFP Testing on FXB, FBR, and MBR Effluents

Control samples of each stream were analyzed for critical parameters (Table 3.28). Prior to chlorination, the FBR effluent contained a DOC concentration of 6 mg/L, whereas the other two streams contained negligible quantities of organic matter. It should be mentioned that DBPFP samples were collected from the FBR at a time before feed acetic acid concentration had been optimized. Since the acetic acid feed concentration was later reduced, the NOM and DBP results are conservative. A BDOC of 1.1 mg/L was measured in the FBR effluent. This BDOC level is higher than the 0.15 to 0.3 mg/L range of acceptable BDOC level for microbial growth in the distribution system. The AOC level in the FBR effluent of 178 μg/L is higher than the suggested 50 μg/L level to control coliform growth in distribution systems. The AOC concentration in the MBR effluent was higher than the AOC concentration in the MBR feed (i.e., FXB effluent), reflecting the fact that the MBR system was still being optimized at the time of the DBPFP tests. As expected, background THM4 and HAA5 levels (prior to chlorination) were non-detect.

Following free chlorine addition with an excess 7-day residual of 7.6 to 8.6 mg/L, THM4 and HAA5 levels were detected in all three streams. TTHM and HAA5 concentrations in the chlorinated FBR stream exceeded Stage 1 and Stage 2 D/DBP maximum contaminant levels of 80 μg/L and 60 μg/L, respectively. HAAs were the dominant DBPs in the biological and MBR effluents. All four TTHM species and all five HAA5 species were detected during the DBPFP testing with FBR effluent.

The reported 7-day TTHM and HAA concentrations are equivalent to formation potential levels since the concentrations on day zero (controls) were non-detect. It should be noted that a detectable level of DOC was measured in the FXB effluent, resulting in a BDOC of 0.23 mg/L. This is unexpected because the DOC in the control FXB effluent sample (i.e., prior to chlorination) was non-detect. THMs and HAAs in the MBR were below the Stage 1 and Stage 2 MCLs.

As expected, chloramination resulted in low levels of TTHMs and lower levels of HAA5 relative to free chlorination.

Table 3.29 DBPFP Testing Results
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Prior to Chlorination (Control)					
Stream	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)**	**THM4, $_0$ (μg/L)**	**HAA5, $_0$ (μg/L)**
FXB Effluent	<0.5	ND	47	ND	ND
FBR Effluent	6.0	1.1	178	ND	ND
MBR Effluent	<0.5	ND	95	ND	ND

Table 3.29	DBPFP Testing Results Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency				
Following DBPFP with Free Chlorine- Day 7					
Stream	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)***	**THM4, 7 (μg/L)**	**HAA5, 7 (μg/L)**
FXB Effluent	NA	NA	NA	20	26
FBR Effluent	NA	NA	NA	110	140
MBR Effluent	NA	NA	NA	24	39
Following DBPFP with Combined Chlorine- Day 7					
Stream	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)***	**THM4, 7 (μg/L)**	**HAA5, 7 (μg/L)**
FXB Effluent	NA	NA	NA	ND	17
FBR Effluent	NA	NA	NA	2.2	24
MBR Effluent	NA	NA	NA	ND	13
Notes: NA: not analyzed					

The DBPFP yields are presented in Table 3.30. The highest DBP formation yields were observed for the tests using FBR effluent. HAA formation yields were higher than THM yields for the same samples. Even though the DOC was non-detect in the MBR effluent, an HAA concentration of 13 μg/L was measured after chloramination, resulting in a yield of > 26 μg/mg DOC.

Table 3.30	DBPFP Yields Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency			
	THM4FP Yield (μg/mg DOC)		**HAA5FP Yield (μg/mg DOC)**	
Stream	**Free Chlorine**	**Combined Chlorine**	**Free Chlorine**	**Combined Chlorine**
FXB Effluent	5.0	0	6.6	4.3
FBR Effluent	32.0	2.1	40.7	7.0
MBR Effluent	0.2	0	0.4	>26(1)
Notes: (1) DOC was ND				

A follow-up 72-hr SDS test was conducted on the FBR effluent. A free chlorine dose of 2.6 mg/L was used, which resulted in a 3-day residual of 0.4 mg/L. The SDS-TTHM4 and SDS-HAA5 concentrations were 40 and 23 μg/L, respectively.

7.9.2.2 DBPFP Testing on Ozonated FXB Effluent

Following ozonation of the FXB effluent and the acetic acid-spiked FXB effluent samples, DBPFP testing was conducted with both free and combined chlorine (Table 3.32).

Bromate was formed at concentrations ranging from 1.8 to 8.7 μg/L. The bromide levels of 200 μg/L for the blended water (i.e., 90 percent SPW and 10 percent FXB effluent) are on the higher side. For comparison, bromate concentrations measured following ozonation at the Rio Vista WTP are less than 5 μg/L.

Aldehydes were formed at moderate levels when the FXB effluent was ozonated. As expected, total aldehydes (acetaldehyde, formaldehyde, glyoxal, pyruvic aldehyde, and pentanal) were slightly higher in the ozonated FXB effluent spiked with acetic acid relative to the unspiked FXB effluent. It should be noted that the filtration process at the Rio Vista WTP downstream of ozonation may further reduce the aldehyde levels in the finished water.

Ozonation increased the concentration of BDOC and AOC, a phenomenon widely reported in the literature. In a full-scale treatment process, the biodegradable organic matter would be reduced through the filters prior to final chlorination by biological oxidation. Chlorination and chloramination of the samples resulted in a decrease in the BDOC concentration, probably as a direct result of NOM oxidation by the disinfectant.

High concentrations of TTHMs and HAAs were measured in the ozonated samples following DBP formation testing with free chlorine. It should be noted that since the measured free chlorine residuals after 7 days of incubation were higher than the target residual range of 3 to 5 mg/L, these DBP results are conservative. In addition, in a full-scale treatment process, the preozonated water would be filtered prior to final chlorination. This filtration process would be expected to remove some of the DBP precursors by biological oxidation, resulting in lower DBP levels than those shown in Table 3.31.

Table 3.31 DBPFP Testing Results-Ozone Test Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer Castaic Lake Water Agency

Raw Samples					
Stream	**TOC (mg/L)**	**DOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)**	**Bromide, low (mg/L)**
FXB Effluent	2.4	2.5	0.53	200	200
FXB Effluent+AA	9.2	8.8	2.5	1266	200

Table 3.31 DBPFP Testing Results-Ozone Test
Treatment of Perchlorate Contaminated Groundwater from the Saugus Aquifer
Castaic Lake Water Agency

Ozonated Samples Prior to Chlorination (Control)									
Stream	**DOC (mg/L)**	**TOC (mg/L)**	**BDOC (mg/L)**	**AOC (μg/L)**	**Br (μg/L)**	**BrO_3 (μg/L)**	**Aldehyde (μg/L)**	**$THM4,_0$ (μg/L)**	**$HAA5,_0$ (μg/L)**
FXB Effluent	2.6	2.4	3.7	240	190	8.7	40	ND	ND
FXB Effluent +AA	3.2	8.8	5.6	1,446	200	1.8	54	ND	ND

Following DBPFP with Free Chlorine- Day 7					
Stream	**TOC (mg/L)**	**DOC (mg/L)**	**BDOC (mg/L)**	**$THM4,_7$ (μg/L)**	**$HAA5,_7$ (μg/L)**
FXB Effluent	2.0	1.9	0.22	200	56
FXB Effluent+AA	8.6	8.5	1.5	180	65

Following DBPFP with Combined Chlorine- Day 7					
Stream	**TOC (mg/L)**	**DOC (mg/L)**	**BDOC (mg/L)**	**$THM4,_7$ (μg/L)**	**$HAA5,_7$ (μg/L)**
FXB Effluent	2.3	2.2	0.38	23	12
FXB Effluent+AA	8.8	9.0	0.50	25	13

While HAAs were the dominant DBPs in the chlorinated FXB, FBR, and MBR effluents, TTHMs were the dominant DBPs in the blended FXB effluent samples, which is confirmed by typical DBP concentrations measured in the full-scale Rio Vista WTP distribution System (i.e., approximately 65 μg/L for THMs and 15 μg/L for HAAs).

7.9.3 Comparison of DBP Formation Results

THMFP and HAAFP results for all streams are plotted in Figures 3.53 and 3.54. It must be emphasized that the chlorination and ozone results are conservative. The HAA concentrations in the ozonated samples are lower than the TTHM concentrations, suggesting that the SPW water favors the formation of THMs over HAAs. Non-blended water tended to form HAAs over THMs.

In summary THMs and HAAs tend to form in the effluent of the biological systems upon the addition of free chlorine. The THMs and HAAs in the FXB effluent (which was already at steady-state operation) were lower than the current Stage MCLs. Higher DBP concentrations measured in the chlorinated and ozonated FBR effluent are premature since the FBR was not optimized.

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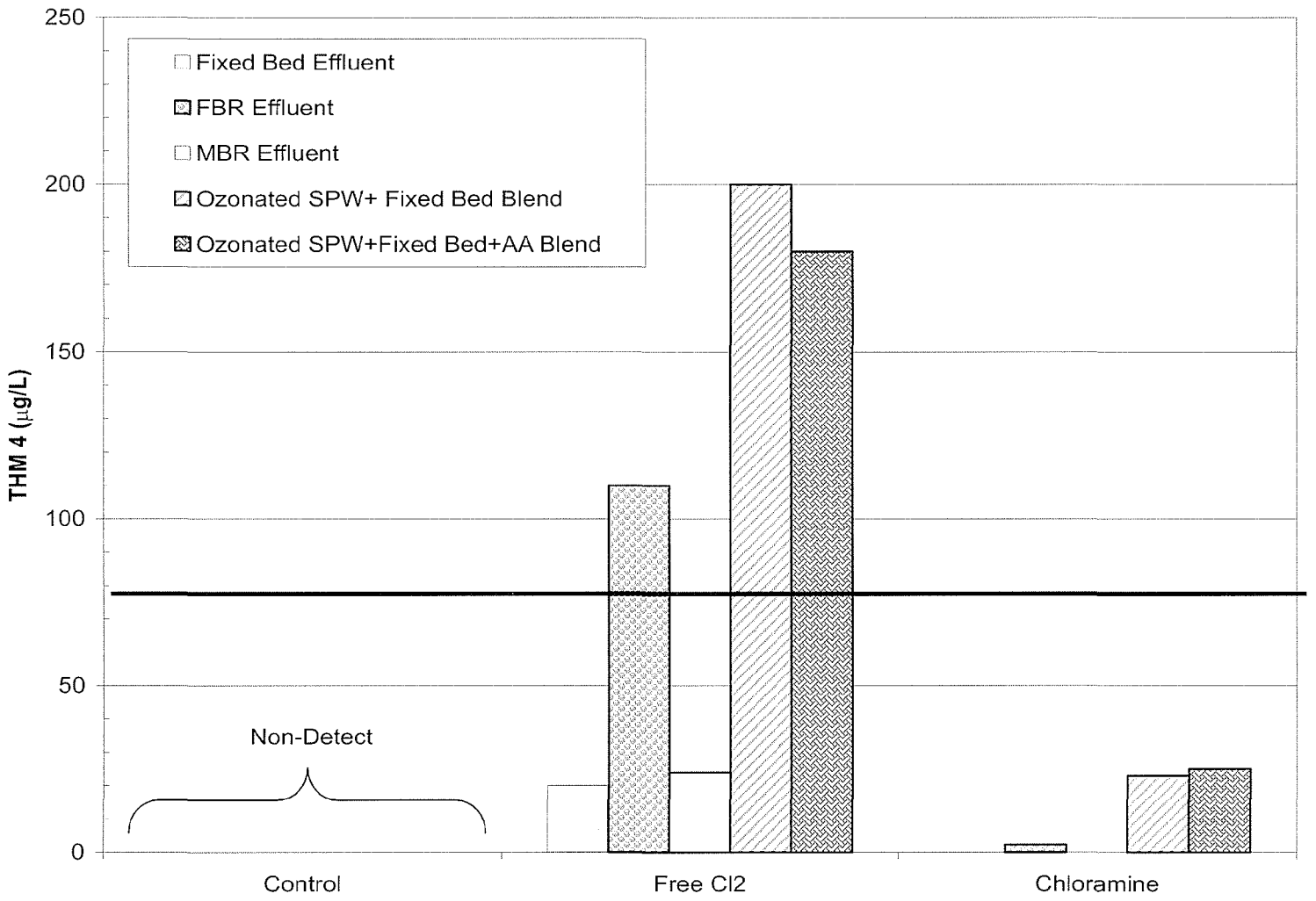

COMPARISON OF DBPFP THM4 SAMPLES FROM SEVERAL STREAMS

FIGURE 3.53

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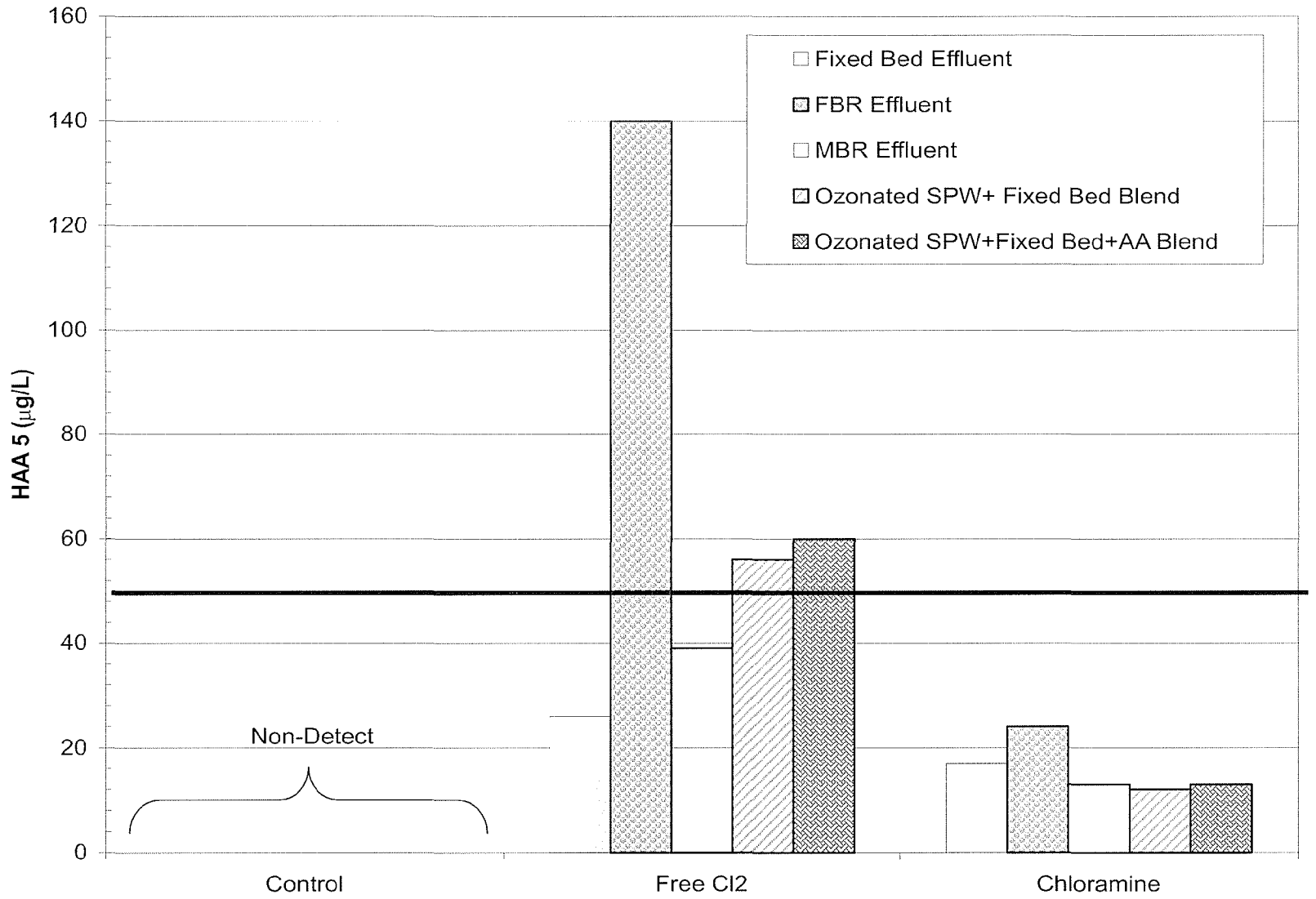

COMPARISON OF DBPFP HAA5 SAMPLES FROM SEVERAL STREAMS

FIGURE 3.54

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As expected, chloramination results in THM and HAA levels significantly lower than the Stage 2 MCLs.

7.10 Summary of DBPFP Results

7.10.1 DBPFP Testing on Fixed Bed, Fluidized Bed, and MBR Effluents

Following free chlorine addition with an excess residual after 7 days of incubation, DBP levels were formed in all streams, with levels in the FBR stream exceeding current MCLs of 80 μg/L and 60 μg/L for THMs and HAAs, respectively. It should be noted that the FBR was not optimized prior to the DBPFP tests. Because the FBR feed acetic acid concentrations were higher than ultimately required, the FBR DBPFP tests are considered conservative. HAAs were the dominant DBPs in the three samples. As expected, chloramination resulted in low levels of THMs and lower levels of HAAs as compared to free chlorination. Higher DBP formation yields were calculated in the FBR effluent relative to the FXB effluent. A follow-up 72-hour SDS test was conducted on the FBR effluent. The SDS-THM4 and SDS-HAA5 concentrations were lower than the D/DBPR Stage 2 MCLs, measured at 40- and 23-µg/L, respectively.

7.10.2 DBPFP Testing on Ozonated Fixed Bed Effluent

To simulate DBP formation potential of FXB effluent that is post-treated at the Rio Vista Water Treatment Plant (WTP), a blend of 90 percent State Project Water (SPW) and 10 percent FXB effluent was ozonated and contacted with free or combined chlorine. Following ozonation, bromate was formed at concentrations ranging from 1.8 to 8.7 μg/L due to high bromide levels of 200 μg/L for the blended water. Aldehydes were formed at moderate levels, even in the effluent spiked with acetic acid. The ozonation of the samples resulted in an increase in the BDOC and AOC concentrations. It should be noted that the filtration process at the Rio Vista WTP downstream of ozonation may further reduce the aldehydes and BDOC levels in the finished water. High levels of THMs and HAAs were measured in the ozonated samples following DBP formation testing with free chlorine. THM4 concentrations were two times the Stage 2 MCL. However, residual chlorine concentrations were excessive during incubation and, more importantly, a large fraction of DBP precursors would likely be removed downstream of ozonation, prior to chlorination at the Rio Vista WTP. The HAA concentrations in the ozonated samples, although relatively high, were lower or equal to the Stage 2 MCL. Seven-day incubation of ozonated water with combined chlorine generated only 23 μg/L TTHM4 and 12 μg/L HAA5.

8.0 CONCLUSION

All three ion-exchange resins removed perchlorate to below detection for run times exceeding model predictions. Preliminary NDMA formation potential tests with pre- and post-disinfection, as well as spent resin characterization tests suggest that the operation and disposal of these resins under the conditions tested should not raise any concern. It

should be noted however that in a full-scale process, the temporal discharge of groundwater following a resin change-out may pose a challenge due to potential restrictions in chloride level imposed by the relative agency (e.g., county sanitation district or regional water quality control board).

Consistent perchlorate removal to below detection was achieved in the FXB filter using only organisms indigenous to the Saugus aquifer. With influent DO and nitrate concentrations of 7 and 15 mg/L, respectively, the lowest EBCT and acetic acid concentration that allowed consistent perchlorate removal to below detection was 15 minutes and 7.8 mg/L as carbon, respectively. Run times ranged from 24 hours to several days. Effluent from the FXB filter was biologically stable and contained no fecal coliforms. Challenge tests demonstrated that the FXB filter was robust with respect to backwashing episodes, changes in feed water quality, system shut-downs, and electron donor addition failures. Large step increases in feed nitrate concentration (e.g., 15 mg/L) required a period of bio-acclimation before perchlorate removal to below detection could be reestablished in the FXB filter. A short-term post-treatment test performed on the FXB system with an SMBR demonstrated that the SMBR would be able to meet regulatory requirements in terms of aeration and filtration in a single step. DBP formation tests for the fixed bed reactor resulted in THM and HAA levels lower than the Stage 2 MCLs.

The fluidized-bed reactor did not achieve perchlorate removal to below detection over a period greater than 8 days, in spite of numerous mechanical and operational adjustments made to the system. However, testing did demonstrate that biological perchlorate removal can be achieved using indigenous microorganisms, a feature that had not yet been demonstrated for the FBR system. Because the FBR was not optimized, challenge testing was not performed.

A number of critical design parameters have been established based on the test results. These will be used during the pre-design of a selected system. Based on the performance of these systems, preliminary budget level costs have been developed, which will be presented in the pre-design report.

9.0 REFERENCES

Na, C., Cannon, F.S., and Hagerup, B. 2002. "Perchlorate Removal via Iron-Preloaded GAC and Borohydride Regeneration." Journal AWWA, 94(11): 90-102.

Brown, J.C., V.L. Snoeyink, and M.J. Kirisits. 2002. "Removal of Perchlorate at Low µg/L Concentrations by Sorption and Biological Reduction in an Activated Carbon Filter." Journal AWWA, 94(2): 70-79.

Herman, D.C. and Frankenberger Jr., W.T. 1999. "Bacterial Reduction of Perchlorate and Nitrate in Water." Journal of Environmental Quality, 28: 1018-1024.

DWR's 2009 Comprehensive Water Package,
Special Session Policy Bills and Bond Summary,
November 2009

2009 Comprehensive Water Package

Special Session Policy Bills and Bond Summary

November 2009

The California
Department of
Water Resources

2009 Comprehensive Water Package

Bill Summary SB 1

November 2009 | Department of Water Resources

Governor Schwarzenegger and state lawmakers successfully crafted a plan to meet California's growing water challenges. A comprehensive deal was agreed to, representing major steps towards ensuring a reliable water supply for future generations, as well as restoring the Sacramento-San Joaquin Delta and other ecologically sensitive areas.

The plan is comprised of four policy bills and an $11.14 billion bond. The package establishes a Delta Stewardship Council, sets ambitious water conservation policy, ensures better groundwater monitoring, and provides funds for the State Water Resources Control Board for increased enforcement of illegal water diversions. The bond will fund, with local cost-sharing, drought relief, water supply reliability, Delta sustainability, statewide water system operational improvements, conservation and watershed protection, groundwater protection, and water recycling and water conservation programs.

Senate Bill No. 1
Delta Governance / Delta Plan

SB 1 establishes the framework to achieve the co-equal goals of providing a more reliable water supply to California and restoring and enhancing the Delta ecosystem. The co-equal goals will be achieved in a manner that protects the unique cultural, recreational, natural resource, and agricultural values of the Delta. Specifically, this bill:

- Creates the Delta Stewardship Council, consisting of seven members with diverse expertise providing a broad statewide perspective. The Chairperson of the Delta Protection Commission is a permanent member of the Council. The Council is also tasked with:
  - Developing a Delta Plan to guide state and local actions in the Delta in a manner that furthers the co-equal goals of Delta restoration and water supply reliability;
  - Developing performance measures for the assessment and tracking of progress and changes to the health of the Delta ecosystem, fisheries, and water supply reliability;
  - Determining if a state or local agency's project in the Delta is consistent with the Delta Plan and the co-equal goals, and acting as the appellate body in the event of a claim that such a project is inconsistent with the goals; and
  - Determining the consistency of the Bay-Delta Conservation Plan (BDCP) with the co-equal goals.
- Ensures that the Department of Fish and Game and the State Water Resources Control Board identify the water supply needs of the Delta estuary for use in determining the appropriate water diversion amounts associated with BDCP.

- Establishes the Sacramento-San Joaquin Delta Conservancy to implement ecosystem restoration activities within the Delta. In addition to the restoration duties the Conservancy is required to:
  - Adopt a strategic plan for implementation of the Conservancy goals;
  - Promote economic vitality in the Delta through increased tourism and the promotion of Delta legacy communities;
  - Promote environmental education about, and the public use of, public lands in the Delta; and
  - Assist in the preservation, conservation, and restoration of the region's agricultural, cultural, historic, and living resources.

- Restructures the current Delta Protection Commission (DPC), reducing the membership from 23 to 15 members, and tasks DPC with the duties of:
  - Adopting an economic sustainability plan for the Delta, which is to include flood protection recommendations to state and local agencies;
  - Submitting the economic sustainability plan to the Delta Stewardship Council for inclusion in the Delta Plan.

- Appropriates funding from Proposition 84 to fund the Two-Gates Fish Protection Demonstration Program, a project in the central Delta which will utilize operable gates for protection of sensitive species and management of water supply.

2009 Comprehensive Water Package

Bill Summary SB 6

November 2009 Department of Water Resources

Senate Bill No. 6
Groundwater Monitoring

SB 6 requires, for the first time in California's history, that local agencies monitor the elevation of their groundwater basins to help better manage the resource during both normal water years and drought conditions. Specifically, this bill:

- Requires the Department of Water Resources (DWR) to establish a priority schedule for the monitoring of groundwater basins and the review of groundwater elevation reports, and to make recommendations to local entities to improve the monitoring programs.
- Requires DWR to assist local monitoring entities with compliance with this statute.
- Allows local entities to determine regionally how best to set up their groundwater monitoring program, crafting the program to meet their local circumstances.
- Provides landowners with protections from trespass by state or local entities.
- Provides that if the local agencies fail to implement a monitoring program and/or fail to provide the required reports, DWR may implement the groundwater monitoring program for that region.
- Provides that failure to implement a monitoring program will result in the loss of eligibility for state grant funds by the county and the agencies responsible for performing the monitoring duties.

2009 Comprehensive Water Package

Bill Summary SB 7

November 2009 | Department of Water Resources

Senate Bill No. 7
Statewide Water Conservation

SB 7 creates a framework for future planning and actions by urban and agricultural water suppliers to reduce California's water use. For the first time in California's history, this bill requires the development of agricultural water management plans and requires urban water agencies to reduce statewide per capita water consumption 20 percent by 2020. Specifically, this bill:

- Establishes multiple pathways for urban water suppliers to achieve the statewide goal of a 20 percent reduction in urban water use. Specifically, urban water suppliers may:
  - Set a conservation target of 80 percent of their baseline daily per capita water use;
  - Utilize performance standards for water use that are specific to indoor, landscape, and commercial, industrial and institutional uses;
  - Meet the per capita water use goal for their specific hydrologic region as identified by DWR and other state agencies in the 20 percent by 2020 Water Conservation Plan; or
  - Use an alternate method that is to be developed by DWR before December 31, 2010.

- Requires urban water suppliers to set an interim urban water use target and meet that target by December 31, 2015 and meet the overall target by December 31, 2020.

- Requires DWR to cooperatively work with the California Urban Water Conservation Council to establish a task force that shall identify best management practices to assist the commercial, industrial and institutional sector in meeting the water conservation goal.

- Requires agricultural water suppliers to measure water deliveries and adopt a pricing structure for water customers based at least in part on quantity delivered, and, where technically and economically feasible, implement additional measures to improve efficiency.

- Requires agricultural water suppliers to submit Agricultural Water Management Plans beginning December 31, 2012 and include in those plans information relating to the water efficiency measures they have undertaken and are planning to undertake.

- Makes ineligible for state grant funding any urban or agricultural water supplier who is not in compliance with the requirements of this bill relating to water conservation and efficient water management.

- Requires DWR to, in 2013, 2016 and 2021, report to the Legislature on agricultural efficient water management practices being undertaken and reported in agricultural water management plans.

- Requires DWR, the State Water Resources Control Board, and other state agencies to develop a standardized water information reporting system to streamline water reporting required under the law.

2009 Comprehensive Water Package

Bill Summary SB 8

November 2009 | Department of Water Resources

Senate Bill No. 8
Water Diversion and Use / Funding

SB 8 improves accounting of the location and amounts of water being diverted by recasting and revising exemptions from the water diversion reporting requirements under current law. Additionally, this bill appropriates existing bond funds for various activities to benefit the Delta ecosystem and secure the reliability of the state's water supply, and to increase staffing at the State Water Resources Control Board to manage the duties of this statute. Specifically, this bill:

- Provides a stronger accounting of water diversion and use in the Delta by removing an exemption from reporting water use by in-Delta water users.
- Redefines the types of diversions that are exempt from the reporting requirement.
- Assesses civil liability and monetary penalties on diverters who fail to submit the required reports, and for willful misstatements, and/or tampering with monitoring equipment.
- Appropriates $546 million from Propositions 1E and 84, in the following manner:
  - $250 million (Proposition 84) for integrated regional water management grants and expenditures for projects to reduce dependence on the Delta;
  - $202 million ($32 million Proposition 84 and $170 million Proposition 1E) for flood protection projects in the Delta to reduce the risk of levee failures that would jeopardize water conveyance;
  - $70 million (Proposition 1E) for stormwater management grants; and
  - $24 million (Proposition 84) for grants to local agencies to develop or implement Natural Community Conservation plans.
- Appropriates $3.75 million from the Water Rights Fund to the State Water Resources Control Board for staff positions to manage the duties in this bill relating to water diversion reporting, monitoring and enforcement.

Safe, Clean, and Reliable Drinking Water Supply Act of 2010

Water Bond Summary

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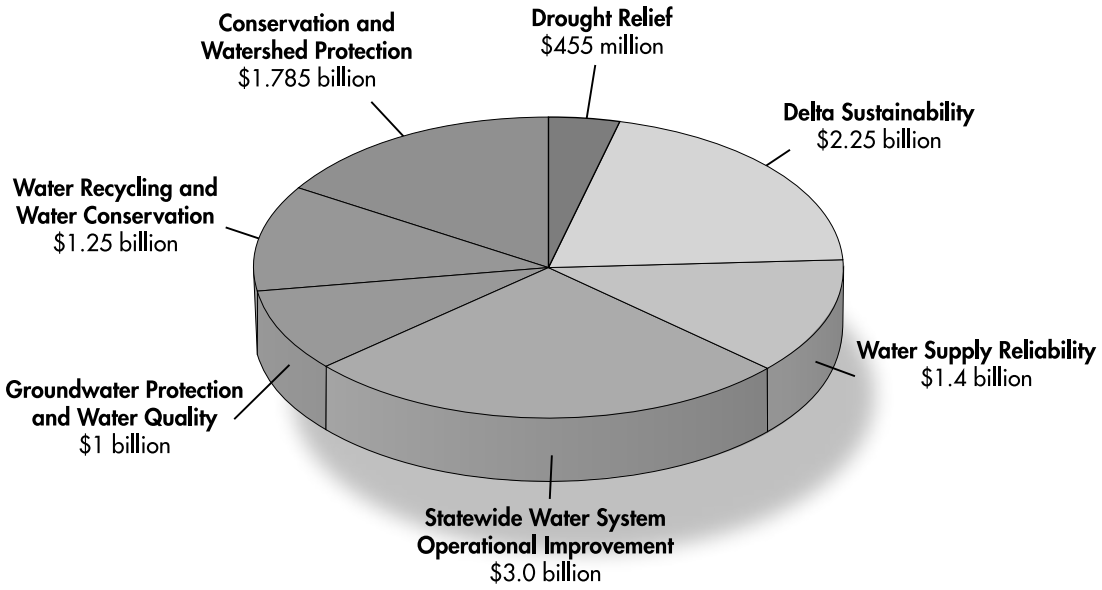
November 2009

The Safe, Clean, and Reliable Drinking Water Supply Act of 2010 is an $11.14 billion general obligation bond proposal that would provide funding for California's aging water infrastructure and for projects and programs to address the ecosystem and water supply issues in California. The bond is comprised of seven categories, including drought relief, water supply reliability, Delta sustainability, statewide water system operational improvement, conservation and watershed protection, groundwater protection and water quality, and water recycling and water conservation.

Total: $11.14 billion

Drought Relief - $455 million. This funding will be available for local and regional drought relief projects that reduce the impacts of drought conditions, including the impacts of reductions to Delta diversions. Projects will include water conservation and water use efficiency projects, water recycling, groundwater cleanup and other water supply reliability projects including local surface water storage projects that provide emergency water supplies and water supply reliability in drought conditions. Funds will be available to disadvantaged communities and economically distressed areas experiencing economic impacts from the drought for drought relief projects and programs. Funds will also be available to improve wastewater treatment facilities to protect water quality or prevent contamination of surface water or groundwater resources.

Delta Sustainability - $2.25 billion. This bond will provide funds for projects to assist in maintaining and restoring the Delta as an important ecosystem. These investments will help to reduce the seismic risk to water supplies derived from the Delta, protect drinking water quality and reduce conflict between water management and environmental protection.



Water Supply Reliability - $1.4 billion. These funds would be in addition to prior funding provided by Proposition 50 and Proposition 84 and would support the existing Integrated Regional Water Management (IRWM) program. IRWM is designed to encourage integrated regional strategies for management of water resources that will protect communities from drought, protect and improve water quality and improve local water security by reducing dependence on imported water. The bond would provide funds for water supply projects in 12 regions throughout the state and would also be available for local and regional conveyance projects that support regional and interregional connectivity and water management.

North Coast	$45,000,000
San Francisco Bay	$132,000,000
Central Coast	$58,000,000
Los Angeles subregion	$198,000,000
Santa Ana subregion	$128,000,000
San Diego subregion	$87,000,000
Sacramento River	$76,000,000
San Joaquin River	$64,000,000
Tulare/Kern	$70,000,000
North/South Lahontan	$51,000,000
Colorado River Basin	$47,000,000
Mountain Counties Overlay	$44,000,000
Interregional Projects	$50,000,000

Statewide Water System Operational Improvement - $3.0 billion. This funding would be dedicated to the development of additional water storage, which, when combined with other water management and flood system improvement investments being made, can increase reliability and offset the climate change impacts of reduced snow pack and higher flood flows. Eligible projects for this funding include surface storage projects identified in the CALFED Bay-Delta Record of Decision; groundwater storage projects and groundwater contamination prevention or remediation projects that provide water storage benefits; conjunctive use and reservoir reoperation projects; local and regional surface storage projects that improve the operation of water systems in the state and provide public benefits.

The bond provides that water suppliers who would benefit from new storage will pay their share of the total costs of the project while the public benefits of new water storage can be paid for by this general obligation bond.

Groundwater Protection and Water Quality - $1 billion. To protect public health, funds will be available for projects to prevent or reduce the contamination of groundwater that serves as a source of drinking water. Funds will also be used to finance emergency and urgent actions on behalf of disadvantaged communities and economically distressed areas to ensure that safe drinking water supplies are available to all Californians.

Water Recycling and Water Conservation - $1.25 billion. Funds will be available for water recycling and advanced treatment technology projects that recycle water or that remove salts and contaminants from water sources. Funds will also be available for urban and agricultural water conservation and water use efficiency plans, projects, and programs. These funds will assist urban water users in achieving water conservation targets.

Conservation and Watershed Protection - $1.785 billion. Funds will be available, through a 50-50 cost share program, for ecosystem and watershed protection and restoration projects in 21 watersheds throughout the state, including coastal protection, wildlife refuge enhancement, fuel treatment and forest restoration, fish passage improvement and obsolete dam removal.

Coastal counties and watersheds	$250,000,000
Wildlife Conservation Board	$365,000,000
San Gabriel and Lower Los Angeles River watersheds	$75,000,000
Santa Monica Mountains Conservancy	$75,000,000
Baldwin Hills Conservancy	$20,000,000
Santa Monica Bay watershed	$25,000,000
Coastal salmonid restoration	$50,000,000
Lake Tahoe watershed restoration	$100,000,000
Farmland Conservancy Program	$20,000,000
River parkways and urban streams restoration	$50,000,000
Sierra Nevada Conservancy	$75,000,000
Salton Sea restoration	$100,000,000
Watershed climate change impacts and adaptation	$10,000,000
Watershed education facilities	$30,000,000
Waterfowl habitat preservation	$10,000,000
Forest restoration	$100,000,000
Klamath dam removal	$250,000,000
Siskiyou County economic development offset	$20,000,000
Agricultural water use efficiency research	$50,000,000
Ocean protection	$50,000,000
CVPIA fish passage improvement	$60,000,000

DWR's Progress on Incorporating Climate Change into Management of California's Water Resources

July 2006

Progress on Incorporating Climate Change into Management of California's Water Resources

July 2006
Technical Memorandum Report
California Department of Water Resources

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Progress on Incorporating Climate Change into Planning and Management of California's Water Resources

Technical Memorandum Report

July 2006

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Executive Summary

Background

On June 1, 2005, Governor Arnold Schwarzenegger issued Executive Order S-3-05 establishing greenhouse gas emissions targets for California and requiring biennial reports on potential climate change effects on several areas, including water resources. The Governor established a Climate Action Team (CAT) to guide the reporting efforts. The CAT selected four climate change scenarios that reflect two greenhouse gas emissions scenarios represented by two Global Climate Models (GCMs). The CAT requested that those four climate change scenarios be used whenever possible in the climate change reporting efforts.

This report is the Department of Water Resources response to the Executive Order. This report describes progress made incorporating climate change into existing water resources planning and management tools and methodologies.

Climate Change and California's Water Resources

California water planners are concerned about climate change and its potential effects on our water resources. Projected increases in air temperature may lead to changes in the timing, amount and form of precipitation - rain or snow, changes in runoff timing and volume, effects of sea level rise on Delta water quality, and changes in the amount of irrigation water needed due to modified evapotranspiration rates.

More than 20 million Californians rely on two massive water projects: the State Water Project (SWP) and federal Central Valley Project (CVP). These complex water storage and conveyance systems are operated by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) for water supply, flood management, environmental protection and recreation.

DWR and Reclamation have formed a joint Climate Change Work Team to provide qualitative and quantitative information to managers on potential effects and risks of climate change to California's water resources. The mission of the team is to coordinate with other state and federal agencies on the incorporation of climate change science into California's water resources planning and management. The team will provide and regularly update information for decision-makers on potential impacts and risks of climate change, flexibility of existing facilities to cope with climate change, and available mitigation measures. This report is the first product of the Work Team.

Report Overview

This report contains eight chapters that present progress and future directions on incorporating climate change science into management of California's water resources. It focuses on assessment methodologies and preliminary study results. The technical chapters of this report,

Chapters 4-7, were peer-reviewed by experts from water resources-related agencies and research institutions. Policy implications and recommendations are beyond the scope of this report.

Uses and Limitations

The purpose of this report is to demonstrate how various analysis tools currently used by DWR could be used to address issues related to climate change. The methods and results presented in this report could be used to guide future climate change analysis and to identify areas where more information is needed.

All results presented in this report are preliminary, incorporate several assumptions, reflect a limited number of climate change scenarios, and do not address the likelihood of each scenario. Therefore, these results are not sufficient by themselves to make policy decisions.

Chapter 1: Introduction

Chapter 1 describes the purpose of this report, details the DWR-Reclamation Climate Change Work Team's mission and goals, and provides a summary of each chapter of the report. The complete text of Executive Order S-3-05 is in an appendix.

Chapter 2: Potential Impacts of Climate Change on California's Water Resources

Chapter 2 provides a statewide overview of California's water resources. Causes of climate change are summarized with an emphasis on aspects of climate change that pose a potential threat to California's water resources. It identifies measures that could be taken to adapt to or mitigate the effects of climate change. Topics covered in Chapter 2 include:

- Overview of California's water resources
- The role of water management and use in greenhouse gas emissions
- Observed and projected changes in air temperature
- Observed and projected changes in precipitation and runoff
- Observed and projected sea level rise and potential effects on groundwater and the Delta
- Potential effects of climate change on
  - Future water demands
  - Colorado River basin
  - Fish
- Sudden climate change
- Climate change and water supply planning challenges

Chapter 3: DWR Climate Change Studies

Chapter 3 presents the background and approach used for the climate change studies completed for this report. Climate change researchers have used global climate models to simulate projected changes in air temperature and precipitation. The global results were converted to represent regional changes in air temperature and precipitation in a process known as downscaling. DWR staff used the downscaled data to conduct preliminary impacts assessments for water resources. The studies use 2050 climate change projections for precipitation and runoff and 2020 land use estimates. The four climate change scenarios and the impacts assessment methodology are described in this chapter.

Chapter 4: Impacts of Climate Change on the State Water Project and Central Valley Project

Chapter 4 presents potential impacts of the selected climate change scenarios on SWP and CVP operations. Analysis includes changes in reservoir inflows, delivery reliability and annual average carryover storage due to 2050 level climate change induced shifts in precipitation and runoff patterns and 2020-level land use. The chapter discusses interaction of various operating rules and regulations such as water allocations, flood control, in-stream flow requirements, and Delta water quality requirements under climate change scenarios. Current management practices and existing system facilities were used in the analysis for this report. No changes to management practices or system facilities were made to try to mitigate the effects of climate change or sea level rise. Implications for possible changes to operations to mitigate climate change impacts are discussed, however exploring these operations changes is left for future work. The studies presented in this chapter did not incorporate potential effects of sea level rise. Future work will investigate possible changes in system operations and Delta outflow requirements that may be needed to lessen effects of sea level rise on Delta water quality.

Current management practices and existing system facilities were used in the analysis for this report. No changes were made to lessen the effects of climate change or sea level rise.

No changes were made to:

- ❑ System structures, such as added water storage, pumping, or canal capacity
- ❑ Reservoir operating rules, such as changing the space required for flood control
- ❑ Streamflow requirements
- ❑ Water quality standards
- ❑ Delta outflow requirements
- ❑ Operations to account for sea level rise

Some of the main results related to climate change impacts on the SWP and CVP include:

- ❑ In three of the four climate scenarios simulated, there were significant shortages in CVP north-of-Delta reservoirs during droughts. In future studies, operational changes are necessary to avoid these shortages. At this time, it is not clear whether the necessary changes in operations will be insignificant or substantial.

- ❑ Changes in annual average SWP south-of-Delta Table A deliveries ranged from a slight increase of about 1 percent for a wetter scenario to about a 10 percent reduction for one of the drier climate change scenarios.

- Increased winter runoff and lower Table A allocations resulted in slightly higher annual average Article 21 deliveries in the three drier climate change scenarios. The boosts in Article 21 did not offset losses to Table A though. The wetter scenario with higher Table A allocations resulted in fewer Article 21 delivery opportunities and slightly lower annual average Article 21 deliveries.

- Changes in annual average CVP south-of-Delta deliveries ranged from increases of about 2.5 percent for a wetter scenario and decreases of as much as 10 percent for drier climate change scenarios. The CVP results of the drier climate change scenarios are in question due to the north-of-Delta shortages mentioned above. These shortages will have to be addressed in future climate change studies.

- For both the SWP and CVP, carryover storage was negatively impacted in the drier climate change scenarios and somewhat increased in the wetter climate change scenario.

Sea level rise effects on water project operations to repulse a greater salt water intrusion under these conditions were not examined due to lack of existing tools for that type of analysis. Surrogates to provide an indication of the increased operation challenges from sea level rise to repulse sea water are discussed in chapter 5. Future work in this area will include the development of the necessary tools to quantify the impacts of sea level rise on saltwater intrusion and the incremental water supply impacts to repulse greater saltwater intrusion forces into the Delta. As discussed in chapter 5 these water supply impacts are expected to be significant.

Chapter 5: Impacts of Climate Change on the Sacramento-San Joaquin Delta

Chapter 5 focuses on potential impacts of climate change on Delta water quality and water levels. The reservoir operations and Delta exports for the four climate change scenarios determined in the studies for Chapter 4 were used to examine potential effects of climate change on Delta water quality. The Delta impacts reflect adjustments in reservoir operations and Delta exports due to shifting precipitation and runoff patterns. The studies in Chapter 4 include the assumption that meeting Delta water quality standards is a top priority for the SWP and CVP operations. Climate change will make meeting Delta water quality standards a larger challenge in the future. (see Table 4.12 in Chapter 4). In the interest of time, no additional changes were made to system operations in Chapter 5 to try to lessen the effects of climate change on Delta water quality as a result of sea level rise.

Sea level rise is an aspect of climate change of great interest in the Delta. Although current analysis tools are not available to determine changes in system operations required to lessen the effects of increased salt intrusion, there are tools that can estimate how much salt could enter the Delta due to sea level rise. For this report preliminary analyses were conducted to examine potential salt intrusion for a one foot rise in sea level. These results will provide information vital to the development of tools to determine changes in system operations that would be needed to maintain compliance with Delta water quality standards.

For the sea level rise scenarios, simulated water quality constituent concentrations without additional changes in system operations were compared to threshold values as a surrogate for evaluating the effects of sea level rise on water project operations to meet existing standards. Assuming these standards are not changed, this analysis shows that more water will be needed to repulse seawater to meet these standards as sea level rises. Tools are being developed to quantify the incremental impacts of sea level rise on water supplies to counteract increased salt water intrusion. Until these tools become available, the analysis below provides an indication of the water project operational challenges due to sea level rise. Chloride loadings at the urban intakes are also estimated.

Some of the main results related to climate change impacts on the Delta include:

- For the four climate change scenarios, Delta inflows typically increase during the late winter and early spring and decrease during the summer and fall. On average, Delta exports are reduced with the largest reductions occurring during the summer and fall. Inflows and exports are most sensitive to climate change during extremely wet or extremely dry periods.

- Flexibility in the system to modify reservoir operations and Delta exports for the climate change scenarios at present sea level results in minor impacts to compliance with chloride standards at Municipal and Industrial intakes.

- A one foot rise in sea level without any changes to the system operations would result in chloride concentrations below the 250 mg/l threshold 90 percent of the time at Old River at Rock Slough. In real time, operational adjustments will take place so these effects will translate into water supply impacts to the SWP and CVP. As stated above these impacts to water supply cannot be quantified at this time. Maintaining chloride concentrations below the 150 mg/l threshold was also more challenging during critical and dry years. These results indicate the need to develop a tool to quantify the additional water supplies that would need to be dedicated to repulse sea water in order to maintain Delta water quality under sea level rise conditions.

- There was complete compliance with the chloride standards at the SWP and CVP for the climate change at present sea level scenarios. Chloride concentrations remained below threshold values for the sea level rise and combined climate change and sea level rise scenarios.

- Chloride mass loadings at the municipal and industrial intakes are typically reduced for the climate change only scenarios due to lower export rates. Increased intrusion of salt water from the ocean for the sea level rise and combined climate change and sea level rise scenarios lead to increased chloride mass loadings at the municipal and industrial intakes.

- For a one foot rise in sea level, maximum daily water levels exceeded the minimum levee crest elevation on Sherman Island twice during the 16-year analysis period. Water levels did not exceed the minimum crest elevation for present sea level conditions.

Chapter 6: Climate Change Impacts on Flood Management

Chapter 6 discusses implications of climate change for managing floods. It presents historical trends that reflect potential climate change effects. Representation of historical periods by climate projection models are compared to historical data. Data requirements for analysis of climate change effects on flood frequency are also discussed.

Over the past century observed data indicate:

- Increasing maximum, mean, and minimum temperatures
- Increasing precipitation in north; decreasing precipitation in south
- Shift in annual runoff to a greater percentage in October-March vs. April-July
- Annual flood peaks increasing in mean and variance

Estimates of future climate temperatures suggest:

- Higher snow levels
- Larger direct runoff from individual storm events
- Earlier spring melt

Uncertainties in future precipitation prevents further analysis at this time

Chapter 7: Climate Change Impacts on Evapotranspiration

Chapter 7 focuses on potential increases in crop water use under climate change scenarios. California is a semiarid region, and to grow crops, water is needed for irrigation in addition to that supplied by precipitation. On a regional basis, most of the water used in agriculture is consumed by evapotranspiration (ET). There is concern that the ET might increase with climate change, which could increase the demand for developed water. This chapter provides theoretical energy budget analyses of climate change impacts on ET. Physiological processes that influence ET may explain changes in the energy budget for climate change conditions. Application of analysis tools to assess changes in estimated net irrigation requirements for crops is presented.

Some of the main issues related to climate change effects on evapotranspiration include:

- Evapotranspiration is comprised of two parts: (1) evaporation from soil, water and plant surfaces; and (2) transpiration, which occurs when water vaporizes inside the plant leaves and diffuses through the pores (i.e., stomata) to the ambient air. Both of these contributions to ET could be influenced by climate change.

- For a 3°C increase in air temperature, increases in evapotranspiration for a reference grass crop ranged from 3 percent to 6 percent. Although this is a small percentage, the volume of water, when summed over the entire state, is substantial. It is assumed that other crops will show a similar response to climate change.

- Potential higher demands for irrigation water due to increases in evapotranspiration rates could possibly be offset by improved water use efficiencies including adjusting cropping patterns and using more efficient on-farm irrigation methods.

- There is a need for canopy level experiments to validate assumptions relating canopy resistance to elevated atmospheric carbon dioxide concentrations to ensure accurate ET projection in response to climate change.

- The importance of crop life cycles and their physiological responses to expected climate change need more analysis to better project irrigation demand resulting from ET.

- The Simulation of Evapotranspiration and Applied Water (SIMETAW) model shows promise as an analytic tool to investigate potential ET of applied water responses to climate change. SIMETAW could be used in conjunction with other DWR analytic modeling tools to help managers better understand implications of climate change on agricultural water demands in California.

Chapter 8: Future Directions

Chapter 8 presents directions for further work in incorporating climate change into the management of California's water resources. Emphasis is placed on associating probability estimates with potential climate change scenarios in order to provide policymakers with both ranges of impacts and the likelihoods associated with those impacts. A better understanding of the likelihoods associated with potential climate change impacts will aid decision-makers in planning appropriate response strategies.

Future efforts will also involve addressing data and analysis gaps that were identified during these preliminary studies. For these preliminary studies, four scenarios that were readily available were selected by the Climate Action Team mainly for expediency. In collaboration with climate change scientists, criteria will be developed to assist water resource planners in determining which climate change scenarios to examine. For sea level rise studies, a tool will be developed to determine how system operations may need to be modified to maintain Delta water quality under sea level rise conditions. That tool would provide an essential component for a suite of modeling tools for climate change impacts and risk assessment.

With the accomplishments to date and planned future directions, DWR is working with other agencies and researchers to provide leadership in incorporating climate change impacts and risks into the planning and management of California's precious water resources.

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
July 2006

Chapter 1: Introduction

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1 Introduction

1.1 Background

Before the United Nations World Environment Day in San Francisco in June 2005, Governor Arnold Schwarzenegger said:

> "As of today California is going to be the leader in the fight against global warming. … I say the debate is over. We know the science. We see the threat. And we know the time for action is now."

Executive Order S-3-05 (see Section 1.7) established the following goals for reducing green house gas emissions:

- By 2010, reduce emissions to the 2000 level
- By 2020, reduce emissions to the 1990 level
- By 2050 reduce emissions to 80 percent below 1990 emissions

The Executive Order requires the secretary of the California Environmental Protection Agency to report to the Governor and legislature biannually on progress toward reaching the goals. Biennial reports are also required on potential climate change impacts and possible mitigation and adaptation plans focusing on these topics:

- Water supply
- Public health
- Agriculture
- California coastline
- Forestry

The first reports were due to the Governor and legislature in January 2006. To meet this deadline, and guide the preparation of the reports, a Climate Action Team (CAT) was formed with members from various State agencies and commissions. In addition to the overview reports being produced under the guidance of the CAT, the California Department of Water Resources (DWR) has established a complimentary report titled "Incorporating Climate Change into Management of California's Water Resources." This report describes progress on incorporating climate change science into water resources planning and management.

1.2 Climate Change and California's Water Resources

California water planners are concerned about climate change and its potential effects on our water resources. More than 20 million Californians rely on two massive water projects: the State Water Project (SWP) and federal Central Valley Project (CVP). These complex water storage and conveyance systems are operated by DWR and the Bureau of Reclamation (Reclamation) for water supply, flood management, environmental protection and recreational uses.

The ability of the SWP and the CVP to meet the water demands of its customers and the environment depends heavily on the accumulation of winter mountain snow melting into spring and summer runoff. A warming planet may reduce this natural water storage mechanism. Projected increases in air temperature may lead to changes in the timing, amount and form of precipitation – rain or snow, changes in runoff timing and volume, sea level rise effects on Delta water quality, and changes in the amount of irrigation water needed due to modified evapotranspiration rates.

1.3 DWR-Reclamation Climate Change Work Team

In the past, climate change was typically considered qualitatively in the planning process. Legislative mandates in California including Executive Order S-3-05 and the latest update to the California Water Plan (Bulletin 160) call for more quantitative assessments of climate change effects. To address these concerns, DWR and Reclamation formed a joint Climate Change Work Team to provide qualitative and quantitative information to managers on potential effects and risks of climate change to California's water resources.

The mission of the Climate Change Work Team is to coordinate with other State and federal agencies on the incorporation of climate change science into California's water resources planning and management. The team will provide and regularly update information for decision-makers on potential impacts and risks of climate change, flexibility of existing facilities to cope with climate change, and available mitigation measures.

In water resources planning, climate change studies often focus on what might happen without providing information about how likely it is to happen. A major long-term objective of the Work Team is to extend impacts analysis to include likelihoods associated with each climate change effect. In order to meet this objective, the Work Team set these goals:

- Build coalitions with experts in climate change and seek their guidance in estimating risk of climate change effects
- Support mandates on climate change
  - Governor's Executive Order S-3-05, June 1, 2005
  - California Water Plan Bulletin 160
- Assess impacts to operations of the SWP and CVP for several climate change scenarios
- Assess risk for the SWP and CVP systems based on impact studies and estimates of impact likelihood
- Evaluate risk-mitigation options

This report presents progress to date by the Work Team on incorporating climate change science into planning and management of California's water resources. This report also provides direction for continued efforts at developing probabilistic risk assessments of climate change impacts for water resources management. Figure 1.1 depicts the progress of the Work Team towards its goals. The target shape of the figure represents the focus of our efforts towards the ultimate goal, or bulls-eye, of probabilistic risk assessments. The components of Figure 1.1 that are shaded blue or white represent progress reflected in this report. The yellow and red components of Figure 1.1 represent future directions.

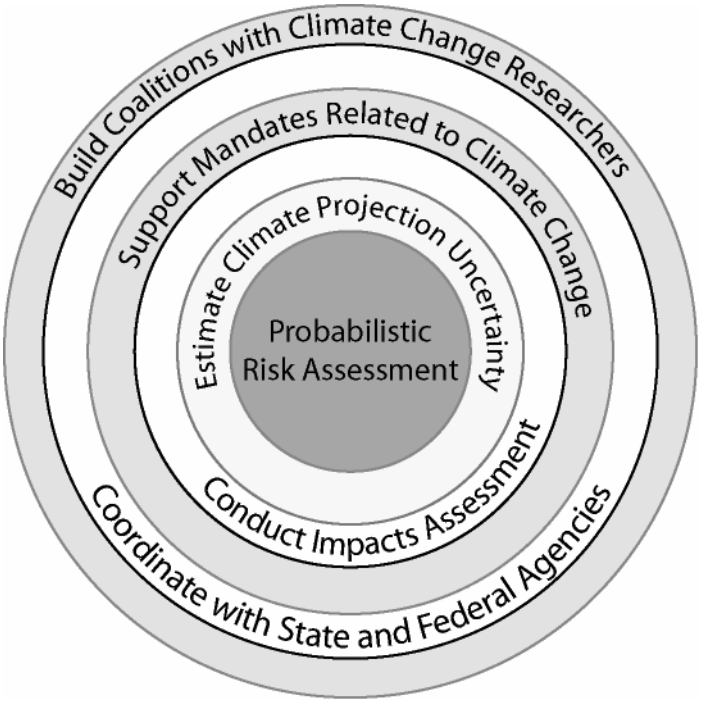

Figure 1.1: DWR-Reclamation Climate Change Work Team Goals

1.4 Report Overview

This report contains eight chapters that present progress and future directions on incorporating climate change science into management of California's water resources. It focuses on assessment methodologies and preliminary study results. The technical chapters of this report, Chapters 4-7, were peer reviewed by experts from water resources related agencies and research institutions. Policy implications and recommendations are beyond the scope of this report.

Chapter 2 provides a statewide overview of California's water resources. Causes of climate change are summarized with an emphasis on aspects of climate change that pose a potential threat to California's water resources. It then identifies measures that could be taken to adapt to or mitigate the effects of climate change.

Chapter 3 presents the background and approach used for the climate change studies completed for this report. It also describes climate change scenarios used in this report.

Chapter 4 presents potential impacts of the selected climate change scenarios on SWP and CVP operations. Analysis includes changes in reservoir inflows, delivery reliability and annual average carryover storage due to climate change induced shifts in precipitation and runoff patterns. It discusses interaction of various operating rules and regulations such as water allocations, flood control, in-stream flow requirements, and Delta water quality requirements under climate change scenarios. It also presents implications for possible changes to operations to mitigate climate change impacts. Exploring these changes is left for future work.

Chapter 5 focuses on potential impacts of climate change on Delta water quality and water levels. It presents effects of modified Delta inflows and exports on compliance with water quality standards. It also discusses implications of sea level rise including a study of levee overtopping potential.

Chapter 6 discusses implications of climate change for managing floods. It presents historical trends that reflect potential climate change effects. Representation of historical periods by climate projection models are compared to historical data. It discusses data requirements for analysis of climate change effects on flood frequency.

Chapter 7 focuses on potential increases in crop water use under climate change scenarios. It discusses potential responses of evapotranspiration to global warming. It characterizes physiological processes that influence ET and might be influenced by climate change. Also, it presents application of analysis tools to assess changes in estimated net irrigation requirements for crops.

Chapter 8 presents directions for further work in incorporating climate change into the management of California's water resources. Emphasis is placed on associating probability estimates with potential climate change scenarios in order to provide policymakers with both ranges of impacts and the likelihoods associated with those impacts.

1.5 Uses and Limitations

The purpose of this report is to demonstrate how various analysis tools currently used by DWR could be used to address issues related to climate change. The methods and results presented in this report could be used to guide future climate change analysis and to identify areas where more information is needed.

Current management practices and existing system facilities were used in the analysis for this report. No changes to management practices or system facilities were made to try to mitigate the effects of climate change or sea level rise. All results presented in this report are preliminary, incorporate several assumptions, reflect a limited number of climate change scenarios, and do not address the likelihood of each scenario. These results are not sufficient by themselves to make policy decisions.

1.6 Acknowledgements

The report authors would like to acknowledge the peer reviewers for their time and valuable technical input on this report:

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1.7 Appendix: Executive Order S-3-05

Executive Order

EXECUTIVE DEPARTMENT

STATE OF CALIFORNIA

EXECUTIVE ORDER S-3-05
by the
Governor of the State of California

WHEREAS, California is particularly vulnerable to the impacts of climate change; and

WHEREAS, increased temperatures threaten to greatly reduce the Sierra snowpack, one of the State's primary sources of water; and

WHEREAS, increased temperatures also threaten to further exacerbate California's air quality problems and adversely impact human health by increasing heat stress and related deaths, the incidence of infectious disease, and the risk of asthma, respiratory and other health problems; and

WHEREAS, rising sea levels threaten California's 1,100 miles of valuable coastal real estate and natural habitats; and

WHEREAS, the combined effects of an increase in temperatures and diminished water supply and quality threaten to alter micro-climates within the state, affect the abundance and distribution of pests and pathogens, and result in variations in crop quality and yield; and

WHEREAS, mitigation efforts will be necessary to reduce greenhouse gas emissions and adaptation efforts will be necessary to prepare Californians for the consequences of global warming; and

WHEREAS, California has taken a leadership role in reducing greenhouse gas emissions by: implementing the California Air Resources Board motor vehicle greenhouse gas emission reduction regulations; implementing the Renewable Portfolio Standard that the Governor accelerated; and implementing the most effective building and appliance efficiency standards in the world; and

WHEREAS, California-based companies and companies with significant activities in California have taken leadership roles by reducing greenhouse gas (GHG) emissions, including carbon dioxide, methane, nitrous oxide and hydrofluorocarbons, related to their operations and developing products that will reduce GHG emissions; and

WHEREAS, companies that have reduced GHG emissions by 25 percent to 70 percent have lowered operating costs and increased profits by billions of dollars; and

WHEREAS, technologies that reduce greenhouse gas emissions are increasingly in demand in the worldwide marketplace, and California companies investing in these technologies are well-positioned to profit from this demand, thereby boosting California's economy, creating more jobs and providing increased tax revenue; and

WHEREAS, many of the technologies that reduce greenhouse gas emissions also generate operating cost savings to consumers who spend a portion of the savings across a variety of sectors of the economy; this increased spending creates jobs and an overall benefit to the statewide economy.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, by virtue of the power invested in me by the Constitution and statutes of the State of California, do hereby order effective immediately:

1. That the following greenhouse gas emission reduction targets are hereby established for California: by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; by 2050, reduce GHG emissions to 80 percent below 1990 levels; and

2. That the Secretary of the California Environmental Protection Agency ("Secretary") shall coordinate oversight of the efforts made to meet the targets with: the Secretary of the Business, Transportation and Housing Agency, Secretary of the Department of Food and Agriculture, Secretary of the Resources Agency, Chairperson of the Air Resources Board, Chairperson of the Energy Commission, and the President of the Public Utilities Commission; and

3. That the Secretary shall report to the Governor and the State Legislature by January 2006 and biannually thereafter on progress made toward meeting the greenhouse gas emission targets established herein; and

4. That the Secretary shall also report to the Governor and the State Legislature by January 2006 and biannually thereafter on the impacts to California of global warming, including impacts to water supply, public health, agriculture, the coastline, and forestry, and shall prepare and report on mitigation and adaptation plans to combat these impacts; and

5. That as soon as hereafter possible, this Order shall be filed with the Office of the Secretary of State and that widespread publicity and notice be given to this Order.

IN WITNESS WHEREOF I have here unto set my hand and caused the Great Seal of the State of California to be affixed this the first day of June 2005.

/s/ Arnold Schwarzenegger

Governor of California

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
July 2006

Chapter 2:
Potential Impacts of Climate Change on California's Water Resources

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2 Potential Impacts of Climate Change on California's Water Resources

2.1 Introduction

The purpose of this chapter is to:

- provide a brief description of California's water resources
- summarize the anthropogenic causes of climate change
- describe the aspects of climate change that pose a potential threat to the State's water management systems

This chapter is general and statewide in scope. It describes impacts that could occur through the end of this century. Subsequent chapters are primarily focused on the effects of climate change on Central Valley water management systems based on selected downscaled climate model projections for mid-century.

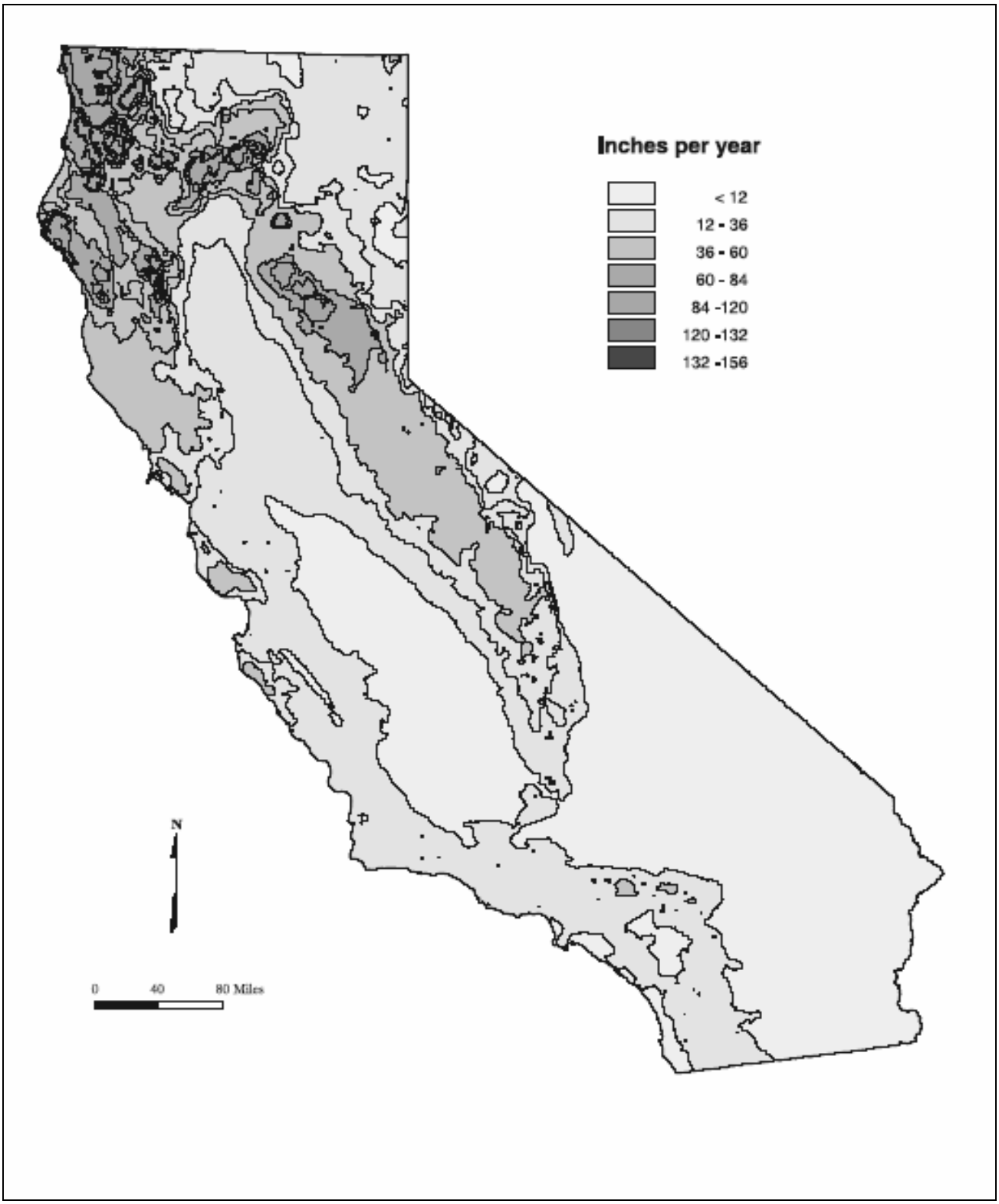
2.2 Background - California's Water Resources

2.2.1 Distribution of Precipitation

California's water resources vary significantly throughout the State as the result of varying climates and the distribution of precipitation. On average, more than 140 inches of precipitation falls annually in the mountains of northwestern California while fewer than four inches falls in parts of the desert in the southeast portion of the State. Figure 2-1 depicts the distribution of average annual precipitation in the State. Statewide average annual precipitation is about 23 inches (DWR, 2003).

Variability in the distribution of precipitation in California is due in part to hemispheric-scale atmospheric circulation patterns. Most winter storms typically move from the Pacific Ocean east across the northern part of the State. A progressively smaller percentage of storms move across the State to the south.

Most of the State's precipitation falls in the northern Coast Range, Klamath and Cascade ranges and the western slope of the Sierra Nevada due to orographic effects. The Mojave Desert, San Joaquin Valley floor and areas east of the Sierra Nevada receive much less precipitation, partly because they are in a rain shadow.



Source: DWR, 2003

Figure 2-1 Distribution of Average Annual Precipitation in California, 1961 to 1990

2.2.2 California's Water Management Systems

The majority of California's population of about 37 million people is concentrated in and near major urban centers. About half of the State's population resides in Southern California where annual precipitation and runoff is much less than in Northern California.

Much of the State's agriculture also is in areas with limited precipitation, including the San Joaquin Valley and the Imperial Valley. Agriculture is critical to the State's economy and usually consumes about 40 percent of the State's total annual developed water supply (DWR, 2005a). California uses this water to produce more than 350 crops, which in 2003 were valued at $29.4 billion. California produces more than half of the vegetables, nuts, and fruits produced in the U.S. (USDA, 2003).

An extensive network of reservoirs and aqueducts has been developed throughout much of California to provide water to major urban and agricultural areas. This network serves to store and transport runoff from where it is plentiful to where it is scarce. It also serves to store winter and early spring runoff so that it will be available when water demand is the highest in the late spring and summer. Figure 2-2 shows the location of major federal, State and local surface reservoirs and aqueducts in California.

The largest system of surface reservoirs and aqueducts in California is in the Central Valley. The historical natural average annual runoff in the Central Valley is about 33.6 million acre-feet, or about 48 percent of California's total natural runoff (DWR, 1951). About two-thirds of the runoff in the Central Valley typically originates in the Sacramento Valley.

Surface reservoirs collecting runoff in the Central Valley have a combined total capacity of about 29 million acre-feet. The two largest water projects in the Central Valley, the State Water Project (SWP) and the federal Central Valley Project (CVP), provide a combined average total of about 10 million acre-feet of water annually for urban and agricultural uses. More than 20 million Californians rely on the SWP and the CVP for at least part of their water supply. These projects irrigate an average of nearly 3.6 million acres of farmland each year (DWR, 2005a).

Other major water storage and conveyance systems in California include the All-American Canal and the Colorado River Aqueduct, both of which divert water from the Colorado River in Southern California. The All-American Canal supplies water to cities and agriculture in the Imperial and Coachella valleys. The Colorado River Aqueduct supplies water to the south coast region. In the recent past, California has diverted as much as 5.3 million acre-feet of water annually from the Colorado River. This is in excess of the State's allotment of 4.4 million acre-feet (DWR, 2005a). Additional discussion of the Colorado River and California's diversions from the river is in Section 2.8.

Figure 2-2 Major Federal, State and Local Water Storage and Conveyance Systems in California

Groundwater also plays a critical role in providing for the State's water needs. In an average year, groundwater meets about 30 percent of California's applied urban and agricultural water demands. This increases to more than 40 percent during drought years. In 1995, an estimated 13 million Californians, nearly 43 percent of the State's population, were served by groundwater (DWR, 2003).

2.2.3 Climate Change and California's Water Resources

Theories concerning climate change and global warming existed as early as the late 1800s. It wasn't until the late 1900s that understanding of the earth's atmosphere had advanced to the point where many climate scientists began to accept that the earth's climate is changing. Today, many climate scientists agree that some warming has occurred over the past century and will continue through this century.

The United Nations Intergovernmental Panel on Climate Change predicts that changes in the earth's climate will continue through the 21st century and that the rate of change may increase significantly in the future because of human activity (IPCC, 2001b). Many researchers studying California's climate believe that changes in the earth's climate have already affected California and will continue to do so in the future.

Climate change may seriously affect the State's water resources. Temperature increases could affect water demand and aquatic ecosystems. Changes in the timing and amount of precipitation and runoff could occur. Sea level rise could adversely affect the Sacramento-San Joaquin River Delta and coastal areas of the State. Some of the projected effects of climate change on California's water resources and the consequences of those effects are summarized in Table 2-1.

Climate change is identified in the 2005 update of the California Water Plan (Bulletin 160-05) as a key consideration in planning for the State's future water management (DWR, 2005a). The 2005 Water Plan update qualitatively describes the effects that climate change may have on the State's water supply. It also describes efforts that should be taken to quantitatively evaluate climate change effects for the next Water Plan update.

Table 2-1 Potential Effects of Climate Change on California's Water Resources and Expected Consequences

Potential Water Resource Impact	Expected Consequence
Reduction of the State's average annual snowpack	• Potential loss of 5 million acre-feet or more of average annual water storage in the State's snowpack • Increased challenges for reservoir management and balancing the competing concerns of flood protection and water supply
Changes in the timing, intensity, location, amount, and variability of precipitation	• Potential increased storm intensity and increased potential for flooding • Possible increased potential for droughts
Long-term changes in watershed vegetation and increased incidence of wildfires	• Changes in the intensity and timing of runoff • Possible increased incidence of flooding and increased sedimentation
Sea level rise	• Inundation of coastal marshes and estuaries • Increased salinity intrusion into the Sacramento-San Joaquin River Delta • Increased potential for Delta levee failure • Increased potential for salinity intrusion into coastal aquifers (groundwater) • Increased potential for flooding near the mouths of rivers due to backwater effects
Increased water temperatures	• Possible critical effects on listed and endangered aquatic species • Increased environmental water demand for temperature control • Possible increased problems with foreign invasive species in aquatic ecosystems • Potential adverse changes in water quality, including the reduction of dissolved oxygen levels
Changes in urban and agricultural water demand	Changes in demand patterns and evapotranspiration rates

2.3 The Role of Water Management and Use in Greenhouse Gas Emissions

2.3.1 Executive Order S-03-05

Executive Order S-3-05, signed by Governor Arnold Schwarzenegger June 1, 2005, establishes aggressive greenhouse gas emission reduction goals for California. These goals are:

- by 2010, reduce emissions to 2000 levels
- by 2020, reduce emissions to 1990 levels
- by 2050, reduce emissions to 80 percent below 1990 levels

Since water management and use are a significant part of California's energy matrix, both in terms of energy generation and consumption, they are an important consideration in meeting the emission reduction goals established by the Governor.

2.3.2 Water Supply and Treatment

In the draft "Statewide Assessment of Energy Used to Manage Water," the California Energy Commission estimated that an average of about 44 million tons of carbon dioxide is emitted into the atmosphere each year to provide water in California. Any reductions in energy consumption related to water will help the State meet its greenhouse gas reduction goals.

California's aqueduct systems are one of the larger users of electricity in the State. Other significant uses of electrical power related to water in California include:

- pumping groundwater from wells
- treating drinking water
- delivering of water to consumers through local distribution systems
- treating wastewater and wastewater reclamation.

Diesel, gasoline, and natural gas-powered pumps are used for some water supply and treatment operations. Diesel-powered pumps are most prevalent in agriculture.

End uses of water also result in the consumption of electrical energy and natural gas, such as heating of water for domestic, commercial, and industrial operations. Various industrial processes that use water also result in energy consumption.

2.3.3 Hydroelectric Power

Hydroelectric power is generated at most publicly-owned water supply reservoirs in California and at many privately-owned reservoirs. Hydroelectric power is also generated by run-of-river hydroelectric plants and by power recovery plants along aqueducts and water distribution systems. Most of California's hydroelectric power is produced in the Sierra Nevada and Cascade

Range. This is due to the relatively large amount of precipitation that falls there and the amount of elevation change available for power generation.

Hydroelectric power production varies from year to year in California with changing hydrologic conditions. Hydroelectric power produced outside of California is also imported into the State to help meet energy needs. Hydroelectric power production is a critical consideration for meeting greenhouse gas emission reduction goals set by Executive Order S-3-05. Other than the construction of hydroelectric power facilities, hydroelectric power production essentially does not result in the emission of greenhouse gasses. As discussed in Section 2.5, climate change could reduce hydroelectric power production by existing facilities, especially at reservoirs in the foothills of the Sierra Nevada. This is due to expected losses in annual snow pack and changes in the timing of annual runoff as the result of climate change.

2.3.4 Future Plans

The 2005 California Water Plan Update (DWR, 2005) estimates that water use efficiency can reduce annual urban water use by 1.1 million to 2.3 million acre-feet by 2030. It is also estimated that water use efficiency can reduce annual agricultural water use by 0.5 million to 2.0 million acre-feet by 2030. Accelerating efforts to attain those water use reductions by 2015 could result in a cumulative reduction of greenhouse gas emissions of approximately 30 million tons by 2030.

The Department of Water Resources is developing water use efficiency measures that can help California meet the greenhouse gas emission reduction goals established by the Governor. These measures are described in a Department staff report titled "Reduction of Greenhouse Gas Emissions through Water Use Efficiency Measures, October, 2005."

In the next sections of this chapter, past and potential future changes in temperature, precipitation, and sea level are described. An overview of the potential impacts of possible future changes is also presented.

2.4 Changes in Air Temperature

2.4.1 Past Changes

The Earth's climate has had numerous periods of cooling and warming in the past. Significant periods of cooling have been marked by massive accumulations of sea and land-based ice extending from the Earth's poles to as far as the mid-latitudes. Periods of cooling have also been marked by lower sea levels due to the accumulation of water as ice, and cooling and contraction of the Earth's oceans. Periods of warming caused recession of the ice toward the poles, warming and thermal expansion of the Earth's oceans, and sea level to rise. More discussion on past changes in sea level is in Section 2.6.

Figure 2-3 depicts significant periods of cooling and warming over about the past 400,000 years based on analysis of ice cores. The causes of the temperature changes are unknown, although

they may be due to changes in solar radiation, the Earth's orbit, the composition of the atmosphere, ocean circulation patterns and other factors. Average temperatures in the Northern Hemisphere appear to have been relatively stable from about 1000 to the mid-1800s based on temperature proxy records from tree rings, corals, ice cores and historical observations (IPCC, 2001a). However, there is a significant amount of uncertainty related to proxy temperature records, especially those extending far back into the past.

The United Nations Intergovernmental Panel on Climate Change stated that the Earth's climate has warmed since the pre-industrial era and that some of this change is attributable to the activities of humans (IPCCb, 2001). Global average near-surface air temperatures and ocean surface temperatures have increased 0.6 ± 0.2°C over the 20th century (IPCCa, 2001). Much of the rise occurred during 1910 to 1945 and 1976 to 2000, as depicted in Figure 2-4.

There is evidence that temperatures in the western United States and California have increased during the past century based on temperature measurements, apparent trends in reduced snowpack and earlier runoff, and other evidence such as changes in the timing of blooming plants (NWS, 2005) (Mote, 2005) (Cayan, 2001). More discussion of observed changes in temperature and related changes in snowpack and runoff in the western United States and California is contained in Section 2.5 and Chapter 6.

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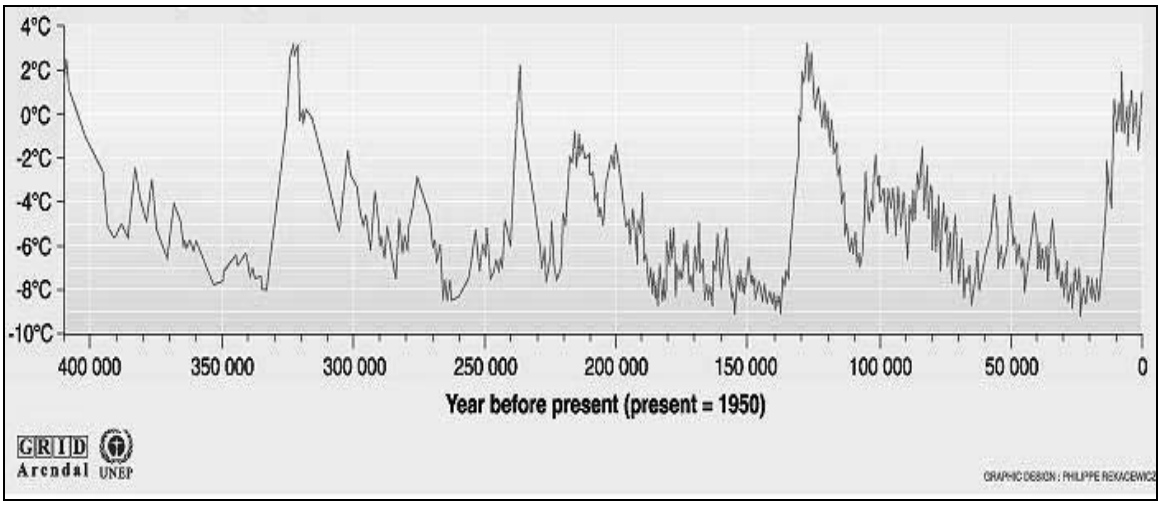

Figure 2-3 Changes in Air Temperature Over About the Past 400,000 Years

Explanation: Graph depicts changes in air temperature as evidenced by isotopic analysis of ice cores obtained at the Russian Vostok station in central east Antarctica. For additional explanation visit: http://cdiac.esd.ornl.gov/trends/temp/vostok/jouz_tem.htm.
Source: United Nation's Environment Programme Global Resource Information Database - Arendal website at http://www.grida.no/climate/vital/02.htm.

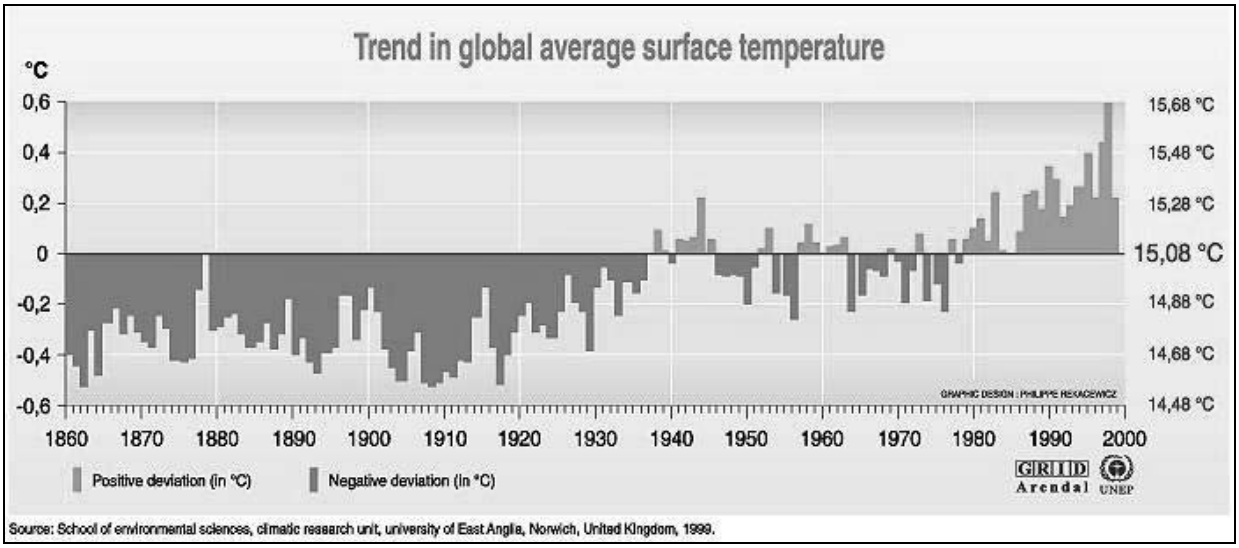

Figure 2-4 Trend in Global Average Temperature from 1860 to 2000

Explanation: The figure depicts global average combined land-surface air and sea surface temperatures from 1861 to 1998 relative to the average temperature between 1961 and 1990. The left vertical scale is in degrees Celsius.
Source: United Nation's Environment Programme Global Resource Information Database - Arendal website at: http://www.grida.no/climate/vital/17.htm.

2.4.2 Causality

Human-induced changes in the Earth's temperature have been tied to increased concentrations of greenhouse gases in the atmosphere caused by the production and burning of fossil fuels and land uses. The primary gases of concern are carbon dioxide, methane, and nitrous oxide. Table 2-2 lists changes in atmospheric concentrations of these gases from 1750 to 1998, as well as their efficacy in causing warming. Figure 2-5 depicts changes in atmospheric carbon dioxide concentration measured at Mauna Loa Hawaii from 1958 to 2005.

Table 2-2 Abundance of Well-Mixed Greenhouse Gases in 1750 (pre-industrial age) and in 1998 and Radiative Forcing Due to the Change in Abundance

Gas	Abundance (Year 1750)	Abundance (Year 1998)	Radiative Forcing (Wm^{-2})
Carbon Dioxide	278	365	1.46
Methane	700	1745	0.48
Nitrous Oxide	270	314	0.15

Source: IPCC, 2001a
Explanation: Volume mixing ratios for carbon dioxide are in parts per million and are in parts per billion for methane and nitrous oxide. Wm^{-2} = watts per square meter.

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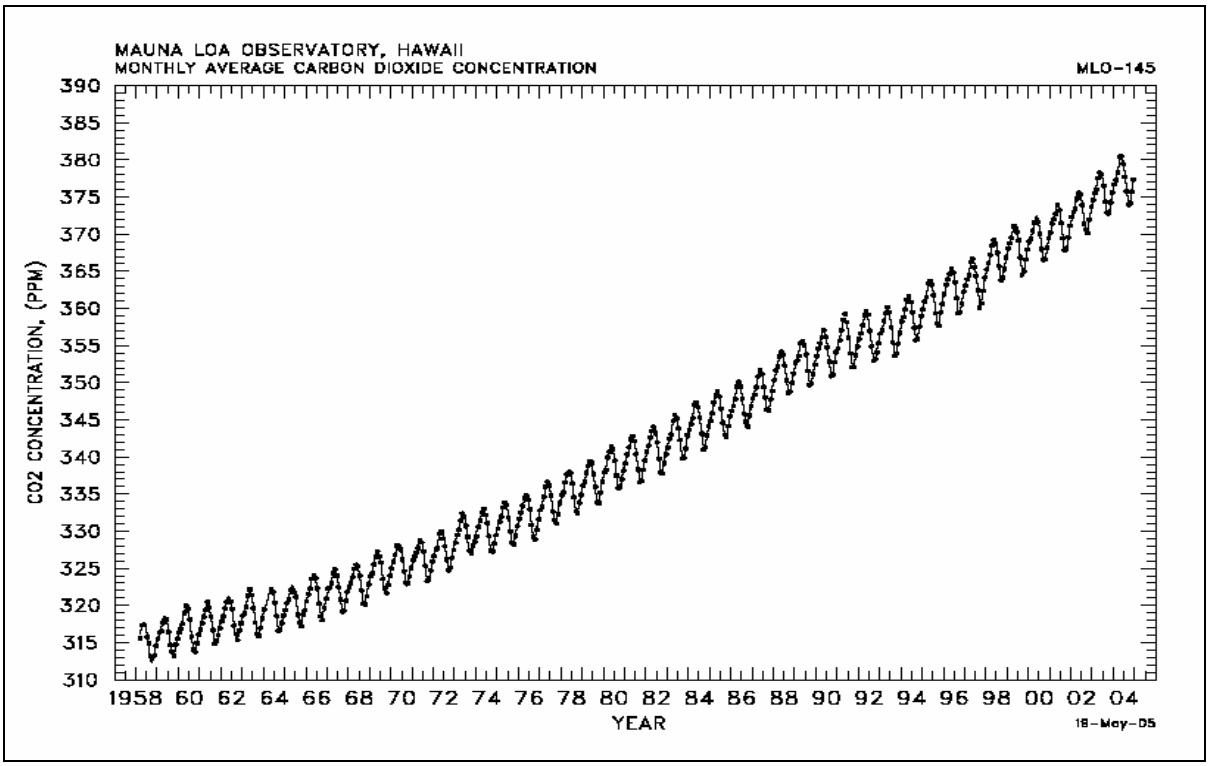


Figure 2-5 Changes in Atmospheric Carbon Dioxide Concentration Measured at Mauna Loa, Hawaii from 1958 to 2005.

Source: United States Department of Energy, Carbon Dioxide Information Analysis Center website at: http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm .
Explanation: PPM = parts per million. Annual decreases in atmospheric carbon dioxide concentration at Mauna Loa, Hawaii occur each summer and are due to seasonal increases in plant respiration in the Northern Hemisphere.

2.4.3 Temperature Projections

The United Nations Intergovernmental Panel on Climate Change reports that global average surface temperatures are projected to rise between 1.4 to 5.8°C from 1990 to 2100, based on various climate models and greenhouse gas emission scenarios (IPCC, 2001a). Figure 2-6 is a generalized representation of the range of temperature projections reported by the IPCC in its Third Assessment Report (TAR). Information on the various projections making up the range, as well as their basis can be found in the TAR[1].

[1] Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001a). http://www.grida.no/climate/ipcc_tar/wg1/index.htm

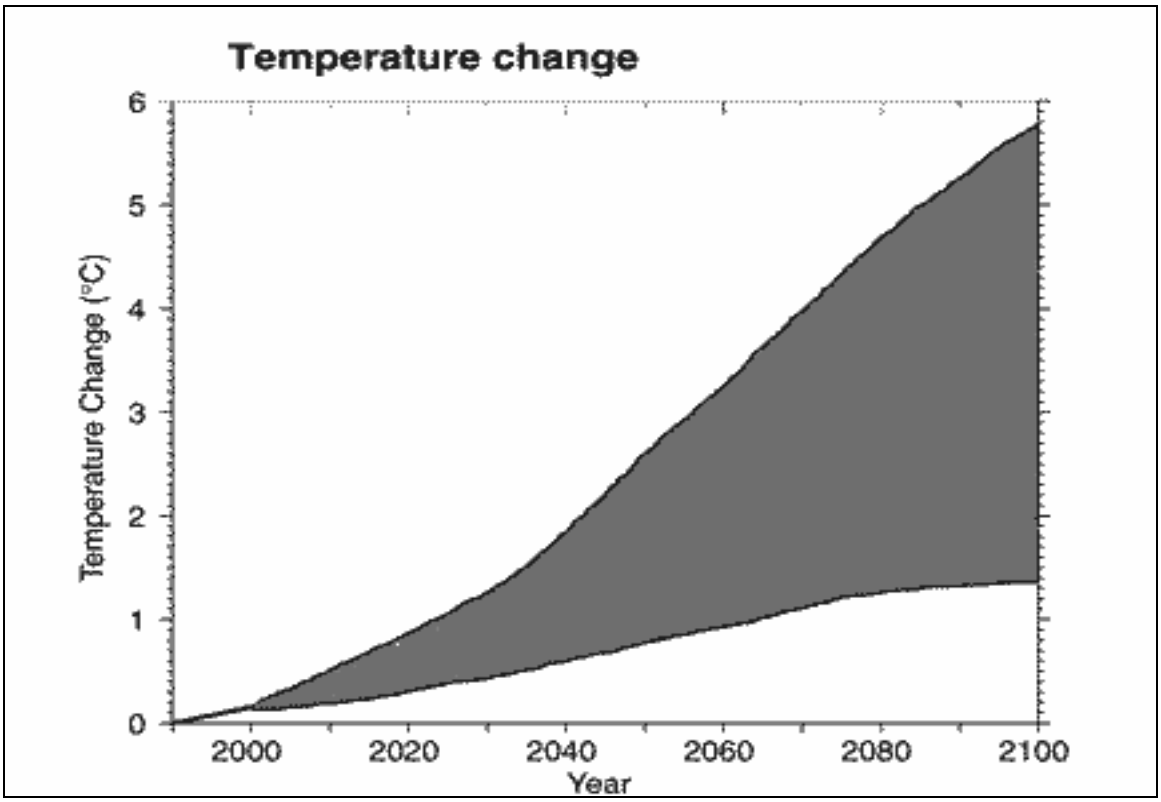


Figure 2-6 Range of Projections Reported by the Intergovernmental Panel on Climate Change for Increasing Global Average Surface Temperature Through 2100.

Source: United States Environmental Protection Agency website at: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ClimateFutureClimateGlobalTemperature.html

Climate change and temperature projections can be developed on a regional basis using techniques to "downscale" from the results of global models. The level of uncertainty related to regional climate change and temperature projections is generally higher than global projections since downscaling adds more uncertainty. One relatively large group of model projections that was recently examined for California provides a range of about 2.5 to 9 degrees Celsius temperature rise for Northern California by 2100. An analysis of the distribution of the projections generally showed a central tendency at about 3 degrees Celsius of rise for 2050, and about 5 degrees Celsius for 2100 (Dettinger, 2005).

2.5 Changes in Precipitation and Runoff

Climate change appears to have already affected precipitation and runoff in California. More changes are expected in the future as additional changes in the Earth's climate occur. Some of the possible effects of climate change on precipitation as well as potential consequences of those effects are listed in Table 2-3.

While all possible changes in precipitation due to climate change are of potential concern for management of the State's water resources, this section deals mainly with potential changes in the amount, form and variability of precipitation. Existing climatologic and hydrologic data are generally suitable for evaluating historical trends for these three factors. Most research and climate change modeling efforts have focused on potential changes in the amount and form of precipitation in California. Historical information and research efforts are not as abundant or as conclusive for other past and possible future changes in precipitation in California.

2.5.1 Worldwide Precipitation Observations and Projections

Worldwide trends in precipitation over land are hard to determine. The difficulties arise from limited measurements worldwide and measurement problems, such as "undercatch" for precipitation gauges (Hulme, 1995). Where available, streamflow measurements and other information can be used as a proxy record for precipitation.

Worldwide precipitation is reported to have increased about 2 percent since 1900. While global average precipitation has been observed to increase, changes in precipitation over the past century vary in different parts of the world. Some areas have experienced increased precipitation while other areas have experienced a decline (NOAA, 2005). Figure 2-7 illustrates worldwide variation in changes in precipitation over the past century.

Precipitation and streamflow records indicate an increase in precipitation over land at a rate of about 0.5 to 1 percent per decade for the middle and high latitudes of the northern hemisphere, except for East Asia. No comparable wide-scale changes in precipitation have been observed for the Southern Hemisphere. Land surface rainfall in the subtropics has decreased an average of about 0.3 percent per decade (IPCC, 2001a).

Total atmospheric water vapor content has been noted to increase at a rate of several percent each decade in the Northern Hemisphere since about 1980 (IPCC, 2001a). Some studies suggest that regional cloudiness has increased over the past century. Satellite data show a general trend for increasing cloud cover over land and the oceans since the early 1980s. This trend appears to have reversed in the early 1990s (NOAA, 2005).

Table 2-3 Possible Effects of Climate Change on Precipitation in California and Potential Consequences

Possible Changes in Precipitation	Potential Consequences
Amount	Increased precipitation could benefit water supplies and improve environmental conditions in some areas, especially where water supply diversions have significantly affected streamflow. Increased precipitation could also increase the incidence of flooding, depending on the timing and intensity of precipitation. Decreased precipitation could have serious consequences for water supplies and the environment.
Form	Climate warming is expected to increase minimum snow elevations in California's mountains and cause more precipitation to fall in the form of rain rather than snow. This will result in reductions of annual snowpack and reduce effective water storage for maintaining spring and summer streamflow/water supply diversions. Reductions in snowpack could also negatively affect hydroelectric power generation and flood control operations.
Intensity, Duration, and Timing of Precipitation Events	Increased intensity or duration of precipitation events could increase the frequency and severity of flooding. Decreases could reduce flooding. Climate change could affect the incidence of precipitation events where rain falls on accumulations of snowpack. If the incidence or severity of such events increase, it could have serious flood control and water supply implications.
Variability	Increased variability in annual precipitation could present significant challenges for water managers in meeting water demands and providing flood control. Increased surface storage capacity, operational changes for reservoirs and additional use of groundwater storage could be required. Decreased variability could benefit water management.
Location	Shifts in the annual average distribution of precipitation in the State, due to possible changes in regional circulation patterns or other possible causes, could benefit some regions and negatively affect others. California's major water storage and conveyance systems are located and designed in accordance with the historic distribution of precipitation. Significant shifts in the distribution of precipitation could pose serious water management challenges, jeopardize the effectiveness of the State's existing water supply infrastructure and alter ecosystems.

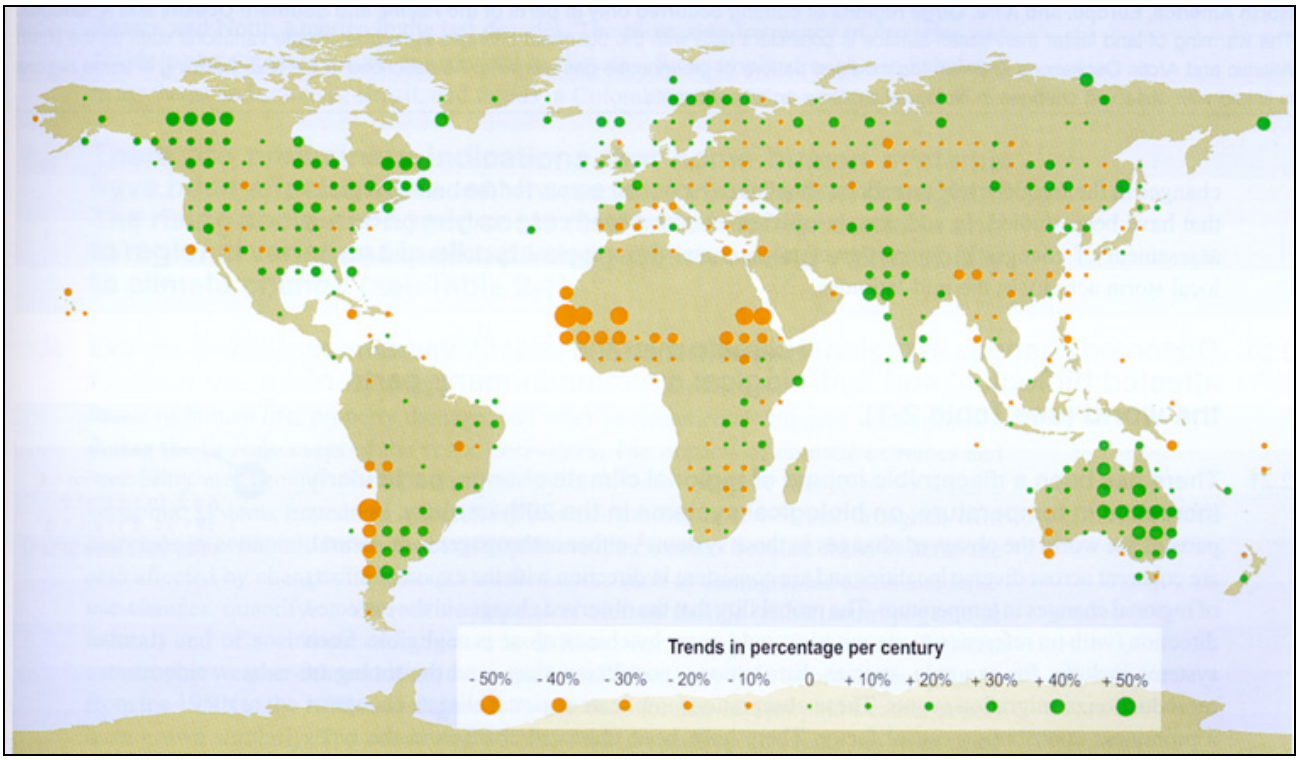


Figure 2-7 Worldwide Precipitation Trend for 1900 to 2000
Source: (IPCC, 2001b) http://www.grida.no/climate/ipcc_tar/vol4/english/fig2-6a.htm

The Intergovernmental Panel on Climate Change predicts that increasing global surface temperatures are very likely to result in changes in precipitation (IPCCb, 2001). Rising temperatures are expected to increase the activity of the world's hydrologic cycle and increase the moisture content of the atmosphere. Water vapor in the atmosphere is a greenhouse gas and will likely provide a positive feedback mechanism for climate warming.

Global average precipitation is expected to increase during the 21st century as the result of climate change based on global climate models for a wide range of greenhouse gas emission scenarios. Regional changes in precipitation will vary (IPCCa 2001). Global climate models are generally not well suited for predicting regional changes in precipitation due to their coarse discretization compared to the scale of regionally-important factors that affect precipitation.

Climate warming may have resulted in an increased occurrence of high-intensity rainfall in various areas with significant regional variation, including the United States (Groisman, 2005; Easterling, 2000). Continued warming through the 21st century may result in further increases in the occurrence of high-intensity rainfall (IPCC, 2001a; Groisman, 2005).

2.5.2 Precipitation Trends in the Western United States and California

An analysis of trends in total annual precipitation in the western United States by the National Weather Service, Climate Prediction Center provides evidence that annual precipitation has increased in much of California, the Colorado River Basin, and the West since the mid-1960s. Figure 2-8 depicts linear trends in annual precipitation in the western United States for areas referred to as "climate divisions."

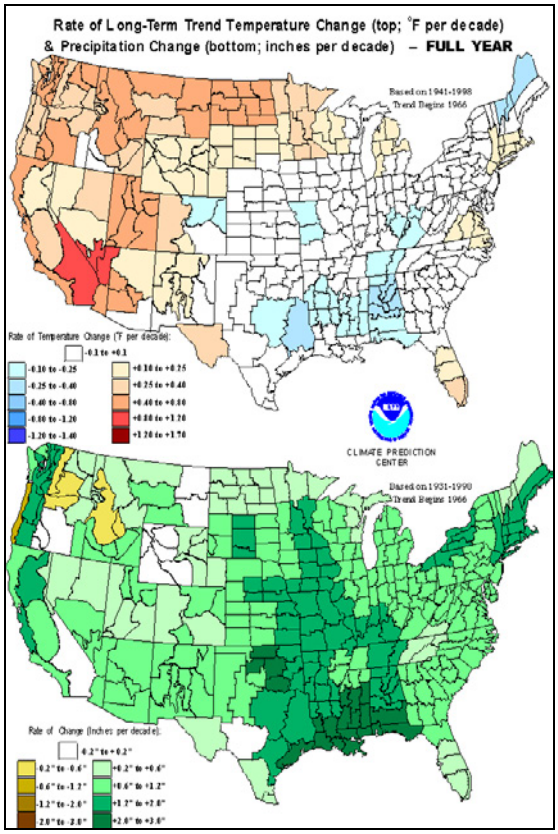


Figure 2-8 Long-Term Linear Trend Rates for Annual Precipitation in Western United States

Explanation: Rate of change is depicted for areas referred to as climate divisions. Trends are based on precipitation data from 1931-1998; however, the linear trends shown are from 1966 to 1998. For additional information concerning this figure and the determination of depicted precipitation trends visit: http://www.cpc.ncep.noaa.gov/trend_text.shtml#limits.

Adapted From: National Weather Service, Climate Prediction Website at http://www.cpc.ncep.noaa.gov/anltrend.gif

Most of the precipitation in the western U.S. falls in November through March, although monsoonal rainfall can be a locally-important factor in the Southwest from July to September. California's precipitation season is generally considered to start about mid-October and end in

April. However, most of the State's precipitation typically falls in the months just before and just after the beginning of each calendar year.

Mote and others (Mote, 2005) evaluated trends in annual November through March precipitation for the western United States and southwest Canada. Figure 2-9 depicts linear trends in November through March precipitation for two periods, 1930 to 1997 and 1950 to 1997. Precipitation trends for most of California and the Southwest are positive (increasing precipitation) during both periods.

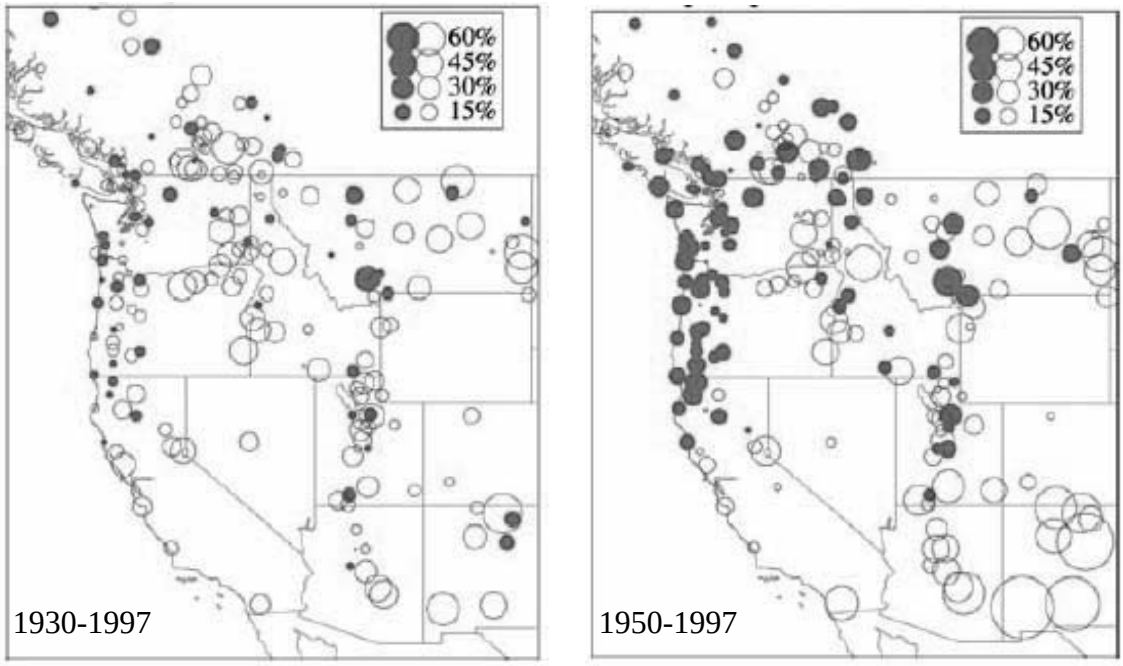


Figure 2-9 Precipitation Trends for the Western United States and Southwest Canada from 1930 to 1997 (left figure) and 1950 to 1997 (right figure)

Explanation: Depicted linear trends are for annual precipitation occurring from November through March. Decreasing precipitation trends are depicted in solid red circles. Increasing precipitation trends are depicted in open blue circles.

Source: Adapted from Mote (2005).

Former State Climatologist James Goodridge compiled an extensive collection of long-term precipitation records from throughout California. These data sets were used to evaluate whether there is a trend in precipitation in the State over the past century. Long-term runoff records in selected watersheds in the State were also examined. Figure 2-10 illustrates the variability in statewide annual average precipitation from 1890-2002. Statewide average precipitation was determined from 102 stations throughout the State. Based on a linear regression of the data, the long-term historical trend for statewide average annual precipitation appears to be relatively flat (no increase or decrease) over the entire record. However, it appears that there may be an upward trend in precipitation toward the latter portion of the record.

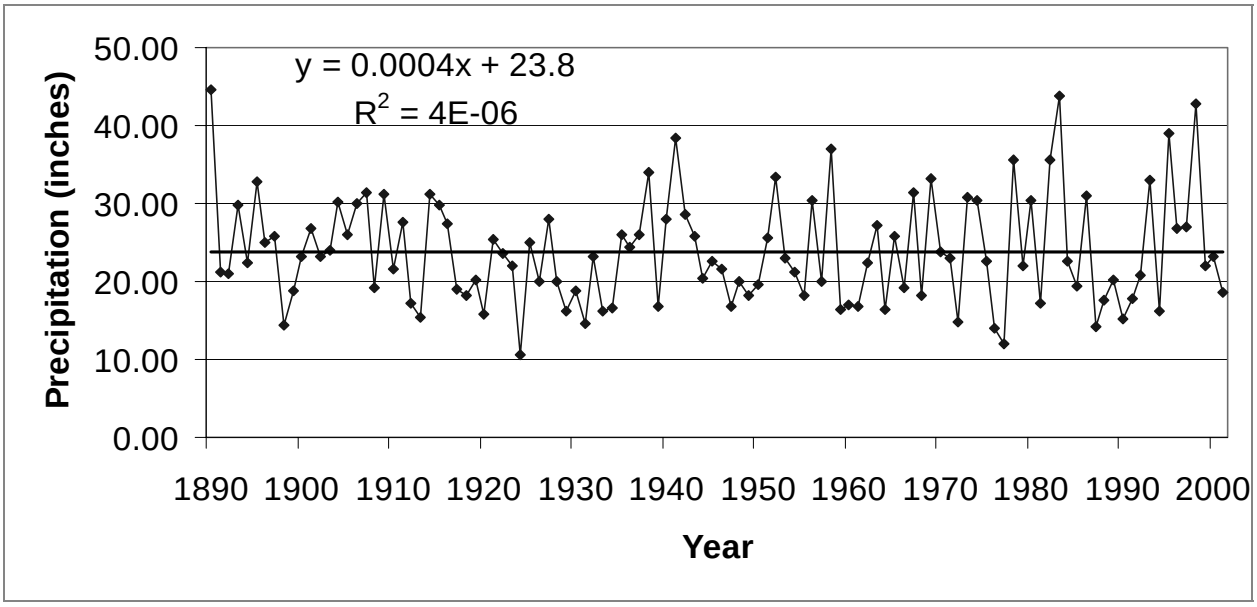


Figure 2-10 Annual Average Precipitation for California from 1890 to 2002 with Linear Trend

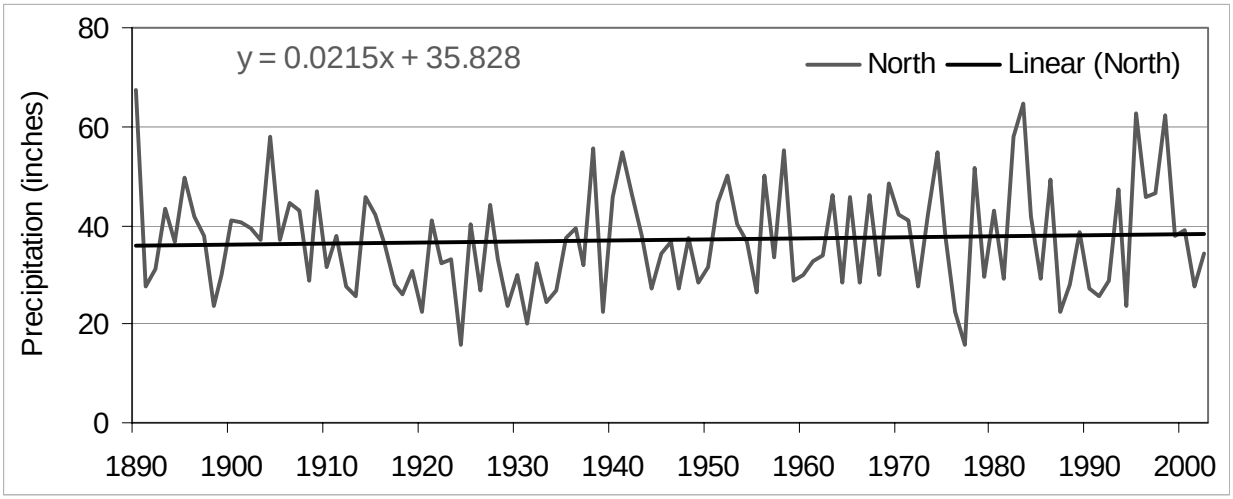
Most of the State's precipitation occurs as the result of storms from the Pacific Ocean. Hemispheric-scale circulation patterns typically cause most of these storms to move eastward across the northern part of the State. The largest amounts of precipitation fall in the mountains due to orographic effects. While a significant number of Pacific storms also cross the central and southern portions of the State, annual precipitation tends to decrease with decreasing latitude.

State precipitation records were sorted into three regions by latitude as follows:

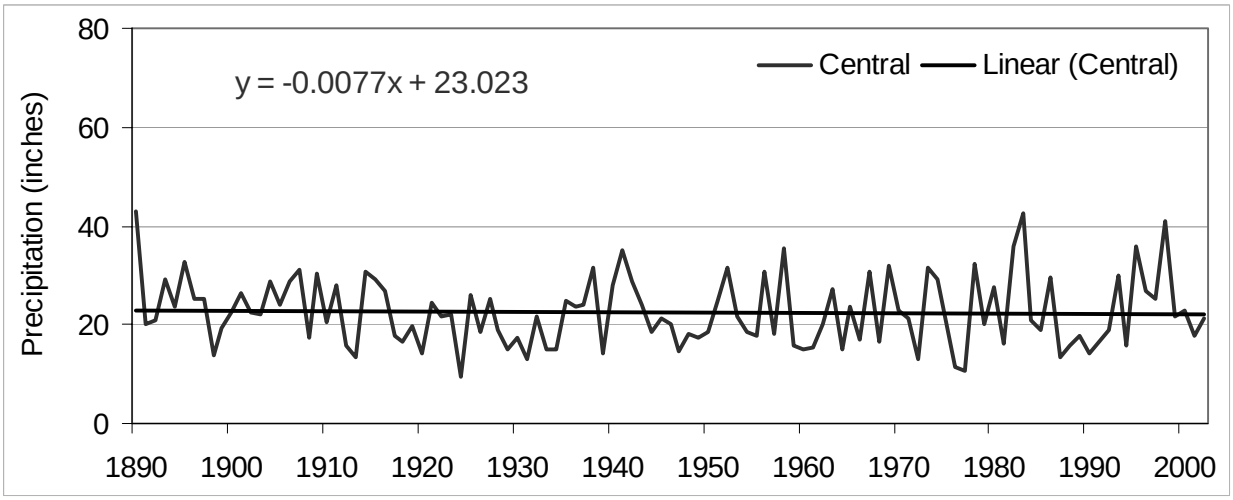
- North; from the California - Oregon border to 39 degrees latitude (latitude where California's eastern border begins to trend northwest at Lake Tahoe);
- Central; 39 to 35 degrees latitude (approximate latitude of Santa Maria); and
- South; 35 degrees latitude to the California – Mexico border.

Annual average precipitation values from 1890 to 2002 are plotted with linear trend lines for these three regions in Figure 2-11. The plots depict decreasing precipitation with decreasing latitude. Precipitation in the northern portion of the State appears to have increased slightly from 1890 to 2002. Increasing runoff trends observed for various Northern California watersheds, as discussed in Section 2.5.3 below, are consistent with the apparent increasing precipitation trend in this part of the State. Precipitation in the central and the southern portions of the State appear to have slightly decreasing trends from 1890 to 2002.

a) Northern Region: California-Oregon border to 39º latitude



b) Central Region: 39º - 35 º latitude



c) Southern Region: 35 º latitude to California-Mexico border

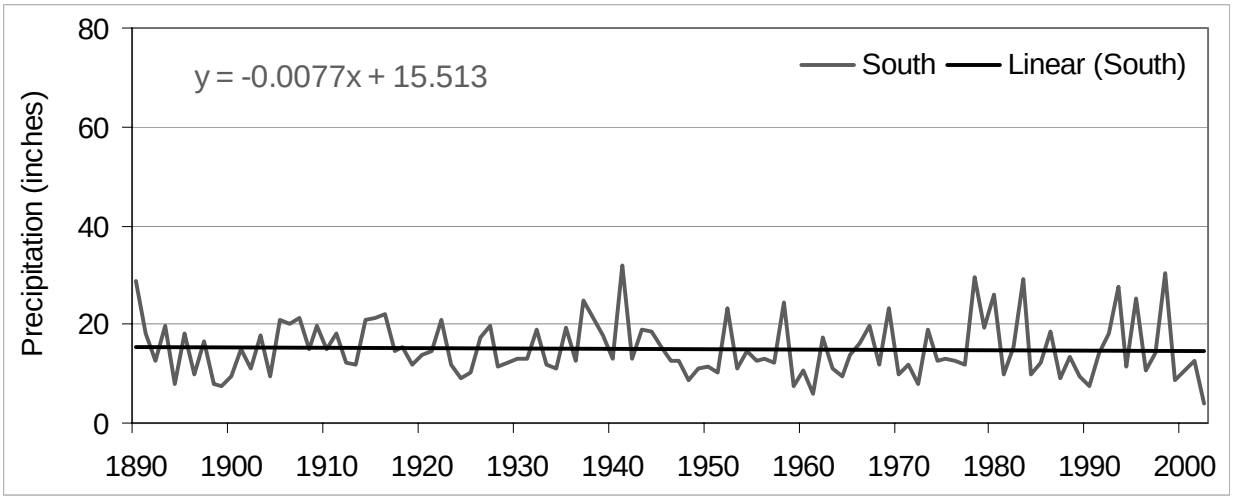


Figure 2-11 Annual Average Precipitation from 1890 to 2002 with Linear Trends by Region

Differences in California precipitation trends between those observed by the National Weather Service, Mote and others, and above analysis are likely due to differences in the:

- the period of analysis
- number and location of precipitation measurement stations used
- geographic regions selected for analysis

While increasing precipitation on a global scale is generally an expected result of climate change, significant regional differences in precipitation trends can be expected. More analysis of precipitation trends in California is probably needed for determining whether changes in California's regional annual precipitation totals have occurred as the result of climate change or other factors.

In addition to possible long-term trends in annual amounts of precipitation, increased variability of annual precipitation is also a possible outcome of climate change. Figure 2-12 depicts the coefficient of variation (standard deviation divided by the mean) based on a 10-year moving average of mean and standard deviation values for statewide annual average precipitation. There appears to be an upward trend in the variability of precipitation over the past century with end-of-period variability values about 75 percent larger than beginning-of-period values. This indicates that there tended to be more extreme wet and dry years at the end of the century than there were at the beginning of the century. This trend may continue with on-going climate change.

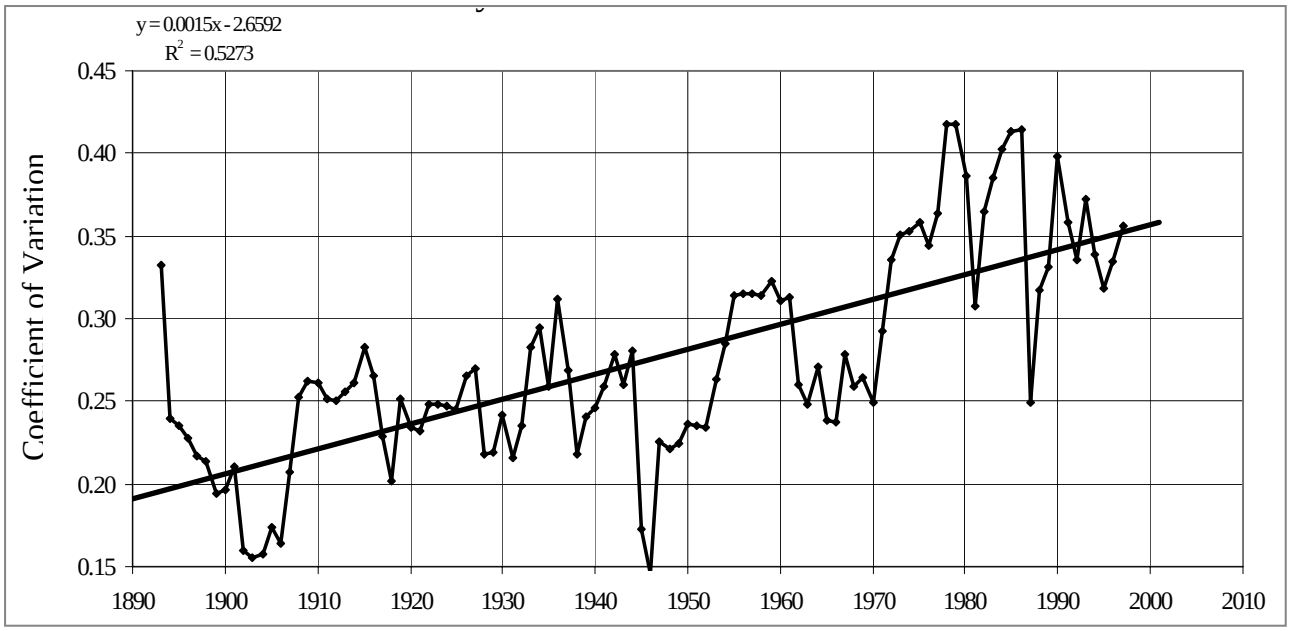


Figure 2-12 Coefficient of Variation for Annual Average Precipitation in California from 1890 to 2001 with Trend Line

2.5.3 Trends in Snowfall and Related Runoff in California

Precipitation in California's higher mountains during the late fall and winter typically falls in the form of snow. Significant accumulations of snow, referred to as snowpack, typically occur each year in the Sierra Nevada along the eastern flank of the Central Valley. A significant annual snowpack also typically occurs in the Cascade Range north and northeast of the Central Valley, and in the Klamath Mountains in the northwest corner of the State. Most of the runoff from the State's snowpack flows into the Central Valley, although snowmelt is also important for flows in rivers and streams on the east slope of the Sierra, such as the Truckee, Carson, and Owens rivers, and for the Klamath River and its tributaries.

California's annual snowpack is, on average, mostly accumulated from November though the end of March. It typically melts from April though July. Snowmelt provides significant quantities of water to streams and reservoirs for several months after the annual storm season has ended. The length and timing of each year's period of snowpack accumulation and melting can vary somewhat due to temperature and precipitation conditions.

California's snowpack is important to the State's annual water supply, because of its volume and when it typically melts. Average runoff from melting snowpack is usually about 20 percent of the State's total annual natural runoff, and probably about 35 percent of the State's total useable annual surface water supply. The State's snowpack is estimated to contribute an average of about 15 million acre-feet of runoff each year, about 14 million acre-feet of which is estimated to occur in the Central Valley. In comparison, total reservoir capacity in the Central Valley is about 24.5 million acre-feet in watersheds with significant annual accumulations of snow (DWR, 2005c).

California's reservoir managers use snowmelt to help fill reservoirs once the threat of large winter and early spring storms and related flooding risks have passed. Water stored in reservoirs is used to help meet downstream water demands when flows from snowmelt begin to recede and are typically not sufficient for satisfying downstream uses.

Some of the annual runoff collected in California's reservoirs is held from one year to the next. Water stored from one year to the next is typically referred to as "carryover storage". California's annual precipitation and snowpack can vary significantly from year to year in California. There may also be decadal-scale variation in precipitation over the Sierra (Freeman, 2002), and possibly other parts of California. Carryover storage can help meet water demand in years where precipitation and runoff is low.

Rising temperatures as the result of climate change threaten California's snowpack. An inchoative analysis of annual runoff trends in the Sacramento Valley was performed by Maurice Roos of DWR in the late 1980s (Roos, 1989). The purpose of the analysis was to determine if changes in the timing of annual runoff in the Sacramento Valley watershed had occurred as the result of possible increasing temperatures and diminished snowpack. It was concluded that, since the beginning of the 20th century, the amount of annual runoff from April though July in the upper Sacramento River watershed had a downward trend compared to each year's total runoff. This was determined to be a possible indication of a long-term reduction in the State's snowpack due to temperature rise.

An updated evaluation of runoff trends was performed for this report. Figure 2-13 presents combined unimpaired April through July runoff for four rivers in the Sacramento Valley (Sacramento, Feather, Yuba, and American rivers) as a percent of total water year runoff from 1906 to 2005. Figure 2-14a presents total April through July unimpaired runoff volume for the same period of record and for the same four rivers. Figure 2-14b presents total unimpaired water year runoff volume for the same period and rivers.

Based on the linear trends depicted in Figure 2-13 and Figure 2-14 for the four Sacramento Valley rivers:

- April through July runoff, as compared to total water year runoff, has declined about 9 percent over the past 100 years
- April through July runoff volume has decreased over the same period and total water year runoff during the same period has remained about the same

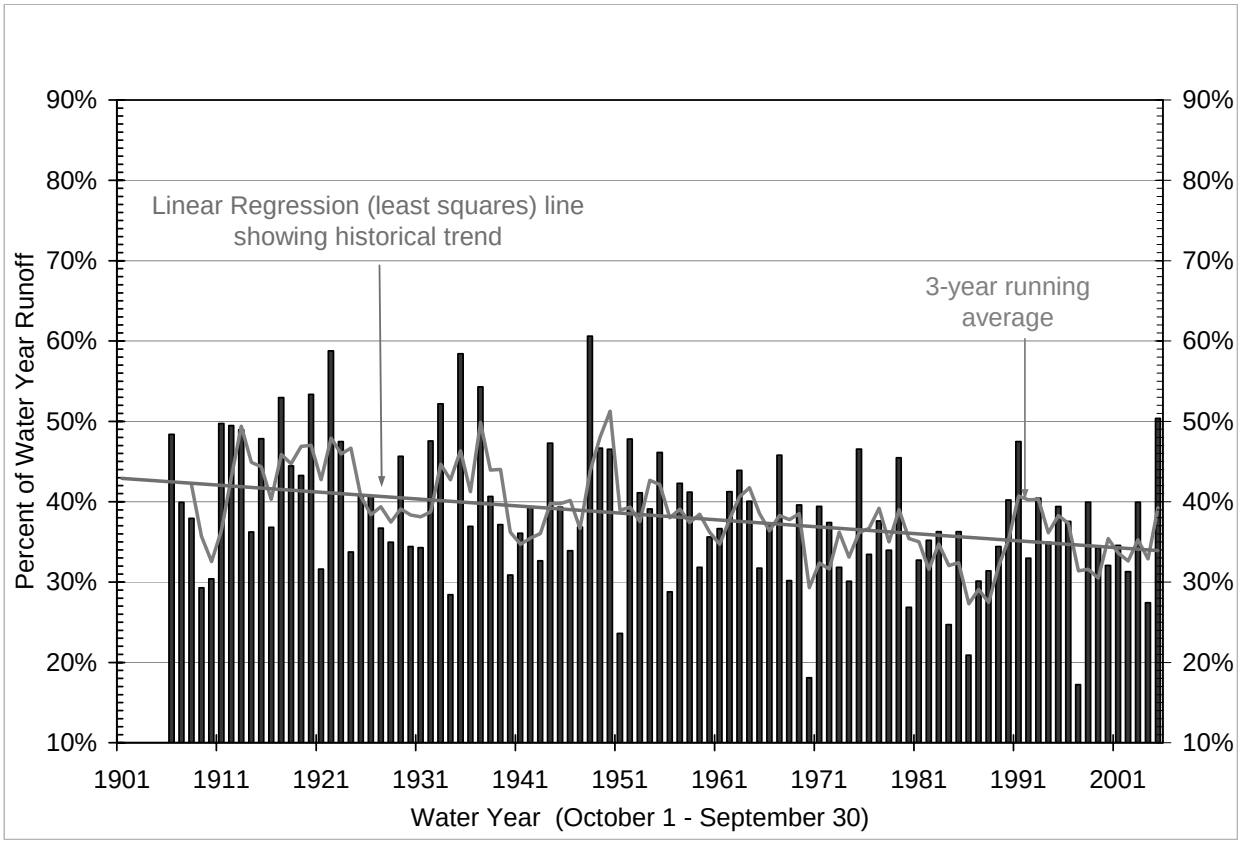
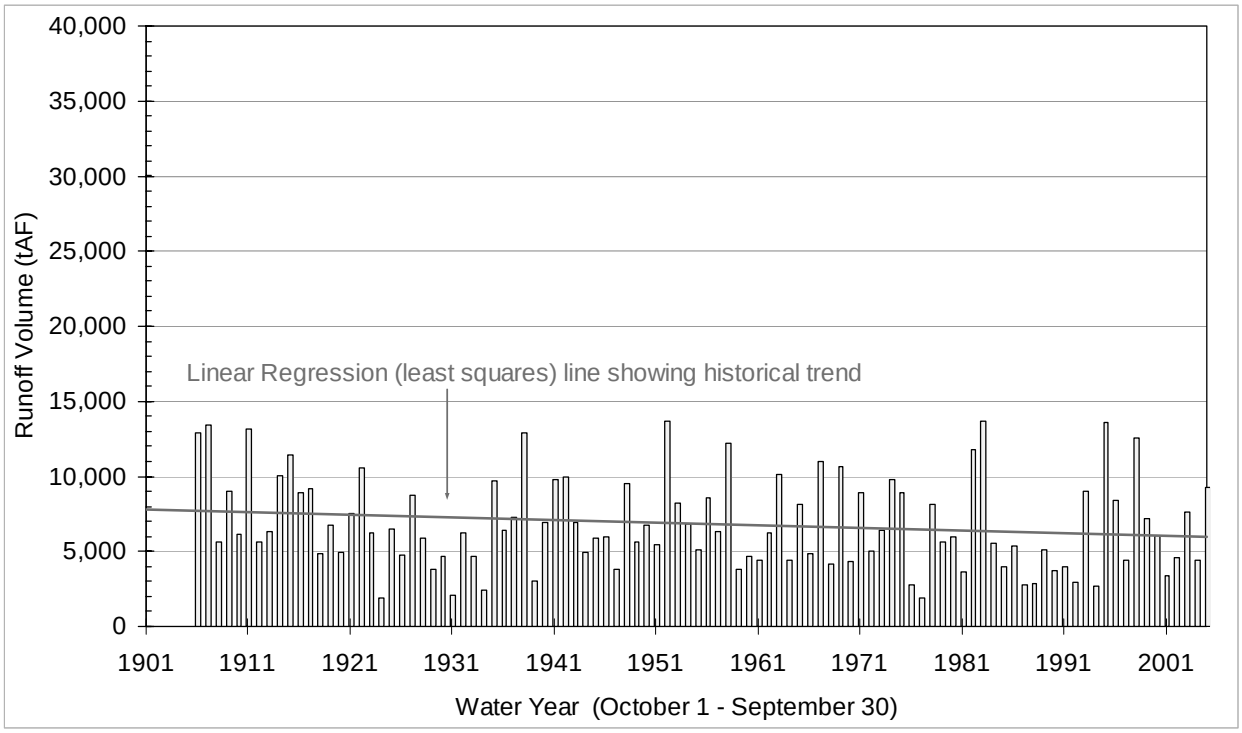


Figure 2-13 Annual April through July Unimpaired Runoff for Four Sacramento Valley Rivers Compared to Total Unimpaired Annual Runoff*

* Based on the flows of four rivers in the Sacramento Valley; Sacramento River at Bend Bridge (near Red Bluff), Feather River into Lake Oroville, Yuba River at Smartville, and American River below Lake Folsom.

a) Annual April through July Runoff Volume



b) Total Water Year Runoff Volume (October-September)

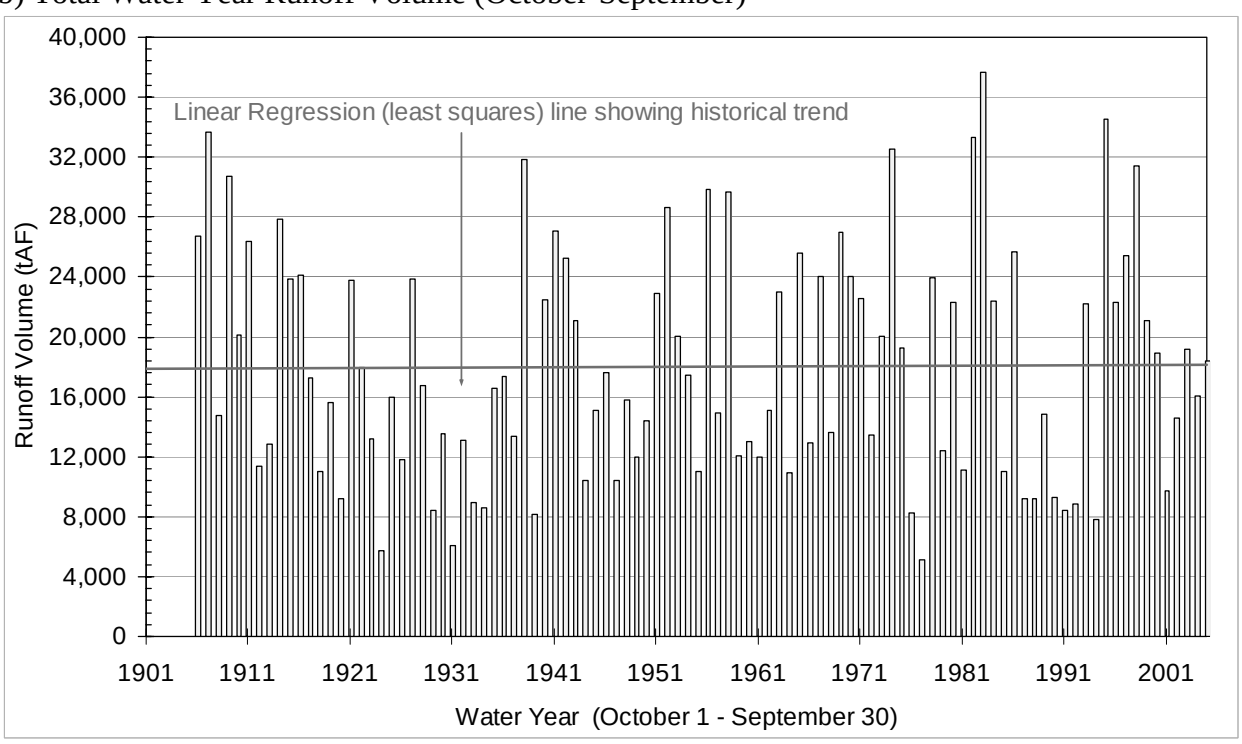


Figure 2-14 Unimpaired Runoff Volume for Four Sacramento Valley Rivers*

* Based on the flows of four rivers in the Sacramento Valley; Sacramento River at Bend Bridge (near Red Bluff), Feather River into Lake Oroville, Yuba River at Smartville, and American River below Folsom Lake. (taf) = thousand acre feet.

Figure 2-15 presents combined unimpaired runoff from April through July for four rivers in the San Joaquin River watershed (Stanislaus, Tuolumne, Merced, and San Joaquin rivers) as a percentage of total water year runoff from 1901 to 2005. Figure 2-16a presents total unimpaired April through July runoff volume for the same four rivers and for the same period of record. Figure 2-16b presents total unimpaired water year runoff volume.

The trends depicted in Figure 2-15 and Figure 2-16 for the four San Joaquin Valley rivers indicate that:

- April through July runoff, as compared to total water year runoff, has declined about 7 percent over about the past 100 years
- while total water year runoff volume decreased somewhat during the past 100 years, April through July runoff volume decreased at even a greater rate.

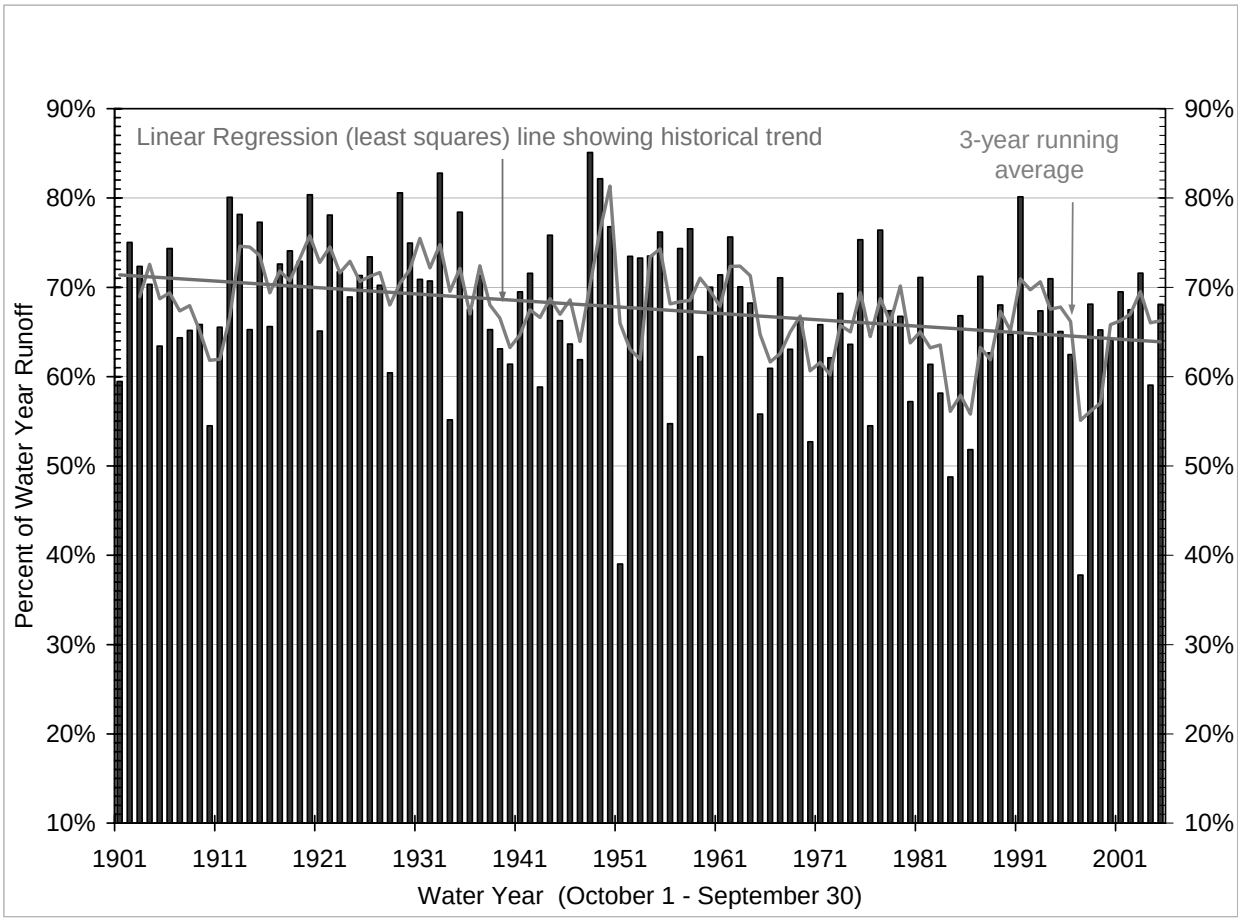
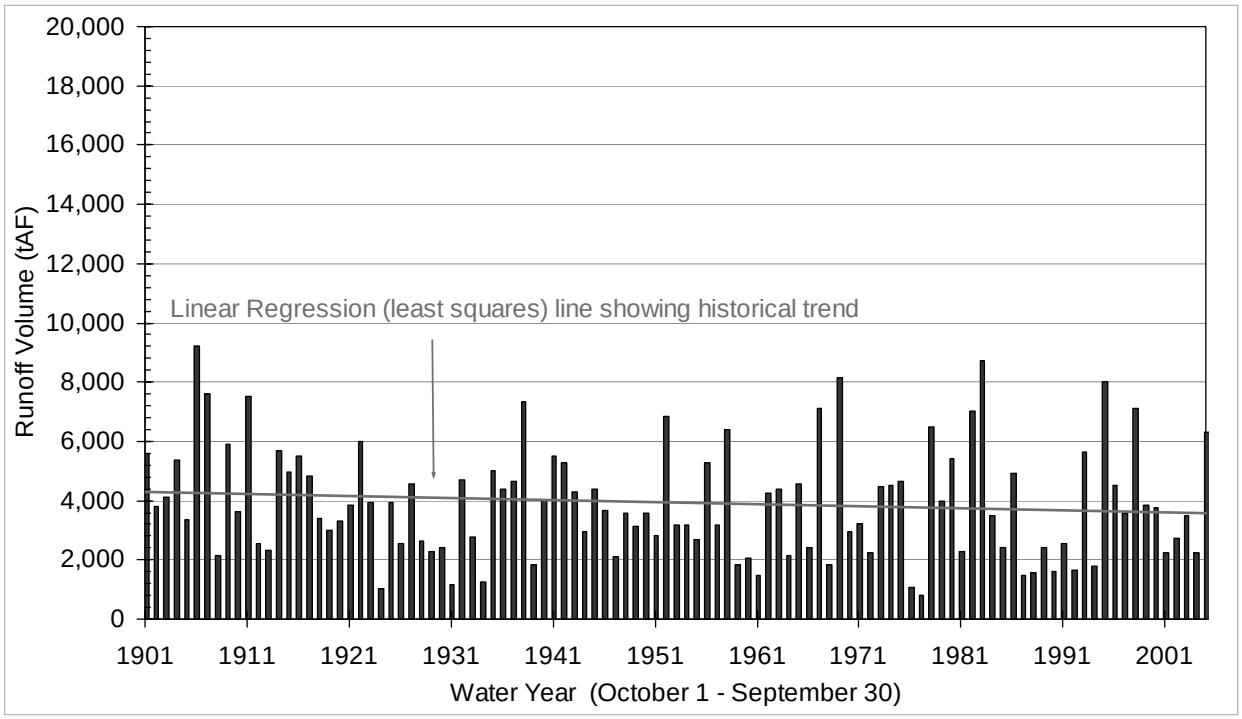


Figure 2-15 Annual April through July Unimpaired Runoff for Four San Joaquin Valley Rivers Compared to Total Unimpaired Annual Runoff*

*Based on the flows of four rivers in the San Joaquin Valley; Stanislaus River into New Melones Reservoir, Tuolumne River into Don Pedro Reservoir, Merced River into Lake McClure, and San Joaquin River into Lake Millerton.

a) Annual April through July Runoff Volume



b) Water Year Runoff Volume

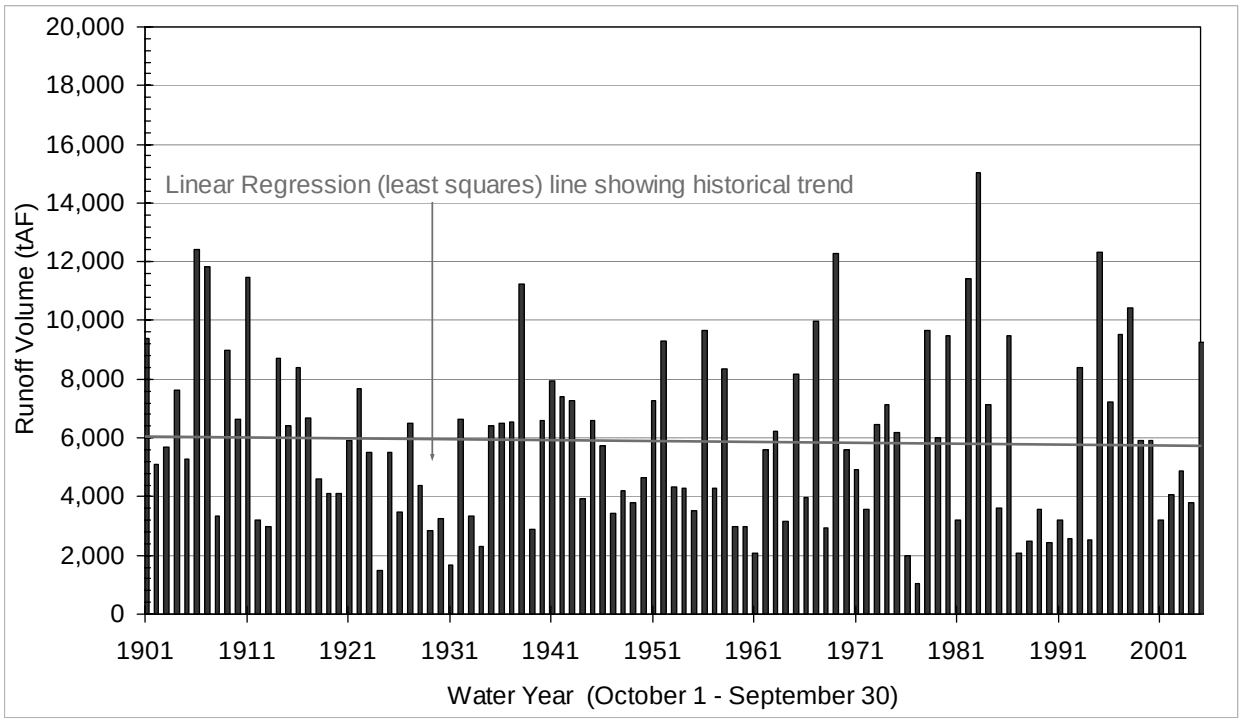


Figure 2-16 Total Unimpaired Runoff Volume for Four San Joaquin Valley Rivers*

*Based on the flows of four rivers in the San Joaquin Valley; Stanislaus River into New Melones Reservoir, Tuolumne River into Don Pedro Reservoir, Merced River into Lake McClure, and San Joaquin River into Lake Millerton. (taf) = thousand acre feet.

Some investigators have evaluated trends in Sierra runoff for different time periods over the past century. Figure 2-17 depicts two trends in April through July runoff as a percentage of total annual runoff for eight western Sierra rivers. No statistically significant downward or upward trend was determined for the period before 1945. However, the trend following 1945 is toward diminished runoff from April through July as compared to total annual runoff (Dettinger, 2005a).

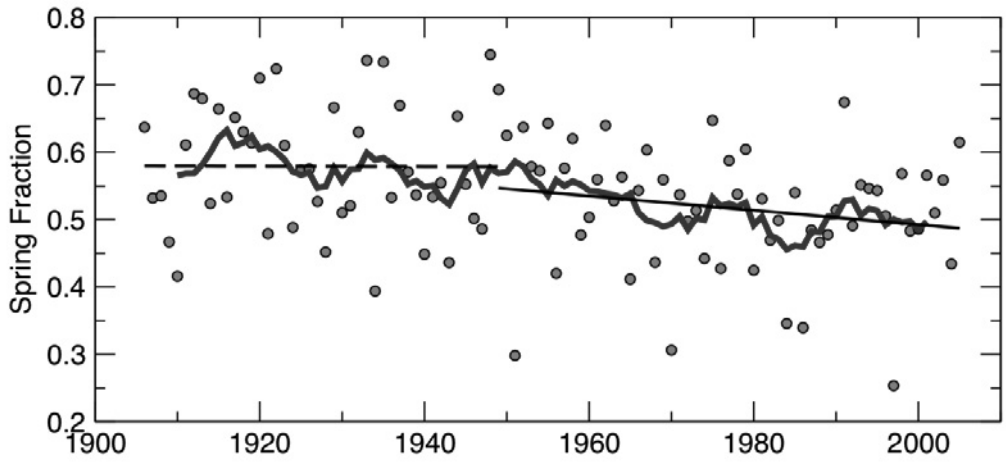


Figure 2-17 Annual April through July Unimpaired Runoff in the Central Valley Compared to Total Unimpaired Annual Runoff

Source: Dettinger, 2005a. (Updated by original author).
Explanation: Individual points depict yearly combined values for the Sacramento River at Bend Bridge (near Red Bluff), Feather River into Lake Oroville, Yuba River at Smartville, American River below Folsom Reservoir, Stanislaus River into New Melones Reservoir, Tuolumne River into Don Pedro Reservoir, Merced River into Lake McClure, and Kings River into Pine Flat Reservoir. The blue curve is the nine-year moving average of annual values. The dashed line is the linear trend prior to 1945. The solid line is the linear trend after 1945.

Updated runoff data for the Sacramento Valley and San Joaquin Valley, as discussed above, continue to support the conclusion from earlier analyses that there appears to be a long-term trend toward reduced April though July runoff compared to total annual runoff from the Sierra. It is reasonable to conclude that this trend is the likely result of climate change and warming and an attendant decline in Sierra snowpack. A portion of the trend may also be attributable to progressively earlier melting of Sierra snowpack due to warming.

The trend toward diminished April through July runoff, as compared to total annual runoff, appears to be stronger for the Sacramento Valley than for the San Joaquin Valley, as evidenced by Figure 2-13 and Figure 2-15. This may be due to elevation differences between the northern and southern Sierra. Rising temperatures could be expected to impact the northern Sierra snowpack to a greater degree than the southern Sierra snowpack because the northern Sierra is generally lower in elevation than the southern Sierra.

Table 2-4 summarizes runoff statistics and linear trends for the Sacramento and San Joaquin Valleys, selected river basins in the two valleys, and selected rivers elsewhere in the State where data could be readily obtained and where unimpaired flows could be determined or inferred. The

long-term trend in April through July runoff volumes for the Sacramento and San Joaquin valleys is downward, as are the trends for individual Sacramento Valley basins listed in the table. April through July runoff volume trends for most of the San Joaquin Valley basins listed in the table are also downward. These trends are consistent with the previously discussed conclusion that the Sierra snowpack is undergoing decline, possibly because of warming. Total water year runoff in the Sacramento Valley has an increasing trend while total water year runoff in the San Joaquin Valley appears to be decreasing on a long-term basis.

Outside of the Central Valley, the most noteworthy temporal change evident in Table 2-4 is an increasing trend in total water year runoff in the major river basins in the north coast portion of the State.

Table 2-4 Runoff Statistics and Trends for Selected River Basins in California

Basin/River System	Period of Record	Period A-J[1] Average (TAF)[3]	Period WY[2] Average (TAF)	Period A-J Linear Trend (TAF/yr)[4]	Period WY Linear Trend (TAF/yr)[4]
Central Valley River Systems					
Sacramento River System[5]	1906-2005	6,847	18,024	-17	3
San Joaquin System[6]	1901-2005	3,922	5,900	-7	-3
Sacramento Valley Basins					
Sacramento at Bend Bridge	1906-2005	2,522	8,476	-3	6
Feather	1906-2005	1,901	4,490	-6	2
Yuba	1901-2005	1,096	2,372	-3	-2
American	1901-2005	1,359	2,739	-5	-3
North San Joaquin Valley Basins					
Cosumnes	1908-2005	127	369	0	0
Mokelumne	1901-2005	487	758	-1	-1
Stanislaus	1901-2005	745	1,175	-2	-1
Tuolumne	1901-2005	1,248	1,911	-1	0
Merced	1901-2005	646	997	-1	0
San Joaquin	1901-2005	1,283	1,816	-2	-1
South San Joaquin Valley Basins					
Kings	1901-2005	1,238	1,683	-2	-1
Kaweah	1901-2005	285	432	0	0
Tule	1930-2005	63	145	0	0
Kern at Isabella	1930-2005	453	697	0	1
Kern at Bakersfield	1901-2005	473	739	0	2

Table 2-4 Runoff Statistics and Trends for Selected River Basins in California (continued)

Basin/River System	Period of Record	Period A-J[1] Average (TAF)[3]	Period WY[2] Average (TAF)	Period A-J Linear Trend (TAF/yr)[4]	Period WY Linear Trend (TAF/yr)[4]
Eastern Sierra Basins					
East Carson and West Walker	1922-2005	326	433	1	2
Truckee	1906-2005	274	452	-1	0
North Coast Basins					
Klamath	1928-2005*	1,665	4,646	1	7
Salmon	1912-2005*	521	1,288	0	2
Eel	1911-2005	914	5,493	0	12
Napa	1930-2005*	8	72	0	0
Russian	1941-2005	101	897	0	1
Central and South Coast Basins					
Arroyo Seco near Soledad	1906-2005	23	122	0	0
Arroyo Seco near Pasadena	1911-2005	2	7	0	0
Nacimiento	1916-2005	23	200	0	0
Santa Ana	1901-2005	21	60	0	0

Footnotes:
[1] A-J = April through July.
[2] WY = Water Year.
[3] TAF = Thousand acre-feet.
[4] Trend rounded to the nearest thousand acre-foot/year.
[5] Composite of runoff data for the Sacramento River at Bend Bridge, Feather River into Lake Oroville, Yuba River at Smartville, and American River below Lake Folsom.
[6] Composite of runoff data for the Stanislaus River into New Melones Reservoir, Tuolumne River into Don Pedro Reservoir, Merced River into Lake McClure, and the Kings River into Pine Flat Reservoir.

2.5.4 Projected Changes in Precipitation for California

2.5.4.1 Changes in the Amount of Precipitation

As discussed above, there are indications that total annual precipitation in some Northern California watersheds has been increasing. While the cause of this apparent change is unknown, it may be due in part to climate change since warming is expected to result in a more active hydrologic cycle.

Climate model projections for changes in total annual precipitation in California through the end of this century are mixed. Models predicting the greatest amount of warming generally predicted

moderate decreases in precipitation. Models projecting smaller increases in temperature tend to predict moderate increases in precipitation. When some of the most extreme projections are underweighted, the central tendency in the projections is toward moderately decreased precipitation (Dettinger, 2005b).

2.5.4.2 Changes in Snowpack

As discussed in Section 2.4, temperatures in California are projected to increase from about 2.5 to about 9 degrees Celsius by the end of this century as the result of climate change. One expected consequence of this is further reduction in the State's annual snowpack and earlier melting of snow.

Historically, average snowline elevations in California have ranged from about 4,500 feet in the north to above 6,000 feet in the southern Sierra. DWR staff estimates that the average snow-covered area totals about 13,200 square miles in the water supply producing basins of the Central Valley and the Trinity River above Lewiston. This is about 8 percent of the State's total land surface. The northern Sierra and Trinity mountains account for about 7,000 square miles of the 13,200 square mile total. The west slope of the southern Sierra accounts for the remainder.

Rising temperatures will cause reductions in the State's snowpack by raising snowline elevations and reducing the area where annual snowpack accumulates. A rudimentary analysis of the impact of rising temperatures on snowpack, shows that a 3 degree Celsius rise will likely cause snowlines to rise about 1,500 feet based on a moist lapse rate of 500 feet per 1 degree Celsius. This would cause a significant reduction in the amount of snow-covered area in the State and an estimated average annual loss of about 5 million acre-feet of effective water storage in snowpack.

Climate model studies support projections for continued reductions in the State's snowpack as the result of warming. Simulations under various amounts of temperature rise indicate that California's snowpack is very vulnerable to warming. One set of simulations by N. Knowles and D. R. Cayan (Knowles, 2002) provide the following projections for loss in April Sierra snowpack snow-water equivalent (in comparison to existing conditions) as a result of rising temperatures:

- 0.6 degree Celsius rise, ~5 percent loss
- 1.6 degrees Celsius rise, ~33 percent loss
- 2.1 degrees Celsius rise, ~50 percent loss

These three levels of average temperature rise were projected by Knowles and Cayan to occur by 2030, 2060 and 2090, respectively.

Losses in snow were projected to occur mainly at low to mid-altitudes. Loss of snowpack was projected to be greater in the northern Sierra and Cascades than in the southern Sierra due to the relative proportions of land at low and mid-elevations. At the highest temperature projection (increase of 2.1 degrees Celsius), the northern Sierra and Cascades were projected to lose 66

percent of their April snowpack, while the southern Sierra was projected to lose 43 percent of its snowpack.

Newer climate model studies, including those for the Intergovernmental Panel on Climate Change's 4th Assessment, due to be published in 2007, will provide a new set of temperature projections in addition to those already available. Most existing temperature projections, as well as those expected from the 4th Assessment, indicate that losses in the State's snowpack are likely to continue increasing through the end of this century.

Warming and loss of the State's snowpack will affect the operation of most major multipurpose reservoirs at low and mid-elevations in the Sierra. Operation of these reservoirs now includes maintaining empty flood-control space during winter months and then gradually allowing them to fill with snowmelt during the spring after the threat of storms and flooding has passed. Higher snow lines and more precipitation falling in the form of rain rather than snow will increase winter inflows to these reservoirs. Higher winter inflows will also likely mean that a greater portion of the total annual runoff volume will occur in the winter. Thus, more annual runoff will likely be passed through reservoirs and will not be available for hydropower production and water supply uses later in the year. Higher winter inflows may also diminish the ability of reservoir managers to store a portion of a year's runoff volume as annual carryover storage.

2.5.4.3 Other Effects

As discussed at the beginning of this section, climate change could affect the intensity, duration, and timing of precipitation events in California. It could also affect the spatial distribution and temporal variability of precipitation. Significant changes in one or more of these factors could have serious consequences for water resources management. While there may be some evidence that year-to-year variation in California's precipitation has increased over the past century, additional work is needed to determine the possible nature and extent of any changes that may already be occurring or could occur as a result of climate change.

2.6 Sea Level Rise

One of the major areas of concern related to global climate change is rising sea level. Worldwide average sea level appears to have risen about 0.3 to 0.6 of a foot over the past century based on tide gauge data (IPCC, 2001a). Rising worldwide average sea level over the past century has primarily been attributed to:

- warming of the world's oceans and the related thermal expansion of ocean waters (steric changes)
- the addition of water to the world's oceans from the melting of land-based ice, such as from Greenland and southeast Alaska (eustatic changes)

Some researchers have attributed most of the worldwide rise to steric changes, although there is some uncertainty about the relative contributions of steric and eustatic changes (Munk, 2002). Worldwide average sea level is projected to rise from between 0.3 of a foot and 2.9 feet by 2100, as discussed below (IPCC, 2001a).

California's coastline is about 1,075 miles in length, not including inland bays, estuaries and offshore islands. The State's coastal features include broad coastal plains and wide beaches in much of Southern California. Extensive stretches of mountainous and rugged coastline occur in the central and northern parts of the State, along with more limited coastal plains than those in Southern California. California's coastal topography is shown in Figure 2-18. The State's coastline also includes major inland bays and estuaries, including the San Francisco Bay and the Sacramento-San Joaquin River Delta (Delta), as shown in Figure 2-19.

Future sea level rise, while projected to be a relatively slow and gradual process, presents a somewhat alarming prospect for California, especially in the case of the more extreme projections. The effects of sea level rise will include:

- increased erosion of beaches, bluffs and other coastal features
- inundation of coastal land and marshes
- local flooding near the mouths of rivers and streams due to backwater effects (especially on coastal plains)
- increased potential for sea water intrusion into coastal aquifers
- increased sea water intrusion into estuaries, including the Sacramento-San Joaquin River Delta
- increased potential for levee failure in the Delta
- potential adverse impacts on flow control and diversion facilities in the Delta
- inundation and critical alteration of aquatic ecosystem habitat development projects in the Delta

.

Of the effects listed above, perhaps the most significant from the standpoint of the State's water resources are increased sea water intrusion and increased potential for levee failure in the Delta. Increased sea water intrusion into the Delta threatens the operations of the State Water Project and the Central Valley Project, as well as other Delta water supply diversions due to water quality degradation. Water quality degradation in the Delta also potentially threatens the Delta's fragile ecosystem, which supports threatened and endangered species. Finally, increased sea water intrusion into the Delta could threaten some groundwater supplies through the interaction of Delta waters with underlying and adjoining portions of the Central Valley groundwater basin.

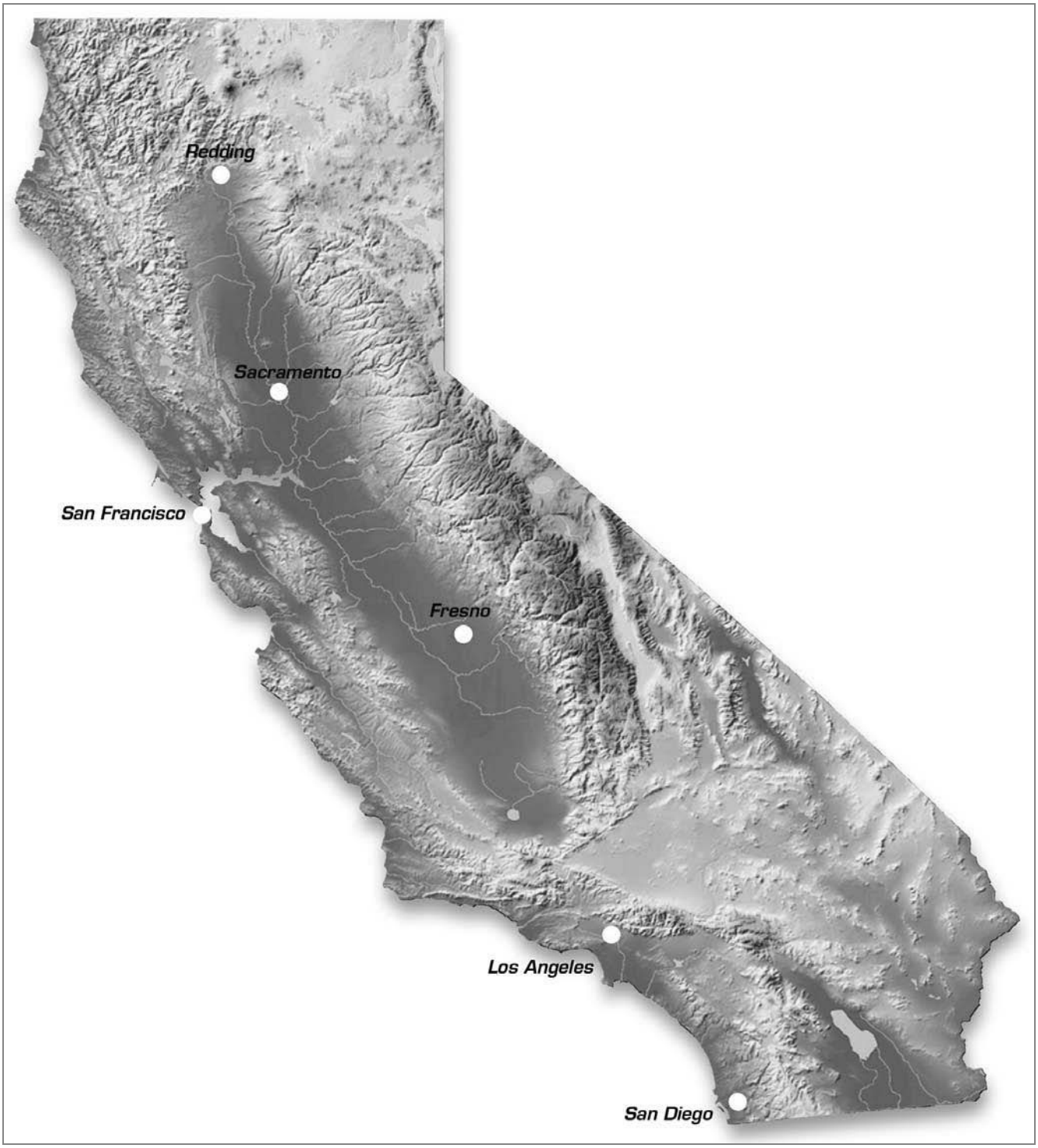


Figure 2-18 California's Topography and Coastline

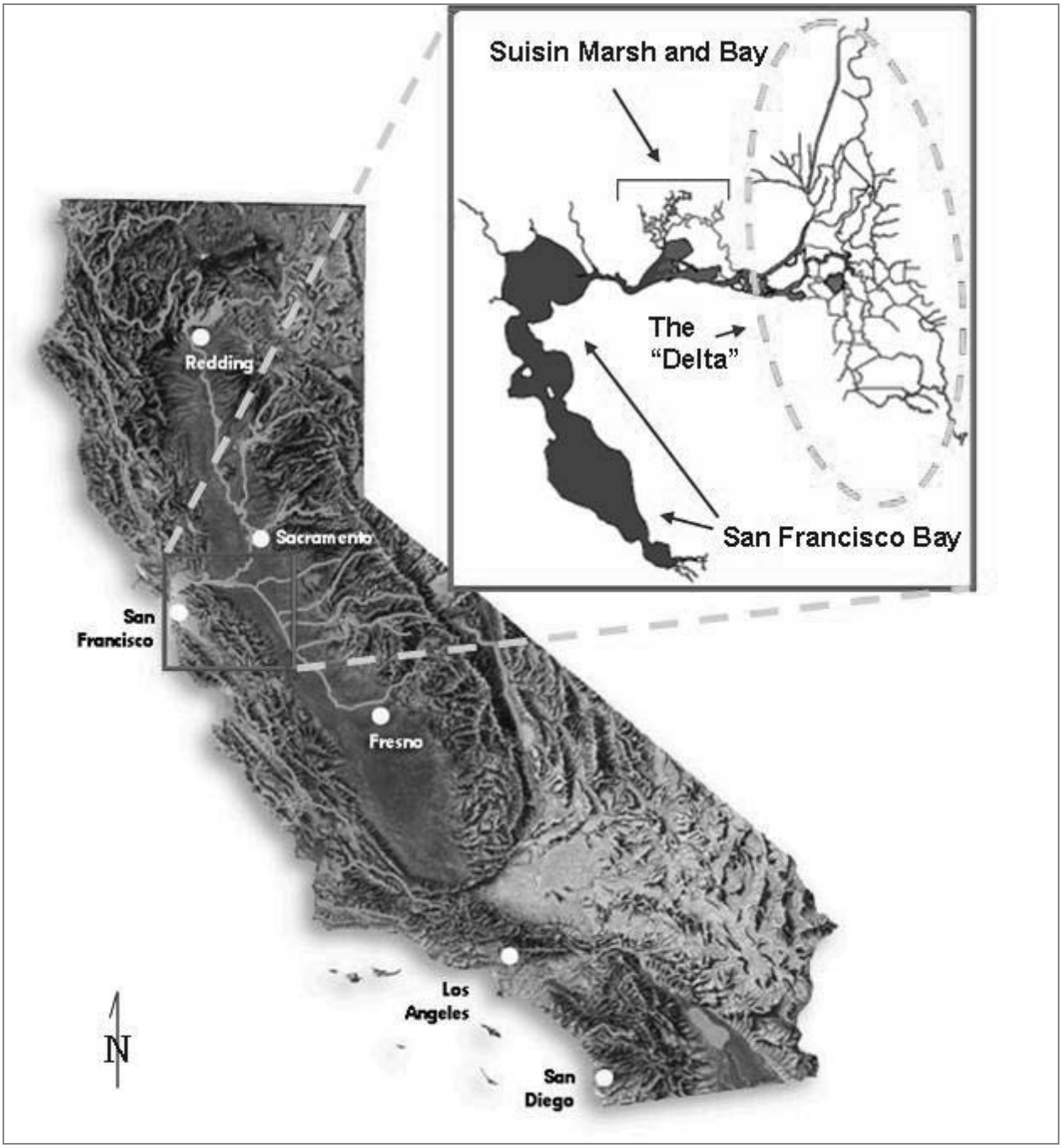


Figure 2-19 Location of the San Francisco Bay, Suisun Marsh and Sacramento-San Joaquin River Delta

2.6.1 Historical Sea Levels

2.6.1.1 Sea Level Prior to Recorded History

The Earth has been subject to many periods of cooling (glacial periods) and warming (interglacial periods). Periods of glaciation are marked by massive accumulations of land- and sea-based ice extending from the Earth's poles sometimes as far as the Earth's mid-latitudes. Interglacial periods are marked by warming and the recession of ice toward the poles. Sea level during glacial periods is lowered as a significant amount of the world's water accumulates as snow and ice through precipitation. Sea level during interglacial periods rises through the melting of massive ice sheets accumulated during glacial periods.

Geologic evidence shows that for the past million years ocean levels have repeatedly risen and fallen on a somewhat cyclical basis. Figure 2-20 depicts several glacial and interglacial periods and fluctuating ocean levels over the past 800,000 years.

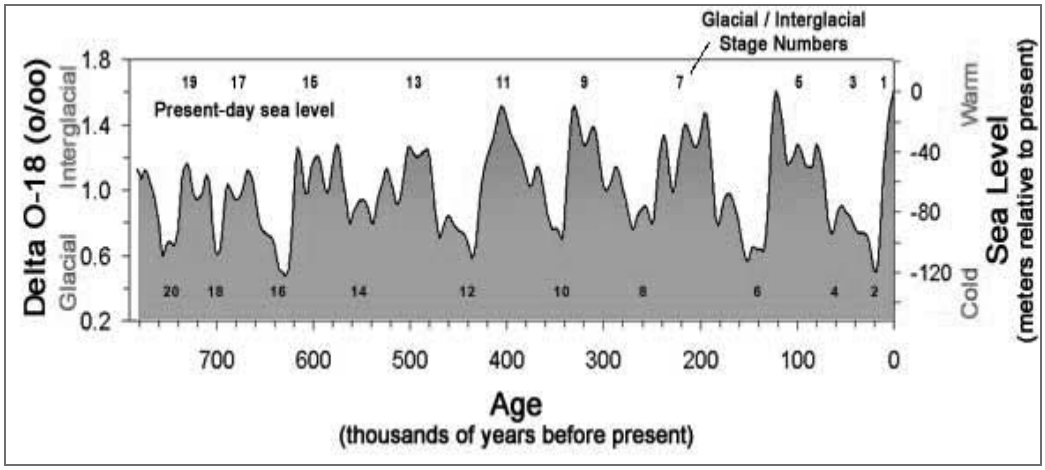


Figure 2-20 Changes in Global Sea Level over the Past 800,000 Years
Adapted from: http://coastalchange.ucsd.edu/st4_climatechange/sealevel.html
Coastal Morphology Group, Integrative Oceanography Division, Scripps Institution of Oceanography

The exact causes for the glacial periods and intervening periods of warming are unknown. Geologic evidence shows that global ocean levels have risen significantly since the most recent period of glaciation. The surface of the world's oceans during the coldest portion of the last glacial period, about 18,000 to 20,000 years ago, is estimated to have been about 400 feet lower than today's level, as shown in Figure 2-21. Most of the rise in sea level since this time was due to the large-scale melting of continental ice sheets, most of which occurred from 6,000 to 15,000 years ago. The average rate of sea level rise from about 6,000 years ago to present may have been about 0.5 mm/yr, or about 0.16 of a foot per century (IPCC, 2001a).

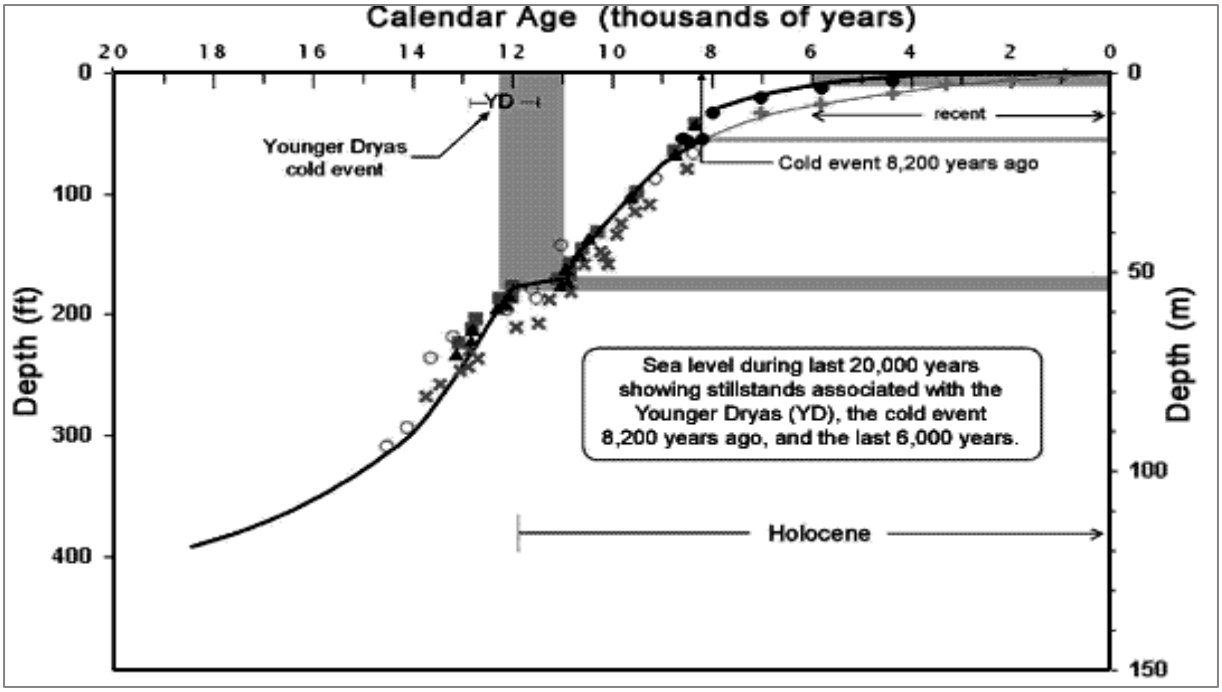


Figure 2-21 Change in Sea Level Over the Past 18,000 Years

Adapted from: Inman, et.al, 2002 http://coastalchange.ucsd.edu/st4_climatechange/sealevel.html
Explanation: The solid black and solid blue lines depict the estimated trend in sea level. The individual points of varying colors depict estimates of sea level at several locations by various researchers. A discussion about the "Younger Dryas" can be found at: http://en.wikipedia.org/wiki/Younger_Dryas#Abrupt_climate_change.

2.6.1.2 Sea Level Measurements

Direct sea level measurements began as early as the beginning of the 18th century in Europe with the use of tide gauges. Measurements for six European tide gauging stations with notably long records are depicted in Figure 2-22. All stations show a rise in relative sea level[2].

Rates of change in relative sea level measured by tide gauges along the coast of the United States over the 20th century are depicted in Figure 2-23. Since global sea level rise during the last century is believed to have been between about 0.3 and 0.6 of a foot, gauges exhibiting rates of sea level rise that significantly exceed this range could be on land masses that are subsiding. Gauges where sea level appears to rising more slowly than the worldwide average, not changing, or declining in comparison to worldwide trends may be on land masses that are rising. Table 2-5 lists areas of the U.S. coast that have been subject to recent subsidence or uplift and the causes for the changes.

Figure 2-24 depicts the locations of tide gauges along the coast of California, including eight gauges that have at least 50 years or more of record. Relative sea level trends for the eight gauges up to 2000 are shown in Figure 2-25. The trends for these gauges are summarized in Table 2-6

[2] See Section 2.6.2.3 for a discussion on "relative" sea level rise.

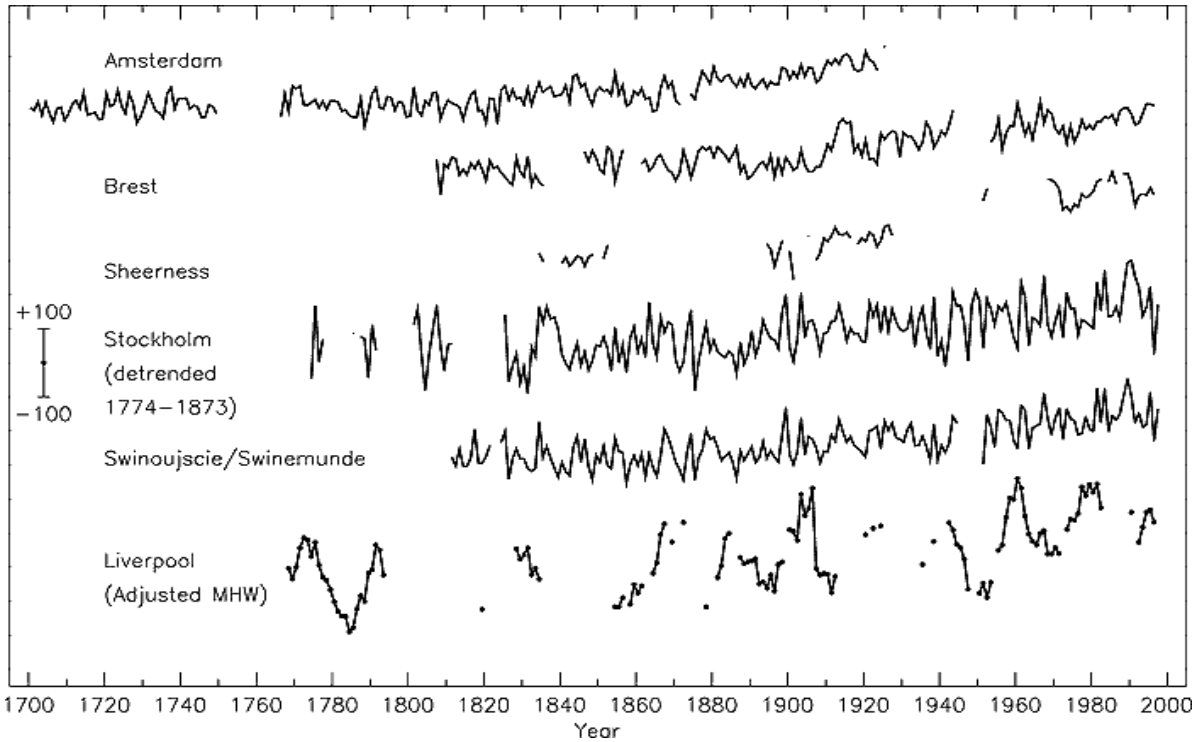


Figure 2-22 Relative Change in Sea Level Measured at Six Locations in Northern Europe Beginning at about 1700 AD

Locations: Amsterdam, Netherlands; Brest, France; Sheerness, UK; Stockholm, Sweden; Swinoujscie, Poland (formerly Swinemunde, Germany); and Liverpool, United Kingdom.
Scale: ± 100 mm.
Note: Data for Stockholm, Sweden is detrended over the period 1774 to 1873 to remove the first order contribution of postglacial rebound; Data for Liverpool, United Kingdom are "Adjusted Mean High Water" rather than Mean Sea Level and include a nodal (18.6 year) term.
Source: IPCCa, 2001
http://www.grida.no/climate/ipcc_tar/wg1/fig11-7.htm

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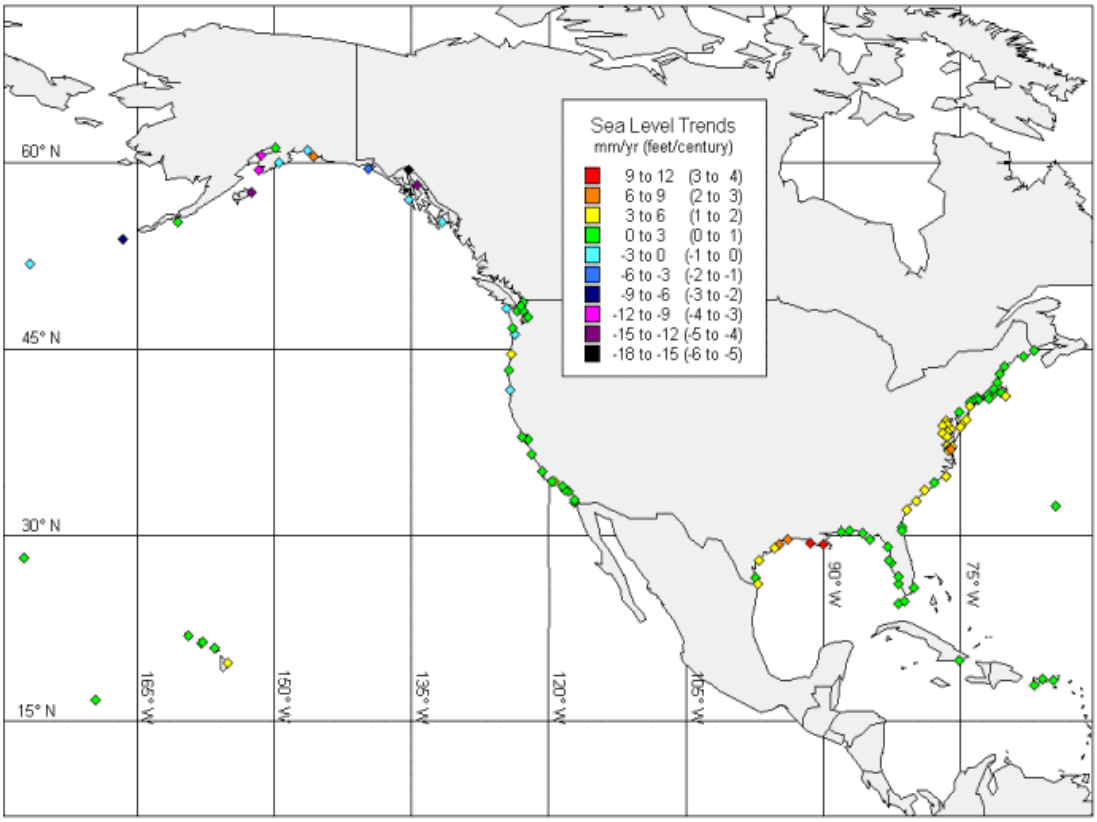

Figure 2-23 Rates of Relative Sea Level Rise Along the Coast of the United States
Source: National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services' website at: http://co-ops.nos.noaa.gov/sltrends/slrmap.shtml .

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Table 2-5 Areas of the US Coast with Significant Amounts of Uplift or Subsidence

Coastline Area	Elevation Trend	Reason
Mid-Atlantic	Much of the coastline in this area is sinking slowly	Glacial rebound in the Hudson Bay region to the north
Mississippi River Delta region and the Texas coast	Sinking of the coastline--rapid sinking near the Mississippi River Delta	Lithospheric loading and sediment compaction due sediment deposition by the Mississippi River, and subsidence related to oil and gas extraction in some areas
Island of Hawaii	Sinking of the island	Lithospheric loading and local volcanic and seismic activity.
Portions of the coast of Northern California, Oregon, and Washington	Slow uplift	Tectonic effects
Portions of Alaska's coast and the Aleutian Islands	Rapid uplift	Glacial rebound and/or tectonic uplift, depending on the area

Source: Table developed from information obtained at: http://140.90.121.76/sltrends/slrmap.shtml and http://hvo.wr.usgs.gov/volcanowatch/1994/94_10_14.html

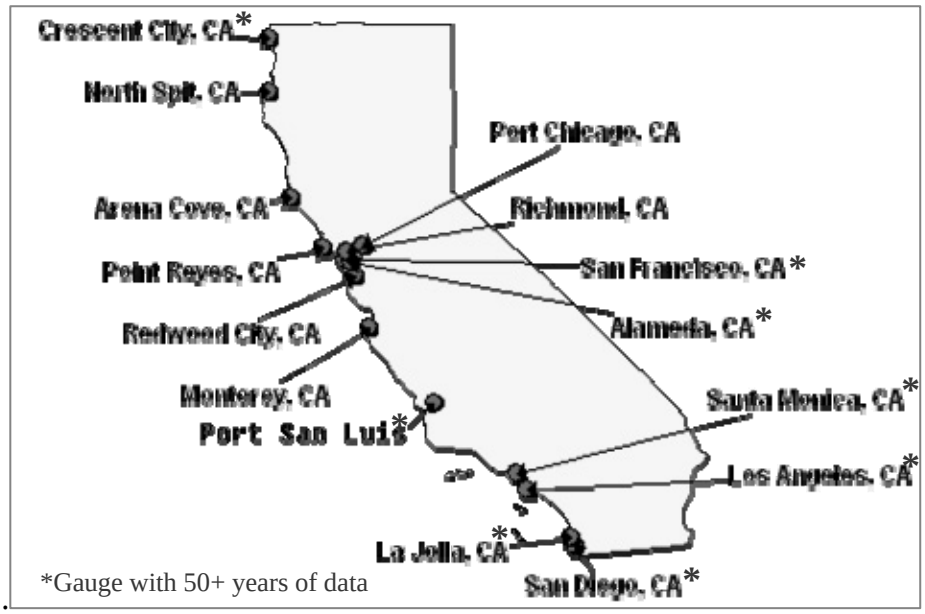
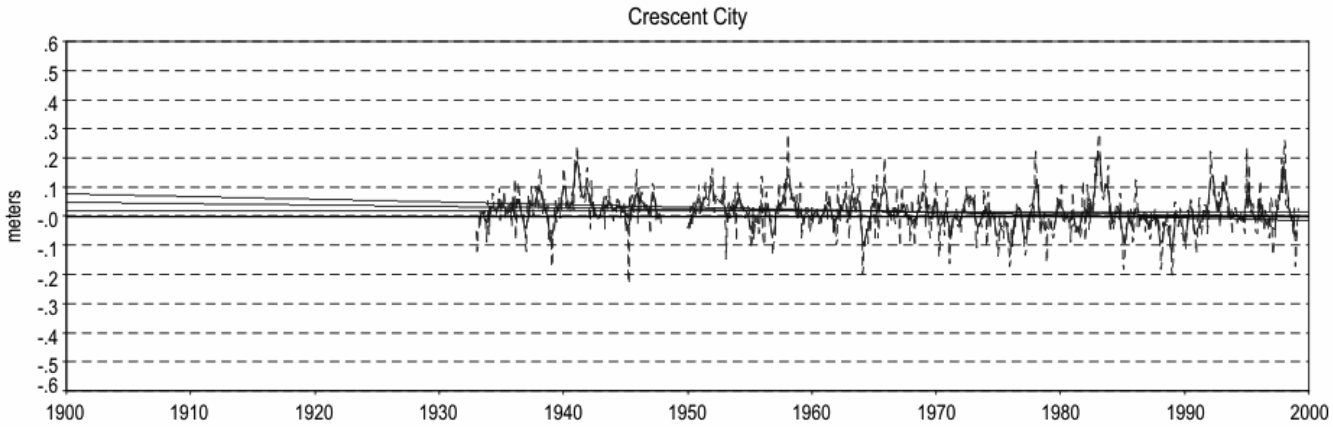
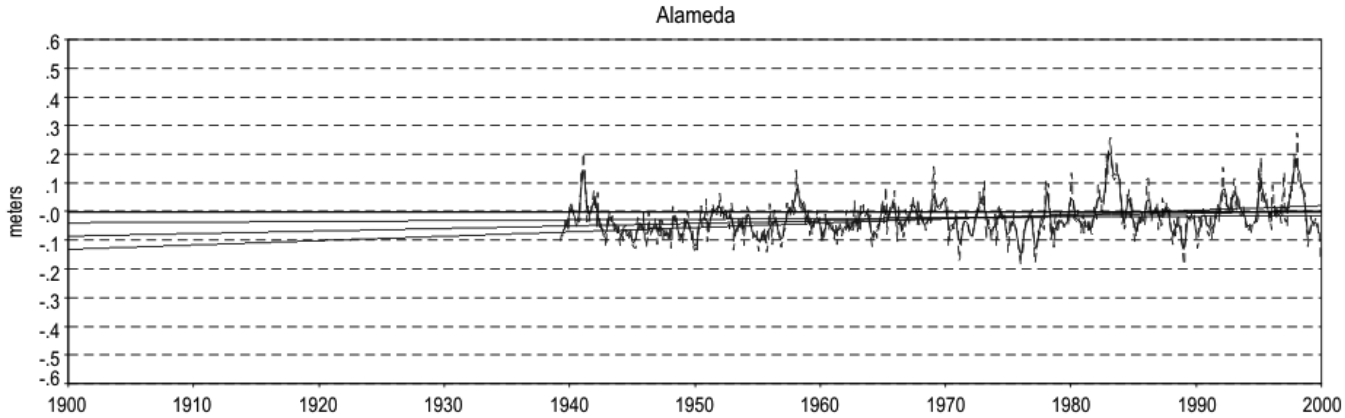


Figure 2-24 Location of Coastal Tide Gauges in California

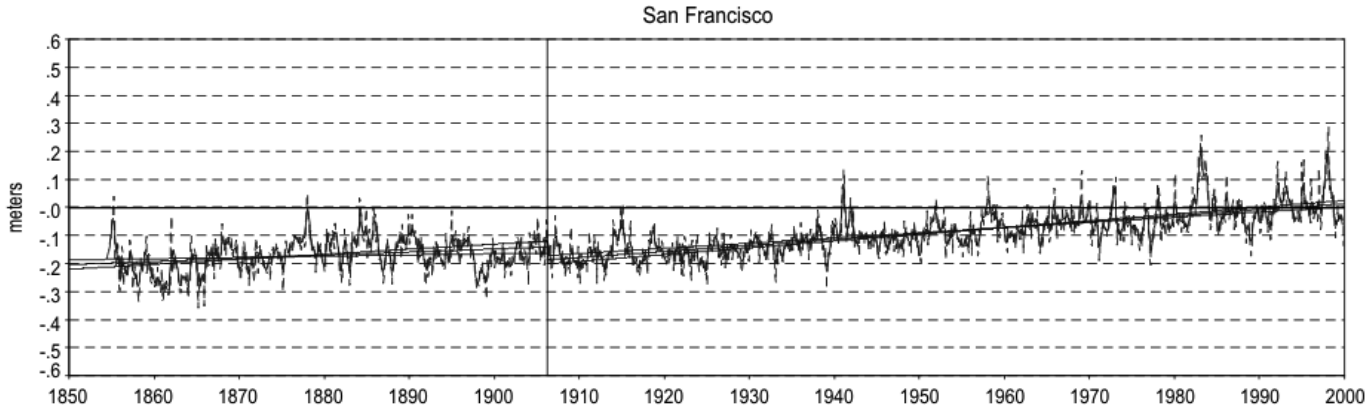
Adapted from: National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services' website at: http://co-ops.nos.noaa.gov/sltrends/slrmap.shtml -- http://140.90.121.76/coastline.shtml?region=ca



Gauge No. 9419750--Crescent City. The mean sea level trend is -0.48 millimeters/year (-0.16 feet/century) with a standard error of 0.23 mm/yr based on monthly mean sea level data from 1933 to 1999.

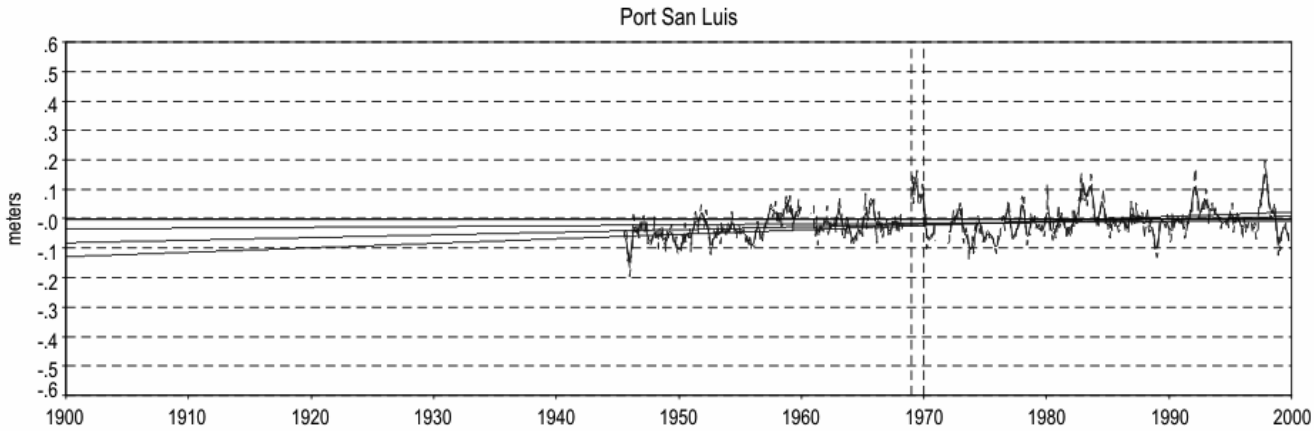


Gauge No. 9414750--Alameda. The mean sea level trend is 0.89 millimeters/year (0.29 feet/century) with a standard error of 0.32 mm/yr based on monthly mean sea level data from 1939 to 1999.

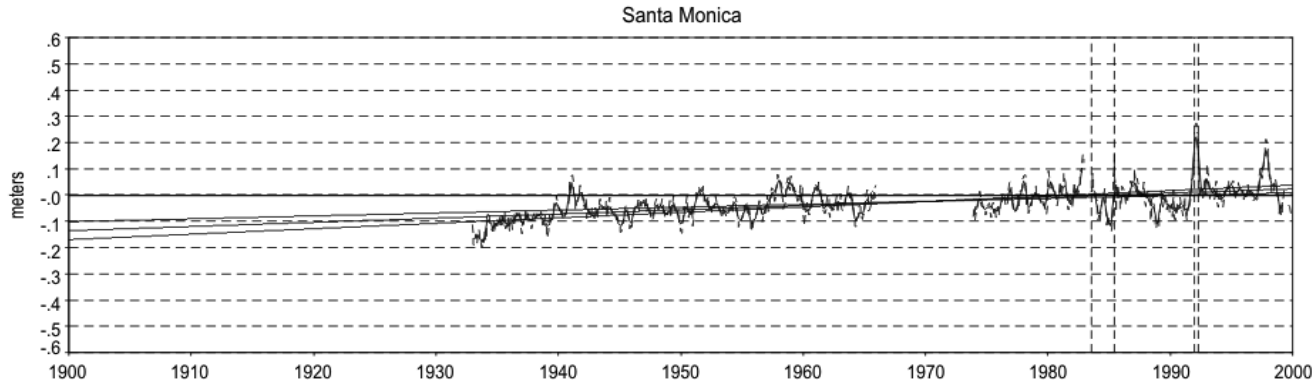


Gauge No. 9414290--San Francisco. The mean sea level trend is 2.13 millimeters/year (0.70 feet/century) with a standard error of 0.14 mm/yr based on monthly mean sea level data from 1906 to 1999.

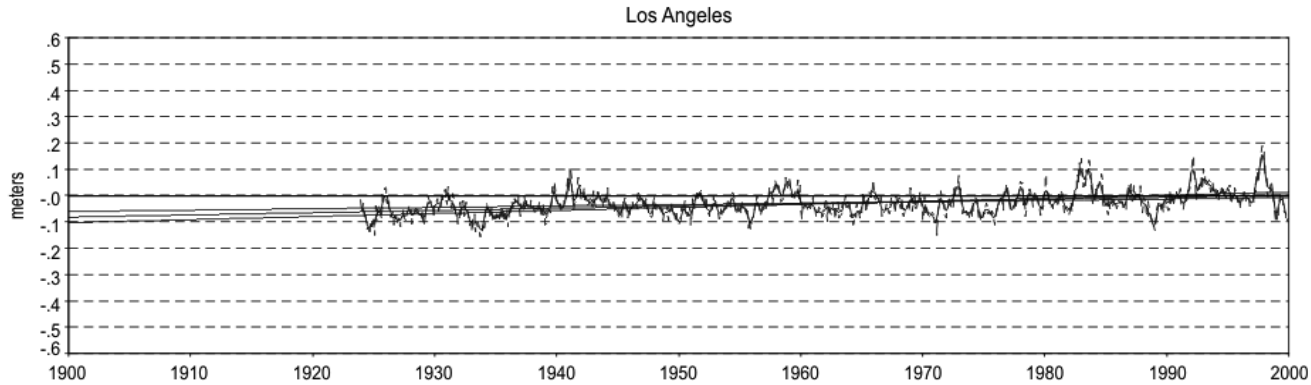
Figure 2-25 Relative Sea Level Trends for Eight Tide Gauges along California's Coast (part 1 of 3)



Gauge No. 9412110--Port San Luis**.** The mean sea level trend is 0.9 millimeters/year (0.30 feet/century) with a standard error of 0.32 mm/yr based on monthly mean sea level data from 1945 to 1999.

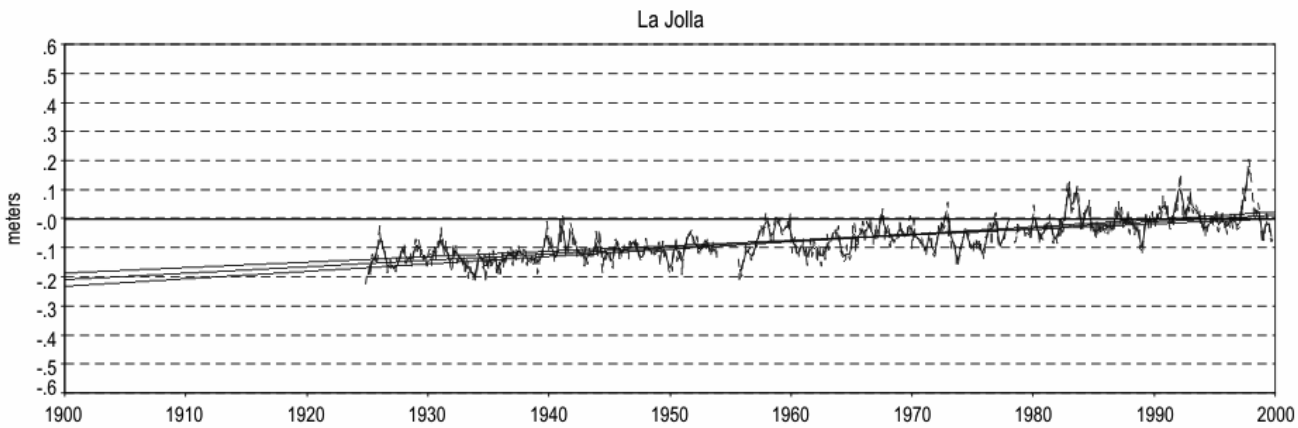


Gauge No. 9410840--Santa Monica. The mean sea level trend is 1.59 millimeters/year (0.52 feet/century) with a standard error of 0.25 mm/yr based on monthly mean sea level data from 1933 to 1999.

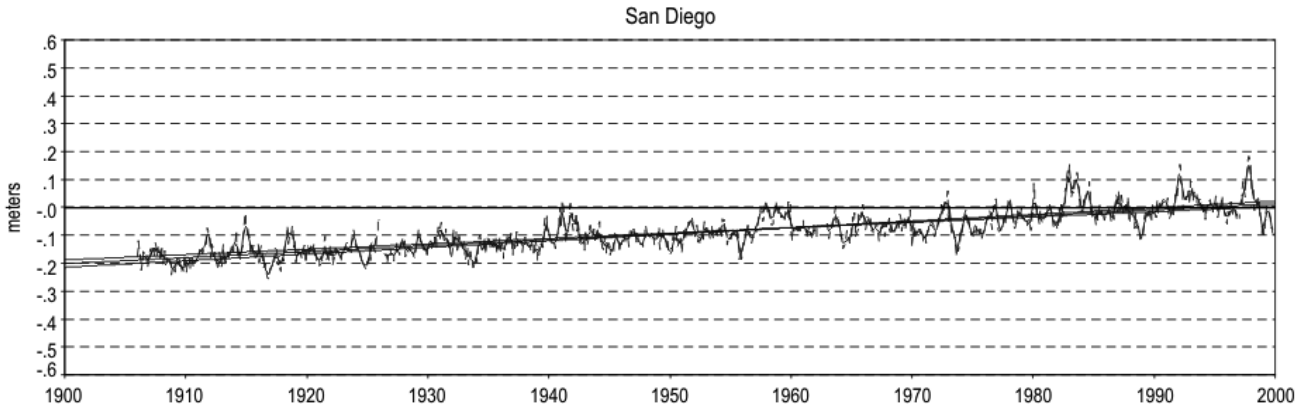


Gauge No. 9410660--Los Angeles. Mean sea level trend is 0.84 millimeters/year (0.28 feet/century) with a standard error of 0.16 mm/yr based on monthly mean sea level data from 1923 to 1999.

Figure 2-25 Relative Sea Level Trends for Eight Tide Gauges along California's Coast (part 2 of 3)



Gauge No. 9410230--La Jolla. The mean sea level trend is 2.22 millimeters/year (0.73 feet/century) with a standard error of 0.17 mm/yr based on monthly mean sea level data from 1924 to 1999.



Gauge No. 9410170--San Diego. The mean sea level trend is 2.15 millimeters/year (0.71 feet/century) with a standard error of 0.12 mm/yr based on monthly mean sea level data from 1906 to 1999.

Figure 2-25 Relative Sea Level Trends for Eight Tide Gauges along California's Coast (part 3 of 3)

Explanation: Solid blue curve is the five-month running average of monthly mean sea level with the average seasonal cycle removed. Linear trend lines illustrate 95 percent confidence interval after accounting for the average seasonal cycle. For most stations, the plotted values are relative to the 1983-2001 mean sea level datum recently established by the National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products (CO-OPS). Solid vertical lines indicate the occurrence of any major earthquakes in the vicinity of the gauge. Dashed vertical lines bracket any periods of questionable data.

Source: Graphs and explanations derived from National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services' website at: http://co-ops.nos.noaa.gov/sltrends/sltrends_states.shtml?region=ca

Table 2-6 Relative Sea Level Trends for Eight Tide Gauges Along the Coast of California with 50 Years or More of Record

CO-OPS Gauge Number--Name	Sea Level Trend (feet/century)
9419750--Crescent City	-0.16
9414750—Alameda	0.29
9414290--San Francisco	0.70
9412110--Port San Luis	0.30
9410840--Santa Monica	0.52
9410660--Los Angeles	0.28
9410230--La Jolla	0.73
9410170--San Diego	0.71

Figure 2-25 and Table 2-6 show relative sea level along the coast of California is rising at all but one of the coastal gauges with 50 years or more of record. The one gauge showing a drop in relative sea level is at Crescent City. The apparent drop in sea level there is likely due to land-mass uplift given the gauge's proximity to the Mendocino Triple Tectonic Plate Junction. Information about this tectonic junction can be found at: http://pubs.usgs.gov/publications/text/Farallon.html.

The rate of relative sea level rise at the seven gauges with 50 years or more of record is fairly consistent with the worldwide sea level rise trend of 0.3 to 0.6 of a foot over the past century. Differences in the rate of rise at the various gauges may be due, at least in part, to changes in land mass elevation.

2.6.1.3 Projected Sea Level Rise

The Intergovernmental Panel on Climate Change projects worldwide average sea level to rise about 0.3 of a foot to 2.9 feet from 1990 to 2100 (IPCC, 2001a). The range in the projections reflects the results of multiple climate models for multiple greenhouse gas emission scenarios. Figure 2-26 depicts the varying sea level rise projections. A study by the U.S. Environmental Protection Agency published in 1995 assigned probability estimates for various magnitudes of sea level rise (Titus, 1995).

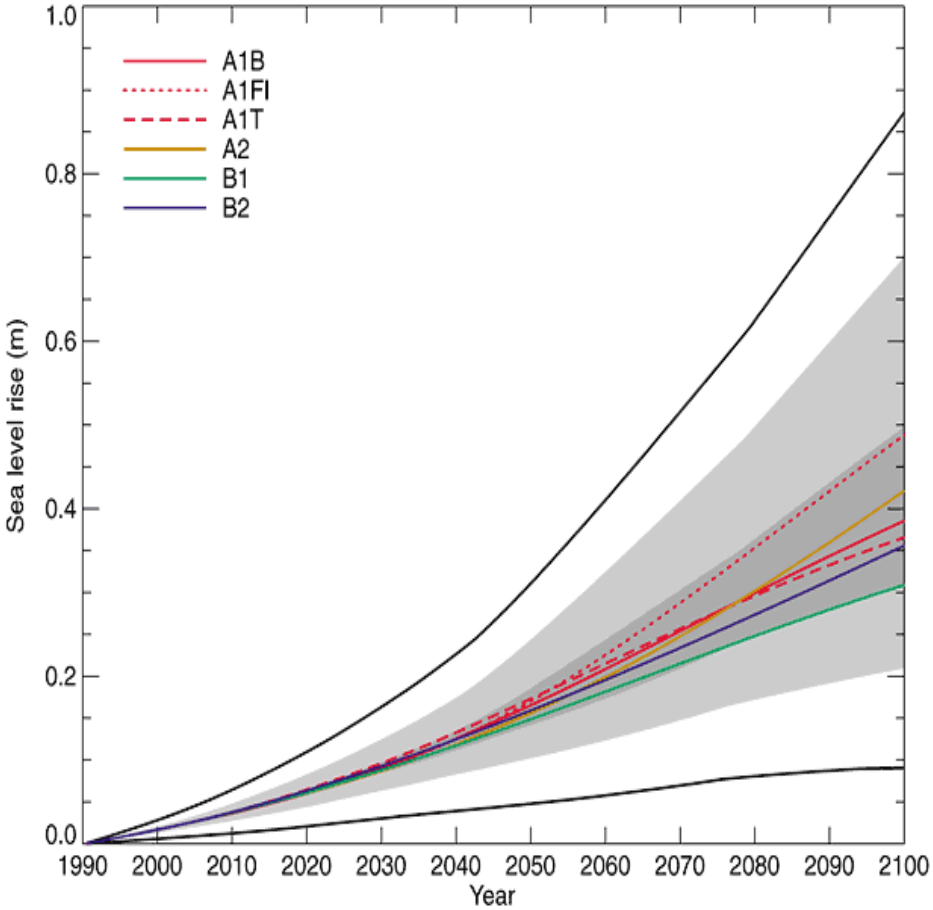


Figure 2-26 Projected Rise in Global Average Sea Level from 1900 to 2100

Source: Adapted from IPCC, 2001a (http://www.grida.no/climate/ipcc_tar/wg1/fig11-12.htm)
Explanation: Global average sea level rise from 1990 to 2100 for the SRES (Special Report on Emission Scenarios; IPCC 2000) scenarios and seven climate models. The region in dark shading shows the range of the average of models for all 35 SRES scenarios. The region in light shading shows the range of all models for all 35 scenarios. The colored lines in the key and in the graph represent the average of modeling results for six GHG emission scenarios. The region delimited by the outermost black lines shows the range of all models and scenarios including uncertainty in land-ice changes, permafrost changes and sediment deposition. This range does not allow for uncertainty relating to ice-dynamic changes in the West Antarctic ice sheet For additional explanation of this figure see IPCC, 2001a (http://www.grida.no/climate/ipcc_tar/wg1/index.htm).

As can be noted from Figure 2-26, many of the model projections for sea level rise show an acceleration in the rate of rise over that observed during the past century. This projected acceleration generally follows the projected acceleration in the rate of global average temperature rise by some climate models for some greenhouse gas emission scenarios (see section 2.4). As mentioned earlier, the rate of relative sea level rise experienced at many locations along California's coast is somewhat consistent with the worldwide average rate of rise observed over the past century. Therefore, it may be reasonable to expect that changes in worldwide average sea level through this century will also be experienced by California's coast.

As mentioned at the beginning of this section, sea level rise poses a significant threat for California. Perhaps the most noteworthy effect of sea level rise on California's water resources will be to the Sacramento-San Joaquin River Delta. Sea level rise over the next century will likely have a significant effect on the Delta's ecosystem, land uses and water supply function, even if the rate of rise over this century is about the same as that observed during the past century. Increased rates of rise, such as those projected for the highest levels of future greenhouse gas emissions and temperature rise could have profound effects on the Delta.

2.6.1.4 Short-Term Changes in Sea Level

Sea level rise at any given location is a function of changes in worldwide average sea level; however, local and regional effects superimposed on global trends can be significant. Rising or falling land elevations can affect what levels an area experiences. Land masses can rise or fall relative to the center of the Earth through tectonic movement. Changes in the elevation of a land mass can also occur due to the activities of humans, such as the extraction of petroleum or groundwater. For example, significant amounts of coastal land subsidence (up to 3 meters) have occurred on the coast of Texas near Houston and Galveston due to petroleum extraction. Groundwater extraction along the Texas coast has also caused subsidence (Gibeaut, 2000). In California, petroleum extraction in Long Beach has resulted in coastal subsidence, but in a limited area. Some coastal area subsidence has also occurred in the Santa Clara Valley south of San Francisco Bay as the result of groundwater extraction (DWR, 1998).

Changes in land elevation as the result of tectonic movement typically occur very slowly (relative to a human timescale), although local land masses have been observed to rise or sink rapidly as the result of seismic activity. As discussed earlier, coastal land masses that are subsiding (sinking) will tend to experience sea levels that appear to be rising faster than the worldwide rate of sea level rise. Coastal areas that are undergoing uplift (rising) will tend to experience sea levels that appear to be going up more slowly than the worldwide average, or will experience sea levels that appear to be declining or not changing compared to worldwide trends.

While rising worldwide average sea level and land mass elevation changes play a long-term role in sea levels experienced at a particular location, other effects can play an important role in the short term. Such effects include:

- gravitational effects of the sun and moon (astronomical tides)
- dynamic interaction of tides with coastlines
- ocean currents
- hydraulic and salinity changes caused by rivers (especially in bays and estuaries)
- barometric pressure
- interannual and decadal changes in ocean temperatures, such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation[3], as well as periodic ocean temperature changes on other timescales
- waves and storm surge

[3] For more information concerning short-term changes in ocean temperature visit: (http://topex-www.jpl.nasa.gov/science/pdo.html)

Of these factors, all but the first two could be affected by climate change. Figure 2-27 and Figure 2-28 illustrate the variability of annual average relative sea level at the San Francisco and La Jolla tide gauges, respectively. These figures also show the 19-year running average of annual average sea level at each gauge for comparison. The 19-year running average was selected since all significant variations in the relative movements of the earth, moon and sun that affect astronomical tides complete their full cycle about every 18.6 years. The San Francisco tide gauge is located a short distance inside of the Golden Gate Bridge on the shore of the San Francisco Presidio. The La Jolla gauge is located at the end of the Scripps Institution of Oceanography pier in La Jolla.

Short-term changes in sea level at a particular location can be quite significant, especially when superimposed on long-term changes. The combined effect could place California's coastal resources and the Delta at an even greater risk than worldwide changes in sea level alone.

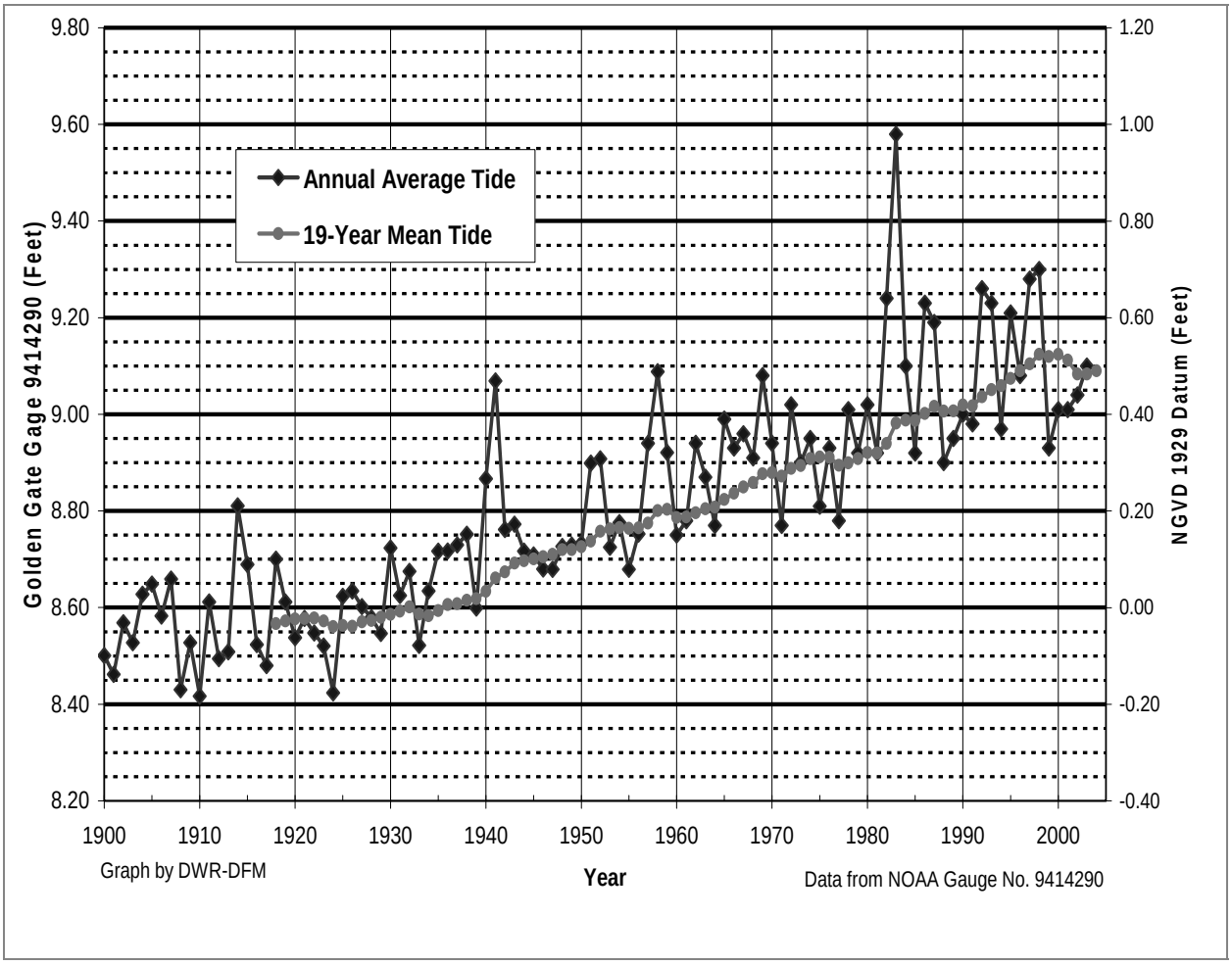


Figure 2-27 Graph of Annual Average Relative Sea Level and the 19-Year Running Average Sea Level at the San Francisco Tide Gauge

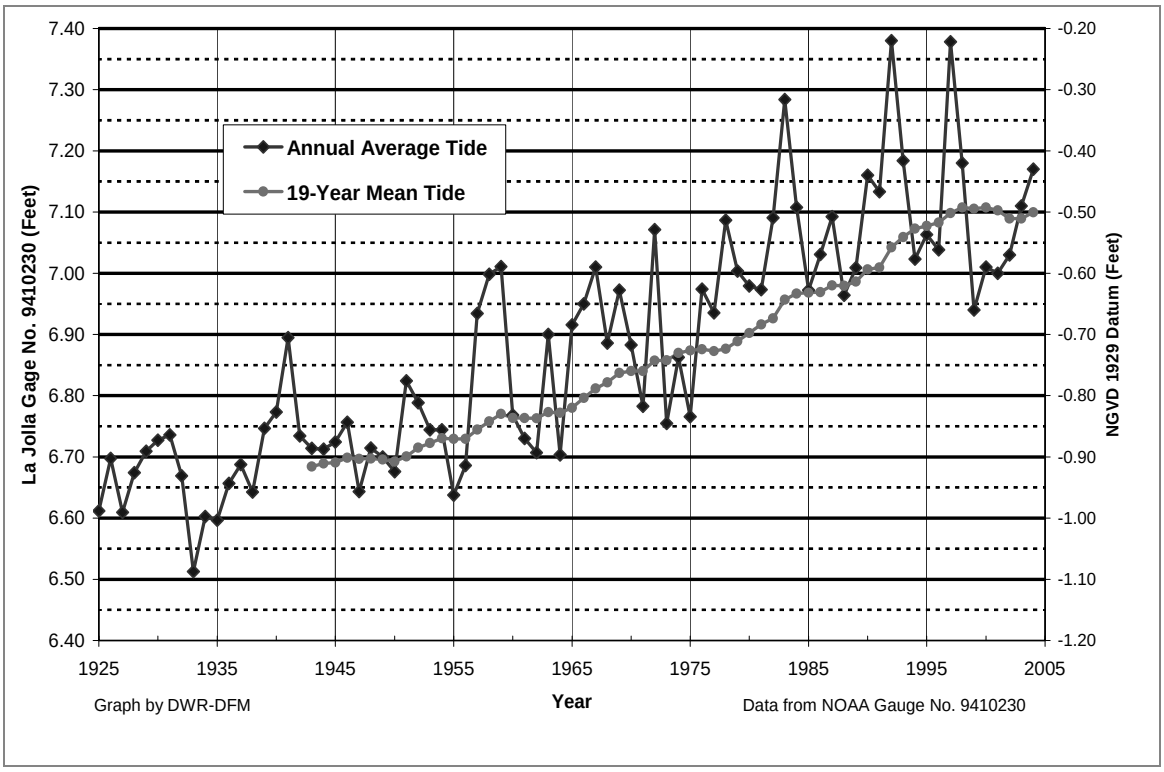


Figure 2-28 Graph of Annual Average Relative Sea Level and the 19-Year Running Average Sea Level at the La Jolla Tide Gauge

2.6.2 Consequences of Sea Level Rise

2.6.2.1 Sea Water Intrusion into Estuaries and River Systems

As mentioned previously, sea level rise during this century will cause increased sea water intrusion into California's coastal marshes and estuaries. Increased intrusion will likely disrupt marsh and estuary ecosystems, especially at the higher projections of sea level rise. Sea water intrusion into the Sacramento - San Joaquin River Delta could cause negative effects on fishes, as discussed in Section 2.9 and increase Delta salinity levels, as discussed in Chapter 5, Section 5.5. Increased salinity levels in the Delta would have a detrimental effect on Delta water supply operations if existing operations in the Delta remain the same and the Delta's configuration is not changed.

2.6.2.2 Sea Water Intrusion into Groundwater

Groundwater plays a significant role in providing California's water supply. In an average year, groundwater meets about 30 percent of California's urban and agricultural water demand. This percentage increases to more than 40 percent during drought years. In 1995, an estimated 13 million Californians, nearly 43 percent of the State's population, were served by groundwater. The demand on groundwater will likely increase as California's population grows (DWR, 2003).

Most of the State's groundwater is produced from alluvial groundwater basins. Alluvial basins are typically valleys that have been partially filled with sediment. Coarser sediment, such as sand, serves to store and transmit significant quantities of water to wells. Layers of finer sediment, such as clay, tend to restrict the movement of groundwater.

DWR has delineated 431 groundwater basins in California beneath about 40 percent of the State's surface area (DWR, 2003). The locations of these basins are illustrated in Figure 2-29.

More than 200 groundwater basins have been identified along the coast of California. Many of these basins play, or could potentially play a significant role in providing a local water supply. Many of California's larger urban areas, including the Los Angeles metropolitan area, overly coastal groundwater basins and derive a significant potion of their supply from groundwater. Regionally and nationally-significant agricultural areas that overlay coastal groundwater basins include the Salinas Valley, Santa Maria Valley and the Ventura-Oxnard Plain.

While most groundwater produced in coastal areas is derived from groundwater basins, groundwater is also produced from mountain and hillside areas underlain by rock, old marine deposits, or volcanic deposits. Such areas typically produce small quantities of groundwater compared to alluvial basins.

Figure 2-30 is a simple illustration of a cross-section of a coastal groundwater basin. The deposits of some coastal groundwater basins in California extend a significant distance beyond the coastline and contain saline ocean water. Under natural conditions, fresh water in coastal aquifers flows toward the ocean keeping saline ocean water from moving inland. However, if inland groundwater levels are lowered through pumping, ocean water may move inland.

Many groundwater basins along California's coast are very susceptible to sea water intrusion, or the intrusion of brackish water from bays and estuaries. Sea water intrusion into California's coastal aquifers was first noted in the 1930s and 1940s. Some of the earliest observations were in Los Angeles and Orange counties. Other areas where a significant amount of seawater intrusion has occurred include Ventura, Santa Cruz and Monterey counties, and some areas around San Francisco Bay and the Sacramento-San Joaquin River Delta. (DWR, 1958; DWR, 1975; DWR, 2003). Sea water intrusion in the Salinas Valley has been observed as far as 5 miles inland (DWR, 1994).

Rising sea level increases the potential for sea water intrusion into coastal groundwater aquifers and other coastal groundwater resources by increasing the pressure of ocean water exerted against water-bearing deposits extending inland from the coast. Rising sea level can also increase the potential for intrusion of sea water into coastal groundwater basins through the inundation of areas that were formerly above sea level.

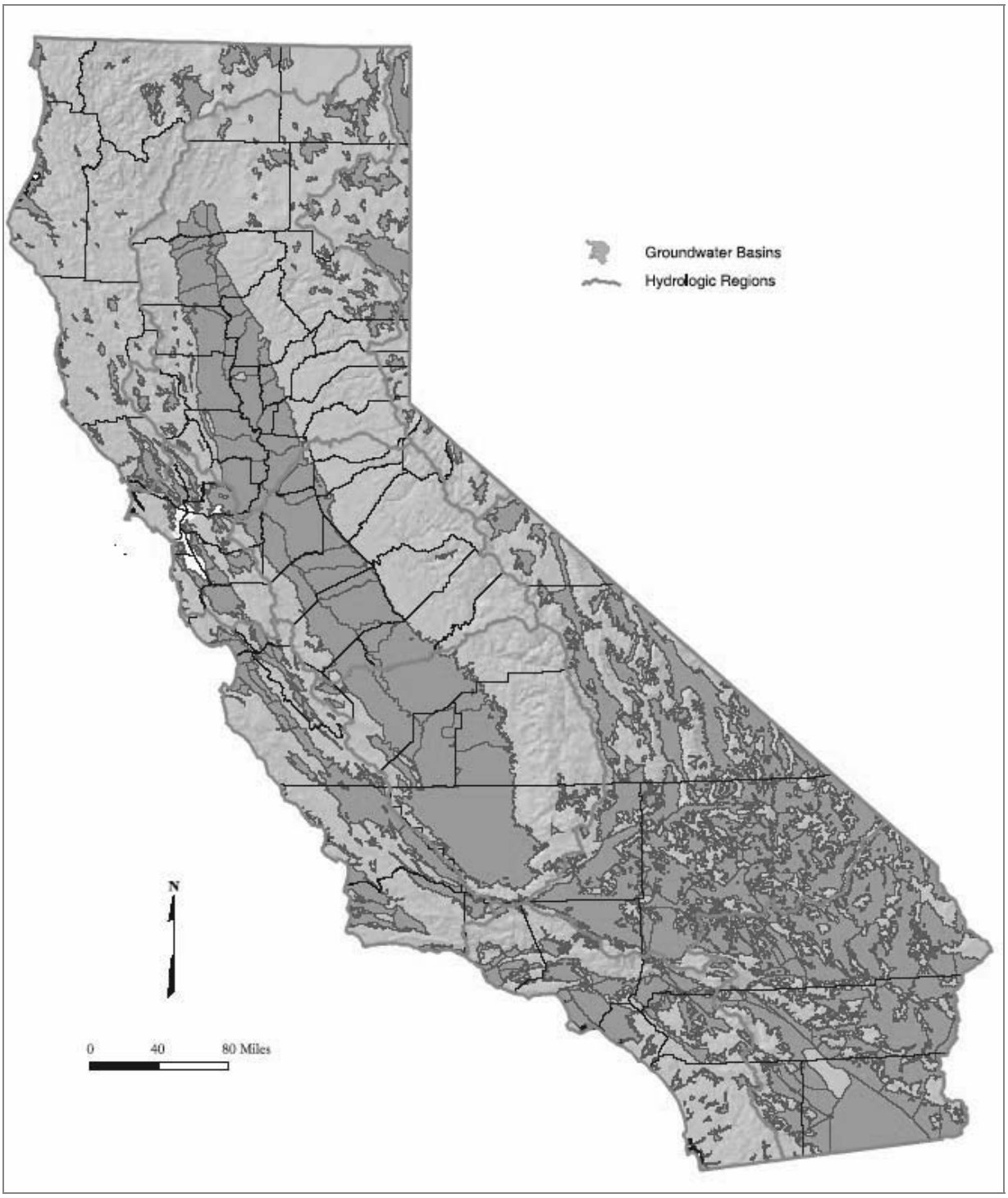


Figure 2-29 California's Groundwater Basins

Source: DWR, 2003

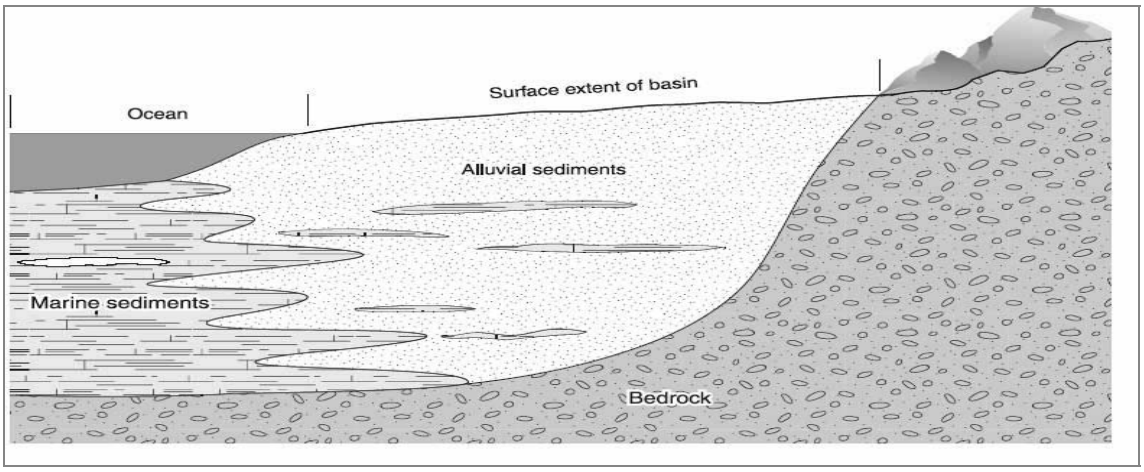


Figure 2-30 Simplified Cross-Section of a Coastal Aquifer
Source: DWR, 2003

The threat posed to coastal groundwater resources by sea level rise can be lessened by various means including controls on well construction and groundwater production, and the operation of hydraulic barrier projects. Hydraulic barrier projects typically involve the injection of treated wastewater or imported water into coastal aquifers to prevent ocean water from moving inland.

The threat to groundwater from the inundation of land by sea level rise can be lessened through shoreline engineering, such as the installation of sea walls. It is anticipated that shoreline engineering projects will be undertaken along many low-lying areas of California's coast to protect areas with high real estate values. Shoreline engineering may be difficult, impractical, or environmentally unacceptable for some of California's bays, estuaries and coastal marshes. Some of these areas might be subject to uncontrolled inundation due to sea level rise.

2.6.2.3 Flooding Risk in the Sacramento-San Joaquin River Delta

The Sacramento-San Joaquin River Delta is highly susceptible to flooding. The Delta includes 70 islands and tracts. Most have land surfaces at or below mean sea level. Land surface on some Delta Islands is as much as 25 feet below mean sea level (DWR, 2005a). The location of the Delta is depicted in Figure 2-19, and a detailed view of the Delta and its islands is shown in Figure 2-31.

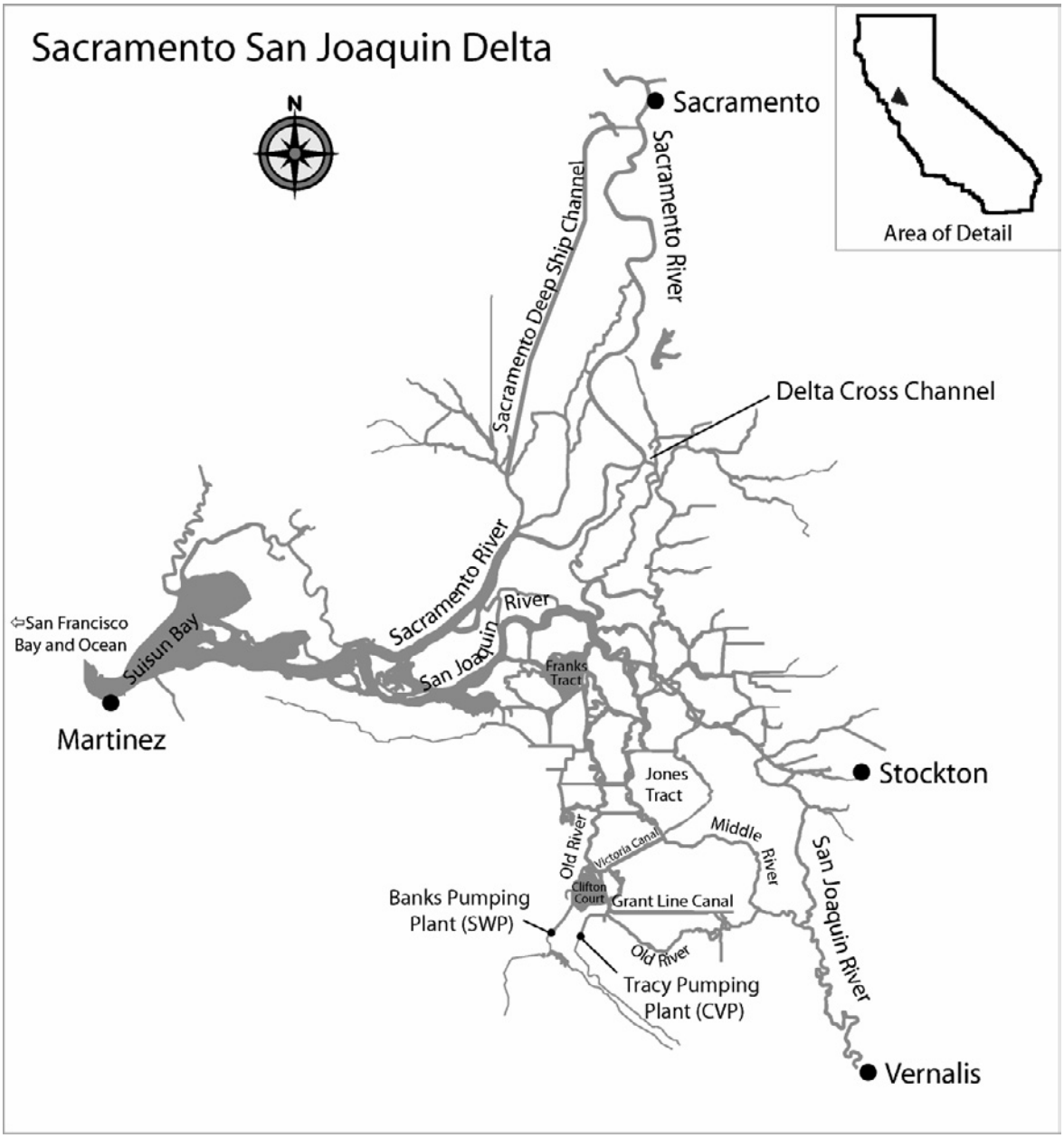


Figure 2-31 Sacramento-San Joaquin River Delta

The islands and tracts of the Delta are protected from the constant threat of inundation by about 1,100 miles of levees. Levee failure can occur due to seepage, piping, slippage, subsidence, sloughing or earthquakes, even during dry weather. Levee failure impacts include potential loss of human life, irreparable harm to the Delta's fragile ecosystem and its listed and endangered species, disruption of utilities and highways and water supply disruption. Water supply disruption can occur when levee failure and island flooding cause salinity levels in the Delta to increase to unacceptable levels due to:

- large amounts of saline ocean water to being drawn into the Delta from the San Francisco Bay, and
- increases in the volume of the Delta's tidal prism and resultant increases in the tidal exchange of saline water in the Delta.

Once a levee fails in the Delta and island flooding occurs, salinity conditions can take weeks or even months to return to normal, depending on the amount and location of levee failures and hydrologic conditions.

2.6.2.3.1 Future Increased Risk of Flooding in the Delta Due to Land Surface Subsidence and Climate Change

Flood risk in the Delta is increasing with time due to land surface subsidence and sea level rise. Land subsidence and sea level rise also increase the consequences of levee failure.

As mentioned earlier, worldwide average sea level rise is projected to be about 0.3 of a foot to 2.9 feet from 1990 to 2100 (IPCC, 2001a). Rising sea levels are likely to have a direct effect on water levels in the Delta because the bottom of essentially all Delta channels and waterways are at or below current mean seal level. Rising sea level will cause backwater effects upstream of the Delta.

Global sea level rise combined with short-term or episodic factors that increase sea level and water levels in the Delta will reduce available levee freeboard unless levees are raised. Short-term and episodic increases in water levels in the Delta include high river flows, ocean/atmosphere phenomena such as El Nino's, storm surge, barometric high tides and high astronomical tides (particularly during perigee, perihelion, and either new or full moon). Figure 2-32 illustrates the relative impact that sea level rise will have on astronomical tides in the Delta. An especially high level of risk would occur if several periodic events were to occur at the same time in the Delta.

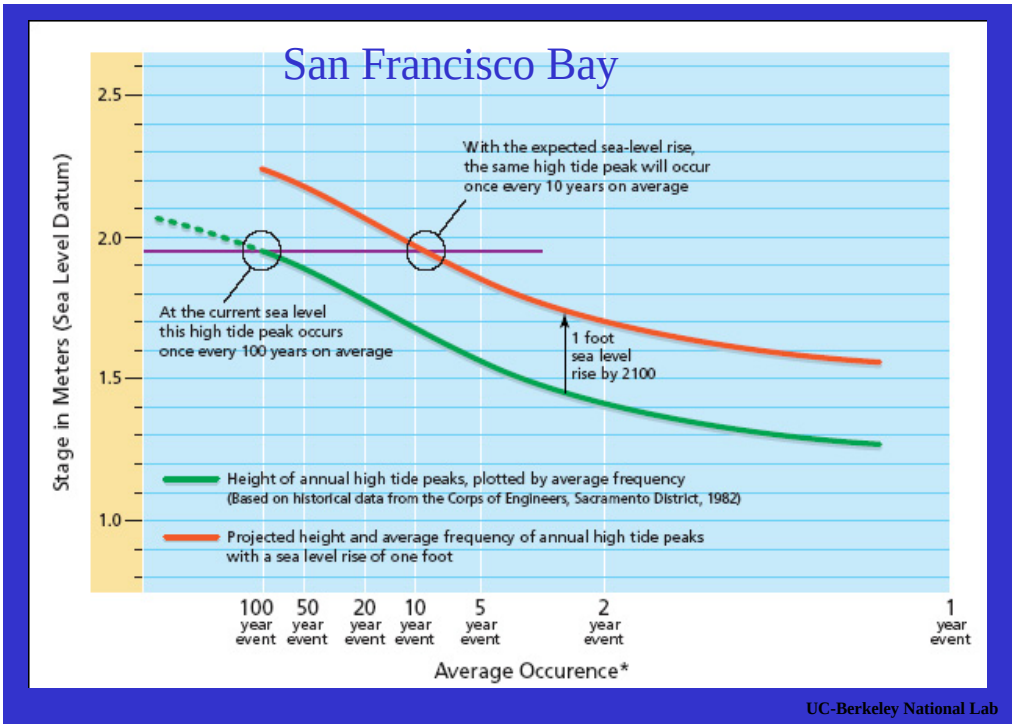


Figure 2-32 Impact of One Foot of Sea Level Rise on the Relative Effect of Astronomical Tides in the Delta

Source: Lawrence Berkeley National Lab (Miller, 1998).

Climate change may affect the magnitude and frequency of flood flows entering the Delta. In their paper on the potential impacts of climate change on California hydrology, Miller and others (2003) present peak river flow data based on climate change simulations. These data show an increased probability of higher annual peak flows for Central Valley rivers. These potential increased flows have yet to be quantified with any confidence. Higher flows will lead to higher water surface elevations in the Delta, especially in its upper reaches.

Ocean temperature anomalies, such as an El Nino, can cause a short-term rise in sea level along California's coast and thus increase water levels in the Delta. For example, the maximum water surface anomaly associated with the 1997-1998 El Nino event increased the level of the ocean along California's coast between about 0.6 to 0.8 of a foot during January 1998 (Bromirski, 2005). This level of rise was due to a combination of steric effects and poleward propagating, coastally-trapped waves. Climate change may increase the frequency or duration of El Nino events (Wara, 2005), although there is a significant amount of uncertainty about possible changes in the nature and occurrence of temperature anomalies in the Pacific as the result of climate change (Kerr, 2005).

Wind driven storm surge can also increase water surface elevations in the Delta. Stronger winds associated with some winter storms would lead to even greater changes in water surface

elevations. Such changes are a function of channel geometry and the distance of open water with respect to wind direction, referred to as "fetch."

Subsidence also must be considered as a risk to Delta levees. The surfaces of many of the Delta's islands and tracts are dominated by soils rich in peat. Peat is a complex organic material that is principally composed of degraded plant matter. Subsidence in the Delta primarily occurs when peat soils are exposed to oxygen and undergo microbial decomposition due to agricultural practices. Subsidence also occurs when peat soils are lost by wind erosion and occasional peat fires. The peat soils of the Sacramento-San Joaquin Delta have subsided at rates of up to about 2 inches per year in the past. Subsidence rates have been the highest in the central Delta islands (Mount, 2004).

Subsidence increases the threat of flooding in the Delta by increasing the differential forces that levees experience. Subsidence also increases the volume of water that can inundate an island or tract when a levee fails. Together, the continued subsidence of Delta islands and rising sea level pose a double-sided threat for Delta levees and flooding. Other factors such as possible increases in peak river flows as the result of climate change further increase the threat to Delta levees.

2.7 Future Water Demand

California's water supply future will be determined by two principal factors, the condition of the State's water resources and water demand. Climate change will likely have a significant effect on California's future water resources, as discussed elsewhere in this report. Climate change will likely also have an effect on future water demand. However, many other factors such as population, land development and economic conditions that are not directly related to climate change will also affect future demand. Table 2-7 provides a summary of some of the potential effects of climate change on future water demand. Table 2-8 lists selected factors that could affect future water demand that will not be directly affected by climate change.

Today there is much uncertainty about future water demand, especially those aspects of future demand that will be directly affected by climate change and warming. While climate change is expected to continue through at least the end of this century, the magnitude and, in some cases, the nature of future changes are uncertain. This uncertainty serves to complicate the analysis of future water demand, especially where the relationship between climate change and its potential effect on water demand is not well understood.

Of the water demand factors that could be directly affected by climate change, potential changes in evapotranspiration, agronomic practices, and environmental water demand might be the most significant for California. Of the changes in demand not directly affected by climate change, changes in demand related to population growth and technological innovation could be the most significant. The following discussion is mostly limited to these aspects of future water demand. Chapter 7 provides additional discussion on evapotranspiration and possible changes in evapotranspiration due to climate change.

Table 2-7 Summary of the Potential Effects of Climate Change on Future Water Demand

Type of Demand	Potential Effect
Crop Irrigation	Increasing temperatures will increase evapotranspiration rates and related water demand where all other factors remain unchanged. Increasing concentrations of atmospheric carbon dioxide may act to reduce increases in plant transpiration (a component of evapotranspiration) in response to increased temperatures. Other factors related to climate change, such as possible changes in humidity, cloudiness and wind could also affect evapotranspiration rates. Evaporation rates from soil and plant surfaces may rise due to temperature increase, depending on changes in other factors that affect evaporation rates. Increased evaporation rates could increase salt accumulation on plant surfaces, especially where overhead irrigation is used. Salt accumulation in surficial soils could also increase. Additional irrigation water demand may result because of possible increased salt control requirements. Some changes in crop type, planting cycles, time of planting, and crop productivity will likely occur as the result of increased temperatures. Statewide and regional irrigation water demand may increase or decrease as the result of these changes. Use of water for frost protection will likely be reduced with increasing temperatures and projected reductions in the annual number of days when frost occurs. Frost protection is typically an important consideration for orchards and vineyards.
Landscape Irrigation	Increased temperatures, as well other atmospheric/climatic factors related to climate change, will affect landscape irrigation in manner similar to that described for crop irrigation, above.
Domestic Water Uses (excluding landscape irrigation)	Domestic water use typically increases with increasing temperature. Increased water demand can occur due to the use of evaporative cooling, increased laundering of clothing, increased bathing, increased drinking water requirements for humans and pets and recreational uses of water.

Table 2-7 Summary of the Potential Effects of Climate Change on Future Water Demand (continued)

Type of Demand	Potential Effect
Commercial and Industrial Water Use (including agro-industrial facilities such as dairies, poultry farms, packing plants, etc.)	Commercial and industrial water use will likely increase as the result of warming due to such factors as increased evaporative cooling demand. Increased consumption of water by concentrated animal feeding facilities, such as dairies and poultry farms, would also likely occur.
Evaporation Losses from Natural Water Bodies and Open Water Storage and Conveyance Facilities	Evaporation losses from water bodies and open conveyances will probably increase as the result of rising temperatures especially in arid portions of the State with low humidity and limited cloud cover.
Environmental Water Requirements	Delta outflow requirements will likely increase to maintain Delta salinity conditions in response to sea level rise; if the Delta's existing configuration, operation of its water supply facilities, and its ecosystem conditions are to remain as they are now. Higher temperatures will likely result in increased environmental water demand for controlling water temperatures for sensitive aquatic species, including anadromous fish. Increased use of reservoir storage and thermal control releases from reservoirs will be required for controlling aquatic habitat temperatures.

Table 2-8 Selected Factors Affecting Future Water Demand in California that are Not Directly Related to Climate Change

Factor	Potential Effect
Population Change	Future increases in population will affect water demand, depending on the location and types of development needed to support an increased population. The conversion of agricultural lands into housing and related community development may not result in a significant increase in water use for a given area, depending on the agricultural use(s) that existed prior to land conversion, and on the type of housing and other facilities constructed. Redevelopment and densification of existing urban land may result in increased water demand in some areas. Development of raw, uncultivated land will directly increase water demand. In general, increases in California's population will tend to increase future water demand.
Changes in Agriculture	Changes in the type and amount of crops grown due to changes in agricultural markets and government crop subsidy programs may help increase or decrease agricultural water demand.
Changes in Landscaping Practices	Changes in consumer preferences and changes in land use ordinances relating to landscaping may affect future landscape water demand.
Changes in Environmental Water Use Requirements	The findings of continuing scientific research related to the condition and preservation of aquatic ecosystems in the State, including the Delta, may affect environmental water demand.
Water Law and Policy	Changes in water law and policy could affect water demand.
Technological Innovation	Lowered consumption rates could result from improvements in water use efficiency for irrigation, domestic, commercial, and industrial uses. Increased reuse of wastewater could help reduce demand on existing and future sources of water. Advances in desalinization technology may reduce demands on the State's freshwater resources, especially in areas along the south coast.

2.7.1 Evapotranspiration

The collective term *evapotranspiration* refers to the vaporization of water from soil and plant surfaces (i.e., evaporation) and vaporization that occurs in plant leaves with water diffusing through pores (stomata) to ambient air (i.e., transpiration). Transpiration is controlled by water availability from the soil, plant morphological and physiological characteristics, and atmospheric conditions which determine how much energy is available to vaporize water inside leaves. Climate and plant type are important determinants of evapotranspiration rates. Even small increases in evapotranspiration rates from crops and landscaping as the possible result of climate change could affect California's overall water demand. This is because of the relatively large amount of the State that is dedicated to irrigated agriculture and the significant amount of landscaping in urban areas.

Increased temperature and atmospheric carbon dioxide concentrations are the two most consistently projected aspects of climate change that will impact evapotranspiration rates for crops and landscaping in California. Hidalgo and others (2005) concluded that a temperature increase of 3 degrees Celsius will result in a 5 percent increase in plant transpiration, unless there is a compensating decrease in solar radiation or other component of the plant energy budget. Increasing carbon dioxide concentrations in the atmosphere may tend to reduce transpiration losses from plants. Other important factors affecting evapotranspiration include wind, dew point (humidity), cloudiness and minimum temperature.

A number of studies related to physiological, biochemical and phenological plant responses to increased atmospheric carbon dioxide concentrations have been published including those studies using data from the 18 free-air carbon dioxide enrichment research sites around the world (Long, 2004). Stomatal responses at elevated atmospheric carbon dioxide concentrations seem to decrease water vapor diffusion; however, more information is needed to better understand the effects of increasing concentrations of atmospheric carbon dioxide on transpiration.

Increased atmospheric carbon dioxide concentrations may also serve to increase vegetal production. Possible increases in production could, in turn, serve to increase total transpiration from individual plants, as well as increase the per-plant water demand for tissue production and direct evaporation from vegetal surfaces. Long and others (2004) found that carbon dioxide concentrations expected by mid-century would increase dry matter production about 20 percent and seed yield by 24 percent for some plant types, including most crops and trees.

Urbanization can affect local evapotranspiration rates through regional greenhouse gas emissions, increasing amounts of plant physiological stressors such as atmospheric ozone, and through higher temperatures associated with urban island heat effects. Slone and others (2005) reported that temperatures over urban centers can be elevated while temperatures over irrigated land tend to be lower than temperatures over undeveloped areas. A significant increase in urbanization in California is expected by the end of this century.

2.7.2 Agronomic Practices

As noted in Table 2-7, climate change and increasing temperatures can affect total crop water demand by inducing changes in crop type, planting cycles and time of planting. Few studies have assessed the possible impacts of climate change on crop patterns in California (Hayhoe, 2004).

Plant physiological responses to increasing temperature will be mixed, therefore there are likely to be varying agronomic responses to climate change. For example, fewer frost days would allow citrus production to extend to higher latitudes and elevations, including in the Central Valley. However, fewer frost days would be detrimental for tree crops having a chill requirement.

There has been a long-term shift toward planting permanent crops in many parts of California, such as trees and vines. Climate change may increase the variability in precipitation and increase the frequency of droughts. Since agricultural water supplies tend to be curtailed before urban supplies during droughts, the possible consequences of increased droughts for agriculture could become more severe because of increased planting of permanent crops. Droughts typically do not cause lasting damage where crops are planted annually.

2.7.3 Changes in Environmental Water Demand

Climate change could have a significant effect on environmental water demand in California. Two aspects of environmental water demand that will likely be impacted the most are salinity control requirements for the Sacramento-San Joaquin River Delta and temperature control demand for various rivers and the Delta.

2.7.3.1 Delta Salinity Control

The Delta is a key component of California's water supply infrastructure. A major portion of the State's agricultural and urban water supply passes through the Delta to State Water Project and Central Valley Project water diversion facilities.

Salinity levels in the Delta depend on outflow from the Delta to the San Francisco Bay and Pacific Ocean. Saline water from the San Francisco Bay is pushed out of the Delta during periods of high Delta outflow. Saline water can enter the Delta and increase salinity a significant distance inland during low outflow.

Delta outflow primarily depends on the amount of freshwater entering the Delta and the diversion of water from the Delta for the Central Valley Project, the State Water Project, and in-Delta uses which collectively reduce outflow. Most of the inflow to the Delta comes from the Sacramento, Cosumnes, Mokelumne, and San Joaquin rivers. Flows from these rivers are typically highest during the winter and spring in response to annual precipitation and snowmelt. The lowest flows typically occur in the late summer and fall.

The greatest challenge for maintaining salinity levels in the Delta typically comes in the late summer and fall when natural Delta inflow is usually the lowest. Reservoir releases during this

time help maintain river flows into the Delta in the absence of enough natural runoff. The rate of pumping from the Delta can be reduced during this period to help maintain Delta outflow and prevent salinity intrusion. Pumping operations have been severely cut back during dry years; especially when reservoir storage levels are very low due to drought.

As discussed in Section 2.5, climate change is expected to cause more precipitation in the form of rain rather than snow, reductions in water storage in annual snowpack, earlier snowmelt and sea level rise. Each of these factors could present significant reservoir management challenges, particularly for reservoirs in the Sierra foothills. These reservoirs will likely experience changes in the rate and timing of inflow. Changes in reservoir operations and reduced annual storage in snowpack could result in less water being available in the summer and fall to meet Delta outflow and salinity control requirements.

2.7.3.2 Water Temperature Control

Increased air temperatures as the result of climate change will likely increase water temperatures in the State's lakes and waterways. Increased water temperatures pose a threat to aquatic species that are sensitive to temperature, including anadromous fish. Increased water temperatures will also cause decreased dissolved oxygen concentrations in water and other water quality changes, and will likely increase production of algae and some aquatic weeds.

Intermittent temperature problems now exist for some aquatic species in some Central Valley rivers and streams, and in portions of the Delta. Intermittent temperature problems also occur in other areas of the State; including in the Klamath, Eel, and Russian river basins. High water-temperature problems typically occur during the summer and early fall.

Water resource managers often release cold water stored in reservoirs to control downstream water temperatures for aquatic life. Most of the water held in the State's reservoirs is accumulated in the winter and spring when temperatures are lower than at other times of the year. Reservoirs that are downstream of significant snowpack receive cold water from snowmelt through the spring and sometimes into the summer.

Climate change and rising temperatures will increase demand for temperature control releases from many reservoirs. However, coldwater storage in reservoirs needed to supply releases may decrease as the result of climate change due to:

- diminished snowpack and less inflow of late-season cold snowmelt, especially for lower elevation reservoirs in the Sierra Nevada
- increased heating of reservoir inflow
- increase heating of reservoir content and releases
- possible loss of reservoir storage for thermal control releases due to changes in reservoir operations in response to changes in runoff timing

Increased temperature control requirements together with a possible decreased capacity to provide temperature control releases from reservoirs as the result of climate change, could pose a double-sided threat for some aquatic species.

2.7.4 Population

California has experienced rapid population growth since the mid 1800s. This growth is due in part to California's strong economy, natural beauty and relatively mild climate.

California's population is approaching 37 million. The California Department of Finance projects the State's population to be about 44 million by 2020 and about 55 million by 2050 (DOF, 2004). California's population could be as high as 90 million by the end of the century (Landis, 2003). Figure 2-33 depicts growth in the State's population from 1850 to 2005, and projected growth to 2050.

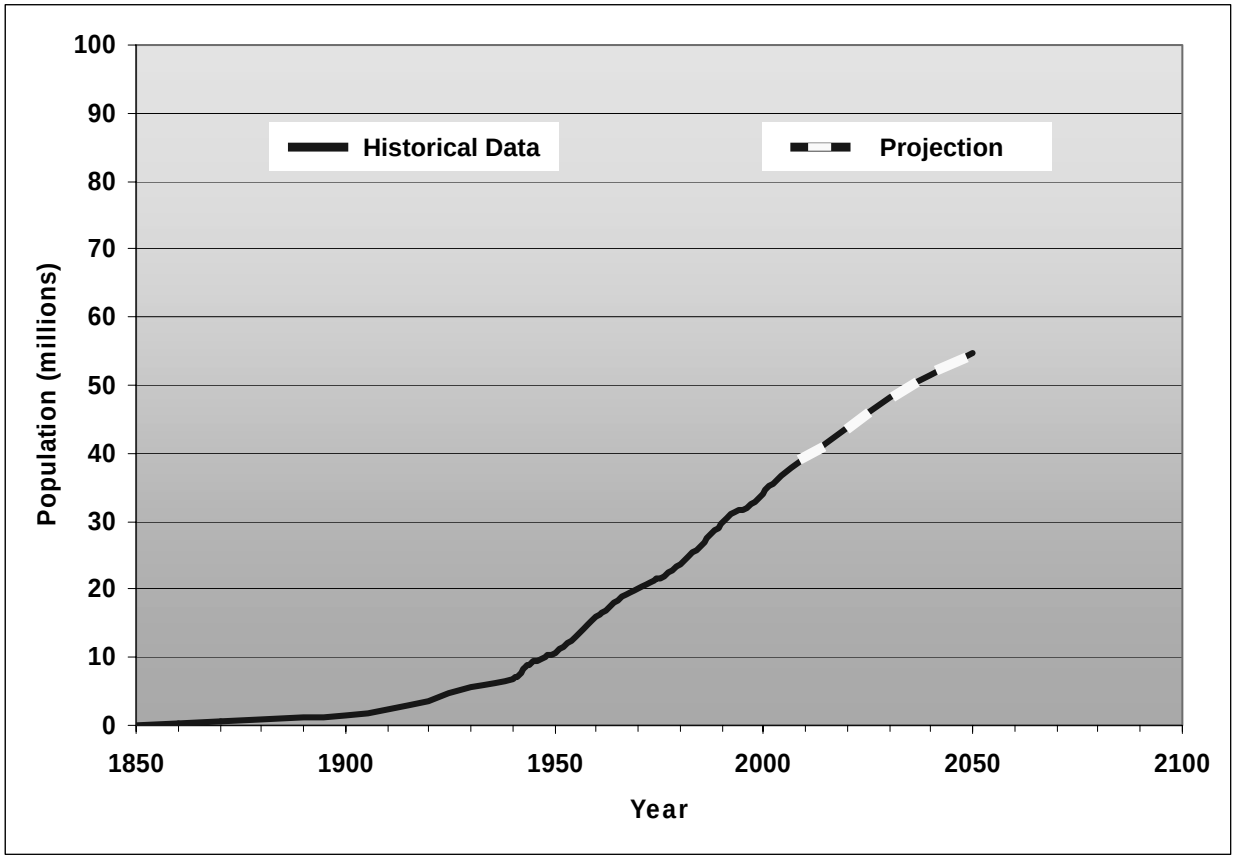


Figure 2-33 Historical and Projected Future Population Growth in California

Data source: DOF (2005)

Future increases in population will affect water demand, depending on the location and types of land development that occur to support an increased population. Much of California's future development is projected to occur on valley floor areas, including in the Central Valley along major transportation systems (Landis, 2003). While climate change is generally not expected to have a major effect on future population growth in California, it could have some effect on the where development occurs.

The conversion of agricultural lands into housing, commercial and industrial uses may not result in an increase in water use for a given area, depending on the agricultural use(s) that existed before conversion and on the specific type of development. Redevelopment and densification of existing urban land may result in increased water demand in some areas. Urbanization of undeveloped land will serve to increase water demand directly. While there is much uncertainty about California's future population growth and development, an increase in the State's population is generally expected to increase the State's total water demand, absent additional measures to conserve water.

2.7.5 Technological Innovation

Technological innovation could play a significant role in determining California's future water demand, as well as future supply. Innovation in water conservation practices could serve to reduce water demand by allowing water to be used more efficiently. Innovation in water resource management could allow California's water resource systems to be managed more efficiently and allow more water supply yield with the same or less environmental impact. Innovation in water resource management and water use would occur with or without climate change. However, given the potential impacts of climate change, there will be an increased impetus for innovation.

A key area for future technological innovation is agricultural water use efficiency. Tanaka and others (2005) have determined that by the year 2100, agricultural water use will fall by 24 percent, while loss of income from agriculture will decrease only 6 percent. This discrepancy between water use and income comes from a predicted shift to higher-value crops and more efficient use of water. A theoretical body of work suggests that horticultural breeding improvements alone can attain a maximum increase in water use efficiency of about 15 percent (Cowan, 1977).

An area of innovation that could affect future water supply conditions, at least in some parts of the State, is sea water desalinization. The unit cost of desalinization has fallen in recent years, however, desalinization remains a relatively expensive and energy-intensive means of obtaining water compared to other water sources. More improvements in desalinization technologies could reduce costs and energy requirements. Desalinization could become a more competitive source of water, especially in coastal areas of Southern California where water is often imported from long distances and at high cost partly because of energy requirements.

2.8 Colorado River Basin

This report is primarily focused on the potential effects of climate change on the Central Valley and associated water resource systems. This is because the Central Valley and its water resource systems supply most of California's water, and because much of the effort to assess the impacts of climate change on the State's water resources has been directed toward the Central Valley. Climate change will affect water resource systems that obtain water from areas outside of the Central Valley. While the timing and scope of this report preclude substantive discussion of most of these systems, it is important to mention the single largest source of water supply for California outside of the Central Valley, the Colorado River.

The Colorado River is an important source of water for Southern California. In the past, California has diverted as much as 5.3 million acre-feet annually from the Colorado River. This is in excess of the State's annual allotment of 4.4 million acre-feet. Even at the allotment of 4.4 million acre-feet per year, the River still supplies about half of Southern California's average annual net water use (DWR, 2005a).

California's diversions from the Colorado River are primarily through the All-American Canal and the Colorado River Aqueduct. The All-American Canal supplies water to cities and agriculture in the Imperial Valley, and to agriculture in the Coachella Valley. The Colorado River Aqueduct supplies water to agriculture and cities of the south coast. Figure 2-34 illustrates the location of the All-American Canal and the Colorado River Aqueduct, as well as the greater service areas for the two systems.

An overview of past, present, and future climate in the Colorado River Basin is presented in a 2005 DWR special report prepared for the Association of California Water Agencies and Colorado Water Users Association conferences (DWR, 2005b). The report discusses hydroclimatic issues for the Colorado River Basin and their implications for water users in the basin. Portions of that report are cited below.

Figure 2-34 The Colorado River Aqueduct, All American Canal and Their Service Areas

Source: California Department of Water Resources, http://www.crss.water.ca.gov/data/ca_service_area.cfm

2.8.1 Description of the Colorado River Basin and its Water Resources

The Colorado River Basin extends into seven western states and Mexico, each of which has strong interests in the river and its water. The states are Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming, as shown in Figure 2-35. While the volume of natural runoff in the basin is relatively small in comparison to its area, an average of about 15 million acre-feet of runoff is generated each year in the Colorado River Basin above Lees Ferry. Lees Ferry is labeled as "Compact Point" in Figure 2-35.

The Colorado River and its tributaries are the major source of water for many of the rapidly growing cities of the seven basin states and northern Baja California. The cities include Denver, Salt Lake City, Las Vegas, Phoenix, Tucson, Los Angeles and San Diego and other communities in south coastal California.

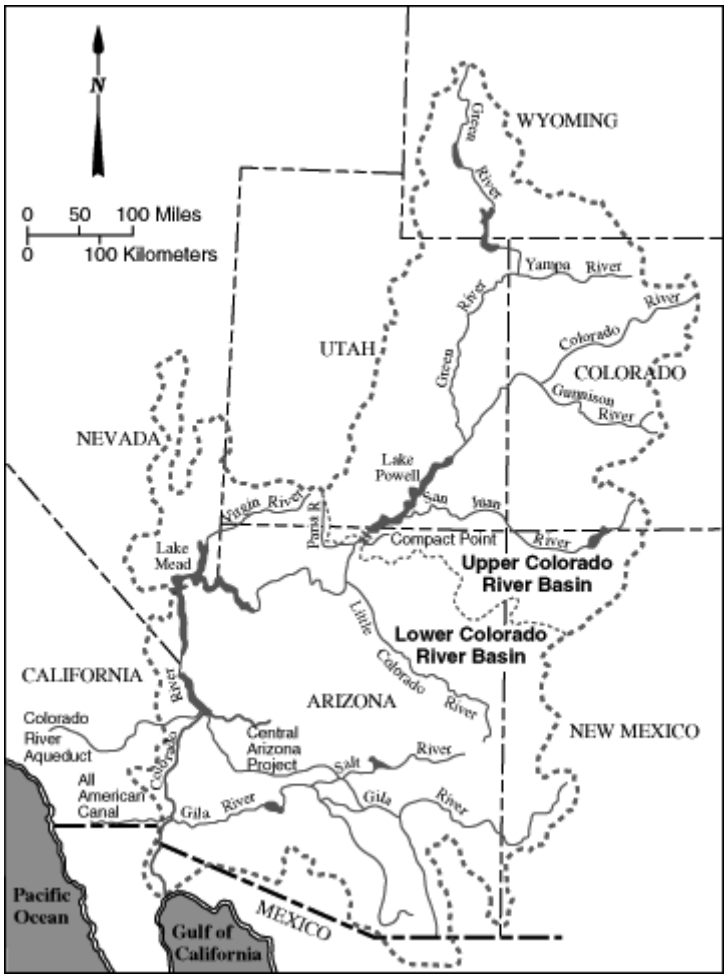


Figure 2-35 Map of the Colorado River Basin

Source: (Dettinger, 1995) http://geochange.er.usgs.gov/sw/changes/natural/codrought/

The Colorado River rises into the snow capped mountains of north central Colorado and flows southwesterly about 1,400 miles to Mexico and the Gulf of California. The River's major tributaries are the Green River, originating in the Wind River Mountains of southwest Wyoming, the Gunnison River from west central Colorado and the San Juan River from southwest Colorado.

The Colorado River basin is estimated to cover an area of about 244,000 square miles, about 8 percent of the land of the conterminous United States. About 2,000 square miles of the basin is in Mexico. The basin is typically considered to consist of two parts, an upper and lower basin, with the dividing point at the Lees Ferry gauging station in north-central Arizona, just downstream of Glen Canyon Dam and Lake Powell.

The upper Colorado River basin is nearly half the total drainage area of the entire basin or 109,300 square miles. Most of the water flowing in the Colorado River originates in the upper basin mountains, but significant tributaries also exist in the lower basin including the Little Colorado River in northeastern Arizona, the Virgin River in southwestern Utah and southeastern Nevada and the Gila River system of south central Arizona and extreme western New Mexico.

The Colorado River basin is one of the driest major watersheds in the United States. Average annual basin precipitation is 13.9 inches, with an annual average of 15.2 inches in the upper basin and 12.9 inches in the lower basin. Much of the Colorado River basin is desert receiving less than 10 inches of precipitation per year. High elevation areas receive significantly more precipitation, over 50 inches at some locations. The wetter areas of the Colorado River Basin consist of the Wind River Mountains in Wyoming, Rocky Mountains in Colorado, San Juan Mountains in southwest Colorado, the Uinta Mountains in northeast Utah and the Mogollon Rim in east central Arizona. The driest areas of the basin are in the basin's southwest corner near Yuma, Arizona. This area receives about 3 inches of annual precipitation. Figure 2-36 illustrates the distribution of average annual precipitation in the basin.

Most of the precipitation in the Colorado River basin is from winter storms originating in the Pacific Ocean. Most of the runoff from these storms comes from the high mountainous areas in the basin's upper reaches. These areas are favored by orographic precipitation and winter snowpacks. While these areas only constitute about 15 percent of the basin's entire area, they generate about 85 percent of its entire natural runoff.

Occasionally, more often in El Nino years, major winter storms from the Pacific Ocean move across Southern California and into the lower portions of the basin. These southern-track storms can provide heavy winter rainfall at low elevations in Arizona, and heavy snow in the San Juan Mountains of southwestern Colorado.

A major factor that sets the climate of the Southwest United States and southern part of the Colorado River Basin apart from the rest of the country is the North American monsoon system. Typically, during the months of July, August, and the first half of September, regional circulation patterns change and cause moisture-laden air to move into the Southwest from the Pacific Ocean, the Gulf of California, and the Gulf of Mexico. As this moist air moves into the

southwest, a combination of orographic uplift and daytime heating from the sun causes thunderstorms to develop.

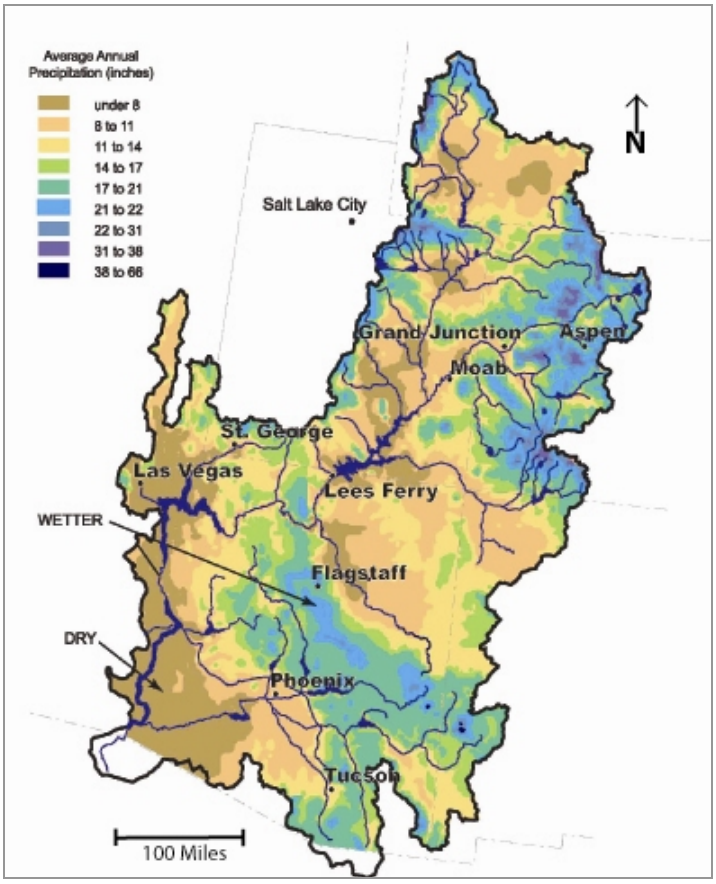


Figure 2-36 Distribution of Average Annual Precipitation in the Colorado River Basin
Adapted from The University of Arizona's Institute for the Study of Planet Earth CLIMAS
http://www.ispe.arizona.edu/climas/learn/swnutshell/sld004.htm

Summer monsoonal rainfall is an important fraction of the total annual precipitation received in southeastern Arizona, much of New Mexico, and southern Colorado. Most of the monsoonal rain is from thunderstorms and is highly localized and sometimes very intense. Although monsoonal rainfall is very important to nourishing watershed vegetation in parts of the southwest, and can cause local flooding, it does not contribute much to flows in the Colorado River or its major tributaries.

Finally, in the summer of some years, the remnants of a Pacific hurricane off the west coast of Mexico will move north over northwestern Mexico and into the Southwest United States. These tropical storms can produce regional rainfall over the desert and flash floods in some of the mountain watersheds.

Since the latter part of 1999, the upper Colorado River basin has experienced an extended severe drought. Water year 2005 saw improved hydrologic conditions in the basin. Figure 2-37 illustrates the volume of water stored in Lake Powell and Lake Mead since the construction of both reservoirs. The decline in reservoir storage after 1999 illustrates the significance of the

recent drought. While hydrologic conditions improved in Water Year 2005 and the severity of drought conditions in the basin has eased somewhat, it is premature to declare that the drought in the upper basin is over (DWR, 2005b).

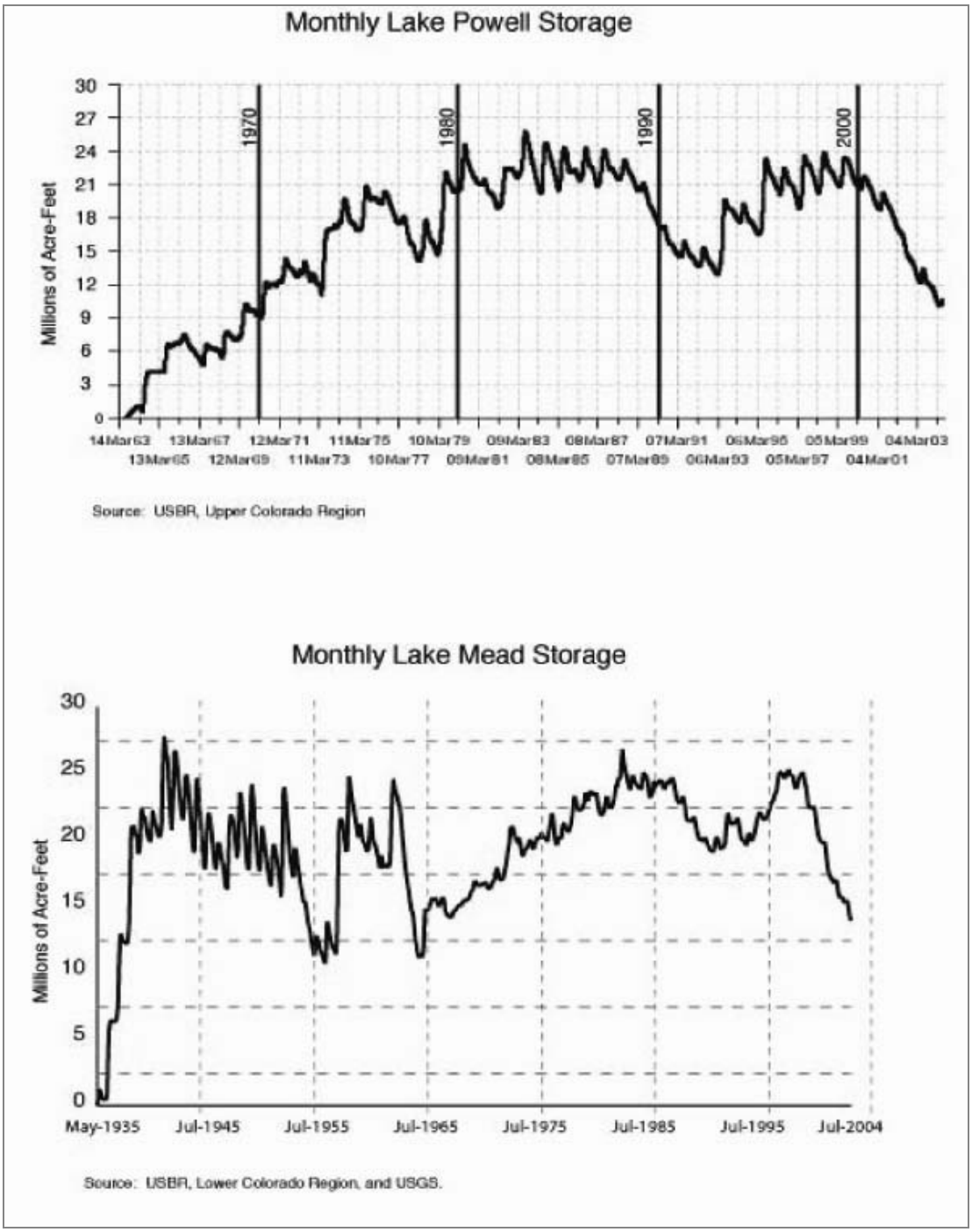


Figure 2-37 Monthly Storage Volumes in Lake Powell and Lake Mead since their Construction

2.8.2 Allocation of Water in the Colorado River Basin

The 1922 Colorado River Compact formally divided the Colorado River basin at Lees Ferry into two parts: an upper basin and lower basin, as described earlier. Each basin was apportioned 7.5 million acre-feet of Colorado River water annually for water supply purposes. A 1944 treaty between the United States and Mexico guarantees Mexico 1.5 million acre-feet annually. The burden of this guarantee is shared equally by the upper and lower basins.

The upper basin states allocated use among themselves in 1948. The allocation of water in the lower basin was decided by the U.S. Supreme Court in 1964. The court decided that the annual apportionment of 7.5 million acre-feet for the lower basin would be allocated as follows: 4.4 million acre-feet to California, 2.8 million acre-feet to Arizona, and 0.3 million acre-feet to Nevada. One of the salient points of the Supreme Court decree was that Arizona's use of Gila River water is not part of its 2.8 million acre-feet allocation. In addition, all lower basin states have the right to use tributary flows before they join the Colorado River without affecting their appropriation of Colorado River water.

2.8.3 Climate Change and the Colorado River Basin

Flows in the upper Colorado River basin are mostly a function of snowmelt. Warmer air temperatures as the projected result of climate change would tend to reduce the basin's middle elevation snowpack. Warmer air temperatures would also tend to cause earlier melting of annual accumulations of snow. Annual snowmelt could begin several weeks sooner than it does now, depending on the amount of warming that occurs.

Warming in the upper Colorado River Basin could cause an increase in winter runoff due to higher minimum snow elevations during winter storms and less precipitation falling and accumulating in the form of snow. Since reservoir storage in the Colorado River Basin is so large in comparison to average annual basin runoff (roughly four times average runoff), a change in the timing of annual runoff in the basin as the result of climate change would not be expected to significantly affect basin yield. Figure 2-38 illustrates locations of the larger reservoirs in the basin.

Recently completed climate model runs for the upcoming Intergovernmental Panel on Climate Change's 4th Assessment indicate a winter temperature increase of 1.1 to 2.0 degrees Celsius in the Colorado River basin by 2050, with continued temperature rise expected through the end of the century. Upper basin runoff from annual snowmelt would likely peak five to 25 days earlier than the average time of peak runoff for the 1951-80 historical period (Garfin, 2005).

Possible changes in amount of precipitation received by the Colorado River basin as the result of climate change could affect basin yield and thus are potentially of more concern for water supplies than predicted changes in the timing of runoff. As discussed previously, about 85 percent of upper basin runoff is contributed by its high elevation watersheds. Therefore, possible changes in high mountain watersheds and the amount runoff from them could be the most important. Although climate models provide precipitation projections, projections for a specific region, such as the Southwest, vary considerably between models and are probably not reliable (Garfin, 2005).

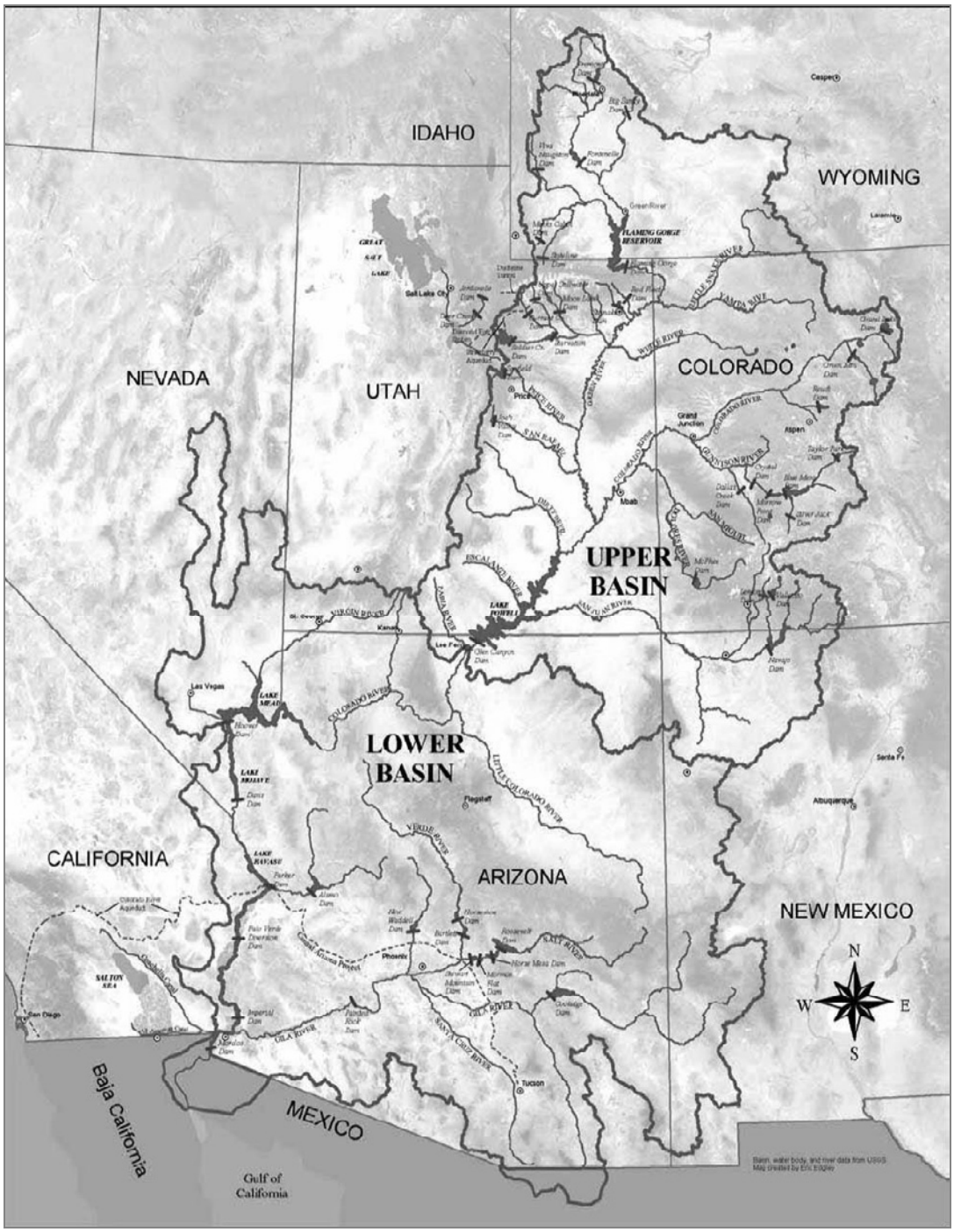


Figure 2-38 Size and Locations of Reservoirs in the Colorado River Basin

From http://www.water.utah.gov/interstate/thecoloradoriverart.pdf

Warmer temperatures from climate change could be expected to cause drying of water-producing areas of the vast Colorado River watershed somewhat sooner each year than what occurs today. One study indicates that a precipitation increase of 10 percent may be required to offset the drying effect of a 2 degree Celsius rise in temperature (Nash and Gleick, 1993).

More extreme precipitation events are generally expected to accompany increasing temperatures associated with climate change. More extreme precipitation events in the Colorado River watershed would in turn be expected to increase sediment production. Basin sediment production would also likely increase given that a higher percentage of the basin's precipitation would likely fall in the form of rain rather than snow due to increased temperatures. If more frequent wild fires were to occur because of earlier drying of watersheds, or simply because of increased summer temperatures, sediment production would be increased further. Increased sediment production would adversely affect water quality and increase the rate of reservoir capacity loss due to sedimentation.

There are likely to be changes in water demand in the Colorado River basin as the result of climate change. Changes in demand at any particular location will probably be small, however, the aggregate change for the basin could be significant since so much land is involved.

One of the key questions concerning possible changes in water demand is what effect climate change will have on evapotranspiration rates for crops and landscaping. Also of concern are possible changes in water use by water loving plants knows as phreatophytes along rivers and streams. Phreatophytes can cause a significant loss in stream flow and shallow groundwater.

As discussed in Section 2.7.1, evapotranspiration rates increase with temperature if other factors that effect evapotranspiration, such as cloudiness, humidity, and atmospheric carbon dioxide content remain the same. However, higher atmospheric carbon dioxide levels expected in the future will act to reduce water consumption by plants, as evidenced by laboratory tests.

Increasing temperatures in the Colorado River Basin will likely increase reservoir evaporation losses. Evaporative losses from open portions of conveyances such as the Central Arizona Project, Colorado River Aqueduct, and the All-American Canal would likely increase as well.

2.8.4 Summary

The Colorado River Basin provides water to Southern California. Expected changes to the Colorado River Basin associated with climate change include:

- Less precipitation falling as snow and an earlier snow melt
- Increased evaporation from reservoirs and conveyance facilities
- Increased sediment production due to more extreme events and more precipitation falling as rain than snow
- Changes in water demand

Changes in the amount of water available to California from the Colorado River Basin may change if long-term decreases in runoff occur.

2.9 Possible Effects on Fish

This section describes aspects of climate change that could affect the abundance of fish in California's inland waters. It focuses on a few key species that have major implications for water management, including rainbow trout, coho and Chinook salmon and Delta smelt. The analysis omits numerous fishes throughout the State for which the influence of climate change and its implications for water management seem less clear.

In California, the timing and amounts of water released from reservoirs and diverted from streams are limited by their effects on various native fishes, especially those that are listed as threatened or endangered under the federal and State endangered species acts. These include winter-run and spring-run Chinook salmon, coho salmon, coastal and Central Valley forms of steelhead rainbow trout, Lahontan cutthroat trout, razorback sucker and Delta smelt. California constitutes the warm, southern end of the geographic range of most of these species.

By 2100, climate change is expected to raise average air temperatures by about 1.4 to 5.8 degrees Celsius in California, raise stream water temperatures by at least as much, greatly reduce California's snowpack, shift the seasonal pattern of surface-water runoff to more in winter and less in spring and summer, and raise sea level by 0.3 of a foot to 2.9 feet (IPCCa, 2001). These physical changes are likely to influence the ecology of aquatic life in California and have several major effects -- all of them negative -- on cold-water fishes.

In many low- and middle-elevation California streams today, summer temperatures often come close to the upper tolerance limits for salmon and trout. Thus, anticipated climate change that raises air temperatures a few degrees Celsius may be enough to raise water temperatures above the tolerance of salmon and trout in many streams, favoring instead non-native fishes such as carp and sunfish.

Unsuitable summer temperatures are a problem because many of the threatened and endangered fishes spend the summer in cold-water streams, either as adults, juveniles, or both. Adults of some populations, such as spring-run Chinook, spend the summer near their upstream spawning grounds waiting for conditions suitable for spawning in fall or winter. Chinook salmon and steelhead, for example, prefer temperatures of less than 18-20 degrees Celsius in mountain streams, although they may tolerate higher temperatures for short periods (Moyle, 2002).

2.9.1 Regional Effects

The specific nature of ecological effects on fishes will differ among regions of the State. The following three regions are important for water supply and will see major effects from climate change:

- Region 1 – Basins with snowpack. River basins that drain the Sierra Nevada and Cascade Range and store water as snowpack;
- Region 2 – Basins without snowpack. River basins without significant snowpack, including all coastal streams south of the Klamath River basin; and
- Region 3 - The Sacramento-San Joaquin River Delta.

Streams on the eastern slope of the Sierra Nevada and in Southern California, as well as the Colorado River, are also important for water supply, but the effects of climate change on fishes there are less clear.

Winter-run and spring-run Chinook salmon, coho salmon, and coastal and Central Valley steelhead trout spawn in Region 1. Coho salmon and steelhead trout occupy coastal streams in the second region. Delta smelt spend their entire lives in the third region, while steelhead trout and Central Valley Chinook salmon migrate through it. All of these fishes are listed under the federal Endangered Species Act.

2.9.1.1 Region 1- Basins with Snowpack

The Sierra-Cascade basins are predicted to get less snow and more rain, more winter and less spring and summer runoff, and warmer runoff. Spring-run Chinook salmon and steelhead trout in some streams migrate upriver into the foothills and mountains early in the year, spend the summer in deep, cold pools, and spawn the following fall (salmon) or winter (steelhead). Adult survival over the summer depends upon the availability of cold water. The combination of streams being both warmer and shallower in the summer due to climate change may diminish most summer habitat for steelhead and potentially all such habitat now used by spring-run salmon.

Many salmon and rainbow trout spawn and rear below dams, or at hatcheries associated with dams. Climate change could reduce the volume of cold water in foothill reservoirs since they would receive less snowmelt and have reduced carryover storage. Thus, releases of cold water to support fish spawning and rearing below such reservoirs may decline and fish production could also decline.

2.9.1.2 Region 2 - Basins without Snowpack

Streams in basins without significant snowpack will likely be warmer in the dry season than now (as well as in the winter), matching the expected rise in air temperature. Warmer inland areas as the result of climate change may increase summer coastal fog which could provide mitigating effects for coastal areas and streams.

Juvenile coho salmon and coastal steelhead trout remain in fresh water through the summer. Climate change could make coastal streams too warm for coho salmon in the summer, especially for the more extreme projections of temperature rise. Steelhead trout could disappear from the more southerly streams in their current range (in Central and Southern California), and would probably be less abundant elsewhere.

2.9.1.3 Region 3 - Sacramento-San Joaquin River Delta

The Sacramento-San Joaquin Delta will become saltier if sea level rise predictions are correct, Delta operations remain the same and the Delta retains its present physical configuration. The predicted decline in natural runoff during the spring, summer and fall could make the Delta even

saltier, and over a larger area. River water at the upstream end of the Delta will still be fresh in summer, but is likely to be warmer than now if measures are not taken.

The Delta smelt occurs in the Sacramento-San Joaquin Estuary and nowhere else. During periods of drought, its center of abundance has been the channel of the Sacramento River in the upstream part of the Delta (Moyle, 2002). Delta smelt rarely occur in waters above 24 degrees Celsius and cannot survive long in water above 25 degrees Celsius (Swanson and others, 2000). Current peak temperatures in the lower Sacramento River at Hood and Rio Vista, for example, are already within a few degrees of these temperature thresholds (CDEC).

In short, a possible result of climate change is that Delta smelt will have little or no suitable habitat in summer. Waters in the lower Delta may be too salty and lacking in food, while fresh water in the upper Delta may be too warm. Thus, the species may become much less numerous or may even go extinct.

2.9.2 Summary

As evident from the above discussion, climate change could have a significant impact on threatened and endangered fish in California. Climate change could also have serious implications for fish that are not now identified as threatened and endangered, but might be affected to a point where they become designated as such.

2.10 Sudden Climate Change

Most global climate models predict that climate change due to human causes will be a continuous and somewhat gradual process through the end of this century. With proper foresight, planning and action, water managers will likely be able to help California adapt to many of the water supply challenges posed by climate change, even at some of the higher projections for change. However, sudden and unexpected changes in climate could leave water managers unprepared and could, in their extreme, have serious implications for California and its water supplies.

Sudden climate change could occur if progressive changes in the earth's climate cause a physical threshold or "trigger point" to be reached where one of the earth's major atmospheric or oceanic systems changes significantly, or ceases to function. One possible example of this that has received a significant amount of attention is a possible change in the global thermohaline circulation system depicted in Figure 2-39.

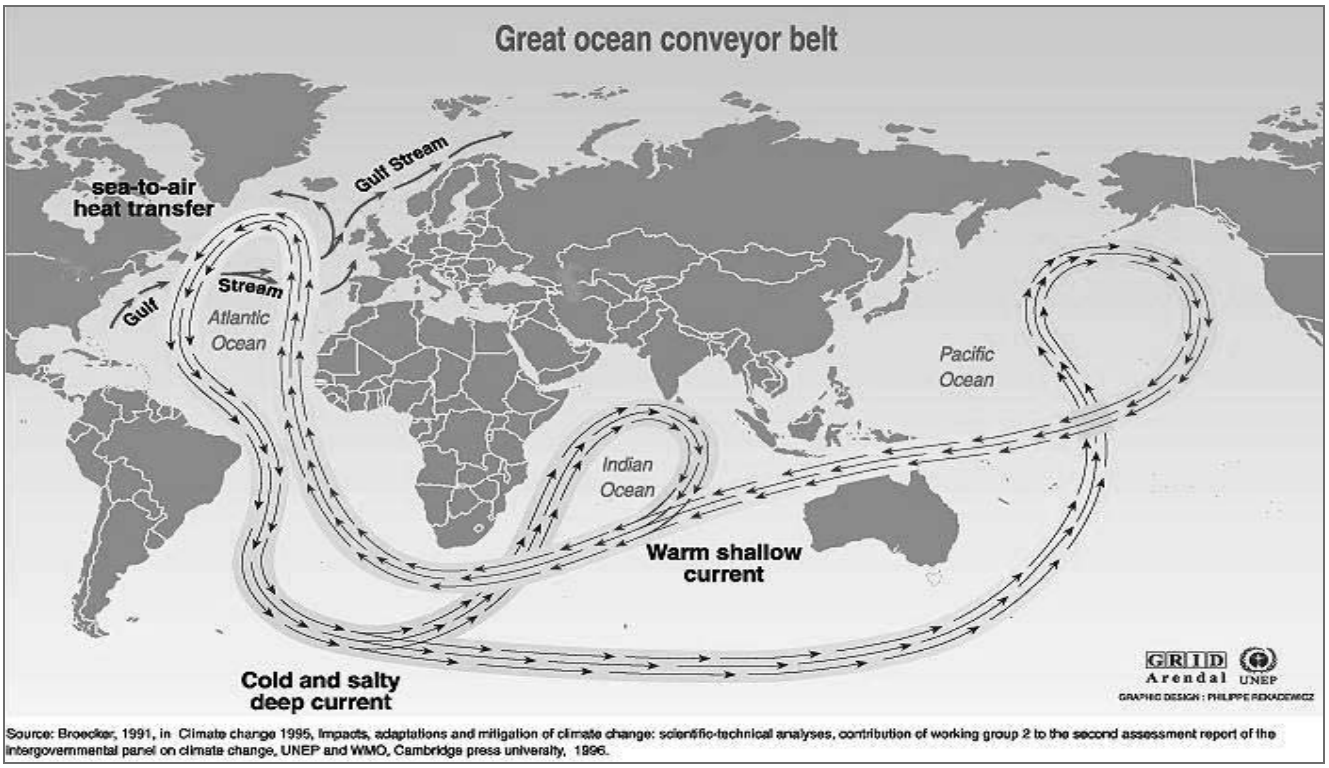


Figure 2-39 The Global Thermohaline Circulation System
Source: GRIDA, 2005.

There is evidence that circulation in the North Atlantic Ocean in relation to the global thermohaline system is slowing (Nature, 2005). While the complete shutdown of the system would likely lead to relatively rapid and significant changes in the earth's climate, such a scenario is considered by most scientists to be unlikely to occur in the next 50 years. The IPCC reports that none of the climate models it used in its evaluations project the complete shutdown of the system before 2100 (IPCC, 2001a).

Relatively sudden and often short-term changes in the climate of California and the western United States have occurred during at least the past 2000 years, as evidenced by precipitation and streamflow measurements over about the past 100 years and paleoclimatological information derived from physical evidence such as annual growth rings in trees. Of particular concern are extreme droughts, some of which appear to have occurred over large areas of the western United States and extended over several decades (MacDonald, 2005, Woodhouse, 2005). The exact cause of these events is unknown. However, there is speculation that some of the more recent droughts may have been due, at least in part, to oscillating conditions in the world's oceans.

Finally, other phenomena that could cause sudden and unexpected changes in the earth's climate include volcanic activity and the impact of meteorites or other extraterrestrial matter with the earth's surface. Large volcanic eruptions during recorded history have been observed to have caused temporary regional and sometimes global-scale cooling from one to several years (Kelly, 1996). While both volcanic eruptions and the impact of large extraterrestrial objects with the

Earth could suddenly affect the State's climate and water resources, the frequency of their occurrence together with their projected effects are extremely difficult to predict.

2.11 Summary

As discussed in previous sections, climate change could cause significant impacts on California's water resources and water demand. Changes in temperature and precipitation patterns in the State have been observed over the past century. Further changes are expected over the next century due to climate change. Changes in sea level are also expected to occur in response to the changing climate. These changes in precipitation and temperature patterns across the State may have profound impacts on ecologic and water resources systems in the State.

There is a significant amount of uncertainty about the magnitude of climate change that will occur over this century. It is unlikely that this level of uncertainty will diminish significantly in the foreseeable future (Dettinger, 2005b). There is also uncertainty about changes in hydrologic conditions, aquatic ecosystems and water demand that could occur as the result of various amounts of climate change. In the following chapters of this report, an initial attempt is made to quantify the impacts of climate change on some aspects of California's water resources.

2.12 References

Sources for illustrations are referenced below each illustration. References cited in the chapter text are listed below.

Bromirski (2005). Dr. Peter Bromirski, Assistant Project Scientist, Scripps Institute of Oceanography, La Jolla, CA, personal communication 10-10-2005.

CDEC [California Data Exchange Center]. California Department of Water Resources.

CRU (2000). Climatic Research Unit, School of Environmental Sciences University of East Anglia, United Kingdom Website. http://www.cru.uea.ac.uk/cru/info/thc/ November 30, 2005.

Cayan (2001). Changes in the Onset of Spring in the Western United States.[Cayan, D.R., Susan A. Kammerdiener, Michael D. Dettinger, Joseph M. Caprio, and David H. Peterson] Bulletin of the American Meteorological Society. Vol. 82, No. 3, March 2001.

Cowan, (1977). *Stomatal diffusion in relation to leaf metabolism and environment*. [Cowan, I.R. and Farquhar, C.D.] Symp. Soc. Exp. Biol. 31, 471-505. 1977.

DOF (2005). *Data File: Historical and Projected Population for California*. California Department of Finance.

DWR (1951). Water Resources of California [California Water Resources Board (now California Department of Water Resources)].

DWR (1958). Sea-Water Intrusion in California, Bulletin 63. [California Department of Water Resources]. November, 1958.

DWR (1975). Sea-Water Intrusion in California, Inventory of Coastal Ground Water Basins, Bulletin 63-5. [California Department of Water Resources]. October, 1975.

DWR (1994). The California Water Plan Update, Bulletin 160-93. [California Department of Water Resources]. October, 1994.

DWR (1998). California Water Plan Update, Bulletin 160-98. [California Department of Water Resources]. 1998.

DWR (2003). *California's Groundwater; Bulletin 118, Update 2003.* [California Department of Water Resources].

DWR (2005a). California Water Plan, Update 2005 (Draft). [California Department of Water Resources]. Final Draft.

DWR (2005b). Special Publication for Association of California Water Agencies and Colorado River Water Users Association Conferences, prepared by the California Department of Water Resources, Sacramento. November, 2005.

DWR (2005c). Water Conditions in California, *California Cooperative Snow Surveys Bulletin 120*. [California Department of Water Resources].

Dettinger (2005a). Changes in Streamflow Timing in the Western United States in Recent Decades. [Michael D. Dettinger] U.S. Geological Survey. Fact Sheet, *http://pubs.usgs.gov/fs/2005/3018/pdf/FS2005_3018.pdf*

Dettinger (2005b). From climate-change spaghetti to climate-change distributions for 21st Century California. [Michael D. Dettinger] San Francisco Estuary and Watershed Science. Vol. 3, Issue 1 (March 2005), Article 4. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4

Easterling, (2000). *Observed Variability and Trends in Extreme Climate Events: A Brief Review*. [D.R. Easterling, J.L. Evans, P. Ya. Groisman, T.R. Karl[1], K.E. Kunkel, P. Ambenje] Bulletin of the American Meteorological Society, **81**, March 2000, 417-425. http://www.ncdc.noaa.gov/oa/pub/data/special/extr-bams2.pdf

Freeman (2002). Looking for Recent Climatic Trends and Patterns in California's Central Sierra. [Gary J. Freeman]. 2002 PACLIM Conference Proceedings.

Garfin (2005). *Climate and Hydrology in the Colorado River Basin, September 2005 (advance copy)* . [Greg Garfin, University of Arizona].

Gibeaut, J. C. (2000). *Texas Coastal Hazards Atlas Volume 1*. Bureau of Economic Geology, University of Texas, Austin.

Givati (2004). *Quantifying Precipitation Suppression Due to Air Pollution* . [Amir Givati and Daniel Rosenfeld, The Hebrew University of Jerusalem] Journal of Applied Meteorology: Vol. 43, No. 7, pp. 1038–1056.

GRIDA (2005). United Nations Environment Programme, Global Resource Information Database-Arendal (GRIDA) Website at: http://www.grida.no/climate/vital/32.htm. November 30, 2005.

Groisman (2005). *Changes in precipitation distribution spectra and contemporary warming of the extratropics: implications for intense rainfall, droughts, and potential forest fire danger.* [Pavel Ya. Groisman, NOAA/NESDIS/NCDC, Asheville, NC; and R. W. Knight, D. R. Easterling, D. Levinson, R. R. Heim, Jr., T. R. Karl, P. H. Whitfield, G. C. Hegerl, V. N. Razuvaev, B. G. Sherstyukov, J. G. Enloe, and N. S. Stroumentova]. Preceedings of the 16th Conference on Climate Variability and Change, 85th American Meterological Society Meeting, San Diego, CA, January 2005. http://ams.confex.com/ams/Annual2005/techprogram/paper_85857.htm

Hayhoe (2004). *Emissions pathways, climate change, and impacts onCalifornia.* [Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville] Proceedings of the National Academy of Sciences of the United States of America 101:12422-12427.

Hidalgo (2005). Sources of variability of evapotranspiration in California. [Hidalgo, H.G., Cayan, D.R., Dettinger, M.D.] J. Hydrometerology. 6, 3-19.

Hulme (1995). *Estimating Global Changes in Precipitation.* Weather, Vol. 50, No. 2, February 1995.

Inman, et. al. (2002). *Facing the Coastal Challenge: Modeling Coastal Erosion in Southern California, October 27, 2002* [Douglas L. Inman, Patricia M. Masters, Scott A. Jenkins, Coastal Morphology Group Integrative Oceanography Division Scripps Institution of Oceanography University of California, San Diego.] (http://repositories.cdlib.org/sio/cmg/12/)

IPCC (2001a). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*.[Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K.Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp. ISBN 0521 80767 0. http://www.grida.no/climate/ipcc_tar/wg1/index.htm

IPCC (2001b). *Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Watson, R.T. and the Core Writing Team (eds.)]. Cambridge University Press, Cambridge,United Kingdom, and New York, NY, USA, 398 pp.

IPCC (2000). Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios, Nebojsa Nakicenovic and Rob Swart (Eds.), Cambridge University Press, UK. pp 570, http://www.grida.no/climate/ipcc/emission/.

Kerr (2005). *El Niño or La Niña? The Past Hints at the Future.* [Richard A Kerr]. Science Vol. 309, 29 July 2005. www.sciencemag.org

Kelly (1996). "The Spatial Response of the Climate System to Explosive Volcanic Eruptions." [Kelly, P. M., Jones, P. D., and Jia Pengqun,] International Journal of Climatology 16 (5), 537-550.

Knowles (2002). *Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary.* [Knowles, N., and D. R. Cayan]. Geophys. Res. Lett., 29(18), 1891, doi:10.1029/2001GL014339.

Lempert (2003). *Shaping the Next One-Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis* [Lempert, R. J., S.W. Popper and S.C. Bankes], RAND Corporation, ISBN 0-08330-3275-5. 2003.

Landis (2003). *How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint through the Year 2100* (August 1, 2003). [John D. Landis and Michael Reilly] Institute of Urban & Regional Development. IURD Working Paper Series. Paper WP-2003-04. http://repositories.cdlib.org/iurd/wps/WP-2003-04 ,

Long (2004). *Rising atmospheric carbon dioxide: plants FACE the future.* [Long, S.P., Ainsworth, E.A., Rogers, A. and Ort, D.R.] (2004) Annu. Rev. Plant Biol. 55, 591-628.

MacDonald (2005). *Southern California and the "Perfect Drought"* [MacDonald G., S. Rian and H. Hildalgo]. Special Publication for Association of California Water Agencies and Colorado River Water Users Association Conferences, November, 2005.

Miller (2003). Miller, N.L., K.E. Bashford, E. Strem, 2003: Potential Impacts of Climate Change on California Hydrology, J. Amer. Water Resoures Assoc., 771-784.

Miller (1998). Climatically Sensitive California: Past, Present, and Future Climate. Presentation at California Workshop on Regional Climate Variability and Change, Santa Barbara, CA 9-11 March 1998

Mote (2005). *Declining mountain snowpack in western North America.* [Mote, P. W., A. F. Hamlet, M. Clark, and D. P. Lettenmaier] Bulletin of the American Meteorological Society 86(1):39-49

Mount (2004). Subsidence, Sea Level Rise, Seismicity in the Sacramento-San Joaquin Delta: Report to the Levee Integrity Subcommittee of the California Bay-Delta Authority Independent Science Board, December 2004. [Jeffery Mount and Robert Twiss, members of the CalFED Independent Science Board]. http://science.calwater.ca.gov/pdf/isb/ISB_subcom_levee_report_120104.pdf#search='mount%20%26%20twiss

Moyle (2002). Inland Fishes of California. University of California Press.

Munk (2002). Twentieth Century Sea Level: An Enigma. [Walter Munk] Proceedings of the National Academy of Sciences, Vol. 99, No. 10, pp. 6550-6555, May 14, 2002.

NOAA (2005). Global Warming, FrequentlyAsked Questions. [National Oceanic and Atmospheric Administration , National Climatic Data Center]. http://lwf.ncdc.noaa.gov/oa/climate/globalwarming.html#Q5 October 23, 2005

NWS (2005). National Weather Service, Climate Prediction Website. December 12, 2005. http://www.cpc.ncep.noaa.gov/charts.shtml

Nash and Gleick (1993). The Colorado River Basin and Climatic Change: The Sensitivity of Streamflow and Water Supply to Variations in Temperature and Precipitation. [Nash, L. and P. Gleick.] U.S. Environmental Protection Agency, EPA230-R-93-009, Washington, D.C. 121 pp.

Nature (2005). *Oceanography: The Atlantic heat conveyor slows.* [Detlef Quadfasel], Nature, Volume 438 Number 7068. December 1, 2005.

PASSC (2005). *Earth Impact Database.* University of New Brunswick, Planetary and Space Science Centre http://www.unb.ca/passc/ImpactDatabase/index.html. December 1, 2005.

Roos (1989). *Possible Climate Change and its Impact on Water Supply in California.* Oceans '89 Conference. [Maurice Roos, California Department of Water Resources]. Institute of Electrical and Electronic Engineering; Seattle, Washington.

Sloan (2005). L. C. Sloan, L. Kueppers, M. Snyder, D. Cayan, M. Tyree, M. Kanamitsu, H. Kanamaru, N. Miller, J. Jin, G. Franco, B. Weare. Have urban and agricultural land use changes affected California's climate? 2nd Annual Climate Research Conference and First Scientific Conference West Coast Governors' Global Warming Initiative. http://www.climatechange.ca.gov/events/2005_conference/presentations/2005-09-14/2005-09-14_SLOAN.PDF

Swanson (2000). Comparative environmental tolerances of threatened delta smelt (Hypomesus transpacificus) and introduced wakasagi (H. nipponensis) in an altered California estuary. [Swanson, C., T. Reid, P.S. Young, and J.J. Cech, Jr.] Oecologia 123: 384-390.

Tanaka (2005). Climate Warming and Water Management Adaptation for California. [Tanaka, S.K., Zhu, T, Lund, J.R., Howitt, R.E., Jenkins, M.W., Pulido, M.A., Tauber, M., Ritzema, R.S., Ferreira, I.C.]. Climatic Change, (in press).

Titus (1995). *The probability of sea level rise.* [James G. Titus, Vijay K. Narayanan]. Washington, D.C.: U.S. Environmental Protection Agency. 186 pp. EPA 230-R95-008. (http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ResourceCenterPublicationsProbability.html)

USDA (2003). *California Agricultural Statistics 2003,* U.S. Department of Agriculture, 2003. .

Wara (2005). *Permanent El Nino–Like Conditions During the Pliocene Warm Period.* [Michael W. Wara, Ana Christina Ravelo, and Margaret L. Delaney]. Science Vol.309, 29 July 2005. www.sciencemag.org

Woodhouse (2005) *Paleoclimate Overview* [Connie Woodhouse]. Special Publication for Association of California Water Agencies and Colorado River Water Users Association Conferences, November, 2005.

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
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Chapter 3:
DWR Climate Change Studies

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3 DWR Climate Change Studies

3.1 Introduction

This chapter provides an overview of climate change studies being conducted by the California Department of Water Resources (DWR). DWR is doing the studies to determine potential effects of climate change on management of California's water resources in support of the governor's Executive Order S-3-05 described below. This chapter explains the background and approach for conducting these climate change studies. It also describes the specific climate change scenarios selected for study. Subsequent chapters of this report will present the results of the studies.

3.2 Background

In June 2005, Gov. Arnold Schwarzenegger issued Executive Order S-3-05 on climate change. It set future greenhouse gas emissions targets for California. It also requires reports every two years on climate change impacts to five areas including water resources. The first of those reports is due to the governor in January 2006. To comply with the Executive Order a Climate Action Team (CAT) was formed with representatives from various state agencies, including the Resources Agency. A subcommittee of the CAT selected four climate change scenarios for analysis for the initial climate change report. The California Energy Commission (CEC) is coordinating the publication of that report.

This report is supplemental and complementary to the CEC report. This report focuses only on water resources. DWR staff has conducted preliminary studies on incorporating climate change into the planning and management of California's water resources. Whenever appropriate, the four climate change scenarios selected by the CAT were used in the DWR studies. DWR has coordinated efforts with other groups conducting modeling studies of climate change impacts on water resources. The groups include the University of California, Berkeley, (CalSim-II); University of California, Davis, (CALVIN); and the Natural Heritage Institute (WEAP).

In addition to these DWR studies for the governor, the California Water Plan Update 2005 includes a qualitative discussion of the possible statewide effects of climate change (DWR, 2005). An expanded, more quantitative discussion of statewide impacts will be included in future Water Plan Updates and will use information from the studies described in this report and other studies done outside DWR.

3.3 Climate Change Scenarios

The four climate change scenarios selected by the CAT were chosen from among several available scenarios compiled for the United Nation's Intergovernmental Panel on Climate Change's (IPCC's) Fourth Assessment Report which is due out in 2007. The four climate change scenarios consist of two greenhouse gas (GHG) emissions scenarios, A2 and B1, each

represented by two different Global Climate Models (GCMs), the Geophysical Fluid Dynamic Lab model (GFDL) and the Parallel Climate Model (PCM). The four climate change scenarios are:

- GFDL A2
- PCM A2
- GFDL B1
- PCM B1

The A2 emissions scenario assumes high growth in population, regional based economic growth, and slow technological changes, which results in significantly higher greenhouse gas emissions. The B1 scenario represents low growth in population, global based economic growth and sustainable development that results in the lowest increase of greenhouse gas emissions of the IPCC scenarios. Both the GFDL and PCM models project future warming. The GFDL model indicates a greater warming trend than the PCM model.

Among the criteria used to select these climate change scenarios were ability of the models to represent El Niño events and availability of the data for analysis to meet the January 2006 governor's deadline for the report (Cayan, 2005). In addition, both models estimated historical climate trends reasonably well. The emissions scenarios and models are described further in later sections of this report.

3.3.1 Emissions Scenarios

The World Meteorological Organization and the United Nations Environment Programme formed the Intergovernmental Panel on Climate Change (IPCC) to periodically evaluate the science, impacts, and socioeconomics of climate change including adaptation and mitigation options. In order to conduct climate change studies, the IPCC has developed scenarios of future greenhouse gas emissions. The first set of IPCC emissions scenarios was released in 1990 and 1992. In 1994, those emissions scenarios were evaluated. And in 1996 a 50-member team representing 18 countries began updating the emissions scenarios. The updated emissions scenarios are documented in the 2000 IPCC Special Report on Emissions Scenarios (SRES).

The SRES emissions scenarios were developed and peer-reviewed using an open process with six major steps (IPCC, 2000):

1. Literature review of existing scenarios
2. Analysis of major scenario characteristics, driving forces, and their relationships
3. Formulation of four narrative scenario storylines to describe alternative futures
4. Quantification of each storyline using a variety of modeling approaches
5. An open review of the resulting emission scenarios and their assumptions
6. Three revisions of the scenarios and the report after the open review: the formal IPCC Expert Review and the final combined IPCC Expert and Government Review

To encompass the vast uncertainty about what may happen by the year 2100, the IPCC developed four storylines. Each story reflects different directions of major greenhouse gas emissions influences, including population, technology and economic factors. Each story evolves dynamically over time. The divergent visions for the future world are intended to represent different combinations of the main greenhouse gas sources, thus spanning the relevant ranges of greenhouse gas emissions. The four stories are referred to as A1, A2, B1 and B2, and the major characteristics of each storyline are summarized below (IPCC, 2000):

A1: The A1 story is about a future with low population growth, rapid economic growth, and rapid introduction of new and more efficient technologies. Other characteristics of the story include convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.

A2: The A2 story is about a heterogeneous future with high population growth, regional economic growth, and fragmented technological changes. Self reliance and preservation of local identities are major themes in the A2 story.

B1: The B1 story is about a convergent future with low population growth, rapid economic growth, and sustainable technology. Economic growth moves rapidly towards a service- and information-based economy. Use of natural resources is reduced, and clean and resource-efficient technologies are introduced. The B1 storyline emphasizes global solutions to economic, social, and environmental sustainability.

B2: The B2 story envisions a future with moderate population growth, intermediate levels of economic growth, and less rapid and more diverse technological development than the A1 and B1 stories. Local solutions to economic, social, and environmental sustainability are emphasized.

Based on the four stories, the IPCC used six models and various approaches to quantify the characteristics of each story. A total of 40 scenarios were developed, each of which represents an alternative interpretation and quantification of one of the stories. All of the scenarios based on a given story are known as a scenario family. None of the scenarios include future policies that explicitly address climate change such as the United Nations Framework Convention for Climate Change or the Kyoto Protocol greenhouse gas emissions targets. However other policies included in the scenarios may affect greenhouse gas emissions. Disaster scenarios were not considered. The likelihood of each scenario was not evaluated, and thus no SRES scenario was identified as the best-guess or business-as-usual scenario.

The IPCC objectively presents the scenarios by not indicating a preference for any scenario, nor do they assign probabilities of occurrence to any of the scenarios. The IPCC intended for the scenarios to be widely used for climate change assessment: "*We recommend that the new scenarios be used not only in the IPCC's future assessments of climate change, its impacts, and adaptation and mitigation options, but also as the basis for analyses by the wider research and policy community of climate change and other environmental problems*" (IPCC, 2000).

The Climate Action Team has selected scenarios from the A2 and B1 storylines for water resources impact analysis. For these scenarios global population estimates in the year 2100 range from 7 billion people for the B1 scenario to 15 billion people for the A2 scenario (IPCC, 2001). The A2 scenario results in the highest greenhouse gas emissions, and the B1 scenario results in the lowest greenhouse gas emissions of the SRES scenarios (Figure 3.1).

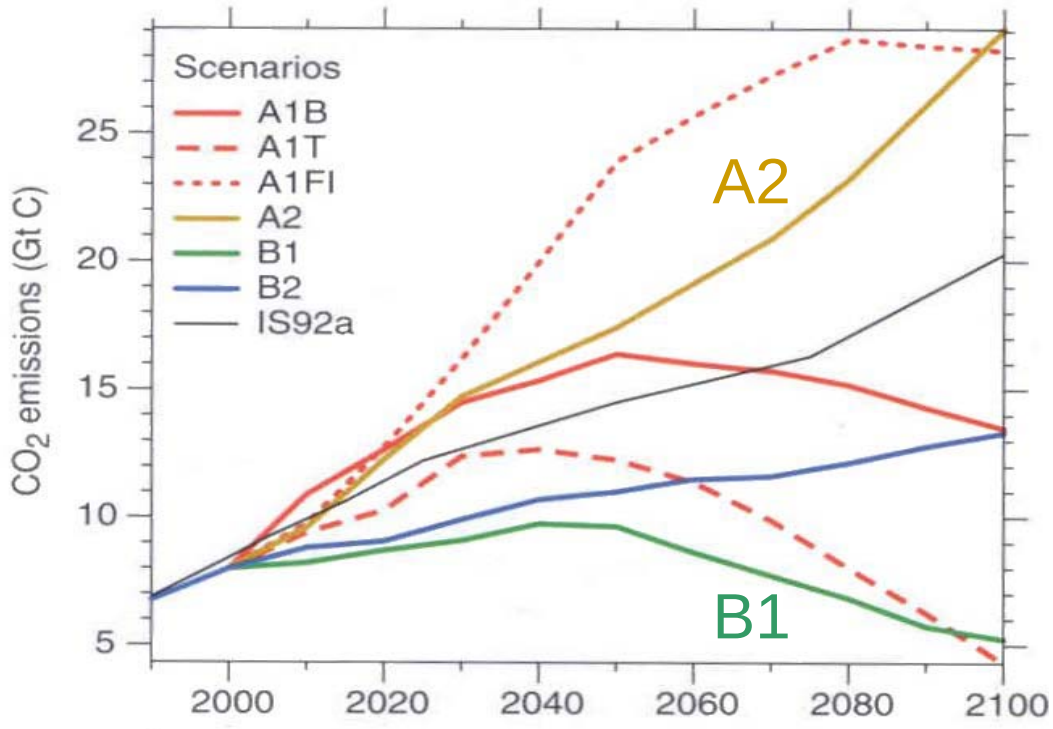

Figure 3.1 Emissions of CO_2 from Human Activities for IPCC's SRES Scenarios
Adapted from Technical Summary Figure 17 (IPCC, 2001)

3.3.2 Global Climate Models

Six Global Climate Models were used to develop IPCC's SRES emissions scenarios. The Climate Action Team (CAT) has selected the A2 and B1 emissions scenarios, each represented by two different global climate models, the Geophysical Fluid Dynamics Lab climate model (GFDL) and Parallel Climate Model (PCM). The Geophysical Fluid Dynamics Lab is part of the National Oceanic and Atmospheric Administration (NOAA). The PCM model was developed by the National Center for Atmospheric Research. The model versions, scenario name and run numbers for the four selected scenarios are given in Table 3.1. For this report, the four scenarios will be referred to by the model and scenario name.

Table 3.1 Model and Emissions Scenario Labels for Four Climate Change Scenarios

Scenario Label for this Report	GCM and SRES Scenario Description
GFDL A2	GFDL version2.1 SRESA2 run1
PCM A2	NCAR PCM version 1 SRESA2 run1
GFDL B1	GFDL version2.1 SRESB1 run1
PCM B1	NCAR PCM version 1 SRESB1 run2

The GFDL and PCM models are both state-of-the-art global climate models that represent linked oceanic, land, and atmospheric processes, including realistic representations of changes in sea surface temperatures due to the El Niño Southern Oscillation (ENSO). The climate processes in a global climate model are driven by factors known as forcings. The forcings used in these two models are summarized in Figure 3.2. Both models include forcings from greenhouse gas emissions, ozone, direct effects of sulfate aerosols, solar irradiance, and volcanic aerosols. In addition, the GFDL model includes forcings from black and organic carbon and land use or land cover. The GFDL model has a resolution of 2.0 degrees latitude by 2.5 degrees longitude, and the PCM model has a resolution of 2.8 degrees latitude by 2.8 degrees longitude. Both models were used to simulate 21st century climate change scenarios for the IPCC fourth assessment report, known as AR4, which is due out in 2007. Those simulations are archived at Lawrence Livermore National Lab's (LLNL's) Program for Climate Model Diagnosis and Intercomparison (PCMDI). The PCMDI website is http://www-pcmdi.llnl.gov/.

Model results and information for the four climate change scenarios selected by the CAT were made available for analysis on the California Climate Change Center's Web site managed by Scripps Institute for Oceanography, http://meteora.ucsd.edu/cap/cccc_model.html. Data are provided for the following variables:

- Surface latent heat flux; W/m^2
- Specific humidity at 925mb and 850mb
- Surface specific humidity; g/kg
- Total precipitation; mm/day
- Sea level pressure; mb
- Downward shortwave at the surface; W/m^2
- Upward shortwave at the surface; W/m^2
- Air temperature at 925mb, 850mb and 500mb; Kelvin
- Surface (2m) air temperature, Kelvin
- Maximum and minimum surface air temperature; Kelvin
- Zonal (east/west) wind at 925mb, 850mb and 500mb; m/s
- Surface (10m) zonal (east/west) wind; m/s
- Meridional (north/south) wind at 925mb, 850mb and 500mb; m/s
- Surface (10m) meridional (north/south) wind; m/s

Model Name/Forcing	G	O	SD	SI	BC	OC	MD	SS	LU	SO	V
GFDL v2.1	■	■	■		■	■			■	■	■
PCM	■	■	■							■	■

Shading indicates that the forcing is included on interannual or longer time scales. Forcings that only varied seasonally are not shaded.

Climate Model Forcing Factors:

G well mixed greenhouse gases
O tropospheric and stratospheric ozone
SD sulfate aerosol, direct effects
SI sulfate aerosol, indirect effects
BC black carbon aerosols
OC organic carbon aerosols
MD mineral dust
SS sea salt
LU land use/land cover
SO solar irradiance
V volcanic aerosols

Figure 3.2 Climate Model Forcings used for Climate Change Studies
Adapted from Table 5.2 (Santer et al., 2006)

A summary of the general air temperature and precipitation trends for the four climate change scenarios at the end of the 21st century is presented in Table 3.2. All four scenarios show an increase in air temperature. The PCM B1 scenario is the only scenario that shows an increase in precipitation.

For the climate change studies presented in this report, a 2050 projection level was used to reflect a water resource planning horizon. For each global climate model, projection data were available at two data points in California (Table 3.3). Average air temperature and precipitation values were computed from the global climate model results for a 30-year historical period from 1961-1990 and for a 30-year future projection period centered around 2050 (2035-2064) (Table 3.4 to Table 3.7). For comparison purposes, average historical air temperature and precipitation data for the 30 year historical period from 1961-1990 are also shown. The historical average values are based on the nearest two data stations for each site. The historical air temperature values were greater than the simulated values since the elevations of the data stations were lower than the elevations of the global climate model output locations (Table 3.3). Thus a temperature correction was applied to the historical average air temperature to adjust the value to a value that corresponds to the elevation of each global climate model output location. The historical average air temperature values for the global climate model output are within acceptable lapse rate (change of temperature with elevation) values for adjusting observed historical values (Table 3.4 and Table 3.5). The precipitation values were not adjusted for elevation since there is no straight forward correlation between precipitation and elevation.

Looking at the 2050 projections increases in air temperature range from 0.8ºC to 2.4ºC (Table 3.4 and Table 3.5). For most scenarios, warming is slightly higher in Northern California than Southern California. Projected changes in precipitation for 2050 are typically less than an inch per year. Values for both the air temperature and the precipitation projections were more

dependent on the global climate model used to represent the emissions scenario than on the emissions scenario. In other words, the projected values from a given global climate model, GFDL or PCM in this case, were closer to each other than the values for a given emissions scenario, A2 or B1 in this case. Additional global climate model results are presented in chapters 2 and 6.

Table 3.2 Air Temperature and Precipitation Trends for Climate Change Scenarios

Scenario	End of 21st Century Projection Trends
GFDL A2	Relatively strong warming Modest drying
PCM A2	Modest warming Modest drying
GFDL B1	Modest warming, Modest drying
PCM B1	Weak temperature warming Weak precipitation increase

Source: Cayan, 2005.

Table 3.3 GCM Grid Points in California

Location	Latitude degrees	Longitude degrees	Elevation m	Avg. Elevation Historical Data m
Northern California				56
GFDL	39.438	121.250	958	
PCM	40.464	120.937	1126	
Southern California				263
GFDL	35.393	118.750	850	
PCM	34.883	118.125	690	

Table 3.4 Air Temperature Projections for Northern California, °C

Northern CA	1961-1990 Average		2035-2064 Average	Difference
Historical Average	13.2		N/A	N/A
Corrected for Elevation	9.5 GFDL	8.9 PCM		
GFDL A2	9.5		11.8	2.3
GFDL B1			11.6	2.1
PCM A2	8.2		9.5	1.3
PCM B1			9.0	0.8

Table 3.5 Air Temperature Projections for Southern California, °C

Southern CA	1961-1990 Average		2035-2064 Average	Difference
Historical	16.2		N/A	N/A
Corrected for Elevation	13.6 GFDL	14.5 PCM		
GFDL A2	12.4		14.7	2.3
GFDL B1			14.5	2.1
PCM A2	14.5		15.7	1.2
PCM B1			15.4	0.9

Table 3.6 Precipitation Projections for Northern California, in/yr

Northern CA	1961-1990 Average	2035-2064 Average	Difference
Historical	27.46	N/A	N/A
GFDL A2	36.56	35.81	-0.75
GFDL B1		36.31	-0.25
PCM A2	25.03	24.41	-0.62
PCM B1		25.86	0.83

Table 3.7 Precipitation Projections for Southern California, in/yr

Southern CA	1961-1990 Average	2035-2064 Average	Difference
Historical	14.24	N/A	N/A
GFDL A2	17.92	17.70	-0.22
GFDL B1		16.15	-1.77
PCM A2	11.36	12.06	0.70
PCM B1		11.28	-0.08

3.3.3 Regional Downscaling

In order to conduct water resources impact analyses for climate change scenarios, the coarse spatial representation of the global climate model data must be refined in a process called downscaling. For the scenarios selected by the CAT, the regional climate data were produced by statistical downscaling of the global climate model output using the Variable Infiltration Capacity (VIC) model. The VIC model provides monthly output at 1/8th degree latitude/longitude resolution for the entire state of California. Daily data were computed by perturbing a historical data set based on the monthly computed climate change data from VIC. For hydrologic analysis, the VIC model output also provides stream flow, snow pack, snowmelt timing and soil moisture content (Maurer and Duffy, 2005; Maurer, 2005). Information on obtaining the downscaled data is available at the California Climate Change Center's Web site http://meteora.ucsd.edu/cap/cccc_model.html. Available climate data for a simulation period from 1950-2100 are:

- Precipitation
- Air temperature
- Wind speed
- Surface air humidity
- Soil moisture in three layers

Stream flow data for the simulation period 1950-2100 are available at the following locations:

- Smith River at Jedediah Smith State Park
- Sacramento River at Shasta Dam
- Feather River at Oroville
- North fork of the American River at North Fork Dam
- American River at Folsom Dam
- Yuba River system outflow at Marysville
- Sacramento River at the Delta
- Stanislaus River at New Melones Dam
- Tuolumne River at Don Pedro
- Merced River at Lake McClure
- King River at Pine Flat Dam

Results of the downscaled climate change data are presented in chapters 2 and 6.

3.4 Water Resources Impacts Approach

As the title of this report suggests, its main goal is to present initial methodologies and results for incorporating climate change into management of California's water resources. This report

presents preliminary studies using existing analysis tools at DWR to quantify potential water resources related effects of climate change. Whenever appropriate, studies focus on the four climate change scenarios selected by the CAT (Figure 3.3). The climate change scenario data were developed by experts in the field of climate change. The goal of DWR staff is to develop methods for incorporating that data into water resources planning and management, not to make predictions about future climate conditions. These initial studies focus on potential effects of climate change to four main California water resources areas:

- State Water Project (SWP) and Central Valley Project (CVP) operations
- Delta water quality including possible increases in sea level
- Flood management and water supply forecasting
- Changes in evapotranspiration rates and thus consumptive use of irrigation water

Each of these topics is covered in detail in separate chapters of this report.

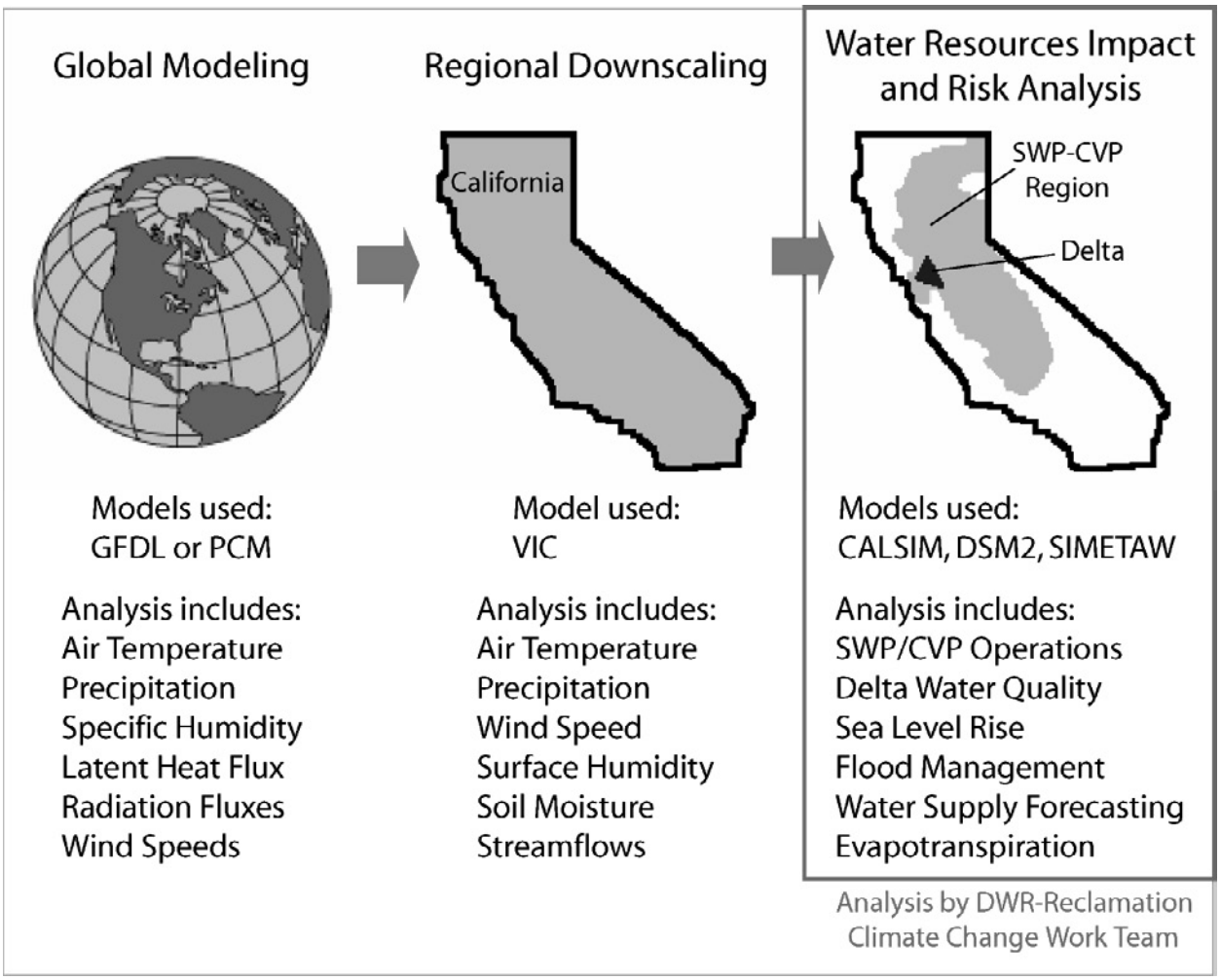

Figure 3.3 Approach for Analyzing Potential Water Resources Impacts of Climate Change

3.5 Acknowledgements

Internal review of this chapter was provided by Rich Juricich.

Analysis of historical and future air temperature and precipitation values from global climate model results were provided by Michael Anderson.

VIC data were processed and provided for download by Mary Tyree and Erik Peterson of Scripps Institution of Oceanography.

VIC data were produced by Ed Maurer at the Santa Clara University.

Information on the Global Climate Model models and emissions scenarios were provided by Dan Cayan from Scripps Institution of Oceanography and Mike Dettinger from the U.S. Geological Survey and Scripps Institution of Oceanography.

3.6 References

Cayan, D., 2005. E-mail dated posted on California Climate Change Center website discussing climate change scenario selection by the CAT. July 25, 2005. http://meteora.ucsd.edu/cap/cccc_model_prelim.html#dan25jul

DWR, 2005. California Water Plan Update 2005, Volume 1-Stategic Plan, Chapter 4: Preparing for an Uncertain Future, California Department of Water Resources, Sacramento, CA, Public Review Draft. http://www.waterplan.water.ca.gov/cwpu2005/index.cfm

IPCC, 2000. Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios, Nebojsa Nakicenovic and Rob Swart (Eds.), Cambridge University Press, UK. pp 570, http://www.grida.no/climate/ipcc/emission/.

IPCC, 2001. Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the IPCC, J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P. J. van der Linden and D. Xiaosu (Eds.), Cambridge University Press, UK. pp 944. http://www.grida.no/climate/ipcc_tar/wg1/index.htm

Maurer, E.P., 2005, Uncertainty in hydrologic impacts of climate change in the Sierra Nevada Mountains, California under two emissions scenarios, Climatic Change (submitted 29 April 2005)

Maurer, E.P. and P.B. Duffy, 2005, Uncertainty in Projections of Streamflow Changes due to Climate Change in California, Geophys. Res. Let. 32(3), L03704 doi:10.1029/2004GL021462

Santer, B.D., J.E. Penner, and P.W. Thorne, 2006: How well can the observed vertical temperature changes be reconciled with our understanding of the causes of these changes? In: Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, USA (in press).

3.7 List of Abbreviations

AR4-IPCC Fourth Assessment Report

CalSim - II-Operations model of the State Water Project and Central Valley Project

CALVIN-Economics driven optimization model of State Water Project and Central Valley Project operations

CAT-Climate Action Team

CEC-California Energy Commission

DWR-California Department of Water Resources

ENSO-El Niño Southern Oscillation

GCM-Global Climate Model

GFDL-Geophysical Fluid Dynamic Lab model

GHG-Greenhouse Gas

IPCC-Intergovernmental Panel on Climate Change

LLNL-Lawrence Livermore National Lab

NCAR-National Center for Atmospheric Research

NOAA-National Oceanic and Atmospheric Administration

PCM-Parallel Climate Model

PCMDI-Program for Climate Model Diagnosis and Intercomparison

SRES-Special Report on Emissions Scenarios [IPCC, 2000]

VIC-Variable Infiltration Capacity Model

WEAP-Water Evaluation and Planning Program

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
July 2006

Chapter 4:
Preliminary Climate Change Impacts Assessment for State Water Project and Central Valley Project Operations

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4 Preliminary Climate Change Impacts Assessment for State Water Project and Central Valley Project Operations

4.1 Introduction

Planning and design of the Central Valley Project (CVP) and State Water Project (SWP) has, for the most part, assumed an unchanging climate. Of course, it was always accepted that, in California, there would be years of plentiful precipitation followed by years of scarcity; that there would be wet, cool winters followed by hot, dry summers. Weather was expected to change. In fact, it was to overcome these changing weather patterns that the CVP and SWP were primarily built; the people of California needed flood protection during the wet periods and water during the dry. But at a climactic timescale of 30 years or more, it was assumed that the average of the weather patterns would remain about the same; the frequency and severity of future droughts would be much like that of the past; precipitation would continue to fall as winter snow, and the snow would continue to melt in the spring and early summer to fill our reservoirs. That was the assumption, and a changing climate may threaten to destabilize the infrastructure and operations dependent on that assumption.

As titled, this chapter discusses a preliminary assessment of climate change impacts on the SWP and CVP. Impacts were quantified for four scenarios predicted by two global climate models at two carbon dioxide emission rates (see Table 4.1). All four climate scenarios predict a warming trend for California. The effect on annual average precipitation is varied: Three of the scenarios predict a modestly drier climate and one predicts a weak increase in precipitation. The significant change is in the timing of runoff. Most precipitation that feeds the SWP and CVP falls in the Sierra Nevada and the southern end of the Cascades that border the eastern and northern boundaries of the Central Valley. Much of it comes as snow. A warming climate will result in a greater share of rainfall and a more rapid melt of the snowpack. As such, more runoff will occur in the winter and early spring and less during the late spring and early summer.

Table 4.1 Air Temperature and Precipitation Prediction Trends for Four Scenarios

Selected Climate Model	Emission Scenario	Description
PCM	B1	Weak temperature warming Weak precipitation increase in California
PCM	A2	Modest warming Modest drying
GFDL v2.0	B1	Modest warming, Modest drying
GFDL v2.0	A2	Relatively strong warming Modest drying

The focus of this chapter is impacts on water supply. Flood control is only discussed with respect to its operational conflicts with water supply goals. Of course, the SWP and CVP do more than provide water and flood protection to California; among other things, the projects generate and use large quantities of power; they control river temperatures to protect Chinook salmon and steelhead. Climate change effects on these operations will also be discussed.

It is important to note that this is just a starting point for analyzing climate change impacts on SWP and CVP operations. Current management practices and existing system facilities were used in the analysis for this report. No changes were made to lessen the effects of climate change or sea level rise. Only four scenarios are included, and we have not addressed the likelihood of one scenario over another. Furthermore, as will be discussed in the following sections, we have not included all of the ways in which climate change may impact water supply. Therefore, what is written here is not sufficient, by itself, to make final policy decisions. Its sole intent is to introduce readers to the methods of analysis and the potential significance of climate change impacts on CVP and SWP water supply.

4.2 Description of the CVP and SWP

The CVP, operated and maintained by the U.S. Bureau of Reclamation (Reclamation), is the largest surface water storage and delivery system in California, with a geographic scope covering 35 of the state's 58 counties. Authorized project purposes include flood control, navigation, agricultural and domestic water supply, fish and wildlife protection, and power generation. The CVP is composed of some 20 reservoirs with more than 11 million acre-feet (MAF) of storage capacity, 11 power plants, and over 500 miles of major canals and aqueducts. Within the Sacramento Basin, the CVP operates Shasta and Folsom reservoirs, among others. Water is imported from the Trinity River into the Sacramento Basin through Clear Creek Tunnel. Tracy Pumping Plant exports water from the Sacramento-San Joaquin Delta for storage in San Luis Reservoir and delivery to contractors in the San Joaquin Valley. The CVP also operates New Melones Lake on the Stanislaus River and Millerton Lake on the San Joaquin River, and it exports water from the San Joaquin Basin to the Tulare Basin through the Friant-Kern Canal. Overall, the project supplies water to 250 long-term water contractors in the Central Valley, Santa Clara Valley, and the San Francisco Bay Area. Key CVP reservoirs and their storage capacities are listed in Table 4.2.

Table 4.2 Key CVP Reservoirs

Reservoir	Capacity (TAF)
Trinity	2447
Shasta	4552
Folsom	975
San Luis (CVP share)	972
New Melones	2420
Millerton	521

The SWP is operated by DWR. It consists of 32 storage facilities, 660 miles of aqueducts and pipelines, 17 pumping plants, and eight hydroelectric powerplants. Using these facilities, the SWP provides urban and agricultural water supply, flood control, recreation, fish and wildlife enhancement, power generation, and salinity-control in the Sacramento-San Joaquin Delta. The project delivers water to over two-thirds of California's population and approximately 600,000 acres of farmland through 29 urban and agricultural water districts. These agencies have long-term water supply contracts totaling 4.2 million acre-feet per year. The principal storage facility for the SWP is Lake Oroville on the Feather River in the Sacramento Valley. Banks Pumping Plant exports water from the Sacramento-San Joaquin Delta for storage in San Luis Reservoir and delivery to water contractors in the San Francisco Bay Area, San Joaquin Valley, Central Coast, and Southern California. Key SWP reservoirs and their capacities are listed in Table 4.3.

Table 4.3 Key SWP Reservoirs

Reservoir	Capacity (TAF)
Oroville	3558
San Luis (SWP share)	1067

4.3 Modeling Methodology for Quantifying Climate Change Impacts on CVP and SWP Operations

Traditionally, planning simulation models have been used to measure the effects of hydrologic, structural, or regulatory changes on SWP and CVP operations. A base case is simulated to establish expected annual average deliveries and carryover storage if no change is made. Study scenarios are then run by incorporating the expected changes to hydrology, such as those caused by climate change, or planned changes in facilities or project regulations. The impacts of the changes can then be determined by comparing base case operational statistics with those of the study scenarios.

The DWR and Reclamation have jointly developed computer model CalSim-II that simulates much of the water resources infrastructure in the Central Valley of California and Delta region. CalSim-II models all areas that contribute flow to the Delta. The geographical coverage includes: The Sacramento River Valley; the San Joaquin River Valley; the Sacramento-San Joaquin Delta; the Upper Trinity River and the CVP and SWP service areas. CalSim-II simulates operation of the CVP-SWP system for 73 years using a monthly time step. The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed level of development. The historical flow record October 1922-Septrember 1994, adjusted for the influence of land-use change and upstream flow regulation, is used to represent the possible range of water supply conditions.

CalSim-II uses optimization techniques to route water through a CVP-SWP system network representation. The network includes over 300 nodes and over 900 arcs, representing 24 surface reservoirs and the interconnected flow system. A linear programming (LP)/mixed integer linear programming (MILP) solver determines an optimal set of decisions for each time period given a

set of weights and system constraints. The physical description of the system is expressed through a user interface with tables outlining the system characteristics. The priority weights and basic constraints are also entered in the system tables. The programming language used, Water Resources Engineering Simulation Language (WRESL), serves as an interface between the user and the LP/MILP solver, time-series database, and relational database. Specialized operating criteria are expressed in WRESL.

The hydrology in CalSim-II was developed jointly by DWR and Reclamation. Water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiency, return flows, non-recoverable losses, and groundwater operation are components that make up the hydrology used in CalSim-II. Demands are preprocessed independent of CalSim-II and vary according to the specified level of development (e.g., 2001, 2020) and according to hydrologic conditions. Agricultural land-use-based demands are calculated from an assumed cropping pattern and a soil moisture budget. Urban demands are typically set to contract amount, but with reductions in wet years based on recent historical data. Both land-use-based demands and contract entitlements serve as upper bound on deliveries. Environmental demands such as minimum reservoir storage requirements, minimum in-stream flows and deliveries to national wildlife refuges, and wildlife management areas are as stipulated in current regulatory requirements and discretionary interagency agreements. Sacramento Valley and tributary rim basin hydrologies are developed using a process designed to adjust the historical sequence of monthly stream flows to represent a sequence of flows at a future level of development. Adjustments to historic water supplies are determined by imposing future level land use on historical meteorological and hydrologic conditions. San Joaquin River basin hydrology is developed using fixed annual demands and regression analysis to develop accretions and depletions. The resulting hydrology represents the water supply available from Central Valley streams to the CVP and SWP at a future level of development. Groundwater has only limited representation in CalSim-II. This resource is modeled as a series of interconnected lumped-parameter basins. Groundwater pumping, recharge from irrigation, stream-aquifer interaction and interbasin flow are calculated dynamically by the model.

CalSim-II uses DWR's Artificial Neural Network (ANN) model to simulate the flow-salinity relationships for the Delta. The ANN model correlates DSM2 model-generated salinity at key locations in the Delta with Delta inflows, Delta exports, and Delta Cross Channel operations. The ANN flow-salinity model estimates electrical conductivity at the following four locations for the purpose of modeling Delta water quality standards: Old River at Rock Slough, San Joaquin River at Jersey Point, Sacramento River at Emmaton, and Sacramento River at Collinsville. In its estimates, the ANN model considers antecedent conditions up to 148 days, and considers a "carriage-water" type of effect associated with Delta exports.

CalSim-II uses logic for determining deliveries to north-of-Delta, and south-of-Delta CVP and SWP contractors. The delivery logic uses runoff forecast information, which incorporates uncertainty and standardized rule curves (i.e. Water Supply Index versus Demand Index Curve). The rule curves relate forecasted water supplies to deliverable "demand," and then use deliverable "demand" to assign subsequent delivery levels to estimate the water available for delivery and carryover storage. Updates of delivery levels occur monthly from January 1 through May 1 for the SWP and March 1 through May 1 for the CVP as runoff forecasts become

more certain. The south-of-Delta SWP delivery is determined based on water supply parameters and operational constraints. The CVP system wide delivery and south-of-Delta delivery are determined similarly upon water supply parameters and operational constraints with specific consideration for export constraints.

4.4 Generating CalSim-II Input from Global Climate Model Output

To simulate the proposed climate change scenarios, CalSim-II climate change input was needed. At a minimum, the input had to represent climate change effects on rainfall and snowmelt runoff. Global climate models (GCMs), listed previously in Table 4.1, provided projected climate data, however, the GCM data were not suitable for direct CalSim-II input for two reasons. First, CalSim-II needed streamflow data whereas the GCMs provided precipitation data. Second, CalSim-II needed data at specific locations, such as inflows to major reservoirs, whereas the GCMs provide data at a coarse resolution of only about six grid points over all of California. In other words, the type and scale of GCM output did not fit as CalSim-II input. An intermediate hydrologic model was needed.

Fortunately, such a hydrologic simulation was available. Ed Maurer, of the University of Santa Clara, had run the GCM results of interest through a macro-scale hydrologic model called the Variable Infiltration Capacity or VIC model. VIC converted the GCM precipitation data into runoff data at a $1/8^{th}$ degree grid. Both rainfall and snowmelt runoff were represented in this model. The runoff data was further processed by SCRIPPS to produce regional scale streamflow data centered on the following locations:

1) Smith River at Jedediah Smith State Park
2) Sacramento River at Shasta Lake
3) Feather River at Lake Oroville
4) Yuba River
5) North Fork of the American River
6) American River at Folsom Lake
7) Stanislaus River at New Melones Reservoir
8) Tuolumne River at New Don Pedro Reservoir
9) Merced River at Lake McClure
10) Kings River at Pine Flat Reservoir

Thus, streamflow data was available, but the regional scale of the data was still too coarse for direct CalSim-II input.

Miller, et al (2001) proposed using perturbation ratios to transfer regional scale climate change behavior to local scale historic data. This technique was used to transfer average climate change effects observed in VIC regional runoff to historic CalSim-II reservoir inflows. First, historic and projected time references were selected – 1976 and 2050 respectively. VIC monthly streamflows were averaged around these years. To adequately represent the effects of climate change, the period of average was thirty years - a recognized climatological time-scale – centered on the reference year; 1976 average monthly streamflows were calculated using the 1961-1990 VIC data, and 2050 average monthly streamflows were calculated using the 2035-2064 VIC data. Finally, perturbation ratios were calculated by dividing the 2050 VIC average

monthly streamflows by their respective 1976 VIC average monthly streamflows. The results are listed in Table 4.4, Table 4.5, Table 4.6, and Table 4.7.

Let's consider the GFDL A2 results listed in Table 4.4. The June perturbation ratio for the Smith River region was 0.62. This shows that, on average, 2050 June streamflows in this region are projected to be 38 percent less (0.62 – 1 = -0.38) than the historic reference 1976 streamflows. For comparison, consider the June perturbation ratio in the Smith River region for scenario PCM B1 – the mildly wetter climate change scenario. Results for this scenario are listed in Table 4.7. A ratio of 0.85 is listed indicating a 15 percent reduction in average streamflow in 2050 as compared to 1976. So while PCM B1 is mildly wetter than current conditions, there is still a projected reduction in runoff in the Smith River region during the late spring.

Table 4.4 Streamflow Perturbation Ratios for Scenario GFDL A2

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Smith R at Jed Smith State Park	0.66	0.80	1.19	1.12	1.06	1.01	0.76	0.64	0.62	0.67	0.78	0.85
Stanislaus R at New Melones Dam	0.97	0.78	1.30	1.34	1.20	1.37	1.07	0.72	0.57	0.43	0.64	0.84
Kings R at Pine Flat Dam	0.81	0.83	1.35	1.33	1.36	1.35	1.24	1.00	0.61	0.38	0.52	0.72
Merced R at Lake McClure	0.81	0.56	2.04	1.30	1.10	1.38	1.26	0.83	0.48	0.25	0.39	0.69
Yuba R System Outflow	1.16	0.80	1.37	1.16	1.20	1.24	0.86	0.62	0.49	0.47	0.64	0.77
NF American R at NF Dam	1.34	0.73	1.43	1.07	1.17	1.25	0.83	0.56	0.40	0.26	0.48	0.69
Sacramento R at Shasta Dam	0.90	0.92	1.36	1.12	1.13	1.06	0.84	0.71	0.77	0.78	0.86	0.92
Feather R at Oroville	0.98	0.87	1.31	1.25	1.24	1.22	0.89	0.69	0.58	0.68	0.81	0.84
American R at Folsom Dam	1.22	0.70	1.35	1.13	0.95	1.28	0.77	0.48	0.45	0.44	0.67	0.83
Tuolumne R at New Don Pedro	0.88	0.80	1.36	1.31	1.08	1.31	1.19	0.84	0.49	0.48	0.68	0.81

Table 4.5 Streamflow Perturbation Ratios for Scenario PCM A2

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Smith R at Jed Smith State Park	0.65	0.88	0.90	0.91	1.09	1.12	0.87	0.79	0.73	0.76	0.95	1.14
Stanislaus R at New Melones Dam	0.95	1.12	0.72	1.05	1.31	1.11	1.11	0.85	0.81	0.75	0.87	0.92
Kings R at Pine Flat Dam	0.96	1.13	0.83	1.00	1.42	1.19	1.22	1.02	0.81	0.69	0.79	0.89
Merced R at Lake McClure	0.99	1.69	0.84	0.93	1.33	1.18	1.21	0.88	0.70	0.60	0.71	0.89
Yuba R System Outflow	0.69	1.10	0.82	0.95	1.25	1.14	0.95	0.74	0.67	0.67	0.91	0.91
NF American R at NF Dam	0.58	1.19	0.71	1.00	1.26	1.14	0.91	0.69	0.61	0.49	0.90	0.90
Sacramento R at Shasta Dam	0.86	1.02	0.95	0.86	1.06	1.05	0.91	0.78	0.86	0.89	0.94	0.96
Feather R at Oroville	0.81	1.00	0.93	0.90	1.24	1.13	1.00	0.79	0.73	0.85	0.93	0.93
American R at Folsom Dam	0.69	1.13	0.65	1.01	1.35	1.05	0.91	0.65	0.68	0.68	0.92	0.93
Tuolumne R at New Don Pedro	0.98	1.17	0.75	1.02	1.27	1.11	1.15	0.93	0.71	0.81	0.90	0.92

Table 4.6 Streamflow Perturbation Ratios for Scenario GFDL B1

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Smith R at Jed Smith State Park	0.56	1.20	1.16	1.18	0.98	1.26	0.85	0.74	0.69	0.74	0.92	0.99
Stanislaus R at New Melones Dam	0.82	1.36	1.13	1.47	0.84	1.03	0.99	0.72	0.55	0.48	0.67	0.85
Kings R at Pine Flat Dam	0.80	0.98	1.03	1.33	0.90	1.05	1.03	0.88	0.57	0.45	0.60	0.75
Merced R at Lake McClure	0.86	1.40	1.50	1.29	0.57	1.20	1.24	0.79	0.47	0.31	0.45	0.71
Yuba R System Outflow	0.77	2.04	1.05	1.33	0.81	1.15	0.87	0.64	0.49	0.50	0.70	0.80
NF American R at NF Dam	0.82	2.89	0.99	1.28	0.60	1.16	0.85	0.59	0.37	0.29	0.54	0.72
Sacramento R at Shasta Dam	0.77	1.26	1.11	1.32	0.96	1.17	0.90	0.78	0.80	0.84	0.91	0.95
Feather R at Oroville	0.72	1.20	1.11	1.38	1.02	1.13	0.89	0.69	0.61	0.72	0.86	0.88
American R at Folsom Dam	0.84	2.54	0.91	1.46	0.56	0.90	0.73	0.56	0.42	0.47	0.72	0.86
Tuolumne R at New Don Pedro	0.83	1.21	1.08	1.41	0.81	1.02	1.13	0.80	0.51	0.55	0.76	0.85

Table 4.7 Streamflow Perturbation Ratios for Scenario PCM B1

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Smith R at Jed Smith State Park	0.99	0.90	0.90	1.06	1.00	1.37	1.12	1.02	0.85	0.85	0.95	1.23
Stanislaus R at New Melones Dam	0.96	1.19	0.73	1.26	1.18	1.28	1.20	0.95	0.81	0.83	0.92	0.93
Kings R at Pine Flat Dam	0.94	1.13	0.78	1.16	1.15	1.13	1.12	1.06	0.81	0.85	0.86	0.91
Merced R at Lake McClure	0.95	1.45	0.64	1.20	1.21	1.32	1.19	0.96	0.73	0.80	0.86	0.90
Yuba R System Outflow	0.92	1.09	0.69	1.26	1.10	1.38	1.19	0.94	0.82	0.85	0.97	0.97
NF American R at NF Dam	0.86	1.23	0.60	1.34	1.08	1.47	1.21	0.92	0.73	0.75	0.96	0.94
Sacramento R at Shasta Dam	1.14	0.94	0.90	1.10	0.97	1.30	1.17	1.02	0.97	0.98	0.99	1.00
Feather R at Oroville	0.99	0.94	0.78	1.18	1.11	1.29	1.17	0.97	0.90	0.95	0.99	0.99
American R at Folsom Dam	0.86	1.21	0.60	1.38	1.21	1.40	1.20	0.88	0.74	0.84	0.97	0.97
Tuolumne R at New Don Pedro	0.98	1.18	0.73	1.21	1.16	1.24	1.21	1.03	0.75	0.89	0.93	0.93

The CalSim-II climate change scenario input was produced using the above listed perturbation ratios. Base CalSim-II reservoir inflows were generated from the WY1922-1994 historical record. For each climate change scenario, the historical inflows were perturbed or altered by multiplying the historical inflow timeseries with corresponding perturbation ratios obtained from the VIC streamflow analysis; perturbation ratios were matched with CalSim-II inflow timeseries data based on month and geographic proximity.

The reservoir inflows that constitute the bulk of water supply for the State Water Project (SWP) and the Central Valley Project (CVP) are limited in number. They include the Sacramento River

at Shasta, the Feather River at Oroville, the American River above Folsom, all in the Sacramento Valley, and the Stanislaus, the Tuolumne, the Merced and the San Joaquin Rivers in the San Joaquin Valley. These and others, such as the Trinity River and Yuba River, are the historical inflows that were perturbed for each climate change scenario. Focusing on Sacramento Valley impacts, average monthly Shasta, Oroville and Folsom inflows for the Base and four climate change scenarios are compared in Figure 4.1, Figure 4.2, and Figure 4.3 respectively. The period of average is WY1922-1994. As shown, the climate change perturbations generally resulted in higher flows in the winter and lower in the spring and early summer as expected.

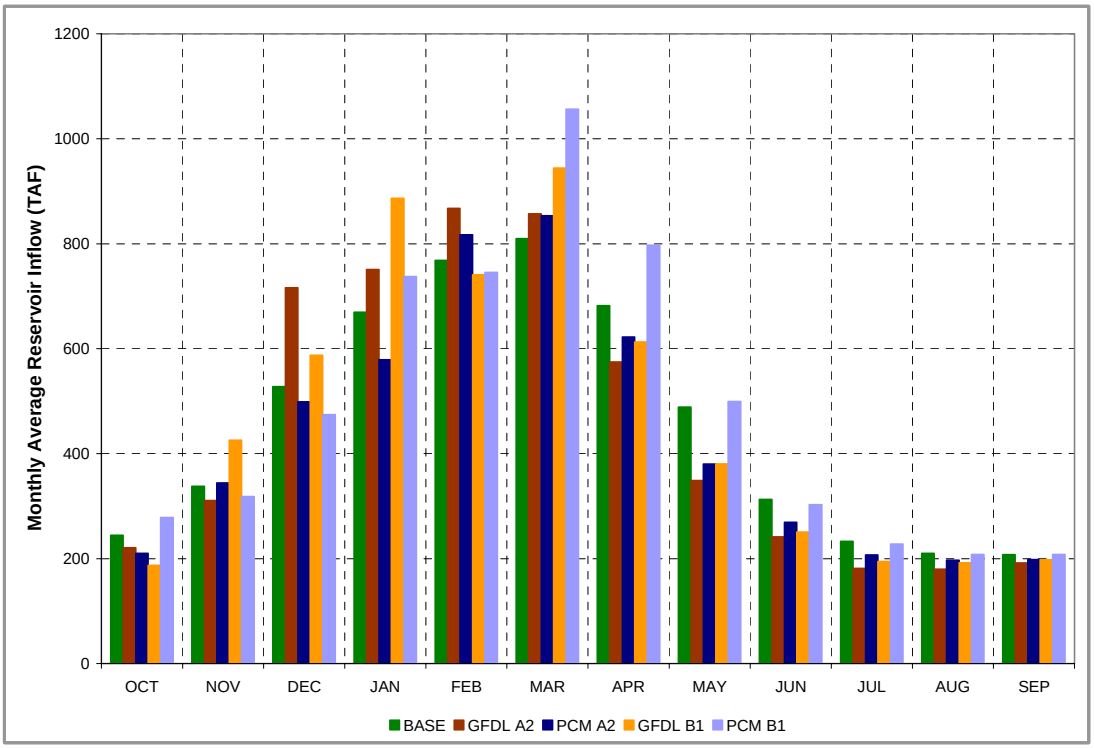

Figure 4.1 Lake Shasta Average Monthly Inflow (1922-1944)

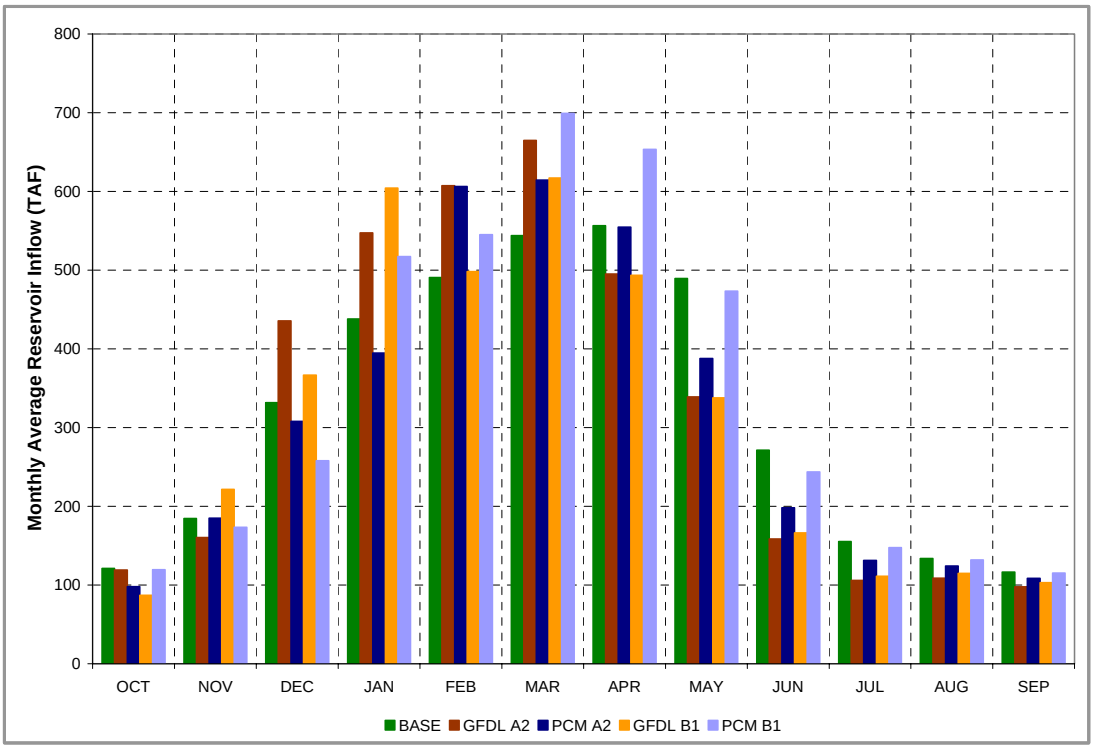

Figure 4.2 Lake Oroville Average Monthly Inflow (1922-1994)

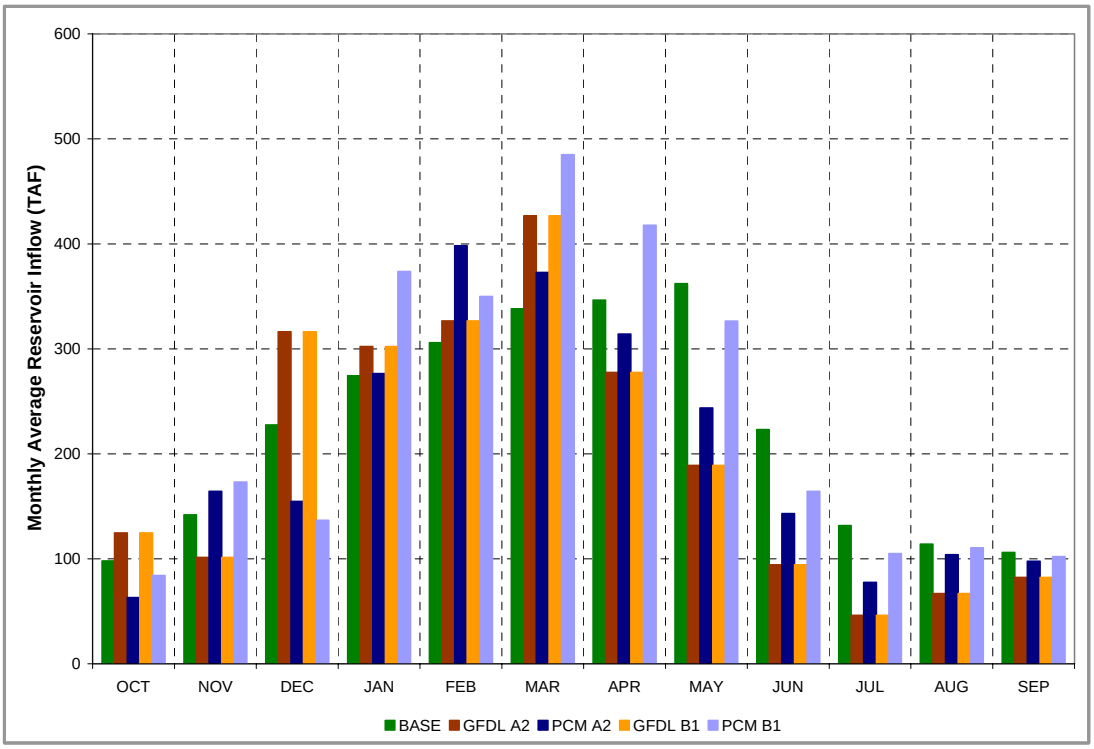

Figure 4.3 Folsom Lake Average Monthly Inflow (1922-1994)

Annual average Shasta, Oroville, and Folsom inflows are listed in Table 4.8, Table 4.9, and Table 4.10. The annual average flows for the climate change scenarios were calculated from the perturbed CalSim-II timeseries input. Inflows were averaged over the 1922 – 1994 historical period, the 1928 – 1934 and 1986 – 1992 droughts, and the 1981 – 1983 wet period.

Table 4.8 Lake Shasta Annual Average Inflow (TAF)

		BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Long-term (1922 – 1994)	Value	5492	5442	5177	5601	5854
	Change	--	-51	-315	109	362
May 1928 - Oct 1934	Value	3332	3227	3114	3321	3545
	Change	--	-106	-219	-12	213
WY 1987 - WY 1992	Value	3817	3720	3603	3859	4115
	Change	--	-97	-214	42	299
WY 1980 - WY 1983 (Wet Period)	Value	7582	7599	7223	7829	8143
	Change	--	17	-359	247	561

Table 4.9 Lake Oroville Annual Average Inflow (TAF)

		BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Long-term (1922 – 1994)	Value	3833	3840	3712	3722	4079
	Change	--	6	-122	-111	245
May 1928 - Oct 1934	Value	2174	2109	2061	2038	2282
	Change	--	-66	-113	-136	108
WY 1987 - WY 1992	Value	2002	2032	1968	1964	2163
	Change	--	30	-34	-38	161
WY 1980 - WY 1983 (Wet Period)	Value	6064	6170	5936	5995	6465
	Change	--	106	-128	-69	401

Table 4.10 Folsom Lake Annual Average Inflow (TAF)

		BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Long-term Annual Average	Value	2670	2355	2410	2368	2829
	Change	--	-315	-260	-302	159
May 1928 - Oct 1934	Value	1519	1281	1321	1277	1552
	Change	--	-238	-198	-242	33
WY 1987 - WY 1992	Value	1355	1225	1237	1239	1479
	Change	--	-130	-117	-116	125
WY 1980 - WY 1983 (Wet Period)	Value	4470	4022	4109	4057	4802
	Change	--	-449	-361	-414	332

So through a sequence of global climate models (GFDL and PCM), a regional hydrologic model (VIC), derivation of climate change runoff perturbation ratios, and, finally, applying those perturbation ratios to CalSim-II historic reservoir inflows, the CalSim-II climate change scenario input was created. The sequence of models is illustrated in Figure 4.4.

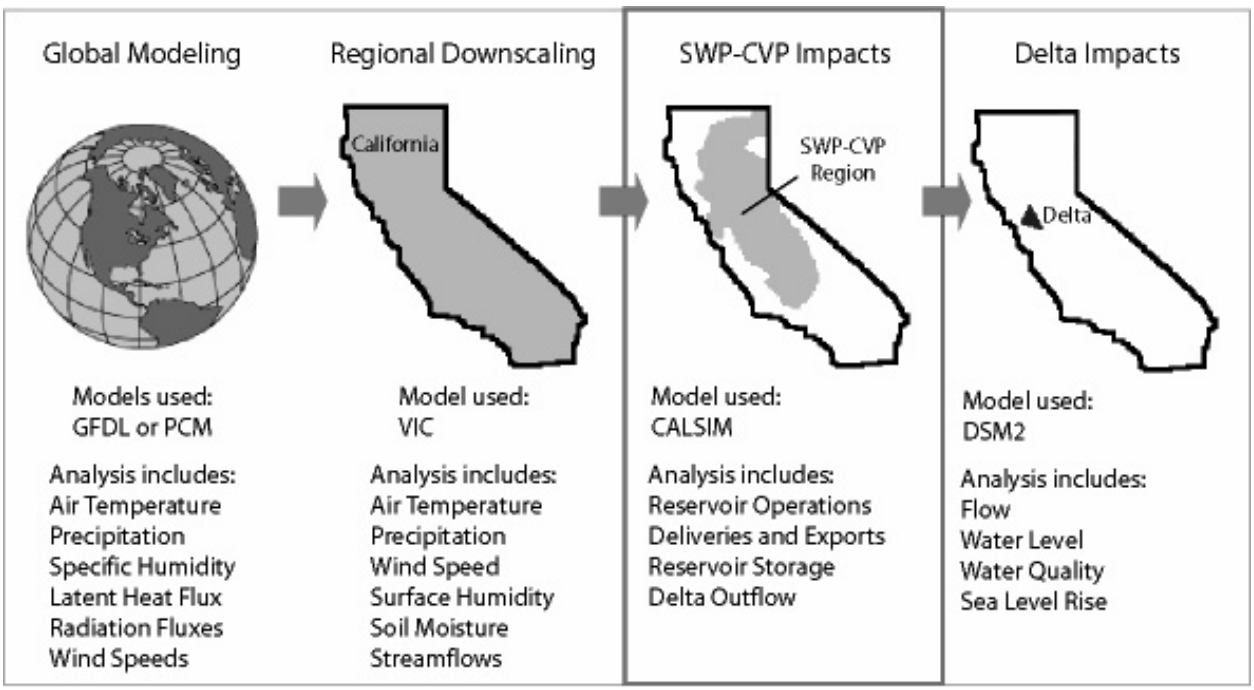

Figure 4.4 Modeling Sequence for Generating CalSim-II Climate Change Scenarios

4.5 Study Scenarios

4.5.1 Base Scenario

The base CalSim-II simulation was adapted from one of the studies presented in 2004 by the Bureau of Reclamation in support of its latest Operations Criteria and Plan (OCAP). Table 4.11 lists project and non-project demand assumptions by region. Regulatory standards and operations criteria are listed in Table 6-2 of Chapter 6 of the report *Long-Term Central Valley Project Operations Criteria and Plan* (USBR 2004). The specific study used from the OCAP analysis was Study D at a 2020 level of development. Some key regulatory and operational assumptions in this study are:

1) Delta exports, outflow and water quality are regulated according to the State Water Resources Control Board D1641 and the Water Quality Control Plan.
2) CVPIA 3406 (b)(2) is NOT included.
3) The Environmental Water Account (EWA) is NOT included.

Table 4.11 Demand Assumptions for the Base Scenario

	Base Condition
Period of Simulation	73 years (1922-1994)
HYDROLOGY **Level of Development (Land Use)**	2020 Level, DWR Bulletin 160-98
Demands **North of Delta (exc American R)** CVP SWP (FRSA) Non-Project	 Land Use based, limited by Full Contract Land Use based, limited by Full Contract Land Use based
CVP Refuges	Firm Level 2
American River Basin Water rights CVP	 2020, Sacramento Water Forum[1] 2020, Sacramento Water Forum[2]
San Joaquin River Basin Friant Unit Lower Basin Stanslaus River Basin	 Regression of historical Fixed annual demands New Melones Interim Operations Plan
South of Delta CVP CCWD SWP (w/ North Bay Aqueduct) SWP Article 21 Demand	 Full Contract 195 TAF/YR[3] 3.4-4.2 MAF/YR MWDSC up to 50 TAF/month, Dec-Mar, others up to 84 TAF/month

[1] Sacramento Water Forum 2025 Level Demands defined in the Sacramento Water Forum's EIR
[2] Same as footnote 1
[3] Delta diversions include operations of Los Vaqueros Reservoir operations

4.5.2 Climate Change Scenarios

Four climate change scenarios were simulated for this analysis: GFDL A2, PCM A2, GFDL B1, and PCM B1. GFDL and PCM are the global climate models that generated the climate scenarios. A2 and B1 indicate the different assumed rates of carbon loading in each scenario (see Table 4.1). Global climate model results were downscaled for input as CalSim-II inflow as described in Section 4.4.

The following monthly inflows were perturbed with the factors listed in Table 4.4 - Table 4.7:

1) Trinity River at Trinity Lake
2) Sacramento, McCloud, and Pit Rivers at Shasta Lake
3) Feather River at Lake Oroville
4) Yuba River upstream of the confluence with the Feather River
5) North and South Forks of the American River at Folsom Lake
6) Stanislaus River at New Melones Lake
7) Tuolumne River at New Don Pedro Reservoir
8) Merced River at Lake McClure
9) San Joaquin River at Millerton Lake

Since the monthly perturbation factors repeat themselves on an annual basis, the annual hydrology of both base and climate change scenarios maintain the same pattern of wet years and droughts. Specifically, the droughts of 1929-1934, 1976-1977, and 1987-1992 are preserved and, overall, a wet year in the base is a wet year in the climate change scenarios; there is just modestly less or more precipitation on an annual basis depending on the scenario.

The significant change in inflows between the base and climate change scenarios was in the seasonal distribution of runoff. Generally, as shown in Figure 4.1 - Figure 4.3, more runoff occurred from December through March while less came in the remainder of the year. This seasonal change in runoff was most significant in scenarios GFDL A2 and GFDL B1. It was least significant in PCM B1, and PCM A2 lies somewhere in between. A simple explanation for the change in seasonal runoff patterns is that more precipitation will fall as rain than snow in a warmer climate. More rainfall leads to more runoff in the wet months whereas less snowfall results in a smaller snowpack and less snowmelt in the dry months.

What wasn't changed between the base and climate change scenarios? There were no structural changes – no added storage, pumping, and canal capacity. No changes were made to system regulations. The CVP and SWP continued meeting minimum in-stream flow requirements. The projects continued meeting the Delta outflow and water quality standards established by the State Water Resources Control Board in Decision 1641 and the Water Quality Control Plan. Water use remained at a year 2020 level of development, and operational rules such as flood control and delivery allocations are applied consistently in base and climate change scenarios.

Current management practices and existing system facilities were used in the analysis for this report. No changes were made to lessen the effects of climate change or sea level rise.

No changes were made to:

- ❑ System structures, such as added water storage, pumping, or canal capacity
- ❑ Reservoir operating rules, such as changing the space required for flood control
- ❑ Streamflow requirements
- ❑ Water quality standards
- ❑ Delta outflow requirements
- ❑ Operations to account for sea level rise

4.5.3 Climate Change Impacts Not Considered in the Study Scenarios

There are also some key climate change impacts that were not considered in the study scenarios. With changing rates of evapotranspiration, it is expected that urban (landscaping) and agricultural demand for CVP and SWP water will change accordingly, but no changes in demand were included in the climate change scenarios. Another anticipated result of a warming climate is a rising sea level. While the climate change scenarios are held to the same

Delta salinity standards as in the base scenario, the effect of a rising sea level on the projects' ability to meet those standards was not accounted for; it is assumed in all scenarios that sea level remains unchanged. Future work will include development of a tool for modifying system operations to maintain Delta water quality standards under sea level rise conditions. Note that sea level rise scenarios discussed in Chapter 5 section 5.5 use operations based on present sea level.

Furthermore, the method of downscaling global climate model information for CalSim-II input only captures the general trends of average rainfall and seasonal shifts in runoff. There is no information included about changes in weather variability. In each of the scenarios, the frequency and length of the droughts remained the same. If climate change influences these underlying weather phenomena, then we are missing important information necessary to determine impacts to CVP and SWP operations.

4.6 Results

Results of the CalSim-II base and climate change scenarios are presented and compared in this section. Given that the primary purpose of the CVP and SWP is water supply, the key CVP and SWP operational measures presented are water shortages, contractor deliveries, and carryover storage. Then, to begin the search for operational flexibility in dealing with climate change impacts on water supply, the significance of various operational constraints was analyzed. Of course, the CVP and SWP have other important responsibilities such and fish and wildlife enhancement and power supply. Therefore, at the end of the section, climate change impacts on in-stream temperatures and power supply are also discussed.

Before reviewing the results, though, please note that the purpose of this report is to demonstrate how various analysis tools currently used by DWR could be used to address issues related to climate change. The methods and results presented in this report could be used to guide future climate change analysis and to identify areas where more information is needed. All results presented in this report are preliminary, incorporate several assumptions, reflect a limited number of climate change scenarios, and do not address the likelihood of each scenario. Therefore, these results are not sufficient by themselves to make policy decisions.

4.6.1 Shortages

To discuss CalSim-II shortages, we must first discuss water use priorities. There are many competing demands for the water that flows into the Central Valley. They include farm irrigation, urban and industrial use, ecosystem protection and restoration, and reservoir storage for hydropower production, recreation or for later use in the next inevitable drought. In CalSim-II, distribution of water is prioritized as listed in Table 4.12.

Table 4.12 CalSim-II Water Use Prioritization

First Priority	prior right water users, minimum in-stream flow requirements, WQCP requirements
Second Priority	SWP Table A contractors, CVP contractors
Third Priority	reservoir storage for the next year (carryover)
Fourth Priority	SWP Article 21 deliveries

While CVP and SWP contractor deliveries take precedence over next year's storage, a balance between the two is struck in the allocation decision. During the winter and spring, the SWP and CVP decide how much of contractor demand can be met for the year based on available storage and forecasted runoff. Part of the allocation decision is to ensure that enough water is left in storage at the end of the year in case of impending drought. Once the allocation decision is made though, deliveries to meet that allocation take priority over maintaining the storage carryover target.

Given this simple explanation of prioritization, there are two types of shortages in CalSim-II. One is an acceptable, though not desirable, result of making water allocations based on imperfect forecasts. In wetter years, the SWP and CVP sometimes allocate more south-of-Delta (SOD) deliveries than can be delivered through the pumps due to various export constraints. For the base and four climate change scenarios, this type of shortage is infrequent and, compared to total annual deliveries, insignificant. This type of shortage is also implicitly included in the delivery analysis; if it's not delivered, we don't count it.

The other type of shortage is usually unacceptable. This is when the first priority obligations – prior right contracts, minimum in-stream flow requirements, Delta requirements – are not met. The only way for this shortage to occur in CalSim-II is for one or more North-of-Delta reservoirs to be drawn down to dead storage. At this point, the model has lost control of meeting the watershed's most basic needs not to mention the lawful obligations of the CVP and SWP. Such a simulation is broken. The lower priority metrics are questionable: Could the shortage of high priority water uses be avoided at the expense of lower priority uses through some simple changes in operating rules? And the results of a broken simulation can not be confidently compared to an unbroken simulation.

Table 4.13 shows that Shasta and Folsom reservoirs were at dead storage for a significant number of months in scenarios GFDL A2, PCM A2, and GFDL B1. These months are all concentrated in the critical year of 1924 and the droughts of 1929-1934, 1976-1977, and 1987-1992. During these months, streamflow requirements were not met on the Sacramento and American rivers and the CVP was unable to contribute its Coordinated Operation Agreement defined share of in-basin use. The base scenario had one month of shortage on the American and Sacramento rivers – October 1977. Due to the severity of the 1976-1977 drought, this is frequently unavoidable in CalSim-II simulations.

Table 4.13 Months of Critical Shortages (Storage at Dead Pool)

	Shasta (months)	Oroville (months)	Folsom (months)
BASE	1	0	1
GFDL A2	31	0	28
PCM A2	29	0	22
GFDL B1	21	0	20
PCM B1	0	0	0

The length of shortages in GFDL A2, PCM A2, and GFDL B1 indicate that the delivery results presented for these scenarios in the next section are not always reliable. Too much risk was taken in the delivery allocation decisions of these three scenarios and not enough storage was carried into the drought periods as a result. In future climate change simulations, modifications to the rule that divides available water into delivery and carryover should be investigated as a means to prevent these shortages. Since CVP allocations are dependent on Shasta and Folsom storage, such modifications will likely alter the resulting delivery capability of the CVP as compared to the results presented in the next section.

4.6.2 Delivery and Storage Analysis

As shown previously in Figure 4.1, Figure 4.2, and Figure 4.3, the general effect of climate change on runoff is that more comes in the winter, when we don't need it, and less comes in spring and summer, when we do need it. One would expect that this shift in runoff will make it more difficult for the CVP and SWP to capture water and deliver it to their customers. The resulting annual average deliveries to Table A contractors listed in Table 4.14 fit these expectations for three of the four climate change scenarios. GFDL B1, with 2,861 TAF annual average deliveries, was 10.2 percent less than the Base scenario annual average of 3,186 TAF. PCM A2 and GFDL A2 also reduced Table A deliveries below the Base. On the other hand, in PCM B1, the scenario that was slightly wetter than the Base, the SWP managed to make 1.2 percent more Table A deliveries on an annual average basis – increasing deliveries from 3,186 to 3,224 TAF. The dry year samples of Table A deliveries listed in Table 4.14 show that the SWP did better in the Base scenario than in GFDL A2, PCM A2, and GFDL B1 in most instances. The exception was the single dry year of 1977 – no doubt the result of the higher Table A allocation in the Base scenario for the first year of the 1976-1977 drought. PCM B1 results in higher dry year Table A deliveries than the Base in all instances except for the 1976-1977 drought.

Table 4.14 SWP average and dry year Table A deliveries (TAF)

	Average	*Single dry year 1977*	*2-year drought 1976-1977*	*4-year drought 1931-1934*	*6-year drought 1987-1992*	*6-year drought 1929-1934*
BASE	3186	222	1620	1521	1786	1679
GFDL A2	2879	229	892	1355	1396	1554
PCM A2	2964	279	1049	1343	1651	1458
GFDL B1	2861	285	952	1386	1502	1507
PCM B1	3224	267	1413	1870	1807	1949

While Table 4.14 contrasts annual average deliveries of the Base and climate change scenarios, a more useful comparison is delivery capability. This comparison was made using delivery exceedance probability curves which show the likelihood that some quantity of water or more was delivered in a given scenario. Each curve was assembled from the 73-year annual delivery sample provided by the CalSim-II simulation. For instance, let's say that in one simulation SWP Table A contractors were delivered more than 4 million acre-feet of water in 16 of the 73-year simulation. Therefore, one point on the curve would match the 78 percent (16/73 = 78 percent) probability of exceedance with a delivery of 4 million acre-feet.

Figure 4.5 shows the exceedance probability curves for SWP Table A deliveries. GFDL A2, PCM A2, and GFDL B1, all with slightly drier climates and significant shifts in seasonal runoff, resulted in consistently lower delivery capability. It does not matter whether the deliveries are low or high. PCM B1, with the slightly wetter climate and no significant reduction in runoff in the late spring and summer, resulted in higher delivery capability for SWP Table A contractors at the lower end of the delivery spectrum and roughly equivalent capability at the higher end. This is consistent with the results shown in the dry-period analysis of Table 4.14. The 50 percent exceedance level delivery represents the median delivery of the 73-year simulation. As shown in Figure 4.5, the Base scenario delivery with a 50 percent probability of exceedance was highest at 3551 TAF. PCM B1 was close behind. GFDL A2 has the lowest delivery at 50 percent exceedance; at 3,154 TAF, it is 11.2 percent less than the base scenario.

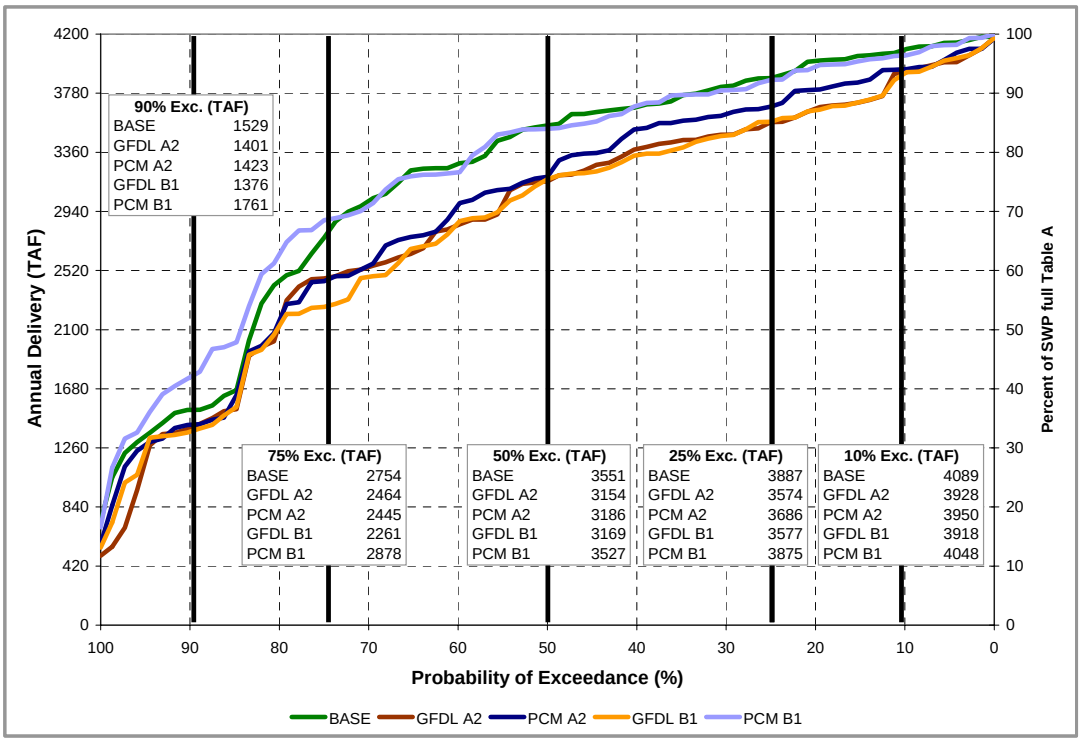

Figure 4.5 Exceedance Probability Plot of SWP Table A Deliveries

Carryover storage was analyzed in a similar fashion. SWP carryover storage is the sum of Oroville storage and SWP San Luis storage on September 30 – the end of the water year. Figure 4.6 shows the probability of exceedance plot for SWP carryover storage. Again, this is constructed from the 73-year simulation sample. As shown, the persistence of SWP carryover storage in scenarios GFDL A2, PCM A2, and GFDL B1 was consistently lower than the Base. The greatest difference was at the 10 percent exceedance level; GFDL B1, at 2,677 TAF carryover, is 28 percent less than the SWP carryover of 3,718 TAF for the Base scenario. However, during the dry years, the SWP was able to change operations and allocations sufficiently to make up for this carryover deficit and avoid unnecessary shortages. Note the convergence of the SWP carryover exceedance curves as you go from 10 percent probability to 90 percent. Base and GFDL A2 carryover were respectively 1,342 TAF and 1,202 TAF at the 90 percent exceedance level. This is a 10 percent reduction in carryover as compared to the 28 percent reduction at the 10 percent exceedance level. Overall, with the drier climate scenarios, less water was delivered to Table A contractors and more risk with SWP carryover storage was taken to do it. The SWP carryover storage in scenario PCM B1 tended to be slightly more dependable than the base for carryover under 2,250 TAF and slightly less dependable than the base for carryover greater than 2,250 TAF. This is also consistent with results shown earlier. The wetter climate of PCM B1 paid off during the drought periods when plenty of storage was available to dampen the added seasonal variability. The SWP was able to capture and deliver this water during the droughts. During the wetter periods though, the storage capacity wasn't available to capture the larger winter runoff. To maintain deliveries, carryover was then reduced.

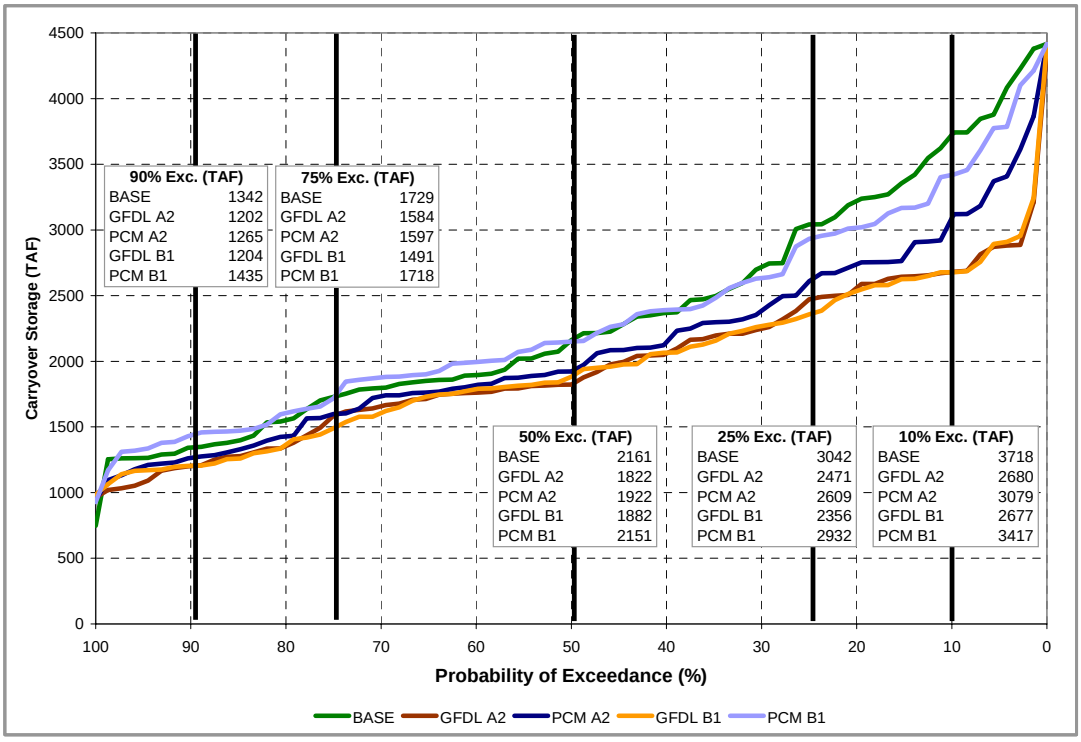

Figure 4.6 Exceedance Probability Plot of SWP Carryover Storage

SWP Article 21 deliveries were not affected by climate change in the same way as Table A deliveries. Having a lower priority than storage, as discussed in Section 4.6.1, Article 21 deliveries were only made when San Luis was full and Delta surplus and Banks pumping capacity were available. Whereas the bulk of Table A deliveries came in the summer and are dependent on the storage of winter precipitation, Article 21 deliveries were primarily made in the winter when surplus conditions existed. The larger winter runoff and lower Table A allocations resulted in higher average Article 21 deliveries for scenarios GFDL A2, PCM A2, and GFDL B1 as shown in Table 4.15. GFDL A2 annual average Article 21 deliveries were increased by 7 TAF from the Base – 99 to 106 TAF. In contrast, GFDL A2 annual average Table A deliveries were decreased 307 TAF from the Base – 3,186 to 2,879 TAF (see Table 4.14). Table 4.15 shows that PCM B1 annual average Article 21 deliveries were reduced in comparison to the Base scenario by 11 TAF. During the 1929-1934 drought, Article 21 contractors lost 69 TAF in scenario PCM B1 as compared to the Base scenario. This happened because higher Table A deliveries were made during this drought in PCM B1 than in the Base. Table 4.14 shows that PCM B1 and Base annual average Table A deliveries during the 1929-1934 drought were 1,949 TAF and 1,679 TAF respectively – a difference of 270 TAF. With higher Table A deliveries, San Luis did not fill as frequently resulting in less Article 21 delivery opportunities.

Table 4.15 SWP average and dry year Article 21 deliveries (TAF)

	Average	*Single dry year 1977*	*2-year drought 1976-1977*	*4-year drought 1931-1934*	*6-year drought 1987-1992*	*6-year drought 1929-1934*
BASE	99	0	0	157	34	111
GFDL A2	106	0	0	188	119	133
PCM A2	103	0	0	194	27	149
GFDL B1	101	0	0	170	52	132
PCM B1	88	0	0	54	39	42

Article 21 delivery capability is illustrated for the Base and climate change scenarios in Figure 4.7. As shown, in all scenarios, no Article 21 deliveries were made in more the 40 percent of the 73 years of simulation. PCM B1 had no Article 21 deliveries in 50 percent of the years. The drier climate change scenarios – GFDL A2, PCM A2, and GFDL B1 – resulted in more frequent Article 21 deliveries. Yet, at the lower probabilities of exceedance, such as 5 percent and 10 percent, the Base and PCM B1 scenarios tended to produce larger Article 21 deliveries.

As expected, the shift in seasonal runoff and slightly drier climate of scenarios GFDL A2, PCM A2 and GFDL B1 reduced annual average deliveries to CVP South-of-Delta contractors. Table 4.16 lists CVP SOD deliveries. The annual average deliveries in the Base and GFDL A2 scenarios were 2,716 and 2,435 TAF respectively – a 10.3 percent reduction. Just as with SWP Table A deliveries, scenario PCM B1 increased annual average CVP SOD deliveries as compared to the Base. The increase was 69 TAF – 2.5 percent of Base CVP SOD deliveries. With the drier climates, less was delivered to CVP SOD contractors during each of the droughts in scenarios GFDL A2, PCM A2, and GFDL B1. Drought CVP SOD deliveries were larger in PCM B1 than in the base in all instances except for 1976-1977.

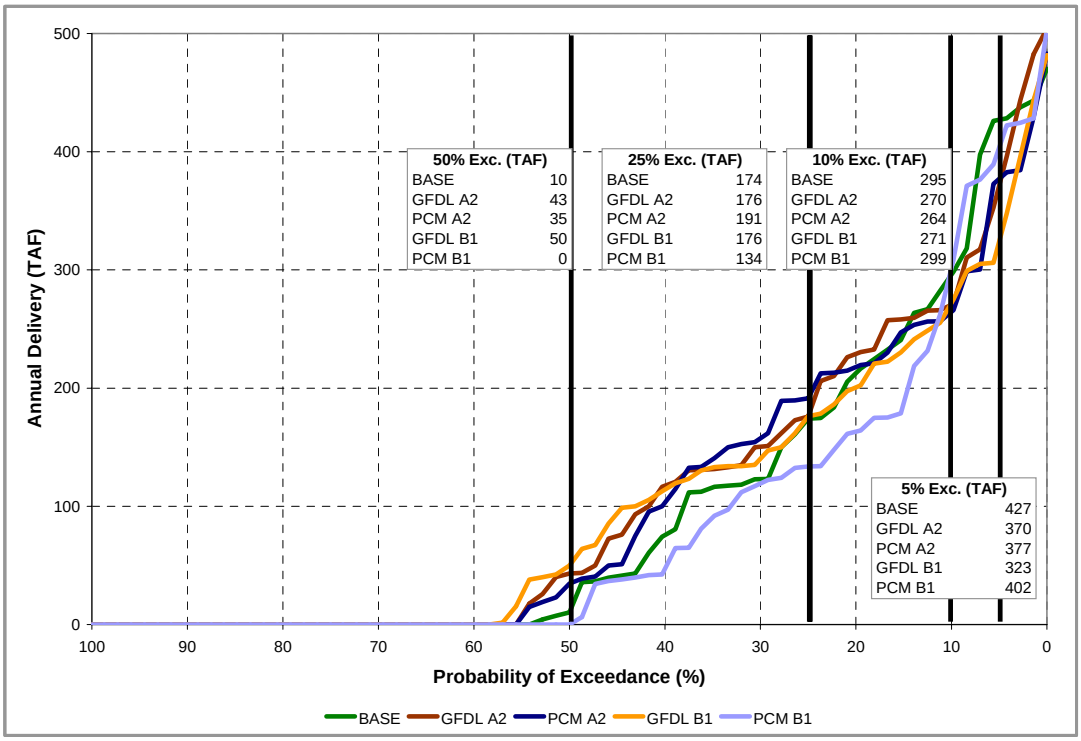

Figure 4.7 Exceedance Probability Plot of SWP Article 21 Deliveries

Table 4.16 CVP South-of-Delta contractor deliveries (TAF)

	Average	*Single dry year 1977*	*2-year drought 1976-1977*	*4-year drought 1931-1934*	*6-year drought 1987-1992*	*6-year drought 1929-1934*
BASE	2716	1358	1704	1362	1806	1538
GFDL A2	2435	1108	1434	1217	1529	1320
PCM A2	2545	1243	1583	1225	1580	1341
GFDL B1	2489	1217	1546	1240	1634	1344
PCM B1	2785	1354	1686	1541	1953	1688

Capability of CVP SOD deliveries decreased for the drier scenarios both at the high and low ends of the probability spectrum. Figure 4.8 shows that the Base median (50 percent exceedance) CVP SOD delivery was 2,963 TAF. The median delivery of scenario GFDL A2 is 2,533 TAF. This equals a 14.5 percent reduction in delivery capability at a 50 percent probability of exceedance. PCM B1 shows more capability than the base in the 60 percent-100 percent exceedance probability range. Annual deliveries of this size (1,500 TAF – 2,750 TAF) typically occurred in the drier years. As such, the higher capability of CVP SOD deliveries in PCM B1 as compared to the base conforms to the higher dry year deliveries shown in Table 4.16.

CVP carryover storage was reduced in the in the drier scenarios and increased in the wetter scenario as compared to the Base. Figure 4.9 plots exceedance probability for CVP carryover storage – defined as the sum of Trinity, Shasta, Folsom, and CVP San Luis storage on September 30, the end of the water year. For GFDL A2, PCM A2, and GFDL B1, higher risks of shortage were taken (lower carryover) and still resulted in lower SOD CVP deliveries. With PCM B1, carryover was more dependable and helped the CVP increase deliveries in the droughts.

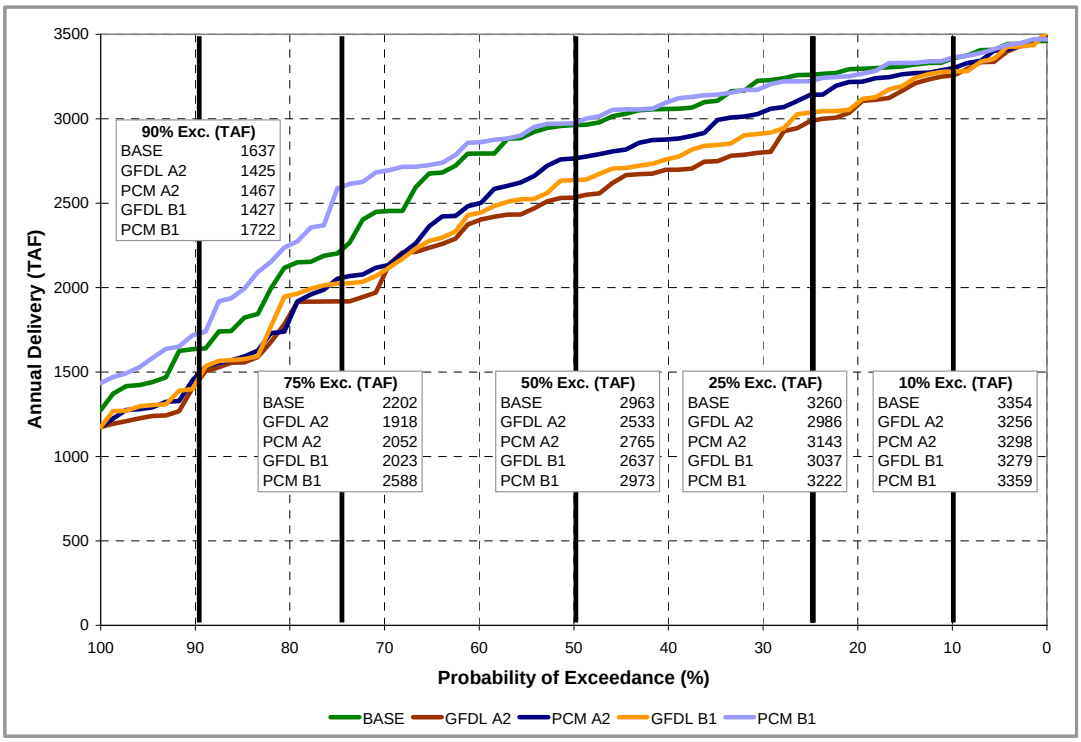

Figure 4.8 Exceedance Probability Plot of CVP South-of-Delta Deliveries

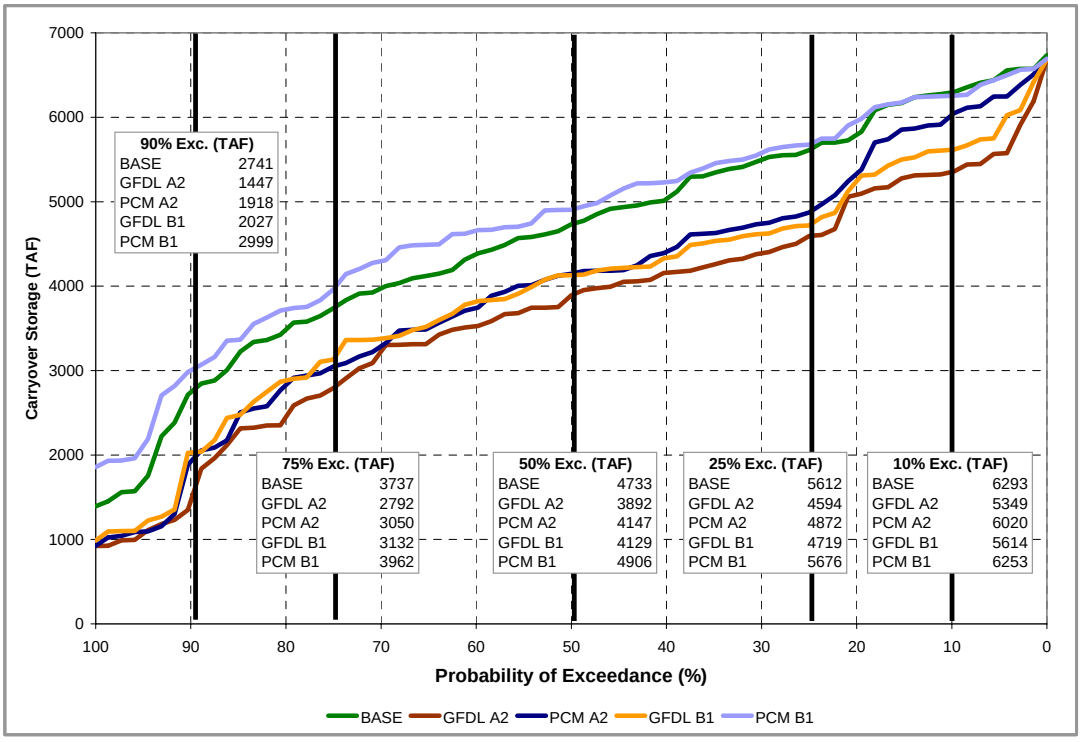

Figure 4.9 Exceedance Probability Plot of CVP Carryover Storage

Table 4.17 shows the annual average CVP north-of-Delta (NOD) deliveries were not as significantly affected by climate change as the CVP SOD deliveries. Base and GFDL A2 annual average CVP NOD deliveries were 2,251 and 2,181 TAF respectively. This equals a 3.1 percent reduction. In contrast, GFDL A2 CVP SOD deliveries were reduced 10.3 percent. There were some significant changes in CVP NOD deliveries during the dry periods. For instance, as shown in Table 4.17, Base and GFDL A2 annual average CVP NOD deliveries during the 1929-1934 drought were 1,940 TAF and 1,742 TAF respectively – a decrease of 10.2 percent. However, this decrease was less of a result of lowered allocations as it was of the critical shortages at Shasta and Folsom. When these reservoirs were drawn down to dead storage during the drought, settlement contractors and refuges were shorted their promised supply. These shortages are reflected in the annual average deliveries presented in Table 4.17.

Table 4.17 CVP North-of-Delta contractor deliveries (TAF)

	Average	*Single dry year 1977*	*2-year drought 1976-1977*	*4-year drought 1931-1934*	*6-year drought 1987-1992*	*6-year drought 1929-1934*
BASE	2251	1847	2076	1815	2061	1940
GFDL A2	2181	1803	2026	1551	1937	1742
PCM A2	2204	1798	2040	1572	1999	1759
GFDL B1	2204	1823	2048	1669	2024	1823
PCM B1	2265	1847	2073	1849	2089	1967

Why were CVP NOD deliveries not as affected by climate change as CVP SOD deliveries? The reason is that different classes of water contracts have different allocation rules. Over 80 percent of CVP NOD deliveries were for settlement contracts or refuges, and delivery allocations for these water users were independent of available storage. NOD settlement contractors and refuges receive 100 percent of contract demand in all years except Shasta critical years; in these years, 75 percent of contract demand is met. (Shasta critical years are defined as years in which Shasta natural inflow totaled less than 3.2 million acre-feet, or as years where the two year total Shasta natural inflow was less than 7.2 million acre-feet and the previous years natural inflow was less than 4 million acre-feet.) SOD exchange contracts and refuges are allocated water in the same way, but these water users represent only around 34 percent of SOD demand. In the Base scenario, nine of the 73 years were Shasta critical. From analysis of Shasta inflow, drier scenarios GFDL A2 and GFDL B1 have exactly the same distribution of Shasta critical years as the Base, drier scenario PCM A2 would add only a single Shasta critical year, and wetter scenario PCM B1 would reduce the number of Shasta critical years by three. For purposes of this study, though, it was assumed that the distribution of Shasta critical years in each climate change scenario remained unchanged from the Base. In the years this assumption was false – one in PCM A2, three in PCM B1 – only small changes in Shasta inflow would be required for the exact definition of Shasta critical to be met. Therefore, the assumption is reasonable. With no change in the number or order of Shasta critical years, water allocations for 80 percent of CVP NOD deliveries and 34 percent of CVP SOD deliveries were the same for the Base and climate scenarios. On the other hand, 66 percent of CVP SOD deliveries and only 20 percent of CVP NOD deliveries were exposed to allocation cuts due to climate change effects on available storage. Thus, total CVP SOD deliveries were more exposed to the negative effects of climate change than CVP NOD deliveries.

Figure 4.10 shows the CVP NOD delivery capability curves for all five scenarios. Capability of these deliveries in the climate change scenarios closely tracked that of the Base in the 0 percent

to 90 percent exceedance probability range. No critical shortages occurred in the years that fall in this range. Given that settlement contract and refuge deliveries were equal in all five scenarios during these years and that these types of deliveries make up more than 80 percent of the total, the fact that the capability curves for CVP NOD deliveries track so closely is expected. In the 0 percent to 90 percent exceedance probability range, GFDL A2, PCM A2, and GFDL B1 have slightly lower deliveries than the Base or PCM B1. This is due to the less than 20 percent of deliveries that are subject to allocation decisions based on available storage. The divergence of the capability curves in the 90 percent to 100 percent exceedance probability range reflects the years of shortage. GFDL A2 shorted settlement contractors and refuges the most. The Base and PCM B1 scenarios continue to track closely in the 90 percent to 100 percent range because neither experienced extreme shortages.

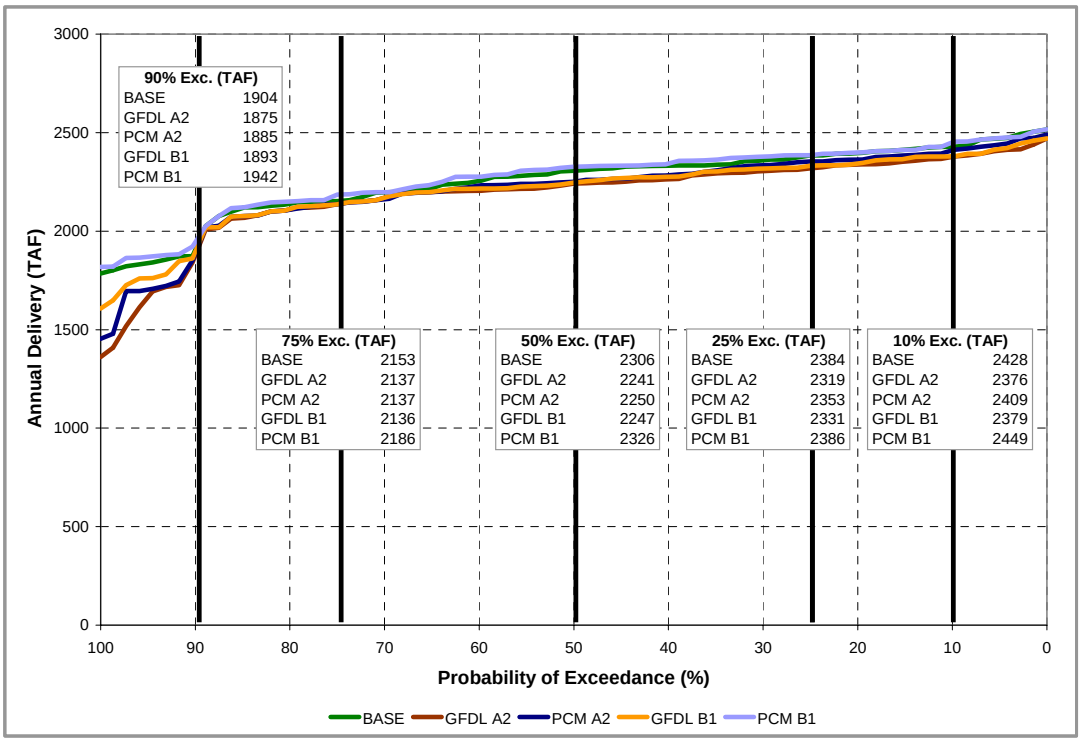

Figure 4.10 Exceedance Probability Plot of CVP North-of-Delta Deliveries

As shown in the above delivery and storage analysis, SWP Table A deliveries and CVP SOD deliveries were negatively affected by the drier climate change scenarios – GFDL A2, PCM A2, and GFDL B1. Carryover was also reduced in these scenarios. With less annual average runoff and a shift in seasonal flows, both projects were less effective capturing, storing, and delivering water. The wetter scenario, PCM B1, had an opposite effect despite the seasonal shift in runoff. During droughts, the additional water was readily captured and delivered with available storage and export capacity. Obviously, the likelihood of a wetter or drier climate will be an important consideration in climate change planning studies. In this case, PCM B1 is the outlier. Does this mean the wetter scenario is less probable than a drier scenario? That is a question that must be addressed.

4.6.3 North-of-Delta Operations Analysis

The purpose of this section is to discuss the interaction between some basic North-of-Delta operational constraints, the climate changed runoff, and impacts to water supply. The constraints of focus are flood control storage and minimum in-stream flow (MIF) requirements. Maintaining flood pool storage in reservoirs during the winter months reduces water supply capacity. Therefore, flood control operations could limit the projects' ability to capture the increased reservoir inflow due to climate change. On the other hand, MIF requirements draw water from NOD storage during extended dry periods. This can lead to a NOD-SOD storage imbalance which adds to the risk of critical NOD shortages like those that occurred in scenarios GFDL A1, PCM A1, and GFDL B1.

Figure 4.11, Figure 4.12, and Figure 4.13 show the monthly frequency that flood pool capacity limited the capture of water for long-term storage in Shasta, Oroville, and Folsom reservoirs respectively. In these frequency plots, flood control included instances that flood pool capacity is zero and the reservoirs were full -- typically in late spring and early summer. It also included late summer and early fall releases to initially free up flood pool capacity. The flood control frequency plots have nothing to do with flooding downstream; they simply show the probability that water was released from a reservoir to preserve flood pool capacity or overtopping of the reservoir in the case that the reservoir was full.

The climate change scenarios, as compared to the Base, increased inflows to Shasta, Oroville and Folsom over the December to March flood season. Shasta and Oroville reserve most of their capacity for water supply, while Folsom's primary function is flood control. It is expected that flood control frequency of Folsom will be greater than that of Shasta or Oroville. As shown in Figure 4.11, Shasta was at flood control capacity less than 40 percent of the time in December and January in all scenarios; therefore, Shasta had a better than 60 percent chance of being able to capture the additional flows in these months. In February, Shasta storage was limited by flood pool less than 45 percent of the time in the five scenarios. While in March, the presence of the flood pool becomes more significant in the GFDL B1 and PCM B1 scenarios with an approximately 50 percent control frequency. Scenarios Base, GFDL A2, and PCM A2 have a Shasta flood control frequency of around 40 percent in March.

Figure 4.12 shows that Oroville is likely to have available capacity to capture increased inflows in December, January, and February in all four climate change scenarios. Only in March does the flood control frequency of Oroville rise above 50 percent for three of the climate change scenarios; at 63 percent flood control frequency, Oroville was least effective capturing the PCM B1 increased inflows in March.

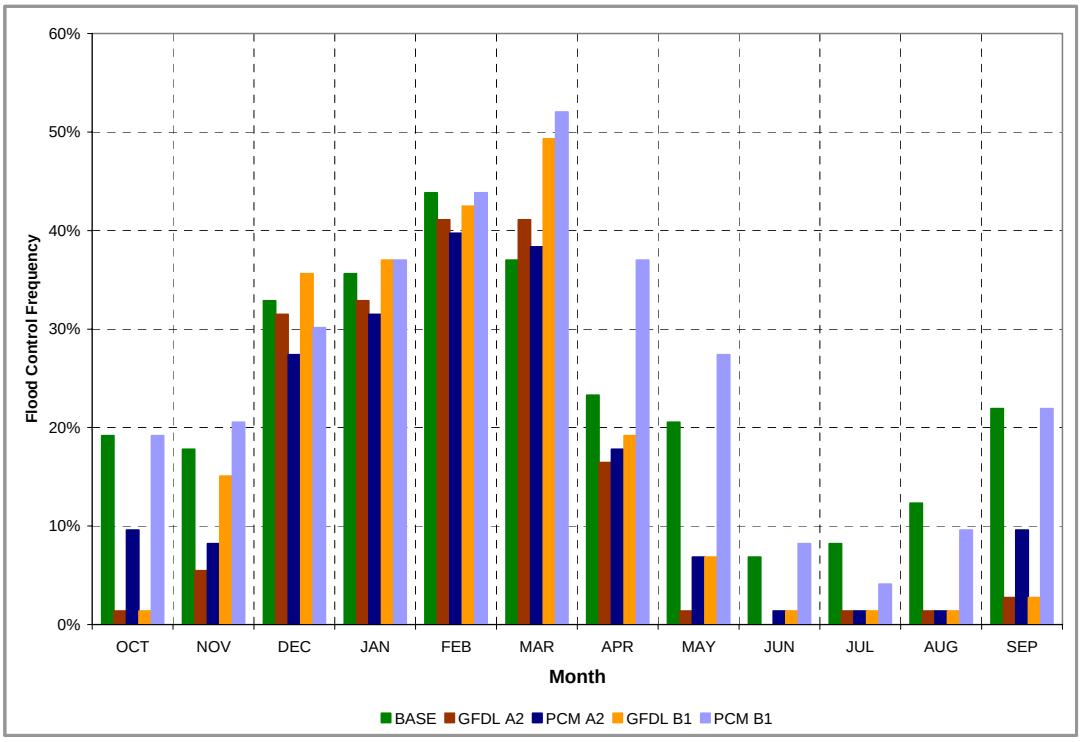

Figure 4.11 Monthly flood control frequency of Lake Shasta

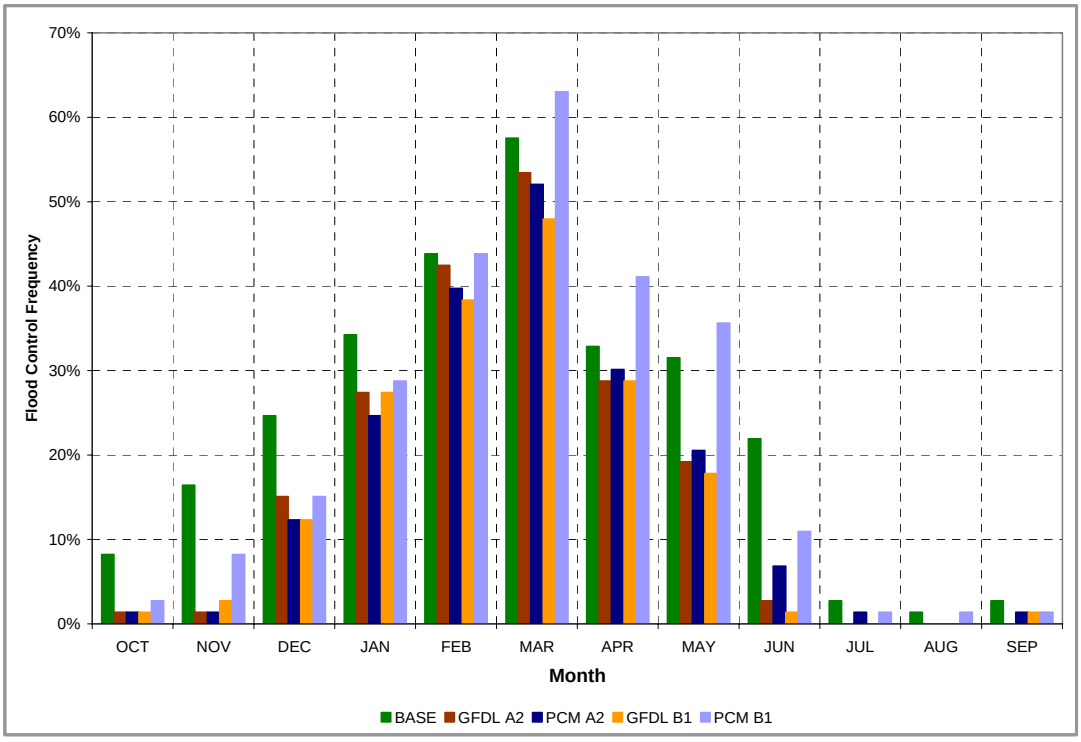

Figure 4.12 Monthly flood control frequency of Lake Oroville

Folsom was the least able of the three reservoirs to capture increased winter inflows. Figure 4.13 shows that in January, February, and March, the Folsom flood control frequency approached or surpassed 70 percent in the four climate change scenarios. PCM B1 reaches nearly 80 percent in February and March. The analysis assumes that flood pool operations will remain consistent with historical rules. However, with increased winter runoff, demands for greater flood protection may further encroach on water supply storage.

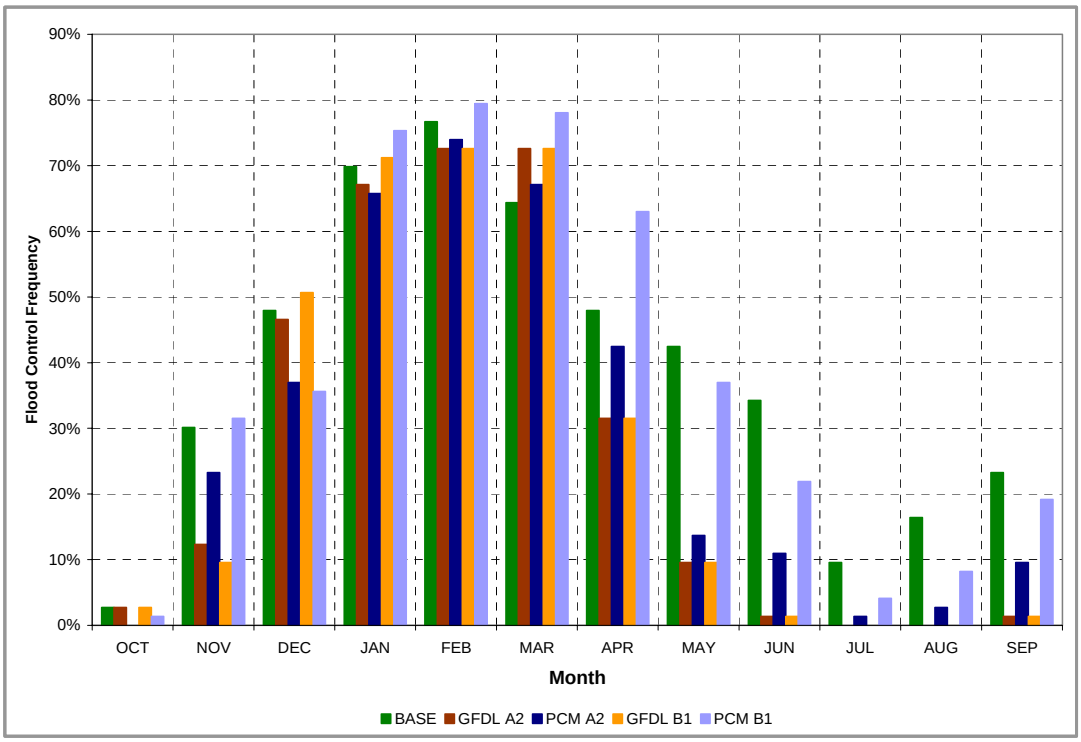

Figure 4.13 Monthly flood control frequency of Folsom Lake

While flood control operations may prevent the capture of increased winter runoff, MIF requirements downstream of the reservoirs will draw down NOD storage when reservoir inflows are low. Figure 4.14, Figure 4.15, and Figure 4.16 show the dry-period frequency that Shasta, Oroville, and Folsom releases are controlled by MIF requirements on the Sacramento, Feather, and American rivers respectively. Each river has 2 to 3 MIF requirements at different locations. When flow is reduced to one of the MIF requirements, reservoir releases on that river have reached a minimum and the MIF requirement is effectively controlling operations.

The reason the control frequency plots for MIF requirements focus on the dry periods – 1924, 1929-1934, 1976-1977, and 1987-1992 – is that those are the periods where there are critical shortages in Shasta and Folsom in the GFDL A2, PCM A2, and GFDL B1 scenarios. Figure 4.14 and Figure 4.16 show that MIF requirements are largely responsible for draining these reservoirs during the dry periods. Of course, there are downstream Delta requirements that are being met by these releases also. One can conclude that changes in SOD delivery allocations during the dry periods will not likely alleviate all of the Shasta and Folsom shortages. The water will have to be released during these years whether it's going South-of-Delta or not. The only way to prevent the shortages with changes in allocation rules is to reduce deliveries in the wet years preceding a drought in hopes of enough carryover storage to get the project through.

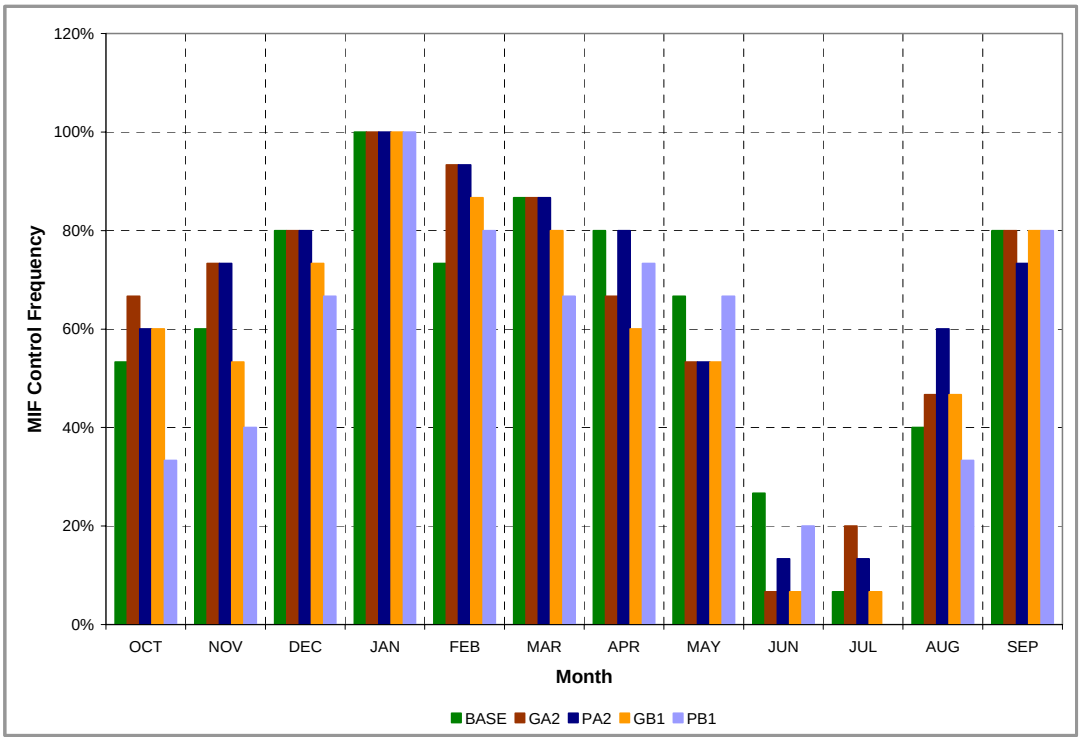

Figure 4.14 MIF requirement control frequency on the Sacramento River during dry periods (1924, 1929-1934, 1976-1977, 1987-1992)

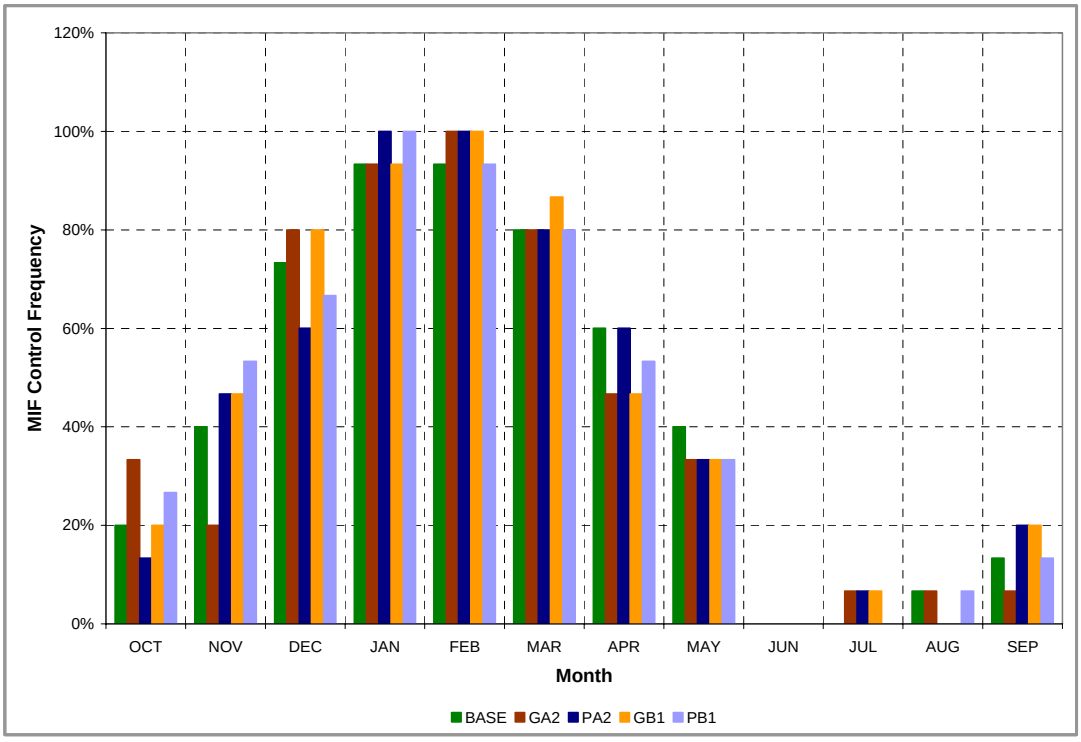

Figure 4.15 MIF requirement control frequency on the Feather River during dry periods (1924, 1929-1934, 1976-1977, 1987-1992)

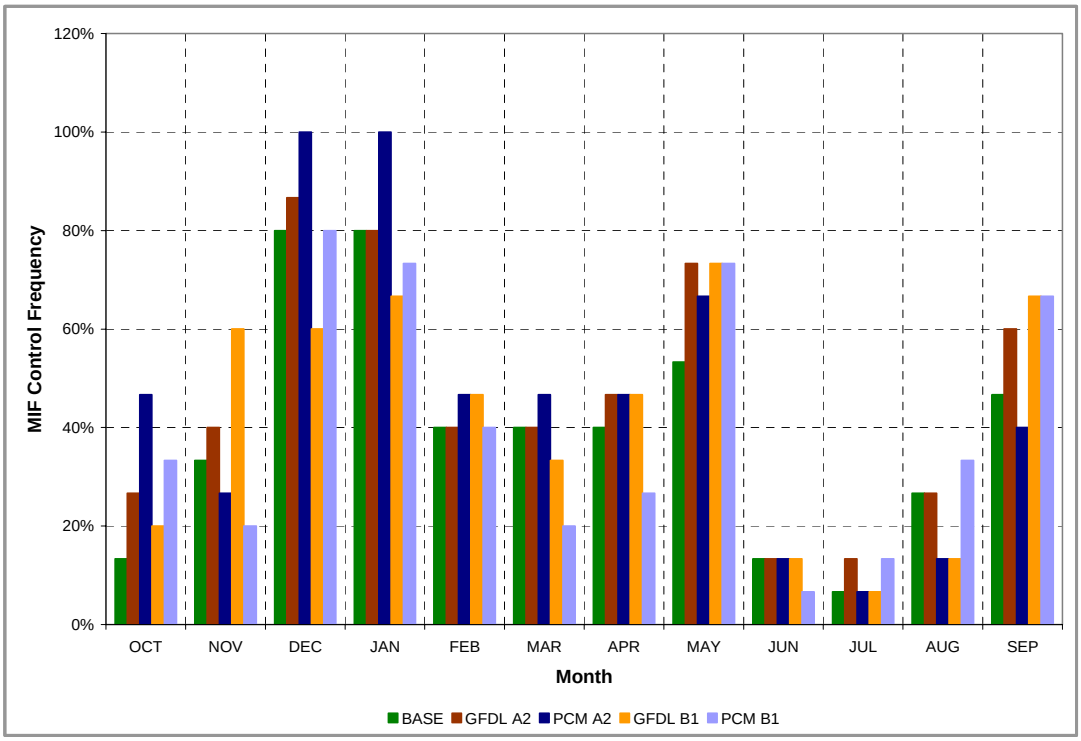

Figure 4.16 MIF requirement control frequency on the American River during dry periods (1924, 1929-1934, 1976-1977, 1987-1992)

4.6.4 Delta Operations Analysis

The CVP and SWP have three mechanisms to operate, or control, the Sacramento-San Joaquin Delta – NOD reservoir releases to the Sacramento River, the Delta Cross Channel, and Tracy and Banks exports. NOD storage releases can be increased to meet Delta outflow requirements, improve water quality, or increase exports. The Delta Cross Channel gates are opened during certain periods of the year to reduce salinity in the Delta interior with water from the Sacramento River and closed for certain periods of the year to prevent migrating fish from getting lost in the interior. Exports can be reduced to protect water quality, fish, or to maintain Delta outflow requirements or increased to capture available surplus water that would otherwise flow out to the San Francisco Bay. Delta locations of the Sacramento River inflow, Cross Channel, and the Banks and Tracy pumping plants are shown in Figure 4.17.

Operation of the Delta Cross Channel gates is largely pre-processed in CalSim-II. The only dynamic decision in the model with respect to the gates is to keep them closed when Delta inflow on the Sacramento River exceeds 25,000 cubic feet per second. While this is a frequent condition, it does not cause many differences in Delta Cross Channel gate operations when comparing the Base and climate change scenarios. There are occasions when the gates are closed in one scenario and open in another, but this is an infrequent occurrence.

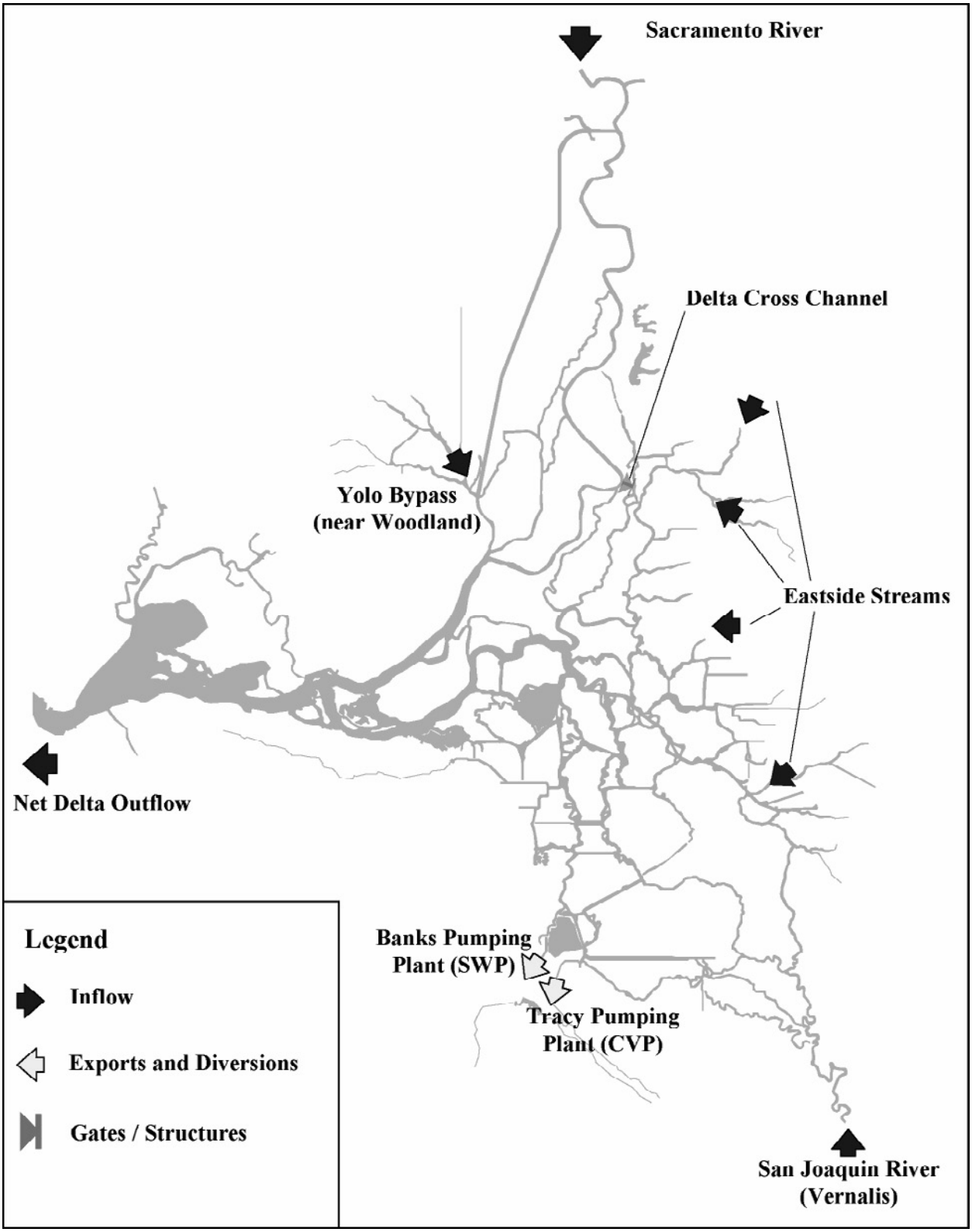

Figure 4.17 Map of the Sacramento – San Joaquin Delta

Annual average changes in Delta inflow are listed in Table 4.18. Total Delta inflow includes the Sacramento River, Yolo Bypass, Eastside streams, San Joaquin River (SJR), and Marsh Creek. Inflow from the Eastside streams and Marsh Creek do not change from the Base to the climate change scenarios. Changes in inflow are centered on the San Joaquin River, Sacramento River, and Yolo Bypass.

Table 4.18 Annual Average Delta Inflow (WY1922-1994)

Study	San Joaquin River			Sacramento River and Yolo Bypass			Total Delta Inflow		
	Annual Average Inflow (TAF)	Change from Base (TAF)	Change from Base (%)	Annual Average Inflow (TAF)	Change from Base (TAF)	Change from Base (%)	Annual Average Inflow (TAF)	Change from Base (TAF)	Change from Base (%)
BASE	2,622	0	0%	17,430	0	0%	20,850	0	0%
GFDL A2	2,508	-114	-4%	16,956	-474	-3%	20,258	-591	-3%
PCM A2	2,542	-81	-3%	16,601	-829	-5%	19,939	-911	-4%
GFDL B1	2,260	-362	-14%	17,018	-412	-2%	20,071	-778	-4%
PCM B1	2,691	69	3%	18,301	870	5%	21,789	939	5%

So far, there has been no discussion of effects in the San Joaquin basin due to the altered reservoir inflows under the climate change scenarios. That will have to wait for another report. However, with respect to Delta operations, it's important to look at the changes in Delta inflow on the San Joaquin River. In the dry months, where SJR Delta inflow is reduced, either exports must be reduced or more NOD storage releases must be made to support Banks and Tracy pumping. Furthermore, Banks permitted pumping capacity is dependent on SJR Delta inflow at Vernalis from December 15 to March 15. During this period, Banks permitted capacity is 6,680 cfs when SJR inflow is at or below 1,000 cfs. One-third of SJR inflow is added to permitted capacity if SJR inflow exceeds 1,000 cfs. Given Banks physical capacity is approximately 8,500 cfs, this permitted capacity condition is significant when SJR monthly inflows are within the range of 60 to 330 TAF per month. Figure 4.18 shows the monthly SJR Delta inflows as averaged over WY1922-1994. From December to March, monthly average inflow falls within this range.

Figure 4.19 shows combined monthly Sacramento River and Yolo Bypass Delta inflows as averaged over WY1922-1994. Average inflows of the climate change scenarios tend to be higher than the base scenario December through March. This is due to increased NOD reservoir inflow in these months when flood control operations were in effect and storage capacity was not available. During the summer and early fall months, Sacramento inflows for scenarios GFDL A2, PCM A2, and GFDL B1 are lower than in the Base. One explanation is that in the Base scenario larger NOD reservoir releases must be made to support the higher exports and SOD deliveries.

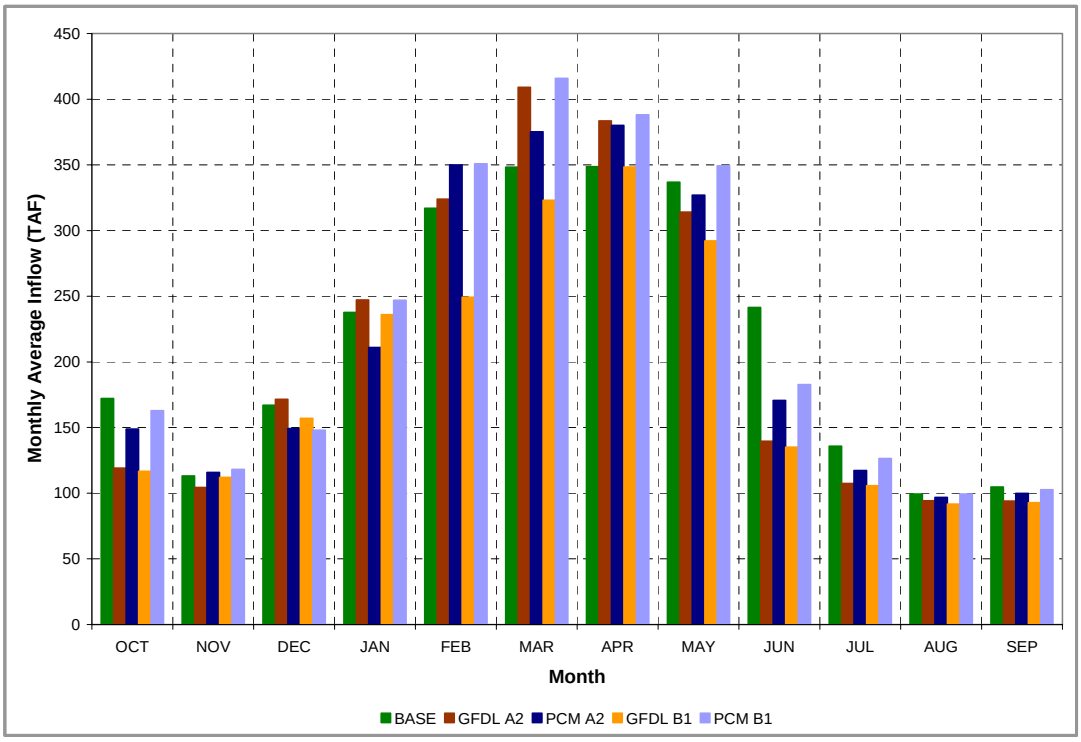

Figure 4.18 Monthly average San Joaquin River Delta inflow at Vernalis (WY1922-1994)

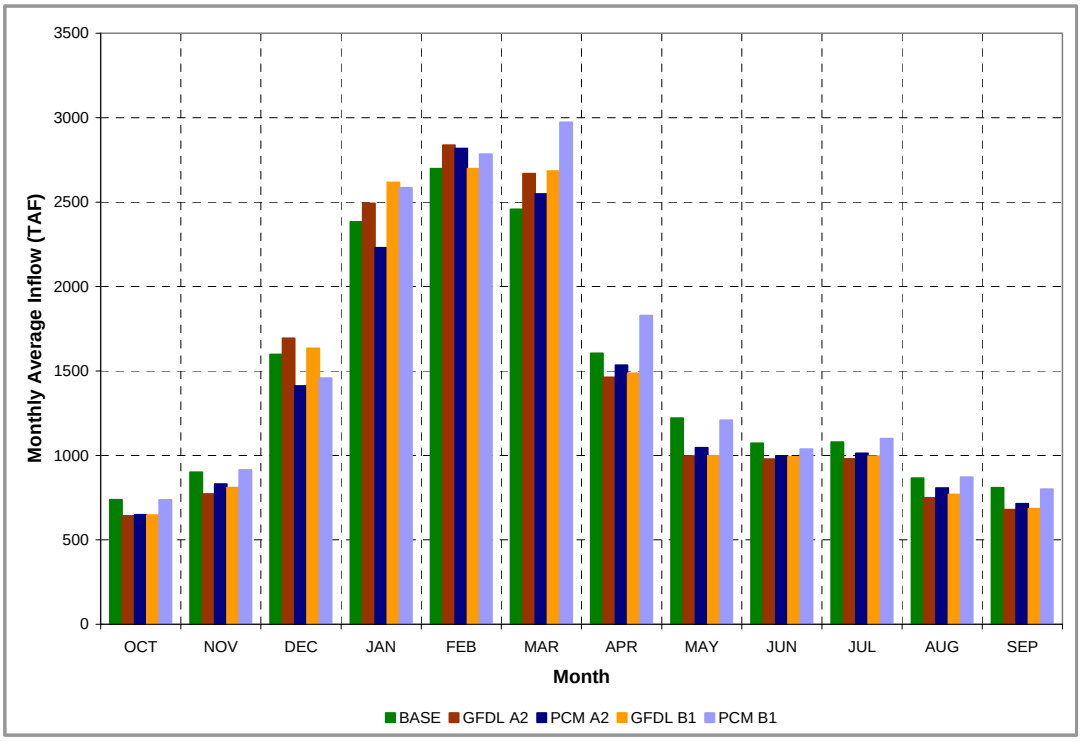

Figure 4.19 Monthly average Sacramento River--Yolo Bypass Delta inflow (WY1922-1994)

Changes in required, surplus, and total Delta outflow, as compared to the Base are listed in Table 4.19. Required Delta outflow is defined in Table 3 of the Water Quality Control Plan (WQCP). It also includes outflow necessary to maintain water quality standards as set in the WQCP. As shown, there are no significant changes in required Delta outflow on an annual average basis. Surplus Delta outflow is where the changes are concentrated. This outflow typically comes in the winter and spring due to rain and snowmelt runoff. In PCM A2, Surplus Delta outflow decreases by 7 percent as compared to the base scenario, while in PCM B1, it increases by 11 percent on average.

Table 4.19 Annual Average Delta Outflow (WY1922 – 1994)

Study	Required Delta Outflow			Surplus Delta Outflow			Total Delta Outflow		
	Annual Average Outflow (TAF)	Change from Base (TAF)	Change from Base (%)	Annual Average Outflow (TAF)	Change from Base (TAF)	Change from Base (%)	Annual Average Outflow (TAF)	Change from Base (TAF)	Change from Base (%)
BASE	5,621	0	0%	8,187	0	0%	13,808	0	0%
GFDL A2	5,627	5	0%	8,170	-18	0%	13,796	-12	0%
PCM A2	5,633	12	0%	7,652	-535	-7%	13,285	-524	-4%
GFDL B1	5,622	1	0%	7,923	-264	-3%	13,546	-263	-2%
PCM B1	5,590	-32	-1%	9,060	872	11%	14,649	841	6%

Figure 4.20 shows monthly Delta outflow as averaged over WY1922-1994. Notice that outflows for the base and climate change scenarios are roughly equivalent on average July-November. As set in Table 3 of the WQCP, required Delta outflow in these months will not change from scenario to scenario. Little surplus would be expected in these months also. The slight increases in base outflows during these months were attributed to maintaining water quality standards with higher exports. This, at times, required higher Delta outflows. In the winter, Delta outflows of the climate change scenarios tended to be higher than those of the base. Given higher Delta inflows during this period and limited pumping capacity, this pattern was expected.

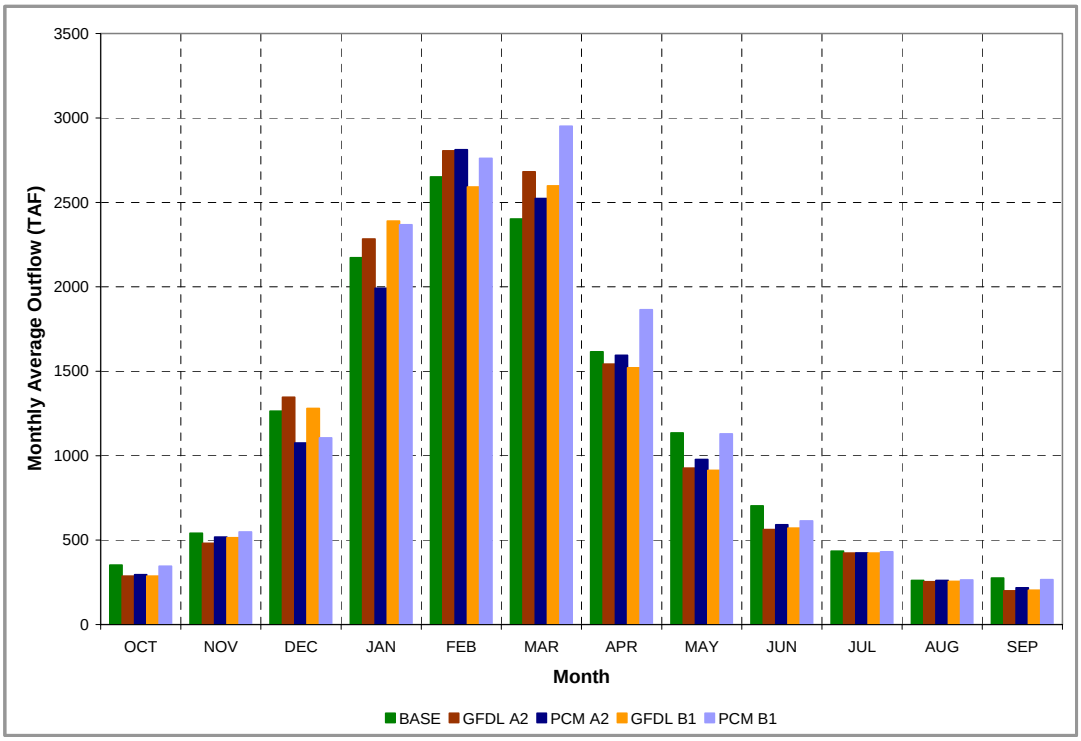

Figure 4.20 Monthly average Delta outflow (WY1922-1994)

Previously, it was shown that the combined SWP and CVP SOD deliveries in the drier climate change scenarios were consistently less than the base scenario. It was expected that SOD exports would decrease also. Table 4.20 lists annual average exports and calculates changes with respect to the base. Total exports in GFDL A2, PCM A2, and GFDL B1 decrease by 10 percent, 6 percent, and 9 percent respectively. Overall, SOD deliveries were increased for the SWP and CVP in scenario PCM B1. A corresponding 2 percent increase in total exports is shown in Table 4.20.

Table 4.20 Annual Average Delta Exports

Study	Tracy Exports			Banks Exports			Total Exports		
	Annual Average Exports (TAF)	Change from Base (TAF)	Change from Base (%)	Annual Average Exports (TAF)	Change from Base (TAF)	Change from Base (%)	Annual Average Exports (TAF)	Change from Base (TAF)	Change from Base (%)
BASE	2554	0	0%	3351	0	0%	5905	0	0%
GFDL A2	2286	-269	-11%	3046	-305	-9%	5332	-573	-10%
PCM A2	2391	-164	-6%	3131	-220	-7%	5522	-383	-6%
GFDL B1	2369	-186	-7%	3027	-324	-10%	5395	-510	-9%
PCM B1	2620	66	3%	3383	33	1%	6004	98	2%

Figure 4.21 shows monthly total Delta exports as averaged over WY1922-1994. During the winter, average exports were not significantly changed from the base to the climate change scenarios. Even with the added Delta inflow of the climate change scenarios during the wet months, exports at Tracy and Banks were unable to capture most of it because of a combination of permitted pumping capacity, physical pumping capacity, SOD conveyance constraints, and the export to inflow ratio of the WQCP. Base and PCM B1 exports were significantly higher in the summer and fall months as compared to the drier climate change scenarios. The higher exports were to support the higher delivery allocations in the Base and PCM B1 scenarios.

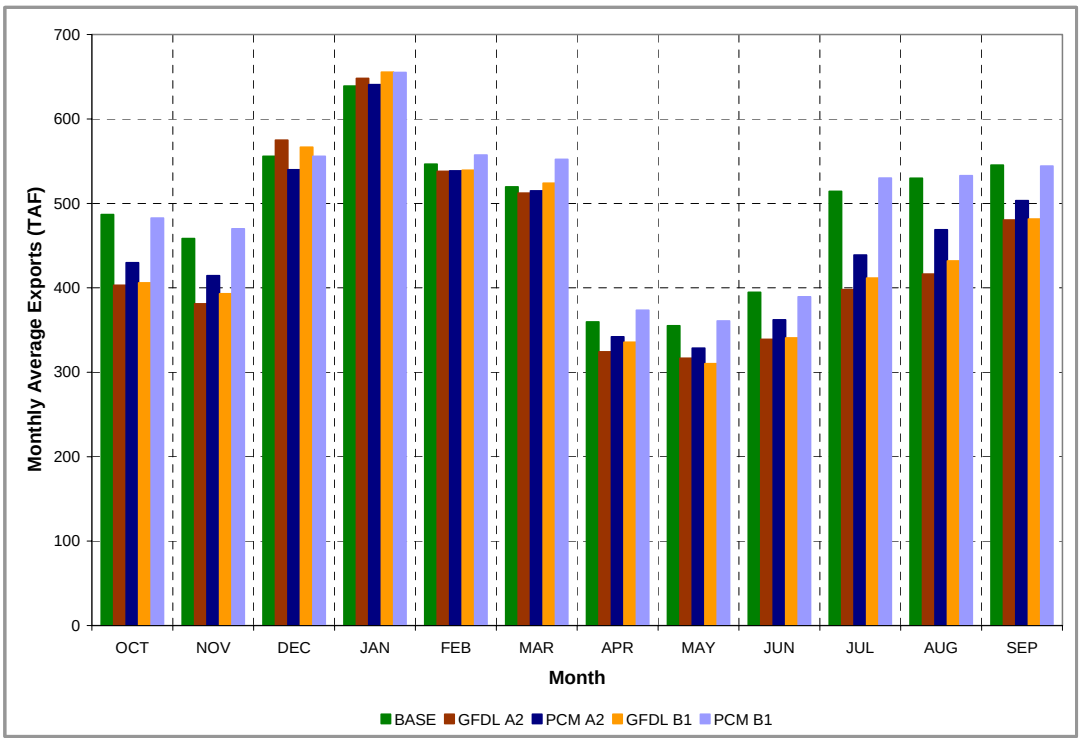

Figure 4.21 Monthly average total Delta exports (WY1922-1994)

There are a number of system constraints, physical and regulatory, that inhibit SWP and CVP Delta exports to SOD contractors. They include:

1) Permitted and physical pumping capacity
2) SOD conveyance capacity including storage capacity, channel and pumping capacity, and contractor demand
3) April-May SJR pulse flow limits on exports (April 15-May15)
4) WQCP water quality standard limits on exports as calculated using ANN
5) WQCP export-inflow ratio

The frequency that these export constraints control exports was quantified for the Base and climate change scenarios. For Banks, the frequency that permitted or physical pumping capacity was reached on a monthly basis is shown in Figure 4.22. This constraint is most significant in

January when surplus Delta outflow was likely. Figure 4.23 shows that SOD conveyance constraints are most likely to constrain exports in March. The April-May pulse flow export limits were applied from April 15 to May 15. Since the simulation time-step is one month, the simulated constraint was actually a day-weighted average of the pulse flow constraint and permitted capacity. As shown in Figure 4.24, the simulated April-May export constraint controlled Banks pumping about 90 percent of the time in these two months in all scenarios. Figure 4.25 shows the frequency that exports are constrained in each simulation by the various WQCP water quality standards; while frequency of water quality constraints varies significantly from month to month and scenario to scenario, November is the month where water quality was most likely to control Banks exports in all five simulations. The frequency that the export-inflow ratio controls Banks is shown in Figure 4.26

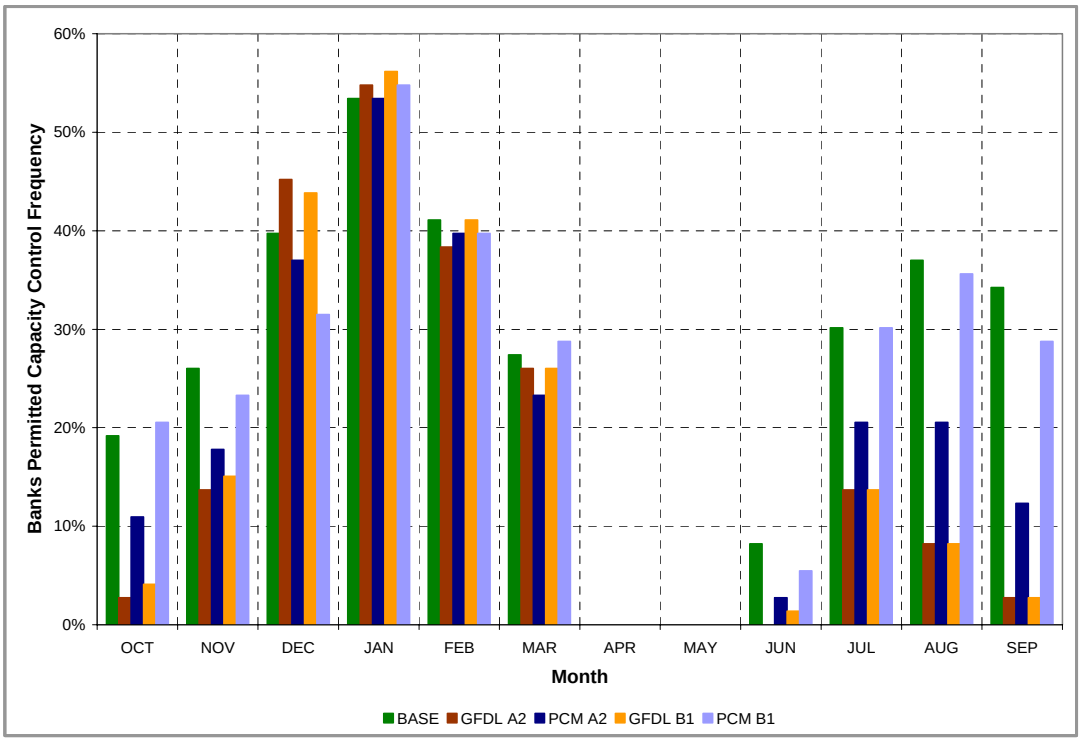

Figure 4.22 Operational control frequency of Banks permitted capacity

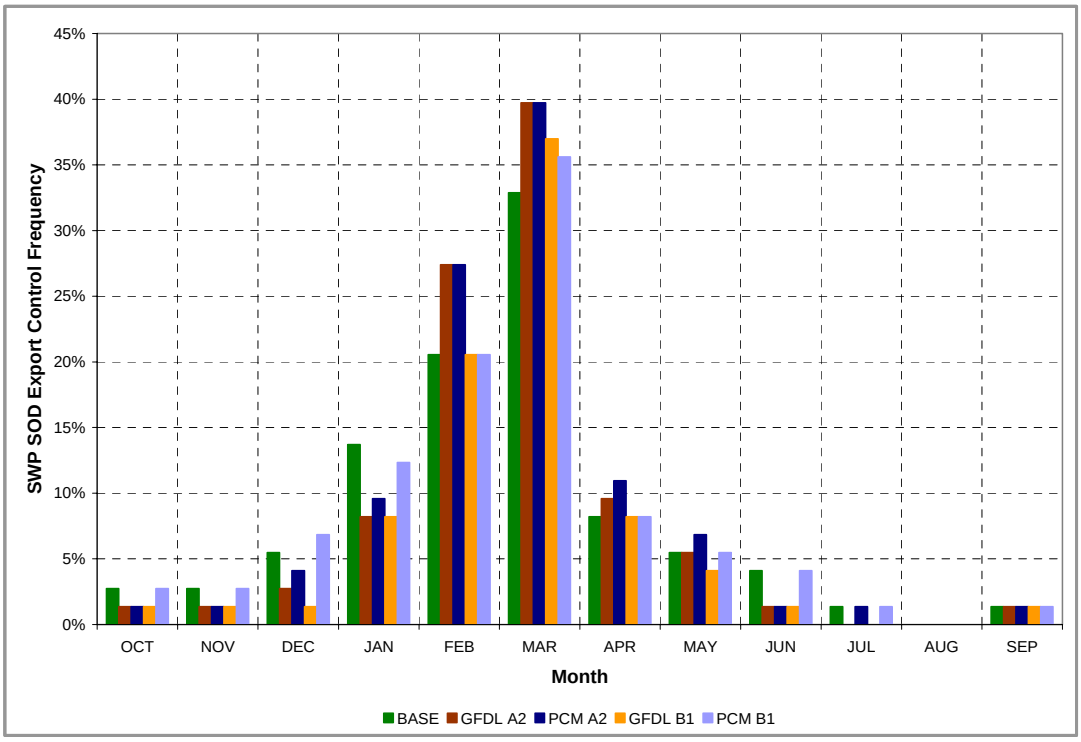

Figure 4.23 Operational control frequency of SWP SOD conveyance capacity on Banks exports

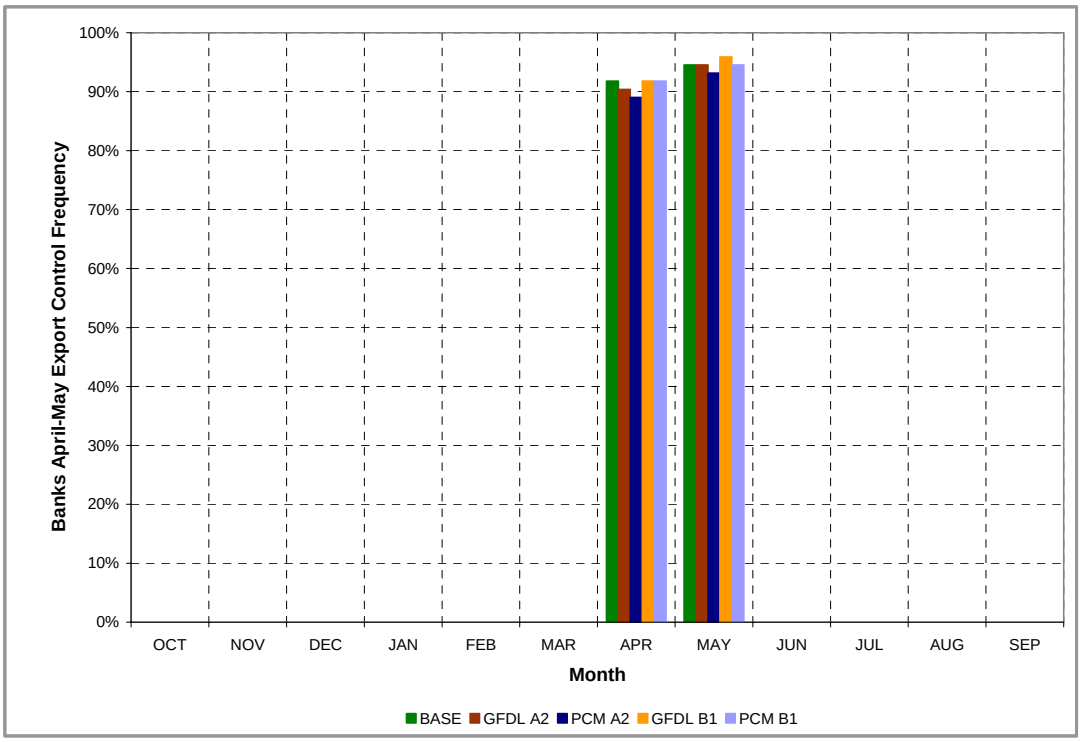

Figure 4.24 Operational control frequency of the April-May San Joaquin River pulse flow export constraints on Banks pumping

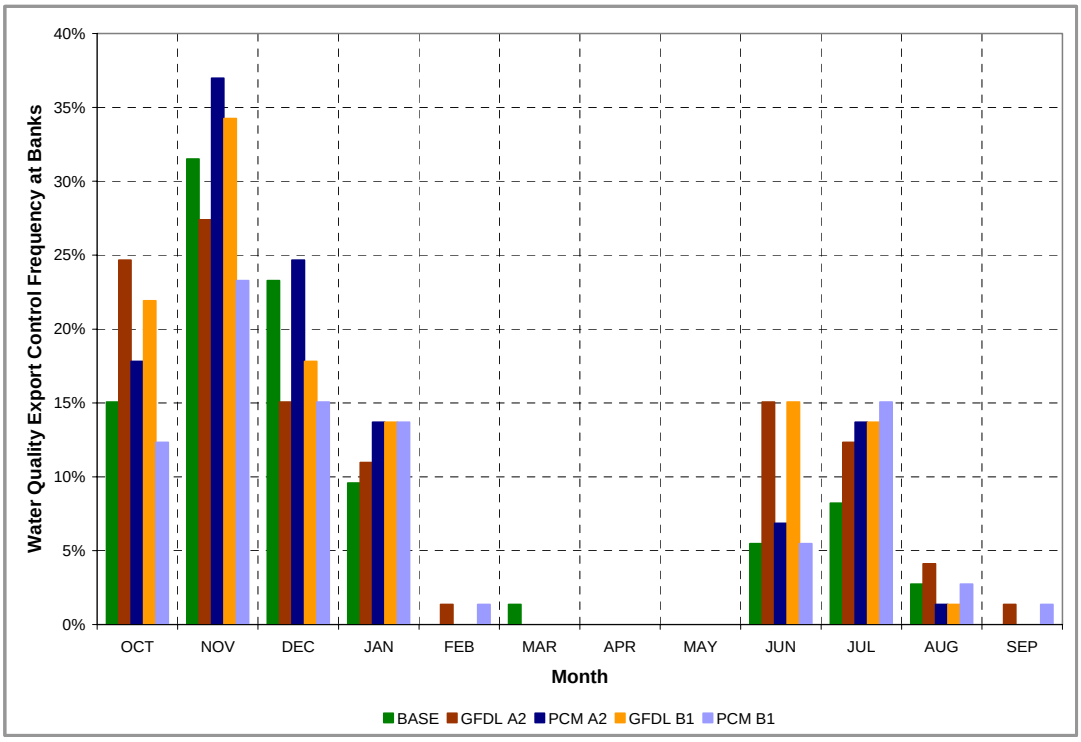

Figure 4.25 Operational control frequency of Delta water quality standards on Banks pumping

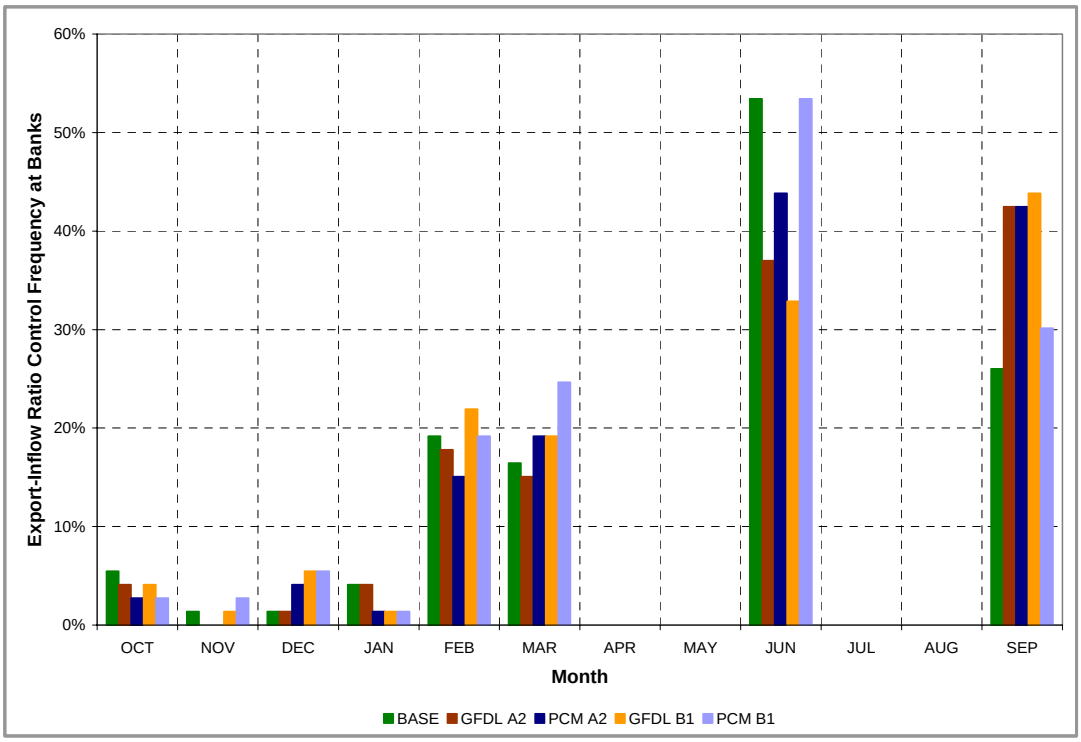

Figure 4.26 Operational control frequency of Banks pumping by the export-inflow ratio

With increased Delta inflow from December to March in the climate change scenarios, it would be useful, from a water supply standpoint, to capture some of the surplus Delta outflow. From the operational control frequency information contained in Figure 4.22 to Figure 4.26, the key constraint in this period was Banks permitted and physical capacity. In March, SWP SOD conveyance often becomes the constraining parameter. This suggests that changes in Banks permitted capacity and SWP SOD conveyance capacity – surface storage, canals, pumps, groundwater banking – should be tested for its potential to compensate for climate change impacts on SOD water supply.

Figure 4.27 shows the frequency that Banks exports are not constrained by physical or permitted capacity, SOD conveyance capacity, April-May export restrictions, water quality, or the export-inflow ratio. In this case, a decision was made to preserve Oroville storage at the expense of San Luis storage. As expected, the least flexibility in Banks pumping is in December-March when it is most needed to capture the additional Delta inflow in the climate change scenarios. Due to decreased exports, there is some unused summer Banks capacity in the drier climate change scenarios as compared to the Base. Would it be helpful to increase San Luis carryover at the expense of Oroville? It is possible that greater available capacity in Oroville would help to capture the increased winter runoff, but no conclusions could be made without further tests. Special Feather River fish criteria from October 15 to November 30 limit Oroville releases for Delta export. So even though there is a high frequency of no export controls in these months, it is likely that Oroville releases could not be made to take advantage. The CVP could take advantage of available Banks capacity for delivery to Cross Valley Canal in the summer and fall. However, given the critical shortages on Shasta and Folsom in the drier climate change scenarios, it is not clear that the CVP would want to release additional water from these reservoirs.

Tracy Pumping Plant has a physical capacity of 4,600 cfs with exports further limited to a range of 4,200 cfs – 4,600 cfs by a constriction on the upper Delta-Mendota canal. Figure 4.28 shows the frequency that the combined physical pumping capacity and upper DMC constraint limit Tracy exports. Sometimes, typically in the winter, there is no place SOD for the CVP to put the water. Figure 4.29 shows the frequency that this occurs. As shown in Figure 4.30, the April-May export constraint regularly limits Tracy exports in these months – just as it did with Banks. However, the April-May constraint does not control Tracy as frequently as Banks because of CVP SOD conveyance limits. Figure 4.31 shows the regularity that the WQCP water quality standards limit Tracy pumping, and Figure 4.32 shows the same information for the export-inflow ratio.

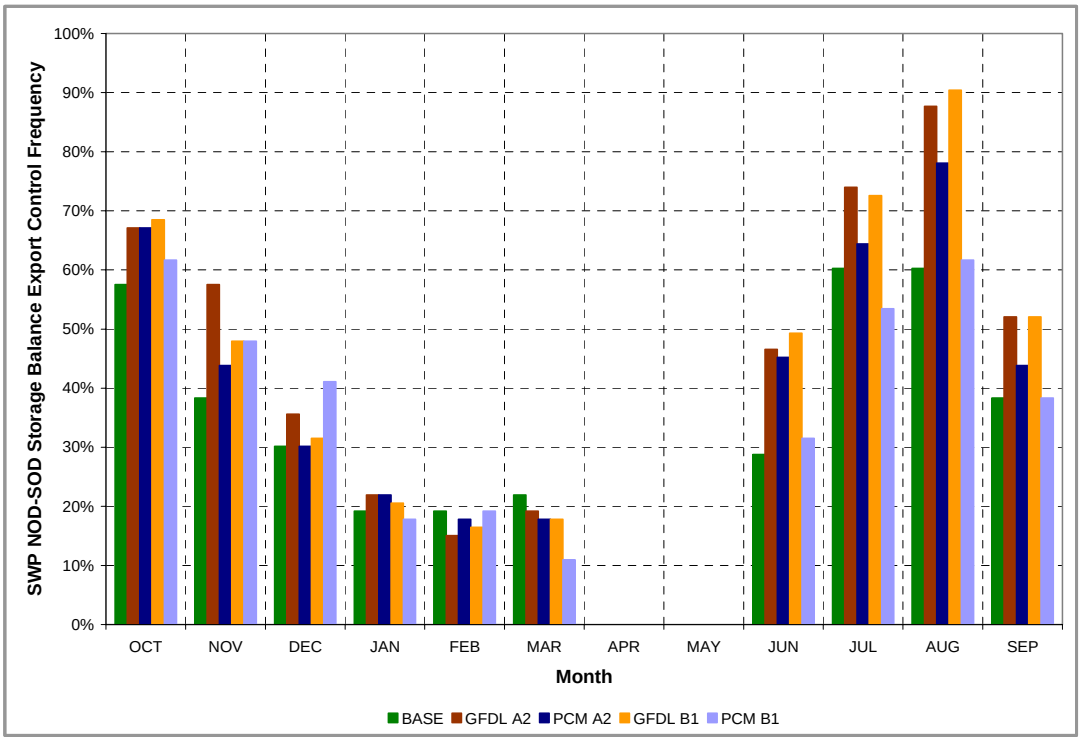

Figure 4.27 Frequency of the decision to favor SWP NOD storage over SWP SOD storage by limiting Oroville releases and Banks pumping

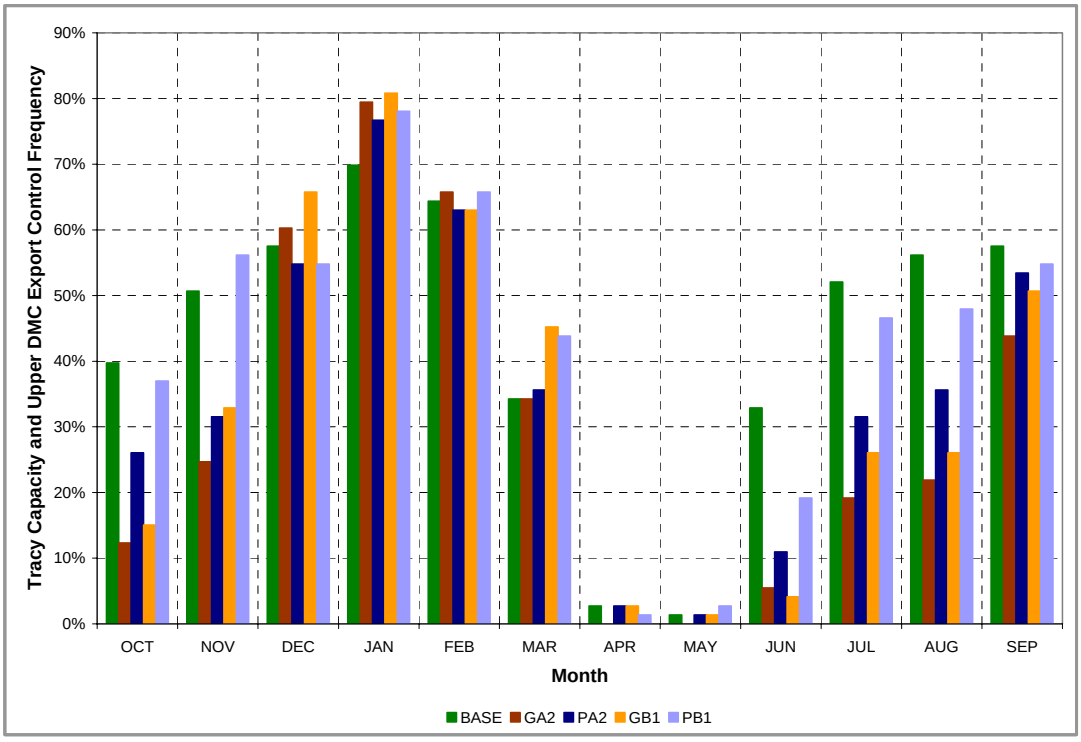

Figure 4.28 Operational control frequency of Tracy pumping capacity and upper Delta-Mendota Canal conveyance capacity

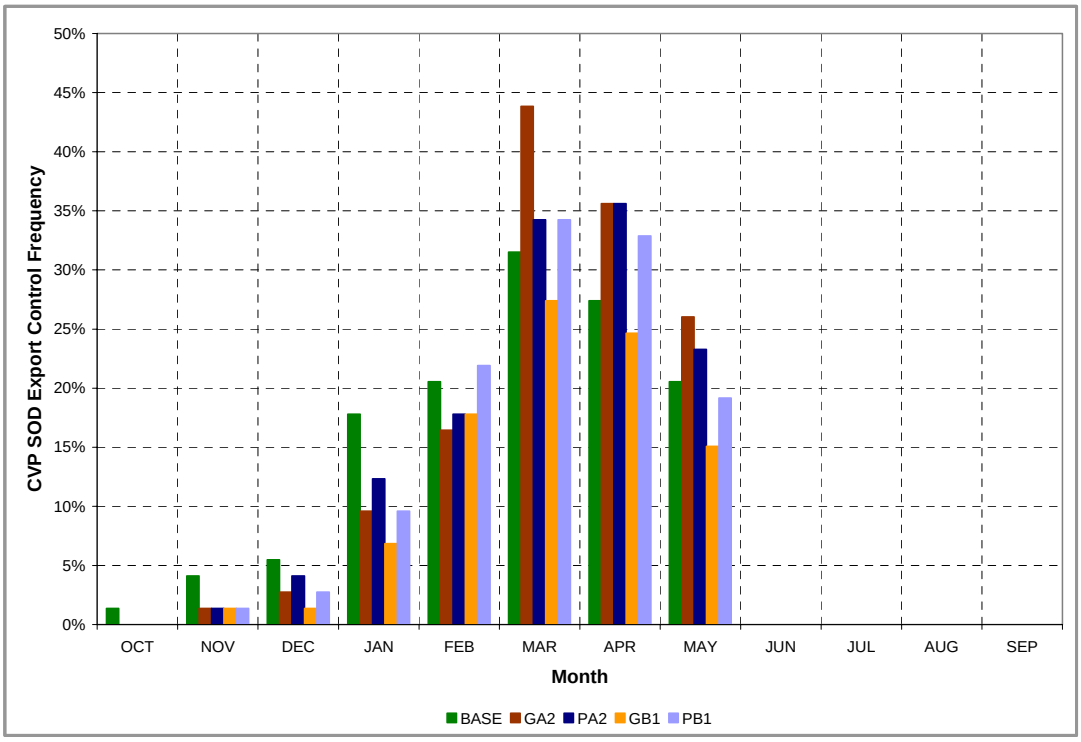

Figure 4.29 Operational control frequency of CVP SOD conveyance capacity on Tracy exports

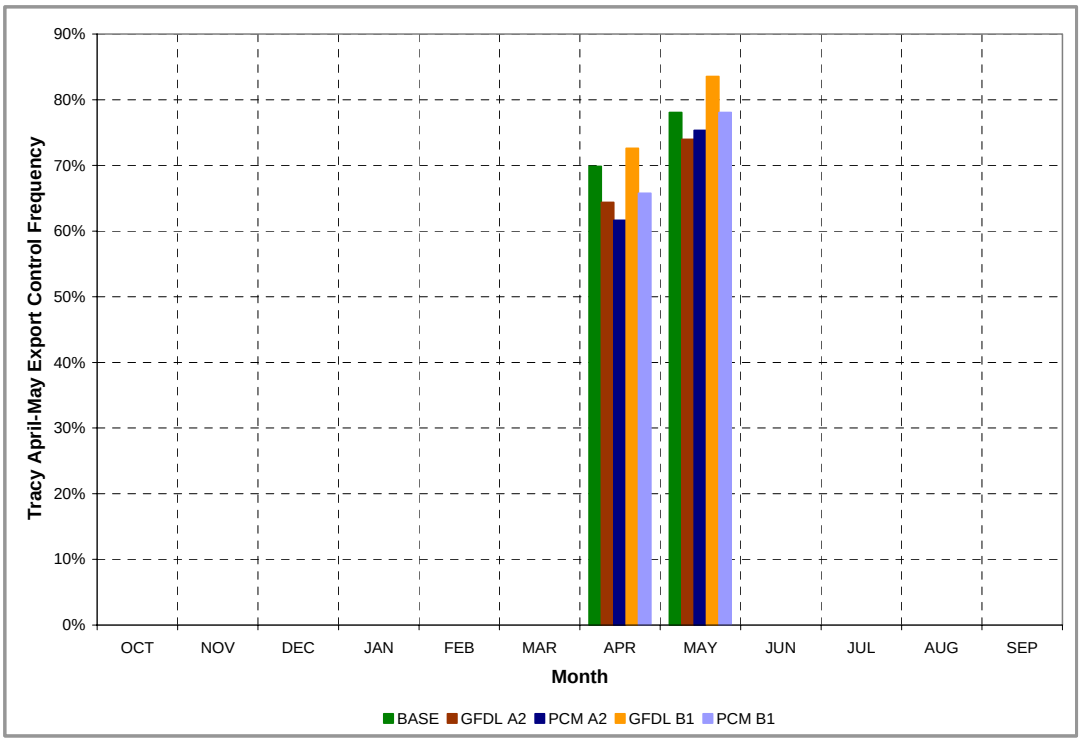

Figure 4.30 Operational control frequency of the April-May San Joaquin River pulse flow export constraints on Tracy pumping

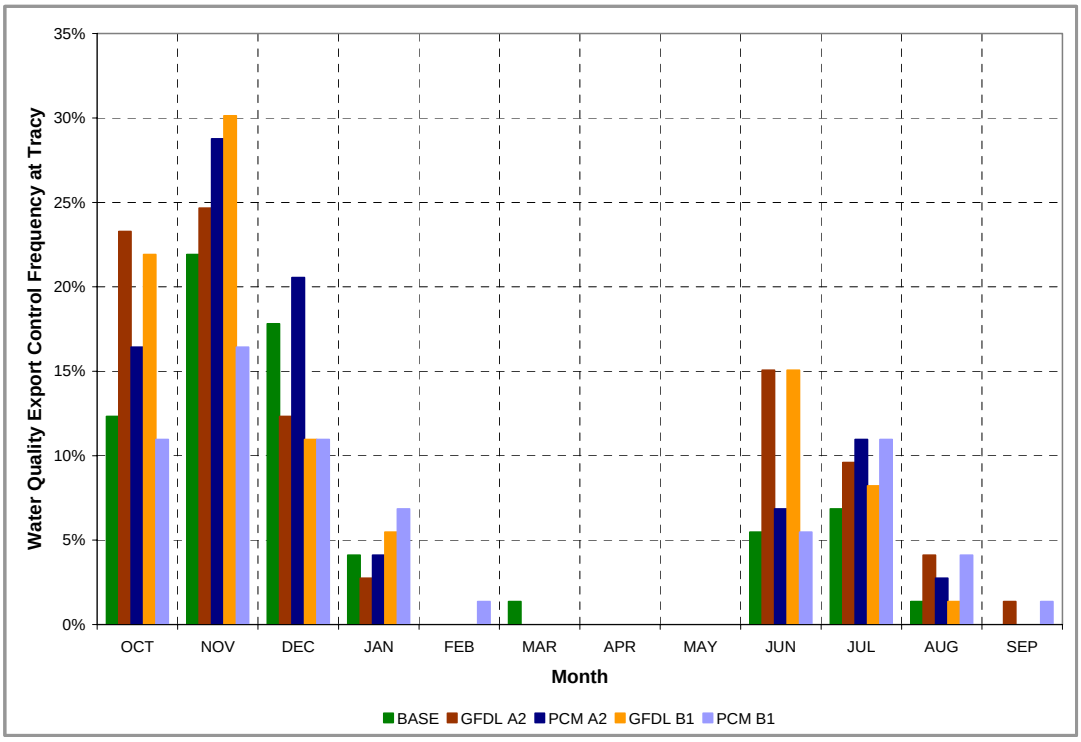

Figure 4.31 Operational control frequency of water quality standards of Tracy pumping

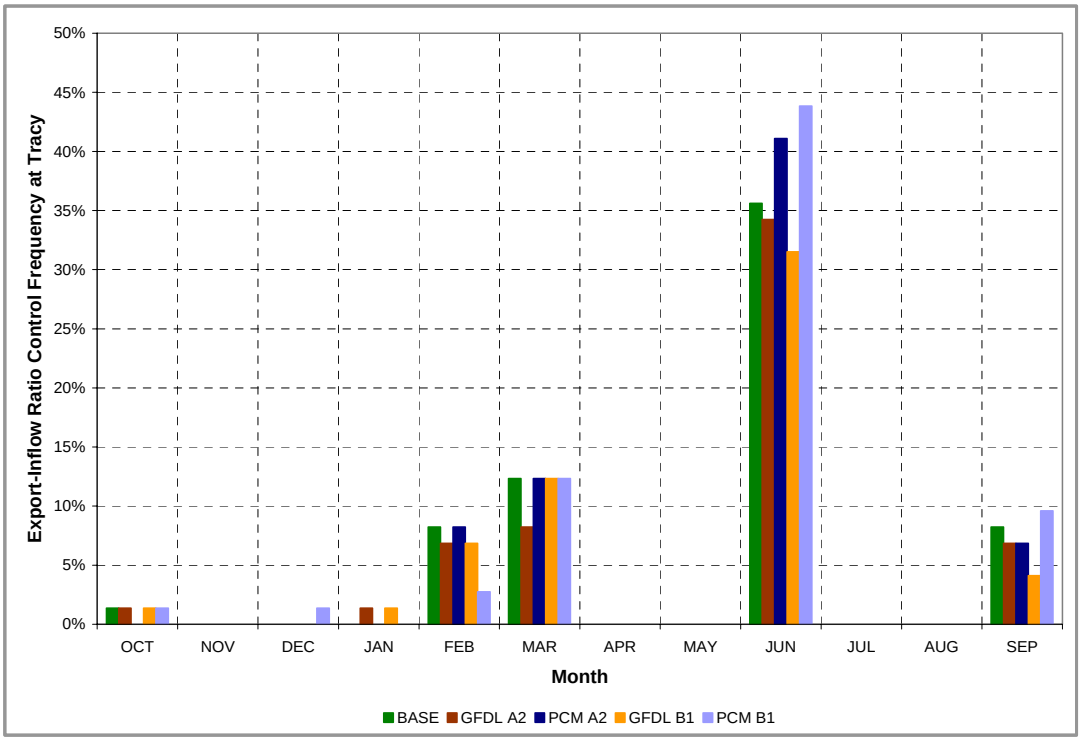

Figure 4.32 Operational control frequency of the export-inflow ratio of Tracy pumping

In the key months of December through March, Tracy exports were most frequently limited by pumping capacity or the upper Delta-Mendota Canal constriction as shown in Figure 4.27. It has been proposed to install an intertie between the Delta-Mendota Canal (DMC) and the California Aqueduct. This would relieve the upper DMC constraint and would be worth more study in the context of climate change.

Figure 4.33 shows the frequency that Tracy Pumping Plant has remaining export capacity -- none of the above mentioned constraints are controlling Tracy exports. Just as with Banks, Tracy is less likely to have available export capacity in the December – March period when it is most needed. In the drier climate change scenarios, there is some flexibility for higher Tracy exports in the summer and fall. However, given the shortages in Shasta and Folsom in these drier scenarios, it is doubtful that higher releases from these reservoirs to support higher exports would be beneficial.

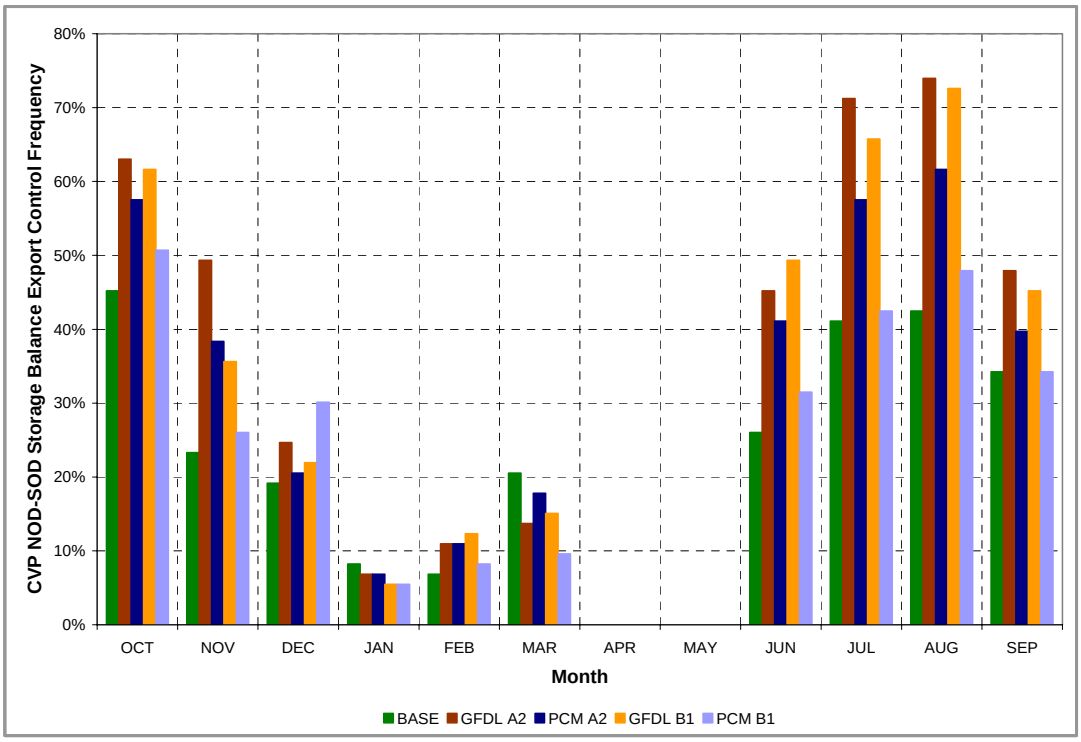

Figure 4.33 Frequency of the decision to favor CVP NOD storage over CVP SOD storage by limiting Shasta and Folsom releases and Tracy pumping

4.6.5 Power Supply

Climate change impacts to CVP and SWP power supply were calculated using Bureau of Reclamation and DWR spreadsheet models. These models estimate monthly power generation using reservoir storage and release data from CalSim-II, and they estimate monthly power loads based on CalSim-II pumping rates. The CVP and SWP facilities included in the power supply analysis are listed in Table 4.21.

Estimates of the average annual SWP power generation and load for each study are compared to the base study in Table 4.22. The summary includes the long-term period of 1922-1993 as well as two six-year droughts. The negative values for net generation indicate that the SWP consumes more power than is generated. For the period 1922-1993, the GFDL A2, PCM A2 and GFDL B1 studies show a decrease in net generation ranging from 7 percent to 11 percent while the PCM B1 study has a smaller decrease of 1 percent. The SWP net power generation effects for the drought of 1929-1934 ranges from a decrease of 11 percent for the PCM A2 study to an increase of 14 percent for the PCM B1 study. For 1987-1992, the GFDL A2, PCM A2 and GFDL B1 studies have a decrease in net generation ranging from 8 percent to 21 percent while the PCM B1 study is only 1 percent less than the base study.

Estimates of the average annual CVP power generation and load for each study are compared to the base study in Table 4.23 for the long-term period of 1922-1994 and the two six-year droughts. For 1922-1994, the GFDL A2, PCM A2 and GFDL B1 studies show a decrease in net generation ranging from 6 percent to 10 percent while the PCM B1 study increases net generation by 6 percent. The CVP net power generation effects for the drought of 1929-1934 ranges from a decrease of 15 percent for the GFDL A2 study to an increase of 7 percent for the PCM B1 study. For 1987-1992, the GFDL A2, PCM A2 and GFDL B1 studies have a decrease in net generation ranging from 3 percent to 12 percent while the PCM B1 study is 8 percent greater than the base study.

Table 4.21 Generation and Load Facilities Included in Power Supply Analysis

SWP Facilities		CVP Facilities	
Generation	Load	Generation	Load
Oroville	Banks	Trinity	Tracy
Thermalito	South Bay	Carr	Banks
Gianelli	Del Valle	Spring Creek	Contra Costa
Alamo	Gianelli	Shasta	O'Neill
Mojave	Dos Amigos	Keswick	San Luis
Devil Canyon	Las Perillas	Folsom	San Felipe
Warne	Badger	Nimbus	Dos Amigos
Castaic	Buena Vista	New Melones	Folsom
	Teerink	San Luis	Corning
	Chrisman	O'Neill	Red Bluff
	Edmonston		San Luis Relift
	Oso		DMC Relift
	Pearblossom		Tehama-Colusa Relift
			Miscellaneous

Table 4.22 Annual Average SWP Power Generation and Load

Calendar year period	Study	Powerplant generation (GWh)	Pumping plant load (GWh)	Net generation (GWh)	Percent change from base
1922-1993	Base	4,840	9,577	-4,737	0%
	GFDL A2	4,552	8,764	-4,212	-11%
	PCM A2	4,576	8,988	-4,412	-7%
	GFDL B1	4,479	8,703	-4,224	-11%
	PCM B1	4,989	9,686	-4,696	-1%
1929-1934	Base	2,666	5,289	-2,623	0%
	GFDL A2	2,577	5,039	-2,462	-6%
	PCM A2	2,453	4,788	-2,335	-11%
	GFDL B1	2,486	4,888	-2,402	-8%
	PCM B1	2,954	5,934	-2,980	14%
1987-1992	Base	2,610	5,386	-2,776	0%
	GFDL A2	2,365	4,561	-2,196	-21%
	PCM A2	2,489	5,057	-2,568	-8%
	GFDL B1	2,368	4,698	-2,330	-16%
	PCM B1	2,721	5,465	-2,745	-1%

Table 4.23 Annual Average CVP Power Generation and Load

Water year period	Study	Powerplant generation (GWh)	Pumping plant load (GWh)	Net generation (GWh)	Percent change from base
1922-1994	Base	4,733	1,313	3,420	0%
	GFDL A2	4,265	1,191	3,074	-10%
	PCM A2	4,310	1,239	3,071	-10%
	GFDL B1	4,440	1,227	3,213	-6%
	PCM B1	4,969	1,355	3,614	6%
1929-1934	Base	2,864	790	2,074	0%
	GFDL A2	2,487	719	1,768	-15%
	PCM A2	2,543	723	1,820	-12%
	GFDL B1	2,641	720	1,922	-7%
	PCM B1	3,077	856	2,221	7%
1987-1992	Base	3,248	840	2,408	0%
	GFDL A2	2,858	736	2,122	-12%
	PCM A2	2,949	743	2,205	-8%
	GFDL B1	3,116	783	2,334	-3%
	PCM B1	3,513	912	2,600	8%

A comparison of monthly average SWP power generation and load and CVP power generation and load are presented in Figure 4.34, Figure 4.35, Figure 4.36 and Figure 4.37, respectively. For the drier scenarios, SWP power generation decreases in all months compared to the Base with the exception of scenario GFDL A2 which has a slight increase in March. The largest decrease occurs in May. For the wetter scenario, PCM B1, SWP power generation increases in February through September and decreases in October through January. The largest increase in SWP power generation occurs in March.

SWP power load decreases in all months for the drier scenarios because of reduced water deliveries. With the wetter scenario, SWP power load increases in all months except January and February.

For the drier scenarios, CVP power generation decreases in all months compared to the Base with the exceptions of scenario GFDL A2 which has a slight increase in March and scenario GFDL B1 which has slight increases in January and March. The largest decreases in CVP power generation occur in September and October when storage impacts are greatest. For the wetter scenario, PCM B1, CVP power generation increases in all months except June and December which have slight decreases. The largest increase in CVP power generation occurs in March.

For the drier scenarios, CVP power load increases slightly in January through March due to higher exports and decreases in other months due to reduced deliveries. With the wetter scenario, there are slight increases in CVP power load in all months except October.

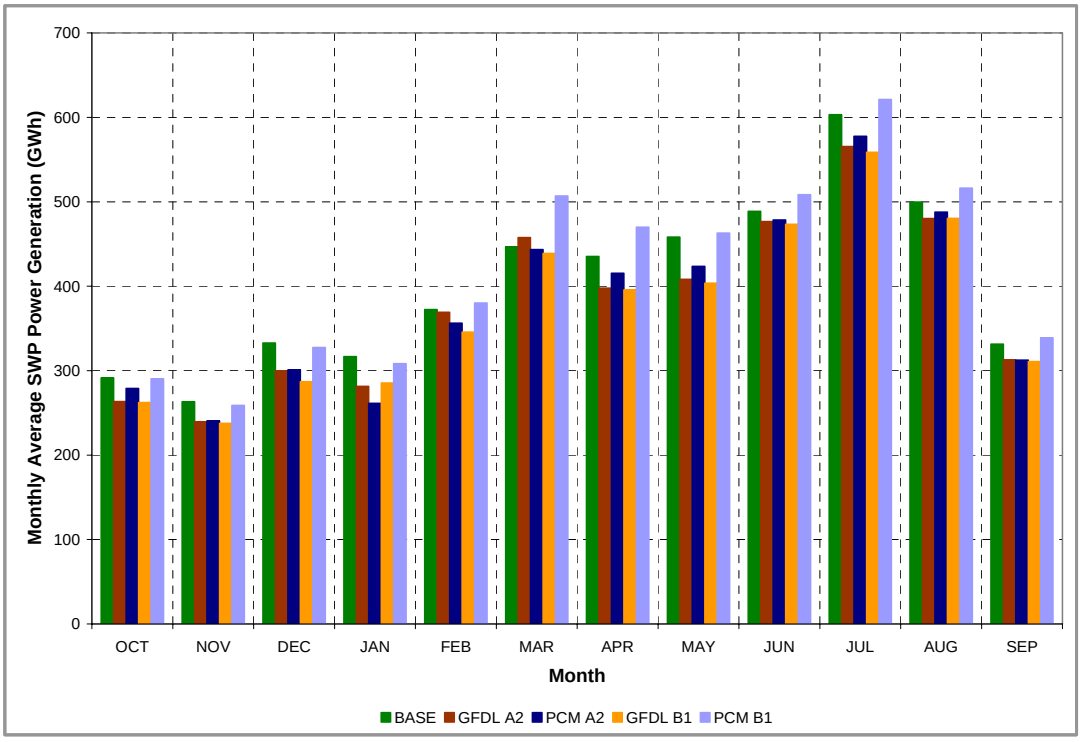

Figure 4.34 Monthly Average SWP Power Generation

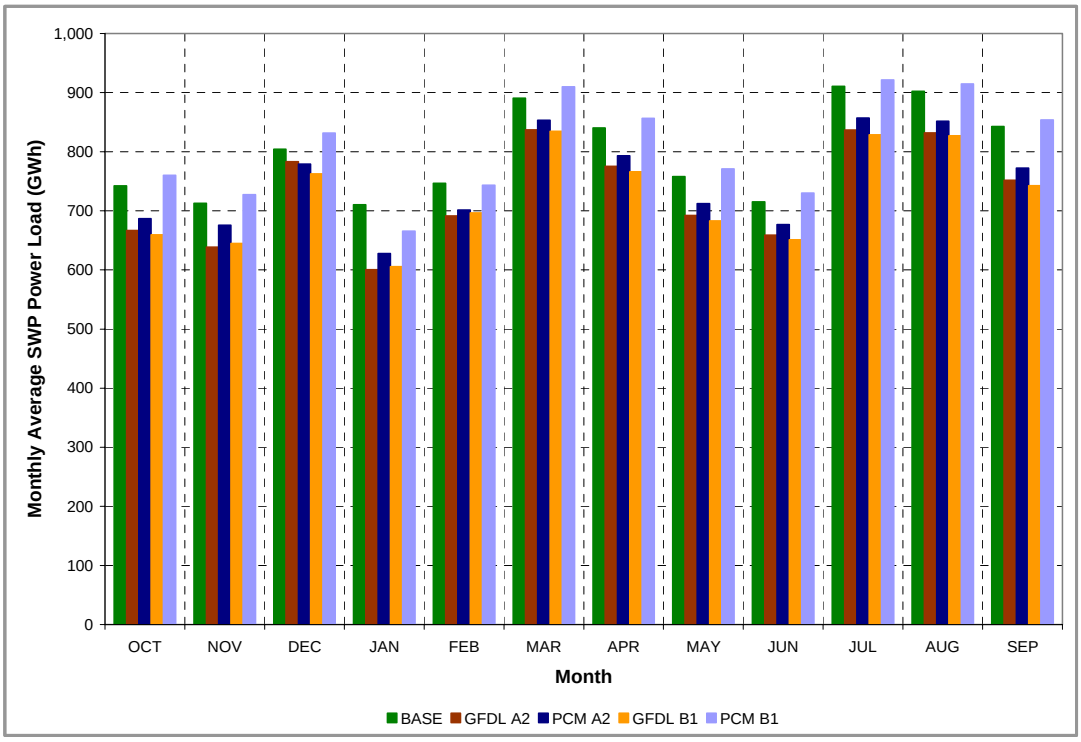

Figure 4.35 Monthly Average SWP Power Load

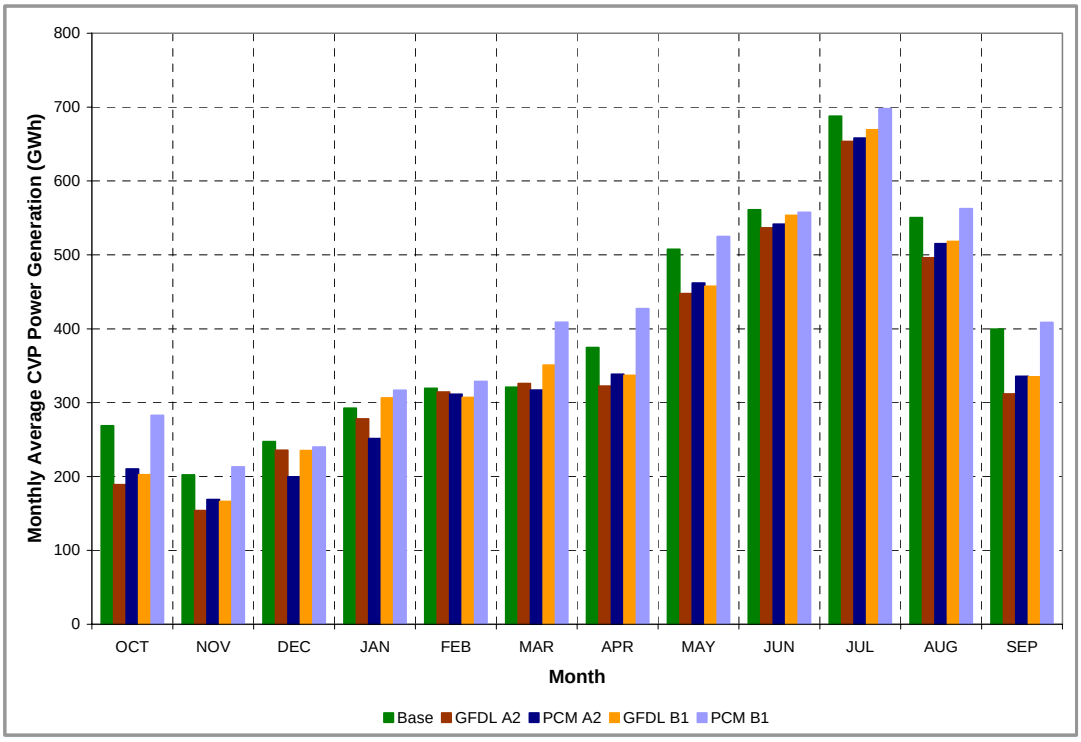

Figure 4.36 Monthly Average CVP Power Generation

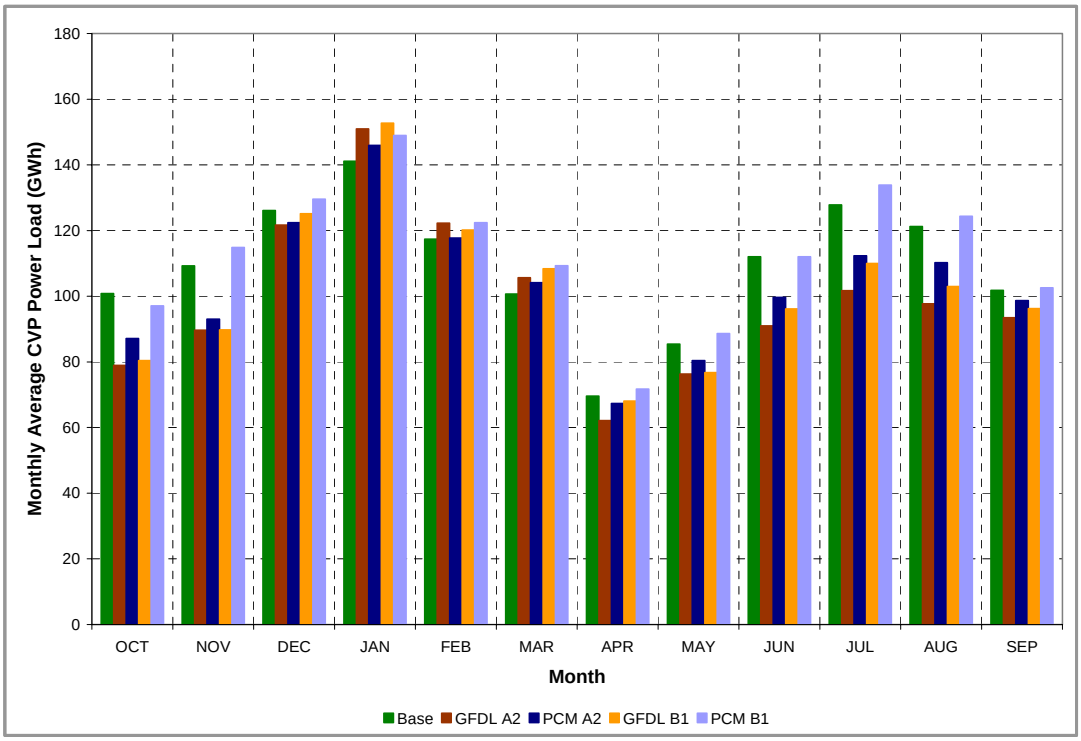

Figure 4.37 Monthly Average CVP Power Load

4.6.6 In-Stream Temperature Analysis

Water temperature has been recognized as key to the habitat needs of steelhead and Chinook salmon in the rivers of the Central Valley. River temperatures that are too high can kill salmon and steelhead by impairing metabolic function, or indirectly by increasing the probability of disease, predation, or other secondary mortality factors. Temperature tolerances also vary by life stage.

The water temperature of the river is a result of several factors: the temperature of water released from the major dams (Shasta, Oroville and Folsom) in the Sacramento Valley (a function of temperature stratification within each reservoir); the depths from which dam releases are made; the seasonal management of the deep cold-water pool reserves; ambient seasonal air temperatures and other climatic conditions; tributary accretions and water temperatures; and residence time in the re-regulating reservoirs downstream of each major dam, and in the river itself. To assist with downstream temperature control, temperature control devices (TCD) were installed at Shasta, Oroville, and Folsom dams. The TCDs can selectively withdraw water from different reservoir levels. The TCDs are generally operated to conserve cold water for the summer and fall months, when river temperatures become critical for fisheries. Therefore, the TCD is operated to make upper-level releases in the winter and spring, mid-level releases in the late spring and summer, and low-level release in the late summer and fall.

To assist in the water temperature impact evaluations of the various climate change scenarios, the Bureau of Reclamation temperature model was used to estimate temperatures in the Trinity,

Sacramento, Feather, American, and Stanislaus river systems. The reservoir component of the temperature model simulates TCD operation. The joint DWR/Bureau of Reclamation simulation model, CALSIM-II, provided monthly CVP/SWP operations input to the temperature model for a 72-year hydrologic period from1922 to 1993.

The climate change scenario impacts on the distribution and volume of reservoir inflow, and its resulting effect on seasonal reservoir storage, influence the cold-water pool volume. Three of the four climate change scenarios indicate an average reduction in reservoir storage, and therefore a corresponding reduction in cold-water pool volume. In addition, all four climate change scenarios show an expected increase in air temperature. This increase is reflected in increased river temperature. A summary of river temperatures at several key locations along the Sacramento River is shown in Table 4.24. Increased air temperature in the winter and early spring is especially important since inflow and air temperature during this period drive accumulation of the cold-water pool.

Table 4.24 Average Water Temperatures along the Sacramento River

	Study 1: Base		Study 2: GFDL A2		Study 3: PCM A2		Study 4: GFDL B1		Study 5: PCM B1	
	Average	1928-1934	Average	1928-1934	Average	1928-1934	Average	1928-1934	Average	1928-1934
American River	59.8	60.5	62.9	63.7	61.4	62.2	62.6	63.4	60.7	61.5
Balls Ferry	52.3	53.9	54.6	56.5	53.8	55.7	54.4	56.1	52.9	54.2
Bend Bridge	53.3	54.7	55.4	57.1	54.6	56.4	55.2	56.7	53.8	55.0
Butte City	57.1	58.3	59.5	61.0	58.5	59.9	59.2	60.6	57.8	58.9
Colusa Basin Drain	59.4	60.4	62.2	63.3	61.0	62.0	61.9	63.0	60.3	61.3
Feather River	59.8	60.6	62.7	63.7	61.3	62.2	62.4	63.3	60.6	61.5
Freeport	59.9	60.7	63.0	63.8	61.5	62.3	62.7	63.6	60.9	61.6
Jellys Ferry	53.1	54.5	55.2	56.9	54.4	56.2	55.0	56.5	53.6	54.7
Keswick	50.6	52.2	53.0	54.8	52.1	54.0	52.8	54.5	51.2	52.5
Keswick Above Spring Creek	50.8	52.3	53.2	55.1	52.3	54.3	53.1	54.8	51.4	52.6
Red Bluff	53.8	55.3	56.0	57.7	55.2	56.9	55.8	57.3	54.4	55.6
Shasta	49.8	51.4	52.1	54.0	51.3	53.2	52.0	53.7	50.5	51.6
Vina	54.8	56.1	57.0	58.6	56.2	57.7	56.8	58.2	55.4	56.5
Wilkins Slough	58.4	59.6	61.1	62.4	60.0	61.2	60.8	62.0	59.2	60.3

4.7 Conclusion

The purpose of this report was to provide a preliminary assessment of climate change impacts on CVP and SWP operations. Results of four climate change scenarios from global climate models GFDL and PCM were downscaled to regional hydrologic data using VIC. The regional streamflows were used to determine average monthly changes in reservoir inflows at a 2050 climate (2035 to 2064) as compared to a historical 1976 climate (1961 to 1990). The resulting perturbation factors were superimposed on historical reservoir inflows to create input for the four climate change simulations of CVP and SWP operations. The perturbed reservoir inflows were input into CalSim-II – the current planning simulation model for the CVP and SWP. Simulation results of the four climate change scenarios were compared to a historic climate simulation scenario in order to determine changes in water deliveries and carryover storage.

4.7.1 Study Limitations

There were some limitations in our analysis. First, the only representation of climate change in the CalSim-II simulations was the perturbed reservoir inflows. No consideration was given in these scenarios to heightened water demand due to changes in evapotranspiration or rainfall; nor was consideration given to increased Delta salinity due to a rising sea level. Both could significantly impact delivery capability.

Also, the method of downscaling global climate model information for CalSim-II input only captures the general trends of average rainfall and seasonal shifts in runoff. There is no information included about changes in weather variability. In each of the scenarios, the frequency and length of the droughts remained the same. If climate change influences these underlying weather phenomena, then we are missing important information necessary to determine impacts to CVP and SWP operations.

Another analytical limitation of our simulated results was the critical shortages of water in Shasta and Folsom during the droughts in scenarios GFDL A2, PCM A2, and GFDL B1. When these reservoirs were at dead storage, the simulated CVP operation was allowed to break rules and contracts that the Base and PCM B1 scenarios otherwise weren't. The result is that CVP deliveries reported for scenarios GFDL A2, PCM A2, and GFDL B1 are likely inaccurate. Alterations to CVP allocation rules governing the balance between deliveries and carryover may be necessary to prevent these shortages.

Given these and other analytical limitations, the results presented in this report are strictly preliminary. They are intended to be used to guide future climate change analysis and to identify areas where more information is needed. The results are not sufficient by themselves to make policy decisions.

4.7.2 Results

While there were limitations to our analysis, the results were nevertheless significant. General shifts in seasonal and annual average runoff, as predicted by the climate change scenarios, resulted in considerable impacts to SWP and CVP delivery capabilities, especially in the drier scenarios. Annual average SWP Table A deliveries were reduced by 10.2 percent in GFDL B1, while GFDL A2, the driest scenario, reduced annual average CVP SOD deliveries by 10.3 percent. SWP Article 21 deliveries tended to be slightly higher in the dry scenarios as compared to the Base because San Luis storage was less aggressively used for Table A and more Delta surplus was available in the winter; as such, San Luis was more likely to fill and the conditions for Article 21 deliveries -- full San Luis, Delta surplus, available Banks capacity -- were more likely to be met. However, the increased Article 21 deliveries did not offset reductions to Table A deliveries. PCM B1, the wetter climate change scenario, generated slightly higher SWP Table A and CVP SOD deliveries and slightly lower Article 21 deliveries; the difference between PCM B1 and the Base was most significant in the dry periods when storage capacity was available to make use of the extra water.

In response to climate change, California will need to search for physical, regulatory, and operational flexibilities in the SWP and CVP systems to maintain project delivery capabilities. With more runoff in the winter, there is likely to be a heightened conflict between the water

supply and flood control uses of North-of-Delta reservoirs. Better storm forecasting technology, allowing for earlier flood releases, or increased storage capacity could reduce the conflict. With higher Delta inflows in the winter months, greater winter SOD exports are desirable. For Banks Pumping Plant, permitted capacity and SOD conveyance including storage, pump, and channel capacity often limited exports from December to March. Therefore, future studies on changes in Banks permitted capacity should consider including climate change scenarios for estimating potential water supply benefits. Tracy exports were often limited by the upper Delta-Mendota Canal constriction. As such, it would be useful to simulate the proposed DMC-California Aqueduct intertie in the context of a climate change scenario.

CalSim-II results were processed to produce net impacts to SWP and CVP power generation. The SWP, using more power than it generates, increased its net load on an annual average basis by 11 percent in both GFDL simulations. The CVP, a net power generator, lost 10 percent of its power production on an annual average basis in both GFDL scenarios. Power generation on average increased for the CVP in scenario PCM B1. Of course, annual average changes in power generation are not as telling as seasonal changes. For the drier climate scenarios, lower storage resulted in reduced SWP and CVP power generation during the key summer months. Summer power generation was slightly higher for PCM B1.

Base and climate change scenario results were input into the Bureau of Reclamation temperature model for in-stream temperature analysis. High temperatures can be hazardous to salmon and steelhead. Therefore, downstream temperature controls are part of CVP and SWP operations of Shasta, Oroville, and Folsom. According to Table 4.24, the climate change scenarios resulted in warming of river temperatures at several key locations on an annual average basis. The timing of impacts will have to be explored in future studies.

As stated in the introduction, this is just the starting point for analyzing climate change impacts on SWP and CVP operations. There is still much work to be done to fully consider climate change effects in project planning studies. Furthermore, future studies should consider measures to relieve the negative effects of climate change. Analysis of the interaction of hydrologic changes and system constraints can suggest where more flexibility would be most useful. Eventually, the accumulated data and analysis can be used by our scientists, engineers, and political leaders to make sound policy decisions concerning the SWP, CVP, and climate change.

4.8 Acknowledgements

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4.9 References

Miller, Norman L., et al (2001). Climate Change Sensitivity Study of California Hydrology: A Report to the California Energy Commission, *LBNL Technical Report No. 49110.*

United States Bureau of Reclamation (USBR) (2004). Chapter 6: Analytical Approach and Methods. In: *Long-Term Central Valley Project Operations Criteria and Plan.* United States Bureau of Reclamation. Sacramento, CA.

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
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Chapter 5:
Preliminary Climate Change Impacts Assessment for the Sacramento-San Joaquin Delta

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5 Preliminary Climate Change Impacts Assessment for the Sacramento-San Joaquin Delta

5.1 Introduction

The Sacramento-San Joaquin Delta is a dynamic network of natural and man-made channels. Freshwater from the southward flowing Sacramento River and from the northward flowing San Joaquin River converge with salty tidal flows from San Francisco Bay (Figure 5.1). Historically the Delta was a vast marsh. After the Gold Rush, farmers began building levees in the Delta to reclaim farmland. After years of farming, many of the Delta islands have subsided and are currently below sea level. Today the Delta consists of 57 leveed islands and more than 700 miles of sloughs and channels. This complex ecosystem is home to more than 500 species, including 20 endangered species such as the Delta smelt and salt harvest Suisun Marsh mouse. The Delta is also part of the migration path of young salmon heading out to the ocean and for adult salmon returning to spawn in their natal streams.

The Sacramento-San Joaquin Delta can be considered the hub of California's water supply system. About two-thirds of Californians and millions of acres of farmland rely on water from the Delta. Pumping plants in the south Delta are integral components for water distribution to central and southern California from the State Water Project (SWP) and the federal Central Valley Project (CVP). The Delta also provides local water supply for municipal and industrial and agricultural uses. The Delta supports more than $500 million in annual crop production (DWR, 2006).

The Sacramento River provides most of the freshwater inflow into the Delta (Figure 5.2). From 1980-1991, on average nearly 25 percent of the freshwater inflows to the Delta were used for municipal, industrial and agricultural water supplies, while the remaining 75 percent flowed to San Francisco Bay as Delta outflow. The actual distribution of Delta inflows varies from year to year depending on factors such as the amount and timing of precipitation and operations of upstream reservoirs.

Climate change could affect the Delta water balance shown in Figure 5.2. Warmer air temperatures are expected to shift the timing and form -- rain or snow -- of winter precipitation (see Chapter 2 and Chapter 6). Less snowpack would lead to less spring runoff. These shifting precipitation and runoff patterns would affect reservoir operations and Delta exports (see Chapter 4). Since the major inflows into the Delta are controlled by reservoir releases, Delta inflow patterns would be affected as well. More changes to reservoir releases and Delta exports might be required for compliance with Delta water quality standards. Changes in crop evapotranspiration rates could affect the amount of water needed for agricultural uses (see Chapter 7).

Future projected sea level rise would also affect the Delta. Higher water levels could threaten Delta island levees. Increased saltwater intrusion from the ocean could require increased freshwater releases from upstream reservoirs to maintain compliance with Delta water quality standards.

This chapter presents an initial demonstration of modeling tools use to quantify potential impacts of climate change on Delta water quality and water levels. The results demonstrate advancements on incorporating climate change into existing modeling methodologies, however the results produced are not sufficient by themselves for making management decisions. All results are preliminary and are for illustration purposes only. Sections 5.3 and 5.4 present potential effects of shifting precipitation and runoff patterns on Delta inflows and diversions for present sea level conditions. Section 5.5 addresses potential effects of sea level rise alone and in conjunction with shifting precipitation and runoff patterns.

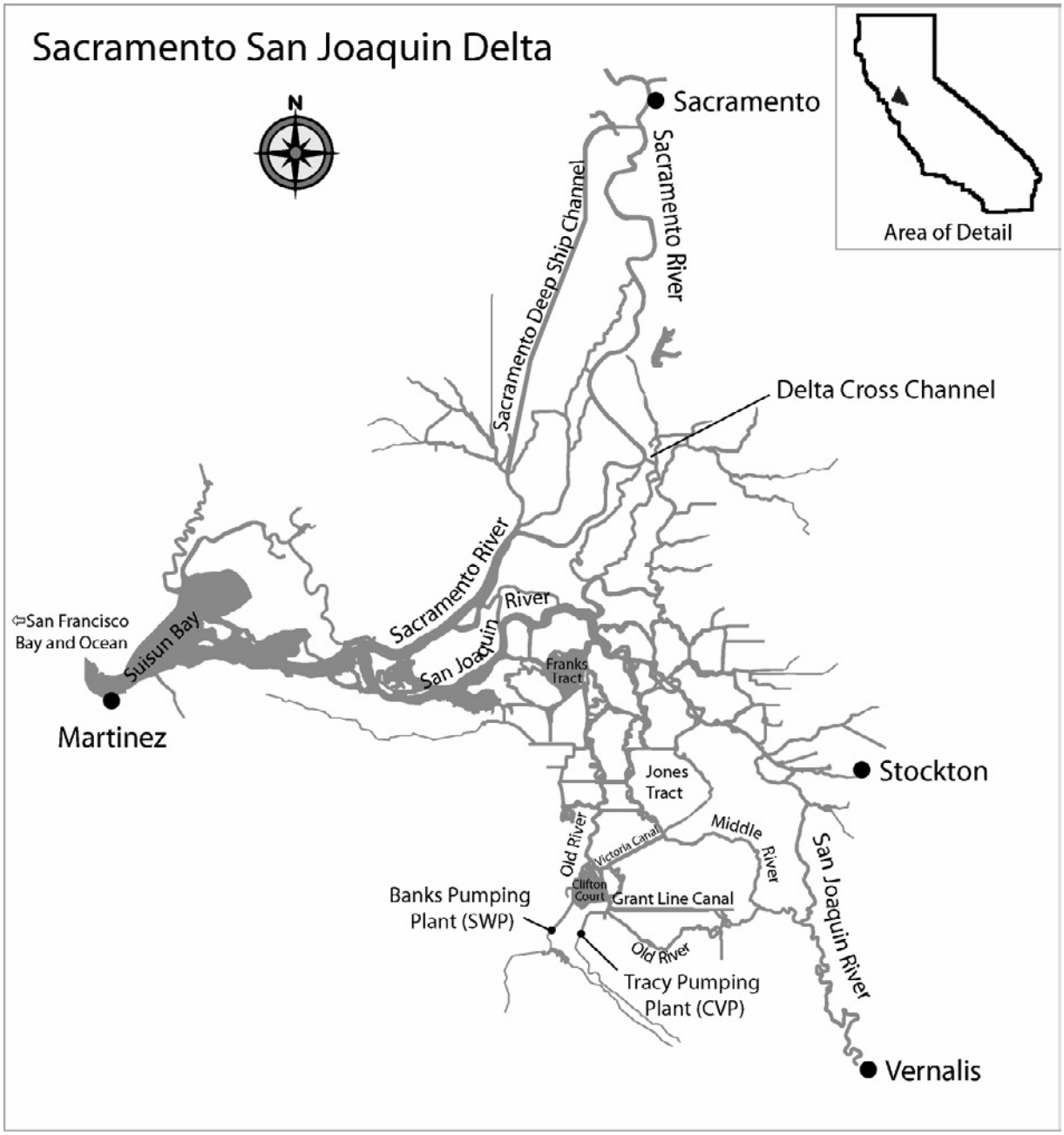


Figure 5.1: The Sacramento-San Joaquin Delta

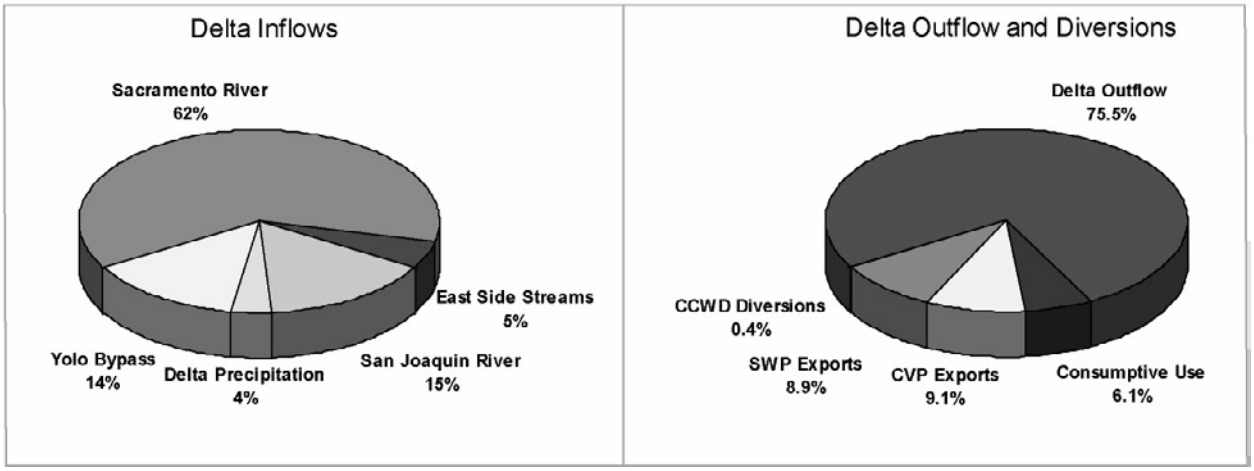


Figure 5.2: Average Annual Delta Inflows, Outflow and Diversions from 1980-1991
Adapted from Delta Atlas (DWR, 1995a)

5.2 Approach

A series of numerical models are being used for preliminary quantification of potential impacts of climate change on Delta flows, water levels and water quality (Figure 5.3). First, climate change scenarios are modeled using a Global Climate Model (GCM) to produce estimates of future air temperature and precipitation changes. These global scale changes are then reduced to a regional scale by a process called downscaling (see Chapter 3). The regional downscaling converts future projections of air temperature and precipitation into estimates of future streamflows. For these studies, the future streamflows are entered into a model, CalSim-II, which then simulates the operations of the SWP and CVP (see Chapter 4 and http://modeling.water.ca.gov/hydro/model/index.html). Using current management practices and existing system facilities, CalSim-II provides estimates of reservoir releases and Delta exports for each climate change scenario. The resulting Delta inflows and exports are then used to drive a model of the flows, water levels and water quality in the Delta, the Delta Simulation Model 2 (DSM2) (http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm). Results of the Delta model are then analyzed for the potential effects on water quality at several key locations. DSM2 is also used to estimate impacts of sea level rise.

All results presented in this report are preliminary. These studies are a starting point for analyzing climate change impacts on Delta hydrodynamics and water quality. Current management practices and existing system facilities were used in the analysis for this report. No changes were made to lessen the effects of climate change or sea level rise. Only four climate change scenarios and one sea level rise scenario were examined, and the likelihood of each scenario was not addressed. Several assumptions were also included in the analyses (see Section 5.2.3). The results presented here are not sufficient by themselves for making final policy decisions. These results are intended to illustrate the application of CalSim-II and DSM2 for climate change impacts assessment. Future efforts will involve improvements of the models and the study assumptions, and will address the likelihood of various climate change scenarios.

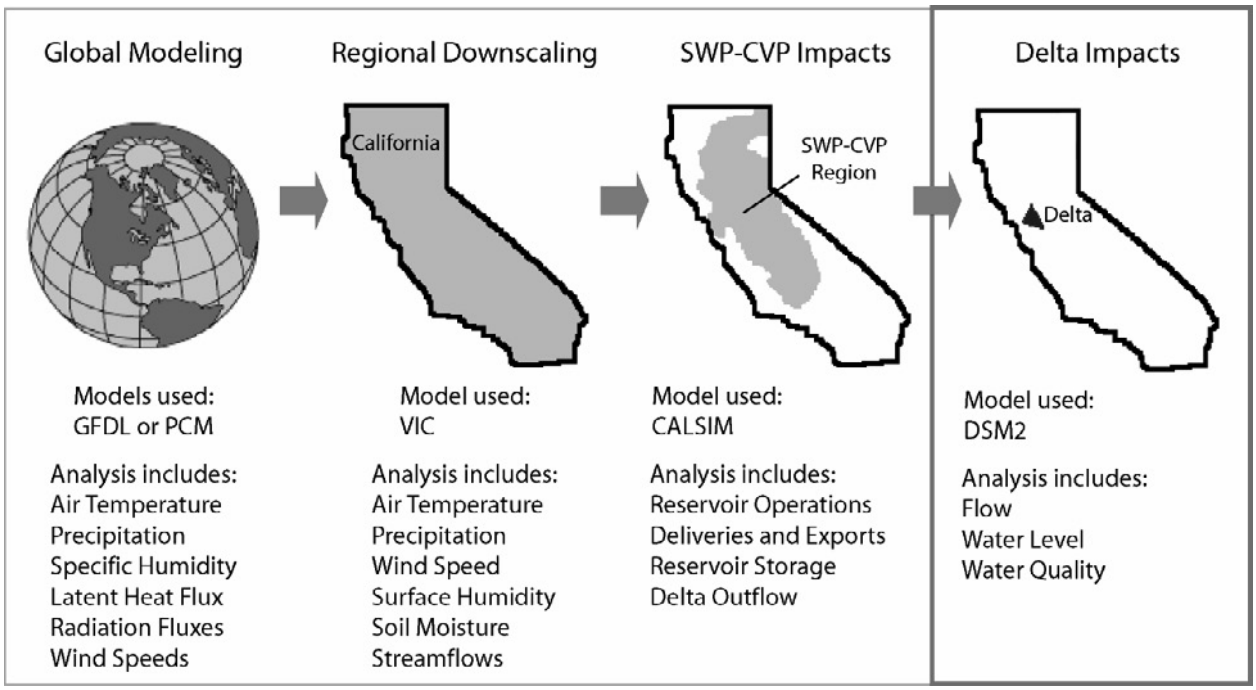


Figure 5.3: Delta Impacts Analysis Approach

5.2.1 Base Case

The base case for these studies is a 2020 level of development scenario using operations based on the "Long-Term Central Valley Project Operations Criteria and Plan" (USBR, 2004). Assumptions for the base case and climate change scenarios are presented later in Section 5.2.3.

5.2.2 Climate Change Scenarios

The studies presented in this report focus on the four climate change scenarios selected by the Climate Action Team appointed in response to the governor's Executive Order S-3-05 on climate change. The four climate change scenarios consist of two greenhouse gas (GHG) emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), known as A2 and B1, each represented by two different GCMs, the Geophysical Fluid Dynamic Lab model (GFDL) and the Parallel Climate Model (PCM) (see Chapter 3).

The A2 emissions scenario assumes high population growth, regional based economic growth, and slow technological changes that result in significantly higher GHG emissions. The B1 scenario represents low population growth, global based economic growth and sustainable development that result in the lowest increase of GHG emissions of the IPCC scenarios. Both the GFDL and PCM models project future warming, with GFDL indicating a greater warming trend than PCM. The PCM B1 scenario is the only scenario that shows a slight increase in precipitation. Precipitation is reduced in the other three scenarios.

Although the GCM models represent climate change through the end of the 21st century, the planning horizon for water resources is typically about 30 years. So the studies presented here focus on the climate change projections at about mid-century (Table 5.1). Thirty years of projected streamflows centered around the year 2050 (2035-2064) were used to develop the climate change influenced runoff patterns simulated in the SWP and CVP operations model, CalSim-II (see Chapter 4). However, land use projections were not available for 2050, so the climate change scenarios use land-use estimates for 2020. Thus when the climate change scenarios are described as being at the 2050 projection level, this refers to the runoff estimates only.

Table 5.1: Air Temperature and Precipitation Projections for 2050

Scenario	Average Change in Air Temperature °C		Average Change in Precipitation, in/yr	
	Northern CA	Southern CA	Northern CA	Southern CA
2050 GFDL A2	2.3	2.3	-0.75	-0.22
2050 PCM A2	2.1	2.1	-0.25	-1.77
2050 GFDL B1	1.3	1.2	-0.62	0.70
2050 PCM B1	0.8	0.9	0.83	-0.08

5.2.3 Assumptions

Major assumptions made in these studies are summarized below:

Runoff Estimations for Climate Change Scenarios (see Chapter 4 section 4.4)

- ❑ Runoff estimates reflect 2050 projections.
- ❑ Climate change scenarios maintain historical hydrologic variability.

CalSim-II Simulations of SWP and CVP Operations (see Chapter 4 section 4.5)

- ❑ Simulations were run for a 73-year analysis period based on wy1922-1994.
- ❑ Operating rules were not modified for climate change scenarios.
- ❑ For climate change scenarios, reservoir inflows reflect 2050 projections.
- ❑ For all scenarios, land use and water demands represent a constant 2020 level of development. The level of development does not change as the simulation progresses through time.

Current management practices and existing system facilities were used in the analysis for this report. No changes were made to lessen the effects of climate change or sea level rise.

No changes were made to:

- ❑ System structures, such as added water storage, pumping, or canal capacity
- ❑ Reservoir operating rules, such as changing the space required for flood control
- ❑ Streamflow requirements
- ❑ Water quality standards
- ❑ Delta outflow requirements
- ❑ Operations to account for sea level rise

- Delta exports, outflow and water quality are regulated according to the State Water Resources Control Board Decision 1641 (D1641) and the Water Quality Control Plan.
- Meeting Delta water quality standards is the top priority when changing SWP and CVP operations. Climate change will make this a larger challenge in the future. (see Table 4.12 in Chapter 4).

CalSim-II Simulations of SWP and CVP Operations (continued)

- Regulations from the Central Valley Project Improvement Act (CVPIA) 3406 (b)(2) are not included.
- The Environmental Water Account (EWA) is not included.
- San Joaquin River hydrology, operations and water quality do not reflect recent improvements subjected to the 2005 California Water and Environmental Modeling Forum (CWEMF)/CALFED peer review.
- New Melones Reservoir operations are governed by the Interim Plan of Operations.
- Operations were not modified to reflect sea level rise conditions

Delta Simulations

- Simulations were run for a 16-year analysis period based on wy1976-1991.
- Delta inflows and exports provided by CalSim-II output were not further modified to try to mitigate for Delta water quality effects of climate change or sea level rise.
- Contra Costa Water District (CCWD) diversions from Old River at Rock Slough and Old River at Highway 4 were combined and diverted from Rock Slough since CalSim-II did not simulate the two diversions separately.
- Operations of south Delta temporary fish and agricultural barriers were not simulated.[1]
- Pulse flows in April and May for the Vernalis Adaptive Management Plan (VAMP) were not simulated.
- Delta Island Consumptive Use for the 2020 level of development was used for all scenarios.
- Delta island return flow water quality varies monthly in a given year, but does not vary from year to year.
- For one-foot sea level rise scenarios, sea level rise was assumed to affect tidal elevation only. Tidal period and amplitude were assumed to be unchanged.
- Martinez EC is either the same or is increased for sea level rise scenarios (see section 5.5.1.1)
- Vernalis EC is the same for present sea level and one-foot sea level rise scenarios.

[1] Barrier operations can significantly influence Delta water quality and circulation patterns. The intent of the preliminary studies was to focus on the effects of climate change without having to separate which impacts were due to climate change and which were due to barrier operations.

5.2.4 Delta Simulations

The base case and four climate change scenarios were evaluated using DSM2 to quantify effects on Delta water quality and water levels. Each scenario was simulated at present sea level and for a one-foot sea level rise. DSM2 is a one dimensional model of flow, water levels and conservative and non-conservative constituent transport. The boundaries of the Delta representation in DSM2 are the I Street Bridge in Sacramento on the Sacramento River, Vernalis on the San Joaquin River, and Martinez downstream of the confluence of the two rivers as they flow into San Francisco Bay (Figure 5.1). Tidal water level fluctuations, river inflows, Delta exports, and irrigation withdrawals and return flows are all represented in DSM2. To represent the effects of the tidal cycle, DSM2 uses a 15-minute computational time step.

For DSM2 planning studies, a 16-year study period based on water years (wy) 1976-1991 (Oct. 1, 1975 to Sept. 30, 1991) is used. The study period reflects the variability in California's hydrology and includes the wettest (wy1983) and driest (wy1977) periods on record.

Reservoir inflows for the study period were modified to reflect climate change by multiplying the base-case runoff by monthly adjustment factors for each climate change scenario (see Chapter 4). Thus these studies reflect potential changes in magnitude and timing of runoff, but they do not represent potential changes in hydrologic variability since the base case represents historical hydrologic variability. System operations were then simulated using CalSim-II. Monthly average results from the CalSim-II simulations provided the following major Delta inflows, exports and diversions (Figure 5.4):

Delta Inflows

- Sacramento River at I Street Bridge in Sacramento
- San Joaquin River at Vernalis
- Eastside Streams (combined Mokelumne and Cosumnes river flows)
- Calaveras River
- Yolo Bypass

Delta Exports and Diversions

- SWP at Banks Pumping Plant
- CVP at Tracy Pumping Plant
- Contra Costa Water District (combined diversions Old River at Rock Slough and at Hwy. 4)
- North Bay Aqueduct
- Vallejo

The Delta inflows, exports and diversions provided from CalSim-II already incorporate mitigation for climate change through system operations using present operating rules. Tidal fluctuations in water level at Martinez are represented in DSM2 on a 15-minute time step by an adjusted astronomical tide that is based on historical data and reflects the spring-neap tidal cycle (Ateljevich, 2001a). Delta Island Consumptive Use (DICU) is represented at more than 250 locations (DWR, 1995b). Delta Cross Channel operations are provided by CalSim-II and did not change for any of the scenarios.

For this study, water quality analysis focused on salinity. DSM2 simulates electrical conductivity (EC) directly. Other salinity constituents such as chlorides can be estimated from the EC concentrations using statistical regression equations. For the DSM2 simulations, EC values must be specified for all Delta inflows. For the Sacramento River, eastside streams, Calaveras River and Yolo Bypass, constant EC values for each location are used in all of the scenarios (Table 5.2). San Joaquin River EC at Vernalis is provided for each scenario from output from the CalSim-II simulations. EC at Martinez is estimated for each scenario using a regression relationship that correlates the astronomical tide and Delta outflow to salinity (Ateljevich, 2001b). Delta Island return flow quality estimates were made based on available field data (DWR, 1995c). The quality of the return flows varies monthly, but does not vary from year to year. The same return flow quality values were used for all scenarios.

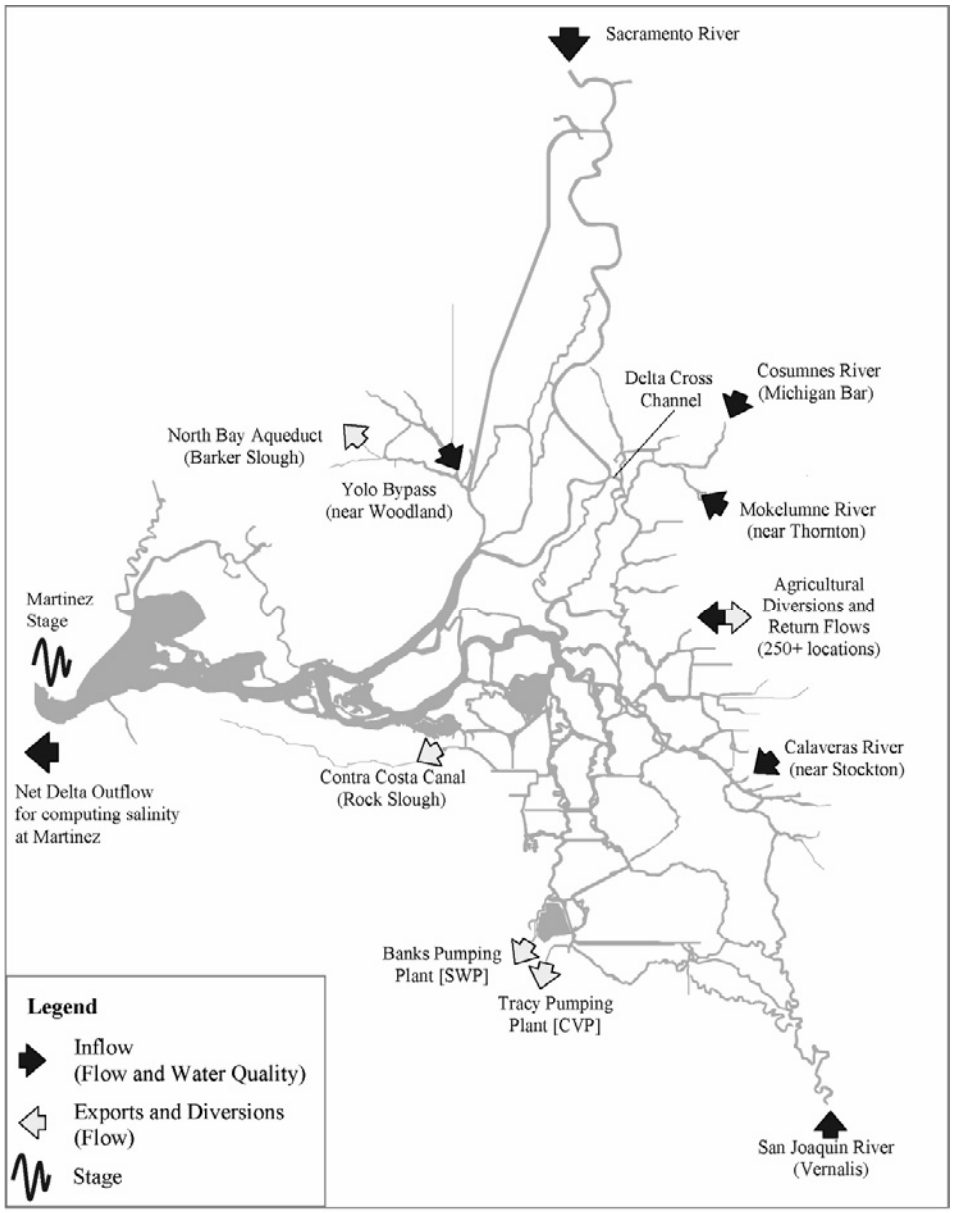


Figure 5.4: Inflows, Exports, Diversions and EC Inputs for DSM2 Simulations

Table 5.2: Constant EC Concentrations for DSM2 Simulations

Location	EC, uS/cm
Sacramento River	175
Eastside Streams	150
Calaveras River	150
Yolo Bypass	175

For sea level rise scenarios (see section 5.5), the tidal elevations at Martinez were raised uniformly by one-foot. This assumes that sea level rise does not affect the period of the tidal cycle. Estimates of additional salt transported from the ocean to Martinez under a one-foot sea level rise were not available. Due to time constraints, a preliminary approach for estimating salinity increases at Martinez for a one-foot sea level rise is applied only to the base case. In order to examine potential combined effects of sea level rise and climate change, scenarios that combined changes in Delta inflows and exports due to climate change with a one-foot sea level rise assumed that the salinity at Martinez for the one-foot sea level rise was the same as the Martinez EC for the present sea level version of that scenario. For example, the specified EC at Martinez was the same for the 2050 GFDL A2 present sea level and one-foot sea level rise scenarios. Since the salinity at Martinez would likely increase with rising sea levels, this assumption provides a lower bound for potential sea level rise effects on water quality for a one-foot rise in sea level. For these studies, system operations were not changed to try to lessen the increased salt intrusion for the sea level rise scenarios.

5.3 Climate Change Impacts on Delta Inflows and Exports for Present Sea Level Conditions

Output from CalSim-II provided Delta inflows and exports for DSM2 simulations of present sea level conditions for the base case and four climate change scenarios (Figure 5.5 to Figure 5.8). Tabular values of selected Delta inflows and exports are provided in the appendix in Section 5.11. Table 5.3 to Table 5.6 show monthly average changes in Delta inflows and exports for the climate change scenarios relative to the base case, and yearly changes are shown in Table 5.7 and Table 5.8. These results are preliminary representations of climate change impacts, and they reflect the assumptions listed in Section 5.2.3. See Chapter 4 for further information on climate change impacts to system operations.

Delta inflows tend to increase during the late winter and early spring and decrease during the summer and fall. The largest reductions in exports tend to occur in summer and fall. Inflows and exports are most sensitive to climate change during extremely wet or extremely dry periods. For example, the largest reduction in the magnitude of Delta inflows occurs during the summer of 1983 when base runoff was very high. For the climate change scenarios, the reduction in inflow for each month is determined by a monthly scaling factor as described in Chapter 4. For example, in the GFDL A2 scenario the June runoff into Shasta and Oroville is reduced by about 30 percent. Since the base runoff for 1983 was very high, the 30 percent reduction in the runoff resulted in the largest Delta inflow reduction. Contra Costa Water District (CCWD) diversions

were the same for all scenarios since they receive a high priority when CalSim-II allocates water. See Chapter 4 for more details on effects of climate change on SWP and CVP operations.

Table 5.3: Average Monthly Change in Sacramento River Inflow to the Delta, cfs

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
GFDL A2	-1,600	-2,156	-1,518	930	265	2,441	-1,040	-2,667	-1,647	-1,571	-1,600	-2,156
PCM A2	-294	-1,056	-1,515	-910	-57	811	-1,010	-2,168	-841	-1,104	-294	-1,056
GFDL B1	-1,175	-1,719	-1,611	1,547	-369	2,456	-728	-2,605	-1,540	-1,205	-1,175	-1,719
PCM B1	254	-163	-178	1,639	386	5,265	1,814	17	-289	272	254	-163

Table 5.4: Average Monthly Change in San Joaquin River Inflow to the Delta, cfs

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
GFDL A2	-1,324	-436	634	479	713	1,921	901	-393	-2,812	-1,173	-115	-426
PCM A2	-410	296	-592	-404	1,447	980	813	-110	-1,847	-705	-67	-196
GFDL B1	-1,362	208	82	364	-1,773	-175	288	-870	-2,866	-1,159	-136	-422
PCM B1	-198	287	-617	361	1,257	1,600	823	255	-1,628	-420	-26	-113

Table 5.5: Average Monthly Change in SWP Exports, cfs

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
GFDL A2	-756	-646	-91	-107	-73	-146	-516	-106	-158	-407	-445	-865
PCM A2	-630	-12	-338	-292	-57	-167	-284	-69	-142	-351	-10	-626
GFDL B1	-756	-489	107	-160	-131	-152	-417	-454	-382	-382	-433	-999
PCM B1	-169	3	-213	-28	-106	198	-117	75	-75	8	91	-75

Table 5.6: Average Monthly Change in CVP Exports, cfs

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
GFDL A2	-474	-36	-266	126	-444	149	-303	-235	-690	-1,143	-867	-305
PCM A2	-306	-94	-255	159	-490	169	-243	-125	-263	-582	-350	-99
GFDL B1	-473	-46	-164	143	-365	219	-215	-178	-447	-754	-554	-81
PCM B1	-16	245	-269	125	-71	130	-48	63	55	122	-4	-37

Table 5.7: Annual Change in Delta Inflows

Water Year	Year Type*	Base Flows TAF		Change in Sacramento River Flows, TAF				Change in San Joaquin River Flows, TAF			
		SAC River	SJR River	GFDL A2	PCM A2	GFDL B1	PCM B1	GFDL A2	PCM A2	GFDL B1	PCM B1
1976	C	9,322	1,345	-1,011	-611	-933	-198	-148	-88	-154	-41
1977	C	6,222	1,086	-511	-157	-145	99	-37	-19	-59	-8
1978	AN	20,144	4,094	826	-148	792	2,021	-260	-148	-787	-94
1979	BN	13,383	2,974	-1,457	-892	-1,562	492	-443	-144	-614	260
1980	AN	20,158	4,794	-622	-175	-430	1,092	101	0	-1,096	367
1981	D	11,976	1,840	-922	-866	-693	251	-343	-38	-360	45
1982	W	31,303	6,056	-585	-373	-573	735	131	61	-796	438
1983	W	35,501	13,934	-5,199	-3,185	-4,618	-130	-1,874	-838	-2,971	-148
1984	W	23,068	5,767	201	56	315	1,196	32	183	-229	340
1985	D	12,050	1,556	-588	-183	-286	78	-204	-56	-216	-10
1986	W	18,784	4,732	-871	-776	-821	208	568	493	-874	589
1987	D	9,765	1,333	-1,008	-828	-988	353	-115	-93	-119	-44
1988	C	8,694	932	-158	-192	-71	314	-25	-19	-26	-3
1989	D	12,086	973	756	-426	838	2,093	-29	-10	-36	4
1990	C	8,128	893	-243	-289	-215	-122	-15	-9	-26	14
1991	C	7,611	965	-535	-145	-136	333	-21	-12	-26	8

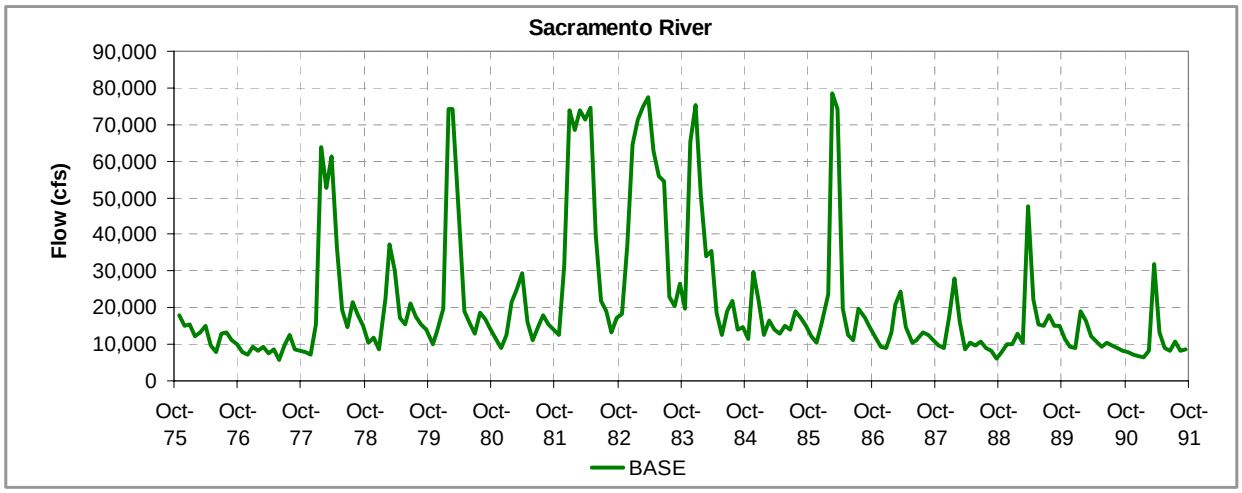
*Sac 40-30-30 water year types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical

Table 5.8: Annual Change in Delta Exports

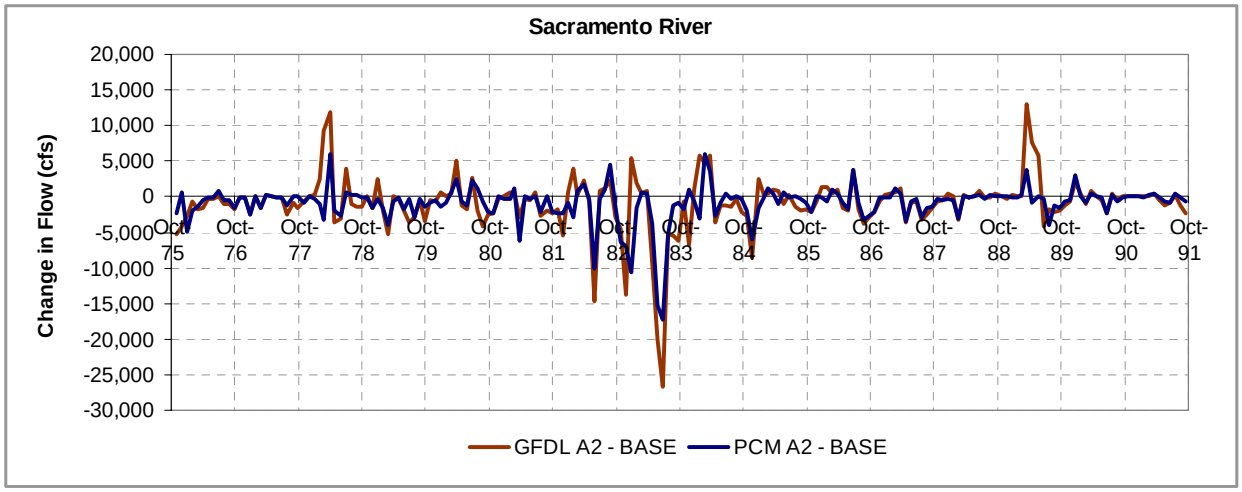
Water Year	Year Type*	Base Exports TAF		Change in SWP Exports TAF				Change in CVP Exports, TAF			
		SWP	CVP	GFDL A2	PCM A2	GFDL B1	PCM B1	GFDL A2	PCM A2	GFDL B1	PCM B1
1976	C	2,967	2,158	-635	-385	-588	-229	-23	45	22	-34
1977	C	995	1,391	-3	-83	-59	75	-462	-97	-153	38
1978	AN	3,608	2,736	-217	-115	-438	-102	-143	-29	-171	19
1979	BN	3,703	2,895	-446	-101	-589	118	-447	-223	-374	62
1980	AN	4,105	2,965	-478	-263	-457	1	-992	-572	-786	-152
1981	D	3,326	2,748	-674	-558	-716	-167	-195	-71	-128	8
1982	W	4,706	3,229	191	244	179	281	-393	-153	-286	-172
1983	W	3,676	2,827	34	0	29	0	176	15	168	14
1984	W	3,417	2,501	-288	-86	-305	-3	-309	-102	-174	-25
1985	D	3,516	2,869	-239	-189	-278	76	-415	-11	-169	-42
1986	W	4,201	2,799	-583	-432	-664	56	-520	-420	-471	-227
1987	D	2,570	1,904	-903	-770	-972	-284	-377	-239	-277	395
1988	C	1,541	1,729	32	-12	20	72	-191	-117	-100	265
1989	D	2,723	2,248	-382	-194	-344	-71	-299	-289	-162	99
1990	C	1,605	1,563	-303	-277	-314	-161	-24	-90	-25	-77
1991	C	1,110	1,495	162	63	-17	161	-574	-143	-149	103

*Sac 40-30-30 water year types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical

a) Base Case Delta Inflows



b) Change in Inflow for Climate Change A2 Scenarios



c) Change in Inflow for Climate Change B1 Scenarios

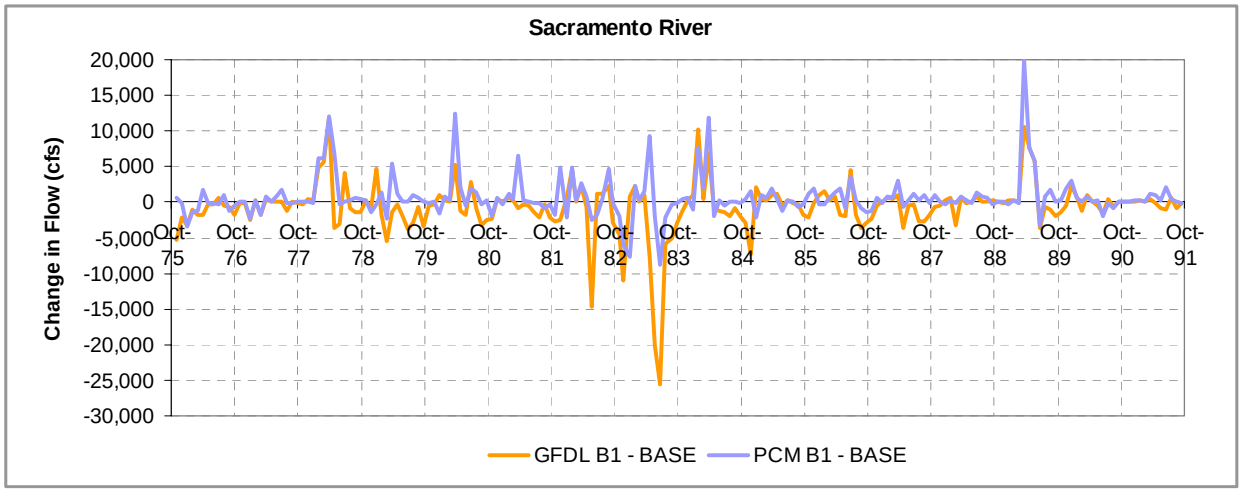
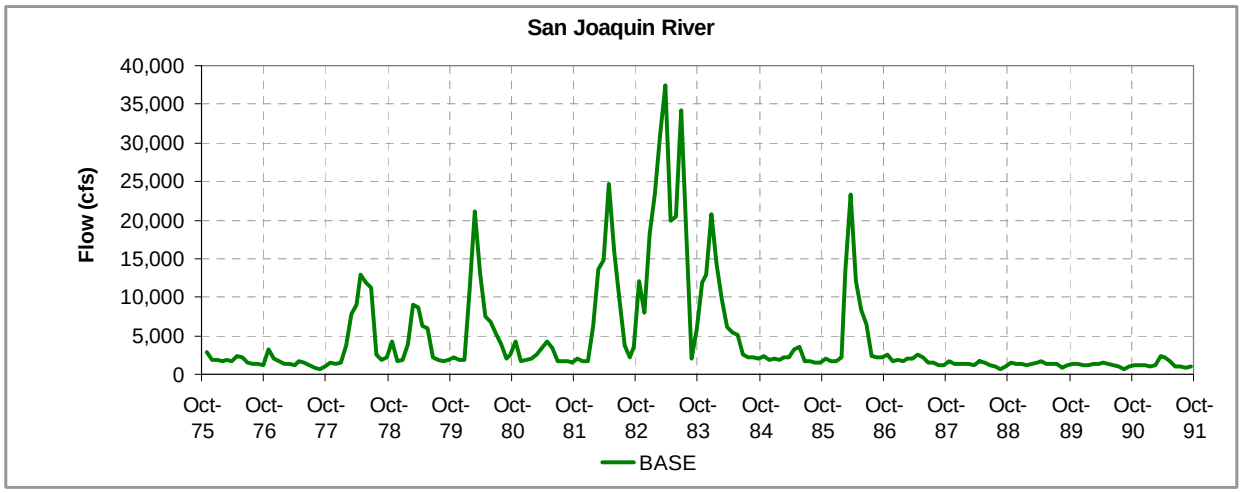
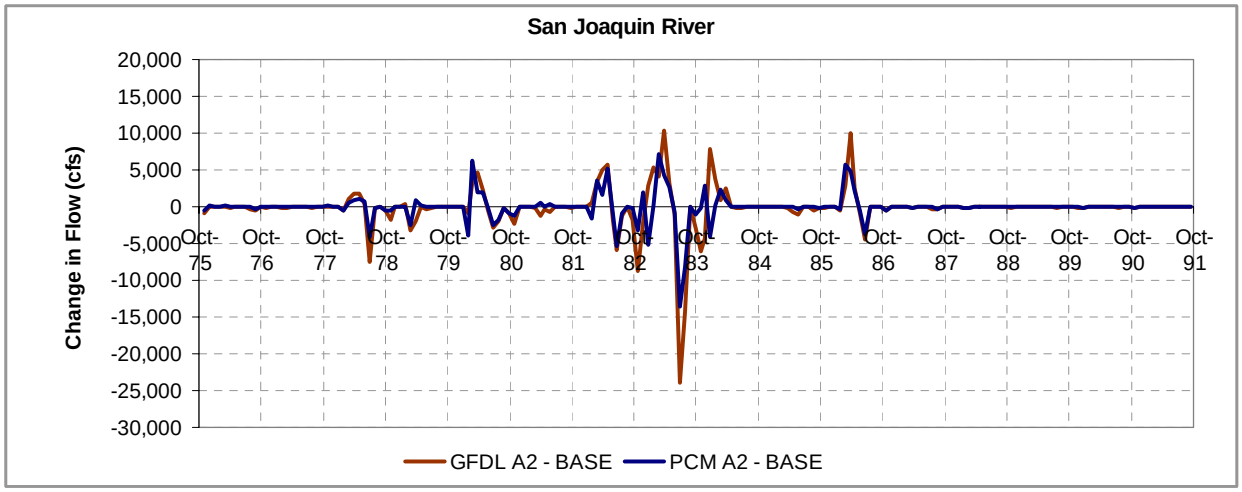


Figure 5.5: Delta Inflows from the Sacramento River

a) Base Case Delta Inflows



b) Change in Inflow for Climate Change A2 Scenarios



c) Change in Inflow for Climate Change B1 Scenarios

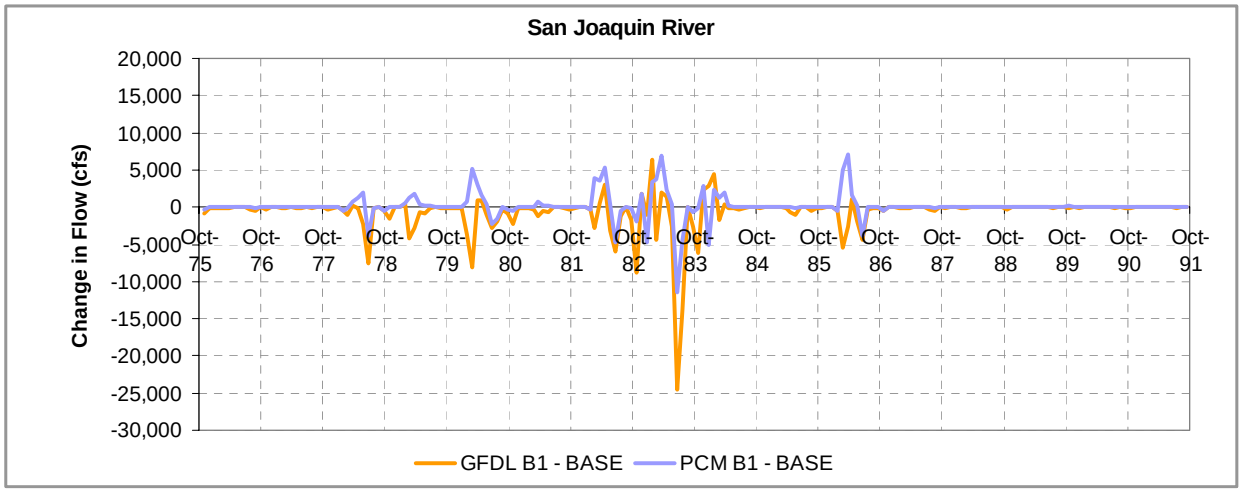
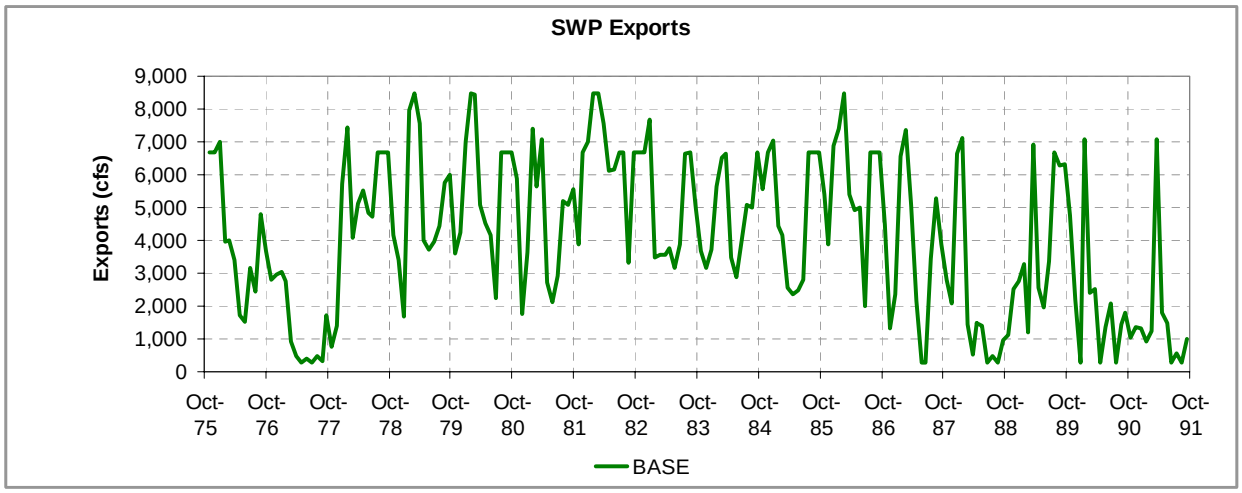
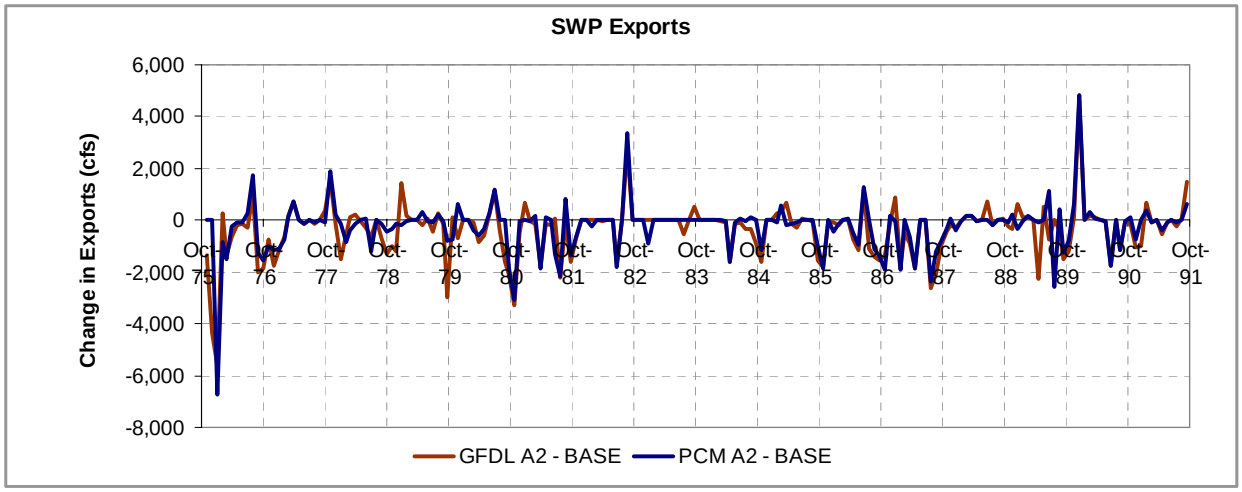


Figure 5.6: Delta Inflows from the San Joaquin River

a) Base Case Delta Exports



b) Change in Exports for Climate Change A2 Scenarios



c) Change in Exports for Climate Change B1 Scenarios

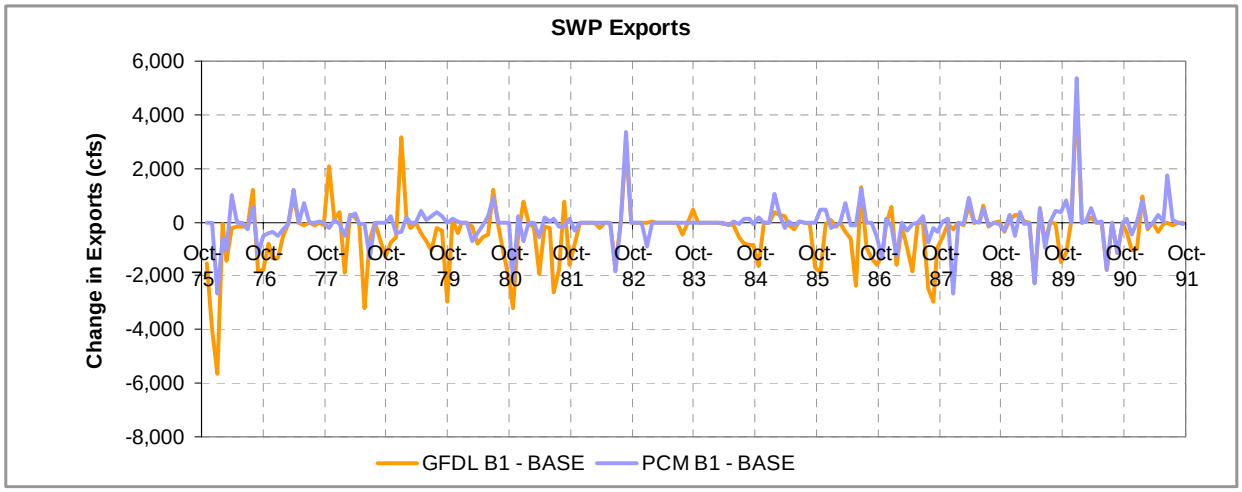
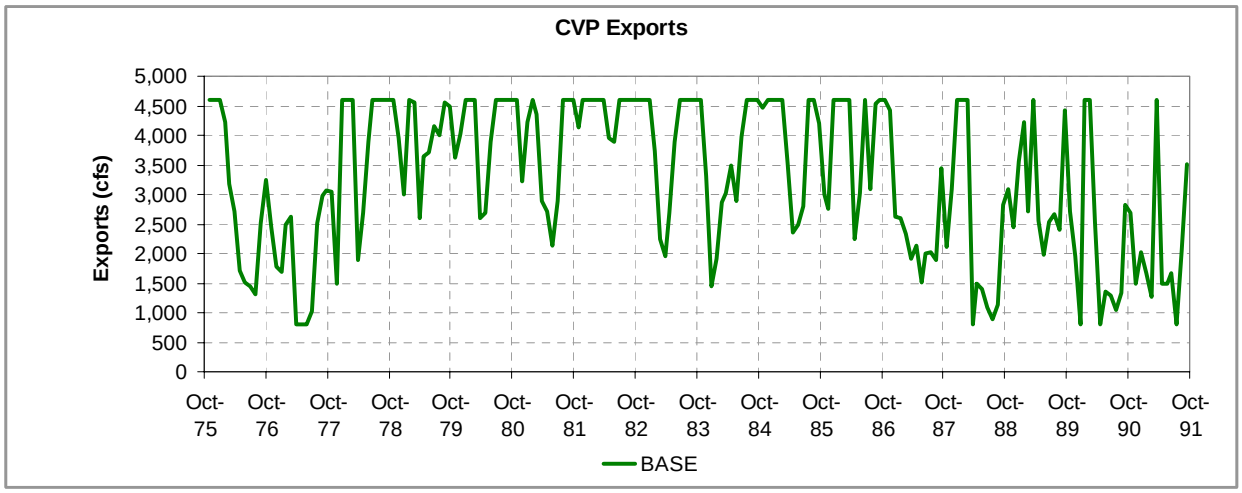
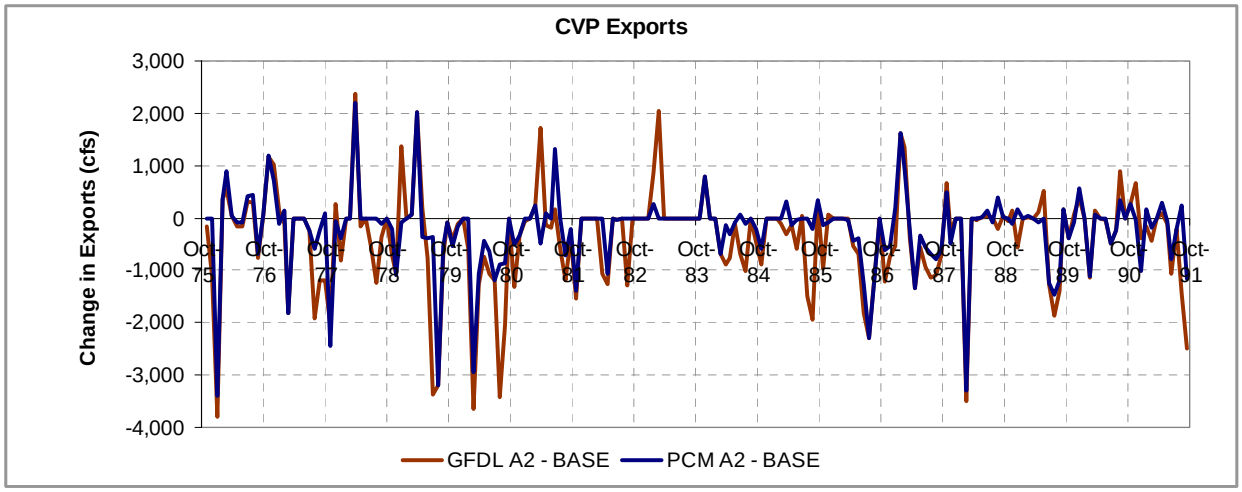


Figure 5.7: Delta Exports from the State Water Project

a) Base Case Delta Exports



b) Change in Exports for Climate Change A2 Scenarios



c) Change in Exports for Climate Change B1 Scenarios

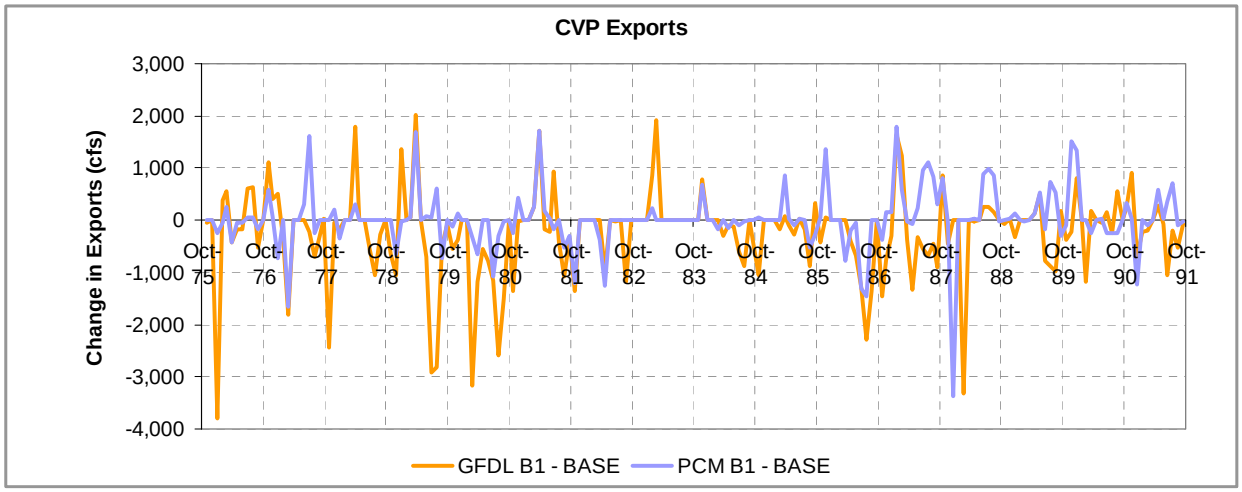


Figure 5.8: Delta Exports from the Central Valley Project

5.4 Climate Change Impacts on Water Quality for Present Sea Level Conditions

Initial analysis of potential impacts of climate change on Delta water quality for present sea level conditions focuses on compliance with selected Delta water quality standards from the Water Quality Control Plan and the State Water Resources Control Board Decision 1641 (D1641) (SWRCB, 1995). Analysis of other water quality parameters of concern, such as disinfection by-product formation potential is beyond the scope of this report. Initial analysis focused on specified limits for chloride concentrations (Table 5.9) at four municipal and industrial intake locations (Figure 5.9). Chloride mass loadings at each intake were also examined. All results are preliminary and incorporate several assumptions (see Section 5.2.3). These preliminary results are intended to illustrate the use of CalSim-II and DSM2 for climate change impacts assessment. The results are not sufficient by themselves for making policy decisions.

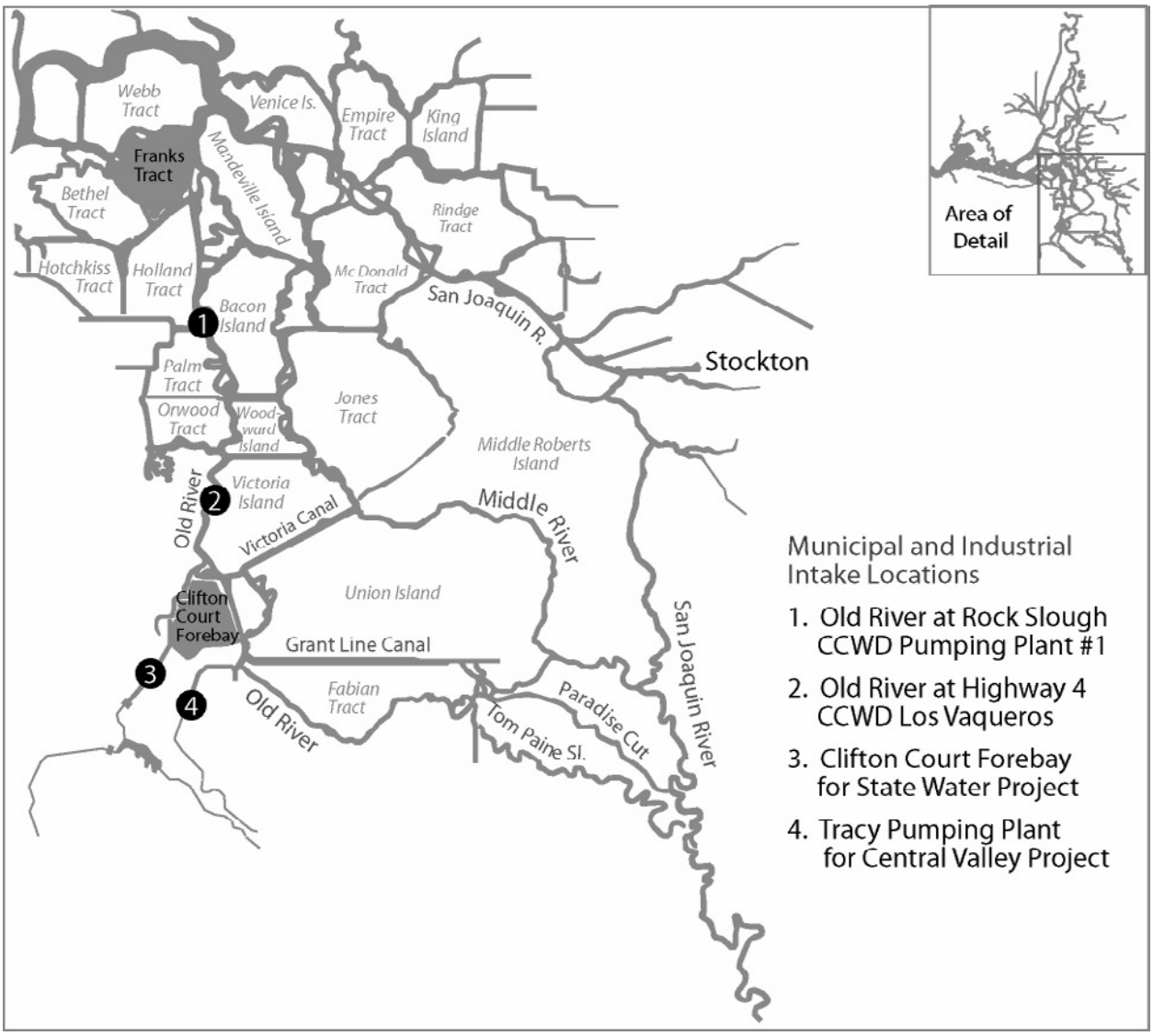


Figure 5.9: Delta Water Quality Impact Analysis Locations

Table 5.9: Delta Water Quality Standards

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Municipal and Industrial Compliance Locations	Daily average Cl < 250 mg/l											
Contra Costa Pumping Plant #1	Cl<150 mg/l for a required # of days based on year type											

5.4.1 Municipal and Industrial Water Quality for Present Sea Level Conditions

For this study, two municipal and industrial chloride standards from D1641 (SWRCB, 1995) were examined. The first standard specifies that maximum allowable daily average chloride concentrations can not exceed 250mg/l (Table 5.9). The second standard states that daily average chloride concentrations must be less than 150 mg/l for a specified number of days per calendar year based on the water year type (Table 5.10). This second chloride standard also requires that chloride concentration must be less than 150 mg/l for two consecutive weeks before those days can be counted towards meeting the standard.

Table 5.10: D1641 150 mg/l Chloride Standard

Water Year Type	Minimum Number of Days with Chloride Concentration ≤ 150 mg/l
Wet	240 (60% of the time)
Above Normal	190 (52% of the time)
Below Normal	175 (48% of the time)
Dry	165 (45% of the time)
Critical	155 (42% of the time)

*Chloride concentrations must be below 150 mg/l for at least two weeks before those days can be counted towards meeting the standard.

CalSim-II and DSM2 results were analyzed to determine compliance with the chloride standards at four municipal and industrial intakes (Figure 5.9) for the base and climate change scenarios:

- CCWD at Old River diversion at Rock Slough (for Contra Costa Canal)
- CCWD at Old River diversion at Highway 4 (for Los Vaqueros)
- SWP at Clifton Court Forebay
- CVP at Tracy

For these studies in both CalSim-II and DSM2, Contra Costa Water District's diversions were all withdrawn from Old River at Rock Slough[2]. This assumption could have local impacts on hydrodynamics and water quality. Although CCWD diversions were not simulated at Old River at Highway 4, water quality results are presented for that location since it is a potential diversion point.

In CalSim-II, the Artificial Neural Network (ANN) that represents Delta water quality provides chloride concentrations at a few Delta locations. The DSM2 simulations for this study determined EC concentrations throughout the Delta. These EC values can be converted to chloride concentrations using regression relationships based on field data (e.g. Suits, 2001 or Freeport, 2003[3]). For the analysis presented in this chapter, the simulated EC concentrations were converted to chlorides using the following equations from Suits (2001):

Contra Costa Water District Old River Diversion at Rock Slough

$$Cl = \frac{EC - 89.6}{3.73} \qquad \text{Eqn 5.1}$$

Old River at Highway 4, SWP at Clifton Court and CVP at Tracy

$$Cl = \frac{EC - 160.6}{3.66} \qquad \text{Eqn 5.2}$$

where,

Cl = chloride concentration in mg/l

EC = electrical conductivity in uS/cm

5.4.1.1 250 mg/l Chloride Standard

Monthly Average Results

One of the municipal and industrial beneficial use standards in D1641 specifies a maximum daily chloride concentration of 250 mg/l (Table 5.9). CalSim-II simulations attempt to meet this standard at Old River at Rock Slough. Monthly time step CalSim-II simulations represent this standard by setting a monthly average chloride target at Old River at Rock Slough of 225 mg/l. In CalSim-II the monthly average chloride concentrations at Rock Slough are determined by an ANN. CalSim-II tries to operate the system to meet the maximum allowable chloride standard at all time, but that isn't always possible (Table 5.11). For the base case, the 225mg/l chloride

[2] CalSimII calculates CCWD's combined Old River at Rock Slough (Contra Costa Canal) and Old River at Highway 4 (Los Vaqueros) diversions. For DSM2 studies, these combined diversions are taken from Old River at Rock Slough. In order to represent the two diversions separately, it would be necessary to develop a series of rules to emulate the CCWD operation of those diversions.

[3] Examining long term average chloride concentrations at Old River at Rock Slough using two sets of regression relationships, chloride concentrations from the Suits (2001) regression equation were an average of about 15mg/l higher than chloride concentrations determined from the Freeport (2003) regression equations.

target was met about 92 percent of the time for the DSM2 analysis period of wy1976-wy1991. Times when the target maximum chloride concentration was not met occurred in November to January. For the four climate change scenarios, the percent time for meeting the maximum chloride concentration target was met differed from the base case by less than 2 percent.

Table 5.11: Percent of Time Monthly Average Chloride Concentration <225mg/l

	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
CalSim-II results	92.2	91.1	92.2	90.1	93.8
DSM2 results	92.7	95.3	94.8	95.8	93.8

Monthly system operations from CalSim-II are used to run the more detailed Delta model, DSM2. DSM2 runs on a 15-minute time step and includes physically-based descriptions of flow and water quality constituent transport. DSM2 represents the spring-neap tidal cycle and diversions to and return flows from Delta islands. Thus, chloride concentrations simulated by the physically-based model DSM2 can differ from those estimated by the correlation-based ANN in CalSim-II. For studies in this report, average differences in monthly average chloride concentration at Old River at Rock Slough were about 5mg/l lower for the DSM2 simulations than for the ANN results. For comparison purposes, the percent time that the monthly average chloride concentrations at Rock Slough were less than the 225 mg/l target for both CalSim-II and DSM2 results are shown in Table 5.11. Since the DSM2 simulations tend to have slightly lower chloride concentrations that those estimated by the ANN, the monthly average DSM2 simulation results are less than 225 mg/l a bit more frequently than the CalSim-II results.

Daily Average Results

Daily average EC results from DSM2 for the 16-year simulation period were converted to daily average chloride concentrations using equations 5.1 and 5.2. Exceedance plots for daily average chloride concentrations at Rock Slough are shown in Figure 5.10. Percentiles and average chloride concentrations are shown in Table 5.12. Exceedance plots and percentile tables for other municipal and industrial intake locations are presented in the appendix in section 5.12. The distribution of chloride concentrations is similar for the base case and climate change scenarios at all four municipal and industrial intake locations.

Daily average chloride concentrations based on DSM2 simulation results can be used to examine compliance with the 250 mg/l maximum allowable daily average chloride concentration standard (Table 5.9). Compliance with the maximum daily average chloride concentration standard is given in Table 5.13. Increases in chloride standard compliance for the climate change scenarios relative to the base case are shown in Table 5.14. At Old River at Rock Slough, compliance with the 250 mg/l standard is at least 97 percent for all scenarios. Compliance was reduced in September through February of dry years when freshwater inflows to the Delta are low, which leads to higher salt intrusion from the ocean. Increased winter runoff for the climate change scenarios lead to slight improvements in compliance with the chloride standard at Old River at Rock Slough. There was complete compliance with the 250 mg/l standard for SWP and CVP intakes for all of the scenarios.

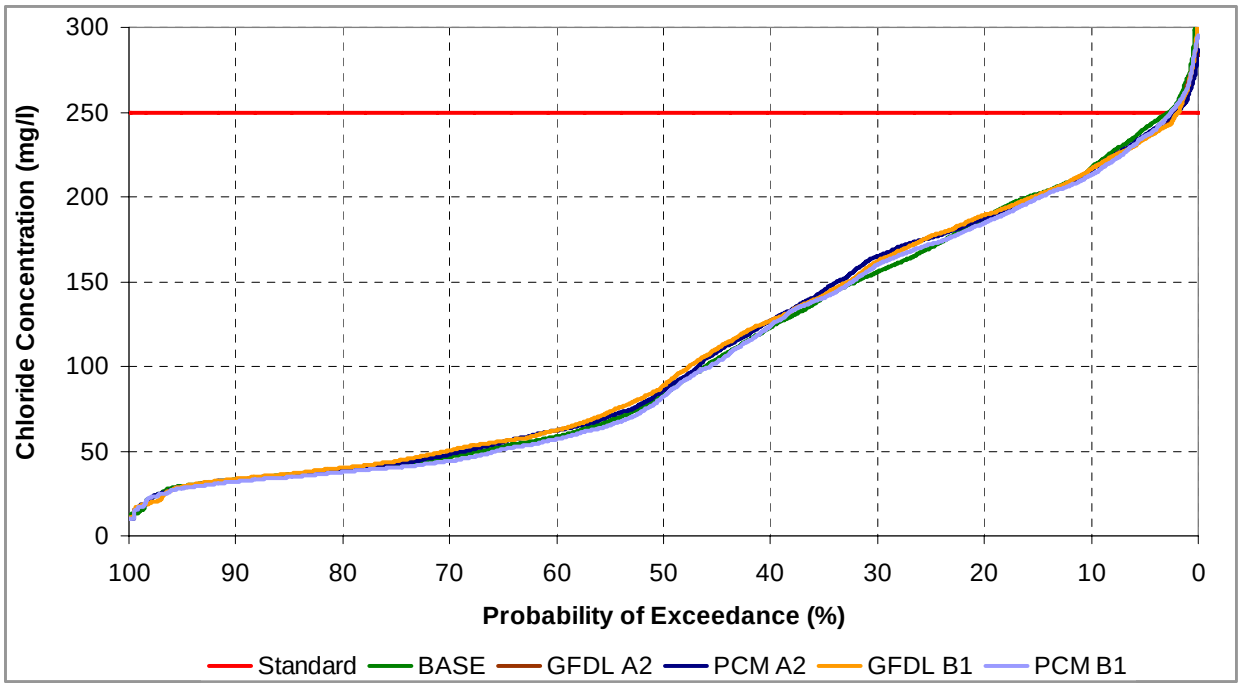


Figure 5.10: Probability of Exceedance for Chlorides at Old River at Rock Slough

Table 5.12: Chloride Concentration Percentiles for Old River at Rock Slough (mg/l)

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	30	33	42	83	170	217	240	109
GFDL A2	27	33	43	89	175	217	234	110
PCM A2	29	33	43	86	176	216	236	110
GFDL B1	29	34	44	89	177	216	234	111
PCM B1	28	32	40	82	172	213	236	107

Examining the daily average chloride concentrations from DSM2 resulted in higher compliance values for the 250 mg/l maximum chloride concentration standard at Old River at Rock Slough (Table 5.13) than the estimated compliance from examining the monthly average results from CalSim-II relative to the target monthly average chloride concentration of 225mg/l (Table 5.11). For these studies, the 225 mg/l target monthly average chloride concentration in CalSim-II provides a conservative estimate of compliance with of the daily average 250 mg/l maximum chloride concentration standard.

Although the Contra Costa Water District intake at Old River at Highway 4 is not a D1641 compliance location, chloride concentrations were also examined at that location. At Old River at Highway 4, daily average chloride concentrations were less than 250 mg/l 99.9 percent of the time for the base case and 100 percent of the time for the four climate change scenarios. There was complete compliance with the 250 mg/l chloride standard at the SWP and CVP intakes for all scenarios. These results demonstrate that existing flexibility in the system was able to accommodate changing reservoir inflows due to climate change with only minor impacts to compliance with the 250 mg/l chloride standard.

Table 5.13: Municipal and Industrial Intake Chloride Standard Compliance

Scenario/ Location	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
CCWD-Old River at Rock Sl.	97.2%	98.0%	98.0%	98.2%	97.4%
CCWD-Old River at Hwy 4*	99.9%	100%	100%	100%	100%
SWP-Clifton Court	100%	100%	100%	100%	100%
CVP-Tracy	100%	100%	100%	100%	100%

* Contra Costa Water District's intake at Old River at Highway 4 is not a compliance location for D1641. It is shown for comparison purposes.

Table 5.14: Change in Municipal and Industrial Intake Chloride Standard Compliance

Scenario/ Location	GFDL A2	PCM A2	GFDL B1	PCM B1
CCWD-Old River at Rock Sl.	0.8%	0.8%	0.9%	0.2%
CCWD-Old River at Hwy 4*	0.1%	0.1%	0.1%	0.1%
SWP-Clifton Court	0.0%	0.0%	0.0%	0.0%
CVP-Tracy	0.0%	0.0%	0.0%	0.0%

* Contra Costa Water District's intake at Old River at Highway 4 is not a compliance location for D1641. It is shown for comparison purposes.

5.4.1.2 150 mg/l Chloride Standard

At Old River at Rock Slough, another water quality standard states that the daily average chloride concentration should be below 150 mg/l for a specified number of days per calendar year depending on the water year type (Table 5.9 and Table 5.10). This standard also states that chloride concentrations must be below 150mg/l for at least two weeks before those days can be counted towards meeting the standard. Daily average chloride concentrations were computed from DSM2 EC results using equation 5.1. There was complete compliance with this standard for the base case or the two A2 scenarios (Table 5.15). For the two B1 scenarios, compliance

with the standard was reduced during a dry year. The values in Table 5.15 reflect the requirement that chloride concentrations be less than 150 mg/l for at least two weeks before those days can be counted toward the standard. For these studies, the compliance pattern does not change for any of the scenarios if all days with chloride concentrations less than 150 mg/l are considered. For the two cases that had non-compliance, the number of days with chloride concentrations less than 150 mg/l with and without the 2 consecutive week requirement is shown in Table 5.16. In most cases, existing system flexibility was able to adjust to climate change while maintaining compliance with the 150 mg/l chloride standard.

Table 5.15: Old River at Rock Slough 150mg/l Chloride Standard Compliance
Number of days that chloride concentrations were below 150 mg/l for at least 2 weeks

Year	Yr. Type*	Standard: Min Days Cl≤150 mg/l	Base	GFDL A2	PCM A2	GFDL B1	PCM B1
1976	C	155	177	168	169	167	178
1977	C	155	161	190	169	170	158
1978	AN	190	247	255	250	259	250
1979	BN	175	259	264	239	264	247
1980	AN	190	269	265	262	264	262
1981	D	165	260	275	261	257	261
1982	W	240	365	365	365	365	365
1983	W	240	365	365	365	365	365
1984	W	240	295	306	306	307	296
1985	D	165	216	211	199	215	223
1986	W	240	287	252	259	252	258
1987	D	165	176	196	187	197	217
1988	C	155	230	236	229	234	245
1989	D	165	184	169	170	**153**	**139**
1990	C	155	222	195	195	196	210

*Sac 40-30-30 water year types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical
Gray shading and bold text indicate non-compliance with the standard.

Table 5.16: Effect of 2 Week Requirement on 150mg/l Chloride Standard Compliance for Two Climate Change Scenarios at Old River at Rock Slough

	Year	Yr. Type*	Standard: Min Days Cl≤150 mg/l	Number of Days Cl≤150 mg/l	
				GFDL B1	PCM B1
# Days with Cl≤150 mg/l for at least 2 weeks	1989	D	165	**153**	**139**
Total # Days with Cl≤150 mg/l	1989	D	165	**156**	**155**

*Sac 40-30-30 water year types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical
Gray shading and bold text indicate non-compliance with the standard.
Results are only shown for scenarios that did not comply with the standard (see Table 5.15)

5.4.1.3 Chloride Mass Loading Rates

Chloride mass loadings at municipal and industrial intakes were estimated using equation 5.3. The mass loading estimates for CCWD are based on the combined diversion rate for CCWD's Old River diversions at Rock Slough and Highway 4 and the chloride concentrations at Rock Slough (see footnote 2 on page 5-1 for explanation of combined diversions).

$$Cl\ MassLoading\ (metric\ tons/day) = Cl\ (mg/l) * Exports\ (cfs) * \underbrace{2.832x10^{-8}}_{\frac{mg}{l}\ to\ \frac{metric\ tons}{ft3}} * \underbrace{86{,}400}_{\frac{ft^3}{\sec}\ to\ \frac{ft^3}{day}} \qquad \text{Eqn 5.3}$$

Since the export rates at Old River at Rock Slough are the same for all of the scenarios (Table 5.39), the chloride mass loadings are similar for all of the scenarios (Table 5.17). Export rates for the SWP and CVP vary for each scenario (Table 5.37 and Table 5.38). Mass loadings for the SWP and CVP are an order of magnitude higher than those at Rock Slough because the export rates at those locations are also an order of magnitude higher (Table 5.37 and Table 5.38). For the SWP, average chloride mass loadings decrease by 4 percent-9 percent for the climate change scenarios relative to the base case (Table 5.18). For the CVP, the B1 scenarios show little change relative to the base case, while the A2 scenarios have about 5 percent lower chloride mass loadings than the base case (Table 5.19). Reduced chloride mass loadings for the climate change scenarios are due to reduced export rates for those scenarios.

Table 5.17: Chloride Mass Loading Percentiles (metric tons/day) for Old River at Rock Slough

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	0*	9	19	45	80	115	146	54
GFDL A2	0	7	20	47	77	119	141	54
PCM A2	0	9	20	47	77	113	145	54
GFDL B1	0	8	20	47	78	119	140	55
PCM B1	0	9	19	45	77	115	148	54

*Zero values reflect times when no diversions were made.

Table 5.18: Chloride Mass Loading Percentiles (metric tons/day) for State Water Project

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	48	80	264	460	1086	1763	2068	711
GFDL A2	48	73	247	480	923	1387	1713	646
PCM A2	48	69	255	451	957	1560	1945	667
GFDL B1	47	71	230	477	951	1495	1883	670
PCM B1	47	75	265	459	1009	1660	1954	685

Table 5.19: Chloride Mass Loading Percentiles (metric tons/day) for Central Valley Project

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	59	146	317	575	1037	1325	1540	686
GFDL A2	56	145	271	534	1001	1260	1444	648
PCM A2	53	142	314	532	1074	1305	1413	663
GFDL B1	65	164	340	560	1050	1282	1475	686
PCM B1	51	118	337	582	1056	1267	1491	688

5.5 Sea Level Rise

Historical records show that in the 20th century sea levels rose globally with an average increase ranging from 3.9 in to 7.9 in (IPCC, 2001). Over the past 100 years, sea level at Golden Gate has risen more than 8 inches (Figure 5.11) (Roos, 2004). Sea levels are expected to continue to rise under global warming due to thermal expansion of the ocean and melting of glaciers and polar ice caps. Simulations of future climate change for all of the Intergovernmental Panel on Climate Change's (IPCC's) emissions scenarios show increases in global sea levels ranging from 0.3 feet to 2.9 feet (IPCC, 2001).

For California's water supply, the largest effect of sea level rise (SLR) would likely be in the Sacramento-San Joaquin Delta (DWR, 2005). Rising sea levels would increase pressure on the levees that protect the Delta islands, many of which are below sea level. A one-foot increase in sea level is projected to increase the frequency of a 100-year peak tide to a 10-year event (DWR, 2005). Increased intrusion of salt water from the ocean into the Delta could degrade the quality of the freshwater that is pumped out of the Delta for municipal, industrial and agricultural purposes. This could lead to increased releases of water from upstream reservoirs or reduced pumping from the Delta to maintain compliance with Delta water quality standards. Salt water intrusion could also degrade groundwater aquifers. Additional information on sea level rise can be found in Chapter 2 in section 2.6.

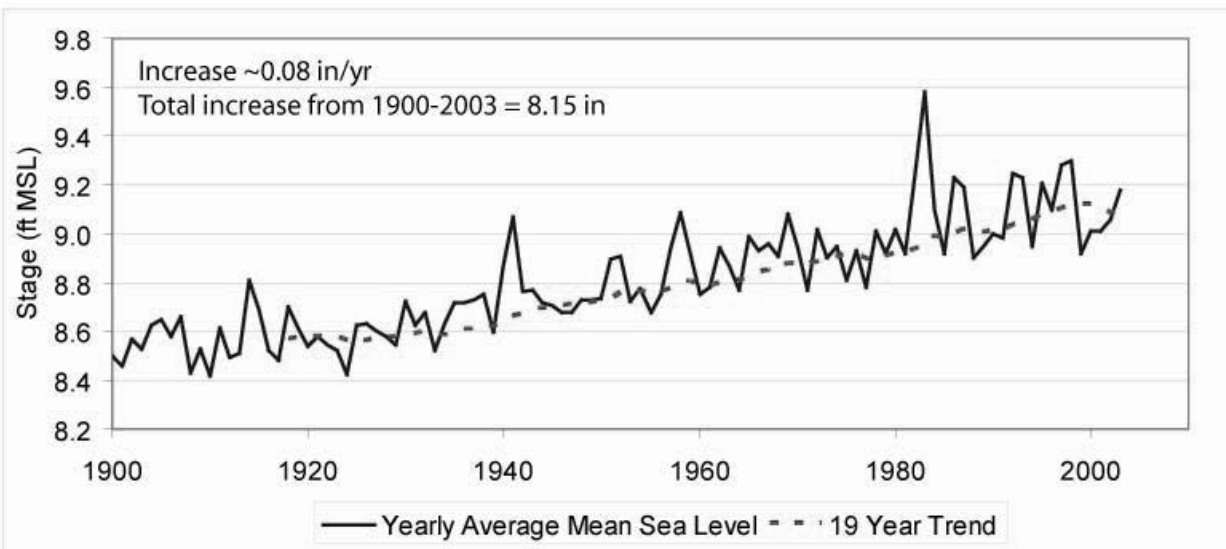


Figure 5.11 Historical Annual Mean Sea Level at Golden Gate, 1900-2003

5.5.1 Analysis Approach

In order to do a complete analysis of potential sea level rise impacts on the Delta, both increased salt intrusion and changes in system operations such as reservoir releases and Delta exports would need to be examined. Currently an analysis tool is not available to determine changes in system operations required to lessen the effects of increased salt intrusion due to sea level rise. However, existing tools can be used to quantify potential salt intrusion into the Delta for sea level rise with present system operations. The results of such studies improve understanding of the salinity transport in the Delta and provide an important starting point for the development of tools and analysis techniques for determining changes in system operations to maintain compliance with Delta water quality standards for sea level rise conditions. In this report water quality concentrations for a one-foot sea level rise without changes in system operations are compared to water quality standards. This information is presented as a surrogate for evaluating the effects of sea level rise on water project operations to meet existing standards.

This report provides preliminary assessments of potential impacts of sea level rise on Delta water quality and on levee overtopping potential assuming present system operations. Additional information on possible effects of sea level rise on the Delta, such as increasing the risk of levee failures, is presented in Chapter 2 in section 2.6. These studies are a first step in developing a more complete sea level rise analysis approach. All results are preliminary and are intended to illustrate the use of DSM2 for sea level rise analysis.

Preliminary modeling studies were conducted to assess potential effects of a one-foot rise in sea level on the Delta. DSM2 simulations were run for

- Present sea level with base case system operations (see section 5.4)
- Present sea level with system operations modified for climate change (see sections 5.4)
- One-foot sea level rise with base case system operations (see sections 5.5.2 and 5.5.4)
- One-foot sea level rise with system operations modified for climate change (see sections 5.5.3 and 5.5.4)

For all of the sea level rise scenarios, the tidal stage (water level) was increased uniformly by one-foot at the DSM2 downstream boundary at Martinez. This assumes that sea level rise does not change the tidal period or amplitude. Representation of Martinez EC for the sea level rise simulations is described in section 5.5.1.1. All other Delta inflows, exports and water quality boundary conditions were identical to the present sea level simulations (see sections 5.3 and 5.11). No operational changes were made to lessen potential effects of sea level rise.

Water quality analysis for the sea level rise scenarios focused on the comparisons of simulated constituent concentrations compared to standard thresholds for the municipal and industrial intakes (Table 5.9). These results are a demonstration of a preliminary application of DSM2 to access water quality changes for a one foot rise in sea level. The results do not reflect operations changes to try to reduce the effects of salt water intrusion from sea level rise, and therefore the results by themselves are not sufficient for making management decisions.

5.5.1.1 Martinez Salinity for Sea Level Rise Scenarios

One area of uncertainty in modeling sea level rise conditions with DSM2 is the representation of salt water intrusion at Martinez, the downstream boundary for DSM2. For this report, two assumptions were used for estimating salinity at Martinez for a one-foot sea level rise (Anderson and Miller, 2005):

- Assume Martinez EC is the same as in the present sea level scenarios
- Increase Martinez EC based on a regression relationship (equation 5.4)

Comparing results for DSM2 studies using each of these assumptions for Martinez EC provides a range of potential effects of a one-foot rise in sea level.

Assume Martinez EC Does Not Change

The first method used to estimate Martinez EC for a one-foot rise in sea level was to assume that the EC is the same as in the present sea level scenario. This provides a lower-bound estimate of salt water intrusion into the Delta for a one-foot increase in sea level.

Assume Martinez EC Increases

The second method used to estimate Martinez EC for a one-foot rise in sea level was to use a preliminary regression relationship based on the Martinez EC for present sea level conditions (Anderson and Miller, 2005):

$$MartinezEC_{1\,ft\,SLR} = 1.0022 * MartinezEC_{Present\,Sea\,Level} + 840.87 \qquad \text{Eqn. 5-4}$$

This regression relationship was based on results from a preliminary one year (calendar year 1992) multi-dimensional modeling study using models from Resource Management Associates (RMA). Since the effects of sea level rise on EC at the DSM2 downstream boundary at Martinez had not been quantified, a multi-dimensional modeling study was done to represent flows and salt water intrusion from Golden Gate into the Delta for a one-foot sea level rise (Figure 5.12). Results from the RMA modeling studies at Martinez for base and one-foot sea level rise conditions were used to develop the regression relationship shown in equation 5-4 (Figure 5.13). This regression relationship can be used to estimate Martinez EC for a one-foot sea level rise for DSM2 simulations.

Equation 5-4 is only applicable for a one-foot rise in sea level. Since this relationship is linear with a coefficient of nearly 1 (1.0022), equation 5-4 indicates that a one-foot rise in sea level at Golden Gate corresponds to an approximate increase in EC at Martinez of 840 uS/cm. Therefore use of this regression equation to estimate the Martinez EC for a one-foot rise in sea level will provide a higher estimate of salt water intrusion than using the assumption that the Martinez EC does not change. An increase in EC of 840 uS/cm is relatively small during time periods when Martinez EC is high (20,000-35,000 uS/cm) and freshwater inflows are low and salt water intrusion is of most concern, typically during the summer and early fall.

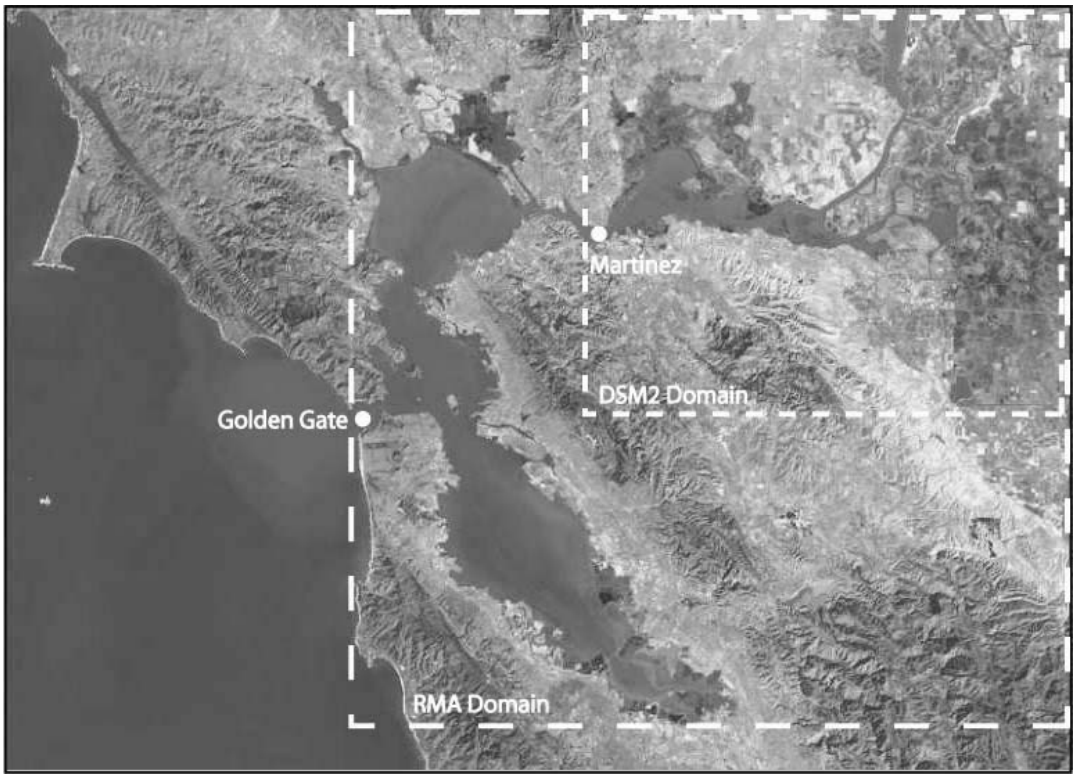


Figure 5.12 Modeling Domains for RMA and DSM2
Satellite image from USGS. (Anderson and Miller, 2005)

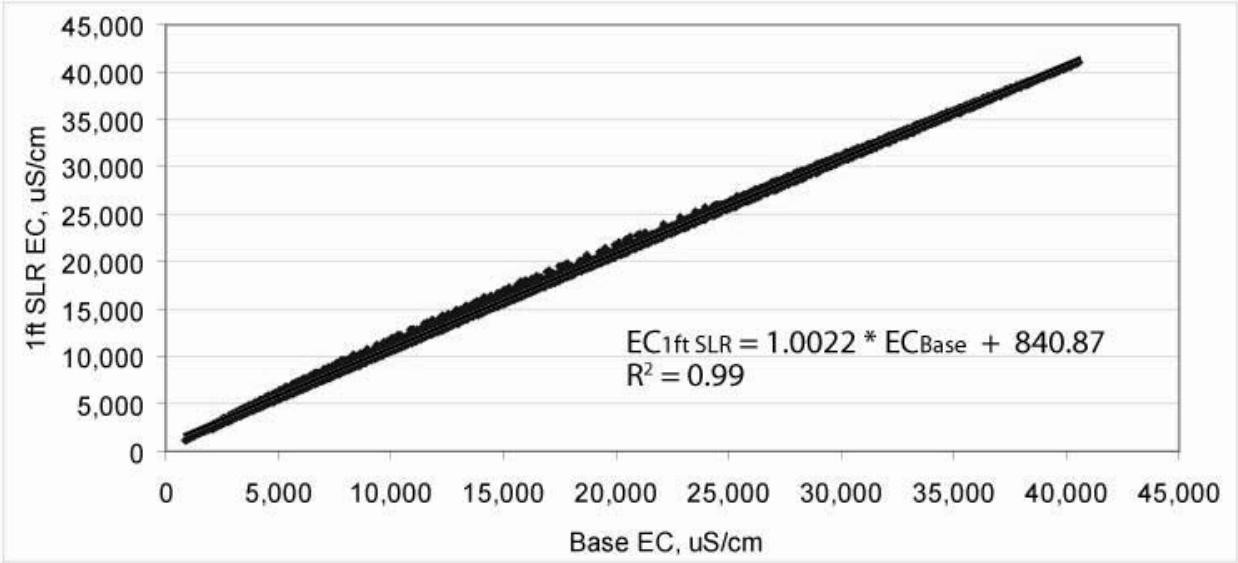


Figure 5.13: Regression Relationship for EC at Martinez for a One-Foot Sea Level Rise.
(Anderson and Miller, 2005)

The RMA modeling study from which the regression relationship in equation 5-4 was developed was a preliminary study that included the following assumptions:

- Historical tidal stage at Golden Gate was increased uniformly by one-foot,
- Ocean salinity is not affected by sea level rise [the same EC boundary condition of a constant ocean salinity was applied for both the base and 1ft SLR scenarios],
- Historical Delta inflows and exports were not modified to mitigate for salt water intrusion due to sea level rise [historical Delta inflows and exports were used for both the base and 1ft SLR scenarios],
- Agricultural return flows do not significantly affect EC at Martinez [Delta island diversions and return flows were not simulated],
- Temporary agricultural and fish barriers in the South Delta were not simulated, and
- Historical Delta inflows and exports for 1992 provide adequate ranges of flows and EC to develop an EC relationship at Martinez for one-foot sea level rise conditions that can be applied for any time period.

5.5.2 Sea Level Rise Effects on Delta Water Quality

Potential effects of a one-foot rise in sea level on Delta water quality were examined for DSM2 results using two different assumptions regarding Martinez EC (see section 5.5.1.1)

- Assume Martinez EC is the same as in the present sea level scenarios
- Assume that Martinez EC increases for a one-foot sea level rise

These results are a preliminary demonstration of the use of DSM2 to estimate a range of impacts given uncertainties in quantifying how much salt would be transported into the Delta under sea level rise with no modifications to system operations to try to reduce the salt water intrusion. Several assumptions that are involved in these studies are described in sections 5.2.3 and 5.5.1.1. Since available methodologies didn't allow consideration of changes to system operations for sea level rise scenarios, simulated constituent concentrations are compared with threshold values for selected water quality standards as a surrogate for evaluating the effects of sea level rise on water project operations to meet existing standards.

Daily average EC results from DSM2 for the 16-year simulation period were converted to daily average chloride concentrations using equations 5.1 and 5.2. Exceedance plots for daily average chloride concentrations at Rock Slough are shown in Figure 5.14. Percentiles and average chloride concentrations are shown in Table 5.20. Exceedance plots and percentile tables for other municipal and industrial intake locations are presented in the appendix in section 5.13. The sea level rise scenarios show an average increase in chloride concentrations of 15-20mg/l compared to the base case. Differences between the two sea level rise scenarios are typically 5-10mg/l. This indicates that raising the water levels at Martinez has more of an impact on chloride concentrations at Old River at Rock Slough than raising the Martinez salt concentrations. For

the SWP and CVP, the average increase in chloride concentrations was about 10 mg/l (see section 5.13). Differences between the two sea level rise scenarios were less than 2mg/l.

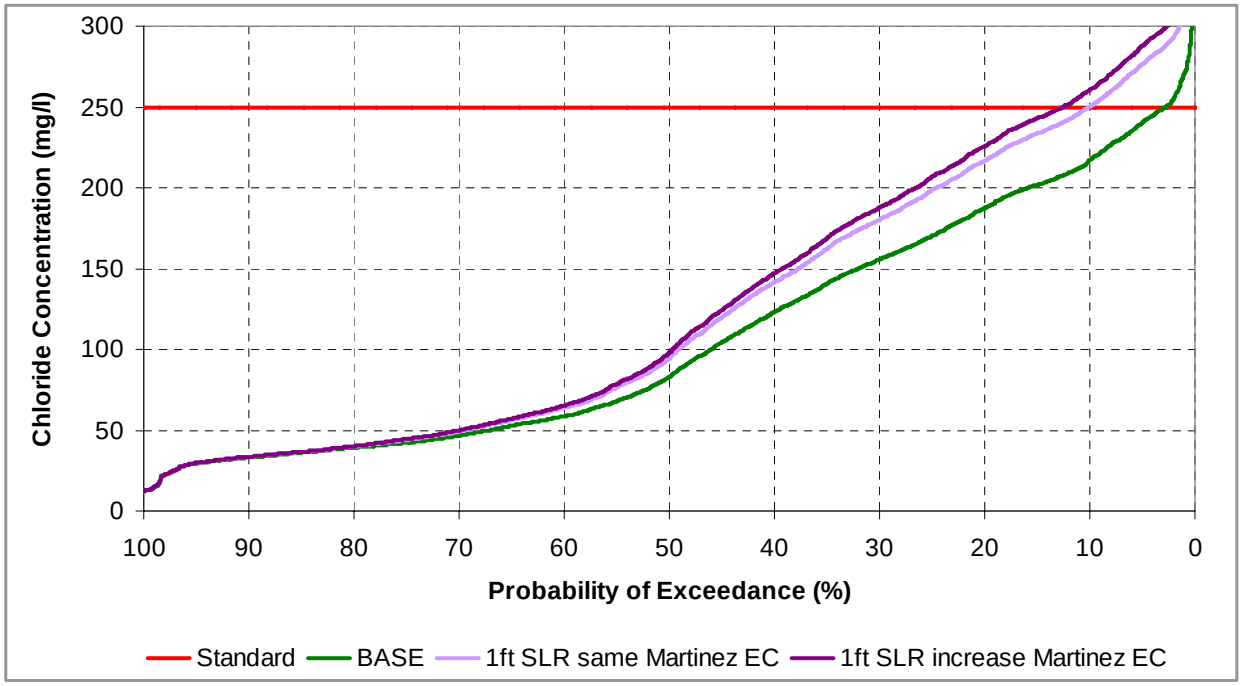


Figure 5.14: Probability of Exceedance for Chlorides at Old R. at Rock Sl. for a One-Foot Sea Level Rise and no Changes in System Operations

Table 5.20: Chloride Concentration Percentiles (mg/l) for Old R. at Rock Sl. for a One-Foot Sea Level Rise and no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	30	33	42	83	170	217	240	109
1ft SLR same Martinez EC	30	33	44	94	199	250	276	123
1ft SLR increase Martinez EC	30	34	45	98	207	261	288	128

5.5.2.1 250 mg/l Chloride Threshold for Sea Level Rise Scenarios

Daily average chloride concentrations based on DSM2 simulation results for the two sea level rise scenarios without any changes in system operations were compared with the 250 mg/l maximum allowable daily average chloride concentration threshold (Table 5.9). The frequency that chloride concentrations were below the 250 mg/l threshold is presented in Table 5.21. Changes in the frequency that concentrations were below the threshold for sea level rise relative to the base case are shown in Table 5.22. For the base case, chloride concentrations are below the 250 mg/l chloride threshold at Old River at Rock Slough about 97 percent of the time. For the two sea level rise scenarios, chloride concentrations are below the threshold value at Old River at Rock Slough 88 percent to 90 percent of the time. For the scenario that assumes an

increase in EC at Martinez the threshold value is exceeded about 2.5 percent more often than for the scenario that assumes that the EC at Martinez does not change. Chloride concentrations rarely exceeded 250mg/l at Old River at Highway 4 for both the base and the sea level rise scenarios. The 250 mg/l threshold was never exceeded at both the SWP and CVP for the base case and sea level rise scenarios.

Table 5.21: Frequency that Chloride Concentrations were below the 250 mg/l Threshold for a One-Foot Sea Level Rise and no Changes in System Operations

Scenario/ Location	BASE	1ft Sea Level Rise same Martinez EC	1ft Sea Level Rise increase Martinez EC
CCWD-Old River at Rock Sl.	97.2%	89.9%	87.5%
CCWD-Old River at Hwy 4	99.9%	99.7%	99.4%
SWP-Clifton Court	100%	100%	100%
CVP-Tracy	100%	100%	100%

Table 5.22: Change in Frequency that Chloride Concentrations were below the 250mg/l Threshold for a One-Foot Sea Level Rise and no Changes in System Operations Compared to the Base Case

Scenario/ Location	1ft Sea Level Rise same Martinez EC	1ft Sea Level Rise increase Martinez EC
CCWD-Old River at Rock Sl.	-7.3%	-9.8%
CCWD-Old River at Hwy 4	-0.2%	-0.5%
SWP-Clifton Court	0%	0%
CVP-Tracy	0%	0%

5.5.2.2 150 mg/l Chloride Threshold for Sea Level Rise Scenarios

For the two sea level rise scenarios with no changes in system operations, daily average chloride concentrations were computed from DSM2 EC results using equation 5.1, and the results were compared to the 150 mg/l threshold (Table 5.9 and Table 5.10). There was complete compliance with the 150 mg/l standard in the base case (Table 5.23). For the sea level rise scenario that assumed no change in Martinez EC, the 150 mg/l threshold was exceeded in the critically dry years of 1976 and 1977. For the sea level rise scenario that assumed an increase in Martinez EC, the 150 mg/l threshold was exceeded in 1976, 1977, and 1989, a dry year. In most cases, existing operations lead to chloride concentrations below the 150 mg/l threshold, even under sea level rise conditions.

Table 5.23: Comparison of Chloride Concentrations to the 150 mg/l Threshold at Old River at Rock Sl. for a One-Foot Sea Level Rise and no Changes in System Operations Number of days with chloride concentrations below 150 mg/l

Year	Yr. Type*	Min Days Cl≤150 mg/l	Base	1ft SLR same Martinez EC	1ft SLR increase Martinez EC
1976	C	155	177	**126**	**118**
1977	C	155	161	**102**	**94**
1978	AN	190	247	240	237
1979	BN	175	259	226	223
1980	AN	190	269	263	261
1981	D	165	260	232	217
1982	W	240	365	365	365
1983	W	240	365	365	365
1984	W	240	295	289	288
1985	D	165	216	198	197
1986	W	240	287	265	257
1987	D	165	176	168	165
1988	C	155	230	209	206
1989	D	165	184	166	**162**
1990	C	155	222	181	176

*Sac 40-30-30 water year types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical
Gray shading and bold text indicate values that exceeded the threshold.

5.5.2.3 Chloride Mass Loading for Sea Level Rise Scenarios

Chloride mass loadings at municipal and industrial intakes were estimated based on chloride concentrations and export rates (equation 5.3). The mass loading estimates for CCWD are based on the combined diversion rate for CCWD's Old River diversions at Rock Slough and Highway 4 and the chloride concentrations at Rock Slough (see footnote 2 on page 5-1 for explanation of combined diversions). Since operations were not changed to try to lessen the effects of sea level rise, the export rates for each intake were the same for the base and sea level rise scenarios. Thus differences in mass loading rates are due only to differences in chloride concentrations.

For all intake locations, sea level rise increased the average chloride mass loadings by 13 percent-17 percent for Old River at Rock Slough, by 11 percent-14 percent for the SWP and by 7 percent-9 percent for the CVP. These ranges reflect the two sea level rise assumptions of no change in Martinez EC and increasing Martinez EC. The sea level rise scenarios increased the chloride mass loadings, and the climate change scenarios decreased them (see section 5.4.1.3). The combined affects of sea level rise and climate change are presented in section (5.5.3.3).

Table 5.24: Chloride Mass Loading Percentiles (metric tons/day) for Old River at Rock Slough for a One-Foot Sea Level Rise with no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
Base	0	9	19	45	80	115	146	54
1ft SLR same Martinez EC	0	9	20	50	92	132	165	61
1 ft SLR increase Martinez EC	0	9	20	51	96	138	172	63

Table 5.25: Chloride Mass Loading Percentiles (metric tons/day) for State Water Project for a One-Foot Sea Level Rise and no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
Base	48	80	264	460	1086	1763	2068	711
1ft SLR same Martinez EC	49	84	267	514	1202	1925	2299	786
1 ft SLR increase Martinez EC	50	86	270	527	1238	2014	2394	812

Table 5.26: Chloride Mass Loading Percentiles (metric tons/day) for Central Valley Project for a One-Foot Sea Level Rise and no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
Base	59	146	317	575	1037	1325	1540	686
1ft SLR same Martinez EC	58	147	328	611	1140	1433	1648	734
1 ft SLR increase Martinez EC	58	147	331	618	1163	1461	1696	749

5.5.3 Combined Climate Change and Sea Level Rise Effects on Delta Water Quality

Potential effects of a one-foot rise in sea level coupled with shifting precipitation and runoff patterns from climate change were examined. The results are preliminary and reflect several assumptions (see section 5.2.3) including:

- Martinez EC is the same as in the present sea level scenarios. Due to time constraints for this report, combined sea level rise and climate change scenarios were not run for the increased Martinez EC sea level rise scenario.
- System operations were only modified to reflect the changing precipitation and runoff patterns due to climate change. System operations were not modified to account for sea level rise.

For the combined sea level rise and climate change scenarios, daily average EC results from DSM2 for the 16-year simulation period were converted to daily average chloride concentrations using equations 5.1 and 5.2. Exceedance plots for daily average chloride concentrations at Rock Slough for the combined climate change and one-foot sea level rise scenarios with no changes to system operations for sea level rise are shown in Figure 5.15. Percentiles and average chloride concentrations are shown in Table 5.27. Exceedance plots and percentile tables for other municipal and industrial intake locations are presented in the appendix in section 5.14. For the combined climate change and sea level rise scenarios, average increases in chloride concentrations range from13-17mg/l compared to the base case. For the SWP and CVP, the average increase in chloride concentrations for the combined climate change and sea level rise scenarios was about 10 mg/l (see section 5.14).For all of these intakes, the increases in chloride concentrations are similar to increases due to sea level rise alone.

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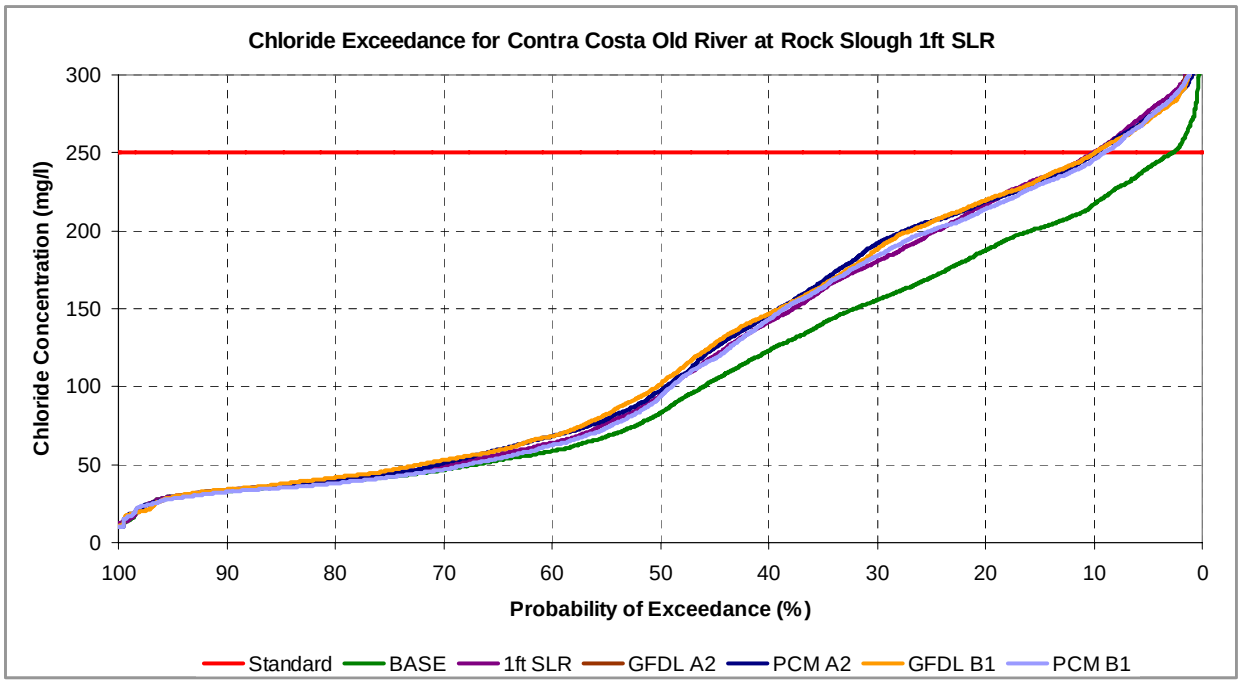

Figure 5.15: Probability of Exceedance for Chlorides at Old River at Rock Slough for Climate Change and a One-Foot Sea Level Rise with no Changes in Operations for SLR

Table 5.27: Chloride Concentration Percentiles (mg/l) for Old R. at Rock Sl. for Climate Change and a One-Foot Sea Level Rise with no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	30	33	42	83	170	217	240	109
1ft SLR same Mtz EC	30	33	44	94	199	250	276	123
GFDL A2 1ft SLR	27	33	45	102	205	251	272	125
PCM A2 1ft SLR	29	34	44	97	206	249	273	125
GFDL B1 1ft SLR	29	34	46	102	205	250	271	126
PCM B1 1ft SLR	28	33	42	94	200	245	272	122

*All sea level rise scenarios in this table assume that Martinez EC is the same as in the present sea level scenarios.

5.5.3.1 250 mg/l Chloride Threshold for Combined Sea Level Rise and Climate Change Scenarios

For the combined climate change and sea level rise scenarios with no additional changes to system operations for sea level rise, daily average chloride concentrations based on DSM2 simulation results were compared to the 250 mg/l daily average chloride concentration threshold

(Table 5.9). The frequency that chloride concentrations were below the 250 mg/l threshold is given in Table 5.28. Changes in the frequency that chloride concentrations were below the threshold relative to the base case are shown in Table 5.29. For the base case, the 250 mg/l chloride standard is met at Old River at Rock Slough about 97 percent of the time. For the combined climate change and one-foot sea level rise scenarios with no changes in system operations for sea level rise, chloride concentrations at Old River at Rock Slough were less than the threshold value about 90 percent of the time. This result is similar to the sea level rise only scenario (Table 5.21). Chloride concentrations rarely exceeded 250mg/l threshold at Old River at Highway 4 for all scenarios. Chloride concentrations never exceeded the 250 mg/l threshold at both the SWP and CVP for the base and combined climate change and sea level rise scenarios.

Table 5.28: Frequency that Chloride Concentrations were below the 250 mg/l Threshold for Climate Change and a 1-ft Sea Level Rise with no Changes to Operations for SLR

Scenario/ Location	BASE	1ft SLR	GFDL A2 1ft SLR	PCM A2 1ft SLR	GFDL B1 1ft SLR	PCM B1 1ft SLR
Contra Costa-Old R. at Rock Sl.	97.2%	89.9%	89.6%	90.3%	90.1%	90.9%
Contra Costa-Old R at Hwy 4	99.9%	99.7%	100.0%	100.0%	99.8%	99.8%
SWP-Clifton Court	100%	100%	100%	100%	100%	100%
CVP-Tracy	100%	100%	100%	100%	100%	100%

*Note that all sea level rise scenarios shown in this table assume that Martinez EC is the same as in the present sea level scenarios.

Table 5.29: Change in Frequency that Chloride Concentrations were below the 250mg/l Threshold for Climate Change and a 1ft Sea Level Rise with no Changes to Operations for Sea Level Rise Compared to the Base Case

Scenario/ Location	1ft SLR	GFDL A2	PCM A2	GFDL B1	PCM B1
Contra Costa-Old River at Rock Sl.	-7.3%	-7.7%	-6.9%	-7.2%	-6.3%
Contra Costa-Old River at Hwy 4	-0.2%	0.1%	0.1%	-0.1%	-0.1%
SWP-Clifton Court	0%	0%	0%	0%	0%
CVP-Tracy	0%	0%	0%	0%	0%

*Note that all sea level rise scenarios shown in this table assume that Martinez EC is the same as in the present sea level scenarios.

5.5.3.2 150 mg/l Chloride Threshold for Combined Sea Level Rise and Climate Change Scenarios

For the combined climate change and sea level rise scenarios with no additional changes in system operations for sea level rise, daily average chloride concentrations were computed from DSM2 EC results using equation 5.1, and the results were compared to the 150 mg/l chloride threshold (Table 5.9 and Table 5.10). The 150 mg/l threshold was never exceeded in the base case (Table 5.30). For the combined climate change and one-foot sea level rise scenarios with no changes in system operations for sea level rise, the threshold value was exceeded in the critically dry years of 1976 and 1977, and for some of the scenarios in 1989. In most cases, existing operations maintained compliance with the 150 mg/l chloride standard, even under combined climate change and sea level rise conditions.

Table 5.30: Comparison of Chloride Concentrations to the 150 mg/l Threshold at Old R. at Rock Sl. for Climate Change and a One-Foot Sea Level Rise with no Changes in Operations for SLR Number of Days that Chloride Concentrations were Below 150 mg/l

Year	Yr. Type*	Min Days Cl≤150 mg/l	Base	1ft SLR	GFDL A2 1ft SLR	PCM A2 1ft SLR	GFDL B1 1ft SLR	PCM B1 1ft SLR
1976	C	155	177	**126**	**112**	**113**	**112**	**129**
1977	C	155	161	**102**	**107**	**105**	**113**	**107**
1978	AN	190	247	240	248	245	238	245
1979	BN	175	259	226	231	233	230	240
1980	AN	190	269	263	258	256	255	255
1981	D	165	260	232	240	229	239	241
1982	W	240	365	365	343	365	341	365
1983	W	240	365	365	365	365	365	365
1984	W	240	295	289	299	301	301	291
1985	D	165	216	198	201	198	198	195
1986	W	240	287	265	242	250	242	246
1987	D	165	176	168	180	172	178	181
1988	C	155	230	209	211	207	209	224
1989	D	165	184	166	**152**	165	**142**	**137**
1990	C	155	222	181	182	162	183	162

*Sac 40-30-30 water year types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical
Gray shading and bold text indicate values that exceed the threshold.
All sea level rise scenarios assume that Martinez EC is the same as in the present sea level scenarios.

5.5.3.3 Chloride Mass Loading for Combined Sea Level Rise and Climate Change Scenarios

Chloride mass loadings at municipal and industrial intakes were estimated based on chloride concentrations and export rates (equation 5.3). The mass loading estimates for CCWD are based on the combined diversion rate for CCWD's Old River diversions at Rock Slough and Highway 4 and the chloride concentrations at Rock Slough (see footnote 2 on page 5-1 for explanation of combined diversions). Diversion rates for CCWD were identical for all scenarios. SWP and CVP operations were changed to reflect shifts in precipitation and runoff due to climate change, but they were not changed to try to lessen the effects of sea level rise.

For all intake locations, sea level rise increased the average chloride mass loadings by about 15 percent for Old River at Rock Slough, by 5 percent for the SWP and by 3 percent-7 percent for the CVP. For Old River at Rock Slough and for the Central Valley Project B1 scenarios, the mass loadings are similar to the sea level rise only scenario. For the SWP and for the CVP A2 scenarios, reduced exports for the climate change scenarios lead to lower mass loadings than in the sea level rise only scenario. This demonstrates that shifts in system operations due to changes in runoff patterns can lessen the effects of sea level rise at the intakes that are further away from the ocean.

Table 5.31: Chloride Mass Loading Percentiles (metric tons/day) for Old River at Rock Sl. for Climate Change and a One-Foot Sea Level Rise with no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
Base	0	9	19	45	80	115	146	54
1ft SLR same Martinez EC	0	9	20	50	92	132	165	61
GFDL A2 1ft SLR same Mtz EC	0	7	21	53	92	137	163	62
PCM A2 1ft SLR same Mtz EC	0	9	22	53	90	129	163	62
GFDL B1 1ft SLR same Mtz EC	0	8	22	54	90	136	157	63
PCM B1 1ft SLR same Mtz EC	0	9	20	48	91	131	167	61

Note: Export rates were identical for all scenarios.

Table 5.32: Chloride Mass Loading Percentiles (metric tons/day) for the State Water Project for Climate Change and a One-Foot Sea Level Rise with no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
Base	48	80	264	460	1086	1763	2068	711
1ft SLR same Martinez EC	49	84	267	514	1202	1925	2299	786
GFDL A2 same Mtz EC	51	74	245	530	1026	1536	1959	718
PCM A2 same Mtz EC	51	70	251	498	1075	1802	2188	740
GFDL B1 same Mtz EC	49	73	254	516	1091	1749	2118	744
PCM B1 same Mtz EC	48	76	262	521	1152	1922	2226	758

Note: Export rates were modified for climate change, but not for sea level rise.

Table 5.33: Chloride Mass Loading Percentiles (metric tons/day) for the Central Valley Project for Climate Change and a One-Foot Sea Level Rise with no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
Base	59	146	317	575	1037	1325	1540	686
1ft SLR same Martinez EC	58	147	328	611	1140	1433	1648	734
GFDL A2 same Mtz EC	55	143	275	563	1099	1360	1576	695
PCM A2 same Mtz EC	53	141	320	569	1168	1408	1549	710
GFDL B1 same Mtz EC	65	175	346	586	1141	1394	1625	735
PCM B1 same Mtz EC	51	121	350	613	1160	1401	1635	736

Note: Export rates were modified for climate change, but not for sea level rise.

5.5.4 Sea Level Rise Effects on Potential to Overtop Delta Levees

This study examined potential effects of a one-foot increase in sea level on the potential to overtop levees on three islands in the western Delta, Sherman Island, Twitchell Island, and Jersey Island. These are the Delta islands closest to the ocean, and so they are most vulnerable to potential overtopping due to sea level rise. The lowest crest elevations on levees on those islands are shown in Figure 5.16. Simulated water levels for present sea level and one-foot sea level rise scenarios were compared to these low-crest elevations to determine potential overtopping (Table 5.34). For the purpose of this analysis, potential overtopping was defined as any time the daily maximum water level in the channel exceeded the minimum crest elevation on the levee. Actual levee overtopping and effects of wind-induced waves were not simulated. Results are preliminary and are presented for illustrative purposes only.

Results for the present sea level scenarios indicated that water levels were never high enough to potentially overtop the study levees, even when Delta inflows were modified by climate change. For all of the one-foot sea level rise scenarios, there were two potential levee overtoppings during the 16-year simulation when simulated water levels exceeded the minimum levee crest elevations. For both the base and climate change sea level rise scenarios, the potential overtoppings occurred at the same time and affected all five study locations. Actual overtopping events and their effects on water levels and water quality were not simulated.

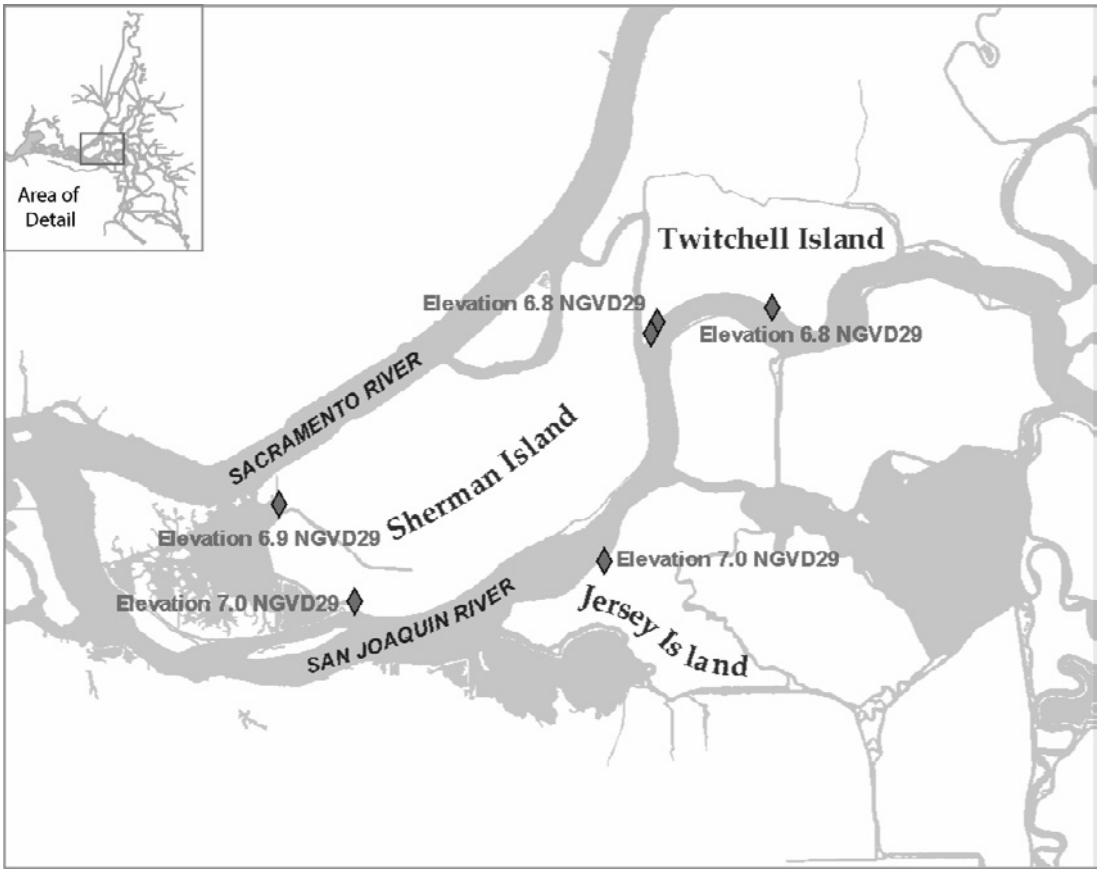

Figure 5.16: Locations of Lowest Levee Elevation on Three Delta Islands

Table 5.34: Summary of Levee Overtopping Events for Sea Level Rise Scenarios

Location	Min Crest Elevation, ft	Number of Potential Overtopping Events in 16 yrs			
		Base	4 Climate Change Scenarios	1 ft SLR	4 Climate Change Scenarios 1ft SLR
NW Sherman Island	6.9	0	0	2	2
SW Sherman Island	7.0	0	0	2	2
SW Twitchell Island	6.8	0	0	2	2
SE Twitchell Island	6.8	0	0	2	2
W Jersey Island	7.0	0	0	2	2

These results indicate that for the scenarios examined, sea level rise is more likely to increase the potential to overtop the study levees than changes in Delta inflows due to climate change. However, this analysis does not provide insight into potential changes in frequency of extreme events due to climate change. Since these climate change studies use perturbation ratios to modify historically-based reservoir inflows (see Chapter 4), the climate change scenarios preserve the historical hydrologic variability and do not reflect any potential changes in the

frequency of extreme events. Thus for the combined sea level rise and climate change scenarios, the potential levee overtoppings occurred at the same time during periods as the sea level rise only scenario. All of the potential overtoppings corresponded to periods with historically high water levels. Levees in other parts of the Delta may be more vulnerable to overtopping due to shifts in reservoir release patterns. Future studies could examine potential effects of sea level rise on levees throughout the Delta.

5.6 Summary

5.6.1 Climate Change for Present Sea Level

The DSM2 model was used for preliminary assessment of potential climate change effects on the Delta for four scenarios. The four scenarios correspond to two greenhouse gas emissions scenarios represented by two global climate models. All four climate change scenarios represent warmer future conditions, and three scenarios reflect drier conditions. The fourth climate change scenario projects slightly wetter conditions.

Projected runoff for the climate change scenarios was used to drive an SWP and CVP operations model that provided Delta inflows and exports (see Chapter 4). These studies include the assumption that meeting Delta water quality standards is a top priority for the SWP and CVP operations. Thus the impacts assessment for the Delta already included some mitigation for climate change through modified system operations for maintaining Delta water quality standards. So Delta water quality effects for the four climate change scenarios were relatively minor. There were no significant changes in compliance with 250 mg/l chloride standard at the municipal and industrial intakes, and there was complete compliance with that standard at the SWP and CVP intakes for all of the scenarios. The only reduction in compliance with the 150mg/l chloride standard occurred for the two B1 climate change scenarios. Chloride mass loadings at the SWP for all climate change scenarios and CVP for the A2 scenarios were reduced for the climate change scenarios due to lower export rates. Overall, existing system flexibility was able to provide Delta water quality compliance for most of the climate change conditions examined.

For the water quality analysis, the choice of global climate model had more influence on the results than the choice of greenhouse gas emissions scenario. One way to address the uncertainties associated with climate models and emissions scenarios is to conduct analysis using multiple climate models representing multiple emissions scenarios.

5.6.2 Sea Level Rise

An analysis tool is not currently available to determine changes in system operations to maintain Delta water quality under sea level rise conditions. As a first step towards developing such a tool, preliminary studies were conducted for a one-foot sea level rise with present system operations. Simulated water quality constituent concentrations for sea level rise conditions with no changes in system operations were compared to threshold values as a surrogate for evaluating the effects of sea level rise on water project operations to meet existing standards.

Preliminary sea level rise studies examined changes in chloride concentrations at municipal and industrial intakes for a one-foot increase in sea level. Due to the uncertainties in how much salt would be transported into the Delta for sea level rise conditions, two scenarios were examined to provide a range of potential impacts. One scenario assumed that the EC at the DSM2 downstream boundary at Martinez did not change relative to present sea level conditions, and the second scenario assumed that Martinez EC increased based on results of a multi-dimensional modeling study.

Without adjusting system operations to try to lessen the effects of sea level rise, chloride concentrations at Old River at Rock Slough were below the 250 mg/l threshold about 90 percent of the time. In real time, operational adjustments will take place so these effects will translate into water supply impacts to the SWP and CVP. As stated above these impacts to water supply cannot be quantified at this time. Increased salt intrusion for the sea level rise scenarios lead to chloride concentrations that exceeded the 150 mg/l standard during some critical and dry years. Chloride mass loadings at all of the urban intakes increased due to higher chloride concentrations. Impacts were similar for the two salt intrusion assumptions.

5.6.3 Combined Climate Change and Sea Level Rise

Preliminary impacts assessments were also conducted for combined climate change and one-foot sea level rise scenarios. System operations were changed to reflect shifts in runoff patterns for climate change, but they were not changed to try to lessen the impacts of sea level rise. Comparisons of chloride concentrations with threshold values at municipal and industrial intakes and potential for overtopping Delta levees were examined. Comparisons of chloride concentrations with threshold values were similar to those for the sea level rise only scenarios. Chloride mass loadings for Old River at Rock Slough were similar for all of the combined climate change and sea level rise scenarios since the export rates were the same. For the SWP and CVP, chloride mass loadings for the combined climate change and sea level rise scenarios were lower than for the sea level rise only scenarios due to reduced export rates.

For the potential levee overtopping analysis, no potential overtoppings occurred for the present sea level conditions. A one-foot rise in sea level resulted in two potential overtoppings during the 16-year analysis. The overtopping potential was not changed when combined sea level rise and climate change conditions were examined. Effects of wind were not considered.

5.7 Future Directions

Future directions for Delta climate change studies may include extending existing analyses, improving analysis tools, investigating mitigation measures, and characterizing uncertainty.

A key area of interest is examining effects of sea level rise alone or combined with climate change on system operations. For the analysis approach presented in this report, an Artificial Neural Network (ANN) could be developed to represent sea level rise effects on Delta water quality. By incorporating a sea level rise ANN into the operations model CalSim-II, changes in system operations to reduce salt water intrusion into the Delta could be determined for sea level rise alone or combined with other climate change factors such as shifting runoff patterns. For

more detailed studies of sea level rise effects on the Delta using DSM2, an improved characterization of potential salt intrusion into the Delta could be developed.

Additional topics related to sea level rise that could be examined included extending the potential levee overtopping analysis to other areas of the Delta. Existing simulation results could be used to estimate sea level rise effects on the stability of Delta levees. Potential effects for a range of increases in sea level could be examined.

Flexibility of the existing system to mitigate for climate change could be explored. Possible mitigation measures could include modifying reservoir releases, Delta exports, Delta Cross Channel operations, and temporary barrier operations. If present system flexibility isn't sufficient for mitigation, additional measures could be investigated such as modifying operating rules or considering new system components such as the proposed South Delta operable gates.

The main focus of future efforts will be to characterize uncertainty related to the climate change projections. For managers to make decisions, information is needed on both the magnitude of potential effects and the likelihood of those effects.

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5.9 References

Anderson and Miller. (2005). Chapter 5: Estimation of Electrical Conductivity at Martinez for Sea Level Rise Conditions. In: *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 26th Annual Progress Report to the State Water Resources Control Board*. California Department of Water Resources. Sacramento, CA. October, 2005. http://modeling.water.ca.gov/delta/reports/annrpt/2005/2005Ch5.pdf

Ateljevich E. (2001a). Chapter 10: Planning Tide at the Martinez Boundary. In: *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 22nd Annual Progress Report to the State Water Resources Control Board*. California Department of Water Resources. Sacramento, CA. http://modeling.water.ca.gov/delta/reports/annrpt/2001/2001Ch10.pdf

Ateljevich E. (2001b). Chapter 11: Improving Estimates of Salinity at the Martinez Boundary. In: *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 22nd Annual Progress Report to the State Water Resources Control Board*. California Department of Water Resources. Sacramento, CA. http://modeling.water.ca.gov/delta/reports/annrpt/2001/2001Ch11.pdf

DWR (1995a). Sacramento San Joaquin Delta Atlas, California Department of Water Resources, Sacramento, CA, July 1995.

DWR (1995b). Estimation of Delta Island Diversions and Return Flows, California Department of Water Resources, Sacramento, CA, February 1995.

DWR (1995c). Representative Delta Island Return Flow Quality for DSM2, California Department of Water Resources, Sacramento, CA, May 1995.

DWR (2005). California Water Plan Update 2005, Volume 1-Stategic Plan, Chapter 4: Preparing for an Uncertain Future, California Department of Water Resources, Sacramento, CA, Public Review Draft. http://www.waterplan.water.ca.gov/cwpu2005/index.cfm

DWR (2006). http://www.publicaffairs.water.ca.gov/swp/delta.cfm accessed 1-19-06

Freeport (2003). Freeport Regional Water Project Draft EIR-EIS, Volume 3: Modeling Technical Appendix to the Draft Environmental Impact Report/Environmental Impact Statement, U.S. Department of the Interior, U.S. Bureau of Reclamation, the Freeport Regional Water Agency, Sacramento County Water Agency, and East Bay Municipal Water District, July 2003, http://www.freeportproject.org/deir/deir.html. Regression equations are on pg 4-34 of the following document http://www.freeportproject.org/deir/vol3/section04-3.pdf.

IPCC (2001). Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the IPCC, J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P. J. van der Linden and D. Xiaosu (Eds.), Cambridge University Press, UK. pp 944. http://www.grida.no/climate/ipcc_tar/wg1/index.htm

Roos (2004). Maury Roos, California State Hydrologist, California Department of Water Resources, personal communication.

Suits, B. (2001). Relationships between EC, chloride and bromide at Delta export locations. Technical Memo, California Department of Water Resources, Sacramento, CA, May 29, 2001

SWRCB (1995). Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary, 95-1WR, State Water Resources Control Board, California Environmental Protection Agency, Sacramento, CA, May 1995.

USBR (2004). Chapter 6: Analytical Approach and Methods. In: *Long-Term Central Valley Project Operations Criteria and Plan.* United States Bureau of Reclamation. Sacramento, CA. June 2004.

USBR (2005). CALSIM II San Joaquin River Model (Draft), United States Bureau of Reclamation. Sacramento, CA. April, 2005. http://science.calwater.ca.gov/pdf/calsim/CALSIMSJR_DRAFT_072205.pdf

5.10 Abbreviations

ANN-Artificial Neural Network

CalSim-II -SWP and CVP operations model

CCWD-Contra Costa Water District

CVP- Central Valley Project

CVPIA-Central Valley Project Improvement Act

CWEMF-California Water and Environmental Modeling Forum

D1641-State Water Resources Control Board Decision 1641 on Delta water quality standards

DICU-Delta Island Consumptive Use

DSM2-Delta Simulation Model 2

DWR-California Department of Water Resources

EC-Electrical conductivity, a measure of salinity

EWA-Environmental Water Account

GCM-Global Climate Model

GFDL-Geophysical Fluid Dynamic Lab model

GHG-Greenhouse Gas

HWY-Highway

IPCC-Intergovernmental Panel on Climate Change

PCM-Parallel Climate Model

SAC-Sacramento River

SJR-San Joaquin River

SLR-Sea Level Rise

SWP-State Water Project

VIC-Variable Infiltration Capacity Model

WY-Water Year (October 1 to September 30)

5.11 Appendix A: DSM2 Inputs

This appendix provides tables of selected DSM2 input values.

Delta Inflows

- Sacramento River at I Street Bridge in Sacramento (Table 5.35)
- San Joaquin River at Vernalis (Table 5.36)

Delta Exports and Diversions

- State Water Project at Banks Pumping Plant (Table 5.37)
- Central Valley Project at Tracy Pumping Plant (Table 5.38)
- Contra Costa Water District (combined Old River diversions from Rock Slough and Highway 4) (Table 5.39)

Table 5.35: DSM2 Input from CalSim-II: Sacramento River Flows (cfs) at Sacramento

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-75	17,863	12,673	15,573	12,573	18,478
Nov-75	15,078	10,890	15,630	12,904	15,027
Dec-75	15,560	12,797	10,636	12,305	12,111
Jan-76	12,235	11,534	10,353	11,179	10,769
Feb-76	13,354	11,566	11,863	11,525	12,199
Mar-76	15,068	13,413	14,648	13,372	16,710
Apr-76	9,702	9,426	9,545	9,416	9,575
May-76	8,046	7,712	7,866	7,698	7,962
Jun-76	12,821	12,959	13,584	13,365	12,460
Jul-76	13,228	12,146	12,819	12,773	14,190
Aug-76	10,993	9,908	10,486	10,253	9,844
Sep-76	10,147	8,321	8,635	8,385	9,643
Oct-76	7,811	7,763	7,771	7,765	7,796
Nov-76	7,248	7,212	7,217	7,214	7,237
Dec-76	9,348	6,752	6,757	6,753	6,959
Jan-77	8,192	8,340	8,205	8,391	8,523
Feb-77	9,469	7,897	7,842	7,662	7,767
Mar-77	7,440	7,684	7,668	7,931	8,175
Apr-77	8,567	8,571	8,571	8,647	8,568
May-77	5,704	5,676	5,676	5,727	6,472
Jun-77	9,537	9,491	9,488	9,584	11,312
Jul-77	12,700	10,150	11,568	11,522	12,680
Aug-77	8,588	7,802	8,600	8,577	8,462
Sep-77	8,245	6,735	8,250	8,155	8,249
Oct-77	7,735	7,075	6,849	7,453	7,737
Nov-77	7,130	7,243	7,144	7,545	7,131
Dec-77	15,471	15,716	15,260	15,648	15,269
Jan-78	63,890	66,446	62,893	68,715	70,086
Feb-78	52,536	61,753	49,313	58,126	58,664
Mar-78	61,373	73,262	67,423	73,271	73,503
Apr-78	36,433	32,776	34,568	32,730	43,377
May-78	19,397	16,344	16,791	16,361	19,043
Jun-78	14,823	18,805	15,368	18,962	14,920
Jul-78	21,490	20,468	21,705	20,659	21,695
Aug-78	17,756	16,396	18,032	16,428	18,322
Sep-78	14,949	13,515	14,838	13,525	15,417
Oct-78	10,305	10,412	10,261	10,496	10,554
Nov-78	11,755	10,079	10,253	10,900	10,332
Dec-78	8,667	11,206	8,289	13,404	8,383
Jan-79	22,527	20,491	20,858	20,771	23,862
Feb-79	37,221	31,858	33,244	31,778	34,859
Mar-79	30,147	30,228	29,440	28,700	35,538
Apr-79	17,240	16,918	17,122	16,936	18,364
May-79	15,250	13,358	13,481	13,342	15,409
Jun-79	21,138	17,435	20,789	17,316	21,275
Jul-79	17,481	14,629	14,538	14,535	18,448
Aug-79	15,445	14,908	15,200	14,721	16,023
Sep-79	14,046	10,527	12,708	10,577	14,030

Table 5.35: DSM2 Input from CalSim-II: Sacramento River Flows (cfs) at Sacramento (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-79	10,199	9,803	9,370	9,755	10,054
Nov-79	13,383	12,681	12,956	13,059	13,480
Dec-79	19,685	20,398	18,276	20,596	18,114
Jan-80	74,269	74,316	73,465	74,559	75,159
Feb-80	74,367	74,720	75,069	74,488	74,648
Mar-80	44,213	49,229	46,649	49,392	56,602
Apr-80	18,884	17,753	18,154	17,725	20,898
May-80	15,671	13,984	14,392	13,918	15,258
Jun-80	12,820	15,485	15,166	15,686	14,695
Jul-80	18,699	16,812	19,812	17,870	20,024
Aug-80	17,014	12,895	16,269	13,809	16,721
Sep-80	14,012	11,504	11,831	11,526	14,227
Oct-80	11,568	9,276	9,283	9,277	9,655
Nov-80	8,853	8,603	8,892	9,311	9,412
Dec-80	12,513	12,582	12,248	12,624	12,215
Jan-81	21,469	22,017	21,090	22,187	22,650
Feb-81	25,217	25,758	26,399	25,526	25,751
Mar-81	29,580	26,680	23,329	28,722	36,183
Apr-81	16,214	15,974	16,247	15,917	16,484
May-81	10,949	10,411	10,592	10,410	10,949
Jun-81	14,721	15,407	14,771	13,366	14,573
Jul-81	17,771	15,035	15,594	15,589	17,623
Aug-81	15,247	13,362	15,291	15,001	14,382
Sep-81	13,857	11,589	11,746	11,625	13,609
Oct-81	12,566	10,777	10,230	9,964	10,767
Nov-81	31,571	26,160	29,202	29,009	36,384
Dec-81	73,957	74,668	73,141	74,593	71,835
Jan-82	68,660	72,623	65,754	73,359	73,558
Feb-82	73,878	74,226	74,623	74,011	74,190
Mar-82	71,357	73,606	73,039	73,639	74,034
Apr-82	74,475	73,798	74,184	73,832	75,220
May-82	39,827	25,178	29,784	25,134	37,372
Jun-82	21,942	22,822	21,678	23,054	20,123
Jul-82	18,866	20,072	19,778	20,071	19,391
Aug-82	13,160	15,367	17,654	15,486	17,839
Sep-82	17,174	14,366	15,851	14,366	17,032
Oct-82	18,126	13,611	11,672	13,582	16,192
Nov-82	37,037	23,328	30,128	26,130	31,073
Dec-82	64,483	69,855	53,805	65,208	56,758
Jan-83	71,244	73,187	69,680	73,465	73,568
Feb-83	75,088	75,443	75,780	75,178	75,365
Mar-83	77,464	78,354	77,903	78,435	79,055
Apr-83	62,634	53,326	58,813	54,985	71,943
May-83	56,061	36,111	40,874	36,041	54,021
Jun-83	54,463	27,774	37,161	28,819	45,678
Jul-83	23,061	17,810	17,761	17,220	20,917
Aug-83	20,551	15,086	19,287	15,496	20,220
Sep-83	26,629	20,383	25,821	23,725	26,584

Table 5.35: DSM2 Input from CalSim-II: Sacramento River Flows (cfs) at Sacramento (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-83	19,560	18,926	17,794	18,379	20,092
Nov-83	65,368	58,660	66,296	65,578	66,043
Dec-83	75,185	76,378	74,491	76,092	74,203
Jan-84	50,683	56,494	47,666	60,827	58,266
Feb-84	34,027	38,624	39,952	34,452	36,023
Mar-84	35,425	41,224	38,921	42,305	47,338
Apr-84	18,696	15,098	16,030	17,764	16,792
May-84	12,643	11,476	11,870	11,464	12,820
Jun-84	19,109	17,812	19,570	17,638	18,568
Jul-84	21,758	20,377	21,425	19,743	21,795
Aug-84	14,080	13,763	14,187	13,266	14,183
Sep-84	14,779	12,694	14,475	12,857	14,665
Oct-84	11,554	8,854	9,588	8,693	11,936
Nov-84	29,685	21,119	23,591	22,448	31,207
Dec-84	21,806	24,234	20,176	23,951	19,602
Jan-85	12,452	12,730	12,348	12,856	13,483
Feb-85	16,394	16,905	17,631	16,676	16,981
Mar-85	14,160	15,214	14,520	15,131	16,039
Apr-85	12,790	13,613	11,785	13,992	13,247
May-85	14,989	14,016	15,616	14,531	13,849
Jun-85	14,037	14,331	14,008	14,228	14,252
Jul-85	19,094	17,618	19,092	18,904	19,097
Aug-85	17,293	15,333	16,993	16,981	16,591
Sep-85	14,941	13,139	14,170	13,117	14,585
Oct-85	12,015	9,803	9,836	9,866	13,121
Nov-85	10,466	9,763	10,561	10,429	12,359
Dec-85	15,952	17,338	15,763	16,933	15,634
Jan-86	23,798	25,091	23,209	25,287	23,469
Feb-86	78,551	79,043	79,619	78,795	79,214
Mar-86	74,396	75,360	74,894	75,150	75,843
Apr-86	19,689	18,055	18,799	17,987	21,630
May-86	12,499	10,540	10,741	10,535	11,724
Jun-86	11,145	14,936	14,934	15,649	14,786
Jul-86	19,681	17,973	18,771	17,934	20,008
Aug-86	17,254	13,466	14,070	13,628	16,407
Sep-86	15,048	12,126	12,302	12,172	13,601
Oct-86	11,832	9,715	9,758	9,594	10,523
Nov-86	9,365	8,659	9,277	8,836	9,973
Dec-86	8,963	9,138	8,880	9,095	8,821
Jan-87	13,430	13,782	13,318	14,007	14,193
Feb-87	20,787	21,380	21,964	21,151	21,399
Mar-87	24,272	25,424	24,766	25,359	27,271
Apr-87	14,647	11,084	11,220	11,123	13,941
May-87	10,242	9,405	9,625	9,715	10,549
Jun-87	11,241	10,612	11,017	10,924	12,352
Jul-87	13,153	9,857	10,225	10,409	13,477
Aug-87	12,465	9,952	10,892	9,818	13,397
Sep-87	11,011	9,363	9,597	9,153	10,943

Table 5.35: DSM2 Input from CalSim-II: Sacramento River Flows (cfs) at Sacramento (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-87	9,814	9,200	9,460	9,197	10,879
Nov-87	8,896	8,497	8,500	8,494	8,944
Dec-87	17,578	17,945	17,358	17,846	17,277
Jan-88	28,123	28,131	27,735	28,818	28,374
Feb-88	16,008	12,799	13,010	12,698	15,957
Mar-88	8,685	8,883	8,847	9,280	9,580
Apr-88	10,475	10,273	10,314	10,294	10,800
May-88	9,754	9,819	9,810	9,811	9,667
Jun-88	10,922	11,737	11,101	11,803	12,339
Jul-88	9,130	8,938	8,823	9,194	9,980
Aug-88	8,130	7,991	8,366	8,236	8,709
Sep-88	6,195	6,589	6,279	6,407	5,882
Oct-88	7,771	7,785	7,777	7,785	7,778
Nov-88	9,993	9,718	10,072	9,933	10,092
Dec-88	9,968	10,284	9,822	10,199	9,732
Jan-89	12,814	12,943	12,666	13,035	13,125
Feb-89	10,328	10,454	10,556	10,346	10,260
Mar-89	47,840	60,757	51,571	58,410	67,796
Apr-89	22,084	29,703	21,145	29,705	29,670
May-89	15,373	21,237	15,441	21,241	21,200
Jun-89	15,170	11,053	14,845	11,523	11,856
Jul-89	18,046	16,272	14,002	17,339	18,780
Aug-89	15,192	13,066	14,029	14,109	16,907
Sep-89	15,211	13,196	13,563	13,237	15,276
Oct-89	11,409	10,180	10,663	9,987	11,725
Nov-89	9,196	8,561	8,707	8,656	11,200
Dec-89	8,934	11,069	11,981	11,185	11,917
Jan-90	18,954	19,488	18,981	19,807	19,642
Feb-90	16,333	15,351	15,533	15,152	16,342
Mar-90	12,359	13,148	12,784	13,440	13,128
Apr-90	10,745	10,735	10,744	10,734	10,737
May-90	9,169	8,763	9,022	8,760	9,371
Jun-90	10,434	8,178	8,183	8,809	8,425
Jul-90	9,577	10,091	9,776	10,097	9,454
Aug-90	8,949	8,485	8,255	8,268	8,017
Sep-90	8,293	8,275	8,246	8,290	8,296
Oct-90	7,745	7,737	7,745	7,736	7,746
Nov-90	7,223	7,216	7,223	7,216	7,223
Dec-90	6,721	6,715	6,721	6,715	7,010
Jan-91	6,576	6,577	6,539	6,808	6,820
Feb-91	8,350	8,366	8,605	8,439	8,472
Mar-91	31,783	32,148	32,136	32,314	33,002
Apr-91	13,266	12,800	13,143	13,105	14,314
May-91	8,786	7,652	8,089	7,999	8,964
Jun-91	8,093	7,229	7,304	7,044	10,171
Jul-91	10,700	11,045	11,079	11,296	11,223
Aug-91	8,100	6,830	7,907	7,336	8,264
Sep-91	8,471	6,190	7,793	8,392	8,355

Table 5.36: DSM2 Input from CalSim-II: San Joaquin River Flows (cfs) at Vernalis

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-75	2,946	2,063	2,421	2,019	2,652
Nov-75	1,805	1,753	1,918	1,732	1,856
Dec-75	1,910	1,858	1,885	1,837	1,904
Jan-76	1,721	1,669	1,693	1,648	1,715
Feb-76	1,933	1,879	2,039	1,858	2,021
Mar-76	1,775	1,662	1,690	1,661	1,734
Apr-76	2,450	2,442	2,447	2,445	2,450
May-76	2,262	2,249	2,256	2,254	2,261
Jun-76	1,486	1,449	1,470	1,463	1,483
Jul-76	1,427	1,152	1,407	1,108	1,423
Aug-76	1,347	857	911	858	1,139
Sep-76	1,178	1,160	1,171	1,162	1,179
Oct-76	3,209	3,101	3,131	2,915	3,171
Nov-76	2,100	2,050	2,078	2,050	2,090
Dec-76	1,693	1,642	1,670	1,643	1,682
Jan-77	1,306	1,189	1,220	1,191	1,264
Feb-77	1,383	1,260	1,294	1,265	1,340
Mar-77	1,275	1,268	1,272	1,256	1,275
Apr-77	1,702	1,698	1,700	1,624	1,702
May-77	1,581	1,574	1,577	1,480	1,581
Jun-77	1,236	1,216	1,223	1,209	1,236
Jul-77	798	684	788	685	788
Aug-77	680	646	673	647	680
Sep-77	982	956	975	958	981
Oct-77	1,454	1,442	1,626	1,200	1,454
Nov-77	1,351	1,270	1,350	1,262	1,351
Dec-77	1,524	1,518	1,522	1,535	1,524
Jan-78	3,727	3,247	3,248	3,248	3,251
Feb-78	7,843	8,901	8,385	6,816	7,735
Mar-78	9,089	10,909	10,055	9,268	9,773
Apr-78	12,921	14,729	13,976	12,726	14,273
May-78	11,897	12,235	12,588	9,647	13,952
Jun-78	11,295	3,840	7,262	3,687	7,372
Jul-78	2,470	2,263	2,263	2,263	2,263
Aug-78	1,908	1,908	1,908	1,908	1,908
Sep-78	2,194	1,614	1,614	1,614	1,725
Oct-78	4,206	2,408	3,694	2,621	4,202
Nov-78	1,648	1,606	1,681	1,604	1,650
Dec-78	1,829	1,787	1,823	1,898	1,831
Jan-79	3,851	4,284	3,770	4,278	4,363
Feb-79	9,064	5,809	6,625	4,816	10,257
Mar-79	8,638	6,609	9,480	5,839	10,407
Apr-79	6,349	6,369	6,482	5,729	6,790
May-79	5,904	5,597	5,868	5,008	6,114
Jun-79	2,190	2,093	2,116	2,094	2,334
Jul-79	1,849	1,803	1,818	1,805	1,849
Aug-79	1,764	1,694	1,705	1,695	1,764
Sep-79	1,870	1,820	1,837	1,797	1,883

Table 5.36: DSM2 Input from CalSim-II: San Joaquin River Flows (cfs) at Vernalis (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-79	2,255	2,200	2,236	2,081	2,281
Nov-79	1,808	1,732	1,788	1,618	1,821
Dec-79	1,945	1,866	1,923	1,752	1,958
Jan-80	11,058	10,135	7,211	7,463	11,747
Feb-80	21,061	24,227	27,335	12,986	26,166
Mar-80	13,100	17,772	15,092	14,019	16,080
Apr-80	7,544	9,844	9,434	8,528	9,136
May-80	6,767	6,218	6,527	5,690	7,183
Jun-80	5,214	2,445	2,766	2,405	2,891
Jul-80	3,864	1,952	2,135	1,920	2,262
Aug-80	2,014	1,788	1,916	1,766	2,006
Sep-80	2,611	1,708	1,770	1,689	2,211
Oct-80	4,278	1,988	2,940	1,979	3,763
Nov-80	1,742	1,688	1,718	1,634	1,740
Dec-80	1,885	1,829	1,859	1,776	1,883
Jan-81	2,106	2,023	2,057	2,019	2,085
Feb-81	2,547	2,280	2,523	2,280	2,604
Mar-81	3,483	2,240	3,957	2,220	4,303
Apr-81	4,327	3,907	4,340	3,906	4,588
May-81	3,461	2,767	3,806	2,710	3,750
Jun-81	1,710	1,671	1,702	1,676	1,683
Jul-81	1,678	1,631	1,668	1,637	1,645
Aug-81	1,625	1,589	1,617	1,486	1,600
Sep-81	1,567	1,311	1,561	1,310	1,549
Oct-81	2,104	2,042	2,100	2,027	2,100
Nov-81	1,708	1,661	1,689	1,657	1,703
Dec-81	1,760	1,711	1,741	1,707	1,754
Jan-82	6,242	6,697	4,673	5,878	5,941
Feb-82	13,580	16,895	17,143	10,856	17,456
Mar-82	14,865	19,929	16,487	15,515	18,363
Apr-82	24,622	30,388	29,743	27,701	29,908
May-82	16,058	14,288	15,150	12,939	16,504
Jun-82	9,692	3,738	4,247	3,738	5,012
Jul-82	3,715	2,511	2,804	2,511	3,191
Aug-82	2,199	2,199	2,199	2,199	2,199
Sep-82	3,563	1,837	3,331	1,837	3,382
Oct-82	12,098	3,340	8,876	3,369	10,131
Nov-82	7,981	5,876	9,890	9,739	9,744
Dec-82	18,184	21,017	13,073	17,211	13,383
Jan-83	23,332	28,727	23,427	29,754	26,805
Feb-83	31,051	35,096	38,220	26,681	34,742
Mar-83	37,383	47,697	41,589	39,407	44,295
Apr-83	19,986	23,136	22,652	21,521	22,363
May-83	20,416	19,270	19,789	17,881	20,879
Jun-83	34,195	10,326	20,598	9,633	22,664
Jul-83	17,655	3,333	9,375	3,997	13,234
Aug-83	2,082	2,082	2,082	2,082	2,082
Sep-83	5,958	3,069	4,827	3,339	5,236

Table 5.36: DSM2 Input from CalSim-II: San Joaquin River Flows (cfs) at Vernalis (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-83	11,980	5,880	11,773	5,759	11,820
Nov-83	12,960	8,708	15,882	15,330	15,748
Dec-83	20,682	28,501	16,607	23,593	15,626
Jan-84	14,354	18,070	14,455	18,775	16,712
Feb-84	9,683	10,593	12,064	7,987	10,999
Mar-84	6,092	8,591	6,980	6,525	8,034
Apr-84	5,530	5,551	5,552	5,433	5,680
May-84	5,064	4,948	5,015	4,908	5,065
Jun-84	2,627	2,428	2,540	2,356	2,629
Jul-84	2,243	2,184	2,235	2,188	2,243
Aug-84	2,137	2,099	2,135	2,101	2,139
Sep-84	1,969	1,938	1,959	1,932	1,969
Oct-84	2,343	2,301	2,327	2,288	2,343
Nov-84	1,922	1,900	1,914	1,894	1,922
Dec-84	1,971	1,948	1,963	1,942	1,971
Jan-85	1,791	1,764	1,782	1,758	1,791
Feb-85	2,211	2,174	2,201	2,169	2,211
Mar-85	2,191	2,098	2,172	2,081	2,188
Apr-85	3,241	2,573	3,241	2,574	3,241
May-85	3,491	2,376	3,086	2,383	3,419
Jun-85	1,744	1,731	1,745	1,752	1,746
Jul-85	1,651	1,635	1,652	1,660	1,653
Aug-85	1,580	1,133	1,581	1,018	1,582
Sep-85	1,577	1,346	1,339	1,352	1,527
Oct-85	2,119	2,012	2,086	2,001	2,114
Nov-85	1,698	1,740	1,674	1,738	1,695
Dec-85	1,776	1,818	1,753	1,817	1,774
Jan-86	2,182	1,674	1,751	1,662	1,765
Feb-86	13,469	16,280	19,260	7,964	18,396
Mar-86	23,294	33,269	28,189	20,725	30,362
Apr-86	12,075	14,596	14,225	13,234	13,765
May-86	8,356	7,526	7,894	6,515	8,604
Jun-86	6,517	2,130	2,801	2,130	2,752
Jul-86	2,389	2,370	2,378	2,129	2,387
Aug-86	2,169	2,154	2,161	2,070	2,168
Sep-86	2,169	2,153	2,160	2,062	2,167
Oct-86	2,566	2,105	2,112	2,104	2,127
Nov-86	1,748	1,742	1,745	1,696	1,748
Dec-86	1,794	1,787	1,790	1,741	1,794
Jan-87	1,675	1,663	1,669	1,618	1,674
Feb-87	2,041	2,019	2,029	1,974	2,039
Mar-87	1,961	1,855	1,870	1,855	1,934
Apr-87	2,475	2,464	2,467	2,467	2,483
May-87	2,287	2,268	2,274	2,273	2,299
Jun-87	1,531	1,476	1,491	1,491	1,566
Jul-87	1,514	1,205	1,466	1,196	1,555
Aug-87	1,252	825	833	826	1,064
Sep-87	1,197	1,171	1,182	1,173	1,208

Table 5.36: DSM2 Input from CalSim-II: San Joaquin River Flows (cfs) at Vernalis (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-87	1,676	1,588	1,593	1,590	1,658
Nov-87	1,330	1,279	1,301	1,282	1,327
Dec-87	1,288	1,236	1,258	1,238	1,286
Jan-88	1,280	1,169	1,185	1,173	1,261
Feb-88	1,326	1,206	1,224	1,212	1,313
Mar-88	1,254	1,250	1,250	1,250	1,252
Apr-88	1,719	1,713	1,714	1,713	1,716
May-88	1,586	1,578	1,578	1,577	1,582
Jun-88	1,262	1,239	1,240	1,238	1,251
Jul-88	969	993	1,020	979	1,003
Aug-88	688	670	677	666	685
Sep-88	1,033	1,014	1,022	1,010	1,029
Oct-88	1,554	1,345	1,522	1,309	1,552
Nov-88	1,279	1,201	1,273	1,227	1,278
Dec-88	1,391	1,358	1,384	1,358	1,389
Jan-89	1,183	1,175	1,178	1,176	1,180
Feb-89	1,360	1,349	1,351	1,349	1,355
Mar-89	1,596	1,592	1,595	1,590	1,596
Apr-89	1,727	1,695	1,714	1,696	1,737
May-89	1,439	1,403	1,418	1,407	1,453
Jun-89	1,292	1,255	1,256	1,277	1,322
Jul-89	1,292	1,200	1,286	1,116	1,281
Aug-89	803	789	793	784	811
Sep-89	1,164	1,150	1,154	1,149	1,173
Oct-89	1,370	1,321	1,322	1,308	1,579
Nov-89	1,324	1,225	1,236	1,314	1,328
Dec-89	1,254	1,154	1,161	1,157	1,258
Jan-90	1,194	1,183	1,186	1,188	1,201
Feb-90	1,380	1,363	1,365	1,372	1,392
Mar-90	1,315	1,314	1,314	1,313	1,315
Apr-90	1,570	1,566	1,568	1,564	1,571
May-90	1,307	1,304	1,305	1,301	1,308
Jun-90	1,164	1,162	1,163	1,161	1,164
Jul-90	1,062	935	1,013	907	1,065
Aug-90	728	721	724	716	730
Sep-90	1,085	1,080	1,082	1,007	1,086
Oct-90	1,212	1,051	1,052	1,016	1,257
Nov-90	1,173	1,173	1,173	1,133	1,173
Dec-90	1,130	1,130	1,130	1,130	1,130
Jan-91	1,006	1,004	1,033	1,003	1,033
Feb-91	1,128	1,133	1,149	1,106	1,149
Mar-91	2,387	2,383	2,385	2,383	2,387
Apr-91	2,245	2,230	2,237	2,228	2,246
May-91	1,690	1,672	1,681	1,670	1,692
Jun-91	1,106	1,074	1,092	1,088	1,118
Jul-91	1,073	1,035	1,056	1,006	1,087
Aug-91	777	757	767	755	780
Sep-91	1,026	1,008	1,017	1,008	1,029

Table 5.37: DSM2 Input from CalSim-II: State Water Project Exports (cfs)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-75	6,680	5,334	6,680	5,136	6,680
Nov-75	6,680	2,328	6,680	2,673	6,680
Dec-75	7,013	1,380	300	1,343	4,367
Jan-76	3,972	4,234	3,115	3,903	3,365
Feb-76	3,987	2,609	2,467	2,564	2,921
Mar-76	3,416	2,757	3,199	3,197	4,403
Apr-76	1,721	1,557	1,638	1,551	1,677
May-76	1,517	1,357	1,436	1,352	1,479
Jun-76	3,152	2,884	3,430	2,989	2,909
Jul-76	2,424	3,386	4,162	3,629	2,996
Aug-76	4,808	2,775	3,553	2,984	3,632
Sep-76	3,672	1,828	2,119	1,906	3,174
Oct-76	2,792	2,063	1,780	1,987	2,391
Nov-76	2,945	1,177	1,780	1,582	2,558
Dec-76	3,049	1,888	1,925	1,715	2,558
Jan-77	2,764	2,096	2,013	2,232	2,493
Feb-77	919	1,077	1,034	855	858
Mar-77	497	1,219	1,200	1,455	1,706
Apr-77	300	300	300	300	300
May-77	413	300	300	300	1,105
Jun-77	300	300	300	300	300
Jul-77	461	300	352	329	461
Aug-77	306	300	300	300	342
Sep-77	1,703	2,079	1,609	1,564	1,701
Oct-77	763	2,347	2,634	2,869	542
Nov-77	1,386	1,245	1,623	1,527	1,477
Dec-77	5,717	4,210	5,565	6,102	5,635
Jan-78	7,455	6,934	6,589	5,577	6,930
Feb-78	4,092	4,233	3,679	4,380	4,316
Mar-78	5,115	5,337	4,977	5,280	5,440
Apr-78	5,516	5,490	5,546	5,464	5,452
May-78	4,844	4,532	4,899	1,620	4,758
Jun-78	4,713	4,046	3,490	4,047	3,374
Jul-78	6,680	6,680	6,680	6,680	6,680
Aug-78	6,680	5,991	6,526	6,001	6,680
Sep-78	6,680	5,362	6,227	5,368	6,680
Oct-78	4,174	3,199	3,828	3,427	4,421
Nov-78	3,417	2,198	3,262	2,847	2,991
Dec-78	1,695	3,108	1,504	4,863	1,312
Jan-79	7,964	8,108	7,937	8,106	8,134
Feb-79	8,500	8,500	8,500	8,285	8,500
Mar-79	7,561	7,561	7,561	7,561	7,561
Apr-79	4,020	3,844	4,317	3,626	4,429
May-79	3,718	3,780	3,657	3,018	3,795
Jun-79	3,948	3,494	3,868	2,918	4,188
Jul-79	4,454	4,744	4,676	4,245	4,830
Aug-79	5,754	5,608	5,731	5,436	5,970
Sep-79	6,005	3,021	5,188	3,030	6,006

Table 5.37: DSM2 Input from CalSim-II: State Water Project Exports (cfs) (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-79	3,597	3,693	2,835	3,676	3,743
Nov-79	4,239	3,534	4,844	3,851	4,279
Dec-79	7,019	7,008	7,015	7,000	7,021
Jan-80	8,500	8,500	8,500	8,500	8,500
Feb-80	8,437	8,347	8,069	8,267	7,726
Mar-80	5,072	4,241	4,471	4,264	4,656
Apr-80	4,535	3,940	4,204	3,967	4,403
May-80	4,163	4,375	4,417	3,682	4,365
Jun-80	2,250	3,405	3,407	3,433	3,181
Jul-80	6,680	6,296	6,680	6,494	6,680
Aug-80	6,680	5,053	6,680	5,478	6,680
Sep-80	6,680	4,577	4,834	4,578	6,680
Oct-80	5,889	2,631	2,791	2,665	3,713
Nov-80	1,759	1,288	1,704	1,299	1,989
Dec-80	3,629	4,282	3,639	4,403	2,941
Jan-81	7,382	7,354	7,366	7,353	7,375
Feb-81	5,654	5,499	5,808	5,418	5,610
Mar-81	7,074	5,293	5,231	5,134	6,529
Apr-81	2,707	2,564	2,801	2,544	2,890
May-81	2,127	1,935	2,126	1,915	2,152
Jun-81	2,909	2,957	1,605	300	3,015
Jul-81	5,219	3,016	3,038	3,425	5,038
Aug-81	5,079	4,970	5,913	5,837	4,900
Sep-81	5,546	3,940	4,198	3,978	5,665
Oct-81	3,896	3,225	3,244	3,092	3,602
Nov-81	6,680	6,680	6,680	6,680	6,680
Dec-81	7,002	6,993	6,998	6,992	7,001
Jan-82	8,500	8,500	8,238	8,500	8,500
Feb-82	8,500	8,500	8,500	8,500	8,500
Mar-82	7,561	7,535	7,561	7,352	7,561
Apr-82	6,125	6,125	6,125	6,125	6,125
May-82	6,177	6,177	6,177	6,177	6,177
Jun-82	6,680	4,984	4,873	5,025	4,869
Jul-82	6,680	6,680	6,680	6,680	6,680
Aug-82	3,304	6,077	6,680	6,115	6,680
Sep-82	6,680	6,680	6,680	6,680	6,680
Oct-82	6,680	6,680	6,680	6,680	6,680
Nov-82	6,680	6,680	6,680	6,680	6,680
Dec-82	7,678	7,678	6,761	7,678	6,755
Jan-83	3,472	3,477	3,476	3,477	3,474
Feb-83	3,548	3,548	3,548	3,548	3,548
Mar-83	3,555	3,555	3,555	3,555	3,555
Apr-83	3,749	3,749	3,749	3,749	3,749
May-83	3,171	3,171	3,171	3,171	3,171
Jun-83	3,877	3,877	3,877	3,877	3,877
Jul-83	6,638	6,119	6,638	6,194	6,638
Aug-83	6,680	6,680	6,680	6,680	6,680
Sep-83	5,039	5,573	5,039	5,496	5,039

Table 5.37: DSM2 Input from CalSim-II: State Water Project Exports (cfs) (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-83	3,682	3,682	3,682	3,682	3,682
Nov-83	3,144	3,144	3,144	3,144	3,144
Dec-83	3,723	3,723	3,723	3,723	3,723
Jan-84	5,640	5,640	5,640	5,640	5,640
Feb-84	6,531	6,509	6,531	6,506	6,531
Mar-84	6,635	6,564	6,619	6,564	6,635
Apr-84	3,499	1,880	1,914	3,413	3,356
May-84	2,899	2,781	2,825	2,776	2,916
Jun-84	3,974	3,875	4,039	3,425	3,880
Jul-84	5,093	4,771	5,062	4,269	5,198
Aug-84	4,981	4,630	5,090	4,132	5,086
Sep-84	6,680	5,772	6,680	5,850	6,606
Oct-84	5,541	3,916	4,371	3,928	5,726
Nov-84	6,680	6,680	6,680	6,680	6,680
Dec-84	7,040	7,036	7,039	7,035	7,040
Jan-85	4,443	4,703	4,340	4,822	5,478
Feb-85	4,167	4,490	4,719	4,438	4,432
Mar-85	2,560	3,215	2,356	2,791	2,362
Apr-85	2,356	2,230	2,221	2,249	2,393
May-85	2,497	2,183	2,424	2,219	2,387
Jun-85	2,795	2,843	2,790	2,829	2,833
Jul-85	6,680	6,680	6,680	6,680	6,680
Aug-85	6,680	6,647	6,680	6,601	6,680
Sep-85	6,680	5,123	5,685	5,003	6,680
Oct-85	5,411	3,610	3,525	3,524	5,886
Nov-85	3,894	3,880	3,899	3,804	4,363
Dec-85	6,900	6,825	6,480	6,995	6,687
Jan-86	7,407	7,238	7,264	7,234	7,268
Feb-86	8,500	8,500	8,500	8,500	8,500
Mar-86	5,388	5,384	5,460	5,002	6,084
Apr-86	4,901	4,149	4,423	4,276	4,806
May-86	4,988	3,857	4,063	2,623	4,857
Jun-86	2,020	3,206	3,323	3,329	3,288
Jul-86	6,680	5,564	6,680	5,711	6,680
Aug-86	6,680	5,297	5,562	5,319	6,680
Sep-86	6,680	5,134	5,253	5,098	6,102
Oct-86	4,471	3,129	2,563	3,236	3,110
Nov-86	1,302	1,147	1,445	1,251	1,445
Dec-86	2,356	3,245	2,325	2,916	2,166
Jan-87	6,572	4,826	4,640	4,970	5,308
Feb-87	7,360	6,872	7,356	7,210	7,360
Mar-87	5,086	4,197	4,435	4,156	4,764
Apr-87	2,141	300	300	300	2,064
May-87	300	300	300	300	300
Jun-87	300	300	300	300	526
Jul-87	3,445	810	1,071	985	2,692
Aug-87	5,279	3,225	4,076	2,304	5,073
Sep-87	3,863	2,927	3,056	2,910	3,498

Table 5.37: DSM2 Input from CalSim-II: State Water Project Exports (cfs) (cont.)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-87	2,809	2,360	2,481	2,263	2,860
Nov-87	2,071	1,875	2,146	1,985	2,175
Dec-87	6,629	6,341	6,220	6,375	3,961
Jan-88	7,107	7,070	7,075	7,071	7,100
Feb-88	1,428	1,588	1,612	1,322	1,368
Mar-88	511	702	664	1,102	1,424
Apr-88	1,482	1,448	1,464	1,450	1,507
May-88	1,407	1,412	1,411	1,411	1,399
Jun-88	300	1,043	300	892	803
Jul-88	482	300	300	300	382
Aug-88	300	300	300	300	300
Sep-88	942	1,005	950	966	876
Oct-88	1,138	910	1,049	772	820
Nov-88	2,515	2,167	2,742	2,573	2,810
Dec-88	2,780	3,420	2,456	3,057	2,273
Jan-89	3,282	3,395	3,246	3,554	3,660
Feb-89	1,212	1,308	1,377	1,222	1,156
Mar-89	6,937	6,937	6,937	6,936	6,937
Apr-89	2,551	300	2,468	300	300
May-89	1,975	2,489	1,974	2,488	2,504
Jun-89	3,345	2,589	4,465	2,569	2,370
Jul-89	6,670	6,680	4,086	6,680	6,680
Aug-89	6,275	5,862	6,680	6,191	6,680
Sep-89	6,328	4,834	5,076	4,860	6,680
Oct-89	4,778	3,580	3,983	3,617	5,591
Nov-89	2,198	2,299	2,836	2,259	2,158
Dec-89	300	4,944	5,144	5,049	5,641
Jan-90	7,078	7,074	7,075	7,076	7,080
Feb-90	2,385	2,546	2,686	2,391	2,410
Mar-90	2,530	2,667	2,604	2,718	3,041
Apr-90	300	300	300	300	300
May-90	1,358	1,320	1,344	1,318	1,377
Jun-90	2,074	300	300	300	300
Jul-90	300	300	300	300	300
Aug-90	1,430	300	300	300	300
Sep-90	1,794	1,777	1,744	1,719	1,793
Oct-90	1,023	862	1,117	671	1,169
Nov-90	1,361	300	609	300	888
Dec-90	1,306	300	1,324	300	1,351
Jan-91	921	1,591	1,277	1,888	1,710
Feb-91	1,254	1,178	1,173	976	1,048
Mar-91	7,065	7,064	7,065	7,064	7,065
Apr-91	1,801	1,270	1,389	1,419	2,084
May-91	1,478	1,370	1,412	1,400	1,495
Jun-91	300	300	300	300	2,022
Jul-91	555	300	446	423	655
Aug-91	300	382	300	300	300
Sep-91	983	2,475	1,609	967	890

Table 5.38: DSM2 Input from CalSim-II: Central Valley Project Exports (cfs)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-75	4,600	4,449	4,600	4,554	4,600
Nov-75	4,600	3,497	4,600	4,600	4,600
Dec-75	4,600	800	1,200	800	4,342
Jan-76	4,229	4,600	4,600	4,600	4,183
Feb-76	3,174	3,723	4,071	3,740	3,417
Mar-76	2,717	2,757	2,758	2,303	2,291
Apr-76	1,721	1,557	1,638	1,551	1,677
May-76	1,517	1,357	1,436	1,352	1,479
Jun-76	1,436	1,753	1,853	2,031	1,480
Jul-76	1,315	1,602	1,752	1,940	1,357
Aug-76	2,518	1,756	1,830	2,001	2,345
Sep-76	3,242	3,271	3,302	3,257	3,247
Oct-76	2,448	3,625	3,637	3,565	3,024
Nov-76	1,767	2,780	2,481	2,172	1,842
Dec-76	1,689	1,841	1,590	2,197	950
Jan-77	2,489	2,387	2,623	2,134	2,504
Feb-77	2,616	800	800	800	955
Mar-77	800	800	800	800	800
Apr-77	800	800	800	800	800
May-77	800	800	800	800	1,105
Jun-77	1,026	800	800	800	2,643
Jul-77	2,509	600	1,927	1,813	2,272
Aug-77	2,979	1,789	2,732	2,679	2,979
Sep-77	3,078	1,889	3,169	3,101	3,083
Oct-77	3,050	1,013	600	600	3,051
Nov-77	1,489	1,758	1,420	1,444	1,691
Dec-77	4,600	3,795	4,209	4,427	4,257
Jan-78	4,600	4,600	4,600	4,600	4,600
Feb-78	4,600	4,600	4,600	4,600	4,600
Mar-78	1,894	4,262	4,091	3,681	2,206
Apr-78	2,692	2,538	2,692	2,692	2,692
May-78	3,896	3,896	3,896	3,896	3,896
Jun-78	4,600	4,046	4,600	4,047	4,600
Jul-78	4,600	3,354	4,600	3,546	4,600
Aug-78	4,600	4,232	4,488	4,323	4,600
Sep-78	4,600	4,600	4,600	4,600	4,600
Oct-78	4,600	3,885	4,390	3,954	4,600
Nov-78	3,964	2,907	2,872	2,906	3,325
Dec-78	3,010	4,377	2,914	4,377	2,993
Jan-79	4,600	4,600	4,600	4,600	4,600
Feb-79	4,548	4,600	4,600	4,600	4,600
Mar-79	2,589	4,600	4,600	4,600	4,281
Apr-79	3,646	3,844	3,284	3,626	3,647
May-79	3,718	2,948	3,334	3,018	3,795
Jun-79	4,161	800	3,811	1,247	4,211
Jul-79	3,999	800	800	1,191	4,596
Aug-79	4,549	3,838	4,008	4,048	3,822
Sep-79	4,478	4,389	4,401	4,397	4,478

Table 5.38: DSM2 Input from CalSim-II: Central Valley Project Exports (cfs)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-79	3,620	3,220	3,071	3,074	3,495
Nov-79	4,013	3,913	3,844	3,644	4,146
Dec-79	4,600	4,600	4,600	4,600	4,600
Jan-80	4,600	4,015	4,600	4,600	4,600
Feb-80	4,600	943	1,655	1,419	4,273
Mar-80	2,591	1,335	1,537	1,401	1,944
Apr-80	2,699	1,951	2,252	2,155	2,699
May-80	3,884	2,819	3,239	3,102	3,884
Jun-80	4,600	3,405	3,407	3,433	3,512
Jul-80	4,600	1,186	3,720	2,010	4,310
Aug-80	4,600	2,563	3,727	3,105	4,578
Sep-80	4,600	4,600	4,600	4,600	4,600
Oct-80	4,600	3,289	4,083	3,246	4,351
Nov-80	3,231	2,900	2,895	3,212	3,659
Dec-80	4,227	4,159	4,223	4,222	4,227
Jan-81	4,600	4,600	4,600	4,600	4,600
Feb-81	4,349	4,600	4,600	4,600	4,600
Mar-81	2,892	4,600	2,394	4,600	4,600
Apr-81	2,707	2,564	2,801	2,544	2,890
May-81	2,127	1,935	2,126	1,915	2,152
Jun-81	2,897	3,073	4,214	3,833	2,729
Jul-81	4,600	4,023	4,600	4,175	4,600
Aug-81	4,600	3,407	3,893	3,521	4,080
Sep-81	4,600	4,228	4,400	4,247	4,309
Oct-81	4,129	2,581	2,729	2,771	2,912
Nov-81	4,600	4,600	4,600	4,600	4,600
Dec-81	4,600	4,600	4,600	4,600	4,600
Jan-82	4,600	4,600	4,600	4,600	4,600
Feb-82	4,600	4,600	4,600	4,600	4,600
Mar-82	4,600	3,542	4,600	4,600	4,229
Apr-82	3,954	2,690	2,897	2,973	2,690
May-82	3,895	3,895	3,895	3,895	3,895
Jun-82	4,600	4,571	4,571	4,571	4,600
Jul-82	4,600	4,600	4,600	4,600	4,600
Aug-82	4,600	3,302	4,578	3,416	4,600
Sep-82	4,600	4,600	4,600	4,600	4,600
Oct-82	4,600	4,600	4,600	4,600	4,600
Nov-82	4,600	4,600	4,600	4,600	4,600
Dec-82	4,600	4,600	4,600	4,600	4,600
Jan-83	3,741	4,600	3,995	4,600	3,970
Feb-83	2,251	4,298	2,251	4,173	2,251
Mar-83	1,955	1,955	1,955	1,955	1,955
Apr-83	2,687	2,687	2,687	2,687	2,687
May-83	3,892	3,892	3,892	3,892	3,892
Jun-83	4,600	4,600	4,600	4,600	4,600
Jul-83	4,600	4,600	4,600	4,600	4,600
Aug-83	4,600	4,600	4,600	4,600	4,600
Sep-83	4,600	4,600	4,600	4,600	4,600

Table 5.38: DSM2 Input from CalSim-II: Central Valley Project Exports (cfs)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-83	4,600	4,600	4,600	4,600	4,600
Nov-83	3,310	4,093	4,093	4,093	4,006
Dec-83	1,445	1,445	1,445	1,445	1,445
Jan-84	1,919	1,919	1,919	1,919	1,919
Feb-84	2,869	2,173	2,173	2,872	2,692
Mar-84	3,032	2,154	2,898	2,741	3,026
Apr-84	3,499	2,743	3,188	3,413	3,356
May-84	2,899	2,781	2,825	2,776	2,916
Jun-84	3,974	3,274	4,039	3,381	3,880
Jul-84	4,600	3,591	4,483	3,717	4,590
Aug-84	4,600	4,600	4,600	4,600	4,600
Sep-84	4,600	4,128	4,394	4,151	4,600
Oct-84	4,468	3,589	3,888	3,403	4,533
Nov-84	4,600	4,600	4,600	4,600	4,600
Dec-84	4,600	4,600	4,600	4,600	4,600
Jan-85	4,600	4,600	4,600	4,600	4,600
Feb-85	4,600	4,490	4,600	4,438	4,600
Mar-85	3,523	3,204	3,846	3,593	4,378
Apr-85	2,356	2,230	2,221	2,249	2,393
May-85	2,497	1,912	2,469	2,219	2,387
Jun-85	2,795	2,843	2,790	2,829	2,833
Jul-85	4,600	3,103	4,600	4,416	4,600
Aug-85	4,600	2,669	4,386	3,712	4,073
Sep-85	4,191	4,423	4,529	4,532	3,927
Oct-85	3,006	2,036	2,867	2,588	3,049
Nov-85	2,765	2,842	2,671	2,820	4,129
Dec-85	4,600	4,600	4,600	4,600	4,600
Jan-86	4,600	4,600	4,600	4,600	4,600
Feb-86	4,600	4,600	4,600	4,600	4,600
Mar-86	4,600	4,600	4,573	4,600	3,828
Apr-86	2,254	1,725	1,808	1,865	2,049
May-86	3,016	2,318	2,627	2,340	2,962
Jun-86	4,600	2,785	3,323	3,329	3,288
Jul-86	3,097	800	800	800	1,651
Aug-86	4,525	3,383	3,345	3,161	4,522
Sep-86	4,600	4,600	4,600	4,600	4,600
Oct-86	4,600	3,377	3,988	3,145	4,217
Nov-86	4,424	3,683	3,896	3,681	4,569
Dec-86	2,622	2,084	2,822	2,316	2,789
Jan-87	2,590	4,221	4,223	4,221	4,393
Feb-87	2,336	3,676	3,287	3,570	2,926
Mar-87	1,901	1,526	1,677	1,533	1,885
Apr-87	2,141	800	800	800	2,064
May-87	1,507	956	1,182	1,194	1,730
Jun-87	2,001	1,072	1,438	1,458	2,949
Jul-87	2,015	879	1,315	1,339	3,138
Aug-87	1,895	800	1,117	1,436	2,740
Sep-87	3,440	2,715	2,830	2,526	3,751

Table 5.38: DSM2 Input from CalSim-II: Central Valley Project Exports (cfs)

Date	BASE	GFDL A2	PCM A2	GFDL B1	PCM B1
Oct-87	2,102	2,778	2,603	2,960	2,904
Nov-87	3,080	2,841	2,593	2,634	3,024
Dec-87	4,600	4,600	4,600	4,600	1,241
Jan-88	4,600	4,600	4,600	4,600	4,600
Feb-88	4,600	1,106	1,314	1,279	4,600
Mar-88	800	800	800	800	800
Apr-88	1,482	1,448	1,464	1,450	1,507
May-88	1,407	1,412	1,411	1,411	1,399
Jun-88	1,093	1,132	1,245	1,348	1,990
Jul-88	878	883	800	1,125	1,857
Aug-88	1,125	916	1,511	1,280	1,995
Sep-88	2,814	2,849	2,820	2,830	2,785
Oct-88	3,097	3,034	3,089	3,022	3,099
Nov-88	2,434	2,577	2,321	2,463	2,470
Dec-88	3,557	2,995	3,723	3,226	3,696
Jan-89	4,213	4,211	4,211	4,211	4,212
Feb-89	2,720	2,746	2,769	2,721	2,704
Mar-89	4,600	4,600	4,600	4,600	4,600
Apr-89	2,551	2,670	2,468	2,668	2,684
May-89	1,975	2,489	1,974	2,488	2,504
Jun-89	2,544	1,273	1,298	1,778	2,370
Jul-89	2,658	800	1,201	1,781	3,380
Aug-89	2,390	1,009	1,198	1,418	2,914
Sep-89	4,426	4,600	4,600	4,600	4,121
Oct-89	2,719	2,325	2,333	2,337	2,625
Nov-89	1,959	2,019	1,872	1,728	3,475
Dec-89	800	1,189	1,367	1,610	2,128
Jan-90	4,600	4,600	4,600	4,600	4,600
Feb-90	4,600	3,451	3,488	3,413	4,600
Mar-90	2,530	2,667	2,604	2,718	2,287
Apr-90	800	800	800	800	800
May-90	1,358	1,320	1,344	1,318	1,377
Jun-90	1,278	800	800	1,430	1,042
Jul-90	1,039	800	800	800	800
Aug-90	1,339	2,223	1,675	1,887	1,099
Sep-90	2,821	2,821	2,821	2,821	2,826
Oct-90	2,697	2,952	2,955	2,941	3,022
Nov-90	1,485	2,140	1,459	2,397	1,510
Dec-90	2,019	1,631	998	1,327	800
Jan-91	1,668	1,515	1,821	1,449	1,669
Feb-91	1,262	822	1,082	1,056	1,167
Mar-91	4,600	4,600	4,600	4,600	4,600
Apr-91	1,491	1,576	1,793	1,760	2,084
May-91	1,478	1,370	1,412	1,400	1,495
Jun-91	1,656	600	861	600	2,022
Jul-91	800	600	600	600	1,508
Aug-91	2,034	600	2,270	1,498	1,946
Sep-91	3,520	1,017	2,362	3,450	3,498

Table 5.39: DSM2 Input from CalSim-II: Contra Costa Water District Diversions (cfs)

Water Yr	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	220	187	148	120	99	197	0	145	249	164	168	279
1977	241	66	49	115	162	197	180	241	249	324	273	279
1978	241	193	177	143	162	99	111	220	281	511	538	464
1979	413	183	172	120	103	200	0	220	474	329	356	264
1980	236	183	146	120	61	99	0	220	418	327	355	264
1981	236	188	146	120	103	99	0	220	430	332	356	264
1982	236	185	145	120	103	34	0	220	479	327	355	264
1983	233	185	145	120	103	99	0	220	410	329	356	279
1984	223	143	181	122	101	99	0	220	435	329	356	281
1985	224	183	145	120	103	99	0	220	434	330	356	264
1986	237	150	145	120	56	150	0	220	420	327	355	264
1987	234	183	145	120	103	99	0	220	437	329	338	264
1988	96	71	99	120	99	99	0	220	281	153	231	103
1989	213	183	145	120	103	99	111	220	481	511	538	264
1990	213	183	145	120	103	197	0	241	249	250	233	166
1991	184	193	177	143	162	197	180	241	249	324	273	279

Note: Values represent combined Old River at Rock Slough and Old River at Highway 4 diversions.
CCWD diversions were identical for the base case and all climate change scenarios.

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5.12 Appendix B: Additional Chloride Exceedance Plots and Percentile Tables for Present Sea Level Scenarios

This appendix provides chloride exceedance plots and percentile tables computed from daily average DSM2 results at selected municipal and industrial intake locations.

- ❑ CCWD at Old River diversion at Highway 4 (Figure 5.17 and Table 5.40)
- ❑ SWP at Clifton Court Forebay (Figure 5.18 and Table 5.41)
- ❑ CVP at Tracy (Figure 5.19 and Table 5.42)

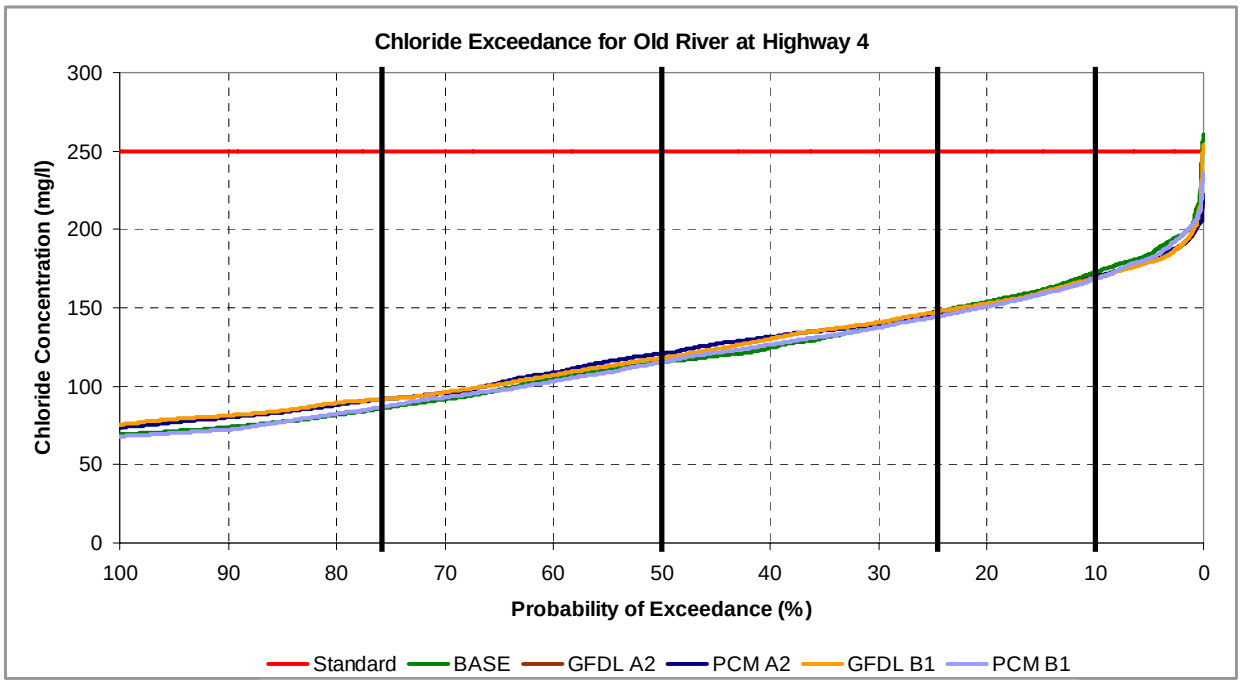

Figure 5.17: Probability of Exceedance for Chlorides at Old River at Highway 4

Table 5.40: Chloride Concentration Percentiles (mg/l) for Old River at Highway 4

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	11	21	33	69	133	170	183	85
GFDL A2	10	21	33	76	136	166	179	86
PCM A2	10	20	32	74	137	167	180	86
GFDL B1	14	22	35	75	137	167	179	87
PCM B1	10	20	31	68	133	166	181	83

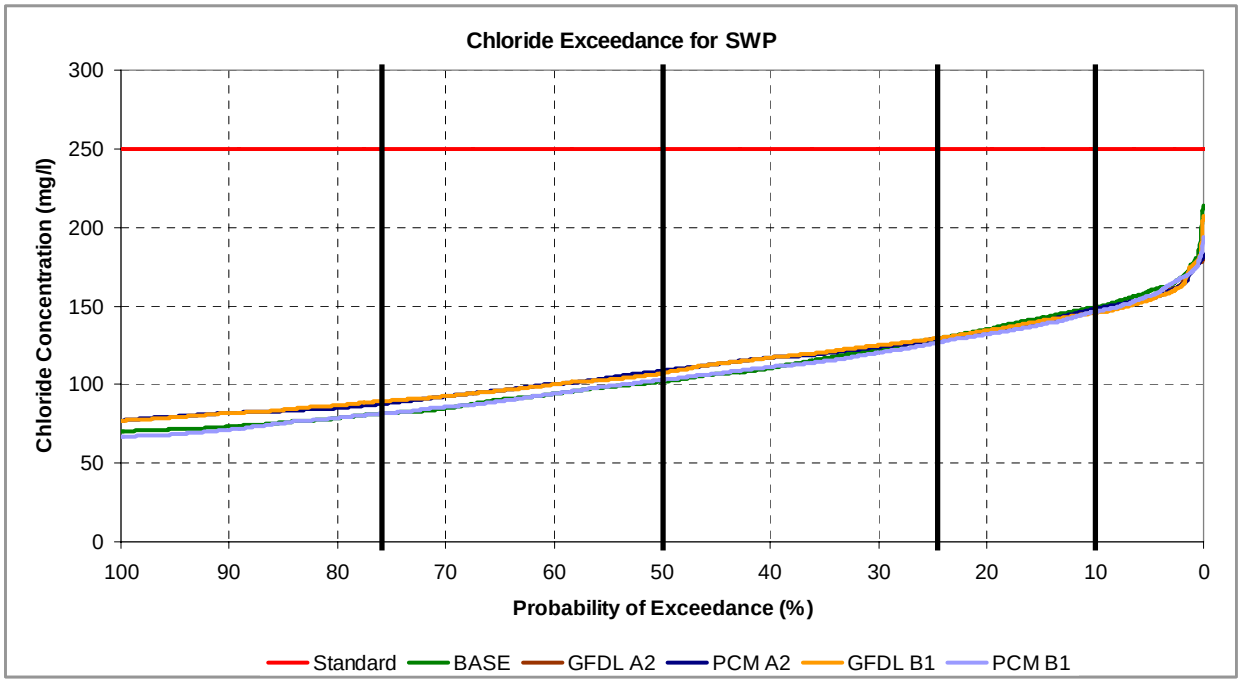

Figure 5.18: Probability of Exceedance for Chlorides at the State Water Project

Table 5.41: Chloride Concentration Percentiles (mg/l) for the State Water Project

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	10	22	34	70	119	148	158	78
GFDL A2	10	21	37	77	121	146	154	80
PCM A2	10	20	35	77	121	146	154	80
GFDL B1	10	25	39	77	122	145	153	81
PCM B1	10	19	33	67	116	145	156	76

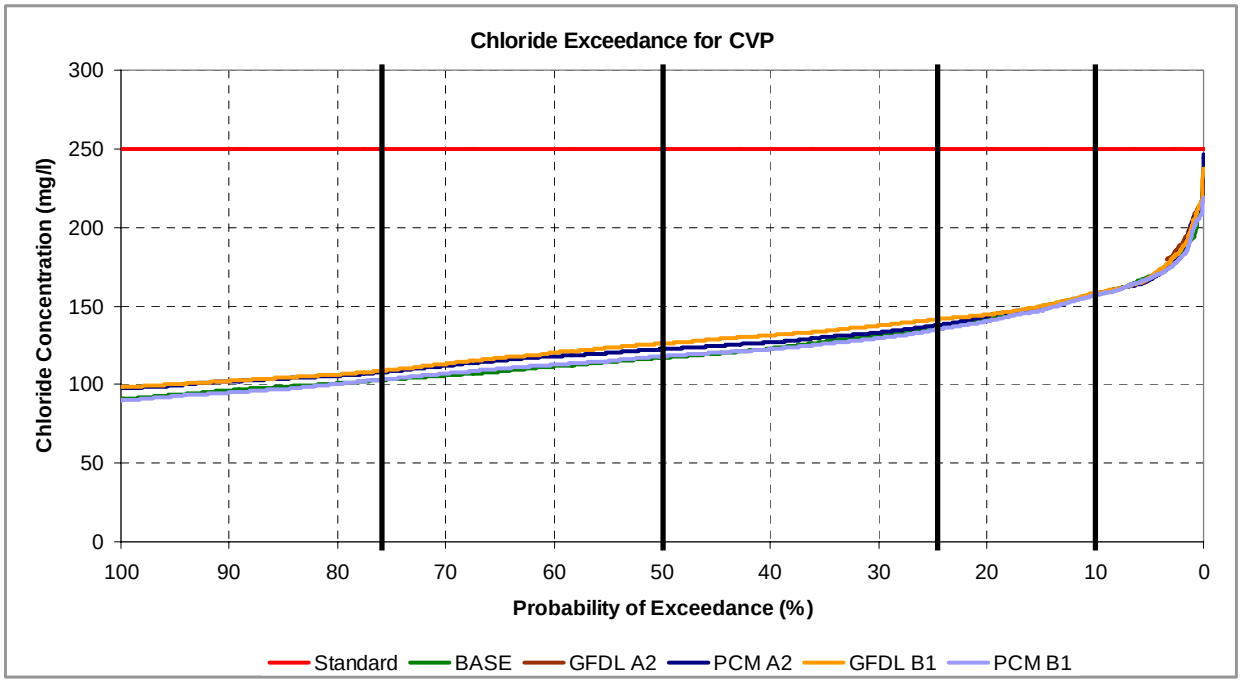

Figure 5.19: Probability of Exceedance for Chlorides at the Central Valley Project

Table 5.42: Chloride Concentration Percentiles (mg/l) for the Central Valley Project

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	10	16	53	91	129	155	168	91
GFDL A2	10	18	60	100	134	156	169	96
PCM A2	10	15	56	97	131	156	166	94
GFDL B1	11	26	60	99	135	156	167	97
PCM B1	10	15	54	90	127	155	167	90

5.13 Appendix D: Additional Chloride Exceedance Plots and Percentile Tables for One-Foot Sea Level Scenarios

This appendix provides chloride exceedance plots and percentile tables computed from daily average DSM2 results for one-foot sea level rise scenarios at selected municipal and industrial intake locations. No operations changes were made to try to reduce the effects of sea level rise.

- CCWD at Old River diversion at Highway 4 (Figure 5.20 and Table 5.43)
- SWP at Clifton Court Forebay (Figure 5.21 and Table 5.44)
- CVP at Tracy (Figure 5.22 and Table 5.45)

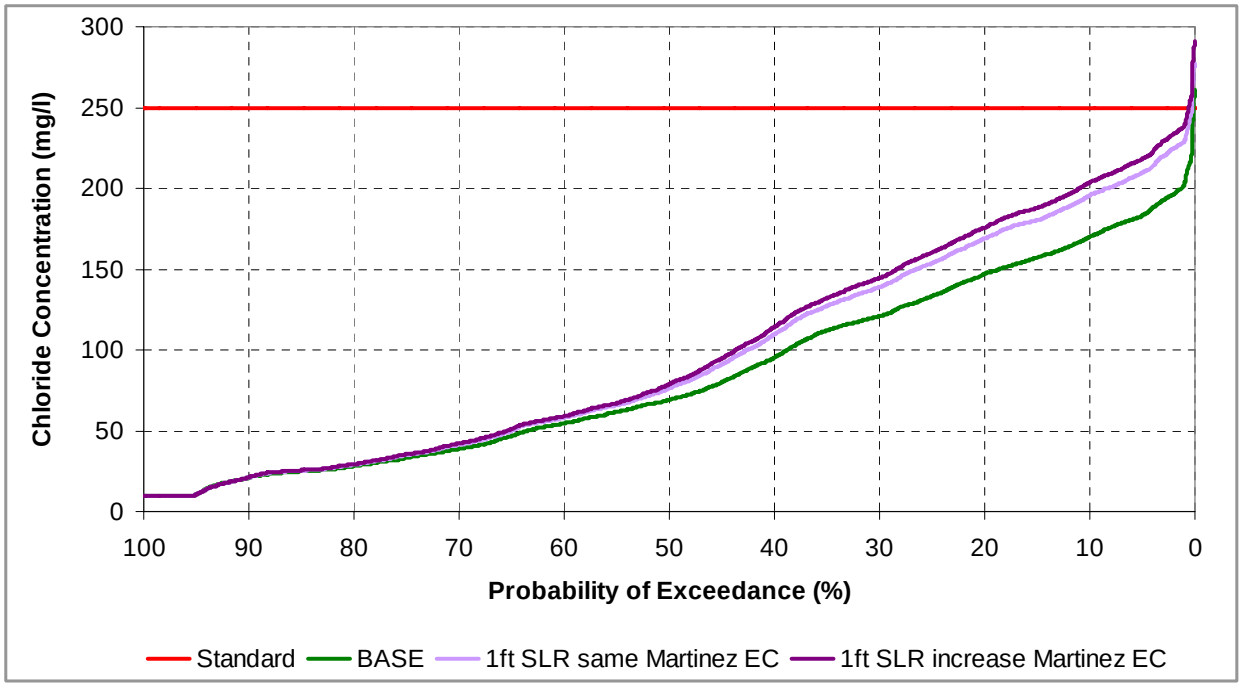

Figure 5.20: Probability of Exceedance for Chlorides at Old R. at Hwy 4 for a One-Foot Sea Level Rise and no Changes in System Operations

Table 5.43: Chloride Concentration Percentiles (mg/l) for Old R. at Hwy 4 for a One-Foot Sea Level Rise and no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	11	21	33	69	133	170	183	85
1ft SLR same Martinez EC	11	21	35	76	154	196	210	96
1ft SLR increase Martinez EC	11	21	35	79	160	204	218	99

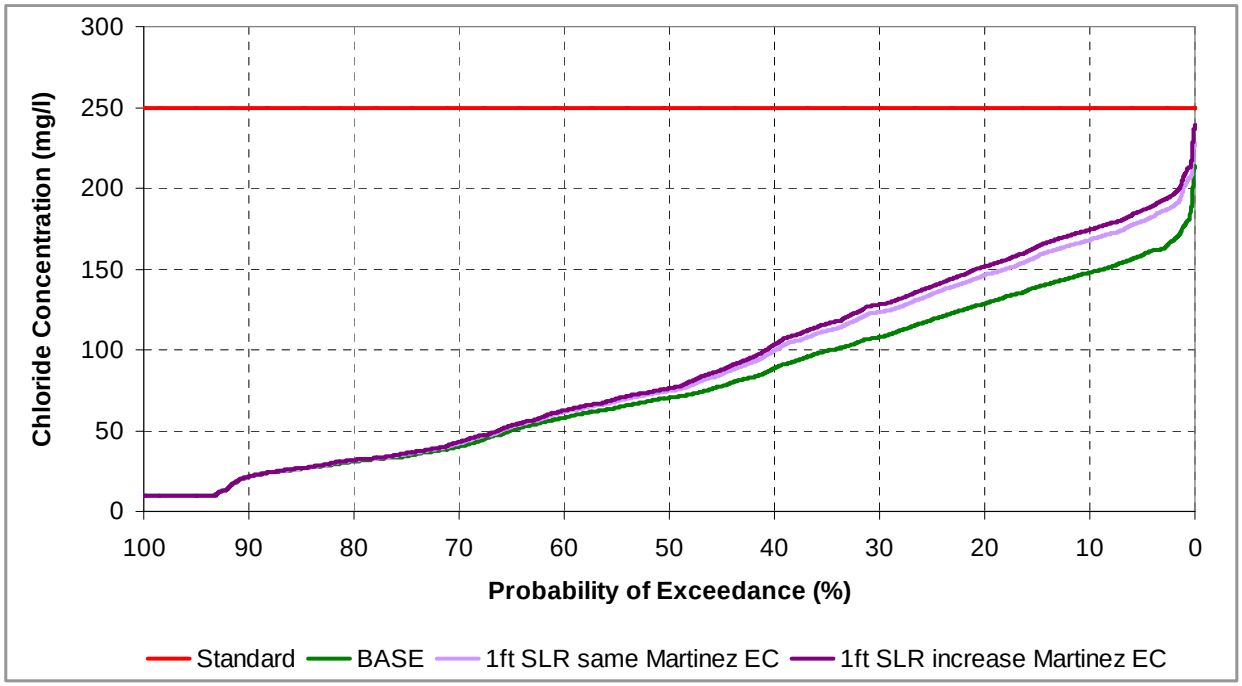

Figure 5.21: Probability of Exceedance for Chlorides at the State Water Project for a One-Foot Sea Level Rise and no Changes in System Operations

Table 5.44: Chloride Concentration Percentiles (mg/l) for the State Water Project for a One-Foot Sea Level Rise and no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	10	22	34	70	119	148	158	78
1ft SLR same Martinez EC	10	21	36	75	135	168	180	87
1ft SLR increase Martinez EC	10	22	36	76	139	174	186	89

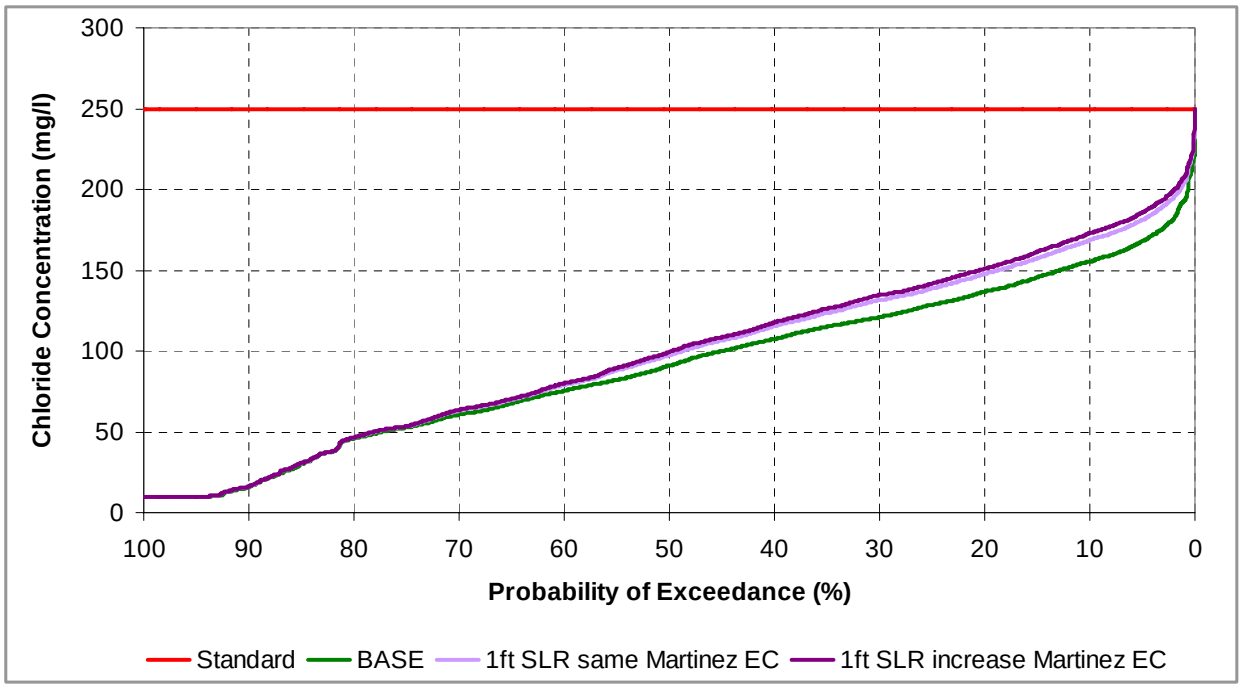

Figure 5.22: Probability of Exceedance for Chlorides at the Central Valley Project for a One-Foot Sea Level Rise and no Changes in System Operations

Table 5.45: Chloride Concentration Percentiles (mg/l) for the Central Valley Project for a One-Foot Sea Level Rise and no Changes in System Operations

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	10	16	53	91	129	155	168	91
1ft SLR same Martinez EC	10	16	53	97	139	169	181	97
1ft SLR increase Martinez EC	10	16	53	99	142	173	186	98

5.14 Appendix E: Additional Chloride Exceedance Plots and Percentile Tables for Combined Climate Change and One-Foot Sea Level Scenarios

This appendix provides chloride exceedance plots and percentile tables computed from daily average DSM2 results for combined climate change and one-foot sea level rise scenarios at selected municipal and industrial intake locations. No changes in operations were made to account for sea level rise (SLR).

- ❑ CCWD at Old River diversion at Highway 4 (Figure 5.23 and Table 5.46)
- ❑ SWP at Clifton Court Forebay (Figure 5.24 and Table 5.47)
- ❑ CVP at Tracy (Figure 5.25 and Table 5.48)

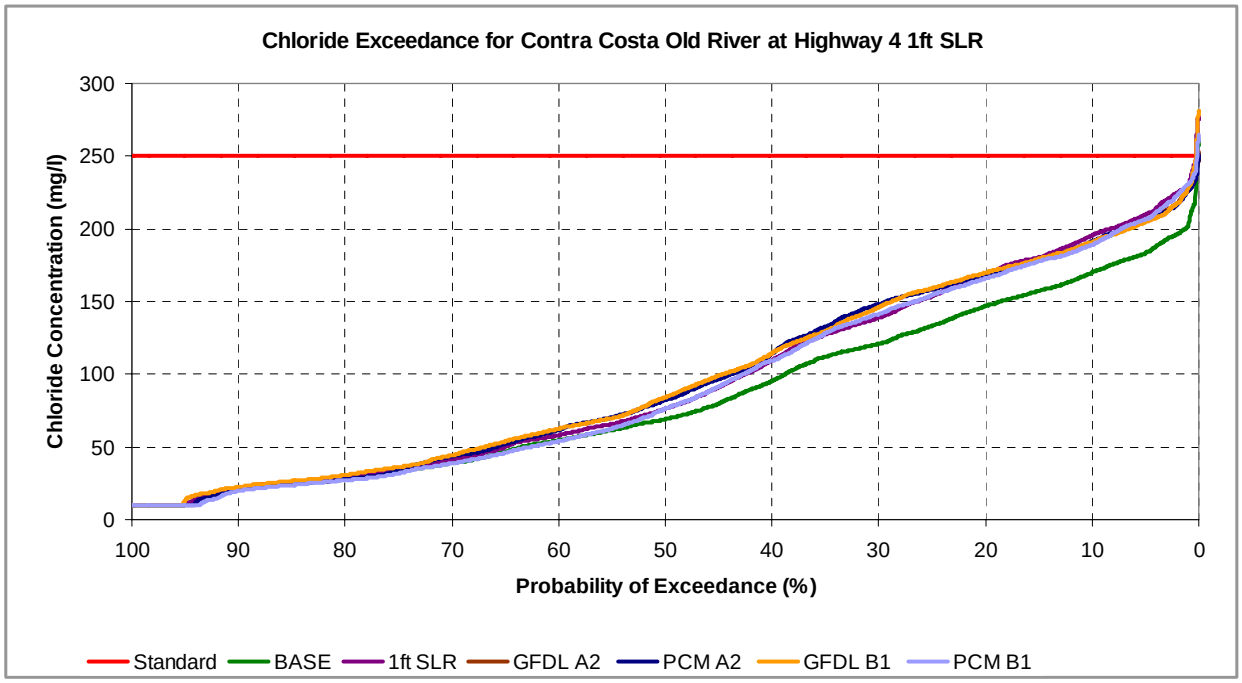

Figure 5.23: Probability of Exceedance for Chlorides at Old River at Highway 4 for Climate Change and a One-Foot Sea Level Rise and no Changes in Operations for SLR

Table 5.46: Chloride Concentration Percentiles (mg/l) for Old R. at Highway 4 for Climate Change and a One-Foot Sea Level Rise and no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	11	21	33	69	133	170	183	85
1ft SLR same Mtz EC	11	21	35	76	154	196	210	96
GFDL A2 1ft SLR	10	21	35	85	158	191	205	97
PCM A2 1ft SLR	10	21	35	82	158	191	206	97
GFDL B1 1ft SLR	13	22	36	84	159	191	205	98
PCM B1 1ft SLR	10	20	32	76	154	189	207	94

*All sea level rise scenarios in this table assume that Martinez EC is the same as in the present sea level scenarios.

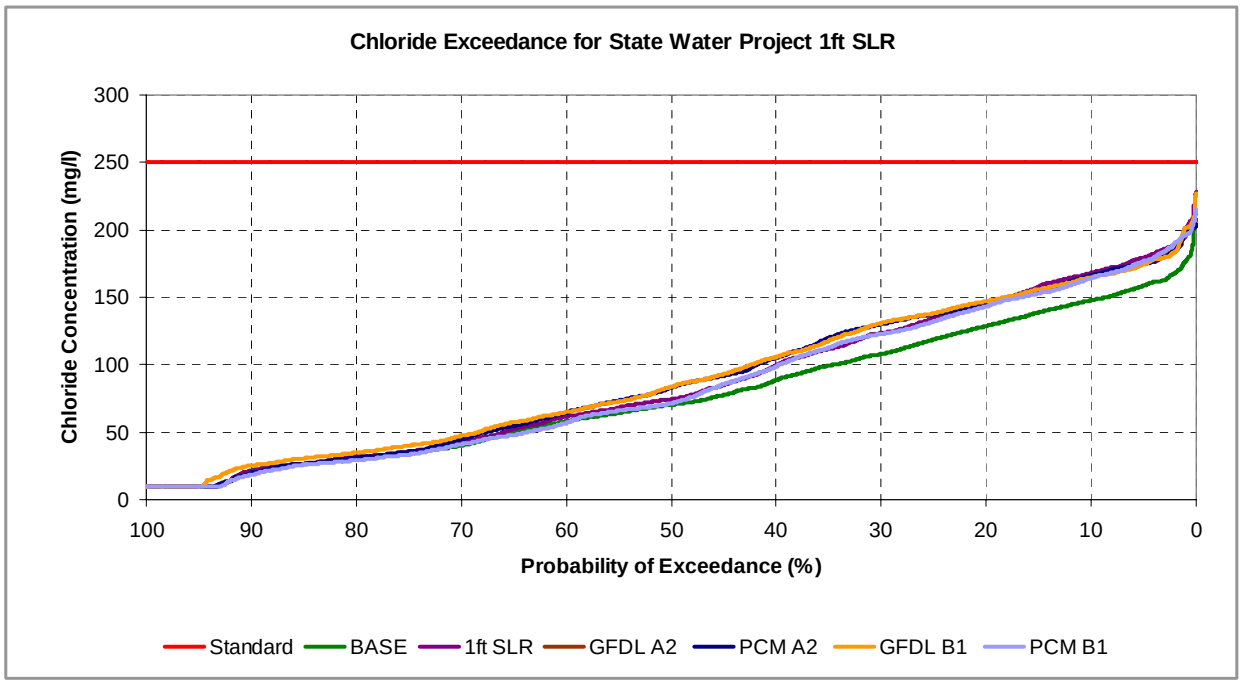

Figure 5.24: Probability of Exceedance for Chlorides at the State Water Project for Climate Change and a One-Foot Sea Level Rise and no Changes in Operations for SLR

Table 5.47: Chloride Concentration Percentiles (mg/l) for the State Water Project for Climate Change and a One-Foot Sea Level Rise and no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	10	22	34	70	119	148	158	78
1ft SLR same Mtz EC	10	21	36	75	135	168	180	87
GFDL A2 1ft SLR	10	22	38	83	138	166	175	89
PCM A2 1ft SLR	10	20	35	83	137	166	175	89
GFDL B1 1ft SLR	10	25	40	84	138	165	174	90
PCM B1 1ft SLR	10	18	33	71	132	164	177	85

*All sea level rise scenarios in this table assume that Martinez EC is the same as in the present sea level scenarios.

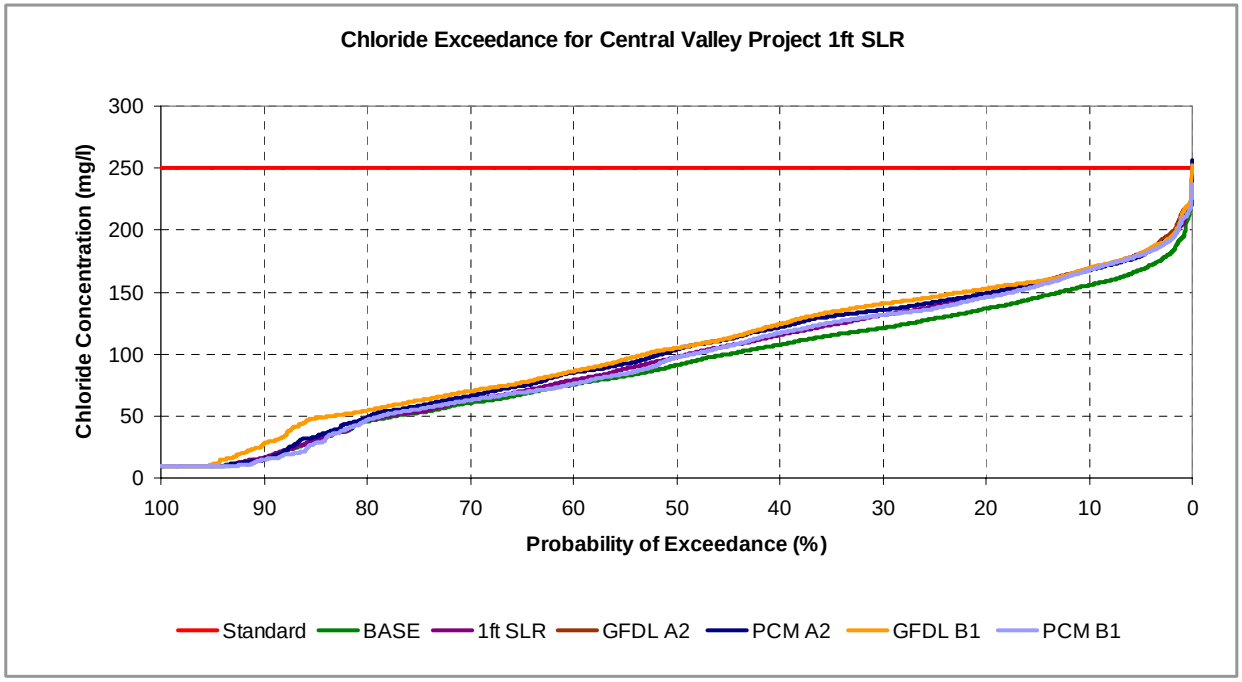

Figure 5.25: Probability of Exceedance for Chlorides at the Central Valley Project for Climate Change and a One-Foot Sea Level Rise and no Changes in Operations for SLR

Table 5.48: Chloride Concentration Percentiles (mg/l) for the Central Valley Project for Climate Change and a One-Foot Sea Level Rise and no Changes in Operations for SLR

	5%	10%	25%	50%	75%	90%	95%	Avg
BASE	10	16	53	91	129	155	168	91
1ft SLR same Mtz EC	10	16	53	97	139	169	181	97
GFDL A2 1ft SLR	10	18	63	105	145	170	182	103
PCM A2 1ft SLR	10	15	58	104	142	168	179	100
GFDL B1 1ft SLR	11	28	63	105	146	169	181	103
PCM B1 1ft SLR	10	15	55	97	137	167	180	96

*All sea level rise scenarios in this table assume that Martinez EC is the same as in the present sea level scenarios.

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
July 2006

Chapter 6:
Climate Change Impacts on Flood Management

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6 Climate Change Impacts on Flood Management

6.1 Introduction

Changing climate can have a significant impact on the timing and magnitude of precipitation and runoff in California. Climate is the time-averaged state of temperature, winds, precipitation and runoff. Flooding, however, results from individual weather events which can be considered random phenomena on the time scale of climate (e.g. 30 to 50 years). From year to year, there is a large amount of variability in winter rainfall and associated runoff patterns. This large variability creates uncertainty when evaluating changes in weather events due to climate change.

One way to address this uncertainty is to look at long-term precipitation, temperature, and runoff records in California and identify any trends that may have occurred over the past century. Future change can then be inferred from trends identified in the past record. However, a straight extrapolation of historical trends into the future may not be accurate.

Climate modeling tries to simulate these nonlinear components and their evolution with changing greenhouse gas levels in the atmosphere. Results from these global-scale simulations have been downscaled to provide information on potential changes over California. However, the model results provided relate to climate properties, not weather properties. Because of this, the results cannot be used directly to evaluate changes in specific rainfall and runoff patterns leading to floods or to changes in frequency of floods or droughts.

The climate model simulation data can be used to compare simulated future trends in precipitation, temperature, and runoff to historical trends. The model-derived trends also can be used to guide extrapolation of historical trends. Based on these efforts and using some assumptions, changes in runoff to a given rainfall pattern can be estimated using watershed models.

Such analyses are just the start of work that needs to be completed to evaluate climate change impacts on precipitation and the associated water supply or flood runoff in California. This chapter presents the initial work that has been done and outlines future work and data needed to complete such work. The topics covered in this chapter are illustrated in Figure 6-1. This chapter starts with a literature review of work on climate change and runoff in California. The chapter then examines the historical record for existing trends and investigates the information that can be obtained from the climate change scenarios selected for study by the state's Climate Action Team. After discussing the elements of the climate change scenario data that are not suitable for flood analysis, the chapter concludes with a description of climate change scenario data that would be suitable for analyzing climate change impacts on flood frequency and outlines future work directions. It is important to note that the work presented here is an analysis of past and potential future changes to California hydrology. It is not a recommendation for making changes to existing flood risk, flood frequency, or water supply practices and analyses.

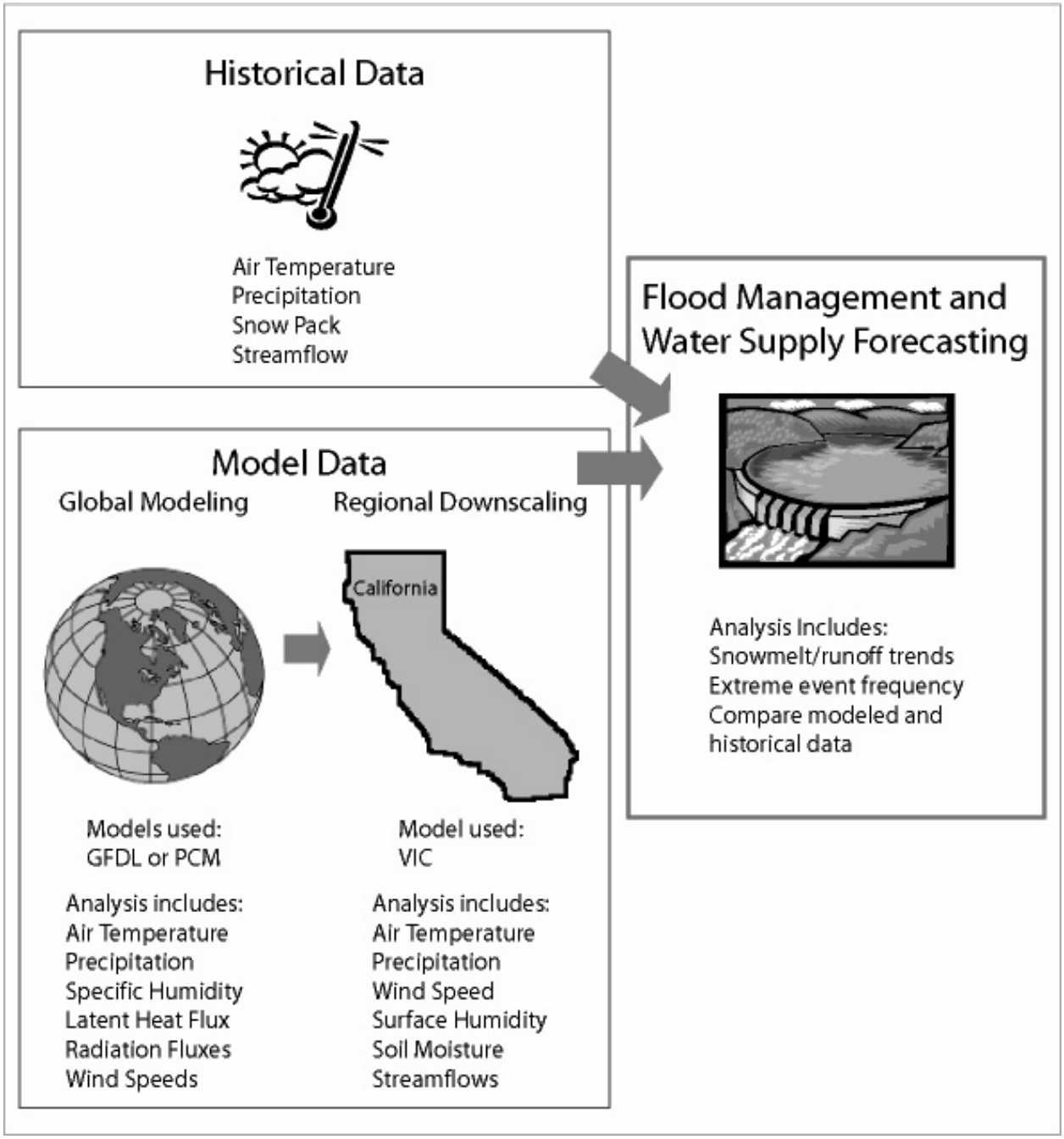


Figure 6-1 Relation of climate change scenario simulations to flood analysis

6.2 Literature Review of Flood Analysis and Climate Change

In 1988, the United Nations Environmental Programme and the World Meteorological Organization established the Intergovernmental Panel on Climate Change (IPCC). It released the First Assessment Report in 1990, the Second Assessment Report in 1995, and the Third Assessment Report in 2001 (IPCC FAR 1990, SAR 1995, TAR 2001). Beginning in 2000, the U.S. Global Climate Change Research Program (USGCRP) has released a series of regional and

sectorial assessment reports. The IPCC TAR and USGCRP Report of the Water Sector (USGCRP Water 2001) provide up-to-date summaries of the potential consequences of global warming.

The IPCC reports that climate model projections with a transient 1 percent annual increase in greenhouse gas emissions show an increase in the global mean near-surface air temperature of 1.4 to 5.8 ^{o}C, with a 95 percent probability interval of 1.7 to 4.9 ^{o}C by 2100 (Wigley and Roper 2001). Both reports indicate that likely changes during the 21st century include: higher maximum and minimum temperatures with a decreasing diurnal range over U.S. land areas, more intense precipitation events, increased summer continental drying, and increased risk of drought. Climate model projections of precipitation amounts remains uncertain, however, the rain to snow ratio, at least in the Sierra Nevada appears to be increasing under the climate change scenarios discussed in the USGCRP Water Sector Report (USGCRP Water 2001).

Further research has been done to investigate the potential impacts of climate change on California hydrology using climate model projections and land surface-hydrology models. Table 6-1 lists the references grouped by the type of study conducted. As can be seen from Table 6-1, there are three main types of studies that have been conducted: regression studies, computer model simulation of watersheds using GCM data directly, and computer model simulation of watersheds using climate change data that has been downscaled. Downscaling means inferring finer detail data from the GCM results. This process is based on statistical properties of a region or through the use of a finer-grid scale dynamic model of the atmosphere and land surface.

Table 6-1Climate Change Studies and Runoff in California

STUDY TYPE	REFERENCES
Regression	Revelle and Waggoner (1983) Stewart et al. (2004)
GCM	Gleick (1987) Lettenmaier and Gan (1990) Dettinger et al. (2004)
GCM with Downscaling	Miller et al. (1999) Knowles and Cayan (2001) Wilby and Dettinger (2000) Miller (2003) Wood et al. (2004) Van Rheenen et al. (2004) Christensen et al. (2004) Kim (2005) Maurer and Duffy (2005)
Other	Jeton et al. (1996) Bardini et al. (2001) Knowles and Cayan (2004)

Also noted in Table 6-1 are studies that do not fit into the above three categories. These studies include watershed studies with set incremental changes to temperature and precipitation (Jeton et al., 1996), an analysis of the changes to the Sacramento and San Joaquin River Delta associated with runoff changes in the upper watersheds (Knowles and Cayan, 2004), and an assessment of climate change data and known impacts to date combined with an assessment of mitigation measures for DWR (Bardini et al., 2001).

The consensus of the above-cited studies is that climate change will impact the timing and magnitude of runoff and flooding patterns in California. Expected impacts include more precipitation falling as rain rather than snow and an earlier melt to the winter snowpack. The uncertainty lies in the magnitude of these changes and any changes associated with the frequency and magnitude of future floods and droughts. The following sections investigate historical changes to precipitation, temperature, and runoff as well as potential changes identified by the latest climate change simulations and their associated consequences.

6.3 Historical Precipitation, Temperature, and Runoff Trends

Former state climatologist James Goodridge compiled an extensive collection of long-term precipitation and temperature data across the state. These data sets have been used to identify precipitation and temperature trends that have occurred in the last 100 years. Long-term runoff records in selected watersheds were also examined for trends. Results are presented below. In order to determine if the identified trends were statistically significant, a t-test with an alpha value of 0.05 was used.

6.3.1 Precipitation

Figure 6-2 shows the statewide average of annual precipitation from 102 stations across California from 1890 to 2002. The average annual precipitation for California of 23.8 inches has not changed significantly over the past century. In an effort to determine if there has been a change in precipitation distribution over the state, the precipitation records were sorted by latitude placed into three categories: south, central, and north. The division between south and central is 35 degrees north latitude and the division between central and north is 39 degrees north latitude.

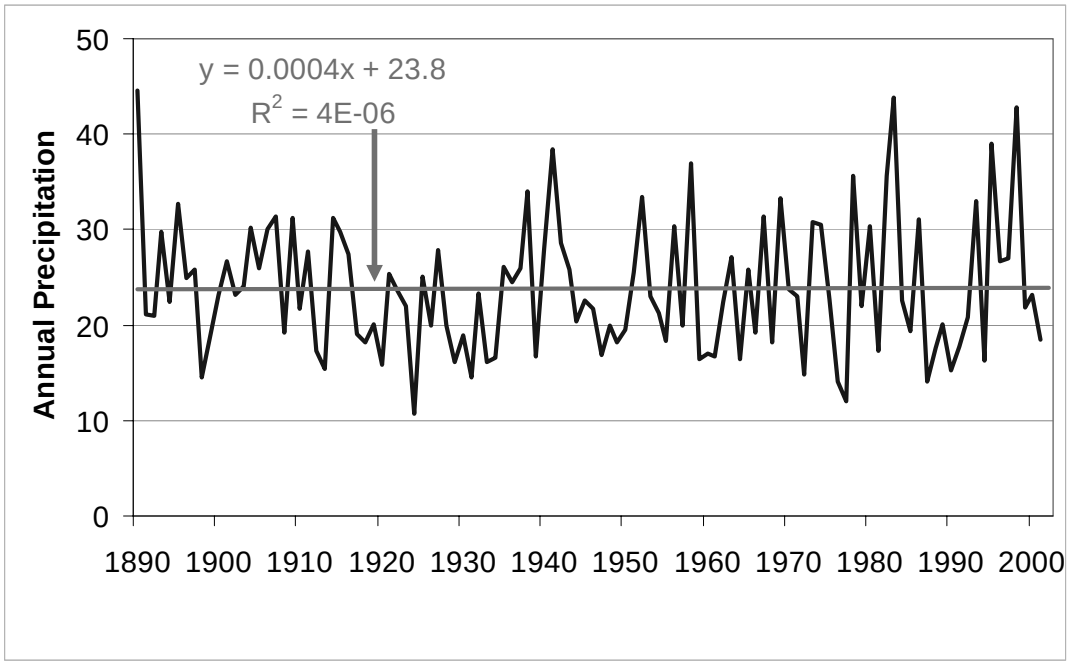


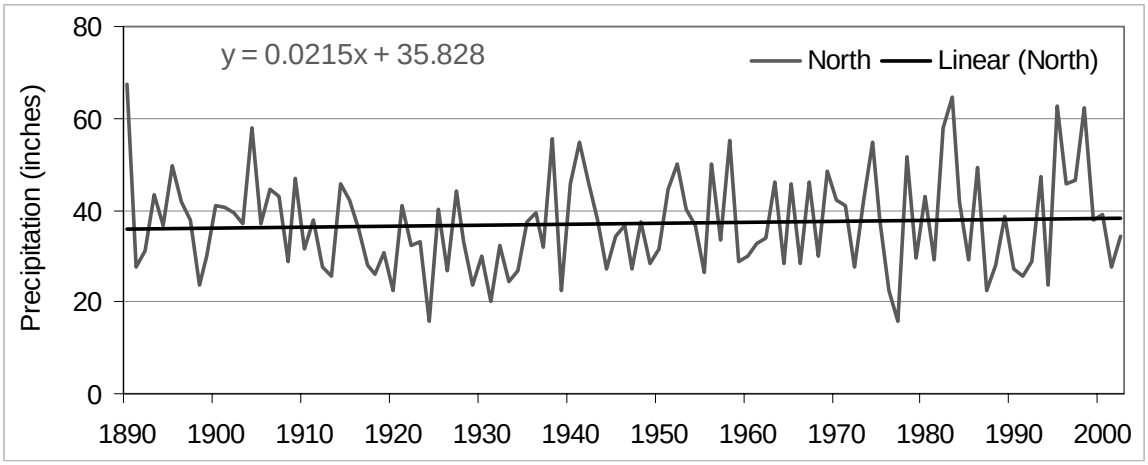
Figure 6-2 Average annual precipitation for California 1890-2002 with trend line.

Average annual precipitation is plotted with trend lines in Figure 6-3 for the south, central, and north regions for 1890-2002. The south and central regions both show a minor decreasing trend in precipitation while the north part of the state shows a minor increase. The trends do not yield a significant change in the average precipitation over the course of the century. But if focus is shifted to the last 30 years, an increasing trend can be found for all three regions as is shown in Figure 6-4. This may be an artifact of the big El Nino seasons of 1983 and 1998. Using the t-test, only the trends for central and northern California were determined to be statistically significant.

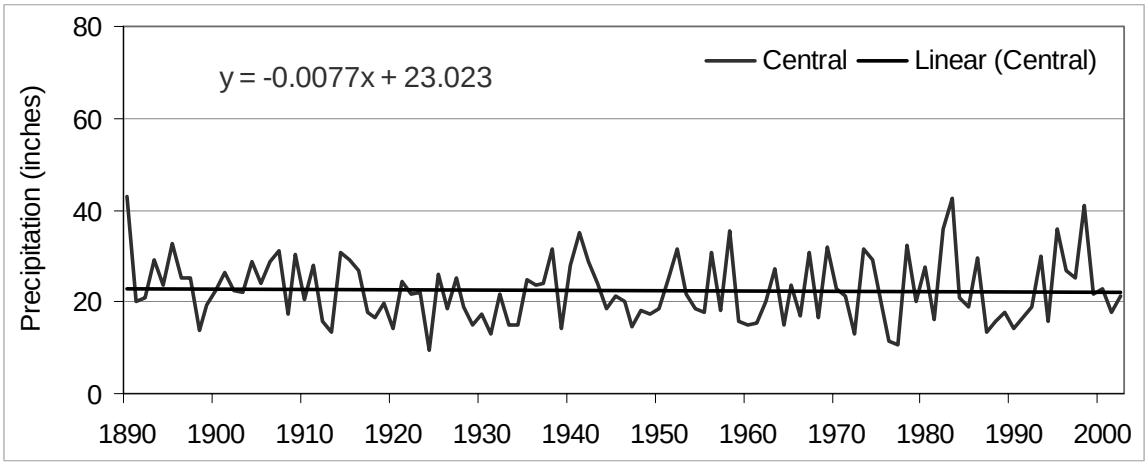
Figure 6-4 depicts annual precipitation for the three regions and a fit linear trend for the past 30 years. This increasing trend over the past 30 years is consistent with the research presented in Chapter 2 which points to increasing precipitation over the state. But it does contradict data presented in Bardini and others (2001). Their data pointed to potential decreasing precipitation. The differences can likely be related to the difference in the period selected to identify the trend. Extremes at the beginning or end of the time series can significantly impact the magnitude of the identified trend.

While the average precipitation has little or no trend over the past century, the variability has a distinct and statistically significant increase, which can be seen in Figure 6-5. Figure 6-5 depicts the coefficient of variation (standard deviation divided by the mean) based on a 10-year moving average of mean and standard deviation values of the annual precipitation time series. There is a distinct upward trend in the variability over the past century with end of period values about 75 percent larger than beginning- of-period values. This increase in variability is much larger than any of the linear trends identified in the average values of the data. There is some evidence from scattered precipitation measurements from 1850 to 1900 that the 19th century was more variable than the 20th.

a) Northern Region: California-Oregon border to 39º latitude



b) Central Region: 35 º - 39º latitude



c) Southern Region: 35 º latitude to California-Mexico border

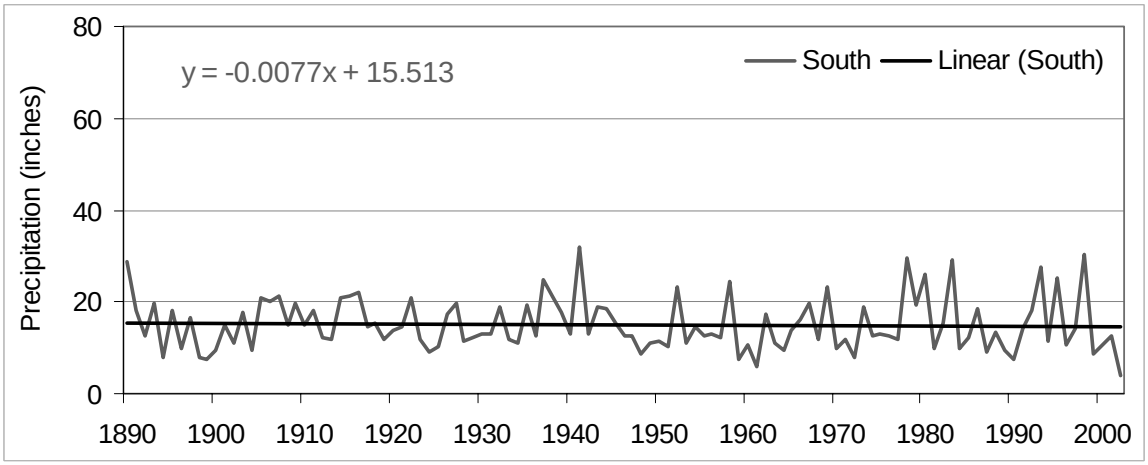


Figure 6-3 Annual average precipitation with trends by region

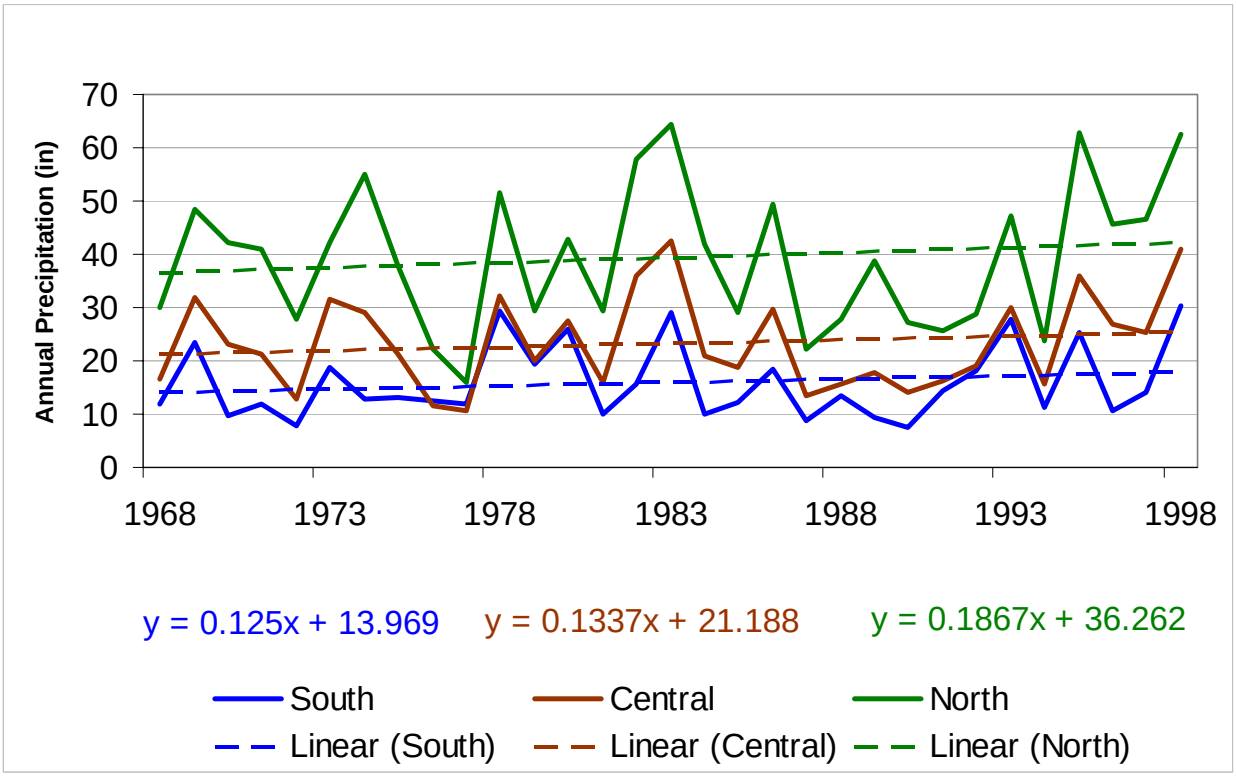


Figure 6-4 Linear trends of annual precipitation for the past 30 years

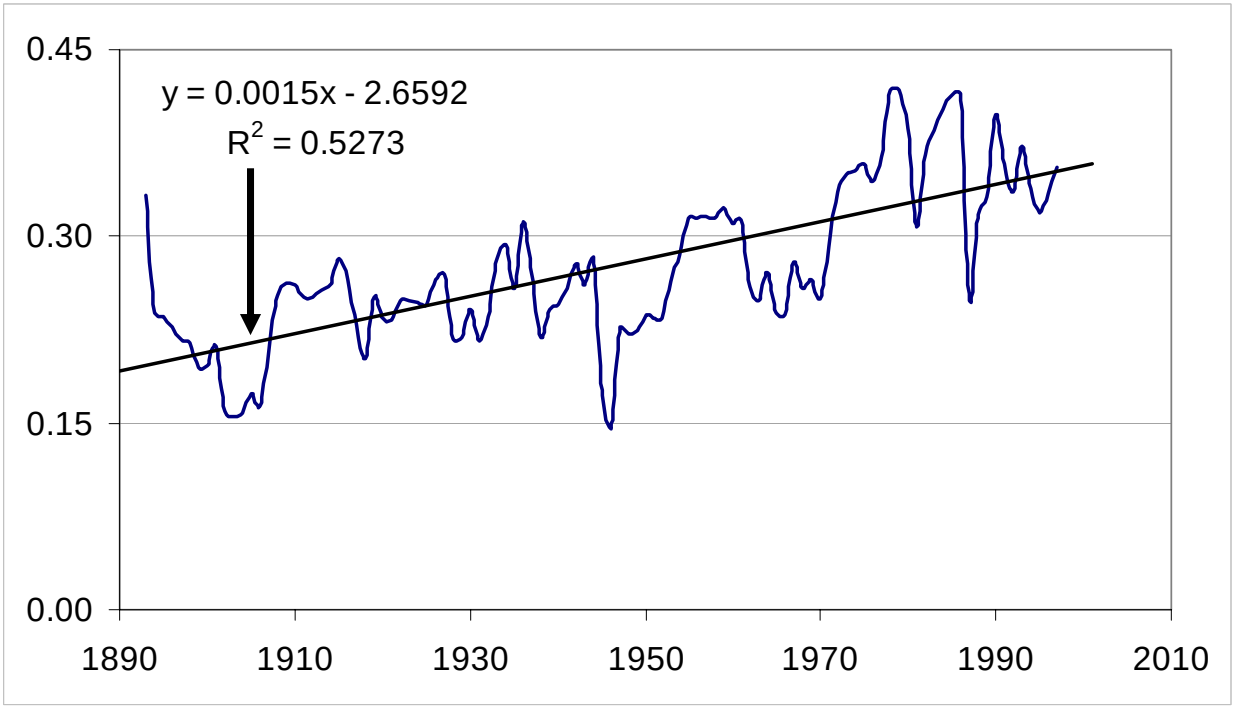


Figure 6-5 Coefficient of variation for statewide average precipitation with trend line

6.3.2 Temperature

In California, increases in atmospheric temperature have already been observed over the past 100 years. Using 226 temperature stations with data record lengths on the order of 100 years, the following trends were identified. The annual maximum, average, and minimum temperatures for California are shown in Figure 6-6. All three time series show a statistically significant increasing trend of about 2 degrees Fahrenheit per century. The minimum temperatures show the largest trend while the maximum temperatures show the smallest.

In terms of variability, Figure 6-7 depicts the trends in the variability of annual maximum, average, and minimum temperatures averaged over the state. For the maximum and average temperatures, there is not a statistically significant trend. For the minimum temperatures, there is a statistically significant decreasing trend in the variability. This, along with the identified trend in state average minimum temperatures indicate that the lower bound of temperature in the state is moving upward and that this upward trend is damping out the variability of the minimum temperature. As a consequence, on average, there may be fewer cold extreme temperature days in the future as a result of global warming. This result is coincident with other studies (see for example Easterling et al, 2000.)

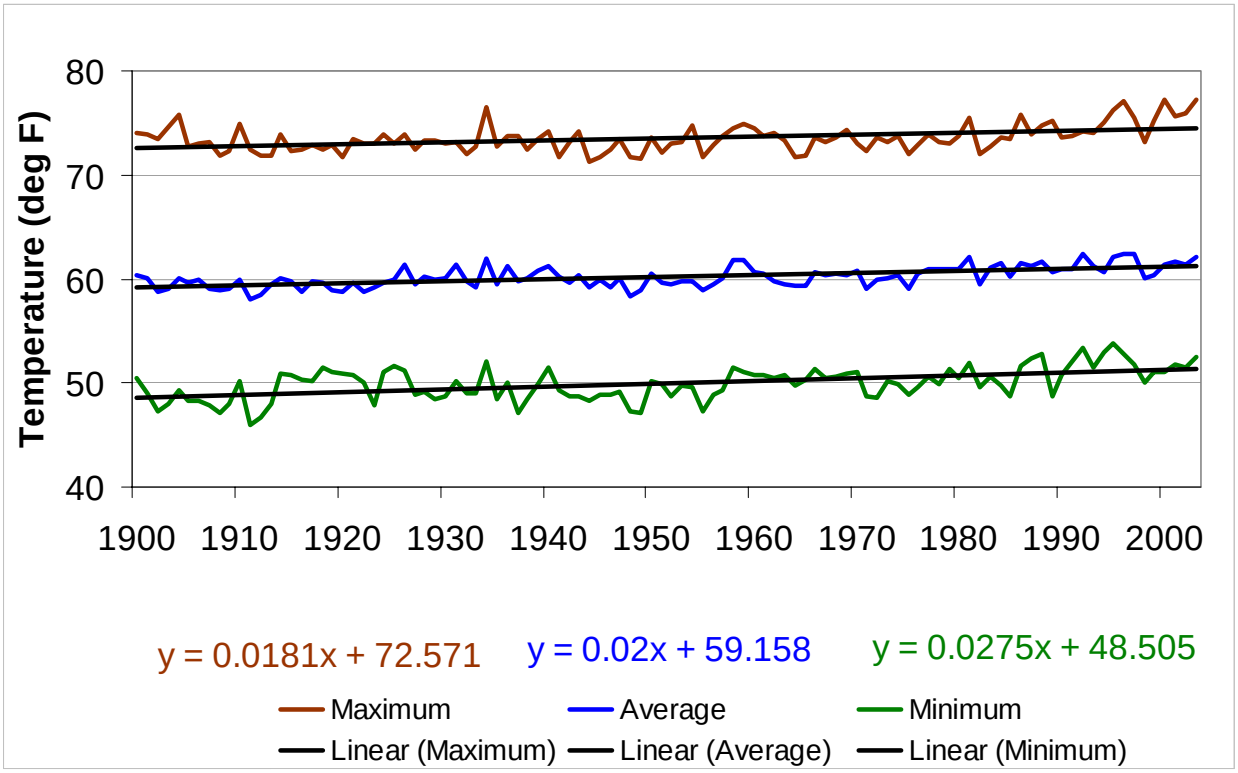
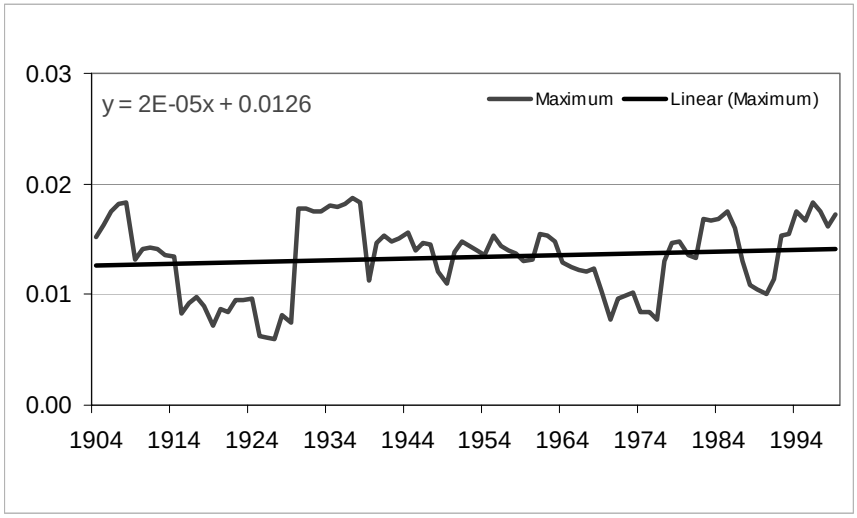
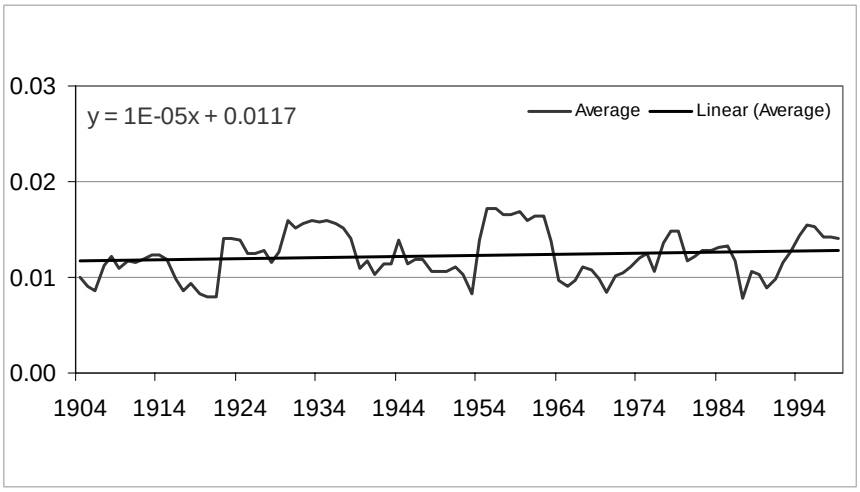


Figure 6-6 State average maximum, average, and minimum temperature time series

a) Coefficient of Variation over time for maximum temperature



b) Coefficient of Variation over time for average temperature



c) Coefficient of Variation over time for minimum temperature

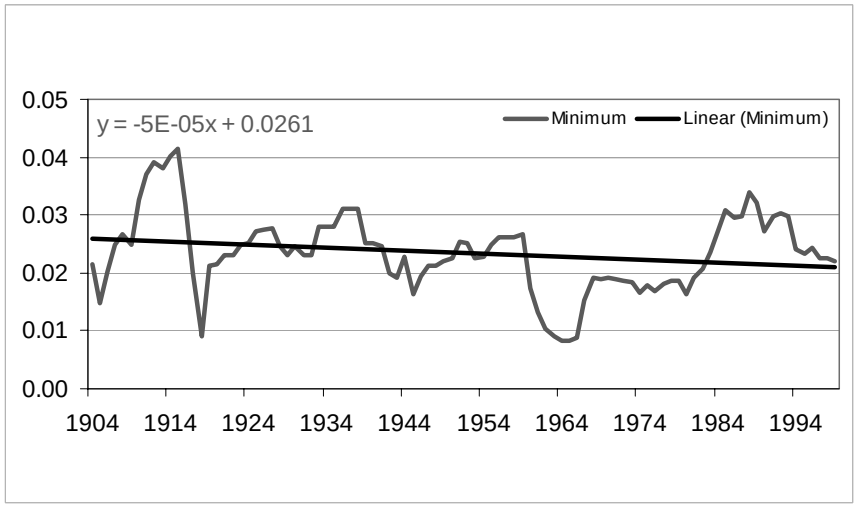


Figure 6-7 Variability of annual maximum, average and minimum temperature

Other state temperature trends can be identified. Figure 6-8 shows the change in trend of average temperature identified over the past 100 years versus latitude in 2.5 degree increments. The magnitude of the temperature trend decreases with latitude from over 3 degrees Fahrenheit per century in the south part of the state to less than a degree Fahrenheit in the northernmost part of the state.

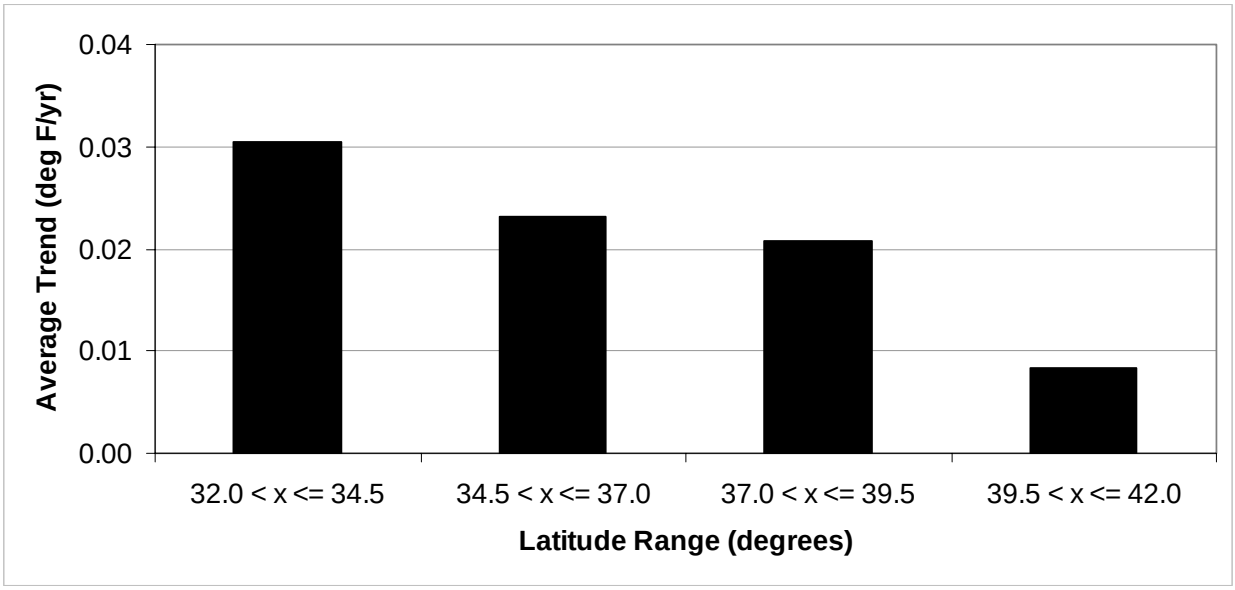


Figure 6-8 Temperature trend variation with latitude

Former state climatologist James Goodridge found a difference in temperature trend with population as seen in Figure 6-9. The lowest trend line is associated with a rural county with a population of less than 100,000 people while the topmost trend line is associated with a highly urbanized county with a population greater than 1 million. As noted in the figure, these trends are based on 65 stations sorted by county population. Note that all three lines show an increasing trend in temperature indicating that temperatures have been increasing even in rural areas. In addition, in urban areas, temperature increases are accentuated indicating that future temperature increases will be even greater in urban areas.

Peterson (2003) of the National Climatic Data Center offers a different point of view. He conducted a study that rigorously removed elevation, equipment, and location variations from temperature records at urban and rural sites. His work indicates that there is no urban heating effect. This is an area of ongoing research and debate among scientists.

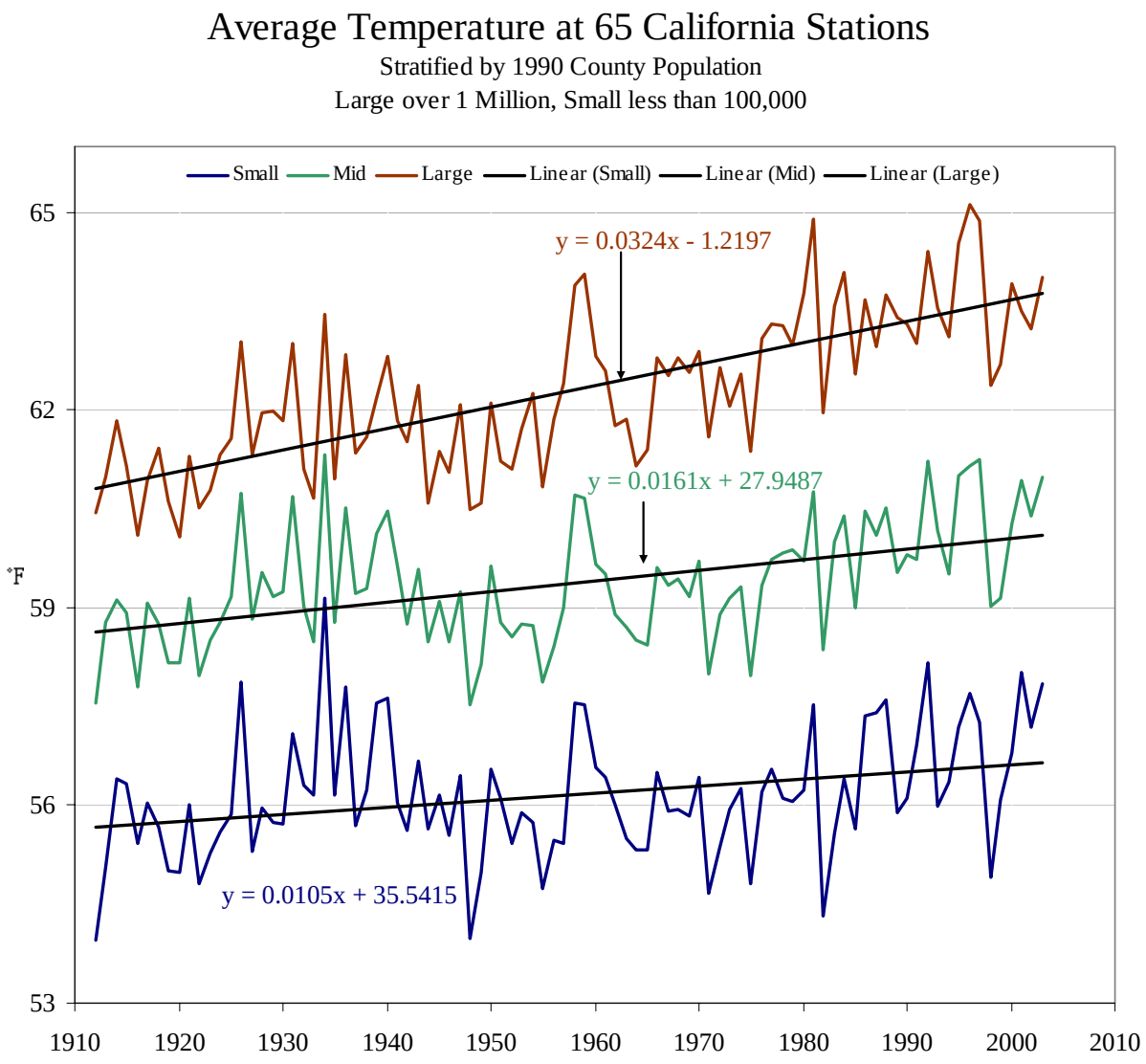


Figure 6-9 Temperature trends by county population in California.

6.3.3 Runoff

Runoff trends can be divided into two categories. The first is trends in annual-water-year-runoff volumes. The second is trends associated with peak runoff for different return periods. Both trends are investigated here.

6.3.3.1 Annual Runoff

Annual water year (October 1 to September 30) unimpaired runoff time series were computed for 24 rivers across the state whose locations are shown in Figure 6-10. The time frame for most basins runs from 1905 to 2005. Total period and split period statistics were generated for each basin. The dividing year for the split period statistics is 1955 which is approximately halfway through the observed record.

Table 6-2 lists the total period, pre-1955 period and post-1955 period average annual runoff in thousand acre-feet for the 25 basins. Table 6-2 also includes the percent change from pre-1955 to post 1955. The sum of all 25 basins shows a 9 percent increase in average annual runoff from 1905-1955 to 1956-2005. In general, the northern rivers show a larger increase in average annual runoff than the southern rivers.

Table 6-2 Average Annual Water Year Runoff for Selected California Watersheds

Station	Total Period (taf)	Pre 1955 (taf)	Post 1955 (taf)	% Change
Klamath Copco to Orleans	4,646	4,144	4,916	19%
Salmon River at Somes Bar	1,288	1,212	1,338	10%
Eel River at Scotia	5,493	4,921	6,007	22%
Russian near Healdsburg	897	817	921	13%
Napa River at St. Helena	72	60	76	27%
Sacramento River at Bend Bridge	8,476	8,052	8,901	11%
Feather River at Oroville	4,490	4,360	4,621	6%
Yuba River at Smartville	2,372	2,375	2,369	0%
American River at Folsom Reservoir	2,739	2,759	2,717	-2%
East Carson and West Walker Rivers	433	396	459	16%
Truckee River at Farad	402	395	408	3%
Cosumnes River at Michigan Bar	369	348	389	12%
Mokelumne River at Pardee Reservoir	758	762	753	-1%
Stanislaus River at New Melones Reservoir	1,175	1,178	1,171	-1%
Tuolumne River at New Don Pedro Reservoir	1,911	1,875	1,951	4%
Merced River at Exchequer Reservoir	997	988	1,008	2%
San Joaquin River at Millerton Reservoir	1,816	1,798	1,835	2%
Kings River at Pine Flat Reservoir	1,683	1,650	1,720	4%
Kaweah River at Terminus Reservoir	432	412	454	10%
Tule River at Lake Success	145	139	148	6%
Kern River at Lake Isabella	697	633	730	15%
Arroyo Seco nr Soledad	122	120	124	3%
Nacimiento River below Nacimiento Dam	200	183	213	16%
Arroyo Seco nr Pasadena	7	6	8	26%
Total	41,620	39,582	43,239	9%

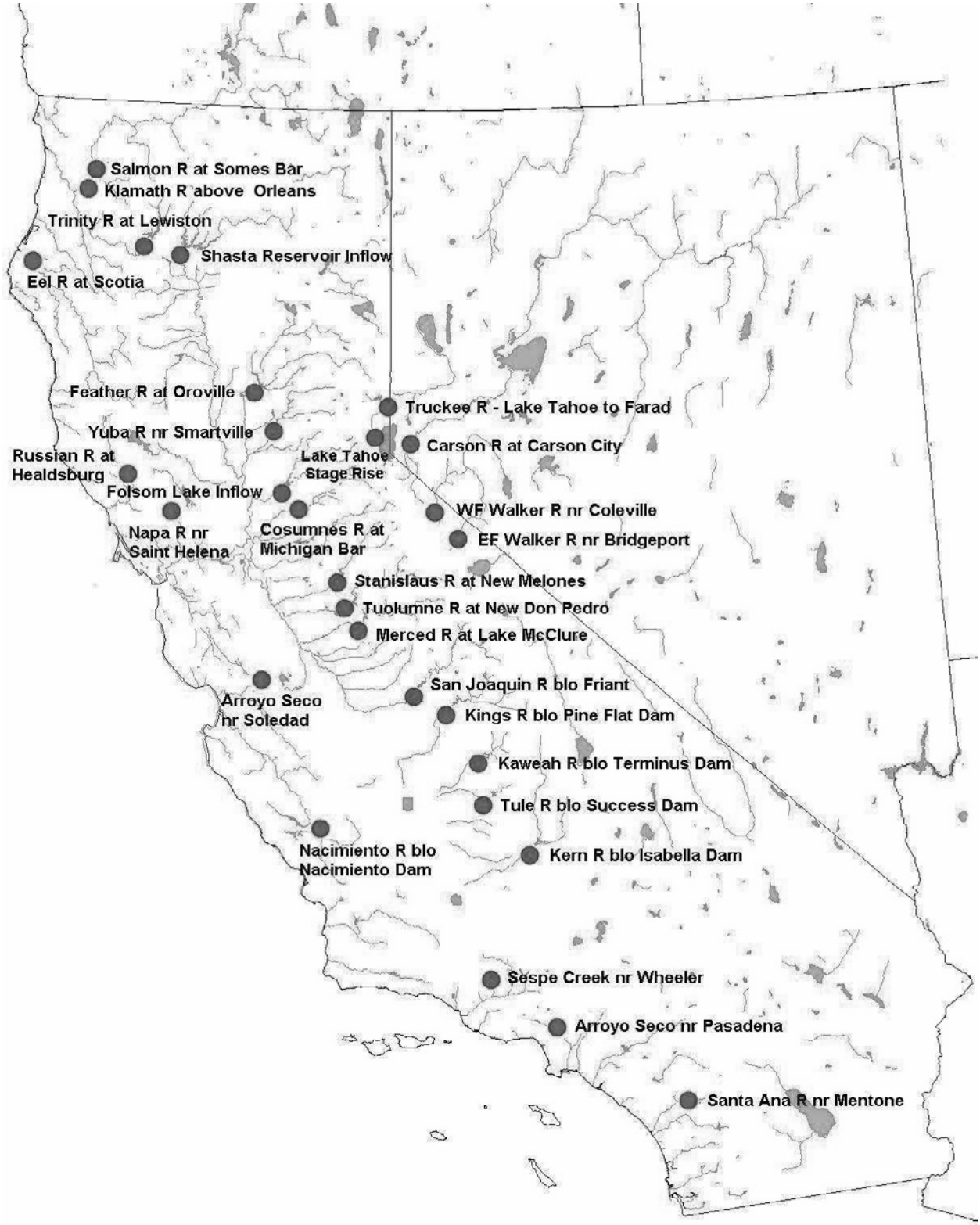


Figure 6-10 Map of Runoff Forecast Points

In addition to the individual basin runoff, runoff of four major rivers is used to compute the Sacramento and San Joaquin River Indices. The index values not only look at current year runoff, but incorporate a term for last year's conditions as well. Figure 6-11 shows the time series plot and linear trend fit for the Sacramento River Index and Figure 6-12 shows the time series plot and linear trend fit for the San Joaquin River Index. From these figures it can be seen that there is a slight decreasing trend in the San Joaquin Index and a slight increasing trend in the Sacramento River Index. These results are consistent with the precipitation trend results over the past century described earlier. However, neither trend was identified as being statistically significant.

In terms of runoff variability, the coefficient of variation is plotted for the Sacramento and San Joaquin River Indices in Figure 6-13. Both time series show an increase with the linear trend fit, but only the Sacramento trend is statistically significant. In fact, the variability increases markedly in both series from the 1970s through the mid-1990s. Since 1995, both series' variability has dropped back to values consistent with the beginning of the period.

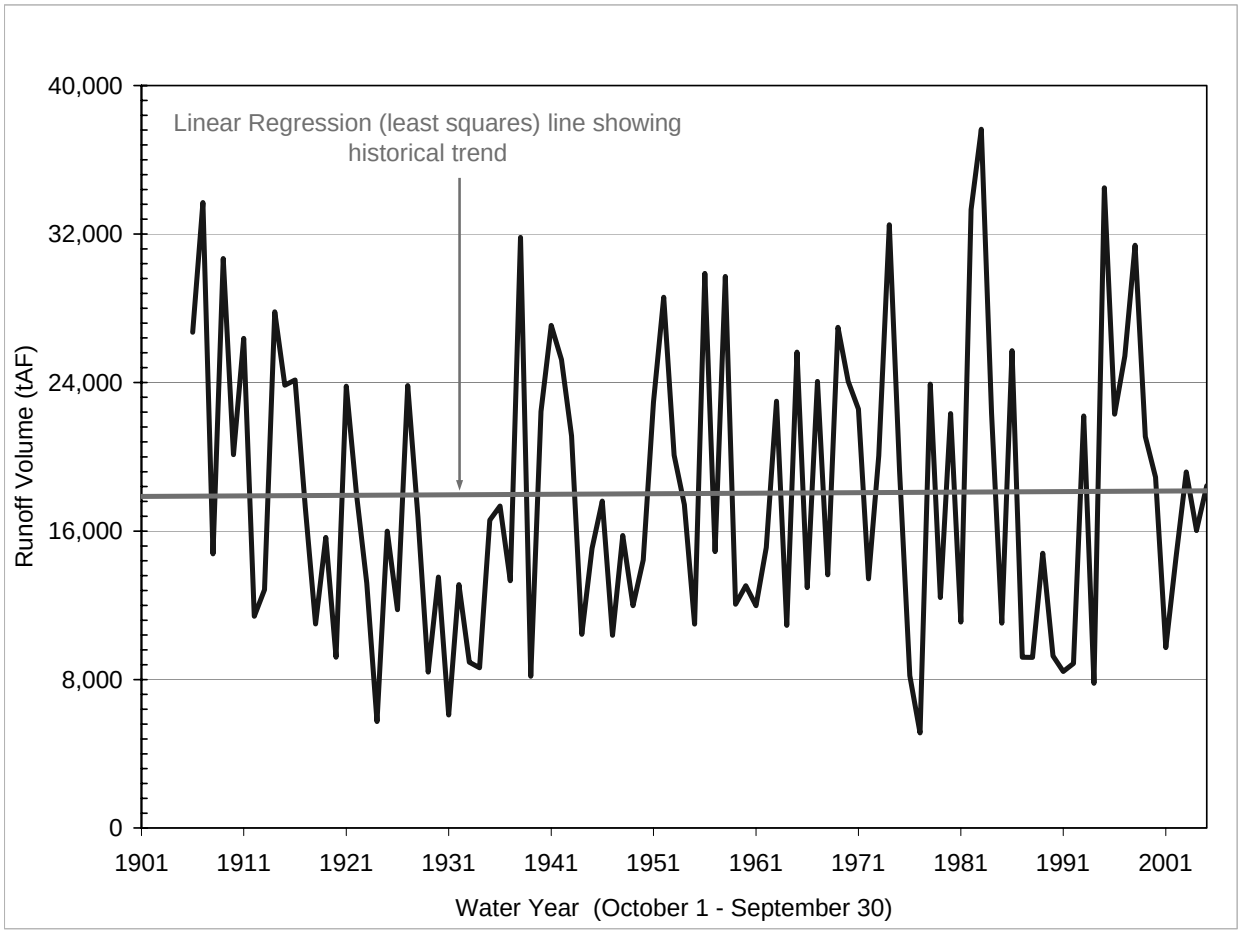


Figure 6-11 Time series of Sacramento River Index water year runoff with fit linear trend

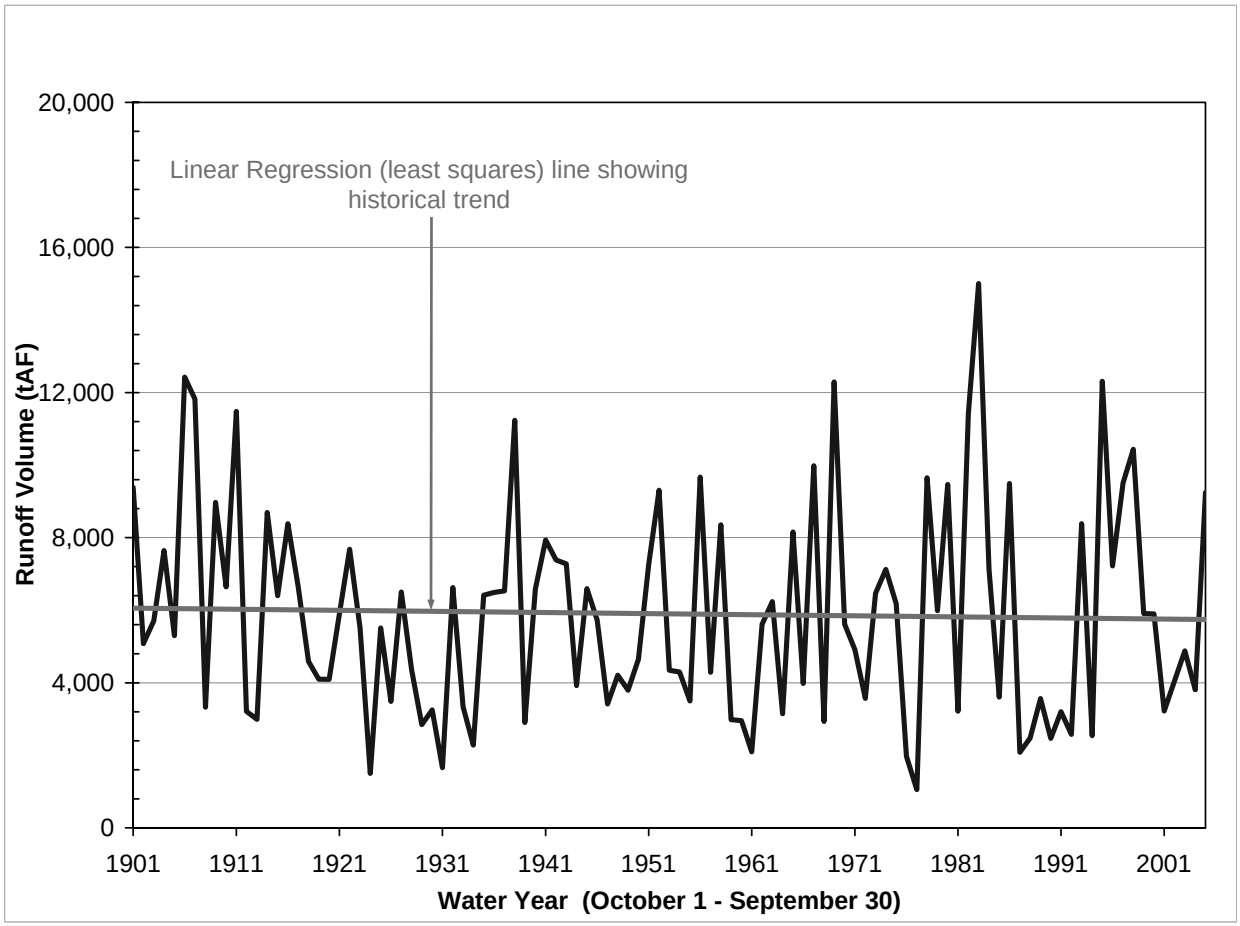


Figure 6-12 Time series of San Joaquin River Index water year runoff with fit linear trend

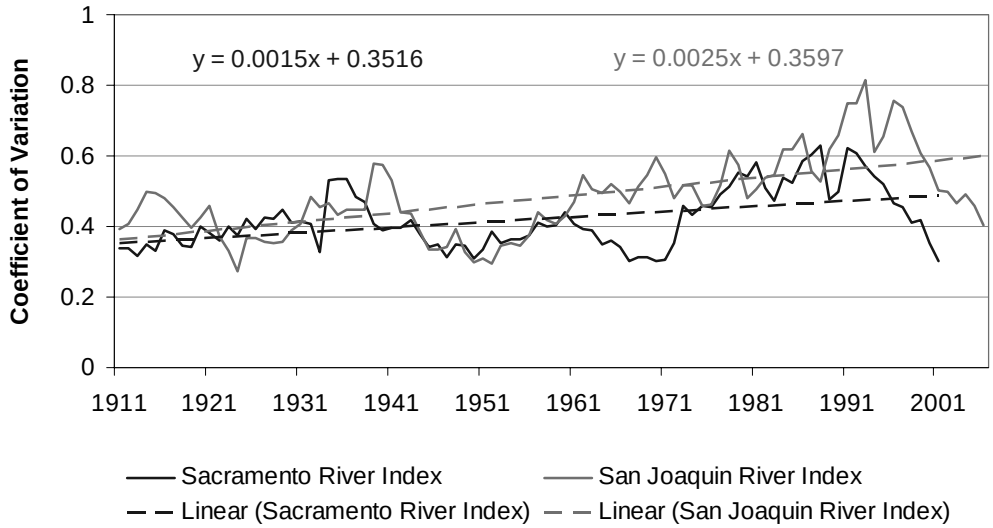


Figure 6-13 Variability of Sacramento and San Joaquin River Index through time

Another element to annual runoff is the timing of that runoff. Winter storms deliver snow to higher elevations that historically has melted in April – July. This spring runoff serves as a significant portion of the water supply for dry summers and falls. The April – July runoff over time is shown in Figure 6-14 for the Sacramento River system and in Figure 6-15 for the San Joaquin River system. Both indices show a decrease in the fraction of annual runoff made up from April – July runoff over the past 100 years. This indicates that a greater percentage of the annual runoff is occurring earlier in the year when flood control needs supersede water storage in reservoirs with flood control and water supply purposes. However, in terms of the t-test for statistical significance, neither trend was identified as statistically significant.

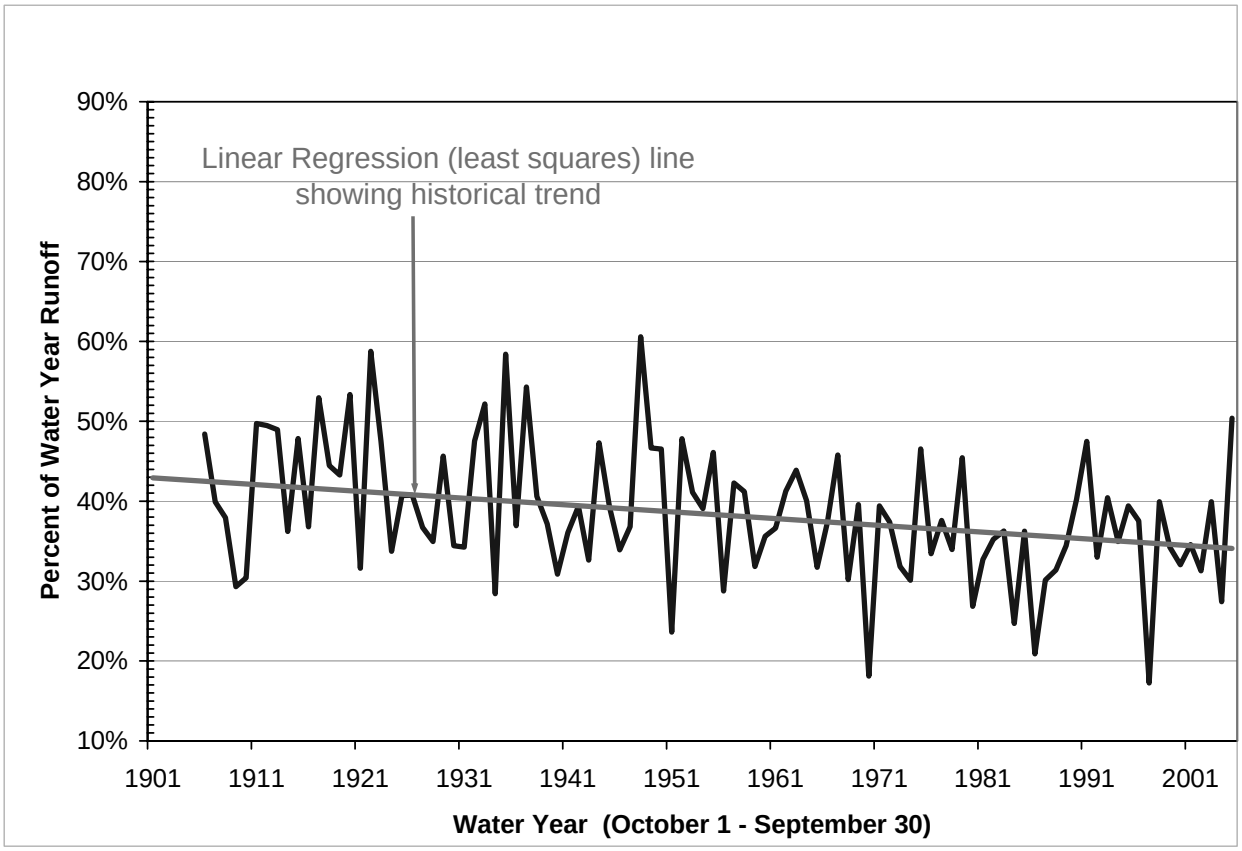


Figure 6-14 April-July Runoff as a percent of water year runoff for the Sacramento River System

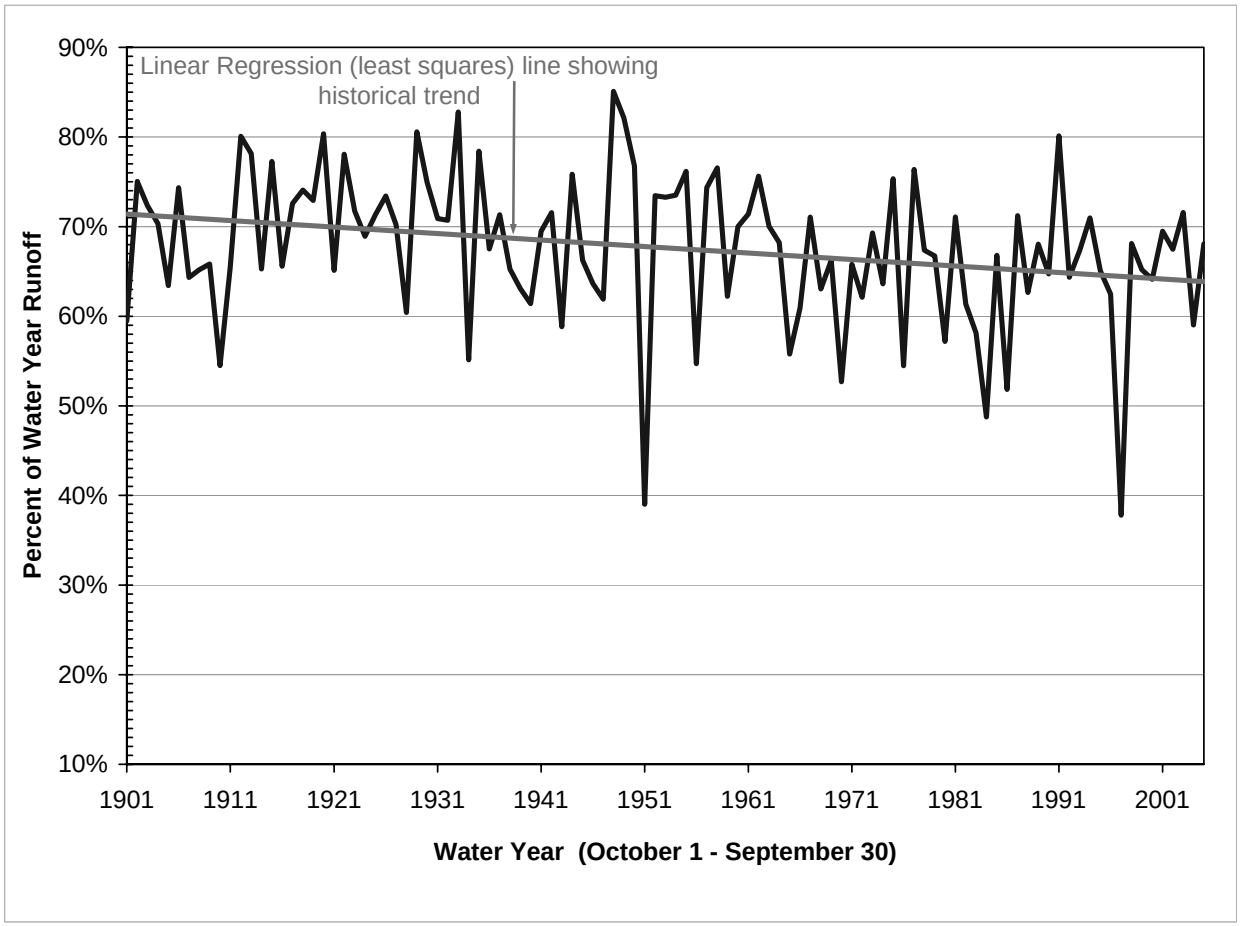


Figure 6-15 April-July Runoff as a percent of water year runoff for the San Joaquin River System

Another indication that spring runoff is occurring earlier in the year can be seen in Figure 6-16. It depicts the flow centroid day at the Michigan Bar stream gage on the Cosumnes River computed from historical flow data. A flow centroid day is the number of days after October 1 for 50 percent of the annual volume to pass. For watersheds with snowmelt, this day is usually in April or May (Julian day 182-243). The Cosumnes River is a lower-elevation watershed with a maximum elevation of slightly less than 8,000 feet. It has a modest snowpack in the upper reaches of the basin. There is also a 40,000 acre-foot reservoir on a tributary to the North Fork (Jenkinson Reservoir) that diverts water from the basin. In the absence of a major runoff event (seen as the sharp downward spikes in the time series such as 1986 and 1997) in the basin, the snowmelt makes up a significant portion of the annual runoff in the watershed and drives the location of the flow centroid day. As can be seen from the above figure, the movement over time of the flow centroid day to earlier in the year indicates that, on average, the snowmelt in the basin is occurring earlier (from mid March in 1908 to the beginning of March in 1998). Based on the linear trend line fit to the data, this change in timing is about 10 days over 90 years. However, based on the t-test, the trend was not identified as statistically significant.

With more of the annual runoff including some snow melt occurring earlier in the year, runoff historically used for water supply starts to overlap the time period when reservoir space is reserved for flood control. This overlap may lead to the need to carefully review early spring reservoir operation.

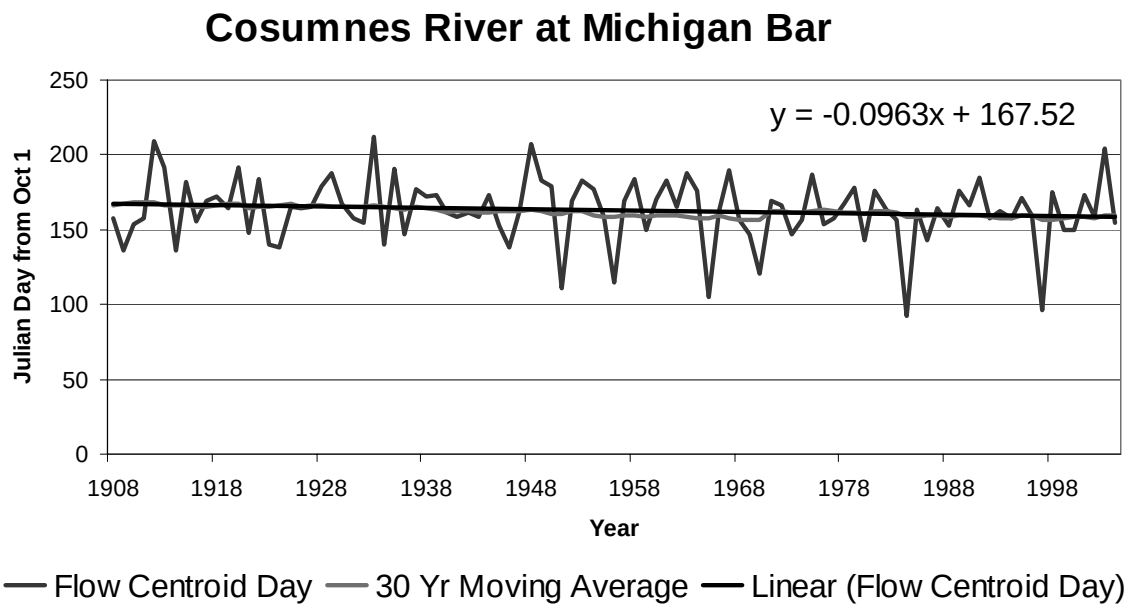


Figure 6-16 Flow centroid day versus time for the Cosumnes River at Michigan Bar

6.3.3.2 Annual Maximum Flood from Three Day Average Flows

For peak runoff analysis, six rivers were chosen with long peak flow records. The peak flows evaluated here are three-day average peak flows. The six rivers chosen include three in the Central Valley: Feather, American, and Tuolumne; and three coastal rivers: the Eel River in the north, the Arroyo Seco in central California, and the Santa Margarita River in the south. Their locations are shown in Figure 6-17.

For the analysis, total period mean, standard deviation, and skew statistics are computed for each river. In addition, the records were divided into two time periods with 1955 as the boundary. The year 1955 was chosen as the boundary because it divides the data sets in half. Mean, standard deviation and skew statistics were computed for the two time periods as well. These values are shown in Table 6-3. As can be seen from Table 6-3, the means and standard deviations all increased from the pre 1955 time period to the post 1955 time period with the exception of the Arroyo Seco mean which remained constant. The skew statistics increased except for the Arroyo Seco which remained constant and the Santa Margarita, which decreased.

Figure 6-17 Map of station location for peak flow analysis

Using these statistics, Bulletin 17-B (Water Resources Council, 1982) procedures were used to compute the 10-year, 50-year, and 100-year return period flows for the six rivers for the total period, pre-1955 period, and post-1955 period. The Bulletin 17-B procedures fit the data to a log-Pearson type III distribution. The flow values for the different return periods are shown in Table 6-4. Percent differences from Pre-1955 conditions to Post-1955 conditions are shown in Table 6-5.

Table 6-3 Comparison of discharge statistics by basin and time period (values in 1000 cfs)

River Basin	American	Feather	Tuolumne	Eel	Arroyo Seco	Santa Margarita
Total Period Mean	32.73	47.61	14.51	110.08	3.12	1.37
Total Period Std Dev	33.68	42.06	15.26	71.13	2.53	2.71
Total Period Skew	2.14	1.89	2.42	2.14	1.02	3.04
Pre55 Mean	28.04	42.38	12.22	92.99	3.09	1.24
Pre55 Standard Deviation	24.23	33.00	10.85	47.97	2.38	2.35
Pre55 Skew	1.76	1.38	1.72	0.47	1.03	3.51
Post55 Mean	37.00	52.23	17.20	123.26	3.09	1.42
Post55 Standard Deviation	41.00	49.68	19.33	84.18	2.71	2.93
Post 55 Skew	1.88	1.81	2.12	2.05	1.02	2.88

Table 6-4Comparison of different return period flows by basin and time period

River Basin (Values in 1000 cfs)	American (1905-2004)	Feather (1904-2004)	Tuolumne (1897-2000)	Eel (1917-2004)	Arroyo Seco (1902-2004)	Santa Margarita (1931-2004)
Total Period Q10	72	101	32	210	7	6
Total Period Q50	150	186	65	334	14	10
Total Period Q100	194	228	83	392	15	12
Pre 1955 Q10	58	88	26	162	6	5
Pre 1955 Q50	103	152	48	236	13	9
Pre 1955 Q100	126	182	58	268	14	11
Post 1955 Q10	88	117	40	257	7	7
Post 1955 Q50	199	221	88	446	14	11
Post 1955 Q100	266	274	117	540	15	13

Table 6-5 Percent increase in return period discharges from pre-1955 to post-1955 by basin

River Basin	American	Feather	Tuolumne	Eel	Arroyo Seco	Santa Margarita
Q10	51%	32%	49%	58%	7%	22%
Q50	92%	46%	85%	88%	10%	23%
Q100	111%	51%	102%	101%	11%	23%

As can be seen from Table 6-5, the 100-year three-day peak flows have more than doubled for the American, Tuolumne, and Eel rivers. The only river with little change in its return period flows is the Arroyo Seco. Examination of the data shows that there was only one major event (defined as a value greater than the mean plus two standard deviations) for the Feather, American, and Tuolumne Rivers in the pre-1955 period. In the post 1955 period, the number of major events jumps to four. For the coastal rivers a similar pattern emerges. From this information it can be seen that the annual peak three-day mean discharges are becoming more variable and larger for many sites in California.

Climate model studies such as Miller and others (2003) and Dettinger and others (2004) indicate that this trend will continue in response to global warming. Stedinger and Crainiceanu (2001) examine frequency analysis issues when the underlying statistical moments are not stationary as has been assumed in this section. They find that the stationary model works just as well at identifying flood risk as more complex models that try to incorporate trends in historical data.

6.3.4 Historical Trend Summary

Over the past 100 years the following trends have been identified and were described in preceding sections:

Precipitation

- No significant trend exists in statewide average precipitation from 1890-2000
- A small increasing trend in statewide precipitation is found from 1970-2000
- A slight increasing trend in precipitation appears in the north part of the state
- A slight decreasing trend in precipitation appears in the south part of the state
- Precipitation variability increased during the 20th century

Temperature

- A slight increasing temperature trend is observed in statewide average of maximum, average and minimum temperatures
- Larger temperature trends are associated with urban areas
- Variability in minimum temperature is slightly decreasing
- Variability in maximum and average temperature is slightly increasing

Runoff – Annual

- Annual runoff shows increasing trend in Sacramento River System
- Annual runoff shows slight decreasing trend in San Joaquin River System
- April-July runoff as percentage of annual runoff is decreasing in both Sacramento and San Joaquin River Systems
- Variability in annual runoff is increasing

Runoff – Peak Flow

- Increase in 10, 50 and 100 year return period peak flows are observed for six basins studied
- Variability in annual peak flows is increasing in six basins studied
- Change between the first and last half of the record are large except for Arroyo Seco

6.4 Climate Change Scenario Simulation Data

6.4.1 GCM Simulation Results

The studies presented in this report focus on the four climate change scenarios selected by the Climate Action Team appointed in response to the governor's Executive Order S-3-05 on climate change. The four climate change scenarios consist to two greenhouse gas (GHG) emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), known as A2 and B1, each represented by two different Global Climate Models (GCMs), the Geophysical Fluid Dynamic Lab model (GFDL) and the Parallel Climate Model (PCM).

The A2 emissions scenario assumes high population growth, regional based economic growth, and slow technological changes which results in significantly higher GHG emissions. The B1 scenario represents low population growth, global based economic growth and sustainable development which results in the lowest increase of GHG emissions of the IPCC scenarios. For more information on the GCMs and scenarios used in this report, refer to Chapter 3. For the following sections examining impacts based on climate change simulation results, the four climate change scenarios are referred to as:

- GFDL A2
- PCM A2
- GFDL B1
- PCM B1

Precipitation and temperature time series for southern and northern California were created using the GCM simulation results. Precipitation results are shown in Figure 6-18 for Northern California and Figure 6-19 for Southern California. Note that scenario simulations for a given GCM do not differ until after year 2000. For both Northern and Southern California, neither model accurately reproduces historical precipitation variability. Because of this, future variability represented by the model can not be considered reliable.

In terms of average precipitation, for Northern California, the GFDL model predicts a 20 percent decrease in precipitation after 2050 for the A2 scenario and a 10 percent decrease for the B1 scenario. The PCM model predicts no change for either scenario. For Southern California, the GFDL model predicts a 10 percent decrease in precipitation after 2050 for both scenarios while the PCM model predicts a 1 percent decrease in precipitation for both scenarios. By 2100 however, the PCM model predicts a 10 percent increase in precipitation for both scenarios.

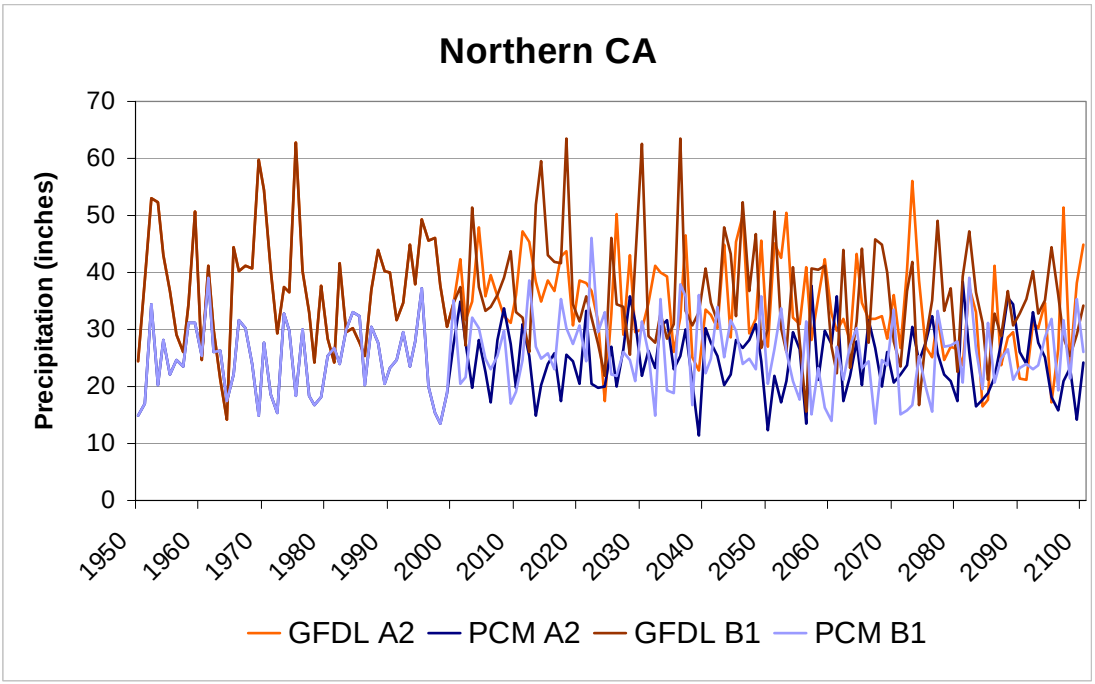


Figure 6-18 GCM precipitation results for Northern California

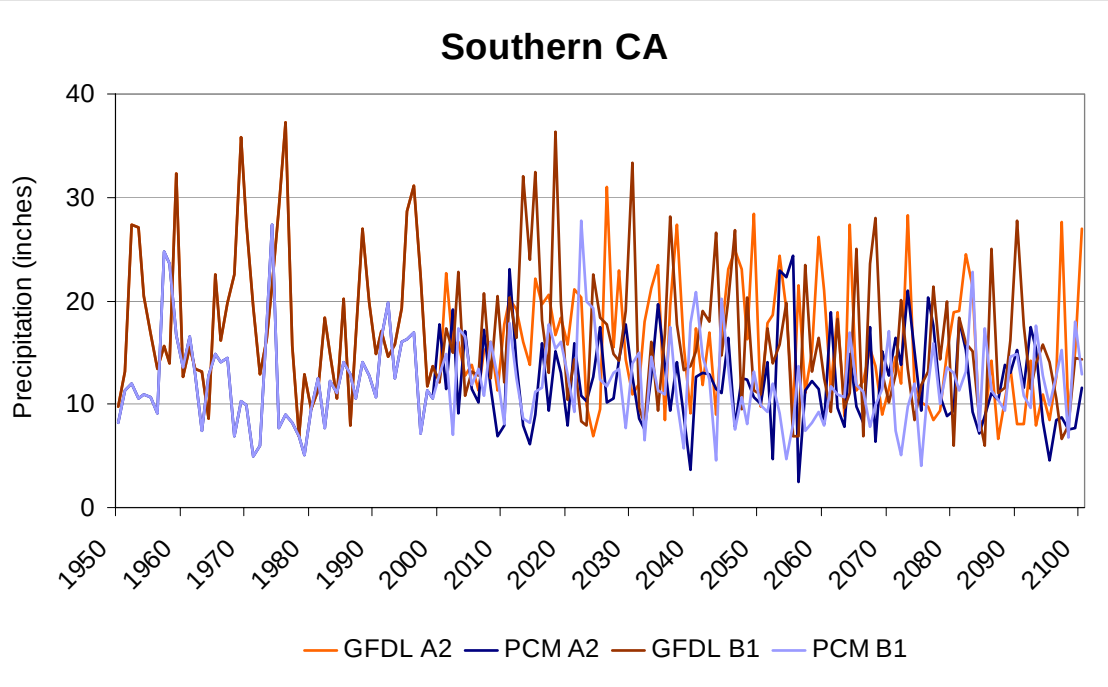


Figure 6-19 GCM precipitation results for Southern California

Temperature results for both models are shown in Figure 6-20 for Northern California and in Figure 6-21 for Southern California. For Northern California, the GFDL model predicts a larger temperature increase than the PCM model. By 2050, the PCM model predicts a one degree Celsius increase in temperature for both scenarios while the GFDL model predicts a 2.25-degree increase for both scenarios. Increases up to 5 degrees C occur by 2100 in the GFDL model.

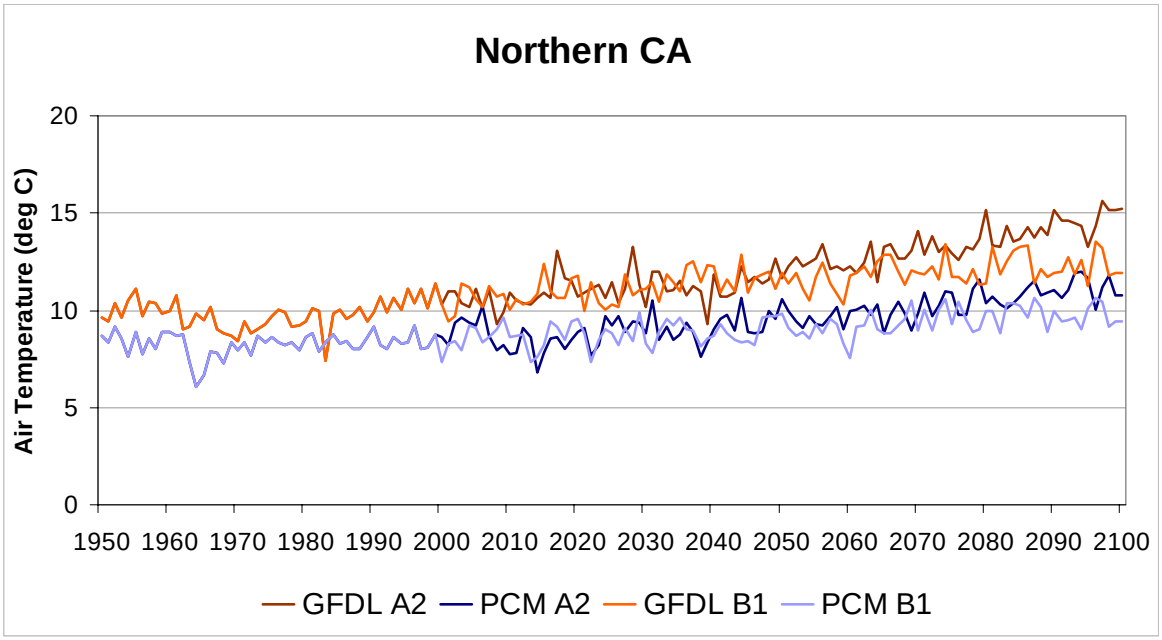


Figure 6-20 GCM temperature results for Northern California

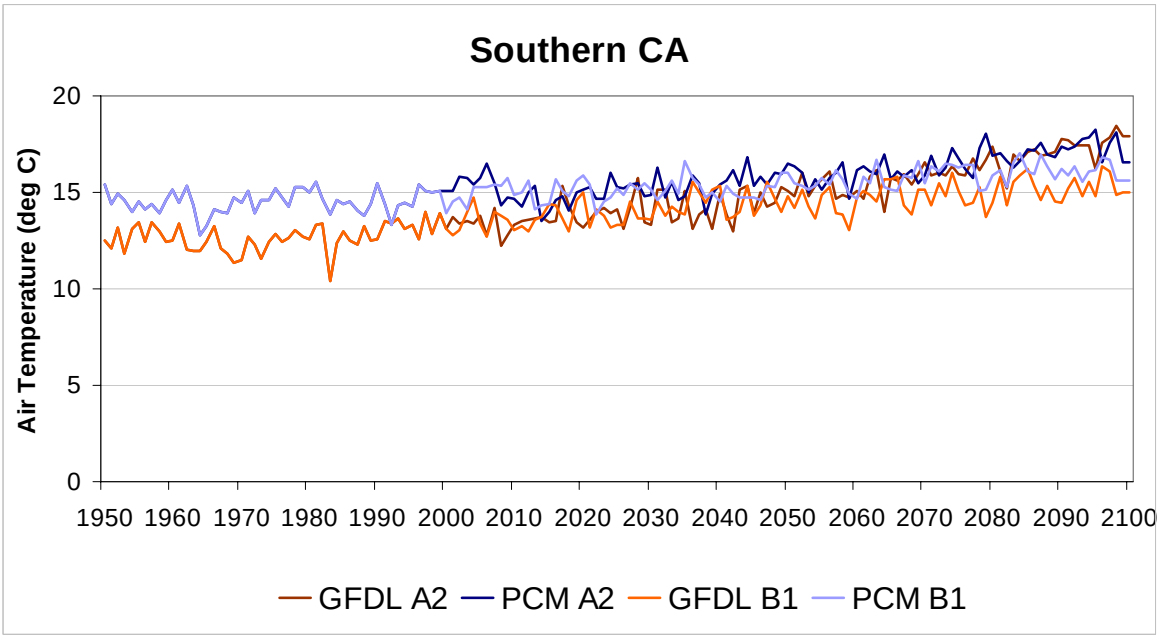


Figure 6-21 GCM temperature results for Southern California

The GCM results presented here are at a scale of about 100-200 km horizontal resolution. California's topography is highly varied which leads to a more complex temperature and precipitation patterns than can be expected from a GCM simulation at this resolution. Because of this, downscaling procedures were carried out on the GCM scale results to create finer resolution (10-20 km) data suitable for analysis over California.

6.4.2 Downscaled Results

Professor Ed Maurer of Santa Clara University statistically downscaled monthly data from each of the GCM simulations to California and then used the data to drive a land surface model known as the VIC (Variable Infiltration Capacity) model. Details of the downscaling and VIC model can be found in Maurer (2005). Data from these simulations were provided to Department of Water Resources staff for analysis. VIC model results for 12 sites across the state were averaged to obtain the precipitation and temperature time-series plots shown in Figure 6-22 and Figure 6-23 respectively. Runoff results from the VIC model were sampled from seven Central Valley watersheds. Annual, October through March, and April through July runoff volumes were analyzed and compared to historical records.

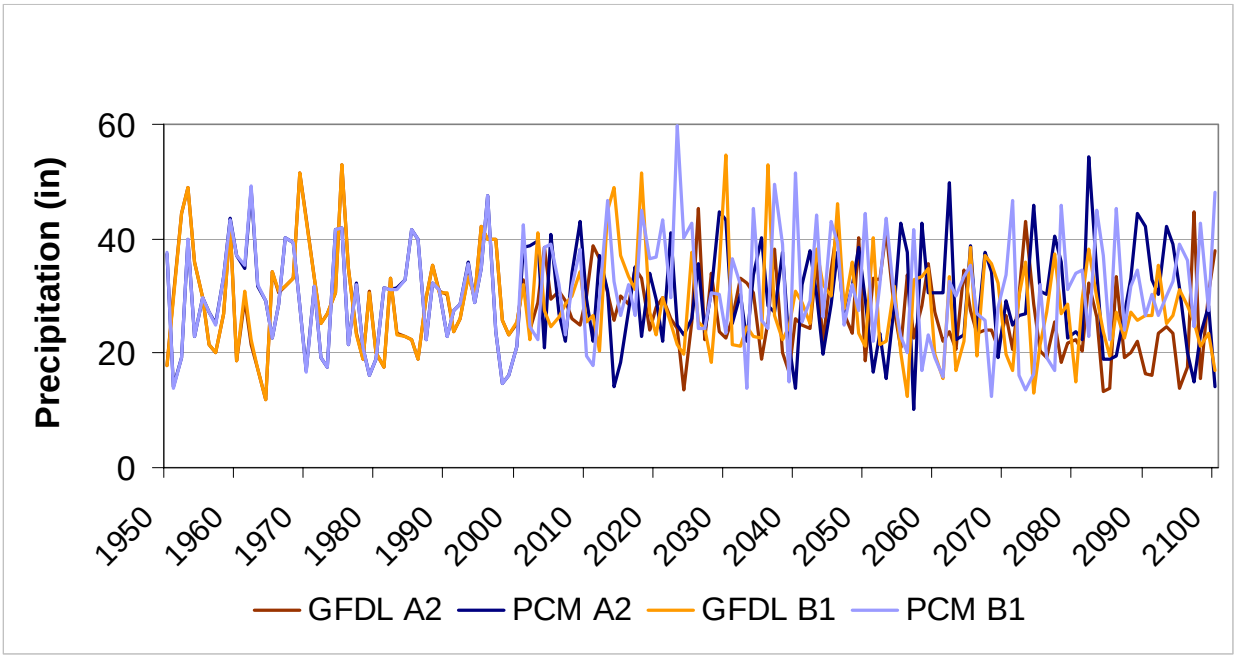
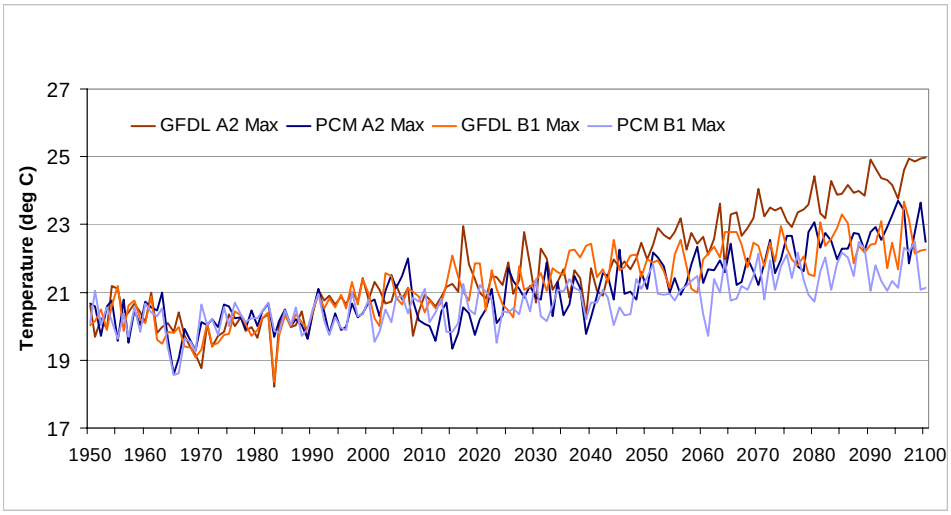
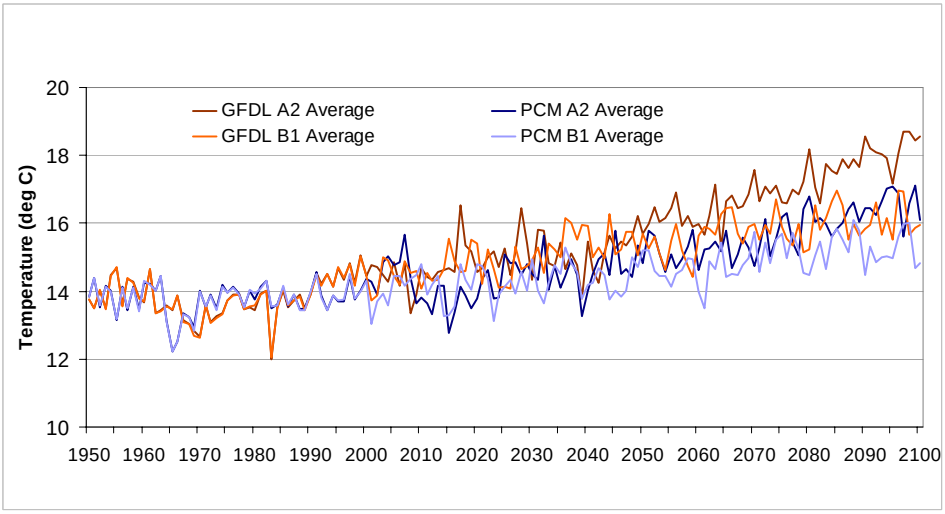


Figure 6-22 Downscaled precipitation time series from VIC model

a) Maximum air temperature from VIC model



b) Average Temperature from VIC model



c) Minimum temperature from VIC model

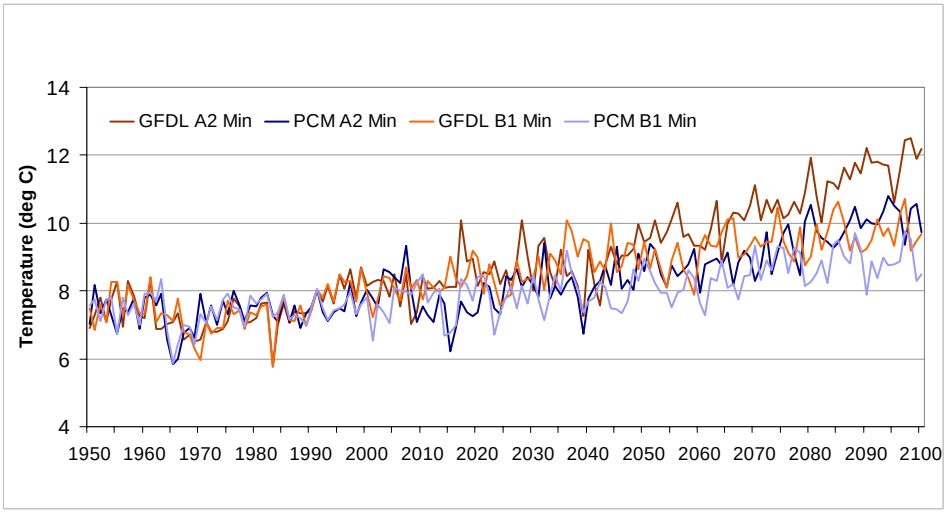


Figure 6-23 Downscaled average maximum, and minimum temperature time series

6.4.2.1 Precipitation

The scenario simulation results shown in Figure 6-22 depict little change in precipitation by 2050. Comparison of 30-year averages for the end of the 20th century and middle 21st century show a 5 percent decrease in precipitation for the GFDL model for both scenarios. The PCM model on the other hand shows no change for the A2 scenario and a 5 percent increase for the B1 scenario.

6.4.2.2 Temperature

For temperature there is a distinct increasing trend in average, maximum, and minimum temperature for both models and both scenarios. By 2050, the PCM model shows an average 1 degree C increase in average, maximum, and minimum temperature, while the GFDL shows an average 2 degree C increase. As in the GCM results, increases up to 5 degrees C exist by 2100 in the GFDL model results.

6.4.2.3 Runoff

In order to verify the ability of the scenario simulation data to represent water supply elements in California, the October-March, April-July, and annual runoff volume averages and standard deviations for the years 1951-2000 were compared for seven basins. The percent differences, computed as (modeled – observed)/observed, from observed average values for October-March are shown in Table 6-6, for April-July in Table 6-7, and annual values in Table 6-8. The percent differences from observed values for the standard deviations are shown in Table 6-9 for October-March, Table 6-10 for April-July, and Table 6-11 for annual values. In general, the simulated runoff values were closer to the observed values during the October-March period. Only the American and Kings basins have errors greater than 10 percent. However, in April-July, which is the important time period for water supply, the simulated data does not match up as well. Two basins, the Feather and Merced watersheds match up within 7 percent or less. The Sacramento and Tuolumne errors are between 10 percent and 20 percent, while the others are all greater than 30 percent.

The standard deviation represents the year-to-year variability in the system. As can be seen from Table 6-9, Table 6-10, and Table 6-11 with a few exceptions, both models had difficulty representing the historical year-to-year variability for the October through March, April through July, and annual periods. Both the GFDL and PCM models show less variability than has been observed. This inability to capture the historical year-to-year variability means that any prolonged dry or wet periods during the future portion of the simulations are suspect and cannot be interpreted as prolonged flood or drought cycles.

Table 6-6 Modeled vs Observed Percent Differences in Oct-Mar Runoff Average

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	2%	1%	3%	2%
Feather	Oroville	7%	6%	8%	8%
American	Folsom	37%	36%	37%	35%
Stanislaus	New Melones	1%	-1%	1%	0%
Merced	Lake McClure	-4%	-3%	-6%	-5%
Tuolumne	Don Pedro	-3%	-4%	-4%	-5%
Kings	Pine Flat	-13%	-14%	-15%	-14%

Table 6-7 Modeled vs Observed Percent Differences in Apr-July Runoff Average

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	18%	16%	20%	19%
Feather	Oroville	6%	7%	2%	4%
American	Folsom	42%	43%	40%	42%
Stanislaus	New Melones	32%	33%	30%	31%
Merced	Lake McClure	5%	3%	6%	6%
Tuolumne	Don Pedro	13%	14%	11%	12%
Kings	Pine Flat	44%	47%	44%	43%

Table 6-8 Modeled vs Observed Percent Differences in Annual Runoff Average

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	25%	25%	9%	9%
Feather	Oroville	7%	6%	-1%	-2%
American	Folsom	-32%	-32%	-35%	-36%
Stanislaus	New Melones	-11%	-11%	-13%	-13%
Merced	Lake McClure	3%	4%	2%	2%
Tuolumne	Don Pedro	2%	3%	1%	1%
Kings	Pine Flat	33%	34%	35%	34%

Table 6-9 Modeled vs Observed Percent Differences in Oct-Mar Runoff Standard Deviation

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	-21%	-21%	-15%	-17%
Feather	Oroville	8%	9%	23%	20%
American	Folsom	12%	12%	22%	21%
Stanislaus	New Melones	11%	9%	21%	24%
Merced	Lake McClure	-18%	-18%	-17%	-13%
Tuolumne	Don Pedro	9%	9%	17%	21%
Kings	Pine Flat	13%	9%	20%	26%

Table 6-10 Modeled vs Observed Percent Differences in Apr-Jul Runoff Standard Deviation

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	8%	14%	27%	21%
Feather	Oroville	33%	33%	16%	25%
American	Folsom	35%	35%	21%	25%
Stanislaus	New Melones	30%	31%	21%	20%
Merced	Lake McClure	10%	7%	3%	0%
Tuolumne	Don Pedro	4%	4%	4%	6%
Kings	Pine Flat	61%	61%	75%	78%

Table 6-11 Modeled vs Observed Percent Differences in Annual Runoff Standard Deviation

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	26%	26%	19%	20%
Feather	Oroville	-15%	-16%	-17%	-16%
American	Folsom	-15%	-16%	-15%	-14%
Stanislaus	New Melones	-20%	-20%	-16%	-16%
Merced	Lake McClure	1%	2%	10%	11%
Tuolumne	Don Pedro	-5%	-6%	1%	1%
Kings	Pine Flat	26%	26%	44%	45%

With the understanding that the simulated runoff does not match historically observed statistics very well, the following tables show the percent change from historical conditions that occurs for the 2035-2064 period relative to the 1961-1990 period. Table 6-12 shows the percent changes in the mean for October through March. The April-July percent changes in the mean are shown in Table 6-13 and the annual changes in the mean are shown in Table 6-14.

While the magnitude of the changes may be suspect due to the large errors in representing the historical conditions, some general trends can be noted. With the exception of the PCM-A2 simulation for inflows to Shasta reservoir, all October through March runoff values are larger in the 30 years centered on 2050 (future) than the 30 years centered on 1975 (present). For the April through July runoff all future values are less than present with the exception of inflows to Shasta and Oroville for the PCM-B1 scenario. On an annual basis, the PCM model predicts changes less than 10 percent for all basins for both scenarios. However, the changes are positive (increase in annual runoff) for the B1 scenario and negative (decrease in annual runoff) for the A2 scenario. The GFDL model predicts less than 20 percent changes all basins for both scenarios. The GFDL predicts decreases in annual runoff with the exception of Shasta and Oroville inflows for the B1 scenario.

Table 6-12 Percent Differences in Future to Present Oct-Mar Runoff Average

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	8%	7%	9%	3%
Feather	Oroville	14%	10%	11%	13%
American	Folsom	13%	17%	0%	4%
Stanislaus	New Melones	16%	12%	9%	14%
Merced	Lake McClure	22%	13%	2%	13%
Tuolomne	Don Pedro	13%	9%	5%	11%
Kings	Pine Flat	15%	17%	4%	11%

Table 6-13 Percent Differences in Future to Present Apr-Jul Runoff Average

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	-9%	0%	-20%	-22%
Feather	Oroville	-14%	-5%	-26%	-30%
American	Folsom	-23%	-13%	-43%	-40%
Stanislaus	New Melones	-13%	-9%	-34%	-33%
Merced	Lk McClure	-10%	-14%	-27%	-29%
Tuolomne	Don Pedro	-6%	-8%	-25%	-26%
Kings	Pine Flat	-6%	-12%	-29%	-28%

Table 6-14 Percent Differences in Future to Present Annual Runoff Average

Watershed	Inflow Location	PCM-B1	PCM-A2	GFDL-B1	GFDL-A2
Sacramento	Shasta	2%	4%	-2%	-6%
Feather	Oroville	3%	4%	-5%	-5%
American	Folsom	-2%	4%	-19%	-15%
Stanislaus	New Melones	1%	1%	-13%	-10%
Merced	Lk McClure	2%	-3%	-16%	-13%
Tuolomne	Don Pedro	1%	-1%	-13%	-11%
Kings	Pine Flat	2%	-2%	-17%	-14%

6.4.2.4 Peak Flow Runoff

Data provided from the GCM simulations is at a monthly time scale. Such data are not suitable to investigate peak flow runoff changes associated with climate change. Peak flows are associated with given weather events that are a fundamentally different scale from climate. In order to generate data appropriate for peak flow runoff analyses, the GCM simulations would have to be able to correctly simulate the magnitude, location, and variability of the atmospheric circulations associated with extreme rainfall and runoff. For future climate scenarios, a large sample of GCM realizations would enable a probabilistic approach to assess changes in extreme precipitation and runoff frequency. At this time, this analysis is left for future work.

6.4.3 Summary of GCM Model Results

There is great uncertainty in the magnitude, timing, and location of precipitation and runoff changes associated with climate change. Historical trends depend on the time frame chosen, although most changes are small. The magnitude of model-derived changes is less than the magnitude of the differences between observed and modeled statistics for the historical period. One way to avoid this problem is to use multiple simulations and compute averages of the multiple simulations. These ensemble averages are then used to analyze expected changes associated with climate change.

It should be noted that maximum, minimum and average temperatures have risen in the past and are expected to continue to rise across the state based on model simulations. There is some range (1 to 5 degrees C) in the amount of warming expected depending on the model and scenario. While changes in flood frequency can not be quantified from the simulation results, some elements of climate change based runoff changes can be quantified. These are explored in the next section.

6.5 Potential Impacts

Changes in runoff associated with climate change can be related to the changes in watershed response due to the modification of the seasonal snowpack. Increasing temperatures will likely push the snow level in watersheds to higher elevations leaving more of the watershed available to contribute to direct winter runoff processes. In addition, higher elevation snow levels decrease the available watershed area for snowpack to develop. Both of these issues are explored in this section. For other studies, see a special issue of Climatic Change (Vol. 62, 2004) which included a number of studies on climate change impacts on California water resources.

A simple hydrologic model of the Feather River watershed, HED71 (Buer, 1988), is used to illustrate the effects of greater contributing area on direct runoff. It is a simple forecasting model and is not a physically based model of the watershed. However, the HED71 model has the ability to specify the elevation where the snowpack starts. Elevations below this are used to generate direct runoff from an input precipitation event. As such the HED71 model can be used to evaluate the relative changes in runoff associated with different contributing areas.

A winter storm pattern of rainfall was chosen which dropped a total of 10 inches of rain in a 72 hour period. This corresponds to a 10-15 year return period event. The timing of the rainfall is shown in Figure 6-24. The HED71 model was run with a base case snow elevation of 4500 feet. Three scenario simulations were run with snow elevations at 5000, 6000, and 7000 feet which are associated with a respective 1, 3, and 5 degree Celsius rise in mean atmospheric temperature. These values are based on the assumption of a 500 foot increase in snow elevation for each 1 degree Celsius increase in mean atmospheric temperature. The percent increases in contributing area over the base case for these three temperature changes are 57 percent, 184 percent, and 250 percent respectively. Note that for the 5 degree increase in temperature, only 2 percent of the watershed is covered with snow and is assumed not to contribute to direct runoff.

Based on these simulations, the peak runoff from this storm increased 23 percent, 83 percent and 131 percent respectively. The runoff hydrographs scaled by the peak flow of the base case are

shown in Figure 6-25. As can be seen from Figure 6-25, there is a significant increase in direct runoff volume associated with higher elevations for snowpack due to the increased contributing area of the watershed. The more than doubling of the peak runoff associated with a 5 degree Celsius increase in mean atmospheric temperature would cause significant changes in the return period of peak runoff associated with a specified rainfall event.

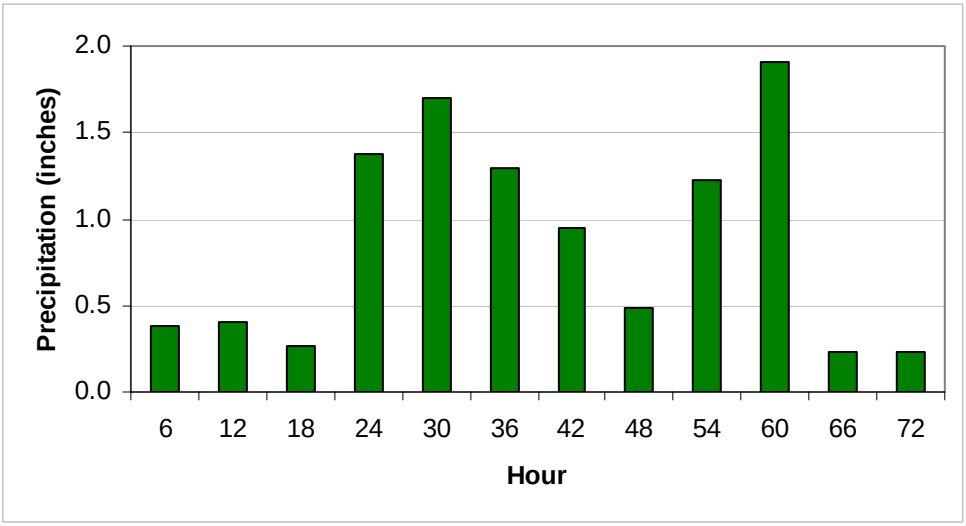


Figure 6-24 Input hyetograph to HED71 model.

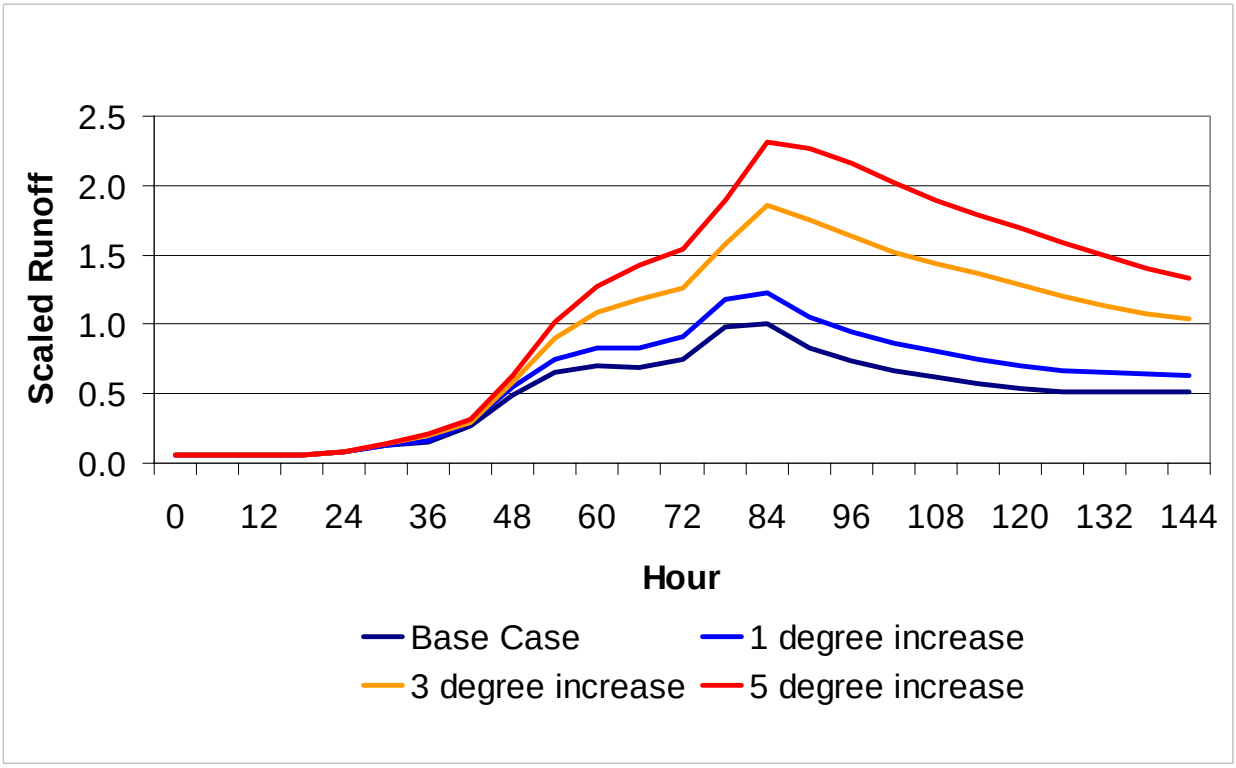


Figure 6-25 Direct runoff changes due to increasing contributing area of watershed

As pointed out earlier, higher snow elevations not only mean more area to contribute to direct runoff for a given winter storm, but there is less area for snowpack to develop at higher elevations. The impact of higher snow elevations due to higher atmospheric temperatures is estimated using area-elevation curves for watersheds. Computations assumed a 500 foot increase in elevation of snowpack for each degree Celsius of atmospheric temperature warming. Table 6-15 lists the percentage of watershed area covered with snow for 25 basins given mean atmospheric temperature increases from 1 to 5 degrees Celsius.

Table 6-15 Snow Covered Area Changes with Temperature for Selected Watersheds

Basin	Mean elevation	Average Apr. 1 snow line	Total area	Snow Covered Area	1° C Rise	2° C Rise	3° C Rise	4° C Rise	5° C Rise
	[ft]	[ft]	[mi2]	[percent of basin]	[% of basin]	[% of basin]	[% of basin]	[% of basin]	[% of basin]
Trinity	4,740	4,000	700	63%	56%	47%	36%	24%	11%
Sac/Delta	4,130	4,000	418	48%	36%	26%	19%	10%	7%
McCloud	4,370	4,000	607	56%	40%	25%	16%	10%	6%
Pit	4,830	4,000	4,768	81%	62%	42%	24%	11%	6%
Shasta	4,550	4,000	6,400	71%	54%	36%	21%	10%	6%
Bend	3,870	4,000	9,030	54%	41%	28%	17%	8%	5%
Feather	4,940	4,500	3,624	72%	56%	36%	20%	9%	2%
Yuba	4,470	4,500	1,191	50%	42%	34%	28%	17%	8%
American	4,300	4,500	1,900	48%	42%	34%	26%	19%	12%
Cosumnes	3,100	4,500	530	25%	15%	9%	6%	3%	1%
Mokelumne	5,030	5,000	575	50%	43%	38%	31%	26%	20%
Stanislaus	5,530	5,000	935	60%	55%	48%	42%	33%	26%
Tuolumne	5,960	5,000	1,530	60%	54%	49%	44%	39%	35%
Merced	5,470	5,500	1,020	47%	43%	42%	38%	32%	26%
San Joaquin	7,130	5,500	1,640	72%	67%	62%	57%	49%	43%
Kings	7,700	5,500	1,540	76%	73%	69%	64%	59%	54%
Kaweah	5,600	6,000	563	44%	39%	34%	27%	23%	18%
Tule	3,950	6,000	390	23%	15%	13%	8%	6%	3%
Kern	7,410	6,000	2,080	73%	65%	56%	49%	41%	33%
Truckee	6,790	5,500	430	100%	84%	58%	35%	17%	8%
Tahoe	7,030	6,000	510	100%	55%	41%	29%	18%	8%
W. Carson	8,050	6,000	70	100%	100%	100%	71%	51%	25%
E. Carson	7,530	6,000	350	86%	77%	66%	54%	47%	22%
W. Walker	8,650	6,500	180	100%	94%	83%	67%	53%	41%
E. Walker	8,250	6,500	360	97%	83%	69%	50%	36%	26%
Average	5,735	5,120	1,654	66%	56%	46%	35%	26%	18%

As can be seen from Table 6-15, the northern watersheds lose the majority of their area for snowpack development once the temperature increases reach or exceed 2 degrees Celsius. Lower elevation basins such as the Cosumnes, may lose their snowpack entirely in drier years. Higher elevation basins tributary to the San Joaquin River are less impacted than the northern basins. However, these basins produce less annual runoff than the basins in the north. Increasing peak flows due to winter storms and smaller snowpacks in terms of the percentage of the watershed

covered can have significant impacts on the operation of flood control and water supply structures in California.

Knowles and Cayan (2004) and Mote and others (2005) discuss how snow responds to climate change based on latitude and elevation. Knowles and Cayan (2004) note that the greatest changes to snowpack due to climate change are in the 4000 to 9000 foot elevation range for the Sacramento River Basin. Mote and others (2005) show that the trends in spring snowpack in the western United States are largely due to long-term warming trends. Year-to-year variability due to changes in the Pacific Ocean like El Nino at most only account for one third of the magnitude of the trend. They also note that future warming will likely change most seasonal snowpack sites to sites that will accumulate and melt several times each year.

6.6 Discussion

Over the past century there have been observed changes to the average, maximum, and minimum temperatures and their variability, changes to the annual precipitation variability, and changes to the three-day peak discharge statistics. Over the past 30 years there has been a small increase in observed statewide average annual precipitation as well.

For this report, four climate-change simulations (two models x two scenarios) were evaluated for information on potential impacts to runoff patterns in California. Increasing temperatures are likely to lead to increased elevations for snowpack formation which leads to a greater contributing area available for winter storm runoff. In a sample calculation, the peak runoff for a given event is shown to double under a 5 degree Celsius warming. The percent decrease in watershed area available for snowpack was also shown for 1 to 5 degree Celsius warming. In addition to these changes, warmer temperatures may lead to early melting of the snowpack. Analysis of observed data indicates that a two-week shift has already occurred for lower elevations. The combination of earlier melt times, greater variability and greater potential for direct storm runoff may challenge the current system of flood protection and water supply in the state. Because of this, future work is needed in the following areas.

In order to better understand the risks associated with global climate change on California's runoff patterns, it is important to be able to quantify the uncertainty in projected changes to flood and drought frequencies and to the quantity and timing of water supply runoff. Future efforts to address these issues include:

- Continue historical data trend and variability evaluation
- Periodically update frequency-based data for design computations
- Evaluate new climate change model-derived data sets
- Develop new water supply forecasting technologies that can adapt to the changing distribution of the state's annual water supply
- Incorporate methodologies to quantify the uncertainty in potential climate change based impacts into the water supply planning process

For flood frequency analysis, future synthetic daily flow datasets may eventually be produced from climate change model output that will be suitable for flood frequency analyses. As these

future datasets become available, they must be evaluated for their ability to represent current magnitude and variability as well as predicted changes due to climate change. At this time there is no dataset that would provide meaningful results.

Another area that may produce useful flood forecasting information examines historical data in order to identify critical atmospheric circulation parameters and their threshold values associated with extreme flooding events. As the circulation patterns in the GCMs improve and are shown to represent current conditions (location, frequency, variability) correctly, circulation patterns under increased greenhouse gas concentrations can be examined for the flood producing patterns or critical threshold characteristics. Improved forecasting technologies will help the implementation of adaptive strategies to mitigate the atmospheric and hydrologic changes that may increase flood risk.

For water supply analyses, it is important to identify potential changes to the land covered by snowpack and to identify changes to the magnitude and timing of snowpack growth and decay. Earlier melt patterns may necessitate new forecast bulletin products such as a March to May runoff forecast being created to complement existing April-July water supply forecasts. The inclusion of March in the forecast process introduces a large element of variability. Uncertainties related to this variability would have to be quantified as part of the water supply forecast product. Improved understanding of the potential future changes to the magnitude and timing of water supply runoff will enable better forecast products which can improve adaptive strategies for water supply operations in the state.

6.7 References

Bardini, G., S. Guillen, B. Pierotti, H. Rooks, S. Sou. 2001. *Climate Change in Califonria: Potential Consequences and strategies to cope and adapt*. California Department of Water Resources Report. 91 pp.

Barnett, T., R. Malone, W. Pennell, D. Stammer, B. Semtner and W. Washington. 2004. "The Effects of Climate Change on Water Resources in the West: Introduction and Overview", *Climatic Change*, 62, 1-11.

Buer, S. 1988. Program Manual: HED71 for Headwater Runoff Forecasting. California Department of Water Resources Division of Flood Management.

Christensen, N.S., A.W. Wood, N. Voisin, D. P. Lettenmaier and R. N. Palmer. 2004. "The effects of climate change on the hydrology and water resources of the Colorado River Basin", *Climatic Change*, 62, 337-363.

Dettinger, M., D. Cayan, M. Meyer, and A. Jeton, 2004. "Simulated hydrologic responses to climate variations and change in the Merced, Carson, and American Rivers, Sierra Nevada, 1900-2099", *Climatic Change*, 62, 283-317.

Easterling, (2000). *Observed Variability and Trends in Extreme Climate Events: A Brief Review.* [D.R. Easterling, J.L. Evans, P. Ya. Groisman, T.R. Karl1, K.E. Kunkel, P. Ambenje] Bulletin of the American Meteorological Society, **81**, March 2000, 417-425. http://www.ncdc.noaa.gov/oa/pub/data/special/extr-bams2.pdf

Gleick, P.H., 1987. "The development and testing of a water balance model for climate impact assessment: Modeling the Sacramento basin", *Water Resources Research*, 23, 1049-1061.

Intergovernmental Panel on Climate Change, 1990. *Climate Change: The IPCC Scientific Assessment*, J.T. Houghton, G.J. Jenkins, and J.J. Ephraums (eds.) Cambridge University Press. Cambridge, UK, 365 pp.

Intergovernmental Panel on Climate Change, 1995. *Climate Change 1995: The Science of Climate Change*, J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.) Cambridge University Press. Cambridge, UK, 572 pp.

Intergovernmental Panel on Climate Change, 2001. *Climate Change 2001: The Scientific Basis*. Cambridge Univ. Press. 881 pp.

Jeton, A.E., M.D. Dettinger, and J.L.. Smith, 1996. "Potential effects of climate change on streamflow: Eastern and western slopes of the Sierra Nevada, California and Nevada". *U.S. Geological Survey, Water Resources Investigations Rep*. 95-4260, 44pp.

Kim, J. 2005. "A projection of the effects of climate change induced by increased CO2 on extreme hydrologic events in the western U.S.", *Climatic Change*, 68, 153-168.

Knowles, N. and D.R. Cayan, 2001. *Global climate change: Potential effects on the Sacramento-San Joaquin watershed and the San Francisco Estuary*.

http://meteora.ucsd.edu/~knowles/papers/Globaland California.pdf

Knowles, N. And D.R. Cayan. 2004. "Elevational dependence of projected hydrologic changes in the san francisco estuary and watershed", *Climatic Change*, 62, 319-336.

Lettenmaier, D.P. and T.Y. Gan, 1990. "Hydrologic sensitivities of the Sacramento-San Joaquin River Basin, California, to global warming". *Water Resources Res*, 26, 69-86.

Maurer, E.P. 2005. "Uncertainty in hydrologic impacts of climate change in the Sierra Nevada Mountains, California under two emissions scenarios", *Climatic Change,* (submitted 29 April 2005).

Maurer, E.P. and P. B. Duffy. 2005. "Uncertainty in projections of streamflow changes due to climate change in California", *Geophysical Research Letters*, 32, L03704.

Miller, N.L., J. Kim, R.K. Hartman, and J. Farrara, 1999. "Downscaled climate and streamflow study of the Southwestern United States", *J. American Water Resources Association*, 35, 1525-1537.

Miller, N.L., K.E. Bashford, and E. Strem, 2003. "Potential impacts of climate change of California hydrology". *J. Amer. Water Resourc. Assoc*, 39, 771-784.

Mote, PW, AF Hamlet, MP Clark, and DP Lettenmaier, 2005. Declining mountain snowpack in western North America, Bulletin of the American Meteorological Society, 86:39-49.

Peterson, T., 2003. "Assessment of Urban Versus Rural In Situ Surface Temperatures in the Contiguous United States: No Difference Found", *Journal of Climate*, 16: 2941–2959.

Revelle, R.R. and P.E. Waggoner,1983. "Effects of a carbon dioxide induced climatic change on water supplies in the Western United States". In *Changing Climate*, National Academy of Sciences Press, Washington, D.C.

Stedinger, J.R, and C. M. Crainiceanu, "Climate Variability and Flood-Risk Management, Risk-Based Decision Making", in *Water Resources IX, Proceedings of the Ninth Conference, United Engineering Foundation , Santa Barbara, CA, Oct. 15-20, 2000*, pp. 77-86, Amer. Society of Civil Engineers, Reston, VA, 2001.

Stewart, I.T., D.R. Cayan and M. D. Dettinger, 2004. "Changes in snowmelt runoff timing in western North America under a `business as usual' climate change scenario", *Climatic Change*, 62, 217-232.

USGRCP Water, 2000. *Water: The potential consequences of climate variabbility and change*. A report of the National Assessment Group for the USGCRP. 151 pp.

VanRheenen, N.T. A.W. Wood, R.N. Palmer and D.P. Lettenmaier. 2004. "Potential implications of pcm climate change scenarios for sacramento–san joaquin river basin hydrology and water resources", *Climatic Change*, 62, 257-281.

Water Resources Council, 1982. Guidelines for determining flood flow frequency, Bulletin 17B, United States Geological Survey Office of Water Data Coordination.

Wigley, T.M.L. and S.C.B. Roper, 2001. "Interpretation of high projections for global-mean warming". *Science*, 293, 451-454.

Wilby, R.L. and M.D. Dettinger, 2000. "Streamflow changes in the Sierra Nevada, California, simulated using statistically downscaled general circulation model output". In *Linking Climate Change to Land Surface Change*, Ed. S. McLaren and D. Kniven, Kluwer Academic Pub., 99-121.

Wood, A.W., L. R. Leung, V. Sridhar and D. P. Lettenmaier. 2004. "Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs" *Climatic Change*, 62, 189-216.

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Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
July 2006

Chapter 7:
Climate Change Impacts on Evapotranspiration

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7 Climate Change Impacts on Evapotranspiration

7.1 Introduction

Possible increases in crop water demand and reduced water resource availability due to climate change are a growing concern among scientists and policy makers. We discuss the potential response of evapotranspiration (ET) to global climate change. Evapotranspiration is the vaporization or release of water vapor to the atmosphere from the terrestrial landscape. There are two parts to ET. First is evaporation, which includes vaporization of water from the soil and wet plant surfaces. Second is transpiration, which is vaporization that occurs within the leaves with the water vapor diffusing through pores in the leaves to the atmosphere. Water for transpiration comes from the soil through the plants and to the atmosphere. So the transpiration rate depends on the integration of soil, plant, and atmospheric factors. The evaporation rate depends on soil factors and frequency and amount of precipitation and irrigation, which determine water availability for vaporization.

In this chapter, we provide the current ET demand in California together with possible future ET demand under climate change. Population growth and likely crop pattern shifts are considered as factors that affect climate change ET estimates. An energy budget analysis to examine the net energy flux involved with ET and the physiological processes that influence ET are provided to explain the ET mechanisms affected by climate change. We describe a promising water management simulation model, SIMulation ET of Applied Water (SIMETAW). It is described in relation to climate prediction to estimate future net irrigation needs for crops.

7.2 Evaporative Demand for Applied Water in California

7.2.1 Current settings

California has produced the highest agricultural value in the country for the past 50 years. In 1997, 10.8 million acres of the state were devoted to harvested crops with another 14.4 million acres devoted to pasture and rangeland. Half of the fruits, nuts and vegetables in the country are produced in California. It is the only state producing commercial quantities of almonds, artichokes, clingstone peaches, figs, raisins, walnuts, pistachios, nectarines, olives, dates, and prunes. California also leads the nation in dairy production. In 2003, the latest available information for California agriculture production, California earned $29.4 billion in agriculture income (USDA, 2003).

This land of milk and honey results from a geography of fertile valleys, coastal plains, and gently rolling foothills and sharp tall mountains. The tall mountains in the north and on the eastern side of the state accumulate snow in winter for a water reserve during the next growing season. A semiarid Mediterranean climate provides a long frost-free growing season in most of the state. And there is abundant sunshine, a key to a plentiful agriculture and lush native vegetation.

The native vegetation of the state has a net primary productivity (NPP) that reflects the natural carrying capacity with respect to water and other natural resources. The native NPP is less than that of the state's crop production mainly because of the supplemental irrigation water applied. Figure 7-1 provides a regional map of California with the state's 10 hydrologic regions and Figure 7-2 is a map of 18 reference evapotranspiration (ET_o) zones California. The hydrological zones have traditionally been used for water resources planning and the ETo zone map has further refined ET estimation in California. Reference evapotranspiration is the ET from a vegetated surface with an approximate height of 0.12 m that is similar to clipped, cool-season grass (ASCE-EWRI, 2005). DWR's California Irrigation Management Information System (CIMIS) network (Snyder and Pruitt, 1992) was the main source of data used to develop the ET_o map. The Pruitt and Doorenbos (1977) hourly ET_o equation rather than the hourly ASCE-EWRI Penman-Monteith equation is used in CIMIS. The results, however, are similar for both equations (Ventura et al., 1999). The monthly and annual total ET_o for each of the eighteen zones is listed in Table 7.1 to illustrate the variability through the year and between zones. The ETo rates listed for the zones show the spatial patterns and relative variation of average annual ETo with extremes from 32.9 to 71.6 inches per year.

Rainfall and irrigation water are the principal sources of water for agricultural production. Irrigation water includes groundwater pumped from aquifers and surface water delivered through natural and man-made and watercourses. The surface water generally originates in the mountains as snowmelt and surface runoff from precipitation. It is temporarily stored in reservoirs for later distribution during the peak-demand season. Excluding water used to meet instream flow requirements, Delta water quality, and other environmental uses, 80 percent of the developed water supply supports agriculture while 20 percent serves urban uses.

Most of the agricultural water contributes to crop ET. But water is also used for cultural practices, such as leaching salts and for frost protection. It is also used for groundwater recharge. The term consumptive use is used and it refers to the water vaporized to produce a crop or ET. Evapotranspiration of applied water (ET_{aw}) is equal to ET minus effective precipitation, the amount of rainfall available for use by a crop. Therefore, ET_{aw} is the amount of irrigation water that is consumed by the crop. Additional irrigation water is applied to account for non-uniform distribution of the irrigation water and to control salinity. Most of the applied irrigation water contributes to ET_{aw}, so it is essential information for water resources planning and management. Projections for the actual demand for irrigation water are predicted using estimates of irrigation application efficiency. These estimates depend on the irrigation system and management, water requirements for leaching and other cultural practices, and ET_{aw} or applied irrigation water is transpired by crops and evaporated from soil and plant surfaces.

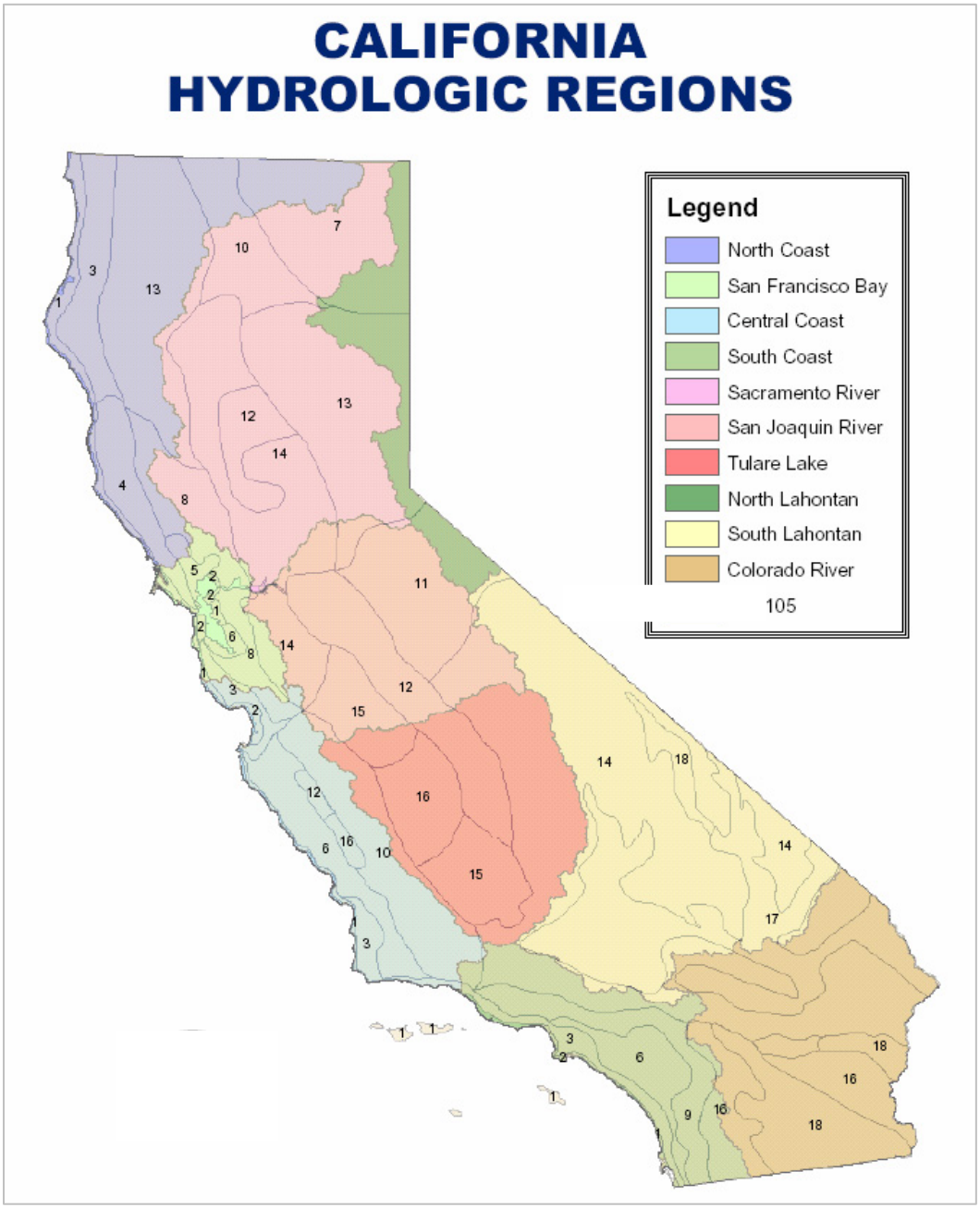

Figure 7-1 Hydrological regions coded by color
(Numbers are the ET zones listed in the legend and coded by color in Figure 7-2)

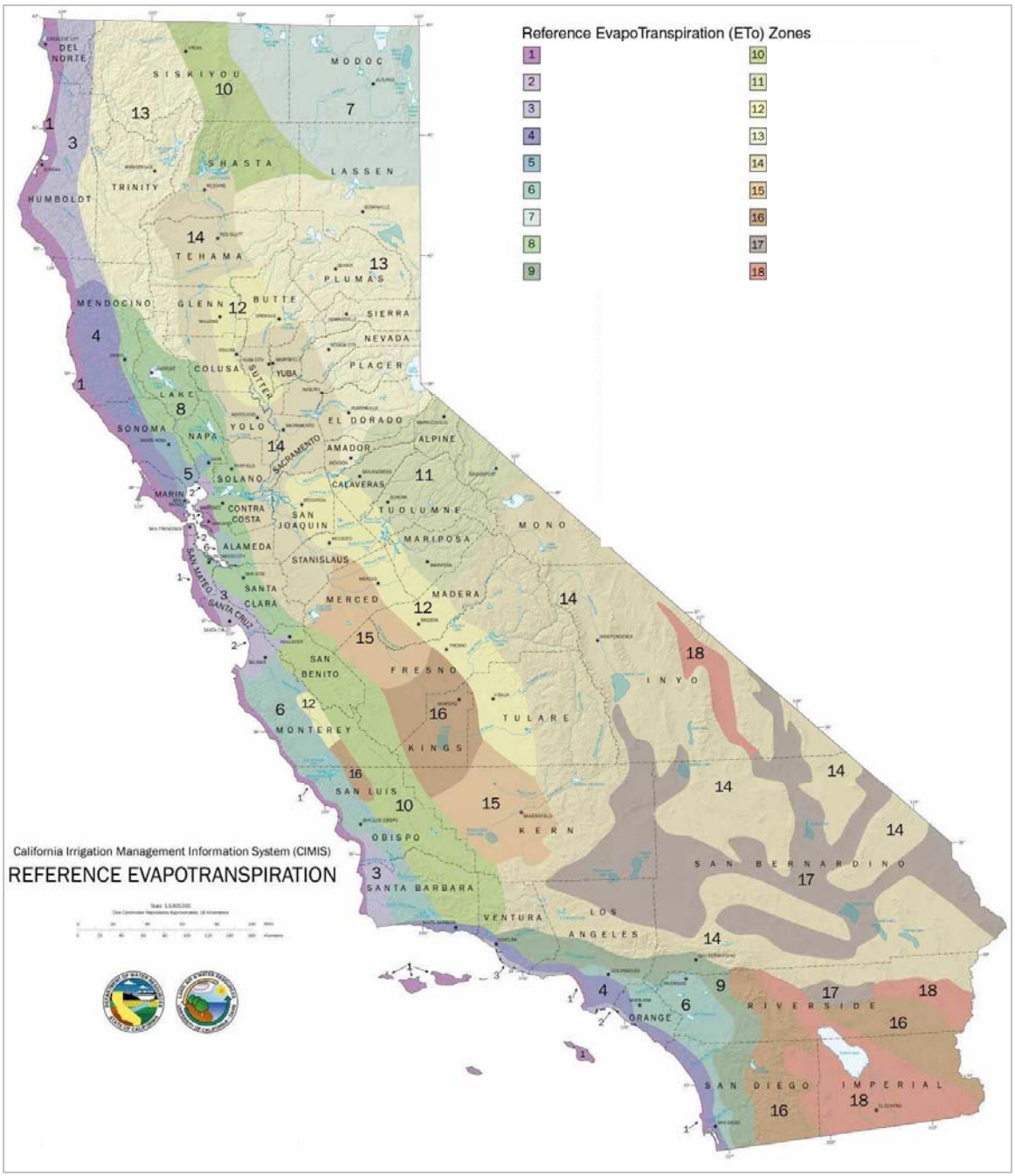

Figure 7-2. Reference evapotranspiration zones

Table 7.1. Monthly and total reference evapotranspiration (ETo) by ETo zone for the California ETo zone map in inches per month.

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	0.9	1.4	2.5	3.3	4.0	4.5	4.7	4.0	3.3	2.5	1.2	0.6	32.9
2	1.2	1.7	3.1	3.9	4.7	5.1	5.0	4.7	3.9	2.8	1.8	1.2	39.0
3	1.9	2.2	3.7	4.8	5.3	5.7	5.6	5.3	4.2	3.4	2.4	1.9	46.3
4	1.9	2.2	3.4	4.5	5.3	5.7	5.9	5.6	4.5	3.4	2.4	1.9	46.6
5	0.9	1.7	2.8	4.2	5.6	6.3	6.5	5.9	4.5	3.1	1.5	0.9	43.9
6	1.9	2.2	3.4	4.8	5.6	6.3	6.5	6.2	4.8	3.7	2.4	1.9	49.7
7	0.6	1.4	2.5	3.9	5.3	6.3	7.4	6.5	4.8	2.8	1.2	0.6	43.3
8	1.2	1.7	3.4	4.8	6.2	6.9	7.4	6.5	5.1	3.4	1.8	0.9	49.4
9	2.2	2.8	4.0	5.1	5.9	6.6	7.4	6.8	5.7	4.0	2.7	1.9	55.1
10	0.9	1.7	3.1	4.5	5.9	7.2	8.1	7.1	5.1	3.1	1.5	0.9	49.1
11	1.6	2.2	3.1	4.5	5.9	7.2	8.1	7.4	5.7	3.7	2.1	1.6	53.1
12	1.2	2.0	3.4	5.1	6.8	7.8	8.1	7.1	5.4	3.7	1.8	0.9	53.4
13	1.2	2.0	3.1	4.8	6.5	7.8	9.0	7.8	5.7	3.7	1.8	0.9	54.3
14	1.6	2.2	3.7	5.1	6.8	7.8	8.7	7.8	5.7	4.0	2.1	1.6	57.0
15	1.2	2.2	3.7	5.7	7.4	8.1	8.7	7.8	5.7	4.0	2.1	1.2	57.9
16	1.6	2.5	4.0	5.7	7.8	8.7	9.3	8.4	6.3	4.3	2.4	1.6	62.5
17	1.9	2.8	4.7	6.0	8.1	9.0	9.9	8.7	6.6	4.3	2.7	1.9	66.5
18	2.5	3.4	5.3	6.9	8.7	9.6	9.6	8.7	6.9	5.0	3.0	2.2	71.6

The average annual ET_{aw} in the state's ten hydrologic regions, during the most recently recorded normal water year 2000 (DWR-DPLA, 2005), ranged from 13.56 acre-inch per acre per year to 44.52 acre-inch per acre per year (Table 7.2). These ET_{aw} values are weighted by the acreages of crops grown in each region. They also reflect the variability in planting and harvest dates, ETo, and effective precipitation for each crop in each hydrologic region. Crop coefficients used to calculate crop ET_{aw} from ET_o came from a variety of sources including DWR Bulletin 113-3, April 1975, Bulletin 113-4, April 1986 and Food and Agriculture Organization of the United Nations Irrigation and Drainage Paper 56 Crop Evapotranspiration, 1998. Soil available water estimates were based on data in soil survey publications from the USDA National Resources Conservation Service. Records of daily precipitation from weather stations located near agricultural areas are used in a model along with ETo data and soil information to estimate the amount of precipitation available for crop consumption. The ET_{aw} values extend from October 1, 1999 through September 30, 2000. ET_{aw} values vary from year-to-year with changes in the proportions of irrigated acreage planted to each crop category, change in cultivars planted, the quantity and distribution (spatial and temporal) of precipitation, water applied for cultural practices, irrigation water management, variation in ETo and other factors.

The statewide average annual ET_{aw} for 20 important agricultural crop categories are listed in Table 7.3. These average ETaw values reflect the distribution of crops across the ETo zones in California. They are based upon the same data from Water Year 2000 used to estimate the average ET_{aw} for each hydrologic region. Safflower used the least water, averaging 9.48 acre-inch per acre while alfalfa used the most, averaging 42.72 acre-inch per acre.

Table 7.2 Estimated Annual ET of applied water by hydrologic region during the 2000 water year in acre feet per acre, from DWR-DPLA 2005

Region	Name	ETaw (acre-inch/acre)
01	North Coast	20.28
02	San Francisco Bay	14.16
03	Central Coast	13.56
04	South Coast	27.60
05	Sacramento River	28.92
06	San Joaquin River	26.04
07	Tulare Lake	26.76
08	North Lahontan	28.92
09	South Lahontan	44.52
10	Colorado River	42.96

Table 7.3 ET of applied water in acre inch per acre for some of the main commodities grown in California.

Commodity	ETaw (acre-in/acre)
Grains	12.72
Rice	37.44
Cotton	28.44
Sugar Beet	30.72
Corn	22.20
Dry Bean	18.36
Safflower	9.48
Other Field Crops	22.44
Alfalfa	42.72
Pasture	34.68
Processing Tomatoes	24.36
Fresh Market Tomatoes	20.40
Cucurbits	18.72
Onions Garlic	29.16
Potatoes	20.04
Other Truck Crops	15.84
Almonds Pistachios	33.12
Other Deciduous Orchards	32.16
Subtropical Crops	30.36
Vineyards	17.3

7.2.2 Projected ET changes for the California landscape impacted by climate change

Hidalgo et al. (2005) investigated the impacts of climate change on irrigation water demand with respect to reference ET (ET_o) in California and found that the highest interseasonal variability of ET_o daily anomalies occurs during the spring, mainly in response to variations in cloudiness. Daily ET_o values were closely associated with net radiation (R_n), relative humidity, and cloud cover, and are less related to average daily temperature. In the next section about energy budget the relationships between climatic factors are discussed along with relative influences they exert. Although Hidalgo et al (2005) concluded that to maintain ET_o in the current condition requires a decrease in R_n of about 6 percent to compensate for a temperature increase of 3ºC, they did not account for increased stomatal resistance that is likely to result from higher CO_2 concentration, which is discussed in detail later in this chapter. Hidalgo et al. were clearly correct in that the effects of climate change on ET_o are difficult to forecast because of the uncertainty of cloud cover and relative humidity. Allen et al. (1991) concluded that a CO_2 induced climate change resulted in an increased ET_o which then translated to an increased ET_{aw}.

7.2.3 Landscape influences on ET that complicate climate change effects

Climate influences biophysical features in the landscape, but the physical landscape also influences climate and affects the interaction between climate and landscape. For example, crop irrigation reduces the air temperature and urban surfaces commonly increase temperature.

Future urban growth affects the statewide ET demand by decreasing irrigated agriculture land. In population studies, Landis and Reilly (2004) reported that the greatest urban expansion is likely to happen on flat land of valley floors. They listed the greatest risk to important farmland as land in the Inland Empire and in the Central Valley.

Increasing urbanization can increase the heat-island effect (a localized elevation in temperature over the ambient air temperature) and could lead to small increases in advection of additional heat to nearby crops. Advection is the horizontal transfer of heat or scalars, such as water vapor or CO_2, that results when wind blows air reflecting characteristics of one surface over another surface with different characteristics. Energy fluxes over irrigated crops are usually vertical, but there can be edge effects when local advection occurs. When there is warm air advection, the horizontal transfer of energy can increase ET on crop edges. This can lead to moderate stress, which reduces plant size, or severe stress that reduces ET and photosynthesis. This is quite noticeable where irrigated fields are surrounded by bare, dry soil. Affected crops are often shorter and appear more stressed on the edges than in the middle of the field. There is also regional warm air advection, which occurs when heat is horizontally transferred over cropped areas. This often happens in the Central Valley where warm air from the drier foothills moves over irrigated land in the middle of the valley. For regional advection, however, the heat transfer is mostly vertical. This means there is more available energy for evaporation than is supplied by net radiation and soil heat flux. The result is a reduced ET_c/ET_{pot} ratio because Et_{pot} increases due to advection. Urbanization could lead to some additional warming and it might increased advection. Although small in its reach, increased advection could result from urban expansion into irrigated crops in an increasing dentate edge.

Other effects on ET from growing urbanization next to agricultural land include physiological impacts from air toxicants, most notably ozone, and regional atmospheric dimming from particulates and pollutants above and around urban centers and held in place by inversion due to high atmospheric pressure during the summer growing season.

7.2.4 Changes in cropping and irrigation methods that interact with climate change

Throughout the 150 years of California agriculture, many changes in crop types and shifts in cropping patterns have occurred. In addition to land loss to urbanization, land use conversions for agriculture are driven by irrigation water availability, changes in multiple cropping, and changes in the crops due to economics. Biophysical changes that result from climate change could contribute to these factors. For example, with warming temperatures, citrus production could move farther north in the Central Valley and deciduous orchard crops that have large chill requirements might have reduced production or be forced out of the area. Shifts in cropping patterns are likely to continue with increased water cost and possibly with changes in regional climates. There are, however, no comprehensive studies of projected changes in California agriculture resulting from climate change (Hayhoe et al., 2004). Water resources availability will likely be the main environmental variable determining shifts in crop distribution (Field et al., 1999).

Based on surveys conducted jointly by the University of California and California Department of Water Resources, a definite trend towards growing more perennial crops and using low-volume, pressurized irrigation systems has occurred during the past 30 years (CDWR Bulletin 160-05). While this has improved the economic benefits resulting from irrigation and has likely improved on-farm irrigation efficiency during years with adequate water supplies, growers have reduced ability to adapt during dry periods. For example they don't have annual field or row crops that could be fallowed during droughts. With adequate water supplies, this trend is good, but it is financially dangerous in terms of drought response and mitigation.

The value integration network simulation model (CALVIN) and the statewide water and agricultural production simulation model (SWAP) were developed at the University of California, Davis, and they were coupled to investigate climate change in California by modifying crop yields and amount of irrigated water used (Tanaka et al., 2005). They concluded that by the end of the century there will be a 24 percent decrease in the amount of water devoted to agriculture and only a 6 percent decrease in agricultural income. The differences in water use and income were attributed to growing higher value crops and increased irrigation application efficiency. Higher application efficiencies mean higher ratios of water consumption by evapotranspiration to water applied. This can reduce both diversions for irrigation and reduced return flow. In some instances, this may reduce supplies to downstream projects depending on whether the reduction in diversions or return flow is larger. Generally, if outflows from basins are near minimum values, only reductions in ET upstream will free up water for transfer from irrigated agriculture.

7.3 Energy Budget

An energy budget can account for all input and output energy fluxes to a terrestrial landscape. Among these fluxes is the mass balance of water phase change of liquid water to gaseous water vapor. This accounting is a useful analytic tool to investigate the affect of climate change on

evapotranspiration. The Penman-Monteith equation, which is described in Appendix 1, is a partly empirical algorithm that was derived from energy budget considerations. It was modified by the ASCE-EWRI (2005) to derive a reference evapotranspiration (ETo) rate from meteorological measurements of minimum and maximum temperature, humidity, solar radiation and wind speed. There is, however, a difficulty in estimating crop evapotranspiration (ETc) or ETo for a climate-changed environment because of a lack of knowledge about canopy resistance to water vapor loss in an elevated CO_2 environment. Nonetheless, using FACE measurements of stomatal resistance (Long et al., 2004) for elevated CO_2 and the same approach used by Allen et al. (1989) to estimate canopy from stomatal resistance for use in estimating ETo, an increase in CO_2 concentration to 550 ppm is expected to increase the daily mean canopy resistance from 70 to 87 s m^{-1}.

It is important that the ASCE-EWRI (2005) has fixed the ET_o canopy resistance at 70 s m^{-1} for daily calculations and it is unlikely to be changed in the near future. The equation, however, should be updated if the canopy resistance changes. This is necessary because crop coefficient values were mostly developed by calculating the ratio $K_c = ET_c/ET_o$, where ET_o was the ET of the reference grass surface and ET_c was the crop ET. Consequently, the standardized reference ET equation should provide a good estimate of the ET of a 0.12 m tall, cool-season grass surface or the K_c values will surely be incorrect. It is possible that K_c values could change because of differences in stomatal responses to climate change, but changing the ET_o equation and assuming that the K_c ratio will be conserved is more plausible than maintaining a standardized equation that gives an incorrect estimate of the K_c ratio denominator. To investigate possible ET changes in response to climate change, the daily (24-hour) ASCE-EWRI (2005) ET_o equation is used and the temperatures and canopy resistance are changed to investigate how the ET of a 0.12 m tall, cool-season grass might change. It is assumed that other crops will respond similarly to the grass and the K_c values will not change.

The Consumptive Use Program (CUP) was developed by DWR and the University of California, Davis to estimate crop evapotranspiration for planning purposes. CUP was written, using MS Excel software, as a tool to help California growers and water purveyors obtain accurate estimates of crop water requirement information from monthly mean data. The program takes input weather data and estimates monthly reference evapotranspiration (ETo) using the Penman-Montieth equation. Then the program uses a curve fitting technique to derive one year of daily weather and ETo data from the monthly data. A feature to vary the canopy resistance as well as the temperature allows users to investigate the effects of increasing canopy resistance on ET_o. Current monthly mean climate data from Davis, CA and a canopy resistance of 70 s m^{-1} were input into CUP to calculate ET_o rates using the Penman-Monteith equation. The process was repeated using an elevated 3^oC minimum and maximum temperature, holding all other variables constant. The process was repeated a third time with an increase in the minimum and maximum temperature and the dew point temperature by 3^oC while holding other variables constant. Finally, the combination of the air and dew point temperature increase by 3^oC and a canopy resistance increase to 87 s m^{-1} was computed. Figure 7-3 shows a comparison of the smoothed curves of calculated ET_o for the four scenarios. Increasing only air temperature, resulted in a 18.7 percent increase in ET_o. Increasing the air and dew point temperatures led to a 8.5 percent increase in ET_o. Increasing the temperatures and the canopy resistance to 87 s/m led to a 3.2 percent increase in ET_o over current conditions. While the percentage increase is small when the

canopy resistance is included, the volume of water relative to California is considerable. Other factors like changes in solar radiation due to changes in cloudiness or air pollution and changes in wind speed were not considered.

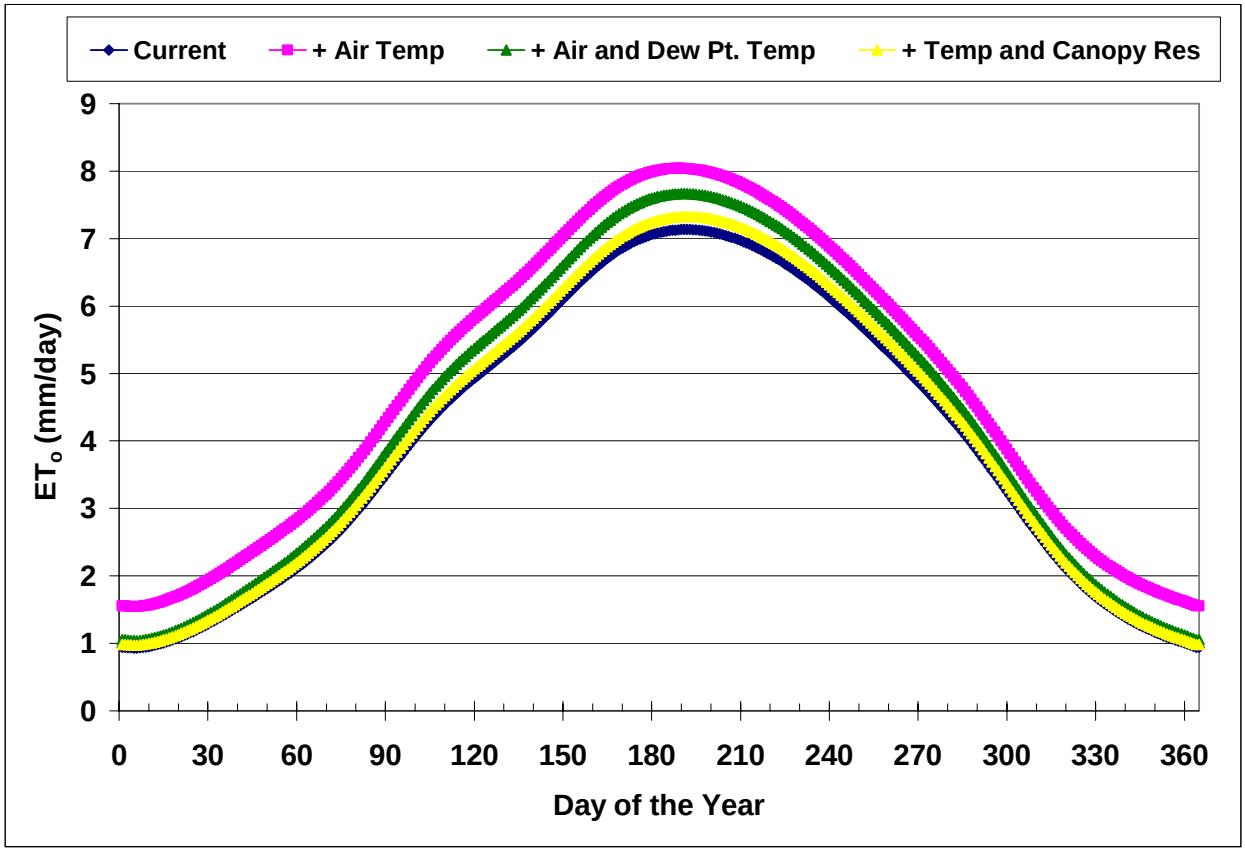

Figure 7-3 ET_o comparison for current and climate change conditions
ETo comparison for current conditions (navy), for minimum and maximum temperature elevated 3°C (pink), for minimum and maximum and dew point temperature elevated by 3°C(green), and for temperature elevated 3°C and canopy resistance increased to 87 s/m (yellow).

7.4 Plant Physiology and Climate Change

7.4.1 Plant physiological and morphological adaptation

Plants adapt to a changed physical environment through physiologically and morphologically modification. For changes in temperature and CO_2, the two main plant adaptations are to control the water continuum between soil and atmosphere and to adjust photosynthetic carbon fixation.

In transpiration, water vaporizes inside leaves and diffuses through stomata (i.e., pores in the leaf surface) to the ambient air. Simultaneously, CO_2 is diffusing from the atmosphere into the leaves through the same stomata. When stomata partially close, CO_2 flow into the leaves and H_2O flow from the leaves are both affected at the same time. However, since mesophyl resistance (i.e., resistance of the cell walls to passage of the CO_2) is typically much higher than stomatal resistance, stomatal closure has less effect on CO_2 uptake than it does on transpiration, which is

restricted by the smaller stomatal aperture. In experiments carried out in enriched CO_2 environments, which are described later, typical agronomic plants exhibited a 20 percent reduction in stomatal conductance and a 20 percent increase in photosynthesis (Long et al., 2004).

In addition to being influenced by the environment, plants also influence their environment. Evaporation from the soil is directly affected by the plant canopy shading. The canopy size and density (i.e., coverage) and the rate of development all influence crop ET. The plant coverage is often quantified with the leaf area index (LAI), which is determined as the ratio of the canopy leaf area per unit ground area under the canopy. Theoretically, there is an optimal LAI that reduces soil evaporation on one hand, which increases water for transpiration and other plant processes, and that minimizes self shading of leaves that decreases growth and reproduction. The rate of canopy growth and closure is often quantified using the relative growth rate (RGR) or the growth per unit of biomass. The RGR optimization depends on below ground and above ground assimilate allocation that influence depth of rooting for water and nutrient attainment as well as canopy development, photosynthesis, and ground shading. To varying degrees, depending on the specific crop or even cultivars, there is a possibility for adaptation during plant growth and development (phenotypic plasticity) or for genetically fixed trait expression regardless of the environment.

What is most important for the ET, is not the total amount of leaf area produced but the rate of canopy development and closure (Hsiao and Xu, 2005), which can take up to two months in herbaceous crops. That is, the LAI is less important than the rate at which the canopy foliage develops and shades the ground. The rate of canopy closure is important for determining the relative contributions of evaporation and transpiration to ET. At planting, soil evaporation comprises 100 percent of the ET_c, but the contribution from the soil decreases until it is small relative to transpiration once a canopy reaches about 75 percent ground cover for field and row crops, and about 70 percent for tree and vine crops. This change occurs because the crop canopy intercepts most of the radiation before it reaches the ground once 75 percent ground cover is attained.

7.4.2 Transpiration and photosynthesis

Several plant physiology processes are often simultaneously influenced by environment factors. Figure 7-4 shows the relation of photosynthesis and transpiration together with the climatological factors influencing the two processes. Nitrogen assimilation, which occurs through the plant roots, can be affected by transpiration rate. It is included because of its importance as a control node in the photosynthetic process. Nitrogen is particularly important as part of the of Rubisco assimilation pathway. Rubisco is said to be the most abundant protein, and is an enzyme with a low efficiency that is pivotal as the initial and limiting step in the fixation of carbon in photosynthesis of most agronomic crops. Appendix 2, detailing the photosynthesis response curve to CO_2, provides a fuller description of Rubisco and photosynthesis).

There are several photosynthetic pathways found in different plant species. In the C_3 pathway, which is the most widespread and is the photosynthetic system of most agriculture plant species, CO_2 is initially fixed by Rubisco during the day (i.e. in the presence of light) and then converted

to a three-carbon intermediate. In the C_4 pathway CO_2 is initially fixed by PEP carboxylase during the day to form four-carbon acids. The C_3 and C_4 plants also differ anatomically, with C_4 plants maintaining a higher c_i (intercellular CO_2 concentration) and a lower stomatal conductance for the same CO_2 assimilation rate.

Both light and dark respiration are included Figure 7-4 because respiration accounts for about 25 percent of plant energy expenditure. Respiration is an intercellular process in which molecules, particularly pyruviate in the citric acid cycle, are oxidized with the release of energy. It involves the complete breakdown of sugar or other organic compounds to CO_2 and H_2O. In addition to respiration relating photosynthesis, transpiration and nitrogen metabolism in an energy currency, optimization respiration is also important in the differential responses of plant biomass production to changes in atmospheric CO_2, which in turn is related to nitrogen form involved in intermediate metabolism. This concept is developed further in the physiological response section.

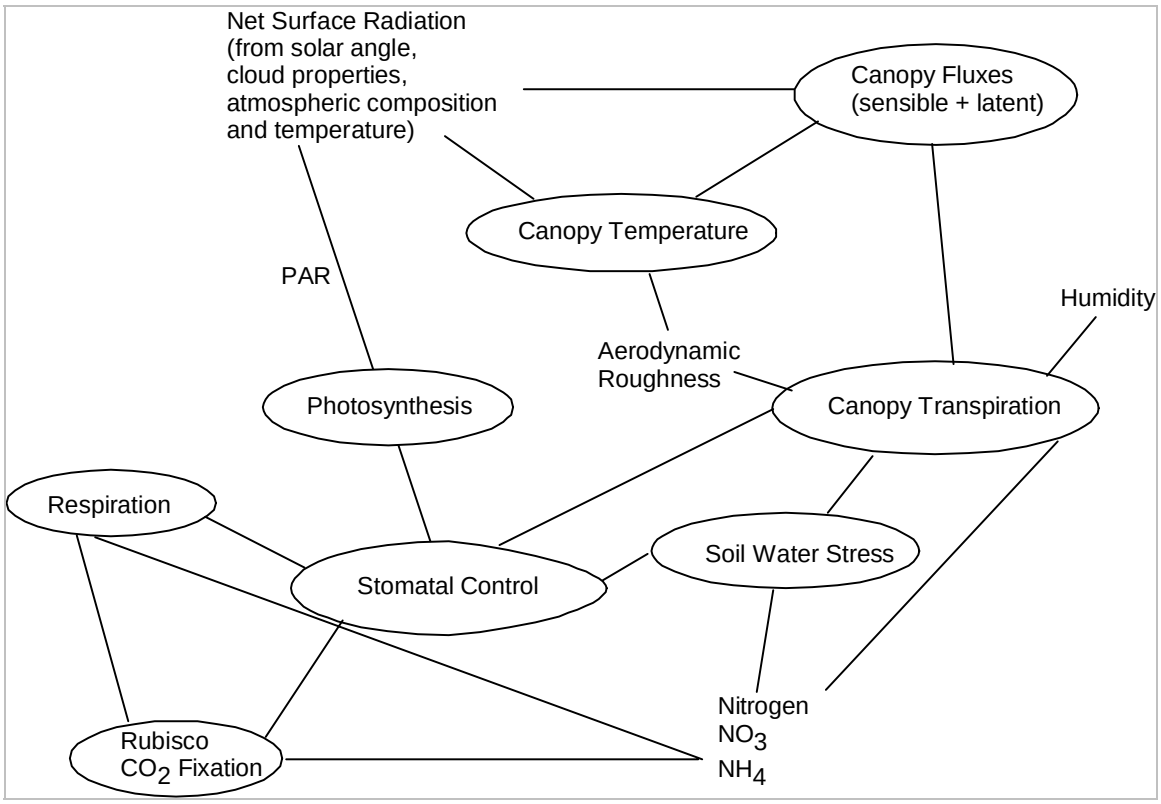

Figure 7-4 Relation of transpiration, photosynthesis and nitrogen.
Photsynthetically available radiation (PAR) indicates the total energy available for photosynthesis

In summary, the relation of the three physiology processes diagramed in Figure 1 are not necessarily direct but rather optimizations which can be either passive or active. Therefore, care is needed in extrapolating relations such as the total leaf area and stomatal density where feedback loops involving Rubisco density and its long term adaptations influence the relation of

stomata function in CO_2 enriched environments. This concept will be discussed in a later section. The water use efficiency (WUE) quantitatively relates assimilation to transpiration. Assimilation is used here as the incorporation of an inorganic resource such as CO_2 or NH_4 into organic compounds; it is often synonymous with net photosynthesis. WUE = A/T, where A is assimilation and T is transpiration. Transpiration efficiency has been used to describe the ratio of carbon gained to water transpired at the whole plant level, that is assimilation per transpiration (Condon and Hall, 1977). In agronomy, WUE is typically regarded as the ratio of carbon fixed per unit water use; so at a crop level it is the amount of dry matter production per unit of total water transpired (T).

7.4.3 Effect of increased CO_2 on plant physiology and morphology

In an atmosphere with increased CO_2, the balance between photosynthesis and transpiration appears to change (Long et al., 2004). Plants adjust their stomatal opening to maintain the CO_2 concentration within the plant leaf intercellular space (c_i) so that it does not limit photosynthesis. Less stomatal opening is required at high atmospheric CO_2 concentration (c_a). Many researchers report that stomatal conductance decreases with rising atmospheric CO_2 concentration to maintain a constant (c_i/c_a) (Long et al, 2004; Hsiao and Jackson, 1999). Because the stomata partially close to maintain the concentration gradient between the air and stomatal cavities under elevated CO_2 concentration and the water vapor gradient is unchanged, the photosynthesis rate is little affected and the transpiration rate declines because of the stomatal closure, resulting in a small increase in WUE though an increase in photosynthetic demand (see Appendix 2 The photosynthesis Response Curve to CO_2).

With increased CO_2 for fixing carbon in photosynthesis, the diffusion of CO_2 into the plant leaf and water vaporization out through the same stomata is influenced by the availability of activation sites for fixing CO_2, which in turn is influenced by the availability of nitrogen to make the sites (i.e. enzymes, which for most crops is Rubisco). New findings suggest respiration could prove important to nitrogen assimilation at elevated CO_2 (Rachmilevitch et al., 2004). The forms of nitrogen used by a plant and elevated CO_2 can influence respiration (Rachmilevitch et al., 2004). The form of nitrogen used in plant intermediate metabolism, whether NO_3 or NH_4, varies between species and even at different growth stages for the same plant. Plants that use NO_3 as their primary nitrogen source are unable to sustain rapid growth under elevated CO_2 because of interferences with respiration.

Figure 7-5 provides response relationships to increased atmospheric CO_2 for processes shown in Figure 7-4. The initial finding for this summarization of responses to CO_2 increase comes from growth chamber studies performed usually on individual leaves or individual plants. More recently, a good body of evidence for plant physiological responses to elevated CO_2 (about 570 $\mu mole\ mol^{-1}$) has been reported from FACE field studies on small plots.

Long et al. (2004) summarized the findings from these FACE sites in a meta analysis, which allows statistical analysis of the studies as a whole to understand elevated CO_2 influences. They found that biomass assimilation increased by about 20 percent while seed production increased about 24 percent. However, nitrogen in the leaves of longer-term plants decreased 17 percent and Rubisco decreased 15 percent. The LAI increased but not significantly.

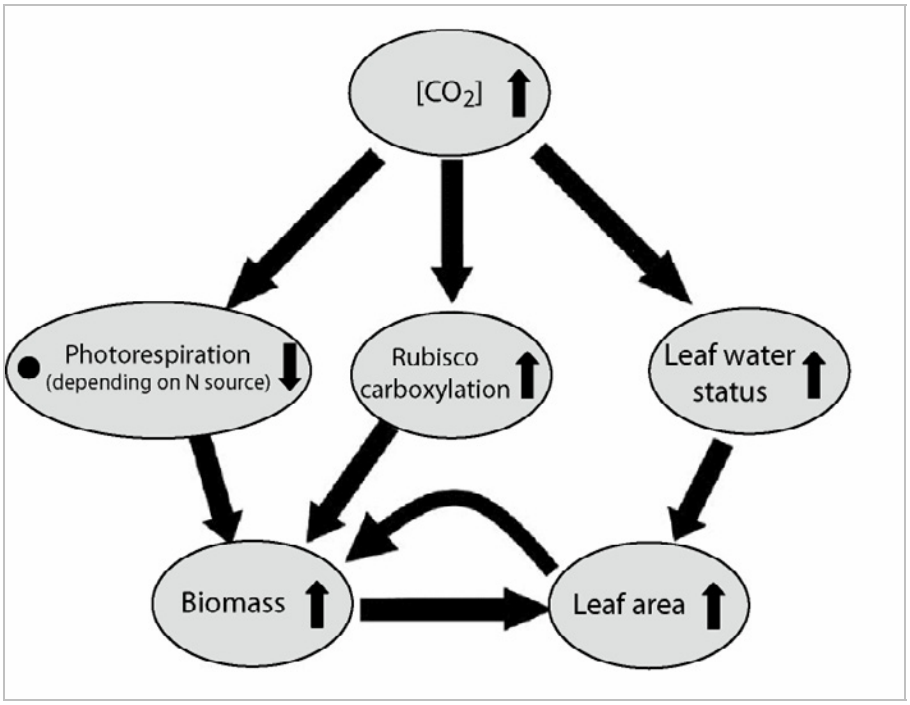

Figure 7-5. CO_2 effects and interactions on C_3 plant production.
CO2 effects and interactions on C3 plant production. The small arrows inside ovals indicate influence of CO2 on process (modified from Long et al, 2004)

Influences of elevated temperature and CO_2 on crop growth and phenology are topics of importance in determining ET for a future California landscape. For both herbaceous plant life and woody perennials, the influence of climate change on leaf senescence needs further study. Physiological changes like the apparent earlier or faster leaf aging in deciduous tress at elevated CO_2 can reduce seasonal ET. Evaporation from the soil is mainly affected by wetness of the soil surface, hydraulic properties of the soil, energy availability, and wind speed beneath the canopy so that advances in regional climate scale models are needed to understand influences of radiation and wind speed trends. Wind speed in particular is difficult to model and projects and accurate modeling of wind speed is unlikely to occur in the near future. Physiological changes like the apparent earlier or faster leaf aging in deciduous tress at elevated CO_2 can reduce seasonal ET and can be estimated.

It is widely held that increased CO_2 concentration could improve WUE, and needs more analysis at least on a whole plant level, if not the plant community level. When using whole plant examination of climate change impact that considers WUE by scaling up from relations such as LAI and stomata conductance there is a need to consider the influence of carbon assimilation from increased carbon fixation efficiency. Groups are using a variety of methods to investigate WUE. The isotope discrimination methodology for WUE is a direct measure that is easily obtained from any tissue in a plant. Seed companies are using this technique to develop plants with increased assimilation relative to transpiration to achieve a better WUE at elevated CO_2 or temperature. There is, however, a likely maximum theoretical upper bound to the gains in plant

WUE that are obtainable (Cowan and Farquhar, 1977). The likely upper bound to WUE brings into focus the need to look at a systems level for both understanding and for possible water use reductions per unit production. A system vision needs to considers the CO_2 and temperature environmental influence on plants, the plants influence on the local ET environment and the on farm water delivery to plants.

7.5 A Simulation Model for Estimating ET of Applied Water (SIMETAW)

7.5.1 SIMEATAW model description

SIMETAW (Simulation of Evapotranspiration of Applied Water) is a computer application program that can simulate several decades of daily weather data from climate records. It is useful for studying the effect of climate change on Crop evapotranspiration (ET_c) and evapotranspiration of applied water (ET_{aw}). SIMETAW was written mainly for use in water demand planning. SIMETAW can use either observed daily climate records or it can simulate daily weather data from monthly means for a specified period of years. The observed or simulated daily data are then used to estimate reference evapotranspiration (ET_o). Crop evapotranspiration is calculated for each day in the period of record using the product of the daily ET_o values and a crop coefficient (K_c) factor. The seasonal change in Kc factors is determined using a slightly modified procedure that was originally presented by Doorenbos and Pruitt (1977). This method enables the representation of day-to-day variations in evaporative demand.

Monthly climate data include solar radiation (R_s), maximum (T_x) and minimum (T_n) air temperature, wind speed at 2 m height (U_2), dew point temperature (T_d), number of rainy days per month (NRD), and monthly total rainfall (Pcp). SIMETAW computes ET_o using the daily (24-hour) Penman-Monteith equation (ASCE-EWRI, 2005). Daily ET_c rates are estimated by multiplying ET_o by a crop coefficient (K_c) factor. In addition, observed or simulated daily rainfall, soil water holding characteristics, effective rooting depths, maximum soil depths, and ET_c are used to determine effective rainfall and to generate hypothetical irrigation schedules to estimate the seasonal and annual ET_{aw}. All of the water balance calculations are done on a daily rather than monthly basis, which improves the estimation of effective rainfall and, hence, ET_{aw}. A two-stage soil evaporation model is used to estimate bare soil evaporation as a function of mean ET_o and wetting frequency in days. The bare soil evaporation rates are used to determine the off-season evapotranspiration and as a base-line for in-season K_c calculations. Since ET_c is unlikely to fall below the evaporation from an unirrigated bare soil, the crop Kc factors are not allowed to fall below the bare soil K_c value on any given date. In addition, SIMETAW accounts for the influence of orchard cover crops on K_c values, and it adjusts for tree and vine crop immaturity.

Combining atmospheric general circulation models (GCMs) with regional landscape models for downscaled model climatic results can provide estimates of future monthly climate variables, which can be used as simulation input for SIMETAW. Daily means of R_s, T_x, T_n, U_2, and T_d by month are used to simulate daily weather data for several decades and the Penman-Monteith equation is then used to estimate daily ET_o for the period of record. Increasing or decreasing one or more of the weather variables in the monthly climate prediction will influence the daily

weather simulation and hence ET_o calculation. For example, changing the rainfall pattern to have more precipitation in the fall and spring with less in the winter can be used to study the impact on the ET_{aw}. The ability to change the canopy resistance in response to higher CO_2 concentration was included in SIMETAW to more accurately estimate the effect of climate change on ET_o by accounting for both canopy resistance and temperature changes.

7.5.2 Input data requirement

Either observed or simulated daily climate data are used in SIMETAW to determine ET_o. When monthly data are input, the daily data are simulated. Data from CIMIS or from a non-CIMIS data source can be input as long as data are in the correct format. For the water balance calculations, soil and crop information are input to calculate ET_c and ET_{aw}.

A main feature of SIMETAW is that it simulates daily weather data from monthly climate data and estimates reference ET_o. Because of this feature, SIMETAW can be used to examine a range of climate scenarios for California's agricultural water demand using GCM scenarios and regional downsizing models. Using four climate change scenarios and a downsizing model to determine a running mean of monthly climate data centered around 2020 and 2050, SIMETAW can simulate daily weather data, and determine ET_o, ET_c, and ET_{aw} for some major crops grown in California. Possible values for canopy resistance can be input into the program to determine the effect of canopy resistance on ET_o.

SIMETAW was developed for water demand planning and it can help to plan for the effects of climate change as well as for current climate conditions. At this time, the limitation is the downscaling of GCMs to a regional scale. When regional long range predictions of R_s, T_x, T_n, T_d, U_2, and precipitation resulting from climate change are available, predicted daily means of the data by month can be input into SIMETAW to provide estimates of agricultural water demand.

7.5.3 Output files

Files created by SIMETAW are listed as following:

- Several years of raw or simulated daily weather data including calculated ET_o from raw or simulated data by weather station
- Several years of daily calculated crop coefficients, crop evapotranspiration and water balance calculations by crop within a study area
- One year mean of simulated or non-simulated daily and monthly ET_c and ET_{aw} data averaged over the data set
- Several years of simulated or non-simulated seasonal and annual total of ET_c and ET_{aw} by crop within a study area
- Simulated or non-simulated seasonal and annual total of ET_c and ET_{aw} averaged over the years of record

7.5.4 Weather simulation

Weather simulation models are often used in conjunction with other models to evaluate possible crop responses to environmental conditions. In SIMETAW, daily climate data are used to estimate ET_o and K_c values are used with the ET_o to estimate ET_c. Rainfall data are then used with estimates of ET_c to determine ET_{aw}. Either daily climate records or simulated daily data can be used for the calculations.

7.5.4.1 Rainfall

Characteristics and patterns of rainfall are highly seasonal and localized, and it is difficult to create a general, seasonal model that is applicable to all locations. Recognizing the fact that rainfall patterns are usually skewed to the right toward extreme heavy amount and that rain status of the previous day tends to affect the present day condition, a gamma distribution and Markov chain modeling approach was applied to described rainfall patterns for periods within which rainfall patterns are relatively uniform. This approach consists of two models: two-state, first order Markov chain and a gamma distribution function. These models require long-term daily rainfall data to estimate model parameters. SIMETAW, however, uses monthly averages of total rainfall amount and number of rain days to obtain all parameters for the Gamma and Markov Chain models.

7.5.4.2 Wind speed

The simulation of wind speed is a simpler procedure, requiring only the gamma distribution function as described for rainfall. Although using a gamma distribution provides good estimates of extreme values of wind speed, there is a tendency to have some unrealistically high wind speed values generated for use in ET_o calculations. Because wind speed depends on atmospheric pressure gradients, no correlation between wind speed and the other weather parameters used to estimate ET_o exists. Therefore, the random matching of high wind speeds with conditions favorable to high evaporation rates leads to unrealistically high ET_o estimates on some days. To eliminate this problem, an upper limit for simulated wind speed was set at twice the mean wind speed. This is believed to be a reasonable upper limit for a weather generator used to estimate ET_o because extreme wind speed values are generally associated with severe storms and ET_o is generally not important during such conditions.

7.5.4.3 Temperature, solar radiation, and humidity

Temperature, solar radiation, and humidity data usually follow a Fourier series distribution. Therefore, the model of these variables may be expressed as:

$$Xki = mki\ (1 + dki\ Cki) \qquad (1)$$

where k = 1, 2 and 3 (k=1 represents maximum temperature; k = 2 represents minimum temperature; and
k =3 represents solar radiation), mki is the estimated daily mean, and Cki is the estimated daily coefficient of variation of the ith day, i = 1, 2, … , 365 and for the kth variable.

SIMETAW simplifies the parameter estimation procedure of Richardson and Wright (1984), requiring only monthly means as inputs. From a study of 34 locations within the United States, the coefficient of variability (CV) values appear to be inversely related to the means. The same approach is used to calculate the daily CV values. In addition, a series of functional relationships were developed between the parameters of the mean curves and the parameters of the coefficient of variation curves, which made it possible to calculate Cki coefficients from mki curves without additional input data requirement.

7.5.5 Validation of daily simulated weather data of SIMETAW

Validity of the SIMETAW model was tested by comparing simulated with observed daily weather data. In this section, nine years of daily measured weather data from the CIMIS station in Davis were compared with 30 years of simulated daily weather data. Figure 7-6, Figure 7-7, and Figure 7-8 show that R_s, T_x, and P values from the simulation were well correlated with values from CIMIS. Similar results were observed for T_n, u_2, and T_d data. Although comparisons are only shown for Davis, similar results were found in other climatic regions of the state.

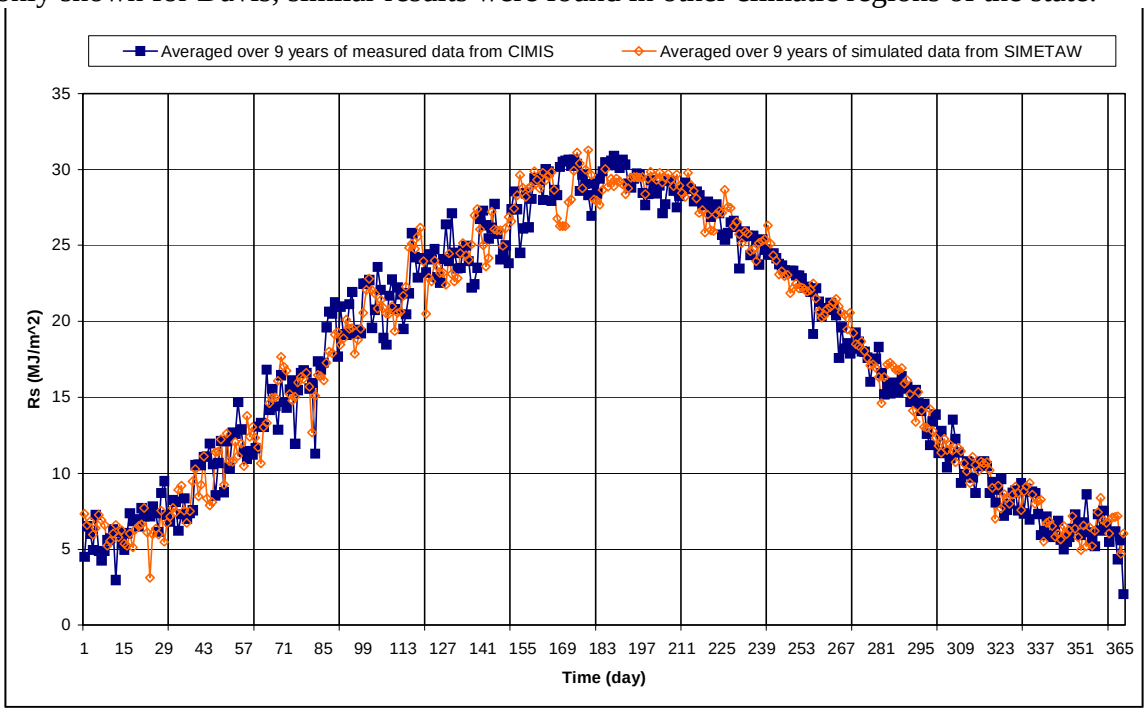

Figure 7-6. Comparison of measured and simulated daily solar radiation at Davis

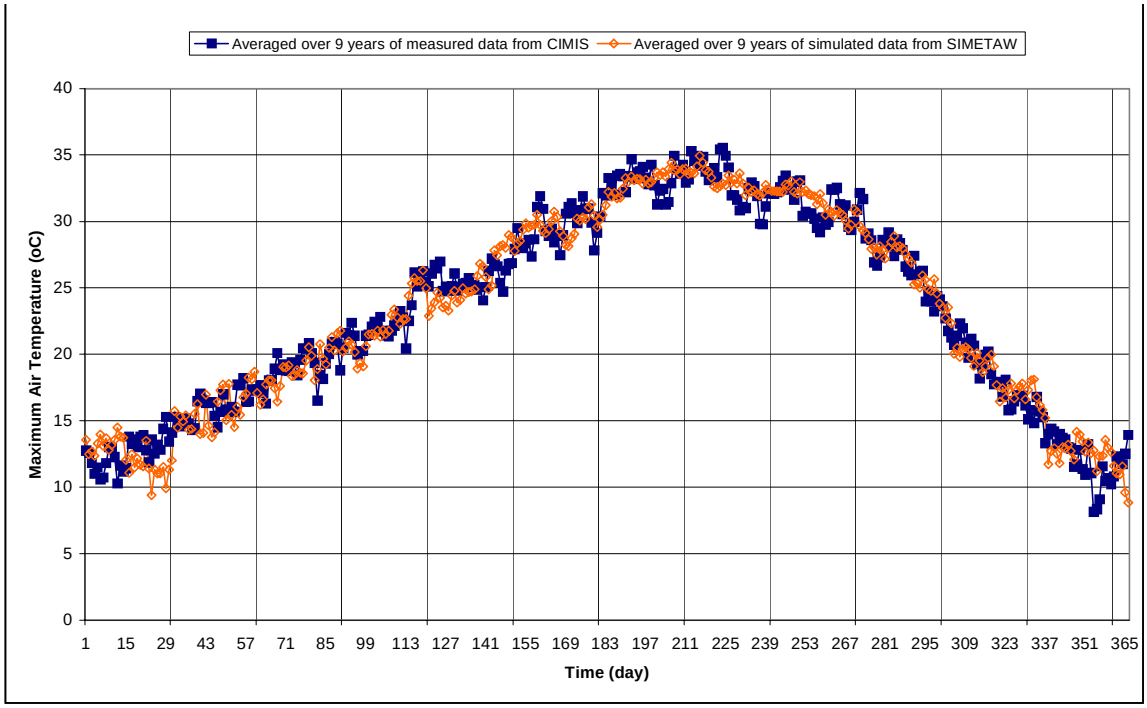

Figure 7-7. Comparison of measured and simulated air temperature at Davis

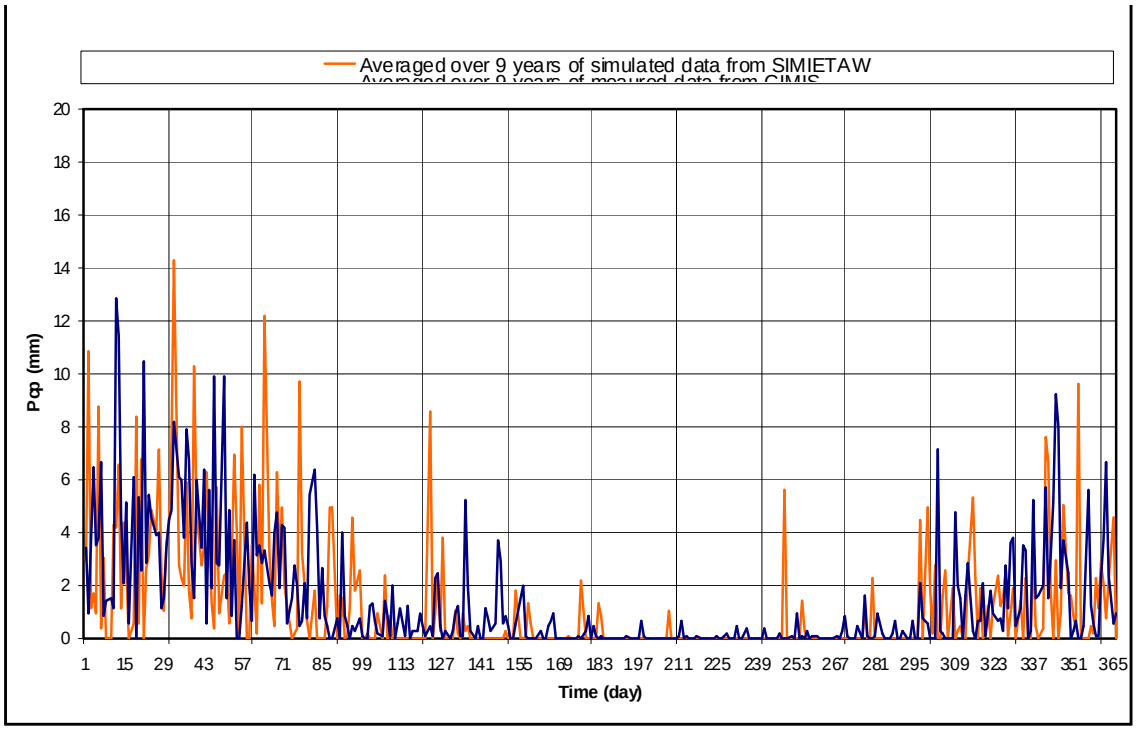

Figure 7-8. Comparison of measured and simulated precipitation at Davis

Using weather data from CIMIS stations near Davis, Oceanside, and Bishop, comparisons were made between ET_o from CIMIS and ET_o simulated from SIMETAW and averaged over the period of record (Figure 7-9, Figure 7-10, and Figure 7-11). CIMIS-based estimates of ET_o closely matched those from the SIMETAW program.

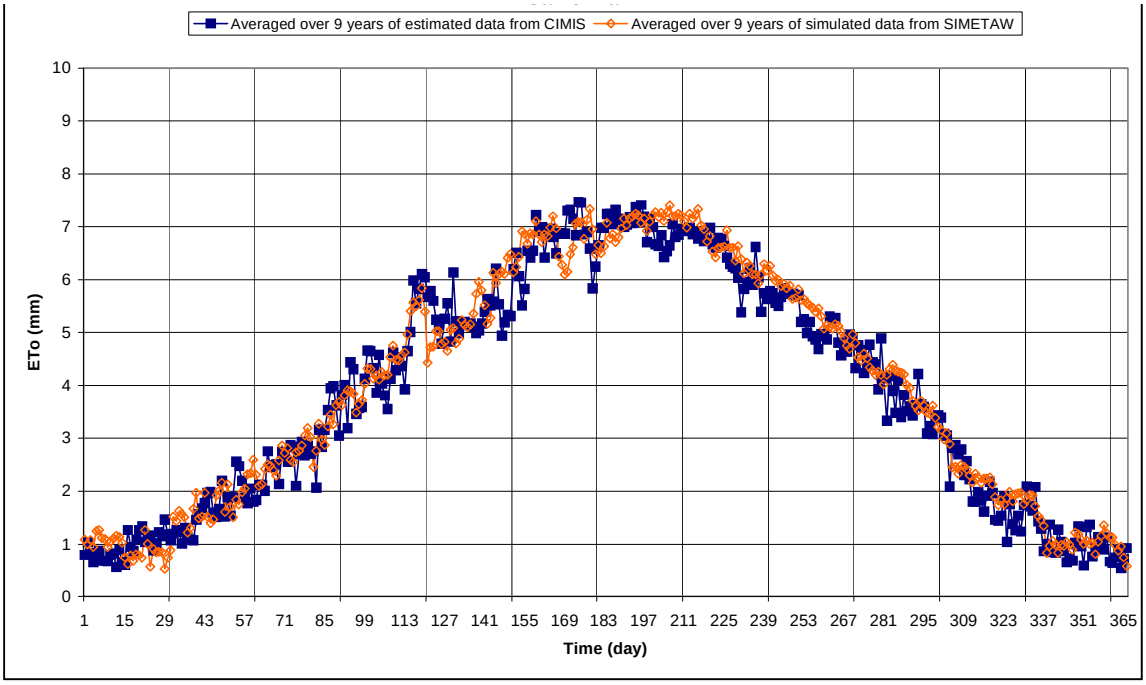

Figure 7-9. Comparison of estimated and simulated reference ET at Davis

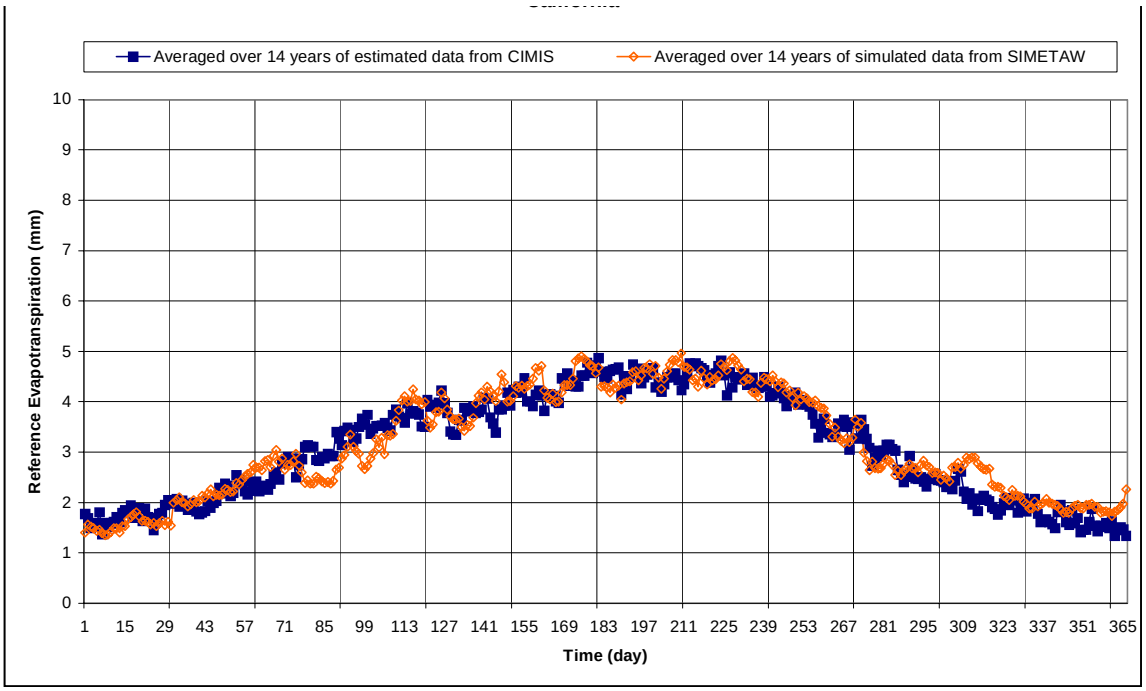

Figure 7-10. Comparison of estimated and simulated reference ET at Oceanside

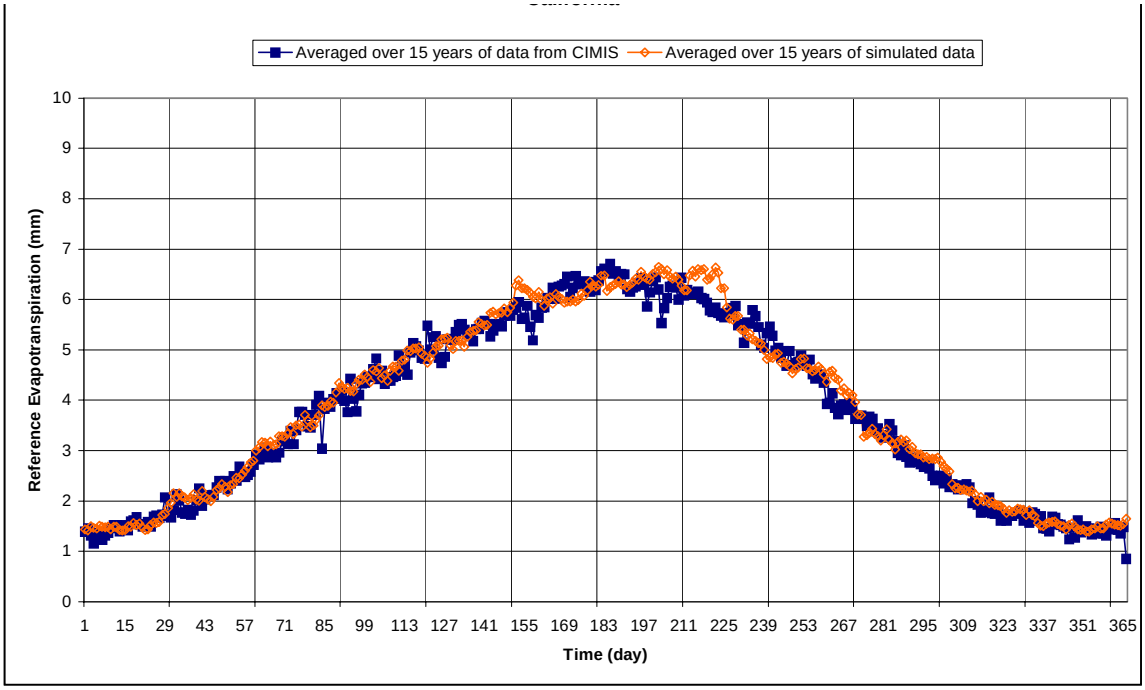

Figure 7-11. Comparison of estimated and simulated reference ET at Bishop

7.5.6 Canopy resistance sensitivity test for SIMETAW calculation of ET

To determine the influence of canopy resistance on ET_o rates, three values of canopy resistance (70, 85, and 100 s m^{-1}) with the current monthly climate data from Davis were used with SIMETAW to simulate 30 years of daily ET_o data. As canopy resistance value increased to 85 and 100 s m^{-1}, the ET_o rate decreased by 4.7 percent and 9.0 percent, respectively (Figure 7-12). The ET_o increase due to a 3^oC temperature increase, however, will more than offset the decrease due canopy resistance. The effect of CO_2 concentration on canopy resistance and ET_o rates was roughly estimated and more intensive research on canopy resistance under higher temperature and CO_2 concentrations is needed to confirm the estimates.

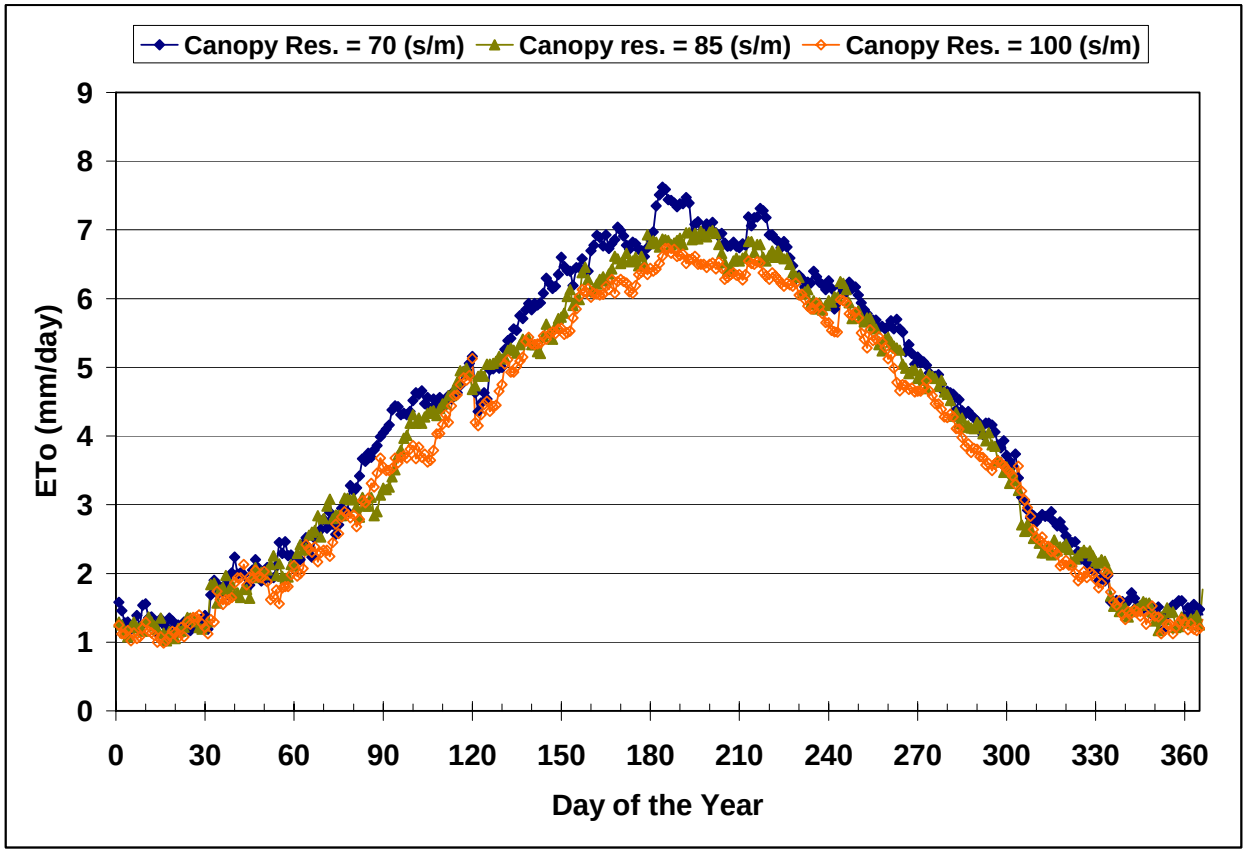

Figure 7-12. Comparison of simulated daily ET_o using the canopy resistance values 70, 85, and 100 s/m and current climate data from Davis

7.6 Using SIMETAW as a DWR Modeling Tool for Climate Change Planning

The preceding sections on using SIMETAW to calculate ET_o, ET_c and ET_{aw} demonstrate the potential to use SIMETAW, with downscaled GCM simulation data as input, for calculation of ET_o, ET_c, and $ET_{aw.}$ SIMETAW has potential as both a stand alone model for evaluating hypothetical climate change impact on ET_c and ET_{aw} or by coupling with downscaled GCM models to provide predictions of future agricultural water needs (Figure 7-13). The ET_c and ET_{aw} output from SIMETAW can serve as input to the DWR Consumptive Use Model to calculate crop water requirement for given planning areas. This possible integration is discussed in Chapter 8 of this report.

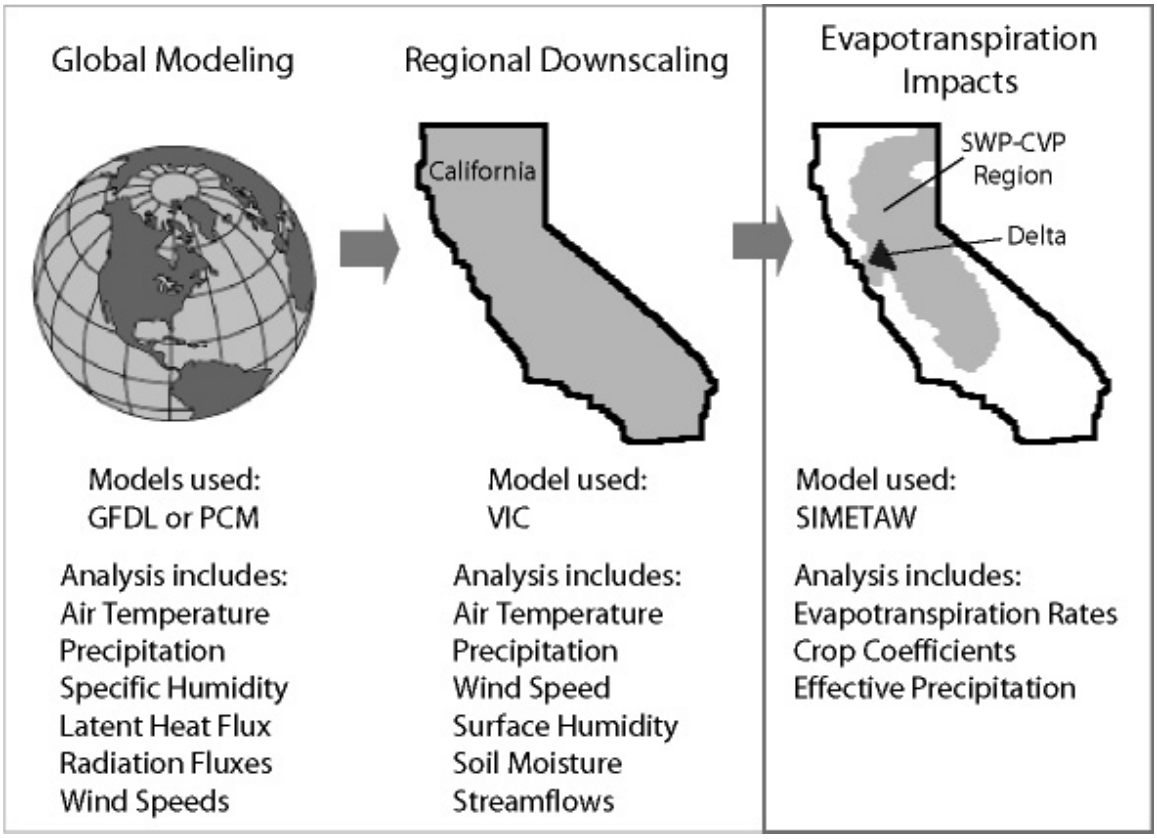

Figure 7-13. Use of SIMETAW for climate change impacts on water resource planning

7.7 Conclusions

It is difficult to accurately estimate the direct effect of global temperature on ET. As long as the minimum temperature and the dew point temperature continue to increase faster than the maximum temperature, the aerodynamic term of the Penman-Monteith ET_o equation is unlikely to increase substantially. This has been the pattern during the past five decades of global temperature rise. Increasing air temperature causes the weighting factor of the radiation-term of the Penman-Monteith equation to increase, but, because of the effect on stomatal closure, increasing CO_2 concentration causes it to decline. Based on limited information, the two effects seem to partially offset one another with the temperature rise resulting in a slightly greater influence on ET than CO_2 in our analysis. Though the net rise in ET we derived is small the influence in water demand for California as a whole is notable. Since natural environments of elevated temperature and CO_2 do not exist on a scale large enough to provide natural boundary layer conditions, it is difficult to study the effects of climate change on ET. More research is needed on the influence of elevated CO_2 and air temperature on canopy resistance.

The SIMETAW model is a promising analytic tool for water management planning that can use input from regional downscaled climate change models. Although it seems that little increase in ET is expected, the net statewide water demand from even a small ET increase is important for

water management. The effect of global change on regional precipitation, wind speed, and cropping pattern shifts are unknown at this time. Climate change could affect California agriculture and water resources, and wise planning is required to avoid serious problems.

7.8 Acknowledgments

We thank Jeff Amthor, Peter Curtis and Arnold Bloom for their thoughtful suggestions. Ed Morris, Jean Woods and Harry Spanglet read and made comments on an earlier version of this chapter for which we are grateful.

7.9 References

Allen, R.G., Jensen, M.E., Wright, J.L., and Burman, R.D. 1989. Operational estimates of reference evapotranspiration. Agron. J. 81: 650-662.

Allen, R.G., F.N. Gichuki and C. Rosenzweig. 1991. CO_2-induced Climatic Changes and Irrig. Water Requirements. J. Wat. Resour. Plan.& Man. ASCE 117(2):157-178.

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. (1998) "Crop Evapotranspiration: Guidelines for computing crop water requirement." Irrig. And Drain. Paper 56, Food and Agriculture Organization of the United Nations, Rome, 300 pp.

Amthor JS (1999). Increasing atmospheric CO2 concentration, water use, and water stress: scaling up from the plant to the landscape. In: Y Luo, HA Mooney (eds) Carbon Dioxide and Environmental Stress. Academic Press, San Diego, 33-59.

ASCE-EWRI. (2005). The ASCE Standardized Reference Evapotranspiration Equation. Technical Committee report to the Environmental and Water Resources Institute of the American Society of Civil Engineers from the Task Committee on Standardization of Reference Evapotranspiration. 173 p.

California Department of Water Resources, Division of Planning and Local Assistance (2005). Bulletin 160–05: Draft California Water Plan (California Department of Water Resources, Sacramento).

California Department of Water Resources, Division of Planning and Local Assistance (2005).

Condon, A.G. and Hall, A.E. (1997) Adaptation to diverse environments: variation in water-use efficiency within crop species. In L.E. Jackson (ed) Ecology in Agriculture. Academic Press, San Diego, 79-116.

Cowan, I.R. and Farquhar, C.D. (1977). Stomatal diffusion in relation to leaf metabolism and environment. Symp. Soc. Exp. Biol. 31, 471-505.

Field, C. B., Daily, G. C., Davis, F. W., Gaines, S., Matson, P. A., Melack, J. and Miller, N. L. (1999). Confronting Climate Change in California: Ecological Impacts on the Golden State (Union of Concerned Scientists, Cambridge, MA, and Ecological Society of America, Washington, DC).

Gilgen, H., Wild, M. and Ohmura, A. (1998). Means and trends of short wave irradiance at the surface estimated from Global Energy Balance Archive Data. J. of Clim. 11: 2042-2061.

Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville. (2004). Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences of the United States of America 101:12422-12427.

Hidalgo, H.G., Cayan, D.R., Dettinger, M.D. (2005). Sources of variability of evapotranspiration in California. J. Hydrometerology. 6, 3-19.

Hsiao, T.C. and Jackson, R.B. (1999). Interactive effects of water stress and elevated CO_2 on growth, photosynthesis, and water use efficiency. In: Y Luo, HA Mooney (eds) Carbon Dioxide and Environmental Stress. Academic Press, San Diego, 3-31.

Hsiao, T.C. and Xu, L. (2005). Evapotranspiration and relative contribution by the soil and the plant. In California Department of Water Resources. 2005. Bulletin 160-05 Vol. 4 Reference Guide.

Landis, J.D. and Reilly, M (2004). How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint through the Year 2100 Institute of Urban and Regional Development, University of California, Berkeley.

Long, S.P., Ainsworth, E.A., Rogers, A. and Ort, D.R. (2004). Rising atmospheric carbon dioxide: plants FACE the future. Ann. Rev. Plant Biol. 55, 591-628.

Monteith, J. L.(1965) Evaporation and environment. In: The state and movement of water in living organisms, XIXth symposium, Soc. for Exp. Biol. Swansea, Cambridge University Press, p 205-234.

Penman, H. L. (1948) Natural evaporation from open water, bare soil and grass. Proc. Roy. Soc. London, A193: 120-145.

Pruitt, W. O. and Doorenbos, J. (1977) Empirical calibration, a requisite for evaporation formulae based on daily or longer mean climatic data? ICID conference on Evapotranspiration, Budapest, Hungary, May 26-28, 1977. International Commission on Irrigation and Drainage.

Rachmilevitch, S., Cousins, A.B., Bloom, A.J. (2004). Nitrate assimilation in plant shoots depends on photorespiration. Proceedings of the National Academy of Sciences of the United States of America 101:11506-11510.

Roderick and Farquhar (2002). The cause of decreased pan evaporation over the past 50 years. Science 298: 1410-1411.

Snyder, R. L. and Pruitt, W.O. (1992) Evapotranspiration data management in California. Proceedings/Water Forum '92, August 2-6, 1992, Baltimore, MD.

Stanhill, J. and Cohen, S. (2001). Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. Agric. and For. Meteorol. 107: 255-278.

Tanaka, S.K., Zhu, T, Lund, J.R., Howitt, R.E., Jenkins, M.W., Pulido, M.A., Tauber, M., Ritzema, R.S., Ferreira, I.C. (2005). Climate Warming and Water Management Adaptation for California. Climatic Change, (in press).

U.S. Department of Agriculture (2003) California Agricultural Statistics 2003.

Ventura, F., D. Spano, P. Duce and R.L. Snyder. 1999. An evaluation of common evapotranspiration equations. Irrig. Sci. 18:163-170.

7.10 Appendix 1 Energy Budget Analysis for Climate Change

7.10.1 Physical bases for temperature, sensible heat and water vapor transfer

Any moving object has kinetic energy that is proportional to the product of half of the mass and the square of its velocity. Although air molecules have small mass, they move fast (1,600-2,000 km h^{-1}) and there are many (2.65×10^{25}) molecules per cubic meter. Therefore, there are many collisions between air molecules and objects within the air volume. When the air molecules strike an object such as a thermometer some kinetic energy is transferred to the object. In the case of a glass thermometer, the energy resulting from air molecule impacts increases movement of molecules in the glass and transfers by conduction into the instrument where it transfers to the liquid temperature indicator. As energy is absorbed, liquid in the thermometer expands and moves up the thermometer tube. When molecules strike the outside of the thermometer at a faster velocity, and more frequently more heat is transferred and the measured temperature rises. If molecules strike the thermometer at lower velocity and at lower frequency the liquid contracts and the measured temperature drops. The kinetic energy contained in air is commonly called "sensible heat" because it is heat (energy) that one can sense. Generally, small volumes of air have uniform heat content, but big differences can occur between the large air parcels due to energy transfers by radiation, conduction and latent heat exchanges. Wind and turbulence cause

air parcels with different sensible heat content to move and mix with other air parcels and to transfer sensible heat between objects.

Evaporation of liquid water requires energy to break hydrogen bonds between water molecules. It is widely believed that evaporation increases with air temperature. Strictly speaking, it is actually the water temperature at the surface that determines the evaporation rate. Air temperature can affect the evaporation rate if sensible heat is transferred from the air to the water surface. The rate of heat transfer, however, depends on turbulence as well as the temperature difference between the air and water. Sensible heat transfer to a wet surface depends on atmospheric stability, wind speed, and surface roughness. For transpiration from plants, the rate of water vapor transfer is further complicated by plant morphology that affects energy absorption and turbulence and by plant physiology (i.e., stomatal opening and closing) in response to environmental factors including water availability and CO_2 concentration.

Vaporization of water occurs when energy (sensible heat or radiant energy) is used to break hydrogen bonds between the water molecules. Therefore, the rate of energy consumed in the vaporization process provides a measure of the evaporation rate. Evapotranspiration rates are commonly estimated using energy balance by considering the net radiation (R_n), heat conduction into and out of the soil and plants (G), atmospheric sensible heat flux density (H), and atmospheric latent heat flux density (LE). Net radiation is the amount of short- and long-wave radiation absorbed by a surface, and it is the main source of energy for vaporization. Net radiation (R_n) is commonly partitioned into soil heat flux density (*G*), sensible heat flux density, and latent heat flux density (*LE*) and the energy consumed in the evaporation process is therefore expressed as:

$$LE = R_n - G - H \qquad (\mathrm{W\ m^{-2}}) \qquad (1)$$

where L is the latent heat of vaporization ($L \approx 2454$ J g^{-1} at 20^oC) and *E* is the water vapor flux density (g m^{-2} s^{-1}). In equation 1, R_n is positive when the energy flux is towards the surface and LE, G and H are positive for fluxes away from the surface.

Using Equation 1, one could measure R_n, G, and H to estimate LE. Then the rate of evaporation is calculated by dividing LE by L to determine the mass flux density of water vapor. There are methods available to measure the components in Equation 1, but they are not widely used because it is somewhat difficult and expensive to measure the variables, especially H, accurately. Efforts to obtain a simple and inexpensive technique continue, but there is still no perfect method. Other methods to estimate ET using more readily available variables are available.

7.10.2 Penman-Monteith equation

Penman (1948) presented a method to estimate *LE* for short, uniform vegetation using readily available weather variables measured at one level assuming the surface was wet with a canopy resistance $r_c = 0$. Monteith (1966) refined Penman's equation to adjust LE for canopy resistances greater than zero. The so-called Penman-Monteith equation is expressed as:

$$LE = \left(\frac{\Delta}{\Delta + \gamma *}\right)(R_n - G) + \left(\frac{\rho C_p}{\Delta + \gamma *}\right)\left(\frac{e_s - e}{r_a}\right) \qquad (\mathrm{W\ m^{-2}}) \qquad (2)$$

In Equation 2, Δ is the slope of the saturation vapor pressure curve at the air temperature, $\gamma \approx 0.066$ kPa K^{-1} is the psychrometric constant, r_c is the canopy resistance, r_a is the aerodynamic resistance, ρ is the air density (g m^{-3}), C_p is the specific heat at constant pressure (J $g^{-1}K^{-1}$), e_s is the saturation vapor pressure, and *e* is the actual atmospheric vapor pressure. For more information on the variables in Equation 2, see ASCE-EWRI (2005). The parameter $\gamma^* = \gamma\left(1+\frac{r_c}{r_a}\right)$ in Equation 2 is a modified psychrometric constant, which was introduced by Monteith to account for the effects of canopy resistance on *ET*. The left-hand term of Equation 2 is often called the radiation or available energy term and the right-hand term is called the aerodynamic term because it accounts for the contribution of aerodynamic transfer of sensible heat to *ET*.

Aerodynamic resistance (r_a) is equal to the reciprocal of the aerodynamic conductance (g_a), which is defined as the rate that 1 m of a particular scalar will transfer through 1 m^2 horizontal plane. Therefore, g_a and r_a have the units m s^{-1} and s m^{-1}, respectively. When r_a increases, then g_a decreases, the vertical transfer of sensible and latent heat decreases, and the LE rate falls. Like r_a, the canopy resistance (r_c) equals the reciprocal of the canopy conductance (g_c) and the canopy conductance is the rate at which 1 m^3 of air will pass through 1 m^2 of horizontal plane. When r_c increases, g_c decreases and LE is reduced. The r_c is the resistance to water vapor transfer from the canopy elements and soil to a level near the top of a canopy and r_a is the resistance to vapor transfer from that level to the ambient air above the canopy. The r_a and r_c resistances are in series, so the higher of the two resistances limits the LE rate. As plant stomata close, r_c increases, γ^* increases, and LE decreases (Equation 2). When the surface is wet, then $r_c = 0$, $\gamma^*=\gamma$ and the Penman-Monteith equation reduces to the Penman (1948) form.

7.10.3 Aerodynamic term response to temperature rise

The Penman-Monteith equation is useful to investigate the effect of possible climate change on evapotranspiration. Roderick and Farquar (2002) noted that the global mean maximum and minimum temperatures have increased by approximately 0.1 and 0.2 ^oC per decade during the last 50 years and there has been no observable change in the vapor pressure deficit ($e_s - e$) during the same time period. The minimum temperature is highly correlated with the dew point temperature, which is directly related to the actual vapor pressure of the atmosphere. The fact that the minimum has risen faster than the maximum temperature supports the idea that the dew point temperature and hence the actual vapor pressure (e) have risen and compensated for the temperature induced rise in saturation vapor pressure (e_s).

The temperature weighting function term $\left(\frac{\rho C_p}{\Delta+\gamma^*}\right)$ in Equation 2 decreases with rising temperature and with increasing r_c (Figure 7-14). Since e_s - e has not changed in recent decades and the weighting function decreases with increasing temperature, it is likely that the aerodynamic term of Equation 2 has not changed or slightly decreased with global temperature rise during the past 50 years. Unless the e_s term begins to increase more rapidly than e, the aerodynamic term is unlikely to be greatly affected by global temperature increase.

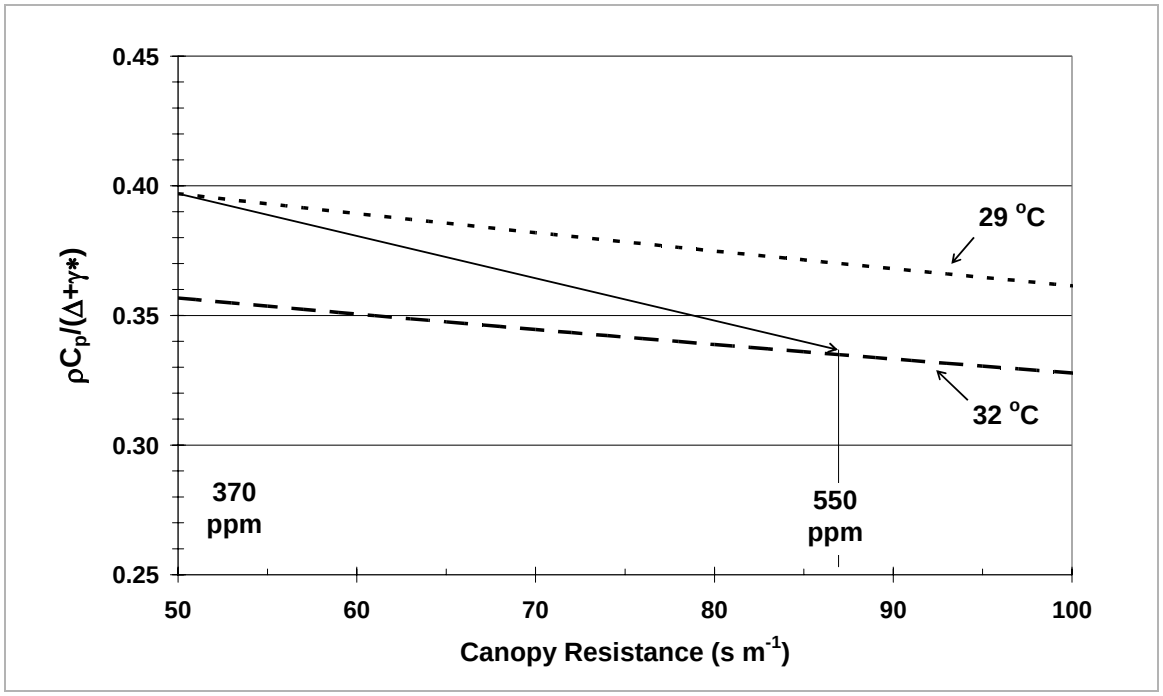

Figure 7-14. A plot of $(\rho C_p)/(\Delta + \gamma^*)$ versus canopy resistance for a 3 °C temperature increase as a function of canopy resistance

7.10.4 Radiation term response to temperature rise

A 3 °C temperature rise will increase the $\left(\frac{\Delta}{\Delta + \gamma^*}\right)$ radiation-term weighting function by about 4.5 percent so the effect is to increase the contribution of the radiation term to LE, causing a higher ET rate. There is, however, some evidence that increased turbidity of the atmosphere has globally decreased the amount of solar (short-wave) radiation reaching the surface (Roderick and Farquar, 2002), and the radiation-term weighting function increase with temperature is partially offset by decreasing solar radiation received at the surface.

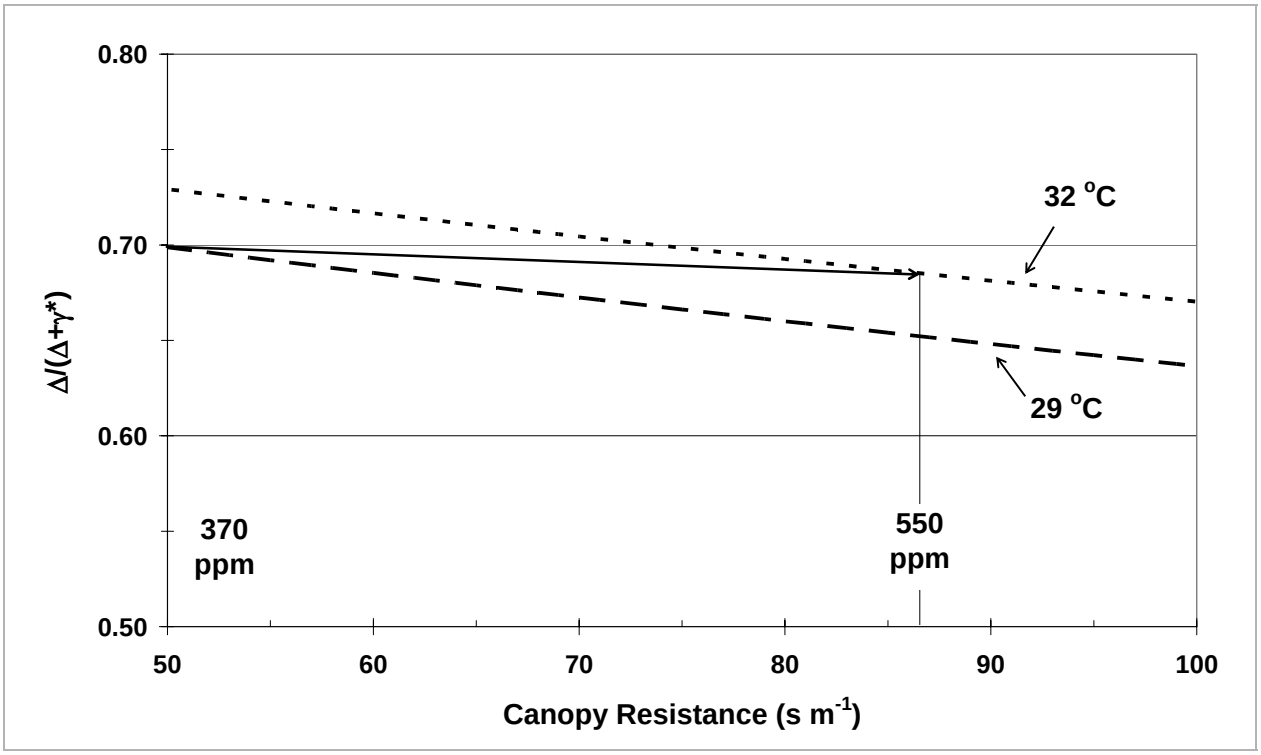

Figure 7-15. A plot of $\Delta/(\Delta+\gamma^*)$ versus canopy resistance for a 3 °C temperature increase as a function of canopy resistance.

Another factor that is often neglected in predictions of temperature effects on ET is the influence of increased CO_2 on stomatal closure and hence canopy resistance. Stomata exhibit partial closure with increasing CO_2 content, but, there is little information on the effect of CO_2 concentration on canopy resistance. The typical enhanced CO_2 concentrations reported in the FACE projects was about 550 ppm, and Long et al. (2004) indicated that the leaf stomatal conductance decreased about 20 percent for C_3 species plants under those conditions. Then using the same procedure to estimate canopy resistance for reference evapotranspiration (Allen et al., 1989) with today's CO_2 concentration, the midday canopy resistance is predicted to increase from about 50 to 87 s m^{-1} as shown in Fig. 7.3. Therefore, if the canopy resistance does increase to 87 s m^{-1}, the increase in the radiation-term weighting factor due to a 3 °C increase in temperature is nearly offset by the higher canopy resistance. For comparison, the midday canopy resistances of tall alfalfa (50 cm) and tall grass (12 cm) are approximately 30 s m^{-1} and 50 s m^{-1}, respectively (ASCE-EWRI, 2005). The r_c is high at night (≥ 200 s m^{-1}) when the stomata are closed. There is a decrease in rc after sunrise to the minimum value and then an increase in the late afternoon as the sun descends toward the horizon. The mean 24-hour r_c is about 70 s m^{-1} for the grass and about 45 s m^{-1} for the alfalfa (ASCE-EWRI, 2005). Again, there is a paucity of research on the effect of CO_2 concentration on canopy resistance, but it clearly will increase and the reduction in the radiation-term weighting function will at least partially offset the increase due to temperature. The magnitude of the change depends on how much the temperature and CO_2 concentration increase. Clearly, more research is needed to determine the influence of temperature and CO_2 concentration on canopy resistance before a truly accurate assessment is possible.

Evaporation from ponds, lakes, rivers, and other bodies of water can also be impacted by climate change. Recently, several groups have reported decreasing evaporation rates from standard pans, and they used this as evidence that the climate is cooling rather than warming. However, the surface resistance of water is zero and the aerodynamic resistance is high, so $\gamma^* = \gamma$ in Equation 2 and the equation simplifies to the Penman (1948) equation. Again, $e_s - e$ has not changed in recent decades, so the change in the aerodynamic term is unlikely to influence evaporation from bodies of water. Increasing temperature does increase the weighting function of the radiation term and there is no stomatal influence, so canopy resistance will not counteract the temperature effect on the radiation term of the ET_o equation. There is some evidence for the reduction in solar radiation due to pollution effects on atmospheric turbidity or perhaps reflectivity of clouds and other factors (Stanhill and Cohen, 2001; Gilgen et al., 1998), and this might be the cause for reduced pan evaporation reported in some regions of the world.

Assuming a little or no increase in the radiation-term weighting function in response to rising temperature, the increasing CO_2 concentration effect on canopy resistance, and a decrease in short-wave radiation at the surface, little or no increase in the radiation term contribution to ET is expected with climate change. Since the aerodynamic term also shows little response to climate change, it is anticipated that the effect of climate change on *ET* will be minimal. Other environmental responses to climate change such as precipitation and wind patterns and changes in cropping and irrigation methods, however, could greatly affect water resource availability and hence irrigation water requirements.

7.11 Appendix 2 The photosynthesis Response Curve to CO_2

The assimilation of CO_2 as a function of intercellular CO_2 is provided in Figure 7-16.
The rate of carbon assimilation is determined by supply and demand for CO_2. The supply of CO_2 is determined by diffusion in the gas and liquid phases. It can be limited by essential constraints in the pathway from the atmosphere to the leaf sites of carbon fixation (carboxylation) most notably at the canopy boundary and at the stomata, which are related to the plants energy budget. The demand for CO_2 is determined by the rate of processing CO_2 in the chloroplast, which is determined most importantly by biochemistry, in particular Rubisco, the first enzyme in the metabolic pathway for assimilation of CO_2. It can also be limited by environmental factors such as irradiance. The electron transport plot relative to CO_2 concentration is included in Figure 7-16 for comparison to the carbon assimilation. The assimilation of CO_2 plot in Figure 7-16 has two principal regions, the first occurs at lower CO_2 concentrations and is referred to as the CO_2 limited region. The second at the higher CO_2 concentrations is the place where available limits to precursors of Rubisco are limiting. Two horizontal lines of Figure 7-16 indicate the intercellular CO_2 concentration at the atmospheric CO_2 concentration given the supply function indicated by the line from the atmospheric concentration to the response curve. The slope of the supply function is the leaf conductance measured. The possible long-term adjustment of plants to elevated CO_2 by sifting the supply curve downward is referred to as downregulation. Long et al (2004) concluded that there is a substantial reduction in Rubisco at elevated CO_2, suggesting acclimation to elevate CO_2, but that there was not downregulation.

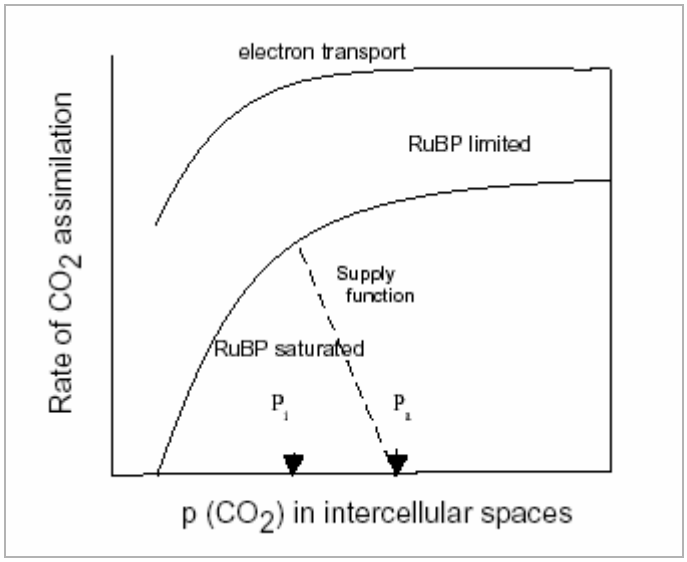

Figure 7-16. Photosynthesis Response Curve to CO_2
(After Lambers et al, 1998)

7.12 Appendix 3 The Penman-Monteith equation for reference evapotranspiration (ET_o) used in SIMETAW

Reference evapotranspiration (ET_o) is estimated from daily weather data using a modified version of the Penman-Monteith equation (Allen et al., 1998; ASCE-EWRI, 2005). The equation is:

$$ET_o = \frac{0.408\ \Delta\ (R_n - G) + \gamma \frac{900}{T + 273}\ u_2\ (e_s - e_a)}{\Delta + \gamma\ (1 + 0.34\ u_2)} \qquad (3)$$

where Δ is the slope of the saturation vapor pressure at mean air temperature curve (kPa $^oC^{-1}$), R_n and G are the net radiation and soil heat flux density in MJ $m^{-2}d^{-1}$, γ is the psychrometric constant (kPa $^oC^{-1}$), T is the daily mean temperature (^oC), u_2 is the mean wind speed in m s^{-1}, e_s is the saturation vapor pressure (kPa) determined as the mean saturation vapor pressure calculated from the daily maximum and minimum air temperature (^oC), and e_a is the actual vapor pressure (kPa) calculated from the mean dew point temperature (^oC) for the day. The coefficient 0.408 converts the R_n – G term from MJ $m^{-2}d^{-1}$ to mm d^{-1}, and the coefficient 900 combines several constants and converts units of the aerodynamic component to mm d^{-1}. The product 0.34 u_2 in the denominator is an estimated ratio of the 0.12-m tall canopy surface resistance (r_c=70 s m^{-1}) to the aerodynamic resistance (r_a=205/u^2 s m^{-1}). It is assumed that the temperature, humidity, and wind speed are measured between 1.5 m (5 ft) and 2.0 m (6.6 ft) above a grass-covered soil surface. For a complete explanation of the equation, see (ASCE-EWRI, 2005).

7.13 List of Abbreviations

ASCE-American Society of Civil Engineers
CALVIN-The California value integration network model
CIMIS-California Irrigation Management Information System
CUP-Consumptive use program
ET-Evapotranspiration
ETo-Reference Evapotranspiration
ETAW-Evapotranspiration of applied water
EWRI- Environmental and Water Resources Institute
FACE-Free-Air Carbon dioxide enrichment
GCM-General Circulation Model
LAI-Leaf Area Index
NPP-Net primary production
PAR-Photosynthetically Available Radiation
RGR-Relative Growth Rate
SIMETAW-SIMulation ET of Applied Water
SWAP-statewide water and agricultural production model (WUE-Water use efficiency
WUE-Water use efficiency

Progress on Incorporating Climate Change into Management of California's Water Resources

1st Progress Report
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Chapter 8:
Future Directions

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8 Future Directions

8.1 Introduction

This report demonstrates growth in federal and state agency capability to provide planners with relevant information on potential climate change impacts. The joint Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) Climate Change Work team has built coalitions with California climate change research groups to improve federal and state agency knowledge on climate modeling and uncertainties in future climate projections. Additional products from work team activities include identification of data and technology gaps and development of innovative analytical approaches using familiar planning tools. The work team will continue to evolve to meet the needs of water resources managers and to use new information and methodologies as they become available. Future activities will focus on probabilistic based potential effects of climate change. A summary of future directions is presented in this chapter.

8.2 SWP-CVP Operations Impacts

The State Water Project (SWP) and Central Valley Project (CVP) operations impacts studies presented in this report only considered climate change affects on runoff patterns. However, a warming climate may lead to changes in the seasonal pattern and magnitude of evaporation/evapotranspiration and, thereby, higher water demands. Rising sea levels would lead to greater fresh water demands in the Delta to maintain water quality. Both increased demands and increased salinity in the Delta could have significant impacts on the ability of the SWP and CVP to meet California's future needs. Impacts from a wider range of climate change effects need to be addressed.

In the climate change scenario studies presented in this report, one significant issue was the critical shortages of water in reservoirs north of the delta that occurred when present operating rules were applied. Future directions would include examining increases in carryover storage in Shasta and Oroville reservoirs to prevent loss of operational control of the Sacramento and Feather rivers during droughts. Corresponding reductions to delivery allocations would be required. If those measures weren't sufficient to provide a reliable water supply, additional measures would be investigated such as rebalancing of the water sharing mechanisms established in the Coordinated Operations Agreement.

System flexibility should be sought to mitigate climate change effects on SWP and CVP deliveries. In the current analysis, flood control spaces were left unchanged. In the future, it is planned to vary the flood control space with different climate change scenarios. Furthermore, refined flood forecasting might allow more runoff to be captured in the early spring than is otherwise possible now. Also, operational rules and regulations will have to be reassessed given a changed hydrology. Current operations studies using the CalSimII model use an Artificial Neural Network (ANN) to represent Delta water quality. Future directions include development

of a new ANN or similar tool that would be incorporated into CalSimII to represent Delta water quality for sea level rise conditions.

Lastly, we need to explore ways of increasing supply to or reducing demand of SWP and CVP contractors. New reservoirs, increased pumping capacity, and groundwater banking are ways that more winter runoff can be captured for later delivery. On the demand side, CalSim-II doesn't deal with specific conservation measures. But the effects of conservation – whether from drip irrigation or low-flow toilets – can be represented in the input water demands and the effects to CVP and SWP operations simulated.

8.3 Delta Impacts

Improving analysis of potential effects of a rising sea level on the Delta will be a focus of future studies. Changes in salt water intrusion from the ocean need to be represented for different sea level increases. Better understanding and mathematical representation of salt water intrusion under conditions of sea-level rise should be incorporated into planning tools such as CalSim-II and DSM2. For this report, results from the sea level rise simulations could be used for levee stability analyses.

Flexibility of the existing water-conveyance system to lessen the effects of climate change will also be explored. In addition to potential changes to system operations mentioned in the previous section, mitigation measures in the Delta could include modifying Delta Cross Channel operations, changing land use patterns and temporary barrier operations. If present system flexibility can't sufficiently decrease the impacts of climate change, other measures will be investigated such as modifying operating rules or considering new system components such as gates proposed to be installed the south Delta.

8.4 Flood Management

In order to better understand the risks associated with global climate change on California's water resources, it is important to be able to quantify climate change effects on the ability to provide adequate flood control and to quantify climate change impacts on seasonal water supply. The Division of Flood Management at DWR will address these issues. It plans to:

1) continue the evaluation of historical data to identify trends and changes in precipitation and runoff patterns
2) periodically update frequency-based data for design computations
3) evaluate new climate change model-derived data for use in flood frequency and water supply forecasting applications
4) develop new forecasting technologies that can adapt to the changing distribution of the state's annual water supply
5) incorporate methodologies to quantify the uncertainty in the expected changes in the annual cycle of water supply into the water supply forecast process

For flood frequency analysis, future efforts at synthetic daily flow data produced from climate change model output may be suitable for traditional flood frequency analyses. As these data become available, they must be evaluated for their ability to represent present-day magnitude and

variability as well as predicted changes caused by climate change. At this time, however, there are no such data that would provide meaningful results.

Another area which may produce useful flood forecasting information examines historical data in order to identify critical atmospheric circulation parameters and their threshold values associated with extreme floods. As the circulation patterns in the GCMs improve and are shown to represent present-day conditions correctly, circulation patterns under increased greenhouse gas concentrations can be examined for the flood producing patterns or critical threshold characteristics. Improved forecasting technologies will help implement adaptive strategies to decrease flood risk changes associated with climate change.

8.5 Evapotranspiration

To further analyze the effects of climate change on evapotranspiration (ET) future efforts will focus on improvements to the SIMETAW (Simulation of Evapotranspiration of Applied Water) model. SIMETAW development and analysis for climate change studies will be a complex process. How will a world with higher atmospheric CO_2 and higher temperatures influence the resistance to water vapor diffusion to the atmosphere (the boundary layer around plants)? No one knows. While we are continuing to search the literature and research programs for boundary-layer data at elevated temperatures and CO_2 concentrations, we need to explore the SIMETAW model's performance by using reasonable analogs for boundary-layer values. Direct measurement of boundary-layer information is limited in the near future, but we are developing an analysis to work around the limitation.

To validate the SIMETAW calculation of ET using downscaled model weather data, a set of comparative simulations is needed using historic California Irrigation Management Information System (CIMIS) data and downscaled regional model output for the same time period. Analysis periods and CIMIS sites will be chosen to obtain a range of extremes of the primary SIMETAW input variables: net radiation, wind speed, relative humidity, temperature and precipitation.

Simulations for several principal herbaceous crops, a row crop, tomatoes, and a field crop, alfalfa, will be tested with SIMETAW first at Central Valley CIMIS stations and then at other CIMIS sites throughout the state. The simulations will be analyzed at 2020 and 2050. The 2020 year is meant to correspond with the current CalSimII capabilities. The 2050 year is the far planning horizon. All four climate change scenarios selected by the Climate Action Team (see Chapter 3) will be analyzed at each location and time. An orchard crop, almonds, will then be added to contrast boundary layer and cropping patterns with the herbaceous crops. Eventually, a wider geographic range and longer list of crops is needed for a comprehensive analysis.

Currently there is no comprehensive study of crop changes or regional cropping pattern shifts in relation to climate change. There are methodologies and experts that we can reach to describe differences in climate change impacts on: (1) crop water use efficiencies (WUE) at a systems level, for the growers' water delivery on site, and as crop differences in WUE, and (2) crop production values both for growers and for water resource planners. This is a high priority need.

As an ad hoc climate change group, it might serve us to establish guidelines for managing regional climate downscaled data. Questions regarding averaging techniques including span of time to use, and quality assurance of the downscaled data are important to address. A workshop including other experts, such as statisticians, would be helpful.

For future SIMETAW studies, an average period is planned to describe the two analysis times. For 2020, we plan to use 2015 through 2025 for averaging; and for 2050, we plan to use 2045 through 2055 for averaging. If possible, we think it is useful to coordinate with the other parts of the work team to have a standard in analysis time sampling.

For an understanding of ET demand there is a need to track irrigation conservation technologies and irrigation system pattern shifts including precision agriculture. This information can help anticipate probable shifts in agricultural applied water.

There is also a need to proportionally sum the evapotranspiration and evaporative demands impacted by different climate change scenarios on an annual perspective over the entire state. The precision of this analysis will improve as we improve our knowledge of evaporative processes and refine the SIMETAW model for climate change study.

8.6 Modeling Tool Integration

Several different mathematical models and analysis techniques can be used to assess impacts of climate change by translating changes in factors such as precipitation, sea level and crop evapotranspiration into water supply changes. Examples of modeling tools used in this report include the SWP-CVP operations model CalSim-II (Chapter 4), the Delta hydrodynamics and water quality model DSM2 (Chapter 5), and the Simulation of Evapotranspiration of Applied Water model SIMETAW (Chapter 7). Additional tools may also be available for climate change studies. Future directions include identifying 1) additional tools that could be used for climate change studies 2) input data requirements for each tool, 3) output produced by each tool and 4) more efficient ways to use these tools separately or in conjunction with other models to address water resources planning and management related climate change issues.

8.7 Coordination of State Climate Change Research Activities by the California Energy Commission

At the national and international levels a considerable amount of funds are being devoted to climate change science. Most of these research initiatives are designed to elucidate fundamental scientific questions such as the role of clouds on climate, or the direct and indirect effect of aerosols. The 2001 National Assessment of the Potential Consequences of Climate Variability and Change was a landmark effort resulting in a series of regional assessments that identified key vulnerabilities to a changing climate. Recently the U.S. Climate Change Science Program has embarked on the production of several synthesis and assessment products designed to support decision making on how to prepare for a changing climate.

Even though all of these national and international efforts are extremely informative, they usually are not adequate to answer policy relevant questions at the state and local levels or for detailed long-term planning in California. For this reason, The California Energy Commission through its Public Interest Energy Research (PIER) Program has created the first state-sponsored climate change research program in the nation designed to complement national and international research efforts producing policy-relevant research products. The Commission has created the California Climate Change Center (Center) with the University of California to implement its research plan on climate change. The Center is producing research products that are directly applicable for the preparation of long-term plans. Examples of such plans are the State Water Plans prepared by the Department of Water Resources and the Integrated Energy Policy Reports prepared by the California Energy Commission.

All the state agencies in California are supporting research on climate change. For example, the Air Resources Board is supporting studies on greenhouse gas tailpipe emissions from automobiles and recently has requested expanding its research program on climate change. The Department of Water Resources has an in-house effort designed to use existing planning modeling tools to better understand the potential effects of climate change on water resources in the state. CALFED is funding projects on the potential effect of climate change in the Delta region. Informally all of these efforts are being coordinated through extensive exchanges of information between technical staff from the different agencies and by the fact that some key researchers are involved in most of these research activities. The annual conferences on climate change organized by the Energy Commission and the California Environmental Protection (CalEPA) Agency are also a forum for exchange of ideas and for coordination.

Governor Schwarzenegger signed an Executive Order on June 1, 2005 requiring, among other things, the preparation of periodic assessment reports on the impacts of climate change on key sectors of the California economy. This effort, headed by CalEPA, is also serving as a catalyst for additional coordination and more intense research efforts.

In short, a great deal of coordinated research activities on climate change is already occurring in California. Formalizing these coordinated activities may be advisable, but extreme care should be taken to avoid hampering these activities with onerous requirements.

8.8 Risk Assessment

A major goal of the work team is to extend the analysis prospective for long-term water resources planning from "assessing impacts" to "assessing risk". Impacts assessment identifies possible outcomes resulting from a given change. Risk assessment takes the impacts assessment and investigates the likelihood or probability of occurrence that a particular outcome may occur. The work team's goal of extending our analyses from impacts assessment to risk assessment is shown in Figure 8.1. The bulls-eye nature of the figure symbolizes the work-team's goal of aiming for risk-based assessments for resource management with respect to climate change.

This report represents an example of an impacts assessment based on four scenarios defining an expected range of potential climate change impacts. Such assessments are good for informing

managers of potential future issues that may require management action. However in order for managers to make decisions related to potential climate change impacts, they need information on the probability that any particular scenario will occur relative to other scenarios under consideration.

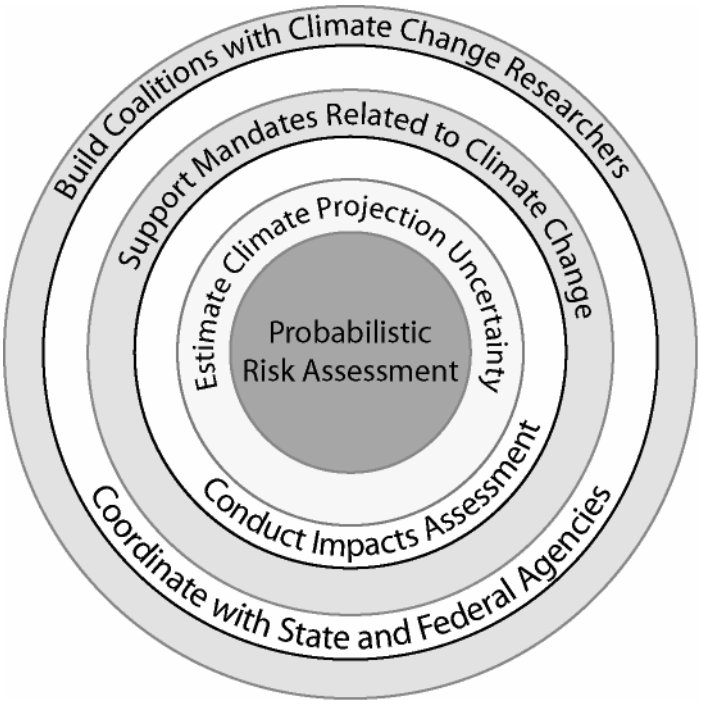

Figure 8.1: DWR-Reclamation Climate Change Work Team Goals
Yellow and red shading indicates future directions.

8.8.1 Compilation of Additional Climate Change Scenarios

An integral component of risk assessment is having as large of a data set as possible to define the range of potential outcomes. The work team plans to collaborate with climate change research groups on the selection of an ensemble of climate change scenarios for analysis, representing a spectrum of climate models and emission scenarios. For this report, analysis focused on four scenarios reflecting two greenhouse gas (GHG) emissions scenarios each represented by two Global Climate Models (GCM's) (see Chapter 3). However, many other emissions scenarios and climate models may be considered for generating future climate scenarios.

Greenhouse Gas Emissions Scenarios

The Intergovernmental Panel on Climate Change's (IPCC's) emissions scenarios cover a wide range of main demographic, economic, and technological driving forces GHG and sulfur emissions and are representative of the literature (IPCC, 2000). Four main storylines representing possible future evolutions of these factors were identified (see Chapter 3).

Scenarios were developed that represent a specific quantitative interpretation of one of the four storylines. All of the scenarios within a given storyline are referred to as a scenario family.

Following an integrated assessment framework, initially six global climate models (GCMs) were used to represent the various climate change scenarios. One advantage of a multi-model approach is that the resultant 40 SRES (Special Report on Emissions Scenarios) encompass the current range of uncertainties of future GHG emissions arising from different characteristics of these models. In addition, the current knowledge of uncertainties that arise from scenario driving forces such as demographic, social and economic, and broad technological developments that drive the models, are described in the storylines. Figure 8.2 shows the SRES emissions scenario tree starting with the four storylines and showing the 40 specific scenarios modeled.

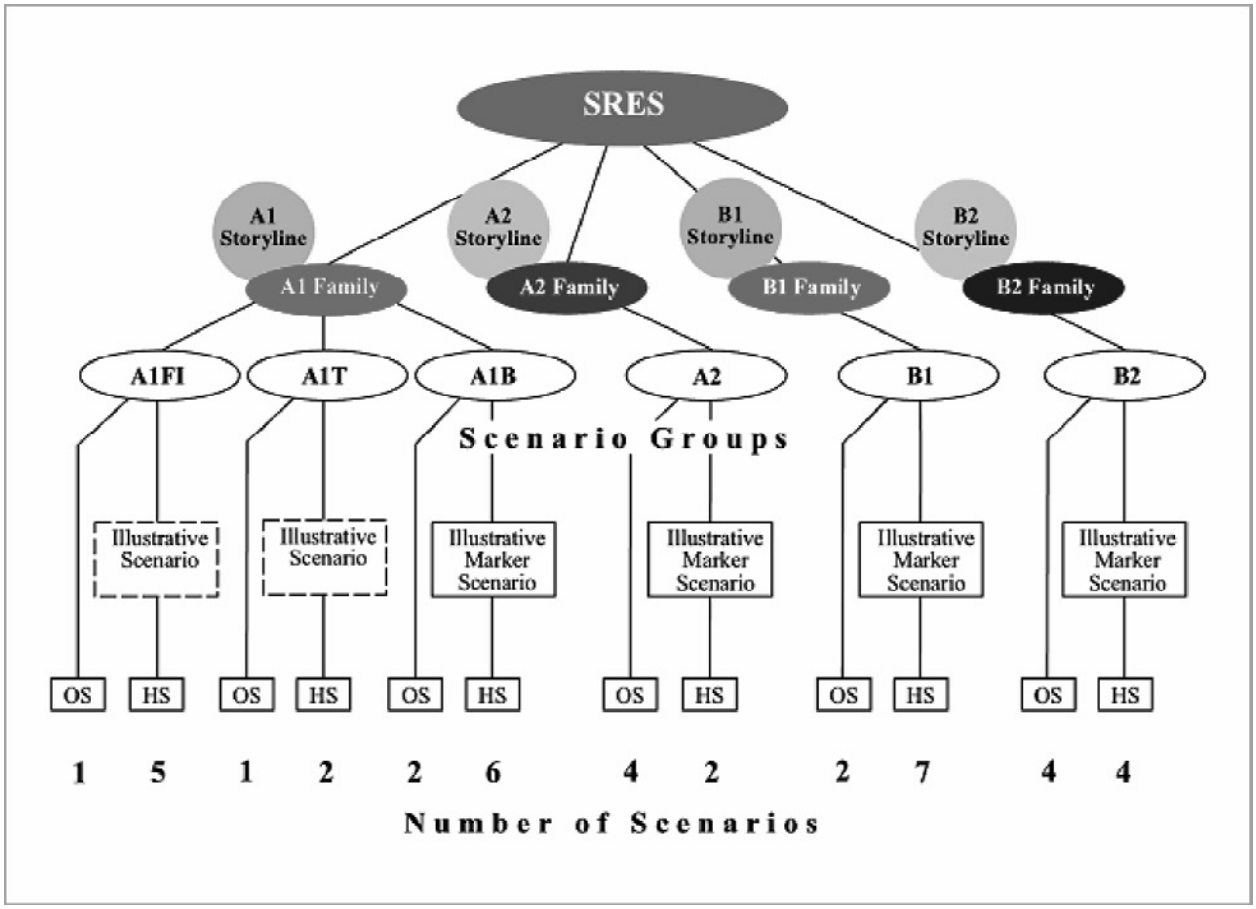

Figure 8.2: Schematic Representation of 40 Emissions Scenarios

Global Climate Models

Nineteen different GGMs have been used to represent the 40 SRES greenhouse gas emissions scenarios (Santer, 2006). The climate processes in a GCM are driven by factors known as forcings, such as greenhouse gas emissions, ozone concentrations, sulfate aerosols, solar irradiance, mineral dust, sea salts, land use/land cover and volcanic aerosols. Different climate

models use different combinations of these forcings to represent the evolution of the climate system (Figure 8.3). The studies presented in this report used climate change projections from two GCMs. Climate change projections produced by additional GCMs are desired to span the range of uncertainty associated with the representation of the climate system.

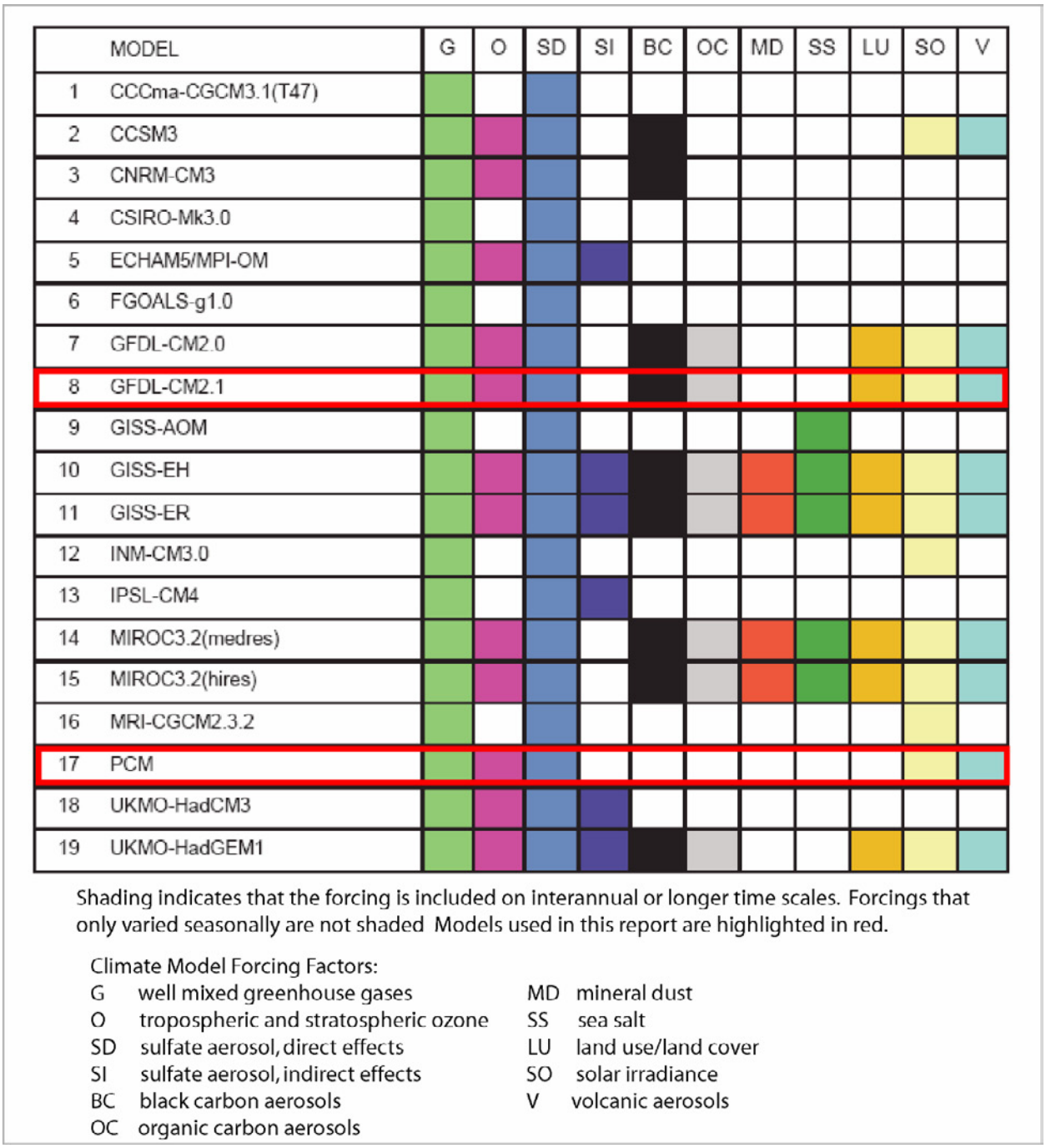

Figure 8.3: Forcing Factor Represented in Various Global Climate Models
Adapted from Table 5.2 (Santer et al., 2006)
Red highlighting indicated models used in this report.

8.8.2 Probability Assessments

As described in the previous section, the work team will compile a larger ensemble of climate change scenarios, hopefully 20 to 30 or more scenarios. The ensemble uncertainty would then be quantified at the regional-scale in terms of probability distributions of annual shifts in precipitation and air temperature. Ensemble members' probabilistic classification (scenario probabilities) would make use of techniques such as those developed by Dettinger (2004). Assumptions would be clearly noted. These scenario probabilities would then be combined with associated impacts assessed using methodologies discussed in this report in order to produce risk information on a variety of system metrics such as annual water deliveries, end-of-September storage, or summer stream temperature. This risk information becomes the baseline for subsequent mitigation studies which look to reduce the risk of negative impacts.

This effort will provide decision makers with both ranges of impacts of climate change and their associated likelihoods. Perceived risk allows planners to make statements about the probability of impacts exceeding certain established thresholds and can be weighed against reliability levels for establishing planning directions. A better understanding of the likelihoods associated with potential climate change impacts will aid decision makers in planning appropriate response strategies. With the accomplishments to date and planned future directions, DWR is collaborating with other agencies and researchers to provide leadership in incorporating climate change impacts and risks into the planning and management of California's precious water resources.

8.9 References

Dettinger, M. (2004). From Climate Change Spaghetti to Climate Change Distributions, Discussion paper prepared for the California Energy Commission, pp25, http://www.energy.ca.gov/reports/2004-04-22_500-04-028.PDF

IPCC. (2000). Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios, Nebojsa Nakicenovic and Rob Swart (Eds.), Cambridge University Press, UK. pp 570, http://www.grida.no/climate/ipcc/emission/.

Santer, B.D., J.E. Penner, and P.W. Thorne. (2006). How well can the observed vertical temperature changes be reconciled with our understanding of the causes of these changes? In: Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.)]. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, USA (in press).

8.10 Abbreviations

ANN-Artificial Neural Network
CalSimII-Simulation model of the SWP and CVP
CIMIS-California Irrigation Management Information System
CVP-Central Valley Project
GCM-Global Climate Model
GHG-Greenhouse Gas
IPCC-Intergovernmental Panel on Climate Change
SIMETAW-Simulation of Evapotranspiration of Applied Water Model
SRES-IPCC Special Report on Emissions Scenarios
SWP-State Water Project
WUE-Water Use Efficiency

Emissions Pathways, Climate Change, Impacts on California,
Katharine Hayhoe, et al., August 24, 2004

Emissions pathways, climate change, and impacts on California

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Contributed by Christopher B. Field, June 23, 2004

The magnitude of future climate change depends substantially on the greenhouse gas emission pathways we choose. Here we explore the implications of the highest and lowest Intergovernmental Panel on Climate Change emissions pathways for climate change and associated impacts in California. Based on climate projections from two state-of-the-art climate models with low and medium sensitivity (Parallel Climate Model and Hadley Centre Climate Model, version 3, respectively), we find that annual temperature increases nearly double from the lower B1 to the higher A1fi emissions scenario before 2100. Three of four simulations also show greater increases in summer temperatures as compared with winter. Extreme heat and the associated impacts on a range of temperature-sensitive sectors are substantially greater under the higher emissions scenario, with some interscenario differences apparent before midcentury. By the end of the century under the B1 scenario, heatwaves and extreme heat in Los Angeles quadruple in frequency while heat-related mortality increases two to three times; alpine/subalpine forests are reduced by 50–75%; and Sierra snowpack is reduced 30–70%. Under A1fi, heatwaves in Los Angeles are six to eight times more frequent, with heat-related excess mortality increasing five to seven times; alpine/subalpine forests are reduced by 75–90%; and snowpack declines 73–90%, with cascading impacts on runoff and streamflow that, combined with projected modest declines in winter precipitation, could fundamentally disrupt California's water rights system. Although interscenario differences in climate impacts and costs of adaptation emerge mainly in the second half of the century, they are strongly dependent on emissions from preceding decades.

California, with its diverse range of climate zones, limited water supply, and economic dependence on climate-sensitive industries such as agriculture, provides a challenging test case to evaluate impacts of regional-scale climate change under alternative emissions pathways. As characterized by the Intergovernmental Panel on Climate Change, demographic, socioeconomic, and technological assumptions underlying long-term emissions scenarios vary widely (1). Previous studies have not systematically examined the difference between projected regional-scale changes in climate and associated impacts across scenarios. Nevertheless, such information is essential to evaluate the potential for and costs of adaptation associated with alternative emissions futures and to inform mitigation policies (2).

Here, we examine a range of potential climate futures that represent uncertainties in both the physical sensitivity of current climate models and divergent greenhouse gas emissions pathways. Two global climate models, the low-sensitivity National Center for Atmospheric Research/Department of Energy Parallel Climate Model (PCM) (3) and the medium-sensitivity U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3), model (4, 5) are used to calculate climate change resulting from the SRES (Special Report on Emission Scenarios) B1 (lower) and A1fi (higher) emissions scenarios (1). These scenarios bracket a large part of the range of Intergovernmental Panel on Climate Change nonintervention emissions futures with atmospheric concentrations of CO_2 reaching ≈550 ppm (B1) and ≈970 ppm (A1fi) by 2100 (see *Emissions Scenarios* in *Supporting Text*, which is published as supporting information on the PNAS web site). Although the SRES scenarios do not explicitly assume any specific climate mitigation policies, they do serve as useful proxies for assessing the outcome of emissions pathways that could result from different emissions reduction policies. The scenarios at the lower end of the SRES family are comparable to emissions pathways that could be achieved by relatively aggressive emissions reduction policies, whereas those at the higher end are comparable to emissions pathways that would be more likely to occur in the absence of such policies.

Climate Projections

Downscaling Methods. For hydrological and agricultural analyses, HadCM3 and PCM output was statistically downscaled to a 1/8° grid (≈150 km^2) (6) and to individual weather stations (7) for analyses of temperature and precipitation extremes and health impacts. Downscaling to the 1/8° grid used an empirical statistical technique that maps the probability density functions for modelled monthly precipitation and temperature for the climatological period (1961–1990) onto those of gridded historical observed data, so the mean and variability of observations are reproduced by the climate model data. The bias correction and spatial disaggregation technique is one originally developed for adjusting General Circulation Model output for long-range streamflow forecasting (6), later adapted for use in studies examining the hydrologic impacts of climate change (8), and compares favorably to different statistical and dynamic downscaling techniques (9) in the context of hydrologic impact studies.

Station-level downscaling for analyses of temperature and precipitation extremes and health impacts used a deterministic method in which grid-cell values of temperatures and precipi-

Freely available online through the PNAS open access option.

Abbreviations: DJF, December, January, February; HadCM3, Hadley Centre Climate Model, version 3; JJA, June, July, August; PCM, Parallel Climate Model; SRES, Special Report on Emission Scenarios; SWE, snow water equivalent.

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Table 1. Summary of midcentury (2020–2049) and end-of-century (2070–2099) climate and impact projections for the HadCM3 and PCM B1 and A1fi scenarios

			2020–2049				2070–2099			
			PCM		HadCM3		PCM		HadCM3	
	Units	1961–1990	B1	A1fi	B1	A1fi	B1	A1fi	B1	A1fi
Change in statewide avg temperatures										
Annual	°C	15.0	1.35	1.5	1.6	2.0	2.3	3.8	3.3	5.8
Summer (JJA)	°C	22.8	1.2	1.4	2.2	3.1	2.15	4.1	4.6	8.3
Winter (DJF)	°C	7.6	1.3	1.2	1.4	1.45	2.15	3.0	2.3	4.0
Change in statewide avg precipitation										
Annual	mm	544	−37	−51	+6	−70	+38	−91	−117	−157
Summer (JJA)	mm	20	−3	+2	−1	−7	+4	−46	−5	−1
Winter (DJF)	mm	269	−45	−55	+4	−44	+13	−13	−79	−92
Sea level rise	cm	—	8.7	9.5	11.6	12.7	19.2	28.8	26.8	40.9
Heatwave days										
Los Angeles	Days	12	28	35	24	36	44	76	47	95
Sacramento	Days	58	91	101	93	104	109	134	115	138
Fresno	Days	92	113	120	111	116	126	147	126	149
El Centro	Days	162	185	185	176	180	191	213	197	218
Length of heatwave season*	Days	115	135	142	132	141	149	178	162	204
Excess mortality for Los Angeles†										
Without acclimatization	avg no. of deaths/yr	—	—	—	—	—	394	948	667	1,429
With acclimatization	avg no. of deaths/yr	165	—	—	—	—	319	790	551	1,182
Change in April 1 snowpack SWE										
1,000–2,000 m elevation	%	3.6 km^3	−60	−56	−58	−66	−65	−95	−87	−97
2,000–3,000 m elevation	%	6.5 km^3	−34	−34	−24	−36	−22	−73	−75	−93
3,000–4,000 m elevation	%	2.3 km^3	−11	−15	4	−16	15	−33	−48	−68
All elevations	%	12.4 km^3	−38	−37	−26	−40	−29	−73	−72	−89
Change in annual reservoir inflow‡										
Total	%	21.7 km^3	−18	−22	5	−10	12	−29	−24	−30
Northern Sierra	%	15.2 km^3	−19	−22	3	−9	9	−29	−20	−24
Southern Sierra	%	6.5 km^3	−16	−23	10	−14	17	−30	−33	−43
Change in April–June reservoir inflow‡										
Total	%	9.1 km^3	−20	−24	−11	−19	−1	−46	−41	−54
Northern Sierra	%	5.5 km^3	−21	−24	−16	−19	−6	−45	−34	−47
Southern Sierra	%	3.6 km^3	−18	−24	−2	−19	5	−47	−52	−65
Change water year flow centroid‡										
Total	Days	03/26	0	2	−15	−7	−7	−14	−23	−32
Northern Sierra	Days	03/13	0	3	−16	−5	−3	−11	−18	−24
Southern Sierra	Days	05/01	−10	−7	−19	−12	−22	−34	−34	−43

avg, average; JJA, June, July, August; DJF, December, January, February; SWE, snow water equivalent.

*The number of days between the beginning of the year's first and end of the year's last heatwave.

†Reference period is 1990–1999, and projections are for the period 2090–2099.

‡Results are for inflows to seven major dams and reservoirs in the Sacramento/San Joaquin water system, including three in the Northern Sierra (Shasta, Oroville, and Folsom) and four in the Southern Sierra (New Melones, New Don Pedro, Lake McClure, and Pine Flat).

tation from the reference period were rescaled by simple monthly regression relations to ensure that the overall probability distributions of the simulated daily values closely approximated the observed probability distributions at selected long-term weather stations (7). The same regression relations were then applied to future simulations, such that rescaled values share the weather statistics observed at the selected stations. At the daily scales addressed by this method, the need to extrapolate beyond the range of the historically observed parts of the probability distributions was rare even in the future simulations (typically <1% of the future days) because most of the climate changes involve more frequent warm days than actual truly warmer-than-ever-observed days (7).

Except where otherwise noted, we present projected climate anomalies and impacts averaged over 2020–2049 (with a midpoint of 2035) and 2070–2099 (here designated as end-of-century, with a midpoint of 2085), relative to a 1961–1990 reference period.

Temperature. All simulations show increases in annual average temperature before midcentury that are slightly greater under the higher A1fi emissions scenario (see Fig. 4, which is published as supporting information on the PNAS web site). By end-of-century, projected temperature increases under A1fi are nearly twice those under B1, with the more sensitive HadCM3 model producing larger absolute changes (Table 1). Downscaled seasonal mean temperature projections (10) show consistent spatial patterns across California, with lesser warming along the southwest coast and increasing warming to the north and northeast (Fig. 1). Statewide, the range in projected average temperature increases is higher than previously reported (11–14), particularly for summer temperature increases that are equal to or greater than increases in winter temperatures.

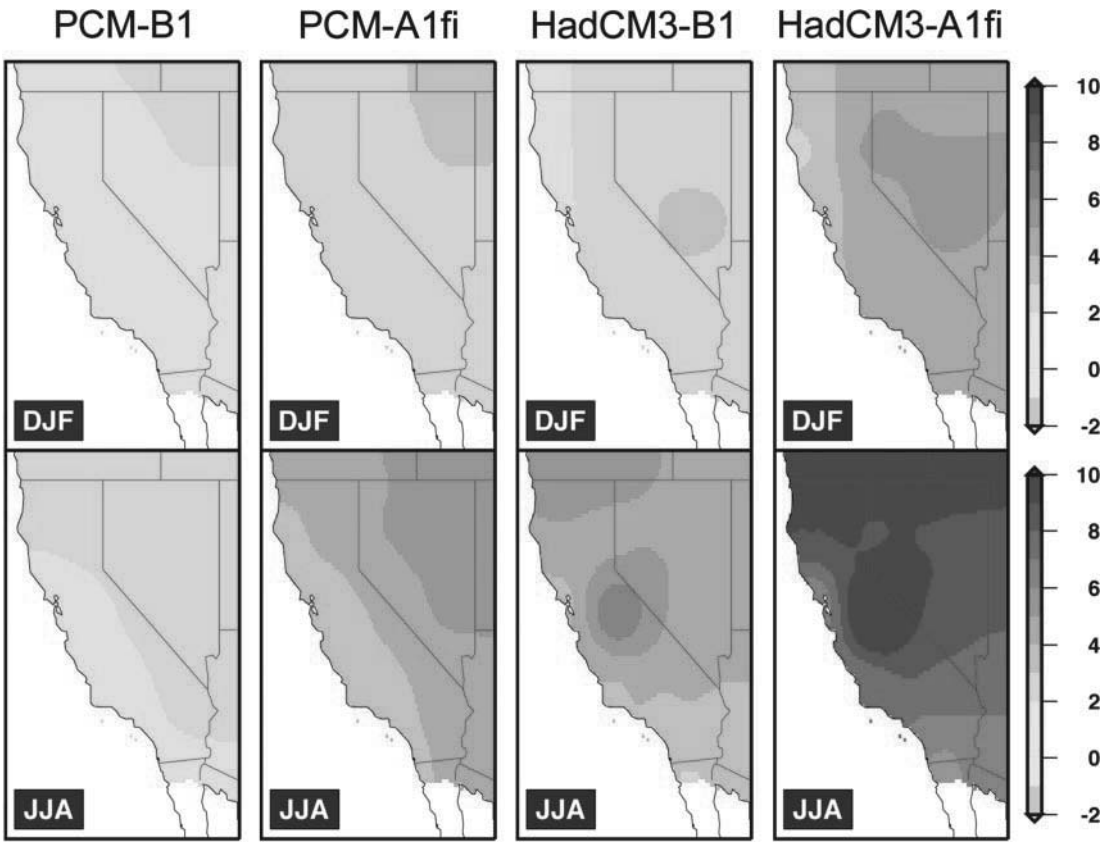

Fig. 1. Downscaled winter (DJF) and summer (JJA) temperature change (°C) for 2070–2099, relative to 1961–1990 for a 1/8° grid. Statewide, SRES B1 to A1fi winter temperature projections for the end of the century are 2.2–3°C and 2.3–4°C for PCM and HadCM3, respectively, compared with previous projections of 1.2–2.5°C and 3–3.5°C for PCM and HadCM2, respectively. End-of-century B1 to A1fi summer temperature projections are 2.2–4°C and 4.6–8.3°C for PCM and HadCM3, respectively, compared with previous projections of 1.3–3°C and 3–4°C for PCM and HadCM2, respectively (11–14).

Precipitation. Precipitation shows a tendency toward slight decreases in the second half of the century with no obvious interscenario differences in magnitude or frequency (see Figs. 5–10, which are published as supporting information on the PNAS web site). Three of four simulations project winter decreases of −15% to −30%, with reductions concentrated in the Central Valley and along the north Pacific Coast. Only PCM B1 projects slight increases (≈7%) by the end of the century (Table 1). These results differ from previous projections showing precipitation increases of 75–200% by 2100 (11–13), but they are consistent with recent PCM-based midrange projections (14, 15). The larger-scale pattern of rainfall over North America is more uniform across scenarios, showing an area of decreased (or lesser increase in) precipitation over California that contrasts with increases further up the coast (see Fig. 11, which is published as supporting information on the PNAS web site). Because interdecadal variability often dominates precipitation over California, projected changes in climate and impacts associated with the direct effects of temperature should be considered more robust than those determined by interactions between temperature and precipitation or precipitation alone.

Extreme Heat and Heat-Related Mortality

Temperature extremes increase in both frequency and magnitude under all simulations, with the most dramatic increases occurring under the A1fi scenario. Changes in local temperature extremes were evaluated based on exceedance probability analyses, by using the distribution of daily maximum temperatures downscaled to representative locations (16). Exceedance probabilities define a given temperature for which the probability exists that X% of days throughout the year will fall below that temperature (i.e., if the 35°C exceedance probability averages 95% for the period 2070–2099, this means that an average of 95% or ≈347 days per year are likely to lie below 35°C). For the four locations examined for extreme heat occurrence (Los Angeles, Sacramento, Fresno, and Shasta Dam), mean and maximum temperatures occurring 50% and 5% of the year increase by 1.5–5°C under B1 and 3.5–9°C under A1fi by the end of the century. Extreme temperatures experienced an average of 5% of the year during the historical period are also projected to increase in frequency, accounting for 12–19% (B1) and 20–30% (A1fi) of days annually by 2070–2099 (see Fig. 12, which is published as supporting information on the PNAS web site).

The annual number of days classified as heatwave conditions (3 or more consecutive days with temperature above 32°C) increases under all simulations, with more heatwave days under A1fi before midcentury (see Fig. 13, which is published as supporting information on the PNAS web site). Among the four locations analyzed, increases and interscenario differences are proportionally greatest for Los Angeles, a location that currently experiences relatively few heatwaves. By the end of the century, the number of heatwave days in Los Angeles increases four times under B1, and six to eight times under A1fi. Statewide, the length of the heatwave season increases by 5–7 weeks under B1 and by 9–13 weeks under A1fi by the end of this century, with interscenario differences emerging by midcentury (Table 1; see also Fig. 14, which is published information on the PNAS web site).

The connection between extreme heat and summer excess mortality is well established (17). Heat-related mortality estimates for the Los Angeles metropolitan area were determined

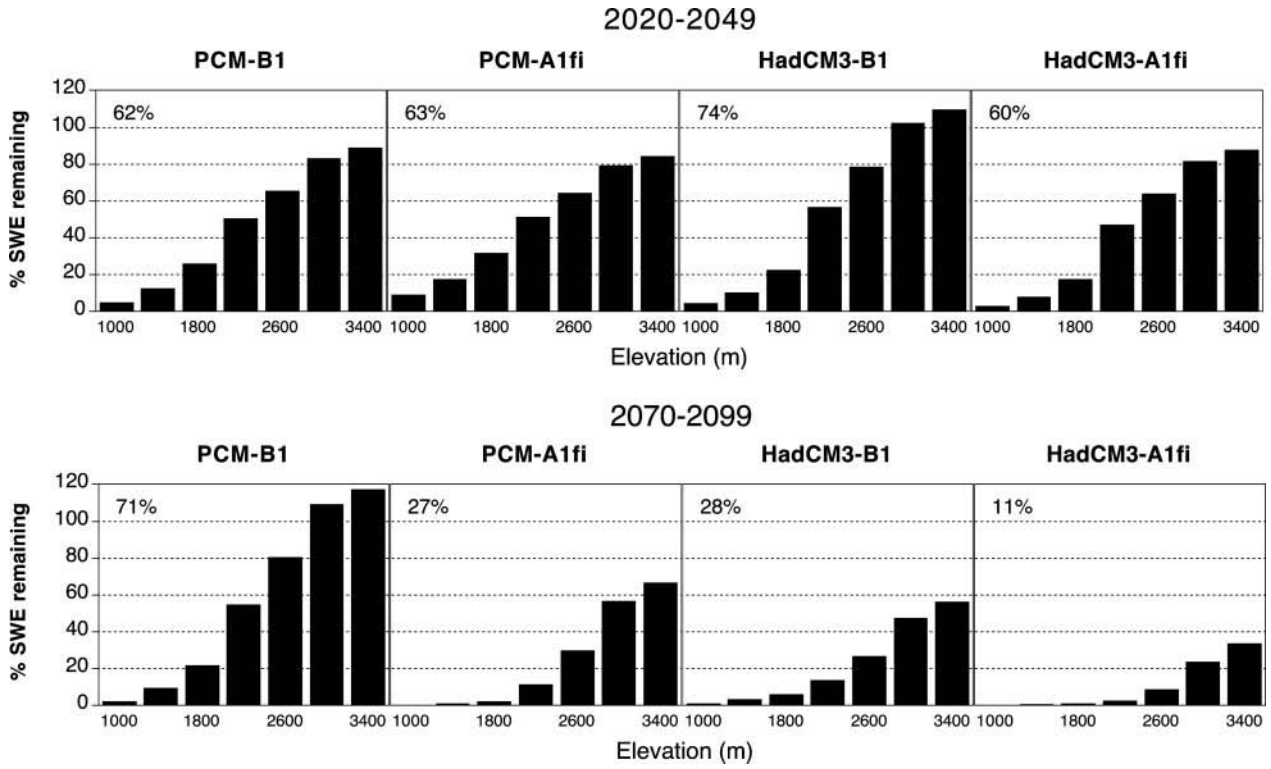

Fig. 2. Average snowpack SWE for 2020–2049 and 2070–2099 expressed as a percent of the average for the reference period 1961–1990 for the Sierra Nevada region draining into the Sacramento–San Joaquin river system. Total SWE losses by the end of the century range from 29–72% for the B1 scenario to 73–89% for the A1fi scenario. Losses are greatest at elevations below 3,000 m, ranging from 37–79% for B1 to 81–94% for A1fi by the end of the century. Increases in high elevation SWE for midcentury HadCM3 B1 and end-of-century PCM B1 runs result from increased winter precipitation in these simulations.

by threshold meteorological conditions beyond which mortality tends to increase. An algorithm was developed to determine the primary environmental factors (including maximum apparent temperature, number of consecutive days above the threshold apparent temperature, and time of year) that explain variability in excess mortality for all days with apparent maximum temperatures at or above the derived daily threshold apparent temperature (18) value of 34°C (see *Heat-Related Mortality* in *Supporting Text*). Estimates do not account for changes in population or demographic structure.

From a baseline of ≈165 excess deaths during the 1990s, heat-related mortality in Los Angeles is projected to increase by about two to three times under B1 and five to seven times under A1fi by the 2090s if acclimatization is taken into account (see *Heat-Related Mortality* in *Supporting Text*). Without acclimatization, these estimates are about 20–25% higher (Table 1). Actual impacts may be greater or lesser depending in part on demographic changes and societal decisions affecting preparedness, health care, and urban design. Individuals likely to be most affected include elderly, children, the economically disadvantaged, and those who are already ill (19, 20).

Impacts on Snowpack, Runoff, and Water Supply

Rising temperatures, exacerbated in some simulations by decreasing winter precipitation, produce substantial reductions in snowpack in the Sierra Nevada Mountains, with cascading impacts on California winter recreation, streamflow, and water storage and supply. Snowpack SWE was estimated by using daily, bias-corrected and spatially downscaled temperature and precipitation to drive the Variable Infiltration Capacity distributed land surface hydrology model. The Variable Infiltration Capacity model, using the resolution and parameterization also implemented in this study, has been shown to reproduce observed streamflows when driven by observed meteorology (10) and has been applied to simulate climate change (8) in this region. April 1 SWE decreases substantially in all simulations before midcentury (see Fig. 15, which is published as supporting information on the PNAS web site). Reductions are most pronounced at elevations below 3,000 m, where 80% of snowpack storage currently occurs (Table 1 and Fig. 2). Interscenario differences emerge before midcentury for HadCM3 and by the end of the century for both models. These changes will delay the onset of and shorten the ski season in California (see *Impact of Decreasing Snowpack on California's Ski Industry* in *Supporting Text*).

Water stored in snowpack is a major natural reservoir for California. Differences in SWE between the B1 and A1fi scenarios represent ≈1.7 km^3 of water storage by midcentury and 2.1 km^3 by the end of the century for HadCM3. For PCM, overall SWE losses are smaller, but the difference between the A1fi and B1 scenarios is larger by the end of the century, representing >4 km^3 of storage. Reductions for all simulations except PCM under the lower B1 emission scenario are greater than previous projections of diminishing snowpack for the end of the century (8, 21). By 2020–2049 the SWE loss is comparable to that previously projected for 2060 (22).

Warmer temperatures and more precipitation falling as rain instead of snow also causes snowmelt runoff to shift earlier under all simulations (Table 1), which is consistent with earlier studies (23). The magnitude of the shift is greater in the higher-elevation Southern basins and under the higher A1fi scenario. Stream inflows to major reservoirs decline because of diminished snowpack and increased evaporation before midcentury, except where winter precipitation increases (Table 1). The greater reductions in inflows seen under A1fi are driven by both higher temperatures and lower average precipitation as compared with B1.

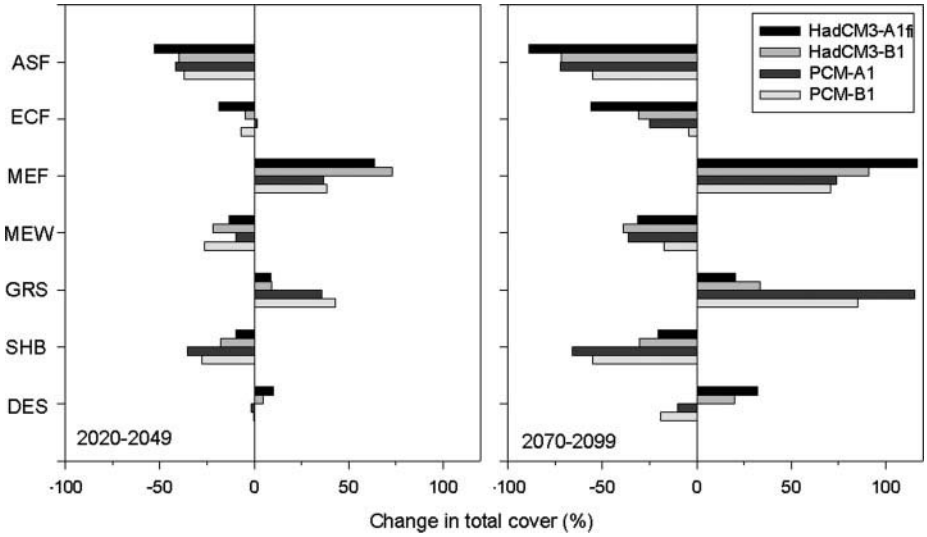

Fig. 3. Statewide change in cover of major vegetation types for 2020–2049 and 2070–2099, relative to simulated distributions for the 1961–1990 reference period. ASF, alpine/subalpine forest; ECF, evergreen conifer forest; MEF, mixed evergreen forest; MEW, mixed evergreen woodland; GRS, grassland; SHB, shrubland; DES, desert. Increasing temperatures drive the reduction in alpine/subalpine forest cover and cause mixed conifer forest to displace evergreen conifer forest in the Sierra Nevada Mountains and the North Coast. Mixed conifer forest in the South Coast expands because of increased humidity and reduced fire frequency. Because of drier conditions and increased fire frequency in inland locations, grassland displaces shrubland and woodland, particularly in the PCM simulations, whereas warmer and drier conditions under HadCM3 cause an expansion of desert cover in the southern Central Valley.

Earlier runoff may also increase the risk of winter flooding (7). Currently, state operators maintain ≈12 km^3 of total vacant space in the major reservoirs to provide winter and early spring flood protection,[n] a volume approximately equal to that stored in the natural snowpack reservoir by April 1st. Capturing earlier runoff to compensate for future reductions in snowpack would take up most of the flood protection space, forcing a choice between winter flood prevention and maintaining water storage for the summer and fall dry period use. Flood risk and freshwater supply are also affected by higher sea levels, which are projected to rise 10–40 cm under B1 and 20–65 cm under A1fi by 2100 (Table 1; see also Fig. 16, which is published as supporting information on the PNAS web site).

Declining Sierra Nevada snowpack, earlier runoff, and reduced spring and summer streamflows will likely affect surface water supplies and shift reliance to groundwater resources, already overdrafted in many agricultural areas in California (24). This could impact 85% of California's population who are agricultural and urban users in the Central Valley, San Francisco Bay Area, and the South Coast, about half of whose water is supplied by rivers of the Central Valley. Under A1fi (both models) and B1 (HadCM3), the projected length, frequency, and severity of extreme droughts in the Sacramento River system during 2070–2099 substantially exceeds what has been experienced in the 20th century. The proportion of years projected to be dry or critical increases from 32% in the historical period to 50–64% by the end of the century under all but the wetter PCM B1 scenario (see Table 2, which is published as supporting information on the PNAS web site). Changes in water availability and timing could disrupt the existing pattern of seniority in month-dependent water rights by reducing the value of rights to mid- and late-season natural streamflow and boosting the value of rights to stored water. The overall magnitude of impacts on water users depends on complex interactions between temperature-driven snowpack decreases and runoff timing, precipitation, future population increases, and human decisions regarding water storage and allocation (see *Impacts on Water Supply* in *Supporting Text*).

Impacts on Agriculture and Vegetation Distribution

In addition to reductions in water supply, climate change could impact California agriculture by increasing demand for irrigation to meet higher evaporative demand, increasing the incidence of pests (25), and through direct temperature effects on production quality and quantity. Dairy products (milk and cream, valued at $3.8 billion annually) and grapes ($3.2 billion annually) are the two highest-value agricultural commodities of California's $30 billion agriculture sector (26). Threshold temperature impacts on dairy production and wine grape quality were calculated by using downscaled temperature projections for key counties, relative to average observed monthly temperatures.[o]

For dairy production, losses were estimated for temperatures above a 32°C threshold (27), as well as for additional losses between 25°C (28) and 32°C. For the top 10 dairy counties in the state (which account for 90% of California's milk production), rising temperatures were found to reduce production by as much as 7–10% (B1) and 11–22% (A1fi) by the end of the century (see Table 3, which is published as supporting information on the PNAS web site). Potential adaptations may become less practical with increasing temperature and humidity (29).

For wine grapes, excessively high temperatures during ripening can adversely affect quality, a major determinant of market value. Assuming ripening occurs at between 1,150 and 1,300 biologically active growing degree days (30), ripening month was determined by summing modeled growing degree days above 10°C from April to October, for both baseline and projected scenarios. Monthly average temperature at the time of ripening was used to estimate potential temperature impacts on quality. For all simulations, average ripening occurs 1–2 months earlier and at higher temperatures, leading to degraded quality and marginal/impaired conditions for all but the cool coastal region

[n]See the U.S. Army Corps of Engineers Flood Control Requirements for California Reservoirs, Sacramento District Water Control Data System, Sacramento, CA (www.spk-wc.usace.army.mil).

[o]See Western U.S. Climate Historical Summaries (Western Regional Climate Center) at www.wrcc.dri.edu/climsum.html.

under all scenarios by the end of the century (see Table 3, which is published as supporting information on the PNAS web site). As with other perennial crops, adaptation options to shift varieties or locations of production would require significant time and capital investment.

The distribution of California's diverse vegetation types also changes substantially over the century relative to historical simulations (Fig. 3; see also Fig. 17, which is published as supporting information on the PNAS web site). Projections of changes in vegetation distribution are those given by MC1, a dynamic general vegetation model that simulates climate-driven changes in life-form mixtures and vegetation types; ecosystem fluxes of carbon, nitrogen, and water; and fire disturbance over time (31). Vegetation shifts driven primarily by temperature, such as reductions in the extent of alpine/subalpine forest and the displacement of evergreen conifer forest by mixed evergreen forest, are consistent across models and more pronounced under A1fi by the end of the century. Changes driven by precipitation and changes in fire frequency are model-dependent and do not exhibit consistent interscenario differences. Most changes are apparent before mid-century, with the exception of changes in desert cover. The shift from evergreen conifer to mixed evergreen forest and expansion of grassland are consistent with previous impact analyses (13), whereas the extreme reduction in alpine/subalpine forest and expansion of desert had not been reported in previous impacts assessments (12, 13).

Conclusions

Consistent and large increases in temperature and extreme heat drive significant impacts on temperature-sensitive sectors in California under both lower and higher emissions scenarios, with the most severe impacts occurring under the higher A1fi scenario. Adaptation options are limited for impacts not easily controlled by human intervention, such as the overall decline in snowpack and loss of alpine and subalpine forests. Although interscenario differences in climate impacts and costs of adaptation emerge mainly in the second half of the century, they are largely entrained by emissions from preceding decades (32). SRES scenarios do not explicitly assume climate-specific policy intervention, and thus this study does not directly address the contrast in impacts due to climate change mitigation policies. However, these findings support the conclusion that climate change and many of its impacts scale with the quantity and timing of greenhouse gas emissions (33). As such, they represent a solid starting point for assessing the outcome of changes in greenhouse gas emission trajectories driven by climate-specific policies (32, 34), and the extent to which lower emissions can reduce the likelihood and thus risks of "dangerous anthropogenic interference with the climate system" (35).

We thank Michael Dettinger and Mary Meyer Tyree for providing assistance with data and analysis, and Frank Davis for providing review of earlier drafts of this manuscript. PCM model results were provided by PCM personnel at the National Center for Atmospheric Research, and HadCM3 model results were provided by Dr. David Viner from the U.K. Met Office's Climate Impacts LINK Project. This work was supported in part by grants from the David and Lucile Packard Foundation, the William and Flora Hewlett Foundation, the Energy Foundation, the California Energy Commission, the National Oceanic and Atmospheric Administration Office of Global Programs, and the Department of Energy.

1. Nakićenović, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T. Y., Kram, T., *et al.* (2000) *Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios* (Cambridge Univ. Press, Cambridge, U.K.).
2. Parry, M. (2002) *Global Environ. Change* **12** (3)**,** 149–153.
3. Washington, W. M., Weatherly, J. W., Meehl, G. A., Semtner, A. J., Bettge, T. W., Craig, A. P., Strand, W. G., Arblaster, J., Wayland, V. B., James, R. & Zhang, Y. (2000) *Clim. Dyn.* **16,** 755–774.
4. Gordon, C., Cooper, C., Senior, C. A., Banks, H., Gregory, J. M., Johns, T. C., Mitchell, J. F. B. & Wood, R. A. (2000) *Clim. Dyn.* **16,** 147–168.
5. Pope, V. D., Gallani, M. L., Rowntree, P. R. & Stratton, R. A. (2000) *Clim. Dyn.* **16,** 123–146.
6. Wood, A. W., Maurer, E. P., Kumar, A. & Lettenmaier, D. P. (2002) *J. Geophys. Res.* **107,** 4429, 10.1029/2001JD000659.
7. Dettinger, M. D., Cayan, D. R., Meyer, M. K. & Jeton, A. E. (2004) *Clim. Change* **62,** 283–317.
8. VanRheenan, N. T., Wood, A. W., Palmer, R. N. & Lettenmaier, D. P. (2004) *Clim. Change* **62,** 257–281.
9. Wood, A. W., Leung, L. R., Sridhar, V. & Lettenmaier, D. P. (2004) *Clim. Change* **62,** 189–216.
10. Maurer, E. P., Wood, A. W., Adam, J. C., Lettenmaier, D. P. & Nijssen, B. (2002) *J. Clim.* **15,** 3237–3251.
11. Field, C. B., Daily, G. C., Davis, F. W., Gaines, S., Matson, P. A., Melack, J. & Miller, N. L. (1999) *Confronting Climate Change in California: Ecological Impacts on the Golden State* (Union of Concerned Scientists, Cambridge, MA, and Ecological Society of America, Washington, DC).
12. Wilkinson, R., Clarke, K., Goodchild, M., Reichman, J. & Dozier, J. (2002) *The Potential Consequences of Climate Variability and Change for California: The California Regional Assessment* (U.S. Global Change Research Program, Washington, DC).
13. Wilson, T., Williams, L., Smith, J. & Medelsohn, R. (2003) *Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy*, Publication No. 500-03-058CF (California Energy Commission, Public Interest Energy Research Environmental Area, Sacramento).
14. Leung, L. R., Qian, Y., Bian, X., Washington, W. M., Han, J. & Roads, J. O. (2004) *Clim. Change* **62,** 75–113.
15. Snyder, M. A., Bell, J. L., Sloan, L. C., Duffy, P. B. & Govindasamy, B. (2002) *Geophys. Res. Lett.* **29,** 1514–1517.
16. Miller, N. L., Bashford, K. E. & Strem, E. (2003) *J. Am. Water Resour. Assoc.* **39,** 771–784.
17. Kalkstein, L. S. & Davis, R. E. (1989) *Ann. Assoc. Am. Geogr.* **79,** 44–64.
18. Watts, J. D. & Kalkstein, L. S. (2004) *J. Appl. Meteorol.* **43,** 503–513.
19. McGeehin, M. A. & Mirabelli, M. (2001) *Environ. Health Perspect.* **109,** 185–189.
20. Chestnut, L. G., Breffle, W. S., Smith, J. B. & Kalkstein, L. S. (1998) *Environ. Sci. Policy* **1,** 59–70.
21. Knowles, N. & Cayan, D. R. (2002) *Geophys. Res. Lett.* **29,** 1891–1895.
22. Knowles, N. & Cayan, D. R. (2004) *Clim. Change* **62,** 319–336.
23. Gleick, P. H. & Chalecki, E. L. (1999) *J. Am. Water Resour. Assoc.* **35,** 1429–1441.
24. California Department of Water Resources, Division of Planning and Local Assistance (1998) *Bulletin 160–98: California Water Plan* (California Department of Water Resources, Sacramento).
25. Harrington, R. & Stork, N. E., eds. (1995) *Insects in a Changing Environment* (Academic, London).
26. California Agricultural Statistics Service (2002) *California Agriculture Statistical Review* (California Agricultural Statistics Service, Sacramento).
27. Ahmed, M. M. M. & El Amin, A. I. (1997) *J. Arid Environ.* **35,** 737–745.
28. Mellado, M. (1995) *Veterinaria* **26,** 389–399.
29. Pittock, B., Wratt, D., Basher, R., Bates, B., Finlayson, M., Gitay, H., Woodward, A., Arthington, A., Beets, P., Biggs, B., *et al.* (2001) in *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (Cambridge Univ. Press, Cambridge, U.K.).
30. Gladstones, J. (1992) *Viticulture and Environment* (Winetitles, Underdale, South Australia), 310 pp.
31. Lenihan, J., Drapek, R., Bachelet, D. & Neilson, R. (2003) *Ecol. Appl.* **13,** 1667–1681.
32. Swart, R., Mitchell, J., Morita, T. & Raper, S. (2002) *Global Environ. Change* **12,** 155–165.
33. Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J. & Xiaosu, D., eds. (2001) *Climate Change 2001: The Scientific Basis* (Cambridge Univ. Press, Cambridge, U.K.).
34. Arnell, N. W., Livermore, M. J. L., Kovats, S., Levy, P. E., Nicholls, R., Parry, M. L. & Gaffin, S. R. (2004) *Global Environ. Change* **14,** 3–20.
35. United Nations (1992) *United Nations Framework Convention on Climate Change* (United Nations, Rio de Janeiro, Brazil).

Pondering a Climate Conundrum in Antarctic, *Nature*
January 13, 2002

NSF Press Release

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NSF PR 02-03 - January 13, 2002

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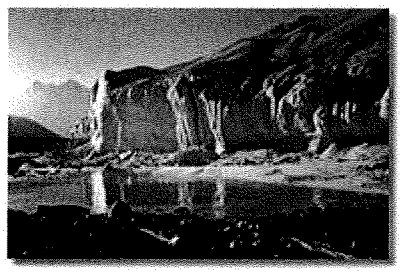
Pondering a Climate Conundrum in Antarctica

Unique, distinct cooling trend discovered on Earth's southernmost continent

Antarctica overall has cooled measurably during the last 35 years - despite a global average increase in air temperature of 0.6 degrees Celsius during the 20th century - making it unique among the Earth's continental landmasses, according to a paper published today in the online version of *Nature*.



Sunlight plays off the Canada Glacier in the Wrigth Valley, one of the McMurdo Dry Valleys.
Photo credit: Peter Doran/National Science Foundation
Select image for larger version
(Size: 1MB)

Researchers with the National Science Foundation (NSF) Long-term Ecological Research (LTER) site in Antarctica's Dry Valleys - a perpetually snow-free, mountainous area adjacent to McMurdo Sound - argue in the paper that long-term data from weather stations across the continent, coupled with a separate set of measurements from the Dry Valleys, confirm each other and corroborate the continental cooling trend.

"Our 14-year continuous weather station record from the shore of Lake Hoare reveals that seasonally averaged surface air temperature has decreased by 0.7 degrees Celsius per decade," they write. "The temperature decrease is most pronounced in summer and autumn. Continental cooling, especially the seasonality of cooling, poses challenges to models of climate and ecosystem change."

The U.S. Antarctic Program field camp at Lake Hoare in the McMurdo Dry Valleys, with the Canada Glacier in the background.
Photo credit: Peter West/National Science Foundation
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The findings are puzzling because many climate models indicate that the Polar regions should serve as bellwethers for any global warming trend, responding first and most rapidly to an increase in temperatures. An ice sheet many kilometers thick in places perpetually covers almost all of Antarctica.

Temperature anomalies also exist in Greenland, the largest ice sheet in the Northern Hemisphere, with cooling in the interior concurrent with warming at the coast.

Note About Images

Peter Doran, of the University of Illinois at Chicago, the lead author of the paper, and his co-authors, acknowledge that other studies conducted in Antarctica have deduced a warming trend elsewhere in the continent. But they note that the data indicate that the warming occurred between 1958 and 1978. They

also note that the previous claims that Antarctic is warming may have been skewed because the measurements were taken largely on the Antarctic Peninsula, which extends northwards toward South America. The Peninsula itself is warming dramatically, the authors note, and there are many more weather stations on the Peninsula than elsewhere on the continent.

Averaging the temperature readings from the more numerous stations on the Peninsula has led to the misleading conclusion that there is a net warming continent-wide. "Our approach shows that if you remove the Peninsula from the dataset, and look at the spatial trend. The majority of the continent is cooling," said Doran.

He added that documentation of the continental cooling presents a challenge to climate modelers. "Although some do predict areas of cooling, widespread cooling is a bit of a conundrum that the models need to start to account for," he said.

The Dry Valleys are the largest ice-free area in Antarctica, a desert region that encompasses perennially ice-covered lakes, ephemeral streams, arid soils, exposed bedrock and alpine glaciers. All life there is microscopic.

The team argues that the cooling trend could adversely affect the unique ecosystems in the region, which live in a niche where a delicate balance between freezing and warmer temperatures allows them to survive and where liquid water is only available during the very brief summer. They argue that a net cooling of the continent could drastically upset that balance.

"We present data from the Dry Valleys representing the first evidence of rapid terrestrial ecosystem response to climate cooling in Antarctica, including decreased lake primary productivity and declining soil invertebrates," they write.

Their data, they argue, are "the first to highlight the cascade of ecological consequences that result from the recent summer cooling."

-NSF-

Editors: For available photography and b-roll, call Dena Headlee, (703) 292-8070/dheadlee@nsf.gov

For more information about the Dry Valleys LTER, see: http://huey.colorado.edu/LTER/

For more information about NSF's network of LTER sites, see: http://lternet.edu/

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Buried Soil Cement Evaluation after 2004/05 Winter Storm, PACE

May 8, 2007

PACIFIC ADVANCED CIVIL ENGINEERING, INC.

17520 Newhope Street, Suite 200 ▪ Fountain Valley, California 92708 ▪ 714.481.7300 ▪ fax: 714.481.7299

MEMORANDUM

DATE: May 8, 2007

TO: Glenn Adamick/Newhall Land

FROM: Mark Krebs, P.E.
David Jaffe, P.E.

RE: Buried Soil Cement Evaluation after 2004/05 Winter Storms

---

Bank protection on the Santa Clara River and main tributaries of the river constructed by Newhall Land since 1999 has primarily utilized a buried soil cement technique. Soil cement bank protection uses 89 to 94% native soil material excavated within the project area and introduces 6 to 11% cement. With a small amount of moisture, mixing and compaction of the processed soil material, a non-erodible bank protection in produced. In most cases the soil cement is placed on a 1 to 1 or 1.5 to 1 slope face. This slope face is then “buried” or backfilled with native soils at a slope between 3 to 1 to 5 to 1. This soil backfill is then planted with native plant species. The native plantings and gradual slope of the soil in these areas will encourage river bank stabilization and resist most frequent river flow events.

The majority of the river bank protection construction in this method includes a horizontal location of the bank protection that is located outside of or adjacent to the existing riparian edge. The placement of the bank protection outside of the existing river corridor substantially decreases the likelihood that the river scour will remove the buried soil & vegetation placed over the soil cement bank protection. As noted above, the majority of the bank protection is located outside of the existing riparian corridor where areas will typically experience velocities much less than the main channel creek velocities (typically velocities of 2-8 fps along the banks while velocities >15 fps in the main channel occur adjacent to these locations during the 100-year discharge). Lower, non-erosive, velocities in the areas along the buried bank stabilization indicate that it is unlikely that all or part of the buried bank stabilization will become exposed.

A real world example was provided in winter 2004/2005. The 2004/2005 winter rainy season proved to be one of the wettest years on record and produced an approximate 50 year flood in the Santa Clara River at the LA/Ventura County line. River flows at this location have been estimated by LA County at 49,800 cfs, the second highest on record.

The 2004/2005 storm runoff and river/tributary flows provided a good test for the buried soil cement bank protection. Figures #1 and #2 show the Santa Clara River between Bouquet Canyon Creek and San Francisquito Creek along the Bridgeport project. The Bridgeport soil cement bank protection was constructed in 1999 and has substantial revegetation growth in the backfilled area. As shown in the photos the 2004/2005 storms cleared vegetation in the active channel (riverbed) but no damage occurred in the revegetated Bridgeport area.

Several buried soil cement bank protection projects were constructed along San Francisquito Creek in 2003. These projects include West Creek, Creekside and Hidden Creek which are located between Copper Hill Road and Newhall Ranch Road. Though not revegetated at the

time of the photo, Figures #3 and #4 of the San Francisquito Creek show the major flooding did not expose any of the buried soil cement.

Figure #5 shows the limit of the 2004/2005 flooding of the Santa Clara River in the proposed Newhall Ranch development. The proposed project bank protection is shown as overlay on the aerial photo and it indicates that if the bank protection had been in place during these heavy flow events very little, if any, would have become exposed.

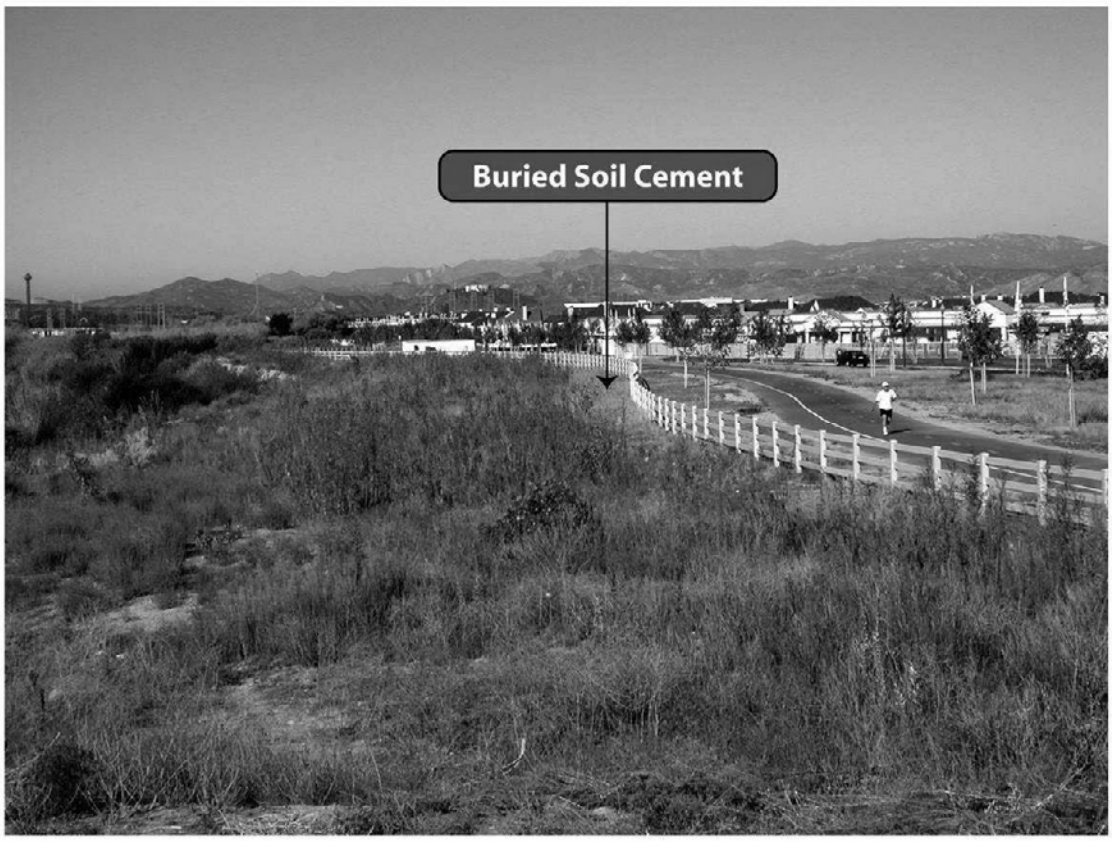

Figure 1: Existing buried and revegetated soil cement bank protection along Santa Clara River at Bridgeport.

Figure 2: Buried soil cement at Bridgeport after 2004/05 storms

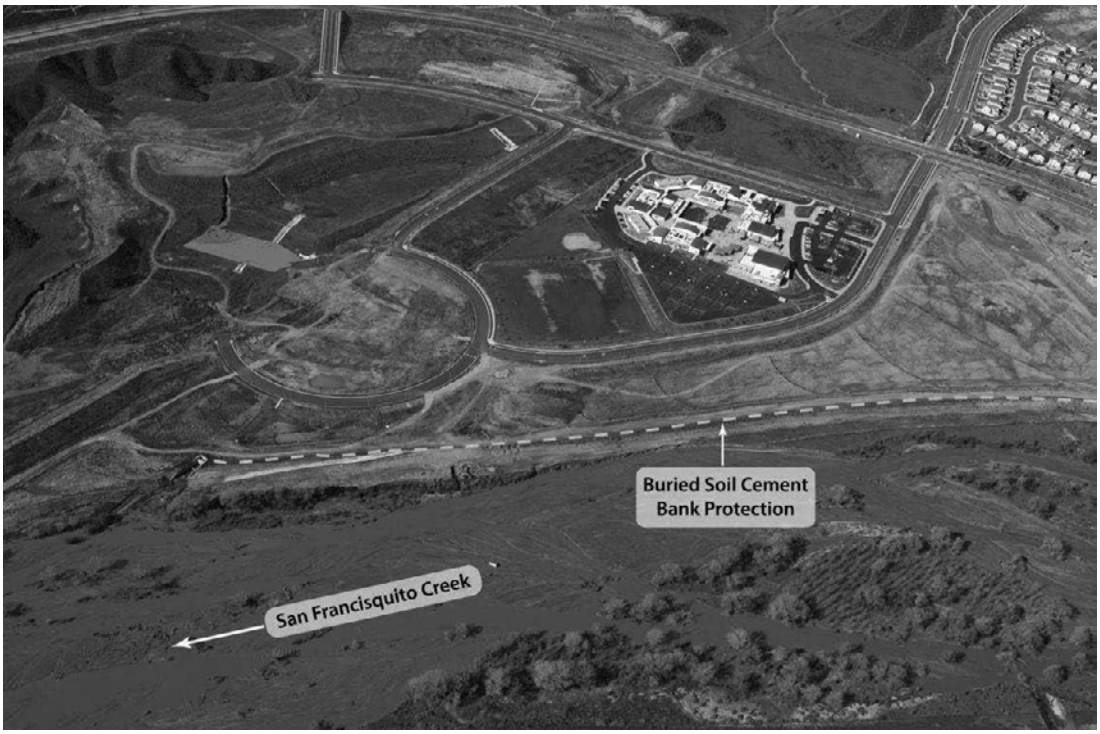

Figure 3: Aerial photograph of buried soil cement bank protection on San Francisquito Creek near Copper Hill Road following the 2004/2005 winter high flow events.

Figure 4: San Francisquito Creek after 2004/05 winter high flow event

July 2007

In Hot Water

Water Management Strategies to Weather the Effects of Global Warming

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NRDC
THE EARTH'S BEST DEFENSE

About NRDC

The Natural Resources Defense Council is an international nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in NewYork City, Washington, D.C., Los Angeles, San Francisco, the Midwest, and Beijing. Visit us at www.nrdc.org.

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Foreword

The effects of global warming on the health of the planet has been a topic of discussion for decades. However, only recently have the potential impacts of climate change on Western communities become a focus for water resource scientists, planners, and managers. In the American southwest, the severe drought on the Colorado River that began in 2000 served as a wakeup call to water utility managers regarding the possible implications of global warming. Those implications are sobering.

During the last century, long-range forecasts of population growth and water demands in the West have often been underestimated. Add to this fact the reality that stable and reliable water supplies in the West are, for the most part, already allocated. In this age of scarce water supplies, the prospect of climate change should serve as a catalyst for paradigm shifts in the way we manage water. Long-term climate change is adding even more uncertainty to the already difficult task of water resource planning and management.

To respond to the challenges posed by climate change, water managers will need to reevaluate their assumptions concerning storage and use of existing supplies, the amount of water expected to be available in the future, and how scarce or limited supplies should be shared among competing interests. Continued scientific study and dialogue will be of paramount importance to this effort, not only in terms of providing data to help individual utilities manage their respective situations, but also to facilitate the development of practical local, regional, and national policies.

With this in mind, the Natural Resources Defense Council, Desert Research Institute, and Southern Nevada Water Authority co-sponsored a 2005 conference entitled "Urban Water Supplies and Climate Change in the West." The objectives of the conference were threefold: to educate participants about the most recent studies of climate change and potential water supply impacts; to increase understanding and facilitate dialogue between water scientists and water managers; and to discuss options for addressing the potential impacts of climate change on water supplies. The presentations and discussion at that conference led to this report.

It is clear that global warming is occurring, particularly in the West. In general, temperatures are increasing. Scientists predict that this will likely lead to more runoff from rain, less alpine snow pack, larger winter streamflows, and hotter, drier summers. Communities are likely

to face more flooding and more frequent drought. As the West experiences earlier snowmelts and warmer, rainier winters, rivers and streams will be altered. Natural recharge to groundwater basins could decrease.

To cope with these changes effectively, water utilities will need to act quickly to develop diverse and flexible water resource portfolios that will allow them to reduce demands and adapt their supplies to changing climatic and hydrological conditions. However, from a regional and national perspective, perhaps the most important goal for water utilities will be to pursue increased cooperation and collaboration. In the past, models of water resource planning have emphasized competition for water resources. However, as communities throughout the West become more dependent upon each other to manage available resources, and as these resources prove to be interconnected in a myriad of ways, this competitive model of resource allocation is no longer prudent. Without open, collaborative dialogue among utilities and other stakeholders, competition for scarce water resources will only result in conflict, stalemate, and shortages.

The accompanying report and recommendations, and the conference that led to them, represent a first step toward addressing some of these difficult long-term issues. This report summarizes the broad potential water management impacts of climate change, the many existing climate-related activities of water managers around the West, and a full range of recommendations for water managers and staff to consider as they incorporate global warming into the planning and management of their agencies.

As the drought on the Colorado River has shown us in the West, even seemingly "permanent" water resources are susceptible to climatic variability. The time to prepare is now.

Patricia Mulroy
General Manager
Southern Nevada Water Authority

Executive Summary

The world's climate is warming—by an average of 1.3 degrees Fahrenheit in the past century. Unless current trends are reversed, global warming pollution is projected to keep increasing rapidly, raising temperatures by as much as 11.5 degrees Fahrenheit by the end of this century and compromising our water supply, flood management systems, and aquatic ecosystems. Experts predict that rising temperatures will lead to less alpine snowpack, earlier and larger peak streamflows, potential reductions in total streamflows, greater evaporative losses, declining ecosystem health, sea level rise, more extreme weather events—including both floods and droughts—and hotter, drier summers. We're already seeing evidence of these trends around the West.

Water managers—including water districts and local, state, and federal agencies with water-related resource management responsibilities—play a key role in Western communities by identifying potential water-related problems and pointing the way to solutions. As stewards of one of the West's most valuable —and scarce—resources, water managers can lead the response to ongoing climate changes and help stave off further damage.

WATER MANAGEMENT IN A CHANGING CLIMATE

Global warming presents challenges regarding water supply, water quality, ecosystem protection, and flood management—issues that water managers face every day. NRDC has created a blueprint for action, including a set of specific strategies water managers and other decision makers can use as they incorporate climate change issues into management decisions.

Action 1: Evaluate the Vulnerability of Water Systems to Global Warming Impacts

• ***Conduct agency assessments of climate change impacts on water supply.*** Assessments should analyze water supply and other impacts from projected climate change effects, including reductions of snow pack and earlier

peak streamflows, as well as from projected increases in temperature, which may result in greater environmental protection requirements and higher urban and agricultural water demand.

• ***Work with other water managers to evaluate regional vulnerability.*** Regional analyses can help water managers understand the common challenges they face and lay the groundwork for cooperative responses. They are especially important for water agencies in large watersheds and regions facing similar climate change–related challenges.

Action 2: Develop Response Strategies to Reduce Future Impacts of Global Warming

■ ***Consider the impact of climate change on future water management tools.*** Water management tools will be affected significantly—but not equally—by climate change. In general, climate change will make increases in efficiency more effective and reduce the yields from traditional surface storage and diversion projects. The table on the next page shows which water management tools will be most helpful in a climate-altered world.

■ ***Put conservation first.*** Increased investments in water efficiency represent a sound and basic "no regrets" water management approach to future climate change impacts. Cost-effective water conservation investments can generate significant benefits for water supplies and aquatic ecosystems, as well as reduced energy consumption and greenhouse gas emissions.

■ ***Incorporate climate and energy issues into statewide water planning.*** State-level planning efforts should incorporate climate change vulnerability analyses, global warming impacts on management tools, and the energy implications of water management decisions.

■ ***Consider integrated regional water management strategies.*** Water managers should carefully consider an integrated regional water management approach to climate change response. A robust climate change response strategy should include:

• Analysis of potential climate impacts on existing systems, as well as future water supply strategies

• Multiple benefits (e.g., supply, water quality, energy, flood management, and ecosystem benefits)

• An examination of unique regional conditions

• Potential partners to assist in financing and implementation (e.g., energy, stormwater, wastewater, and land use agencies)

• Institutional strengths and responsibilities

The Impacts of Climate Change on Water Management

Global warming is not an issue that we can afford to address with a "wait and see" approach. We must take action immediately or we are at risk of irreversibly damaging some of the West's precious water resources:

• For every rise of one degree Celsius (1.8 degrees Fahrenheit) in the West, researchers predict that snow levels will retreat upward by 500 feet in elevation.

• Extreme weather events such as floods and large storms could increase in size and frequency, straining the limits of flood control systems and exposing some floodplains and low-lying coastal regions to damage reminiscent of Hurricane Katrina.

• The IPCC projects that sea level will rise by 7 to 23 inches by 2100, affecting water supplies, eroding wetlands, diminishing coastal protection from storms, and exposing residents to severe flood damage. This projection assumes no acceleration of ice melt in Greenland or Antarctica. A new study, published after the deadline for consideration by the IPCC, projects that sea levels will rise by 20 to 55 inches this century based on recent observations.

• The stability of levees in the San Francisco Bay-Delta, which provides a portion of the water supply for more than 20 million Californians, will be threatened by rising sea levels.

• Higher temperatures will decrease salmon, trout, and other fish habitat, thereby increasing conflicts over water resources. Scientists estimate that up to 38 percent of locations currently suitable for coldwater fish could become too warm to provide habitat by 2090.

• A full range of potential water supply and demand strategies

• A full range of flood management options

• "Efficiency first" investments

• A clear "with and without" project analysis for major infrastructure investments

• Stronger, enforceable environmental protections, such as flow and temperature requirements for protected species

• Economic analysis and "beneficiary pays" financing

• Clear objectives and performance standards

• Educating the public and decision makers about climate change

■ ***Collaborate with energy utilities.*** Water conservation generates substantial water and energy savings, and thus reductions in greenhouse gas emissions. Water agencies should work with local energy utilities to develop joint programs, such as rebate offers, to encourage customers to conserve water and energy.

■ ***Consider climate change when making commitments about future water deliveries.*** In particular, agencies should avoid promising increased water deliveries based solely on current hydrology, without consideration of future climatic conditions.

■ ***Factor in flood management.*** For agencies with flood management responsibilities, an awareness of climate change should be integrated into future management decisions. Managers should investigate opportunities such as the reoperation of existing facilities, floodplain restoration, groundwater recharge, and flood-compatible agriculture. To reduce future damage, floodplains should be managed with an awareness that they will be inundated more frequently. This suggests placing an increased emphasis on land use issues.

■ ***Protect and restore aquatic ecosystems.*** Degraded aquatic ecosystems result in the loss of species and create endangered species conflicts. Healthy aquatic ecosystems will be more resistant to climate impacts, help reduce conflicts, and provide other benefits to water quality, recreation, and flood protection.

Action 3: Prevent Future Impacts by Reducing Greenhouse Gas Emissions

■ ***Support policies including mandatory caps on emissions.*** The IPCC found with at least 90 percent certainty that the current global warming trend is caused primarily by greenhouse gas emissions—particularly carbon dioxide—released through the burning of fossil fuels. Enforcing a mandatory national cap on the pollution that causes global warming is the single most important step in controlling and reducing the future impacts of global warming. While caps would be most effective at the federal level, local, state, and regional initiatives are also important tools in the face of federal inaction.

Table ES-1: Performance of Water Management Strategies After Considering Global Warming Effects

More effective	Not affected	Less effective
• Landscape conservation • Conservation rate structures • Agricultural water conservation • Water marketing • Urban stormwater management • Saltwater groundwater intrusion barriers to protect coastal aquifers • Water system reoperation • Interagency collaboration and integrated water management strategies • Floodplain management • Watershed restoration	• Wastewater recycling • Interior water conservation • Groundwater cleanup	• Traditional river diversions • Traditional groundwater pumping • Traditional surface storage facilities • Ocean water desalination*

*Given existing energy requirements.

■ ***Take action at the district level.*** Water agencies should develop programs to reduce their energy consumption and greenhouse gas emissions. A thorough understanding of the energy implications of water management decisions can lead to a range of options for achieving this goal. (NRDC's 2004 report *Energy Down the Drain* explores this relationship in detail.)

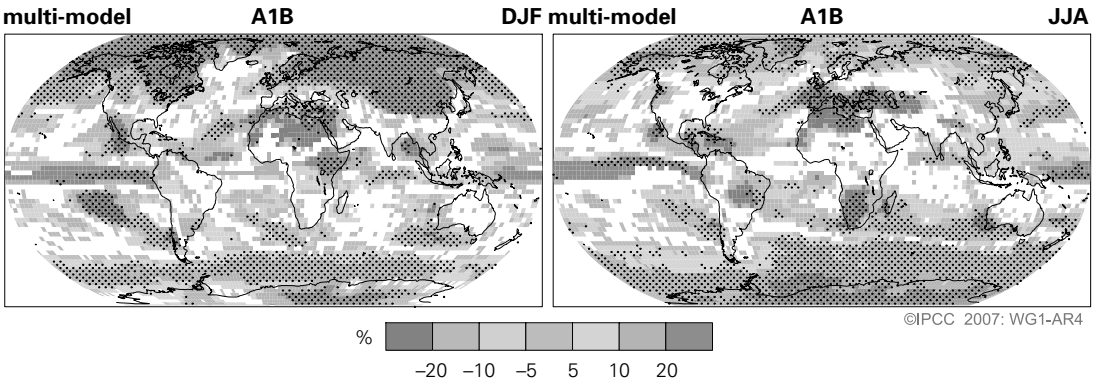
Action 4: Increase Awareness of Global Warming and Water Impacts

■ ***Educate customers and decision makers.*** Global warming is not just an environmental concern—it affects the future of all Western communities, particularly through water-related issues. Addressing the impacts of climate change on water management will require increased awareness and involvement by water district customers and decision makers, including elected officials.

■ ***Raise public awareness.*** Given the global nature of climate change and the need for far-reaching actions to address its causes, raising public awareness is essential to encouraging effective action. Water managers can play an important role in increasing awareness of global warming and the need to take action. Outreach can take the form of advertisements, media outreach, discussions with business groups, conferences, community forums, and more.

Western communities look to water managers for leadership on water issues. With global warming changing

Figure ES-1: Projected Patterns of Precipitation Changes for Period 2090-2099, relative to 1980-1999



Source: IPCC 2007:: WG1-AR4

the way we think about water in the American West and around the globe, water managers and other decision makers must lead the way in ensuring that our drinking water supply is safe, that our communities are protected from floods, and that our aquatic ecosystems support healthy fish and wildlife populations. The time to prepare is now.

HIGHLIGHTS OF EFFORTS TO INCORPORATE CLIMATE CHANGE INTO WATER MANAGEMENT

Across the West, water agencies and other water managers have begun taking action to address the challenges presented by climate change. Here are a few highlights of those efforts.

Evaluating the Vulnerability of Water Systems to Global Warming Impacts

• Many Western communities, including Seattle, Portland, Denver, the San Francisco Bay Area, and water districts in the Sierra Nevada foothills have undertaken analyses of potential impacts to their existing water systems.

• New Mexico and California have released statewide vulnerability analyses.

• In 2005, the American Water Works Association Research Foundation released *Climate Change and Water Resources: A Primer for Municipal Water Providers*.

Implementing Response Strategies to Reduce Future Impacts

• Denver Water has decided to dramatically accelerate its long-range water conservation program, partially in response to potential impacts from global warming.

• California's Department of Water Resources has issued multiple reports regarding climate impacts, including *Progress on Incorporating Climate Change into Management of California's Water Resources*.

• Southern California's Santa Ana Watershed Project Authority has created a national model for integrated regional water management, producing far-reaching water supply, water quality, energy, and climate benefits.

Preventing Future Impacts by Reducing Greenhouse Gas Emissions

• In California, three water agencies—the Santa Clara Valley Water District, the East Bay Municipal Utility District, and the Marin Municipal Water District—supported AB 32, which Governor Schwarzenegger signed into law in September 2006, creating the nation's first state-level mandatory cap on greenhouse gas emissions.

• The Santa Clara County Water District has helped to create a public/private partnership called Sustainable Silicon Valley, which is working to reduce the emission of global warming gases and other pollutants.

• The Bay Area's East Bay Municipal Utility District (EBMUD) has joined the California Climate Action Registry to report its greenhouse gas emissions, earning the district a "Green Power Leadership" award from the Environmental Protection Agency. Since EBMUD joined the registry, more than a dozen California water agencies have joined as well as Seattle Public Utilities and the Salt River Project.

• The Marin Municipal Water District has joined the Cities for Climate Protection campaign, uniting with dozens of other Western cities that run municipal water utilities to create a strategic agenda to reduce global warming.

Increasing Public and Decision Maker Awareness

• The Santa Clara Valley Water District has added a discussion of global warming to its website, stating that "The reality of global warming and climate change is the most significant long-term threat to water resources management in Silicon Valley."

• In January 2007, the San Francisco Public Utilities Commission convened a Water Utility Climate Change Summit attended by more than 150 water managers and other stakeholders. The conference received significant media coverage.

Chapter 1

An Overview of Major Scientific Findings on Climate Change

All elements of water systems, from watershed catchment areas to reservoirs and conveyance systems to wastewater treatment, will likely be affected by climate change and variability.[1] Rising temperatures, a greater proportion of annual precipitation falling in the form of rain instead of snow, altered streamflow timing, reduced snowpack, increased evaporation and transpiration, greater risk of fires, and a sea level rise—all effects of climate change—will require changes in how our current water systems are managed. And with virtually every major water supply source in the West already overallocated beyond its physical and/or legal capacity to be sustained, the consequences could be significant for Western water supply, water quality, and aquatic ecosystems.

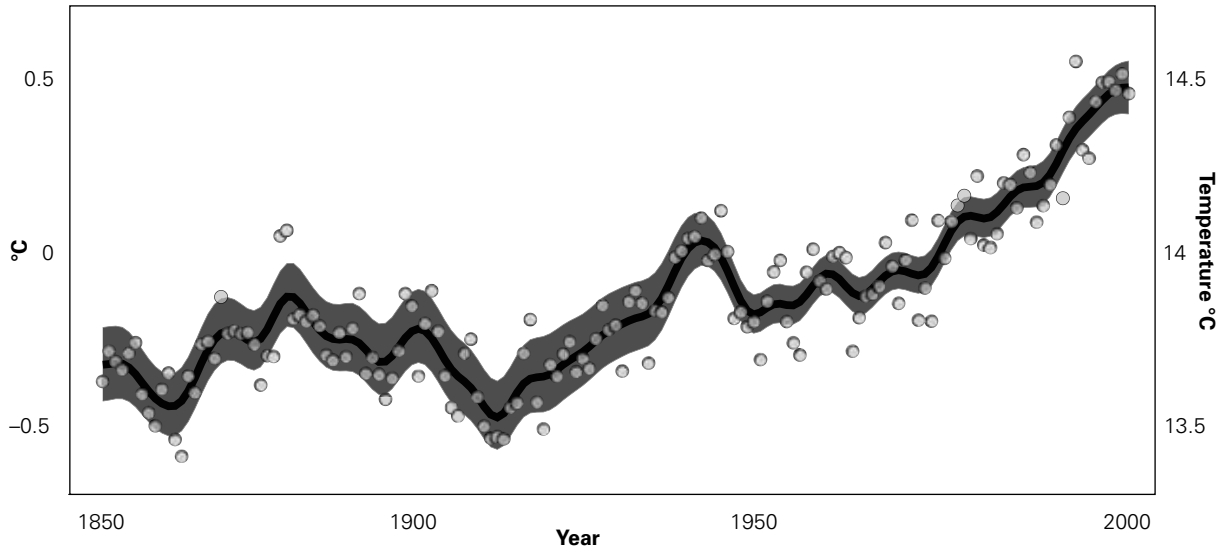
There is broad scientific agreement that climate change is occurring, that emissions of heat-trapping pollution are the primary cause, and that the resulting climate change and variability pose significant dangers to our environment, our health, and our economy.

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report released in 2007 found, with at least 90 percent certainty, that human activities are causing global warming.[2] This comprehensive review confirms and lends even greater confidence to the conclusions of the U.S. National Research Council's (NRC) Committee on the Science of Climate Change 2001 report, *Climate Change Science: An Analysis of Some Key Questions,* which found that greenhouse gases are accumulating in the earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising.[3] It also found that the combustion of fossil fuels (coal, oil, and natural gas) is the major source of greenhouse gas emissions (see Figures 1-1 and 1-2).

The IPCC in 2007 projected that the rate of warming over the 21st century—up to 11.5 degrees Fahrenheit—would be much greater than the changes observed during the 20th century. The IPCC projects the following changes as a result of increased temperatures:

- more frequent hot extremes, heat waves, and heavy precipitation events
- more intense hurricanes and typhoons
- decreases in snow cover, glaciers, ice caps, and sea ice

Figure 1-1: Changes in Global Average Temperatures, 1850-2000



Source: IPCC 2007: WG1-AR4

Global Warming Basics

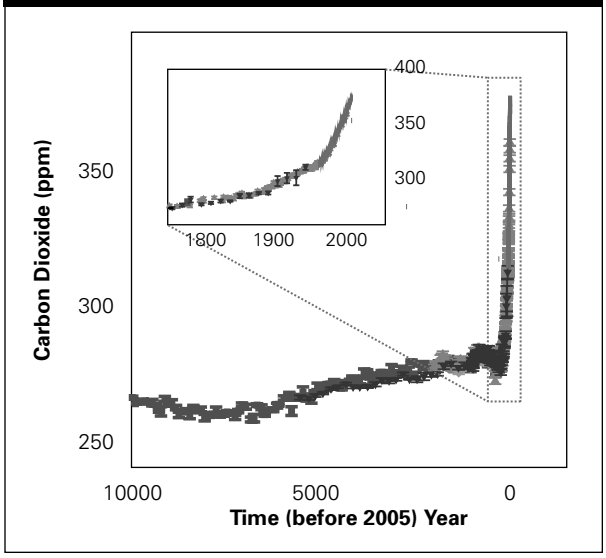
The basic dynamic of global warming is that the earth's temperature is largely regulated by gases that trap heat in the earth's atmosphere. This so-called greenhouse effect allows the earth's temperature to be in the range at which all life on earth has evolved. Increased concentrations of specific gases increase the heat-trapping ability of the atmosphere and are responsible for increasing temperatures. The composition of the earth's atmosphere is particularly important, because certain gases (including water vapor, carbon dioxide, methane, halocarbons, ozone, and nitrous oxide) absorb heat radiated from the earth's surface. Changes in the composition of the atmosphere alter the intensity of the greenhouse effect.

Although natural variability in climate occurs, it is now clear that human activities have been causing most of the global warming since the mid-20th century. We are exerting a major and growing influence on some of the key factors that govern climate by changing the composition of the atmosphere and by modifying the land surface. The concentration of carbon dioxide (CO_2) has risen about 30 percent since the late 1800s. The concentration of CO_2 is now higher than it has been in for at least the last 650,000 years. This increase is the result of the burning of coal, oil, and natural gas and the destruction of forests around the world to provide space for agriculture and other human activities. Rising concentrations of CO_2 and other greenhouse gases are intensifying earth's natural greenhouse effect. Projections of population growth and energy use indicate that, on our current course, the CO_2 concentration will continue to rise, likely reaching between two and three times late-19th-century levels by 2100. This dramatic doubling or tripling will have occured in the space of about 200 years.

Sources: National Assessment Synthesis Team, 2001. *Climate Change Impacts on the United States, report for the United States* Global Change Research Program. Cambridge University Press, p.12. http://prod.gcrio.org/nationalassessment/.

Climate Change 2007: The Physical Science Basis: Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p.4.

Figure 1-2: Changes in Atmospheric Concentrations of Carbon Dioxide from Ice Core and Modern Data



Source: IPCC 4 Summary for Policy Makers, p. 3

• a rise in global mean sea level of 7 to 23 inches (this projection does not include accelerated ice-sheet melting and other factors)[4]

Recent studies indicate that the range of possible sea level rise may be even greater. A report in *Science* magazine projects a 20- to 55-inch rise in sea levels over the 21st century, based upon recent observations.[5] This study was published after the deadline for consideration for the IPCC's Fourth Assessment Report.

Changes caused by a warming climate will not necessarily occur in a steady and predictable fashion. A recent report from the NRC, *Abrupt Climate Change: Inevitable Surprises*, shows that some major and widespread climatic changes have occurred with startling speed. The study notes that abrupt changes were most common when the earth's climate was being heated most rapidly, concluding that "greenhouse warming and other human alterations of the earth system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events."[6]

Although difficult to predict or plan for, climatic shifts—gradual or dramatic—are among the scenarios that water managers must consider in future modeling and planning. Fortunately, some in the water management community are actively engaged in the analysis of climate change impacts and are undertaking analyses of water system vulnerabilities to future climate change effects. For example, in 2005, the American Water Works Association Research Foundation (AWWARF) and the National Center for Atmospheric Research (NCAR) released a report entitled *Climate Change and Water Resources: A Primer for Municipal Water Providers,* and in July 2006 the California Department of Water Resources released *Progress on Incorporating Climate Change into Management of California's Water Resources.*[7,8] It is clear that water managers will have to adapt to changing climate conditions.

> **"The water supply for any utility will depend on the quantity and timing of local and regional precipitation, both of which may change with global climate change… Climate change is an additional source of uncertainty that will become increasingly relevant to water resource managers in the 21st century. Just as with any other source of uncertainty, best practice requires understanding as much as possible about the changes that can occur and their implications for operation and management of the utility."**
>
> Source: Kathleen Miller and David Yates, Climate Change and Water Resources: A Primer for Municipal Water Providers (AWWARF 2006).

Chapter 2

How Climate Change Will Affect Western Water Supply and Management

The snow and ice of western mountain ranges are the lifeblood of water supply and storage in the western United States; their melting snowpack feeds rivers that provide that area of the country with as much as 75 percent of its water supply.[1] An elaborate system of reservoirs, aqueducts, pumping plants, treatment facilities, and other engineered facilities moves the West's water supply from two principal sources: (1) surface water, which is often stored in reservoirs and (2) groundwater.

This water supply infrastructure, matched by an even more elaborate set of laws and policies that govern water use and rights, was designed and engineered for timing and magnitudes of runoff based on our understanding of past hydrological conditions, including temperature, precipitation, and snowmelt patterns.

Climate change and variability will affect the timing, amounts, and form of precipitation, in turn, affecting all elements of water systems from watershed catchment areas to reservoirs, conveyance systems, and wastewater treatment plants.[2] These systems are already stressed today. Overdraft and contamination of groundwater sources have reduced the availability of groundwater supplies in many areas. Saltwater intrusion in coastal aquifers is a problem in many areas. Climate change has the potential to exacerbate these situations, requiring increased attention from water managers. Extreme events such as droughts and major flood events are particularly challenging for water managers. Climate modeling indicates that these kinds of extreme events are likely to become more frequent and intense in the future. In fact, there is strong evidence that wildfires, precipitation patterns, and

Figure 2-1: Total Surface and Groundwater Withdrawals by U.S. County

The Western United States withdraws more water than any other region in the nation. The changes to hydrology and water supply that are likely to be caused by global warming threaten to have serious implications for western water management. Source: USGS 2004

> **"Climate change has the potential of affecting a wide variety of water resource elements. These range from water supply, hydroelectric power, sea level rise, more intense precipitation events, water use, and a number of miscellaneous items which include water temperature changes."**
>
> Source: Maurice Roos, California's state hydrologist in draft materials prepared for the California Energy Commission for the Public Interest Research Program (PIER) on Climate Change.

snowmelt are already being influenced by anthropogenic climate change.[3]

CLIMATE CHANGE EFFECTS WILL RESHAPE WATER SUPPLY IN THE WEST

As the U.S. National Assessment water sector report summarizes, "More than 20 years of research and more than 1,000 peer-reviewed scientific papers have firmly established that a greenhouse warming will alter the supply and demand for water, the quality of water, and the health and functioning of aquatic ecosystems."[4] The most significant impacts of global warming on water management—rising temperatures, increasing proportions of annual precipitation in the form of rainfall, disrupted streamflow timing, altered snowpack conditions, increased evaporation and transpiration, greater risk of fires, and sea level rise—are discussed in more detail in the following sections.

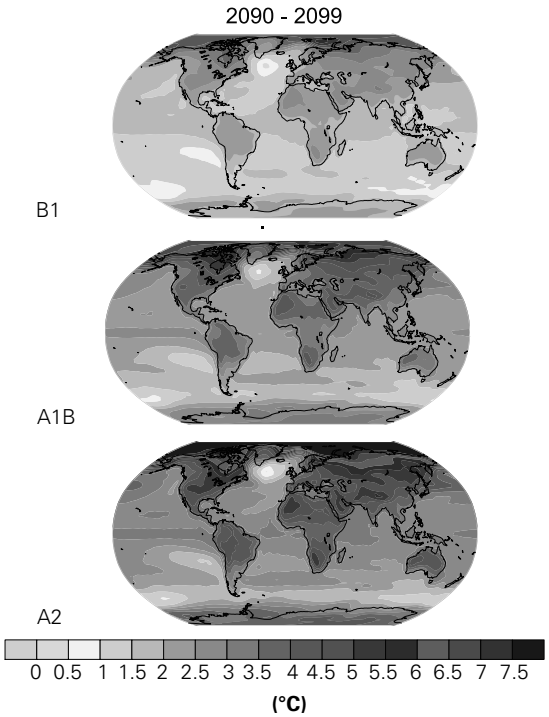
Rising Temperatures Could Mean Earlier Snowmelts and Outflows

The IPCC 2007 report found that "11 of the last 12 years (1995 to 2006) rank among the 12 warmest years... since 1850".[5] Climate models also consistently indicate a warmer future for the U.S. West (see Figure 2-2). Evidence of warming trends is already being seen in winter temperatures in the Sierra Nevada, which rose by almost 2 degrees Celsius (4 degrees Fahrenheit) during the second half of the 20th century. Trends toward earlier snowmelt and runoff to the San Francisco Bay-Delta over the same period have also been detected.[6] Water managers are particularly concerned with the mid-range elevation levels where snow shifts to rain under warmer conditions, thereby changing the snow storage. Research is also indicating earlier melting and spring flows, as described in more detail in a later section.

Greater Extremes in Precipitation Will Challenge Flood Control and Water Storage

Climatologists expect that global average precipitation will increase, however, some areas will become wetter while others will become drier. In addition, the timing, location, and form (rain versus snow) will likely differ from historical norms. Studies have found an average increase in precipitation in the continental United States of about 10 percent over the last century. The intensity of precipitation has increased for very heavy and extreme precipitation days, with most of the increase in the highest annual one-day precipitation events. Plots of global and U.S. precipitation changes over roughly the past century reveal considerable variation by region. Such findings have serious implications for flood control as well as water supply storage.[7]

Figure 2-2: Projections of Surface Temperature Changes for Late 21st Century



Source: *Climate Change 2007: The Physical Scientific Basis: Summary for Policymakers*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

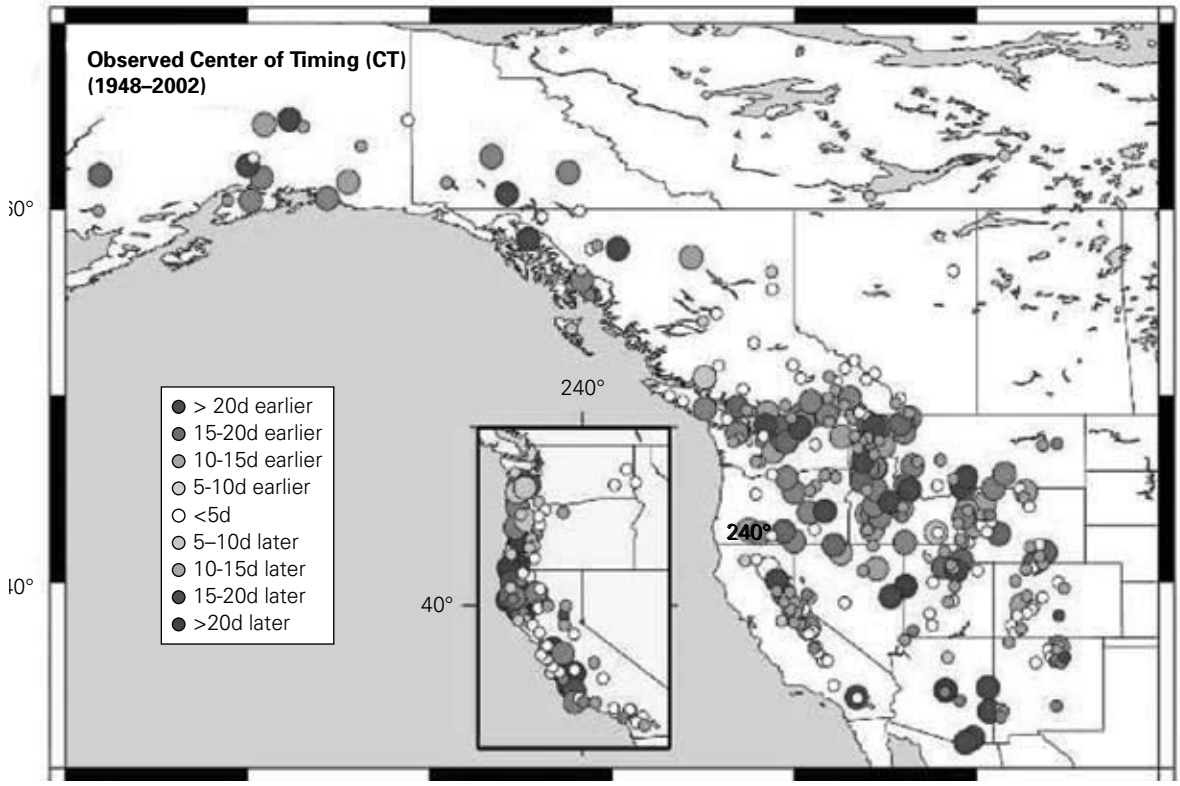
Although there is uncertainty regarding how climate change will affect regional precipitation patterns throughout the American West, several analyses indicate that the Southwest may be drier and that high latitudes may be wetter in the future. For example, a 2007 National Research Council report on Colorado River basin hydrology concluded, "Over the next 10–40 years, there is a tendency in the results of climate model super-ensembles to forecast slightly increased annual precipitation in the Northwestern United States by about ten percent above current values and to forecast slightly decreased annual precipitation in the Southwestern United States by less than ten percent below current values, with relatively little change in annual precipitation amounts forecast for the headwaters regions of the Colorado River."[8] Potential changes in precipitation patterns will have far reaching implications for water managers, particularly in oversubscribed river basins—which includes most rivers in the West.

Reduced Snowpack and Earlier Snowmelt Disrupt Streamflows

In the West, streamflow is often strongly influenced by runoff from melting winter snowpacks. Streamflow is characterized by timing, magnitude, frequency, and duration of water flows, all of which are affected by climate change. Water management strategies for supply and flood control are therefore highly attuned to streamflow timing, making any changes in streamflow timing a critical management issue.

Recent studies indicate that changes have already occurred in snowmelt and spring runoff throughout the western region of North America. The United States Geological Survey (USGS), which has been measuring

Figure 2-3: Accelerated Runoff in the West, 1948-2002



Spring runoff in the West, measured in terms of center of timing—the date at which 50% of annual runoff is reached—now occurs 1–4 weeks earlier than 50 years ago.

Source: Steward, Iris T., Daniel R. Cayan, Michael D. Dettinger, April 2005. "Changes toward Earlier Streamflow Timing across Western North America". Journal of Climate. http://meteora.ucsd.edu/cap/pdffiles/stewart_timing.pdf

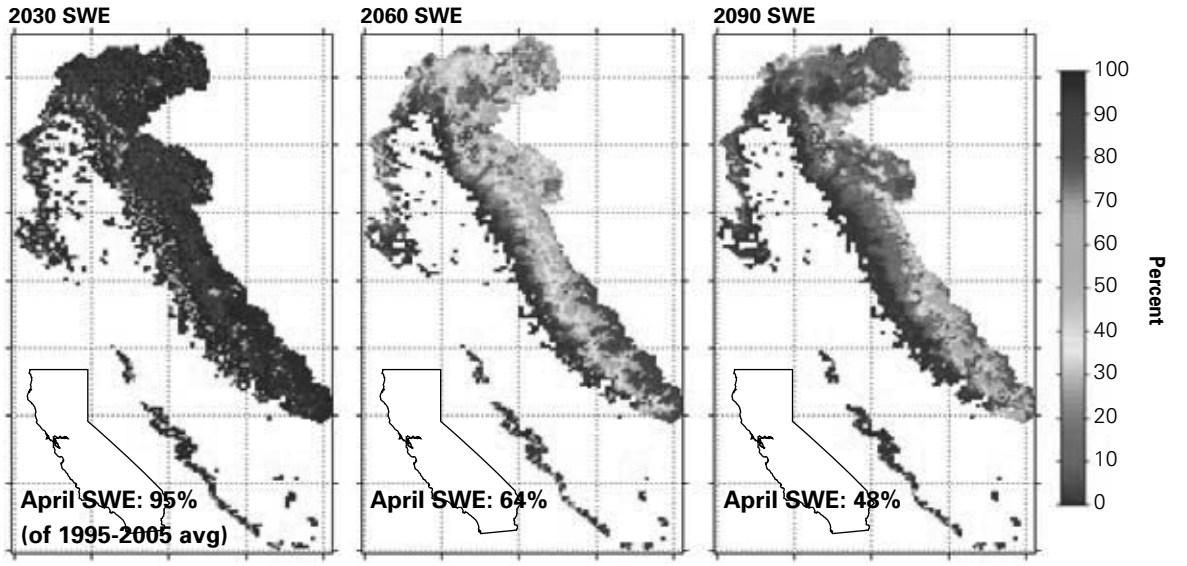
streamflows and spring runoff since the late 19th century, observes that "both measures indicate that flows in many western streams arrive a week to almost 3 weeks earlier now than they did in the middle of the 20th century. The largest changes have been identified in the Pacific Northwest, but the trends also are present in the Sierra Nevada of California, in the Rocky Mountains, and in parts of British Columbia and southern Alaska."[9] Figure 2-3 shows accelerated spring runoff across the West for the latter half of the 20th century.

Water agencies have found the same changes in streamflow when analyzing climate changes impacts upon their water systems. For example, Seattle Public Utilities sponsored a study by University of Washington's Climate Impact Group (CIG) to examine global warming's potential effects on Seattle's water system. Their modeling indicates an average decrease in combined inflow volumes to its two primary water sources, the Cedar and Tolt Reservoirs, of approximately 6 percent per decade through 2040—totaling about 5,000 acre-feet by 2040 when compared to historical record.[10]

Other recent studies indicate that both early snowmelt and diminished snowpack in the West may be related to increased temperatures due to global warming.[11] Runoff indexes for both the Sacramento and San Joaquin rivers in California, for example, show a marked decline in flows during the critical April to July period over the past century. And researchers have shown that for most of the second half of the 1900s, snowmelt-generated runoff came increasingly early in the water year in many basins in California.[12] A declining fraction of the annual runoff was occurring during the months of April to June in middle-elevation basins, while an increasing fraction was occurring earlier in the water year, particularly in March.[13] Other studies have reached similar findings of increasing winter and spring floods under conditions in which rain falls on snow.[14]

Future changes in snowpack are a cause for concern. One study projected that snow levels will retreat 500 feet in elevation in California for every rise of one degree Celsius.[15] Figure 2-4 shows projections for snowpack impacts in California through the 21st century. An analysis by Peter Gleick published in the journal *Water Resources Research* examined the potential for shifts in runoff in California due to increased temperature.[16] For the study, Gleick used a water-balance model developed for the Sacramento Basin. He based his climate change scenarios on increases in average monthly temperature of 2 and 4 degrees Celsius (4 and 7 degrees Fahrenheit) and changes in precipitation of +/–10 and 20 percent. The study found that summer runoff decreased in all scenarios, whereas winter runoff rose in all those scenarios in which precipitation was kept constant or increased. With an increase in temperature of 4 degrees Celsius (7 degrees

Figure 2-4: Evolution of Average Annual Snow Water Equivalent as a Percentage of Average 1995-2005 Values



Source: Knowles, N. and Dan Cayan. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. September 28, 2002. Geophysical Research Letters. Vol. 29, No. 18.

Fahrenheit) and an increase in precipitation of 20 percent, the winter runoff rose by 75 percent and the summer runoff decreased by 49 percent.

Increased Evapotranspiration Reduces Total Streamflows

Although there is still significant uncertainty regarding how climate change will affect precipitation patterns in the West, a significant body of analysis suggests that total streamflows in the future will be reduced in comparison with historical levels. This change has powerful implications for water managers.

Increased temperatures are expected to lead to increased evaporation and transpiration, which will increase water loss from standing water and decrease soil moisture levels. A seminal study by Gleick and Nash of the Colorado River basin demonstrated the crucial role evapotranspiration plays in water availability. The authors found that with no change in precipitation, a 2 degree Celsius increase in temperature would reduce mean annual runoff by 4 to 12 percent and that the reduction in runoff for a 4 degree Celsius increase would be between 9 and 21 percent. The authors concluded that if temperature rose by 4 degree Celsius, precipitation would need to jump by nearly 20 percent to maintain historical runoff levels.[17]

In 2007, the National Research Council reached similar conclusions in a review of the science regarding hydrologic variability in the Colorado River basin. The investigation included analyses of historical hydrology and likely future variability, as a result of climate change. The report projects that future reductions in total Colorado River streamflow are likely:

"This body of research collectively points to a future in which warmer conditions across the Colorado River region are likely to contribute to reductions in snowpack, an earlier peak in spring snowmelt, higher rates of evapotranspiration, reduced late spring and summer flows and a reduction in annual runoff and streamflow."[18]

This projected reduction in total runoff is anticipated as a result of increased losses to evapotranspiration. Specifically, "(h)igher temperatures will cause higher evaporative losses from snowpack, surface reservoirs, irrigated land and land cover surfaces across the river basin."[19]

The report discusses the significance of this change from a policy perspective. "Any future decreases in Colorado River streamflow, driven primarily by increasing temperatures, would be especially troubling because the quantity of water allocations under the Law of the River already exceeds the amount of mean annual Colorado River flows."[20]

Other efforts have also projected potential decreases in total streamflows. For example, analysis by the California Climate Change Center in 2006 found that climate change could lead to significant reductions in total reservoir inflows and total Delta inflows. Approximately two-thirds of model runs revealed likely reductions in total inflows for major northern California reservoirs, with maximum projected reductions of approximately 12 percent.[21] It is important to note that this analysis does not clearly separate the factors anticipated to cause this reduction.

Potential reductions in total streamflows have far-reaching implications for water managers. This is particularly true because, in many cases, additional water

Table 2-1: Predicted Changes in California's Reservoir and Delta Inflows in 2050 with Climate Change

	Lake Shasta			Folsom Lake			Total Delta Inflows		
	Annual Avg. Inflow (TAF)	Change From Base (TAF)	Change From Base (%)	Annual Avg. Inflow (TAF)	Change From Base (TAF)	Change From Base (%)	Annual Avg. Inflow (TAF)	Change From Base (TAF)	Change From Base (%)
Base	5492			2670			20850		
GFDL A2	5442	–51	–1%	2355	–315	–11.80%	20258	–592	–3%
PCM A2	5177	–315	–5.70%	2410	–260	–9.70%	19939	–911	–4%
GFDL B1	5601	109	2.00%	2368	–302	–11.30%	20071	–778	–4%
PCM B1	5854	362	6.60%	2829	159	6.00%	21789	939	5%

Data derived from Chapter 4 of California Department of Water Resources, Progress on Incorporating Climate Change into Management of California's Water Resources. Technical Memorandum Report. July 2006.

development could be designed to capture flows that are not captured by the current infrastructure. If future average streamflows are lower, it suggests that this infrastructure could be wasted—designed to capture flows that may not be there in the future.

A Warmer Climate Increases the Risk of Fires

Fire is already a serious concern in the West. Where wildlands meet development, fire poses a particular danger to life and property. But fire also provides important benefits and is a necessary process in the West's ecosystems. Many plants actually depend on periodic fire cycles to maintain health and some plants require fire for seed germination. Whether a benefit to the ecosystem or a threat to property, fire can have serious water supply impacts in terms of reduced downstream water quality and loss of reservoir storage capacity due to sedimentation.[22]

Studies show that earlier loss of snowpack will lead to increased stress on vegetation, reduced summer soil moisture, and, therefore, increased threat of fire, particularly in the arid West. There is strong evidence from research at Scripps Institute that this is already occurring in the western United States.[23] Two primary ways for climate change and variability to increase the threat of fire are: an oscillation between periods of increased precipitation and periods of drought—as projected in some climate scenarios—could increase fuel loads and create extreme fire conditions, and; warmer temperatures and consequent low moisture content in soils and fuel could create increased fire risk. Heat waves and high winds would exacerbate these conditions. Frank Davis at University of California Santa Barbara notes that "fire behavior models predict a sharp increase in both ignition and fire spread under warmer temperatures combined with lower humidities and drier fuels."[24]

A particularly interesting finding from the Southwest Regional Assessment is the relationship of climate to fire cycles evident in the tree-ring record.[25] Reconstruction from tree-ring data of wildfire occurrence in the Southwest reveals simultaneous changes occurring after 1700 that reflect climate impacts to wildfire patterns over interannual to centennial time scales.[26] Research by Swetnam et al. highlights the importance of understanding how lag times between climatic events and vegetation response influence subsequent fire patterns.[27] These lag times have important implications for long-range fire hazard forecasting and ecosystem management. For example, based on a 300-year record of climate and fire derived from tree-ring analysis, a pattern of one or more wetter-than-normal El Niño winters in the Southwest, followed by a drier-than-normal La Niña winter, establishes preconditions for unusually large and intense wildfires.[28] Further, certain kinds of episodic ecological disturbances, such as insect outbreaks, may be traceable to patterns in climatic variability.[29]

Sea Level Rise Threatens Water Supply, Water Quality and Wetlands

Global warming drives two primary mechanisms of sea level rise: thermal expansion of seawater as the oceans warm, and; melting of mountain glaciers and massive bodies of polar ice—particularly the Antarctic and Greenland ice sheets.

The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report projects that sea levels will rise by 7 to 23 inches by the year 2100—a consequence that brings profound implications for water resources in the West.[30] This estimate does not account for the accelerated melting of the Antarctic and Greenland ice sheets.

The melting of ice sheets brings the largest potential rise in total sea levels, as their complete melting would result in a 70-meter increase in global sea levels.[31]

A great deal of uncertainty exists regarding ice sheet dynamics and the limitations of current modeling. For example, a NASA/University of Kansas study published in the March 24, 2006 issue of *Science* by Jonathan Overpeck and co-authors, estimated that the last time Arctic temperatures were as high as those projected for the 21st century (about 125,000 years ago), sea levels was 4 to 6 meters higher than it is today.[32] It is difficult to estimate how long it would take for sea level to rise this much, University of Texas researchers determined that the Greenland ice sheet is currently melting three times faster than during the previous five years, underscoring the already accelerating rates of ice sheet melting.[33] Although uncertainties exist in forecasting the rate of ice sheet melting, acceleration in sea level rise is real, bringing serious implications for coastal land and water supply.

On the West coast, sea level rise presents potentially severe impacts. For example, for the San Francisco Bay and the Sacramento-San Joaquin River Delta, global warming impacts will compromise ecosystem health, water supply, and water quality (see "The Rising Costs of Rising Sea Level"). Sea level rise could also affect water supply by causing wetland erosion and surface water and

The Rising Costs of Rising Sea Level

The predicted increase in physical damage to the coastal structures and coastal erosion associated with sea level rise inundation will have significant and far-reaching costs. The IPCC Third Assessment Report estimates that in the case of a 0.5-meter sea level rise, the financial costs of cumulative flooding impacts to U.S. coastal property would reach at least $20 billion to $150 billion. Storm surges and floods have the potential to breach levees, leading to massive economic and social costs—as seen in the aftermath of Hurricane Katrina in New Orleans. These costs must be considered when evaluating the reliability of future water supply projects, particularly those that include the building of storage facilities and physical ocean barriers, such as levees.

Source: Burkett, V., J.O. Codignotto, D.L Forbes, N. Mimura, R.J. Beamish, V. Ittekkot. "Coastal Zones and Marine Ecosystems" in *Climate Change 2001: Impacts, Adaption, and Vulnerability,* James J. McCarthy, Osvaldo F. Canziani, Neil A. Leary, David J. Dokken, Kasey S. White, eds. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. 881 p.

groundwater salination. The inundation of wetlands induced by climate change could weaken their critical role as a natural water filtration system.[34] In addition, inundation due to sea level rise will increase salinity intrusion into coastal aquifers.[35]

CLIMATE CHANGE WILL AFFECT FLOOD MANAGEMENT

Flood management has been the cause of growing concern—and cost—throughout the United States, particularly in the West as floodplains are urbanized. According to data from the National Weather Service, from 1955 to 2003 the average annual cost of flood damages combined for California, Washington, Oregon, Nevada, New Mexico, Utah, Colorado, Arizona, and Montana has been more than $332 million in today's dollars.[36] However, for the period between 1994 and 2003 the annual average was almost $930 million per year—an increase reflecting the growing severity of a situation that will only be made worse by the effects of climate change.

In the West, the majority of the annual precipitation occurs in the winter and early spring. That timing creates a tension between flood control and water supply. Most large reservoirs serve a dual purpose: providing flood protection during the wet months and water supply during the rest of the year. In order to provide flood protection, reservoirs must keep a percentage of their total storage capacity empty in the event that space is needed to capture high flows and prevent flooding downstream. But as the end of the wet season nears, water managers must balance the risk need to maintain sufficient storage space in their reservoirs for flood protection against the risk of leaving too much storage space and not filling reservoirs with water that will be needed during the dry season.

Scientists indicate that climate change will exacerbate the problem of flooding by increasing the frequency and magnitude of large storms, which in turn will cause an increase in the size and frequency of flood events. The increasing cost of flood damages and potential loss of life will put more pressure on water managers to provide greater flood protection. At the same time, changing climate conditions (decreased snowpack, earlier runoff, larger peak events, etc.) will make predicting and maximizing water supply more difficult. Water managers should be prepared to respond to these new challenges by improving floodplain management, and considering the reoperation of existing reservoirs and other water supply infrastructure.

Walking the Tightrope: Managing Dams for Water Supply and Flood Protection

Even under normal circumstances, maximizing water supplies is complicated by the inherent unpredictability of weather. To walk this tightrope, water managers work throughout the spring with snowpack data, and often aided

> **"Intensification of the hydrological cycle could make reservoir management more challenging, since there is often a tradeoff between storing water for dry-period use and evacuating reservoirs prior to the onset of the flood season to protect downstream communities. It may become more difficult to meet delivery requirements during prolonged periods between reservoir refilling without also increasing the risk of flooding."**
>
> Source: Climate Change and Water Resources, AWWARF

by computer models, to assess likely runoff into storage facilities. However this is an imprecise science at best because forecasting seasonal weather patterns for even a few weeks, let alone a month or two, is highly uncertain. The changes in snowpack and precipitation patterns related to global warming will make maximizing water supplies without increasing the risks of flooding even more challenging.

Despite some increases in winter precipitation, much of the mountainous West has experienced declines in spring snowpack over the past 50 years. According to two studies by climate scientists at the University of

The Other New Orleans: California's Delta and Sea Level Rise

Sea level rise has the potential to be among the most visible, harmful, and costly impacts of climate change. A rising sea level presents particular challenges for low-lying urban areas. California's San Francisco Bay-Delta provides an important example of the potential water supply impacts of climate-driven sea level rise.

The Delta represents the upper tidal reach of San Francisco Bay, the largest estuary on the western coast of the Americas. The Delta's watershed includes 40 percent of the state. The Delta is a significant surface water source and the state's largest riverine ecosystem—a resource of enormous environmental and economic value.

Farm flooding resulting from 2004 Jones Tract levee failure

More than 20 million people rely on it for a portion of their water supply; water for Central Valley farms, parts of the San Francisco Bay Area, and Southern California is diverted by massive water pumps in the Southern Delta. And although most of the 1,000-square-mile tule marsh that was once the Delta has been converted to farmland, the Delta still plays a critical role in supporting the biggest salmon run south of the Columbia River. Every winter its islands fill with swans, geese, and sandhill cranes. The hundreds of miles of channels that wind through dozens of leveed agricultural islands are a Mecca for boaters, windsurfers, and anglers. Four-hundred-thousand Californians live in Delta communities. The Delta is also crisscrossed by infrastructure, including power lines, and highways.

The Achilles heel of the San Francisco Bay-Delta may be the confluence of three factors: subsidence, sea level rise, and high levels of water diversions. When the Delta's light peat soils are farmed, they blow away, compact, and oxidize, causing the elevation of these farmlands to fall. Today, thousands of acres of Delta islands are 20 feet or more below sea level. It's not uncommon to stand on Delta farmland and look up at a boat 20 feet overhead as it sails by on the other side of a levee. In parts of the Delta, subsidence is continuing at 1 to 3 inches per year.

A recent study by Jeffrey Mount of the University of California at Davis and Bob Twiss of the University of California at Berkeley found that the Delta's future is threatened by several factors: ongoing subsidence, shaky century-old levees, floods, earthquakes, and sea level rise. Mount and Twiss estimated that the Delta has a 64 percent chance of a catastrophic failure of multiple Delta levees by 2050. Such a failure would threaten the Delta's residents, farms, and infrastructure.

If many islands were to flood simultaneously, particularly during the summer when less fresh water flows from the rivers that feed the Delta, it could draw salty San Francisco Bay water into the Delta, threatening important water supplies. The economic impacts of such a catastrophic failure could be widespread and long lasting. The failure of New Orleans' levees has awakened California water users and agencies to the long-term risks to stability of the Delta. Of all of the challenges facing the San Francisco Bay-Delta, sea level rise may be the most critical. There are more than 1,100 miles of Delta levees, many of which are in poor repair. Improving and raising all of these levees several feet may be financially infeasible.

Sources: U.S. Geological Survey, "Delta Subsidence in California," April 2000. http://science.calwater.ca.gov/pdf/fs00500.pdf.

Mount, Jeffrey, UC Davis, and Bob Twiss, UC Berkeley. "Subsidence, Sea Level Rise and Seismicity in the Sacramento-San Joaquin Delta." *San Francisco Estuary and Watershed Science,* Vol. 3, No. 1, March 2005.

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> **"Models project that increasing atmospheric concentrations of greenhouse gases result in changes in frequency, intensity and duration of extreme events, such as more hot days, heat waves, heavy precipitation events and fewer cold days. Many of these projected changes would lead to increased risks of floods and droughts in many regions..."**
>
> Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Synthesis Report, Summary for Policymakers*

Washington and the University of Colorado, snowpack has decreased by 15 to 75 percent in parts of Oregon, western Washington, northern California and the northern Rockies, mainly because of climate change.[37] Increased temperatures cause a greater percentage of wintertime precipitation to fall as rain instead of snow.[38] The resulting reduction in snowpack causes a drop in the total amount of spring snowmelt runoff. The snowpack that does form is melting earlier in the year, further exacerbating changes in stream hydrology.[39]

The magnitude and frequency of larger high flow events are predicted to increase under climate change for two primary reasons. The first is related to the decrease in snowpack. Several 2002 climate change studies found that in California, peak streamflow occurred up to two months earlier in the year due to a decrease in the number of freezing days in the season, a drop in snowpack, and an increase in early snow melt.[40] The studies also showed that such changes "suggest that 50 percent of the season runoff will have occurred early in the year for many snow melt driven watersheds in the West, and the resulting early snow melt implies higher streamflow increases and an increased likelihood of more flood events in future years."[41]

A second factor causing higher peak flows is the basic relationship among temperature, evaporation rates, and the amount of moisture in the atmosphere. Climate models show that the warming of the earth's surface increases evaporation and the amount of water vapor in the atmosphere. Increases in water vapor, a primary factor in providing moisture for rain, will mean heavier precipitation during storm events. The USGS modeled the effects of climate change on increased storm intensity and found that the risk of a 100-year flood event will grow larger in the 21st century. Instead of a 1 percent chance that in any year there will be a 100-year flood event, the likelihood in a single year could become as high as one in seventeen.[42]

CLIMATE CHANGE WILL AFFECT WATER QUALITY

Changes in precipitation, flow, and temperature associated with climate change will likely exacerbate water quality problems. Changes in precipitation affect water quantity, flow rates, and flow timing.[43] Decreased flows can exacerbate the effect of temperature increases, raise the concentration of pollutants, increase residence time of pollutants, and heighten salinity levels in arid regions.[44]

On the one hand, higher water flows can dilute point-source pollutants, drive up loadings from non-point source pollutants, and reduce the residence time for contaminants. Higher flows can also increase the export of pollutants to coastal wetlands and deltas.[45] In addition, higher flows can cause higher turbidity in lakes, which reduces the light penetration crucial to the health of aquatic life.[46] On the other hand, where surface flows decline, erosion rates and sediment transport may drop, and lake clarity may improve but this may increase the concentration of pollutants.

The effect of climate change on water quality will also be felt at our beaches, as the rate of beach closures will likely go up. In recent years, beaches have been closed repeatedly because of unhealthy levels of bacteria and other contaminants in the water.[47] The primary cause of these high bacterial levels is runoff from storms. Rain that is channeled into storm drains and backed up into sewage systems flushes bacteria, feces, pesticides and pollutants such as motor oil and trash into coastal waters. The increase in severe storm events predicted by global warming models is likely to mean more polluted runoff in a climate-altered future.

Finally, as discussed earlier, climate change is likely to increase fire risks in much of the West. This increase in burning in western watersheds has the potential to increase downstream fire-related sedimentation and other water quality problems. For example, heavy rainfall in Colorado in 1996, following the 12,000-acre Buffalo Creek fire, deposited 600,000 cubic yards of sediment into a Denver Water storage facility in the Upper South Platte River basin.[48] This amounted to more than 13 years of average siltation in just a few days. Such events may be larger and more frequent with climate change.

> **"Aquatic and wetland ecosystems are very vulnerable to climate change. The metabolic rates of organisms and the overall productivity of ecosystems are directly regulated by temperature. Projected increases in temperature are expected to disrupt present patterns of plant and animal distribution in aquatic ecosystems. Changes in precipitation and runoff modify the amount and quality of habitat for aquatic organisms, and thus, they indirectly influence ecosystem productivity and diversity."**
>
> Source: Pew Center on Global Climate Change, *Aquatic Ecosystems and Global Climate Change: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States,* 2002.

CLIMATE CHANGE WILL AFFECT AQUATIC ECOSYSTEMS

The United States is home to more than 800 fish species and thousands of aquatic invertebrates and insects found nowhere else.[49] The extinction rate for freshwater species in this country equals or exceeds that of other ecosystems.[50] The aquatic ecosystems found within our streams, lakes, and wetlands have been negatively affected for decades by changes in the environment such as dam construction and flow diversions, loss of habitat associated with development, decreased water quality, and now, climate change. Climate change will further exacerbate the current challenges faced by aquatic ecosystems. Understanding how climate change impacts aquatic ecosystems will allow water managers to implement appropriate strategies that support long-term aquatic ecosystem health, reduce endangered species related conflicts, and minimize impacts on water supplies. There are two major ways that climate change will impact ecosystems: increased temperatures and altered hydrology.

Increased Temperatures

Water temperature influences aquatic ecosystems primarily in terms of ecological and biological factors such as dissolved oxygen levels and the ability of a species to exist within the range of temperatures. Climate change will increase air temperatures, and hotter air will translate into warmer water temperatures in streams and rivers.[51,52] Warmer water will cause increased stress on aquatic species that may already be near their limit of temperature tolerance because they inhabit low-elevation areas or are near the southern edge of their distribution.

In response to climate change, many species will need to expand their range northward, or into cooler, higher elevations upstream, otherwise they will disappear from the watershed. Studies have found that a 4 degree Celsius increase would require some species to move approximately 420 miles northward to find temperature conditions similar to that of their original habitat.[53] The ability of species to adjust their range depends on its ability to move and find suitable habitat. Although avian species may be more mobile, resident fish and plants are less likely to be able to disperse to new locations, even over several generations. Migration barriers and the highly fragmented nature of most of our remaining riverine ecosystems pose many challenges to such geographic shifts.

Even if species can move within a watershed, new conditions at higher elevations may not be suitable for the displaced species. Fish that need deep pools or the lower flow velocities conditions typical of lower elevations within a watershed may be unable to find such conditions in the steeper reaches upstream. Dams and other infrastructure may also prevent access to portions of the river upstream. Overcoming these challenges is made all the more difficult by the fact that the current rapid rate of climate change will pressure species to adapt over decades, not the centuries normally needed to adapt to historic climate change.

Increased water temperatures and seasonally reduced streamflows will alter many ecosystem processes, with potential direct societal costs.[54] In addition to negatively impacting species, higher water temperatures will decrease water quality. As water temperatures rise, the amount of dissolved oxygen in water drops.

On the lower San Joaquin River in California, reduced dissolved oxygen levels have caused fish kills and created temporary seasonal barriers to the migration of salmon. Upstream dams and diversions have lowered streamflows. Lower flows have in turn led to increased water temperatures, concentrated nutrient loading from agriculture runoff and wastewater discharge.[55]

When higher water temperatures promote the growth of algae, this can further cut the amount of dissolved oxygen in the water, creating stressful or fatal conditions for fish. Higher water temperatures can also negatively impact ecosystem dynamics, including predator-prey relationships. On the Columbia River in Washington, for instance, warmer temperatures have created a thermal

Fish at Risk: Salmon in the Klamath River and Silvery Minnow in the Rio Grande

In recent years, the West has seen numerous water resource conflicts pitting protection of threatened and endangered species against the need for water supplies. The salmon kills on the Klamath River and the near extinction of the silvery minnow on the Rio Grande are the kinds of conflicts likely to become more common due to climate change impacts on already impaired aquatic water ecosystems.

A series of dams and diversions provide water for agriculture on the Klamath River in the northern California. At the same time, these dams and diversions significantly reduce in-streamflows. In 2002, low flows contributed to high water temperatures, which impeded migration and caused the death of more than 35,000 adult salmon. As a result of the adult fish kills in 2002 and the severely reduced population of juveniles the following year, salmon fisheries were heavily restricted in 2006 in California to protect the few returning Klamath adults, even though strong runs of salmon were returning on other rivers along the coast and in the Central Valley. The fishing restrictions hit the already struggling fishing industry hard.

Similarily, the Rio Grande silvery minnow was listed under the Endangered Species Act in 1994; it faced possible because of loss of habitat and the effects of dams and diversions constructed for municipal and agricultural use. Continued declines in the silvery minnow population lead to lawsuits against the Bureau of Reclamation and the Army Corps of Engineers. Today, this species is found in less than 5 percent of its historic range and is heavily managed to prevent its extinction.

Climate change will add new stresses to those associated with water supply diversions. As a result, aquatic ecosystems and sensitive species may be pushed to the point of collapse, thereby increasing the likelihood of even greater conflicts and the need to reduce water supply diversions to meet regulatory protections.

Source: Ikenson, B., 2002. "Rio Grand Silvery Minnow." *Endangered Species Bulletin,* March/June 2002, Vol. XXVII, No. 2.

barrier to migration for Coho salmon and have resulted in increased predation on juveniles by predator species.[56]

Not all impacts of warming will be harmful. For species that are limited in range due to cold temperatures, particularly in the northern latitudes, a warmer climate may have benefits. However, the benefits to relatively few species are vastly outweighed by the negative impacts that climate change will have on other species and ecosystems in the western states.

Altered Hydrology

The effects of climate change on seasonal variations in streamflows may have significant impacts on fish species, regardless of changes in water temperature. The hydrology of streams—including the timing, magnitude, frequency, and duration of flows—significantly influences the nature of stream ecosystems, particularly the physical characteristics such as the shape of the channel. Many species time their movements up or downstream or out to sea to take advantage of often temporary in-streamflow conditions. Regional shifts in climate that substantially and permanently alter the timing and magnitude of flows can further impact habitat suitability for many species.[57] As a result, alterations in timing and amount of rainfall can significantly impact their ability to reproduce and cause decreases in population numbers.

In the West, the typical snowmelt-driven stream hydrology entails high spring flows followed by lower summer, fall and winter base flows. But global warming is causing earlier snowmelt by increasing winter and springtime temperatures. Earlier snow melt changes the timing of high flows that are important to aquatic species for reproduction and predator avoidance.[58] In many western streams, spring runoff is critical to the rearing of

juvenile fish and the downstream migration for salmon on their way to the sea.

Earlier runoff can also result in lower streamflows in the summer and fall. Lower flows may result in warmer and shallower stream conditions that make it more difficult for migratory fish. Similar impacts of reduced in-streamflows already occur on many major rivers due to impoundment or flow diversion. Climate change could exacerbate this problem by shifting seasonal patterns of precipitation and in-streamflow.

Increased frequency and magnitude of peak flows have been observed and they are predicted by a number of climate models.[59,60] In the West, models show that an increased percentage of precipitation falling as rain instead of snow will mean higher peak flows even if total precipitation stays the same. The resulting increase in peak flows has implications for public safety as discussed earlier in this report and can also negatively impact aquatic ecosystems. Increased intensity of precipitation will lead to more runoff, which in turn can cause more sediment and pollution from the contributing watershed to make their way into water bodies. Higher flows can increase the rate at which beneficial nutrients are flushed out of the watershed and can displace species downstream to potentially less suitable habitat. The cumulative effects of higher peak flows can also cause significant shifts in species composition and may change some habitats so much that some species are eliminated from affected areas.[61]

For many species that are already struggling, the relatively rapid change in seasonal hydrology combined with increasing water temperatures will further degrade important habitats, increasing the need for environmental protection measures, such as flow and temperature requirements. The extent to which water supplies are affected by management actions requiring decreased flow diversion will largely depend on whether there are other management options to mitigate the impacts related to climate change. Adequate flows are essential to sustain aquatic ecosystems and sensitive species. But nonflow actions such as removing migration barriers, improving water quality, and restoring habitat can significantly reduce the need for additional flows.

Cold-Water Fish Such as Trout and Salmon Threatened by Warmer Waters

Cold-water species such as trout and salmon will be particularly vulnerable to warming waters. A study by Eaton and Scheller found that higher maximum temperatures in streams across the continental United States caused by an average air temperature increase of about 4 degrees Celsius would result in a decline of about 50 percent in thermally suitable habitat for 57 species that require cold or cool water—including game fish such as trout, salmon, and perch. Other researchers have predicted that an increase in air temperature of 3 degrees Celsius in streams of the Rocky Mountain region would reduce suitable stream habitat for trout by up to 54 percent.

Of particular concern is the number of streams that will cease to support a wide range of trout and salmon species due to increased temperatures. An analysis based on emission scenarios provided by the Intergovernmental Panel on Climate Change (IPCC) found that up to 38 percent of locations currently suitable for cold-water fish will become too warm to provide habitat by 2090.

Sources: Eaton, J.G., and R.M. Scheller, 1996. "Effects of Climate Warming on Fish Thermal Habitat in Streams of the United States." *Limnology & Oceanography* 41:1,109-1,115.

Keleher, C.J., and F.J. Rahel, 1996. "Thermal Limits to Salmonid Distributions in the Rocky Mountain Region and Potential Habitat Loss Due to Global Warming: A Geographic Information System (GIS) Approach." *Transactions of the American Fisheries Society* 125:1-13.

Rahel, F.J., C.J. Keleher, and J.L. Anderson, 1996. "Habitat Loss and Population Fragmentation for Coldwater Fishes in the Rocky Mountain Region in Response to Climate Warming." *Limnology & Oceanography* 41:1116-1123.

O'Neal, K., 2002. *The Effects of Global Warming on Trout and Salmon in U.S. Streams*. Natural Resources Defense Council and Defenders of Wildlife.

HOW CLIMATE CHANGE WILL AFFECT WESTERN HYDROPOWER

The West relies on dams, in addition to water supply and flood control, for hydropower generation. In California, for example, hydropower provides an annual average of 15 percent of California's electricity production.[62] But hydropower production is heavily influenced by variations in weather. In 2001, low snowpack in the Pacific Northwest diminished hydropower generation and contributed to energy shortages along the West Coast, illustrating just how vulnerable hydropower in the West is to climate change.[63]

Global warming could have a detrimental effect on the relationship between hydropower production and energy

demand. As discussed in earlier sections, scientists anticipate a shift in hydrology that includes in reduced winter snowpack, higher peak flows, earlier snowmelt runoffs in spring, and decreased summer streamflows. This shift would likely increase hydropower production supply in winter and spring, but decrease it during summer when less water is available as inflows. However demand for power, intensified by climate change, is likely to follow an opposite trajectory. An overall increase in temperatures could lead to lower winter demand for heating and greater summer demand for air conditioning. Thus, when energy is needed in summer to meet the greater demand for air conditioning, hydropower's energy production will likely be hindered, given the predicted decrease in summer flows. Another vulnerability of higher peak streamflows is an elevated risk of reservoir spills, are a key vulnerability of higher peak streamflows, which would contribute to an overall reduction of net generation.

The Portland Water Bureau (PWB) sponsored a study by Richard Palmer and Margaret Hahn of the University of Washington. The study concluded that a change in runoff timing would create problems for both water supply reliability and hydropower capacity. In Palmer and Hahn's analysis of future climate change scenarios, they found that the PWB system's winter flows could increase by as much as 15 percent and that late spring flows could decrease by 30 percent.[64] These changes, combined with an summertime increases in water and electricity use, present serious challenges for PWB. Simply put, early runoff results in water being less available when demand is highest for both water supply and hydropower energy production. Further, the Palmer and Hahn study found that global warming could exacerbate this water and energy supply problem because one of its key effects is an increased possibility of flooding. As fewer freezing days may raise runoff levels, the need intensifies to manage hydroelectric dams for greater flood protection at the expense of hydropower production and water supplies.[65]

For more information regarding the Palmer and Hahn study, please see the Portland Water Bureau Case Study in Appendix A.

Chapter 3

The Water and Energy Connection

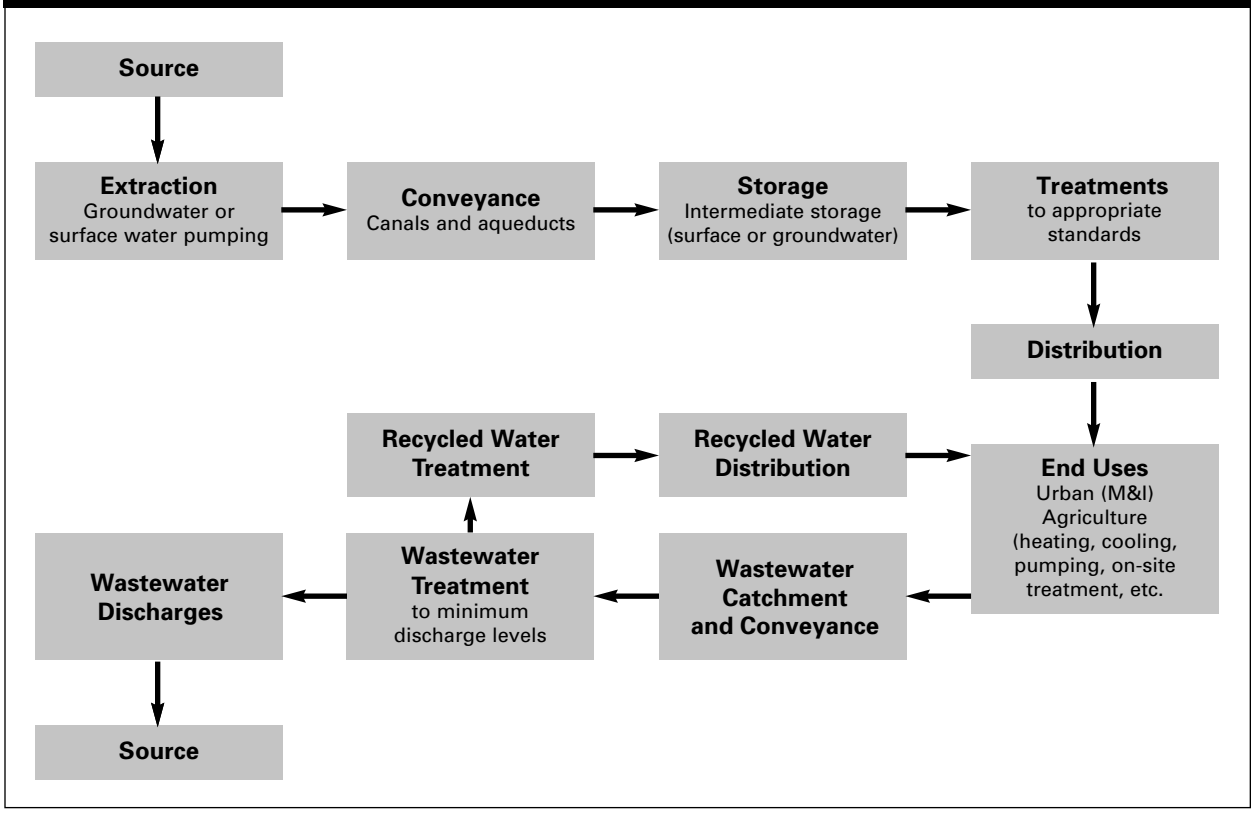
The strong connection between energy use and water management is often overlooked. Because the energy implications of water supply decisions can be so large,[1] the water/energy nexus will be increasingly important to future efforts to reduce greenhouse gas emissions. The California Energy Commission estimates that 19 percent of the state's electricity use, more than 30 percent of the natural gas use (aside from what is consumed by power plants), and 88 million gallons of annual diesel fuel consumption, are associated with water use.[2] In fact, the California State Water Project (SWP) is the single largest energy user in the state. The water and energy connection is discussed in greater detail in the report *Energy Down the Drain*, by NRDC and The Pacific Institute.

Water use efficiency and water recycling, along with groundwater recharge and stormwater management options, can provide significant opportunities for water managers to simultaneously improve water supply reliability, cut costs, save energy and reduce greenhouse gas emissions. An improved understanding of the relationship between energy and water will assist water managers incorporating climate change into management plans (see Figure 3-1).

The four principal elements of water systems use energy are: (1) water extraction, conveyance, and storage; (2) water treatment and distribution within service areas; (3) end use, including on-site water pumping, treatment, and thermal inputs (heating and cooling); and (4) wastewater collection, treatment, and discharge. Energy intensity, or embedded energy, is the total amount of energy calculated on a whole-system basis that is required for the use of a given amount of water in a specific location (see Figure 3-1).

Energy inputs to water systems, and related greenhouse gas emissions, vary considerably by energy sources and geographic location of both end users and water sources and end users. Water use in certain areas is highly energy intensive due to the combined requirements of extraction, conveyance, local treatment and distribution, and wastewater collection and treatment processes. In areas where a large percentage of power is provided by coal-fired plants, the greenhouse gas intensity of water use is particularly high.

Figure 3-1: Flow Diagram of Energy Inputs to Water Systems



Source: This schematic and method is based on Wilkinson (2000) with refinements by Gary Klein, California Energy Commission; Gary Wolff, Pacific Institute; and others. It is available as a simple spreadsheet tool from Wilkinson at Wilkinson@es.ucsb.edu.

Source and Conveyance of Water

Significant amounts of energy are often required to extract a source of water usable and to move the water to where it will be treated and used. Most water used in the United States is diverted from surface sources, such as rivers, streams and lakes, or pumped from groundwater aquifers. Conveying water often requires pumps to lift the water over hills and mountains, a process that can require large amounts of energy. In California, the State Water Project lifts water 2,000 feet over the Tehachapi Mountains—the highest lift of any major water system in the world. Where water is stored in intermediate facilities, additional energy may be required to store and then recover it. Smaller amounts of freshwater are produced from saltwater, brackish water, or wastewater using desalination or recycling technologies. Desalination requires energy to remove salts from water through reverse osmosis or other processes. Water recycling also requires energy to remove pollutants from wastewater.

Treatment and Distribution

Water treatment facilities use energy to pump and process water. The amount of energy required for treatment depends on source water quality. The energy required nationally for water treatment is expected to increase over the next decade as treatment capacity expands, new water quality standards are put in place, and new treatments are developed to improve drinking water quality, including taste and color. After water is treated, additional energy is typically required for local pumping and pressurization, but gravity pressurization and distribution is also possible when reservoirs are sufficiently higher than residences and businesses. Agricultural water generally is not treated before use.

End Uses

Water users require energy to further treat water supplies (e.g., softeners and filters), circulate and pressurize water supplies (e.g., building circulation pumps), and heat and cool water for various purposes. End use energy comprises

a major portion of water-related energy use. For example, water heating for one inefficient showerhead can use up to 2,800 kilowatt hours per year—almost as much energy as it takes to pump the annual water supply for two Southern California homes over the Tehachapi Mountains.[3]

Wastewater Collection and Treatment

Wastewater is collected and treated by a wastewater system (unless a septic system or other alternative is being used) and discharged. Wastewater is often pumped to treatment facilities where gravity flow is not possible and standard treatments requires energy for pumping, aeration, and other processes.

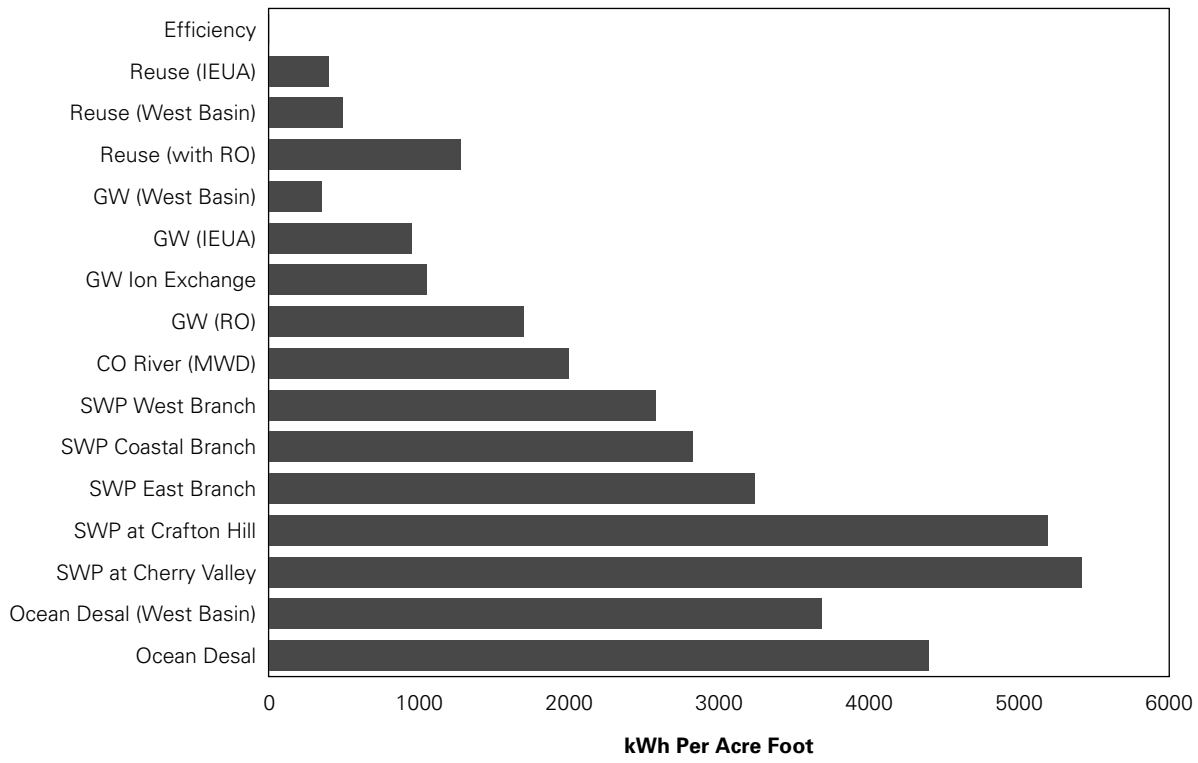
Reducing Water-Related Energy Use

Water use efficiency is the single best way to reduce water-related energy use. As noted above, the energy required for end uses of water (e.g., washing machines, cooling towers) is a major component of energy use in the urban water supply cycle. Water use efficiency saves end use energy, as well as the upstream energy needed to convey, treat, and distribute that water and the downstream energy needed to treat and dispose of wastewater. Therefore, improving water use efficiency, particularly for energy intensive uses of water, is important regardless of the source of the water or location of its use.

An analysis of water management options for the San Diego County Water Authority found that the total energy savings from relying on improved water use efficiency instead of additional State Water Project deliveries to provide the next 100,000 acre-feet of supply would be approximately 770 million kWh, This would be enough to supply electricity to 118,000 households—25 percent of the homes in San Diego—for a year.[4]

Most local sources are more energy efficient than imported water supplies. Figure 3-2 shows the energy intensity of water supply options for two southern California water agencies:

Figure 3-2: Energy Intensity of Alternative Supply Sources in Two Southern California Water Agencies



Source: Wilkinson based on data from Inland Empire Utilities Agency (IEUA), West Basin Municipal Water District, and California Department of Water Resources.

the Inland Empire Utilities Agency and the West Basin Municipal Utility District. The analysis indicates that water use efficiency is the least energy intensive option and that recycled water and local groundwater sources are a relative energy bargain compared with imported supplies. Even the Chino desalter, a reverse osmosis (RO) process for contaminated groundwater that includes groundwater pumping and RO filtration, is far less energy intensive than any of the imported sources of water. From an energy standpoint, local sources of reclaimed water and groundwater—including contaminated sources requiring advanced treatment—are remarkably efficient. Similar findings were made for the Central Basin Municipal Water District.

The energy intensity of many water supply sources may increase in the future due to regulatory requirements for water quality.[5] Advanced treatment systems such as reverse osmosis (RO) are being used to treat groundwater, reclaimed supplies, and ocean water. They can produce very high quality water. As a result, they are likely to face fewer energy impacts from more stringent water quality regulations. By contrast, some of the raw water supplies, such as Colorado river and Delta water, may require larger incremental energy inputs for treatment, due to high salinity, including arsenic and perchlorate. This may further increase the advantage of obtaining water from local sources.

Recent State and National Actions to Address Energy-Water Issues

Recently, the link among water, energy, and climate has been getting increased attention. For example, the California Energy Commission (CEC) issued a report on the water/energy relationship and incorporated recommendations into its *Integrated Energy Policy Report* (IEPR) submitted to the state legislature in December 2005. According to the IEPR, investing in water conservation can achieve 95 percent of the energy and demand-reduction goals planned by the state's investor-owned energy utilities for the 2006–2008 program period at 58 percent of the cost of traditional energy efficiency measures.[6] The CEC report noted that "water agencies are seldom given credit, nor are they able to secure funding, for the electricity savings that result from water conservation and efficiency efforts."[7]

In the IEPR, the CEC recommended that "the California Public Utilities Commission (CPUC), Department of Water Resources, the Energy Commission, local water agencies and other stakeholders should assess efficiency improvements in hot and cold water use in homes and businesses and include these improvements in 2006–2008 programs."[8] To address this important implementation obstacle to integrated water and energy conservation programs, the CPUC has embarked upon a process for rulemaking on issues related to embedded energy, and is currently evaluating proposals for pilot programs that focus on saving embedded energy through improved water use efficiency.[9]

Building on the CEC work, California's Climate Action Team recently took the unprecedented step of identifying water use efficiency as a tool to reduce climate change emissions and the California State Legislature is considering legislation requiring water agencies to evaluate the energy impacts of its water management alternatives. As California implements AB 32, The Global Warming Solutions Act, water efficiency measures are among the suite of actions that will be evaluated for their ability to help the state meet its greenhouse gas emission reduction goals.

On the national level, the U.S. Department of Energy's Sandia National Laboratory is leading the National Energy/Water Roadmap Program initiated in 2005, as requested by Congress. The purpose of this integrated energy/water research and development program is "to assess the effectiveness of existing programs within the Department of Energy and other Federal agencies in addressing energy and water related issues, and to assist the DOE in defining the direction of research, development, demonstration, and commercialization efforts."[10]

These efforts represent the beginning of better-integrated water, energy, and climate policy. Information about the energy and climate implications of water use can help improve public policy and facilitate combined investment and management strategies among energy, water, and wastewater entities. Potential benefits include improved allocation of capital, avoided capital and operating costs, reduced burdens on ratepayers, emission reductions, and environmental benefits.

Chapter 4

A Guide for Water Managers: Designing a Comprehensive Response to Climate Change

Many water managers are already taking action to understand and address impacts related to climate change. This section is designed to summarize some of these actions and review "best management practice" approaches to these important challenges. Given the wide range of potential climate change impacts on water systems across the West, water managers have numerous options at their disposal to address the effects of climate change.

If well designed, these tools can provide a robust response, potential climate change impacts on water management, and a broad array of additional benefits. This chapter outlines four critical steps water managers can take to ensure a steady supply of quality water in the face of the challenges that climate change poses to the system. It sets forth strategies to make each step successful given the limited resources every water manager faces. Here are the four steps:

1. Vulnerability analysis: Evaluating the vulnerability of water supply systems, flood management systems, watersheds, and aquatic ecosystems to water-related climate impacts.

2. Response strategies: Implementing response strategies to reduce future impacts of climate change in two major areas: water supply and water management, including flood management and aquatic ecosystems.

3. Prevention: Taking immediate and sustained action to reduce greenhouse gas emissions in order to minimize future impacts.

4. Public outreach: Increasing public awareness of climate change and potential water-related impacts and opportunities.

VULNERABILITY ANALYSIS

An essential first step for water managers is to examine both local and regional effects of climate change. Given that a variety of factors can influence how climate change affects water resources, including the geographic location of sources, end uses, and the nature of the existing water supply infrastructure, each water resource agency should undertake an agency-level analysis to understand how climate change will impact their specific water-related resources and to lay the groundwork for the development of a response plan.

Agencies should also consider joining with other agencies to undertake analysis on a regional level because the impacts of climate change will affect agencies that derive water supplies from a larger shared resource (e.g., the

Colorado River, San Francisco Bay-Delta) and because some agencies in the same region may face similar challenges (e.g., the Sierra Nevada, the Rocky Mountains and the Northwest). Regional analysis will also facilitate cooperative responses and leverage limited resources to produce better results.

Elements that should be considered in conducting local and regional analyses of the effects of climate change on water supply are provided on the following pages. See Appendix A for detailed case studies illustrating how particular water agencies have tackled the challenge of climate change at the local, state and regional levels.

Assessing Water Supply System Vulnerabilities

Water supply systems are designed and operated to meet numerous objectives including water supply, flood protection, hydropower generation, and in-streamflow requirements—all of which are based on a retrospective view of hydrology. As climate change occurs, water infrastructure systems will face conditions different from those for which they were designed, presenting significant challenges for managers. Vulnerability analysis should be done to investigate how specific systems will react to climate-related changes. An analysis should examine a range of fundamental factors, including watershed characteristics, allocation, storage versus runoff ratio, diversity of water supply, flood management, shared regional water resources, water quality impacts, resource allocation and environmental water requirements.

Location and Watershed Characteristics

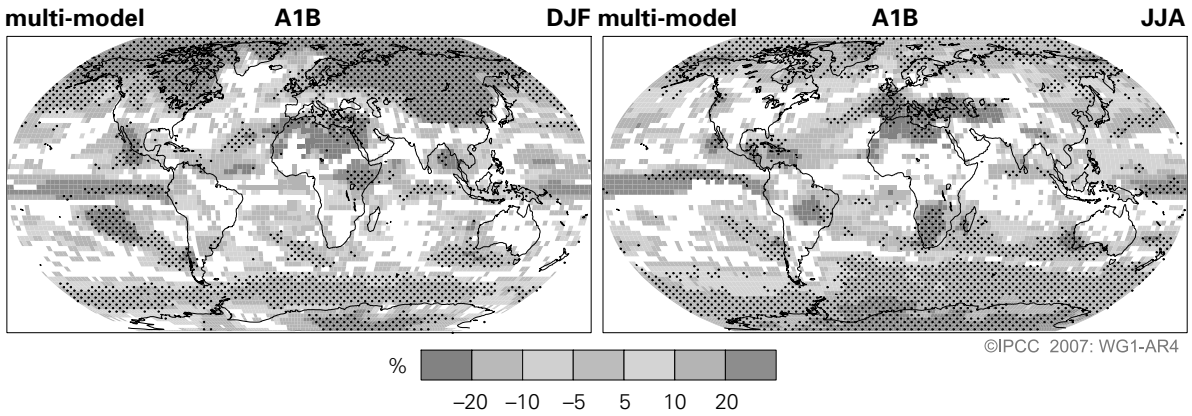
The geographic location and the watershed characteristics of the area being assessed are critical starting points. Although precipitation predictions are coarse, there are studies predicting regional changes related to climate change. Some analyses suggest that northern latitudes may become slightly wetter and drier regions, such as the Southwest, may receive even less precipitation.[1] As the science improves regarding regional impacts on precipitation patterns and total precipitation, water agencies will be increasingly able to identify regional or watershed-specific impacts. In addition, watersheds in the Southwest may be more significantly affected in the future by increases in evaporative losses within watersheds and from reservoirs.[2] Potential regional changes should be considered as a basis for further analysis.

Watershed characteristics are important. Elevations within the watershed will affect many attributes of a watershed's runoff characteristics including snowline, evaporation, dew point, and temperature. Other important characteristics are vegetation, slope aspect, and soils. A useful model focusing on the Sierra Nevada was developed by the American River Watershed Institute to examine these elements. Climate scenarios can be analyzed for specific watershed conditions to examine potential impacts.[3,4]

Allocation

Vulnerability analyses should include a determination of how much of the annual runoff is committed to use, including extraction for municipal, industrial, and agricultural uses; and in-stream, recreational, and

Figure 4-1: Projected Patterns of Precipitation Changes for Period 2090-2099, relative to 1980-1999



Source: IPCC 2007: WG1-AR4

environmental uses. If most, all, or more than all of the annual runoff is needed to meet existing uses, then the system is already stressed. Therefore, changes to the timing of hydrology from climate change, much less a change in natural inflow quantities, are likely to exacerbate the stress and result in negative impacts on the reliability of supplies. It is important to assess the reliability of water supplies to meet demands under both past and future climate variability.

Storage Versus Runoff Ratio

Vulnerability analyses should examine to what extent structural storage (dams) and non-structural storage (snowpack, groundwater) are relied on to meet demands. Although individual water supply systems vary in the degree to which they rely on storage, most of the West's water supplies depend on snowpack, reservoirs, and groundwater basins to provide annual and carryover storage. The amount of surface and groundwater storage in relation to the mean annual runoff diverted for beneficial use is one simple indicator of a water provider's reliance on snowpack. It is, however, important to recognize that each of these forms of storage has different operational characteristics. Climate change is expected to negatively affect water storage by reducing the snowpack and changing the timing and volume of runoff inflow, which may affect the yield of existing reservoirs. Climate change could also impact groundwater storage by reducing natural recharge and surface water supplies available for groundwater recharge.

Water managers have a wide range of tools to meet future needs. Some tools, such as water transfers, dam reoperation, floodplain management, and landscape conservation, can help conserve water in storage or provide "virtual" storage through cooperation with other agencies. Thus, water managers could respond to a potential future loss of supplies from existing storage by implementing a range of water management tools.

Diversity of Water Supply

Different water supply sources, including groundwater, surface supplies, transfers, and importation, have important water management implications. With climate change likely causing alterations in timing of precipitation and runoff, reduction of natural snowpack storage, and management of surface supplies, a portfolio of water supply alternatives can serve as a hedge strategy. Having a variety of alternatives available, such as wastewater recycling, increased groundwater, water conservation, and transfers among users, can reduce vulnerability of an individual system.

Water agencies seeking to diversify their existing water supplies should carefully consider potential pitfalls. For example, many river basins are already overcommitted and environmentally degraded. In some areas groundwater is overdrafted or contaminated. In many cases, increasing the diversity of supply for one agency could increase stress for other communities or environments (e.g. over allocated river systems). Moving from a reliance on vulnerable supplies (e.g. surface and groundwater sources) toward water use efficiency and reuse represent measures to diversify water supply portfolios that are appropriate in nearly all circumstances.

Flood Management

Water managers are constantly challenged with balancing flood safety and water supply. Surface storage operations are often designed to provide multiple benefits, including recreation, hydropower production, and flood safety. Flood management presents a particular challenge because when storage space within a multipurpose reservoir is set aside for attenuating flood flows, storage operating rules often can pit flood protection against operations that would maximize water supply.

Climate change is likely to complicate these operational choices. The earlier snowmelt brought on by a warming climate could increase the likelihood that snowmelt runoff will need to be released to maintain flood storage, but this may increase the risk that a given reservoir will not end the rainy season full. In some watersheds, an increase in storm intensity could directly increase peak flows and increase the likelihood of "rain on snow" events, which can result in dramatic increases in flows. If peak flows increase, the existing operating rules may no longer provide an appropriate level of protection. There will likely be a need to increase flood reservation capacity within existing storage facilities thereby exacerbating existing tensions with water supply. However, in some areas with limited existing snowpack, declining snowpack could decrease the likelihood of "rain on snow" events, providing an opportunity to reoperate existing facilities.

Shared Regional Water Resources

Dividing water resources among several water providers can result in shared risks and benefits. A relevant factor in assessing climate change impacts on water supply is whether a particular water supply is wholly appropriated

by local, regional, state, or federal entities. As illustrated by the Colorado River Compact, the effects of climate change may be addressed by increased coordination and planning among agencies and states.

Water Quality Impacts

Water supply could be threatened by water quality changes resulting from increased temperatures, increased peak runoff; decreased summer flows; and sea level rise with saltwater intrusion into coastal aquifers, streams, and estuaries. Where water quality standards are already an issue, climate change will likely exacerbate conditions. Watersheds may see an increase in sediment and non-point source pollution related to larger storm events. In California, for example, saltwater intrusion exacerbated by sea level rise could result in groundwater degradation. In the San Francisco Bay-Delta, saltwater intrusion could increase the salinity of Delta water. Increases in sedimentation due to climate change could result in lost storage capacity, degraded water quality, and increased treatment costs.

Assessing Water Demand Vulnerabilities

A critical consideration in evaluating the stresses and vulnerabilities of a water system is the current level of demand and the ability to manage increases in demand. Demand for water is as much a response to land use and resource management policies as it is a response to climate signals. Higher temperatures will push up demand for agricultural and landscape irrigation water. Those demands may be offset by conservation, changes in crop types, and irrigation practices for agriculture as well as increased use of xeriscaping and more efficient irrigation systems on the municipal side.

Conservation

Communities throughout the West have implemented a wide variety of water conservation measures to improve water use efficiency. Some of these efforts have produced striking results (see Appendix B). Per capita consumption gives a rough estimate of the degree to which a water provider can mitigate water supply impacts through increased investments in water conservation measures. For example, areas with large landscape water use have greater potential for benefits from landscape water conservation. Communities with high interior per capita use have the potential for significant savings from interior water conservation tools. It is important to note that because the technology of water conservation will improve over time. This water source will grow in the future.

Peak summer water use should also be considered when evaluating possible conservation opportunities. This factor takes into account the difference between summer and winter water use patterns. High peak summer water use in many municipal systems indicates a high degree of outdoor use, which can be reduced through landscape water conservation programs. Many providers have also developed effective indoor residential and industrial/commercial/institutional water user programs to reduce overall consumption.

Resource Allocation

The allocation of water to various sectors (agriculture, commercial, institutional, industrial, and residential) is an important consideration when analyzing the potential flexibility of a water provider to cope with dry years. Each sector has varying degrees of flexibility and requires different strategies for managing decreased water supplies, particularly in extremely dry years. For example, agricultural water users can fallow fields planted with annual crops during critical dry years. Different sectors will be affected differently by climate change. For example, outdoor residential and agricultural water consumption may increase with warmer temperatures. Industrial use may not.

Assessing Environmental and Water Quality Requirements

Rising temperatures, decreased summer streamflows, and increased evapotranspiration will likely increase the need for in-streamflow to meet ecosystem and water quality needs. Environmental requirements such as minimum in-streamflows and water quality standards are increasingly common for western rivers, wetlands, and lakes. Such requirements can significantly affect the operations of both large and small water systems. Most large dams must release water to maintain downstream water quality and provide benefits to aquatic ecosystems, including protected species. Often minimum flow requirements are based on meeting critical temperature and other standards that will require greater releases to maintain. Agencies should assess the degree to which climate change will alter existing environmental conditions with an eye on potential future environmental constraints on operations.

RESPONSE STRATEGIES FOR DEALING WITH WATER SUPPLY IMPACTS

Although prompt action to lessen greenhouse gas emissions can reduce the future impacts of climate change on western water supplies, it is clear that climate change will produce supply impacts for which water managers should be prepared. A vulnerability analysis can reveal the extent of the climate change-related risks to an existing system. This section discusses how climate change will affect the tools available to respond to these climate impacts and presents a framework for a robust, resilient, and flexible water management approach to handling the effects of climate change on water resources.

Seven Guiding Principles for Responding to Water Supply Impacts

The scope of the potential impacts of climate change makes this issue different from other challenges facing water managers. The following guiding principles are designed to assist forward-thinking water decision-makers in crafting strategies to respond to this challenge.

Strengthen Institutional Capacity. Responding to climate change will require a broad set of management and technical skills, including expertise that builds on traditional water management, such as:

- reoperating existing water systems
- understanding climate impacts
- evaluating opportunities to finance and implement integrated strategies for multiple benefits

Water managers should evaluate their institutional strengths and weaknesses, seek opportunities to improve institutional capacity, and reognize that responding to climate change will require new skills. As Roger Revelle and Paul Waggoner recommended in a 1990 American Association for the Advancement of Science publication, "Governments at all levels should reevaluate legal, technical, and economic procedures for managing water resources in the light of climate changes that are highly likely."[5]

Build In Flexibility. Climate change places managers in a difficult position. There is now a strong scientific consensus that climate change is happening and that it will result in significant impacts because preparing effectively will require investment of effort and time, water managers should begin such efforts immediately. However, there is still uncertainty regarding how rapidly these impacts will develop and how climate change will affect some water resource characteristics (e.g., total precipitation.)

The solution to this apparent paradox is to design flexible responses to climate change. Locking in large, long-term capital investments under conditions of uncertainty is a risky strategy. Whenever possible, flexibility is desirable as a management strategy. Specifically, strategies that allow for mid-course corrections and redirection of investments toward the most effective tools and that reduces the risk of stranded investments will increase the flexibility of water systems and the ability of water managers to adapt to changing conditions.

Increase Resilience. Even absent any change in climate, we can expect both wet and dry conditions. The relatively new science of paleoclimatology has revealed that the climate in the West has, historically, experienced significant variation, including extended drought periods. For example, the Colorado River basin has seen extended drought periods. In particular, the period used as the historical baseline for Colorado River water allocations was one of the wettest periods in five centuries, resulting in an overallocated river.[6] Climate change is likely to result in even greater divergence from the recent historical record. Scientists agree that we will see increased temperatures in coming years and we may see wetter wet periods and drier dry periods. Therefore, it makes sense to consider a range of water management options that build resilience through cost-effective strategies to meet future needs under conditions of greater variability and uncertainty.

Seek "No Regrets" and "Multiple Benefits" Strategies. Management strategies that cost-effectively improve a water system's ability to deal with existing stresses and problems (e.g., drought, population growth, land-use changes, and environmental impacts) are often characterized as no-regrets strategies because they make sense today, even before factoring in climate change. Where possible, water managers should seek to implement no-regrets strategies and secure multiple benefits (e.g., water, energy, and cost savings, emissions reductions and reduced environmental impacts) through well-designed policies, investments, and strategies. The focus of good policy is to build resilience in various systems ranging from whole water systems to local landscape conservation programs.

Multiple benefits strategies address more than one objective through a single targeted investment or policy measure. Some multiple benefit strategies that can enhance performance and build resilience through a single investment include:

• improving water use efficiency

• designing policies and management systems that provide better signals to consumers regarding the cost and scarcity of resources

• instituting flood plain management approaches that reduce damage from flooding, provide habitat, and increase groundwater recharge

Address Multiple Stresses. Climate change is just one of a number of factors putting pressure on water supply systems. Rapid population growth, land-use changes, contamination of surface and groundwater resources, and the need for ecosystem protection and restoration are all occurring simultaneously. Many water managers and users are effectively addressing these combined challenges through measures such as dramatically improving water use efficiency and restoring and protecting watersheds and groundwater sources. (See Appendix A.)

Invest in Cross-Agency Relationships. Many of the measures discussed in this chapter begin with developing relationships among agencies that can be partners in innovative approaches to water management. (Integrated approaches are discussed in more detail later in this section and Appendix A includes a number of case studies showing ways in which water managers across the West are developing their own integrated approaches.) Water managers seeking to position their agencies to best respond to climate challenges should begin by strengthening their relationships with potential partner agencies, including neighboring water agencies, as well as those with authority on energy, wastewater, stormwater, environmental quality, and land use issues.

Incorporate Climate Change into Ongoing Project Design. Water managers constantly face a wide range of design decisions regarding existing and new facilities. The design of those facilities should incorporate climate impacts. Managers should begin such work now, rather than waiting for the completion of a comprehensive response plan to address climate change. Several examples illustrate where climate issues are being incorporated into design decisions. For example, the California Department of Water Resources (DWR) is working to design operable barriers in the Sacramento-San Joaquin River Delta. Those barriers are designed to use tidal currents to control water levels and circulation in the south Delta. DWR recognizes that climate change is likely to produce significant sea level rise. Such changes could affect the operations and effectiveness of these Delta barriers. To reduce this risk, DWR decided to redesign these barriers so they could be retrofitted in the future to accommodate up to an additional foot of sea level rise. Given the probable useful life of these barriers, DWR believed that this was an appropriate design target. This decision required a redesign for a larger foundation, capable of accommodating larger gates in the future—and resulted in significant expense.[7]

The San Francisco Public Utilities Commission (SFPUC) is currently developing a long-term wastewater master plan designed, in part, to address climate change impacts. Perhaps the most significant climate change-related challenge for San Francisco is the potential for rising sea levels to result in seawater intruding through outfalls into waste treatment facilities.[8] Such saltwater intrusion could kill the microbes that serve as the foundation of secondary treatment. The SFPUC has already experienced these seawater intrusion events, even without storms, as the result of 7 inches of sea level rise in the past century. The SFPUC is currently designing valves to prevent such sea level rise-related inflows into the wastewater system. Seattle Public Utilities has made several significant design decisions to address potential climate change impacts.[9] Such water agencies are beginning to discuss how climate change could affect decisions such as the design of drinking water treatment facilities.

By incorporating climate change in ongoing design decisions, water managers can reduce risks and expenses in the future.

Expand Dialogue with the Scientific Community. The scientific community is an essential resource to water managers. Expanded dialogue with the scientific community can increase the effectiveness of measures designed to meet the challenges posed by climate change. A healthy dialogue with water managers will also help scientists develop a more realistic and accurate analysis of potential climate change impacts on water management. The September 2005 conference in Las Vegas, co-sponsored by the Natural Resources Defense Council, the Southern

Nevada Water Authority, and the Desert Research Institute represents an example of this kind of extended dialogue. Such conferences should be held with greater frequency.

The AWWARF Public Advisory Forum developed the following two recommendations regarding climate and science:

* Cooperation of water agencies with the leading scientific organizations can facilitate the exchange of information on state-of-the-art thinking about climate change and impacts on water resources.

• The timely flow of information from the scientific global change community to the public and the water-management community would be valuable. Such lines of communication need to be developed and expanded.[10]

Given the need discussed earlier to improve institutional capacity, a robust dialogue between water managers and scientists could be particularly valuable as water agencies move past vulnerability analyses to develop future response strategies that incorporate climate issues.

Determining the Best Mix of Water Management Tools

A century ago, water managers had a limited range of water management tools. Today, water managers have a much greater range of options to manage water in communities around the West:

• Technological advances have dramatically improved the water use efficiency of wide range of devices, including low-flow showerheads, low-flush toilets, water-efficient washing machines and dishwashers, and water-saving irrigation systems guided by satellite weather data.

• Wastewater recycling, groundwater cleanup, urban stormwater capture projects, water marketing, and active groundwater storage projects have also become proven water management tools.

• Pricing mechanisms, such as inclining block rates (the practice of increasing volumetric prices with increasing water use) and seasonal rates (which modify summer water rates to encourage landscape conservation), can encourage efficient water use.

• In some coastal areas, urban water agencies are beginning to explore desalination, previously dismissed as impractically expensive.

Given the impressive array of water management tools available, how should water managers determine the best mix of responses to climate change—particularly as the performance of water management tools will be affected in different ways as a result of climate change? This section is designed to help water managers answer this question. (See Table 4-1 for a summary of NRDC's findings.)

Water Management Tools that Will Perform Better as the Climate Changes

Some water management tools are likely to perform better in the future in the face of global warming. This effect is likely to be most significant for tools that reduce landscape water use.

Table 4-1: Performance of Water Management Strategies After Considering Global Warming Effects

More effective	Not affected	Less effective
• Landscape conservation • Conservation rate structures • Agricultural water conservation • Water marketing • Urban stormwater management • Saltwater groundwater intrusion barriers to protect coastal aquifers • Water system reoperation • Interagency collaboration and integrated water management strategies • Floodplain management • Watershed restoration	• Wastewater recycling • Interior water conservation • Groundwater cleanup	• Traditional river diversions • Traditional groundwater pumping • Traditional surface storage facilities • Ocean water desalination*

*Given existing energy requirements.

Landscape Irrigation Conservation. Urban water conservation programs often underemphasize the demands of urban landscaping. With climate change likely to increase evaporation and transpiration rates in planted landscapes, a lawn or landscape could consume more water in the future than it consumes today. One implication of this trend is that landscape irrigation conservation programs have the potential to save more water in a warmer future than they do today.

Landscape irrigation already represents a significant percentage of urban water use in the West. For example, it accounts for approximately half of urban water use in California, or about 10 percent of statewide water use.[11] Urban water agencies are increasingly turning to landscape irrigation to find new opportunities to increase urban water use efficiency.[12] For example:

• The Southern Nevada Water Agency offers customers a $1 per square foot rebate for all turf that is removed and replaced with drought-tolerant landscaping.[13]

• The Metropolitan Water District of Southern California has developed a website (www.bewaterwise.com) devoted to educating ratepayers about landscape conservation opportunities.[14]

• The East Bay Municipal Utility District (EBMUD) in California has published a comprehensive book aimed at encouraging appropriate landscape design. EBMUD also offers residential landscape conservation rebates of up to $1,000.[15]

• The Marin Municipal Water District, also in California, offers financial incentives to encourage the installation of weather-based irrigation controllers.[16]

As climate change reduces late season snowmelt, measures such as landscape conservation that reduce peak summer demands—often a key constraint on water systems—could be particularly effective. Water managers should incorporate such conservation measures in their plans to meet future water needs and respond to climate change impacts.

Conservation Water Rate Structures. Water rate structures are among the most effective tools to encourage water conservation because they give customers a price signal about the value of this resource. To maximize the effectiveness of this signal, agencies should strive to recover as much revenue as possible through volumetric charges, rather than high fixed charges. Increasing block, or tiered rate structures, offer an initial allocation at a base rate. Additional tiers or blocks of water increase in price. Some utilities offer a lifeline, or below cost rate, for low-income customers. University of California economists Hewitt and Hanemann found a significant positive response to block rate structures in California applications.[17] In addition, seasonal water rates, which increase prices during the warm irrigation season, can be particularly effective in encouraging landscape conservation and in reducing peak summer demands. Water managers seeking to encourage conservation in the future should pay particular attention to rate structures designed to encourage conservation.

> **"We have to attack both sides of the supply-demand equation when faced with more variable water supply due to global warming."**
>
> Source: Chips Barry, General Manager, Denver Water, 2006.

Agricultural Water Conservation. According to the U.S. Department of Agriculture, agricultural water represents 81 percent of all consumptive water use in the nation.[18] In the West, agriculture represents 90 percent of the consumptive use of the developed water supply.[19] Future agricultural water use is difficult to predict because of complex interactive impacts of climate change on international trade, crop selection, and yields. Nevertheless, as in the case of urban landscaping, rising temperatures may increase evapotranspiration rates-meaning that irrigating an acre of crops such as alfalfa or lettuce could take more water in the future than is currently required.[20] As a result, agricultural water conservation and fallowing could generate even more water savings in the future than they do today.

Even without considering potential climate change impacts, there is significant potential for agricultural water conservation around the West. For example, in much of the arid West, flood irrigation is still the predominant irrigation technology, and in states including Arizona, Montana, and Idaho, water application rates often exceed 5 feet per acre.[21] In agricultural areas working to cope with the impacts of climate change, conservation programs and related water transfers could provide valuable revenue.

Market-Based Transfers, Sales of Water. With agricultural water conservation and fallowing programs increasing in effectiveness as temperatures rise, there also may be

Restoring the Wet Meadows of Sierra Nevada's Feather River Basin

A public/private partnership called the Feather River Coordinated River Management Group (CRM) has been working for more than a decade to implement wet meadow restoration projects in the Sierra Nevada's Feather River Basin. The Feather River is an important source of water for California's State Water Project, which provides a portion of the water supply for Southern California, the San Joaquin Valley, and Silicon Valley. There are 250,000 acres of high altitude meadows and valleys in the Feather River's Sierra Nevada watershed. These mountain meadows have been degraded by decades of grazing, road building, and other activities. Streams have eroded deep gullies in meadows, rapidly draining groundwater from these natural high-altitude reservoirs; and incised creek beds have dramatically reduced natural infiltration of runoff.

The Feather River CRM has used several techniques to help restore its degraded meadows. For example, creek beds have been regraded to restore natural drainage elevations by the replacement of incised gullies with barriers and pools. Subsequent monitoring has verified that such projects can significantly increase natural storage in these meadows, thus retaining additional winter rainfall and snowmelt. This additional stored water is naturally released later in the spring and summer. Analysis of the CRM Big Meadow Cottonwood Creek project found that groundwater levels were within 1 foot of the surface for an average of 8 days prior to restoration, and an average of 223 days after. As a result, the ephemeral stream in the meadow returned to nearly perennial flows, increasing from 214 to 344 days of flow.

This project creates additional active water storage, which could have increasingly important water supply and ecosystem benefits in the future. These projects can also decrease stream temperatures, addressing a key potential climate change impact on cold-water fisheries. As a result, the CRM estimates that large-scale restoration projects have the potential to create large amounts of increased natural groundwater storage.

Sources: http://www.feather-river-crm.org/.

Wilcox, Jim, January 2005. "Water Management Implications of Restoring Meso-Scale Watershed Features." http://www.feather-river-crm.org/publications/tech/IAHS%20Full%20Paper.htm.

a growing incentive for some farmers to sell a portion of their water supplies through voluntary, market-based transfers. Three factors suggest that incentives for water marketing that moves water from low-value agriculture to high-value urban uses are likely to increase as a result of global warming. First, as urban water agencies face reduced yields from existing water systems, they may be increasingly motivated to pursue, and increasingly willing to pay for, water transfers. Increasing scarcity could raise prices received by agriculture for marketed water. Second, climate change will create increasing uncertainty for agriculture. It may be a challenge for some farmers to cope with warming temperatures and more extreme weather events, increasing their interest in water transfers that could provide them with greater flexibility and revenue. And third, around the West, many agricultural water users have more senior water rights than their urban counterparts have. To a certain extent, this system will insulate the holders of senior water rights holders from the impacts of climate change—making their water supply more reliable than that of junior holders (including many growing urban areas). All of these factors suggest that the economic rationale for water marketing may increase.

It should be noted that water marketing does not create new water, it simply reallocates it. Various sources of water can potentially be transferred by market transactions, each constrained by legal, regulatory, market, and physical parameters. A California Legislative Analyst's Office report identifies the following sources:[22]

- Land fallowing and crop shifts to less water-intensive crops.
- Water recycling, such as recycling water from wastewater treatment plants for industrial and irrigation purposes.
- Groundwater pumping instead of using surface water rights, thereby freeing up surface water for transfer.
- Storing excess surface water from wet years in underground aquifers to be pumped in the future when surface supplies are low.
- Water conservation, in both the agricultural and urban sectors. This includes, for example, farmers using water-saving irrigation technologies and homes and businesses using water-efficient landscaping and bathroom fixtures.

FEATHER RIVER CRM.

Cottonwood Creek in California's Sierra Nevada, with Degraded Meadow. Before (left) and After (right) Restoration.

• Withdrawals from surface storage supplies that were not otherwise planned to be made.

If a water marketing system is to work optimally, care must be taken to design appropriate transfers and to avoid impacts to third parties and the environment. Efficient markets require that buyers and sellers bear the full costs and benefits of transfers. However, when water is transferred, third parties are likely to be affected. Where such externalities are ignored, the market transfers not only water, but also other benefits and costs from non-consenting third parties to the participants in the transfer.[23] Finally, the practice of "paper water" transfers—attempts to sell rights to water that exist only on paper—must be prevented.[24] Paper transfers can be highly disruptive, leading to environmental impacts and water management challenges.

Watershed Restoration. Watershed restoration has the potential, in some cases, to help mitigate impacts of climate change. As climate change reduces natural storage through a reduction of snowpack, watershed restoration efforts may be increasingly valuable to reduce peak flows, recharge groundwater, and delay spring runoff. Restoration projects may also decrease stream temperatures—reducing another impact of climate change—and provide additional environmental benefits such as riparian habitat. (See Restoring the Wet Meadows.)

Urban Stormwater Management. Throughout the West, there are abundant opportunities to manage urban stormwater to reduce runoff, flood damage, and pollution and to improve water supply availability and quality. As climate change affects rainfall volumes and storm intensity, the value of water supply tools that provide stormwater management benefits may increase.[25] Climate change will likely force urban communities to invest in additional flood management, creating willing partners for water agencies seeking to invest in integrated stormwater management and water supply strategies.

One approach is to direct stormwater runoff from impermeable surfaces, such as roofs and paved areas, to landscaped areas where the water can percolate into the soil, and recharge the groundwater. Impervious surfaces increase runoff during storm events. The first "flush" often collects and concentrates contaminants from those surfaces such as oils and sediment. When flows exceed the infiltration capacity of the soils, water flows into storm drains. By diverting a portion of the first flows, improved stormwater management reduces demands on storm drain systems. This strategy slows the rate of runoff and allows for recharge. Designs such as shallow depressions, or "swales" and the sloping of both the paved areas and the landscaped areas to follow normal drainage patterns facilitate the redirection of stormwater runoff to landscaped areas where it is intercepted and infiltrated into groundwater aquifers. Some of the most innovative work in this area has been done by Tree People, a non-profit organization in Los Angeles that is advocating the construction of a citywide system of cisterns, groundwater infiltration facilities and urban forestry in order to recharge groundwater and provide other benefits.[26]

Another stormwater management related strategy, called "daylighting," involves taking surface flows that are currently conveyed in underground culverts and restoring them to creeks. Daylighting can offer groundwater recharge and environmental benefits, as well as increase property values and recreation in adjacent communities.

Another strategy involves diverting water into groundwater infiltration basins from urban streams during high flow events.

Reoperation of Water Systems. Water agencies have extensive experience with water system management, particularly the operation of storage facilities to meet the different demands of flood management and water supply. As a result of climate change, it will likely be necessary in the future to reconsider operating rules for major water supply systems. The Intergovernmental Panel on Climate Change (IPCC) called for "a systematic reexamination of engineering design criteria, operating rules, contingency plans, and water allocation policies," noting that "water demand management and institutional adaptation are the primary components for increasing system flexibility to meet uncertainties of climate change."[27] Investigations of reoperation opportunities should be broadly conceived to reflect the interactions of the many elements of complex water systems.

For example, the Seattle Public Utilities (SPU) analysis of potential climate change impacts to the water supply system (see Appendix A) helped SPU identify potential future management challenges that could arise from climate change. SPU created a series of adaptive management strategies for reoperating the water system to improve day-to-day management and to provide greater flexibility. They now use a dynamic reservoir elevation rule curve to help guide the management of flood storage capacity and refill of mountain reservoirs, thereby adjusting reservoir level targets based on real-time snowpack measurements and soil moisture conditions. This information, coupled with simulation models, helps to set reservoir targets during the refill season. Using a dynamic rule curve allows SPU to be more adaptive than if they used a traditional fixed rule curve.

SPU's experience during the winter of 2005 demonstrates the operational flexibility that can be provided by utilizing the dynamic rule curve. Low snowpack in the winter reduced the probability of floods from snowmelt. Due to this reduced probability of flooding, SPU water managers captured more spring rains than in a normal year. This adaptation of operations to weather conditions provided Seattle with enough water to return to normal supply conditions by early summer, despite the lowest snowpack on record. It also demonstrated the flexibility in the water system to adjust operations for changing weather conditions, whether they are low snowpack or abnormal levels of precipitation. This system reoperation not only helps in managing the system for the variations in weather that occur now, but also can be used in the future to adjust to further climate change.[28]

The potential to reoperate reservoirs can also be increased by investments in groundwater storage, downstream channel conveyance capacity and integrated operations of operationally connected reservoir systems.

Saltwater Intrusion Barriers. In many coastal areas, increased seawater intrusion resulting from sea level rise threatens coastal aquifers. In some areas, high rates of groundwater pumping are already drawing saltwater into aquifers, threatening the utility of aquifers and wells. In order to prevent such intrusion, some water districts are injecting freshwater into aquifers to create a saltwater intrusion barrier. For example, Southern California's West Basin Municipal Water District is injecting highly treated wastewater into coastal aquifers. As sea level rise increases, such saltwater intrusion barriers may be increasingly important to protect coastal aquifers. These barriers may be given additional value in the future because of the importance of local groundwater storage as part of wastewater reclamation and stormwater management programs. As agencies expand their use of wastewater reclamation and stormwater management programs to respond to climate change, seawater intrusion barriers may become key tools.

Water Management Tools Relatively Unaffected by Climate Change

In general, the tools discussed in this section are more resistant to the effects of climate change because they do not rely on precipitation, snowpack or other climate-sensitive water sources. During the past several decades, these tools have proven themselves to be highly productive and cost-effective. For example, in California, these tools are expected to be the backbone of efforts to meet future water needs. They will likely become even more valuable in water management portfolios.

Water managers are starting to link major new investments in water conservation to their desire to prepare for potential climate change impacts. For example, Denver Water is addressing the potential effects of climate change by ramping up its water conservation efforts with its recent $400 million conservation plan. This plan is designed to cut annual water use by 22 percent, or 16.7 billion gallons per year, during the next 10 years. Although this plan was initially developed without regard to potential climate change effects upon its system, Denver Water is now seeking to reach this 22 percent reduction goal far

more rapidly in order to further protect water users from climate change impacts. The plan includes new strategies and increased investments in existing conservation programs, such as rebates for low-flow toilets and efficient clothes washers. The plan's new programs include:

• establishing a water efficiency rating program for new construction so that builders who do not meet new standards could find it more difficult to connect to the water system.

• installing water meters for landscape irrigation systems.

• initiating water audits of homes before they are sold, and requiring the replacement of leaking or inefficient plumbing fixtures.

• installing low-flow urinals in new commercial buildings.

The actions in the plan are expected to pay for themselves, through reduced water bills, within six years. Denver water users have already cut consumption by about 20 percent since local drought conditions began in 2002. The plan's first year has been approved by Denver Water's board and executive staff, with an initial $8 million.[29]

Interior Water Conservation. Although climate change is likely to improve the performance of landscape conservation programs, it will leave interior water conservation programs relatively unaffected. Interior water conservation technology, including water efficient showerheads, toilets, urinals, dishwashers and washing machines, will not perform significantly differently as a result of climate change. However, the value of the saved water may increase over time.

Water Recycling. Just as other forms of recycling have become commonplace, wastewater recycling has increased dramatically in recent decades. Today, for example, Southern California recycles approximately 500,000 acre-feet of water annually.[30] (This represents approximately 10 percent of total wastewater generated in this region.) The California Department of Water Resources projects that by 2030, an additional 0.9 million to 1.4 million acre-feet of water recycling will be developed. This still represents a small fraction of total wastewater. One of the advantages of this tool is its resistance to drought effects. Similarly, because the sourcewater supply for water recycling is municipal wastewater, it is far less susceptible to potential climate change impacts than traditional water supply projects.

Groundwater Cleanup and Protection. Although traditional groundwater pumping may be negatively affected by climate change (discussed in more detail in the next section), water projects, such as those in the Santa Ana watershed that are designed to clean up contaminated groundwater, may be less affected (see Integrated Regional Management Case Study: Santa Ana). The relative stability of groundwater cleanup, in the context of global warming, comes from the fact that the purpose of many of these projects is not simply to withdraw water but to comply with regulatory requirements and to create more usable, uncontaminated groundwater storage capacity. Where groundwater cleanup is intended to provide opportunities for conjunctive use, water managers should pay careful attention to the potential impacts of climate change on the source of water to be stored.

Water Management Tools That May Perform Poorly in the Future

The water management tools that are most likely to be negatively affected by climate change are those that rely primarily on historical precipitation, runoff, and recharge patterns, including both groundwater and surface water sources.

Traditional Groundwater Extraction. As discussed above, some analyses suggest that climate change may lead to significant reductions in groundwater. Shorter periods of high streamflows may decrease percolation, while longer, hotter summers are likely to decrease soil moisture. Therefore, projects that rely on traditional pumping of natural infiltration of precipitation could suffer a loss of yield in the future. In already overdrafted areas, this impact could increase competition for groundwater resources. We have not identified conjunctive use, the combined use of surface and groundwater systems, including active groundwater recharge, as a separate category in this report. Climate change impacts on conjunctive use projects will be determined in significant part by the source of stored water. Conjunctive use projects designed to rely on current snowpack or traditional river diversions may be negatively affected by climate change; however, conjunctive use projects using recycled wastewater may not be affected. Conjunctive use projects in low elevation coastal areas may be negatively affected by sea level rise.

The Conservation Technology Edge: A Water Management Tool That Will Be Increasingly Important in the Face of Climate Change

Conservation will remain a highly effective water management tool in a climate-altered world. Because climate change may make snowpack-based supplies and diversions less reliable over time, the advantages of new supplies produced by technological innovation should increase. The water sector analysis of the National Assessment of the Potential Consequences of Climate Variability and Change confirms this finding: "Evidence is accumulating that such improvements can be made more quickly and more economically, with fewer environmental and ecological impacts, than future investments in new supplies." Conservation tools have been central to the significant progress made in Los Angeles, the San Francisco Bay Area, Seattle, and Denver to meet the needs of growth without increasing water use (see Appendix B).

Innovation and technology development in the areas of end-use water applications have progressed rapidly in the past few decades. Techniques and technologies from laser leveling of fields and high-efficiency irrigation systems to the design of toilets, urinals, and showerheads have changed the demand side of the equation. Efficiency standards and code requirements have been particularly effective in promoting widespread application of these water saving technologies. End-use applications of water now require much less volume than before to provide equivalent or superior services, and uses of these new technologies often provide immediate economic savings.

These analyses of conservation potential are based on existing technology. Despite significant investments in conservation already, considerable potential remains. In California, 2.5 million toilets have been replaced with high-efficiency models since 1992. There's still room for expansion, with approximately 10 million low-efficiency toilets remaining to be replaced.

The impetus for technological development and innovation in efficient use comes from both price signals and policy. As water gets more expensive and because legal requirements are enacted prohibiting waste and limiting extraction from natural systems, technology has provided a wide range of options for expanding the benefits derived from a given amount of water. Broader application of these techniques will yield significant new supplies and innovations are likely to create improved water conservation technologies. The waterless urinal represents an example of such a relatively recent innovation. It is reasonable to anticipate that ongoing technological innovation will continue to expand the potential benefits of water conservation. In addition, collaborations among agencies with different missions (e.g., water and energy) are expanding water conservation efforts. In short, water use efficiency programs have several significant advantages that are likely to grow over time as a result of collaborations among agencies, technological innovation, and the direct and indirect effects of climate change.

Sources: California State Water Plan, Department of Water Resources, Vol. 2, p.16.1. http://www.waterplan.water.ca.gov/docs/cwpu2005/

Gleick, Peter H. et al., 2000. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States.* The report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program, Pacific Institute for Studies in Development, Environment, and Security.

Gleick, Peter H., Dana Haasz, Christine Henges-Jeck, Veena Srinivasan, Gary Wolff, Katherine Kao Cushing, and Amardip Mann, November 2003. *Waste Not, Want Not: The Potential for Urban Water Conservation in California.* Pacific Institute.

Finally, conjunctive use projects designed to take advantage of floodplain restoration, storing and infiltrating high flows, may be an increasingly important tool in the future. Water managers should evaluate local conditions to understand the implications of climate change on local groundwater resources.

Traditional River Diversions. Declining snowpack, receding glaciers, increased evaporation, flood control requirements, more frequent droughts, reduced dry-season runoff, and potential reductions in total runoff could render surface water diversion projects less reliable in the future. For example, the Canadian city of Calgary has concluded that the melting of glaciers as a result of climate change could reduce the long-term yield of its surface water supply.[31] Colorado River water users are increasingly concerned about reduced flows and loss of stored supplies to evaporation, due to climate change.[32]

Changes in river hydrography expected as a result of global warming will likely result in alterations in stream-

flows and a direct reduction in water supply reliability. The most obvious impact in this regard is the increase in peak flows and the reduction of dry season streamflows.

The environmental impacts of climate change could exacerbate impacts on the reliability of surface water diversions. As discussed in Chapter 2, climate change could lead to environmental impacts including increased stream temperatures, exacerbated water quality problems and damage to sensitive and listed species—impacts likely to result in more requirements to protect aquatic resources, and greater competition for and conflict over surface water resources.

In addition, as rivers approach the ocean, climate change-driven sea level rise could result in a serious reduction in the reliability and cost-effectiveness of traditional river diversion projects. This has serious implications for coastal communities that rely on low-elevation surface water diversions or on groundwater diversions with a direct connection to surface waters. The Sacramento–San Joaquin Delta is an example of an area vulnerable to these potential effects.

Traditional Surface Storage. Although dams are central to water supply in the West, they have often led to high-profile, protracted policy conflicts. This is true of proposed dams on the Colorado, Yellowstone, Green, Missouri, Platt, Tuolumne, Stanislaus, and American rivers. There are cases in which new surface storage projects have generated significantly less conflict, particularly when the surface storage system is well designed, such as in the case of the existing Los Vaqueros Reservoir in the eastern San Francisco Bay Area. This off-stream project was designed to improve water quality and provide emergency supplies and was seen by many as having fewer environmental impacts than traditional surface storage development.[33,34] However, most dam sites have high financial and environmental costs, with low potential water supply yields. Given the high capital cost of surface storage projects, water managers should consider how climate change will affect this water management option.

> **"Immediate prospects for major new water supply reservoirs or inter-basin transfers are limited. Consequently, new water project prototypes that emphasize conservation, landscaping, new technologies, and other measures are being promoted across the West."**
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> Source: Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability*. National Research Council, p.96.

Western dam operators could face increased challenges from seven potential climate-related impacts: reductions in reservoir inflows, increases in the percentage of precipitation falling as rain, rather than snow (and related increases in flood control requirements), decreased snowpack, more severe weather events (both droughts and floods), greater environmental requirements, increased evaporative losses from reservoirs and increased spills from existing reservoirs.

Potential climate change impacts have been cited by some agricultural water agencies as justification for more surface storage facilities.[35] Some new surface or groundwater storage may be developed in the West to cope with the challenges presented by climate change. However, it is important for water managers to recognize that, just as climate change can reduce the yield of existing reservoirs, it can also reduce the potential water yield of new dams.

Although site-specific analyses will be required to evaluate potential climate change impacts on proposed new storage facilities, particularly in highly engineered watersheds, some general conclusions are clear. In relatively undeveloped watersheds, a shift toward more rainfall and less snowpack is likely to reduce the yield of most new proposed dams. With shorter high-flow periods, the window for filling off-stream storage facilities could be shorter in the future. Potential reductions in total streamflows as a result of climate change could have profound implications for new surface storage projects. Frequently, new surface storage facilities utilize junior water rights in a river basin. If climate change reduces average total runoff in a basin, water managers could find themselves in a position where they have constructed a new surface storage facility to capture runoff that may be lost in the future as a result of climate change impacts.

In highly engineered watersheds, the potential interactions of existing and proposed facilities can be complex. For example, the climate change effects listed earlier could reduce potential yield from a proposed new storage facility but at the same time, increased climate-driven spills from existing dams could increase the amount of water that could be captured by a new facility.

Finally, surface storage projects in some river systems could face increased operating restrictions to mitigate for the environmental impacts of climate change. The most likely additional operating restrictions include flow

Summary of Potential Climate Change Impacts on Potential New Traditional Surface Storage Facilities

Climate Change Impacts that Could Reduce Potential Yields from New Traditional Surface Storage

- potential decreases in total annual runoff
- decreased late-season runoff, as a result of reduced snowpack
- increased winter runoff, as a result of greater rainfall, increasing spills and flood control storage requirements
- more extreme weather events (droughts and storms)
- increased evaporative losses from reservoirs.
- potential new environmental requirements regarding flow and temperature

Climate Change Impacts that Could Increase Potential Yields

- increased uncaptured spills from existing storage facilities

and temperature requirements. Such requirements could decrease the expected water supply yield of existing and proposed surface storage facilities.

The authors of this report are not aware of any proposed new surface storage facilities that have undergone a comprehensive analysis mentioning the seven factors addressed above. It is likely in many cases that estimates of potential yields from proposed new surface storage projects will be reduced when climate impacts are considered. As a result, these projects, already expensive today, could be more expensive per acre-foot of yield, when future climate change impacts are considered. The potential impact of climate change on new surface storage facilities should be carefully evaluated.

This report is not the first to suggest diminishing prospects for traditional surface storage development in the West and an increase in alternative approaches. For example, the National Research Council's 2007 report on Colorado River basin hydrology observed that "(t)he declining prospects for traditional water supply projects are perhaps more correctly seen not as an end to 'water projects', but as part of a shift toward non traditional means for enhancing water supplies and better managing water demands."[36] The report went on to state that "(i)mmediate prospects for major new water supply reservoirs or inter-basin transfers are limited. Consequently, new water project prototypes that emphasize conservation, landscaping, new technologies, and other measures are being promoted across the West."[37]

Desalination. Evaluating the performance of desalination in the context of climate change raises issues different from those raised by other water management tools and some of these emerging issues support different conclusions. Ocean water, the source for many proposed desalination projects will be far less affected than freshwater sources by climate change. However, water managers making decisions on siting and design for coastal desalination facilities should carefully consider the likelihood of significant sea level rise as a result of climate change. For water managers in coastal areas with existing water systems that could be negatively affected by climate change (e.g. those that rely on snowpack and rivers), the reliability of seawater desalination could be an important consideration.

However, desalination raises another significant issue in the context of climate change. As discussed in Chapter 3, ocean water desalination is a very energy intensive water supply option. Indeed, energy is the primary operating cost of ocean water desalination facilities. Climate change prevention efforts are likely to result in a dramatic increase in efforts to reduce energy consumption, in order to decrease greenhouse gas emissions. Thus, a dramatic increase in energy-intensive seawater desalination facilities raises significant issues in the context of climate change. In addition, because of its high energy requirements, seawater desalination is also particularly vulnerable to any future energy price fluctuations.

Although climate change will not have the same impact on this tool as it is likely to have on water management tools that rely on rivers, historical groundwater recharge and snowpack, consideration of climate change raises serious concerns regarding the energy implications of desalination. Energy requirements of desalination have declined significantly in the past decade, largely as a result of the improvement of membrane technology for reverse osmosis plants and improvements in pressure recovery.[38] In addition, desalination of less saline sources, such as brackish and contaminated groundwater, requires significantly less energy. Efforts to reduce greenhouse gas emissions will raise additional issues regarding desalination. This climate change-related implication for desalination is less direct than the impacts affecting the other tools discussed in this section. As technology improves, this con-

cern will lessen. In fact, if the energy required for ocean desalination declines by a relatively small amount, some Southern California water agencies could save energy by substituting ocean water desalination for diversions from the Bay-Delta estuary.

Integrated Regional Water Management Planning

Many of the tools discussed above—water conservation, wastewater reclamation, and stormwater management—offer potential benefits to other public entities, including wastewater and stormwater agencies, energy utilities, and

Six Concerns Regarding Surface Storage Analyses

In some cases, project evaluation methodologies have exacerbated controversies around proposed surface storage projects. Future evaluations of surface storage projects should address these issues. Problematic approaches in past dam feasibility studies include:

1. Projections based on historical hydrology: Traditional water development has not considered the potential impacts of global warming on future hydrology. The case of the Colorado River shows how important assumptions regarding future hydrology can be. On the Colorado River, a relatively short hydrologic record led water managers to conclude that the river's long-term average flow would be higher than it has proven to be. As a result, the Colorado River Compact assumed that river flows would average 17 million acre-feet. In fact, average flows have proven to be less than 15 million acre-feet.This discrepancy has significantly increased conflicts on the river. With additional climate change impacts, reliance on historic hydrology will be even riskier.

2. Lack of demand side analysis: The supply side approach has traditionally focused on increasing supply through dams and diversions. Demand management and alternative approaches, which can be less expensive and environmentally damaging, have often been overlooked or their potential underestimated. Addressing both supply and demand side strategies—and comparing all available tools on a level playing field—is a key feature of an integrated approach to water management planning.

3. Flawed economic analysis: Some surface storage studies, particularly those undertaken by the federal government, have failed to include credible economic analysis. For example, the U.S. Bureau of Reclamation is currently studying a potential surface storage project in California's upper San Joaquin River basin to provide additional supply for agricultural water users. Water from this facility is likely to cost far more than the new water supply would be worth to the agricultural community. When the Bureau of Reclamation last studied a surface storage project in this region, the agency concluded that raising Friant Dam would produce water costing approximately $3,000 per acre-foot-twice the cost of desalinated seawater and approximately 100 times the cost of water provided by federal water contracts in the region. Recent analysis of Auburn Dam by the Bureau of Reclamation revealed lower water yields and a significantly higher cost than had been previously estimated.

4. Subsidies that encourage waste: In many water projects, a reliance on subsidies and artificially low water prices encourage under-investment in efficiency and over-use of water resources. Supply-side subsidies skew water management plans against conservation programs. These subsidies have, historically, been focused primarily on dramatically lowering costs for agricultural water users.

5. Underestimates of environmental damage: There is a long history of promises regarding environmental benefits from dams. However, dam building has a clear record of negative impacts on the environment. For example, 60 years ago, Friant Dam in California was authorized, in part, due to claimed benefits to the San Francisco Bay-Delta. In practice, Friant Dam has resulted in severe degradation of water quality and fisheries.

6. Unrealistic anticipated benefits: For many dam projects, a portion of the cost has been written off (i.e. paid by taxpayers rather than water users) because of claimed environmental, recreation, or other benefits. These benefits have frequently proven to be illusory.

Sources:

http://www.sciencedaily.com/releases/2006/05/060529082300.htm.

Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007.

Department of the Interior, Bureau of Reclamation Mid-Pacific Region, Fish and Wildlife Service, October 1995. "Least-Cost CVP Yield Increase Plan," pp.III-41, III-51.

Bureau of Reclamation Mid-Pacific Region, December 2006. "Auburn-Folsom South Unit Special Report: Benefits and Cost Update."

local governments. These approaches are also often less centralized and less capital-intensive than traditional water development. Integrated regional water management offers the potential to maximize the benefits from these new tools.

Wastewater, stormwater, and conservation programs are often best implemented through collaborations among agencies. Where a water supply agency does not have wastewater or stormwater responsibilities, designing and implementing climate change response strategies in these areas will require interagency collaboration. In addition, water conservation offers significant energy benefits, inviting the participation of energy utilities and state agencies with energy regulatory and planning responsibilities. Finally, water conservation and stormwater management programs can benefit greatly through the participation of local governments with land-use authority.

Agencies with different missions do not always share identical service boundaries, creating a potential obstacle to interagency efforts. In many cases, this obstacle can be overcome by bringing together multiple agencies on a regional basis. Such an integrated regional approach can offer broad benefits. Integrated regional water management is emerging as a particularly important strategy. The 2005 California State Water Plan identifies integrated regional water management as an initiative co-equal with statewide water management planning efforts.[39]

California's Proposition 50, The Water Security, Clean Drinking Water, Coastal and Beach Protection Act, and Proposition 84, which were approved by the voters in November of 2002 and 2006 respectively, provided a total of $1.5 billion in general obligation bond financing for integrated regional water management efforts across the state. This new direction represents a decreased reliance on large traditional water projects and on state and federal agencies to guide planning and decision making. Increasingly, innovative thinking is showing how integrated regional strategies can supplement traditional statewide and federal planning.

Integrated regional planning has several advantages. It encourages collaboration among the diverse agencies in a particular region. As in the case of the projects in the Santa Ana watershed to clean up contaminated groundwater and generate electricity through "cow-power" (see Integrated Regional Management Case Study: Santa Ana), an integrated approach can reveal opportunities that cannot be implemented without cooperation among stakeholders and agencies. It tailors strategies to meet unique local needs. It can maximize the potential for multiple funding partners and multiple benefits, including reduced dependence on water supplies vulnerable to climate change impacts, reduced urban runoff pollution, groundwater cleanup and improved groundwater management, flood damage reduction, ecosystem restoration, energy conservation, and public education. And integrated regional planning offers the potential for water managers to address, in one program, multiple stresses facing current water supplies. These include population growth, land-use changes, contamination of surface and groundwater resources, and the need for ecosystem protection and restoration.

Moreover, an integrated approach can increase system flexibility. The massive investment required for a traditional water project can be highly inflexible because, if the construction cost of such a water project proves to be higher than expected, water managers with a partially constructed project cannot redirect investments, without losing the yield of the entire project. These large projects create a significant sunk cost risk. By contrast, investments in an integrated portfolio of conservation, reclamation, and stormwater projects, all of which can be scalable and less capital-intensive, can be more easily redirected to respond to changing conditions or to adjust for an underperforming water management tool.

Effective integrated planning can require the use of many water management tools, with varying potential benefits in different regions. For example, without debating the merits of desalination in general, we can examine how desalination might fit into an integrated regional strategy. In Southern California's Chino Basin, desalination is being used to clean up contaminated groundwater, thus fixing an existing problem and generating water supply reliability and wetland restoration benefits. In San Diego, desalination, although energy intensive and expensive, could provide high quality water that could be blended with existing supplies, facilitating energy-conserving wastewater reclamation programs. In contrast, on California's Central Coast, seawater desalination could be highly growth-inducing, leading to urban sprawl, with potentially serious environmental impacts. The implications of this technology and the case for public funding can be very different in different regional settings.

Integrated Water and Energy Management

Integrated water management efforts should pay particular attention to energy issues. Managing and using water more efficiently can reduce related energy requirements and greenhouse gas emissions. Efficiency as used here

Integrated Regional Management Case Study: The Santa Ana River Watershed

Water managers in Southern California's Santa Ana River watershed are leaders in designing integrated regional water management strategies, relying on an array of tools to produce a wide range of water management and environmental benefits.

The Santa Ana River drains 2650 square miles and runs 100 miles from the peaks of the San Bernardino Mountains to the beaches of Orange County. Five million people live within this "Inland Empire" watershed, a population that is expected to double within 50 years.The watershed is also home to the world's densest populations of cows, a fact that surprises most outsiders. At its peak, the basin held more than 300 dairies, with up to 400,000 head of cattle, operated in less than 220 square miles of the upper part of the watershed—the Chino Basin. These cows produce 1 million tons of manure per year and another 2 million tons of manure currently sit on dairy lands. Runoff from these dairies has contaminated one of Southern California's largest groundwater sources with salts, dissolved solids and nitrates.

Urbanization, dairy operations, habitat destruction and other activities have taken a toll on the Santa Ana River's ecosystem. Today, some of the river's residents, including the Santa Ana sucker, the Least Bell's vireo and the southwestern willow flycatcher, are listed under the Endangered Species Act.

In 1968, local water agencies formed the Santa Ana Watershed Project Authority (SAWPA) in order to develop an integrated approach to address the challenges discussed above. After decades of effort, this integrated approach includes strategies such as water conservation, wastewater reclamation, and storm water infiltration. What makes the SAWPA case study so interesting is that it shows how multiple problems can be addressed simultaneously.

The juxtaposition of the local dairy industry with growing cities has created challenges—and opportunities—for local leaders. The Inland Empire Utility Agency (IEUA) is diverting dairy waste for composting and marketing to agricultural users. The methane derived from anaerobic digestion of this waste is used to generate renewable electricity. Thus, by diverting dairy waste and reducing ongoing groundwater contamination, IEUA has created a new energy source and a marketable compost product.

The value of new water sources, as well as regulatory and legal pressure to clean up groundwater contamination have also led IEUA to construct two groundwater desalters, which use desalination technology to clean up contaminated groundwater. (Desalting groundwater requires far less energy than desalinating seawater.) The two desalters have a combined capacity of more than 23 million gallons per day.These facilities provide usable water supply and help remediate contaminated groundwater basins. Agencies in the watershed are also recharging the basin's aquifers using storm water runoff and recycled wastewater.

The energy and climate benefits of this integrated approach are also notable. By reducing reliance on energy-intensive imported water (see discussion in Chapter 3), IEUA is able to reduce the electricity consumed to meet water supply needs. In addition to avoiding energy and other costs associated with imported water supplies, increasing local supplies reduces pressure on stressed ecosystems such as the San Francisco Bay-Delta. IEUA has also built a new energy-efficient headquarter building that has received a platinum certification from the U.S. Green Building Council's LEED program. The building uses waste heat to reduce heating and cooling costs, and photovoltaic cells to generate electricity.

The benefits of SAWPA's integrated approach are impressive, including:

- creation of local drought-proof water supplies.
- reduced reliance on imported water supplies that are vulnerable to environmental constraints and climate impacts.
- reductions in groundwater contamination
- flood management improvements
- enhanced wetlands
- marketable organic composed dairy waste
- improved air quality
- renewable energy generation
- reduced energy use and greenhouse gas emissions
- marketable greenhouse gas credits

The roots of this effort are more than three decades old. Climate considerations did not lead SAWPA and IEUA to launch this integrated regional effort. However, the energy and climate benefits of their approach are significant. The integrated approach reduces the vulnerability of the region to water supply impacts from climate change. It also shows how water utilities can make cost-effective contributions to efforts to reduce greenhouse gas emissions, through water and energy conservation, wastewater reclamation, better groundwater management and renewable electricity generation.

This integrated approach demonstrates how far water management has come from the days when dams and increased water diversions were the all-purpose solutions to meeting water supply needs. In California, the SAWPA effort has become a model for other integrated efforts around the state.

Sources: Santa Anna Integrated Watershed Plan, 2005 Update, Santa Anna Water shed Project Authority, Riverside, CA, June 2005.

Atwater, Rich and Paul Sellew. "Organics management, clean water and renewable energy: Focus on California." *BioCycle: The Journal of Composting & Organics Recycling*, February 2002.

http://www.ieua.org/desalter.html.

The LEED program itself reflects an integrated approach to green building. IEUA was able to use its institutional strengths to design on-site stormwater recharge facilities and to locate the headquarters building adjacent to a wastewater treatment plant, in order to provide renewable energy from its digesters and reclaimed water for use on site. The design reduced potable water demand by 73 percent and energy use by 90 percent.

describes the useful work or service provided by a given amount of water. Significant economic and environmental benefits can be cost-effectively achieved through improving water system efficiency. The energy/water nexus will make water conservation programs more attractive to agencies planning a response to climate change. In particular, as greenhouse gas emission reduction programs increasingly emphasize energy conservation, water agencies are likely to find additional benefits from more fully integrating energy and water management. Taking both

12 Elements to Consider When Designing an Integrated Response to Climate Change

When evaluating options for responding to the water management challenges presented by climate change, water agencies should consider the benefits of comprehensive integrated regional water management planning (IRWMP). Such strategies should incorporate the following elements:

1. Climate Impacts on Existing Systems and Future Strategies. Water agencies should analyze the potential impacts of climate change on existing facilities and on the tools under consideration to meet future demands.

2. Unique Regional Conditions. A careful examination of regional conditions will reveal challenges and suggest unique opportunities for future strategies to produce multiple benefits.

3. Evaluation of Multiple-Benefits and Funding Partners. IRWMP can provide potential multiple benefits and attract new funding partners to address water, energy, and environmental challenges.

4. Efficiency First. In most cases, greater investments in water-use efficiency are cost-effective and environmentally preferable—and result in significant energy savings. California electricity utilities recently adopted a "loading order" that requires investments in efficiency as a first priority before additional supply-oriented power strategies are pursued.[54] Water utilities should consider adopting a similar approach in response to anticipated climate change impacts.

5. A Full Range of Water Supply and Demand Options. All of the many supply and demand-side water management options should be considered in designing an effective response to climate change.

6. A Full Range of Flood Management Options. Land use controls, setback levees, floodways, and other floodplain management techniques are likely to become increasingly important flood management tools in the future. Given the high cost of new surface storage facilities and levees, and the residual flood risk for communities behind levees (e.g., pre-Katrina New Orleans), decision makers should encourage appropriate land use in floodplains to reduce risk to life and property.

7. Clear Objectives and Performance Standards. In order to evaluate the costs and benefits of alternative strategies, water managers should include clear objectives and performance standards to evaluate all tools on a level playing field.

8. "With-and-Without Project" Baseline Analysis. Analysis of proposed surface storage projects and other large infrastructure investments should include an accurate baseline and a clear "with and without project" analysis. Such analysis can help avoid stranded investments.

9. Economics and Cost-Based Financing. IRWMP should include careful evaluation of the economic costs and benefits of alternative strategies. Financing plans in which beneficiaries, rather than taxpayers, pay for the benefits they receive will provide incentives to ensure cost-effective investments.

10. Enforceable Environmental Protections. IRWMP efforts to restore and enhance the aquatic environment should take the form of specific, enforceable commitments.

11. Institutional Capacity. IRWMP will benefit from efforts to strengthen particular disciplines, including economics, climate-related expertise, and designing interagency partnerships.

12. Outreach to the Public and Decision Makers. IRWMP efforts to educate the public will increase public acceptance of investments to address climate-related problems. Agencies preparing plans to respond to climate change should also encourage decision makers to take prompt action to lessen future climate change-related impacts by reducing greenhouse gas emissions.

Together, the above recommendations represent a new approach to the foreseeable water management impacts of climate change. Though this approach is a dramatic departure from historic water project planning efforts, it is based on the experiences of water agencies around the West. This integrated regional approach can produce water supply, water quality, environmental, and other water management benefits, as well as greenhouse gas reduction and other societal benefits.

resources into account will improve the cost-effectiveness of water use efficiency programs, allowing, for example, higher rebates that should result in greater participation. Eventually, greenhouse gas reduction programs are likely to generate new opportunities for funding and revenue for water agencies that master the connections between energy and water.

The energy intensity of water varies considerably by source, geographic location and end use. A number of water management entities, government agencies, professional associations, private-sector users, and non-governmental organizations have already demonstrated potential savings in the area of combined end-use efficiency strategies:

• *Water-efficiency improvements:* Implementing cost-effective water efficiency improvements can generate significant energy savings. For example, in some areas, water, and energy utilities have designed joint rebate programs for appliances that save water and energy (e.g. washing machines). Some efficiency improvements can result in direct energy savings for water districts. For example, most of the electricity use in water and wastewater treatment plants is for pumping. Programs that reduce the volume of wastewater can result in significant energy savings for agencies with treatment plants. In addition, water conservation efforts that reduce peak water use can also reduce energy consumption, thus reducing peak energy demands as well.

• *Operations-efficiency improvements:* Energy management benefits can also be obtained by improving pumping equipment and operational control systems at existing facilities, including the use of high-efficiency motors and adjustable-speed drives, efficient pumps, and effective instrumentation and controls. In many applications, these measures can be implemented with payback periods of three years or less.[40]

Response Strategies for Addressing Other Water Resource Impacts

Climate change will have direct effects on water supply resources as discussed in the sections above. However, impacts to water supplies will be compounded by indirect effects that climate change will have on other water resources including aquatic ecosystems and flood management. It is essential to understand and address these important water resource in order to formulate an effective response plan to minimize water supply impacts.

Goods and Services of Aquatic Ecosystems

Water supply
Drinking, cooking, washing and other household uses
Manufacturing, thermoelectric power generation and other industrial uses
Irrigation of crops, parks, golf courses, etc.
Aquaculture

Supply of goods other than water
Fish
Waterfowl
Clams, mussels, other shellfish, crayfish
Timber products

Nonextractive benefits
Biodiversity
Transportation
Recreational swimming, boating, etc.
Pollution dilution and water quality protection
Hydroelectric generation
Bird and wildlife habitat
Enhanced property values
Coastal shore protection

Source: Pew Report on the Climate Effects on Aquatic Ecosystems.

Aquatic Ecosystems

Climate change will likely have significant impacts on riverine and estuarine ecosystems throughout the West, diminishing the wide array of societal benefits these ecosystems provide. As water managers consider how to respond to climate change, they should evaluate the need to manage and protect aquatic systems to maintain these benefits. In the West, water supply has often been prioritized over competing concerns, resulting in a loss of other benefits—particularly environmental benefits. As a result, many western rivers have been degraded to the point where species have been listed as threatened or endangered.

Today, the public seeks—and environmental laws require—a better balance among beneficial uses, and water managers must help find that balance. Water resource managers and the public share a mutual interest in addressing the impacts of global warming on aquatic ecosystems, in order to reduce future conflicts such as

> **"The manner in which humans adapt to a changing climate will greatly influence the future status of inland freshwater and coastal wetland ecosystems. Minimizing the adverse impacts of human activities through policies that promote more science-based management of aquatic resources is the most successful path to continued health and sustainability of these ecosystems. Management priorities should include providing aquatic resources with adequate water quality and amounts at appropriate times, reducing nutrient loads, and limiting the spread of exotic species."**
>
> Source: Pew Center on Global Climate Change, Aquatic Ecosystems and Global Climate Change: Potential Im*pacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States*, 2002.

those that have occurred on the Klamath, Rio Grande, and other rivers.

Around the West, many water managers have been leaders in implementing practices that can minimize the effects of climate change and help preserve the health of aquatic ecosystems. These practices include:

Protecting the Ability for Aquatic Species to Adapt to Changing Conditions. Species naturally seek out conditions favorable to their survival and success. In a warmer climate, some aquatic species experiencing increased stress will try to move higher within watersheds to find suitable habitat. Therefore, maintaining or improving conditions necessary for migration within a watershed is critical for the survival of species at the limits of their temperature tolerances. For example:

• Existing water infrastructure has, in many cases, reduced the ability of species to move throughout a watershed. Barriers such as dams and diversion structures should be assessed to determine the potential for improving movement of critical species. In some cases, particularly regarding antiquated infrastructure, retrofitting structures to enable passage, or removing barriers altogether, can allow species to utilize suitable habitat upstream.

• Maintaining free-flowing rivers allows natural migration to take place and helps maintain other physical processes such as sediment transports that are critical for functioning ecosystems. When developing new storage, seek to locate new storage off-stream or utilize groundwater resources.

Restoring aquatic ecosystems. Restoring in-stream, riparian and floodplain ecosystems will increase the resilience of ecosystems to the effects of climate change and other stressors. Aquatic ecosystems where the natural, physical (i.e., sediment transport) and biological processes (i.e., recruitment of new riparian trees) are largely intact will be healthier and better able to support aquatic species, reducing the challenges that managers will face as climate change impacts intensify. Specifically, managers should consider that:

• Restoration of riparian habitat can play a crucial role in mitigating the effects of increased temperatures. Shading from trees reduces water temperatures. Riparian vegetation provides nutrients critical to aquatic species and improves the stability of stream banks, reduces bank erosion, and creates important aquatic habitat. In addition, large trees that fall into streams provide important in-stream habitat, particularly for juvenile salmon and other small fish.

• In many systems, restoration of periodic high flows is vital for maintaining in-stream habitat. High flows, often in the spring, are needed to establish riparian vegetation. Mobilization of sediment in the channel during high flows is essential for maintaining spawning habitat for salmon and trout. High flows also help move out-migrating juvenile anadromous fish downstream. They can also inundate natural floodplains, which are critical for some species to reproduce.

• Restoration of floodplain ecosystems can provide increased flood protection, groundwater infiltration for water supply, and improved water quality by reducing runoff into streams.

Improving Water Quality by Reducing Runoff of Pollutants. Runoff from urban, agricultural and other managed landscapes into rivers and streams can severely impair water quality through discharges of excess nutrients, sediment, and toxic chemicals. Poor water quality can in turn reduce the biological productivity of rivers and stress aquatic species. Increased flows may be required to mitigate adverse water quality impacts, or meet water quality standards. Reductions in polluting runoff can be achieved through a variety of approaches:

• Support practices such as increased use of permeable surfaces that allow infiltration of rainwater. Impervious surfaces can produce up to 16 times the volume of urban runoff compared to natural, permeable surfaces, reducing natural groundwater recharge and moving pollution into waterways. These practices can not only directly support multiple benefits including water quantity and community aesthetics, but can be more cost effect water quality solutions compared to traditional storm water management which relies on wastewater treatment.

• Riparian and floodplain habitats act as buffers between surface water sources and adjacent land uses, by filtering runoff and reducing direct input of pollutants.

• Watershed education programs have been effective at informing people about actions they can take to protect their local rivers and lakes. Water supply and flood management districts have a unique ability to educate their customers about the need to protect the quality of their water supplies.

Managing Water Supply Systems to Meet the Temperature Needs of Sensitive Species. Maintaining the health of aquatic ecosystems while meeting water supply needs will require data collection, analysis and actions to mitigate or prevent temperature impacts on sensitive species. Such efforts include:

• Data collection and computer modeling of seasonal water temperatures downstream of reservoirs to enable water managers to identify potential temperature problems before a crisis occurs.

• Data collection and computer modeling of reservoir temperatures under different operations scenarios to help water managers identify opportunities to reoperate reservoirs in order to preserve cold water for release later in the year, and to minimize potential water supply impacts.

• Retrofitting existing surface storage with flow curtains or installing flow outlets at a range of elevations within the reservoir to help meet water temperature needs downstream.

• Managing local groundwater levels to preserve subsurface inflow of cold water that may be critical to maintaining cold-water habitat for fish. Local groundwater pumping can also harm riparian vegetation that provides temperature and other ecosystem benefits.[41]

Flood Control

The frequency and the size of flood events are expected to increase due to climate change. Water managers are considering the challenge of reoperating reservoirs that serve the dual purpose of flood control and water supply. Because there are competing operational elements between these two purposes, reoperation may result in reduced water supply yield. Flood protection actions downstream of reservoirs, such as levee setbacks, can in some cases reduce the tension that dam operators face in managing for water supply and flood protection.

The most common form of flood protection has been the construction of storage facilities, levees and flood bypasses, but today there are a number of options for improving flood protection that may be more cost effective and provide additional benefits. This section discusses a number of planning considerations as well as structural and nonstructural options for improving flood management in order to address the impacts of climate change. Emphasis has been placed on response measures that not only increase flood protection, but also benefit ecosystem health, water quality, and water supply. Many of these measures may be significantly more cost effective than traditional approaches—particularly over time—because they reduce the potential for flood damage.

Manage Floodplains Knowing that They Will Flood Eventually. Regardless of existing reservoirs or levees, most lands within the floodplain of a river will flood at some point, damaging property and resulting in the potential loss of life. It is not a question of *if*, but rather *when* such floods will happen. However, many local, state, and federal land-use and planning agencies only plan for the 100-year flood event. With climate change likely increasing the frequency and size of peak events, existing flood control systems may not be adequate. As such, the extent to which land uses within the floodplain can be limited to those compatible with periodic flooding will reduce the cost of flood damages and the need for increased levels of protection.

Many cities and counties currently use planning guidelines and zoning requirements to manage development within the floodplain to provide for public safety. Often only areas within the 100-year floodplain are subject to such regulations. Land that is adjacent to a river but protected by a levee built to withstand a 100-year flood event may not be considered to be within the floodplain. Areas deemed to have a 100-year level of protection may not be adequately protected in the future. The California

> **"A reasonably foreseeable flood is a flood event that is realistically probable for a particular area. In many cases, this event could exceed a predicted "100-year" flood... Sources of information on reasonably foreseeable floods may include historic floods, paleo-floods, hydrologic modeling using transposition, historical flood damage data, and hydrologic models."**
>
> Source: California Floodplain Management Report, 2002

Department of Water Resources notes that "during a typical 30 year mortgage period, a homeowner living behind a levee has a 26 percent chance of experiencing a flood larger than a 100 year event. This is almost twice the likelihood of a house fire."[42]

The single most effective flood management strategy is to avoid development in floodplains that is not compatible with occasional flooding.

Plan for More Extreme Flood Challenges. Current climate modeling does not yet provide precise estimates of the degree to which climate change will increase the frequency and magnitude of flood events in any given area. The need to prevent future flood damage and the time required to implement mitigation measures suggests the importance of immediate planning for increases in flood events. Because simply planning for the 100-year flood may not be adequate in the future, water resource managers should therefore plan for the "reasonably foreseeable flood", taking into consideration the hydrologic impacts of climate change among other factors.

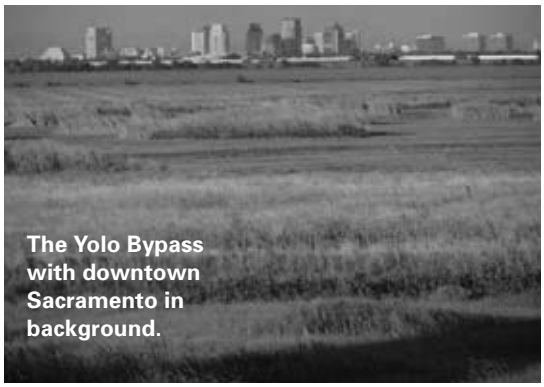
Restore Floodplain Habitat. Traditional flood control projects have been designed to control flows without considering the importance of maintaining floodplains as part of a healthy riverine ecosystem. Floodplain ecosystems provide essential habitat for a multitude of plants, aquatic species, and other wildlife. Lands adjacent to rivers, particularly those subject to frequent or deep flooding should be strongly considered for preservation or restoration as floodplain habitat. In the last several decades, a growing number of flood management projects are incorporated floodplain protection and restoration as a strategy to reduce flood damage and increase ecosystem health.

Promote Flood-Compatible Agriculture. One of the best economic uses of floodplain lands is for agriculture compatible with periodic flooding. Not only does this encourage the preservation of productive agricultural lands, but periodic flooding also replenishes nutrients and soils, reducing the need for fertilizers. In addition, managed inundation of seasonal agricultural lands can provide valuable habitat for wildlife. The purchase of flood easements on private lands being used for flood control can also deliver financial benefits to farmers while creating a more cost effective way of meeting the need for improved flood management.

Build Flood-Resistant Infrastructure. In the valleys of large rivers such as the Sacramento, floodplain areas can extend great distances due to the low slope of the land. Making all of such land off-limits to development may not be necessary or feasible. Where construction occurs in an area that could be inundated to a shallow depth by a reasonably foreseeable flood event, structures should be built to withstand damage by requiring raised foundations or non-inhabited first floors. It is important for decision-makers to acknowledge and for residents to understand

Multi-beneficial Floodplains: The Yolo Bypass

The Yolo Bypass in California's Central Valley is a good example of incorporating agriculture and wildlife habitat into a local flood management plan. In the winter and spring months, the Bypass is employed as a flood control tool that plays a critical role in the Central Valley flood control system including protecting Sacramento and other neighboring cities. When flooded, the Bypass provides valuable habitat for native fish, and a resting stop for migratory birds. During the dry months of the year the Yolo Bypass is farmed with annual crops. Because of the important habitat the Yolo Bypass provides it is home to a national wildlife refuge.



The Yolo Bypass with downtown Sacramento in background.

TSPAULD

that this approach will not eliminate risk as climate change increases the frequency and magnitude of floods.

Expand Flood Insurance. The most common form of flood insurance is obtained through the National Flood Insurance Program (NFIP). NFIP makes flood insurance available to communities that have enacted ordinances requiring, among other things, that all new construction have its lowest floor elevated at or above 100-year flood elevation. Under federal law, flood insurance must be purchased when obtaining a federally backed loan for a home within the Flood Insurance Rate Maps 100-year floodplain. But it is well recognized that these maps are often out of date and do not include areas that are within the 100-year floodplain due to the existence of levees. Cities and counties should assess the adequacy of their flood mapping based on existing and likely future flood hydrology. Additionally, all homes and businesses in areas at risk of flooding in a reasonably foreseeable flood event should be required to have flood insurance, particularly if they would be at risk of flooding to significant depth in the event of a levee failure.

Floodplain Mapping: The Need for Further Information

The West is growing rapidly and millions of people will be living in areas with the potential to flood. Yet many communities do not have the necessary information to determine the risk or the type of flooding they face. Floodplain mapping involves analyzing the hydrology of flood events of varying sizes and then charting what areas are likely to flood given current flood protection. Programs such as the Flood Insurance Rate Maps are essential tools in enabling cities and counties to make informed management decisions. They also help ensure that development within floodplains is sufficiently protected. Cities and counties, in coordination with state and federal agencies, should ensure that floodplain mapping is adequate by using updated hydrological information that reflects reasonably foreseeable flood events. Development, especially the increase in impermeable surfaces, can significantly alter natural hydrology, increasing downstream risks. Therefore, mapping should also incorporate the flood impacts related to past and future development within the watershed.

Improve Monitoring, Forecasting, and Early Warning Systems. Collection of river and streamflow data is a critical component of water supply and flood management. To adequately manage rivers and meet ecosystem needs, water officials rely on streamflow data taken at all times of the year. Data collected during storm events is particularly relevant. Because every year is different, long records of data collection are extremely valuable in predicting future flows and rare high-flow events. Streamflow gauging is also an essential tool for developing early warning systems as part of evacuation plans that can both reduce flood damages and the loss of life. Unfortunately, recent cuts in federal spending have decreased the number of gauges throughout the West, undermining water resource managers and those responsible for public safety and ecosystem health. As climate change alters current hydrology, a robust stream gauge system will be essential to assist water managers and other decision makers.

Watershed and meteorological conditions vary greatly depending upon place, so no single strategy or suite of strategies will be appropriate for all locations. As a result, land-use planners and water resource managers should consider all options. They should also give priority to the response measures which are most cost effective, provide the most multiple benefits, and are easiest to implement given cost and political considerations.

PREVENTION

Decision makers in the West have traditionally looked to water leaders, particularly those from rapidly growing urban areas, to inform them about problems related to water supply, and to develop solutions. The scope and extent of potential worst-case climate change impacts, ranging from lost snowpack to rising sea levels, could result in serious challenges for water managers. As in the case of the gasoline additive methyl tertiary-butyl ether MTBE (see The MTBE Story: Urban Water Agency Leadership) the wisest course for water managers is to be proactive, to reach out to decision makers and the public, and to encourage preventative action. Regarding climate change, prevention means comprehensive, ambitious, and prompt action to reduce greenhouse gas pollution. Such actions could have profound benefits for water management for decades to come.

The MTBE Story: Urban Water Agency Leadership

Perhaps the best example of proactive action by water managers in responding promptly to threats to urban water supplies is the effort to address the contamination of groundwater by the gasoline additive methyl tertiary butyl ether (MTBE). Water agencies were on the forefront of efforts regarding MTBE contamination long before regulatory agencies took action regarding this suspected carcinogen. A decade ago, urban water managers became aware of the threat posed by MTBE contamination to water supplies. MTBE threatened thousands of wells across the country in places where this gasoline additive had leached into groundwater.

Instead of waiting for regulators to assess the scope of the problem and design a response, water managers proactively educated the public and decision makers about MTBE's sources, potential health impacts, and potential costs to water agencies. They took the lead in urging regulatory agencies and legislators to address the threat posed by MTBE. Water agencies also opposed oil company efforts to obtain a congressional waiver of liability. The consensus regarding MTBE among water managers led to the involvement of the American Water Works Association (AWWA). Thanks to water managers, states began banning MTBE, reducing future contamination—and future costs—far more rapidly than would otherwise have been the case. The MTBE case illustrates the impact that proactive water managers can have on public education and prevention on critical water issues.

There were several reasons for this decision to take a leadership role in the MTBE debate. The scientific evidence regarding MTBE contamination was clear. The water management implications of MTBE were serious in terms of public health, the contamination of existing water supplies, and economic costs. Regulatory agencies were slow to respond to the problem when action by policymakers could have had a major impact. And finally, water managers are respected community leaders; decision makers and the public look to them for information about serious water-related problems. Each of these factors now applies in the case of climate change.

For many of the same reasons as the MTBE case, water managers should take the lead in advocating climate change prevention measures.

This would not be the first time that water managers have taken the lead on water management issues without waiting for intervention by regulatory agencies. In December 1991 in California, urban water agencies and environmental organizations signed a memorandum of understanding regarding urban water conservation. This landmark agreement included 14 best management practices for urban conservation. Membership in the California Urban Water Management Council has now grown to 354 members.[43] These urban water agencies could have waited for the state legislature or regulatory agencies to mandate conservation efforts. Although the state has raised significant concerns regarding the pace of implementation of the best management practices, this agreement remains a significant pro-active step.[44]

Western water agencies and other decision makers with water management responsibilities have already demonstrated a broad approach as they begin to reduce climate change impacts. The pace of action to prevent future damage from climate change is accelerating dramatically. Concerns about water impacts are a significant factor in these developments, and water managers are beginning to take clear, action to help prevent climate change. This section provides a brief survey of best practices regarding these actions at the local, state, regional, and national levels.

Action at the Local Level

Although reducing the future impacts of climate change will require action at all levels of government, steps taken at the local level can result in innovative approaches to prevention, and can point the way to broader action. Several examples of such local action are cited here.

Action by Individual Water Agencies

Some water agencies are laying the groundwork for programs to reduce their greenhouse gas emissions. For example, the East Bay Municipal Utilities District (EBMUD) is working to minimize the district's climate change footprint. EBMUD is the first water district to join the California Climate Action Registry. As a member of the registry, EBMUD pledges to annually track, report, and certify its greenhouse gas emissions. The district has also replaced nearly its entire passenger vehicle fleet

with electric-gas hybrids and installed microturbine and photovoltaic systems on the roofs of its two main offices to power business operations. EBMUD was recently awarded the Environmental Protection Agency's Green Power Leadership Club award for exemplary green power production—the first water/wastewater agency to receive this honor. (See Appendix A for a detailed discussion of EBMUD's approach to climate change.) Since EBMUD joined the registry, more than a dozen California water agencies have joined as well as Seattle Public Utilities and the Salt River Project.

Public/Private Partnerships

In some areas in the West, water agencies are collaborating with local businesses to address global warming. The Santa Clara Valley Water District's (SCVWD) partnership with Sustainable Silicon Valley is an excellent example. Formed in 2001, Sustainable Silicon Valley (SSV) is a collaboration of businesses, government agencies, and nongovernmental organizations aimed at addressing environmental and resource pressures in the San Francisco Bay Area's Silicon Valley.[45] SSV is working towards a goal of reducing regional carbon dioxide emissions to 20 percent below 1990 levels by 2010.

To meet the goal, the partnership is focusing on energy efficiency, fuel efficiency, and increased use of renewable energy. This partnership with high technology firms reveals an understanding of the need to take action to prevent climate change and of the opportunities for businesses pioneering. It also shows an understanding of effective new technologies that assist in achieving this goal. Many Silicon Valley entrepreneurs see climate change reduction efforts as a major growth industry. As part of this effort, SCVWD has installed high-efficiency photovoltaic cells above a parking area on its San Jose campus, reducing carbon dioxide emissions by an estimated 412,699 pounds per year and supplying 20 percent of the facility's energy needs with clean energy. (See Appendix A for a detailed discussion of how SCVWD is working to address climate change.)

Cities for Climate Protection

Local governments across the United States are beginning to address the challenge of reducing climate change emissions. More than 670 cities worldwide have joined the Cities for Climate Protection campaign. These include at least 150 in the United States, more than 45 of which are in the West.[46] These local governments include many with water management responsibilities. Of the western cities that are members of the campaign, more than 30 serve as direct municipal water providers. In addition, the Marin (California) Municipal Water District has signed on to the campaign as an individual water district—the first water district to do so. As part of the agreement, signatories analyze their greenhouse gas emissions, set emissions reduction goals, develop and implement local greenhouse actions plans, and monitor and report results. This campaign represents a major movement of cities to address climate change-related issues directly.

U.S. Mayors' Climate Protection Agreement

On June 13, 2005, the U.S. Conference of Mayors unanimously passed a resolution regarding global warming.[47] Remarkably, this measure received more support than any resolution in the organization's history.[48] Of the more than 410 mayors who had signed the agreement as of March 8, 2007, (representing more than 60 million people), at least 133 are mayors of western cities. At least 85 of those cities provide water services directly through municipal water agencies.[49] The agreement commits signatories to strive to meet or exceed Kyoto Protocol targets for reducing climate change pollution—a reduction of 5.2 percent below 1990 emissions levels by 2012.

Action at the State Level

Around the nation, a growing number of states are also taking action to address climate change. In the West, governors are stressing the potential impacts on water supplies as major reasons for taking comprehensive action. State-based strategies include gubernatorial initiatives, programs to reduce carbon pollution, and a move toward renewable portfolio standards.

Comprehensive Gubernatorial Initiatives

California. On June 1, 2005, Governor Arnold Schwarzenegger signed an executive order establishing greenhouse gas emissions targets for the state. The targets call for reducing California's emissions 11 percent below current levels by 2010, 25 percent by 2020, and 80 percent by 2050. Scientists agree that reductions of about 80 percent below current levels are needed to stave off the most serious effects of climate change.

In addition to highlighting potential impacts to water supply, the California initiative also emphasizes that water managers can be part of a comprehensive climate change strategy. The final March 2006 report from the

Governor's Climate Action Team underscores the fact that water conservation has the potential to generate significant energy savings, thus reducing greenhouse gas emissions. (See the discussion of energy and water issues in Chapter 3 for a more complete discussion of this issue.)

Three California urban water agencies have become directly involved in supporting the state's efforts to mandate cuts in climate change pollution. The East Bay Municipal Utility District, the Santa Clara Valley Water District, and the Marin Municipal Water District have all written to the governor, urging him to adopt an aggressive greenhouse gas pollution control strategy. For example, the Santa Clara Valley Water District stated in its letter to Governor Schwarzenegger, "(W)e are very concerned about the impacts of global warming on Sierra snow pack and on water quality in the Delta. The district has supported policies that would reduce the effects of greenhouse gases. We urge you to take the necessary next steps to further the goals and commitments made by your Administration to prevent and defer global warming in California."[50]

Arizona. On February 2, 2005, Governor Janet Napolitano signed an executive order creating a 36 person Climate Change Advisory Group. The group was charged with producing a Climate Change Action Plan that gives recommendations for reducing greenhouse gas emissions in Arizona.[51] The suite of recommendations issued by the task force would reduce emissions to 20 percent below 2006 levels, while saving the state approximately $6 billion, creating 300,000 new jobs, and saving 172,000 barrels of oil.

Oregon. On April 13, 2005, Governor Ted Kulongoski announced five new initiatives designed to curb climate change. These initiatives, based on the Governor's Advisory Group on Global Warming, include:

- establishing new greenhouse gas reduction goals
- developing a plan for stricter emission standards for vehicles, along the lines of California's program
- developing carbon dioxide reduction schedules for utilities and other large emitters
- reducing state agency energy use by 20 percent by 2025
- increasing renewable and bio-fuel production and use[52]

New Mexico. On June 9, 2005, Governor Bill Richardson signed an executive order setting greenhouse gas emis-

Western Leaders Speak Out About Climate—and Potential Water Impacts

"Global warming threatens California's water supply, public health, agriculture, coastlines and forests, our entire economy and way of life. We have no choice but to take action to reduce greenhouse gas emissions." (California Governor Arnold Schwarzenegger, July 3, 2005)

"Arizona and other Western States have particular concerns about the impacts of climate change and climate variability on our environment, including the potential for prolonged drought, severe forest fires, warmer temperatures, increased snowmelt, reduced snow pack and other effects." (Governor Janet Napolitano, Climate Change Executive Order, February 2, 2005)

"Coastal and river flooding, snowpack declines, lower summer river flows,... and increased pressure on many fish and wildlife species are some of the effects anticipated by scientists at Oregon and Washington universities." (Oregon Strategy for Greenhouse Gas Reductions, Governor's Advisory Group on Global Warming, p. i)

"The southwestern United States will likely suffer significant impacts from temperature changes, such as decreased annual precipitation, faster evaporation of surface water supplies, and increased runoff at the end of winter when snow will melt faster." (Governor Bill Richardson, Climate Change and Greenhouse Gas Reduction Executive Order, June 9, 2005)

"Montana has been locked in the grip of a drought for most of the past two decades...I am very concerned about the connection these conditions have to global climate change... I am intrigued by the fact that every city, state, corporation, province and country that has resolved to control its respective green house gas emissions has reaped substantial economic benefits from those efforts...I ask you to establish a Climate Change Advisory Group that will examine agriculture, forestry, energy, government and other sectors of our state. I want this broad-based group of Montana citizens to identify ways in which we can reduce our collective greenhouse gas emissions while saving money, conserving energy and bolstering our economy." (December 13, 2005 letter from Governor Brian Schweitzer to Richard Opper, director of the state Department of Environmental Quality)

sions reduction targets at 2000 emissions levels by 2012, 10 percent below 2000 levels by 2020, and 75 percent below 2000 levels by 2050. The order created the New Mexico Climate Change Advisory Group to write a plan to meet the targets.[53] New Mexico thus became the first major energy producing state to set targets for cutting global warming emissions.

Montana. On December 13, 2005, Governor Brian Schweitzer called for the creation of a Climate Change Advisory Group, charged with developing recommendations to help Montanans save energy and reduce greenhouse gas emissions. The effects of climate change on water were cited first in the governor's letter, quoted below:

State-Level Programs to Reduce Carbon Pollution

States are taking a wide range of individual actions to reduce the emissions that cause global warming. For example, several states are adopting renewable portfolio standards or California's pioneering legislation regulating automobile tailpipe emissions of greenhouse gases. However, these efforts represent only two possible state-level responses to address global warming. In addition to the broad gubernatorial initiatives discussed above, state-based programs include:

- Automobile tailpipe emissions standards
- Appliance efficiency standards
- Renewable energy generation requirements, known as renewable portfolio standards
- Incentives for renewable energy production and generation
- Green building standards, such as the U.S. Green Building Council's Leadership in Environmental Design (LEED) program
- Requiring utility energy plans to include the cost of carbon emissions

California's Global Warming Solutions Act. The Global Warming Solutions Act (AB 32) authored by Assembly Speaker Fabian Núñez (D-Los Angeles), was signed into law by Governor Arnold Schwarzenegger on September 27, 2006. This made California the first state in the nation to set limits on heat-trapping pollution by implementing the pollution reduction targets laid out by Governor Schwarzenegger in June 2005. It set limits to cut the state's global warming pollution 25 percent by 2020. In recognition of the water supply benefits of reducing global warming, AB32 was supported by three California urban water agencies: the East Bay Municipal Utilities District, the Marin Municipal Water District, and the Santa Clara Valley Water District. Water agency staff and board members lobbied in support of AB 32 and helped spread awareness of the potential water-related impacts of climate change, and contributed to the bill's passage.

California's Vehicle Tailpipe Greenhouse Gas Emissions Program. In 2002, California passed pioneering legislation to reduce global warming pollution from all new passenger cars and trucks sold in the state, the largest automobile market in the United States. The law takes effect with the 2009 model year. At least 10 states, including Arizona, Oregon, and Washington, and Canada have adopted or indicated their intention to adopt California's tailpipe pollution standards. Together, these states and Canada represent one-third of the North American automobile market, providing a significant incentive for automobile manufacturers to improve the emissions of their entire fleet.

Renewable Portfolio Standards. At least seven western states have adopted renewable portfolio standards, which require electric utilities to purchase specified percentages of their power from renewable energy sources by specific target dates.[54] There are many benefits of such standards, including reduced pollution from coal-fired power plants and lower greenhouse gas emissions.

- Arizona: Requires electricity retailers to purchase 15 percent of their power from renewable sources by 2025
- California: Requires 20 percent renewables by 2017
- Colorado: Requires 10 percent renewables by 2015
- Montana: Requires 15 percent renewables by 2015
- Nevada: Requires 20 percent renewables by 2015
- New Mexico: Requires 10 percent renewables by 2011
- Washington: Requires 15 percent renewables by 2020

Action at the Regional Level

Western Regional Climate Action Initiative

On February 26, 2007, the governors of Arizona, New Mexico, Oregon, Washington and California, launched

> **"In the Southwest, water is absolutely essential to our quality of life and our economy... Addressing climate change now, before it is too late, is the responsible thing to do to protect our water supplies for future generations."**
>
> Source: Governor Bill Richardson, February 28, 2006

a joint effort to reduce their emissions of global warming pollution. Through the Western Regional Climate Action Initiative, these states will create a regional system to promote clean energy and energy efficiency to slow emissions of carbon dioxide and other heat-trapping pollutants that are contributing to global warming. The new agreement is similar to the Regional Greenhouse Gas Initiative among 8 northeastern states and will include regulatory and market mechanisms.

West Coast Governors Global Warming Initiative

In September 2003, the governors of California, Oregon, and Washington launched a regional initiative designed to address climate change.[55] This effort includes setting emissions targets for state vehicle fleets, creating targets and incentives for renewable energy, and developing efficiency standards for appliances.

Southwest Climate Change Initiative

In February 2006, Governor Richardson of Arizona and Governor Napolitano of New Mexico announced the creation of the Southwest Climate Change Initiative, aimed at reducing global warming effects and cutting greenhouse gas emissions.

Regional Greenhouse Gas Initiative

The largest regional global warming effort, known as the Regional Greenhouse Gas Initiative (RGGI), has been launched among eight Northeast and mid-Atlantic states.[56] The initiative's goals include capping carbon dioxide emissions from power plants at current levels in 2009 and reducing them by 10 percent from current levels by 2019. RGGI may become the nation's first cap and trade carbon program. This market-based approach to emission reductions is expected to drive investments to the least cost strategies, encourage technological innovation, and bring net economic benefits to the region. State modeling has estimated that, along with expected investments in efficiency, RGGI will result in a net savings on consumer energy bills of more than $100 per household.

Sense of the Senate Resolution—Passed on June 22, 2005

On June 22, 2005, the United States Senate passed a resolution (54–43), which for the first time called for mandatory limits on U.S. global warming pollution. The bipartisan resolution was offered by Senators Bingaman (D-NM), Byrd (D-WV), and Domenici (R-NM). The passage of the resolution marked the first time that a majority of the Senate has voted in support of mandatory caps to limit global warming pollution. The resolution read: Congress finds that

(1) Greenhouse gases accumulating in the atmosphere are causing average temperatures to rise outside of the range of natural variability and are posing a substantial risk of rising sea levels, altered patterns of atmospheric and oceanic circulation, and increased frequency and severity of floods and droughts;

(2) There is a growing scientific consensus that human activity is a substantial cause of greenhouse gas accumulation in the atmosphere; and

(3) mandatory steps will be required to slow or stop the growth of greenhouse gas emissions into the atmosphere.

(b) Sense of the Senate—It is the sense of the Senate that Congress should enact a comprehensive and effective national program of mandatory market-based limits and incentives on emissions of greenhouse gases that slow, stop and reverse the growth of such emissions at a rate and in a manner that

(1) will not harm the United States economy; and

(2) will encourage comparable action by other nations that are major trading partners and key contributors to global emissions.

Action at the National Level

Progress on global warming can be made at the local, state, and regional level. However, the United States will not fully or adequately address climate change-related issues until it develops a mandatory national program to slow, stop, and reverse the emissions of pollutants that cause global warming. Though Congress has not passed

U.S. Climate Action Partnership: A Joint Business and Environmental Program

The business community is taking a leadership role in calling for an ambitious, effective national program to reduce greenhouse gas emissions. On January 22, 2007, the U.S. Climate Action Partnership, a diverse group of businesses and environmental organizations called on the federal government to quickly enact strong national legislation to achieve significant reductions of greenhouse gas emissions. It further stated:

"We, the members of the U.S. Climate Action Partnership, pledge to work with the President, the Congress, and all other stakeholders to enact an environmentally effective, economically sustainable, and fair climate change program consistent with our principles at the earliest practicable date."

This unprecedented alliance, called the U.S. Climate Action Partnership (USCAP), consists of businesses including Alcoa, BP America, Caterpillar, Duke Energy, DuPont, FPL Group, General Electric, Lehman Brothers, PG&E, and PNM Resources, along with four non-profit organizations, including NRDC. The USCAP document, "A Call for Action," includes a goal of reducing greenhouse gas concentrations to a level "that minimizes large-scale adverse climate change impacts to human populations and the natural environment." According to the group, "Each year we delay action to control emissions increases the risk of unavoidable consequences that could necessitate even steeper reductions in the future, at potentially greater economic cost and social disruption." The group supports "mandatory approaches" to reduce heat trapping pollutants, as well as flexible strategies to achieve these reductions. According to these business and environmental leaders, confronting this challenge "will create more economic opportunities than risks for the U.S. economy."

Source: United States Climate Action Partnership, January 2007. "A Call for Action." www.us-cap.org.

comprehensive legislation to this end, there has been some significant action at the federal level. The U.S. Senate has adopted a bipartisan resolution calling for mandatory limits on greenhouse gas emissions.

Mandatory Federal Limits on Global Warming Pollution

Recent scientific consensus has solidified around the need for decisive federal action to limit global warming pollution in order to stave off dangerous impacts on the earth's climate. Industry had recognized this urgency and called on Congress to act. Most significantly, in January of 2007, some of America's largest corporations called for mandatory limits on the pollution that causes global warming under a newly formed alliance called the United States Climate Action Partnership (USCAP). The group, which consists of such industry-leading companies as General Electric, Caterpillar, Duke Energy, Alcoa, Lehman Brothers and DuPont, noted in its report that "each year we delay actions to control emissions increases the risk of unavoidable consequences." USCAP went on to call for "prompt enactment of national legislation in the United States to slow, stop, and reverse the growth of greenhouse gas emissions over the shortest period of time reasonably achievable."[57]

Like USCAP, NRDC supports aggressive emissions reductions measures such as those outlined in Congressman Henry Waxman's *Safe Climate Act* (HR 5642), and in Senators' James Jeffords and Barbara Boxer's *Global Warming Pollution Reduction Act* (S. 3698). Both pieces of legislation call for reducing emissions to 1990 levels by 2020, and for further reductions to levels approximately 80 percent below 1990 levels by 2050. Such cuts are needed to avoid atmospheric concentrations of carbon dioxide that would lead to dangerously increased global temperatures and catastrophic changes in the earth's natural systems.

For up-to-date information, on federal global warming legislation, please visit the NRDC Global Warming web page at: http://www.nrdc.org/globalWarming/default.asp.

PUBLIC OUTREACH

As respected community leaders, water managers can have a significant impact in shaping public opinion and awareness. The role of water managers in shaping public awareness is particularly significant in the American West; where water is scarce, water leaders bear a greater burden in educating the public and decision makers regarding water-related issues. Some water officials are already beginning to educate the public about the connections between climate change and water management. Water districts use a wide range of educational tools: materials for children, billboards and other paid advertising, outreach and meetings with—and letters to—elected officials. These educational efforts can have a significant effect on the public debate when it comes to climate change.

How Water Managers Are Leading the Way

Today, some western urban water managers are meeting the challenge of calling for action on global warming. As early as 1998, the Water Education Foundation, a California nonprofit organization with many board members from water agencies, major water users, and water-related engineering firms, devoted an issue of its magazine to climate change, discussing the growing scientific evidence regarding climate change and potentially significant water-related impacts such as a reduction of snowpack.[58] In October 2001, the American Water Works Association's journal discussed some of the potential climate-related impacts on water supplies that are reviewed in this report.[59] These discussions, in turn, have helped water managers to begin to analyze how their systems are vulnerable to the impacts of climate change.

As public awareness about the threat posed by global warming has grown, so too has the awareness of water managers. In 2005 the American Water Works Association Research Foundation issued a seminal report entitled *Climate Change and Water Resources: A Primer for Municipal Water Providers.* Though written primarily for water managers, the report discusses the importance of public education about the water-related potential impacts of climate change. And there are more signs that awareness among water managers is continuing to build:

• The Santa Clara Valley Water District's website includes strong statements about climate change "The reality of global warming and climate change is the most significant long-term threat to water resources management in Silicon Valley."[60]

• Three San Francisco Bay Area urban water agencies wrote to Governor Schwarzenegger in early 2006, urging him to take prompt action to address climate change. These three urban water agencies have also supported state legislation that would create mandatory caps on greenhouse gas emissions.

• In January 2007, the San Francisco Public Utilities Commission convened a Water Utility Climate Change Summit attended by more than 150 water managers and other stakeholders. The conference received significant media coverage.

The message is beginning to get through to decision makers, as indicated by public comments made by governors around the West about the need to act to reduce climate change impacts. Nearly all of those comments (see Western Leaders Speak Out about Climate) highlight the effect global warming will have on water resources.

Chapter 5

Conclusions and Recommendations

The research, analysis, and best practices reviewed in this report suggest several broad conclusions related to climate change and water management. These conclusions, as well as the conclusions in the American Water Works Association Research Foundation (AWWARF) report, lead to a number of specific recommendations for water managers that fall into the four action areas outlined in the previous chapter: vulnerability analysis, response, prevention, and public awareness.

CONCLUSIONS

The Science Is Clear

The scientific community has provided clear and urgent evidence that global warming is already happening and that it is caused by the increase in greenhouse gas concentrations in the atmosphere, particularly carbon dioxide. This increase is largely human-caused, primarily through the burning of fossil fuels in power plants and cars.

Climate Change Will Affect Water Management

There are a variety of ways in which climate change will negatively affect water resources in the American West. Considered together, these changes could have a significant impact on water supply, water quality, aquatic ecosystems, and flood management. We are already experiencing serious impacts of climate change, including sea level rise, decreased snowpack and earlier peaks in spring runoff.

Immediate and Sustained Action Can Reduce Future Impacts

Broad and strong actions will slow, stop, and reverse rising emissions of greenhouse gases, reducing future impacts on water resources. Immediate action is required to reduce long-lasting climate effects. Cost-effective opportunities for emission reductions can provide immediate multiple benefits.

Water Managers are Taking Action on Climate Issues

Water managers need to provide leadership to address the impacts of climate change on water resources and lead by example by reducing greenhouse gas emissions. Around the West, some water managers have undertaken

a broad range of actions on issues related to all aspects of climate change.

RECOMMENDATIONS

Water managers work with their communities to meet future water needs. The comprehensive recommendations presented in this section are designed to assist managers in helping Western communities face the new challenges posed by climate change.

Vulnerability Analysis

Local, regional, state and national water resource managers should assess the vulnerability of water supplies, flood management and aquatic ecosystems to impacts from climate change.

■ *Conduct Local Analyses*

Water managers should analyze the potential effect of climate change on water supply systems, water demand, and environmental and water quality requirements.

■ *Assess Regional Impacts*

Water managers should undertake cooperative regional vulnerability analyses to develop an understanding of the common challenges they face and lay the groundwork for cooperative responses. Such regional efforts could also produce better results and reduce expenses for individual participating agencies.

■ *Undertake State- and Federal-Level Evaluations*

Agencies should undertake state level analyses of likely climate change impacts on a full range of water management issues. Federal agencies including the Bureau of Reclamation, the the U.S. Army Corps of Engineers, Fish and Wildlife Service, the Federal Emergency Management Agency, the Environmental Protection Agency, the National Oceanic and the Atmospheric Administration, Federal Energy Regulatory Commission and the United States Geologic Survey should undertake evaluations of the likely impacts of climate change on water resources, and federal facilities and on the communities they serve.

Response

The following recommendations are designed to help water managers respond effectively to likely climate change impacts.

■ *Guiding Principles for Water Resource Management Response*

The following general principles are designed to assist forward-thinking water decision makers in crafting strategies to respond to this challenge.

• *Strengthen Institutional Capacity.* Responding to climate change will require agencies to invest in inter-agency collaborations, stakeholder involvement and technical analysis.

• *Maximize Flexibility.* Develop strategies that allow for mid-course corrections and redirection of investments toward the most effective tools, and strategies that reduce the risk of stranded investments in order to increase the ability of water managers to adapt to changing conditions.

• *Increase Resilience.* Water managers should consider a range of water management options that increase their ability to meet future needs under conditions of greater variability and uncertainty.

• *Implement "No Regrets" and "Multiple Benefits" Strategies.* Choose cost-effective strategies providing multiple benefits that make sense both today, and in a world altered by climate change.

• *Address Multiple Stresses.* Climate change is intensifying the stress put on water resources by other factors (e.g., population growth, land-use changes, contamination of surface and groundwater resources, and the need for ecosystem protection.) Water managers should seek to address these combined challenges through measures such as improving water use efficiency and protecting surface and groundwater sources.

• *Invest in Inter-Agency Relationships.* Water managers should partner with neighboring water agencies, as well as with agencies managing energy, environmental resources, wastewater, stormwater, and land use .

• *Incorporate Climate Change into Ongoing Project Design.* Water managers should incorporate climate change impacts into the design of existing and new facilities now, rather than waiting for the completion of comprehensive response plans to address climate issues.

• *Expand Dialogue with the Scientific Community.* Water managers and scientists should exchange information to increase the effectiveness of measures designed to meet the challenges posed by climate change and should develop a more accurate analysis of potential impacts on water resources.

■ *Restore and Protect Aquatic Ecosystems in Preparation for Climate Change*

In recent years, the West has seen numerous water resource conflicts pitting protection of threatened and endangered species against the demand for water supplies. To prevent future conflicts, to minimize impacts to water supplies and to protect our aquatic ecosystems, water managers should incorporate the following actions into their climate change strategies:

• Restore degraded rivers and floodplain habitats to buffer the impacts of climate change and provide critical habitat for sensitive species.

• Improve water quality by reducing runoff of pollutants through watershed management, increasing urban retention and infiltration of precipitation.

• Manage water supply systems to meet the temperature needs of sensitive species.

■ *Implement Water Management Tools That Are Effective in the Context of Climate Change*

Prior to making long-term investment decisions, water managers should carefully consider climate change effects on the tools available to meet future water needs. Climate change is likely to improve, or leave unchanged, the performance of tools such as water use efficiency and water recycling. Other tools that rely on historical hydrology (e.g., traditional river diversions, traditional groundwater pumping and traditional surface storage), are likely to perform less effectively in the future.

■ *Put Conservation First*

Water efficiency represent a sound and basic "no regrets" water management approach to future climate change impacts. Cost-effective water conservation investments can generate significant benefits on multiple fronts, including water supply, environmental, energy use, and greenhouse gas emissions reductions. Water managers should support conservation strategies that:

• *Transform markets through plumbing code changes and appliance standards.* These changes are the most successful and cost-effective way to save water. In California, a recent study found that between 50 percent and 85 percent of the conservation likely to occur under a variety of scenarios by 2030 will be attributable to changes in the plumbing code.[1]

• *Offer rebates for and make investments in interior water use efficiency.* Ultra-low flush or dual-flush toilets, low-flow showerheads and faucets, efficient appliances, and waterless urinals are proven cost-effective tools.

• *Promote landscape conservation.* Promote landscape water conservation including selection of drought-tolerant plants, landscape design that groups plants with similar water needs, efficient irrigation technology (including "smart-controllers" that automatically adjust to changes in weather), training for irrigation managers and maintenance personnel and seasonal rate structures

• *Use water metering and volumetric pricing to provide accurate price signals.* Water metering remains the single most effective water conservation tool. Measures such as submetering for multiple-unit residential and commercial buildings, and dedicated landscape meters, are particularly effective.

• *Price water to reflect its true cost and reduce existing water subsidies.* Water agencies should maximize the percentage of revenue recovered through volumetric charges rather than fixed charges, and should adopt tiered and seasonal water rate structures that encourage efficiency.

• *Support efficient product labeling.* The EPA has initiated the WaterSense program, comparable to the Energy Star™ program, to label products that meet its standards for water efficiency. Such a labeling program will help guide customers to the water-efficient choices already on the market and will encourage manufacturers to develop new, efficient products.

• *Use system leak detection to reduce unaccounted-for water.* In some systems these leaks can account for 30 percent or more of water use.

• *Implement commercial, industrial, and institutional conservation programs.* These can include programs targeted at individual measures, such as cooling towers, pre-rinse spray valves in restaurants, X-ray machines, and more customized initiatives designed to address industrial processes, and institutions, including universities and hospitals.

• *Create statewide and national programs for water conservation*. The California Urban Water Conservation Council is a good model for how to develop, implement, and monitor best management practices for water conservation. The new Alliance for Water Efficiency, which plans to bring together agencies, business interests

and environmental groups, should be an effective voice for advancing national water conservation standards and raising the profile of water conservation. [2]

• *Broaden public awareness.* Except in a handful of water-short regions, the public is generally unaware of the myriad benefits of water conservation. Regional campaigns to boost public awareness could generate substantial water savings.

■ *Incorporate Climate and Energy Issues in Water Planning*

By implementing tools ranging from efficiency improvements to reuse and recharge, there is an enormous opportunity to simultaneously save water and energy and to reduce greenhouse gas emissions. Water agencies should evaluate their energy consumption, particularly energy consumption driven by water use. Such an analysis should consider each phase of water use—storage and diversion, conveyance, treatment, local distribution, end use, wastewater treatment, and disposal.

■ *Collaborate with Energy Utilities.*

Water conservation generates substantial water and energy savings, and thus reductions in greenhouse gas emissions. Water agencies should work with local energy utilities to develop joint programs, such as rebates, to encourage water and energy conservation. Energy utilities should be appropriately credited for the embedded energy savings that accompany water conservation. Furthermore, water conservation activities that also save energy should qualify for public funding available for energy conservation.

■ *Integrate Regional Water Management*

Water managers should approach climate change response by utilizing an integrated regional water management approach, including a broad range of issues, multi-disciplinary analysis, stakeholders and agencies with multiple interests, and solutions tailored to local conditions. An integrated approach can produce broad benefits, including water supply, water quality, fish and wildlife, habitat improvements, recreational opportunities, flood damage reduction, energy supplies, greenhouse gas emissions, and regulatory compliance. Such integrated efforts should consider:

• potential climate change impacts on existing facilities and future water management tools

• unique regional conditions

• potential multiple benefits and potential funding and implementation partners (e.g. water supply, water quality, ecosystem management, recreation, land use and flood management)

• "efficiency first" investments

• a full range of potential demand and supply strategies

• a full range of potential flood management options

• clear objectives and performance standards for evaluating options

An Integrated New Vision for the San Francisco Bay-Delta Ecosystem

California recently created a new "Delta Vision" process to develop a plan to address the multiple crises currently facing the Bay-Delta estuary, including climate change-caused sea level rise and increased flood risks. This plan will be developed by state agencies, with input from a new blue ribbon panel and a stakeholder group, including urban and agricultural water interests. A new plan for the Bay-Delta should include prompt action in several areas:

• strengthening efforts to reduce future global warming, thus minimizing future risks to the Delta,

• implementing short-term actions to protect and restore endangered species, including, when necessary, reductions in Delta pumping

• reducing reliance on the Delta for water supplies (by investing in more reliable alternatives), thus reducing the economic risks associated with reliance on a vulnerable Delta

• stopping ongoing urbanization that is putting more Californians at risk of a Katrina-style disaster as they move into homes on vulnerable Delta islands

• maintaining the most important Delta levees and

• restoring other Delta islands to natural habitat, thus lessening the risk of a catastrophic failure, lowering levee maintenance costs, and helping to restore a healthy ecosystem.

Although a successful solution will cost billions of dollars, the price tag could be far higher if California fails to respond effectively to this challenge.

• "with and without project" baseline analysis for large infrastructure investments

• economic analysis and "beneficiary pays" financing

• enforceable environmental requirements

• strengthening institutional capacity

• educating the public and decision-makers about the need to reduce and prevent climate change

■ ***Evaluate Surface Storage***

Evaluations of any potential surface storage facilities should take place as part of a fully integrated approach, including the following specific actions

• base analyses on likely future hydrology

• give demand side approaches an emphasis at least equal to alternatives that would increase supply

• include a comprehensive economic analysis

• establish beneficiary pays pricing policies, rather than relying on subsidies

• fully incorporate potential environmental impacts

• avoid assigning costs to unrealistic potential benefits

■ ***Carefully Consider Commitments Regarding Future Water Deliveries***

Water agencies, including the Bureau of Reclamation, should consider climate change carefully when making commitments regarding future water deliveries. In particular, agencies should avoid promising increased water deliveries based on current hydrology.

■ ***Factor Climate Change into Flood Management Decisions***

For agencies with flood management responsibilities, an awareness of climate change should be integrated into future management decisions. For example:

• avoid development in floodplains that is not constructed to be compatible with occasional flooding

• dam operators should develop plans to reoperate surface storage facilities and other infrastructure in response to changing hydrology, caused by global warming

• managers should investigate floodplain management opportunities, such as floodplain, riparian and wetland restoration and the establishment of flood-compatible agricultural practices. These actions can generate public safety, flood damage-reduction, environmental and agricultural preservation benefits

• planners should incorporate climate change in analyses of future flood risk, including planning for the "reasonably foreseeable flood", which is larger than the 100-year flood

• support expansions in flood insurance

• improve mapping, monitoring, forecasting, and early warning systems

Prevention

Water managers can contribute to efforts designed to reduce greenhouse gas emissions to reduce future climate change impacts.

■ ***Support Mandatory Caps on Emissions***

Support the creation and enforcement of a mandatory national cap on the pollution that causes global warming (mainly carbon dioxide), as the single most important step in controlling and reducing the future impacts of global warming. The problem can be addressed most effectively addressed through federal caps, but local, state, and regional initiatives are also effective and important tools in the face of federal inaction.

■ ***Support Alternative Energy and Energy Efficiency Programs***

Energy efficiency and renewable energy programs are necessary elements for any plan to achieve a dramatic reduction in carbon emissions. The following programs can be implemented at the state and/or national levels:

• appliance efficiency standards

• renewable energy generation requirements

• incentives for renewable energy production and generation

• green building standards, such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standards

• requiring utility energy plans to include the cost of carbon emissions

■ ***Take Action at the District Level***
Water agencies should develop programs to reduce their energy consumption and greenhouse gas emissions. Districts should consider joining the Cities for Climate Protection campaign.[3]

■ ***Develop Community Partnerships***
Partnerships with the business community and local governments can enable water districts to broaden participation in ambitious greenhouse gas emissions reductions programs.

Public Outreach

Given the global nature of climate change and the need for far-reaching actions to address its causes, raising public awareness is essential to encourage effective action.

■ ***Educate Ratepayers***
Ultimately, water district ratepayers could feel significant impacts and be forced to bear significant costs as a result of climate change. Water managers have a range of tools, such as newsletters, billboards, bill inserts, websites, and more, to educate ratepayers. An increased understanding of the challenges posed by climate change will promote ratepayer acceptance of programs designed to address this issue.

■ ***Educate Decision Makers***
The involvement of water managers is important to convince agency and legislative decision makers that climate change is more than simply an environmental issue. Water managers are in a unique position in the West to educate decision makers about the water supply and economic consequences of climate change and the need to prevent worst-case climate scenarios.

■ ***Educate the Media***
Water managers should strive to improve the media's understanding of these significant potential impacts and help raise awareness to reduce climate change impacts and risk.

■ ***Incorporate Climate Issues into Conferences and Publications***
Water community conferences on water issues regularly include a presentation or two regarding climate issues. Given the significance of the potential effects, climate-related water management issues should play a more central role in water agency conferences, newsletters, reports, and other publications. These efforts should be crafted to help water managers and users to take action.

ADDITIONAL RESEARCH NEEDS

The more we know about global warming and the effect it will have on our water resources, the better prepared water managers can be to prevent the most serious consequences of rising temperatures. Water agencies, academic institutions, and state and federal agencies should consider funding research designed to address the following areas:

- the potential groundwater impacts of climate change
- the impact of climate change on water demands.
- the impact of climate change on potential new surface storage facilities in highly engineered systems
- likely future changes in precipitation patterns (including totals and variability)
- potential future reductions in total streamflows
- improved maps and data showing flood risks and other flood-related information
- improved modeling of changes in the frequency and magnitude of peak flows
- potential impacts on water quality
- potential impacts on aquatic ecosystems
- downscale climate modeling for local and regional applications

Appendix A

Case Studies: Water Agency Action on Climate Change

Throughout the West, agencies of all sizes have conducted vulnerability analyses to evaluate the reliability of their water systems in the face of climate change. A number of agencies, such as the Santa Clara Valley Water District and Seattle Public Utilities have been studying potential climate change effects for years, while others have only recently begun to investigate these potential impacts. Each agency and utility's experience in analyzing potential climate change impacts has produced unique findings and has consistently given critical insight for water managers to prepare for the potential effects of climate change on their particular water systems.

Denver Water

Denver Water, a separate entity from the City of Denver, serves a total of 1,104,400 customers in the Denver Metro area, approximately one-fourth of Colorado's population. The agency uses one-third of the state's treated water supply. Its primary water sources are the Blue and South Platte rivers.

"We want to find out as much as we can about [climate change]," says Denver Water general manager Chips Barry.[1] To achieve that objective, Denver Water hired Stratus Consulting, an environmental and engineering research firm, to conduct an analysis of Denver's system in order to test the district's sensitivity to changes in temperature and precipitation as a result of climate change.[2] The findings of this analysis will be outlined in a general briefing paper presented to Denver Water on its completion. In the district's next Integrated Resources Plan (expected to be completed in 2007), Denver Water plans to include a scenario designed to produce a rough estimate of possible impacts on its supply and demand.[3] "Most of us operate on the premise that the future will be pretty much as it has been in the past," Barry points out. "Global warming has created greater doubt as to that proposition."[4] By reducing the uncertainty regarding the particular impacts of climate change on its system, Denver Water can effectively plan to mitigate its effects and increase supply reliability.

Denver Water is ramping up its water conservation efforts with a $400 million conservation plan designed to cut annual water use, over the next 10 years, to a level 22 percent below levels that prevailed prior to the 2002–2005 regional drought.[5] Although this conservation

CITY LEVEL
Denver Water at a Glance

- hired an environmental engineering and research firm to analyze the effects of global warming on its system, including changes in temperature and precipitation.
- plans to include in its next Integrated Resources Plan a sample scenario of the potential effect of climate change on its supply and demand.
- accelerated investments in conservation, in part as a response to potential global warming impacts.

plan was initially established without regard to potential climate change effects on the Denver Water system, the agency accelerated its implementation, in part because it provides Denver Water with the ability to use saved water to mitigate impacts from climate change. Denver Water's board and executive staff approved the plan with an initial allowance of $8 million for the first year. Moving forward, the plan's funding will be appropriated by the board and executive staff on an annual basis.[6]

Portland Water Bureau

The Portland Water Bureau supplies drinking water to more than 787,000 customers in the Portland region. The primary source of the bureau's water supply system is the Bull Run watershed, located in Mount Hood National Forest, 26 miles east of downtown Portland. Groundwater significantly supplements the agency's supply.

The Portland Water Bureau (PWB) incorporated climate change into its water supply planning analysis by commissioning a seminal study in 2002 by the University of Washington Climate Impacts Group.[7] The study used a series of four linked Global Circulation Models—the Department of Energy's Parallel Climate Model, the Max Planck Institute's ECHAM4 model, and the Hadley Centre's HasCM2 and HasCM3 models—to estimate climate change impacts upon its system. The studies focused particularly on the Bull Run watershed, the district's primary water source.

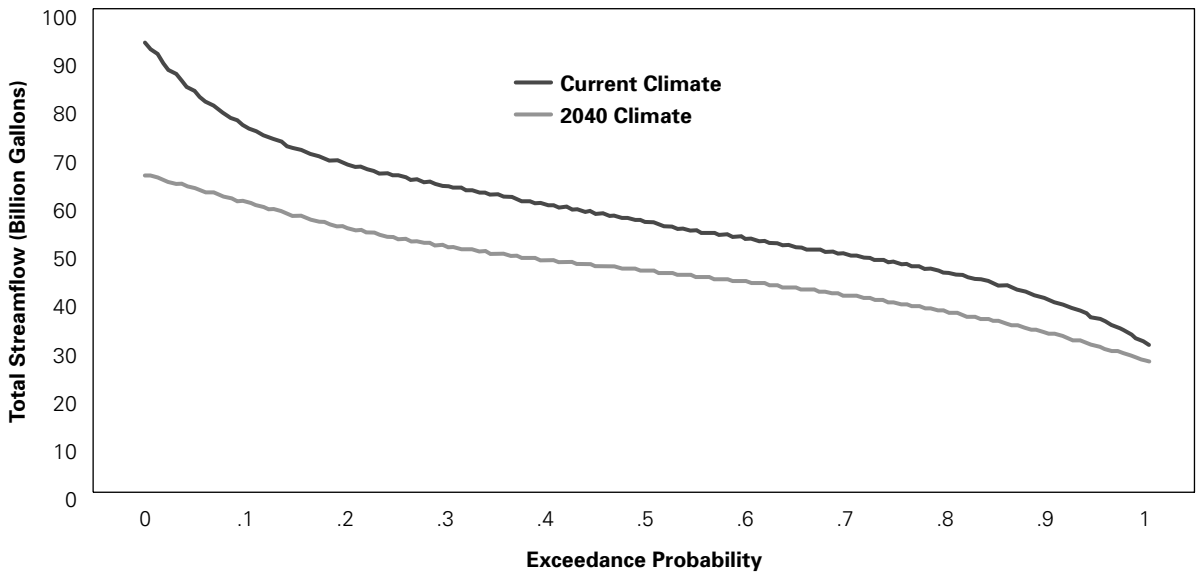
All four models were used to develop water demand forecasts and a hydrologic model for the Bull Run watershed. The output of these models were then applied to its Supply Transmission Model, which takes inputs of demand, weather, and water supplies to create different reliability scenarios. These model runs suggest that the Bull Run watershed will experience warmer and drier summers due to climate change, with an increase in general year-round temperature. The hydrologic models predict that precipitation will increase in the winter and decrease in the spring, with less snow melt remaining in the spring, making the Bull Run Watershed an increasingly rain-driven system with more years of lower summer streamflows into the storage reservoirs. This is particularly an issue in the Portland surface water storage system because the system's reservoirs are kept full during the winter, so an increase in earlier drawdown years with lower summer streamflows will affect overall system yield.[8]

Using the 60-year hydrological record, the study then evaluated the impacts of climate-altered streamflows and increased water demands on water supply performance with consideration given to three factors: (1) changes in water availability, (2) changes in water demand created by anticipated regional growth, and (3) changes in water demand as a result of hotter summer temperatures. The study estimated that the average impact of climate change alone on the current storage system could require approximately 1.3 billion gallons more water per year to meet demand. A change in runoff timing is PWB's supply threat, as it could reduce storage levels in comparison with historical record. This shift in runoff increases the number of years with longer drawdown periods due to lower flows and higher demand, requiring increased use of alterna-

CITY LEVEL
Portland Water Bureau at a Glance

- commissioned a study to analyze the potential effects of climate change on its system, with a particular focus on the district's primary water source.
- found that climate change will alter basic hydrology of the Bull Run watershed.
- projected that demand on the system will increase during the summer as a result of global warming, requiring an additional 1.3 billions gallons to meet demand.
- concluded that overburdening of the system will ultimately result in a reduction of Portland's surface water system safe yield during the summer, requiring additional conjunctive use of Portland's existing groundwater system.

Figure A-1: Portland Water Bureau's Projected Streamflow Shift Due to Climate Change



From the Powerpoint Presentation, "The Impacts of Climate Change on Portland's Water Supply." Portland Water Bureau and University of Washington Climate Impacts Group. 8/29/06

tive sources of supply, in addition to already anticipated reductions due to conservation measures. The study concludes that climate change will alter the basic hydrology of the Bull Run watershed as well as the system's demand, ultimately resulting in a reduction in the reliable yield of Portland's surface water system.

PWB is exploring the many alternatives to enhance its water supply reliability in the face of climate change, with an emphasis on flexibility in infrastructure development. Some of the strategies PWB is considering are conservation and conjunctive use that could be coordinated with reoperated existing surface and groundwater supplies. Other water suppliers in the Portland metropolitan area have conducted similar studies, in recognition of the need to collaboratively assess the impacts of climate change on regions with multiple water supplies.[9]

Santa Clara Valley Water District

The Santa Clara Water District (SCVWD) is the primary water agency for the residents of Santa Clara County, California. SCVWD provides water for the 1.7 million residents of the county, as well as serving as its flood protection agency and as the steward of the county's streams, creeks, underground aquifers, and reservoirs.

The Santa Clara Valley Water District (SCVWD) began incorporating the uncertainties posed by climate change in its water supply planning processes about a decade ago. The district is continuously updating its analyses

CITY LEVEL

Santa Clara Valley Water District at a Glance

- conducted a risk analysis in 2003 and determined that global warming could have serious implications for the district's water supply after 2020.
- concluded that the district's projects to meet water demand beyond 2020 must consider the effects of climate change on water quality, saltwater intrusion, imported and local water supplies, and the water transfer market.
- plans to complete a Water Supply Sustainability Plan in 2008, which will update its Integrated Water Resources Plan to include more detailed regional climate modeling and an analysis of local and regional impacts of future climate scenarios.
- is analyzing its climate footprint and has started tracking and reporting CO_2 emissions.

as more information about climate change emerges. In SCVWD's 2003 Integrated Water Resources Planning Study (IWRP), the district assessed global warming's threat to supply reliability. It applied vulnerability assessment models on five portfolios composed of various water supply options. These five hybrid portfolios were built to meet three planning objectives: high water quality, natural environment protection, and minimum cost impacts.

• SCVWD's "Extend" simulation model analyzed potential portfolio performance through 2040 based on historical hydrology

• The Economic Analysis Tool compared water supply options on equal economic footing

• The Risk Analysis Tool used statistical techniques and estimation of seven risk likelihoods to test the portfolios under a variety of possible future scenarios, including climate change

SCVWD considered its results over three time frames: Phase I (2003 through 2010), Phase II (2011–2020), and Phase III (2021–2040).[10]

In its risk analysis, SCVWD determined that global warming could have serious implications for the district's water supply after 2020. The analysis concluded that the district's projects designed to meet water demand beyond 2020 must consider the effects of climate change on water quality, saltwater intrusion, imported and local water supplies, and the water transfer market. SCVWD has concluded that its water supply is particularly vulnerable to certain climate change effects such as sea level rise, loss of snowpack, and a shift in runoff timing. Pursuant to its 2005 Urban Water Management Plan, SCVWD is assessing various options to address the impacts of climate change, including additional water recycling, additional water banking, and dry-year transfer options. Another option the agency is considering is employing additional treatment options to address water quality impacts such as increased salinity in the Delta, from which the district receives approximately 50 percent of its water supply.[11]

A key aim of the district is to increase the flexibility of its water supply portfolio in the face of potential water supply threats by securing baseline water supply programs, investing in "no regrets" actions, and focusing on the long term.[12] The district is moving forward by developing a robust framework for sustainability and investment decision making. It also plans to complete a Water Supply Sustainability Plan in 2008, which will update its IWRP analyses to include more detailed regional climate modeling and an analysis of both local and regional impacts of future climate scenarios. As a comprehensive water management agency, SCVWD is gearing up to both mitigate and adapt to global climate change. SCVWD is also analyzing its own climate change footprint and reporting its CO_2 emissions as a member of the Sustainable Silicon Valley Initiative (SSV).[13] See page 46 for more on the district's involvement with SSV.

Additionally, SCVWD is communicating its concern about the impacts of climate change to the community it serves and to state decision-makers. SCVWD wrote a letter in March 2006 supporting the governor's acknowledgement of global warming's effects on California industry in his 10-Year Strategic Growth Plan. The following month, the district wrote a letter of support for California Assembly Bill 32 (AB 32), which places a cap on greenhouse gas emissions from the electrical power, industrial, and commercial sectors, and establishes a program to track and report greenhouse gas emissions.

Seattle Public Utilities

Seattle Public Utilities provides water to a customer base of more than 1.3 million people in the metropolitan area of Seattle, Washington. The utility receives almost all of its water supply from two watersheds in the Cascade Mountains: the Cedar and Tolt River watersheds.

Seattle Public Utilities (SPU) has been actively involved in climate change as related to water supply issues for more than 15 years. Based on currently available information regarding the potential effects of climate change, the utility's analyses concluded that it is unlikely to need new water supply sources to meet water demand in the next 40 to 50 years, despite its region's

CITY LEVEL
Seattle Public Utilities (SPU) at a Glance:

• uses a dual approach to climate change vulnerability analysis process that incorporates both a bottom-up perspective (historical hydrology) and a top-down strategy (using modeling to assess local watershed levels).

• forming partnerships with other regional groups—including state agencies, county and city governments, water districts, and an Indian tribe—to better prepare the region for the effects of climate change.

growing population. However, SPU acknowledges the many uncertainties surrounding climate change's potential impacts on its water system. SPU's 2007 Water System Plan describes how the utility will continue to monitor its system vulnerabilities, engage in research, and employ scenario planning in order to make system investments and operational changes that will prepare the utility for possible impacts.[14]

SPU uses a two-pronged approach to investigate its system's vulnerabilities to climate change. To assess climate change from a bottom-up perspective, SPU began by examining its historical hydrology, using streamflow records to reconstruct inflows into its surface water supplies. The utility now has an inflow dataset for the past 76 years, from water year 1929 through 2004. SPU also uses a system stimulation model to estimate the firm yield of its supply in order to meet the utility's 98 percent reliability standard, while accounting for climate variability. This bottom-up approach has underscored that a key vulnerability of SPU's water supply system is the timing of the return of fall rains. SPU's reservoirs are operated on a single-year drawdown cycle, and delays in the fall rainy season can force SPU to draw down deeper into reservoir storage. When this occurs, SPU relies on emergency storage reserves to meet the needs of its customers and downstream habitat. Research on future climate change has not directly addressed the timing of fall rains, but SPU is taking steps to ensure that its emergency supplies can be relied on during times of extreme drought.[15]

Potential climate change-driven loss of snowpack represents another system vulnerability. To mitigate this threat, SPU routinely monitors snowpack conditions and uses a dynamic rule curve that adjusts reservoir refill targets according to actual snowpack and soil-moisture conditions. This approach utilizes real-time conditions to regulate reservoir management and increases the likelihood of a full reservoir refill prior to the summer drawdown period. The dynamic rule curve also assists in managing the utility's risk from increases in precipitation variability, another potential climate change impact. SPU does not have a sizeable reservoir capacity compared to many other water systems, and it therefore relies on the dynamic rule curve and other operational management strategies to make the most of current water supplies.

As mentioned earlier in this report, SPU worked with the University of Washington's Climate Impacts Group (CIG) to analyze its water system's susceptibility to climate change from a top-down perspective. CIG's analysis involved examining the SPU watershed's susceptibility by employing a statistical downscaling method to translate the average monthly meteorological data from the General Circulation Models (GCMs) at nearby grid points down to local weather station locations. This method used cumulative distribution curves and historic weather patterns to generate a time series of meteorological data representing future climate from the GCMs. These data were input into a hydrology model and then fed into Seattle Public Utilities' system simulation model using some simplifying assumptions, including the use of static reservoir operating rules. These loosely linked models complete the process of translating information from the GCMs to the local watershed level.[16]

This downscaling method reveals a series of potential climate change impacts that affect water supply. Although there is significant cumulative modeling uncertainty associated with this method, the modeling results are useful for water supply planning purposes and for reexamining existing and planned water management systems under a wider range of climatic conditions. This model examined several elements that affect water supply, including temperature, snowpack, yield and precipitation. The results show:

- an increase in temperature of 2.3 degrees Fahrenheit in the Seattle region by 2040
- a decrease in snowpack of 50 percent by 2040
- a 6 percent decrease in combined inflows from the Cedar and Tolt reservoirs from June to September per decade through 2040
- a reduction in yield of 24 million gallons per day by 2040

The model results also indicate that the predicted deviation in precipitation does not range significantly outside the range of natural variability.

SPU is widening the scope of its climate change analyses by co-sponsoring regional studies with King County (in which Seattle is located), the Cascade Water Alliance, and the Washington Department of Ecology as part of a larger regional water supply planning process, which also incorporates climate change. A wide cross-section of organizations are participating in the planning process—including state agencies, county and city governments, water districts, and the Muckleshoot Indian Tribe—with the University of Washington's Climate Impacts Group as the technical lead on climate change. The process is designed to develop information regarding

current and emerging water resource management issues in and around King County, including climate change. This partnership is a multi-year effort to analyze water resource conditions and management in order to better meet the region's water demand. The process will examine all available water sources, including reclaimed water and conservation. Climate change is one of five resource management issues under study, with a technical committee in place on each issue to produce reports and recommendations that could be included in water planning processes in the region.[17]

Building on past research and other endeavors, SPU plans to expand its knowledge of the evolving science behind climate change by continuing to partner with leading scientists. This research will help to further refine SPU's understanding of the local impacts of climate change and provide an increased understanding of how its system can adapt over time. SPU is particularly interested in learning more about the impacts of climate change on frequency of flood events, water demand, and fall rains, because the timing and intensity of these events are key vulnerabilities for the Seattle water supply system. Additionally, SPU seeks to develop hydroclimatic reconstructions, a practice that involves using tree-ring samples to reconstruct past hydroclimatic conditions in order to assess its system's vulnerability to climate change. The utility also aims to utilize more scenario planning, employ physical downscaling methods, and quantify the effectiveness of its changes in operations.[18] SPU anticipates revisiting its climate change analysis at least every six years in conjunction with its Water Supply Plan update, or sooner, if new significant information becomes available.

East Bay Municipal Utility District

The East Bay Municipal Utility District supplies water and provides wastewater treatment for customers in parts of Alameda and Contra Costa counties in the Eastern portion of the San Francisco Bay Area, including Oakland and Berkeley. Its water system serves approximately 1.3 million people in a 325-square mile region.

East Bay Municipal Utility District (EBMUD) is another agency that has emerged as a leader in assessing the impacts of climate change on water resources. In 2003, EBMUD conducted a dual-faceted vulnerability analysis to quantify impacts on its system: a planning model operated on a monthly timestep, and an operations model based on a daily hydrograph. Its monthly planning model used a database of historical river flows and tested its sensitivity to climate change by shifting 28 percent of historical April to July runoff volume into the November to March period, to estimate the reliability of system operations with less late-season snowmelt. The 28 percent figure was based on a study conducted by Maurice Roos, Chief Hydrologist of the California Department of Water Resources, which assessed how a shift in climate would impact the Mokelumne watershed, EBMUD's primary water source. Roos estimated that a 5 degree Fahrenheit temperature increase in the Mokelumne watershed might result in a 28 percent shift in runoff. EBMUD's analysis did not reveal significant impacts from this shift, as the historical record shows that in most years there has been more snowmelt in the watershed than can be stored. However, the extent of future precipitation changes in this watershed due to climate change is unknown. In dry years, annual runoff volume is less than the total reservoir capacity, and the timing of snowmelt would have little effect on system reliability. An overall reduction in precipitation, however, would have direct effects on this runoff and the amount of water available for storage. Model simulation of the historical record adjusted for an earlier snowmelt confirmed that the district's water supply and carryover storage would not be reduced significantly in most years. The only exception is water year 1997, which was exceptionally wet and warm in early winter but dry beginning in February. If the spring runoff from snowmelt in that year reduced by 28 percent, EBMUD found that the carryover storage would have been reduced, which would affect system reliability if a drought period were to follow. Such a sequence of events is of concern to

CITY LEVEL

East Bay Municipal Utility District (EBMUD) at a Glance

- conducted a dual-faceted vulnerability analysis to quantify climate change impacts on its system: a planning model operated on a monthly time step and an operations model based on a daily hydrograph.
- concluded that changes in precipitation patterns and flooding due to climate change could compromise system reliability.
- became the first water district to join the California Climate Action Registry by pledging to annually track, report, and certify its greenhouse gas emissions.

EBMUD. The operations model analyzed the impacts of a 5 degree Fahrenheit temperature increase on water year 1997's daily hydrograph based on historical sequence of snowfall and rainfall inputs. The results of this analysis were intuitive: with a climate change-induced runoff shift, flood control consistently was revealed as an issue that the district must be prepared to address.[19,20]

EBMUD has made it a priority to invest in the production, use, and refinement of new supply-forecasting tools. By developing and using these tools, the district further reduces the uncertainties of climate change impacts on its water supply. By better understanding its water system's particular vulnerabilities, EBMUD can effectively managing the stresses on its supply. In order to diversify its water supply sources, the district is also constructing the Freeport Regional Water Project, in partnership with the Sacramento County Water Agency. This project, which will allow EBMUD to divert water from the Sacramento River, was carefully negotiated with Sacramento County, environmentalists and other interests.

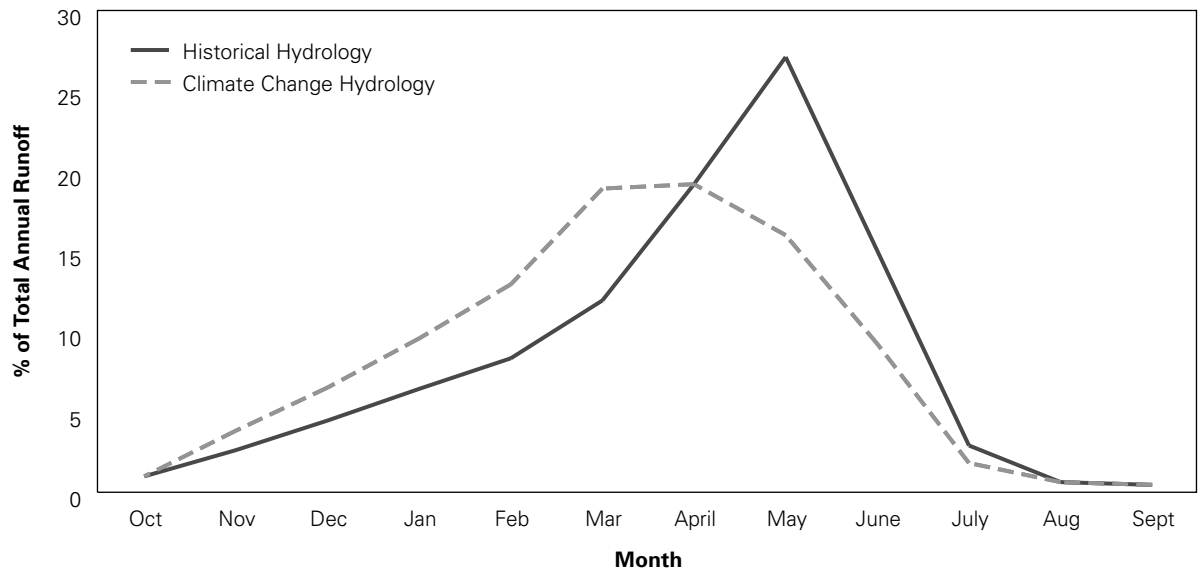
EBMUD is also working to prevent global warming by minimizing its climate change footprint. As discussed, it was the first water district to join the California Climate Action Registry—a non-profit public/private partnership established by California statute, which provides a voluntary greenhouse gas (GHG) registry to promote early actions to reduce GHG emissions. As a member of the Registry, EBMUD pledges to annually track, report, and certify its greenhouse gas emissions. EBMUD's efforts to mitigate its own impact on global warming were recognized by the Environmental Protection Agency, who presented the district with a Green Power Leadership Award. [21]

Furthermore, EBMUD has taken its concerns about global warming beyond district boundaries to California Governor Arnold Schwarzenegger and the state legislature. In a December 2005 letter, General Manager Dennis Diemer urged the Governor and the Climate Action Team to proactively assess how global warming may affect water supply and the economy in California's 10-Year Strategic Growth Plan. Then in March 2006, the District actively supported California's Assembly Bill 32.

Cosumnes, American, Bear and Yuba (CABY) Watersheds

The Cosumnes, American, Bear and Yuba rivers are four adjacent watersheds located in California's central-Sierra region. The CABY alliance involves a diverse membership

Figure A-2: EBMUD's Projected Streamflow Shift Due to Climate Change



EBMUD's comparison of long-term average unimpaired runoff under historical conditions and with its climate change model's 28% shift from April-July runoff volume to the November-March time period.

body including representatives from agriculture, recreation, Native American tribes, the business community and local, state, and federal governments.

Various stakeholders of four watersheds: Cosumnes, American, Bear, and Yuba (CABY) have cited climate change as a guiding principle in their first-ever collective Integrated Regional Water Management Plan (IRWMP). The purpose of the IRWMP is to provide an integrative approach to water management that is oriented toward the collective goals of the region's water users.[22] The plan was adopted by ten participating organizations as of December 2006, including the El Dorado Irrigation District, Gold County Fly Fishers, the U.S. Tahoe National Forest, the Yuba Watershed Council, the Bear River Watershed Group, American Rivers, Natural Heritage Institute, and the Nevada Irrigation District. Implementation by a regional entity is expected to begin in 2007, which will oversee the execution, monitoring, and success of projects in the IRWMP.

As it lays the framework for its IRWMP, CABY is assessing how it can prepare for climate change by maximizing its tools, policies, and current system infrastructure. CABY is using the Water Evaluation And Planning (WEAP) system to help measure potential climate change impacts on hydrology . The WEAP system, developed by the Stockholm Environmental Institute's Boston Center and the Tellus Institute, is a microcomputer tool developed for integrated water resources planning. It analyzes a system's water supply generated through watershed hydrological processes using a water management model driven by water demand and environmental requirements, governed by the natural watershed and the region's network of reservoirs, canals, and diversions. WEAP generates scenarios that examine a full range of water planning issues, including climate change. [23]

Liz Mansfield, CABY Project Director and El Dorado Irrigation District Watershed Coordinator, explains that WEAP can assist the region in developing a plan to manage climate change effects on its regional system. The CABY planning team has highlighted specific vulnerabilities to investigate, such as reservoir operations. A shift in runoff timing could have significant effects on the region's water supply, due to the delicate balance involved in reservoir management. The CABY region is at a high altitude with limited-capacity reservoirs that often remain full year-round for recreational and hydropower purposes. Analyzing how climate change will shift runoff in this region is critical to planning efforts for effective reservoir management.[24]

CABY also recognizes its elevated susceptibility to fire in the face of climate change. The region is densely vegetated, with a high volume of forested areas. CABY's planning community is seeking to understand the extent to which the expected increase in fires brought on by climate change will affect regional water supply and water quality. By gaining a clearer sense of climate change's effects on their system, the CABY planners can develop proactive strategies to meet effectively the needs of the region's water users.

What we are seeing in the CABY regional planning effort is part of a new trend—water managers using climate change vulnerability analyses to shape integrated planning efforts. In the past, climate change analyses have generally been produced as stand-alone documents, CABY uses the findings from its vulnerability analyses as a pillar in its planning framework.

AGENCY LEVEL

CABY at a Glance

- the managers of four watersheds—Cosumnes, American, Bear, and Yuba (CABY)—joined forces to examine how global warming will impact its watershed on a regional level.
- used a microcomputer tool that analyzed climate change vulnerability.
- used the findings of the vulnerability analysis as a foundation of CABY's integrated planning efforts.
- determined that reservoir operations and vulnerability to forest fires were two particular threats to the region, and are planning response strategies to mitigate these risks.

California Department of Water Resources

The California Department of Water Resources manages the State Water Project, including the California Aqueduct. The department's numerous roles include providing flood control services, aiding local water districts in water management and conservation activities, and planning for future statewide water demands.

In July 2006, The California Department of Water Resources (DWR) released the first statewide analysis of

likely climate change effects on water supply. The agency commissioned the study in response to Governor Arnold Schwarzenegger's June 2005 Executive Order, which established greenhouse gas emissions targets for California and required biennial reports regarding potential climate change effects in numerous areas.

Progress on Incorporating Climate Change into Management of California's Water Resources, is the product of the Climate Change Work Team, a group formed by DWR in conjunction with the U.S. Bureau of Reclamation to incorporate climate change science into California's water resources planning and management. DWR is communicating to local water agencies the results of the report and the various analysis tools used therein, which could be used by others to address climate change-related issues. The goal of these efforts is to assist water managers in future climate change analysis and to help them identify information gaps for future research.

DWR's report concludes that climate change has the potential to reduce the yield of the state's two major water projects by as much as 10 percent—a highly noteworthy figure considering that over 20 million California residents receive a portion of their water supply from those two projects (the State Water Project, or SWP, and the federal Central Valley Project, or CVP). The report notes that climate change creates a more active hydrological cycle, thereby altering the timing, intensity, location, amount and variability of precipitation. The study anticipates that these variations in precipitation events may lead to increases in extreme weather events, such as storms, flood events, and droughts. DWR expects more floodwaters to manage in winter, followed by less snowmelt to store in reservoirs for use during the warmer, summer months. By the year 2050, an average loss of 5 million acre-feet or more of annual water storage in the state's snowpack is expected—more than the capacity of the state's largest reservoir, Lake Shasta. In addition, the combination of more frequent extreme events coupled with lower winter reservoir storage levels, which may be required in response to higher peak streamflows, presents a key challenge for operators of the state's reservoirs.

In addition, the study points out that sea level rise due to climate change could have multiple implications for California, including erosion of coastal land area and possible sea water intrusion in coastal aquifers. Sea water flooding may pose a serious threat to land, at the mouths of rivers and streams, and in estuaries.

The San Francisco Bay-Delta, an important source of water for Southern California, the San Joaquin Valley and the Bay Area, is particularly susceptible to several effects of climate change. From a water resources perspective, the most significant effects of climate change on the Delta are increased salinity intrusion, as well as increased vulnerability of Delta levees to sea level rise. An increase in sea water intrusion in the Delta could lead to a degradation of water quality for the State Water Project and the Central Valley Project. Climate change also has significant, if uncertain, implications for the Delta's fragile ecosystem, which is home to various threatened and endangered species. (See The Other New Orleans: California's Delta Water Supply and Sea Level Rise.)

DWR researchers expect that higher air temperatures due to climate change will likely elevate water temperatures in the ocean as well as in the state's lakes and waterways. These increased water temperatures may harm aquatic species sensitive to temperature, particularly threatened and endangered aquatic species. In addition, some foreign invasive species may thrive in these new warmer conditions, further threatening the health of aquatic ecosystems. Water quality could be compromised as well, including a reduction in dissolved oxygen levels. Warmer water will raise the need for temperature control releases from reservoirs. Simultaneously, however, cold-water storage in reservoirs will be constrained due to the expected effects of climate change, such as diminished snowpack and lower storage levels.

According to DWR, future water demand is expected to grow, as a result of global warming. The report finds that warming-caused impacts to evapotranspiration, commercial and industrial use, environmental water demand, and domestic water use may be some of the most significant climate change-related challenges facing California. Increases in evaporative cooling demand and a higher consumption of water by concentrated animal feeding

STATE LEVEL

California Department of Water Resources (DWR) at a Glance

- commissioned a study to determine how global warming will affect California's water resources on a state-wide level.
- helped local and regional water managers understand how its climate change response strategies fit into the larger statewide plan for action, enabling decision makers to plan a more coordinated response to rising temperatures.

facilities are also expected. Moreover, climate change could require more water in order to control rising temperatures for sensitive aquatic species. This need to mitigate rising water temperatures could be an important issue in fragile areas such as the San Francisco Bay-Delta, a delicate ecosystem that provides habitat for many threatened and endangered species. In addition, DWR predicts that basic domestic water demand will rise with higher temperatures, mainly from drinking water for humans and pets, and increased bathing and evaporative cooling. Future population growth in the state promises to bring additional water demand, tightening the squeeze on this limited resource.

DWR emphasizes the need for water agencies and researchers to incorporate climate change impacts and potential associated risks into the planning and management of California's water supply. DWR emphasizes the need to understand the probability of various climate change scenarios and to evaluate how they could affect different regions. By better understanding these potential impacts, decision makers are better equipped to plan appropriate response strategies.[25]

STATE LEVEL

New Mexico Office of the State Engineer and Interstate Stream Commission at A Glance

- commissioned a report to determine what specific global warming effects are likely to be of particular importance in New Mexico.
- recommended proactive, immediate action to mitigate the impacts of climate change, such as exploring options such as desalination of brackish water supplies and water reuse.
- recommended an integrated approach that brings together water management and policy expertise as well as state government, environmental, and agricultural representatives.

New Mexico Office of the State Engineer/ Interstate Stream Commission

The Office of the State Engineer is responsible for administering the state's water resources by supervising, measuring, appropriating, and distributing all surface and groundwater in New Mexico. The Interstate Stream Commission duties include protecting New Mexico's water rights under eight interstate stream basins, ensuring the state's compliances with each basin, and planning for future water needs.

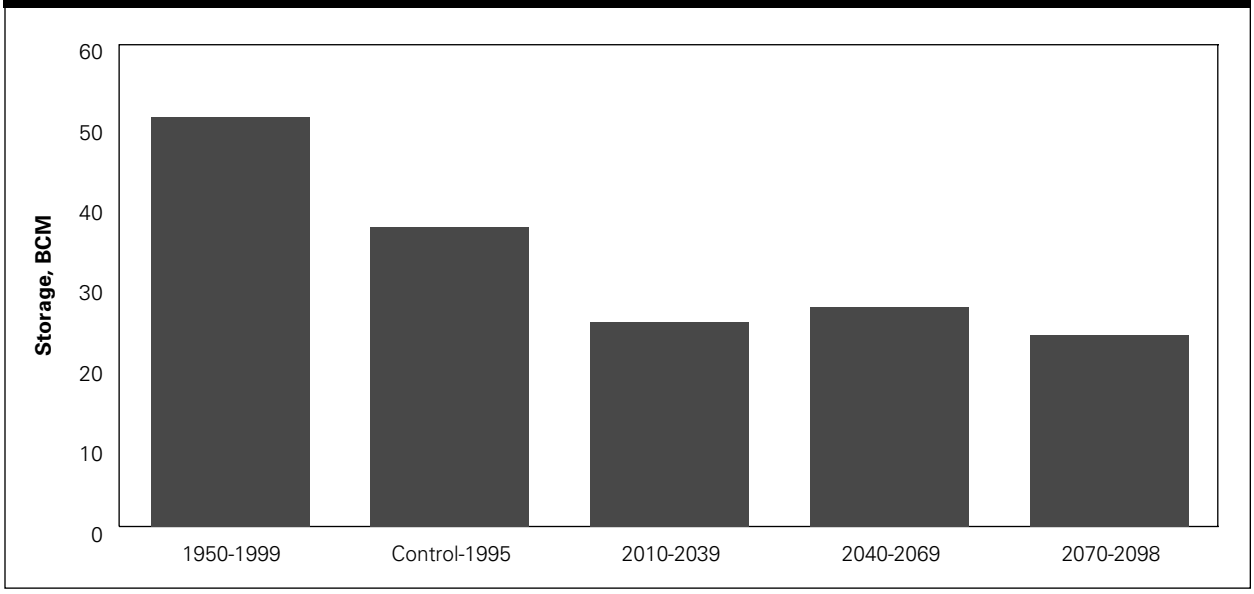
New Mexico is the next state after California to analyze the potential impacts of climate change on its state's water resources. Governor Bill Richardson's 2005 Executive Order directed the New Mexico Office of the State Engineer to prepare an analysis of the likely effects of global warming on the state's ability to manage water resources in collaboration with other state agencies, research institutions, and water planners. The report, *The Impact of Climate Change on New Mexico's Water Supply and Ability to Manage Water Resources,* summarizes its findings.

Based on 18 climate simulations prepared by scientists throughout the world, the report highlights potential impacts to New Mexico that generally reflect those expected throughout the West, including changes in snowpack, variability in available water, increased unpredictability in precipitation patterns, and a rise in extreme events such as droughts and flooding. These changes will bring additional challenges to the management of the state's water resources. One such challenge is the fact that the water resources in the Colorado River Basin—one of New Mexico's primary sources of water supply—are expected to decline by as much as 40 percent over the next century. In addition, mountain snowpack in the state's southern half could vanish by the late 21st century, completely eliminating natural storage that is critical for meeting demands during peak summer months.

Climate change is likely to bring significant implications for the state's rangelands, farmland, and aquatic ecosystems. Warmer temperatures combined with changing precipitation patterns suggest the possibility of increased fire activity in the state's rangelands, which make up more than two-thirds of the state's land area. In turn, the more fires are likely to intensify stress on future water resources. New Mexico's farming community is also predicted to feel serious effects from climate change. Farmland in the state could decrease as much as 25 percent as a result of increased evaporation and earlier spring runoff. Additionally, shifts in water temperature and changes in runoff timing could critically alter aquatic habitats, resulting in species loss or migration and causing new combinations of species.

The state's report emphasizes the need for water managers to begin preparing for these potential impacts. The first step for water managers is to identify and quantify the range of climate change vulnerabilities specific to their area. Water managers are advised to conduct a vulnerability analysis of current reservoir infrastructure in order to ensure that they are capable of withstanding the additional

Figure A-3: Projected Changes in Average Total Colorado River Basin Reservoir Storage



For downscaled climate simulations of the U.S. Department of Energy/National Center for Atmospheric Research Parallel Climate Model (PCM) based on projected 'business-as-usual' (BAU) greenhouse gas emissions and a control climate simulation based on static 1995 greenhouse gas concentrations, and an ensemble of three 105-year future climate. Simulations for three periods, and a comparison with observed historical (1950-1999) climate. From p. 21 of report.

Source: http://www.nmdrought.state.nm.us/ClimateChangeImpact/completeREPORTfinal.pdf

pressures likely to be caused by climate change. The report also suggests that as science and technology advance, water managers should consider expanding water supplies through reuse, desalination of brackish water supplies, weather modification, expanded use of low-quality water, and reduced reservoir evaporation.

The report determines that the key to successful adaptation is a "robust scenario-based planning structure."[26] The report, compiled with input from numerous published reports and assistance from a broad group of professionals, emphasized that while a degree of uncertainty regarding possible effects of global warming will inevitably remain, we can control the degree to which climate change will affect water sources by planning for action today. The report encourages government collaboration with the various stakeholders in water planning—i.e., cities, agriculture, and the environment—as well as within the education and science community, in order to develop comprehensive planning strategies. It advises water resource planners and managers to employ an adaptive, proactive planning approach in conjunction with a "no regrets" decision-making process that focuses on desirable outcomes regardless of uncertainties.

Appendix B

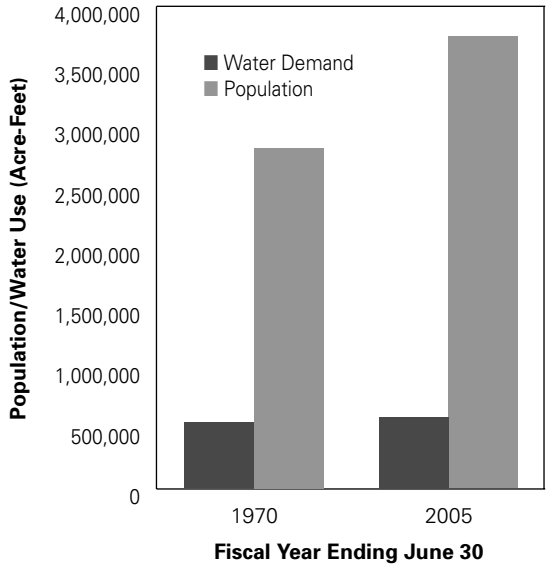
Decoupling Population Growth and Water Use

During the past several decades, many urban communities across the West have grown dramatically. Traditionally, many water planners have assumed that urban water use would grow in proportion to population. Yet in Western states, urban water use remains approximately 10 percent of the total developed water supply.[1]

In fact, as the figures below indicate, some communities have succeeded in keeping water use relatively flat, despite dramatic population growth. Los Angeles, Seattle, the San Francisco Bay area, and Denver have all experienced significant population growth in the past quarter century, yet for each, total water use has remained relatively constant. This remarkable accomplishment has been made possible by significant investments in water conservation

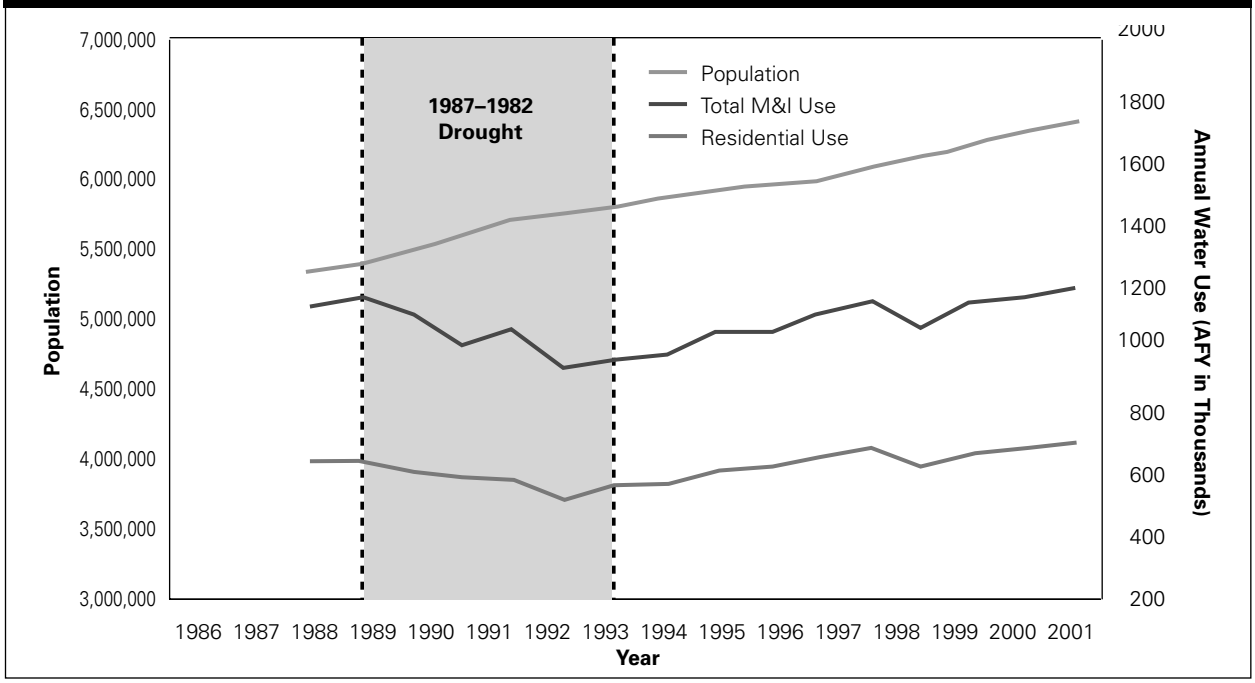
In addition to water conservation investments, some areas have also made major investments in wastewater recycling and groundwater cleanup. Several of these efforts have been prompted by droughts. In Southern California, conservation and recycling investments have also been motivated by pressure to reduce deliveries from the Colorado River and the Mono Lake basin (see Figure B-1). The progress made by these communities demonstrates the effectiveness of efficiency as a water supply tool. As discussed earlier in the report, California's new State Water Plan indicates that these tools are likely to remain the largest sources of supply for future growth. Figures B-2, B-3, and B-4 show similar progress in the San Francisco Bay area, Denver, and Seattle.

Figure B-1: Los Angeles Department of Water and Power Water Use and Population



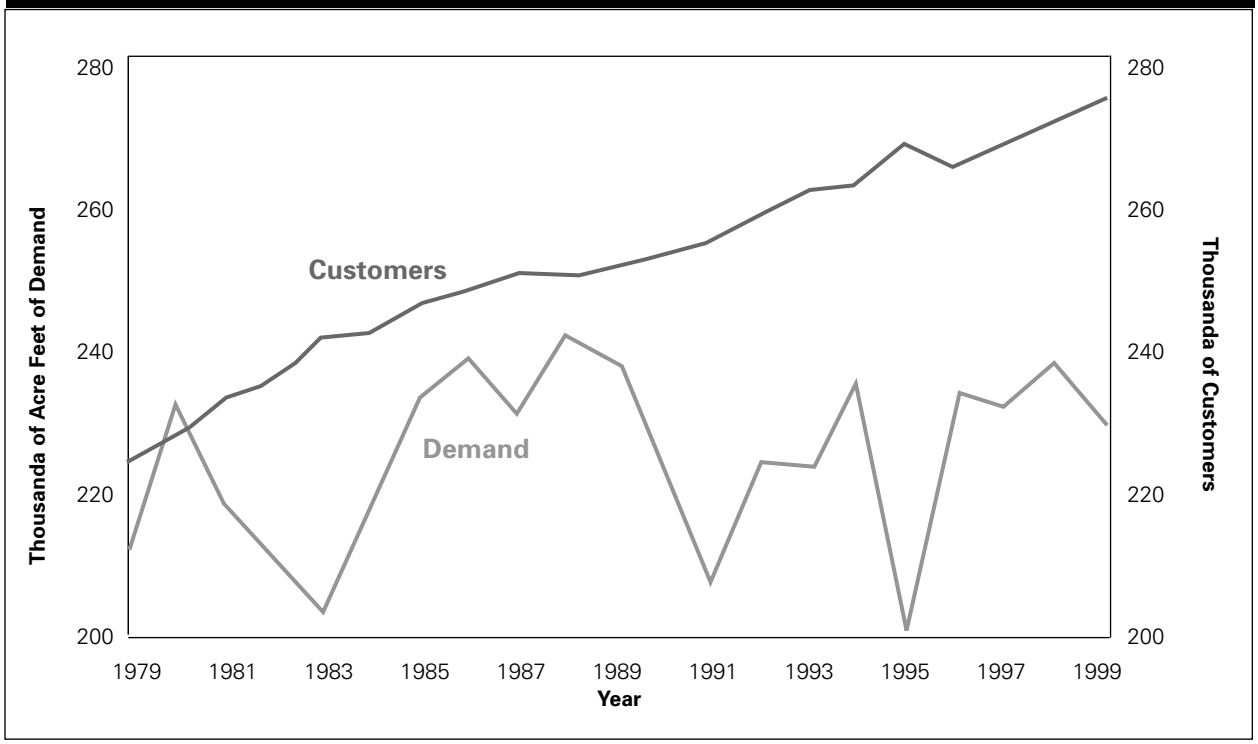
Source: Fatema Akhter, LADWP: 8/31/06 and from California Water Decisions booklet published by Environmental Water Caucus, 7/00.

Figure B-2: San Francisco Bay Area Population and Water Use



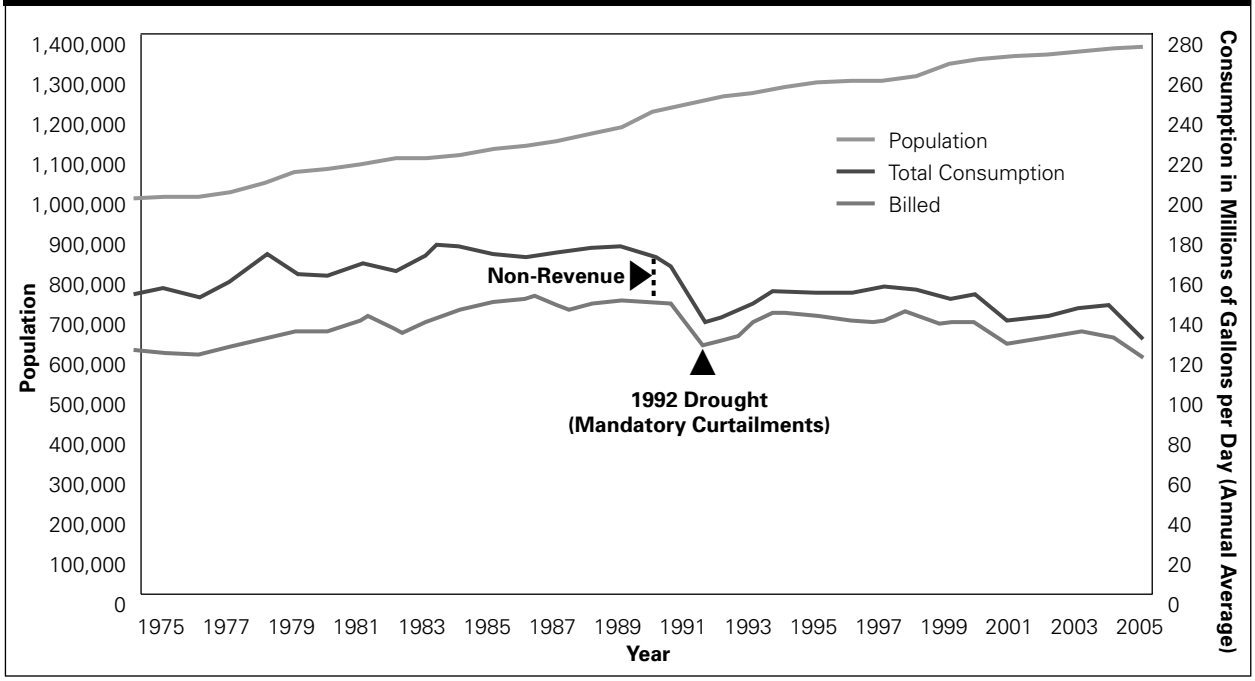
Source: Randy Kanouse, East Bay Municipal Utility District Sacramento Lobbyist. From Bay Area Integrated Regional Water Management Plan, Administrative Draft: 6/06.

Figure B-3: Denver Demand and Customer Growth of Treated Water



Source: Elizabeth Gardener, Denver Water Conservation Manager: 8/29/06.

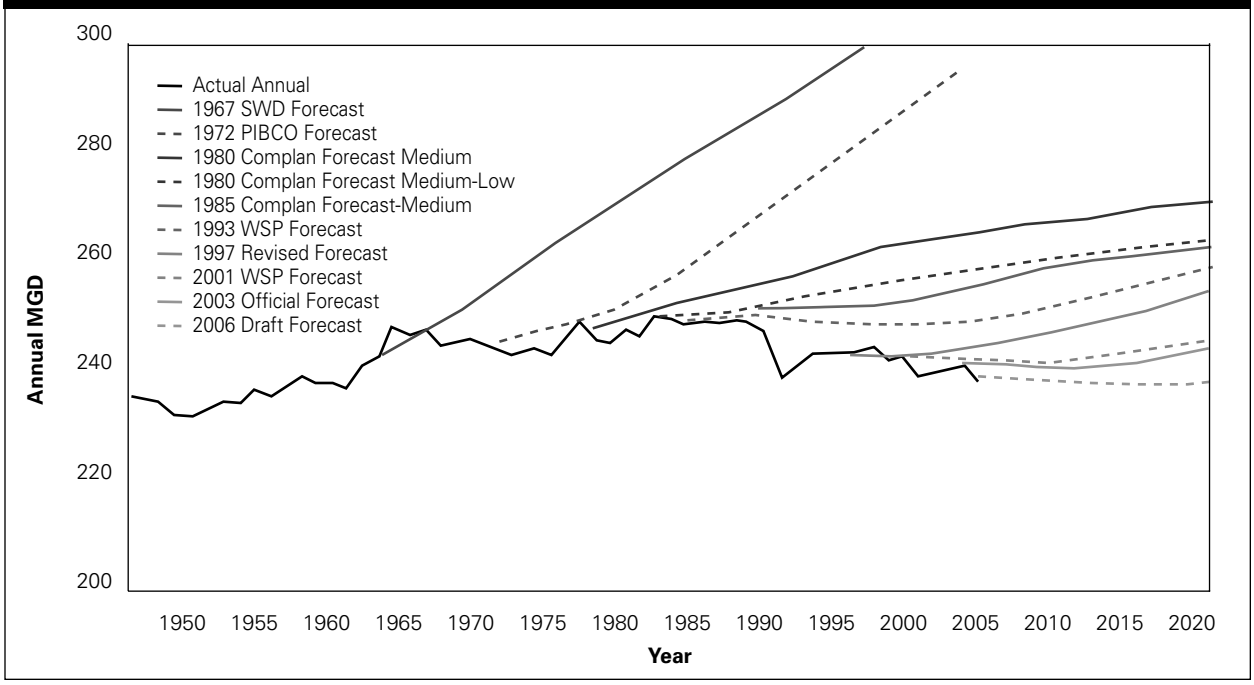
Figure B-4: Population Growth and Water Consumption from Seattle Public Utilities



Source: Pg. 2-15. Seattle Public Utilities, 2007 Water System Plan, Public Review Draft. Online access: http://www.cityofseattle.net/util/About_SPU/Water_System/Plans/2007WaterSystemPlan/index.asp.

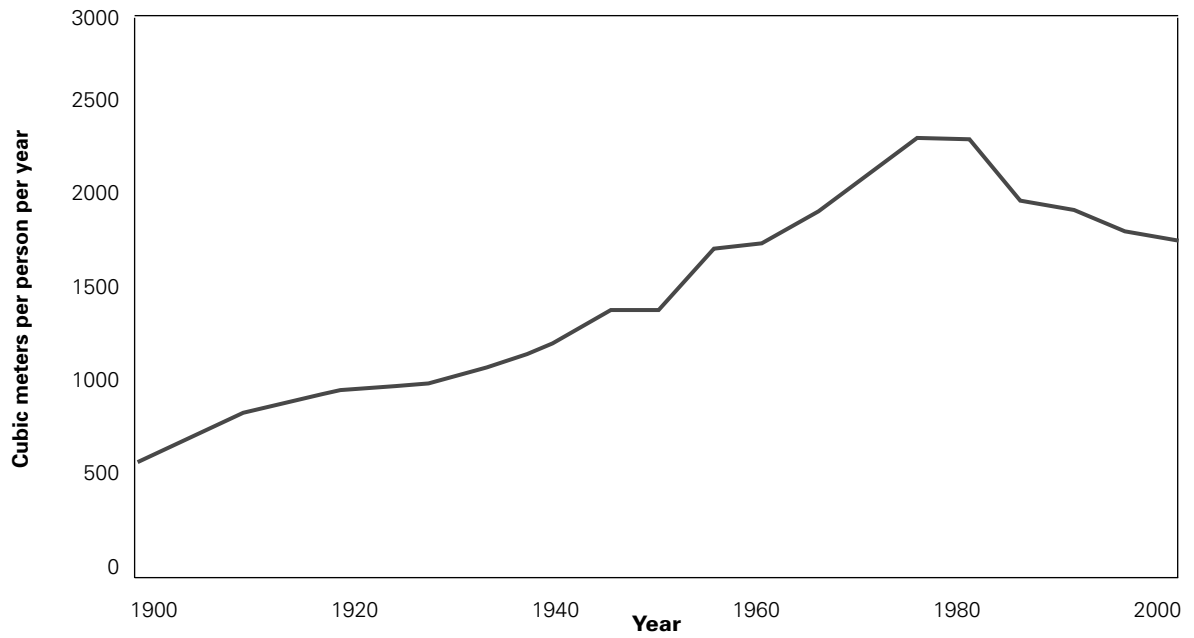
Note: Issaquah, Sammamish Plateau, and Covington area are not included in historic data because they did not become customers until 2004 when contract with CWA was signed.

Figure B-5: Seattle Public Utilities Forecasting Demand



Source: Chuck Clarke, Director, Seattle Public Utilities, personal communication with Barry Nelson.

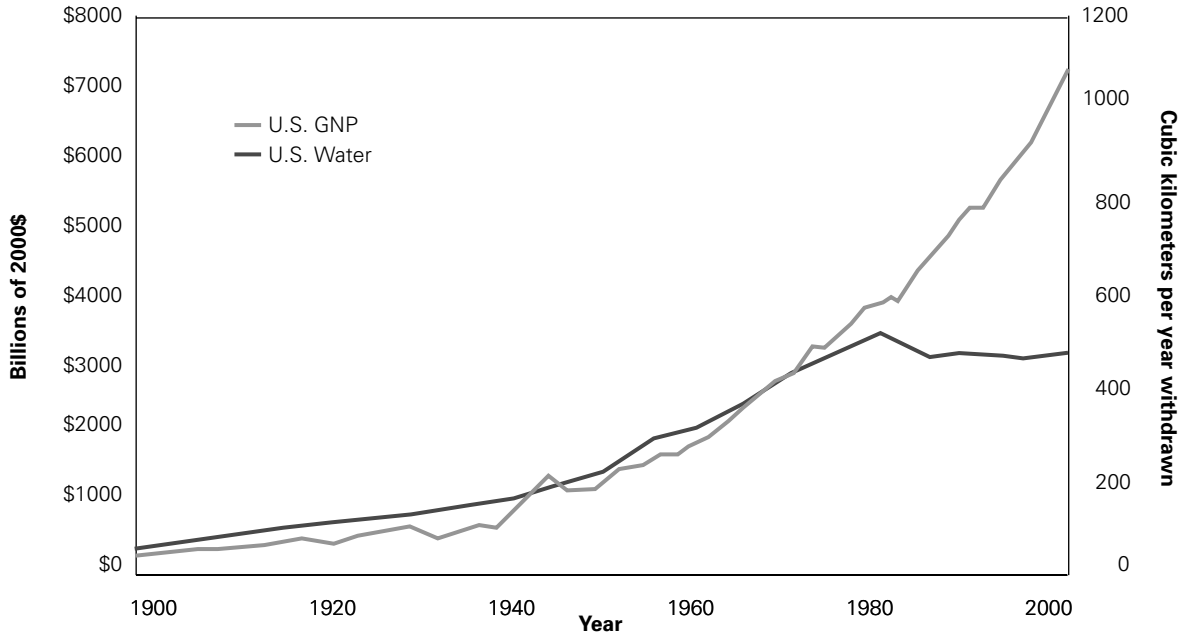
Figure B-6: United States Per Capita Water Withdrawals



Source: Source: Peter Gleick, Pacific Institute (www.pacinst.org). See also, The World's Water (Island Press, Washington DC

Note: Nationally, this figure diminishes to 6.5%.

Figure B-7: U.S. Economic Growth and Total Water Withdrawals



Source: Source: Peter Gleick, Pacific Institute (www.pacinst.org). See also, The World's Water (Island Press, Washington DC

Note: Nationally, this figure diminishes to 6.5%.

This decoupling of population and water use can be seen on the national level as well. Figure B-7 shows that, for the past quarter century, water withdrawals across the nation have remained essentially flat despite a significant increase in GNP. Figure B-6 shows that per capita water withdrawals have declined significantly over the same period. This trend is due to both increased investments in water use efficiency and a shift in the nation's economy toward industries that are less water-intensive.

INCORPORATING DEMAND MANAGEMENT IN PROJECTIONS OF FUTURE WATER USE—THE SEATTLE PUBLIC UTILITIES EXPERIENCE

Even where water agencies have made significant investments in conservation, it has taken a sustained effort for planners to incorporate fully the benefits of conservation—and the decoupling of growth and water use. Figure B-5 from Seattle Public Utilities illustrates this challenge. Total water SPU water demand has been remarkably flat for approximately three decades. For many years, however, demand forecasts projected dramatically higher future demand than has proven to be the case based largely on assumptions that previous water use trends would continue. Demand forecasting methodologies have improved significantly in a number of areas in the past thirty years. For example, since the 1980's, SPU forecasters have worked to incorporate the long-term savings as a result of conservation programs. Figure B-5 indicates, in the most recent SPU projections, demand projections track actual past water use trends.

Water demand forecasts are often designed to be conservative, because water managers are understandably hesitant to risk underestimating future demand. However, overestimations of future demand—frequently based in part on underestimations of the performance of efficiency measures—tend also to overestimate the importance of water management tools designed to increase supply. Today, conservation, water recycling and other demand management tools are now well enough established that water managers can rely on their performance over time. These tools should be carefully incorporated into future demand projections. The results of this effort can be seen in SPU's increasingly accurate demand projections—which now anticipate a continued ability to meet future water needs without a significant increase in supply.

Endnotes

Chapter 1

1 Miller, Kathleen and David Yates, 2005. *Climate Change and Water Resources: A Primer for Municipal Water Providers.* AWWA Research Foundation and the University Corporation for Atmospheric Research.

2 "Climate Change 2007: The Physical Science Basis: Summary for Policymakers." Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p.3.

3 National Research Council, Committee on the Science of Climate Change, Division on Earth and Life Studies, 2001. *Climate Change Science: An Analysis of Some Key Questions*. National Academy Press, Washington, D.C., 2001. http://www.nap.edu.

4 "Climate Change 2007: The Physical Science Basis: Summary for Policymakers." Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

5 Rahmstorf, Stefan *et al*. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise." *Science*, Vol. 315: January 19, 2007, p.368-370.

6 National Research Council, Committee on Abrupt Climate Change, 2002. *Abrupt Climate Change: Inevitable Surprises.* National Academy Press, Washington, D.C., p.1. http:www.nap.edu/catalog/.10136.html. Emphasis added.

7 Miller, Kathleen, and David Yates, 2005. *Climate Change and Water Resources: A Primer for Municipal Water Providers*. AWWA Research Foundation and University Corporation for Atmospheric Research. http://www.awwarf.org/research/TopicsAndProjects/projectSnapshot.aspx?pn=2973

8 California Department of Water Resources, July 2006. *Progress on Incorporating Climate Change into Management of California's Water Resources*http://www.waterplan.water.ca.gov/docs/climate_change/gg_fig3-3.pdf.

Chapter 2

1 USGS, National Streamflow Information Program, 2005. "Changes in Streamflow Timing in the Western United States in Recent Decades." Fact Sheet 2005-3018.

2 Miller and Yates, 2005.

3 Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. "Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity." Sciencexpress, July 6, 2006, p.1, 10.1126, *Science*, 1128824.

4 Gleick, Peter H., 2000. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States.* Report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program, Pacific Institute for Studies in Development, Environment, and Security, p.125.

5 *Climate Change 2007: The Physical Science Basis: Summary for Policymakers.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p.4.

6 Dettinger, Michael D. and Dan R. Cayan, 1994. "Large-scale Atmospheric Forcing of Recent Trends Toward Early Snowmelt Runoff in California." *Journal of Climate,* 8:606-23.

7 Karl, T.R. and R.W. Knight, 1998. "Secular Trends of Precipitation Amount, Frequency, and Intensity in the USA," *Bulletin of the American Meteorological Society*, Vol. 79, pp.231-241.

8 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* National Research Council, p.63.

9 USGS, National Streamflow Information Program, March 2005. "Changes in Streamflow Timing in the Western United States in Recent Decades." Fact Sheet, 2005-3018.

10 Seattle Public Utilities, 2007 Water System Plan. November 2006. Online access: http://www.seattle.gov/util/About_SPU/Water_System/Plans/2007WaterSystemPlan/index.asp, 2/14/07, pp.2-34.

11 Stewart, I., D.R. Cayan, and M.D. Dettinger, 2004. "Changes in Snowmelt Runoff Timing in Western North America Under a 'Business as Usual' Climate Change Scenario." *Climatic Change* 62, 217-232. Mote, P.W., 2003. "Trends in Snow Water Equivalent in the Pacific Northwest and Their Climatic Causes." *Geophysical Research Letters*, 30, DOI 10.1029/2003GL0172588. Knowles, N. and D. Cayan, 2002. "Potential Impacts of Climate Change on the Sacramento/San Joaquin Watershed and the San Francisco Estuary." *Geophysical Research Letters,* 29, No. 18, 1891, doi:10.1029/2001GL014339.

12 Dettinger, Michael D., and Dan R. Cayan. 1994. Large-scale atmospheric forcing of recent trends toward early snowmelt runoff in California. *Journal of Climate* 8: 606-23.

13 Gleick, Peter H. et al., 2000. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States.* The report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program, Pacific Institute for Studies in Development, Environment, and Security, p.77, citing Dettinger and Cayan (1995).

14 Wilby, R.L., and M. Dettinger, 2000. "Streamflow Changes in the Sierra Nevada, California, Simulated Using a Statistically Downscaled General Circulation Model Scenario of Climate Change." In *Linking Climate Change to Land Surface Change*, S. J. McLaren and D. R. Kniveton, eds. Dordrecht: Kluwer Academic Publishers.

15 Roos, Maurice, 2005. "Accounting for Climate Change" in *California Water Plan Update 2005*, Vol. 4, Reference Guide, Public Review Draft, California Department of Water Resources, p.5.

16 Gleick, P.H., 1987a. "The Development and Testing of a Water-Balance Model for Climate Impact Assessment: Modeling the Sacramento Basin." *Water Resources Research*, Vol. 23, pp.1049-1061.

17 Miller, Kathleen and David Yates, 2005. *Climate Change and Water Resources: A Primer for Municipal Water Providers.* AWWA Research Foundation and the University Corporation for Atmospheric Research, American Water Works Association, pp.40-41, based on Nash, L. L. and P. H.Gleick,1993. *The Colorado River Basin and Climatic Change: The Sensitivity of Streamflow and Water Supply to Variations in Temperature and Precipitation*. Report, U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Climate Change Division, EPA 230-R-93-009.Oakland,CA: Pacific Institute for Studies in Development, Environment, and Security See also Nash, L.L. and P.H.Gleick,

1991. "The Sensitivity of Streamflow in the Colorado Basin to Climatic Changes." *Journal of Hydrology*, 125:221-241.

18 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* National Research Council, p.67.

19 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* National Research Council, p.80.

20 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* National Research Council, p.68.

21 "Estimated Impacts of Climate Warming on California Water Availability Under Twelve Futureclimate Scenarios" -California Climate Change Center Report Series Number 2006-003 Prepared For: California Energy Commission Public Interest Energy Research (PIER) Program. Prepared By: Tingju Zhu, Marion W. Jenkins, Jay R. Lund Department of Civil and Environmental Engineering, University of California, Davis. April 2006 http://www.climatechange.ca.gov/research/impacts/pdfs/CEC-500-2006-040.pdf

22 Miller, Kathleen and David Yates, 2005. *Climate Change and Water Resources: A Primer for Municipal Water Providers*. AWWA Research Foundation and the University Corporation for Atmospheric Research, American Water Works Association, p.5.

23 Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam, 2006. "Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity." Sciencexpress, July 6, 2006, p.1, 10.1126, *Science*, 1128824.

24 Davis, F.W., Michaelson J., 1995. "Sensitivity of Fire Regime in Chaparral Ecosystems to Climate Change," in *Global Change and Mediterranean-type Ecosystems*, Moreno, J.M., W.C. Oechel, eds. Springer, New York, pp.203-224.

25 *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change*, 2000. A Report of the Southwest Regional Assessment Group for the U.S. Global Change Research Program.

26 Grissino-Mayer, H.D. and T.W. Swetnam, 2000. "Century Scale Changes in Fire Regimes and Climate in the Southwest." *The Holocene* 10 (2), 207-214.

27 Swetnam, T.W., C.D. Allen, and J.L. Betancourt, 1999. "Applied Historical Ecology: Using the Past to Manage for the Future." *Ecological Applications* 9 (4), 1189-1206.

28 Swetnam, T.W. and J.L. Betancourt, 1998. "Mesoscale Disturbance and Ecological Response to Decadal Climatic Variability in the American Southwest." *Journal of Climate* 11, 3128-3147; Swetnam, T.W. and J.L. Betancourt, 1990. Fire-Southern Oscillation Relations in the Southwestern United States. *Science* 249, 1017-1020.

29 Swetnam, T.W. and J.L. Betancourt, 1998. "Mesoscale Disturbance and Ecological Response to Decadal Climatic Variability in the American Southwest." *Journal of Climate* 11, 3128-3147.

30 *Climate Change 2007: The Physical Science Basis: Summary for Policymakers.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p.11.

31 Rahmstorf, Stefan, 2007. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise." Science 315:368-370

32 Overpeck, Jonathan T., Bette L. Otto-Bliesner, Gifford H. Miller, Daniel R. Mugs, Richard B. Alley, Jeffrey T. Kiehl, 2006. "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise." *Science*, Vol 311: 3/24/06, p.1747.

33 Monaghan, Andrew J., David H. Bromwich, Ryan L. Fogt, Wang, Sheng-Hung, Paul A. Mayewski, Daniel A. Dixon, Alexey Ekaykin, Massimo Frezzotti, Ian Goodwin, Elisabeth Isaksson, Susan D. Kaspari, Vin I. Morgan, Hans Oerter, , Tas D. Van Ommen, Cornelius J. Van der Veen, Jiahong Wen, 2006. "Insignificant Change in Antarctic Snowfall Since the International Geophysical Year." *Science*, Vol. 313:8/11/06, p.827.

34 Ibid.

35 Chung, Francis, Ph.D., P.E. (principal engineer) "Progress on Incorporating Climate Change into Management of California's Water Resources," http://www.climatechange.ca.gov/documents/2006-07_DWR_CLIMATE_CHANGE_FINAL.PDF, p.2-47,2-48.

36 "Flood Damage in the United States." National Weather System website: http://www.flooddamagedata.org/index.html, 9/15/06.

37 "Water Resources: As the West Goes Dry." *Science,* 20 February 2004: 1124-1127. www.sciencemag.org/cgi/content/full/303/5661/1124?maxtoshow=&HITS=10&hits=10.

38 Roos, Maurice, 2005. "Accounting for Climate Change" in *California Water Plan* Update 2005, Vol. 4, Reference Guide, Public Review Draft, California Department of Water Resources, p.5.

39 USGS, National Streamflow Information Program, 2005. "Changes in Streamflow Timing in the Western United States in Recent Decades." Fact Sheet 2005-3018.

40 NASA, 2002. "Climate Change May Bring More Winter Floods and a Drier Growing Season in California." Goddard Space Flight Center, January 17, 2002.

41 NASA, 2002. Climate Change May Bring More Winter Floods and a Drier Growing Season in California." Goddard Space Flight Center, January 17, 2002.

42 Mayell, Hillary, 2002. "Climate Studies Point to More Floods in This Century." *National Geographic News*, January 30, 2002.

43 The following examples are cited in: Gleick, Peter H. et al., 2000. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States.* The report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program, Pacific Institute for Studies in Development, Environment, and Security.

44 Schindler, D.W., 1997. Widespread Effects of Climatic Warming on Freshwater Ecosystems in North America." *Hydrological Processes,* Vol. 11, No. 8, pp.1043-1067. Mulholland, P.J., G.R. Best, C.C. Coutant, G.M. Hornsberger, J.L. Meyer, P.J. Robinson, J.R. Stenberg, R.E. Turner, F. VeraHerrera, and R. Wetzel, 1997. "Effects of Climate Change on Freshwater Ecosystems of the South-eastern United States and the Gulf Coast of Mexico." *Hydrological Processes,* Vol. 11, pp.949-970.

45 Jacoby, H.D., 1990. "Water Quality." In *Climate Change and U.S. Water Resources*, P.E. Waggoner, ed., John Wiley and Sons, New York, pp.307-328. Mulholland, P.J., G.R. Best, C.C. Coutant, G.M. Hornsberger, J.L. Meyer, P.J. Robinson, J.R. Stenberg, R.E. Turner, F. VeraHerrera, and R. Wetzel, 1997. "Effects of Climate Change on Freshwater Ecosystems of the South-eastern United States and the Gulf Coast of Mexico." *Hydrological Processes*, Vol. 11, pp.949-970. Schindler, D.W., 1997. "Widespread Effects of cCimatic Warming on Freshwater Ecosystems in North America." *Hydrological Processes*, Vol. 11, No. 8, pp.1043-1067.

46 Murdoch, P.S., J.S. Baron, and T.L. Miller, 2000. "Potential Effects of Climate Change on Surface-Water Quality in North America." *Journal of the American Water Resources Association*, Vol. 36, No. 2, pp.347-366.

47 Dorfman, Mark, 2006. *Testing the Waters 2006: Water Quality at Vacation Beaches*. Natural Resources Defense Council.

48 Testimony of John Marshall, assistant director, Colorado Department of Natural Resources, before U.S. House of Representatives Committee on Resources, August 25, 2003. http://resourcescommittee.house.gov/archives/108/testimony/johnmarshall.htm.

49 Master, L.L., S.R. Flack, and B.A. Stein, eds., 1998. *River of Life: Critical Watersheds for Protecting Freshwater Biodiversity.* The Nature Conservancy, Arlington, VA.

50 Ricciardi, A., and J.B. Rasmussen, 1999. "Extinction Rates of North American Freshwater Fauna." *Conservation Biology* 13:1,220-1,222.

51 O'Neal, K., 2002. *The Effects of Global Warming on Trout and Salmon in U.S. Streams.* Natural Resources Defense Council and Defenders of Wildlife.

52 Poff, N. LeRoy et al., 2002. *Aquatic Ecosystems and Global Climate Cchange: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States.* Pew Center on Global Climate Change, Arlington, VA.

53 Sweeney, B. W., J. K. Jackson, J. D. Newbold, and D. H. Funk. "Climate Change and the life histories and biogeography of aquatic insects in eastern North America." P. Firth and S. G. Fisher (eds.). Global warming and freshwater ecosystems. Springer-Verlag, New York. 1991, p. 143 – 175.

54 Poff, N. LeRoy et al., 2002. *Aquatic Ecosystems and Global Climate Change: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States.* Pew Center on Global Climate Change, Arlington, VA.

55 Jassby, A. and E. Van Nieuwenhuyse, 2005. "Low Dissolved Oxygen in an Estuarine Channel (San Joaquin River, California): Mechanisms and Models Based on Long-term Time Series." *San Francisco Estuary and Watershed Science*, Vol. 3, No. 2 (September 2005), Art. 2.

56 Poff, N. LeRoy et al., 2002. *Aquatic Ecosystems and Global Climate Change: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States*. Pew Center on Global Climate Change, Arlington, VA.

57 Poff, N. LeRoy et al., 2002. *Aquatic Ecosystems and Global Climate Change: Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States*. Pew Center on Global Climate Change, Arlington, VA.

58 Frederick, K.D. and P.H. Gleick, 1999. *Water and Global Climate Change: Potential Impacts on U.S. Water Resources.* Pew Center on Global Climate Change, Arlington, VA.

59 Kattenberg, A., F. Giorgi, H. Grassl, G.A. Meehl, J.F.B. Mitchell, R.J. Stouffer, T. Tokioka, A.J. Weaver, and T.M.L. Wigley, 1996. "Climate Models-Projections of Future Climate." In *Climate Change 1995: The Science of Climate Change*, J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, eds. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

60 Karl, T.R., R.W. Knight, D.R. Easterling, and R.Q. Quayle, 1996. "Indices of Climate Change for the United States." *Bulletin of the American Meteorological Society* 77:279-292.

61 Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B. Richter, R. Sparks, and J. Stromberg, 1997. "The Natural Flow Regime: A New Paradigm for Riverine Conservation and Restoration." *BioScience* 47:769-784.

62 Luers, Amy Lynd, Daniel R. Cayan, Guido Franco, Michael Hanemann, and Bart Croes, July 2006. "Our Changing Climate: Assessing the Risks to California." Summary report from the California Climate Change Center, CEC-500-2006-077.

63 Kay, Jennifer, Joe Casola, Amy Snover, and the University of Washington Climate Impacts Group (CIG) at King County Climate Change Conference, October 27, 2005. Online access: http://www.cses.washington.edu/cig/outreach/workshops/kc2005.shtml, 11/6/05.

64 Palmer, Richard and Margaret Hahn, January 2002. *The Impacts of Climate Change on Portland's Water Supply: An Investigation of Potential Hydrologic and Management Impacts on the Bull Run System.* Prepared for Portland Water Bureau, Seattle, Washington, p.ii. http://www.tag.washington.edu/papers/papers/PortlandClimateReportFinal.pdf.

65 Gleick, Peter H., September 2000. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States*. Prepared for the U.S. Global Change Research Program.

Chapter 3

1 See *Energy Down the Drain*, August 2004. National Resources Defense Council.

2 California Energy Commission, *Integrated Energy Policy Report*, November 2005, CEC-100-2005-007-CMF, p.139.

3 NRDC report, *Energy Down the Drain*. p.19.

4 Cohen, Ronnie, Barry Nelson, and Gary Wolff, 2004. *Energy Down the Drain.* Natural Resources Defense Council, New York.

5 Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute.

6 California Energy Commission, November 2005. *Integrated Energy Policy Report*, CEC-100-2005-007-CMF, p.150.

7 Klein, Gary, 2005. *California's Water-Energy Relationship*. California Energy Commission, final staff report, prepared in support of the 2005 Integrated Energy Policy Report Proceeding (04-IEPR-01E), November 2005, CEC-700-2005-011-SF.

8 California Energy Commission. *Integrated Energy Policy Report*, November 2005, CEC-100-2005-007-CMF, p.E-6.

9 California Public Utilities Commission. Order instituting rulemaking[0] to examine the commission's post-2005 energy efficiency policies, programs, evaluation, measurement and verification, and related issues. Rulemaking 06-04-010, filed April 13, 2006.

10 Sandia National Laboratory website, 2005. "Energy-Water Roadmap Process." Online access: http://www.sandia.gov/energy-water/roadmap_process.htm.

Chapter 4

1 *Climate Change 2007: The Physical Science Basis: Summary for Policymakers.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

2 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* National Research Council.

3 This model, the Sierra Climate Change Watershed Yield Calculator, can be found online at: http://www.arwi.us/.

4 E-mail exchange with Otis Wollan, Placer County Water Agency board member, August 23, 2006.

5 Waggoner, P.E., ed., 1990. *Climate Change and U.S. Water Resources*. John Wiley and Sons, Inc., New York, p.5. Emphasis in original.

6 Woodhouse, C.A., S.T. Gray, D.M. Meko, 2006. "Updated Streamflow Reconstructions for the Upper Colorado River Basin." *Water Resources Research,* Vol. 42, W05415, 11 May 2006. http://www.ncdc.noaa.gov/paleo/pubs/woodhouse2006/woodhouse2006.html.

7 Jerry Johns, deputy director, California Department of Water Resources, personal communication.

8 Presentation by Tony Franza of the San Francisco Public Utilities Commission at the Water Utility Climate Change Summit, January 30, 2007. San Francisco.

9 Chuck Clarke, director, Seattle Public Utilities, personal communication.

10 American Water Works Association (1997). "Climate Change and Water Resources: Committee Report of the Public Advisory Forum." *Journal of the American Water Works Association* 89(11): 107-110.

11 California Urban Water Conservation Council, December 2005. *Water Smart Landscapes for California,* AB 2717 Landscape Task Force Findings, Recommendations, & Actions. Report to the governor and legislature, p.14.

12 http://www.bewaterwise.com/knowledge01.html.

13 http://www.snwa.com/html/cons_wsl.html.

14 "Climate Change and Water Resources: Committee Report of the Public Advisory Forum." *Journal of the American Water Works Association* 89(11): 107–110.

15 http://www.ebmud.com/conserving_&_recycling/residential/landscape_rebate/default.htm.

16 http://www.marinwater.org/controller?action=menuclick&id=269.

17 Hewitt, J.A. and W.M. Hanemann, 1995. "A Discrete/Continuous Choice Approach to Residential Water Demand Under Block Rate Pricing." *Land Economics* 71:173–92.

18 http://www.ers.usda.gov/Briefing/WaterUse/Questions/qa6.htm.

19 http://www.ers.usda.gov/Briefing/WaterUse/Questions/qa2.htm.

20 "Progress on Incorporating Climate Change into Management of California's Water Resources." http://www.climatechange.ca.gov/documents/2006-07_DWR_CLIMATE_CHANGE_FINAL.PDF.

21 Hutson, Susan S., Nancy L. Barber, Joan F. Kenny, Kristin S. Linsey, Deborah S. Lumia, and Molly A. Maupin, February 2005. "Estimated Use of Water in the United States in 2000." U.S. Geological Survey, http://pubs.usgs.gov/circ/2004/circ1268/htdocs/text-ir.html.

22 Legislative Analyst's Office, September 8, 1999. *The Role of Water Transfers in Meeting California's Water Needs*. http://www.lao.ca.gov/090899_water_transfers/090899_water_transfers.html. [check this URL pls.]

23 Gleick, Peter H. et al., 2000. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States*. The report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program, Pacific Institute for Studies in Development, Environment, and Security, p.119.

24 California defines paper water transfers as "a proposal to market water the seller is legally entitled to use under a water service contract or a water right, but has not historically used. Paper water transfers often involve an offer to sell water that someone else would otherwise use in the absence of the transfer. Example: An offer to transfer return flows that would otherwise be used by a downstream appropriator. To the extent that a paper water transfer results in an increase in consumption by the buyer, the water is really coming from a user other than the seller." For example, in some areas, water users hold contracts or claim rights for more water than they have used historically. In some cases, such as California's State Water Project, total water contracts exceed the delivery capacity of the project. Selling unused "paper water" can have the effect of transferring water currently used by others, or simply increasing diversions from rivers.

25 Applications of stormwater strategies are site dependent. The following examples are provided for illustrative purposes. Local soil conditions, permeability, and other factors must be examined for each specific application.

26 http://www.treepeople.org/vfp.dll?OakTree~getPage~&PNPK=32.

27 Intergovernmental Panel on Climate Change, 1996. "Hydrology and Freshwater Ecology." In *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change.* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

28 Personal communication, Paul Fleming, Seattle Public Utilities strategic advisor, 8/30/06.

29 Phone conversation between Denver Water conservation manager Elizabeth Gardener and Noushin Ketabi, 8/16/06.

30 California State Water Plan, Department of Water Resources, Vol. 2, p.16.1. http://www.waterplan.water.ca.gov/docs/cwpu2005/

31 AWWA Report, p. 13.

32 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007.

33 There is substantially more controversy regarding the Contra Costa Water District's current proposal to expand the existing Las Vaqueros Reservoir, because of the lack of a clear project purpose.

34 The Contra Costa Water District is currently proposing to expand Los Vaqueros Reservoir. The purpose and potential impacts of this proposed expansion are not well defined. As a result, there is significant environmental opposition.

35 California Governor Arnold Schwarzenegger, Governor's Statement on Water Infrastructure, January 10, 2007.

36 Committee on the Scientific Bases of Colorado River Basin Water Management, February 2007. *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability.* National Research Council, p.96.

37 Ibid.

38 California State Water Plan, Department of Water Resources, Vol. 2, p.6.3

39 California State Water Plan, Department of Water Resources, 2005, Vol. 2, p.2.6. http://www.waterplan.water.ca.gov/docs/cwpu2005/vol1/v1ch02.pdf.

40 Burton, Franklin L., 1996. *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. Burton Engineering, Los Altos, CA, Electric Power Research Institute Report CR-106941.

41 Meisner 1990. Meisner, JD; Regier, HA Fisheries (Bethesda) FISHDN, Vol. 15, No. 6, p 10-15, November/December 1990.

42 Teri Bachman. "Heading for a Bad Break." *UC Davis Magazine*. Online edition: Vol. 23, No. 2., Winter 2006.

43 http://www.cuwcc.org

44 CALFED Bay-Delta Program. *Water Use Efficiency Comprehensive Evaluation.* Water Use Efficiency Element, August 2006.

45 http://www.sustainablesiliconvalley.org.

46 Cities for Climate Protection website: http://iclei.org, March 8, 2007.

47 http://www.usmayors.org/uscm/resolutions/73rd_conference/en_01.asp, 3/8/07.

48 Judy Fahys. "Mayors Fight Global Warming at Local Level." *Salt Lake City Tribune*, July 18, 2005.

49 U.S. Mayors Climate Protection Agreement website: http://www.seattle.gov/mayor/climate/, March 9, 2006.

50 Larry Wilson, Santa Clara Valley Water District chairman of the board in a letter to California Governor Arnold Schwarzenegger, 3/14/2006.

51 http://www.azclimatechange.us/.

52 http://www.oregon.gov/ENERGY/GBLWRM/Strategy.shtml.

53 http://www.nmclimatechange.us/.

54 April Reese. "States Lead the Charge Against Global Warming." *High Country News*, October 17, 2005.

55 http://www.ef.org/westcoastclimate.

56 http://www.rggi.org/.

57 United States Climate Action Partnership, January 2007. "A Call for Action." Online access: http://www.us-cap.org/ClimateReport.pdf.

58 "Western Water: Climate Change and Water: What Might the Future Hold?" May/June 1998. Water Education Foundation, Sacramento, CA. http://www.water-ed.org/store/itemdetail.asp?id=96.

59 "Manager to Manager." *American Water Works Association Journal*, October 2001, p.38. http://www.awwa.org/Communications/journal/Archives/J1001TOC.HTM. [this URL doesn't seem to be right]

60 Santa Clara Valley Water District, Water Sustainability Planning website, http://www.valleywater.org/Water/Where_Your_Water_Comes_From/Water%20Supply%20Sustainability%20Planning/Climate%20Change/index.shtm.

Chapter 5

1 Draft Water Use Efficiency Comprehensive Evaluation, CALFED Bay-Delta Program, April, 2006, p.14. http://calwater.ca.gov/Programs/WaterUseEfficiency/adobe_pdf/2006_WUE_Public_Draft.pdf.

2 http://www.cuwcc.org/national_cwe.lasso.

3 http://www.iclei.org/index.php?id=800.

Appendix A

1 Allen Best. "Top Water Official Warns of Climate Change." *Vail Daily*, 9/22/05.

2 Phone conversation with Denver Water raw water manager Marc Waage, 11/9/05.

3 Email from Denver Water raw water manager Marc Waage, 8/24/06.

4 Allen Best. "Top Water Official Warns of Climate Change." *Vail Daily*, 9/22/05.

5 Kim McGuire. "Slowing the Flow." *Denver Post*, 6/4/06.

6 Phone conversation between Denver Water conservation manager Elizabeth Gardener and Noushin Ketabi, 8/16/06.

7 Phone conversation between Lorna Stickel, Portland Water Bureau water resources planning manager, and Noushin Ketabi, 11/18/05.

8 Palmer, Richard and Margaret Hahn. January 2002. Online access: http://www.tag.washington.edu/papers/papers/PortlandClimateReportFinal.pdf, 8/13/06.

9 Miller, Kathleen and David Yates, 2005. *Climate Change and Water Resources: A Primer for Municipal Water Providers*, AWWA Research Foundation and the University Corporation for Atmospheric Research, American Water Works Association.

10 Santa Clara Valley Water District. *Integrated Water Resources Planning Study 2003.* Online access: http://www.valleywater.org/Water/Where_Your_Water_Comes_From/Water%20Supply%20Sustainability%20Planning/_pdf/IWRP_2003_Draft.pdf, 8/11/06.

11 Santa Clara Valley Water District.*Urban Water Management Plan 2005.* Online access: http://www.valleywater.org/Water/Where_Your_Water_Comes_From/Water%20Supply%20Sustainability%20Planning/_pdf/2005-12-20_WSSPUnit_UWMPWithErrataSheets_Final.pdf. Online access: 8/11/06.

12 Phone conversation between Jim Crowley, SCVWD Engineering Unit manager, and Noushin Ketabi, 9/14/05.

13 "Where Your Water Comes From." Santa Clara Valley Water District website: http://www.valleywater.org/Water/Where_Your_Water_Comes_From/Water%20Supply%20Sustainability%20Planning/Climate%20Change/index.shtm, 8/11/06.

14 Seattle Public Utilities, November 2006. *2007 Water System Plan*. [need "online access" URL?] 2/14/07. http://ww.seattle.gov/util/About_SPU/Water_System/Plans/2007WaterSystemPlan/index.asp.

15 Phone conversation among Joan Kersnar, Seattle Public Utilities water system planning manager; Paul Fleming, SPU strategic advisor, and Noushin Ketabi, 8/23/06.

16 Email from Joan Kersnar, 8/26/06.

17 Regional Water Planning Process website: http://www.govlink.org/regional-water-planning/index.htm, 8/27/06.

18 Miller, Kathleen and David Yates, 2005. *Climate Change and Water Resources: A Primer for Municipal Water Providers*, AWWA Research Foundation and the University Corporation for Atmospheric Research.

19 Email exchange between Doug Wallace, East Bay Municipal Utility District environmental affairs officer, and Noushin Ketabi, 12/6/06.

20 Phone conversations between Kevin Richards, East Bay Municipal Utility District associate civil engineer, and Noushin Ketabi, 12/6/05, 8/10/06.

21 East Bay Municipal Water District website: www.ebmud.com, 12/6/06.

22 Consumnes, American, Bear and Yuba website: www.cabyregion.org, 9/21/06.

23 Water And Evaluation Planning System website: www.weap21.org. 8/30/06.

24 Phone conversation between Liz Mansfield, El Dorado Irrigation District watershed coordinator, and Noushin Ketabi, 8/30/06.

25 *Progress on Incorporating Climate Change into Management of California's Water Resources.* Department of Water Resources Technical Report, July 2006. Online access: http://baydeltaoffice.water.ca.gov/climatechange/DWRClimateChangeJuly06.pdf#pagemode=bookmarks&page=1, 8/14/06.

26 New Mexico Office of the State Engineer and Interstate Stream Commission July 2006. *The Impact of Climate Change on New Mexico's Water Supply and Ability to Manage Water Resources.* Online access: http://www.ose.state.nm.us/ClimateChangeImpact/completeREPORTfinal.pdf, 8/29/06.

Appendix B

1 Solley, Wayne B, 1997. *Estimates of Water Use in the Western United States in 1990 and Water-Use Trends 1960-90*. Report to the Western Water Policy Review Advisory Commission. Reston, Virginia: U.S. Geological Survey, Reston, VA., p.6.

2 Solley, Wayne B., Robert R. Pierce, and Howard A. Perlman. *Estimated Use of Water in the United States in 1995*. U.S. Geological Survey Report. United States Government Printing Office, Washington, D.C.,1998, p.

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Minute Order and Statement of Decision for the 2005 UWMP

SUPERIOR COURT OF CALIFORNIA, COUNTY OF LOS ANGELES

DATE: 08/03/07			DEPT. 85
HONORABLE Dzintra Janavs	JUDGE	S. BARRETT	DEPUTY CLERK
HONORABLE	JUDGE PRO TEM		ELECTRONIC RECORDING MONITOR
A. GODINEZ, C.A.	Deputy Sheriff	NONE	Reporter

BS103295

CALIF. WATER IMPACT NETWORK ET

VS

CASTAIC LAKE WATER ETAL

170.6 DAVID P. YAFFE

Plaintiff Counsel NO APPEARANCES

Defendant Counsel

NATURE OF PROCEEDINGS:

RULING ON SUBMITTED MATTER (HEARING ON PETITION FOR WRIT OF MANDATE);

The Court having taken this matter under submission on June 25, 2007 now rules as follows:

Petition for Writ of Mandate is denied and the Court rules in favor of Respondents on the Complaint for Declaratory Relief. Respondents are entitled to costs pursuant to Code of Civil Procedure Section 1032.

Statement of Decision is signed and filed this date.

Objections, if any, to this Statement of Decision shall be filed in Department 85 on or before August 20, 2007

CLERK'S CERTIFICATE OF MAILING/
NOTICE OF ENTRY OF ORDER

I, the below named Executive Officer/Clerk of the above-entitled court, do hereby certify that I am not a party to the cause herein, and that this date I served Notice of Entry of the above minute order of 8-3-07 upon each party or counsel named below by depositing in the United States mail at the courthouse in Los Angeles, California, one copy of the

MINUTES ENTERED
08/03/07
COUNTY CLERK

SUPERIOR COURT OF CALIFORNIA, COUNTY OF LOS ANGELES

DATE: 08/03/07			DEPT. 85
HONORABLE Dzintra Janavs	JUDGE	S. BARRETT	DEPUTY CLERK
HONORABLE	JUDGE PRO TEM		ELECTRONIC RECORDING MONITOR
A. GODINEZ, C.A.	Deputy Sheriff	NONE	Reporter

BS103295

CALIF. WATER IMPACT NETWORK ET

VS

CASTAIC LAKE WATER ETAL

170.6 DAVID P. YAFFE

Plaintiff Counsel NO APPEARANCES

Defendant Counsel

NATURE OF PROCEEDINGS:

original entered herein in a separate sealed envelope for each, addressed as shown below with the postage thereon fully prepaid.

Date: August 3, 2007

John A. Clarke, Executive Officer/Clerk

By: S. BARRETT
S. Barrett, Judicial Assistant

Stephan Volker
436 14th Street #1300
Oakland, CA 94612

Mark Dillon
Gatze Dillon & Ballance
1525 Faraday Avenue #150
Carlsbad, CA 92008

David Boyer
McCormick, Kidman & Behrens
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Costa Mesa, CA 92626

MINUTES ENTERED
08/03/07
COUNTY CLERK

SUPERIOR COURT OF CALIFORNIA, COUNTY OF LOS ANGELES

DATE: 08/03/07	DEPT. 85
HONORABLE Dzintra Janavs JUDGE	S. BARRETT DEPUTY CLERK
HONORABLE JUDGE PRO TEM	ELECTRONIC RECORDING MONITOR
A. GODINEZ, C.A. Deputy Sheriff	NONE Reporter

BS103295

CALIF. WATER IMPACT NETWORK ET

VS

CASTAIC LAKE WATER ETAL

170.6 DAVID P. YAFFE

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MINUTES ENTERED
08/03/07
COUNTY CLERK

FILED
LOS ANGELES SUPERIOR COURT
AUG 03 2007
JOHN A. CLARKE, CLERK
BY S. BARRETT, DEPUTY

SUPERIOR COURT OF CALIFORNIA

COUNTY OF LOS ANGELES

CALIFORNIA WATER IMPACT NETWORK and FRIENDS OF THE SANTA CLARA RIVER, Petitioners/Plaintiffs, vs. CASTAIC LAKE WATER AGENCY; NEWHALL COUNTY WATER DISTRICT; CLWA SANTA CLARITA WATER DIVISION; VALENCIA WATER COMPANY; and DOES 1-20, inclusive, Respondents/Defendants, Real Parties in Interest.	Case No. BS 103 295 STATEMENT OF DECISION [Transferred from Ventura County Superior Court, Case No. CIV 239 359] Assigned for all purposes to: Honorable Dzintra I. Janavs Department 85 Complaint Filed: February 27, 2006

Having taken the matter under submission on June 25, 2007, having considered all the evidence admitted and the parties' oral and written arguments, the Court rules as follows:

Petitioners, California Water Impact Network ("CWIN") and Friends of the Santa Clara River ("Friends") (collectively referred to as "Petitioners") seeks a peremptory writ of mandate, declaratory judgment, and preliminary and permanent injunctions setting aside, enjoining, and restraining the approval by Respondents, Castaic Lake Water Agency ("CLWA"), Newhall County Water District ("NCWD"), and Valencia Water

Company ("VWC") collectively referred to as "Respondents") of their 2005 Urban Water Management Plan ("2005 UWMP" or "Plan").[1]

The 2005 UWMP is a detailed water supply management plan, which describes the water demand, water supply, water conservation, water recycling, and water reliability planning for the CLWA service area. (AR[2] 1:1-425.) The 2005 UWMP was prepared pursuant to the Urban Water Management Planning Act ("UWMP Act" or "Act") (Wat. Code, §§ 10610-10656), which requires every urban water supplier to prepare and adopt an urban water management plan. (Wat. Code, § 10620.) As encouraged by the UWMP Act, Respondents jointly prepared the 2005 UWMP as a cooperative regional plan for the CLWA service area. (Wat. Code, § 10620, subd. (d); *see also* AR 1:13.) In addition, numerous water resource specialists with expertise in water management planning were retained to assist Respondents in preparing the Plan. (AR 4:2479.) As required by the Act, the 2005 UWMP was approved and adopted separately by each Respondent. (AR 2:578-591.)

The 2005 UWMP covers the CLWA service area, which generally encompasses the Santa Clarita Valley. (AR 1:16-19.) Total water supply available to meet demands in the Valley is comprised of a combination of imported water, local groundwater, and local recycled water. (AR 1:8-9.) The groundwater source is supplemented with imported supplies. (AR 1:8-9, 37-38, and 42-47.) Imported water includes State Water Project

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[1]Petitioners also identify CLWA Santa Clarita Water Division as a Respondent. CLWA Santa Clarita Water Division, however, is the retail division of CLWA and is not a separate public entity.

[2]The Administrative Record will be cited as AR [Volume Number]:[Start Bates Page]-[End Bates Page].

("SWP") Table A water[3] and stored water. (AR 1:37.) Local groundwater is extracted from two different aquifer systems that comprise the local groundwater Basin, the Alluvium Aquifer and the Saugus Formation.[4] (AR 1:42.) The Alluvium Aquifer generally underlies the Santa Clara River and its several tributaries; the Saugus Formation underlies essentially the entire Upper Santa Clara River Area. (*Ibid.*)

Petitioners CWIN and FSCR are non-profit public benefit corporations formed under the laws of the State of California. Petitioners dispute the sufficiency of the analysis contained in the 2005 UWMP, as well as the various conclusions reached in the Plan. Specifically, Petitioners assert that the Plan "(1) fails to accurately estimate future demand; (2) overstates supply; and (3) fails to address alternatives to bridge the gap between supply and demand." (Petitioners' Opening Brief ["POB"] 1:6-7.) Petitioners contend that these alleged failings in the Plan constitute a violation of the Act, as well as a violation of the Public Trust Doctrine. (POB 1:6-7.)

Respondents contend that they exceeded the procedural requirements of the Act in adopting their Plan. Beginning in April 2005, Respondents held various public community workshops in the CLWA service area. (AR 1:128, 5:2953-3001 and 3279-3305.) On July 27, 2005, a preliminary draft of the 2005 UWMP was released to the public to solicit public input. (AR 5:3011-3278.) The draft 2005 UWMP was released on August 31, 2005, at a public community workshop, and was subsequently posted on CLWA's

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[3]The SWP Table A Amount is an annual contractual right to SWP water, named for the "Table A" in each SWP contractor's Water Supply Contract.

[4]This groundwater Basin is identified in the DWR Bulletin 118, 2003 Update, as the Santa Clara River Valley Groundwater Basin, East Subbasin. (AR 1:42.)

website. (AR 2:578, 4:2535-2590 and 2608-2952.) Copies were also delivered to the three area public libraries, to the City of Santa Clarita, and to the Counties of Los Angeles and Ventura. (AR 2:578.) This was followed by a six-week written public comment period. (AR 1:135.) On September 28, 2005, and October 26, 2005, joint public hearings were held, during which time Respondent's respective Boards heard staff and consultants describe the contents of the draft Plan, additional public comments were received, and staff and consultants responded to public comments. (AR 2:1150-1257 and 4:2299-2476.)

On November 3, 2005, Respondents circulated the Revised Final Draft 2005 UWMP. (AR 2:579 and 772-1149.) On November 9, 2005, CLWA and NCWD held a joint meeting at which time each Board reviewed and adopted the Revised Final Draft 2005 UWMP. (AR 2:578-586 and 611-696.) Respondent VWC adopted the Revised Final Draft 2005 UWMP on December 14, 2005. (AR 2:587-591.)

Petitioners filed a verified petition for writ of mandate and complaint for declaratory and injunctive relief in the Ventura county Superior Court on February 27, 2006. The action was ordered transferred to the Los Angeles County Superior Court on May 18, 2006.

To establish a violation of the UWMP Act, Petitioners must establish a prejudicial abuse of discretion by showing that Respondents either failed to proceed in the manner required by law in their preparation and adoption of the 2005 UWMP or Respondents' decisions to adopt the 2005 UWMP were not supported by substantial evidence. (Wat. Code, § 10651.) At issue here is a challenge to a quasi-legislative action, which is governed by traditional mandamus. This requires "scrutiny of the nature of the alleged defect" depending upon whether Petitioners' claim is predominantly "one of improper procedure or a

dispute over the facts." (*Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* ("*Vineyard*") (2007) 40 Cal.4th 412, 435.) As explained by the California Supreme Court in *Vineyard*, "while we determine *de novo* whether the agency has employed the correct procedures, . . . we accord greater deference to the agency's substantive factual conclusions," for a court's task "is not to weigh conflicting evidence and determine who has the better argument." (*Ibid.*)

"Substantial evidence" has been defined as "enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached." (*Laurel Heights Improvement Assn. Of San Francisco, Inc. v. The Regents of the University of California* (1988) 47 Cal.3d 376, 393, citing Cal. Code Regs., tit. 14, § 15384, subd. (a).) This is the same "highly deferential substantial evidence standard of review" as prescribed for appellate review of trial court decisions. (*Western States Petroleum Assn. v. Super. Ct.* (1995) 9 Cal.4th 559, 572.) This review standard was recognized by the Court of Appeal in *Friends of the Santa Clara River v. Castaic Lake Water Agency* (2004) 123 Cal.App.4th 1, 9 ("[a]s it is not our function to reweigh the evidence, but to determine if there is substantial evidence to support the findings of the UWMP, the plaintiffs must fail if there is such substantial evidence"). Accordingly, this Court will uphold Respondent's decision to adopt the 2005 UWMP if substantial evidence supports that decision. In addition, this "deferential standard" requires the court to presume the correctness of the agency decision, as all reasonable doubts must be resolved in favor of it. (*Ryan v. Cal. Interscholastic Federation -- San Diego Section* (2001) 94 Cal.App.4th

1048, 1077-1078.) There is an exception to this deferential standard, when a court reviews the record and statutes to determine what is "required by law," and whether the agency has employed the correct procedures, which is subject to *de novo* review. (*Vineyard, supra*, 40 Cal.4th at p. 435; *People ex rel. Lockyer v. Shamrock Foods Co.* (2000) 24 Cal.4th 415, 432.)

The proper standard of review to be applied to Petitioners' public trust claim is the "abuse of discretion" standard. (*Baldwin v. City of Los Angeles* (1999) 70 Cal.App.4th 819, 836 [applying the abuse of discretion standard in mandamus action specifically to public trust issues].) In such cases, the Court should "determine only whether the action taken was arbitrary, capricious, or entirely lacking evidentiary support, or whether it failed to conform to procedures required by law." (*Ibid.*) Further, "[t]he inquiry into arbitrariness or capriciousness is like substantial evidence review in that both require reasonable basis for the decision."

I. The Plan's Water Use Projections and Estimate of Water Conservation Savings Meet The Requirements of the UWMP Act and Are Supported by Substantial Evidence

Petitioners argue that the 2005 UWMP's "conservation measures are unsubstantiated," and that because Respondents have relied upon 10 percent water savings to reach an "*ultimate conclusion*" that "adequate water exists for all future needs," the 2005 UWMP does not adequately quantify current water use and projected water use, as required by the UWMP Act. (POB 9, and Petitioners' Reply Brief ("PRB") 8:24-28 and 9:20-22.) Petitioner's arguments on this issue are without merit.

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A. The Plan Provides Adequate Support and Explanation For the 10 Percent Conservation Savings Estimate

The 10 percent conservation savings provided in the 2005 Plan is an estimate. Petitioners claim that the UWMP Act does not permit such an estimate of conservation savings. (PRB 7:23-24.) That is not so, as the Act specifically permits such an estimate. (Wat. Code, § 10631, subd. (f)(4) [requires a plan to provide a "[a]n *estimate*, if available, of existing conservation savings on water use within the supplier's service area, and the effect of the savings on the supplier's ability to further reduce demand"], emphasis added.)

Table 2-2 meets this requirement in that it provides such an estimate of existing conservation savings and demonstrates the effect of the savings on the suppliers' ability to further reduce demand by comparing it to the projected water demands. (AR 1:26.)

In addition, the UWMP Act does not require description and evaluation of water demand management measures for members of the California Urban Water Conservation Council. (Wat. Code, § 10631, subd. (j).) Instead, the Act simply requires that Council members include in their plans copies of the annual reports they submit to the Council. (*Ibid.*) As Respondents are each members of the Council, and as copies of their annual submitted reports are attached to the Plan, they are in compliance with subdivisions (f) and (g) of Section 10631 of the Act. (Wat. Code, § 10631, subd. (j).) (*See also* AR 1:235-384.)[5]

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[5]Moreover, because Respondents are members of the Conservation Council, the 2005 UWMP need not comply with that provision of the UWMP Act because section 10631, subdivision (h), of the UWMP Act also exempts members of the Conservation Council from the provisions of Section 10631, subdivision (f). (Wat. Code, § 10631, subd. (j).)

In this case, the estimate of conservation savings is supported by empirical data, based on the 1987-1992 drought and the results of *voluntary* conservation efforts. (AR 1:34 [explaining that past extreme conservation measures resulted in a 20 percent reduction in water demand (despite an expected 10 percent *increase* in water needs due to dry weather, overall water requirements actually *decreased* by more than 10 percent as a result of extraordinary conservation measures)]).

B. The Plan Provides Substantial Evidence to Support Its Conclusion That There Is Sufficient Water To Meet Future Demands

Petitioners claim that the 10 percent reduction due to conservation measures skews the Plan's ultimate conclusion that Respondents have identified enough water to meet future demands and point to a deficiency in future water supply identified in Tables 6-3 and 6-4 without the 10 percent reduction. (PRB 8:18-12:4.) Tables 6-2 through 6-4 summarize the supplies and demand for projected average/normal years, single-dry years, and multiple-dry years, respectively. (AR 1:95-97.) In average/normal years, the 10 percent reduction due to conservation measures is not relied upon to meet demands. (AR 1:95.) Only in dry years is the conservation amount necessary to meet demands (AR 1:96-97); however, the conservation estimates cannot be read without an understanding of the water shortage contingency plan outlined in Section 8.6 of the 2005 UWMP, which provides for *mandatory* conservation measures that could be reactivated, pursuant to local ordinances during dry years (AR 1:115-116); and Section 8.7, which provides for mandatory rationing or consumptive reduction measures (AR 1:116-117). Such mandatory conservation measures would be implemented and would ensure a conservation savings of 10 percent. Thus, in a dry year, with the implementation of such mandatory conservation measures, the 10 percent

conservation estimate is more certain than in an average/normal year, in which only voluntary conservation measures may be relied upon.

The 2005 UWMP has identified adequate supplies to meet future demands.

II. The Plan's Identification and Quantification of Surface Water Supplies Meets The Requirements Of The UWMP Act and Is Supported By Substantial Evidence

The UWMP Act requires that an urban water management plan identify and quantify existing and planned sources of water available to the supplier in five-year increments for the entire planning period, which is defined as the next 20 years. (Wat. Code, § 10631, subd. (b).) The Act further requires that a plan describe the reliability and vulnerability of the water supply. (*Id.*) at subd. (c)(1).) For any water source identified that may not be available at a consistent level of use, "given specific legal, environmental, water quality, or climatic factors," the Act requires that a plan include a description of any proposed alternative sources or water demand management measures "to the extent practicable." (*Id.* at subd. (c)(2).)

Chapter 3 of the Plan identifies and quantifies Respondents' current and planned sources of water. (AR 1:35-61.) Current supplies include CLWA's SWP Table A supplies, Flexible Storage Accounts in Castaic Lake, Semitropic Water Bank, and local groundwater. (AR 1:36, Table 3-1.) In addition, the Plan identifies near term future sources of water supply, including Rosedale-Rio Bravo Water Storage District Water Banking and Buena Vista Water Storage District/Rosedale-Rio Bravo Water Storage District Water Storage and Recovery Program. (AR 1:36, Table 3-1; see also AR 1:58-59.)

Chapter 3 in the Plan also contains an explanation of the reasons Respondents must rely on DWR in order to accurately assess the impacts

of varying conditions on SWP supply reliability -- an assessment that is required by the Act. (AR 1:39 & 90.) (See also Wat. Code, § 10620, subd. (d)(2); AR 6:3543.) As regards these supplies, DWR publishes every two years a reliability report that contains data concerning the reliability of current and projected SWP deliveries in conformance with the Act. (AR 1:90.) This reliability data is generated from CALSIM II, DWR's computer simulation model of SWP and Central Valley Project ("CVP") operations. (AR 3:1284, 4:2364-2367, 16:6988 & 6997-7002; *see also* Respondents' Request for Judicial Notice, Exhibit 1, pp. 9-11.)

In preparing its Plan, Respondents relied upon DWR's "Excerpts from the Working Draft of 2005 State Water Project Delivery Reliability" ("Draft 2005 Report"), as directed by DWR. The Draft 2005 Report contained DWR's most recent and authoritative projections of deliveries of the SWP. According to the Draft 2005 Report, the existing SWP facilities operated under current regulatory and operational constraints and, with all contractors requesting delivery of their full Table A Amounts in most years, could deliver 77 percent of total Table A Amounts on a long-term average basis. (AR 1:39 and 12:5398-5418.)

Chapter 6 of the Plan addresses in detail the reliability of Respondents' current and future water supply, including CLWA's SWP Table A supplies. (AR 1:91 and 93-97.) In describing the reliability of the water supply, the UWMP Act requires that a plan provide data for specific hydrologic scenarios: (1) an average year, (2) a single-dry year, and (3) multiple-dry years. (Wat. Code, § 10631, subd. (c)(1).) The discussion in Chapter 6 of the 2005 UWMP addresses each of these hydrologic scenarios and, using DWR's 2005 Draft Report, concludes that: (1) in an average water year, SWP delivery reliability will be 71 percent in 2010, and 77 percent in 2025/2030; (2) in a single-dry year,

SWP delivery reliability will be four percent in 2010, and five percent in 2010 and (3) in multiple-dry years, SWP delivery reliability will be 32 percent in 2010, and 33 percent in 2025/2030. (AR 1:40 and 95-97.)

Chapter 6 of the Plan also contains a comparison of current and future supply and demand for Respondents' service areas under the same three hydrologic scenarios. (AR 1:95-97.) That discussion includes the identification of various potential alternative supplemental and replacement supply sources and demand management measures for those supply sources that may vary between the three hydrologic scenarios. (AR 1:90-93.)

Petitioners contend that the 2005 UWMP overstates the quantity of surface water supplies and their reliability, contending that the Plan: (1) relies upon water supply sources that are the subject of pending litigation; (2) inflates SWP delivery numbers; (3) relies upon a flawed SWP delivery model; and (4) fails to consider other relevant factors that will impact the future reliability of SWP Table A deliveries. Contrary to these contentions, substantial evidence supports each of the Plan's conclusions regarding water supply and reliability.

A. The Plan Adequately Considers Pending Litigation

1. Kern-Castaic Transfer

CLWA's current SWP Table A Amount of 95,200 acre feet per year ("afy") includes 41,000 afy that is a result of the Kern-Castaic Transfer. (*See, Cal. Oak Foundation v. City of Santa Clarita* ("*California Oak*") (2005) 133 Cal.App.4th 1219, 1229-1230.) This transfer was completed in 1999, and is memorialized in a purchase agreement and in amendments to CLWA's and Kern County Water Agency's Water Supply Contracts with DWR. (*See, Friends of Santa Clara River v. Castaic Lake Water Agency* ("*Friends 1*") (2002) 95 Cal.App.4th 1373,

1379-1380.) The Environmental Impact Report ("EIR") for the transfer was challenged in 1999, in *Friends of the Santa Clara River v. Castaic Lake Water Agency* (Los Angeles County Superior Court Case No. BS056954) ("Friends Action"). (*Id.* at 1381.) Although CLWA was ultimately ordered to revise its EIR, no court has ever enjoined implementation of the Kern-Castaic Transfer Project, nor suggested that it should be unwound. (*California Oak, supra*, 133 Cal.App.4th at pp. 1228-1229.)

Under the jurisdiction of the Los Angeles County Superior Court in the Friends Action, CLWA prepared and circulated a revised EIR for the transfer, adopted the revised EIR, and lodged the revised EIR with the Los Angeles County Superior Court as part of its Return to the Peremptory writ of mandate in the Friends Action. Thereafter, the petition was dismissed with prejudice. In January 2005, two new challenges to CLWA's environmental review for the Kern-Castaic Transfer were filed in the Ventura County Superior Court by Planning and Conservation League ("PCL") and by California Water Impact Network ("CWIN"). Those cases were consolidated, transferred to the Los Angeles County Superior Court (Case No. BS098724), and were pending in Department 13 at the time Respondents adopted the 2005 Plan. (AR 1:41.)

All of the above is described in detail in the 2005 UWMP. (AR 1:41-42 and 91.)[6] The 2005 UWMP also identifies in detail the

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[6]The Los Angeles County Superior Court has since ruled that the dismissal with prejudice of Petitioner Friends' earlier CEQA petition challenging the original Kern-Castaic EIR is a retraxit and bars Friends from raising issues concerning the validity of the Kern-Castaic Transfer or the sufficiency of its environmental documents. (*See*, Respondents' RJN, Exhibit "4.") Therefore, Petitioner Friends is barred by the doctrines of retraxit and res judicata from challenging the validity of the Kern-Castaic Transfer (which includes asserting that the Kern-Castaic Transfer could be unwound) in this action. (*Le Parc Community Assn. v. Workers' Comp. Appeals Bd.* (2003) 110 Cal.App.4th 1161, 1169,

substantial evidence that supports its determination that the Kern-Castaic Transfer remains a valid and reliable water source. (AR 1:41-42.) This evidence includes the following: (1) the Kern-Castaic Transfer was completed in 1999, and DWR has allocated and annually delivered the water in accordance with the completed transfer; (2) the Court of Appeal held that the only defect in the 1999 EIR was that it tiered from the Monterey Agreement EIR, which was later decertified. (*Friends 1, supra*, 95 Cal.App.4th at p. 1387); (3) the defect has been remedied by the preparation of a revised EIR that did not tier from the Monterey Agreement EIR; (4) the Monterey Amendments settlement agreement expressly authorized the operation of the SWP in accordance with the Monterey Amendments, which facilitated the Kern-Castaic Transfer; (5) the Court of Appeal refused to enjoin the Kern-Castaic Transfer, and instead rquired preparation of a revised EIR; and (6) the Kern-Castaic Transfer contracts remain in full force and effect, and no court has ever enjoined the use of this portion of CLWA's SWP Table A Amount.

Petitioners cite the *California Oak* decision, in which the Court of Appeal set aside the EIR for its failure to explain the reasons it was appropriate to rely on the Kern-Castaic Transfer despite pending litigation. (*California Oak, supra*, 133 Cal.App.4th at p. 1240.) Here, however, the 2005 UWMP contains a detailed explanation of such reasons.

Substantial evidence supports including the Kern-Castaic Transfer amount as part of CLWA's total SWP table A Amount.

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quoting *Torrey Pines Bank v. Superior Court* (1989) 216 Cal.App.3d 813, 820 and *Rice v. Crow* (2000) 81 Cal.App.4th 725, 733-734.) Additionally, the Court in *CWIN v. CLWA* (LASC Case No. BS098724) recently entered Judgment ruling that the Kern-Castaic Transfer and its underlying contract documents are valid and not subject to being unwound or set aside.

2. Semitropic Groundwater Bank

In 2002, CLWA stored 24,000 acre-feet ("af") of its Table A Amount in an account in Semitropic's Banking Program ("2002 Groundwater Banking Project").[7] (AR 12:5419-5422, 5449.) Prior to opening its account, CLWA adopted a negative declaration under CEQA. (*Ibid.*) CWIN and Friends filed a CEQA action in the Ventura County Superior Court challenging CLWA's adoption of the negative declaration for the 2002 Groundwater Banking Project (*Cal. Water Network v. Castaic Lake Water Agency* [(Ventura County Superior Court Case No. CIV 215327]) ("Network Action"). (AR 1:57.) (Respondents' RJN, Exhibit 5.) Shortly thereafter, Petitioners filed essentially the identical action in the Sacramento County Superior Court (*Friends of the Santa Clara River v. State of California Department of Water Resources* [Sacramento County Superior Court Case No. 03CS00258]) ("Sacramento Action"). (*See*, Petitioners' Joshua Harris Declaration, Exhibit 2.) The *Sacramento Action* challenged the same negative declaration, involved the same parties, and asserted the same violations as the *Network Action*. (*Ibid.*) As the *Network Action* was filed first, the *Sacramento Action* was stayed until judgment was entered in the *Network Action*. (*See*, Petitioners' Joshua Harris Declaration, Exhibit 3.)

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[7]In 2004, CLWA stored 32,522 af of its 2003 Table A Amount in another account in Semitropic's program ("2003 Groundwater Banking Project"). (AR 12:5449-5484.) Only CLWA's 2002 Groundwater Banking Project was legally challenged. (AR 1:57.) Therefore, the 2003 Groundwater Banking Project is conclusively presumed to comply with CEQA. (Pub. Resources Code, § 21167.2.)

On July 14, 2004, the trial court in the *Network Action* entered judgment in favor of CLWA. (AR 1:57; *see also*, Respondents' RJN, Exhibit 6.) Petitioners appealed, and that appeal was pending at the time the 2005 UWMP was adopted. (AR 1:57.)

Petitioners contend that the Plan erroneously relies upon CLWA's 24,000 af of water banked at the Semitropic Storage District since that banking project was still under legal challenge when the 2005 UWMP was adopted. However, as the CLWA was the prevailing party in the trial court at the time of the adoption of the Plan[8], substantial evidence existed to support the Plan's reliance upon the banked water supplies. (*See, e.g.*, Publ. Resources Code, § 21167.3, subd. (b); Cal. Code Reg., tit. 14, § 15231; *see also, Barthelemy v. Chino Basin Mun. Water Dist.* (1995) 38 Cal.App.4th 1609, 1617 [agency actions are presumed to comply with applicable law, until proof is presented to the contrary].) Furthermore, the Plan's reliance on this water supply is limited. The 2002 Groundwater Banking Project has a term of ten years for the water to be withdrawn and delivered to CLWA. It is limited in the Plan for use in a dry year, and only for short-term reliability purposes (*i.e.*, prior to 2013).

Petitioners also claim that there is "contamination in the Semitropic aquifer," and that "water pumped into Semitropic may not meet DWR standards for water wheeling back into the California Aqueduct." (POB 15:5-8.) The record, however, establishes that water transported in SWP facilities would be required to meet DWR pump-in requirements for water quality and would meet all applicable drinking water standards and water quality criteria. (AR 15:6938.) Furthermore, this claim has

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[8]The Second District Court of Appeal subsequently affirmed the trial court's judgment. (*See*, Respondents' RJN, Exhibit 7.)

already been rejected both by the trial court and by the Court of Appeal in the Network Action. Contamination of the Semitropic Basin creates no water quality problems for CLWA or its retailers since, under the terms of the 2002 Groundwater Banking Project, CLWA may recover its water stored at Semitropic by either: (1) having Semitropic pump the water from the groundwater bank and transporting it to CLWA via the California Aqueduct, or (2) requesting an "in lieu exchange" (*i.e.*, that an equivalent amount of Semitropic's SWP water for a particular year be delivered directly to CLWA). (AR 12:5438 and 5452.) (*See also*, Respondents' RJN, Exhibit 6.)

B. The Plan Does Not Rely Upon Inflated SWP Delivery Numbers

Petitioners contend that Respondents improperly relied on DWR's projections for the reliability of the SWP.

DWR is responsible for the delivery of water to 29 state contractors throughout California; which water is then provided to hundreds of intermediate suppliers, the overwhelming proportion of whom have to prepare urban water management plans. (*See*, Wat. Code, §§ 10620 [requiring urban water management plans], and 10617 [defining "urban water supplier" as "a supplier, either publicly or privately owned, providing water for municipal purposes either directly or indirectly to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually. An urban water supplier includes a supplier or contractor for water."]) The notion underlying Petitioners' argument -- that each of these hundreds of urban water suppliers should conduct their own SWP reliability analysis -- has no support in the UWMP Act and, in fact, would render the purposes of the Act unachievable.

Requiring urban water suppliers to conduct their own analysis of SWP reliability would also be contrary to the court-approved settlement

in connection with *PCL*. That settlement requires DWR to prepare SWP delivery reliability reports every two years commencing 2003 and contemplates each SWP contractor's reliance on the data generated in them. (AR 6:3543 and 16:7248.)

Petitioners' claim that SWP deliveries to contractors will never exceed 50 percent is based mainly on dicta from *PCL*. (POB 17:6-20.) Dicta cannot serve as factual support for such argument. (*Fireman's Fund Ins. Co. v. Maryland Casualty Co.* (1998) 65 Cal.App.4th 1279, 1301 ["In every case, it is necessary to read the language of an opinion in the light of its facts and the issues raised, in order to determine which statements of law were necessary to the decision, and therefore binding precedent, and which were general observations unnecessary to the decision. The latter are dicta, with no force as precedent."].)

PCL involved a challenge to an EIR that was certified in 1996, long before DWR had any type of computer modeling tool at the level of sophistication of CALSIM II. The dicta from *PCL* quoted by Petitioners describes the historical "gap" between SWP deliveries and SWP Table A entitlements prior to implementation of the Monterey Amendment to the SWP contracts in 1996. (*PCL, supra,* 83 Cal.App.4th at pp. 901-903.) The Monterey Amendment was intended to narrow that gap. (*Ibid.*) That amendment has been in effect since 1996, and *PCL* does not and could not have analyzed the impacts (positive or negative) of the Monterey Amendment upon the reliability of SWP deliveries.

PCL, however, does defer to the expertise of DWR with respect to SWP operations, which includes projecting SWP capacity and delivery reliability. (*PCL, supra,* 83 Cal.App.4th at pp. 906-907), and the Court of Appeal in *Santa Clarita Organization for Planning the Environment v. County of Los Angeles* (2003) 106 Cal.App.4th 715, citing *PCL*, held that

data from DWR concerning SWP reliability is the standard for planning. (*Id.* at p. 22.)

Furthermore, in asserting that the SWP facilities are incapable of ever delivering supplies to contractors in excess of 50 percent of Table A Amounts, Petitioners demonstrate their misunderstanding of the difference between the actual current capacity of SWP storage facilities and the actual current capacity of SWP conveyance facilities. As explained in the 2005 UWMP, while there are limitations on SWP storage capacity, similar limitations do not exist for its conveyance facilities (AR 1:37-38.)

Petitioners also claim internal inconsistencies in the 2005 UWMP with respect to SWP deliveries and SWP reliability. They argue that Table 3-2 in Chapter 3 of the Plan establishes that "[i]n 2004, CLWA received approximately 50 percent of its Table A allocation, or 47,205 af . . . . In all years prior, it received even less." (POB 16:21-23.) Petitioners contrast what they characterize as "unpredictable allotment schedule and low historical delivery numbers" with the Plan's conclusions regarding reliability of SWP deliveries. (*Id.* at 16:25.)

Petitioners are incorrect. Table 3-2 does not identify the historical total SWP deliveries *to* CLWA, but the historical total SWP deliveries delivered *by* CLWA to the retail water agencies in the Santa Clarita Valley. (AR 1:38.) As Respondents explain, this is not a distinction without a difference. As an example, Table 3-2 indicates that in 2002, CLWA delivered to its retailers 41,768 af of SWP water. 41,768 af, however, is not the total amount of SWP water deliveries received by CLWA in 2002. In addition to the amount reflected Table 3-2 as delivered in 2002, CLWA also stored an additional 24,000 af of its SWP deliveries at Semitropic's Groundwater Bank as part of its 2002

Groundwater Banking Project. (AR 1:57 and 12:5419-5422.) Thus, in 2002, CLWA's SWP deliveries exceeded 65,000 af.

Similarly, in addition to the 44,419 af of SWP water that CLWA delivered to its retailers in 2003, CLWA also stored an additional 32,522 af of its SWP deliveries at Semitropic Groundwater Bank as part of its 2003 Groundwater Banking Project. (AR 1:57 and 12:5449-5454.) Thus, in 2003, CLWA's SWP deliveries were approximately 76,000 af.

Further, while CLWA delivered only 47,205 af of SWP supplies to its retailers in 2004, this has no relationship to the actual amount of SWP supplies delivered to CLWA in 2004, which was approximately 65 percent of its total Table A Amount, or 61,880 af. (AR 11:4642-4643.) (*See also*, Respondents' RJN, Exhibit 2.)

It should also be noted that when reviewing Table 3-2, although the Kern-Castaic Transfer contract documents were executed in 1999, CLWA did not see an increase in its SWP Table A allocation as a result of the Transfer until 2001. Prior to 2000, CLWA's SWP Table A Amount was 53,700 af. Thus, in 2000, CLWA's total SWP deliveries were 60 percent of its total SWP Table A Amount.

Nor is the declaration executed by CLWA's General Manager Dan Masnada, on September 12, 2002, in other litigation inconsistent with the DWR's 2005 Draft Report. (POB 18:14-18.) In that declaration, Mr. Masnada questions the ability of the SWP to maintain high delivery percentages on a yearly basis "in the near term given current hydrologic conditions and existing SWP facilities in operation." (AR 1:760.) Masnada's statement is not inconsistent with the 2005 Draft Report. First, said statements were made concerning the reliability percentage that would be required immediately in the absence of the Kern-Castaic Transfer. (*Ibid.*) Second, as reflected in Table 3-4 of the Plan,

average/normal year near-term SWP delivery reliability for year 2010 is 71 percent, and will increase by the year 2025, to 77 percent. (AR 1:40.) The Plan, however, projects single-dry year reliability to be five percent and multiple-dry year reliability to be 33 percent in year 2025. (AR 1:40 and 96-97.) Thus, the Plan is not projecting 77 percent reliability for SWP deliveries every year, even in year 2025. (*Ibid.*)

Substantial evidence supports Respondents' reliance upon DWR's projections for the reliability of SWP delivery numbers, and such reliance is permitted under the UWMP Act.

C. The Plan Does Not Rely Upon A Flawed SWP Delivery Model

Petitioners argue that DWR's SWP analysis is unreliable because it is based upon the "flawed" "CALSIM II" model. (POB 19:20-21.) Petitioners contend that these "flaws" are identified in the Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operation in Central California. (POB 19:22-26, citing AR 3:1438.)

The Strategic Review, however, acknowledges that CALSIM II was a "substantial improvement" over the previous models that DWR had used for that work, was comparable to other state of the art models for projecting deliveries, and was "admirable" for its "openness and availability." (AR 3:1439.) While the reviewers made suggestions for future improvement of the model and noted that it was of limited use in predicting deliveries in any one year, to date there is no other model that does a better job of predicting deliveries -- nor have Petitioners identified one.

The case that Petitioners cite as undercutting the validity of the CALSIM II model -- *Planning and Conservation League v. U.S. Bureau of Reclamation*, No. C05-3527 (N.D. Cal. Feb. 14, 2006) (hereafter, the "Intertie Case"), Order on Preliminary Injunction -- recognizes that the

model is the best one presently available for projecting water supplies: "CALSIM II is not a perfect model; no model is. But its use alone [does not make out a violation of the National Environmental Policy Act ("NEPA")]." (See Respondents' Request for Judicial Notice, filed October 2, 2006, Exhs. "2" & "3.") While Petitioners cite the Intertie Case as supporting a conclusion that CALSIM II is flawed, the Court's Order simply supports a conclusion that the Bureau of Reclamation's use of CALSIM II for purpose of conducting abbreviated environmental review under NEPA was not warranted. (*Ibid.*) This case does not present that question, and the Intertie Case preliminary injunction ruling is not relevant.

Respondents made use of the best information available to them regarding SWP deliveries. In doing so, they complied with the UWMP Act.

D. The Plan Adequately Considers All Other Relevant Factors That Will Impact The Future Reliability Of SWP Table A Deliveries

The UWMP Act requires that urban water suppliers identify "[a]ctions to be undertaken . . . to prepare for, and implement during, a catastrophic interruption of water supplies including, but not limited to, a regional power outage, an earthquake, or other disaster." (Wat. Code, § 10632, subd. (c).) Respondents described in the 2005 UWMP the effects of a levee failure impacting its SWP water supply for a six-month period. (AR 1:106-121.) Citing a newspaper article's misquote of the statements of DWR Director Lester Snow published after the Draft 2005 UWMP had been published and circulated, Petitioners argue that the six-month anticipated outage is not long enough for contingency planning purposes, and that Respondents should have anticipated a five-year interruption in supply. (POB 21:17-18, citing AR 2:731.)

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Respondents point out, the "five year" statement was, in fact, a misreport of Director Snow's testimony, and Director Snow stated that a levee failure could take at least 15 months to repair. (AR 1:768.) In any case, though, Director Snow's testimony came after the final draft of the 2005 UWMP was issued and the voters subsequently approved bonds to provide for levee strengthening that would address this issue, Respondents provided analysis in support of the 2005 UWMP showing that an interruption of up to *three years* could be accommodated. (*See* AR 1:630-634, 658-659, and 768.) The UWMP Act does not require suppliers to include this analysis in their plan; it simply requires that the analysis be conducted, which has been done here. (Wat. Code, § 10632, subd. (c).)

Petitioners next argue that the Bay-Delta Plan, as enforced in the *State Water Resources Control Board Cases* (2006) 136 Cal.App.4th 674, 777, will require reduced SWP deliveries. The ruling post-dates Respondents' approval of the Plan. Furthermore, Petitioners have not made an adequate record in this Court on the point, nor have they demonstrated that they exhausted their administrative remedies.

Petitioners also contend that the Plan "fails to adequately address the known, foreseeable declines in SWP deliveries due to global warming, despite undisputed evidence documenting accelerating declines in summer Sierra Nevada snow pack and reservoir storage." (POB 22:8-12.)

Projections related to climate change and its potential impact(s) on future SWP deliveries are among the issues DWR will need to address in the future. The record establishes that no conclusion had been reached by DWR at the time of adoption of the 2005 Plan. The material cited by those commenting on the Plan makes clear their belief that Respondents must follow DWR's lead on this issue. (See AR 6:3657,

1:657.) It was appropriate for Respondents to rely on DWR's most recent water supply projections.

III. The 2005 Plan Adequately Assesses Water Quality Issues and Any Impacts on Water Availability

Petitioners contend that the 2005 UWMP fails to comport with the Act by failing to address various water quality issues and by failing to provide alternative or supplemental water sources as a result of those claimed limitations. (POB 25:21 - 31:4.) Petitioners assert that the 2005 UWMP: (1) overstates the quantity and quality of groundwater that can be delivered from the Alluvial Aquifer; (2) inadequately discloses the spread of perchlorate in the groundwater basin and does not identify "alternative water sources"; and (3) inadequately addresses the likelihood that the Newhall Ranch planned community may not be able to convert to potable use the groundwater from the Alluvial Aquifer historically used for its agricultural operations, due to allegedly "excessive" levels of total dissolved solids ("TDS"). (*Ibid.*)

Substantial evidence supports Respondents' contrary conclusions and findings on each issue.

A. Groundwater Overdraft and Excessive Nitrate and Chloride Recharge from SWP Water

Petitioners assert that Respondents' planned pumping from the Alluvial Aquifer represents a "two-fold increase," "threatens to reduce surface flows into the Santa Clara River," and will result in "higher levels of nitrates and increased chlorides due to recharge from SWP supply." (POB 26:12-16, citing AR 3:1850.) The record, however, does not show that Respondents plan a "two-fold increase" in pumping, because the figure they claim has doubled does not reflect historical agricultural and miscellaneous uses of this aquifer. (*See*, AR 1:46.)

Rather, planned pumping from the Alluvial Aquifer is approximately the same as historical pumping, which has ranged from between 20,000 afy to slightly more than 43,000 afy. (*Ibid.*; *see also*, AR 1:169-176 and 11:4634-4637.)

At these levels of pumping, the Alluvia Aquifer "shows no signs of water level-related overdraft." (AR 11:4637.) The groundwater component of overall water supply in the Santa Clarita Valley derives from a groundwater operating plan developed over the last 20 years to meet water requirements while maintaining the groundwater basin in a sustainable condition. (AR 1:45.) The 2005 UWMP's conclusions with respect to the availability of groundwater supplies are based on the groundwater operating plan and the sustainability analyses of two formal reports prepared to analyze the groundwater flow and sustainability (AR 1:45); the groundwater operating plan is summarized in Table 3-6. (AR 1:46.) When overall groundwater pumping is maintained in accordance with the groundwater operating plan, sustainable groundwater conditions will be maintained to support groundwater use on an ongoing basis. (AR 1:47.)

Respondents' conclusion that the planned yield from the groundwater basin is sustainable is supported by substantial evidence. (*See*, AR 1:51.)

The assertion that any "increase in Alluvial pumping" will "result in 'higher levels of nitrates and increased chlorides due to recharges from SWP supply'" also has no support in the record. As an initial matter, there is no nexus between an increase in Alluvial pumping and higher levels of nitrates or chlorides due to recharges from SWP supply. Assuming, however, that there were an "increase" in pumping levels (which is not the plan), and assuming that this would lead to increased

recharge from SWP supply, there is no basis in the record for concluding that this would lead to increased chlorides. To the contrary, the most recent evidence suggests that groundwater "may . . . contain higher concentrations of nitrates and chlorides when compared to SWP water." (AR 1:76; *see also*, AR 1:75 [noting that the chloride content in SWP water varies from below 40 mg/l to over 100 mg/l and does not pose a human health risk, and noting that the nitrate content of SWP water is very low], AR 2:657 & 1218 [General Manager and consultant statement on this point].)

B. The 2005 UWMP Adequately Discloses the Nature of Perchlorate Contamination, Remediation Efforts, and Their Effect on Groundwater

Petitioners generally contend that the 2005 UWMP fails to address adequate and timely remediation of the groundwater basin, and specifically assert that "the reactivation of [the] Q2 [Well] will draw the perchlorate plume towards the Santa Clara River and potentially cause long-term contamination of the river," and that the Plan "fails to adequately address and assure the timely remediation of the growing contamination of the Saugus Formation." (POB 27:9-17.) Each of these assertions, lacks evidentiary support from the record.[9]

As to Petitioners' assertions concerning the Q2 Well, the 2005 UWMP discloses that the well was returned to service in October 2005, after

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[9]In addition, these are not proper arguments for consideration here, as the Act exempts the preparation and adoption of an urban water management plan from CEQA. (Wat. Code, § 10652.) Conversely, the 2005 UWMP's identification of projects, like groundwater banking projects, does not render those projects exempt from CEQA. (*Ibid.*) As a result, while the environmental impacts of an identified project listed in an urban water management plan are not required to be analyzed in the plan, all potentially significant impacts resulting from implementation of such a project must be assessed in the environmental documents for that particular project at the time of its implementation.

the installation of wellhead treatment and after the completion of environmental review related thereto; although, as the Plan acknowledges, that well was not necessary for the anticipated production from the Alluvial Aquifer. (AR 1:48-49 and 78.) More importantly, the 2005 UWMP explains (and Figure 5-1 of the 2005 UWMP illustrates) that the two-year groundwater capture zone analysis of Alluvial wells suggests that inflow to those wells will either be upgradient of the contamination site or will be from Alluvium beyond where perchlorate is to be transported. (AR 1:79-80; *see also*, AR 10:4598-4599 [describing the results of the Alluvial production wells] and AR 16:7177.) Therefore, it does not appear that the Q2 Well will draw that perchlorate plume towards the Santa Clara River. With respect to Petitioners' latter two assertions, the Groundwater Perchlorate Contamination Amendment to the 2000 UWMP and 2005 UWMP belie their assertions, as the documents contain substantial evidence to support the conclusion that adequate non-impacted water is available from the Alluvial Aquifer (AR 1:77 and 195-209; AR 10:4464-4605); that a plan for containing the contamination has been prepared and is being implemented; and that contamination clean-up is planned under the direction of the Department of Toxic Substances Control. (AR 1:81-87.)

Finally, Petitioners argue that the 2005 UWMP should have analyzed alternative sources of water that can be used in place of contaminated supplies "if" remediation plans fail. (POB 28.) Substantial evidence in the record, however, supports the conclusion in the 2005 UWMP that alternative water sources are *not* needed.

The 2005 UWMP assessed the adequacy and availability of groundwater supplies in both the Alluvial Aquifer and Saugus Formation. (AR 1:45-54.) As to the Alluvial Aquifer, the 2005 UWMP disclosed that the

combined active Alluvial groundwater source capacity of non-impacted municipal wells is approximately 58,000 afy. (AR 1:48.) It concluded that this capacity is "more than sufficient to meet the municipal, or urban, component of groundwater supply from the Alluvium, which is currently 20,000 to 25,000 afy of the total planned Alluvial pumping of 30,000 to 40,000 afy." (*Ibid.*) As to the Saugus Formation, the 2005 UWMP found that the combined active Saugus groundwater source capacity for municipal wells is 24,000 afy, which is "more than sufficient to meet the planned use of Saugus groundwater in normal years of 7,500 to 15,000 afy." (AR 1:52.) The 2005 UWMP also addressed Saugus capacity in the near-term:

> During the currently scheduled two-year time frame for restoration of impacted Saugus capacity (as discussed further in Chapter 5), this currently active capacity is more than sufficient to meet water demands, in combination with other sources, if both of the next two years are dry. At that time, the combination of currently active capacity and restored impacted capacity, through a combination of treatment at two of the impacted wells and replacement well construction, will provide sufficient total Saugus capacity to meet the planned use of Saugus groundwater during multiple dry-years of 35,000 af, if that third year is also a dry year. (AR 1:52.)

The Plan further identified that in actual practice, however, pumping from the Saugus Formation was *only* about 6,500 af in 2004; and, on average, Saugus pumping has been *only* about 7,000 afy since 1980. (AR 11:4615.) Because groundwater supplies are both adequate and available, even after accounting for the perchlorate-impacted municipal supply wells, there is no legal requirement to assess "alternative" sources of supply under the UWMP Act or any other law or regulation.

C. The Groundwater for the Newhall Ranch Project and TDS

Petitioners also contend that the 2005 UWMP is inadequate because it does not address a particular development project's (*i.e.*, Newhall

Ranch's) potential for not being able to convert its agricultural water supplies to urban uses due to TDS levels. (POB 28:17-21.)

Petitioners offer no evidence to support the claim that TDS levels are "excessive," and only rely on two comment letters that essentially repeat the same point. (*See* AR 3:1331 and 1852.) As reported in the 2005 UWMP, "all groundwater meets or exceeds drinking water standards." (AR 1:76.) Similarly, the 2004 Santa Clarita Valley Water Report, upon which the 2005 UWMP relies, "CLWA produces water that meets drinking water standards set by [the U.S. Environmental Protection Agency] and [the California Department of Health Services]." (AR 11:4644.) In any case, the UWMP Act does not require an urban water management plan to evaluate specific development projects. (Wat. Code, § 10652.) At the project level, all development projects are required to perform the necessary environmental review under CEQA, and this review will necessarily address project-specific water quality issues, if any.

IV. The UWMP Act Does Not Require Cumulative Impacts Analysis

Petitioners argue that the 2005 UWMP fails to address the cumulative impacts of urbanization on local water resources. (POB 29-31.) Specifically, Petitioners claim that the 2005 UWMP: (1) *fails* to address impacts such as decreased recharge due to decreasing percolation rates caused by the increase in the acreage of impervious surface area; and (2) *fails* to catalogue private groundwater well pumping. (POB 29-31; PRB 30:21-24.)

There is, however, no legal requirement in the UWMP Act for an urban water management plan to discuss "cumulative impacts." The analysis of cumulative impacts is a CEQA requirement only.[10] (Wat. Code,

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[10]CEQA requires that an EIR discuss cumulative impacts if a project's incremental environmental effects, combined with the effects

§ 10652.) Cumulative impacts are not *mentioned* in the UWMP Act. Water Code section 10631, subdivision (c)(2) reads: "For any water source that may not be available at a consistent level of use, given specific legal, environmental, water quality, or climatic factors, describe plans to supplement or replace that source with alternative sources or water demand management measures, to the extent practicable." Therefore, the 2005 UWMP is not inadequate and Respondents did not abuse their discretion for failing to discuss cumulative impacts.

As previously stated, substantial evidence supports the water supply projections in the 2005 UWMP. That is all that is required.

V. The Public Trust Doctrine

Petitioners argue that the 2005 UWMP violates the Public Trust Doctrine, because the 2005 UWMP will "encourage" local governments to approve urban growth, which *may* cause lower flows in the Santa Clara River. (POB 31-34.)

Petitioners' Public Trust doctrine cause of action fails to state a claim.

An urban water management plan is merely a planning document, and itself has no direct impact on public trust resources. For that reason, urban water management plans are specifically exempt from the application of the CEQA. (Wat. Code, § 10652.) Furthermore, a Public Trust Doctrine claim is not ripe unless and until an agency takes an action that has the potential to harm the public trust. (*See, Santa Teresa Citizen Action Group v. City of San Jose* (2003) 114 Cal.App.4th 689, 707-709 [nuisance and public trust causes of action not ripe where alleged injury to water supply depended on the assumption that city

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of other projects, are "cumulatively considerable." (Cal. Code Regs., tit. 14, § 15130, subd. (a).)

would approve uses for recycled water that posed a significant risk to the aquifer from which petitioners obtained their drinking water].)

In view of these conclusions, the Court need not reach the other Public Trust issues raised by Petitioners.

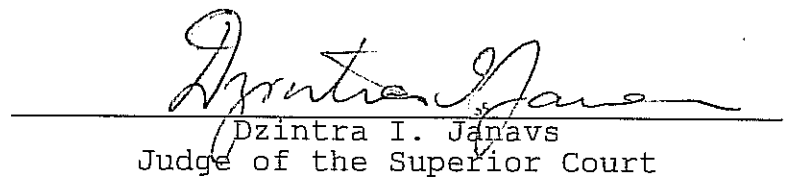
VI. Conclusion

The Court finds that Respondents proceeded in the manner required by law and that the actions by Respondents were supported by substantial evidence. The Petition for Writ of Mandate is denied and the Court rules in favor of Respondents on the Complaint for Declaratory Relief.

As the prevailing parties, Respondents are entitled to costs pursuant to Code of Civil Procedure section 1032.

Objections, if any, to this Statement of Decision shall be filed in Department 85 on or before August 20, 2007.

DATED: August 3, 2007



Dzintra I. Janavs
Judge of the Superior Court

DIJ:dl

FILED
LOS ANGELES SUPERIOR COURT
AUG 15 2007
JOHN A. CLARKE, CLERK
BY S. BARRETT, DEPUTY

SUPERIOR COURT OF THE STATE OF CALIFORNIA

FOR THE COUNTY OF LOS ANGELES

SANTA CLARITA OAK CONSERVANCY, CALIFORNIA OAK FOUNDATION and SANTA CLARITA ORGANIZATION FOR PLANNING THE ENVIRONMENT, Plaintiffs and Petitioners, vs. CITY OF SANTA CLARITA, a municipal corporation, SANTA CLARITA CITY COUNCIL, and DOES 1-25, inclusive, Defendants and Respondents.	CASE NO. BS 084677 **STATEMENT OF DECISION**
GATE KING PROPERTIES, et al., Real Parties in Interest.	

Having taken the matter under submission on August 9, 2007, after parties' submission of proposed Statements of Decision, having considered all the evidence admitted and the parties' oral and written arguments, the Court rules as follows:

Petitioners Santa Clarita Oak Conservancy, California Oak Foundation, and Santa Clarita Organization for Planning the Environment ("Petitioners") seek a Writ of Mandate commanding Respondents City of Santa Clarita and Santa Clarita City Council ("City" or "Respondents") to set

aside its decision certifying the recirculated Final Additional Analysis ("FAA") to the Environmental Impact Report ("EIR") for the Gate King Industrial Park. The Gate-King Project is a research and development/industrial park, consisting of approximately 106 lots on 508.2 acres, of which 68 lots on 170.1 acres will be used for industrial development. The remainder will be retained in open space. (Supplemental Administrative Record ("SAR") volume 24: page 6324) The project's water demand is estimated to be 386 acre feet per year ("afy"). (SAR 10:2620; 24:6341.)

The City originally certified an EIR for the Gate-King Industrial Park Project ("Gate King") in June of 2003 and approved the project which is the subject of this action. (SAR 10:2619.) The 2003 Gate King EIR included a discussion of available water supplies, including the City's reliance on the availability of 41,000 afy of surface water transferred from the Kern County Water Agency to the Castaic Lake Water Agency ("CLWA") in 1999 ("41,000 afy Transfer"). (*Id.*) CLWA is the "wholesale" water agency to the Newhall County Water District ("NCWD"). NCWD has agreed to annex the project and supply water to it. (SAR 10:2620; 24:6324). Various parties challenged the certification of the Gate King EIR, which was upheld by this Court. (*Id.*)

On appeal, the Court of Appeal reversed and directed this Court to issue a writ of mandate vacating the City's certification of the 2003 EIR on the grounds that the EIR failed to contain substantial evidence of sufficient water supplies. (*California Oak Foundation v. City of Santa Clarita* (2005) 133 Cal.App.4th 1219 ("*California Oak*").) The Court of Appeal held that the Gate King EIR did not sufficiently address uncertainties relating to CLWA's entitlement to the 41,000 afy Transfer. (*Id.*) The Court of Appeal found no other defects in the 2003 EIR. (*Id.* at 1236-41.) On February 15, 2006, this Court issued a Writ of Mandate ordering the City to "certify a Final Environmental Impact Report complying with CEQA consistent with the Court of Appeal's opinion in *California Oak* []."

On March 28, 2006, the City recirculated a "Draft Additional Analysis to the Final Environmental Impact Report for the Gate-King Project" ("DAA"), which "completely replace[d]" the water analysis presented in the 2003 EIR. (SAR 10:2615 – 25:6725.) As required under Public Resources Code section 21151.9 and Water Code section 10910, the DAA included a Water Supply Analysis ("WSA") prepared by NCWD. The WSA analyzed the sufficiency of water supplies for the project and concluded that: (1) the project had been included in NCWD's and CLWA's most recent

2005 Urban Water Management Plan ("UWMP") (SAR 24:6321-6351); (2) that, "[b]ased on the analysis set forth in this WSA and as supported by the documents relied on for its preparation, NCWD's total projected water supplies available during the ensuing twenty years will meet the projected water demands associated with the Gate-King Project and existing and other planned uses within NCWD's service area" (SAR 24:6351); and (3) that, based on a number of factors, including the Department of Water Resources ("DWR")'s and the court's treatment of the 41,000 afy to date, it is "unlikely" that DWR's on-going preparation of an EIR and any litigation arising out of it will "unwind" a completed and executed water transfer of 41,000 afy. (SAR 24:6331.) NCWD also based its conclusion about the sufficiency of water on State Water Project ("SWP") water reliability projections provided by DWR in its State Water Project Delivery Reliability Report. (SAR 24:6329.)

Further, the DAA discussed other concerns affecting the reliability of SWP water, providing information about climate change, the reliability of the CALSIM II model (one of DWR's water reliability modeling tools), and other SWP water issues, such as salinity in the Bay Delta. The DAA also acknowledged DWR's on-going ability to curtail Table A water deliveries of SWP water, including the 41,000 afy based on "environmental considerations." (SAR 10:2628, 2657; 31:8038-8040.) After acknowledging that these factors could affect the reliability of SWP deliveries, the DAA evaluated the likelihood that these factors in fact would significantly undermine DWR's, CLWA's and NCWD's water supply reliability projections. The DAA concluded that

> these events do not significantly affect the reliability of the transfer amount, and therefore, it is still appropriate for the City of Santa Clarita to conclude that CLWA and NCWD properly included the transfer amount as part of CLWA's 95,200 afy Table A Amount [].

(SAR 10:2662.)

The City held a public comment period to receive comments on the DAA from March 31, 2006 through May 8, 2006, and the City's Planning Commission held a public hearing on May 2, 2006 to receive public testimony on the DAA. (SAR 10:2612; 28:7240.) On May 25, 2006, the City published the "Final Additional Analysis to the Environmental Impact Report for the Gate-King

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Industrial Park" ("FAA"). (SAR 28:7234 – 37:9677.)[1] The FAA responded to comments regarding the reliability of the 41,000 afy Transfer, and affirmed the finding that, despite some uncertainty, it was appropriate for the City to conclude that the 41,000 afy Transfer was sufficiently reliable to consider it to be an available water source for planning purposes. (SAR 31:8047-8075.) On June 6, 2006, the City's Planning Commission adopted a resolution recommending re-certification of the Gate King EIR with the FAA. (SAR 38:9699-9702.) On July 11, 2006 the City Council adopted a resolution recertifying the Gate King EIR with the FAA. (SAR 38:9944-9949.) The City issued a Notice of Determination regarding the recertification on July 13, 2006. (SAR 38:9950-9951.)

On August 16, 2006, the City filed a Return to Peremptory Writ of Mandate and Request for Discharge ("Return") with this Court. On October 2, 2006, Petitioners filed an Objection to Return to Peremptory Writ and Request for Discharge.

Standard of Review

To establish a violation of the California Environmental Quality Act ("CEQA"), Petitioners must show an abuse of discretion in that the City either failed to proceed in the manner required by law or the determination or decision is not supported by substantial evidence. (*Vineyard Area Citizens for Responsible Growth v. City of Rancho Cordova* ("Vineyard") (2007) 40 Cal. 4th 412, 426, Code Civ. Proc. § 1094.5(b); Pub. Resources Code §§ 21168, 21168.5.) This requires "scrutiny of the nature of the alleged defect" depending upon whether petitioners' claim is predominantly "one of improper procedure or a dispute over the facts." (*Vineyard,* 40 Cal.4th 412, 435.) As explained by the California Supreme Court in *Vineyard*, "while we determine *de novo* whether the agency has employed the correct procedures, . . . we accord greater deference to the agency's substantive factual conclusions," for a court's task "is not to weigh conflicting evidence and determine who has the better argument." (*Id.*)

"Substantial evidence" is defined as "enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other

[1] As the final CEQA document, the FAA includes the DAA plus responses to comments and modifications to the text of the DAA where required. (14 Cal. Code of Regs. § 15362 (b); hereafter "CEQA Guidelines."

conclusions might also be reached." CEQA Guidelines § 15384(a); *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal.* (1988) 47 Cal.3d 376, 393.) Substantial evidence may include facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts, but not argument, speculation, unsubstantiated opinion, or clearly erroneous evidence. (Pub. Res. Code §§ 21080(e)(1)(2), 21082.2(c).)

"[I]n applying the substantial evidence standard, the reviewing court must resolve reasonable doubt in favor of the administrative finding and decision. As such, if there are conflicts in the evidence, their resolution is for the agency." (*River Valley Preservation Project v. Metropolitan Transit Dev. Bd.* (1995) 37 Cal.App.4th 154, 168.) Determinations in an EIR must be upheld if supported by substantial evidence, and the mere presence of conflicting evidence in the administrative record does not invalidate them. (*Chaparral Greens v. City of Chula Vista* (1996) 50 Cal.App.4th 1134, 1143.) An agency's approval of an EIR may not be set aside on the ground that an opposite conclusion would have been equally or more reasonable. (*Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal.* (1988) 47 Cal.3d 376, 393.) The Court passes only upon the EIR's sufficiency as an informative document, not upon the correctness of its environmental conclusions. (*Laurel Heights* at 392.) An EIR's informational content needs to be adequate to fulfill its informational purpose. It need not be perfect: "CEQA requires an EIR to reflect a good faith effort at full disclosure; it does not mandate perfection, nor does it require an analysis to be exhaustive. The absence of information in an EIR does not per se constitute a prejudicial abuse of discretion." (*Dry Creek Citizens Coalition v. County of Tulare* (1999) 70 Cal.App.4th 20, 26.)

"As with all substantial evidence challenges, an appellant challenging an EIR for insufficient evidence must lay out the evidence favorable to the other side and show why it is lacking. Failure to do so is fatal. A reviewing court will not independently review the record to make up for appellant's failure to carry his burden." (*Defend the Bay v. City of Irvine* (2004) 119 Cal.App.4th 1261, 1266; *see also Environmental Council of Sacramento v. City of Sacramento* (2006) 142 Cal.App.4th 1018 at 1029 ["plaintiffs bear the burden of proving a prejudicial abuse of discretion by establishing that the agencies' decisions are not supported by substantial evidence or that they failed to proceed in a manner required by law"].)

A. The City Was Not Legally Precluded From Relying on the 41,000 afy Transfer Pending Completion of Litigation Surrounding the Monterey Agreement and DWR's Programmatic EIR.

Petitioners contend that the City is precluded from relying on the 41,000 afy Transfer for planning purposes. The argument rests predominantly on the relationship between the 41,000 afy Transfer and on-going proceedings involving the Monterey Agreement, summarized hereafter.

In 1999, CLWA entered into a contract with the Kern Delta Water District for transfer of 41,000 afy. The CLWA certified an EIR for the 41,000 afy Transfer tiered on the earlier program EIR that had been prepared for the Monterey Agreement, a multi-party agreement among SWP contractors setting forth allocations and other provisions concerning SWP deliveries.

In *Planning and Conservation League v. Dept. of Water Resources* (2000) 83 Cal.App.4th 892 ("*PCL*"), the PCL successfully challenged the Monterey Agreement program EIR. The Court of Appeal held that the EIR should have been prepared by DWR as the lead agency, rather than by one of the contractors, and that a new EIR must be prepared and certified by DWR. The Court did not invalidate the Monterey Agreement or enjoin the water transfers effected thereunder, but directed the trial court to consider whether the Monterey Agreement should remain in place pending preparation of DWR's new EIR, and to retain jurisdiction pending certification of DWR's EIR.

In *Friends of Santa Clara River v. CLWA* (2002) 95 Cal.App.4th 1373 ("Friends I"), the Court of Appeal ordered CLWA's EIR for the 41,000 afy Transfer decertified because it had been tiered from the Monterey Agreement EIR, adjudged inadequate: "We have examined all of appellant's other contentions and find them to be without merit. If the PCL/tiering problem had not arisen, we would have affirmed the judgment" (*Friends*, *supra*, at 1387.) The Court did not issue any ruling affecting CLWA's ability to continue to use and rely on water supplies from the 41,000 afy Transfer, leaving it to the trial court's discretion whether to enjoin CLWA's use of the water pending its completion of a new EIR. (*Friends*, *supra*, at 1388.)

In September 2002, on remand to the Los Angeles County Superior Court, the *Friends* petitioners applied under CEQA section 21168.9 to enjoin CLWA from continuing to use and rely on water from the 41,000 afy Transfer. The trial court rejected that request, and in December 2003, the Court of Appeal affirmed the trial court's ruling allowing CLWA to continue to use and rely on water

from the 41,000 afy Transfer pending completion of its new EIR. (*Id.*; *see also Friends of the Santa Clara River v. Castaic Lake Water Agency*, 2003 WL 22839353 ("*Friends II*") at SAR 34:8741.)

Meanwhile, in May 2003, before the trial court acted on remand, the parties to the PCL litigation entered into the Monterey Settlement Agreement. Section II of that Agreement provides that SWP would continue to be administered and operated in accord with both the Monterey Amendments and the terms of the Monterey Settlement Agreement. (SAR 34:8832.) The Monterey Settlement Agreement did not invalidate or vacate the Monterey Amendments, or any water transfer effected under them. The Agreement called for DWR to prepare a programmatic EIR for the Monterey Amendment and to evaluate the environmental impacts of eight completed water transfers, including the 41,000 afy Transfer, within the broad context of the Monterey Agreement.

In December, 2004, CLWA certified a new EIR for the 41,000 afy which did not tier off of the Monterey Agreement EIR. DWR did not object to CLWA acting as lead agency for the 41,000 afy Transfer and, in fact, commented favorably on the CLWA's EIR. (SAR 31:8049-8050.) That EIR was again subsequently challenged. (*California Water Impact Network v. Castaic Lake Water Agency*, LASC Case No. BS 098724.)

In March, 2007, the California Supreme Court decided *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412. In *Vineyard*, plaintiff challenged the EIR for a large, residential development project on the basis that the project's projected water supply was so uncertain that the EIR effectively failed to identify the source of the water needed to supply the project in the long term.[2] According to the petitioner, this failure of the EIR could not be cured since the EIR improperly deferred analysis of the project's true water supply impacts.

The Sunrise Douglas EIR projected water supplies to come from two sources: groundwater supplies in the near-term and additional surface water sources in the long-term. With respect to long-term supplies, the court held that the EIR had failed to proceed in accordance with law for failure to provide sufficient information. It leaves "too great a degree of uncertainty regarding the long-term availability of water for this project. Factual inconsistencies and lack of clarity in the [analysis] leave

[2] The Sunrise Douglas project would demand approximately 22,000 afy based on a projected build-out of 22,000 units of housing, housing approximately 60,000 people.

the reader[,] and the decision-maker[,] without substantial evidence for concluding that sufficient water is, in fact, likely to be available for the Sunrise Douglas project at full buildout." (*Vineyard,* 40 Cal.4th at 439.) With respect to the need to identify replacement supplies, the court held that, "[w]here, despite a full discussion, it is impossible to confidently determine that anticipated future water sources will be available, CEQA requires some discussion of possible replacement sources or alternatives to use of the anticipated water, and of the environmental consequences of those contingences." (*Vineyard*, 40 Cal.4th at 432.)

On the other hand, the court upheld as adequate the Sunrise Douglas EIR's analysis of near-term groundwater supplies and held that the EIR's conclusions should not be set aside if supported by substantial evidence. Despite *some uncertainty* about the availability of the near-term supplies, which had been specifically identified but were subject to competing demands, the court held that substantial evidence supported the city's determination that the supplies were sufficiently reliable to be used for planning purposes and did not require an analysis of replacement sources. (*Vineyard*, 40 Cal.4th at 436-438; see also *Western Placer Citizens for an Agric. and Rural Env't v. County of Placer* (2006) 144 Cal.App.4th 890, 908 [an EIR need not identify a "guaranteed" source of water; "if an EIR were required to identify a guaranteed source of water, then no EIR would ever be sufficient."].)

In April, 2007, Department 13 of the Los Angeles Superior Court issued a Statement of Decision in Case No. BS 098724 (the second challenge to CLWA's 2004 EIR referred to above) and ruled that (1) the 41,000 afy Transfer was final and not subject to invalidation; (2) that CLWA was the proper lead agency to have prepared the EIR on the 41,000 afy and; (3) that CLWA was not required to await preparation of DWR's programmatic EIR on the Monterey Agreements before it could certify its own EIR.[3] The court nonetheless identified an analytical "hole" in CLWA's EIR based on its failure to explain the relationship between DWR's ability to impact the 41,000 afy Transfer as a result of its programmatic EIR and the three future water supply scenarios CLWA studied in its EIR. However, like all other courts that have faced this issue, the court refused to invalidate the Transfer or set it aside pending correction of this analytical defect.

[3] The court grants Petitioner's Request for Judicial notice of the trial court's Statement of Decision in *California Water Impact Network v. Castaic Lake Water Agency*, Case No. BS 098724.

1. *PCL, Friends of the Santa Clara River* and *California Oak* Do Not Preclude Reliance on the 41,000 afy Transfer

Petitioners contend that legal uncertainties surrounding the 41,000 afy Transfer due to the *PCL* and *Friends* lawsuits and the on-going preparation by DWR of a programmatic EIR preclude the City from relying on water from that transfer for planning purposes. Specifically, Petitioners contend that because *PCL* requires the Department of Water Resources ("DWR") to prepare an EIR analyzing the effects of the eight SWP water transfers completed under the Monterey Agreement, none of those transfers, including the 41,000 afy Transfer, are sufficiently reliable for planning purposes until DWR has completed and certified that EIR.

PCL, Friends and *California Oak* do not preclude reliance on the 41,000 afy Transfer for planning purposes. While the Courts of Appeal could have simply said that all EIRs requiring reliance on the 41,000 afy Transfer must await the certification of a new FEIR by DWR (and resolution of any litigation challenging such FEIR), they have not done that. In fact, no court has said that.

Although the Court in *Friends* and *California Oak* observed that CLWA "may be able to cure the PCL problem by awaiting action by the [DWR] complying with the PCL decision, then issuing a subsequent EIR, supplement to EIR, or addendum . . . tiering upon a newly certified Monterey Agreement EIR" (*California Oak, supra*, 133 Cal.App.4th at 1229," n.6), neither court said that local water or planning agencies must await the DWR Programmatic EIR. In fact, the *California Oak* court made it clear that as long as the basis for the decision was transparent and reasoned, it was *up to the City* to decide whether the 41,000 afy is sufficiently reliable for planning purposes. (*Id.* at 1237-38, emphasis added.)

2. The Monterey Settlement Agreement and DWR's Pending EIR Does Not Preclude Reliance on the Transfer.

The Monterey Settlement Agreement does not prohibit local agencies from relying on the 41,000 afy Transfer. Rather, the Settlement Agreement simply requires DWR to conduct an "[a]nalysis of the potential environmental [impacts] relating to" several undisputedly final and completed water transfers, not just of the 41,000 afy Transfer (SAR 34:8834) and to analyze all of the transfers in the same manner, even though seven of them, defined in the Agreement as the

"Attachment E Transfers," were beyond challenge. (*Id.*) All of the water transfers were effected as permanent transfers under the Agreement and are to be analyzed in the same way in DWR's new EIR and no material distinction is made between them. Nothing in the Settlement Agreement requires cities and counties to stop land use planning efforts until the DWR's EIR is certified, and no court has so held.

Nor is the fact of DWR's pending programmatic EIR a bar to the City's reliance on the 41,000 afy. While it is possible that DWR's EIR could impact the Transfer (a fact disclosed in the FAA), the preparation of that EIR by DWR is not a legal prerequisite for the approval of this Project by the City. Further, NCWD, the expert water agency that prepared the WSA for the Gate-King project, determined that it is "unlikely" that DWR's on-going preparation of an EIR and any litigation arising out of it will "unwind" completed and executed water transfers, such as the 41,000 afy Transfer. (SAR 24:6331.) The City's reliance on this conclusion was reasonable, based on evidence that showed (1) that DWR has treated and continues to treat the 41,000 afy as a valid, final transfer (SAR 31:8046); (2) that the 41,000 afy Transfer was memorialized in a 1999 supply contract amendment approved by DWR (SAR 31:8050); (3) that DWR has allocated and delivered the water in accordance with the transfer since 2000, seven years ago and increased CLWA's SWP maximum Table Amount by that amount (*Id.*); (4) that CLWA has paid $47 million for the water, monies which have been delivered and which were financed by tax-exempt bonds (*Id.*); (5) that DWR has always treated the transfer as a "permanent" and final Table A transfer and has stated that it is consistent with the implementation of the Monterey Amendments (*Id.*); (6) that DWR praised CLWA's 2004 EIR as a comprehensive and thorough analysis (SAR 10:2672); (7) that no court has ever set aside the Transfer pending preparation of CLWA's EIR or SWR's programmatic EIR; and (8) that DWR included the 41,000 afy in its most recent SWP Reliability Projections. (SAR 10:2671; 31:8050-8051.) These factors support the City's conclusion that neither the DWR (nor the courts) are likely to significantly disturb the 41,000 afy Transfer.

In summary, contrary to Petitioners' arguments, no *legal* bar exists to the City's reliance on the 41,000 afy Transfer for planning purposes. *California Oak* held that it was up to *the City* to determine whether or not to rely on the 41,000 afy Transfer in its planning pending the completion of the

litigation. The Court stated: "*[T]he question is whether the entitlement should be used for purposes of planning future development*, since its prospective availability is legally uncertain. *Although this decision must be made by the City*, the EIR is intended to serve as an informative document to make government action transparent. Transparency is impossible without a clear and complete explanation of the circumstances surrounding the reliability of the water supply." (*Id.* at 1237-38; emphasis supplied.)

The City's recirculated FAA transparently discussed the uncertainties related to the 41,000 afy Transfer, including disclosing the possibility that future actions by DWR could adversely impact the Transfer. Based on the evidence before it, the City reasonably concluded that it was unlikely that the 41,000 afy would cease to be available to serve this project and other projects.

3. The Invalidation of CLWA's EIR Does Not Undermine the City's EIR.

Petitioners contend that the April 2007 Statement of Decision invalidating of CLWA's EIR for the 41,000 afy Transfer in *California Water Impact Network v. Castaic Lake Water Agency* (Case No. BS 098724) undermines the adequacy of the City's FAA, which was certified in July, 2006. But as recognized by the *California Oak* court:

> It is well-established that once a project is approved, new information does not require reopening the approval. (*SCOPE, supra*, 106 Cal.App.4th at p. 723; Cal.Code Regs., tit. 14, § 15162, subd. (c).) Gate King is thus correct that it is "simply too late to raise this [the invalidation of the UWMP 2000] as an issue." (133 Cal.App.4th at 1243.)

As with the invalidation of the 2000 UWMP in the *California Oak* case, the setting aside of CLWA's EIR nearly a year after the City's certification of the FAA cannot re-open the validity of that certification. When the City certified the Gate King FAA in July, 2006, it was entitled to assume that the CLWA's certified EIR was adequate to support CLWA's approval of the 41,000 afy Transfer. (*State of California v. Superior Ct.* (1990) 222 Cal.App.3d 1416, 1419.)

But in any event, the City's FAA anticipated the possibility that CLWA's EIR might be invalidated, but concluded that the Transfer was still likely to prove reliable. The City's FAA said:

> "[T]he City has determined that it is reasonable to conclude that *even if a court finds that the CLWA 2004 EIR legally deficient*, that court, like all others before it, will again refuse to enjoin the permanent 41,000 afy water transfer, and instead require further revisions to the EIR." (SAR 31:8052 (emphasis added).)

That is what happened. Although the court in Department 13 found an "analytical hole" in CLWA's EIR, it refused to set aside the Transfer.

Finally, Petitioners suggest that the City's FAA suffers from the same "analytical hole" as identified in CLWA's EIR, namely that the FAA should have predicted how the outcome of DWR's programmatic EIR might affect the three allocation scenarios examined in the CLWA's EIR—namely (1) a pre-Monterey Amendments scenario without Article 18 cutbacks, (2) a pre-Monterey Amendments scenario with Article 18 cutbacks and (3) a post-Monterey Amendments scenario.

The defect identified in the CLWA EIR does not apply to the FAA. First, Petitioners' failure to exhaust their administrative remedies with respect to these arguments bars them from raising them for the first time now. (Pub. Res. Code § 21177(a); *Sierra Club v. California Coastal Comm'n* (2005) 35 Cal.4th 839, n. 20; *Central Delta Water Agency v. State Water Res. Control Bd.* (2004) 124 Cal.App.4th 245, 274.)

Assuming *arguendo,* that Petitioners' arguments are not barred, CEQA imposes on the City no duty to examine in its project EIR the three "Monterey" allocation scenarios assessed in CLWA's EIR for the 41,000 afy . Public Resources Code § 21002.1 provides that "[t]he purpose of an [EIR] is to identify the significant effects on the environment *of* [*the*] *project* . . . ." (emphasis added.) In CLWA's EIR, the "project" was a 41,000 afy Transfer. In the City's FAA, the "project" was a local industrial park project. None of the Monterey allocation scenarios are a direct or indirect environmental consequence of approval of *this* project. Petitioners stretch CEQA beyond its limits to suggest that the City's FAA should have contained a detailed environmental assessment of the 41,000 afy Transfer, a project under the jurisdiction of a different agency, and with very different environmental ramifications.

Rather, under CEQA, the FAA was required to contain a reasoned and adequate assessment of whether there will be sufficient water to serve *the project* and, to the extent water is deemed *not* available, the environmental impacts of acquiring needed water. (*California Oaks* at 448, *Vineyard* at 432.) In this case, the FAA contained a reasoned, good faith analysis, identified specific, available water supplies, and discussed the reliability of those supplies. Acknowledging potential uncertainties (including DWR's ability to curtail Table A deliveries in the future based on "environmental

considerations,") of the available supplies, the FAA nonetheless concludes that DWR's future activities are "unlikely to 'unwind' [a] completed and executed...transfer[]." (SAR 24:6331) There is no "analytical hole" here. The FAA identifies water available to serve the project, discusses the degree of uncertainty related to those identified supplies, and based on substantial evidence, concludes that the supplies are *sufficiently* reliable to use for planning purposes.

4. The FAA was not required to identify supplies to replace the 41,000 afy

Petitioners claim that *California Oak* and *Vineyard* required the City to identify permanent replacement water supplies to serve the project, should the 41,000 afy Transfer at some point cease to be available. Petitioners misread *California Oak* and *Vineyard*. Rather, *California Oak* requires that the City explain why it can rely on the 41,000 afy Transfer, despite the legal uncertainties, ***or*** identify additional water supplies for the project. (*California Oak, supra*, 133 Cal.App.4th at 1242 [emphasis added].) It does not require that the City do both. (See also *id.* at 1244 calling for the EIR to demonstrate how "demand for water would be met without the 41,000 afy entitlement, ***or*** of why it is appropriate to rely on the 41,000 afy Transfer in any event." (*Id.* at 1242 [emphasis added].) "Whether the [41,000 afy] entitlement should be used for purposes of planning future development" is a decision that "must be made by the City." (*Id.* at 1237-1238.)

In the FAA, the City chose to rely upon the continued availability of 41,000 afy Transfer in its water supply analysis and to explain why. As ordered by the Court of Appeal, it provided a reasoned analysis based on substantial evidence as to why it was appropriate to do so. (SAR 10:2615 – 25:6726; SAR 28:7234 – 37:9677.) Having done so, the City was not required to also identify water supplies to replace the 41,000 afy.

Nor does *Vineyard Area Citizens* require the City to identify replacement sources of water. In *Vineyard*, the Supreme Court held that "where, despite a full discussion, it is *impossible to confidently determine* that anticipated future water sources will be available, CEQA requires some discussion of possible replacement sources or alternatives to use of the anticipated water, and of the environmental consequences of those contingences." (*Vineyard*, 40 Cal.4th at 432.) Here, it was *not* impossible to confidently determine that the 41,000 afy would continue to be available based on the record before the City. While *some* uncertainty existed, there was sufficient certainty for the City to confidently

predict that water supplies would in fact continue to be available. The *Vineyard* court does not require a *guarantee* of certainty for an EIR's water analysis to be considered adequate, just a "likelihood of actually proving available." (*Id.*)

In fact, whether a specifically identified source, such as the 41,000 afy, is *sufficiently* reliable is the kind of factual dispute that *Vineyard Area Citizens* cautioned should be subject to deference as long as the City's conclusion is supported by substantial evidence. (*Vineyard Area Citizens*, 40 Cal.4th at 436.) In *Vineyard,* the court applied this deferential approach to City's conclusion about the reliability of near-term groundwater supplies (5,000 afy). Although the 5,000 afy was specifically identified as available to serve the development, the EIR acknowledged there were competing demands for it. (*Id.*) "*While much uncertainty remains*," the court said, "the record contains substantial evidence demonstrating *a reasonable likelihood* that a water source the provider plans to use for the Sunrise Douglas project . . . will indeed be available at least in substantial part to supply the Sunrise Douglas project's near-term needs." (*Id.* at 437, emphasis added.) The *Vineyards* court did not require either a guarantee of availability or an analysis of replacement sources for the 5,000 afy of near-term supplies.

Here, as in *Vineyards,* the FAA discloses "potential uncertainty" over the 41,000 afy, but also explains why the City concluded that this specifically identified source was not *so* uncertain as to not "bear a likelihood of actually proving available" or to require identification of replacement sources. Under well-established principles, this Court must defer to the City's factual conclusion.

Finally, *Vineyard* recognizes that CEQA does not require the city to "reinvent the water planning wheel" each time it approves an individual development project if a water planning agency has already included the project in its most recently adopted Urban Water Management Plan. (UWMP) (*Vineyard*, 40 Cal.4th at 434.)[4] "The analysis in an individual project's CEQA evaluation may incorporate [an UWMP's] previous overall water planning projections," and need not "reinvent the wheel." (*Id.* at 434; see also Water Code §10910 (c)(1), (2) and (3), allowing incorporation of an UWMP analysis into an EIR) In *Vineyard,* the Sunrise Douglas project was *not* accounted for in the

[4] A UWMP must describe estimated past, present and future water sources, supply and demand for at least 20 years into the future. (Water Code §§ 10610-10656)

applicable UWMP. Here, in contrast, the Gate King project was fully accounted for in NCWD's most recently adopted UWMP, and this information was incorporated into the FAA. (SAR 10:2621; 24:6326.) Under CEQA and the Water Code, the City was entitled to incorporate the UWMP's projections of available water supplies, which included the 41,000 afy, into its water supply analysis. This is what it did.

B. Substantial evidence supports City's reliance on 41,000 afy water transfer

As noted, *California Oak* held that, as long as the City's conclusions were supported by substantial evidence, it is within the City's province to decide whether to rely on the 41,000 afy Transfer for planning purposes. (*California Oak, supra*, 133 Cal.App.4th at 1237-38.)

The FAA, here, contains a discussion of *why* the City chose to rely on the 41,000 afy as a reliable source, despite the identified uncertainties. While disclosing that future activities by DWR involving SWP water (including its programmatic EIR) *could* affect the 41,000 afy Transfer, the FAA concludes that such DWR's future activities were "unlikely" to "unwind" executed and completed agreements with respect to the permanent transfer of SWP Water Amounts." (SAR 10:2661-2664.) To support this conclusion, the FAA explains that the 41,000 afy Transfer was completed in 1999; CLWA has paid approximately $47 million for the additional Table A Amount, the monies have been delivered, the sales price has been financed through CLWA by tax-exempt bonds, and DWR has increased CLWA's SWP maximum Table A Amount and delivered or made available to CLWA the 95,200 afy because it was a permanent transfer/reallocation of SWP Table A entitlement between SWP contractors. (SAR 31:8046-8050.)[5]

The FAA also explains that DWR itself lists the 41,000 afy as part of CLWA's allocation in its published "Notices to State Water Project Contractors" (SAR 31:8046); treats the transfer as a permanent and final transfer (*Id.*); did not object to CLWA's preparation of its own EIR for the 41,000

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[5] Included in the DAA's and FAA's Appendices are the necessary documents to support the FAA's analyses, including the Water Supply Assessment prepared by NCWD PCL decision (SAR 34:8916-8936), the Monterey Settlement Agreement (SAR 34:8816-8897), the Sacramento County Superior Court's "Order Pursuant to Public Resources Code Section 21168.9" (SAR 36:9410-9413), the *Friends* decision (SAR 34:8771-8779), the Los Angeles County Superior Court's Judgment on remand in the *Friends* litigation (SAR 34:8781-8791), CLWA's final EIR for the 41,000 afy Transfer (SAR 16:4029 – 19:5126), and CLWA's Resolution certifying that EIR (SAR 33:8522-8527).

afy (SAR 31:8051) and expressly allocates the 41,000 afy as part of Castaic Lake Water Agency's 95,200 afy in its 2005 State Water Project Delivery Reliability Report (SAR 22:05930), which contains "DWR's current information regarding the annual water delivery reliability of [SWP] for existing and future levels of development . . . , assuming historical patterns of precipitation." (SAR 22:5874.) This evidence—unrefuted by Petitioners—supports the City's determination that, although *possible*, it is *unlikely* that DWR will impose conditions on the Transfer that will significantly impair DWR's own projections about its reliability. (SAR 24:6331.) While the City's determinations about the reliability of the 41,000 afy contain a degree of projection, "[d]rafting an EIR . . . necessarily involves some degree of forecasting." (CEQA Guidelines 15144.) Where an agency uses its best efforts to disclose and forecast all that it reasonably can about the reasonable likelihood of future activities, it has complied with CEQA. (*Id.*)

Importantly also, Petitioners have not produced substantial evidence that DWR *will* significantly change DWR's own projections concerning the reliability of SWP water. Rather, Petitioners simply speculate that DWR might do so. Nor have Petitioners shown why the evidence relied on by the City to conclude such a result is "unlikely" is insubstantial, incorrect or flawed. Petitioners' failure to explain why the evidence favorable to the City's determination is lacking is "fatal" to its case. A reviewing court will not make up for appellant's failure to carry its burden. (*Defend the Bay*, *supra*, 119 Cal.App.4th 1261 at 1266.)

The City reviewed the evidence provided by the expert water agencies, NCWD, CLWA and DWR, as well as the views of commentators opposed to the City considering the 41,000 afy Transfer, and determined that the 41,000 afy was *sufficiently* reliable to be able to confidently use it for planning purposes. This determination is supported by substantial evidence in the record, and thus, comports with CEQA. (*Vineyard Area Citizens*, 40 Cal.4th at 436.)

C. The FAA properly relied on data developed by DWR using the CalSim II model.

Petitioners' criticize the City's reliance on DWR's use of the CALSIM II model and contend that other experts have said the model does not reliably predict water supplies. However, as stated in CEQA Guidelines section 15151 "[d]isagreement among experts does not make an EIR inadequate." Rather, section 15151 provides that "[an] EIR should summarize the main points of disagreement

among the experts. The courts have looked not for perfection but for adequacy, completeness, and a good faith effort at full disclosure." (*Association of Irritated Residents v. County of Madera* (2003) 107 Cal. App. 4th 1383, 1390-91) The City, after disclosing and discussing the expert controversy, appropriately chose to rely upon DWR's Reliability Report, which includes water supply availability data developed using the CALSIM II model. Substantial evidence in the record supports City's determination that DWR, the state's expert agency on water supplies, reasonably employed CALSIM II as the best available tool for assessing water supplies in California.

Petitioners focus on the "Strategic Review of CALSIM II and its Use for Water Planning, Management and Operations in Central California" ("Strategic Review") contending that the Strategic Review supports their contention that CALSIM II should not be used for absolute predictions. (SAR 35:9107-9150.) In relying on DWR's Reliability Report, the City acknowledged the Strategic Review, recognized that it identified some weaknesses with the model, but concluded – as did the Strategic Review – that CALSIM II is a valuable tool for planning purposes. (SAR 31:8074; 35:9110.) In fact, the Strategic Review viewed CALSIM II as "a very impressive modeling effort on the part of all those involved with its development and application," (SAR 35:9110, 9132) and concluded: "Few, if any, modeling organizations in the country have consistently done as good a job on model development and application for such a large, complex, and controversial system as the modeling group which developed CALSIM II. . . . Most areas and suggestions for improvement . . . are meant to aid the model developers in moving further and faster in the direction they are already heading." (SAR 35:9127.) That same experts believe the model can be improved does not detract from it being the best available currently.

Petitioners suggest that the use of CALSIM II for making absolute predictions about future SWP water deliveries conflicts with DWR's and the United States Bureau of Reclamation position on the model, but DWR and the Bureau of Reclamation's ("Bureau") primary position paper on this issue: "Peer Review Response: A Report by DWR/Reclamation in Reply to the Peer Review of the CALSIM II Model" ("Peer Review Response") does not support this. (SAR 37:9592-9660.) The Peer Review Response, which responds to the Strategic Review, states that the CALSIM II Model *can* be

used to make absolute predictions in certain circumstances, including for "local planning efforts by project contractors and local agencies." (SAR 37:9619.)

Petitioners further argue that in an unpublished U.S. District Court opinion, *Planning and Conservation League v. U.S. Bureau of Reclamation*, ("*PCL/Bureau*") the Bureau "essentially admitted that the model is too unreliable for making absolute predictions." But the decision only highlights a fact which is not in dispute, and which the City prominently disclosed in the FAA: there are perceived shortcomings to the CALSIM II model. The *PCL/Bureau* decision (discussed in the FAA, included in the FAA's appendices), did not restrict "the Bureau or any other agency from using or relying on the CalSim-II model but, rather, stated that the Bureau could rely on the model, provided it disclosed relevant shortcomings in the data or model itself." (SAR 31:8074; *see also* 34:8938-8955.) The FAA did disclose these shortcomings.

Finally, the City's responses to comments by the Planning and Conservation League and California Water Impact Network were appropriate. (*See* SAR 31:8097-8098, 8102-8103.) In those responses the City recognized that the CALSIM II model has shortcomings, but concluded that it may still be relied on, as it is relied upon by experts DWR and the Bureau. (*Id.*) CEQA requires nothing more. (*See Greenbaum v. City of Los Angeles* (1984) 153 Cal.App.3d 391, 412-13 [agency has discretion to determine what methodology to use].)

D. The FAA properly evaluated the potential impact of global warming on water supplies.

The FAA appropriately concluded, based on adequate review of global warming literature and relevant studies, that the impact of climate change on water supplies was too speculative to conduct further meaningful quantitative review.

The FAA reviewed literature on global climate change, and has a seven-page discussion of the issue in Topical Response 3. (SAR 31:8076-8082.) The FAA recognizes that a broad consensus has concluded that the global climate is warming and that this change may adversely impact California's water supplies. (*Id.*) After reviewing the relevant studies, however, the FAA determined that the timing and extent of any impact to water supplies remains highly uncertain. (*Id.*) While DWR and other agencies and institutions continue to study the implications of global warming on water supplies, the FAA notes that DWR itself has determined that the science "has not reached a level at which it can

be quantitatively incorporated into delivery projections of the SWP." (SAR 31:8077.) The FAA states that the City reviewed these studies and DWR's approach and independently determined that it would be speculative to try to quantify the effects of climate change on water supply reliability at this point. (SAR 31:8082.)

CEQA permits such an approach. Given DWR's expert opinion that the quantitative impact of global warming on water supplies is speculative, CEQA did not require further analysis of those impacts. CEQA Guidelines § 15145 provides: "If, after thorough investigation, a lead agency finds that a particular impact is too speculative for evaluation, the agency should note its conclusion and terminate discussion of the impact." (*See also Marin Municipal Water Dist. v. KG Land California Corp.* (1991) 235 Cal.App.3d 1652, 1662-63 [upholding approach in which EIR investigated potential long-term impacts, but found analysis would be speculative].)

Petitioners argue that the City was required to make a "good faith effort to analyze the potential impacts on supply reliability based on the available data." It did. FAA Topical Response 3 contains an adequate discussion of global warming, including a summary of the various studies which examine the potential impact on water supplies in California. (SAR 31:8076-8082.) It recognizes that some studies have concluded that less water will be available as a result of global warming. (SAR 31:8078, 8080.) However, the FAA also reviewed studies that found that global warming may result in more water for California. (*Id.*) After summarizing the main points of these studies, the City exercised its discretion as lead agency, and chose to adopt DWR's expert opinion that quantifying the impact of global warming on water supplies at this time would be speculative:

> [B]ased on the above data, the City agrees with DWR that it would be speculative at this time to quantify the effects of climate changes on the reliability of the SWP . . . [a]t this time, the City believes it is appropriate to terminate any further analysis of potential future climatic changes, consistent with Section 15145 of the California Environmental Quality Act Guidelines.

(SAR 31:8082.)

Climate change is clearly an issue of vital importance, particularly to water supplies in California. DWR, the state agency with the most expertise on water supplies in California, has determined that the science on global warming has not reached a point where it can be "quantitatively

incorporated into delivery projections of the SWP." (SAR 31:8077.) The City Council of the City of Santa Clarita is in no better position to do so and CEQA does not require it to do so.

1. The FAA adequately addressed State Water Resources Control Board Order 2006-0006.

The FAA adequately addresses the State Water Resources Control Board's Order 2006-0006 ("Order")[6] concerning the maintenance of salinity standards in the Sacramento Bay Delta. Petitioners argue that the City must forecast the "extent to which meeting the salinity standard in DWR's State Water Board permit may result in reductions to SWP deliveries." However, as explained by the FAA, there are a variety of overlapping methods by which DWR may comply with the Order. (SAR 31:8070-8071.) After examining these methods and considering the current efforts underway by DWR to meet the salinity standards, as well as noting that, even if DWR were to be found in violation of the Order, a reduction in water deliveries is not required. The City's conclusion that the Order does not result in a reduction of State Water Program supplies to the DWR is supported by the evidence.

As described in the FAA, in the event that DWR or the Bureau projects that there may be a "potential exceedance in the salinity objectives" of the Board Order the "two agencies are required to immediately inform the State Board . . . and describe the corrective actions they are initiating to avoid the exceedance." The 'corrective actions' may include, but are not limited to:

> [A]dditional releases from upstream [CVP] facilities or south of the Delta [SWP] or CVP facilities, modification in the timing of releases from Project facilities, reduction in exports, recirculation of water through the San Joaquin River, purchases or exchanges of water under transfers from other entities, modified operations of temporary barriers, reductions in highly saline drainage from upstream sources, or alternative supplies to Delta farmers (including overland supplies).

(SAR 31:8070.) The FAA finds that, "While the reduction of exports is listed as one means of improving salinity concentrations, it is only one of many such methods. As noted above, implementation of a barrier program is another means for improving salinity concentrations and, in fact, DWR and the Bureau are working on such a program." (*Id.*)

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[6] Although the text of the Order itself was not included in the Administrative Record, it is apparent the City had access to the Order as part of its deliberations, as the City's FAA contains a detailed analysis of it. It appears to have been inadvertently omitted from the Supplemental Administrative Record. The Court grants Real Parties' Request for Judicial Notice of SWRCB Order 2006-0006 under Evidence Code §452.

The FAA further notes that, even if there was an "exceedance," an enforcement action would not be automatic, as the Executive Director of the State Water Board would first have to consider if any action was appropriate and whether the "non-compliance was beyond DWR's or the Bureau's control." (SAR 31:8071.) Given the variety of methods available to DWR and the Bureau to meet the salinity standards, the current efforts towards implementation of a barrier program, and the administrative provisions of the Order, the FAA appropriately concludes that "nowhere does the Order mandate that DWR and the Bureau shut down their pumps." (*Id.*) Analyzing the impacts of speculative future enforcement actions is not required under CEQA.

CONCLUSION

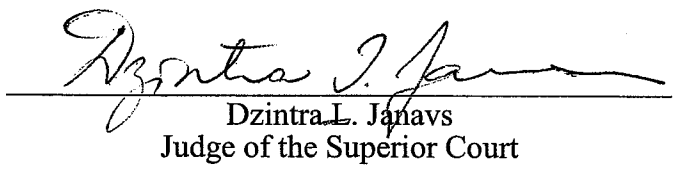
As directed by *California Oak*, the City has adequately analyzed the uncertainties surrounding the 41,000 afy water Transfer and explained in good faith the basis for its reliance on that Transfer. That analysis need not be exhaustive, but with a sufficient degree of analysis to make a decision which intelligently takes account of environmental consequences. (CEQA Guidelines § 15151.) Perfection is not required: adequacy, completeness and a good faith effort at full disclosure are. The City's determinations are not an abuse of discretion, but supported by substantial evidence.

The Court accepts the City's Return to the Writ of Mandate and the Final Additional Analysis to the Environmental Impact Report for the Gate-King Industrial Park as adequate and, accordingly, IT IS SO ADJUDGED that the Peremptory Writ of Mandate is DISCHARGED.

Counsel for respondent shall prepare, serve and lodge in Department 85 a proposed order/judgment discharging the writ on or before August 21, 2007.

Objections to this Statement of Decision and proposed order and judgment shall be served and filed on or before August 31, 2007.

DATED: August 15, 2007



Dzintra L. Janavs
Judge of the Superior Court

Retired Irrigated Farmland, Tentative Tract Map No. TR61105, 2008

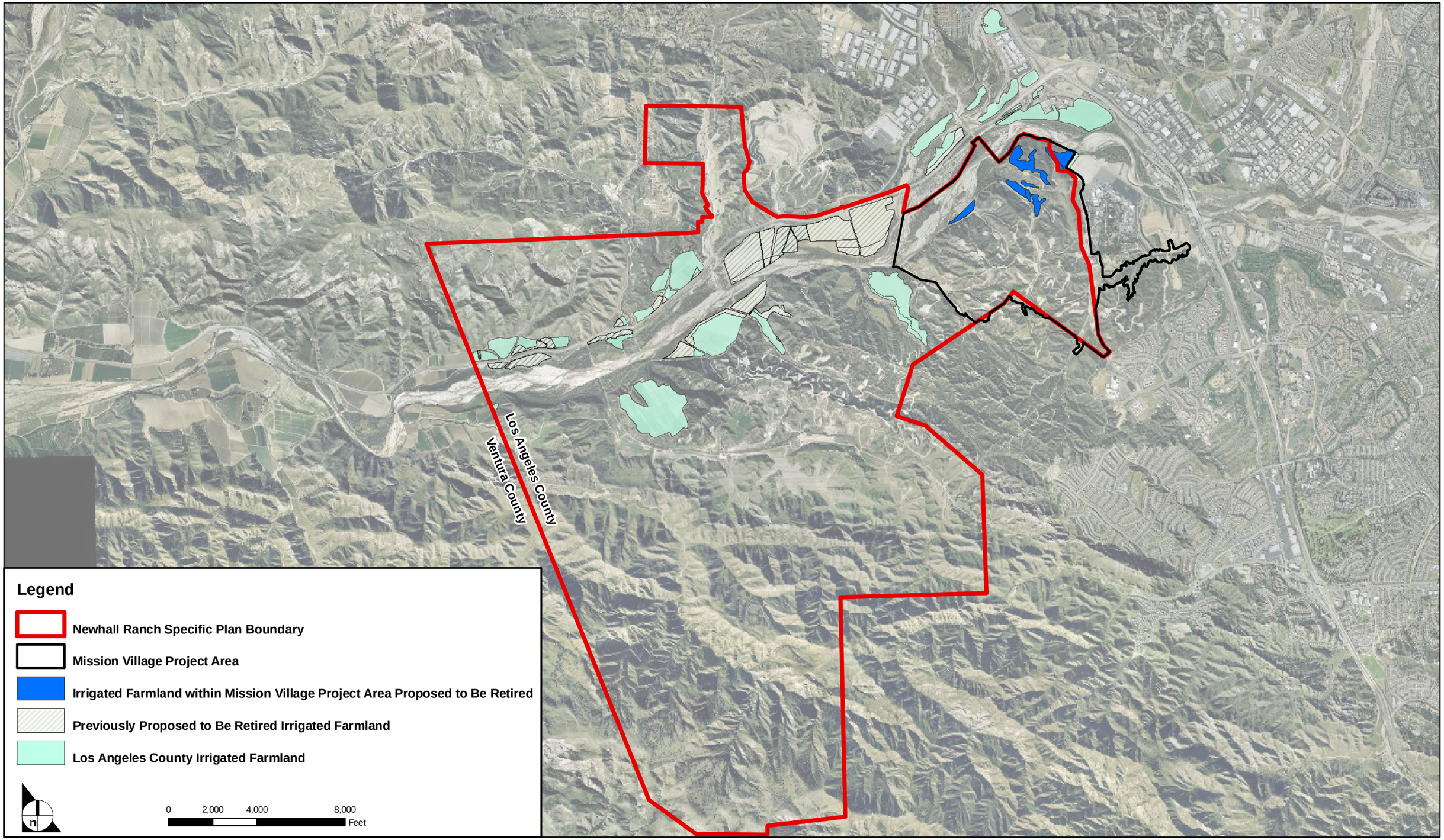
RETIRED IRRIGATED FARMLAND – MISSION VILLAGE
Tentative Tract Map No. TR61105
County Project No. 04-181
2008

The Newhall Land and Farming Company (Newhall) has submitted an application to Los Angeles County for approval of the Mission Village Vesting Tentative Tract Map No. 61105, which is the second tentative map within the Newhall Ranch Specific Plan. As part of the approval of the Specific Plan in 2003, the County required the following Specific Plan mitigation measure (Mitigation Measure 4.11-22):

> "4.11-22. Beginning with the filing of the first subdivision map allowing construction on the Specific Plan site and with the filing of each subsequent subdivision map allowing construction, the Specific Plan applicant, or its designee, shall provide documentation to the County of Los Angeles identifying the specific portion(s) of irrigated farmland in the County of Los Angeles proposed to be retired from irrigated production to make agricultural water available to serve the subdivision**.** As a condition of subdivision approval, the applicant, or its designee, shall provide proof to the County that the agricultural land has been retired prior to issuance of building permits for the subdivision."

The attached illustration, entitled "Exhibit A - Newhall Ranch Irrigated Farmland Proposed to Be Retired - Mission Village," shows irrigated agricultural lands on and near the Specific Plan site, including Mission Village. In association with the Mission Village project, Newhall proposes to retire irrigated agricultural lands on the Mission Village site. As shown on Exhibit B entitled, "Mission Village Irrigated Farmlands to be Retired," this action would allow for the transfer of 529 acre-feet per year (afy) of groundwater historically and presently used for irrigation on the Mission Village site to the Municipal and Industrial (M&I) uses for the Specific Plan site. As shown, the potable water demand for the Mission Village project is 1,961 afy. After subtracting this demand from the total amount of water that would become available once the agricultural land on the Mission Village site is retired, a total of 4,456 afy will still be available to future subdivision maps on the Specific Plan site.

Prior to the issuance of building permits for the Mission Village project, Newhall, or its designee, will provide evidence that irrigated agricultural land on the Mission Village site has been retired to make agricultural water available to serve the subdivision.



SOURCE: Forma 2003

Exhibit A

Newhall Ranch Irrigated Farmland Proposed to Be Retired - Mission Village

032-092 • 07/09

M:\GIS_Data\032-092_Landmark_Village\MXD\Fig_x.x-x_Existing_MV_AgInProjectAreas_071609.mxd

EXHIBIT B
MISSION VILLAGE
IRRIGATED FARMLANDS TO BE RETIRED

(Mitigation Measure 4.11-22)
(all numbers in acre feet)

Proposed Subdivision	A Starting Agricultural Water Supply Available for Conversion to Potable	B Location of Agricultural Fields to be Retired	Types of Planted Crops Retired	C Retired Fields Water Useage	D Subdivision Potable Water Demand	E Ending Agricultural Water Supply Available for Next Subdivision (A-D)
1 Landmark Village TTM 53108*	7038	See Exhibit A	Alfalfa, sudan/pasture,	2940	608	6430
2 WRP *	6430	See Exhibit A	Leased vegetables	141	13	6417
3 Mission Village	6417	See Exhibit A	Leased vegetables	529	1961	4456
Total All Projects				3610	2582	

* Landmark + WRP Potable Demand is 621 afy

Valencia Water Company, Well E-15 Water Quality Compliance Monitoring Results – 2006 to 2009

E15 - GMIO	2006	2007	2008	2009	Units
TH (as CaCO3)	497	468	418	434	mg/L
Ca	125	119	105	109	mg/L
Mg	45	41.3	38.1	39.2	mg/L
Na	104	103	88.3	99.4	mg/L
K	4	3.8	3.9	4.3	mg/L
Tot Alk	222	237	229	224	mg/L
HCO3	271	289	279	273	mg/L
SO4	315	311	286	271	mg/L
Cl	87.5	90.1	96	95	mg/L
NO3	15.8	21.2	13.3	12.8	mg/L
F	0.59	0.83	0.8	0.79	mg/L
pH	7.43	7.2	7.3	7.35	Unit
EC	1293	1314	1308	1303	mg/L
TDS	1066	950	921	815	mg/L
Color	<5	<5	<5	<5	Unit
Odor	1	1	1	1	Unit
Turbidity	0.1	0.06	0.06	0.05	NTU
Al	<DLR	<DLR	<DLR	<DLR	mg/L
An	<DLR	<DLR	<DLR	<DLR	mg/L
Ar	<DLR	<DLR	<DLR	<DLR	mg/L
Ba	<DLR	<DLR	<DLR	<DLR	mg/L
Br	<DLR	<DLR	<DLR	<DLR	mg/L
Cd	<DLR	<DLR	<DLR	<DLR	mg/L
Cr	<DLR	<DLR	<DLR	<DLR	mg/L
Fe	<DLR	<DLR	<DLR	<DLR	mg/L
Mn	<DLR	<DLR	<DLR	<DLR	mg/L
Ni	<DLR	<DLR	<DLR	<DLR	mg/L
Se	<DLR	<DLR	<DLR	<DLR	mg/L
Ag	<DLR	<DLR	<DLR	<DLR	mg/L
Th	<DLR	<DLR	<DLR	<DLR	mg/L
Zn	<DLR	<DLR	<DLR	<DLR	mg/L
LI	1.6	1.34	1.38	1.44	mg/L
Perchlorate	NA	<DLR	<DLR	<DLR	ug/L

E15 - VOC	2006	2007	2008	2009	Units
Benzene	<DLR	<DLR	<DLR	<DLR	ug/L
Carbon Tetrachloride	<DLR	<DLR	<DLR	<DLR	ug/L
1,2-Dichlorobenzene (o-DCB)	<DLR	<DLR	<DLR	<DLR	ug/L
1,4-Dichlorobenzene (p-DCB)	<DLR	<DLR	<DLR	<DLR	ug/L
1,1-Dichloroethane (1,1-DCA)	<DLR	<DLR	<DLR	<DLR	ug/L
1,2-Dichloroethane (1,2-DCA)	<DLR	<DLR	<DLR	<DLR	ug/L
1,1-Dichloroethylene (1,1-DCE)	<DLR	<DLR	<DLR	<DLR	ug/L
cis-1,2-Dichloroethylene (c-1,2-DCE)	<DLR	<DLR	<DLR	<DLR	ug/L
trans-1,2-Dichloroethylene (t-1,2-DC	<DLR	<DLR	<DLR	<DLR	ug/L
Dichloromethane (Methylene Chlorid	<DLR	<DLR	<DLR	<DLR	ug/L
1,2-Dichloropropane	<DLR	<DLR	<DLR	<DLR	ug/L
Total 1,3-Dichloropropene	<DLR	<DLR	<DLR	<DLR	ug/L
Ethyl Benzene	<DLR	<DLR	<DLR	<DLR	ug/L
Methyl tert-Butyl Ether(MTBE)	<DLR	<DLR	<DLR	<DLR	ug/L
Monochlorobenzene (Chlorobenzene)	<DLR	<DLR	<DLR	<DLR	ug/L
Styrene	<DLR	<DLR	<DLR	<DLR	ug/L
1,1,2,2-Tetrachloroethane	<DLR	<DLR	<DLR	<DLR	ug/L
Tetrachloroethylene (PCE)	<DLR	<DLR	<DLR	<DLR	ug/L
Toluene	<DLR	<DLR	<DLR	<DLR	ug/L
1,2,4-Trichlorobenzene	<DLR	<DLR	<DLR	<DLR	ug/L
1,1,1-Trichloroethane (1,1,1-TCA)	<DLR	<DLR	<DLR	<DLR	ug/L
1,1,2-Trichloroethane (1,1,2-TCA)	<DLR	<DLR	<DLR	<DLR	ug/L
Trichloroethylene (TCE)	<DLR	<DLR	<DLR	<DLR	ug/L
Trichlorofluoromethane (FREON 11)	<DLR	<DLR	<DLR	<DLR	ug/L
Trichlorotrifluoroethane (FREON 113)	<DLR	<DLR	<DLR	<DLR	ug/L
Vinyl Chloride (VC)	<DLR	<DLR	<DLR	<DLR	ug/L
m,p-Xylene	<DLR	<DLR	<DLR	<DLR	ug/L
o-Xylene	<DLR	<DLR	<DLR	<DLR	ug/L
Total Xylenes (m,p, & o)	<DLR	<DLR	<DLR	<DLR	ug/L
tert-Amyl-Methyl Ether (TAME)			<DLR		ug/L
Bromobenzene			<DLR		ug/L
Bromochloromethane			<DLR		ug/L
Bromomethane (Methyl Bromide)			<DLR		ug/L
n-Butylbenzene			<DLR		ug/L
sec-Butylbenzene			<DLR		ug/L
tert-Butylbenzene			<DLR		ug/L
Chloroethane			<DLR		ug/L
Chloromethane (Methyl Chloride)			<DLR		ug/L
2-Chlorotoluene			<DLR		ug/L
4-Chlorotoluene			<DLR		ug/L
Dibromomethane			<DLR		ug/L
1,3-Dichloropropane (m-DCB)			<DLR		ug/L
Dichlorodifluoromethane (Freon 12)			<DLR		ug/L
1,3-Dichloropropane			<DLR		ug/L
2,2-Dichloropropane			<DLR		ug/L
1,1-Dichloropropene			<DLR		ug/L
Diisopropyl Ether (DIPE)			<DLR		ug/L
Ethy-tert-Butyl-Ether (ETBE)			<DLR		ug/L
Hexachlorobutadiene			<DLR		ug/L
Isopropyltoluene (Cumene)			<DLR		ug/L
p-Isopropyltoluene			<DLR		ug/L
Napthalene			<DLR		ug/L
n-Propylbenzene			<DLR		ug/L
1,1,1,2-Tetrachloroethane			<DLR		ug/L
1,2,3-Trichlorobenzene			<DLR		ug/L
1,2,4-Trimethylbenzene			<DLR		ug/L
1,3,5-Trimethylbenzene			<DLR		ug/L
Methyl ethyl ketone (Butanone)			<DLR		ug/L
Methyl isobutyl ketone (MIBK)			<DLR		ug/L

	Q1 2006	Q2 2006	Q3 2006	Q4 2006	Q1 2007	Units
Uranium		3.1			4	pCi/L
Radium 228		<1	<1	<1		pCi/L
Radium 228 (CE)			0.3	0.354		pCi/L
Gross Alpha	<3	3.5	<3	4		pCi/L
Gross Alpha (CE)	1.9	2	1.7	2.2		pCi/L
Gross Beta	5.2	<3	<4	<3		pCi/L
Gross Beta (CE)	1.6	1.5	1.5	1.6		pCi/L

Progress Letter Report from Hassan Amini, Ph.D., Project Coordinator for AMEC Geomatrix, to DTSC, September 15, 2009

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September 15, 2009

Project 9967.000.0

Mr. Jose Diaz
Department of Toxic Substances Control
Site Mitigation Branch
9211 Oakdale Avenue
Chatsworth, CA 91311

Re: Former Whittaker-Bermite Facility, Santa Clarita, CA
Summary Report for Month of August 2009

Dear Mr. Diaz:

This letter constitutes a progress report for the month of August 2009, prepared pursuant to Task 4 and Section 6.3 of the "Imminent and Substantial Endangerment Determination and Order and Remedial Action Order" (the Order) that the Department of Toxic Substances Control (DTSC) issued on November 22, 2002, for the former Whittaker-Bermite facility (site) in Santa Clarita, California.

SECTION I – SOIL ISSUES

Specific actions taken on behalf of the respondent, actions expected to be undertaken, and planned activities for soil issues are summarized in the following sections:

OU1 REMEDIATION

Activities for This Report Period (1)

All excavation, bio-treatment, backfilling, and slope restoration activities for the OU1 remediation program were completed during previous reporting periods. During this reporting period, CDM worked on the preparation of the closure report documenting the soil remediation operations for OU1.

Anticipated Activities for This Month

Work on the closure report documenting the soil remediation operations for OU1.

Long-Term Actions

Complete the closure report documenting the soil remediation operations for OU1 and submit to DTSC for review.

Activities for This Report Period (2)

Operated the primary soil vapor extraction (SVE) system at Area 43 and the secondary (hi-vacuum) SVE system at Building 329.

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Newport Beach, CA
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AMEC Geomatrix

Anticipated Activities for This Month

Continue operation and optimization of SVE systems at Building 329 and Area 43.

Long-Term Actions

Continue the SVE operations until volatile organic compound levels are eliminated or reduced to appropriate levels or until asymptotic levels are reached.

REMEDIAL ACTION PLAN

Activities for This Report Period

CDM completed the third draft of the Remedial Action Plan (RAP) for OU2 through OU6 soils (Site-Wide Soils RAP), which was submitted to DTSC on August 14, 2009. The DTSC issued preliminary review comments via email on August 24, 2009. DTSC's preliminary review comments were incorporated and the third draft of the RAP was resubmitted to DTSC on August 31, 2009.

Anticipated Activities for This Month

Allow DTSC review of the Site-Wide Soils RAP. Address DTSC's comments, if any received.

Long-Term Actions

Work with DTSC to finalize the Site-Wide Soils RAP and present for public review.

PILOT STUDIES (SVE)

Activities for This Report Period

CDM had previously prepared a pilot study work plan for SVE. DTSC approved the revised SVE work plan in a letter dated October 22, 2008.

The field pilot programs for Areas 2, 4, 27, 31/45, 53/54/72, Area 14-South, and Hula Bowl Canyon I were completed during prior reporting periods. During this reporting period the field pilot program for Area 14-Central was completed. However, due to the large amount of VOC mass removal achieved for both Area 14-South and 14-Central using the G.E.O. cryogenic/condenser system, the operations in Area 14 were extended for an additional two months while evaluations are completed to determine if further operation of the G.E.O. system with the existing well configuration is warranted prior to scale up of the pilot study operations.

Anticipated Activities for This Month

Prepare the report documenting the results of the pilot studies, and extended SVE pilot operations in Area 14.

Long-Term Actions

Complete planned pilot study activities and prepare documentation reports for submittal to DTSC. Incorporate the results of the SVE Pilot Study to the Site-Wide RAP and the Remedial Design document.

PILOT STUDIES (GEDIT)

Activities for This Report Period

CDM had previously prepared pilot study work plan for in-situ bioremediation of perchlorate impact to deep soils via Gaseous Electron Donor Injection Technology (GEDIT). DTSC provided conditional approval of the GEDIT work plan on November 14, 2008.

The laboratory bench-scale treatability study for the GEDIT pilot study was initiated at CDM's laboratory in Bellevue, Washington, during a previous reporting period. The bench-scale study was continued during this reporting period.

Anticipated Activities for This Month

Continue tracking and monitoring of bench-scale study.

Long-Term Actions

Complete planned pilot study activities and prepare documentation reports for submittal to DTSC. Incorporate the results of the GEDIT Pilot Study to the Site-Wide RAP and the Remedial Design document.

SOILS INTERIM REMEDIAL MEASURES (IRMS) AND REMOVAL ACTIONS

Depleted Uranium (DU) Investigation and Clearance Activities

Activities for this Report Period

Continued to maintain close contact with California Department of Public Health-Radiological Health Branch (CDPH-RHB) regarding the review of the Work Plan and have provided preliminary information to address requests made by CDPH-RHB. Site visit by CDPH-RHB has not been scheduled at this time and is being coordinated by Mr. Jerry Hensley at RHB along with Mr. Jose Diaz at DTSC. Meeting with California Department of Fish and Game representative was completed on August 24th resulting in approval of permit for brush removal as described in our notification. Development of the project Health and Safety Plan (HASP) as well as the Final Status Survey Plan (FSSP) have also been started during this period. Finalization of both plans will be pending information received from CDPH-RHB review of Work Plan.

Anticipated Activities for this Month

It is anticipated that a site visit will be scheduled by CDPH-RHB and DTSC as part of the Work Plan review process. This visit will provide supporting information pertinent to the review of the submitted Work Plan. Pending comments from CDPH-RBH, changes may be necessary to the Work Plan. Work on both the HASP and FSSP will be continued during this period. We are awaiting approval from ACOE and RWQCB prior to moving forward with the brush removal. We expect to initiate coordination for brush removal during this period.

Long Term Actions

Once approval is confirmed with ACOE and RWQCB the brush removal and UXO clearance survey can be coordinated. Pending necessary changes to the Work Plan, submittal of the FSSP to CDPH-RHB will be required. A specific schedule will be developed for brush removal, UXO clearance, DU removal and Final Status Surveys.

UXO/OE Investigation and Clearance Activities

Activities for This Report Period

EODT completed the following activities during this reporting period.

Work Plan Addendum (WPA) Further Investigation and No Further Action Areas
The EODT Work Plan Addendum (WPA) and associated Conceptual Site Model were submitted for DTSC and stakeholders review on July 23, 2009. The WPA field work will characterize the Further Investigations Areas and confirm the No Further Action status of the areas not affected by Munitions and Explosives of Concerns (MEC) as originally referenced in the 2006 Historical Site Assessment (HSA) Report.

Munitions and Explosives of Concern Clearance Activities at Hula Bowl II and III Associated Drainage Area, and the Depleted Uranium (DU) Impacted Area
The Hula Bowl II and III and DU Work Plan Addenda were approved with comments by DTSC in June 2008. EODT continues to coordinate with the DU-Impacted Area contractor Energy Solutions and AMEC Geomatrix to refine a phased removal plan consisting of an initial surface clearance to be followed by a removal to depth in the footprint of the DU excavation. After the MEC surface clearance is complete and actual site conditions are known, along with DTSC, the subsurface removal action alternatives will be planned and completed. Fish and Game permit application has been submitted and approved for brush clearance in the DU clearance area.

Hula Bowl II and III Drainage
EODT is tracking the landfill drainage so the clearance is completed after the drainage 'dam' is in place (so new items do not enter the drainage).

Anticipated Activities for This Month

Work Plan Addendum Further Investigation and No Further Action Areas
Anticipate planning for the field work execution and staffing in coordination with DTSC and the stakeholders.

Munitions and Explosives of Concern Clearance Activities at Hula Bowl II and III Associated Drainage Area, and the Depleted Uranium Impacted Area
Track the progress on the Hula Bowl II and III drainage 'dam' to determine the appropriate time for surface removal.

DU area MEC clearance
EODT will continue to track the progress of the review and approval process and refine the schedule for the surface clearance.

SECTION III – GROUNDWATER AND SURFACE WATER ISSUES

Specific actions taken on behalf of the respondent, action expected to be undertaken and planned activities for groundwater and surface water issues are summarized in the following sections:

GROUNDWATER (OU7) FEASIBILITY STUDY (FS)

Activities for This Report Period (1)

The Draft OU-7 FS report has been prepared and is under internal review. To support the OU-7 FS evaluations, step drawdown testing was conducted in selected OU2/OU6 perched zone wells to assess hydraulic properties.

Anticipated Activities for This Month

Continue the OU-7 FS evaluations. The Draft OU-7 FS report is under review and will be submitted to DTSC in October 2009.

Review the step drawdown testing results for selected OU2/OU6 perched zone wells. This information will be used in the OU-7 FS evaluation of groundwater extraction and dewatering options for the perched groundwater zone.

Long-Term Actions

Prepare the Remedial Action Plan for OU-7.

INTERIM REMEDIAL MEASURES (IRMS) AND PILOT PROGRAMS FOR GROUNDWATER

SAUGUS AQUIFER EXTRACTION PILOT PROGRAM

Activities for This Report Period

The Work Plan, Saugus Aquifer Pilot Remediation Well Network, Operable Unit 7 was submitted to DTSC on September 22, 2008. DTSC provided comments on November 18, 2008 and subsequently provided conditional approval of the Work Plan on December 31, 2008. A request for qualifications and proposals (RFQ/RFP) for implementation of the Saugus Extraction Pilot program was issued during March and a site tour was given to the bidders on March 25th. Responses to RFQ/RFP were received from five firms on the proposal deadline of April 23. Following review of the proposals, presentations and interviews were conducted with the five companies on May 27, 2009. Whittaker team has entered into contract negotiations with the front runner firm for implementation of the Saugus Extraction Pilot program.

Anticipated Activities for This Month

Whittaker team will continue negotiations with the front runner firm and execute a mutually agreeable contract so that the scope of work outlined in the Work Plan, Saugus Aquifer Pilot Remediation Well Network is implemented. DTSC comments on the Pilot Saugus Groundwater Remediation Work Plan will be incorporated as the Work Plan is implemented.

Long-Term Actions

Implement the Saugus Aquifer Extraction Pilot Program. Incorporate the results of the pilot work to the groundwater (OU7) RAP and design document.

NORTHERN ALLUVIUM GROUNDWATER TREATMENT SYSTEM OPERATION

Activities for This Report Period (1)

A Pilot Remediation Pumping Program was started in Northern Alluvium Areas 11, 67, and 75, in 2006. An alternate extraction well 75-MW-35 for higher groundwater extraction and six hot spot wells were connected to the new higher capacity groundwater treatment system in 2007. Sustained pumping of the extraction well 75-MW-35 that began in mid-October 2007 continues to date, with the exception of a brief period of shut down for treatment system maintenance. As of August 31, 2009, approximately 23,017,700 gallons of impacted water have been treated and discharged.

The August monthly compliance sample was collected on August 3, 2009. The sampling results indicated that the system was in compliance during May. Media were replaced in the treatment vessels as follows:

- August 6, 2009 – Removed/replaced perchlorate media in lead vessel.

- August 31, 2009 – Removed/replaced nitrate medial in lead vessel.

After replacement, the nitrate and perchlorate treatment vessels were reconfigured to have the old lag vessel as the lead and the new vessel with fresh media as the lag vessel. Because of a cracked valve on the GAC manifold, only the lead GAC vessel is in operation. Siemens is working on a solution to repair the leaky manifold.

The system was operated routinely throughout the month. The low flow wells were shut down during the routine quarterly sampling event (August 5 to August 12, 2009), however, the high flow well remained on during this time. As of August 31, 2009, approximately 23,017,700 gallons of impacted water have been treated and discharged. Approximately 91 percent of the treated volume was from the extraction wells of the Northern Alluvium pumping system; the remaining 9 percent is from IDW water collected during the quarterly sampling events, storm water collected from various areas of the site, and Saugus well development water.

Anticipated Activities for This Month

Continue the pumping, treatment, and discharge system operation and routine weekly and monthly NPDES compliance sampling and media change outs as needed.

Monitoring of the aquifer response to pumping from the alternate extraction well 75-MW-35 and the downgradient site boundary low flow extraction wells will continue.

Repair GAC manifold and put the second GAC treatment vessel back into service.

Long-Term Actions

Continue operating the extraction and treatment system and conduct additional performance monitoring.

Activities for This Report Period (2)

Potential application of remedial technologies for Northern Alluvium groundwater hot spots, including evaluation of the Area 75 boundary containment established by sustained operation of the low flow pumping wells is being addressed in the OU7 FS.

Anticipated Activities for This Month

Evaluation of potential pilot studies for the Northern Alluvium area of the site will continue. The results presented in the Shaw Technology Demonstration Summary Report for Area 11 will be reviewed for potential applicability to other areas in the Northern Alluvium.

Long-Term Actions

Additional source control measures in Northern Alluvium will be considered and recommended where determined to be necessary.

GROUNDWATER AND MONITORING

Activities for This Report Period (1)

Data review and preparation of the report is in progress for the Second Quarter 2009 quarterly groundwater monitoring. Sampling for the Third Quarter 2009 monitoring event was conducted during August.

Anticipated Activities for This Month

Data review and preparation of the report is in progress for the Second Quarter 2009 quarterly groundwater monitoring.

Long-Term Actions

Continue monitoring and reporting of the proposed network of monitoring wells on the updated schedule presented in Technical Memorandum No. 8.

Activities for This Report Period (2)

RCRA groundwater monitoring of the Area 1 (former Building 317) continues on schedule. Data from the Second Quarter 2009 groundwater monitoring event conducted in May 2009 is being reviewed. Sampling for the Third Quarter 2009 monitoring event was conducted during August.

Anticipated Activities for This Month

Data from the Second Quarter 2009 groundwater monitoring event conducted in May 2009 is being reviewed and report preparation is in progress.

Long-Term Actions

The current RCRA groundwater monitoring program will be modified to include the proposed wells and frequency and DTSC input to the monitoring plan.

STORM WATER MONITORING

Activities for This Report Period

Pursuant to the site Storm Water Pollution Prevention Plan, Environ continued coordinating the implementation of short-term surface water run-off mitigation measures. Implementation of the short-term mitigation measures is being coordinated with CDM, particularly in the areas of the site where soil remediation activities have occurred.

Anticipated Activities for This Month

Upgrades to the short-term mitigation measures will continue as necessary. CDM is working on a plan for upgrading the short-term mitigation measures. Surface water run-off sampling will be conducted following significant rainfall events in accordance with the site-wide surface water runoff sampling plan.

Long-Term Actions

Long-term mitigation of the drainages and excavations will be conducted in conjunction with the soil remediation.

SECTION IV – REQUIREMENTS UNDER THE ORDER THAT WERE NOT COMPLETED

All requirements of the Order were completed. Whittaker has met or exceeded all the substantive requirements of the Order.

SECTION V – PROBLEMS OR ANTICIPATED PROBLEMS IN COMPLYING WITH THE ORDER

Following DTSC's agreement with Whittaker's proposed modifications to implementation plans in compliance with the Order reflected in the letter dated September 28, 2004, DTSC's letter dated July 11, 2005, included a schedule for submitting a number of documents. All deadlines have been met and documents have been submitted per requested schedule.

SECTION VI – RESULTS OF SAMPLE ANALYSIS, TESTS, AND OTHER DATA

Whittaker has instructed its contractors to continue to provide DTSC staff with raw data sets for ongoing quarterly groundwater monitoring events and RI/FS work upon receipt from the lab.

Sincerely yours,
AMEC Geomatrix, Inc.

Hassan Amini, PhD, CHG
Project Coordinator

cc: Eric Lardiere, Esq., Whittaker Corp; Joseph Armao, Winston & Strawn, LLP; William Weaver, CDM; Jessica Donovan, ENVIRON; Paul Bergstrom, Knight Piésold; Larry Sievers, EODT; Tim Bricker, Santa Clarita L.L.C.; Megan Trend, Chubb Financial Solutions; Cindy Hunter, MariKay Fish, Julie Diebenow, AIG Insurance; Vitthal Hosangadi, NOREAS; John Carty, Zurich North America; Hal Dash, Cerrell Associates; Jeff Hogan, City of Santa Clarita; Yueh

Chuang, CH2M Hill; Kathy Stryker Anderson, US Army Corps of Engineers; Robert DiPrimio, Valencia Water Company; Lynn Takaichi, and Meredith Durant, Kennedy Jenks; David Bacharowski, RWQCB; James Leserman, Castaic Lake Water Agency; Steve Cole, Newhall County Water District; Mauricio Guardado, Santa Clarita Water; Neil Elsey, Avion Holdings LLC; Alisa Lacey, Stinson Morrison Hecker LLP; Jeff O'Keefe, Department of Public Health.

Letter from Hassan Amini, Ph.D., Project Coordinator for AMEC Geomatrix, to DTSC, June 8, 2009

June 8, 2009

Project 9967

Mr. Jose Diaz
Department of Toxic Substances Control
Site Mitigation Branch
9211 Oakdale Avenue
Chatsworth, California 91311

Re: Request for Deadline Extension for OU2-6 RAP
Former Whittaker Bermite Facility, Santa Clarita, CA

Dear Mr. Diaz:

Confirming our discussions of May 22 and June 2, this letter presents Whittaker's formal request to extend the deadline for submitting the Remedial Action Plan (RAP) for Operable Units 2 through 6 of the former Whittaker Bermite site (the site) from May 29, 2009, to August 14, 2009.

As you are aware, the Whittaker team prepared and submitted the second draft of the RAP to the Department of Toxic Substance Control (DTSC) on January 30, 2009. DTSC provided comments on April 10, 2009, and referenced the February 18, 2009, letter from the City of Santa Clarita (City) and raised concern that modifications to the terms and conditions of the Porta Bella Development Plan that was referenced in the City letter would significantly delay cleanup of the site. Based on that concern DTSC requested that the RAP should be revised to remove any reference to the Porta Bella Plan. As requested, the Whittaker team is currently revising the RAP and removing specific references to the Porta Bella Plan. Nonetheless, we wish to maintain the references to the integration of site remediation with potential future development on a conceptual level to allow flexibility for any potential future development.

As we discussed during our telephone conversations on May 22nd and June 2nd, 2009, a technical meeting between the DTSC and Whittaker teams will be highly beneficial to discuss application of the selected remedial measures to specific areas referenced in the RAP. To that end, I will contact you to coordinate that meeting. Following our technical meeting and discussions with DTSC, we will make appropriate changes to the text, figures, tables, and appendixes as necessary.

The April 10, 2009, DTSC letter also provided comments related to the Resource Conservation and Recovery Act (RCRA) unit (OU6). DTSC requested a revised "Closure Plan" for the RCRA unit to incorporate pilot and field studies proposed for that area. DTSC anticipates that the revisions to the Closure Plan will trigger Class 2 or 3 modifications to the RCRA Interim Status Hazardous Waste Facility Permit. As I briefed you during our telephone conversations, we are currently reviewing the available closure options for the RCRA unit (i.e., clean closure vs. closure with waste in place). Based on the review of the DTSC comments and our telephone conversations, we understand that modifications to the Closure Plan can be proposed at this time while the pilot and field studies are underway. However, the determination of "clean" vs. "waste in place" closure will need to be made based on the results of the studies as well as an

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assessment of the risks to human health and environment that may be posed by any residual chemicals beneath the RCRA unit. Although we have already started review of this matter, development of modifications to the Closure Plan will require additional time. Therefore, I respectfully request a revised deadline of September 15 for the proposed modifications.

As you are aware, we are making good progress in implementing the work plan for the soil vapor extraction pilot study that has been approved by the DTSC. We have also started the laboratory scale testing portion of our pilot study work plan for Gaseous Electron Donor Injection Technology potentially applicable to deep soil treatment at the site. Meanwhile, we will continue our focus on expediting on-site groundwater containment through implementation of the pilot scale extraction and treatment operation that was approved by DTSC. To that end, we have finished review of the contractors' proposals and have conducted interviews to select a qualified firm. We will make that selection in the next two weeks. In addition, Energy Solutions results of characterization of the depleted uranium (DU) impact in the Areas 57 and 14 and their work plan for DU removal has been finalized and will be submitted to DTSC and the Radiological Health Branch of the California Department of Public Health shortly. In summary, we are making good progress in all areas of compliance with the DTSC order, as I regularly summarize in my monthly project progress summary reports.

Please call me at (949) 642-0245 if you need any additional information. Thank you for your continuous attention and support.

Sincerely,
AMEC Geomatrix, Inc.

Hassan Amini, Ph.D. C.HG.
Project Coordinator

cc: Eric Lardiere, Whittaker Corp; William Weaver, CDM; Jessica Donovan, ENVIRON; Paul Bergstrom, Knight Piésold; Larry Sievers, EODT; Tim Bricker, Santa Clarita L.L.C.; Megan Trend, Chubb Financial Solutions; Cindy Hunter, MariKay Fish, Julie Diebenow, AIG Insurance; Vitthal Hosangadi, NOREAS; John Carty, Zurich North America; Hal Dash, Cerrell Associates; Jeff Hogan, City of Santa Clarita; Yueh Chuang, CH2M Hill; Kathy Stryker Anderson, US Army Corps of Engineers; Robert DiPrimio, Valencia Water Company; Lynn Takaichi, and Meredith Durant, Kennedy Jenks; David Bacharowski, RWQCB; James Leserman, Castaic Lake Water Agency; Steve Cole, Newhall County Water District; Mauricio Guardado, Santa Clarita Water; Neil Elsey, Avion Holdings LLC; Alisa Lacey, Stinson Morrison Hecker LLP; Jeff O'Keefe, Department of Public Health

NEWS RELEASE
DATE: September 14, 2009
FOR IMMEDIATE RELEASE

CONTACT: Dan Masnada (661) 297-1600 ext. 239
Brian Folsom (661) 297-1600 ext. 270

CASTAIC LAKE WATER AGENCY

CLWA TO CELEBRATE COMPLETION OF PROJECT TO RESTORE GROUNDWATER PRODUCTION CAPACITY IMPACTED BY PERCHLORATE CONTAMINATION

The Castaic Lake Water Agency (CLWA), in partnership with the CLWA Santa Clarita Water Division, Newhall County Water District, Valencia Water Company and the City of Santa Clarita, will be holding an event celebrating completion of a project to restore groundwater production capacity impacted by perchlorate contamination and stop migration of a contaminant plume emanating from the former Whittaker-Bermite site in the center of the Santa Clarita Valley. The event is scheduled for Tuesday, September 22, 2009 at 9:30 a.m. at CLWA Rio Vista Intake Pump Station (RVIPS) located at 26401 Bouquet Canyon Road. The RVIPS is the stucco building to the left of In-N-Out Burger near Lowe's Home Improvement Warehouse.

After years of negotiations and studies, regulatory agencies, property owners and water suppliers agreed on the process to clean up ammonium perchlorate contaminating a portion of the local groundwater basin. The contamination is a result of manufacturing and storing explosives, fireworks and munitions over 50 years at the approximate 996 site.

The project to restore the well production capacity and mitigate the migration of the perchlorate plume began in 2007. Pumping and treatment operations will occur on a continuous basis over a number of decades. The affected groundwater will be pumped from two existing wells through a dedicated underground pipeline to the new perchlorate treatment plant located at CLWA's RVIPS. The project will remove the perchlorate from the pumped groundwater using ion exchange technology. The treated groundwater will then be disinfected and pumped into the CLWA distribution system.

Other activities on the project include continual monitoring of the wells and further characterization of the groundwater contamination to ensure migration of the contaminate plume is fully contained. The entire process will be overseen by State regulatory agencies to ensure public health and safety. The successful completion of the project would not be possible without the mutual cooperation of many parties in addition to the four water agencies and the City, including the U.S. Army Corps of Engineers, California Department of Public Health, California Department of Toxic Substances Control, Los Angeles County Department of Public Works, community groups, Whittaker Corporation, and numerous consultants, contractors, and suppliers.

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CLWA Memorandum from Brian J. Folsom to CLWA Board of Directors, October 1, 2009

Castaic Lake Water Agency
Memorandum

ITEM NO. 4.1

October 1, 2009

To: CLWA Board of Directors

From: Brian J. Folsom BJF
Engineering and Operations Manager

Subject: Engineering and Operations Department Report

TREATMENT PLANT OPERATIONS AND MAINTENANCE

Completed Work:

Deliveries to the purveyors in September totaled 4,663 acre-feet (AF), for an average daily flow rate of 51 million gallons per day (MGD). September 2009 deliveries were 8.7% above September 2008 deliveries. The fiscal-year-to-date (FYTD) deliveries for FY 2009/2010 are 15,036 AF, which is 2.2% above FYTD 2008/2009. Monthly flows for 2006, 2007, 2008 and 2009 are presented in the attached table. *(FY 09/10 Action A1.1. Meet all purveyor water demands and Action B3.9: Meet all applicable water quality regulations.)*

FYTD electrical use for FY 2009/10 at the Agency's major facilities is shown in the attached "Energy Usage at Major Facilities" table and equals 2,990,433 kWh at a total cost of $343,452.77.

Inspection and maintenance activities during September included cleaning wash water return basins, chemical feed pump monthly maintenance, on-line analyzer maintenance and fabrication of clarifier screens at RVWTP.

Distribution system maintenance activities during September included preventive maintenance on air release and vacuum valves and pump outs, and exercising of valves. Grading at Sand Canyon Reservoir was completed.

Inspector Activities

Pressure recorders/data loggers readings and GPS coordinates were gathered at various points throughout the system.

Magic Mountain Pipeline/Recycled Water Pipeline Modification: Performed inspections of Security Paving's construction of the Magic Mountain Pipeline Vault Replacement.

Rio Vista Water Treatment Plant Expansion: Inspected soil borings, located underground facilities and collected GPS coordinates of existing utilities throughout jobsite.

Completed 50 dig alerts.

Work in Progress:

Maintenance of air release and vacuum valves and pump-outs throughout the distribution system continues. Ozone injector preventive maintenance is ongoing. At RVWTP, a leak was discovered near the plant water line and the area was excavated to determine the source of the leak. Repair of the leak is nearly complete. Electrical switch gear preventive maintenance and testing at all facilities continues.

Planned Actions:

Install ozone generator cooling water closed loop system. Perform repairs on plant water tank at Rio Vista Water Treatment Plant.

PERCHLORATE CONTAMINATION PROGRAM MANAGEMENT

(FY 2009/10 Action A4.1: Complete construction of the Groundwater Production Restoration Project; Action A4.2: Complete construction and startup of the Perchlorate Treatment Project; Action A4.8: Develop replacement wells for capacity lost due to perchlorate contamination.)

SUMMARY

Work continues on multiple tasks to address the groundwater contamination stemming from past manufacturing activities on the Whittaker-Bermite site. The Agency and purveyors are proceeding to restore the production capacity of the groundwater supply wells contaminated by perchlorate, while working on the objectives of containing the downgradient migration of perchlorate and recovering costs incurred in responding to the perchlorate contamination.

PERCHLORATE CONTAMINATION PROGRAM MANAGEMENT

The following table provides a status report on the activities and tasks:

Task Group	Tasks	Consultant	Status
Settlement Activities	Project Description	K/J	Complete.
	Final Settlement	K/J, Nossaman	Settlement agreement took effect on 7/13/07 with U.S. District Court approval.
DTSC Approval Activities	Remedial Investigation (RI)	K/J	DTSC approved 8/16/05.
	Feasibility Study (FS)	K/J	DTSC approved 8/16/05.
	Final Remedial Action Plan	K/J	Public hearing held 9/7/05. DTSC approved 1/20/06.
U.S. Army Corps of Engineers Feasibility Phase Study	Conceptual Hydrogeology Technical Memorandum	CH2MHill	Final distributed 1/19/05. Progress report with model construction calibration distributed 10/11/05.
DPH Approval Activities (97-005)	Source Water Assessment	B&V, CE	Received comments on revised document from DPH 4/27/06.
	Effective Monitoring and Treatment	B&V, CE, CH2MHill	Received comments on revised document from DPH 4/27/06.
	Water Quality Investigation	B&V, CE	Received comments on revised document from DPH 4/27/06.
	Human Health Risk	B&V	Received comments on revised document from DPH 4/27/06.
	Source Protection Plan	B&V	Received comments on revised document from DPH 4/27/06.

Task Group	Tasks	Consultant	Status
	Alternatives Evaluation	B&V, CE	Received comments on revised document from DPH 5/10/06. Revised document will be returned to DPH with Engineer's Report.
	Engineers Report	B&V	Final submitted to DPH 1/29/09.
	CEQA	B&V	Mitigated Negative Declaration certified 9/14/05.
	Operations and Maintenance Report	K/J	Staff is reviewing K/J draft report submitted on 8/19/09.
	Permit Application	B&V	Will be submitted with documents.
	Public Hearing	B&V	Will take place upon approval of all documents.
	DPH Evaluation and Permit	B&V	Awaiting response from DPH.
Implementation Activities	Easements and Right of Way	K/J	Easement and right-of-way acquisition completed 1/08.
	Treatment Project	K/J	Project is 96% complete.
	Pipeline Project	K/J	Project is 98% complete.
	Well Rehabilitation	SCP/GPC	General Pump completed the rehabilitation work on 2/3/09 and installed the new pumps.
	Start-up and Monitoring	K/J	Scheduled fall 2009.
	Sentinel Wells	Environ	Wells have been installed. Disposal of investigation derived wastes awaits results of laboratory analyses.

The monthly Technical Committee Meeting was held on September 9, 2009. The next Technical Committee Meeting is scheduled for October 13, 2009. The next Whittaker-Bermite Multi-Jurisdictional Task Force meeting is scheduled for December 9, 2009. A ribbon cutting event was held at the new Perchlorate Treatment Facility on September 22, 2009.

FINANCIAL STATUS

The Settlement Agreement among CLWA, the purveyors, Whittaker-Bermite and insurance carriers is in effect. Reimbursement requests have been submitted and payments have been made for expenses through July 31, 2009.

CAPITAL IMPROVEMENT PROJECTS

Sand Canyon Pipeline and Reservoir

Completed Work:

Nye and Nelson, Inc. completed construction work on July 31, 2009. The Agency approved the Certificate of Acceptance for the project on August 26, 2009 and recorded the Notice of Completion on September 2, 2009.

Work In Progress:

Construction contract is in close-out phase.

Planned Actions:

Close out project and process final payment to contractor.

Rio Vista Water Treatment Plant Expansion

(FY 2009/10 Action B1.26: Complete construction of the RVWTP Expansion Project.)

Completed Work:

The contractor has installed the foundation rebar for the new washwater return basin and the formwork for a portion of the chlorine building walls. The contractor has also constructed a portion of the ozone injection sample stations and prepared the subgrade for the new clarifier structure.

Work In Progress:

The contactor is working on the remaining submittals and Kennedy/Jenks Consultants (K/J) is reviewing the submitted submittals. The contractor is installing the formwork for the chlorine building walls and preparing the clarifier structure area for rebar installation. The contractor is also installing electrical duct banks.

Planned Actions:

The contractor will continue to prepare and submit his construction submittals and K/J will continue to review them. Construction activities will continue.

Modification to MWDSC Foothill Feeder Connection

(FY 2009/10 Action B1.25: Complete construction of the permanent raw water connection to MWDSC's Foothill Feeder pipeline.)

Completed Work:

The connection agreement has been executed. The 60% design submittal has been completed.

Work in Progress:

MWDSC and staff are reviewing the 60% submittal.

Planned Actions:

MWDSC and staff will be submitting comments to K/J for action.

Honby Parallel Phase II

(FY 2009/10 Action B1.3: Complete design of the Honby Parallel Pipeline Phase 2; Action B1.24: Complete construction of the Honby Parallel Pipeline Phase 2.)

Completed Work:

The City has approved the pipeline alignment and geotechnical data.

Work in Progress:

Permits, license agreements and easements are in the process of being acquired. K/J is revising the plans and specifications to address LADWP comments.

Planned Actions:

Complete and submit the traffic control plans to the City for approval. Mail notification letters to businesses along the project route to inform them of the project. Acquire permits, license agreement and easements. Submit the revised plans and specifications to LADWP.

RVWTP Relocate Entrance Gate and Security Kiosk

(FY 2009/10 Action B6.2: Complete design of RVWTP entrance gate and security kiosk relocation.)

Completed Work:

Lee & Ro completed the PDR.

Work In Progress:

Staff is in the process of requesting Board approval of the final design services.

Planned Actions:

Start final design.

RVWTP Warehouse and Storage Facilities

(FY 2009/10 Action B1.16: Complete design of the RVWTP Maintenance Facility Expansion Project.)

Completed Work:

Lee & Ro completed the preliminary plans.

Work in Progress:

Staff is reviewing the preliminary plans.

Planned Actions:

Staff will meet with Lee & Ro to discuss staff's comments to the preliminary plans.

ESFP Chemical Storage and Delivery

Completed Work:

SoCal Pacific Construction completed 99% of the construction contract. Remaining work was evaluated and credits and liquidated damages were issued as deductive contract change orders. Notice of Completion for the project was recorded in the Los Angeles County Recorder's Office on August 20, 2009 and the final payment was released on September 30, 2009.

ESFP Chemical Storage and Delivery

(Continued from previous page...)

Work in Progress:

Construction contract is in closeout phase.

Planned Actions:

Agency staff will complete the remaining construction items.

ESFP Drainage and Paving Improvements

(FY 2009/10 Action B1.23: Complete construction of the ESFP Drainage and Paving Improvements Project.)

a) Planning and Preliminary Design for ESFP Drainage and Paving Improvements.

b) ESFP Ozone Injection Station Canopy, Lighting and Pavement Improvements.

Completed Work:

a) Notice to Proceed was issued to Civiltec Engineering, Inc. on November 13, 2008. Civiltec completed topographic survey, subsurface investigations, initial Base Map and submitted the Geotechnical Investigation Report and a draft of a Preliminary Design Report. On September 30, 2009, Civiltec submitted recommended alternatives for discussion.

b) Design drawings have been completed.

Work in Progress:

a) Civiltec Engineering, Inc. is finalizing the recommendations for a Preliminary Design Report draft.

b) The specifications are being finalized.

Planned Actions:

a) Staff will review the proposed design alternatives.

b) Advertise the project for construction bids.

ESFP Railing and Platform Modifications

(FY 2009/10 Action B2.16: Complete modifications of the ESFP railings and platforms.)

Completed Work:

The topographic survey has been completed. Construction drawings for the railing and platform improvements at washwater basin are being finalized. The design of railing and platform improvements at filter gallery was added to the project scope in April 2009. Hilts Consulting Group, Inc. collected and reviewed record drawings information and conducted field investigations and provided 90% submittals plans and specifications for staff review and comments.

Work in Progress:

Hilts Consulting Group is reviewing the comments and modifying the plans and specifications.

ESFP Railing and Platform Modifications

(Continued from previous page...)

Planned Actions:

On October 5, 2009, meet with the consultant to field verify proposed design details. Consultant anticipates submitting final plans and specifications for staff review and approval in October 2009.

Recycled Water Program Phase II

(FY 2009/10 Action B1.27: Complete design and construct Recycled Water Program Phase II.)

Completed Work:

The draft initial study for Phase 2A has been completed. The draft evaluation for the old Honby Pump Station has been completed. The draft design has been completed for the installation of inspection access structures for the old Honby Pipeline.

Work in Progress:

Staff is reviewing the draft initial study for Phase 2A and the draft evaluation of the old Honby Pump Station for Phase 2B. K/J is analyzing potential recycled water facilities near Lost Canyon for Phase 2B. Staff is reviewing the draft design of the inspection access structures for the old Honby Pipeline.

Planned Actions:

Complete the draft environmental documentation for Phase 2A. Finalize the evaluation of the old Honby Pump Station.

Kennedy/Jenks Consultants' General Engineering Services Work Authorization

During September, K/J assisted the Agency staff with various engineering tasks including coordinating with the Los Angeles County Sanitation District regarding the treatment and availability of recycled water at the Saugus Water Reclamation Plant and coordinating with Civiltec Engineering, Inc. on the development of the water system hydraulic model and the system emergency storage study.

FACILITY CAPACITY FEES

(Goal C1.: Fairness Doctrine - Apply all costs using the Fairness Doctrine by applying costs to those who benefit from an expenditure and ensuring that existing and future users will pay their fair share.)

Completed Work:

During September, 20 new certificates were issued and $145,894 was collected in facility capacity fees, representing approximately 11.7 acre-feet of water demand. For the fiscal year, 54 new certificates have been issued and $1,129,853 has been collected in developer impact fees representing 100.26 acre-feet of water demand.

Attachments

CASTAIC LAKE WATER AGENCY

SWP Water Deliveries to Purveyors (Acre-Feet)

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SCWC	807	775	428	545	1,603	2,051	2,648	2,410	2,183	1,495	1,267	936	17,146
VWC	821	875	622	887	1,736	2,050	2,360	1,412	1,614	1,574	1,327	1,035	16,313
NCWD	490	347	158	245	589	454	828	625	647	464	597	455	5,898
LACo	68	75	52	55	113	146	178	161	143	112	105	81	1,289
Total	2,186	2,072	1,260	1,732	4,041	4,701	6,013	4,608	4,586	3,644	3,295	2,508	**40,646**
Cum. YTD	2,186	4,258	5,518	7,250	11,291	15,992	22,005	26,613	31,199	34,843	38,138	40,646	
Cum. FYTD	26,700	28,772	30,032	31,763	35,804	**40,505**	6,013	10,622	15,207	18,852	22,146	24,654	
2007	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
SCWC	984	684	1,217	1,423	2,023	2,370	2,732	2,773	2,229	1,906	1,403	926	20,669
VWC	983	640	1,212	908	1,871	2,003	2,046	1,857	1,767	1,428	1,270	922	16,906
NCWD	436	185	397	578	712	586	765	910	630	443	420	418	6,478
LACo	83	63	92	102	137	151	174	168	138	122	107	69	1,406
Total	2,485	1,572	2,918	3,012	4,742	5,110	5,717	5,707	4,764	3,899	3,200	2,334	**45,459**
Cum. YTD	2,485	4,056	6,974	9,986	14,729	19,838	25,555	31,262	36,026	39,925	43,125	45,459	
Cum. FYTD	27,139	28,711	31,629	34,641	39,383	**44,493**	5,717	11,424	16,188	20,087	23,286	25,621	
2008	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
SCWC	764	707	1,203	1,273	1,795	2,333	2,446	2,283	2,064	2,044	1,162	638	18,712
VWC	815	583	1,631	1,443	1,640	1,845	2,159	1,761	1,577	1,419	1,000	547	16,419
NCWD	414	300	270	344	505	640	767	671	505	493	302	217	5,427
LACo	56	53	92	116	134	158	167	163	144	127	82	62	1,353
Total	2,049	1,642	3,196	3,175	4,074	4,975	5,539	4,879	4,290	4,083	2,546	1,465	**41,912**
Cum. YTD	2,049	3,692	6,887	10,062	14,136	19,111	24,650	29,529	33,819	37,901	40,447	41,912	
Cum. FYTD	27,670	29,312	32,508	35,683	39,757	**44,732**	5,539	10,418	14,708	18,790	21,336	22,801	
2009	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
SCWC	910	367	1,106	1,448	2,135	1,896	2,073	2,300	2,032	0	0	0	14,267
VWC	518	364	923	1,242	1,135	996	2,102	2,063	2,011	0	0	0	11,353
NCWD	242	132	210	415	467	427	937	599	477	0	0	0	3,904
LACo	75	38	73	102	134	121	152	149	143	0	0	0	986
Total	1,744	901	2,312	3,207	3,870	3,440	5,263	5,110	4,663	0	0	0	**30,510**
Cum. YTD	1,744	2,645	4,957	8,164	12,034	15,474	20,737	25,847	30,510	30,510	30,510	30,510	
Cum. FYTD	24,545	25,446	27,758	30,965	34,835	**38,275**	5,263	10,373	15,036	15,036	15,036	15,036	

10/1/2009

CASTAIC LAKE WATER AGENCY

Recycled Water Deliveries to Purveyors (Acre-Feet)

2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SCWC													0
VWC	14	16	6	12	42	66	75	63	67	33	20	12	427
NCWD													0
LACo													0
Total*	14	16	6	12	42	66	75	63	67	33	20	12	**426**
Cum. YTD	14	30	36	48	90	156	231	294	361	394	414	426	
Cum. FYTD	284	300	306	318	360	**426**	75	142	209	242	262	274	

2007	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SCWC													0
VWC	17	14	43	38	58	63	78	67	55	37	25	7	501
NCWD													0
LACo													0
Total*	17	14	43	38	58	63	78	67	55	37	25	7	**501**
Cum. YTD	17	32	74	112	170	233	311	378	433	469	494	501	
Cum. FYTD	291	306	348	386	444	**507**	78	133	187	224	249	256	

2008	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SCWC													0
VWC	4	11	39	37	56	34	26	63	44	38	4	1	358
NCWD													0
LACo													0
Total*	4	11	39	37	56	34	26	63	44	38	4	1	**358**
Cum. YTD	4	16	54	92	147	182	208	271	315	353	357	358	
Cum. FYTD	260	271	310	348	403	**438**	26	89	133	171	175	176	

2009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SCWC													0
VWC	8	3	24	39	30	46	71	59	17	0	0	0	298
NCWD													0
LACo													0
Total*	8	3	24	39	30	46	71	59	17	0	0	0	**298**
Cum. YTD	8	11	35	74	104	150	221	280	298	298	298	298	
Cum. FYTD	184	187	211	250	280	**326**	71	88	105	105	105	105	

10/1/2009

FY 2009/10
Energy Usage at Major Facilities

Service Date From	Service Date To	Usage kWh Total	Usage kVarh Total	Total $ Amount
Earl Schmidt Intake Pump Station				
07/01/09	07/29/09	4,008	4,302	$489.20
07/29/09	08/27/09	7,226	10,163	$6,311.53
		Total		**$6,800.73**
Earl Schmidt Filtration Plant				
07/01/09	07/28/09	118,668	89,844	$12,575.44
07/28/09	08/26/09	124,925	97,018	$13,573.19
		Total		**$26,148.63**
Honby Pump Station				
07/01/09	07/22/09	0		$67.28
07/22/09	08/20/09	0		$94.80
		Total		**$162.08**
Recycled Water Meter				
07/01/09	07/10/09	10,987	4,197	$1,617.58
07/10/09	08/10/09	37,110	14,067	$5,325.10
		Total		**$6,942.68**
Rio Vista Intake Pump Station				
07/01/09	07/29/09	578,750	206	$73,917.27
06/29/09	07/29/09			$10.00
07/29/09	08/27/09	632,506	142,890	$80,482.94
		Total		**$154,410.21**
Rio Vista Water Treatment Plant				
07/01/09	07/29/09	183,775		$15,847.44
07/29/09	08/27/09	190,833		$16,335.09
		Total		**$32,182.53**
Sand Canyon Pump Station				
07/01/09	07/29/09	467,599	168,661	$53,803.10
07/29/09	08/27/09	574,056	202,627	$63,002.81
				$116,805.91
	TOTAL	**2,930,443**		**$343,452.77**

United States Environmental Protection Agency

Perchlorate Update

march 2002

The United States Environmental Protection Agency (EPA) has released its revised draft toxicity assessment, "Perchlorate Environmental Contamination: Toxicological Review and Risk Characterization." When finalized, this assessment will be an important update of EPA's health assessment that reflects the state of the science regarding the health effects of the chemical perchlorate. The preliminary revised human health risk estimates found in the document are still undergoing review and deliberations both by the external scientific community and within EPA, and do not represent EPA policy at this stage.

How To Review and Comment on EPA's Draft Perchlorate Toxicity Assessment

The draft perchlorate toxicity assessment is available at EPA's National Center for Environmental Assessment (NCEA) Web site www.epa.gov/ncea under "what's new." Written public comments on the scientific literature and on EPA's characterization of the science in the draft perchlorate assessment will be accepted by EPA's contractor, Eastern Research Group, for consideration during the Agency's document revision process. These comments will be made available to the peer reviewers. Public comments must be received by April 5, 2002. Send your comments to: Eastern Research Group ERG, Attn: Meetings, 100 Hartwell Avenue, Lexington, MA 02421. If your comments are under 50 pages in length, you can send them via email attachment (in Word, WordPerfect or PDF) to *meetings@erg.com*.

What is Perchlorate?

Perchlorate is both a naturally occurring and man-made chemical. Most of the perchlorate manufactured in the United States is used as the primary ingredient of solid rocket propellant. Wastes from the manufacture and improper disposal of perchlorate-containing chemicals are increasingly being discovered in soil and water.

How Can Perchlorate Affect Human Health?

Perchlorate interferes with iodide uptake into the thyroid gland. Because iodide is an essential component of thyroid hormones, perchlorate disrupts how the thyroid functions. In adults, the thyroid helps to regulate metabolism. In children, the thyroid plays a major role in proper development in addition to metabolism. Impairment of thyroid function in expectant mothers may impact the fetus and newborn and result in effects including changes in behavior, delayed development and decreased learning capability. Changes in thyroid hormone levels may also result in thyroid gland tumors. EPA's draft analysis of perchlorate toxicity is that perchlorate's disruption of iodide uptake is the key event leading to changes in development or tumor formation.

What are the Preliminary Conclusions of the Draft Toxicity Assessment?

The EPA draft assessment concludes that the potential human health risks of perchlorate exposures include effects on the developing nervous system and thyroid tumors. The draft assessment includes a draft reference dose (RfD) that is intended to be protective for both types of effects. It is based on early events that could potentially result in these effects, and factors to account for sensitive populations, the nature of the effects, and data gaps were used. The draft RfD is 0.00003 milligrams per kilogram per day (mg/kg/day). The RfD is defined as an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of adverse effects over a lifetime. As with any EPA draft assessment document containing a quantitative risk value, that risk value is also draft and should not at that stage be construed to represent EPA policy. Thus, the draft RfD for perchlorate is still undergoing science review and deliberations both by the external scientific community and within the Agency.

The assessment provides a hypothetical conversion of the draft RfD to a drinking water equivalent level, assuming factors of 70 kilograms (kg) body weight and 2 liters (L) of water consumption per day. The converted draft estimate would be 1 microgram per liter (ug/L) or 1 part per billion (ppb). If the Agency were to make a determination to regulate perchlorate, the RfD, along with other considerations would factor into the final value.

Does Perchlorate Cause Cancer?

Perchlorate is associated with disruption of thyroid function which can potentially lead to thyroid tumor formation. This draft toxicity assessment accounts for both developmental and tumor formation effects.

Does My Water Contain Perchlorate?

Confirmed perchlorate releases have occurred in at least 20 states throughout the United States (see Figure 2). In EPA Region 9, perchlorate releases have occurred in California, Arizona, and Nevada. Perchlorate has also been released into the Colorado River, which is a drinking water source for some areas of the region. Additional information and maps detailing those sites are available in Chapter 1 of the draft of the "Perchlorate Environmental Contamination: Toxicological Review and Risk Characterization." EPA, other federal agencies, states, water suppliers and industry are already actively addressing perchlorate contamination through monitoring for perchlorate in drinking water and surface water. The full extent of perchlorate contamination is not known at this time.

What is Being Done about Perchlorate?

A peer review of the draft perchlorate toxicity assessment will be held March 5 and 6, 2002 in Sacramento, CA. The purpose of the peer review is to provide an independent review of the scientific information and interpretation used in the document. Once the assessment is finalized, the reference dose will be used in EPA's ongoing efforts to address perchlorate problems. EPA's draft reference dose represents a preliminary estimate of a protective health level and is not a drinking water standard. In the future, EPA may issue a Health Advisory that will provide information on protective levels for drinking water. This is one step in the process of developing a broader response to perchlorate including, for example, technical guidance, possible regulations and additional health information. A federal drinking water regulation for perchlorate, if ultimately developed, could take several years.

In 1998, perchlorate was placed on EPA's Contaminant Candidate List for consideration for possible regulation. In 1999, EPA required drinking water monitoring for perchlorate under the Unregulated Contaminant Monitoring Rule (UCMR). Under the UCMR, all large public water systems and a representative sample of small public water systems are required to monitor for perchlorate over the next two years to determine whether the public is exposed to perchlorate in drinking water nationwide.

How is Perchlorate Removed from Water?

Several types of treatment systems designed to reduce perchlorate concentrations are operating around the United States, reducing perchlorate to below the 4 ppb reporting level. Biological treatment and ion (anion) exchange systems are among the technologies that are being used, with additional treatment technologies under development.

Many other perchlorate studies have been completed during the last several years. A May 2001 summary of 65 perchlorate treatment studies is available online at www.gwrtac.org/ (click on "Technical Documents" then look for "Technology Status Reports"). The summary report was prepared by the Ground-Water Remediation Technologies Analysis Center. Most of the projects described in the report are bench-scale and pilot-scale demonstrations of water treatment technologies, although several entries describe full-scale systems and soil treatment methods. Most of the projects employ biological treatment methods or ion (anion) exchange technology, although reverse osmosis, nanofiltration, granular activated carbon, and chemical reduction are also discussed. Results of federally-funded perchlorate treatment research, managed by the American Water Works Association Research Foundation (AWWARF), are also becoming available (see www. awwarf. com/ research/spperch.asp).

Is Perchlorate-contaminated Water Safe to Drink?

EPA's draft toxicity assessment is preliminary and thus, it is difficult to make definitive recommendations at this stage. Other factors that influence the answer to this question include how much water is consumed, the degree of perchlorate contamination and the health status of the consumer.

Sensitive populations, like pregnant women, children and people who have health problems or compromised thyroid conditions, should follow the advice of their health care provider regarding the amount and type of liquids, including water that should be consumed.

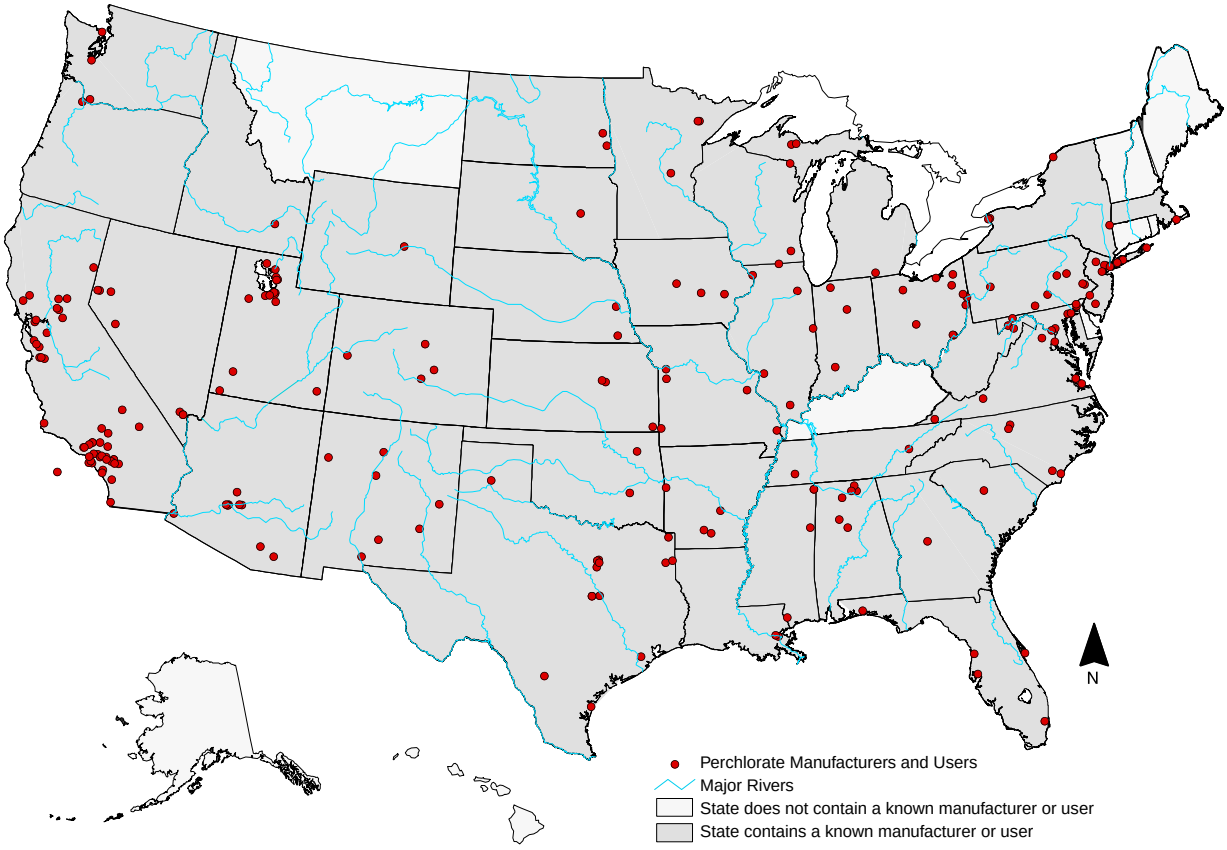

Figure 1: U.S. Perchlorate Manufacturers and Users, as of October 2001

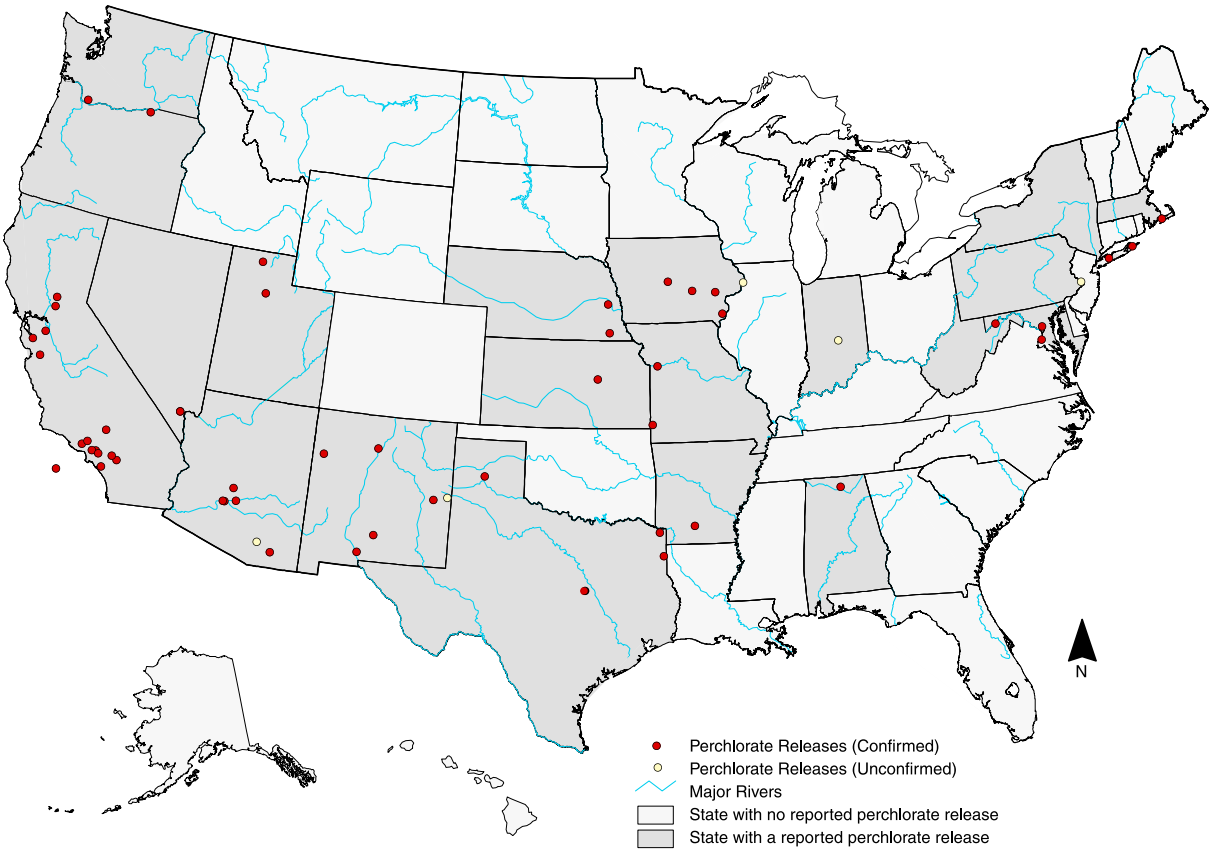

Figure 2: Reported Releases of Perchlorate into the Environment, as of November 2001

For more information

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Direct questions about the Integrated Risk Information System (IRIS) to:
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Direct questions about community involvement or the mailing list to:
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Sacramento, California 95825-1846

In reply refer to:
81420-2008-F-1481-5

DEC 15 2008

Memorandum

To: Operation Manager, Bureau of Reclamation, Central Valley Operations Office, Sacramento, California

From: Regional Director, U.S. Fish and Wildlife Service, Region 8, Sacramento, California

Subject: Transmittal of Formal Endangered Species Act Consultation on the Coordinated Operations of the Central Valley Project and State Water Project

With this memorandum, the U.S. Fish and Wildlife Service (Service) is transmitting the biological opinion on the coordinated operations of the Central Valley Project (CVP) and State Water Project (SWP) in California. We transmitted the official draft biological opinion on November 21, 2008, and subsequently refined the opinion based on input and comments from the Service's Internal Peer Review Team, our contracted peer review, the California Department of Water Resources (DWR), and the Bureau of Reclamation (Reclamation). Additionally, we additionally met numerous times with DWR, Reclamation, the California Department of Fish and Game (DFG) and the National Marine Fisheries Service on development of the biological opinion.

We want to extend our appreciation to Reclamation and DFG for their technical assistance in developing the biological opinion.

If you have any questions, please contact Susan Moore, Cay C. Goude, Steven Detwiler, or Ryan Olah of our Sacramento Fish and Wildlife Office at 414-6600.

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
California and Nevada Region
2800 Cottage Way, Room W-2606
Sacramento, California 95825-1846

In reply refer to:
81420-2008-F-1481-5

DEC 15 2008

Memorandum

To: Operation Manager, Bureau of Reclamation, Central Valley Operations Office Sacramento, California

From: Regional Director, Fish and Wildlife Service, Region 8, Sacramento, California

Subject: Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)

This is in response to the Bureau of Reclamation's (Reclamation) May 16, 2008, request for formal consultation with the Fish and Wildlife Service (Service) on the coordinated operations of the CVP and SWP in California. Reclamation is the lead Federal agency and the California Department of Water Resources (DWR) is the Applicant for this consultation. Your revised biological assessment was received in our office on August 20, 2008. This document represents the Service's biological opinion on the effects of the subject action to the threatened delta smelt (*Hypomesus transpacificus*) and its designated critical habitat. This response is provided in accordance with the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (Act).

Reclamation also requested consultation on the effects of the proposed action on the endangered riparian brush rabbit (*Sylvilagus bachmani riparius*), endangered riparian woodrat (*Neotoma fuscipes riparia*), endangered salt marsh harvest mouse (*Reithrodontomys raviventris*), endangered California clapper rail (*Rallus longirostris obsoletus*), threatened giant garter snake (*Thamnophis gigas*), threatened California red-legged frog (*Rana aurora draytonii*), threatened valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), endangered soft bird's-beak (*Cordylanthus mollis ssp. Mollis*), and the endangered Suisun thistle (*Cirsium hydrophilum var. hydrophilum*). Reclamation determined that the proposed continued operations of the CVP and SWP are not likely to adversely affect these listed species. The Service concurs with Reclamation's determination that the coordinated operations of the CVP and SWP are not likely to adversely affect these species.

The Service conducted a comprehensive peer review of this biological opinion. We formed an Internal Peer Review Team (IPRT), which consisted of individuals from throughout the Service who are experts in the development of complex biological opinions under the ESA. The IPRT reviewed the biological opinion and provided substantive input and comments. Additionally, the Service assembled a team of delta smelt experts from within the Service, California Department

of Fish and Game, Environmental Protection Agency, Reclamation and other academics to provide scientific and technical expertise into the review of the biological assessment and the development of the biological opinion. The Service also contracted with PBS&J, an environmental consulting firm, who formed an independent review team consisting of experts on aquatic ecology and fishery biology to conduct a concurrent review of the draft Effects Section of the biological opinion at the same that we provided the Effects Section to Reclamation and DWR for their review. The Service received the results of the independent review of the draft Effects Section on October 23, 2008; DWR and Reclamation provided the results of their review on October 24, 2008. The Service modified the Effects Section of the biological opinion, as appropriate, based on the comments received from the IPRT, the independent review team, Reclamation and DWR. The Service also contracted with PBS&J to conduct an independent review of the draft Actions (Final shown in Attachment B), as well as a review of DWR's proposed actions. The Service simultaneously provided the draft Actions to Reclamation and DWR for their review. The Service received Reclamation's and DWR's comments on the draft Actions on November 5, 2008. The Service received the results of the independent review of both the Service's and DWR's draft Actions on November 19, 2008. The Service's actions were then modified to respond to comments from the independent review team and in consideration of comments received from DWR. A draft biological opinion was provided to Reclamation on November 21, 2008. Comments were received back from Reclamation and DWR on December 2, 2008. The Service has incorporated all comments and edits, as appropriate, into this biological opinion.

This biological opinion is based on information provided in Reclamation's biological assessment dated August 20, 2008, associated appendices, and input from the various internal and external review processes that the Service has utilized in this consultation, described immediately above. A complete administrative record is on file at the Sacramento Fish and Wildlife Office (SFWO).

Consultation History

July 30, 2004	The Service issued a biological opinion addressing *Formal and Early Section 7 Endangered Species Consultation on the Coordinated Operations of the Central Valley Project and State Water Project and the Operations Criteria and Plan to Address Potential Critical Habitat Issues* (Service file # 1-1-04-F-0140).
February 15, 2005	The Department of the Interior is sued on the July 30, 2004 biological opinion.
February 16, 2005	The Service issued its *Reinitiation of Formal and Early Section 7 Endangered Species Consultation on the Coordinated Operations of the Central Valley Project and State Water Project and the Operational Criteria and Plan to Address Potential Critical Habitat Issues* (Service file # 1-1-05-F-0055).
May 20, 2005	The Department of the Interior is sued on the February 16, 2005 biological opinion.
February 2006 through September 2008	Staff from the California Department of Fish and Game (DFG), DWR, National Marine Fisheries Service (NMFS), Reclamation, and the Service (OCAP Working Team) met monthly to bi-weekly to discuss the development of the biological assessment.
July 6, 2006	Reclamation requested informal consultation on coordinated operations of the CVP and SWP and their effects to delta smelt.
May 25, 2007	Judge Wanger issued a summary judgment that invalidated the 2005 biological opinion and ordered a new biological opinion be developed by September 15, 2008.
May 31, 2007	The Service provided Reclamation with guidance and recommendations concerning the project description used in the 2004 biological opinion.
August 20, 2007	The Service provided a memorandum to Reclamation containing a species list for the proposed action and clarification of the formal consultation timeline.
October 29, 2007	The Service received an electronic version of the draft project description for the biological assessment (Chapter 2) dated August 2007.
December 4, 2007	DFG, NMFS, and the Service received a draft project description dated December 4, 2007.

December 6, 2007	DFG, NMFS, and the Service provided Reclamation with joint preliminary guidance and recommendations for part of the draft project description of CVP operations received on December 4, 2007.
December 14, 2007	Judge Wanger issued an interim order to direct actions at the export facilities to protect delta smelt until a new biological opinion is completed.
December 20, 2007	DFG, NMFS, and the Service provided Reclamation with joint preliminary guidance and recommendations for parts of the draft project description of SWP operations received on December 4, 2007.
January 17, 2008	DFG, NMFS, and the Service provided Reclamation with joint preliminary guidance and recommendations for the remaining portion of the draft project description received on December 4, 2007.
January 21, 2008	The Service sent to Reclamation an electronic version of the entire draft project description with guidance and recommendations developed jointly by DFG, NMFS, and the Service.
January 22, 2008	Reclamation provided DFG, NMFS and the Service with an electronic version of the description of operations of the Suisun Marsh Salinity Control Gates (SMSCG) dated August 2007.
January 23, 2008	DFG, NMFS, and the Service provided DWR with joint preliminary guidance and recommendations on the December 4, 2007, draft project description.
March 4, 2008	The Service provided DWR with joint DFG and Service guidance and recommendations for the August 2007 version of the proposed Suisun Marsh Salinity Control Gate (SMSCG) operations description.
March 6, 2008	DWR provided the Service with an updated description of proposed operations of the SMSCG.
March 10, 2008	The Service received a draft description and effects analysis of aquatic weed management in Clifton Court Forebay.
March 24, 2008	DFG, NMFS, and the Service provided Reclamation with guidance and recommendations on the aquatic weed management section of the biological assessment.
April 21, 2008	Reclamation provided the Service with a revised draft project description for the biological assessment.

April 28 through May 2, 2008	Reclamation conducted an external technical review of their draft biological assessment.
May 2008 through December 2008	Numerous meeting between the Service, Reclamation, DWR, DFG and NMFS on the development of the biological assessment and the biological opinion.
May 8, 2008	The fisheries agencies provided Reclamation and DWR with guidance and recommendations on the draft project description dated April 21, 2008.
May 16, 2008	The Service received a letter from Reclamation dated May 16, 2008, requesting formal consultation on the proposed action. A biological assessment also dated May 16, 2008, was enclosed with the letter.
May 17, 2008	Reclamation provided the Service with a number of revisions and addenda to the May 16, 2008 biological assessment.
May 28, 2008	Reclamation and DWR provided the Service with additional revisions to the May 16, 2008 biological assessment.
May 29, 2008	The Service sent a memo to Reclamation stating that with the revisions provided on May 28, 2008, the Service had received enough information to start the 30-day review period.
June 27, 2008	The Service provided Reclamation with a memo requesting additional information.
July 2, 2008	The Service received a memorandum from Reclamation informing the Service that Reclamation is committed to providing a response to the Services' June 27, 2008, request for additional information by early August, 2008.
August 11, 2008	The Service received Reclamation's August 8, 2008, letter transmitting the revised biological assessment.
August 20, 2008	The Service received the revised biological assessment on electronically from Reclamation.
August 29, 2008	Judge Wanger extended the completion date for the coordination of the CVP and SWP biological opinion to December 15, 2008.
September 25, 2008	The Service received a letter dated September 24, 2008 from the San Luis & Delta-Mendota Water Authority and the State Water Contractors, which provided comments on the biological assessment.
October 17, 2008	The Service received DWR's October 16, 2008 draft conservation actions.

October 17 through 24, 2008	Review of the draft Effects section of the biological opinion by the Service's Internal Peer Review Team (IPRT).
October 17 through 24, 2008	Independent Review of the draft Effects section of the biological opinion conducted by PBS&J.
October 23, 2008	The Service received a letter dated October 20, 2008 from the San Luis & Delta-Mendota Water Authority and the State Water Contractors, which provided comments on fall X2.
October 24, 2008	The Service received comments from Reclamation and DWR on the draft Effects section.
October 24 through November 19, 2008	Review of entire preliminary draft biological opinion by IPRT.
October 24 through November 19, 2008	Independent Review of the Service's draft conservation actions and DWR's draft conservation actions conducted by PBS&J. The Service's draft actions were also submitted to Reclamation.
November 21, 2008	The Service transmitted the draft biological opinion to Reclamation.
November 24, 2008	The Service received a letter dated November 19, 2008 from the San Luis & Delta-Mendota Water Authority and the State Water Contractors, which provided comments on the Effects section and the review conducted by PBS&J.
December 2, 2008	The Service received comments from Reclamation and DWR on the draft biological opinion.

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Project Description

The proposed action is the continued long-term operation of the CVP and SWP. The proposed action includes the operation of the temporary barriers project in the South Delta and the 500 cubic feet per second (cfs) increase in SWP Delta export limit from July through September. In addition to current day operations, several other actions are included in this consultation. These actions are: (1) an intertie between the California Aqueduct (CA) and the Delta-Mendota Canal (DMC), (2) Freeport Regional Water Project (FRWP), (3) the operation of permanent gates that will replace the temporary barriers in the South Delta, (4) changes in the operation of the Red Bluff Diversion Dam (RBDD), and (5) Alternative Intake Project for the Contra Costa Water District (CCWD). A detailed summary of all operational components and associated modeling assumptions are included in the biological assessment in Chapter 9.

Table P-1 Assumptions for the Base and Future Studies

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	OCAP BA 2004 Today CVPIA 3406 (b)(2) with EWA	**Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model - EWA**	**Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model - CVPIA (b)(2) - CONV**	**Today-Existing Conditions, (b)(2), EWA**	**Near Future-Existing Conditions and OCAP BA 2004 Consulted Projects, (b)(2), Limited EWA**	**Future - (b)(2), Limited EWA**	**Future Climate Change-D1641**	**Model Revisions since OCAP BA 2004**
OCAP Base model: Common Assumptions: Common Model Package (Version 8D) *"Same" indicates an assumption from a column to the left*								
Planning horizon	2001	2005[a]	Same	Same	Same	2030[a]	Same	
Period of Simulation	73 years (1922-1994)	82 years (1922-2003)	Same	Same	Same	Same	Same	Extended hydrology timeseries
HYDROLOGY							Inflows are modified based on alternative climate inputs [b]	Revised level of detail in the Yuba and Colusa Basin including rice decomposition operations
Level of development (Land Use)	2001 Level	2005 level	Same	Same	Same	2030 level[c]	Same	
Sacramento Valley (excluding American R.)	Land-use based, limited by contract amounts[d]	Same	Same	Same	Same	CVP Land-use based, Full build out of CVP contract amounts[d]	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	SWP (FRSA)	Land-use based, limited by contract amounts[e]	Same	Same	Same	Same	Same	Same	
	Non-project	Land-use based	Same	Same	Same	Same	Same	Same	
	refuges	Firm Level 2	Same	Same	Recent Historical Firm Level 2 water needs[f]	Same	Firm Level 2 water needs[f]	Same	
American River	Water rights	2001[g]	Same	Same	2005[g]	Same	2025[g]	Same	
	CVP (PCWA American River Pump Station)	No project	Same	Same	CVP (PCWA modified)[g]	Same	Same	Same	
Federal **San Joaquin River[h]**	Friant Unit	Regression of Historical Demands	Limited by contract amounts, based on current allocation policy	Same	Same	Same	Same	Same	Developed land-use based demands, water quality calculations, and revised accretions/depletions in the East-Side San Joaquin Valley
	Lower Basin	Fixed Annual Demands	Land-use based, based on district level operations and constraints	Same	Same	Same	Same	Same	
	River	New Melones Interim Operations Plan	Same	Same	Same	Draft Transitional Operations Plan[r]	Same	Same	Initial storage conditions for New Melones Reservoir were

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
									increased.
South of Delta									
	project facilities)	CVP Demand based on contracts amounts[d]	Same	Same	Same	Same	Same	Same	
	Contra Costa Water District	124 TAF/yr annual average	135 TAF/yr annual average CVP contract supply and water rights[i]	Same	Same	Same	195 TAF/yr annual average CVP contract supply and water rights[i]	Same	
(CVP/SWP	SWP Demand - Table A	Variable 3.1-4.1 MAF/Yr	Same	Same	Variable 3.1-4.2 MAF/Yr [e,j]	Same	Full Table A	Same	Revised SWP delivery logic. Three patterns with Art 56 and more accurately defined Table A / Article 21 split modeled
	SWP Demand - North Bay Aqueduct (Table A)	48 TAF/Yr	Same	Same	71 TAF/Yr[u]	Same	Same	Same	
	SWP Demand - Article 21 demand	Up to 134 TAF/month December to March, total of other demands up to 84 TAF/month in all months	Same	Same	Up to 314 TAF/month from December to March, total of demands up to 214 TAF/month in all other months[e,jw]	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Federal refuges	Firm Level 2	Same	Same	Recent Historical Firm Level 2 water needs[f]	Same	Firm Level 2 water needs[f]	Same	
FACILITIES									
Systemwide		Existing facilities[a]	Same	Same	Same	Same	Same	Same	
Sacramento Valley									
	Red Bluff Diversion Dam	No diversion constraint	Same	Same	Diversion Dam operated May 15 - Sept 15 (diversion constraint)	Same	Diversion Dam operated July - August (diversion constraint)	Same	
	Colusa Basin	Existing conveyance and storage facilities	Same	Same	Same	Same	Same	Same	
	American River	No project	Same	Same	PCWA American River pump station[k]	Same	Same	Same	
	River Water Reliability	No project	Same	Same	Same	Same	American/Sacramento River Diversions[t]	Same	
	Lower Sacramento River	No project	Same	Same	Same	Freeport Regional Water Project (Full Demand)[l]	Same	Same	
Upper									
Delta Region									
Sacramento	SWP Banks Pumping Plant	South Delta Improvements Program Temporary Barriers, 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec 15 through Mar 15[a]	Same	Same	Same	South Delta Improvements Program Permanent Operable Gates (Stage 1). 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec 15 through	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL Mar 15 [a]	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	CVP C.W. Bill Jones (Tracy) Pumping Plant	4,200 cfs + deliveries upstream of DMC constriction	Same	Same	Same	4,600 cfs capacity in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same	Same	
	City of Stockton Delta Water Supply Project (DWSP)	No project	Same	Same	DWSP WTP 0 mgd	Same	DWSP WTP 30 mgd	Same	
	Contra Costa Water District	Existing pump locations	Same	Same	Same	Same	Same[m]	Same	
South of Delta (CVP/SWP project facilities)									
	South Bay Aqueduct (SBA)	Existing capacity 300 cfs	Same	Same	SBA Rehabilitation: 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 diversion point	Same	Same	Same	
REGULATORY STANDARDS									
Trinity River									
	Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/year)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same	Same	Same	Same	Same	Same	
Clear Creek									
	Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
Upper Sacramento River									
	Shasta Lake	NMFS 2004 BO: 1.9 MAF end of Sep. storage target in non-critical years	Same	Same	Same	Same	Same	Same	
	Minimum flow below Keswick Dam	Flows for SWRCB WR 90-5 temperature control, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
Feather River									
	Minimum flow below Thermalito Diversion Dam	1983 DWR, DFG Agreement (600 cfs)	Same	Same	Same	2006 Settlement Agreement (700 / 800 cfs)	Same	Same	
	Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)	Same	Same	Same	Same	Same	Same	
Yuba River									

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Minimum flow below Daguerre Point Dam	Available Yuba River Data[p]	D-1644 Interim Operations[p]	Same	Yuba Accord Adjusted Data[p]	Same	Same	Same	
American River									
	Minimum flow below Nimbus Dam	SWRCB D-893 (see Operations Criteria), and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	(b)(2) Minimum Instream Flow managemen t[s]	Same	American River Flow Management [s]	Same	
	Minimum Flow at H Street Bridge	SWRCB D-893	Same	Same	Same	Same	Same	Same	
Lower Sacramento River									
	Minimum flow near Rio Vista	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
Mokelumne River									
	Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same	Same	Same	Same	Same	Same	
	Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same	Same	Same	Same	Same	Same	
Stanislaus River									
	Minimum flow below Goodwin Dam	1987 USBR, DFG agreement, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
	dissolved oxygen	SWRCB D-1422	Same	Same	Same	Same	Same	Same	
Merced River									

Minimum

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180-220 cfs, Nov-Mar), Cowell Agreement	Same	Same	Same	Same	Same	Same	
	Minimum flow at Shaffer Bridge	FERC 2179 (25-100 cfs)	Same	Same	Same	Same	Same	Same	
Tuolumne River									
	Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/year)	Same	Same	Same	Same	Same	Same	
San Joaquin River									
	Maximum salinity near Vernalis	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
	Minimum flow near Vernalis	SWRCB D-1641, and Vernalis Adaptive Management Plan per San Joaquin River Agreement	Same	Same	Same	Same	Same	Same	
Sacramento River–San Joaquin River Delta									
	Delta Outflow Index (Flow and Salinity)	SWRCB D-1641	Same	Same	Same	Same	Same	Same	Revised Delta ANN (salinity estimation)[v]
	Delta Cross Channel gate operation	SWRCB D-1641	Same	Same	Same	Same	Same	Same	
	Delta exports	SWRCB D-1641, USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same	Same	Same	Same	Same	
OPERATIONS CRITERIA: RIVER-SPECIFIC									
Upper Sacramento River									

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Flow objective for navigation (Wilkins Slough)	3,250 - 5,000 cfs based on CVP water supply condition	Same	Same	Same	Same	Same	Same	
American River									
	Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)	Same	Same	Same	Same	Same	Same	
	Flow below Nimbus Dam	Discretionary operations criteria corresponding to SWRCB D-893 required minimum flow	Same	Same	(b)(2) Minimum Instream Flow management[s]	Same	American River Flow Management [s]	Same	
	Area Water Forum "Replacement" Water	"Replacement" water is not implemented	Same	Same	Same	Same	Same	Same	
Stanislaus River									
	Flow below Goodwin Dam	1997 New Melones Interim Operations Plan	Same	Same	Same	Draft Transitional Operations Plan[r]	Same	Same	
Sacramento **San Joaquin River**									
	Flow at Vernalis	D1641	Same	Same	Same	Same	Same[q]	Same	
OPERATIONS CRITERIA: SYSTEMWIDE									
CVP water allocation									
	Settlement and Exchange	100% (75% in Shasta critical years)	Same	Same	Same	Same	Same	Same	
	CVP refuges	100% (75% in Shasta critical years)	Same	Same	Same	Same	Same	Same	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	CVP agriculture	100%-0% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same	Same	Same	Same	Same	
	CVP municipal & industrial	100%-50% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same	Same	Same	Same	Same	
SWP water allocation	North of Delta (FRSA)	Contract specific	Same	Same	Same	Same	Same	Same	
	South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement	Same	Same	Same	Same	Same	Same	
CVP-SWP coordinated operations									

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Sharing of responsibility for in-basin-use	1986 Coordinated Operations Agreement (FRWP EBMUD and 2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use)	Same	Same	Same	Same	Same	Same	
	Sharing of surplus flows	1986 Coordinated Operations Agreement	Same	Same	Same	Same	Same	Same	
	Sharing of Export/Inflow Ratio	Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) restricts only CVP and/or SWP exports	Same	Same	Same	Same	Same	Same	
	Sharing of export capacity for lesser priority and wheeling related pumping	Cross Valley Canal wheeling (max of 128 TAF/year), CALFED ROD defined Joint Point of Diversion (JPOD)	Same	Same	Same	Same	Same	Same	
Study assumptions from above apply			**Study 6a**	**Study 7a**	**Study 7a**	**Study 7.1a**	**Study 8a**	**NA**	

CVPIA 3406(b)(2): Per May 2003 Dept. of Interior

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
Decision									
	Allocation	800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years[n]	Same	Same	Same	Same	Same	NA	
Study assumptions from above apply			**Study 6b**	**Study 7b**	**Study 7b**	**Study 7.1b**	**Study 8b**	**NA**	
CALFED Environmental Water Account / Limited Environmental Water Account									
	Actions	Dec-Feb reduce total exports by 50 TAF/mon relative to total exports without EWA; VAMP (Apr 15 - May 16) export restriction on SWP; Post (May 16-31) VAMP export restriction on SWP and potentially on CVP if B2 Post-VAMP action is not taken; Ramping of exports (Jun)	Dec/Jan 50 TAF/mon export reduction, Feb 50 TAF export reduction in Wet/AN years, Feb/Mar 100, 75, or 50 TAF reduction dependent on species habitat conditions; VAMP (Apr 15 - May 16) export restriction on SWP; Pre (Apr 1-14) VAMP export reduction in Dry/Crit years; Post (May 16-31) export restriction; June ramping restriction if PostVAMP action was done. Pre- and Post-VAMP and June actions done if foreseeable October debt at San Luis does not exceed 150 TAF.	NA	Same	VAMP (Apr 15 - May 16) 31-day export restriction on SWP; If stored assets and purchases from the Yuba are sufficient, Post (May 16-31) VAMP export restrictions apply to SWP[pq]	Same	NA	The EWA actions, assets, and debt were revised and vetted as part of the Long Term Environmental Water Account EIS/R project

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
Assets	Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. The purchases range from 0 TAF in Wet years to approximately 153 TAF in Critical years NOD, and 57 TAF in Critical years to 250 TAF in Wet years SOD. Variable assets include the following: use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, flexing of Delta E/I Ratio (post-processed from CalSim-II results), additional 500 CFS pumping capacity at Banks in Jul-Sep	Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. NOD share of annual purchase target ranges from 90% to 50% based on SWP Ag Allocation as an indicator of conveyance capacity. Variable/operational assets include use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, additional 500 CFS pumping capacity at Banks in Jul-Sep, source shifting, Semitropic Groundwater Bank, “spill” of San Luis carryover debt, and backed-up stored water from Spring EWA actions.	NA	Same	Purchase of Yuba River stored water under the Lower Yuba River Accord (average of 48 TAF/yr), use of 50% of any CVPIA 3406 (b)(2) releases pumped by SWP, additional 500 CFS pumping capacity at Banks in Jul-Sep.	Same	NA	

		Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II
	Debt	Delivery debt paid back in full upon assessment; Storage debt paid back over time based on asset/action priorities; SOD and NOD debt carryover is explicitly managed or spilled; NOD debt carryover must be spilled; SOD and NOD asset carryover is allowed	Same	NA	Same	No Carryover Debt	Same	NA	
Post Processing Assumptions									
WATER MANAGEMENT ACTIONS (CALFED)									
Water Transfers									
	Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users	Same	NA	Same	Same	Same	NA	
	Phase 8[o]	available capacity	Same	NA	Same	Same	Same		
	Refuge Level 4 water	Evaluate available capacity	Same	NA	Same	Same	Same		
	Notes:								

	Study 3a	Study 6.0 COMPARISON	Study 6.1 COMPARISON	Study 7.0 BASE MODEL	Study 7.1 ANALYTICAL	Study 8.0 ANALYTICAL	Study 9.0 - 9.5 SENSITIVITY	CalSim-II

[a] The OCAP BA project description is presented in Chapter 2.

[b]Climate change sensitivity analysis assumptions and documentation are presented in Appendix R.

[c] The Sacramento Valley hydrology used in the CALSIM II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of 2030 land-use assumptions are being coordinated with the California Water Plan Update for future models.

[d] CVP contract amounts have been reviewed and updated according to existing and amended contracts as appropriate. Assumptions regarding CVP agricultural and M&I service contracts and Settlement Contract amounts are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D: Delivery Specifications section of the Technical Appendix.

[e] SWP contract amounts have been reviewed and updated as appropriate. Assumptions regarding SWP agricultural and M&I contract amounts are documented in Table 1A (North of Delta) and Table 2A (South of Delta) of Appendix D: Delivery Specifications section.

[f] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D:Delivery Specifications. Incremental Level 4 refuge water needs have been documented as part of the assumptions of future water transfers.

[g] PCWA demand in the foreseeable existing condition is 8.5 TAF/yr of CVP contract supply diverted at the new American River PCWA Pump Station. In the future scenario, PCWA is allowed 35 TAF/yr. Assumptions regarding American River water rights and CVP contracts are documented in Table 5 of Appendix D: Delivery Specifications section.

[h] The new CalSim-II representation of the San Joaquin River has been included in this model package (CalSim-II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River have been included since the preliminary model release in August 2005. The model reflects the difficulties of on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to on-going groundwater overdraft problems. In addition, a dynamic groundwater simulation is not yet developed for San Joaquin River Valley. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.

[i] Study 6.0 demands for CCWD are assumed equal to Study 7.0 due to data availablity with the revised CalSim-II model framework. For all Studies, Los Vaqueros Reservoir storage capacity is 100 TAF.

[j] Table A deliveries into the San Francisco Bay Area Region for existing cases are based on a variable demand and a full Table A for future cases. The variable demand is dependent on the availability of other water during wet years resulting in less demand for Table A. In the future cases it is assumed that the demand for full Table A will be independent of other water sources. Article 21 demand assumes MWD demand of 100 TAF/mon (Dec-Mar), Kern demand of 180 TAF/mon (Jan-Dec), and other contractor demand of 34 TAF/mon (Jan-Dec).

[k] PCWA American River pumping facility upstream of Folsom Lake is under construction.

[l] Mokelumne River flows reflect EBMUD supplies associated with the Freeport Regional Water Project.

[m] The CCWD Alternate Intake Project (AIP), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir is not included in Study 8.0. AIP is included as a separate consultation. AIP will be further evaluated after regulatory and operational managment assumptions have been determined.

[n] The allocation representation in CalSim-II replicates key processes, shortage changes are checked by post-processing.

[o] This Phase 8 requirement is assumed to be met through Sacramento Valley Water Management Agreement Implementation.

[p] OCAP BA 2004 modeling used available hydrology at the time which was data developed based on 1965 Yuba County Water Agency -Department of Fish of Game Agreement. Since the OCAP BA 2004 modeling, Yuba River hydrology was revised. Interim D-1644 is assumed to be fully implemented with or without the implementation of the Lower Yuba River Accord. This is consistent with the future no-action condition being assumed by the Lower Yuba River Accord EIS/EIR study team. For studies with the Lower Yuba River Accord, an adjusted hydrology is used.

[q] It is assumed that either VAMP, a functional equivalent, or D-1641 requirements would be in place in 2030.

[r] The Draft Transitional Operations Plan assumptions are discussed in Chapter 2.

[s] For Studies 7.0, 7.1, and 8.0 the flow components of the proposed American River Flow Management are included and applied using the CVPIA 3406(b)(2). For Study 8.0 the American River Flow Management is assumed to be the new minimum instream flow.

[t] OCAP assumes the flexibility of diversion location but does not assume the Sacramento Area Water Forum Water Forum "replacement water" in drier water year types.

[u] Aqueduct improvements that would allow an increase in South Bay Aqueduct demand at the time of model development were expected to be operational within 6 months. However, a delay in the construction has postponed the completion.

[v] The Artificial Neural Network (ANN) was updated for both salinity and X2 calculations. Study 3a does not include an updated ANN, Study 6.1 has an updated salinity but not X2, and all remaining Studies include both the updated salinity and X2.

[w] North Bay Article 21 deliveries are dependent on excess conditions rather than being dependent on San Luis storage.

Figure P-1 Map of California CVP and SWP Service Areas

Coordinated Operations of the CVP and SWP

Coordinated Operations Agreement

The CVP and SWP use a common water supply in the Central Valley of California. The DWR and Reclamation (collectively referred to as Project Agencies) have built water conservation and water delivery facilities in the Central Valley in order to deliver water supplies to affected water rights holders as well as project contractors. The Project Agencies' water rights are conditioned by the State Water Resources Control Board (SWRCB) to protect the beneficial uses of water within each respective project and jointly for the protection of beneficial uses in the Sacramento Valley and the Sacramento-San Joaquin Delta Estuary. The Project Agencies coordinate and operate the CVP and SWP to meet the joint water right requirements in the Delta.

The Coordinated Operations Agreement (COA), signed in 1986, defines the project facilities and their water supplies, sets forth procedures for coordination of operations, identifies formulas for sharing joint responsibilities for meeting Delta standards, as the standards existed in SWRCB Decision 1485 (D-1485) and other legal uses of water, identifies how unstored flow will be shared, sets up a framework for exchange of water and services between the CVP/SWP, and provides for periodic review of the agreement.

Implementing the COA

Obligations for In-Basin Uses

In-basin uses are defined in the COA as legal uses of water in the Sacramento Basin, including the water required under the SWRCB D-1485 Delta standards (D-1485 ordered the CVP and SWP to guarantee certain conditions for water quality protection for agricultural, municipal and industrial [M&I], and fish and wildlife use). The Project Agencies are obligated to ensure water is available for these uses, but the degree of obligation is dependent on several factors and changes throughout the year, as described below.

Balanced water conditions are defined in the COA as periods when it is mutually agreed that releases from upstream reservoirs plus unregulated flows approximately equals the water supply needed to meet Sacramento Valley in-basin uses plus exports. Excess water conditions are periods when it is mutually agreed that releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in-basin uses plus exports. Reclamation's Central Valley Operations Office (CVOO) and DWR's SWP Operations Control Office jointly decide when balanced or excess water conditions exist.

During excess water conditions, sufficient water is available to meet all beneficial needs, and the CVP and SWP are not required to supplement the supply with water from reservoir storage. Under Article 6(g) of the COA, Reclamation and DWR have the responsibility (during excess water conditions) to store and export as much water as possible, within physical, legal and contractual limits. In excess water conditions, water accounting is not required. However, during balanced water conditions, the Projects share the responsibility in meeting in-basin uses.

When water must be withdrawn from reservoir storage to meet in-basin uses, 75 percent of the responsibility is borne by the CVP and 25 percent is borne by the SWP[1]. When unstored water is available for export (i.e., Delta exports exceed storage withdrawals while balanced water conditions exist), the sum of CVP stored water, SWP stored water, and the unstored water for export is allocated 55/45 to the CVP and SWP, respectively.

Accounting and Coordination of Operations

Reclamation and DWR coordinate on a daily basis to determine target Delta outflow for water quality, reservoir release levels necessary to meet in-basin demands, schedules for joint use of the San Luis Unit facilities, and for the use of each other's facilities for pumping and wheeling.

During balanced water conditions, daily water accounting is maintained of the CVP and SWP obligations. This accounting allows for flexibility in operations and avoids the necessity of daily changes in reservoir releases that originate several days travel time from the Delta. It also means adjustments can be made "after the fact" using actual data rather than by prediction for the variables of reservoir inflow, storage withdrawals, and in-basin uses.

The accounting language of the COA provides the mechanism for determining the responsibility of each project for Delta outflow-influenced standards; however, real time operations dictate actions. For example, conditions in the Delta can change rapidly. Weather conditions combined with tidal action can quickly affect Delta salinity conditions, and therefore, the Delta outflow required to maintain joint standards. If, in this circumstance, it is decided the reasonable course of action is to increase upstream reservoir releases, then the response will likely be to increase Folsom releases first. Lake Oroville water releases require about three days to reach the Delta, while water released from Lake Shasta requires five days to travel from Keswick to the Delta. As water from the other reservoirs arrives in the Delta, Folsom releases can be adjusted downward. Any imbalance in meeting each project's designed shared obligation would be captured by the COA accounting.

Reservoir release changes are one means of adjusting to changing in-basin conditions. Increasing or decreasing project exports can immediately achieve changes to Delta outflow. As with changes in reservoir releases, imbalances in meeting each project's designed shared obligations are captured by the COA accounting.

During periods of balanced water conditions, when real-time operations dictate project actions, an accounting procedure tracks the designed sharing water obligations of the CVP and SWP. The Projects produce daily and accumulated accounting balances. The account represents the imbalance resulting from actual coordinated operations compared to the COA-designed sharing of obligations and supply. The project that is "owed" water (i.e., the project that provided more or exported less than its COA-defined share) may request the other project adjust its operations to reduce or eliminate the accumulated account within a reasonable time.

The duration of balanced water conditions varies from year to year. Some very wet years have had no periods of balanced conditions, while very dry years may have had long continuous periods of balanced conditions, and still other years may have had several periods of balanced

[1] These percentages were derived from negotiations between Reclamation and DWR for SWRCB D-1485 standards

conditions interspersed with excess water conditions. Account balances continue from one balanced water condition through the excess water condition and into the next balanced water condition. When the project that is owed water enters into flood control operations, at Shasta or Oroville, the accounting is zeroed out for that respective project. The biological assessment provides a detailed description of the changes in the COA.

State Water Resources Control Board Water Rights

1995 Water Quality Control Plan

The SWRCB adopted the 1995 Bay-Delta Water Quality Control Plan (WQCP) on May 22, 1995, which became the basis of SWRCB Decision-1641. The SWRCB continues to hold workshops and receive information regarding processes on specific areas of the 1995 WQCP. The SWRCB amended the WQCP in 2006, but to date, the SWRCB has made no significant changes to the 1995 WQCP framework.

Decision 1641

The SWRCB imposes a myriad of constraints upon the operations of the CVP and SWP in the Delta. With Water Rights Decision 1641, the SWRCB implements the objectives set forth in the SWRCB 1995 Bay-Delta WQCP and imposes flow and water quality objectives upon the Projects to assure protection of beneficial uses in the Delta. The SWRCB also grants conditional changes to points of diversion for the Projects with D-1641.

The various flow objectives and export restraints are designed to protect fisheries. These objectives include specific outflow requirements throughout the year, specific export restraints in the spring, and export limits based on a percentage of estuary inflow throughout the year. The water quality objectives are designed to protect agricultural, municipal and industrial, and fishery uses, and they vary throughout the year and by the wetness of the year.

Figure P-2 and Figure P-3 summarize the flow and quality objectives in the Delta and Suisun Marsh for the Projects from D-1641. These objectives will remain in place until such time that the SWRCB revisits them per petition or as a consequence to revisions to the SWRCB Water Quality Plan for the Bay-Delta (which is to be revisited periodically).

On December 29, 1999, SWRCB adopted and then revised (on March 15, 2000) Decision 1641, amending certain terms and conditions of the water rights of the SWP and CVP. Decision 1641 substituted certain objectives adopted in the 1995 Bay-Delta Plan for water quality objectives that had to be met under the water rights of the SWP and CVP. In effect, D-1641 obligates the SWP and CVP to comply with the objectives in the 1995 Bay-Delta Plan. The requirements in D-1641 address the standards for fish and wildlife protection, M&I water quality, agricultural water quality, and Suisun Marsh salinity. SWRCB D-1641 also authorizes SWP and CVP to jointly use each other's points of diversion in the southern Delta, with conditional limitations and required response coordination plans. SWRCB D-1641 modified the Vernalis salinity standard under SWRCB Decision 1422 to the corresponding Vernalis salinity objective in the 1995 Bay-Delta Plan. The criteria imposed upon the CVP and SWP are summarized in Figure P-2 (Summary Bay-Delta Standards), Figure P-3 (Footnotes for Summary Bay-Delta Standards), and Figure P-4 (CVP/SWP Map).

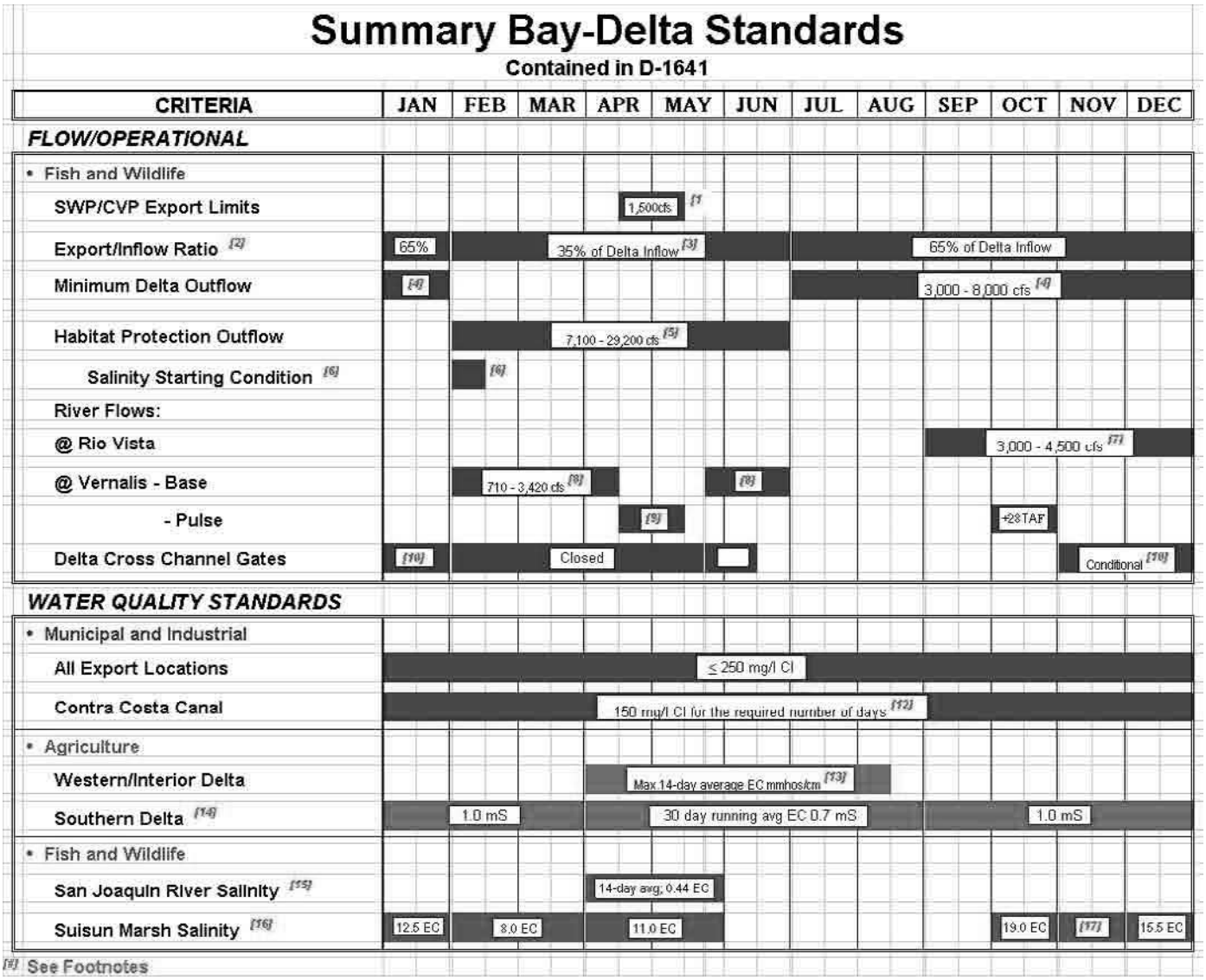

Figure P-2 Summary Bay Delta Standards (See Footnotes below)

Footnotes

[1] Maximum 3-day running average of combined export rate (cfs) which includes Tracy Pumping Plant and Clifton Court Forebay Inflow less Byron-Bethany pumping.

Year Type	All
Apr15 - May15*	The greater of 1,500 or 100% of 3-day avg. Vernalis flow

* This time period may need to be adjusted to coincide with fish migration. Maximum export rate may be varied by CalFed Op's group.

[2] The maximum percentage of average Delta inflow (use 3-day average for balanced conditions with storage withdrawal, otherwise use 14-day average) diverted at Clifton Court Forebay (excluding Byron-Bethany pumping) and Tracy Pumping Plant using a 3-day average. (These percentages may be adjusted upward or downward depending on biological conditions, providing there is no net water cost.)

[3] The maximum percent Delta inflow diverted for Feb may vary depending on the January 8RI.

Jan 8RI	Feb exp. limit
≤ 1.0 MAF	45%
between 1.0 & 1.5 MAF	35%-45%
> 1.5 MAF	35%

[4] Minimum monthly average Delta outflow (cfs). If monthly standard ≤ 5,000 cfs, then the 7-day average must be within 1,000 cfs of standard; if monthly standard > 5,000 cfs, then the 7-day average must be ≥ 80% of standard.

Year Type	All	W	AN	BN	D	C
Jan	4,500*					
Jul		8,000	8,000	6,500	5,000	4,000
Aug		4,000	4,000	4,000	3,500	3,000
Sep	3,000					
Oct		4,000	4,000	4,000	4,000	3,000
Nov-Dec		4,500	4,500	4,500	4,500	3,500

* Increase to 6,000 if the Dec 8RI is greater than 800 TAF

[5] Minimum 3-day running average of daily Delta outflow of 7,100 cfs OR: either the daily average or 14-day running average EC at Collinsville is less than 2.64 mmhos/cm (This standard for March may be relaxed if the Feb 8RI is less than 500 TAF. The standard does not apply in May and June if the May estimate of the SRI IS < 8.1 MAF at the 90% exceedence level in which case a minimum 14-day running average flow of 4,000 cfs is required.) For additional Delta outflow objectives, see **TABLE A**.

[6] February starting salinity: If Jan 8RI > 900 TAF, then the daily or 14-day running average EC @ Collinsville must be ≤ 2.64 mmhos/cm for at least one day between Feb 1-14. If Jan 8RI is between 650 TAF and 900 TAF, then the CalFed Op's group will determine if this requirement must be met.

[7] Rio Vista minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 1,000 below the monthly objective).

Year Type	All	W	AN	BN	D	C
Sep	3,000					
Oct		4,000	4,000	4,000	4,000	3,000
Nov-Dec		4,500	4,500	4,500	4,500	3,500

[8] BASE Vernalis minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 20% below the objective). Take the higher objective if X2 is required to be west of Chipps Island.

Year Type	All	W	AN	BN	D	C
Feb-Apr14 and May16-Jun		2,130 or 3,420	2,130 or 3,420	1,420 or 2,280	1,420 or 2,280	710 or 1,140

[9] PULSE Vernalis minimum monthly average flow rate in cfs. Take the higher objective if X2 is required to be west of Chipps Island.

Year Type	All	W	AN	BN	D	C
Apr15 - May15		7,330 or 8,620	5,730 or 7,020	4,620 or 5,480	4,020 or 4,880	3,110 or 3,540
Oct	1,000*					

* Up to an additional 28 TAF pulse/attraction flow to bring flows up to a monthly average of 2,000 cfs except for a critical year following a critical year. Time period based on real-time monitoring and determined by CalFed Op's group.

[10] For the Nov-Jan period, Delta Cross Channel gates may be closed for up to a total of 45 days.

[11] For the May 21-June 15 period, close Delta Cross Channel gates for a total of 14 days per CALFED Op's group. During the period the Delta cross channel gates may close 4 consecutive days each week, excluding weekends.

[12] Minimum # of days that the mean daily chlorides ≤ 150 mg/l must be provided in intervals of not less than 2 weeks duration. Standard applies at Contra Costa Canal Intake or Antioch Water Works Intake.

Year Type	W	AN	BN	D	C
# Days	240	190	175	165	155

Figure P-3 Footnotes for Summary Bay Delta Standards ***(continued on next page)***

[13] The maximum14-day running average of mean daily EC (mmhos/cm) depends on water year type

Year Type	WESTERN DELTA				INTERIOR DELTA			
	Sac River @ Emmaton		SJR @ Jersey Point		Mokelumne R @ Terminous		SJR @ San Andreas	
	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from date shown to Aug15 *	0.45 EC from April 1 to date shown	EC value fro date shown Aug15 *
W	Aug 15		Aug 15		Aug 15		Aug 15	
AN	Jul 1	0.63	Aug 15		Aug 15		Aug 15	
BN	Jun 20	1.14	Jun 20	0.74	Aug 15		Aug 15	
D	Jun 15	1.67	Jun 15	1.35	Aug 15		Jun 25	0.58
C		2.78		2.20		0.54		0.87

* When no date is shown, EC limit continues from April 1

[14] As per D-1641, for San Joaquin River at Vernalis; however, the April through August maximum 30- day running average EC for San Joaquin River at Brandt Bridge,Old River near Middle River, and Old River at Tracy Road Bridge shall be 1.0 EC until April 1, 2005 when the value will be 0.7 EC.

[15] Compliance will be determined between Jersey Point & Prisoners Point.
Does not apply in critical years or in May when the May 90% forecast of SRI ≤ 8.1 MAF.

[16] During deficiency period, the maximum monthly average mhtEC at Western Suisun Marsh stations as per SMPA is:

Month	mhtEC
Oct	19.0
Nov	16.5
Dec-Mar	15.6
Apr	14.0
May	12.5

[17] In November, maximum monthly average mhtEC = 10.5 for Western Marsh stations and maximum monthly average mhtEC = 15.5 for Eastern Marsh stations in all periods types.

TABLE A

Number of Days When Max. Daily Average Electrical Conductivity of 2.64 mmhos/cm Must Be Maintained. (This can also be met with a maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average Delta outflows of 11,400 cfs and 29,200 cfs, respectively.) Port Chicago Standard is triggered only when the 14-day average EC for the last day of the previous month is 2.64 mmhos/cm or less. PMI is previous month's 8RI. If salinity/flow objectives are met for a greater number of days than required for any month, the excess days shall be applied towards the following month's requirement. The number of day's for values of the PMI between those specified below shall be determined by linear interpolation.

PMI (TAF)	Chipps Island (Chipps Island Station D10)				
	FEB	MAR	APR	MAY	JUN
≤ 500	0	0	0	0	0
750	0	0	0	0	0
1000	28*	12	2	0	0
1250	28	31	6	0	0
1500	28	31	13	0	0
1750	28	31	20	0	0
2000	28	31	25	1	0
2250	28	31	27	3	0
2500	28	31	29	11	1
2750	28	31	29	20	2
3000	28	31	30	27	4
3250	28	31	30	29	8
3500	28	31	30	30	13
3750	28	31	30	31	18
4000	28	31	30	31	23
4250	28	31	30	31	25
4500	28	31	30	31	27
4750	28	31	30	31	28
5000	28	31	30	31	29
5250	28	31	30	31	29
≥ 5500	28	31	30	31	30

*When 800 TAF < PMI < 1000 TAF, the number of days is determined by linear interpolation between 0 and 20 days.

PMI (TAF)	Port Chicago (continuous recorder at Port Chicago)				
	FEB	MAR	APR	MAY	JUN
0	0	0	0	0	0
250	1	0	0	0	0
500	4	1	0	0	0
750	8	2	0	0	0
1000	12	4	0	0	0
1250	15	6	1	0	0
1500	18	9	1	0	0
1750	20	12	2	0	0
2000	21	15	4	0	0
2250	22	17	5	1	0
2500	23	19	8	1	0
2750	24	21	10	2	0
3000	25	23	12	4	0
3250	25	24	14	6	0
3500	25	25	16	9	0
3750	26	26	18	12	0
4000	26	27	20	15	0
4250	26	27	21	18	1
4500	26	28	23	21	2
4750	27	28	24	23	3
5000	27	28	25	25	4
5250	27	29	25	26	6
5500	27	29	26	28	9
5750	27	29	27	28	13
6000	27	29	27	29	16
6250	27	30	27	29	19
6500	27	30	28	30	22
6750	27	30	28	30	24
7000	27	30	28	30	26
7250	27	30	28	30	27
7500	27	30	29	30	20
7750	27	30	29	31	28
8000	27	30	29	31	29
8250	28	30	29	31	29
8500	28	30	29	31	29
8750	28	30	29	31	30
9000	28	30	29	31	30
9250	28	30	29	31	30
9500	28	31	29	31	30
9750	28	31	29	31	30
10000	28	31	30	31	30
> 10000	28	31	30	31	30

Figure P-3 Footnotes for Summary Bay Delta Standards

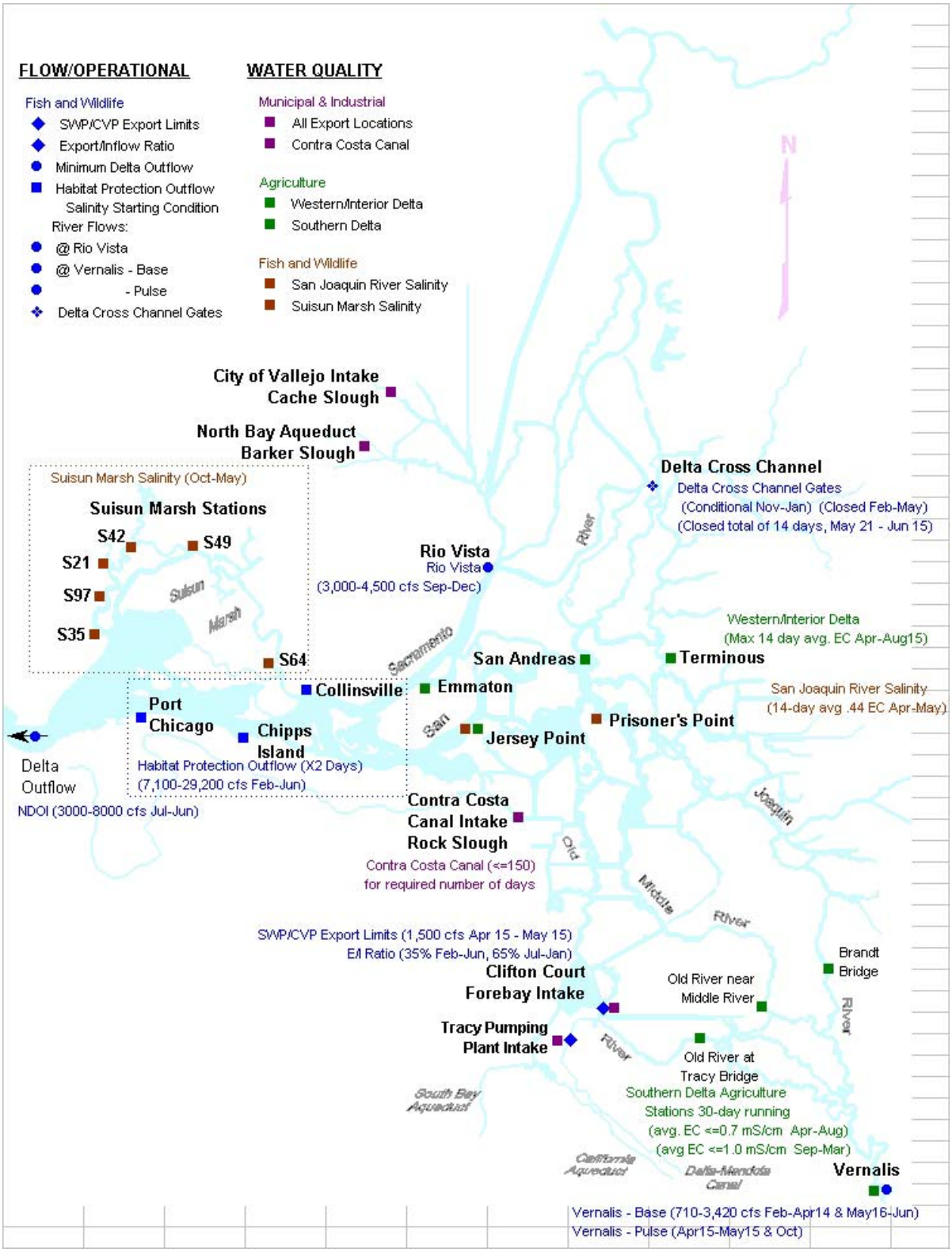

Figure P-4 CVP/SWP Delta Map

Joint Points of Diversion

SWRCB D-1641 granted Reclamation and DWR the ability to use/exchange each Project's diversion capacity capabilities to enhance the beneficial uses of both Projects. The SWRCB conditioned the use of Joint Point of Diversion (JPOD) capabilities based on a staged implementation and conditional requirements for each stage of implementation. The stages of JPOD in SWRCB D-1641 are:

- Stage 1 – for water service to Cross Valley Canal contractors, Tracy Veterans Cemetery and Musco Olive, and to recover export reductions taken to benefit fish.
- Stage 2 – for any purpose authorized under the current project water right permits.
- Stage 3 – for any purpose authorized up to the physical capacity of the diversion facilities. Stage 3 is not part of the project description.

Each stage of JPOD has regulatory terms and conditions which must be satisfied in order to implement JPOD.

All stages require a response plan to ensure water levels in the southern Delta will not be lowered to the injury of local riparian water users (Water Level Response Plan). All stages require a response plan to ensure the water quality in the southern and Central Delta will not be significantly degraded through operations of the JPOD to the injury of water users in the southern and Central Delta.

All JPOD diversion under excess conditions in the Delta is junior to Contra Costa Water District (CCWD) water right permits for the Los Vaqueros Project, and must have an X2 (the two parts per thousand (ppt) isohaline location in kilometers from the Golden Gate Bridge) located west of certain compliance locations consistent with the 1993 Los Vaqueros biological opinion for delta smelt.

Stage 2 has an additional requirement to complete an operations plan that will protect fish and wildlife and other legal users of water. This is commonly known as the Fisheries Response Plan. A Fisheries Response Plan was approved by the SWRCB in February 2007, but since it relied on the 2004 and 2005 biological opinions, the Fisheries Response Plan will need to be revised and re-submitted to the SWRCB at a future date.

Stage 3 has an additional requirement to protect water levels in the southern Delta under the operational conditions of Phase II of the South Delta Improvements Program, along with an updated companion Fisheries Response Plan.

Reclamation and DWR intend to apply all response plan criteria consistently for JPOD uses as well as water transfer uses.

In general, JPOD capabilities will be used to accomplish four basic CVP-SWP objectives:

- When wintertime excess pumping capacity becomes available during Delta excess conditions and total CVP-SWP San Luis storage is not projected to fill before the spring pulse flow period, the project with the deficit in San Luis storage may elect to use JPOD

capabilities. Concurrently, under the CALFED Record of Decision (ROD), JPOD may be used to create additional water supplies for the Environmental Water Account (EWA) or reduce debt for previous EWA actions.

- When summertime pumping capacity is available at Banks Pumping Plant and CVP reservoir conditions can support additional releases, the CVP may elect to use JPOD capabilities to enhance annual CVP south of Delta water supplies.
- When summertime pumping capacity is available at Banks or Jones Pumping Plant to facilitate water transfers, JPOD may be used to further facilitate the water transfer.
- During certain coordinated CVP-SWP operation scenarios for fishery entrainment management, JPOD may be used to shift CVP-SWP exports to the facility with the least fishery entrainment impact while minimizing export at the facility with the most fishery entrainment impact.

Revised WQCP (2006)

The SWRCB undertook a proceeding under its water quality authority to amend the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan) adopted in 1978 and amended in 1991 and in 1995. Prior to commencing this proceeding, the SWRCB conducted a series of workshops in 2004 and 2005 to receive information on specific topics addressed in the Bay-Delta Plan.

The SWRCB adopted a revised Bay-Delta Plan on December 13, 2006. There were no changes to the Beneficial Uses from the 1995 Plan to the 2006 Plan, nor were any new water quality objectives adopted in the 2006 Plan. A number of changes were made simply for readability. Consistency changes were also made to assure that sections of the 2006 Plan reflected the current physical condition or current regulation. The SWRCB continues to hold workshops and receive information regarding Pelagic Organism Decline (POD), Climate Change, and San Joaquin salinity and flows, and will coordinate updates of the Bay-Delta Plan with on-going development of the comprehensive Salinity Management Plan.

Real Time Decision-Making to Assist Fishery Management

Introduction

Real time decision-making to assist fishery management is a process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. For the proposed action high uncertainty exists for how to best manage water operations while protecting listed species. Sources of uncertainty relative to the proposed action include:

- Hydrologic conditions
- Ocean conditions
- Listed species biology

Under the proposed action the goals for real time decision-making to assist fishery management are:

- Meet contractual obligations for water delivery
- Minimize adverse effects for listed species

Framework for Actions

Reclamation and DWR work closely with the Service, NMFS, and DFG to coordinate the operation of the CVP and SWP with fishery needs. This coordination is facilitated through several forums in a cooperative management process that allows for modifying operations based on real-time data that includes current fish surveys, flow and temperature information, and salvage or loss at the project facilities, (hereinafter "triggering event").

Water Operations Management Team

The Water Operations Management Team (WOMT) is comprised of representatives from Reclamation, DWR, the Service, NMFS, and DFG. This management-level team was established to facilitate timely decision-support and decision-making at the appropriate level. The WOMT first met in 1999, and will continue to meet to make management decisions as part of the proposed action. Routinely, it also uses the CALFED Ops Group to communicate with stakeholders about its decisions. Although the goal of WOMT is to achieve consensus on decisions, the participating agencies retain their authorized roles and responsibilities.

Process for Real Time Decision- Making to Assist Fishery Management

Decisions regarding CVP and SWP operations to avoid and minimize adverse effects on listed species must consider factors that include public health, safety, water supply reliability, and water quality. To facilitate such decisions, the Project Agencies and the Service, NMFS, and DFG have developed and refined a set of processes for various fish species to collect data, disseminate information, develop recommendations, make decisions, and provide transparency. This process consists of three types of groups that meet on a recurring basis. Management teams are made up of management staff from Reclamation, DWR, the Service, NMFS, and DFG. Information teams are teams whose role is to disseminate and coordinate information among agencies and stakeholders. Fisheries and Operations Technical Teams are made up of technical staff from state and Federal agencies. These teams review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that fishery agencies' management can use in identifying actions to protect listed species.

The process to identify actions for protection of listed species varies to some degree among species but follows this general outline: A Fisheries or Operations Technical Team compiles and assesses current information regarding species, such as stages of reproductive development, geographic distribution, relative abundance, and physical habitat conditions; it then provides a recommendation to the agency with statutory obligation to enforce protection of the species in question. The agency's staff and management will review the recommendation and use it as a basis for developing, in cooperation with Reclamation and DWR, a modification of water

operations that will minimize adverse effects to listed species by the Projects. If the Project Agencies do not agree with the action, then the fishery agency with the statutory authority will make a final decision on an action that they deem necessary to protect the species.

The outcomes of protective actions that are implemented will be monitored and documented, and this information will inform future recommended actions.

Groups Involved in Real Time Decision-Making to Assist Fishery Management and Information Sharing

Information Teams

CALFED Ops and Subgroups

The CALFED Ops Group consists of the Project agencies, the fishery agencies, SWRCB staff, and the U.S. Environmental Protection Agency (EPA). The CALFED Ops Group generally meets eleven times a year in a public setting so that the agencies can inform each other and stakeholders about current the operations of the CVP and SWP, implementation of the CVPIA and State and Federal endangered species acts, and additional actions to contribute to the conservation and protection of State- and Federally-listed species. The CALFED Ops Group held its first public meeting in January 1995, and during the next six years the group developed and refined its process. The CALFED Ops Group has been recognized within SWRCB D-1641, and elsewhere, as one forum for coordination on decisions to exercise certain flexibility that has been incorporated into the Delta standards for protection of beneficial uses (e.g., E/I ratios, and some DCC closures). Several teams were established through the Ops Group process. These teams are described below:

Data Assessment Team (DAT)

The DAT consists of technical staff members from the Project and fishery agencies as well as stakeholders. The DAT meets frequently[2] during the fall, winter, and spring. The purpose of the meetings is to coordinate and disseminate information and data among agencies and stakeholders that is related to water project operations, hydrology, and fish surveys in the Delta.

Integrated Water Operations and Fisheries Forum

The Integrated Water Operations and Fisheries Forum (IWOFF) provides the forum for executives and managers of Reclamation, DWR, DFG, the Service, NMFS, USEPA and the SWRCB to meet and discuss current and proposed action planning, permitting, funding, and Endangered Species Act compliance, which affect the workloads and activities of these organizations. IWOFF provides a forum for elevation of these matters if staff is unable to reach resolution on process/procedures requiring interagency coordination. IWOFF may also elevate such decisions up to the Director level at their discretion.

[2] The DAT holds weekly conference calls and may have additional discussions during other times as needed.

B2 Interagency Team (B2IT)

The B2IT was established in 1999 and consists of technical staff members from the Project and fisheries agencies. The B2IT meets weekly to discuss implementation of section 3406 (b)(2) of the CVPIA, which mandates the dedication of CVP water supply for environmental purposes. B2IT communicates with WOMT to ensure coordination with the other operational programs or resource-related aspects of project operations, including flow and temperature issues.

Technical Teams

Fisheries Technical Teams

Several fisheries specific teams have been established to provide guidance and recommendations on resource management issues. These teams include:

The Sacramento River Temperature Task Group (SRTTG)

The SRTTG is a multiagency group formed pursuant to SWRCB Water Rights Orders 90-5 and 91-1, to assist with improving and stabilizing Chinook population in the Sacramento River. Annually, Reclamation develops temperature operation plans for the Shasta and Trinity Divisions of the CVP. These plans consider impacts on winter-run and other races of Chinook salmon, and associated Project operations. The SRTTG meets initially in the spring to discuss biological, hydrologic, and operational information, objectives, and alternative operations plans for temperature control. Once the SRTTG has recommended an operation plan for temperature control, Reclamation then submits a report to the SWRCB, generally on or before June 1st each year.

After implementation of the operation plan, the SRTTG may perform additional studies and commonly holds meetings as needed, typically monthly through the summer and into fall, to develop revisions based on updated biological data, reservoir temperature profiles, and operations data. Updated plans may be needed for summer operations protecting winter-run, or in fall for fall-run spawning season. If there are any changes in the plan, Reclamation submits a supplemental report to SWRCB.

Smelt Working Group (SWG)

The SWG evaluates biological and technical issues regarding delta smelt and develops recommendations for consideration by the Service. Since the longfin smelt (*Spirinchus thaleichthys*) became a state candidate species in 2008, the SWG has also developed for DFG recommendations to minimize adverse effects to longfin smelt. The SWG consists of representatives from the Service, DFG, DWR, EPA, and Reclamation. The Service chairs the group, and members are assigned by each agency.

The SWG compiles and interprets the latest near real-time information regarding state- and federally-listed smelt, such as stages of development, distribution, and salvage. After evaluating available information and if they agree that a protection action is warranted, the SWG will submit their recommendations in writing to the Service and DFG.

The SWG may meet at any time at the request of the Service, but generally meets weekly during the months of December through June, when smelt salvage at Jones and Banks has occurred historically. However, the Delta Smelt Risk Assessment Matrix (see below) outlines the

conditions when the SWG will convene to evaluate the necessity of protective actions and provide the Service with a recommendation. Further, with the State listing of longfin smelt, the group will also convene based on longfin salvage history at the request of DFG.

Delta Smelt Risk Assessment Matrix (DSRAM)

The SWG will employ a delta smelt risk assessment matrix to assist in evaluating the need for operational modifications of SWP and CVP to protect delta smelt. This document will be a product and tool of the SWG and will be modified by the SWG with the approval of the Service, in consultation with Reclamation, DWR and DFG, as new knowledge becomes available. The currently approved DSRAM is Attachment A.

If an action is taken, the SWG will follow up on the action to attempt to ascertain its effectiveness. The ultimate decision-making authority rests with the Service. An assessment of effectiveness will be attached to the notes from the SWG's discussion concerning the action.

The Salmon Decision Process

The Salmon Decision Process is used by the fishery agencies and Project agencies to facilitate the often complex coordination issues surrounding DCC gate operations and the purposes of fishery protection closures, Delta water quality, and/or export reductions. Inputs such as fish lifestage and size development, current hydrologic events, fish indicators (such as the Knight's Landing Catch Index and Sacramento Catch Index), and salvage at the export facilities, as well as current and projected Delta water quality conditions, are used to determine potential DCC closures and/or export reductions. The coordination process has worked well during the recent fall and winter DCC operations in recent years and is expected to be used in the present or modified form in the future.

American River Group

In 1996, Reclamation established a working group for the Lower American River, known as American River Group (ARG). Although open to the public, the ARG meetings generally include representatives from several agencies and organizations with on-going concerns and interests regarding management of the Lower American River. The formal members of the group are Reclamation, the Service, NMFS, and DFG.

The ARG convenes monthly or more frequently if needed, with the purpose of providing fishery updates and reports to Reclamation to help manage Folsom Reservoir for fish resources in the Lower American River.

San Joaquin River Technical Committee (SJRTC)

The SJRTC meets for the purposes of planning and implementing the Vernalis Adaptive Management Plan (VAMP) each year and oversees two subgroups: the Biology subgroup, and the Hydrology subgroup. These two groups are charged with certain responsibilities, and must also coordinate their activities within the San Joaquin River Agreement (SJRA) Technical Committee.

Operations Technical Teams

An operations specific team is established to provide guidance and recommendations on operational issues and one is proposed for the South Delta Improvement Program (SDIP) operable gates. These teams are:

Delta Cross Channel Project Work Team

The DCC Project Work Team is a multiagency group under CALFED. Its purpose is to determine and evaluate the affects of DCC gate operations on Delta hydrodynamics, water quality, and fish migration.

Gate Operations Review Team

When the gates proposed under SDIP Stage 1 are in place and operational, a federal and state interagency team will be convened to discuss constraints and provide input to the existing WOMT. The Gate Operations Review Team (GORT) will make recommendations for the operations of the fish control and flow control gates to minimize impacts on resident threatened and endangered species and to meet water level and water quality requirements for South Delta water users. The interagency team will include representatives of DWR, Reclamation, the Service, NMFS, and DFG. DWR will be responsible for providing predictive modeling, and SWP Operations Control Office will provide operations forecasts. Reclamation will be responsible for providing CVP operations forecasts, including San Joaquin River flow, and data on current water quality conditions. Other members will provide the team with the latest information related to South Delta fish species and conditions for crop irrigation. Operations plans would be developed using the Delta Simulation Model 2 (DSM2), forecasted tides, and proposed diversion rates of the projects to prepare operating schedules for the existing CCF gates and the four proposed operable gates. The Service will use the SWG for recommendations regarding gate operations.

Uses of Environmental Water Accounts

CVPIA Section 3406 (b)(2)

On May 9, 2003, the Department of the Interior issued its Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Dedication of (b)(2) water occurs when Reclamation takes a fish, wildlife, or habitat restoration action based on recommendations of the Service (and in consultation with NMFS and DFG), pursuant to Section 3406 (b)(2). Dedication and management of (b)(2) water may also assist in meeting WQCP fishery objectives and help meet the needs of fish listed under the ESA as threatened or endangered since the enactment of the CVPIA.

The May 9, 2003, decision describes the means by which the amount of dedicated (b)(2) water is determined. Planning and accounting for (b)(2) action is done cooperatively and occurs primarily through weekly meetings of the B2IT. Actions usually take one of two forms: in-stream flow augmentation below CVP reservoirs or CVP Jones pumping reductions in the Delta. Chapter 9 of the biological assessment contains a more detailed description of (b)(2) operations, as characterized in the CALSIM II modeling assumptions and results of the modeling are summarized.

CVPIA 3406 (b)(2) Operations on Clear Creek

Dedication of (b)(2) water on Clear Creek provides actual in-stream flows below Whiskeytown Dam greater than those that would have occurred under pre-CVPIA regulations, e.g., the fish and wildlife minimum flows specified in the 1963 proposed release schedule. In-stream flow objectives are usually taken from the AFRP's plan, in consideration of spawning and incubation of fall-run Chinook salmon. Augmentation in the summer months is usually in consideration of water temperature objectives for steelhead and in late summer for spring-run Chinook salmon.

Reclamation will provide Townsend with up to 6,000 AF of water annually. If the full 6,000 AF is delivered, then 900 AF will be dedicated to (b)(2) according to the August 2000 agreement.

CVPIA 3406 (b)(2) Operations on the Upper Sacramento River

Dedication of (b)(2) water on the Sacramento River provides actual in-stream flows below Keswick Dam greater than those that would have occurred under pre-CVPIA regulations, e.g., the fish and wildlife requirements specified in WR 90-5 and the criteria formalized in the 1993 NMFS Winter-run biological opinion as the base. In-stream flow objectives from October 1 to April 15 (typically April 15 is when water temperature objectives for winter-run Chinook salmon become the determining factor) are usually selected to minimize dewatering of redds and provide suitable habitat for salmonid spawning, incubation, rearing, and migration.

CVPIA 3406 (b)(2) Operations on the Lower American River

Dedication of (b)(2) water on the American River provides actual in-stream flows below Nimbus Dam greater than those that would have occurred under pre-CVPIA regulations, (e.g. the fish and wildlife requirements previously mentioned in the American River Division). In-stream flow objectives from October through May generally aim to provide suitable habitat for salmon and steelhead spawning, incubation, and rearing, while considering impacts to American River operations the rest of the year. In-stream flow objectives for June to September endeavor to provide suitable flows and water temperatures for juvenile steelhead rearing while balancing the effects on temperature operations into October and November.

- Flow Fluctuation and Stability Concerns:

  Through CVPIA, Reclamation has funded studies by DFG to better define the relationships of Nimbus release rates and rates of change criteria in the Lower American River to minimize the negative effects of necessary Nimbus release changes on sensitive fishery objectives. Reclamation is presently using draft criteria developed by DFG. The draft criteria have helped reduce the incidence of anadromous fish stranding relative to past historic operations. The primary operational coordination for potentially sensitive Nimbus Dam release changes is conducted through the B2IT process.

CVPIA 3406 (b)(2) Operations on the Stanislaus River

Dedication of (b)(2) water on the Stanislaus River provides actual in-stream flows below Goodwin Dam greater than the fish and wildlife requirements discussed in the East Side Division, and in the past has been generally consistent with the Interim Plan of Operation (IPO) for New Melones. In-stream fishery management flow volumes on the Stanislaus River, as part of the IPO, are based on the New Melones end-of-February storage plus forecasted March to

September inflow as shown in the IPO. The volume determined by the IPO is a combination of fishery flows pursuant to the 1987 DFG Agreement and the Service AFRP in-stream flow goals. The fishery volume is then initially distributed based on modeled fish distributions and patterns used in the IPO.

Actual in-stream fishery management flows below Goodwin Dam will be determined in accordance with the Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Reclamation has begun a process to develop a long-term operations plan for New Melones. The ultimate long-term plan will be coordinated with B2IT members, along with the stakeholders and the public before it is finalized.

CVPIA 3406 (b)(2) Operations in the Delta

Export curtailments at the CVP Jones Pumping Plant and increased CVP reservoir releases required to meet SWRCB D-1641's Objectives for Fish and Wildlife Beneficial Uses, as well as direct export reductions for fishery management using dedicated (b)(2) water at the CVP Jones Pumping Plant, will be determined in accordance with the Interior Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Direct Jones Pumping Plant export curtailments for fishery management protection will be based on coordination with the weekly B2IT meetings and vetted through WOMT, as necessary.

Environmental Water Account

The original Environmental Water Account (EWA) was established in 2000 by the CALFED ROD, and operating criteria area described in detail in the EWA Operating Principles Agreement attachment to the ROD. In 2004, the EWA was extended to operate through the end of 2007. Reclamation, the Service, and NMFS have received Congressional authorization to participate in the EWA at least through September 30, 2010, per the CALFED Bay-Delta Authorization Act (PL-108-361). However, for these Federal agencies to continue participation in the EWA beyond 2010, additional authorization will be required.

The original purpose of the EWA was to enable diversion of water by the SWP and CVP from the Delta to be reduced at times when at risk fish species may be harmed while preventing the uncompensated loss of water to SWP and CVP contractors. Typically the EWA replaced water loss due to curtailment of pumping by purchase of surface or groundwater supplies from willing sellers and by taking advantage of regulatory flexibility and certain operational assets. Under past operations, from 2001 through 2007, when there were pumping curtailments at Banks Pumping Plant to protect Delta fish the EWA often owed a debt of water to the SWP, usually reflected in San Luis Reservoir.

The EWA agencies (the Project and fisheries agencies) are currently undertaking environmental review to determine the future of EWA. Because no decision has yet been made regarding EWA, for the purposes of this project description, EWA is analyzed with limited assets, focusing on providing assets to support VAMP and in some years, the "post – VAMP shoulder". The EWA assets include the following:

- Implementation of the Yuba Accord Component 1 Water, which is an average 60,000 AF of water released annually from the Yuba River to the Delta, is an EWA asset through 2015, with a possible extension through 2025. The 60,000 AF is expected to be reduced

by carriage water costs in most years, estimated at 20 percent, leaving an EWA asset of 48,000 AF per year. The SWP will provide the 48,000 AF per year asset from Project supplies beyond 2015 in the event that Yuba Accord Component 1 Water is not extended.

- Purchases of assets to the extent funds are available.
- Operational assets granted the EWA in the CALFED ROD:
  - A 50 percent share of SWP export pumping of (b)(2) water and ERP water from upstream releases;
  - A share of the use of SWP pumping capacity in excess of the SWP's needs to meet contractor requirements with the CVP on an equal basis, as needed (such use may be under Joint Point of Diversion);
  - Any water acquired through export/inflow ratio flexibility; and
  - Use of 500 cubic-feet per second (cfs) increase in authorized Banks Pumping Plant capacity in July through September (from 6,680 to 7,180 cfs).
  - Storage in Project reservoirs upstream of the Delta as well as in San Luis Reservoir, with a lower priority than Project water. Such stored water will share storage priority with water acquired for Level 4 refuge needs.

Operational assets averaged 82,000 AF from 2001-2006, with a range from 0 to 150,000 AF.

500 cfs Diversion Increase During July, August, and September

Under this operation, the maximum allowable daily diversion rate into Clifton Court Forebay (CCF) during the months of July, August, and September increases from 13,870 AF to 14,860 AF and three-day average diversions from 13,250 AF to 14,240 AF (500 cfs per day equals 990 AF). The increase in diversions has been permitted and in place since 2000. The current permit expired on September 30, 2008. An application has been made to the U.S. Army Corps of Engineers (Corps) for permitting the implementation of this operation. The description of the 500 cfs increased diversion in the permit application to the Corps will be consistent with the following description:

The purpose of this diversion increase into CCF for use by the SWP is to recover export reductions made due to the ESA or other actions taken to benefit fisheries resources. The increased diversion rate will not result in any increase in water supply deliveries than would occur in the absence of the increased diversion rate. This increased diversion over the three-month period would result in an amount not to exceed 90 TAF each year. Increased diversions above the 48 TAF discussed previously could occur for a number of reasons including:

1) Actual carriage water loss on the 60 TAF of current year's Yuba Accord Component 1 Water is less than the assumed 20 percent.

2) Diversion of Yuba Accord Component 1 Water exceeds the current year's 60 TAF allotment to make up for a Yuba Accord Component 1 deficit from a previous year.

3) In very wet years, the diversion of excess Delta outflow goes above and beyond the Yuba Accord Component 1 Water allotment.

Variations to hydrologic conditions coupled with regulatory requirements may limit the ability of the SWP to fully utilize the proposed increased diversion rate. Also, facility capabilities may limit the ability of the SWP to fully utilize the increased diversion rate.

In years where the accumulated export under the 500 cfs increased diversion exceeds 48 TAF, the additional asset will be held in the SWP share of San Luis Reservoir, as long as space is available, to be applied to an export reduction specified by the fish agencies for the immediate water year (WY). For example, if 58 TAF were exported under the increased diversion during July through September, then 10 TAF of additional asset would be in San Luis Reservoir on September 30. The fish agencies may choose to apply this asset to an export reduction during the early winter or take a risk that space for storing the asset will remain in the SWP share of San Luis Reservoir and be available to be applied to the VAMP or post-VAMP export reduction in the spring. If the asset remains available for the VAMP and post-VAMP shoulder, it would increase the export reduction during that period by an equal amount. In this example, the export would be reduced an additional 10 TAF.

As the winter and spring progress, the SWP share of San Luis Reservoir may fill and the space will no longer be available to store the asset. If this happens, the asset will be converted to SWP supply stored in San Luis Reservoir and the SWP exports from the Delta will be reduced at that time by the same volume as the asset. Any reductions in exports resulting from this situation are expected to occur in the December-March period.

Implementation of the proposed action is contingent on meeting the following conditions:

1. The increased diversion rate will not result in an increase in annual SWP water supply allocations other than would occur in the absence of the increased diversion rate. Water pumped due to the increased capacity will only be used to offset reduced diversions that occurred or will occur because of ESA or other actions taken to benefit fisheries.

2. Use of the increased diversion rate will be in accordance with all terms and conditions of existing biological opinions governing SWP operations.

3. All three temporary agricultural barriers (Middle River, Old River near Tracy and Grant Line Canal) must be in place and operating when SWP diversions are increased. When the temporary barriers are replaced by the permanent operable flow-control gates, proposed as Stage 1 of the South Delta Improvements Program, the gates must be operating to their specified criteria.

4. Between July 1 and September 30, prior to the start of or during any time at which the SWP has increased its diversion rate in accordance with the approved operations plan, if the combined salvage of listed fish species reaches a level of concern, real-time decision making will be implemented. The relevant fish regulatory agency will determine whether the 500 cfs increased diversion is or continues to be implemented.

Central Valley Project

Central Valley Project Improvement Act

On October 30, 1992, Public Law 102-575, (Reclamation Projects Authorization and Adjustment Act of 1992) was passed. Included in the law was Title 34, the Central Valley Project Improvement Act (CVPIA). The CVPIA amended previous authorizations of the CVP to include fish and wildlife protection, restoration, and mitigation as project purposes having equal priority with irrigation and domestic water supply uses, and fish and wildlife enhancement having an equal priority with power generation. Changes mandated by the CVPIA include:

- Dedicating 800,000 AF annually to fish, wildlife, and habitat restoration
- Authorizing water transfers outside the CVP service area
- Implementing an anadromous fish restoration program
- Creating a restoration fund financed by water and power users
- Providing for the Shasta Temperature Control Device
- Implementing fish passage measures at Red Bluff Diversion Dam (RBDD)
- Calling for planning to increase the CVP yield
- Mandating firm water supplies for Central Valley wildlife refuges
- Improving the Tracy Fish Collection Facility (TFCF)
- Meeting Federal trust responsibility to protect fishery resources (Trinity River)

The CVPIA is being implemented as authorized. The Final Programmatic Environmental Impact Statement (PEIS) for the CVPIA analyzed projected conditions in 2022, 30 years from the CVPIA's adoption in 1992. The Final PEIS was released in October 1999 and the CVPIA Record of Decision (ROD) was signed on January 9, 2001. The biological opinions were issued on November 21, 2000.

Water Service Contracts, Allocations and Deliveries

Water Needs Assessment

Water needs assessments have been performed for each CVP water contractor eligible to participate in the CVP long-term contract renewal process. Water needs assessments confirm a contractor's past beneficial use and determine future CVP water supplies needed to meet the contractor's anticipated future demands. The assessments are based on a common methodology used to determine the amount of CVP water needed to balance a contractor's water demands with available surface and groundwater supplies. All of the contractor assessments have been finalized.

Future American River Operations - Water Service Contracts and Deliveries

Surface water deliveries from the American River are made to various water rights entities and CVP contractors. Total American River Division annual demands on the American and Sacramento Rivers are estimated to increase from about 324,000 acre-feet in 2005 and 605,000 acre-feet in 2030 without the Freeport Regional Water Project maximum of 133,000 acre-feet during drier years. Reclamation is negotiating the renewal of 13 long-term water service contracts, four Warren Act contracts, and has a role in six infrastructure or Folsom Reservoir operations actions influencing the management of American River Division facilities and water use.

Water Allocation – CVP

The water allocation process for CVP begins in the fall when preliminary assessments are made of the next year's water supply possibilities, given current storage conditions combined with a range of hydrologic conditions. These preliminary assessments may be refined as the WY progresses. Beginning February 1, forecasts of WY runoff are prepared using precipitation to date, snow water content accumulation, and runoff to date. All of CVP's Sacramento River Settlement water rights contracts and San Joaquin River Exchange contracts require that contractors be informed no later than February 15 of any possible deficiency in their supplies. In recent years, February 20th has been the target date for the first announcement of all CVP contractors' forecasted water allocations for the upcoming contract year. Forecasts of runoff and operations plans are updated at least monthly between February and May.

Reclamation uses the 90 percent probability of exceedance forecast as the basis of water allocations. Furthermore, NMFS reviews the operations plans devised to support the initial water allocation, and any subsequent updates to them, for sufficiency with respect to the criteria for Sacramento River temperature control.

CVP M&I Water Shortage Operational Assumptions

The CVP has 253 water service contracts (including Sacramento River Settlement Contracts). These water service contracts have had varying water shortage provisions (e.g., in some contracts, municipal and industrial (M&I) and agricultural uses have shared shortages equally; in most of the larger M&I contracts, agricultural water has been shorted 25 percent of its contract entitlement before M&I water was shorted, after which both shared shortages equally).

The M&I minimum shortage allocation does not apply to contracts for the (1) Friant Division, (2) New Melones interim supply, (3) Hidden and Buchanan Units, (4) Cross Valley contractors, (5) San Joaquin River Exchange settlement contractors, and (6) Sacramento River settlement contractors. Any separate shortage-related contractual provisions will prevail.

There will be a minimum shortage allocation for M&I water supplies of 75 percent of a contractor's historical use (i.e., the last three years of water deliveries unconstrained by the availability of CVP water). Historical use can be adjusted for growth, extraordinary water conservation measures, and use of non-CVP water as those terms are defined in the proposed policy. Before the M&I water allocation is reduced, the irrigation water allocation would be reduced below 75 percent of contract entitlement.

When the allocation of irrigation water is reduced below 25 percent of contract entitlement, Reclamation will reassess the availability of CVP water and CVP water demand; however, due to limited water supplies during these times, M&I water allocation may be reduced below 75 percent of adjusted historical use during extraordinary and rare times such as prolonged and severe drought. Under these extraordinary conditions allocation percentages for both South of Delta and North of Delta irrigation and M&I contractors are the same.

Reclamation will deliver CVP water to all M&I contractors at not less than a public health and safety level if CVP water is available, if an emergency situation exists, but not exceeding 75 percent on contract total (and taking into consideration water supplies available to the M&I contractors from other sources). This is in recognition, however, that the M&I allocation may, nevertheless, fall to 50 percent as the irrigation allocation drops below 25 percent and approaches zero due to limited CVP supplies.

Allocation Modeling Assumptions:

Ag 100% to 75% then M&I is at 100%

Ag 70%	M&I 95%
Ag 65%	M&I 90%
Ag 60%	M&I 85%
Ag 55%	M&I 80%
Ag 50% to 25%	M&I 75%

Dry and Critical Years:

Ag 20%	M&I 70%
Ag 15%	M&I 65%
Ag 10%	M&I 60%
Ag 5%	M&I 55%
Ag 0%	M&I 50%

Project Facilities

Trinity River Division Operations

The Trinity River Division, completed in 1964, includes facilities to store and regulate water in the Trinity River, as well as facilities to divert water to the Sacramento River Basin. Trinity Dam is located on the Trinity River and regulates the flow from a drainage area of approximately 720 square miles. The dam was completed in 1962, forming Trinity Lake, which has a maximum storage capacity of approximately 2.4 million acre-feet (MAF). See map in Figure P-5.

The mean annual inflow to Trinity Lake from the Trinity River is about 1.2 MAF per year. Historically, an average of about two-thirds of the annual inflow has been diverted to the Sacramento River Basin (1991-2003). Trinity Lake stores water for release to the Trinity River and for diversion to the Sacramento River via Lewiston Reservoir, Clear Creek Tunnel, Whiskeytown Reservoir, and Spring Creek Tunnel where it commingles in Keswick Reservoir with Sacramento River water released from both the Shasta Dam and Spring Creek Debris Dam.

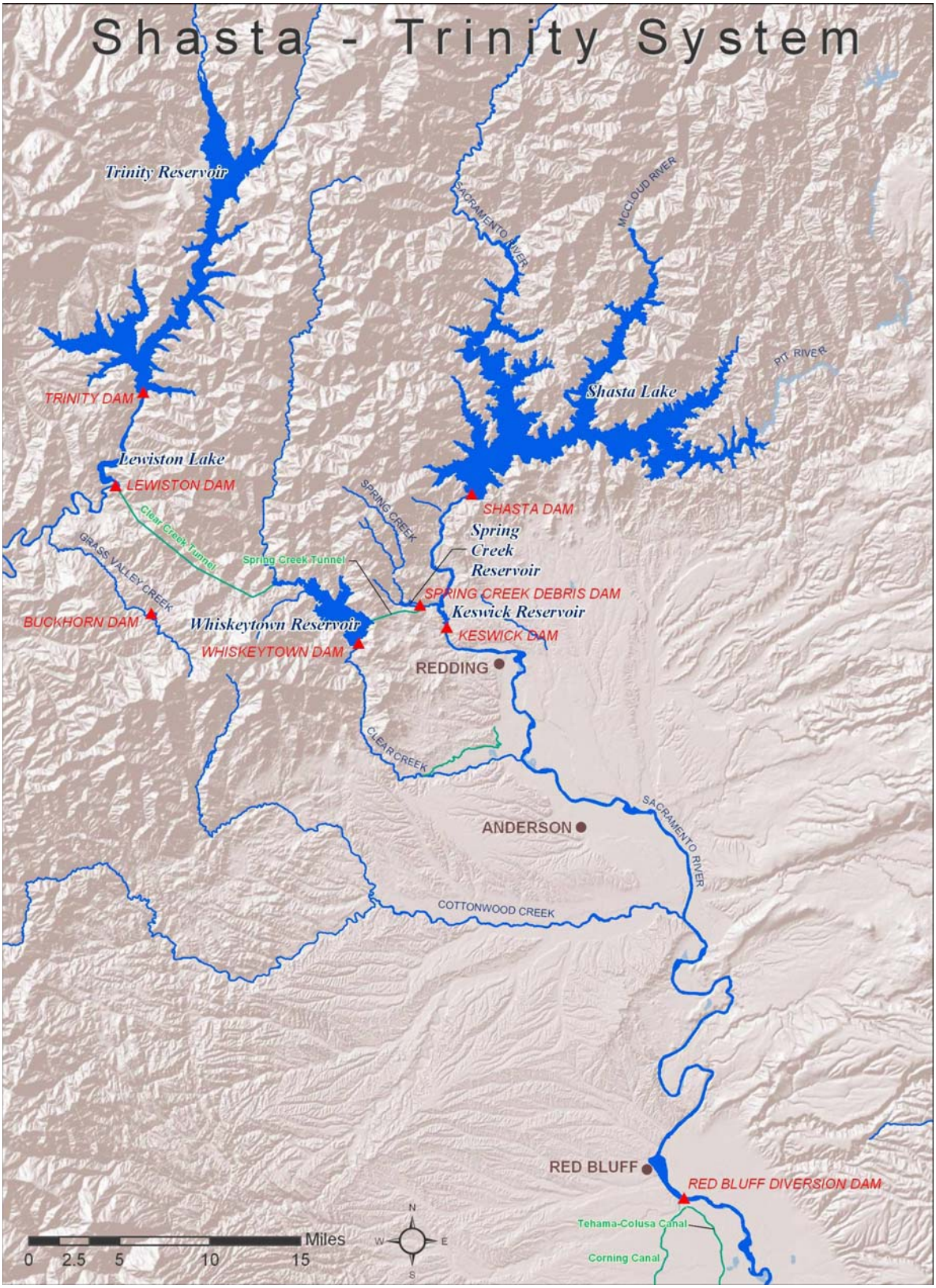

Figure P-5 Shasta-Trinity System

Safety of Dams at Trinity Reservoir

Periodically, increased water releases are made from Trinity Dam consistent with Reclamation Safety of Dams criteria intended to prevent overtopping of Trinity Dam. Although flood control is not an authorized purpose of the Trinity River Division, flood control benefits are provided through normal operations.

The Safety of Dams release criteria specifies that Carr Powerplant capacity should be used as a first preference destination for Safety of Dams releases made at Trinity Dam. Trinity River releases are made as a second preference destination. During significant Northern California high water flood events, the Sacramento River water stages are also at concern levels. Under such high water conditions, the water that would otherwise move through Carr Powerplant is routed to the Trinity River. Total river release can reach up to 11,000 cfs below Lewiston Dam (under Safety of Dams criteria) due to local high water concerns in the flood plain and local bridge flow capacities. The Safety of Dam criteria provides seasonal storage targets and recommended releases November 1 to March 31. During May 2006 the river flows were over 10,000 cfs for several days.

Fish and Wildlife Requirements on Trinity River

Based on the Trinity River Mainstem Fishery Restoration ROD, dated December 19, 2000, 368,600 to 815,000 AF is allocated annually for Trinity River flows. This amount is scheduled in coordination with the Service to best meet habitat, temperature, and sediment transport objectives in the Trinity Basin.

Temperature objectives for the Trinity River are set forth in SWRCB order WR 90-5 (Also see Table P-2 below). These objectives vary by reach and by season. Between Lewiston Dam and Douglas City Bridge, the daily average temperature should not exceed 60 degrees Fahrenheit (°F) from July 1 to September 14, and 56°F from September 15 to October 1. From October 1 to December 31, the daily average temperature should not exceed 56°F between Lewiston Dam and the confluence of the North Fork Trinity River. Reclamation consults with the Service in establishing a schedule of releases from Lewiston Dam that can best achieve these objectives.

For the purpose of determining the Trinity Basin WY type, forecasts using the 50 percent exceedance as of April 1st are used. There are no make-up/or increases for flows forgone if the WY type changes up or down from an earlier 50 percent forecast. In the modeling, actual historic Trinity inflows were used rather than a forecast. There is a temperature curtain in Lewiston Reservoir that provides for lower temperature water releases into the Trinity River.

Table P-2 Water temperature objectives for the Trinity River during the summer, fall, and winter as established by the CRWQCB-NCR (California Regional Water Quality Control Board North Coast Region)

Date	Temperature Objective (°F)	
	Douglas City (RM 93.8)	North Fork Trinity River (RM 72.4)
July 1 through Sept 14	60	-
Sept 15 through Sept 30	56	-
Oct 1 through Dec 31	-	56

Transbasin Diversions

Diversion of Trinity water to the Sacramento Basin provides limited water supply and hydroelectric power generation for the CVP and assists in water temperature control in the Trinity River and upper Sacramento River. The amounts and timing of the Trinity exports are determined by subtracting Trinity River scheduled flow and targeted carryover storage from the forecasted Trinity water supply.

The seasonal timing of Trinity exports is a result of determining how to make best use of a limited volume of Trinity export (in concert with releases from Shasta) to help conserve cold water pools and meet temperature objectives on the upper Sacramento and Trinity rivers, as well as power production economics. A key consideration in the export timing determination is the thermal degradation that occurs in Whiskeytown Lake due to the long residence time of transbasin exports in the lake.

To minimize the thermal degradation effects, transbasin export patterns are typically scheduled by an operator to provide an approximate 120,000 AF volume to occur in late spring to create a thermal connection to the Spring Creek Powerhouse before larger transbasin volumes are scheduled to occur during the hot summer months (Figure P-6). Typically, the water flowing from the Trinity Basin through Whiskeytown Lake must be sustained at fairly high rates to avoid warming and to function most efficiently for temperature control. The time period for which effective temperature control releases can be made from Whiskeytown Lake may be compressed when the total volume of Trinity water available for export is limited.

Export volumes from Trinity are made in coordination with the operation of Shasta Reservoir. Other important considerations affecting the timing of Trinity exports are based on the utility of power generation and allowances for normal maintenance of the diversion works and generation facilities.

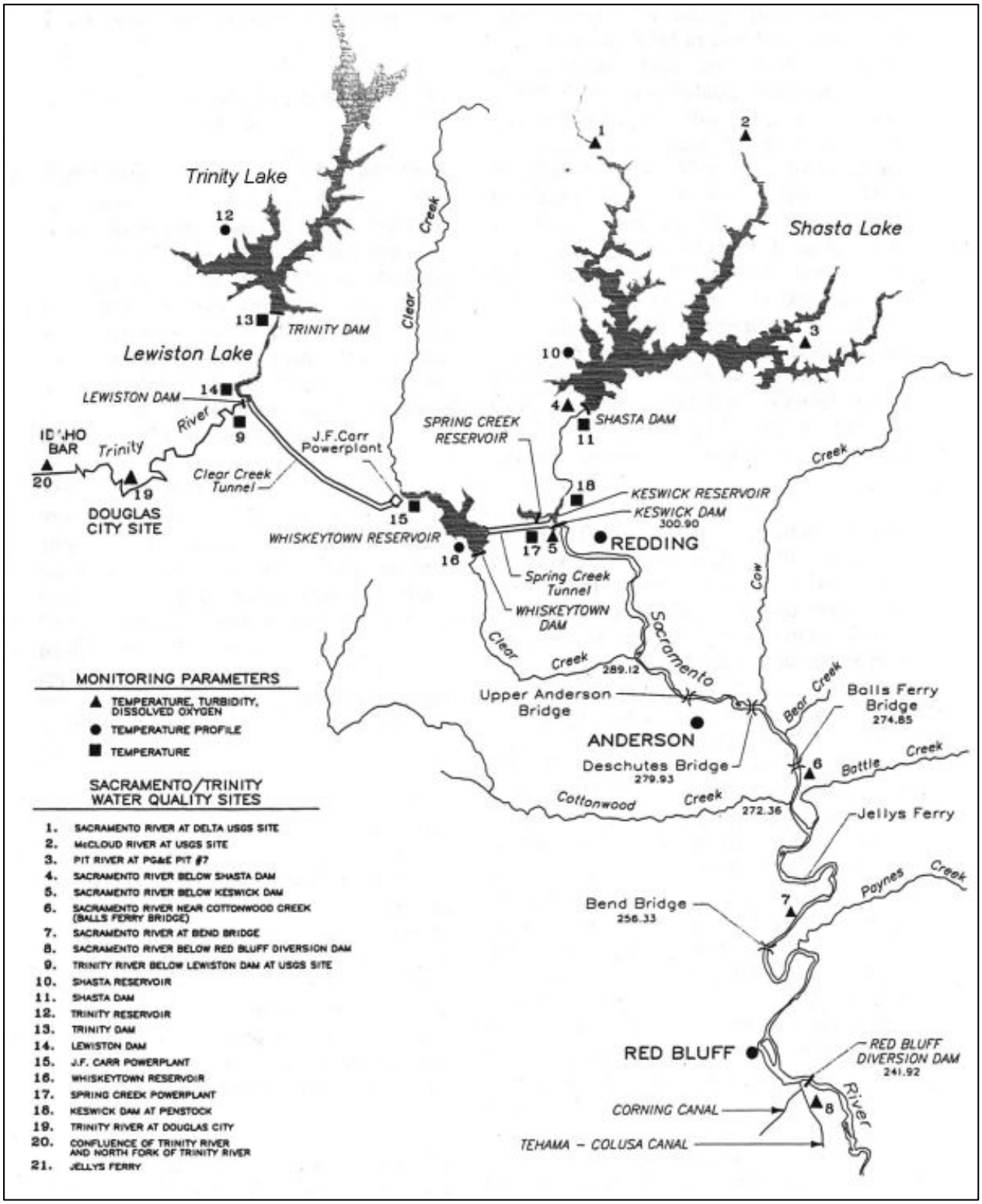

Figure P-6 Sacramento-Trinity Water Quality Network (with river miles [RM])

Trinity Lake historically reached its greatest storage level at the end of May. With the present pattern of prescribed Trinity releases, maximum storage may occur by the end of April or in early May.

Reclamation maintains at least 600,000 AF in Trinity Reservoir, except during the 10 to 15 percent of the years when Shasta Reservoir is also drawn down. Reclamation will address end of WY carryover on a case-by-case basis in dry and critically dry WY types with the Service and NMFS through the WOMT and B2IT processes.

Whiskeytown Reservoir Operations

Since 1964, a portion of the flow from the Trinity River Basin has been exported to the Sacramento River Basin through the CVP facilities. Water is diverted from the Trinity River at Lewiston Dam via the Clear Creek Tunnel and passes through the Judge Francis Carr Powerhouse as it is discharged into Whiskeytown Lake on Clear Creek. From Whiskeytown Lake, water is released through the Spring Creek Power Conduit to the Spring Creek Powerplant and into Keswick Reservoir. All of the water diverted from the Trinity River, plus a portion of Clear Creek flows, is diverted through the Spring Creek Power Conduit into Keswick Reservoir.

Spring Creek also flows into the Sacramento River and enters at Keswick Reservoir. Flows on Spring Creek are partially regulated by the Spring Creek Debris Dam. Historically (1964-1992), an average annual quantity of 1,269,000 AF of water has been diverted from Whiskeytown Lake to Keswick Reservoir. This annual quantity is approximately 17 percent of the flow measured in the Sacramento River at Keswick.

Whiskeytown is normally operated to (1) regulate inflows for power generation and recreation; (2) support upper Sacramento River temperature objectives; and (3) provide for releases to Clear Creek consistent with the CVPIA Anadromous Fish Restoration Program (AFRP) objectives. Although it stores up to 241,000 AF, this storage is not normally used as a source of water supply. There is a temperature curtain in Whiskeytown Reservoir.

Spillway Flows below Whiskeytown Lake

Whiskeytown Lake is drawn down approximately 35,000 AF per year of storage space during November through April to regulate flows for power generation. Heavy rainfall events occasionally result in spillway discharges to Clear Creek, as shown in Table P-3 below.

Table P-3 Days of Spilling below Whiskeytown and 40-30-30 Index from Water Year 1978 to 2005, WY Types: W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical

Water Year	Days of Spilling	40-30-30 Index
1978	5	AN
1979	0	BN
1980	0	AN
1981	0	D
1982	63	W
1983	81	W
1984	0	W
1985	0	D

Water Year	Days of Spilling	40-30-30 Index
1986	17	W
1987	0	D
1988	0	C
1989	0	D
1990	8	C
1991	0	C
1992	0	C
1993	10	AN
1994	0	C
1995	14	W
1996	0	W
1997	5	W
1998	8	W
1999	0	W
2000	0	AN
2001	0	D
2002	0	D
2003	8	AN
2004	0	BN
2005	0	AN
2006	4	W
2007	0	D

Operations at Whiskeytown Lake during flood conditions are complicated by its operational relationship with the Trinity River, Sacramento River, and Clear Creek. On occasion, imports of Trinity River water to Whiskeytown Reservoir may be suspended to avoid aggravating high flow conditions in the Sacramento Basin.

Fish and Wildlife Requirements on Clear Creek

Water rights permits issued by the SWRCB for diversions from Trinity River and Clear Creek specify minimum downstream releases from Lewiston and Whiskeytown Dams, respectively. Two agreements govern releases from Whiskeytown Lake:

- A 1960 Memorandum of Agreement (MOA) with the DFG established minimum flows to be released to Clear Creek at Whiskeytown Dam, Table P-4 .
- A 1963 release schedule for Whiskeytown Dam was developed with the Service and implemented, but never finalized. Although this release schedule was never formalized, Reclamation has operated according to this proposed schedule since May 1963.

Table P-4 Minimum flows at Whiskeytown Dam from 1960 MOA with the DFG

Period	Minimum flow (cfs)
1960 MOA with the DFG	
January 1 - February 28(29)	50
March 1 - May 31	30
June 1 - September 30	0
October 1 - October 15	10
October 16 - October 31	30
November 1 - December 31	100
1963 FWS Proposed Normal year flow (cfs)	
January 1 - October 31	50
November 1 - December 31	100
1963 FWS Proposed Critical year flow (cfs)	
January 1 - October 31	30
November 1 - December 31	70

Spring Creek Debris Dam Operations

The Spring Creek Debris Dam (SCDD) is a feature of the Trinity Division of the CVP. It was constructed to regulate runoff containing debris and acid mine drainage from Spring Creek, a tributary to the Sacramento River that enters Keswick Reservoir. The SCDD can store approximately 5,800 AF of water. Operation of SCDD and Shasta Dam has allowed some control of the toxic wastes with dilution criteria. In January 1980, Reclamation, the DFG, and the SWRCB executed a Memorandum of Understanding (MOU) to implement actions that protect the Sacramento River system from heavy metal pollution from Spring Creek and adjacent watersheds.

The MOU identifies agency actions and responsibilities, and establishes release criteria based on allowable concentrations of total copper and zinc in the Sacramento River below Keswick Dam. The MOU states that Reclamation agrees to operate to dilute releases from SCDD (according to these criteria and schedules provided) and that such operation will not cause flood control parameters on the Sacramento River to be exceeded and will not unreasonably interfere with other project requirements as determined by Reclamation. The MOU also specifies a minimum schedule for monitoring copper and zinc concentrations at SCDD and in the Sacramento River below Keswick Dam. Reclamation has primary responsibility for the monitoring; however, the DFG and the RWQCB also collect and analyze samples on an as-needed basis. Due to more extensive monitoring, improved sampling and analyses techniques, and continuing cleanup efforts in the Spring Creek drainage basin, Reclamation now operates SCDD targeting the more stringent Central Valley Region Water Quality Control Plan (Basin Plan) criteria in addition to the MOU goals. Instead of the total copper and total zinc criteria contained in the MOU,

Reclamation operates SCDD releases and Keswick dilution flows to not exceed the Basin Plan standards of 0.0056 mg/L dissolved copper and 0.016 mg/L dissolved zinc. Release rates are estimated from a mass balance calculation of the copper and zinc in the debris dam release and in the river.

In order to minimize the build-up of metal concentrations in the Spring Creek arm of Keswick Reservoir, releases from the debris dam are coordinated with releases from the Spring Creek Powerplant to keep the Spring Creek arm of Keswick Reservoir in circulation with the main water body of Keswick Lake.

The operation of SCDD is complicated during major heavy rainfall events. SCDD reservoir can fill to uncontrolled spill elevations in a relatively short time period, anywhere from days to weeks. Uncontrolled spills at SCDD can occur during major flood events on the upper Sacramento River and also during localized rainfall events in the Spring Creek watershed. During flood control events, Keswick releases may be reduced to meet flood control objectives at Bend Bridge when storage and inflow at Spring Creek Reservoir are high.

Because SCDD releases are maintained as a dilution ratio of Keswick releases to maintain the required dilution of copper and zinc, uncontrolled spills can and have occurred from SCDD. In this operational situation, high metal concentration loads during heavy rainfall are usually limited to areas immediately downstream of Keswick Dam because of the high runoff entering the Sacramento River adding dilution flow. In the operational situation when Keswick releases are increased for flood control purposes, SCDD releases are also increased in an effort to reduce spill potential.

In the operational situation when heavy rainfall events will fill SCDD and Shasta Reservoir will not reach flood control conditions, increased releases from CVP storage may be required to maintain desired dilution ratios for metal concentrations. Reclamation has voluntarily released additional water from CVP storage to maintain release ratios for toxic metals below Keswick Dam. Reclamation has typically attempted to meet the Basin Plan standards but these releases have no established criteria and are dealt with on a case-by-case basis. Since water released for dilution of toxic spills is likely to be in excess of other CVP requirements, such releases increase the risk of a loss of water for other beneficial purposes.

Shasta Division and Sacramento River Division

The CVP's Shasta Division includes facilities that conserve water in the Sacramento River for (1) flood control, (2) navigation maintenance, (3) agricultural water supplies, (4) M&I water supplies (5) hydroelectric power generation, (6) conservation of fish in the Sacramento River, and (7) protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water. The Shasta Division includes Shasta Dam, Lake, and Powerplant; Keswick Dam, Reservoir, and Powerplant, and the Shasta Temperature Control Device.

The Sacramento River Division was authorized after completion of the Shasta Division. Total authorized diversions for the Sacramento River Division are approximately 2.8 MAF. Historically the total diversion has varied from 1.8 MAF in a critically dry year to the full 2.8 MAF in wet year. It includes facilities for the diversion and conveyance of water to CVP contractors on the west side of the Sacramento River. The division includes the Sacramento

Canals Unit, which was authorized in 1950 and consists of the RBDD, the Corning Pumping Plant, and the Corning and Tehama-Colusa Canals.

The unit was authorized to supply irrigation water to over 200,000 acres of land in the Sacramento Valley, principally in Tehama, Glenn, Colusa, and Yolo counties. Black Butte Dam, which is operated by the U.S. Army Corps of Engineers (Corps), also provides supplemental water to the Tehama-Colusa Canals as it crosses Stony Creek. The operations of the Shasta and Sacramento River divisions are presented together because of their operational inter-relationships.

Shasta Dam is located on the Sacramento River just below the confluence of the Sacramento, McCloud, and Pit Rivers. The dam regulates the flow from a drainage area of approximately 6,649 square miles. Shasta Dam was completed in 1945, forming Shasta Lake, which has a maximum storage capacity of 4,552,000 AF. Water in Shasta Lake is released through or around the Shasta Powerplant to the Sacramento River where it is re-regulated downstream by Keswick Dam. A small amount of water is diverted directly from Shasta Lake for M&I uses by local communities.

Keswick Reservoir was formed by the completion of Keswick Dam in 1950. It has a capacity of approximately 23,800 AF and serves as an afterbay for releases from Shasta Dam and for discharges from the Spring Creek Powerplant. All releases from Keswick Reservoir are made to the Sacramento River at Keswick Dam. The dam has a fish trapping facility that operates in conjunction with the Coleman National Fish Hatchery on Battle Creek.

Flood Control

Flood control objectives for Shasta Lake require that releases be restricted to quantities that will not cause downstream flows or stages to exceed specified levels. These include a flow of 79,000 cfs at the tailwater of Keswick Dam, and a stage of 39.2 feet in the Sacramento River at Bend Bridge gauging station, which corresponds to a flow of approximately 100,000 cfs. Flood control operations are based on regulating criteria developed by the Corps pursuant to the provisions of the Flood Control Act of 1944. Maximum flood space reservation is 1.3 MAF, with variable storage space requirements based on an inflow parameter.

Flood control operation at Shasta Lake requires the forecasting of runoff conditions into Shasta Lake, as well as runoff conditions of unregulated creek systems downstream from Keswick Dam, as far in advance as possible. A critical element of upper Sacramento River flood operations is the local runoff entering the Sacramento River between Keswick Dam and Bend Bridge.

The unregulated creeks (major creek systems are Cottonwood Creek, Cow Creek, and Battle Creek) in this reach of the Sacramento River can be very sensitive to a large rainfall event and produce large rates of runoff into the Sacramento River in short time periods. During large rainfall and flooding events, the local runoff between Keswick Dam and Bend Bridge can exceed 100,000 cfs.

The travel time required for release changes at Keswick Dam to affect Bend Bridge flows is approximately 8 to 10 hours. If the total flow at Bend Bridge is projected to exceed 100,000 cfs, the release from Keswick Dam is decreased to maintain Bend Bridge flow below 100,000 cfs. As the flow at Bend Bridge is projected to recede, the Keswick Dam release is increased to

evacuate water stored in the flood control space at Shasta Lake. Changes to Keswick Dam releases are scheduled to minimize rapid fluctuations in the flow at Bend Bridge.

The flood control criteria for Keswick releases specify releases should not be increased more than 15,000 cfs or decreased more than 4,000 cfs in any 2-hour period. The restriction on the rate of decrease is intended to prevent sloughing of saturated downstream channel embankments caused by rapid reductions in river stage. In rare instances, the rate of decrease may have to be accelerated to avoid exceeding critical flood stages downstream.

Fish and Wildlife Requirements in the Sacramento River

Reclamation operates the Shasta, Sacramento River, and Trinity River divisions of the CVP to meet (to the extent possible) the provisions of SWRCB Order 90-05. If Reclamation cannot meet the SWRCB order an exception will be requested. An April 5, 1960, MOA between Reclamation and the DFG originally established flow objectives in the Sacramento River for the protection and preservation of fish and wildlife resources. The agreement provided for minimum releases into the natural channel of the Sacramento River at Keswick Dam for normal and critically dry years (Table P-5). Since October 1981, Keswick Dam has operated based on a minimum release of 3,250 cfs for normal years from September 1 through the end of February, in accordance with an agreement between Reclamation and DFG. This release schedule was included in Order 90-05, which maintains a minimum release of 3,250 cfs at Keswick Dam and RBDD from September through the end of February in all water years, except critically dry years.

Table P-5 Current Minimum Flow Requirements and Objectives (cfs) on the Sacramento River below Keswick Dam

Water Year Type	MOA	WR 90-5	MOA and WR 90-5	Proposed Flow Objectives below Keswick
Period	**Normal**	**Normal**	**Critically Dry**	**All**
January 1 - February 28(29)	2600	3250	2000	3250
March 1 - March 31	2300	2300	2300	3250
April 1 - April 30	2300	2300	2300	---*
May 1 - August 31	2300	2300	2300	---*
September 1 - September 30	3900	3250	2800	---*
October 1 - November 30	3900	3250	2800	3250
December 1 - December 31	2600	3250	2000	3250

Note: * No regulation.

The 1960 MOA between Reclamation and the DFG provides that releases from Keswick Dam (from September 1 through December 31) are made with minimum water level fluctuation or change to protect salmon to the extent compatible with other operational requirements. Releases

from Shasta and Keswick Dams are gradually reduced in September and early October during the transition from meeting Delta export and water quality demands to operating the system for flood control and fishery concerns from October through December.

Reclamation proposes a minimum flow of 3,250 cfs from October 1 through March 31 and ramping constraints for Keswick release reductions from July 1 through March 31 as follows:

- Releases must be reduced between sunset and sunrise.
- When Keswick releases are 6,000 cfs or greater, decreases may not exceed 15 percent per night. Decreases also may not exceed 2.5 percent in one hour.
- For Keswick releases between 4,000 and 5,999 cfs, decreases may not exceed 200 cfs per night. Decreases also may not exceed 100 cfs per hour.
- For Keswick releases between 3,250 and 3,999 cfs, decreases may not exceed 100 cfs per night.
- Variances to these release requirements are allowed under flood control operations.

Reclamation usually reduces releases from Keswick Dam to the minimum fishery requirement by October 15 each year and to minimize changes in Keswick releases between October 15 and December 31. Releases may be increased during this period to meet unexpected downstream needs such as higher outflows in the Delta to meet water quality requirements, or to meet flood control requirements. Releases from Keswick Dam may be reduced when downstream tributary inflows increase to a level that will meet flow needs. Reclamation attempts to establish a base flow that minimizes release fluctuations to reduce impacts to fisheries and bank erosion from October through December.

A recent change in agricultural water diversion practices has affected Keswick Dam release rates in the fall. This program is generally known as the Rice Straw Decomposition and Waterfowl Habitat Program. Historically, the preferred method of clearing fields of rice stubble was to systematically burn it. Today, rice field burning has been phased out due to air quality concerns and has been replaced by a program of rice field flooding that decomposes rice stubble and provides additional waterfowl habitat. The result has been an increase in water demand to flood rice fields in October and November, which has increased the need for higher Keswick releases in all but the wettest of fall months.

The changes in agricultural practice over the last decade related to the Rice Straw Decomposition and Waterfowl Habitat Program have been incorporated into the systematic modeling of agricultural use and hydrology effects as described in the biological assessment.

Minimum Flow for Navigation – Wilkins Slough

Historical commerce on the Sacramento River resulted in a CVP authorization to maintain minimum flows of 5,000 cfs at Chico Landing to support navigation. Currently, there is no commercial traffic between Sacramento and Chico Landing, and the Corps has not dredged this reach to preserve channel depths since 1972. However, long-time water users diverting from the river have set their pump intakes just below this level. Therefore, the CVP is operated to meet the navigation flow requirement of 5,000 cfs to Wilkins Slough, (gauging station on the

Sacramento River), under all but the most critical water supply conditions, to facilitate pumping and use of screened diversions.

At flows below 5,000 cfs at Wilkins Slough, diverters have reported increased pump cavitation as well as greater pumping head requirements. Diverters are able to operate for extended periods at flows as low as 4,000 cfs at Wilkins Slough, but pumping operations become severely affected and some pumps become inoperable at flows lower than this. Flows may drop as low as 3,500 cfs for short periods while changes are made in Keswick releases to reach target levels at Wilkins Slough, but using the 3,500 cfs rate as a target level for an extended period would have major impacts on diverters.

No criteria have been established specifying when the navigation minimum flow should be relaxed. However, the basis for Reclamation's decision to operate at less than 5,000 cfs is the increased importance of conserving water in storage when water supplies are not sufficient to meet full contractual deliveries and other operational requirements.

Water Temperature Operations in the Upper Sacramento River

Water temperature in the upper Sacramento River is governed by current water right permit requirements. Water temperature on the Sacramento River system is influenced by several factors, including the relative water temperatures and ratios of releases from Shasta Dam and from the Spring Creek Powerplant. The temperature of water released from Shasta Dam and the Spring Creek Powerplant is a function of the reservoir temperature profiles at the discharge points at Shasta and Whiskeytown, the depths from which releases are made, the seasonal management of the deep cold water reserves, ambient seasonal air temperatures and other climatic conditions, tributary accretions and water temperatures, and residence time in Keswick, Whiskeytown and Lewiston Reservoirs, and in the Sacramento River.

SWRCB Water Rights Order 90-05 and Water Rights Order 91-01

In 1990 and 1991, the SWRCB issued Water Rights Orders 90-05 and 91-01 modifying Reclamation's water rights on the Sacramento River. The orders stated Reclamation shall operate Keswick and Shasta Dams and the Spring Creek Powerplant to meet a daily average water temperature of 56°F as far downstream in the Sacramento River as practicable during periods when higher temperature would be harmful to fisheries. The optimal control point is the RBDD.

Under the orders, the water temperature compliance point may be modified when the objective cannot be met at RBDD. In addition, Order 90-05 modified the minimum flow requirements initially established in the 1960 MOA for the Sacramento River below Keswick Dam. The water right orders also recommended the construction of a Shasta Temperature Control Device (TCD) to improve the management of the limited cold water resources.

Pursuant to SWRCB Orders 90-05 and 91-01, Reclamation configured and implemented the Sacramento-Trinity Water Quality Monitoring Network to monitor temperature and other parameters at key locations in the Sacramento and Trinity Rivers. The SWRCB orders also required Reclamation to establish the Sacramento River Temperature Task Group (SRTTG) to formulate, monitor, and coordinate temperature control plans for the upper Sacramento and Trinity Rivers. This group consists of representatives from Reclamation, SWRCB, NMFS, the Service, DFG, Western, DWR, and the Hoopa Valley Indian Tribe.

Each year, with finite cold water resources and competing demands usually an issue, the SRTTG will devise operation plans with the flexibility to provide the best protection consistent with the CVP's temperature control capabilities and considering the annual needs and seasonal spawning distribution monitoring information for winter-run and fall-run Chinook salmon. In every year since the SWRCB issued the orders, those plans have included modifying the RBDD compliance point to make best use of the cold water resources based on the location of spawning Chinook salmon. Reports are submitted periodically to the SWRCB over the temperature control season defining our temperature operation plans. The SWRCB has overall authority to determine if the plan is sufficient to meet water right permit requirements.

Shasta Temperature Control Device

Construction of the TCD at Shasta Dam was completed in 1997. This device is designed for greater flexibility in managing the cold water reserves in Shasta Lake while enabling hydroelectric power generation to occur and to improve salmon habitat conditions in the upper Sacramento River. The TCD is also designed to enable selective release of water from varying lake levels through the power plant in order to manage and maintain adequate water temperatures in the Sacramento River downstream of Keswick Dam.

Prior to construction of the Shasta TCD, Reclamation released water from Shasta Dam's low-level river outlets to alleviate high water temperatures during critical periods of the spawning and incubation life stages of the winter-run Chinook stock. Releases through the low-level outlets bypass the power plant and result in a loss of hydroelectric generation at the Shasta Powerplant. The release of water through the low-level river outlets was a major facet of Reclamation's efforts to control upper Sacramento River temperatures from 1987 through 1996.

The seasonal operation of the TCD is generally as follows: during mid-winter and early spring the highest elevation gates possible are utilized to draw from the upper portions of the lake to conserve deeper colder resources (see Table P-6). During late spring and summer, the operators begin the seasonal progression of opening deeper gates as Shasta Lake elevation decreases and cold water resources are utilized. In late summer and fall, the TCD side gates are opened to utilize the remaining cold water resource below the Shasta Powerplant elevation in Shasta Lake.

Table P-6 Shasta Temperature Control Device Gates with Elevation and Storage

TCD Gates	Shasta Elevation with 35 feet of Submergence	Shasta Storage
Upper Gates	1035	~3.65 MAF
Middle Gates	935	~2.50 MAF
Pressure Relief Gates	840	~0.67 MAF
Side Gates	720*	~0.01 MAF

* Low Level intake bottom.

The seasonal progression of the Shasta TCD operation is designed to maximize the conservation of cold water resources deep in Shasta Lake, until the time the resource is of greatest management value to fishery management purposes. Recent operational experience with the Shasta TCD has demonstrated significant operational flexibility improvement for cold water

conservation and upper Sacramento River water temperature and fishery habitat management purposes. Recent operational experience has also demonstrated the Shasta TCD has significant leaks that are inherent to TCD design.

Reclamation's Proposed Upper Sacramento River Temperature Objectives

Reclamation will continue a policy of developing annual operations plans and water allocations based on a conservative 90 percent exceedance forecast. Reclamation is not proposing a minimum end-of-water-year (September 30) carryover storage in Shasta Reservoir.

In continuing compliance with Water Rights Orders 90-05 and 91-01 requirements, Reclamation will implement operations to provide year round temperature protection in the upper Sacramento River, consistent with the intent of Order 90-05 that protection be provided to the extent controllable. Among factors that affect the extent to which river temperatures will be controllable include Shasta TCD performance, the availability of cold water, the balancing of habitat needs for different species in spring, summer, and fall, and the constraints on operations created by the combined effect of the projects and demands assumed to be in place in the future.

Under all but the most adverse drought and low Shasta Reservoir storage conditions, Reclamation proposes to continue operating CVP facilities to provide water temperature control at Ball's Ferry or at locations further downstream (as far as Bend Bridge) based on annual plans. Reclamation and the SRTTG will take into account projections of cold water resources, numbers of expected spawning salmon, and spawning distribution (as monitoring information becomes available) to make the decisions on allocation of the cold water resources.

Locating the target temperature compliance at Ball's Ferry (1) reduces the need to compensate for the warming effects of Cottonwood Creek and Battle Creek during the spring runoff months with deeper cold water releases and (2) improves the reliability of cold water resources through the fall months. Reclamation proposes Sacramento River temperature control point to be consistent with the capability of the CVP to manage cold water resources and to use the process of annual planning in coordination with the SRTTG to arrive at the best use of that capability.

Anderson-Cottonwood Irrigation District (ACID) Diversion Dam

ACID holds senior water rights and has diverted into the ACID Canal for irrigation along the west side of the Sacramento River between Redding and Cottonwood since 1916. The United States and ACID signed a contract providing for the project water service and agreement on diversion of water. ACID diverts to its main canal (on the right bank of the river) from a diversion dam located in Redding about five miles downstream from Keswick Dam.

Close coordination is required between Reclamation and ACID for regulation of river flows to ensure safe operation of ACIDs diversion dam during the irrigation season. The irrigation season for ACID runs from April through October.

Keswick release rate decreases required for the ACID operations are limited to 15 percent in a 24-hour period and 2.5 percent in any one hour. Therefore, advance notification is important when scheduling decreases to allow for the installation or removal of the ACID diversion dam.

Red Bluff Diversion Dam Operations

The Red Bluff Diversion Dam (RBDD), located on the Sacramento River approximately two miles southeast of Red Bluff, is a gated structure with fish ladders at each abutment. When the gates are lowered, the impounded water rises about 13 feet, creating Lake Red Bluff and allowing gravity diversions through a set of drum fish screens into the stilling basin servicing the Tehama-Colusa and Corning canals. Construction of RBDD was completed in 1964.

The Tehama-Colusa Canal is a lined canal extending 111 miles south from the RBDD and provides irrigation service on the west side of the Sacramento Valley in Tehama, Glenn, Colusa, and northern Yolo counties. Construction of the Tehama-Colusa Canal began in 1965, and it was completed in 1980.

The Corning Pumping Plant lifts water approximately 56 feet from the screened portion of the settling basin into the unlined, 21 mile-long Corning Canal. The Corning Canal was completed in 1959, to provide water to the CVP contractors in Tehama County that could not be served by gravity from the Tehama-Colusa Canal. The Tehama-Colusa Canal Authority (TCCA) operates both the Tehama-Colusa and Corning canals.

Since 1986, the RBDD gates have been raised during winter months to allow passage of winter-run Chinook salmon. As documented in the 2004 NMFS biological opinion addressing the long-term CVP and SWP operations, the gates are raised from approximately September 15 through May 14, each year. In the near term, Reclamation proposes the continued operation of the RBDD using the eight-month gate-open procedures of the past ten years, and to use the research pumping plant to provide water to the canals during times when the gates-out configuration precludes gravity diversions during the irrigation season. Additionally, although covered under a separate NMFS biological opinion, Reclamation proposes the continued use of rediversions of CVP water stored in Black Butte Reservoir to supplement the water pumped at RBDD during the gates-out period. This water is rediverted with the aid of temporary gravel berms through an unscreened, constant head orifice (CHO) into the Tehama-Colusa Canal.

In addition to proposing to operate the RBDD with the gates in for 8 months annually to enable gravity diversion of water into the Tehama-Colusa Canal, Reclamation proposes retention of the provision for a 10-day emergency gate closure, as necessary, contingent upon a case-by-case consultation with NMFS. Reclamation most recently coordinated such an emergency gate closure with NMFS in the spring of 2007. Around that time, dead green sturgeon were discovered in the vicinity of the dam, and Reclamation worked with the other resource agencies to review the gate operation protocol to try and reduce future potential adverse affects to adult green sturgeon that pass the dam. The resulting, new protocol for all gates in operation is to open individual gates to a minimum height of 12 inches to substantially reduce the possibility of injury should adult green sturgeon pass beneath the gates.

American River Division

Reclamation's Folsom Lake, the largest reservoir in the watershed, has a capacity of 977,000 AF. Folsom Dam, located approximately 30 miles upstream from the confluence with the Sacramento River, is operated as a major component of the CVP. The American River Division includes facilities that provide conservation of water on the American River for flood control, fish and wildlife protection, recreation, protection of the Delta from intrusion of saline ocean water, irrigation and M&I water

supplies, and hydroelectric power generation. Initially authorized features of the American River Division included Folsom Dam, Lake, and Powerplant; Nimbus Dam and Powerplant, and Lake Natoma. See map in Figure P-7.

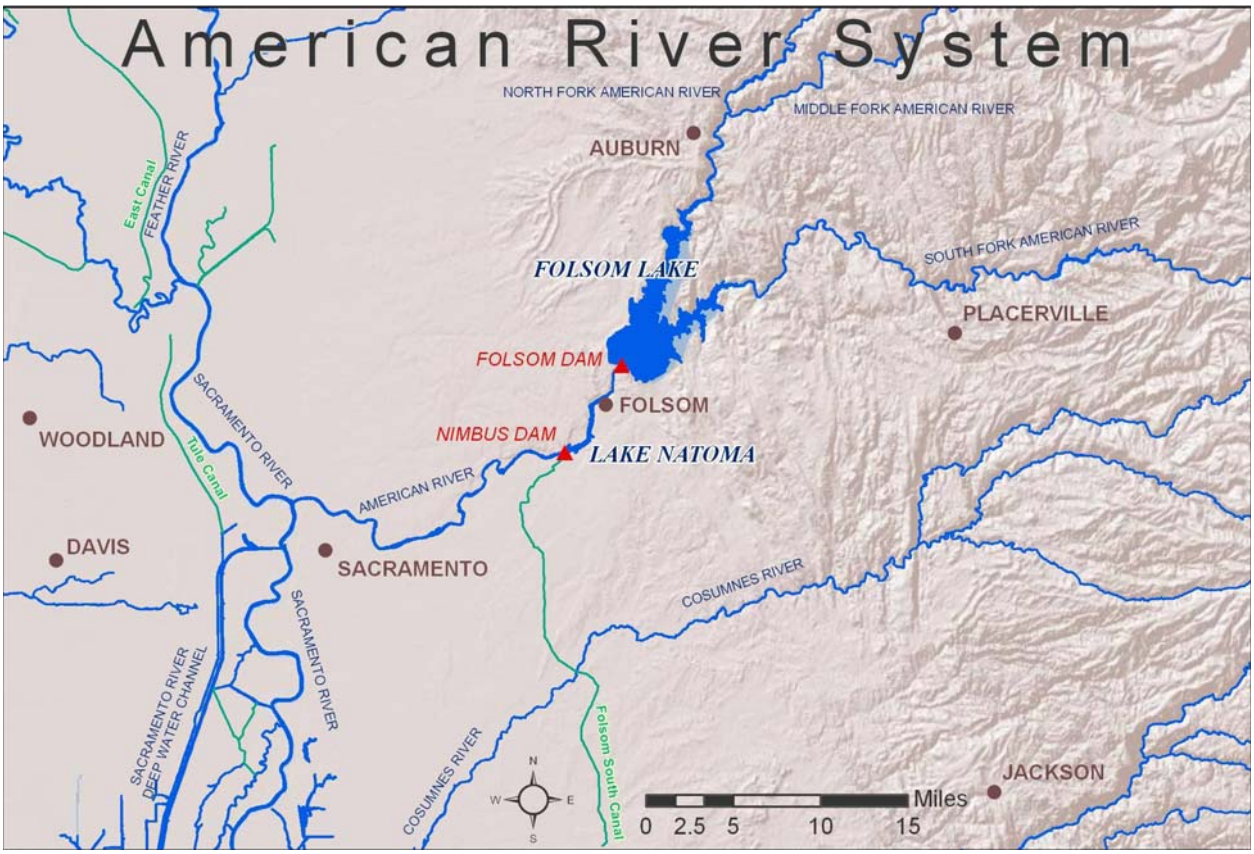

Figure P-7 American River System

Table P-7 provides Reclamation's annual water deliveries for the period 2000 through 2006 in the American River Division. The totals reveal an increasing trend in water deliveries over that period. Present level of American River Division water demands are about 325 TAF per year. Future level (2030) water demands are modeled at near 800 TAF per year. The modeled deliveries vary depending on modeled annual water allocations.

Table P-7 Annual Water Delivery - American River Division

Year	Water Delivery (TAF)
2000	196
2001	206
2002	238
2003	271
2004	266
2005	297
2006	282

Releases from Folsom Dam are re-regulated approximately seven miles downstream by Nimbus Dam. This facility is also operated by Reclamation as part of the CVP. Nimbus Dam creates Lake Natoma, which serves as a forebay for diversions to the Folsom South Canal. This CVP facility serves water to M&I users in Sacramento County. Releases from Nimbus Dam to the American River pass through the Nimbus Powerplant, or, at flows in excess of 5,000 cfs, the spillway gates.

Although Folsom Lake is the main storage and flood control reservoir on the American River, numerous other small reservoirs in the upper basin provide hydroelectric generation and water supply. None of the upstream reservoirs have any specific flood control responsibilities. The total upstream reservoir storage above Folsom Lake is approximately 820,000 AF. Ninety percent of this upstream storage is contained by five reservoirs: French Meadows (136,000 AF); Hell Hole (208,000 AF); Loon Lake (76,000 AF); Union Valley (271,000 AF); and Ice House (46,000 AF). Reclamation has agreements with the operators of some of these reservoirs to coordinate operations for releases.

French Meadows and Hell Hole reservoirs, located on the Middle Fork of the American River, are owned and operated by the Placer County Water Agency (PCWA). The PCWA provides wholesale water to agricultural and urban areas within Placer County. For urban areas, the PCWA operates water treatment plants and sells wholesale treated water to municipalities that provide retail delivery to their customers. The cities of Rocklin and Lincoln receive water from the PCWA. Loon Lake (also on the Middle Fork), and Union Valley and Ice House reservoirs on the South Fork, are all operated by the Sacramento Municipal Utilities District (SMUD) for hydropower purposes.

Flood Control

Flood control requirements and regulating criteria are specified by the Corps and described in the Folsom Dam and Lake, American River, California Water Control Manual (Corps 1987). Flood control objectives for Folsom require the dam and lake are operated to:

- Protect the City of Sacramento and other areas within the Lower American River floodplain against reasonable probable rain floods.
- Control flows in the American River downstream from Folsom Dam to existing channel capacities, insofar as practicable, and to reduce flooding along the lower Sacramento River and in the Delta in conjunction with other CVP projects.
- Provide the maximum amount of water conservation storage without impairing the flood control functions of the reservoir.
- Provide the maximum amount of power practicable and be consistent with required flood control operations and the conservation functions of the reservoir.

From June 1 through September 30, no flood control storage restrictions exist. From October 1 through November 16 and from April 20 through May 31, reserving storage space for flood control is a function of the date only, with full flood reservation space required from November 17 through February 7. Beginning February 8 and continuing through April 20, flood reservation space is a function of both date and current hydrologic conditions in the basin.

If the inflow into Folsom Reservoir causes the storage to encroach into the space reserved for flood control, releases from Nimbus Dam are increased. Flood control regulations prescribe the following releases when water is stored within the flood control reservation space:

- Maximum inflow (after the storage entered into the flood control reservation space) of as much as 115,000 cfs, but not less than 20,000 cfs, when inflows are increasing.
- Releases will not be increased more than 15,000 cfs or decreased more than 10,000 cfs during any two-hour period.
- Flood control requirements override other operational considerations in the fall and winter period. Consequently, changes in river releases of short duration may occur.

In February 1986, the American River Basin experienced a significant flood event. Folsom Dam and Reservoir moderated the flood event and performed the flood control objectives, but with serious operational strains and concerns in the Lower American River and the overall protection of the communities in the floodplain areas. A similar flood event occurred in January 1997. Since then, significant review and enhancement of Lower American River flooding issues has occurred and continues to occur. A major element of those efforts has been the Sacramento Area Flood Control Agency (SAFCA) sponsored flood control plan diagram for Folsom Reservoir.

Since 1996, Reclamation has operated according to modified flood control criteria, which reserve 400 to 670 TAF of flood control space in Folsom and in a combination of three upstream reservoirs. This flood control plan, which provides additional protection for the Lower American River, is implemented through an agreement between Reclamation and the SAFCA. The terms of the agreement allow some of the empty reservoir space in Hell Hole, Union Valley, and French Meadows to be treated as if it were available in Folsom.

The SAFCA release criteria are generally equivalent to the Corps plan, except the SAFCA diagram may prescribe flood releases earlier than the Corps plan. The SAFCA diagram also relies on Folsom Dam outlet capacity to make the earlier flood releases. The outlet capacity at

Folsom Dam is currently limited to 32,000 cfs based on lake elevation. However, in general the SAFCA plan diagram provides greater flood protection than the existing Corps plan for communities in the American River floodplain.

Required flood control space under the SAFCA diagram will begin to decrease on March 1. Between March 1 and April 20, the rate of filling is a function of the date and available upstream space. As of April 21, the required flood reservation is about 225,000 AF. From April 21 to June 1, the required flood reservation is a function of the date only, with Folsom storage permitted to fill completely on June 1.

Fish and Wildlife Requirements in the Lower American River

The minimum allowable flows in the Lower American River are defined by SWRCB Decision 893 (D-893), which states that in the interest of fish conservation, releases should not ordinarily fall below 250 cfs between January 1 and September 15 or below 500 cfs at other times. D-893 minimum flows are rarely the controlling objective of CVP operations at Nimbus Dam. Nimbus Dam releases are nearly always controlled during significant portions of a WY by either flood control requirements or are coordinated with other CVP and SWP releases to meet downstream Sacramento-San Joaquin Delta WQCP requirements and CVP water supply objectives. Power regulation and management needs occasionally control Nimbus Dam releases. Nimbus Dam releases are expected to exceed the D-893 minimum flows in all but the driest of conditions.

Reclamation continues to work with the Sacramento Water Forum, the Service, NMFS, DFG, and other interested parties to integrate a revised flow management standard for the Lower American River into CVP operations and water rights. This project description and modeling assumptions include the operational components of the recommended Lower American River flows and is consistent with the proposed flow management standard. Until this action is adopted by the SWRCB, the minimum legally required flows will be defined by D-893. However, Reclamation intends to operate to the proposed flow management standard using releases of additional water pursuant to Section 3406 (b)(2) of the CVPIA. Use of additional (b)(2) flows above the proposed flow standard is envisioned on a case-by-case basis. Such additional use of (b)(2) flows would be subject to available resources and such use would be coupled with plans to not intentionally cause significantly lower river flows later in a WY. This case-by-case use of additional (b)(2) for minimum flows is not included in the modeling results.

Water temperature control operations in the Lower American River are affected by many factors and operational tradeoffs. These include available cold water resources, Nimbus release schedules, annual hydrology, Folsom power penstock shutter management flexibility, Folsom Dam Urban Water Supply TCD management, and Nimbus Hatchery considerations. Shutter and TCD management provide the majority of operational flexibility used to control downstream temperatures.

During the late 1960s, Reclamation designed a modification to the trashrack structures to provide selective withdrawal capability at Folsom Dam. Folsom Powerplant is located at the foot of Folsom Dam on the right abutment. Three 15-foot-diameter steel penstocks for delivering water to the turbines are embedded in the concrete section of the dam. The centerline of each penstock intake is at elevation 307.0 feet and the minimum power pool elevation is 328.5 feet. A reinforced concrete trashrack structure with steel trashracks protects each penstock intake.

The steel trashracks, located in five bays around each intake, extend the full height of the trashrack structure (between 281 and 428 feet). Steel guides were attached to the upstream side of the trashrack panels between elevation 281 and 401 feet. Forty-five 13-foot steel shutter panels (nine per bay) and operated by the gantry crane, were installed in these guides to select the level of withdrawal from the reservoir. The shutter panels are attached to one another, in a configuration starting with the top shutter, in groups of three, two, and four.

Selective withdrawal capability on the Folsom Dam Urban Water Supply Pipeline became operational in 2003. The centerline to the 84-inch-diameter Urban Water Supply intake is at elevation 317 feet. An enclosure structure extending from just below the water supply intake to an elevation of 442 feet was attached to the upstream face of Folsom Dam. A telescoping control gate allows for selective withdrawal of water anywhere between 331 and 401 feet elevation under normal operations.

The current objectives for water temperatures in the Lower American River address the needs for steelhead incubation and rearing during the late spring and summer, and for fall–run Chinook spawning and incubation starting in late October or early November.

Establishing the start date requires a balancing between forecasted release rates, the volume of available cold water, and the estimated date at which time Folsom Reservoir turns over and becomes isothermic. Reclamation will work to provide suitable spawning temperatures as early as possible (after November 1) to help avoid temperature related pre-spawning mortality of adults and reduced egg viability. Operations will be balanced against the possibility of running out of cold water and increasing downstream temperatures after spawning is initiated and creating temperature related effects to eggs already in the gravel.

The cold water resources available in any given year at Folsom Lake needed to meet the stated water temperature goals are often insufficient. Only in wetter hydrologic conditions is the volume of cold water resources available sufficient to meet all the water temperature objectives. Therefore, significant operational tradeoffs and flexibilities are considered part of an annual planning process for coordinating an operation strategy that realistically manages the limited cold water resources available. Reclamation's coordination on the planning and management of cold water resources is done through the B2IT and ARG groups.

The management process begins in the spring as Folsom Reservoir fills. All penstock shutters are put in the down position to isolate the colder water in the reservoir below an elevation of 401 feet. The reservoir water surface elevation must be at least 25 feet higher than the sill of the upper shutter (426 feet) to avoid cavitation of the power turbines. The earliest this can occur is in the month of March, due to the need to maintain flood control space in the reservoir during the winter. The pattern of spring run-off is then a significant factor in determining the availability of cold water for later use. Folsom inflow temperatures begin to increase and the lake starts to stratify as early as April. By the time the reservoir is filled or reaches peak storage (sometime in the May through June period), the reservoir is highly stratified with surface waters too warm to meet downstream temperature objectives. There are, however, times during the filling process when use of the spillway gates can be used to conserve cold water.

In the spring of 2003, high inflows and encroachment into the allowable storage space for flood control required releases that exceeded the available capacity of the power plant. Under these conditions, standard operations of Folsom calls for the use of the river outlets that would draw

upon the cold water pool. Instead, Reclamation reviewed the release requirements, Safety of Dams issues, reservoir temperature conditions, and the benefits to the cold water pool and determined that it could use the spillway gates to make the incremental releases above powerplant capacity, thereby conserving cold water for later use. The ability to take similar actions (as needed in the future) will be evaluated on a case-by-case basis.

The annual temperature management strategy and challenge is to balance conservation of cold water for later use in the fall, with the more immediate needs of steelhead during the summer. The planning and forecasting process for the use of the cold water pool begins in the spring as Folsom Reservoir fills. Actual Folsom Reservoir cold water resource availability becomes significantly more defined through the assessment of reservoir water temperature profiles and more definite projections of inflows and storage. Technical modeling analysis begins in the spring for the projected Lower American River water temperature management plan. The significant variables and key assumptions in the analysis include:

- Starting reservoir temperature conditions
- Forecasted inflow and outflow quantities
- Assumed meteorological conditions
- Assumed inflow temperatures
- Assumed Urban Water Supply TCD operations

A series of shutter management scenarios are then incorporated into the model to gain a better understanding of the potential for meeting both summer steelhead and fall salmon temperature needs. Most annual strategies contain significant tradeoffs and risks for water temperature management for steelhead and fall–run salmon goals and needs due to the frequently limited cold water resource. The planning process continues throughout the summer. New temperature forecasts and operational strategies are updated as more information on actual operations and ambient conditions is gained. This process is shared with the ARG.

Meeting both the summer steelhead and fall salmon temperature objectives without negatively impacting other CVP project purposes requires the final shutter pull be reserved for use in the fall to provide suitable fall-run Chinook salmon spawning temperatures. In most years, the volume of cold water is not sufficient to support strict compliance with the summer temperature target at the downstream end of the compliance reach (Watt Avenue Bridge) while at the same time reserving the final shutter pull for salmon, or in some cases, continue to meet steelhead objectives later in the summer. A strategy that is used under these conditions is to allow the annual compliance location water temperatures to warm towards the upper end of the annual water temperature design value before making a shutter pull. This management flexibility is essential to the annual management strategy to extend the effectiveness of cold water management through the summer and fall months.

The Urban Water Supply TCD has provided additional flexibility to conserve cold water for later use. Initial studies are being conducted evaluating the impact of warmer water deliveries to the water treatment plants receiving the water. It is expected that the TCD will be operated during the summer months and deliver water that is slightly warmer than that which could be used to

meet downstream temperatures (60°F to 62°F), but not so warm as to cause significant treatment issues.

Water temperatures feeding the Nimbus Fish Hatchery were historically too high for hatchery operations during some dry or critical years. Temperatures in the Nimbus Hatchery are generally in the desirable range of 42°F to 55°F, except for the months of June, July, August, and September. When temperatures get above 60°F during these months, the hatchery must begin to treat the fish with chemicals to prevent disease. When temperatures reach the 60°F to 70°F range, treatment becomes difficult and conditions become increasingly dangerous for the fish. When temperatures climb into the 60°F to 70°F range, hatchery personnel with Reclamation to determine a compromise operation of the temperature shutter at Folsom Dam for the release of cooler water.

Reclamation operates Nimbus to maintain the health of the hatchery fish while minimizing the loss of the cold water pool for fish spawning in the river during fall. This is done on a case-by-case basis and is different in various months and year types. Temperatures above 70°F in the hatchery usually mean the fish need to be moved to another hatchery. The real time implementation of CVPIA AFRP objective flows and meeting SWRCB D-1641 Delta standards with the limited water resources of the Lower American River requires a significant coordination effort to manage the cold water resources at Folsom Lake. Reclamation consults with the Service, NMFS, and DFG through B2IT when these types of difficult decisions are needed. In addition, Reclamation communicates with ARG on real time data and operational trade offs.

A fish diversion weir at the hatchery blocks Chinook salmon from continuing upstream and guides them to the hatchery fish ladder entrance. The fish diversion weir consists of eight piers on 30-foot spacing, including two riverbank abutments. Fish rack support frames and walkways are installed each fall via an overhead cable system. A pipe rack is then put in place to support the pipe pickets (¾-inch steel rods spaced on 2½-inch centers). The pipe rack rests on a submerged steel I-beam support frame that extends between the piers and forms the upper support structure for a rock filled crib foundation. The rock foundation has deteriorated with age and is subject to annual scour which can leave holes in the foundation that allow fish to pass if left unattended.

Fish rack supports and pickets are installed around September 15, of each year and correspond with the beginning of the fall-run Chinook salmon spawning season. A release equal to or less than 1,500 cfs from Nimbus Dam is required for safety and to provide full access to the fish rack supports. It takes six people approximately three days to install the fish rack supports and pickets. In years after high winter flows have caused active scour of the rock foundation, a short period (less than eight hours) of lower flow (approximately 500 cfs) is needed to remove debris from the I-beam support frames, seat the pipe racks, and fill holes in the rock foundation. Compete installation can take up to seven days, but is generally completed in less time. The fish rack supports and pickets are usually removed at the end of fall-run Chinook salmon spawning season (mid-January) when flows are less than 2,000 cfs. If Nimbus Dam releases are expected to exceed 5,000 cfs during the operational period, the pipe pickets are removed until flows decrease.

Delta Division and West San Joaquin Division

CVP Facilities

The CVP's Delta Division includes the Delta Cross Channel (DCC), the Contra Costa Canal and Pumping Plants, Contra Loma Dam, Martinez Dam, the Jones Pumping Plant, the Tracy Fish Collection Facility (TFCF), and the Delta Mendota Canal (DMC). The DCC is a controlled diversion channel between the Sacramento River and Snodgrass Slough. The Contra Costa Water District (CCWD) diversion facilities use CVP water resources to serve district customers directly and to operate CCWD's Los Vaqueros Project. The Jones Pumping Plant diverts water from the Delta to the head of the DMC. See map in Figure P-8.

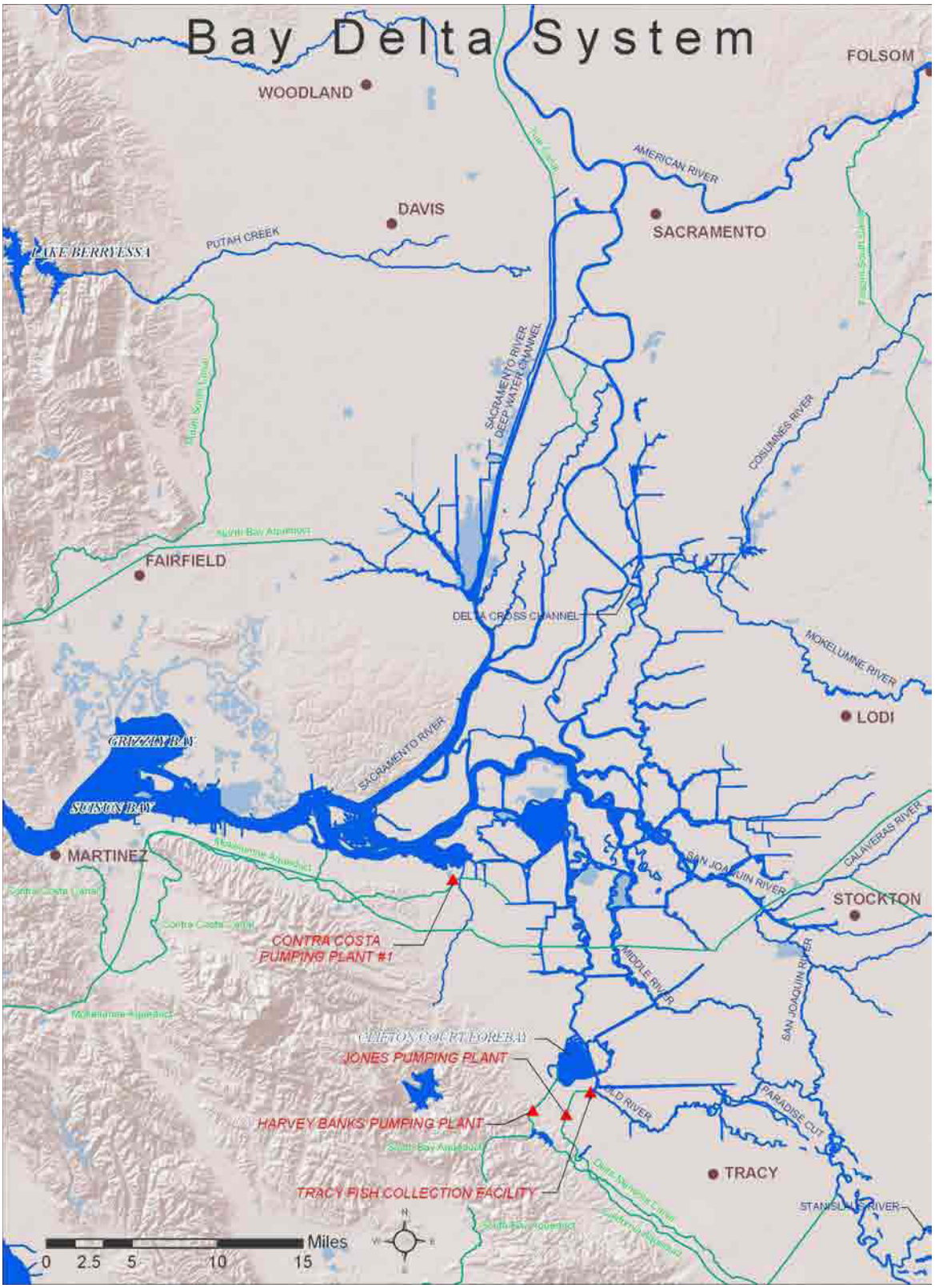

Figure P-8 Bay Delta System

Delta Cross Channel Operations

The DCC is a gated diversion channel in the Sacramento River near Walnut Grove and Snodgrass Slough. Flows into the DCC from the Sacramento River are controlled by two 60-foot by 30-foot radial gates. When the gates are open, water flows from the Sacramento River through the cross channel to channels of the lower Mokelumne and San Joaquin Rivers toward the interior Delta. The DCC operation improves water quality in the interior Delta by improving circulation patterns of good quality water from the Sacramento River towards Delta diversion facilities.

Reclamation operates the DCC in the open position to (1) improve the transfer of water from the Sacramento River to the export facilities at the Banks and Jones Pumping Plants, (2) improve water quality in the southern Delta, and (3) reduce salt water intrusion rates in the western Delta. During the late fall, winter, and spring, the gates are often periodically closed to protect out-migrating salmonids from entering the interior Delta. In addition, whenever flows in the Sacramento River at Sacramento reach 20,000 to 25,000 cfs (on a sustained basis) the gates are closed to reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates.

Flow rates through the gates are determined by Sacramento River stage and are not affected by export rates in the South Delta. The DCC also serves as a link between the Mokelumne River and the Sacramento River for small craft, and is used extensively by recreational boaters and fishermen whenever it is open.

SWRCB D-1641 DCC standards provide for closure of the DCC gates for fisheries protection at certain times of the year. From November through January, the DCC may be closed for up to 45 days for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days for fishery protection purposes during the May 21 through June 15 time period. Reclamation determines the timing and duration of the closures after discussion with the Service, DFG, and NMFS. These discussions will occur through WOMT.

WOMT typically relies on monitoring for fish presence and movement in the Sacramento River and Delta, the salvage of salmon at the Tracy and Skinner facilities, and hydrologic cues when considering the timing of DCC closures. However, the overriding factors are current water quality conditions in the interior and western Delta. From mid-June to November, Reclamation usually keeps the gates open on a continuous basis. The DCC is also usually opened for the busy recreational Memorial Day weekend, if this is possible from a fishery, water quality, and flow standpoint.

The Salmon Decision Process (as provided in the biological assessment) includes “Indicators of Sensitive Periods for Salmon” such as hydrologic changes, detection of spring-run salmon or spring-run salmon surrogates at monitoring sites or the salvage facilities, and turbidity increases at monitoring sites to trigger the Salmon Decision Process.

The Salmon Decision Process is used by NMFS, DFG, the Service and Reclamation to facilitate the often complex coordination issues surrounding DCC gate operations and the purposes of fishery protection closures, Delta water quality, and/or export reductions. Inputs such as fish lifestage and size development, current hydrologic events, fish indicators (such as the Knight’s

Landing Catch Index and Sacramento Catch Index), and salvage at the export facilities, as well as current and projected Delta water quality conditions, are used to determine potential DCC closures and/or export reductions.

Jones Pumping Plant

The CVP and SWP use the Sacramento River, San Joaquin River, and Delta channels to transport water to export pumping plants located in the South Delta. The CVP's Jones Pumping Plant, about five miles north of Tracy, consists of six available pumps. The Jones Pumping Plant is located at the end of an earth-lined intake channel about 2.5 miles in length. At the head of the intake channel, louver screens (that are part of the Tracy Fish Collection Facility) intercept fish, which are then collected, held, and transported by tanker truck to release sites far away from the pumping plants.

Jones Pumping Plant has a permitted diversion capacity of 4,600 cfs with maximum pumping rates typically ranging from 4500 to 4300 cfs during the peak of the irrigation season and approximately 4,200 cfs during the winter non-irrigation season until construction and full operation of the proposed DMC/California Aqueduct Intertie, described later in the project description. The winter-time constraints at the Jones Pumping Plant are the result of a DMC freeboard constriction near O'Neill Forebay, O'Neill Pumping Plant capacity, and the current water demand in the upper sections of the DMC.

Tracy Fish Collection Facility

The Tracy Fish Collection Facility (TFCF) is located in the south-west portion of the Sacramento-San Joaquin Delta and uses behavioral barriers consisting of primary and secondary louvers as illustrated in Figure P-9, to guide entrained fish into holding tanks before transport by truck to release sites within the Delta. The original design of the TFCF focused on smaller fish (<200 mm) that would have difficulty fighting the strong pumping plant induced flows since the intake is essentially open to the Delta and also impacted by tidal action.

Figure P-9 Tracy Fish Collection Facility Diagram

The primary louvers are located in the primary channel just downstream of the trashrack structure. The secondary louvers are located in the secondary channel just downstream of the traveling water screen. The louvers allow water to pass through onto the pumping plant but the openings between the slats are tight enough and angled against the flow of water such a way as to prevent most fish from passing between them and instead enter one of four bypass entrances along the louver arrays.

There are approximately 52 different species of fish entrained into the TFCF per year; however, the total numbers are significantly different for the various species salvaged. Also, it is difficult if not impossible to determine exactly how many safely make it all the way to the collection tanks awaiting transport back to the Delta. Hauling trucks used to transport salvaged fish to release sites inject oxygen in the tanks and contain an eight parts per thousand salt solution to reduce stress. The CVP uses two release sites, one on the Sacramento River near Horseshoe Bend and the other on the San Joaquin River immediately upstream of the Antioch Bridge. During a facility inspection a few years ago, TFCF personnel noticed significant decay of the transition boxes and conduits between the primary and secondary louvers. The temporary rehabilitation of these transition boxes and conduits was performed during the fall and winter of

2002. Extensive rehabilitation of the transition boxes and conduits was completed during the San Joaquin pulse period of 2004.

When South Delta hydraulic conditions allow, and within the original design criteria for the TFCF, the louvers are operated with the D-1485 and the following water velocities: for striped bass of approximately 1 foot per second (ft/s) from May 15 through October 31, and for salmon of approximately 3 ft/s from November 1 through May 14. Channel velocity criteria are a function of bypass ratios through the facility. Due to changes in South Delta hydrology over the past fifty years, the present-day TFCF is able to meet these conditions approximately 55 percent of the time.

Fish passing through the facility will be sampled at intervals of no less than 20 minutes every 2 hours when listed fish are present, generally December through June. When fish are not present, sampling intervals will be 10 minutes every 2 hours. Fish observed during sampling intervals are identified to species, measured to fork length, examined for marks or tags, and placed in the collection facilities for transport by tanker truck to the release sites in the North Delta away from the pumps. In addition, Reclamation will monitor for the presence of spent female delta smelt in anticipation of expanding the salvage operations to include sub 20 mm larval delta smelt detection.

Contra Costa Water District Diversion Facilities

CCWD diverts water from the Delta for irrigation and M&I uses under CVP contract, under its own permit and license at Mallard Slough, and under its own Los Vaqueros water right permit at Old River near State Route 4. CCWD's system includes intake facilities at Mallard Slough, Rock Slough, and Old River near State Route 4; the Contra Costa Canal and shortcut pipeline; and the Los Vaqueros Reservoir. CCWD will be adding a fourth diversion point on Victoria Canal (the Alternative Intake Project described below) to help meet its water quality goals. The Rock Slough intake facilities, the Contra Costa Canal, and the shortcut pipeline are owned by Reclamation, and operated and maintained by CCWD under contract with Reclamation. Mallard Slough Intake, Old River Intake, and Los Vaqueros Reservoir are owned and operated by CCWD.

The Mallard Slough Intake is located at the southern end of a 3,000-foot-long channel running due south from Suisun Bay, near Mallard Slough (across from Chipps Island). The Mallard Slough Pump Station was refurbished in 2002, which included constructing a positive barrier fish screen at this intake. The Mallard Slough Intake can pump up to 39.3 cfs. CCWD's permit issued by the SWRCB authorizes diversions of up to 26,780 acre-feet per year at Mallard Slough. However, this intake is rarely used due to the generally high salinity at this location. Pumping at the Mallard Slough Intake since 1993 has on average accounted for about 3 percent of CCWD's total diversions. When CCWD diverts water at the Mallard Slough Intake, CCWD reduces pumping of CVP water at its other intakes, primarily at the Rock Slough Intake.

The Rock Slough Intake is located about four miles southeast of Oakley, where water flows through a trash rack into the earth-lined portion of the Contra Costa Canal. This section of the canal is open to tidal influence and continues for four miles to Pumping Plant 1, which has capacity to pump up to 350 cfs into the concrete-lined portion of the canal. Prior to completion of the Los Vaqueros Project in 1997, this was CCWD's primary diversion point. Pumping Plant 1 is not screened. Reclamation, in collaboration with CCWD, is responsible for constructing a

fish screen as authorized by CVPIA and required by the 1993 Service biological opinion for the Los Vaqueros Project. Reclamation has received an extension on fish screen construction until December 2008, and is preparing to request a further extension until 2013 because the requirements for screen design will change when CCWD completes the Contra Costa Canal Replacement Project, which will replace the earth-lined section of canal from Rock Slough to Pumping Plant 1 with a pipeline. When completed, the Canal Replacement project will eliminate tidal flows into the Canal intake section and should significantly reduce entrainment impacts and improve the feasibility of screening Rock Slough. Typically, CCWD diverts about 17 percent of its total supply through the Rock Slough intake.

Construction of the Old River Intake was completed in 1997 as a part of the Los Vaqueros Project. The Old River Intake is located on Old River near State Route 4. It has a positive-barrier fish screen and a pumping capacity of 250 cfs, and can pump water via pipeline either to the Contra Costa Canal or to Los Vaqueros Reservoir. Pumping to storage in Los Vaqueros Reservoir is limited to 200 cfs by the terms of the Los Vaqueros Project biological opinions and by D-1629, the State Board water right decision for the Project. Typically, CCWD diverts about 80 percent of its total supply through the Old River Intake.

As described above, the first four miles of the Contra Costa Canal is earth-lined; after Pumping Plant 1, the Contra Costa Canal is concrete-lined and continues for 44 miles to its termination point in Martinez Reservoir. Pumping Plants 1 through 4 lift the water to an elevation of 127 feet. A blending facility just downstream of Pumping Plant 4 allows water from the Los Vaqueros Project pipeline and water from the Contra Costa Canal to mix to maintain CCWD's delivered water quality goals for salinity. Canal capacity is 350 cfs at this blending facility and decreases to 22 cfs at the terminus at Martinez Reservoir, which provides flow regulation. The Contra Loma Reservoir is connected to the Canal and provides flow regulation and emergency storage. Two short canals, Clayton Canal and Ygnacio Canal, are integrated into the distribution system. The Clayton Canal is no longer in service.

Los Vaqueros Reservoir is an off-stream reservoir with a capacity of 100 thousand acre-feet (TAF). Construction was completed and filling started in 1998 as part of the Los Vaqueros Project to improve delivered water quality and emergency storage reliability for CCWD's customers. Releases from Los Vaqueros Reservoir are conveyed to the Contra Costa Canal via a pipeline.

CCWD diverts approximately 127 TAF per year in total, of which approximately 110 TAF is CVP contract supply. In winter and spring months when the Delta is relatively fresh (generally January through July), demand is supplied by direct diversion from the Delta. In addition, when salinity is low enough, Los Vaqueros Reservoir is filled at a rate of up to 200 cfs from the Old River Intake. However, the biological opinions for the Los Vaqueros Project and the Alternative Intake Project, CCWD's memorandum of understanding with the DFG, and SWRCB D-1629 of the State Water Resources Control Board include fisheries protection measures consisting of a 75-day period during which CCWD does not fill Los Vaqueros Reservoir and a concurrent 30-day period during which CCWD halts all diversions from the Delta, provided that Los Vaqueros Reservoir storage is above emergency levels. The default dates for the no-fill and no-diversion periods are March 15 through May 31 and April 1 through April 30, respectively. The Service, NMFS and DFG can change these dates to best protect the subject species. During the no-diversion period, CCWD customer demand is met by releases from Los Vaqueros Reservoir.

In the late summer and fall months, CCWD releases water from Los Vaqueros Reservoir to blend with higher-salinity direct diversions from the Delta to meet CCWD water quality goals.

In addition to the existing 75-day no-fill period (March 15-May 31) and the concurrent no-diversion 30-day period , beginning in the February following the first operation of the Alternative Intake Project, CCWD shall not divert water to store in Los Vaqueros Reservoir for 15 days from February 14 through February 28, provided that reservoir storage is at or above 90 TAF on February 1; if reservoir storage is at or above 80 TAF on February 1 but below 90 TAF, CCWD shall not divert water to storage in Los Vaqueros Reservoir for 10 days from February 19 through February 28; if reservoir storage is at or above 70 TAF on Feb 1, but below 80 TAF CCWD shall not divert water to storage in Los Vaqueros Reservoir for 5 days from February 24 through February 28.

Water Demands—Delta Mendota Canal (DMC) and San Luis Unit

Water demands for the DMC and San Luis Unit are primarily composed of three separate types: CVP water service contractors, exchange contractors, and wildlife refuge contractors. A significantly different relationship exists between Reclamation and each of these three groups. Exchange contractors "exchanged" their senior rights to water in the San Joaquin River for a CVP water supply from the Delta. Reclamation thus guaranteed the exchange contractors a firm water supply of 840,000 AF per annum, with a maximum reduction under the Shasta critical year criteria to an annual water supply of 650,000 AF.

Conversely, water service contractors did not have water rights. Agricultural water service contractors also receive their supply from the Delta, but their supplies are subject to the availability of CVP water supplies that can be developed and reductions in contractual supply can exceed 25 percent. Wildlife refuge contractors provide water supplies to specific managed lands for wildlife purposes and the CVP contract water supply can be reduced under critically dry conditions up to 25 percent.

To achieve the best operation of the CVP, it is necessary to combine the contractual demands of these three types of contractors to achieve an overall pattern of requests for water. In most years sufficient supplies are not available to meet all water demands because of reductions in CVP water supplies which are due to restricted Delta pumping capability. In some dry or critically dry years, water deliveries are limited because there is insufficient storage in northern CVP reservoirs to meet all in-stream fishery objectives including water temperatures, and to make additional water deliveries via the Jones Pumping Plant. The scheduling of water demands, together with the scheduling of the releases of water supplies from the northern CVP to meet those demands, is a CVP operational objective that is intertwined with the Trinity, Sacramento, and American River operations.

East Side Division

New Melones Operations

The Stanislaus River originates in the western slopes of the Sierra Nevada and drains a watershed of approximately 900 square miles. The average unimpaired runoff in the basin is approximately 1.2 MAF per year; the median historical unimpaired runoff is 1.1 MAF per year. Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of April, May, and June. See map in Figure P-10.

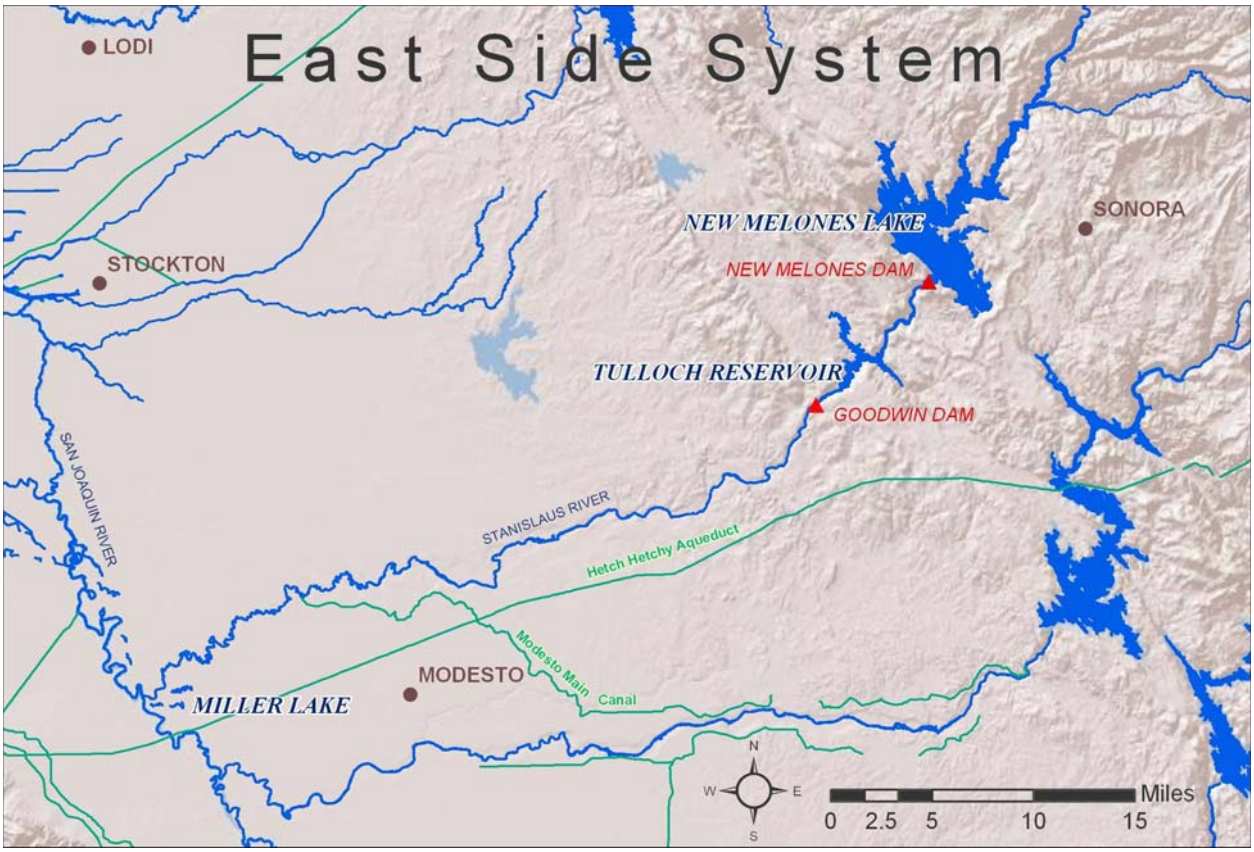

Figure P-10 East Side System

Currently, the flow in the lower Stanislaus River is primarily controlled by New Melones Reservoir, which has a storage capacity of about 2.4 MAF. The reservoir was completed by the Corps in 1978 and approved for filling in 1983. New Melones Reservoir is located approximately 60 miles upstream from the confluence of the Stanislaus River and the San Joaquin River and is operated by Reclamation. Congressional authorization for New Melones integrates New Melones Reservoir as a financial component of the CVP, but it is authorized to provide water supply benefits within the defined Stanislaus Basin per the 1980 ROD before additional water supplies can be used out of the defined Stanislaus Basin.

New Melones Reservoir is operated primarily for purposes of water supply, flood control, power generation, fishery enhancement, and water quality improvement in the lower San Joaquin River. The reservoir and river also provide recreation benefits. Flood control operations are conducted in conformance with the Corps' operational guidelines.

Another major water storage project in the Stanislaus River watershed is the Tri-Dam Project, a power generation project that consists of Donnells and Beardsley Dams, located upstream of New Melones Reservoir on the middle fork Stanislaus River, and Tulloch Dam and Powerplant, located approximately 6 miles downstream of New Melones Dam on the main stem Stanislaus River. New Spicer Reservoir on the north fork of the Stanislaus River has a storage capacity of 189,000 AF and is used for power generation.

Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. Under contractual agreements between Reclamation, the Oakdale Irrigation District (OID), and South San Joaquin Irrigation District (SSJID), Tulloch Reservoir provides afterbay storage to re-regulate power releases from New Melones Powerplant. The main water diversion point on the Stanislaus River is Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam.

Goodwin Dam, constructed by OID and SSJID in 1912, creates a re-regulating reservoir for releases from Tulloch Powerplant and provides for diversions to canals north and south of the Stanislaus River for delivery to OID and SSJID. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to the Central San Joaquin Water Conservation District and the Stockton East Water District.

Twenty ungaged tributaries contribute flow to the lower portion of the Stanislaus River, below Goodwin Dam. These streams provide intermittent flows, occurring primarily during the months of November through April. Agricultural return flows, as well as operational spills from irrigation canals receiving water from both the Stanislaus and Tuolumne Rivers, enter the lower portion of the Stanislaus River. In addition, a portion of the flow in the lower reach of the Stanislaus River originates from groundwater accretions.

Flood Control

The New Melones Reservoir flood control operation is coordinated with the operation of Tulloch Reservoir. The flood control objective is to maintain flood flows at the Orange Blossom Bridge at less than 8,000 cfs. When possible, however, releases from Tulloch Dam are maintained at levels that would not result in downstream flows in excess of 1,250 cfs to 1,500 cfs because of seepage problems in agricultural lands adjoining the river associated with flows above this level. Up to 450,000 AF of the 2.4 MAF storage volume in New Melones Reservoir is dedicated for flood control and 10,000 AF of Tulloch Reservoir storage is set aside for flood control. Based upon the flood control diagrams prepared by the Corps, part or all of the dedicated flood control storage may be used for conservation storage, depending on the time of year and the current flood hazard.

Requirements for New Melones Operations

The operating criteria for New Melones Reservoir are affected by (1) water rights, (2) in-stream fish and wildlife flow requirements (3) SWRCB D-1641 Vernalis water quality requirements, (4) dissolved oxygen (DO) requirements on the Stanislaus River, (5) SWRCB D-1641 Vernalis flow requirements, (6) CVP contracts, and (7) flood control considerations. Water released from New Melones Dam and Powerplant is re-regulated at Tulloch Reservoir and is either diverted at Goodwin Dam or released from Goodwin Dam to the lower Stanislaus River.

Flows in the lower Stanislaus River serve multiple purposes concurrently. The purposes include water supply for riparian water right holders, fishery management objectives, and DO requirements per SWRCB D-1422. In addition, water from the Stanislaus River enters the San Joaquin River where it contributes to flow and helps improve water quality conditions at Vernalis. Requirement D-1422, issued in 1973, provided the primary operational criteria for New Melones Reservoir and permitted Reclamation to appropriate water from the Stanislaus River for irrigation and M&I uses. D-1422 requires the operation of New Melones Reservoir

include releases for existing water rights, fish and wildlife enhancement, and the maintenance of water quality conditions on the Stanislaus and San Joaquin Rivers.

Water Rights Obligations

When Reclamation began operations of New Melones Reservoir in 1980, the obligations for releases (to meet downstream water rights) were defined in a 1972 Agreement and Stipulation among Reclamation, OID, and SSJID. The 1972 Agreement and Stipulation required Reclamation release annual inflows to New Melones Reservoir of up to 654,000 AF per year for diversion at Goodwin Dam by OID and SSJID, in recognition of their prior water rights. Actual historical diversions prior to 1972 varied considerably, depending upon hydrologic conditions. In addition to releases for diversion by OID and SSJID, water is released from New Melones Reservoir to satisfy riparian water rights totaling approximately 48,000 AF annually downstream of Goodwin Dam.

In 1988, following a year of low inflow to New Melones Reservoir, the Agreement and Stipulation among Reclamation, OID, and SSJID was superseded by an agreement that provided for conservation storage by OID and SSJID. The new agreement required Reclamation to release New Melones Reservoir inflows of up to 600,000 AF each year for diversion at Goodwin Dam by OID and SSJID.

In years when annual inflows to New Melones Reservoir are less than 600,000 AF, Reclamation provides all inflows plus one-third the difference between the inflow for that year and 600,000 AF per year. The 1988 Agreement and Stipulation created a conservation account in which the difference between the entitled quantity and the actual quantity diverted by OID and SSJID in a year may be stored in New Melones Reservoir for use in subsequent years. This conservation account has a maximum storage limit of 200,000 AF, and withdrawals are constrained by criteria in the agreement.

In-stream Flow Requirements

Under D-1422, Reclamation is required to release 98,000 AF of water per year, with a reduction to 69,000 AF in critical years, from New Melones Reservoir to the Stanislaus River on a distribution pattern to be specified each year by DFG for fish and wildlife purposes. In 1987, an agreement between Reclamation and DFG provided for increased releases from New Melones to enhance fishery resources for an interim period, during which habitat requirements were to be better defined and a study of Chinook salmon fisheries on the Stanislaus River would be completed.

During the study period, releases for in-stream flows would range from 98,300 to 302,100 AF per year. The exact quantity to be released each year was to be determined based on a formulation involving storage, projected inflows, projected water supply, water quality demands, projected CVP contractor demands, and target carryover storage. Because of dry hydrologic conditions during the 1987 to 1992 drought period, the ability to provide increased releases was limited. The Service published the results of a 1993 study, which recommended a minimum in-stream flow on the Stanislaus River of 155,700 AF per year for spawning and rearing.

Dissolved Oxygen Requirements

SWRCB D-1422 requires that water be released from New Melones Reservoir to maintain DO standards in the Stanislaus River. The 1995 revision to the WQCP established a minimum DO concentration of 7 milligrams per liter (mg/L), as measured on the Stanislaus River near Ripon. .

Vernalis Water Quality Requirement

SWRCB D-1422 also specifies that New Melones Reservoir must operate to maintain average monthly level total dissolved solids (TDS), commonly measured as a conversion from electrical conductivity, in the San Joaquin River at Vernalis as it enters the Delta. SWRCB D-1422 specifies an average monthly concentration of 500 parts per million (ppm) TDS for all months. Historically, releases were made from New Melones Reservoir for this standard, but due to shortages in water supply and high concentrations of TDS upstream of the confluence of the Stanislaus River, the D-1422 standard was not always met during the 1987-1992 drought. Reclamation has always met the D-1641 standard since 1995.

In the past, when sufficient supplies were not available to meet the water quality standards for the entire year, the emphasis for use of the available water was during the irrigation season, generally from April through September. SWRCB D-1641 modified the water quality objectives at Vernalis to include the irrigation and non-irrigation season objectives contained in the 1995 Bay-Delta WQCP. The revised standard is an average monthly electric conductivity 0.7 milliSiemens per centimeter (mS/cm) (approximately 455 ppm TDS) during the months of April through August, and 1.0 mS/cm (approximately 650 ppm TDS) during the months of September through March.

Bay-Delta Vernalis Flow Requirements

SWRCB D-1641 sets flow requirements on the San Joaquin River at Vernalis from February to June. These flows are commonly known as San Joaquin River base flows.

Table P-8 San Joaquin base flows-Vernalis

Water Year Class	February-June Flow (cfs)*
Critical	710-1140
Dry	1420-2280
Below Normal	1420-2280
Above Normal	2130-3420
Wet	2130-3420
*the higher flow required when X2 is required to be at or west of Chipps Island	

Since D-1641 has been in place, the San Joaquin base flow requirements have at times, been an additional demand on the New Melones water supply beyond that provided for in the Interim Plan of Operation (IPO).

CVP Contracts

Reclamation entered into water service contracts for the delivery of water from New Melones Reservoir, based on a 1980 hydrologic evaluation of the long-term availability of water in the

Stanislaus River Basin. Based on this study, Reclamation entered into a long-term water service contract for up to 49,000 AF per year of water annually (based on a firm water supply), and two long-term water service contracts totaling 106,000 AF per year (based on an interim water supply). Water deliveries under these contracts were not immediately available prior to 1992 for two reasons: 1) new diversion facilities were required to be constructed and prior to 1992 were not yet fully operational; and 2) water supplies were severely limited during the 1987 to 1992 drought.

New Melones Operations

Since 1997, the New Melones IPO has guided CVP operations on the Stanislaus River. The IPO was developed as a joint effort between Reclamation and the Service, in conjunction with the Stanislaus River Basin Stakeholders (SRBS). The process of developing the plan began in 1995 with a goal to develop a long-term management plan with clear operating criteria, given a fundamental recognition by all parties that New Melones Reservoir water supplies are over-committed on a long-term basis, and consequently, unable to meet all the potential beneficial uses designated as purposes. Reclamation will continue to use the interim plan.

The IPO defines categories of water supply based on storage and projected inflow. It then allocates annual water quantities for in-stream fishery enhancement (1987 DFG Agreement and CVPIA Section 3406(b)(2) management), SWRCB D-1641 San Joaquin River water quality requirements (Water Quality), SWRCB D-1641 Vernalis flow requirements (Bay-Delta), and use by CVP contractors.

Table P-9 Inflow characterization for the New Melones IPO

Annual water supply category	March-September forecasted inflow plus end of February storage (TAF)
Low	0 – 1400
Medium-low	1400 – 2000
Medium	2000 – 2500
Medium-high	2500 – 3000
High	3000 – 6000

Table P-10 New Melones IPO flow objectives (in thousand AF)

Storage plus inflow		Fishery		Vernalis water quality		Bay-Delta		CVP contractors	
From	To	From	To	From	To	From	To	From	To
1400	2000	98	125	70	80	0	0	0	0
2000	2500	125	345	80	175	0	0	0	59
2500	3000	345	467	175	250	75	75	90	90
3000	6000	467	467	250	250	75	75	90	90

When the water supply condition is determined to be in the "Low" IPO designation, the IPO proposes no operations guidance. In this case, Reclamation would meet with the SRBS group to coordinate a practical strategy to guide annual New Melones Reservoir operations under this very limited water supply condition. In addition, the IPO is limited in its ability to fully provide for the D-1641 Vernalis salinity and base flow objectives using Stanislaus River flows in all year types. If the Vernalis salinity standard cannot be met using the IPO designated Goodwin release pattern, then an additional volume of water is dedicated to meet the salinity standard. This permit obligation is met before an allocation is made to CVPIA (b)(2) uses or CVP Eastside contracts.

CVPIA Section 3406 (b)(2) releases from New Melones Reservoir consist of the portion of the fishery flow management volume utilized that is greater than the 1987 DFG Agreement and the volume used in meeting the Vernalis water quality requirements and/or Ripon dissolved oxygen requirements.

New Melones Reservoir – Future Operations

To provide a basis to develop a long-term operating plan, Reclamation sponsored updates to the San Joaquin River Basin component of CALSIM II to better represent and model how river flows and water quality in the San Joaquin River are likely to affect operations at New Melones Reservoir.

This new information and the resulting CALSIM II model improvements were peer reviewed in 2004 and additional refinements were made to the model based on that review. The resulting model is considered by Reclamation to be the best representation of the significant hydrologic and water quality dynamics that currently affect New Melones operations.

The relationships developed for the current model are significantly different than the assumptions used to develop the 1997 IPO. Given that the 1997 IPO was only meant to be a temporary management tool and that water quality conditions are changing in the basin, the fundamental operating assumptions of the 1997 IPO are not entirely consistent with the improved CALSIM II model.

As an important first step in evaluating the effects of a permanent operating plan for New Melones, Reclamation concludes that the following general assumptions best represents future New Melones operations for the purpose of this consultation. These operational parameters recognize existing priorities in beneficial uses, and the 1928 to 1934 drought is used as the basis to evaluate risks associated with successive dry years. The current analysis of future New Melones operations is based on two sets of project beneficial uses: a primary set of uses tied to pre-existing water rights and long-standing permit terms, and a secondary set of uses that came into effect after the primary set.

The operational parameters for allocation to Eastside Division water service contracts and CVPIA (b)(2) are based on available yield over the 1928-34 drought period. The available project quantity is allocated between water service contracts and CVPIA (b)(2) use.

Table P-11 Fundamental considerations used to define the New Melones Reservoir operations parameters.

CVP Beneficial Uses (Prior to 1992). The pre-1992 long-term beneficial uses for Reclamation's water supply/water rights at New Melones Reservoir are as follows:

- Existing OID/SSJID Settlement Contract
- D-1641 Vernalis Salinity Objective
- Stanislaus River Dissolved Oxygen
- 1987 DFG Fishery Agreement

CVP Beneficial Uses (After 1992). The beneficial uses for Reclamation's water supply/water rights at New Melones Reservoir established after 1992 are as follows:

- D-1641 Vernalis Feb-June Base Flow objective
- CVPIA (b)(2) water to increase Goodwin Dam releases for AFRP instream flow objectives
- CVP Eastside Division water services contracts

Basic Allocation Bands. Similar to the 1997 IPO, the representation of future New Melones operations defines categories of water supply based on projected storage and inflows.

1) High Allocation Years (Projected New Melones Carryover Storage greater than 1.7 MAF End of September)

- DFG allocation is 302 TAF
- Vernalis flow objectives are met
- CVPIA (b)(2) water allocation is 155 TAF
- CVP Eastside contract allocation is 155 TAF
- Vernalis Salinity and Stanislaus River DO objectives are met

2) Mid-Allocation Years

- DFG allocation is 98.3 TAF
- Vernalis flow objectives are met
- CVPIA B2 water allocation to meet instream fishery needs is to be determined in coordination with USFWS, DFG and NMFS in a collaborative planning process
- Vernalis Salinity and Stanislaus River DO objectives are met
- CVP Eastside contract allocation is to be determined after all the instream needs are met

3) "Conference Year" conditions - New Melones Index is less than 1.0 MAF.

- As with the IPO, if the projected end of September New Melones Index (i.e. projected inflow plus storage) is less than 1.0 MAF, Reclamation would meet with USFWS stakeholders, DFG, and NMFS to coordinate a practical strategy to guide New Melones Reservoir operations to meet the most basic needs associated with Stanislaus River instream flows, DO, and Vernalis salinity. Allocation for CVPIA (b)(2) flows would be determined in coordination with USFWS, DFG and NMFS.

San Joaquin River Agreement/Vernalis Adaptive Management Plan (VAMP)

Adopted by the SWRCB in D-1641, the San Joaquin River Agreement (SJRA) includes a 12-year program providing for flows and exports in the lower San Joaquin River during a 31-day pulse flow period during April and May. It also provides for the collection of experimental data during that time to further the understanding of the effects of flows, exports, and the barrier at the head of Old River on salmon survival. This experimental program is commonly referred to as the VAMP (Vernalis Adaptive Management Plan). The SWRCB indicates that VAMP experimental data will be used to create permanent objectives for the pulse flow period. Reclamation and DWR intend to continue a VAMP-like action for the foreseeable future or until the SWRCB adopts new permanent objectives that replace the current program. It is anticipated that new SWRCB objectives will be as protective as the current program and that such protections will remain in place through 2030.

Continuation of the VAMP operations for a period of time after the expiration of SJRA may be considered reasonably foreseeable because it could be accomplished using well established capabilities and authorities already available to Reclamation and DWR. Specifically, flow increases to achieve VAMP targets could be provided using CVPIA section 3406 (b)(1), (b)(2), and (b)(3). Export reductions would be provided by Reclamation using CVPIA section 3406 (b)(1) or (b)(2), and by DWR using the substitution of the water supply acquired from the Yuba Accord flows. The combination of those operations elements would enable Reclamation and DWR to meet VAMP objectives in most years. Chapter 9 of the biological assessment contains an analysis of the capability of DWR to provide for export reduction during the VAMP pulse flow period, using the 48,000 acre feet of substitute supply assumed to be available from the Yuba Accord.

Within the SJRA, the 1997 IPO has been assumed as the baseline operation for New Melones Reservoir, which forms part of the existing flow condition. The existing flow condition is used to compute the supplemental flows which will be provided on the San Joaquin River to meet the target flows for the 31-day pulse during April and May. These supplemental flows that will be provided from other sources in the San Joaquin River Basin under the control of the parties to the SJRA.

The parties to the SJRA include several agencies that contribute flow to the San Joaquin, divert from or store water on the tributaries to the San Joaquin, or have an element of control over the flows in the lower San Joaquin River. These include Reclamation; OID; SSJID; Modesto ID; Turlock ID; Merced ID; and the San Joaquin River Exchange Contractors. The VAMP is based on coordination among these participating agencies in carrying out their operations to meet a steady target flow objective at Vernalis.

The target flow at Vernalis for the spring pulse flow period is determined each year according to the specifications contained in the SJRA. The target flow is determined prior to the spring pulse flows as an increase above the existing flows, and so “adapts” to the prevailing hydrologic conditions. Possible target flows specified in the agreement are (1) 2000 cfs, (2) 3200 cfs, (3) 4450 cfs, (4) 5700 cfs, and (5) 7000 cfs.

The Hydrology Group of the SJRTC develops forecasts of flow at Vernalis, determines the appropriate target flow, devises an operations plan including flow schedules for each contributing agency, coordinates implementation of the VAMP flows, monitors conditions that may affect the objective of meeting the target flow, updates and adjusts the planned flow contributions as needed, and accounts for the flow contributions. The Hydrology Group includes designees with technical expertise from each agency that contributes water to the VAMP. During VAMP, the Hydrology group communicates via regular conference calls, shares current information and forecasts via e-mail and an internet website. The Hydrology group has two lead coordinators, one from Reclamation and one designated by the SJRG. Subsequent to the end of the VAMP, a group similar to the Hydrology Group, with the same or similar role, will be maintained as part of the ongoing coordination of operations in the San Joaquin River basin.

CVP-SWP operations forecasts include Vernalis flows that meet the appropriate pulse flow targets for the predicted hydrologic conditions. The flows in the San Joaquin River upstream of the Stanislaus River are forecasted for the assumed hydrologic conditions. The upstream of the Stanislaus River flows are then adjusted so when combined with the forecasted Stanislaus River flow based on the 1997 IPO, the combined flow would provide the appropriate Vernalis flows consistent with the pulse flow target identified in the SJRA. An analysis of how the flows are produced upstream of the Stanislaus River is included in the SJRA Environmental Impact Statement /Environmental Impact Report. For purposes of CVP/SWP operations forecasts, the VAMP target flows are simply assumed to exist at the confluence of the Stanislaus and San Joaquin Rivers. The assessment of the effects of CVP/SWP operations in the Delta begins downstream of that point.

The VAMP program has two distinct components, a flow objective and an export restriction. The flow objectives were designed to provide similar protection to those defined in the WQCP. Fishery releases on the Stanislaus above that called for in the 1987 DFG Agreement are typically considered WQCP (b)(2) releases. The export reduction involves a combined State and Federal pumping limitation on the Delta pumps. The combined export targets for the 31 days of VAMP are specified in the SJRA: 1500 cfs (when target flows are 2000, 3200, 4450, or 7000 cfs), and 2250 cfs (when target flow is 5700 cfs, or 3000 cfs [alternate export target when flow target is 7000 cfs]). Pumping reductions which cannot be recovered by adjustments in CVP operations are considered a WQCP (b)(2) expense. Reductions of SWP pumping are limited to the amount that can be recovered through operations adjustments and the export of up to 48 TAF of transferred water made available from the Yuba Accord.

Water Temperatures

Water temperatures in the lower Stanislaus River are affected by many factors and operational tradeoffs. These include available cold water resources in New Melones reservoir, Goodwin release rates for fishery flow management and water quality objectives, as well as residence time in Tulloch Reservoir, as affected by local irrigation demand.

Reclamation intends to plan and manage flows to meet a 65° F water temperature objective at Orange Blossom Bridge for steelhead incubation and rearing during the late spring and summer. However, during critically dry years and low reservoir storages this objective cannot be met. The Service, in coordination with NMFS and DFG, identifies the schedule for Reclamation to provide fall pulse attraction flows for salmon. The pulse flows are a combination of water

purchased under the San Joaquin River Agreement and CVPIA (b)(2) and (3) water. This movement of water also helps to transport cold water from New Melones Reservoir into Tulloch Reservoir before the spawning season begins.

San Felipe Division

Construction of the San Felipe Division of the CVP was authorized in 1967 (Figure P-11). The San Felipe Division provides a supplemental water supply (for irrigation, M&I uses) in the Santa Clara Valley in Santa Clara County, and the north portion of San Benito County.

The San Felipe Division delivers both irrigation and M&I water supplies. Water is delivered within the service areas not only by direct diversion from distribution systems, but also through in-stream and offstream groundwater recharge operations being carried out by local interests. A primary purpose of the San Felipe Division in Santa Clara County is to provide supplemental water to help prevent land surface subsidence in the Santa Clara Valley. The majority of the water supplied to Santa Clara County is used for M&I purposes, either pumped from the groundwater basin or delivered from treatment plants. In San Benito County, a distribution system was constructed to provide supplemental water to about 19,700 arable acres.

The facilities required to serve Santa Clara and San Benito counties include 54 miles of tunnels and conduits, two large pumping plants, and one reservoir. Water is conveyed from the Delta of the San Joaquin and Sacramento Rivers through the DMC. It is then pumped into the San Luis Reservoir and diverted through the 1.8-mile long of Pacheco Tunnel inlet to the Pacheco Pumping Plant. Twelve 2,000-horse-power pumps lift a maximum of 490 cfs a height varying from 85 feet to 300 feet to the 5.3-mile-long Pacheco Tunnel. The water then flows through the tunnel and without additional pumping, through 29 miles of concrete, high-pressure pipeline, varying in diameter from 10 feet to 8 feet, and the mile-long Santa Clara Tunnel. In Santa Clara County, the pipeline terminates at the Coyote Pumping Plant, which is capable of pumping water to into Anderson Reservoir or Calero Reservoir for further distribution at treatment plants or groundwater recharge.

Santa Clara Valley Water District is the non-Federal operating entity for all the San Felipe Division facilities except for the Hollister Conduit and San Justo Reservoir. The San Benito County Water District operates San Justo Reservoir and the Hollister Conduit

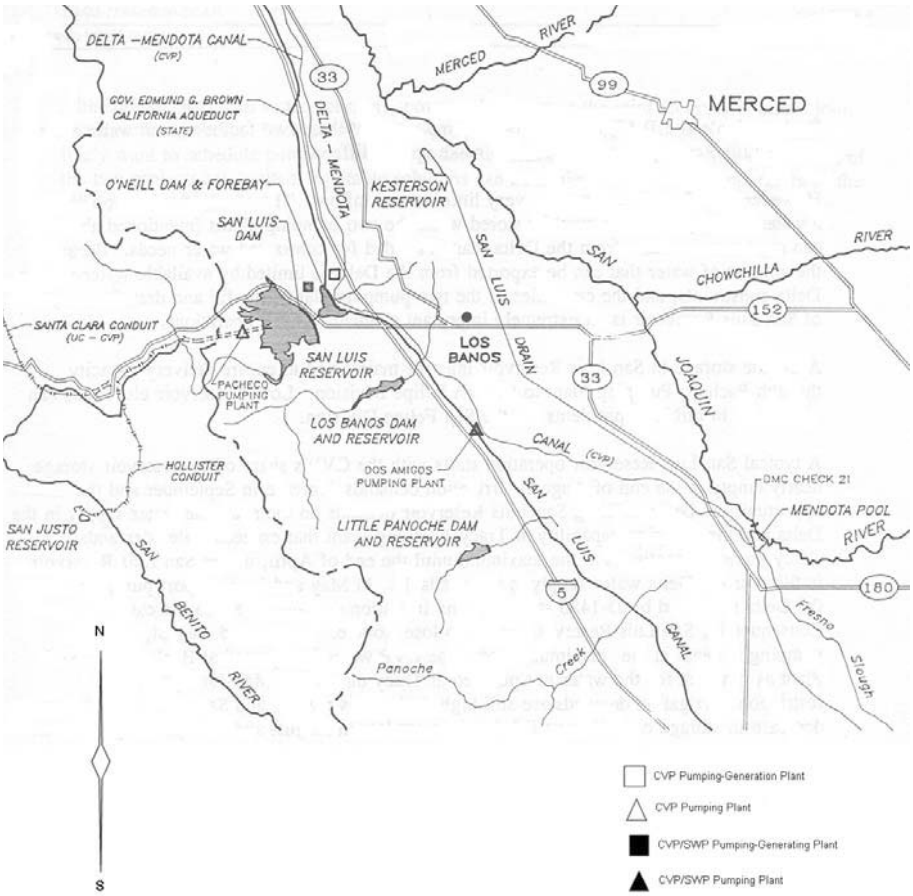

Figure P-11 West San Joaquin Division and San Felipe Division

The Hollister Conduit branches off the Pacheco Conduit 8 miles from the outlet of the Pacheco Tunnel. This 19.1-mile-long high-pressure pipeline, with a maximum capacity of 83 cfs, terminates at the San Justo Reservoir.

The 9,906 AF capacity San Justo Reservoir is located about three miles southwest of the City of Hollister. The San Justo Dam is an earthfill structure 141 feet high with a crest length of 722 feet. This project includes a dike structure 66 feet high with a crest length of 918 feet. This reservoir regulates San Benito County's import water supplies, allows pressure deliveries to some of the agricultural lands in the service area, and provides storage for peaking of agricultural water.

Friant Division

This division operates separately from the rest of the CVP and is not integrated into the CVP OCAP. Friant Dam is located on the San Joaquin River, 25 miles northeast of Fresno where the San Joaquin River exits the Sierra foothills and enters the valley. The drainage basin is 1,676 square miles with an average annual runoff of 1,774,000 AF. Completed in 1942, the dam is a concrete gravity structure, 319-feet high, with a crest length of 3,488 feet. Although the dam was completed in 1942, it was not placed into full operation until 1951.

The dam provides flood control on the San Joaquin River, provides downstream releases to meet senior water rights requirements above Mendota Pool, and provides conservation storage as well as diversion into Madera and Friant-Kern Canals. Water is delivered to a million acres of agricultural land in Fresno, Kern, Madera, and Tulare counties in the San Joaquin Valley via the Friant-Kern Canal south into Tulare Lake Basin and via the Madera Canal northerly to Madera and Chowchilla IDs. A minimum of 5 cfs is required to pass the last water right holding located about 40 miles downstream near Gravelly Ford.

Flood control storage space in Millerton Lake is based on a complex formula, which considers upstream storage in the Southern California Edison reservoirs. The reservoir, Millerton Lake, first stored water on February 21, 1944. It has a total capacity of 520,528 AF, a surface area of 4,900 acres, and is approximately 15-miles long. The lake's 45 miles of shoreline varies from gentle slopes near the dam to steep canyon walls farther inland. The reservoir provides boating, fishing, picnicking, and swimming.

At this time, the Friant Division is generally hydrologically disconnected from the Delta as the San Joaquin River is dewatered in two reaches between Friant Dam and the confluence of the Merced River, except in extremely wet years. Under flood conditions, water is diverted into two bypass channels that carry flood flows to the confluence of the Merced River.

In 2006, parties to NRDC v. Rodgers executed a stipulation of settlement that calls for, among other things, restoration of flows from Friant Dam to the confluence of the Merced River. Implementation of the settlement is not included in this consultation as it is a large project which has not been sufficiently developed to allow for analysis of the effects of implementation of settlement action on listed aquatic species at this time. At some point in the future, consultation may need to be reinitiated to evaluate the effects of the Restoration Program on continued CVP and SWP operations.

State Water Project

The DWR holds contracts with 29 public agencies in Northern, Central and Southern California for water supplies from the SWP. Water stored in the Oroville facilities, along with excess water available in the Sacramento-San Joaquin Delta is captured in the Delta and conveyed through several facilities to SWP contractors.

The SWP is operated to provide flood control and water for agricultural, municipal, industrial, recreational, and environmental purposes. Water is conserved in Oroville Reservoir and released to serve three Feather River area contractors and two contractors served from the North Bay Aqueduct, and to be pumped at the Harvey O. Banks Pumping Plant (Banks) in the Delta and delivered to the remaining 24 contractors in the SWP service areas south of the Delta. In addition to pumping water released from Oroville Reservoir, the Banks pumps water from other sources entering the Delta.

Project Management Objectives

Clifton Court Forebay

Inflows to Clifton Court Forebay (CCF) are controlled by radial gates, whose real-time operations are constrained by a scouring limit (i.e. 12,000 cfs) at the gates and by water level concerns in the South Delta for local agricultural diverters. An interim agreement between DWR and South Delta Water Agency specifies three modes, or "priorities" for CCF gate operation. Of the three priorities, Priority 1 is the most protective of South Delta water levels. Under Priority 1, CCF gates are only opened during the ebb tides, allowing the flood tides to replenish South Delta channels. Priority 2 is slightly less protective because the CCF gates may be open as in Priority 1, but also during the last hour of the higher flood tide and through most of the lower flood tide. Finally, Priority 3 requires that the CCF gates be closed during the rising limb of the higher flood tide and also during the lowest part of the lower tide, but permits the CCF gates to be open at all other times.

When a large head differential exists between the outside and the inside of the gates, theoretical inflow can be as high as 15,000 cfs for a very short time. However, existing operating procedures identify a maximum design flow rate of 12,000 cfs, to minimize water velocities in surrounding South Delta channels, to control erosion, and to prevent damage to the facility.

The SWP is managed to maximize the capture of water in the Delta and the usable supply released to the Delta from Oroville storage. The maximum daily pumping rate at Banks is controlled by a combination of the D-1641, the real-time decision making to assist in fishery management process described previously, and permits issued by the Corps that regulate the rate of diversion of water into Clifton Court Forebay (CCF) for pumping at Banks. This diversion rate is normally restricted to 6,680 cfs as a three-day average inflow to CCF and 6,993 cfs as a one-day average inflow to CCF. CCF diversions may be greater than these rates between December 15 and March 15, when the inflow into CCF may be augmented by one-third of the San Joaquin River flow at Vernalis when those flows are equal to or greater than 1,000 cfs. Additionally, the SWP has a permit to export an additional 500 cfs between July 1 and September 30 (further details on this pumping are found later in the Project Description). The purpose for the current permitted action is to replace pumping foregone for the benefit of Delta fish species, making the summer limit effectively 7,180 cfs.

The hourly operation of the CCF radial gates is governed by agreements with local agricultural interests to protect water levels in the South Delta area. The radial gates controlling inflow to the forebay may be open during any period of the tidal cycle with the exception of the two hours before and after the low-low tide and the hours leading up to the high-high tide each day. CCF gate operations are governed by agreements and response plans to protect South Delta water users, and a more detailed discussion of these operations and agreement will follow under CCF and JPOD sections.

Banks is operated to minimize the impact to power loads on the California electrical grid to the extent practical, using CCF as a holding reservoir to allow that flexibility. Generally more pump units are operated during off-peak periods and fewer during peak periods. Because the installed capacity of the pumping plant is 10,300 cfs, the plant can be operated to reduce power grid

impacts, by running all available pumps at night and a reduced number during the higher energy demand hours, even when CCF is admitting the maximum permitted inflow.

There are years (primarily wetter years) when Banks operations are demand limited, and Banks is able to pump enough water from the Delta to fill San Luis Reservoir and meet all contractor demands without maximizing its pumping capability every day of the year. This has been less likely in recent years, where the contractors request all or nearly all of their contract Table A amount every year. Consequently, current Banks operations are more often supply limited. Under these current full demand conditions, Banks pumping plant is almost always operated to the maximum extent possible to maximize the water captured, subject to the limitations of water quality, Delta standards, and a host of other variables, until all needs are satisfied and all storage south of the Delta is full.

San Luis Reservoir is an offstream storage facility located along the California Aqueduct downstream of Banks. San Luis Reservoir is used by both projects to augment deliveries to their contractors during periods when Delta pumping is insufficient to meet downstream demands.

San Luis Reservoir operates like a giant regulator on the SWP system, accepting any water pumped from Banks that exceeds contractor demands, then releasing that water back to the aqueduct system when Banks pumping is insufficient to meet demands. The reservoir allows the SWP to meet peak-season demands that are seldom balanced by Banks pumping.

San Luis Reservoir is generally filled in the spring or even earlier in some years. When it and other SWP storage facilities south of the Delta are full or nearly so, when Banks pumping is meeting all current Table A demands, and when the Delta is in excess conditions, DWR will use any available excess pumping capacity at Banks to deliver Article 21 water to the SWP contractors.

Article 21 water is one of several types of SWP water supply made available to the SWP contractors under the long-term SWP water supply contracts between DWR and the SWP contractors. As its name implies, Article 21 water is provided for under Article 21 of the contracts[3]. Unlike Table A water, which is an allocated annual supply made available for scheduled delivery throughout the year, Article 21 water is an interruptible water supply made available only when certain conditions exist. As with all SWP water, Article 21 water is supplied under existing SWP water rights permits, and is pumped from the Delta under the same environmental, regulatory, and operational constraints that apply to all SWP supplies.

When Article 21 water is available, DWR may only offer it for a short time, and the offer may be discontinued when the necessary conditions no longer exist. Article 21 deliveries are in addition to scheduled Table A deliveries; this supply is delivered to contractors that can, on relatively short notice, put it to beneficial use. Typically, contractors have used Article 21 water to meet

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[3]Article 21 provides, in part: "Each year from water sources available to the project, the State shall make available and allocate interruptible water to contactors. Allocations of interruptible water in any one year may not be carried over for delivery in a subsequent year, nor shall the delivery of water in any year impact a contractor's approved deliveries of annual [Table A water] or the contractor's allocation of water for the next year. Deliveries of interruptible water in excess of a contractor's annual [Table A water] may be made if the deliveries do not adversely affect the State's delivery of annual [Table A water] to other contractors or adversely affect project operations…"

needs such as additional short-term irrigation demands, replenishment of local groundwater basins, and storage in local surface reservoirs, all of which provide contractors with opportunities for better water management through more efficient coordination with their local water supplies. When Article 21 of the long-term water supply contracts was developed, both DWR and the contractors recognized that DWR was not capable of meeting the full contract demands in all years because not all of the planned SWP facilities had been constructed.

Article 21 water is typically offered to contractors on a short-term (daily or weekly) basis when all of the following conditions exist: the SWP share[4] of San Luis Reservoir is physically full, or projected to be physically full within approximately one week at permitted pumping rates; other SWP reservoirs south of the Delta are at their storage targets or the conveyance capacity to fill these reservoirs is maximized; the Delta is in excess condition; current Table A demand is being fully met; and Banks has export capacity beyond that which is needed to meet current Table A and other SWP operational demands. The increment of available unused Banks capacity is offered as the Article 21 delivery capacity. Contractors then indicate their desired rate of delivery of Article 21 water. It is allocated in proportion to their Table A contractual quantities if requests exceed the amount offered. Deliveries can be discontinued at any time, when any of the above factors change. In the modeling for Article 21, deliveries are only made in months when the State share of San Luis Reservoir is full. In actual operations, Article 21 may be offered a few days in advance of actual filling. Article 21 water will not be offered until State storage in San Luis Reservoir is either physically full or projected to be physically full within approximately one week at permitted pumping rates. Also, any carried-over EWA water asset stored in the State share of San Luis Reservoir (whether it be from the use of the 500 cfs or other operational assets) will not be considered part of the SWP storage when determining the availability of Article 21. This will ensure that the carried-over EWA water asset does not result in increased Article 21 deliveries.

During parts of April and May, the VAMP takes effect as described in the CVP section above. The state and federal pumps reduce their export pumping to benefit fish in the San Joaquin River system. Around this same time, water demands from both agricultural and M&I contractors are increasing, Article 21 water is usually discontinued, and San Luis supplies are released to the SWP facilities to supplement Delta pumping at Banks, thereby meeting contractor demands. The SWP intends to continue VAMP-type export reductions through 2030 to the extent that the limited EWA assets, (as described in an earlier section) will meet the associated water costs. Chapter 9 of the biological assessment includes an analysis of modeling results that illustrates the frequency on which assets are available under a limited EWA to meet the SWP portion of VAMP.

Immediately following VAMP, a "post –VAMP shoulder" may occur. This action is an extension of the reduced pumping levels that occur during VAMP depending on the availability of EWA and limited EWA assets. Chapter 9 includes an analysis of modeling results that illustrates the frequency on which assets are available under a limited EWA to meet the "post – VAMP shoulder".

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[4] Not including any carried-over EWA or limited EWA asset which may reside in the SWP share of San Luis Reservoir.

After VAMP and the "post-VAMP shoulder", Delta pumping at Banks can be increased depending on Delta inflow and Delta standards. By late May, demands usually exceed the restored pumping rate at Banks, and continued releases from San Luis Reservoir are needed to meet contractor demands for Table A water.

During this summer period, DWR is also releasing water from Oroville Reservoir to supplement Delta inflow and allow Banks to export the stored Oroville water to help meet demand. These releases are scheduled to maximize export capability and gain maximum benefit from the stored water while meeting fish flow requirements, temperature requirements, Delta water quality, and all other applicable standards in the Feather River and the Delta.

DWR must balance storage between Oroville and San Luis Reservoirs carefully to meet flood control requirements, Delta water quality and flow requirements, and optimize the supplies to its contractors consistent with all environmental constraints. Oroville Reservoir may be operated to move water through the Delta to San Luis Reservoir via Banks under different schedules depending on Delta conditions, reservoir storage volumes, and storage targets. Predicting those operational differences is difficult, as the decisions reflect operator judgment based on many real-time factors as to when to move water from Oroville Reservoir to San Luis Reservoir.

As San Luis Reservoir is drawn down to meet contractor demands, it usually reaches its low point in late August or early September. From September through early October, demand for deliveries usually drops below the ability of Banks to divert from the Delta, and the difference in Banks pumping is then added to San Luis Reservoir, reversing its spring and summer decline. From early October until the first major storms in late fall or winter unregulated flow continues to decline and releases from Lake Oroville are restricted (due to flow stability agreements with DFG) resulting in export rates at Banks that are somewhat less than demand typically causing a second seasonal decrease in the SWP's share of San Luis Reservoir. Once the fall and winter storms increase runoff into the Delta, Banks can increase its pumping rate and eventually fill (in all but the driest years) the state portion of San Luis Reservoir before April of the following year.

Water Service Contracts, Allocations, and Deliveries

The following discussion presents the practices of DWR in determining the overall amount of Table A water that can be allocated and the allocation process itself. There are many variables that control how much water the SWP can capture and provide to its contractors for beneficial use.

The allocations are developed from analysis of a broad range of variables that include:

- Volume of water stored in Oroville Reservoir
- Flood operation restrictions at Oroville Reservoir
- End-of-water-year (September 30) target for water stored in Oroville Reservoir
- Volume of water stored in San Luis Reservoir
- End-of-month targets for water stored in San Luis Reservoir
- Snow survey results

- Forecasted runoff
- Feather River flow requirements for fish habitat
- Feather River service area delivery obligations
- Feather River flow for senior water rights river diversions
- Anticipated depletions in the Sacramento River basin
- Anticipated Delta conditions
- Precipitation and streamflow conditions since the last snow surveys and forecasts
- Contractor delivery requests and delivery patterns

From these and other variables, the Operations Control Office within DWR estimates the water supply available to allocate to contractors and meet other project needs. The Operations Control Office transmits these estimates to the State Water Project Analysis Office, where staff enters the water supply, contractor requests, and Table A amounts into a spreadsheet and computes the allocation percentage that would be provided by the available water supply.

The staffs of the Operations Control Office and State Water Project Analysis Office meet with DWR senior management, usually including the Director, to make the final decision on allocating water to the contractors. The decision is made, and announced in a press release followed by Notices to Contractors.

The initial allocation announcement is made by December 1 of each year. The allocation of water is made with a conservative assumption of future precipitation, and generally in graduated steps, carefully avoiding over-allocating water before the hydrologic conditions are well defined for the year.

Both the DWR and the contractors are conservative in their estimates, leading to the potential for significant variations between projections and actual operations, especially under wet hydrologic conditions.

Other influences affect the accuracy of estimates of annual demand for Table A and the resulting allocation percentage. One factor is the contractual ability of SWP contractors to carry over allocated but undelivered Table A from one year to the next if space is available in San Luis Reservoir. Contractors will generally use their carryover supplies early in the calendar year if it appears that San Luis reservoir will fill. By using the prior year's carryover, the contractors reduce their delivery requests for the current year's Table A allocation and instead schedule delivery of carryover supplies.

Carryover supplies left in San Luis Reservoir by SWP contractors may result in higher storage levels in San Luis Reservoir at December 31 than would have occurred in the absence of carryover. If there were no carryover privilege, contractors would seek to store the water within their service areas or in other storage facilities outside of their service areas. As project pumping fills San Luis Reservoir, the contractors are notified to take or lose their carryover supplies. If

they can take delivery of and use or store the carryover water, San Luis Reservoir storage then returns to the level that would have prevailed absent the carryover program.

If the contractors are unable to take delivery of all of their carryover water, that water then converts to project water as San Luis Reservoir fills, and Article 21 water becomes available for delivery to contractors.

Article 21 water delivered early in the calendar year may be reclassified as Table A later in the year depending on final allocations, hydrology, and contractor requests. Such reclassification does not affect the amount of water carried over in San Luis Reservoir, nor does it alter pumping volumes or schedules. The total water exported from the Delta and delivered by the SWP in any year is a function of a number of variables that is greater than the list of variables shown above that help determine Table A allocations.

If there are no carryover or Article 21 supplies available, Table A requests will be greater in the January-April period, and there would be a higher percentage allocation of Table A for the year than if carryover and Article 21 were available to meet demand.

Monterey Agreement

In 1994, DWR and certain representatives of the SWP contractors agreed to a set of principles known as the Monterey Agreement, to settle long-term water allocation disputes, and to establish a new water management strategy for the SWP. This project description only includes the system-wide water operations consistent with the Monterey Agreement and not the specific actions by DWR and State Water Contractors needed to implement the agreement.

The Monterey Agreement resulted in 27 of the 29 SWP contractors signing amendments to their long-term water supply contracts in 1995, and the Monterey Amendment has been implemented as part of SWP operations for these 27 SWP contractors since 1996. The original Environmental Impact Report prepared for the Monterey Agreement was challenged, and the EIR was required to be decertified. DWR is currently preparing an EIR on the Monterey Amendment following that litigation and approval of a settlement agreement with the plaintiffs in May 2003. A draft of the new EIR was released in October 2007, the comment period closed in January 2008, and a final EIR is scheduled for completion in the fall of 2008.

The alternatives evaluated in the EIR include continuation of the Monterey Amendment, certain No Project alternatives that would revert some contract terms to pre-Monterey Amendment terms, and two “court ordered no-project” alternatives that would impose a reduction in Table A supplies by implementing a permanent shortage provision together with an offsetting increase in the supply of Article 21 water.

Adoption of any of the alternatives would not measurably change SWP Delta operations, although the internal classification of water provided to SWP contractors could change as to the balance between Table A and Article 21 water, as could the relative allocation of water between urban and agricultural contractors. The Monterey Amendment provides for certain transfers of water from agricultural to urban contractors; impacts from those transfers are all south of the Delta and have no effect on the Delta.

The only impact of Monterey Amendment operations on Delta exports is identified in the draft EIR as the facilitation of approval for out-of-service-area storage programs. Because DWR had

previously approved water storage programs outside of individual SWP contractor's service areas and many such storage programs now exist, this water management method is unlikely to be voided by future actions of DWR. These increased exports can only occur if they are within the diversions permitted at the time. None of the alternatives being considered would result in demand for added Delta diversions above currently assumed levels and all are subject to whatever regulatory restrictions are in force at the time.

Changes in DWR's Allocation of Table A Water and Article 21 Water

The Monterey Amendment revised the temporary shortage provision that specified an initial reduction of supplies for agricultural use when requests for SWP water exceeded the available supply. The Amendment specifies that whenever the supply of Table A water is less than the total of all contractors' requests, the available supply of Table A water is allocated among all contractors in proportion to each contractor's annual Table A amount.

The Monterey Amendment amended Article 21 by eliminating the category of scheduled "surplus water," which was available for scheduled delivery and by renaming "unscheduled water" to "interruptible water." Surplus water was scheduled water made available to the contractors when DWR had supplies beyond what was needed to meet Table A deliveries, reservoir storage targets, and Delta regulatory requirements. Surplus water and unscheduled water were made available first to contractors requesting it for agricultural use or for groundwater replenishment. Because of the contractors' increasing demands for Table A water and the increasing regulatory requirements imposed on SWP operations, DWR is now able to supply water that is not Table A water only on an unscheduled, i.e., interruptible basis.

Pursuant to the revised Article 21, DWR allocates the available interruptible supply to requesting contractors in proportion to their annual Table A amounts.

The result of these contractual changes are that DWR now allocates Table A and interruptible water among contractors in proportion to annual Table A amounts without consideration of whether the water would be used for M&I or agricultural purposes. Agricultural and M&I contractors share any reductions in deliveries or opportunities for surplus water in proportion to their annual Table A amounts.

Historical Water Deliveries to Southern California

The pumping from the Delta to serve southern California has been influenced by changes in available water supply sources to serve the region. The Colorado River and the SWP have been the major supply sources for southern California.

The Quantification Settlement Agreement (QSA) signed in 2003 resulted in a decrease in the amount of Colorado River water available to California. To illustrate the impact of that decrease on demand from the Sacramento-San Joaquin Delta, it is instructive to look at the magnitude of the two imported supply sources available to MWDSC.

During part of this period, MWDSC was also filling Diamond Valley Lake (810,000 acre-feet, late 1998-early 2002) and adding some water to groundwater storage programs. In wetter years, demand for imported water may often decrease because local sources are augmented and local rainfall reduces irrigation demand. Table P-12 below illustrates the effects of the wet years from

1995-1998 on demand for imported water and the effect of reduced Colorado River diversions under the QSA on MWDSC deliveries from the Delta.

Table P-12 Wet Year effects

Calendar Year	Sacramento Valley Water Year Type	Delta Supplies	Colorado Supplies	Total
1994	Critically Dry	807,866	1,303,212	2,111,078
1995	Wet	436,042	997,414	1,433,456
1996	Wet	593,380	1,230,353	1,823,733
1997	Wet	721,810	1,241,821	1,963,631
1998	Wet	410,065	1,073,125	1,483,190
1999	Wet	852,617	1,215,224	2,067,841
2000	Above Normal	1,541,816	1,303,148	2,844,964
2001	Dry	1,023,169	1,253,579	2,276,748
2002	Dry	1,408,919	1,241,088	2,650,007
2003	Above Normal	1,686,973	688,043	2,375,016
2004	Below Normal	1,724,380	733,095	2,457,475
2005	Above Normal	1,616,710	839,704	2,456,414
2006	Wet	1,521,681*	594,544	2,116,225
2007	Dry	1,395,827*	713,456*	2,109,283

* - These figures are preliminary.

Project Facilities

Oroville Field Division

Oroville Dam and related facilities comprise a multipurpose project. The reservoir stores winter and spring runoff, which is released into the Feather River to meet the Project's needs. It also provides pumpback capability to allow for on-peak electrical generation, 750,000 acre-feet of flood control storage, recreation, and freshwater releases to control salinity intrusion in the Sacramento-San Joaquin Delta and for fish and wildlife protection.

The Oroville facilities are shown in Figure P-12. Two small embankments, Bidwell Canyon and Parish Camp Saddle Dams, complement Oroville Dam in containing Lake Oroville. The lake has a surface area of 15,858 acres, a storage capacity of 3,538,000 AF, and is fed by the North, Middle, and South forks of the Feather River. Average annual unimpaired runoff into the lake is about 4.5 million AF.

A maximum of 17,000 cfs can be released through the Edward Hyatt Powerplant, located underground near the left abutment of Oroville Dam. Three of the six units are conventional

generators driven by vertical-shaft, Francis-type turbines. The other three are motor-generators coupled to Francis-type, reversible pump turbines. The latter units allow pumped storage operations. The intake structure has an overflow type shutter system that determines the level from which water is drawn.

Approximately four miles downstream of Oroville Dam and Edward Hyatt Powerplant is the Thermalito Diversion Dam. Thermalito Diversion Dam consists of a 625-foot-long, concrete gravity section with a regulated ogee spillway that releases water to the low flow channel of the Feather River. On the right abutment is the Thermalito Power Canal regulating headwork structure.

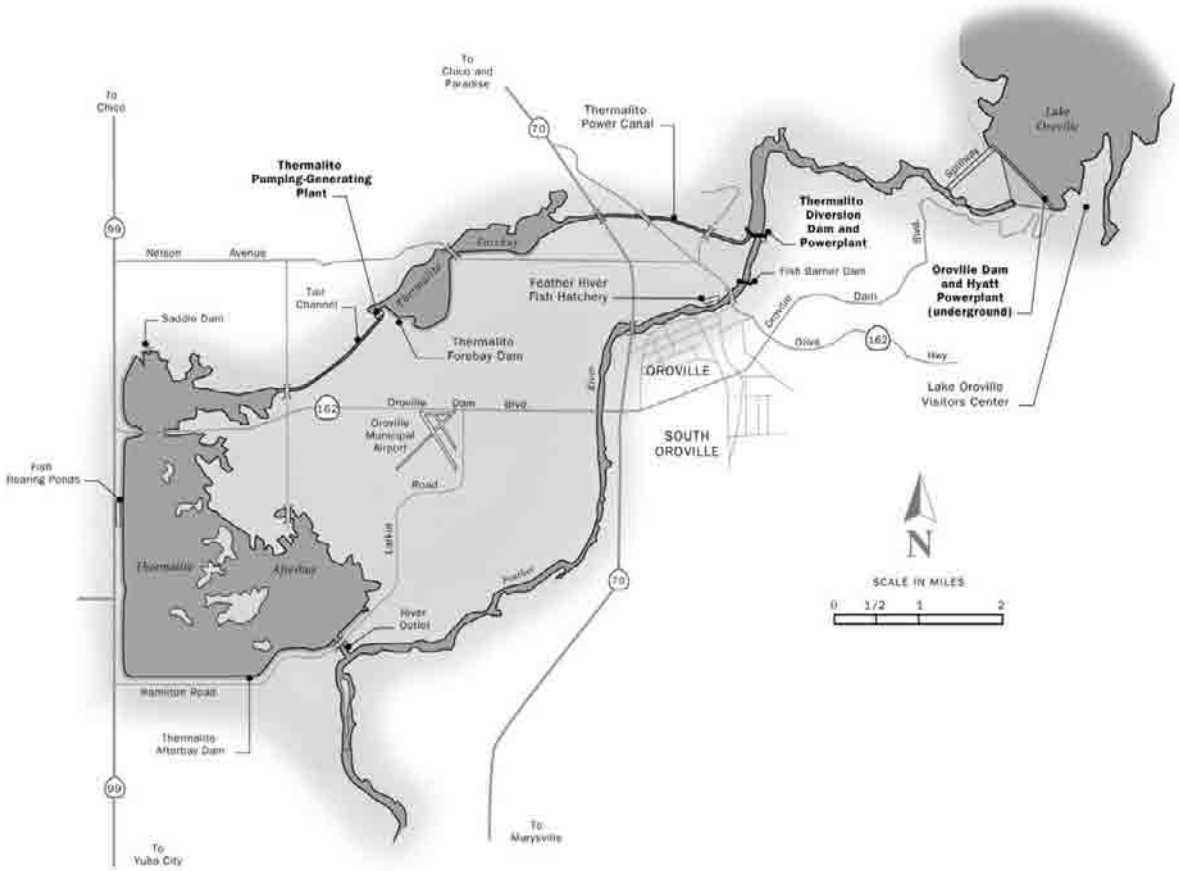

Figure P-12 Oroville Facilities on the Feather River

The purpose of the diversion dam is to divert water into the 2-mile long Thermalito Power Canal that conveys water in either direction and creates a tailwater pool (called Thermalito Diversion Pool) for Edward Hyatt Powerplant. The Thermalito Diversion Pool acts as a forebay when Hyatt is pumping water back into Lake Oroville. On the left abutment is the Thermalito Diversion Dam Powerplant, with a capacity of 600 cfs that releases water to the low-flow section of the Feather River.

Thermalito Power Canal hydraulically links the Thermalito Diversion Pool to the Thermalito Forebay (11,768 AF), which is the off-stream regulating reservoir for Thermalito Powerplant. Thermalito Powerplant is a generating-pumping plant operated in tandem with the Edward Hyatt Powerplant. Water released to generate power in excess of local and downstream requirements is conserved in storage and, at times, pumped back through both powerplants into Lake Oroville during off-peak hours. Energy price and availability are the two main factors that determine if a pumpback operation is economical. A pumpback operation most commonly occurs when energy prices are high during the weekday on-peak hours and low during the weekday off-peak hours or on the weekend. The Oroville Thermalito Complex has a capacity of approximately 17,000 cfs through the powerplants, which can be returned to the Feather River via the Afterbay's river outlet.

Local agricultural districts divert water directly from the afterbay. These diversion points are in lieu of the traditional river diversion exercised by the local districts whose water rights are senior to the SWP. The total capacity of afterbay diversions during peak demands is 4,050 cfs.

The Feather River Fish Hatchery (FRFH), mitigation for the construction of Oroville Dam, produces Chinook salmon and steelhead and is operated by DFG. The FRFH program, operations and production, is detailed in the FERC biological assessment for the Oroville Project and will be detailed in the NMFS FERC biological opinion. Both indirect and direct take resulting from FRFH operations will be authorized through section 4(d) of the Endangered Species Act, in the form of NMFS-approved Hatchery and Genetic Management Plans (HGMPs). DWR is preparing HGMPs for the spring and fall-run Chinook and steelhead production programs at the Feather River Fish Hatchery.

Current Operations - Minimum Flows and Temperature Requirements

Operation of Oroville will continue under existing criteria, consistent with past project descriptions, until a final decision is made in the FERC relicensing process. The release temperatures from Oroville Dam are designed to meet Feather River Fish Hatchery and Robinson Riffle temperature schedules included in the 1983 DFG Agreement, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish and Wildlife", concerning the operations of the Oroville Division of the State Water Project for Management of Fish and Wildlife while also conserving the coldwater pool in Lake Oroville. Current operation indicates that water temperatures at Robinson Riffle are almost always met when the hatchery objectives are met. Due to temperature requirements of endangered fish species and the hatchery and overriding meteorological conditions, the temperature requests for agriculture can be difficult to satisfy.

Water is withdrawn from Lake Oroville at depths that will provide sufficiently cold water to meet the Feather River Fish Hatchery and Robinson Riffle temperature targets. The reservoir depth from which water is released initially determines the river temperatures, but atmospheric conditions, which fluctuate from day to day, modify downstream river temperatures. Altering the reservoir release depth requires installation or removal of shutters at the intake structures. Shutters are held at the minimum depth necessary to release water that meets the Feather River Fish Hatchery and Robinson Riffle criteria. In order to conserve the coldwater pool during dry years, DWR has strived to meet the Robinson Riffle temperatures by increasing releases to the LFC rather than releasing colder water.

Additionally, DWR maintains a minimum flow of 600 cfs within the Feather River Low Flow Channel (LFC) (except during flood events when flows are governed by the Flood Operations Manual and under certain other conditions as described in the 1984 FERC order). Downstream of the Thermalito Afterbay Outlet, in the High Flow Channel (HFC), a minimum release for flows in the Feather River is to be 1,000 cfs from April through September and 1,700 cfs from October through March, when the April-to-July unimpaired runoff in the Feather River is greater than 55 percent of normal. When the April-to-July unimpaired runoff is less than 55 percent of normal, the License requires minimum flows of 1,000 cfs from March to September and 1,200 cfs from October to February (Table P-13). In practice, flows are maintained below 2,500 cfs from October 15 to November 30 to prevent spawning in the overbank areas.

According to the 1983 Agreement, if during the period of October 15 to November 30, the average highest 1-hour flow of combined releases exceeds 2,500 cfs; with the exception of flood management, accidents, or maintenance; then the minimum flow must be no lower than 500 cfs less than that flow through the following March 31. The 1983 Agreement also states that if the April 1 runoff forecast in a given year indicates that the reservoir level will be drawn down to 733 feet, water releases for fish may be reduced, but not by more than 25 percent.

Table P-13 Combined Minimum Instream Flow Requirements in the Feather River Below Thermalito Afterbay Outlet When Lake Oroville Elevation is Projected to be Greater vs. Less Than 733' in the Current Water Year

Conditions	Period	Minimum Flows
When Lake Oroville Elevation is Projected to be Greater Than 733' & the **Preceding** Water Year's April – July Water Conditions are ≥ 55% of Normal (1)	October - February	1,700 cfs
	March	1,700 cfs
	April - September	1,000 cfs
When Lake Oroville Elevation is Projected to be Greater Than 733' & the Preceding Water Year's April – July Water Conditions are < 55% of Normal (1)	October - February	1,200 cfs
	March	1,000 cfs
	April - September	1,000 cfs
When Lake Oroville Elevation is Projected to be Less Than 733' in the **Current** Water Year (2)	October - February	900 cfs < Q < 1,200 cfs
	March	750 cfs < Q < 1,000 cfs
	April - September	750 cfs < Q < 1,000 cfs

Notes:

1) Normal is defined as the Mean April – July Unimpaired Runoff of the Feather River near Oroville of 1,942,000 AF (1911 – 1960).
2) In accordance with FERC's Order Amending License dated September 18, 1984, Article 53 was amended to provide a third tier of minimum flow requirements defined as follows: If the April 1 runoff forecast in a given water year indicates that, under normal operation of Project 2100, the reservoir level will be drawn to elevation 733 feet (approximately 1,500,000 AF), releases for fish life in the above schedule may suffer monthly deficiencies in the same proportion as the respective monthly deficiencies imposed upon deliveries of water for agricultural use from the Project. However, in no case shall the fish water releases in the above schedule be reduced by more than 25 percent.

Current operations of the Oroville Facilities are governed by water temperature requirements at two locations: the FRFH and in the LFC at Robinson Riffle. DWR has taken various temperature management actions to achieve the water temperature requirements, including curtailing pumpback operations, removing shutters at intakes of the Hyatt Pumping-Generating Plant, releasing flow through the river valves (for FRFH only), and redirecting flows at the Thermalito Diversion Dam to the LFC (for Robinson Riffle only).

To date, the river valves have been used infrequently. Prior to 1992, they were used twice: first in 1967 during the initial construction of the dam, and second in 1977 during the drought of record. Since 1992, the river valves have only been used twice for temperature control: in 2001 and 2002. To ensure that the river valves will operate reliably, DWR exercises them annually. When operated to meet temperature criteria, DWR can and does operate the river valves at a flow rate up to the 1,500 cfs needed for FRFH temperature management purposes.

Other than local diversions, outflow from the Oroville Complex is to the Feather River, combining flows from the LFC and Thermalito Afterbay. Outflow typically varies from spring seasonal highs averaging 8,000 cfs to about 3,500 cfs in November. The average annual outflow from the Project is in excess of 3 MAF to support downstream water supply, environmental, and water quality needs.

Table P-14 shows an example of releases from Oroville for various downstream uses during dry hydrologic conditions (WYs 2001 and 2002). As a practical matter, water supply exports are met with water available after Delta requirements are met. Some of the water released for instream and Delta requirements may be available for export by the SWP after Delta standards have been met.

Table P-14 Historical Records of Releases from the Oroville Facilities in 2001 and 2002, by Downstream Use

Downstream Use	Water Year 2001 Release		Water Year 2002 Release	
	Volume (TAF)	Percentage	Volume (TAF)	Percentage
Feather River Service Area	1,024	46	925	34
Instream and Delta Requirements	1,099	50	1,043	38
Flood Management	0	0	0	0
Support of Exports	93	4	773	28
Total	2,216	100	2,741	100

Source: DWR SWP Operations Control Office

Feather River Flow Requirements

The existing Feather River flow requirements below Oroville Dam are based on an August 1983 Agreement between the DWR and DFG. The 1983 Agreement established criteria and objectives for flow and temperatures in the LFC, FRFH, and HFC. This agreement includes the following:

- Established minimum flows between the Thermalito Afterbay Outlet and Verona that vary by WY type
- Required flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except flood management operations
- Required flow stability during the peak of the fall-run Chinook spawning season
- Set an objective of suitable water temperature conditions during the fall months for salmon and during the later spring/summer months for shad and striped bass
- Established a process whereby DFG would recommend each year, by June 1, a spawning gravel maintenance program to be implemented during that calendar year

Low Flow Channel

The 1983 Agreement specifies that DWR release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fishery purposes. This is the total volume of flows from the Diversion Dam Outlet, Diversion Dam Powerplant, and FRFH Pipeline.

High Flow Channel

Based on the 1983 Agreement, Table P-15 summarizes the minimum flow requirement for the HFC when releases would not draw Oroville Reservoir below elevation 733 feet above mean sea level (ft msl).

Table P-15 High Flow Channel minimum flow requirements as measured downstream from the Thermalito Afterbay Outlet.

Forecasted April-through-July unimpaired runoff (percent of normal[1])	Minimum Flow in HFC (cfs)		
	October through February	March	April through September
55 percent or greater	1,700	1,700	1,000
Less than 55 percent	1,200	1,000	1,000

Source: 1983 Agreement

[1] The preceding water year's unimpaired runoff shall be reported in Licensee's Bulletin 120, "*Water Conditions in California-Fall Report*." The term "normal" is defined as the April-through-July mean unimpaired runoff near Oroville of 1,942,000 AF in the period of 1911 through 1960.

Key:

cfs – cubic feet per second

HFC – High Flow Channel

If the April 1 forecast in a given WY indicates that Oroville Reservoir would be drawn down to elevation 733 ft msl, minimum flows in the HFC may be diminished on a monthly average basis,

in the same proportion as the respective monthly deficiencies imposed on deliveries for agricultural use of the Project. However, in no case shall the minimum flow releases be reduced by more than 25 percent. If between October 15 and November 30, the highest total 1-hour flow exceeds 2,500 cfs, DWR shall maintain a minimum flow within 500 cfs of that peak flow, unless such flows are caused by flood flows, or an inadvertent equipment failure or malfunction.

Temperature Requirements

Low Flow Channel

NMFS has established a water temperature requirement for steelhead trout and spring-run Chinook salmon at Feather River RM 61.6 (Robinson Riffle in the LFC) from June 1 through September 30. The water temperature should be maintained at less than or equal to 65°F on a daily average basis.

High Flow Channel

While no numeric temperature requirement currently exists for the HFC, the 1983 Agreement requires DWR to provide suitable Feather River water temperatures for fall-run salmon not later than September 15, and to provide for suitable water temperatures below the Thermalito Afterbay Outlet for shad, striped bass, and other warm water fish between May 1 and September 15.

Current FRFH intake water temperature, as required by the 1983 DFG and DWR Agreement are in Table P-16.

Table P-16 Feather River Fish Hatchery Temperature Requirements

Period		Degrees F (± 4 ºF allowed)
April 1 – November 30		
	April 1 – May 15	51
	May 16 – May 31	55
	June 1 – June 15	56
	June 16 – August 15	60
	August 16 – August 31	58
	September 1 – September 30	52
	October 1 – November 30	51
December 1 – March 31		No greater than 55

Table P-17 summarizes current flow and temperature management in the Feather River Fish Hatchery and the Lower Feather River below Oroville Dam. These operational measures are in place in compliance with FERC license terms, agency agreements or ESA biological opinions and are provided to fully describe the baseline conditions.

Table P-17 Lower Feather River Flows and Temperature Management under Existing Conditions

Type of Measure	Title	Description
Minimum Flows	Minimum Release to Low Flow Channel (this includes water that returns from hatchery)	Maintain minimum flow of 600 cubic feet per second (cfs) within the Feather River downstream of the Thermalito Diversion Dam and the Feather River Fish Hatchery. FERC 1984. [Low Flow Channel Flow Standard]
	Minimum Release to High Flow Channel	Release water necessary to maintain flows in the Feather River below the Thermalito Afterbay Outlet in accordance with the minimum flow schedule presented in the Federal Energy Regulatory Commission (FERC) order, provided that releases will not cause Lake Oroville to be drawn below elevation 733 feet (ft) (approximately 1.5 million acre-feet [maf] of storage). If the April 1 runoff forecast in a given year indicates that the reservoir level will be drawn to 733 ft, water releases for fish may be reduced, but not by more than 25 percent.
Maximum Flows (non-flood control)	Maximum Flow into Feather River Fish Hatchery	Maximum flow into Feather River Fish Hatchery from the Diversion Pool is 115 cfs year round.
	Maximum Flow in the High Flow Channel	Maximum flow at Feather River below Thermalito Afterbay Outlet is **10,000 cfs** when Lake Oroville inflow is less than 10,000 cfs. [High Flow Channel Flow Standard] When Lake Oroville inflow is greater than 10,000 cfs, the maximum flow in the river below Thermalito Afterbay Outlet will be limited to inflow. If higher flow releases coincide with Chinook spawning activity, the ramping rate used to return to the minimum flow requirement will be chosen to avoid redd dewatering.
Ramping Rates	Ramping Rate Criteria	Flows less than 2,500 cfs cannot be reduced more than **300 cfs** during any 24-hour period, except for flood releases, failures, etc.
Water Supply	Releases from Lake Oroville	Releases for water supply, flood control, Sacramento–San Joaquin Delta (Delta) water quality requirements, and instream flow requirements of an average of 3 million acre-feet per year (maf/year) and approximately 1 maf/year to the Feather River Service Area (FRSA) for agricultural, municipal, and industrial uses in accordance with SWP contracts, DWR agreements, and water rights.
	Diversions from Feather River	Diversion of an estimated 60–70 thousand acre-feet per year (TAF/year) from the Feather River by senior water right holders per State Water Resources Control Board (SWRCB) licenses or permits for appropriative users.

Type of Measure	Title	Description
Flood Protection/Management	Flood Protection	The Oroville Facilities are operated for flood control purposes in conformance with the flood management regulations prescribed by the Secretary of the Army under the provisions of an Act of Congress (58 Stat. 890; 33 United States Code [USC] 709). - During floods, water releases from Oroville Dam and Thermalito Afterbay Dam will not increase floodflows above those prior to project existence. Operation of the project in the interest of flood control shall be in accordance with Section 204 of the Flood Control Act of 1958. - At high flows, fluctuate releases at least every couple of days to avoid riverbank/levee damage at one level. - Avoid extended periods of flow over the quantities listed above as much as possible to minimize the risk of seepage damage to orchards adjacent to the Feather River. - Maximum allowable flow is 180,000 cfs year round at the Feather River above the Yuba River. Maximum allowable flow is 300,000 cfs year round at the Feather River below the Yuba River. - Maximum allowable flow is 320,000 cfs year round at the Feather River below the Bear River.

Type of Measure	Title	Description
Temperature Criteria/Targets	At the Feather River Fish Hatchery and Robinson Riffle	Water temperature at Robinson Riffle must be less than 65 degrees between June and September. Water temperature during the fall months, after September 15, should be suitable for fall-run Chinook salmon. Water temperature from May through August should be suitable for American shad, striped bass, etc. At the Feather River Fish Hatchery Temperature (+/- 4°F) April 1–May 15 51° May 16–May 31 55° June 1–June 15 56° June 16–August 15 60° August 16–August 31 58° September 1–September 30 52° October 1–November 30 51° December 1–March 31 no greater than 55°
	Thermalito Afterbay Temperature Control	Operate facilities pursuant to the May 1968 Joint Water Agreement.
Natural Salmonid Spawning and Rearing Habitat	Salmonid Habitat Improvement – Endangered Species Act (ESA) Species Recovery Measures	Maintain conditions in the Low Flow Channel pursuant to 1983 Operating Agreement between DFG and DWR which is to prevent damage to fish and wildlife resources from operations and construction of the project.

Excerpt from Appendix B of the FERC Preliminary Draft Environmental Assessment, Oroville Facilities—FERC Project No. 2100

Flood Control

Flood control operations at Oroville Dam are conducted in coordination with DWR's Flood Operations Center and in accordance with the requirements set forth by the Corps. The Federal Government shared the expense of Oroville Dam, which provides up to 750,000 AF of flood control space. The spillway is located on the right abutment of the dam and has two separate elements: a controlled gated outlet and an emergency uncontrolled spillway. The gated control structure releases water to a concrete-lined chute that extends to the river. The uncontrolled emergency spill flows over natural terrain.

Table P-18 Water Year/Days in Flood Control/40-30-30 Index

Water Year	Days in Flood Control	40-30-30 Index
1981	0	D
1982	35	W
1983	51	W
1984	16	W
1985	0	D
1986	25	W
1987	0	D
1988	0	C
1989	0	D
1990	0	C
1991	0	C
1992	0	C
1993	8	AN
1994	0	C
1995	35	W
1996	22	W
1997	57	W
1998	0	W
1999	58	W
2000	0	AN
2001	0	D
2002	0	D

Feather River Ramping Rate Requirements

Maximum allowable ramp-down release requirements are intended to prevent rapid reductions in water levels that could potentially cause redd dewatering and stranding of juvenile salmonids and other aquatic organisms. Ramp-down release requirements to the

LFC during periods outside of flood management operations, and to the extent controllable during flood management operations, are shown in Table P-19.

Table P-19 Lower Feather River Ramping Rates

Releases to the Feather River Low Flow Channel (cfs)	Rate of Decrease (cfs)
5,000 to 3,501	1,000 per 24 hours
3,500 to 2,501	500 per 24 hours
2,500 to 600	300 per 24 hours

Key:
cfs = cubic feet per second
Source: NMFS 2004a

Proposed Operational Changes with the Federal Energy Regulatory Commission (FERC) Relicensing of the Oroville Project– Near Term and Future Operations

Until FERC issues the new license for the Oroville Project, DWR will not significantly change the operations of the facilities and when the FERC license is issued, it is assumed that downstream of Thermalito Afterbay Outlet, the future flows will remain the same.

There is a great deal of uncertainty as to when the license will be issued and what conditions will be imposed by FERC and the State Water Resources Control Board (SWRCB). The process that DWR has to go through to get the new license is as follows: DWR will finalize the Final Environment Impact Report in May 2008, the SWRCB will prepare the Clean Water Act Section 401 Certification (401 Cert) for the project which may take up to a year and the 401 Cert may have additional requirements for DWR operations of Oroville. Once the 401 Cert is issued, FERC can issue the new license; however, in the interim, the documents or process may be challenged in court. When the new FERC license is issued, additional flow or temperature requirements may be required. At this time, DWR can only assume that the flow and temperature conditions required will be those in the FERC Settlement Agreement (SA); therefore, those are what DWR proposes for the near-term and future Oroville operations.

The proposed future operations in the SA described in the Project Description include 100-200 cfs increase in flows in the LFC of the Lower Feather River and reduced water temperatures at the Feather River Hatchery and in the Low Flow and High Flow channels, after further analysis of alternatives and construction of one or more temperature control facilities. These are described in more detail in the SA. The flows in the HFC downstream of the TAO will not change. It is unlikely that either the proposed minor flow changes in the LFC or the reduced water temperatures will affect conditions in the Sacramento River downstream of the confluence but if they were detectable, they would be beneficial to anadromous fish in the Sacramento River.

The original FERC license to operate the Oroville Project expired in January 2007 and until a new license is issued, DWR will operate to the existing FERC license. FERC has and will continue to issue an annual license until it is prepared to issue the new 50-year license. In preparation for the expiration of the FERC license, DWR began working on the relicensing process in 2001. As part of the process, DWR entered into a SA with State, federal and local agencies, State Water Contractors, Non-Governmental Organizations, and Tribal governments to implement improvements within the FERC Boundary. The FERC boundary includes all of the Oroville Project facilities, extends upstream into the tributaries of Lake Oroville, includes portions of the LFC on the lower Feather River and downstream of the Thermalito Afterbay Outlet into the HFC. In addition to the Settlement Agreement signed in 2006, a Habitat Expansion Agreement was negotiated to address the fish passage issue over Oroville Dam and NMFS and the Service' Section 18 Authority under the Federal Power Act. FERC prepared an EIS for the proposed license and DWR prepared and EIR and biological assessments for FERC based on the terms and conditions in the Settlement Agreement. The SWRCB is working on the Section 401 Certification process and when all the environmental documents and permits are complete, the new 50-year FERC license will be issued for the Oroville Project, possibly in 2009.

FERC requested consultation with NMFS on the Oroville Project SA and DWR prepared and submitted the FERC biological assessment in June 2007 to NMFS and FERC. The SA does not change the flows in the HFC although there will be a proposed increase in minimum flows in the LFC. The SA includes habitat restoration actions such as side-channel construction, structural habitat improvement such as boulders and large woody debris, spawning gravel augmentation, a fish counting weir, riparian vegetation and floodplain restoration, and facility modifications to improve coldwater temperatures in the low and high flow channels. The SA and the FERC biological assessment provide substantial detail on the restoration actions in the Lower Feather River.

Below is a summary of articles in the SA referred to by number and is by no means a complete description of the terms and conditions therein. The numbering of the tables in this section is consistent with the numbering in the SA for direct comparison.

Minimum Flows in the Low Flow and High Flow Channels

When the FERC license is issued, DWR will release a minimum flow of 700 cfs into the LFC. The minimum flow shall be 800 cfs from September 9 to March 31 of each year to accommodate spawning of anadromous fish, unless the NMFS, the Service, DFG, and California SWRCB provide a written notice that a lower flow (between 700 cfs and 800 cfs) substantially meets the needs of anadromous fish. If the DWR receives such a notice, it may operate consistent with the revised minimum flow. HFC flows will remain the same as the existing license, consistent with the 1983 DWR and DFG Operating Agreement to continue to protect Chinook salmon from redd dewatering.

Water Temperatures for the Feather River Fish Hatchery

When the FERC license is issued, DWR will use the temperatures in Table P-20 as targets, and will seek to achieve them through the use of operational measures described below.

Table P-20 Maximum Mean Daily Temperatures,

September 1-September 30	56 °F
October 1 – May 31	55 °F
June 1 – August 31	60°F

The temperatures in Table P-20 are Maximum Mean Daily Temperatures, calculated by adding the hourly temperatures achieved each day and dividing by 24. DWR will strive to meet Maximum Mean Daily Temperatures through operational changes including but not limited to (i) curtailing pump-back operation and (ii) removing shutters on Hyatt intake and (iii) after river valve refurbishment. DWR will consider the use of the river valve up to a maximum of 1500 cfs; however these flows need not exceed the actual flows in the HFC, and should not be less than those specified in HFC minimum flows described above, which will not change with the new FERC license. During this interim period, DWR shall not be in violation if the Maximum Mean Daily Temperatures are not achieved through operational changes.

Prior to FERC license implementation, DWR agreed to begin the necessary studies for the refurbishment or replacement of the river valve. On October 31, 2006, DWR submitted to specific agencies a Reconnaissance Study of Facilities Modification to address temperature habitat needs for anadromous fisheries in the Low Flow Channel and the HFC. Under the provisions of Settlement Agreement Appendix B Section B108(a), DWR has begun a study to evaluate whether to refurbish or replace the river valve that may at times be used to provide cold water for the Feather River Fish Hatchery.

Upon completion of Facilities Modification(s) as provided in A108, and no later than the end of year ten following license issuance, Table P-20 temperatures shall become requirements, and DWR shall not exceed the Maximum Mean Daily Temperatures in Table P-20 for the remainder of the License term, except in Conference Years as referenced in A107.2(d).

During the term of the FERC license, DWR will not exceed the hatchery water temperatures in Table P-21. There will be no minimum temperature requirement except for the period of April 1 through May 31, during which the temperatures shall not fall below 51 ºF.

Table P-21 Hatchery Water Temperatures

September 1-September 30	56 °F
October 1 – November 30	55 °F
December 1 – March 31	55 °F

April 1 – May 15	55 °F
May 16-May 31	59°F
June 1-June 15	60°F
June 16- August 15	64°F
August 16 – August 31	62°F

Upon completion of Facilities Modification(s) as provided in A108 (discussed below), DWR may develop a new table for hatchery temperature requirements that is at least as protective as Table P-21. If a new table is developed, it shall be developed in consultation with the Ecological Committee, including specifically the Service, NMFS, DFG, California SWRCB, and RWQCB. The new table shall be submitted to FERC for approval, and upon approval shall become the temperature requirements for the hatchery for the remainder of the license term.

During Conference Years, as defined in A108.6, DWR shall confer with the Service, NMFS, DFG, and California SWRCB to determine proper temperature and hatchery disease management goals.

Water Temperatures in the Lower Feather River

Under the SA, DWR is committing to a Feasibility Study and Implementation Plan to improve temperature conditions (Facilities Modification(s)) for spawning, egg incubation, rearing and holding habitat for anadromous fish in the Low Flow Channel and HFC (A108.4). The Plan will recommend a specific alternative for implementation and will be prepared in consultation with the resource agencies.

Prior to the Facilities Modification(s) described in Article A108.4, if DWR does not achieve the applicable Table P-22 Robinson Riffle temperature upon release of the specified minimum flow, DWR shall singularly, or in combination perform the following actions:

(1) Curtail pump-back operation,

(2) Remove shutters on Hyatt Intake, and

(3) Increase flow releases in the LFC up to a maximum of 1500 cfs, consistent with the minimum flow standards in the HFC. Table P-22 temperatures are targets and if they are not met there is no license violation.

If in any given year DWR anticipates that these measures will not achieve the temperatures in Table P-22, DWR shall consult with the NMFS, the Service, DFG, and California SWRCB to discuss potential approaches to best managing the remaining coldwater pool in Lake Oroville, which may result in changes in the way Licensee performs actions (1), (2), and (3) listed above.

Table P-22 LFC as Measured at Robinson Riffle.

(all temperatures are in daily mean value (degrees F))

Month	Temperature (° F)
January	56
February	56
March	56
April	56
May 1-15	56-63*
May 16-31	63
June 1 – 15	63
June 16 – 30	63
July	63
August	63
September 1-8	63-58*
September 9 – 30	58
October	56
November	56
December	56
* Indicates a period of transition from the first temperature to the second temperature.	

After completion of the Facilities Modification(s), DWR shall no longer be required to perform the measures listed in (1), (2), and (3), unless Table P-22 temperatures are exceeded. DWR shall operate the project to meet temperature requirements in Table P-22 in the LFC, unless it is a Conference Year as described in Article 108.6. The proposed water temperature objectives in Table P-23 (in Article 108), measured at the southern FERC project boundary, will be evaluated for potential water temperature improvements in the HFC. DWR will study options for Facilities Modification(s) to achieve those temperature benefits.

There would be a testing period of at least five years in length to determine whether the HFC temperature benefits are being realized (A108.5). At the end of the testing period, DWR will prepare a testing report that may recommend changes in the facilities, compliance requirements for the HFC and the definition of Conference Years (those

years where DWR may have difficulties in achieving the temperature requirements due to hydrologic conditions.) The challenges of implementing Table P-23 temperatures will require the phased development of the Table P-23 water temperature objective and likely, a revision to Table P-23 prior to Table P-23 becoming a compliance obligation.

Table P-23 HFC as measured at Downstream Project Boundary

(all temperatures are in daily mean value (degrees F))

Month	Temperature
January	56
February	56
March	56
April	61
May	64
June	64
July	64
August	64
September	61
October	60
November	56
December	56

Habitat Expansion Agreement

The Habitat Expansion Agreement is a component of the 2006 SA to address DWR obligations in regard to blockage and fish passage issues in regard to the construction of Oroville Dam. Because it deals with offsite mitigation it will not included in the new FERC license.

Construction of the Oroville Facilities and Pacific Gas and Electric Company's construction of other hydroelectric facilities on the upper Feather River tributaries blocked passage and reduced available habitat for Central Valley spring-run Chinook salmon and Central Valley steelhead. The reduction in spring-run habitat resulted in spatial overlap with fall-run Chinook salmon and has led to increased redd superimposition, competition for limited habitat, and genetic introgression. FERC relicensing of hydroelectric projects in the Feather River basin has focused attention on the desirability of expanding spawning, rearing and adult holding habitat available for Central Valley spring-run and steelhead. The SA Appendix F includes a provision to establish a habitat enhancement program with an approach for identifying, evaluating, selecting and implementing the most promising action(s) to expand such spawning, rearing and adult holding habitat in the Sacramento River Basin as a contribution to the

conservation and recovery of these species. The specific goal of the Habitat Expansion Agreement is to expand habitat sufficiently to accommodate an estimated net increase of 2,000 to 3,000 spring-run or steelhead for spawning (Habitat Expansion Threshold). The population size target of 2,000 to 3,000 spawning individuals was selected because it is approximately the number of spring-run and steelhead that historically migrated to the upper Feather River. Endangered species issues will be addressed and documented on a specific project-related basis for any restoration actions chosen and implemented under this Agreement.

Anadromous Fish Monitoring on the Lower Feather River

Until the new FERC license is issued and until a new monitoring program is adopted, DWR will continue to monitor anadromous fish in the Lower Feather River in compliance with the project description set out in Reclamation's 2004 OCAP biological assessment.

As required in the FERC SA (Article A101), within three years following the FERC license issuance, DWR will develop a comprehensive Lower Feather River Habitat Improvement Plan that will provide an overall strategy for managing the various environmental measures developed for implementation, including the implementation schedules, monitoring, and reporting. Each of the programs and components of the Lower Feather River Habitat Improvement Plan shall be individually evaluated to assess the overall effectiveness of each action within the Lower Feather River Habitat Improvement Plan.

Delta Field Division

SWP facilities in the southern Delta include Clifton Court Forebay, John E. Skinner Fish Facility, and the Banks Pumping Plant. CCF is a 31,000 AF reservoir located in the southwestern edge of the Delta, about ten miles northwest of Tracy. CCF provides storage for off-peak pumping, moderates the effect of the pumps on the fluctuation of flow and stage in adjacent Delta channels, and collects sediment before it enters the California Aqueduct. Diversions from Old River into CCF are regulated by five radial gates.

The John E. Skinner Delta Fish Protective Facility is located west of the CCF, two miles upstream of the Banks Pumping Plant. The Skinner Fish Facility screens fish away from the pumps that lift water into the California Aqueduct (CA). Large fish and debris are directed away from the facility by a 388-foot long trash boom. Smaller fish are diverted from the intake channel into bypasses by a series of metal louvers, while the main flow of water continues through the louvers and towards the pumps. These fish pass through a secondary system of screens and pipes into seven holding tanks, where a subsample is counted and recorded. The salvaged fish are then returned to the Delta in oxygenated tank trucks.

The Banks Pumping Plant is in the South Delta, about eight miles northwest of Tracy and marks the beginning of the CA. By means of 11 pumps, including two rated at 375 cfs capacity, five at 1,130 cfs capacity, and four at 1,067 cfs capacity, the plant provides the

initial lift of water 244 feet into the CA. The nominal capacity of the Banks Pumping Plant is 10,300 cfs.

Other SWP operated facilities in and near the Delta include the North Bay Aqueduct (NBA), the Suisun Marsh Salinity Control Gates (SMSCG), Roaring River Distribution System (RRDS), and up to four temporary barriers in the South Delta. Each of these facilities is discussed further in later sections.

Clifton Court Forebay Aquatic Weed Control Program

DWR will apply copper based herbicide complexes including copper sulfate pentahydrate, Komeen,® and Nautique® on an as-needed basis to control aquatic weeds and algal blooms in Clifton Court Forebay (Forebay). Komeen® is a chelated copper herbicide (copper-ethylenediamine complex and copper sulfate pentahydrate) and Nautique® is a copper carbonate compound (see Sepro product labels). These products are used to control algal blooms so that such algae blooms do not degrade drinking water quality through tastes and odors and production of algal toxins. Dense growth of submerged aquatic weeds, predominantly *Egeria densa*, can cause severe head loss and pump cavitation at Banks Pumping Plant when the stems of the rooted plant break free and drift into the trashracks. This mass of uprooted and broken vegetation essentially forms a watertight plug at the trashracks and vertical louver array. The resulting blockage necessitates a reduction in the pumping rate of water to prevent potential equipment damage through cavitation at the pumps. Cavitation creates excessive wear and deterioration of the pump impeller blades. Excessive floating weed mats also reduce the efficiency of fish salvage at the Skinner Fish Facility. Ultimately, this all results in a reduction in the volume of water diverted by the State Water Project.

Herbicide treatments will occur only in July and August on an as needed basis in the Forebay dependent upon the level of vegetation biomass in the enclosure. However, the frequency of herbicide applications is not expected to occur more than twice per year. Herbicides are typically applied early in the growing season when plants are susceptible to the herbicides due to rapid growth and formation of plant tissues, or later in the season, when plants are mobilizing energy stores from their leaves towards their roots for over wintering senescence. Past use of aquatic herbicides is presented in Table P-24.

Table P-24 Aquatic herbicide applications in Clifton Court Forebay, 1995- Present.

Note: The past applications are provided to give the reader an indication of the frequency of herbicide applications in the past (baseline).

Year	Date	Aquatic Herbicide
1995	5/15/1995	Komeen®
1995	8/21/1995	Komeen®
1996	6/11/1996	Komeen®
1996	9/10/1996	Komeen®

Year	Date	Aquatic Herbicide
1997	5/23/1997	Komeen®
1997	7/14/1997	Komeen®
1998	7/13/1998	Komeen®
1999	6/11/1999	Komeen®
2000	7/31/2000	Komeen®
2001	6/29/2001	Nautique
2002	6/24/2002	Komeen®
2003	5/12/2003	Nautique
2003	8/13/2003	Copper Sulfate
2004	6/3/2004	Komeen®
2004	7/22/2004	Copper Sulfate
2005	5/3/2005	Komeen®
2005	6/21/2005	Komeen®
2006	6/1/2006	Komeen®
2006	6/29/2006	Komeen®

Additionally, copper sulfate pentahydrate was applied once in 2003 and 2004 by helicopter to control taste and odor producing benthic cyanobacteria.

Aquatic weed management problems in the Forebay have to date been limited to about 700 acres of the 2,180 total water surface acres. Application of the herbicide is limited to only those areas in the Forebay that require treatment. The copper based herbicides, Komeen® or Nautique, are applied by helicopter or boat to only those portions where aquatic weeds present a management problem to the State.

To date, algal problems in the Forebay have been caused by attached benthic cyanobacteria which produce unpleasant tastes and odors in the domestic drinking water derived from the SWP operations. Copper sulfate is applied to the nearshore areas of the Forebay when results of Solid phase microextraction (SPME) (APHA, 2005) analysis exceed the control tolerances (MIB < 5 ng/L and geosmin < 10 ng/L are not detected by consumers in drinking water supplies)(Aquatic Pesticide Application Plan, 2004). Highest biomass of taste and odor producing cyanobacteria was present in the nearshore areas but not limited to shallow benthic zone. Annually, application areas may vary considerably based on the extent of the algal infestation in the Forebay.

DWR receives Clean Water Act pollutant discharge coverage under the National Pollutant Discharge Elimination System (NPDES) Permit No. CAG990005 (General Permit) issued by the SWRCB for application of aquatic pesticides to the SWP aqueducts, forebays, and reservoirs when necessary to achieve management goals. The State Board functions as the Environmental Protection Agency's non-federal representative for implementation of the Clean Water Act in California.

A Mitigated Negative Declaration was prepared by DWR to comply with CEQA requirements associated with regulatory requirements established by the SWRCB. DWR, a public entity, was granted a Section 5.3 Exception by the SWRCB (Water Quality Order 2004-0009-DWQ) and is not required to meet the copper limitation in receiving waters during the exception period from March 1 to November 30 as described in the DWR's Aquatic Pesticide Application Plan. .

Proposed Measures to Reduce Fish Mortality

Komeen® will be applied according to the product label directions as required by state and federal law. The Forebay elevation will be raised to +2 feet above mean sea level for an average depth of about 6 feet within the 700-water surface acre treatment zone. The herbicide will be applied at a rate of 13 gallons per surface acre to achieve a final operational concentration in the water body of 0.64 mg/L Cu^{2+}. (640 ppb). Application rate of 13 gallons per surface area is calculated based on mean depth. The product label allows applications up to 1 mg/L (1000 ppb or 1 ppm). DWR applies Komeen in accordance with the specimen label that states, "If treated water is a source of potable water, the residue of copper must not exceed 1 ppm (mg/L)".

In 2005, 770 surface acres were treated with Komeen®. Clifton Court Forebay has a mean depth of 6 feet at 2 feet above mean sea level; thus the volume treated is 4620 acre-feet.

The concentration of the active ingredient (Cu^{2+}) is calculated from the following equation:

Cu^{2+} (ppm) = Komeen (gallon)/ (Mean Depth (feet) * 3.34)) Source: Komeen® Specimen Label EPA reg No. 67690-25

The calculated concentration of Cu^{2+} for the 2005 application was 0.65 mg/L Cu^{2+}. The copper level required to control *Egeria densa* (the main component of the Clifton Court Forebay aquatic plant community) is 0.5 - 0.75 mg/L Cu^{2+}. Source: Komeen® Specimen Label.

Prior to application of copper based herbicides, toxicity testing and literature review of LC-50 levels for salmon, steelhead, delta smelt, and green sturgeon may be conducted. Once applied, the initial stock copper concentration is reduced rapidly (hours) by dilution (Komeen® applied according to the Specimen Label (SePro Corporation) of the product in the receiving water to achieve final concentration levels. Based on the treatment elevation of +2 feet, only about 20 percent (4,630 AF) of the 22,665 AF Forebay will be treated (AF = Acre-feet= volume). The copper will be applied beginning on one side of

the Forebay allowing fish to move out of the treatment area. In addition, Komeen® will be applied by boats at a slower rate than in previous years when a helicopter was used.

In 2006 DWR proposed the following actions to reduce fish mortality in coordination with DFG and NMFS. Also, the hydroacoustical aquatic plant survey was continued in 2007 when no Komeen application was done. A survey in 2008 is also planned. These actions will continue to be followed in the future.

1. Komeen® or copper sulfate will only be applied in July and August.
2. The salvage of listed fish species at Skinner Fish Facility will be monitored prior to the Komeen® application.
3. The intake (radial) gates at Clifton Court Forebay will be closed 24 hours prior to the scheduled application to improve fish passage out of the designated treatment areas.
4. The radial gates will not be re-opened to allow inflow into the Forebay for 24 hours following the end of the aquatic herbicide application. The Clifton Court intake gates will therefore be closed for 48 hours. The Komeen® Specimen Label recommends a 12-24 hours contact with target weeds to provide effective control. Twenty-four hours is at the high end for recommended contact time according to the Komeen® Specimen Label.
5. Komeen® will be applied by boat, first to the nearshore areas and then outwards in transects away from the shore. The application will be conducted by a private contractor and supervised by a California Certified Pest Control Advisor.
6. The herbicide treatment will be scheduled and planned for minimizing the treatment area by using hydroacoustical plant mapping technology to locate and estimate the area of submerged vegetation beds. The smallest possible area will be treated to minimize both the volume of aquatic herbicide applied and lessen the impacts to fish in the Forebay. Examples of figures from the 2005 hydroacoustical survey are enclosed.
7. Copper monitoring and analysis will follow the procedures described in the DWR Quality Assurance Project Plan submitted to the State Water Resources Control Board in February 2002. There are no plans to measure sediment and detrial copper concentrations. The Quality Assurance Plan was submitted to the SWRCB on February 26, 2002 and no comments were received.

North Bay Aqueduct Intake at Barker Slough

The Barker Slough Pumping Plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery in Napa and Solano Counties. Maximum pumping capacity is 175 cfs (pipeline capacity). During the past few years, daily pumping rates have ranged between 0 and 140 cfs. The current maximum pumping rate is 140 cfs because an additional pump is required to be installed to reach 175 cfs. In addition, growth of biofilm in a portion of the pipeline is also limiting the NBA ability to reach its full capacity.

The NBA intake is located approximately 10 miles from the main stem Sacramento River at the end of Barker Slough. Per salmon screening criteria, each of the ten NBA pump bays is individually screened with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch. This configuration is designed to exclude fish approximately one inch or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2 ft/s. The larger units were designed for a 0.5 ft/s approach velocity, but actual approach velocity is about 0.44 ft/s. The screens are routinely cleaned to prevent excessive head loss, thereby minimizing increased localized approach velocities.

Delta smelt monitoring was required at Barker Slough under the March 6, 1995 OCAP BO. Starting in 1995, monitoring was required every other day at three sites from mid-February through mid-July, when delta smelt may be present and continued monitoring was stopped in 2005. As part of the Interagency Ecological Program (IEP), DWR has contracted with the DFG to conduct the required monitoring each year since the biological opinion was issued. Details about the survey and data are available on DFG's website (http://www.delta.dfg.ca.gov/data/NBA).

Beginning in 2008, the NBA larval sampling will be replaced by an expanded 20-mm survey (described at http://www.delta.dfg.ca.gov/data/20mm) that has proven to be fairly effective at tracking delta smelt distribution and reducing entrainment. The expanded survey covers all existing 20-mm stations, in addition to a new suite of stations near NBA. The expanded survey also has an earlier seasonal start and stop date to focus on the presence of larvae in the Delta. The gear type was a surface boom tow, as opposed to oblique sled tows that have traditionally been used to sample larval fishes in the San Francisco Estuary.

Coordinated Facilities of the CVP and SWP

Joint Project Facilities

Suisun Marsh

Since the early 1970's, the California Legislature, SWRCB, Reclamation, DFG, Suisun Resource Conservation District (SRCD), DWR, and other agencies have worked to preserve beneficial uses of Suisun Marsh in mitigation for perceived impacts of reduced Delta Outflow on the salinity regime. Early on, salinity standards set by the SWRCB to protect alkali bulrush production, a primary waterfowl plant food. The most recent standard under SWRCB D-1641 acknowledges that multiple beneficial uses deserve protection.

A contractual agreement between DWR, Reclamation, DFG and SRCD contains provisions for DWR and Reclamation to mitigate the effects on Suisun Marsh channel water salinity from the SWP and CVP operations and other upstream diversions. The Suisun Marsh Preservation Agreement (SMPA) requires DWR and Reclamation to meet salinity standards (Figure P-13), sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements. In addition to the contractual

agreement, SWRCB D-1485 codified salinity standards in 1978, which have been carried forward to SWRCB D-1641.

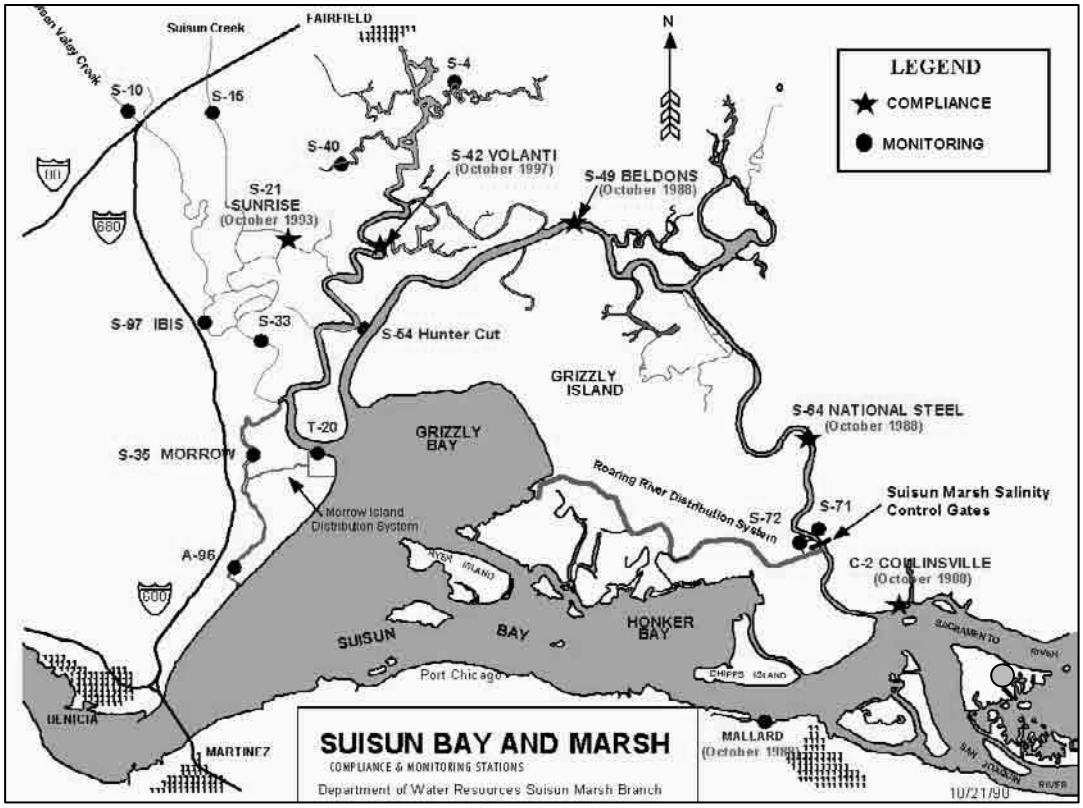

Figure P-13 Compliance and monitoring stations and salinity control facilities in Suisun Marsh.

There are two primary physical mechanisms for meeting salinity standards set forth in D-1641 and the SMPA: (1) the implementation and operation of physical facilities in the Marsh; and (2) management of Delta outflow (i.e. facility operations are driven largely by salinity levels upstream of Montezuma Slough and salinity levels are highly sensitive to Delta outflow). Physical facilities (described below) have been operating since the early 1980s and have proven to be a highly reliable method for meeting standards. However, since Delta outflow cannot be actively managed by the Suisun Marsh Program, Marsh facility operations must be adaptive in response to changing salinity levels in the Delta.

CALFED Charter for Development of an Implementation Plan for Suisun Marsh Wildlife Habitat Management and Preservation

The goal of the CALFED Charter is to develop a regional plan that balances implementation of the CALFED Program, SMPA, and other management and restoration programs within Suisun Marsh. This is to be conducted in a manner that is responsive to the concerns of stakeholders and based upon voluntary participation by private land owners. The Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh (Suisun Marsh Plan) and its accompanying Programmatic Environmental Impact Statement/Report will develop, analyze, and evaluate potential effects of various actions

in the Suisun Marsh. The actions are intended to preserve and enhance managed seasonal wetlands, implement a comprehensive levee protection/improvement program, and protect ecosystem and drinking water quality, while restoring habitat for tidal marsh-dependent sensitive species, consistent with the CALFED Bay-Delta Program's strategic goals and objectives. The Service and Reclamation are NEPA co-leads while DFG is the lead state CEQA agency.

Suisun Marsh Salinity Control Gates

The SMSCG are located on Montezuma Slough about 2 miles downstream from the confluence of the Sacramento and San Joaquin Rivers, near Collinsville. Operation of the SMSCG began in October 1988 as Phase II of the Plan of Protection for the Suisun Marsh. The objective of SMSCG operation is to decrease the salinity of the water in Montezuma Slough The facility, spanning the 465 foot width of Montezuma Slough, consists of a boat lock, a series of three radial gates, and removable flashboards. The gates control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the gates in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west.

When Delta outflow is low to moderate and the gates are not operating, tidal flow past the gate is approximately +/- 5,000-6,000 cfs while the net flow is near zero. When operated, flood tide flows are arrested while ebb tide flows remain in the range of 5,000-6,000 cfs. The net flow in Montezuma Slough becomes approximately 2,500-2,800 cfs. The Corps of Engineers permit for operating the SMSCG requires that it be operated between October and May only when needed to meet Suisun Marsh salinity standards. Historically, the gate has been operated as early as October 1, while in some years (e.g. 1996) the gate was not operated at all. When the channel water salinity decreases sufficiently below the salinity standards, or at the end of the control season, the flashboards are removed and the gates raised to allow unrestricted movement through Montezuma Slough. Details of annual gate operations can be found in “Summary of Salinity Conditions in Suisun Marsh During WYs 1984-1992", or the “Suisun Marsh Monitoring Program Data Summary” produced annually by DWR, Division of Environmental Services.

The approximately 2,800 cfs net flow induced by SMSCG operation is effective at moving the salinity downstream in Montezuma Slough. Salinity is reduced by roughly one-hundred percent at Beldons Landing, and lesser amounts further west along Montezuma Slough. At the same time, the salinity field in Suisun Bay moves upstream as net Delta outflow (measured nominally at Chipps Island) is reduced by gate operation (Figure P-14). Net outflow through Carquinez Strait is not affected. Figure P-14 indicates the approximate position of X2 and how is transported upstream when the gate is operated.

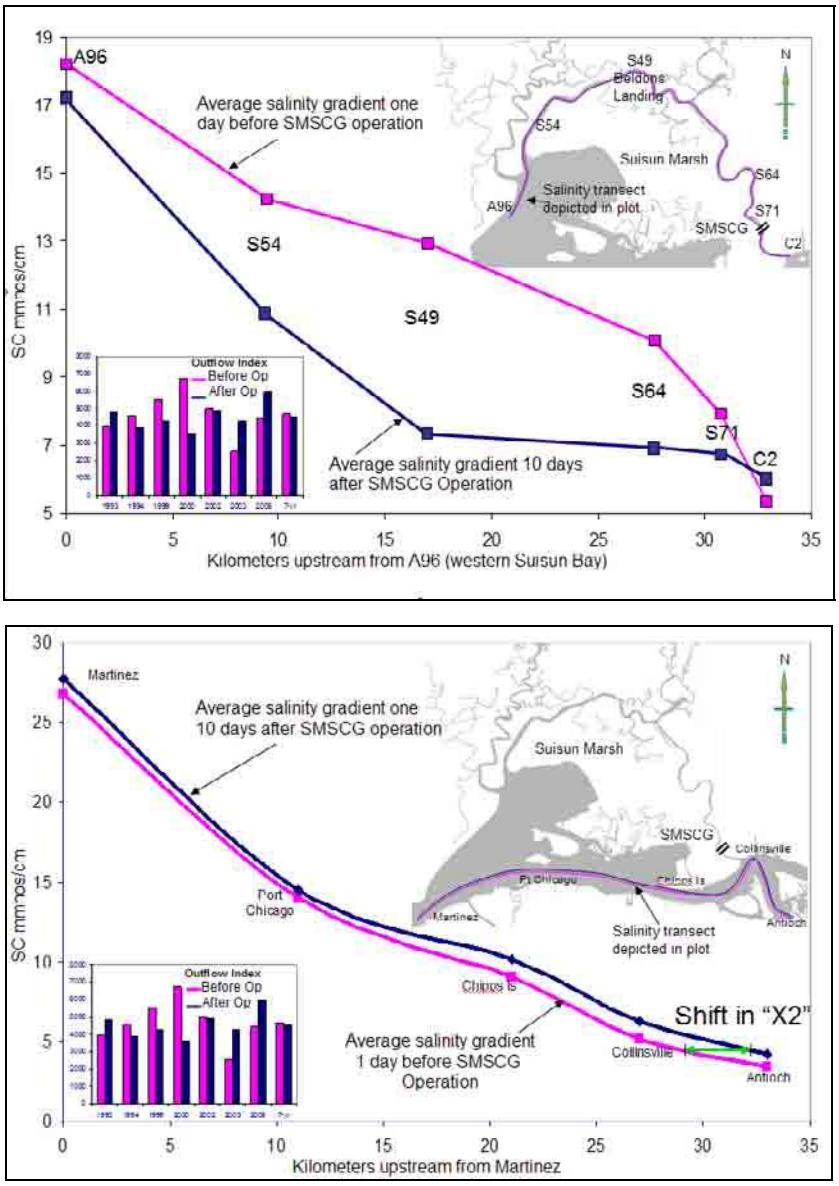

Figure P-14 Average of seven years salinity response to SMSCG gate operation in Montezuma Slough and Suisun Bay.

Note: Magenta line is salinity profile 1 day before gate operation, blue line is salinity 10 days after gate operation.

It is important to note that historical gate operations (1988 – 2002) were much more frequent than recent and current operations (2006 – May 2008). Operational frequency is affected by many drivers (hydrologic conditions, weather, Delta outflow, tide, fishery considerations, etc). The gates have also been operated for scientific studies. Figure P-15 shows that the gates were operated between 60 and 120 days between October and December during the early years (1988-2004). Salmon passage studies between 1998 and 2003 increased the number of operating days by up to 14 to meet study requirements. After discussions with NMFS based on study findings, the boat lock portion of the gate is now held open at all times during SMSCG operation to allow for continuous salmon

passage opportunity. With increased understanding of the effectiveness of the gates in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operation since 2006. Despite very low outflow in the fall of the two most recent WYs, gate operation was not required at all in fall 2007 and was limited to 17 days in winter 2008. Assuming no significant, long-term changes in the drivers mentioned above, this level of operational frequency (10 – 20 days per year) can generally be expected to continue to meet standards in the future except perhaps during the most critical hydrologic conditions and/or other conditions that affect Delta outflow.

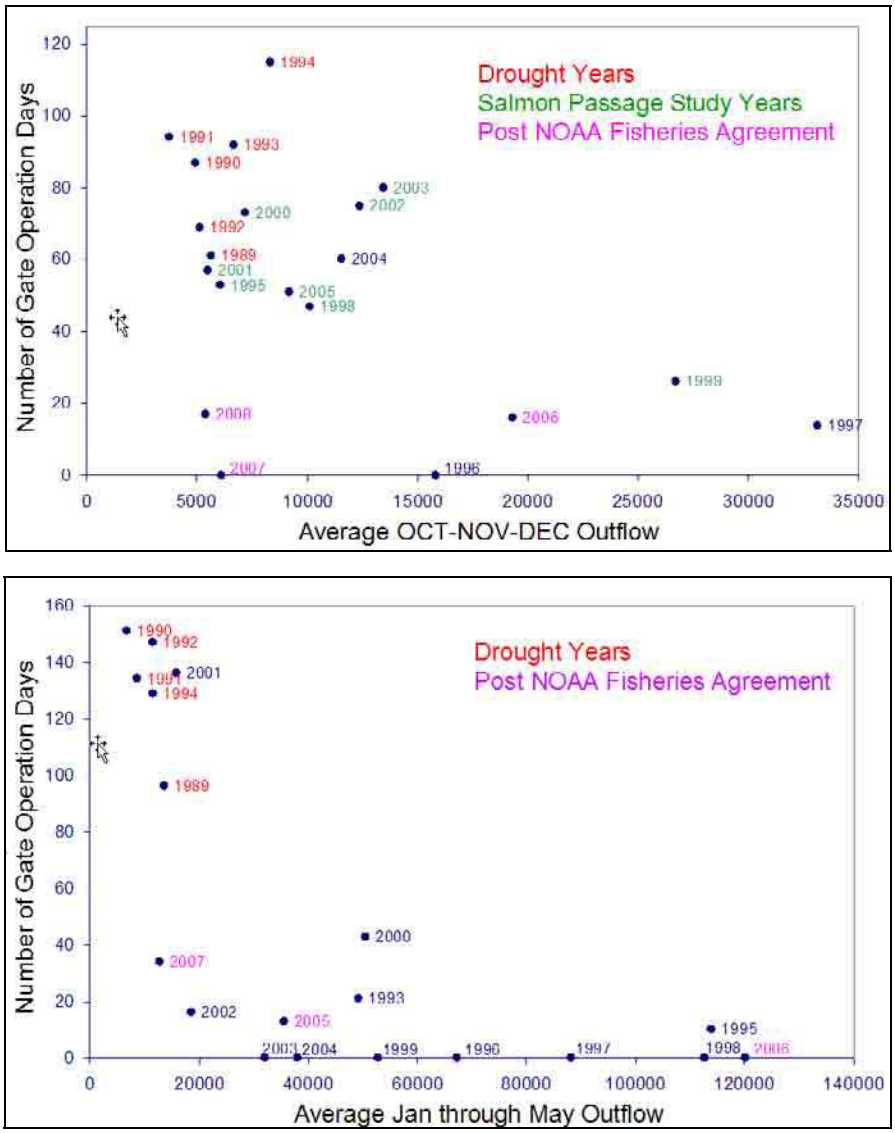

Figure P-15 SMSCG operation frequency versus outflow since 1988.

SMSCG Fish Passage Study

The SMSCG were constructed and operate under Permit 16223E58 issued by the Corps, which includes a special condition to evaluate the nature of delays to migrating fish.

Ultrasonic telemetry studies in 1993 and 1994 showed that the physical configuration and operation of the gates during the Control Season have a negative effect on adult salmonid passage (Tillman et al 1996: Edwards et al 1996).

DWR coordinated additional fish passage studies in 1998, 1999, 2001, 2002, 2003, and 2004. Migrating adult fall-run Chinook salmon were tagged and tracked by telemetry in the vicinity of the SMSCG to assess potential measures to increase the salmon passage rate and decrease salmon passage time through the gates.

Results in 2001, 2003, and 2004 indicate that leaving the boat-lock open during the Control Season when the flashboards are in place at the SMSCG and the radial gates are tidally operated provides a nearly equivalent fish passage to the Non-Control Season configuration when the flashboards are out and the radial gates are open. This approach minimizes delay and blockage of adult Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead migrating upstream during the Control Season while the SMSCG is operating. However, the boat-lock gates may be closed temporarily to stabilize flows to facilitate safe passage of watercraft through the facility.

Reclamation and DWR are continuing to coordinate with the SMSCG Steering Committee in identifying water quality criteria, operational rules, and potential measures to facilitate removal of the flashboards during the Control Season that would provide the most benefit to migrating fish. However, the flashboards would not be removed during the Control Season unless it was certain that standards would be met for the remainder of the Control Season without the flashboards installed.

Roaring River Distribution System

The Roaring River Distribution System (RRDS) was constructed during 1979 and 1980 as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. The system was constructed to provide lower salinity water to 5,000 acres of private and 3,000 acres of DFG managed wetlands on Simmons, Hammond, Van Sickle, Wheeler, and Grizzly Islands.

The RRDS includes a 40-acre intake pond that supplies water to Roaring River Slough. Motorized slide gates in Montezuma Slough and flap gates in the pond control flows through the culverts into the pond. A manually operated flap gate and flashboard riser are located at the confluence of Roaring River and Montezuma Slough to allow drainage back into Montezuma Slough for controlling water levels in the distribution system and for flood protection. DWR owns and operates this drain gate to ensure the Roaring River levees are not compromised during extremely high tides.

Water is diverted through a bank of eight 60-inch-diameter culverts equipped with fish screens into the Roaring River intake pond on high tides to raise the water surface elevation in RRDS above the adjacent managed wetlands. Managed wetlands north and south of the RRDS receive water, as needed, through publicly and privately owned turnouts on the system.

The intake to the RRDS is screened to prevent entrainment of fish larger than approximately 25 mm. DWR designed and installed the screens based on DFG criteria. The screen is a stationary vertical screen constructed of continuous-slot stainless steel wedge wire. All screens have 3/32-inch slot openings. After the listing of delta smelt, RRDS diversion rates have been controlled to maintain an average approach velocity below 0.2 ft/s at the intake fish screen. Initially, the intake culverts were held at about 20 percent capacity to meet the velocity criterion at high tide. Since 1996, the motorized slide gates have been operated remotely to allow hourly adjustment of gate openings to maximize diversion throughout the tide.

Routine maintenance of the system is conducted by DWR and primarily consists of maintaining the levee roads and fish screens. RRDS, like other levees in the marsh, have experienced subsidence since the levees were constructed in 1980. In 1999, DWR restored all 16 miles of levees to design elevation as part of damage repairs following the 1998 flooding in Suisun Marsh. In 2006, portions of the north levee were repaired to address damage following the January 2006 flooding.

Morrow Island Distribution System

The Morrow Island Distribution System (MIDS) was constructed in 1979 and 1980 in the south-western Suisun Marsh as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. The contractual requirement for the Reclamation and DWR is to provide water to the ownerships so that lands may be managed according to approved local management plans. The system was constructed primarily to channel drainage water from the adjacent managed wetlands for discharge into Suisun Slough and Grizzly Bay. This approach increases circulation and reduces salinity in Goodyear Slough (GYS).

The MIDS is used year-round, but most intensively from September through June. When managed wetlands are filling and circulating, water is tidally diverted from Goodyear Slough just south of Pierce Harbor through three 48-inch culverts. Drainage water from Morrow Island is discharged into Grizzly Bay by way of the C-Line Outfall (two 36-inch culverts) and into the mouth of Suisun Slough by way of the M-Line Outfall (three 48-inch culverts), rather than back into Goodyear Slough. This helps prevent increases in salinity due to drainage water discharges into Goodyear Slough. The M-Line ditch is approximately 1.6 miles in length and the C-Line ditch is approximately 0.8 miles in length.

The 1997 Service biological opinion issued for dredging of the facility included a requirement for screening the diversion to protect delta smelt. Due to the high cost of fish screens and the lack of certainty surrounding their effectiveness at MIDS, DWR and Reclamation proposed to investigate fish entrainment at the MIDS intake with regard to fishery populations in Goodyear Slough and to evaluate whether screening the diversion would provide substantial benefits to local populations of listed fish species.

To meet contractual commitments, the typical MIDS annual operations are described in detail in the biological assessment. There are currently no plans to modify operations.

South Delta Temporary Barriers Project

The South Delta Temporary Barrier Project (TBP) was initiated by DWR in 1991. Permit extensions were granted in 1996 and again in 2001, when DWR obtained permits to extend the Temporary Barriers Project through 2007. The Service has approved the extension of the permits through 2008. Continued coverage by the Service for the TBP will be assessed under this biological opinion for the operational effects and under a separate Section 7 consultation for the construction and demolition effects. The NMFS recently submitted a biological opinion to the Corps which provides incidental take coverage for the continuation of the TBP through 2010.

The project consists of four rock barriers across South Delta channels. In various combinations, these barriers improve water levels and San Joaquin River salmon migration in the South Delta. The existing TBP consists of installation and removal of temporary rock barriers at the following locations:

- Middle River near Victoria Canal, about 0.5 miles south of the confluence of Middle River, Trapper Slough, and North Canal
- Old River near Tracy, about 0.5 miles east of the DMC intake
- Grant Line Canal near Tracy Boulevard Bridge, about 400 feet east of Tracy Boulevard Bridge
- The head of Old River at the confluence of Old River and San Joaquin River

The barriers on Middle River, Old River near Tracy, and Grant Line Canal are flow control facilities designed to improve water levels for agricultural diversions and are in place during the growing season. Under the Service biological opinion for the Temporary Barriers, operation of the barriers at Middle River and Old River near Tracy can begin May 15, or as early as April 15 if the spring barrier at the head of Old River is in place. From May 16 to May 31 (if the barrier at the head of Old River is removed) the tide gates are tied open in the barriers in Middle River and Old River near Tracy. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

During the spring, the barrier at the head of Old River is designed to reduce the number of out-migrating salmon smolts entering Old River. During the fall, this barrier is designed to improve flow and DO conditions in the San Joaquin River for the immigration of adult fall-run Chinook salmon. The barrier at the head of Old River barrier is typically in place between April 15 to May 15 for the spring, and between early September to late November for the fall. Installation and operation of the barrier also depends on San Joaquin flow conditions.

Proposed Installation and Operations of the Temporary Barriers

The installation and operation of the TBP will continue until the permanent gates are constructed. The proposed installation schedule through 2010 will be identical to the current schedule. However, because of recent court rulings to protect Delta smelt, the installation of the spring HOR barrier was prohibited in 2008. As a result, the

agricultural barriers installations were delayed according to the current permits until mid-May.

To improve water circulation and quality, DWR in coordination with the South Delta Water Agency and Reclamation, began in 2007 to manually tie open the culvert flap gates at the Old River near Tracy barrier to improve water circulation and untie them when water levels fell unacceptably. This operation is expected to continue in subsequent years as needed to improve quality. Adjusting the barrier weir heights is being considered to improve water quality and circulation. DWR will consult with the Service and NMFS if changes in the height of any or all of the weirs is sought.

As the permanent gates are being constructed, temporary barrier operations will continue as planned and permitted. Computer model forecasts, real time monitoring, and coordination with local, State, and federal agencies and stakeholders will help determine if the temporary rock barriers operations need to be modified during the transition period.

Conservation Strategies and Mitigation Measures

Various measures and conditions required by regulatory agencies under past and current permits to avoid, minimize, and compensate for the TBP impacts have been complied with by DWR. An ongoing monitoring plan is implemented each year the barriers are installed and an annual monitoring report is prepared to summarize the activities. The monitoring elements include fisheries monitoring and water quality analysis, Head of Old River fish entrainment and Kodiak trawling study, salmon smolt survival investigations, barrier effects on SWP and CVP entrainment, Swainson's Hawk monitoring, water elevation, water quality sampling, and hydrologic modeling. DWR operates fish screens at Sherman Island.

San Luis Complex

Water in the mainstem of the California Aqueduct flows south by gravity into the San Luis Joint-Use Complex (Figure P-16), which was designed and constructed by the federal government and is operated and maintained by the DWR. This section of the California Aqueduct serves both the SWP and the federal CVP.

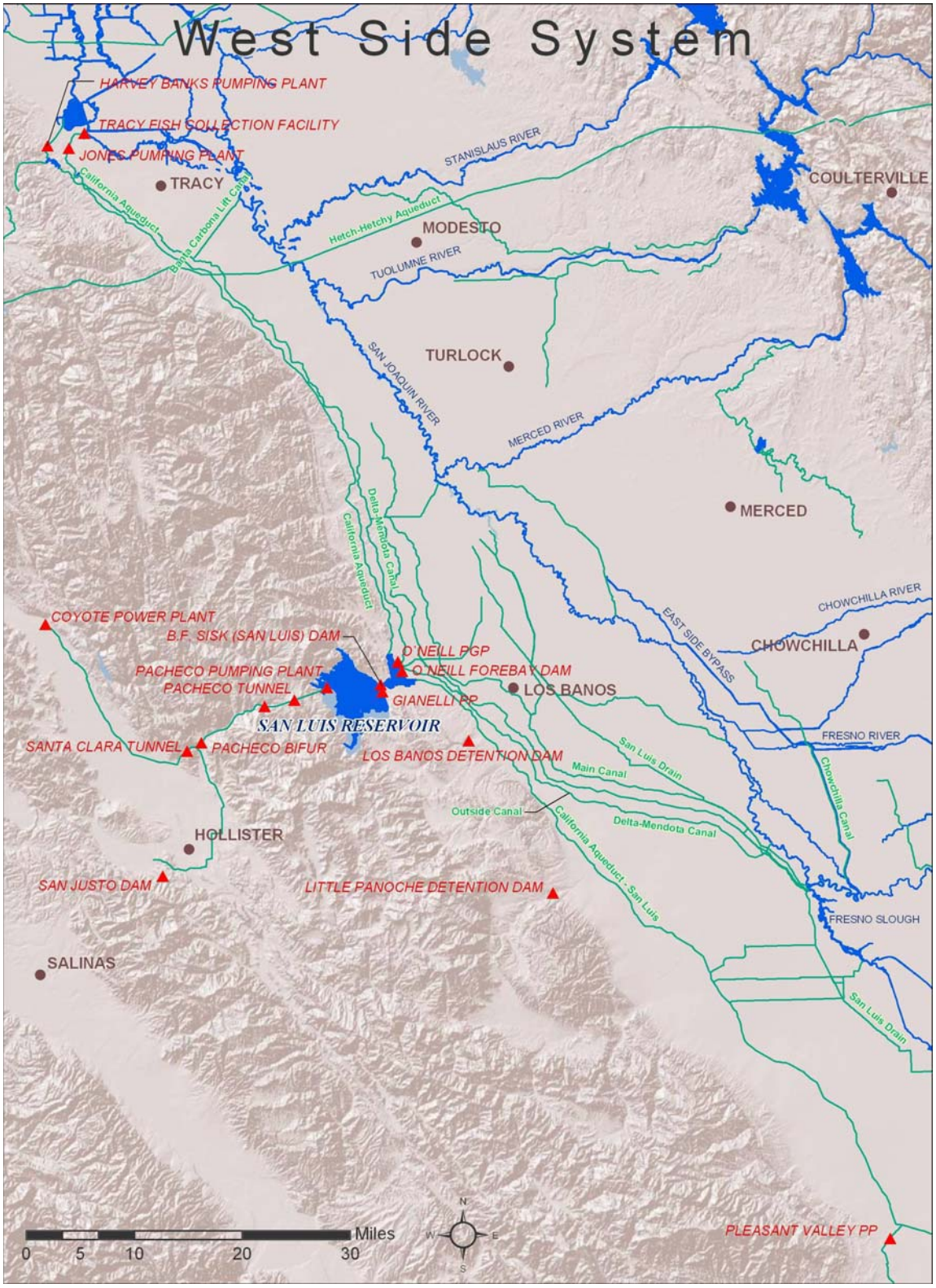

Figure P-16 San Luis Complex

San Luis Reservoir, the nation's largest offstream reservoir (it has no natural watershed), is impounded by Sisk Dam, lies at the base of the foothills on the west side of the San Joaquin Valley in Merced County, about two miles west of O'Neill Forebay. The reservoir provides offstream storage for excess winter and spring flows diverted from the Delta. It is sized to provide seasonal carryover storage. The reservoir can hold 2,027,840 AF, of which 1,062,180 AF is the state's share, and 965,660 AF is the federal share. Construction began in 1963 and was completed in 1967. Filled in 1969, the reservoir also provides a variety of recreational activities as well as fish and wildlife benefits.

In addition to the Sisk Dam, San Luis Reservoir and O'Neill Dam and Forebay, the San Luis Complex consists of the following: (1) O'Neill Pumping-Generating Plant (Federal facility); (2) William R. Gianelli Pumping-Generating Plant (joint Federal-State facilities); (3) San Luis Canal (joint Federal-State facilities); (4) Dos Amigos Pumping Plant (joint Federal-State facilities); (5) Coalinga Canal (Federal facility); (6) Pleasant Valley Pumping Plant (Federal facility); and (7) the Los Banos and Little Panoche Detention Dams and Reservoirs (joint Federal-State facilities).

The O'Neill Pumping-Generating Plant pumps water from the Delta-Mendota Canal to the O'Neill Forebay where it mixes with water from the California Aqueduct. From O'Neill Forebay, the water can either be pumped up into San Luis Reservoir via Gianelli Pumping-Generating Plant or leave via the San Luis Canal. The Dos Amigos Pumping Plant is located on the San Luis Canal and 18 miles southeast of Sisk Dam. It lifts water 113 feet from the Aqueduct as it flows south from O'Neill Forebay.

Los Banos Detention Dam and Reservoir provide flood protection for San Luis Canal, Delta Mendota Canal, the City of Los Banos, and other downstream developments. Between September and March, 14,000 AF of space is maintained for flood control under specified conditions. Little Panoche Detention Dam and Reservoir provide flood protection for San Luis Canal, Delta Mendota Canal and other downstream developments. Water is stored behind the dam above dead storage of 315 AF only during the period that inflow from Little Panoche Creek exceeds the capacity of the outlet works.

To provide water to CVP and SWP contractors: (1) water demands and anticipated water schedules for water service contractors and exchange contractors must be determined; (2) a plan to fill and draw down San Luis Reservoir must be made; and (3) Delta pumping and San Luis Reservoir use must be coordinated.

The San Luis Reservoir has very little natural inflow. Water is redirected during the fall, winter and spring months when the two pumping plants can divert more water from the Delta than is needed for scheduled demands. Because the amount of water that can be diverted from the Delta is limited by available water supply, Delta constraints, and the capacities of the two pumping plants, the fill and drawdown cycle of San Luis Reservoir is an extremely important element of Project operations.

Reclamation attempts to maintain adequate storage in San Luis Reservoir to ensure delivery capacity through Pacheco Pumping Plant to the San Felipe Division. Delivery capacity is significantly diminished as reservoir levels drop to the 326 ft elevation (79,000 acre-feet), the bottom of the lowest Pacheco Tunnel Inlet pipe. Lower reservoir

elevations can also result in turbidity and algal treatment problems for the San Felipe Division water users. These conditions of reduced or impending interruption in San Felipe Division deliveries require operational responses by Santa Clara Valley Water District to reduce or eliminate water deliveries for in-stream and offstream groundwater recharge, and to manage for treatment plant impacts. Depending on availability of local supplies, prolonged reduction or interruption in San Felipe Division deliveries may also result in localized groundwater overdraft.

A typical San Luis Reservoir annual operation cycle starts with the CVP's share of the reservoir storage nearly empty at the end of August. Irrigation demands decrease in September and the opportunity to begin refilling San Luis Reservoir depends on the available water supply in the northern CVP reservoirs and the pumping capability at Jones Pumping Plant that exceeds water demands. Jones Pumping Plant operations generally continue at the maximum diversion rates until early spring, unless San Luis Reservoir is filled or the Delta water supply is not available. As outlined in the Interior's Decision on Implementation of Section 3406 (b)(2) of the CVPIA, Jones Pumping Plant diversion rates may be reduced during the fill cycle of the San Luis Reservoir for fishery management.

In April and May, export pumping from the Delta is limited during the SWRCB D-1641 San Joaquin River pulse period standards as well as by the Vernalis Adaptive Management Program. During this same time, CVP-SWP irrigation demands are increasing. Consequently, by April and May the San Luis Reservoir has begun the annual drawdown cycle. In some exceptionally wet conditions, when excess flood water supplies from the San Joaquin River or Tulare Lake Basin occur in the spring, the San Luis Reservoir may not begin its drawdown cycle until late in the spring.

In July and August, the Jones Pumping Plant diversion is at the maximum capability and some CVP water may be exported using excess Banks Pumping Plant capacity as part of a Joint Point of Diversion operation. Irrigation demands are greatest during this period and San Luis continues to decrease in storage capability until it reaches a low point late in August and the cycle begins anew.

San Luis Unit Operation

The CVP operation of the San Luis Unit requires coordination with the SWP since some of its facilities are entirely owned by the State and others are joint State and Federal facilities. Similar to the CVP, the SWP also has water demands and schedules it must meet with limited water supplies and facilities. Coordinating the operations of the two projects avoids inefficient situations (for example, one entity pumping water at the San Luis Reservoir while the other is releasing water).

Total CVP San Luis Unit annual water supply is contingent on coordination with the SWP needs and capabilities. When the SWP excess capacity is used to support additional pumping for the CVP JPOD allowance it may be of little consequence to SWP operations, but extremely critical to CVP operations. The availability of excess SWP capacity for the CVP is contingent on the ability of the SWP to meet its SWP contractors' water supply commitments. Generally, the CVP will utilize excess SWP capacity; however, there are times when the SWP may need to utilize excess CVP capacity.

Additionally, close coordination by CVP and SWP is required during this type of operation to ensure that water pumped into O'Neill Forebay does not exceed the CVP's capability to pump into San Luis Reservoir or into the San Luis Canal at the Dos Amigos Pumping Plant.

Although secondary to water management concerns, power scheduling at the joint facilities also requires close coordination. Because of time-of-use power cost differences, both entities will likely want to schedule pumping and generation simultaneously. When facility capabilities of the two projects are limited, equitable solutions are achieved between the operators of the SWP and the CVP.

From time to time, coordination between the Projects is also necessary to avoid sustained rapid drawdown limit at San Luis Reservoir which can cause sloughing of the bank material into the reservoir, resulting in water quality degradation and requiring additional maintenance on the dam.

With the existing facility configuration, the operation of the San Luis Reservoir could impact the water quality and reliability of water deliveries to the San Felipe Division, if San Luis Reservoir is drawn down too low. Reclamation has an obligation to address this condition and may solicit cooperation from DWR, as long as changes in SWP operations to assist with providing additional water in San Luis Reservoir (beyond what is needed for SWP deliveries and the SWP share of San Luis Reservoir minimum storage) does not impact SWP allocations and/or deliveries. If the CVP is not able to maintain sufficient storage in San Luis Reservoir, there could be potential impacts to resources in Santa Clara and San Benito Counties. Solving the San Luis low point problem or developing an alternative method to deliver CVP water to the San Felipe Division would allow Reclamation to utilize the CVP share of San Luis Reservoir fully without impacting the San Felipe Division water supply. If Reclamation pursues changes to the operation of the CVP (and SWP), such changes would have to be consistent with the operating criteria of the specific facility. If alternate delivery methods for the San Felipe Division are implemented, it may allow the CVP to utilize more of it available storage in San Luis Reservoir, but may not change the total diversions from the Delta. For example, any changes in Delta pumping that would be the result of additional effective storage capacity in San Luis Reservoir would be consistent with the operating conditions for the Banks and Jones Pumping Plants.

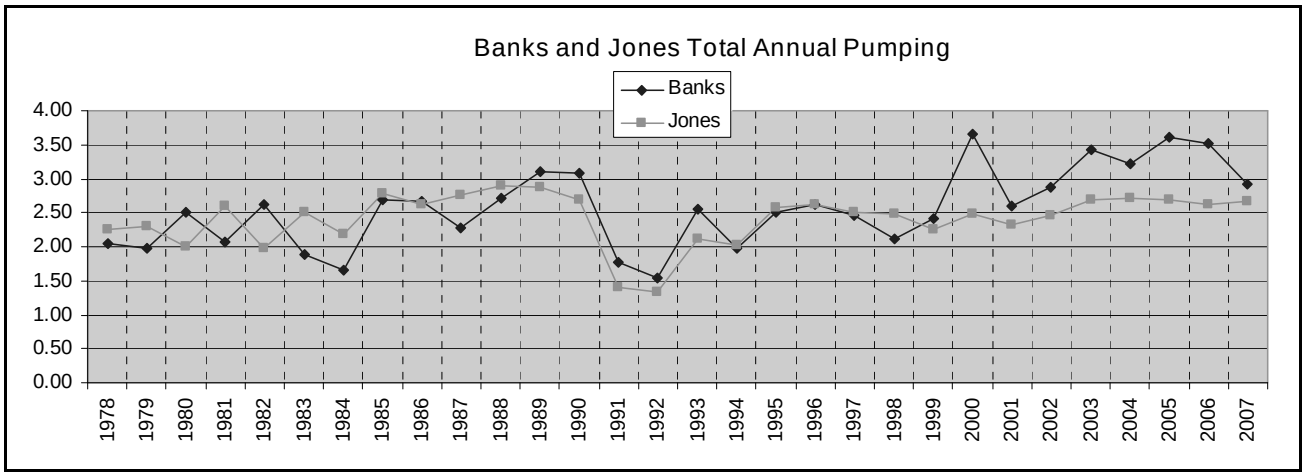

Figure P-17 Total Annual Pumping at Banks and Jones Pumping Plant 1978-2007 (MAF)

Table P-25 Total Annual Pumping at Banks and Jones Pumping Plant 1978-2007 (MAF)

WY	Hydrologic Index 40-30-30	Banks SWP	Banks CVP	Banks Total	Jones SWP	Jones CVP	Jones Total	Contra Costa	CVP Total Delta Pumping	SWP Total Delta Pumping	CVP SOD-Ag Allocation	Shasta Index Critical
1978	AN	2.01	0.04	2.05	0.00	2.26	2.26	0.08	2.38	2.01	100%	
1979	BN	1.76	0.23	1.98	0.00	2.30	2.30	0.09	2.61	1.76	100%	
1980	AN	2.17	0.34	2.52	0.00	2.00	2.00	0.09	2.43	2.17	100%	
1981	D	1.97	0.10	2.07	0.00	2.60	2.60	0.11	2.80	1.97	100%	
1982	W	2.43	0.20	2.63	0.00	1.97	1.97	0.08	2.25	2.43	100%	
1983	W	1.76	0.13	1.89	0.00	2.51	2.51	0.08	2.72	1.76	100%	
1984	W	1.40	0.25	1.65	0.00	2.19	2.19	0.10	2.54	1.40	100%	
1985	D	2.16	0.53	2.68	0.00	2.79	2.79	0.11	3.43	2.16	100%	
1986	W	2.46	0.21	2.67	0.00	2.62	2.62	0.11	2.94	2.46	100%	
1987	D	2.01	0.27	2.28	0.00	2.76	2.76	0.13	3.16	2.01	100%	
1988	C	2.32	0.38	2.71	0.00	2.90	2.90	0.14	3.42	2.32	100%	
1989	D	2.70	0.39	3.10	0.00	2.87	2.87	0.13	3.40	2.70	100%	
1990	C	2.85	0.24	3.09	0.00	2.70	2.70	0.14	3.07	2.85	50%	
1991	C	1.64	0.14	1.78	0.00	1.41	1.41	0.11	1.65	1.64	25%	C
1992	C	1.51	0.04	1.55	0.00	1.34	1.34	0.10	1.49	1.51	25%	C
1993	AN	2.53	0.02	2.56	0.00	2.11	2.11	0.10	2.22	2.53	50%	
1994	C	1.73	0.24	1.97	0.00	2.02	2.02	0.11	2.37	1.73	35%	C
1995	W	2.48	0.03	2.50	0.00	2.58	2.58	0.09	2.70	2.48	100%	
1996	W	2.60	0.01	2.61	0.06	2.57	2.63	0.10	2.68	2.66	95%	
1997	W	2.12	0.34	2.46	0.00	2.51	2.51	0.11	2.96	2.12	90%	
1998	W	2.07	0.04	2.11	0.01	2.46	2.47	0.16	2.66	2.09	100%	
1999	W	2.37	0.04	2.41	0.00	2.26	2.26	0.13	2.44	2.37	70%	
2000	AN	3.45	0.22	3.66	0.00	2.49	2.49	0.13	2.83	3.45	65%	

WY	Hydrologic Index 40-30-30	Banks SWP	Banks CVP	Banks Total	Jones SWP	Jones CVP	Jones Total	Contra Costa	CVP Total Delta Pumping	SWP Total Delta Pumping	CVP SOD-Ag Allocation	Shasta Index Critical
2001	D	2.37	0.23	2.60	0.01	2.31	2.32	0.10	2.65	2.38	49%	
2002	D	2.70	0.17	2.87	0.00	2.46	2.46	0.12	2.75	2.70	70%	
2003	AN	3.39	0.04	3.43	0.00	2.68	2.68	0.14	2.86	3.39	75%	
2004	BN	3.14	0.09	3.23	0.00	2.72	2.72	0.12	2.93	3.14	70%	
2005	AN	3.58	0.03	3.61	0.00	2.68	2.68	0.12	2.83	3.58	85%	
2006	W	3.50	0.01	3.51	0.00	2.62	2.62	0.12	2.74	3.50	100%	
2007	D	2.82	0.11	2.93	0.00	2.67	2.67	0.11	2.90	2.82	50%	

Source: CVO Operations Data Base

Transfers

Parties seeking water transfers generally acquire water from sellers who have surplus reservoir storage water, sellers who can pump groundwater instead of using surface water, or sellers who will fallow crops or substitute a crop that uses less water in order to reduce normal consumptive use of surface diversions.

Water transfers (relevant to this document) occur when a water right holder within the Delta or Sacramento-San Joaquin watershed undertakes actions to make water available for transfer by export from the Delta. With the exception of the Component 1 water pursuant to the Yuba River Accord, this biological opinion does not address the upstream operations that may be necessary to make water available for transfer. Also, this document does not address the impacts of water transfers to terrestrial species. The flows for the Yuba River Accord may provide up to 60,000 acre feet annually for EWA, in the lower Yuba River (estimated to provide up to 48,000 acre feet of additional Delta export), and may provide additional water to the CVP and SWP and their contractors in drier years. The upstream effects of other transfers and effects to terrestrial species would require a separate ESA consultation.

Transfers requiring export from the Delta are done at times when pumping and conveyance capacity at Banks or Jones is available to move the water. Additionally, operations to accomplish these transfers must be carried out in coordination with CVP and SWP operations, such that the capabilities of the Projects to exercise their own water rights or to meet their legal and regulatory requirements are not diminished or limited in any way.

In particular, parties to the transfer are responsible for providing for any incremental changes in flows required to protect Delta water quality standards. All transfers will be in accordance with all existing regulations and requirements.

Purchasers of water for water transfers may include Reclamation, DWR, SWP contractors, CVP contractors, other State and Federal agencies, or other parties. DWR

and Reclamation have operated water acquisition programs in the past to provide water for environmental programs and additional supplies to SWP contractors, CVP contractors, and other parties. The DWR programs include the 1991, 1992, and 1994 Drought Water Banks and Dry Year Programs in 2001 and 2002. Reclamation operated a forbearance program in 2001 by purchasing CVP contractors' water in the Sacramento Valley for CVPIA in-stream flows, and to augment water supplies for CVP contractors south of the Delta and wildlife refuges. Reclamation administers the CVPIA Water Acquisition Program for Refuge Level 4 supplies and fishery in-stream flows. The CALFED Ecosystem Restoration Program will, in the future, acquire water for fishery and ecosystem restoration. DWR, and potentially Reclamation in the future, has agreed to participate in a Yuba River Accord that will provide fish flows on the Yuba River and also water supply that may be transferred at DWR and Reclamation Delta Facilities. It is anticipated that Reclamation will join in the Accord and fully participate in the Yuba Accord upon completion of this consultation. The Yuba River Accord water would be transferred to offset VAMP water costs.

Also in the past, CVP and SWP contractors have also independently acquired water and arranged for pumping and conveyance through SWP facilities. State Water Code provisions grant other parties access to unused conveyance capacity, although SWP contractors have priority access to capacity not being used by the DWR to meet SWP contract amounts.

The Yuba River Accord includes three separate but interrelated agreements that would protect and enhance fisheries resources in the lower Yuba River, increase local water supply reliability, and provide DWR with increased operational flexibility for protection of Delta fisheries resources through Project re-operation, and provision of added dry-year water supplies to state and federal water contractors. These proposed agreements are the:

- Principles of Agreement for Proposed Lower Yuba River Fisheries Agreement (Fisheries Agreement)
- Principles of Agreement for Proposed Conjunctive Use Agreements (Conjunctive Use Agreements)
- Principles of Agreement for Proposed Long-term Transfer Agreement (Water Purchase Agreement)

The Fisheries Agreement was developed by state, federal, and consulting fisheries biologists, fisheries advocates, and policy representatives. Compared to the interim flow requirements of the SWRCB Revised Water Right Decision 1644, the Fisheries Agreement would establish higher minimum instream flows during most months of most WYs.

To assure that Yuba County Water Agency's (YCWA) water supply reliability would not be reduced by the higher minimum instream flows, YCWA and its participating Member Units would implement the Conjunctive Use Agreements. These agreements would establish a comprehensive conjunctive use program that would integrate the surface water and groundwater supplies of the local irrigation districts and mutual water companies that

YCWA serves in Yuba County. Integration of surface water and groundwater would allow YCWA to increase the efficiency of its water management.

Under the Water Purchase Agreement, DWR would enter into an agreement with YCWA to purchase water from YCWA to off-set water costs resulting from VAMP as long as operational and hydrological conditions allow. Additional water purchased by DWR would be available for south-of-Delta CVP and SWP contractors in drier years. The limited EWA would take delivery of 60,000 AF (48,000 AF export) of water in every year; the CVP/SWP would receive additional water in the drier years. In the future Reclamation may become a party to the Water Purchase Agreement.

The Fisheries Agreement is the cornerstone of the Yuba Accord Alternative. To become effective, however, all three agreements (Fisheries, Conjunctive Use, and Water Purchase) must undergo CEQA and NEPA review and be fully approved and executed by the individual parties to each agreement. Also, implementation of the Yuba Accord Alternative would require appropriate SWRCB amendments of YCWA's water-right permits and SWRCB D-1644.

Transfer Capacity

Reclamation assumes as part of the project description that the water transfer programs for environmental and water supply augmentation will continue in some form, and that in most years (all but the driest), the scope of annual water transfers will be limited by available Delta pumping capacity, and exports for transfers will be limited to the months July-September. As such, looking at an indicator of available transfer capacity in those months is one way of estimating an upper boundary to the effects of transfers on an annual basis.

The CVP and SWP may provide Delta export pumping for transfers using pumping capacity at Banks and Jones beyond that which is being used to deliver project water supply, up to the physical maximums of the pumps, consistent with prevailing operations constraints such as E/I ratio, conveyance or storage capacity, and any protective criteria in effect that may apply as conditions on such transfers. For example, pumping for transfers may have conditions for protection of Delta water levels, water quality, fisheries, or other beneficial uses.

The surplus capacity available for transfers will vary a great deal with hydrologic conditions. In general, as hydrologic conditions get wetter, surplus capacity diminishes because the CVP and SWP are more fully using export pumping capacity for Project supplies. CVP's Jones Pumping Plant, with no forebay for pumped diversions and with limited capability to fine tune rates of pumping, has little surplus capacity, except in the driest hydrologic conditions. SWP has the most surplus capacity in critical and some dry years, less or sometimes none in a broad middle range of hydrologic conditions, and some surplus again in some above normal and wet years when demands may be lower because contractors have alternative supplies.

The availability of water for transfer and the demand for transfer water may also vary with hydrologic conditions. Accordingly, since many transfers are negotiated between willing buyers and sellers under prevailing market conditions, price of water also may be

a factor determining how much is transferred in any year. This document does not attempt to identify how much of the available and useable surplus export capacity of the CVP and SWP will actually be used for transfers in a particular year, but recent history, the expectations for the future limited EWA, and the needs of other transfer programs suggest a growing reliance on transfers.

Under both the present and future conditions, capability to export transfers will often be capacity-limited, except in Critical and some Dry years. In these Critical and some Dry years, both Banks and Jones have more available capacity for transfers, so export capacity is less likely to limit transfers. Rather, either supply or demand for transfers may be a limiting factor. During such years, low project exports and high demand for water supply could make it possible to transfer larger amounts of water.

Proposed Exports for Transfers

Although transfers may occur at any time of year, proposed exports for transfers apply only to the months July through September. For transfers outside those months, or in excess of the proposed amounts, Reclamation and DWR would request separate consultation. In consideration of the estimates of available capacity for export of transfers during July-September, and in recognition of the many other possible operations contingencies and constraints that may limit actual use of that capacity for transfers, the proposed use of SWP/CVP export capacity for transfers is as follows:

Water Year Class	Maximum Transfer Amount
Critical	up to 600 TAF
Dry (following Critical)	up to 600 TAF
Dry (following Dry)	up to 600 TAF
All other Years	up to 360 TAF

Other Projects

The following projects may not have final approval. However, Reclamation believes they may be implemented in the near term. Reclamation is including these actions in the project description so that the effects of these actions on aquatic species may be analyzed as it pertains to operations. The analysis does not include any effects to terrestrial species. These will be addressed in separate construction consultation.

DMC/CA Intertie Proposed Action

The proposed action, known as the DMC and CA Intertie (DMC/CA Intertie), consists of construction and operation of a pumping plant and pipeline connections between the

DMC and the CA. The DMC/CA Intertie alignment is proposed for DMC milepost 7.2 where the DMC and the CA are about 500 feet apart.

The DMC/CA Intertie would be used in a number of ways to achieve multiple benefits, including meeting current water supply demands, allowing for the maintenance and repair of the CVP Delta export and conveyance facilities, and providing operational flexibility to respond to emergencies. The Intertie would allow flow in both directions, which would provide additional flexibility to both CVP and SWP operations. The Intertie includes a 467 cfs pumping plant at the DMC that would allow up to 467 cfs to be pumped from the DMC to the CA. Up to 900 cfs flow could be conveyed from the CA to the DMC using gravity flow. The intertie will not be used to increase total CVP exports until certain criteria are in place.

The DMC/CA Intertie will be operated by the San Luis and Delta-Mendota Water Authority (Authority). A three-way agreement among Reclamation, DWR, and the Authority would identify the responsibilities and procedures for operating the Intertie. The Intertie would be owned by Reclamation. A permanent easement would be obtained by Reclamation where the Intertie alignment crossed State property.

Location

The site of the proposed action is an unincorporated area of Alameda County, west of the City of Tracy. The site is situated in a rural area zoned for general agriculture and is under Federal and State ownership. The DMC/CA Intertie would be located at milepost 7.2 of the DMC, connecting with milepost 9.0 of the CA.

Operations

The Intertie would be used under three different scenarios:

1. Up to 467 cfs would be pumped from the DMC to the CA to help meet water supply demands of CVP contractors. This would allow Jones Pumping Plant to pump to its authorized capacity of up to 4,600 cfs, subject to all applicable export pumping restrictions for water quality and fishery protections.

2. Up to 467 cfs would be pumped from the DMC to the CA to minimize impacts to water deliveries due to temporary restrictions in flow or water levels on the lower DMC (south of the Intertie) or the upper CA (north of the Intertie) for system maintenance or due to an emergency shutdown.

3. Up to 900 cfs would be conveyed from the CA to the DMC using gravity flow to minimize impacts to water deliveries due to temporary restrictions in flow or water levels on the lower CA (south of the Intertie) or the upper DMC (north of the Intertie) for system maintenance or due to an emergency shutdown.

The DMC/CA Intertie provides operational flexibility between the DMC and CA. It would not result in any changes to authorized pumping capacity at Jones Pumping Plant or Banks Delta Pumping Plant.

Water conveyed at the Intertie to minimize reductions to water deliveries during system maintenance or an emergency shutdown on the DMC or CA could include pumping of CVP water at Banks Pumping Plant or SWP water at Jones Pumping Plant through use of JPOD. In accordance with COA Articles 10(c) and 10(d), JPOD may be used to replace conveyance opportunities lost because of scheduled maintenance, or unforeseen outages. Use of JPOD for this purpose could occur under Stage 2 operations defined in SWRCB D-1641, or could occur as a result of a Temporary Urgency request to the SWRCB. Use of JPOD in this case does not result in any net increase in allowed exports at CVP and SWP export facilities. When in use, water within the DMC would be transferred to the CA via the Intertie. Water diverted through the Intertie would be conveyed through the CA to O'Neill Forebay.

Freeport Regional Water Project

The Freeport Regional Water Project (FRWP) is currently under construction. Once completed FRWP will divert up to a maximum of about 286 cubic feet per second (cfs) from the Sacramento River near Freeport for Sacramento County (deliveries expected in 2011) and East Bay Municipal Utility District (EBMUD) deliveries expected in late 2009. EBMUD will divert water pursuant to its amended contract with Reclamation. The County will divert using its water rights and its CVP contract supply. This facility was not in the 1986 COA, and the diversions will result in some reduction in Delta export supply for both the CVP and SWP contractors. Pursuant to an agreement between Reclamation, DWR, and the CVP and SWP contractors in 2003, diversions to EBMUD will be treated as an export in the COA accounting and diversions to Sacramento County will be treated as an in-basin use.

Reclamation proposes to deliver CVP water pursuant to its respective water supply contracts with SCWA and EBMUD through the FRWP, to areas in central Sacramento County. SCWA is responsible for providing water supplies and facilities to areas in central Sacramento County, including the Laguna, Vineyard, Elk Grove, and Mather Field communities, through a capital funding zone known as Zone 40.

The FRWP has a design capacity of 286 cfs (185 millions of gallons per day [mgd]). Up to 132 cfs (85 mgd) would be diverted under Sacramento County's existing Reclamation water service contract and other anticipated water entitlements and up to 155 cfs (100 mgd) of water would be diverted under EBMUD's amended Reclamation water service contract. Under the terms of its amendatory contract with Reclamation, EBMUD is able to take delivery of Sacramento River water in any year in which EBMUD's March 1 forecast of its October 1 total system storage is less than 500,000 AF. When this condition is met, the amendatory contract entitles EBMUD to take up to 133,000 AF annually. However, deliveries to EBMUD are subject to curtailment pursuant to CVP shortage conditions and project capacity (100 mgd), and are further limited to no more than 165,000 AF in any 3-consecutive-year period that EBMUD's October 1 storage forecast remains below 500,000 AF. EBMUD would take delivery of its entitlement at a maximum rate of 100 mgd (112,000 AF per year). Deliveries would start at the beginning of the CVP contract year (March 1) or any time afterward. Deliveries would cease when EBMUD's CVP allocation for that year is reached, when the 165,000 AF

limitation is reached, or when EBMUD no longer needs the water (whichever comes first). Average annual deliveries to EBMUD are approximately 23,000 AF. Maximum delivery in any one WY is approximately 99,000 AF.

The primary project components are (1) an intake facility on the Sacramento River near Freeport, (2) the Zone 40 Surface Water Treatment Plant (WTP) located in central Sacramento County, (3) a terminal facility at the point of delivery to the Folsom South Canal (FSC), (4) a canal pumping plant at the terminus of the FSC, (5) an Aqueduct pumping plant and pretreatment facility near Comanche Reservoir, and (6) a series of pipelines carrying water from the intake facility to the Zone 40 Surface WTP and to the Mokelumne Aqueducts. The existing FSC is part of the water conveyance system. See Chapter 9 for modeling results on annual diversions at Freeport in the American River Section, Modeling Results Section subheading.

Alternative Intake Project

CCWD's Alternative Intake Project (AIP) consists of a new 250 cfs screened intake in Victoria Canal, and a pump station and ancillary structures, utilities, and access and security features; levee improvements; and a conveyance pipeline to CCWD's existing conveyance facilities.

CCWD will operate the intake and pipeline together with its existing facilities to better meet its delivered water quality goals and to better protect listed species. Operations with the AIP will be similar to existing operations: CCWD will deliver Delta water to its customers by direct diversion when salinity at its intakes is low enough, and will blend Delta water with releases from Los Vaqueros Reservoir when salinity at its intakes exceeds the delivered water quality goal. Los Vaqueros Reservoir will be filled from the existing Old River intake or the new Victoria Canal intake during periods of high flow in the Delta, when Delta salinity is low. The choice of which intake to use at any given time will be based in large part upon salinity, consistent with fish protection requirements in the biological opinions; salinity at the Victoria Canal intake site is at times lower than salinity at the existing intakes. The no-fill and no-diversion periods described above will continue as part of CCWD operations, as will monitoring and shifting of diversions among the four intakes to minimize impacts to listed species.

The AIP is a water quality project, and will not increase CCWD's average annual diversions from the Delta. However, it will alter the timing and pattern of CCWD's diversions in two ways: winter and spring diversions will decrease while late summer and fall diversions increase because Victoria Canal salinity tends to be lower in the late summer and fall than salinity at CCWD's existing intakes; and diversions at the unscreened Rock Slough Intake will decrease while diversions at screened intakes will increase. It is estimated that with the AIP, Rock Slough intake diversions will fall to about 10 percent of CCWD's total diversions, with the remaining diversions taking place at the other screened intakes. About 88 percent of the diversions will occur at the Old River and Victoria Canal intakes, with the split between these two intakes largely depending on water quality.

The effects of the AIP are covered by the April 27, 2007 Service biological opinion for delta smelt (amended on May 16, 2007).

Red Bluff Diversion Dam Pumping Plant

Reclamation signed the ROD July 16, 2008 for RBDD pumping plant and plans to change the operation of the RBDD to improve fish passage problems. The project features construction of a new pumping plant and operation of the RBDD gates in the out position for approximately 10 months of the year. Reclamation is calling for the construction of a pumping plant upstream from the dam that could augment existing capabilities for diverting water into the Tehama-Colusa Canal during times when gravity diversion is not possible due to the RBDD gates being out. Reclamation completed ESA section 7 consultations with the Service and the NMFS to address construction of a new pumping plant at maximum capacity of 2,500 cfs.

The new pumping plant would be capable of operating throughout the year, providing both additional flexibility in dam gate operation and water diversions for the Tehama-Colusa Canal Authority (TCCA) customers. In order to improve adult green sturgeon passage during their spawning migrations (generally March through July) the gates could remain open during the early part of the irrigation season and the new pumping plant could be used alone or in concert with other means to divert water to the Tehama-Colusa and Corning canals.

Green sturgeon spawn upstream of the diversion dam and the majority of adult upstream and downstream migrations occur prior to July and after August. After the new pumping plant has been constructed and is operational, Reclamation proposes to operate the Red Bluff Diversion Dam with the gates in during the period from four days prior to the Memorial Day weekend to three days after the holiday weekend (to facilitate the Memorial Day boat races in Lake Red Bluff), and between July 1 and the end of the Labor Day weekend. This operation would provide for improved sturgeon and salmon passage.

The pumping plant project will occur in three phases. The first, completion of the NEPA/CEQA process has already been accomplished. The design and permitting phase is commencing, subject to the availability of funding, and is anticipated to take about 18-36 months. As funding permits, property acquisition will also occur during this phase, and further funding commitments would be secured during this time. The final phase, facilities construction, is anticipated to take approximately 18-36 months but this timeline will be updated during final design and permitting.

South Delta Improvements Program Stage 1

The objectives of the SDIP are to: 1) reduce the movement of outmigrating salmon from the San Joaquin River into Old River, 2) maintain adequate water levels and circulation

in South Delta channels, and 3) increase water delivery and reliability to the SWP and CVP by increasing the diversion limit at Clifton Court Forebay to 8500 cfs.[5]

The decision to implement the proposed action is being done in two stages. Stage 1 will address the first two objectives and involves the construction and operation of gates at four locations in the South Delta channels. A decision to implement Stage 2 would address increasing the water delivery reliability of the SWP and CVP by increasing the diversion limit at Clifton Court Forebay. This decision has been deferred indefinitely.

The Final EIR/EIS was completed in December 2006. DWR certified the final EIR as meeting the requirements of the California Environmental Quality Act at that time. The Department plans to issue a Notice of Determination to proceed with implementing Stage 1 of the SDIP once the biological opinions on the continued long term operations of the CVP/SWP and the biological opinions for the dredging and construction of the gates are received.

Reclamation and DWR are seeking to construct and operate the gates proposed for the four locations. Key operational features of these gates are included as part of this project description. Separate biological opinions will be conducted for the impacts of constructing the gates and the channel dredging contained in Stage 1.

The permanent operable gates, which are planned to be constructed in the South Delta in late 2012, will be operated within an adaptive management framework, as described below under "Gate Operations Review Team," so that the benefits from these gate operations can be maximized. The gates can be opened or closed at any time in response to the local tidal level and flow conditions within the South Delta. In this regard, they are very different from the temporary barriers that have been installed for the past several years.

Because these operable gates are designed as "lift gates" that are hinged at the bottom of the channel, "closure" of the gates can be specified at any tidal level, leaving a weir opening for some tidal flow over the gate. The ability to operate the tidal gates to a specified weir crest elevation (i.e., top of the gates) that is relatively precise provides a great deal of flexibility. The top elevation of each individual gate can be slightly different (i.e., steps) to provide less weir flow as the tidal level declines. The top elevation of the gates can also be slowly raised or lowered to adjust the tidal level and/or tidal flow in response to local South Delta conditions.

South Delta Gates

The proposed management of South Delta tidal level and tidal flow conditions involves the use of five gates:

- CCF intake tidal gate (existing),

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[5] This project description does not include any aspect of the SDIP that is not explicitly identified in the text. Examples of SDIP actions that are not included are construction of the four permanent gates and dredging. Both of these activities will be covered by subsequent consultation.

- Grant Line Canal (at western end) flow control gate,
- Old River at DMC flow control gate,
- Middle River flow control gate, and
- Head of Old River fish control gate.

The CCF intake gate already exists and has been used since SWP began Banks operations in 1972 to control flows from Old River and maintain the water level inside of CCF. Unlike the existing CCF intake gate, the four other gates are proposed by SDIP and are not in place. The operation of the CCF intake gate is directly related to SWP export operations, but the operation of the fish and flow control gates, will serve the primary purpose of protecting fisheries and beneficial uses.

These five gates in the South Delta would be operated to accomplish the following purposes:

1. Maintain a relatively high water level within the CCF to allow SWP to maximize Banks pumping during the off-peak (nighttime) hours. The CCF level cannot be allowed to fall below –2 feet msl because of cavitation concerns at the SWP's Banks pumps. The CCF gates are closed when the outside tidal level in Old River drops below the CCF level (to avoid outflow from CCF). As described earlier in this chapter, the CCF gates are also operated under three "gate priorities" to reduce water level impacts to other South Delta water users.

2. Control the inflow to CCF below the design flow of about 15,000 cfs to prevent excessive erosion of the entrance channel. The CCF gates are partially closed when the difference between the CCF level and Old River tidal level is more than 1.0 foot to avoid inflow velocities of greater than 10 feet/sec.

3. Maintain the high-tide conditions in the South Delta by not diverting into CCF during the flood-tide period that precedes the higher-high tide each day. The CCF intake gates are closed for about 6 hours each day to preserve the high-tide level in Old River to supply sufficient water for Tom Paine Slough siphons. This CCF tidal gate operation is referred to as priority 3 by DWR, as described earlier in this chapter.

4. Control the minimum tidal level elevation upstream of the flow-control gates to be greater than a selected target elevation (i.e., 0.0 feet msl). The flow-control gates can be closed (raised) to maintain a specified top elevation (e.g., 0.0 feet msl) as the upstream tidal level declines during ebb tide.

5. Control the tidal flushing upstream of the flow-control gates with relatively low-salinity water from Old River and Middle River downstream of the gates (i.e., high fraction of Sacramento River water). The flow-control gates would remain fully open during periods of flood tide (i.e., upstream flow) and then two of the gates would be fully closed (i.e., top elevation of gates above upstream water surface) during periods of ebb tide (i.e., downstream flow). The remaining gate (i.e., Grant Line) would be maintained at a lower elevation (i.e., 0.0 feet msl) to

allow the ebb tide flow to exit from the South Delta channels so that the flood-tide flow over the gates can be maximized during each tidal cycle.

Control the San Joaquin River flow diversion into Old River. This could increase the flow past Stockton and raise the low DO concentrations in the San Joaquin Deep Water Ship Channel. Reduced flow to Old River might also reduce salinity in the South Delta channels by limiting the volume of relatively high-salinity water from the San Joaquin River that enters the South Delta channels. The head of Old River temporary barrier has been installed in October and November of many years to improve flow and DO conditions in the San Joaquin Deep Water Ship Channel for up-migrating Chinook salmon. In recent years, the barrier has also been installed in April and/or May during a portion of the outmigration period to reduce the percentage of Chinook salmon smolts that are diverted into Old River and toward Banks and Jones. The proposed SDIP gate operations will increase the tidal circulation in the South Delta channels. Gate operations to promote circulation would raise the Old River at Tracy and Middle River gates at each high tide to produce a circulation of water in the South Delta channels down Grant Line Canal. The Old River at Tracy and Middle River gates remain raised (closed) until the next flood-tide period when the downstream level is above the upstream water level. These gates are then lowered (opened) to allow flood-tide (upstream) flows across the gates. Gate operations to promote circulation use a Grant Line gate weir crest at -0.5 feet msl during most periods of ebb tide (downstream flow) to protect the minimum level elevation of 0.0 feet msl. All gates are lowered (i.e., opened) during floodtide periods as soon as the downstream tidal level is above the upstream water level.

Head of Old River Fish Control Gate

Spring Operations/ Real Time Decision Making

Operation (closing) of the head of Old River fish control gate is proposed to begin on April 15. Spring operation is generally expected to continue through May 15, to protect outmigrating salmon and steelhead. During this time, the head of Old River gate would be fully closed, unless the San Joaquin River is flowing above 10,000 cfs or the GORT recommends a partial opening for other purposes. The real time decision making process is described in detail previously.

Summer and Fall Operations

When the Spring operation is completed and through November 30, the head of Old River fish control gate would be operated to improve flow in the San Joaquin River, thus helping to avoid historically-present low dissolved oxygen conditions in the lower San Joaquin River near Stockton. During this period, partial operation of the gate (partial closure to restrict flows from the San Joaquin River into Old River to approximately 500 cfs) may also be warranted to protect water quality in the South Delta channels. Generally, water quality in the South Delta channels is acceptable through June.

Operations during the months of October and November to improve flow and water quality conditions (i.e., low dissolved oxygen) in the San Joaquin River for adult migrating Chinook salmon is expected to provide a benefit similar to that achieved with the temporary barrier. Operations would not occur if the San Joaquin River flow at

Vernalis is greater than 5,000 cfs because it is expected that this flow would maintain sufficient DO in the San Joaquin River.

When the gate is not operated, it is fully lowered in the channel. Operation of the gate is not proposed during the period December through March.

Flow Control Gates

The flow control gates in Middle River, Grant Line Canal, and Old River near the DMC, would be operated (closed during some portion of the tidal cycle) throughout the agricultural season of April 15 through November 30. As with the head of Old River fish control gate, when the gates are not operated, they are fully lowered in the channel. Operation of the gates is not proposed during the period December through March. Any operation of the gates proposed for the December-March period would require re-initiation of ESA consultation.

Spring Operations

During April 15 through May 15 (or until the Spring operation of the head of Old River gate is completed), water quality in the South Delta is acceptable for the beneficial uses, but closure of the head of Old River fish control gate has negative impacts on water levels in the South Delta. Therefore, the flow control gates would be operated to control minimum water levels in most year types. In the less frequent year types, dry or critically dry, when water quality in the South Delta is threatened by this static use of the gates, circulation may be induced to improve water quality in the South Delta channels. Circulation using the flow control gates is described in the summer operations section which follows. During these times, Reclamation and DWR have committed to maintaining 0.0 foot msl water levels in Old River near the CVP Tracy facility and at the west end of Grant Line Canal.

Summer and Fall Operations

When the Spring operation of the head of Old River fish control gate is completed and through November 30, the gates would be operated to control minimum water levels and increase water circulation to improve water quality in the South Delta channels. Reclamation and DWR have committed to maintaining water levels during these times at 0.0 foot msl in Old River near the CVP Tracy facility, 0.0 foot msl at the west end of Grant Line Canal, and 0.5 foot msl in Middle River at Mowry Bridge. It is anticipated that the target level in Middle River would be lowered to 0.0 foot msl following extension of some agricultural diversions.

The proposed gate operations will increase the tidal circulation in the South Delta channels. This is accomplished by tidal flushing upstream of the flow-control gates with relatively low-salinity water from Old River and Middle River downstream of the gates (i.e., high fraction of Sacramento River water). The flow-control gates would remain fully open during periods of flood tide (i.e., upstream flow) and then two of the gates would be fully closed (i.e., top elevation of gates above upstream water surface) during periods of ebb tide (i.e., downstream flow). The remaining gate (i.e., Grant Line) would be maintained at a lower elevation (i.e., 0.0 feet msl) to allow the ebb tide flow to exit from the South Delta channels so that the flood-tide flow over the gates can be

maximized during each tidal cycle. This is the same operation described as Purpose 5 earlier in the description of the SDIP gates.

Gate Operations and Jones and Banks Exports

Because of the hydraulic interconnectivity of the South Delta channels, the CCF, and the export facilities, the permanent operable gates would not be operated entirely independent of Banks and Jones exports. The flow control gate opening and closing frequencies and durations would be adjusted to meet the water level and circulation objectives. Furthermore, the head of Old River Fish Control Gate operation period and duration would be adjusted to address the presence of fish species and the water quality conditions in the San Joaquin River. Opportunities to adjust gate operations in a manner that reduces entrainment and impingement of aquatic species or improves in-Delta water supply conditions that are associated with Delta exports could result.

As described in the Flow Control Gates operations sections, the Middle River, Grant Line Canal, and Old River near DMC flow control gates are operated to improve stage and water quality in the South Delta. The flow control gates increase the stage upstream of the barriers while Banks and Jones are all downstream of the permanent operable gates. The gates are designed to capture the flood tide upstream of the structures, and the operation of the flow control gates is not based on exports.

ESA coverage for the SDIP operable gates is being accomplished through two consultation processes. A separate biological opinion will address terrestrial and aquatic effects from channel dredging and construction and will be included in a separate consultation process.

State Water Project Oroville Facilities

Implementation of the new FERC license for the Oroville Project will occur when FERC issues the new license. Because it is not known exactly when that will occur, it is considered a near term and future project. The current, near term and future operations for the Oroville Facilities were previously described.

Analytical Framework for the Jeopardy Determination

The following analysis relies on four components to support the jeopardy determination for the delta smelt: (1) the *Status of the Species*, which evaluates the delta smelt's range-wide condition, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of the delta smelt in the action area, the factors responsible for that condition, and the role of the action area in the delta smelt's survival and recovery; in this case the action area covers nearly the entire range of the delta smelt so the *Status of the Species/Environmental Baseline* sections are combined into one section; (3) the *Effects of the Action*, which determines

the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the delta smelt; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the delta smelt.

In accordance with the implementing regulations for section 7 and Service policy, the jeopardy determination is made in the following manner: the effects of the proposed Federal action are evaluated in the context of the aggregate effects of all factors that have contributed to the delta smelt's current status and, for non-Federal activities in the action area, those actions likely to affect the delta smelt in the future, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of the delta smelt in the wild.

The following analysis places an emphasis on using the range-wide survival and recovery needs of the delta smelt and the role of the action area in providing for those needs as the context for evaluating the significance of the effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

Analytical Framework for the Adverse Modification Determination

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat.

The following analysis relies on four components to support the adverse modification determination: (1) the *Status of Critical Habitat*, which evaluates the range-wide condition of designated critical habitat for the delta smelt in terms of primary constituent elements (PCEs), the factors responsible for that condition, and the intended recovery function of the critical habitat overall, as well as the intended recovery function of discrete critical habitat units; (2) the *Environmental Baseline*, which evaluates the condition of the critical habitat in the action area, the factors responsible for that condition, and the recovery role of the critical habitat in the action area; in this case the action area covers nearly the entire range of delta smelt critical habitat so the *Status of the Critical Habitat/Environmental Baseline* sections are combined into one section; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the PCEs and how that will influence the recovery role of affected critical habitat units; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the PCEs and how that will influence the recovery role of affected critical habitat units.

In accordance with Service policy and guidance, the adverse modification determination is made in the following manner: the effects of the proposed Federal action on critical habitat are evaluated in the context of the aggregate effects of all factors that have contributed to the current status of the critical habitat range-wide and, for non-Federal activities in the action area, those actions likely to affect the critical habitat in the future, to determine if the critical habitat would remain functional (or retain the current ability for the PCEs to be functionally established in areas of currently unsuitable but capable habitat) to serve the intended recovery role for the species with implementation of the proposed Federal action.

The following analysis places an emphasis on using the intended range-wide recovery function of delta smelt critical habitat and the role of the action area relative to that intended function as the context for evaluating the significance of effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the adverse modification determination.

Status of the Species/Environmental Baseline

The action area for this consultation covers the entire range of the delta smelt, except for the Napa River. For that reason, the Status of the Species and Environmental Baseline sections are combined into one section in this document.

Delta Smelt

Delta Smelt Species Description and Taxonomy

The Service proposed to list the delta smelt as threatened with proposed critical habitat on October 3, 1991 (56 FR 50075). The Service listed the delta smelt as threatened on March 5, 1993 (58 FR 12854), and designated critical habitat for this species on December 19, 1994 (59 FR 65256). The delta smelt was one of eight fish species addressed in the *Recovery Plan for the Sacramento–San Joaquin Delta Native Fishes* (Service 1995). A 5-year status review of the delta smelt was completed on March 31, 2004 (Service 2004); that review affirmed the need to retain the delta smelt as a threatened species. The Service is currently considering information to determine if the listing status of delta smelt should be upgraded from threatened to endangered.

The delta smelt is a member of the Osmeridae family (northern smelts) (Moyle 2002) and is one of six species currently recognized in the *Hypomesus* genus (Bennett 2005). The delta smelt is endemic to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) in California, and is restricted to the area from San Pablo Bay upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties (Moyle 2002) (Figure S-1). Their range extends from San Pablo Bay upstream to Verona on the Sacramento River and Mossdale on the San Joaquin River. The delta smelt was formerly considered to be one of the most common pelagic fish in the upper Sacramento-San Joaquin Estuary.

The delta smelt is a slender-bodied fish, generally about 60 to 70 millimeters (mm) (2 to 3 inches (in)) long, although they can reach lengths of up to 120 mm (4.7 in) (Moyle 2002). Live delta smelt are nearly translucent and have a steely blue sheen to their sides. Delta smelt usually aggregate but do not appear to be a strongly schooling species.

Genetic analyses have confirmed that *H. transpacificus* presently exists as a single intermixing population (Stanley et al. 1995; Trenham et al. 1998). The most closely-related species is the surf smelt (*H. pretiosis*), a marine species common along the western coast of North America. Despite its morphological similarity, the delta smelt is less-closely related to wakasagi (*H. nipponensis*), an anadromous western Pacific species introduced into California Central Valley reservoirs in 1959 and now distributed in the historic range of the delta smelt (Trenham et al. 1998). Genetic introgression among *H. transpacificus* and *H. nipponensis* is low.

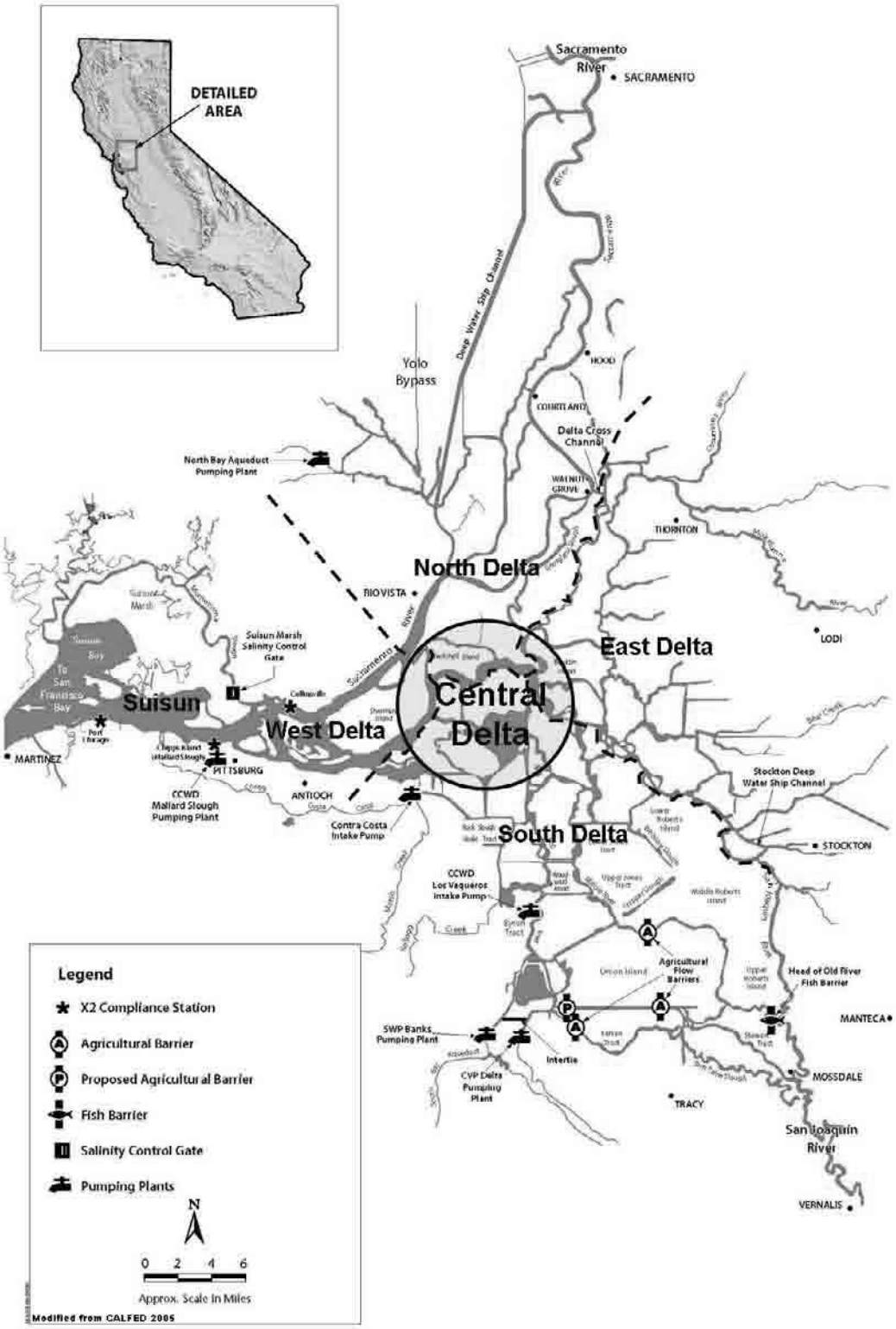


Figure S-1 Map of the Delta with Delta Regions Identified

Existing Monitoring Programs

Most research and monitoring of fish populations in the Bay-Delta is coordinated through the Interagency Ecological Program (IEP). The IEP is a cooperative effort led by state and federal agencies with university and private partners. There are currently 16 fish monitoring programs that are implemented year-round across the entire Bay-Delta system (Honey et al. 2004). Figure S-2 shows the monitoring stations that are sampled in the Bay-Delta Estuary. Each of these programs captures delta smelt to some degree, however, only a select few are commonly used to index the abundance or distribution of delta smelt, and only two are designed specifically to capture delta smelt.

The Fall Midwater Trawl Survey (FMWT) and the Summer Townet Survey (TNS) are the two longest running IEP fish monitoring programs that are used to index delta smelt abundance. They work well because they were originally designed to target age-0 striped bass, which have similar habitat requirements to delta smelt. Two more recent programs, the 20-mm Survey and the Spring Kodiak Trawl Survey (SKT), were designed specifically to sample delta smelt and are also commonly used to evaluate relative abundance and distribution. Each of these four sampling programs targets different life stages and encompasses the entire distribution of delta smelt for the given life stage and time of year. The efficiency of sampling gears used for delta smelt is unknown. However, they were all designed to target open-water pelagic fishes and data from these programs have been used extensively in prior studies of delta smelt abundance and distribution (e.g., Stevens and Miller 1983; Moyle et al. 1992; Jassby et al. 1995; Dege and Brown 2004; Bennett 2005; Feyrer et al. 2007).

Data from the FMWT are used to calculate indices of relative abundance for delta smelt. The program has been conducted each year since 1967, except that no sampling was done in 1974 or 1979. Samples (10-minute tows) are collected at 116 sites each month from September to December throughout the Bay-Delta. Detailed descriptions of the sampling program are available from Stevens and Miller (1983) and Feyrer et al. (2007). The delta smelt recovery index includes distribution and abundance components and is calculated from a subset of the September and October FMWT sampling (http://www.delta.dfg.ca.gov/). The details on the calculation of the recovery index can be found in the Delta Native Fishes Recovery Plan (Service 1995).

Data from the TNS are used to calculate indices of abundance for young-of-year delta smelt during the summer. The TNS has been conducted annually since 1959 (Turner and Chadwick 1972). It involves sampling at up to 32 stations with three replicate tows to complete a survey. A minimum of two surveys is conducted each year. The delta smelt index is generated from the first two TNS surveys (Moyle et al. 1992). The TNS sampling has had an average survey starting date of July 13, but surveys have been conducted as early as June 4 and as late as August 28 in some years (Nobriga et al. 2008).

Data from the 20-mm survey are used to examine the abundance and distribution of young post-larval/early juvenile delta smelt during the spring (Dege and Brown 2004). The survey has been conducted each year since 1995, and involves the collection of three replicate samples at up to 48 sites; additional sites have been added in recent years. A complete set of samples from each site is termed a survey and 5-9 surveys are completed

each year from approximately March though June. This survey also simultaneously samples zooplankton with a Clarke-Bumpus net during one of the three sampling tows at each site.

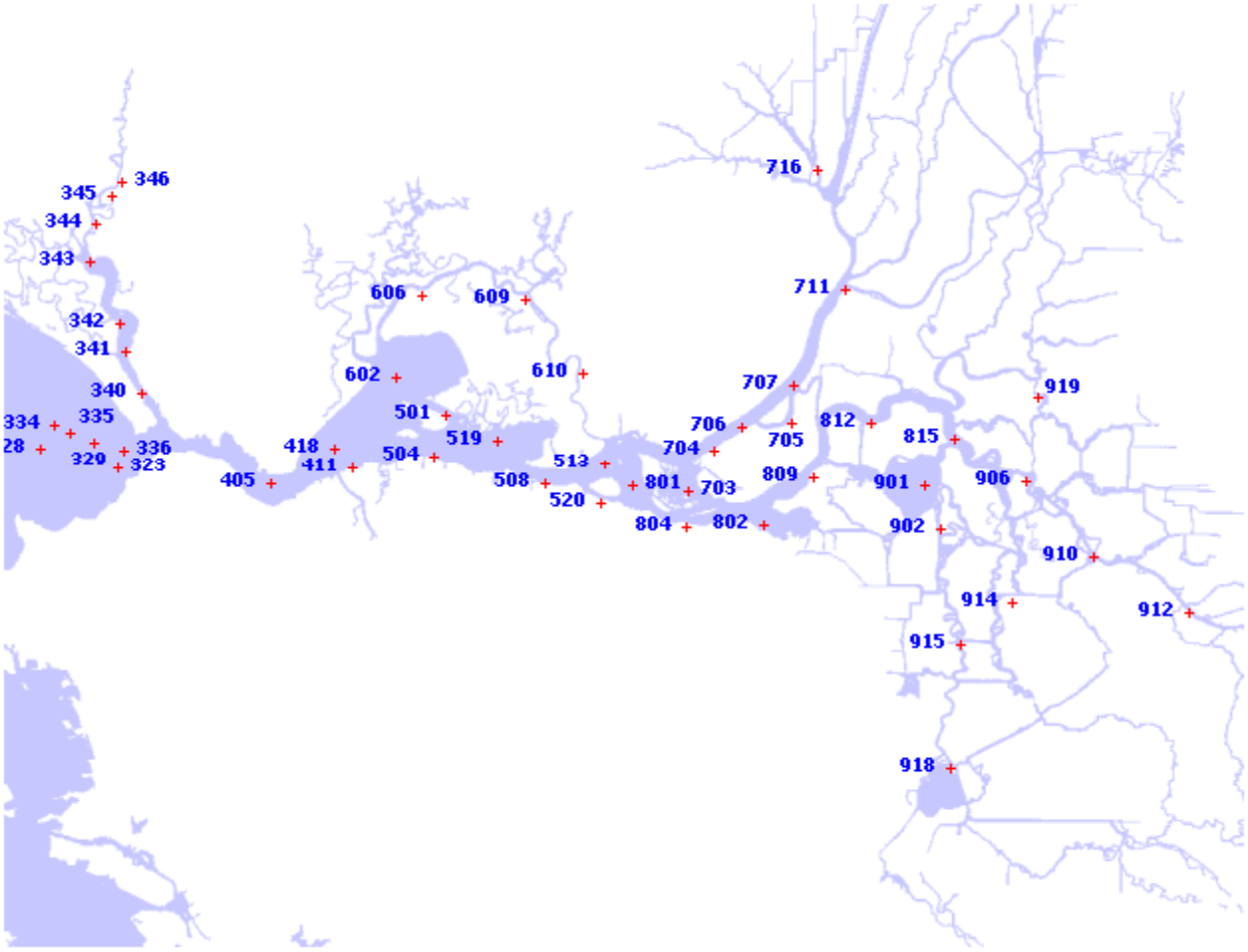


Figure S-2 Map of Bay Delta Estuary Sampling Locations for the TNS and 20-mm Survey (DFG Bay Delta website 2008)

Data from the SKT are used to monitor and provide information on the pre-spawning and spawning distributions of delta smelt. The survey also quantifies the reproductive maturity status of all adult delta smelt collected. SKT sampling has been done since 2002 at approximately 39 stations. Sampling at each station is completed five or more times per year from January to May. Supplemental surveys are often completed when additional information is requested by managers to assist with decisions relating to water project operations.

An additional source of information on delta smelt comes from salvage operations at the Banks and Jones fish facilities. Banks and Jones are screened with fish-behavioral louvers designed to salvage young Chinook salmon and striped bass before they enter the pumps (Brown et al. 1996). In general, the salvage process consists of fish capture,

transport, and ultimately release at locations where they are presumed safe from further influence of Banks and Jones. However, unlike some species, it is commonly acknowledged that delta smelt often do not survive the salvage process. Data on the salvage of delta smelt is typically used to provide an index of entrainment into the diversion pumps, but not as an index of general population abundance. However, there are a number of caveats with these data including unknown sampling efficiency, unknown pre-screen mortality in Clifton Court Forebay, and no sampling of fish smaller than 20mm (Kimmerer 2008). Fortunately, some of this information may become available in the future because of targeted studies on efficiency and pre-screen mortality being conducted by the IEP and Reclamation. Although monitoring from Banks and Jones is limited in geographic range compared to the other surveys, they sample substantially larger volumes of water, and therefore may have a greater likelihood to detect low densities of delta smelt larger than 20mm.

Delta smelt entrainment is presently estimated (or indexed) by extrapolating catch data from periodic samples of salvaged fish (≥ 20 mm). Fish are counted from a sub-sample of water from the facility holding tanks and numbers are extrapolated based on the volume of water diverted during collection of that sample to estimate the number of fish entrained into Banks and Jones during the sampling interval. Intervals typically range from 1-24 hours depending on time of year, debris loads, etc.

Overview of Delta Smelt's Life Cycle

The delta smelt life cycle is completed within the freshwater and brackish LSZ of the Bay-Delta. Figure S-3 portrays the conceptual model used for delta smelt. Delta smelt are moderately euryhaline (Moyle 2002). However, salinity requirements vary by life stage. Delta smelt are a pelagic species, inhabiting open waters away from the bottom and shore-associated structural features (Nobriga and Herbold, 2008). Although delta smelt spawning has never been observed in the wild, clues from the spawning behavior of related osmerids suggests delta smelt use bottom substrate and nearshore features during spawning. However, apart from spawning and egg-embryo development, the distribution and movements of all life stages are influenced by transport processes associated with water flows in the estuary, which also affect the quality and location of suitable open-water habitat (Dege and Brown 2004; Feyrer et al. 2007; Nobriga et al. 2008).

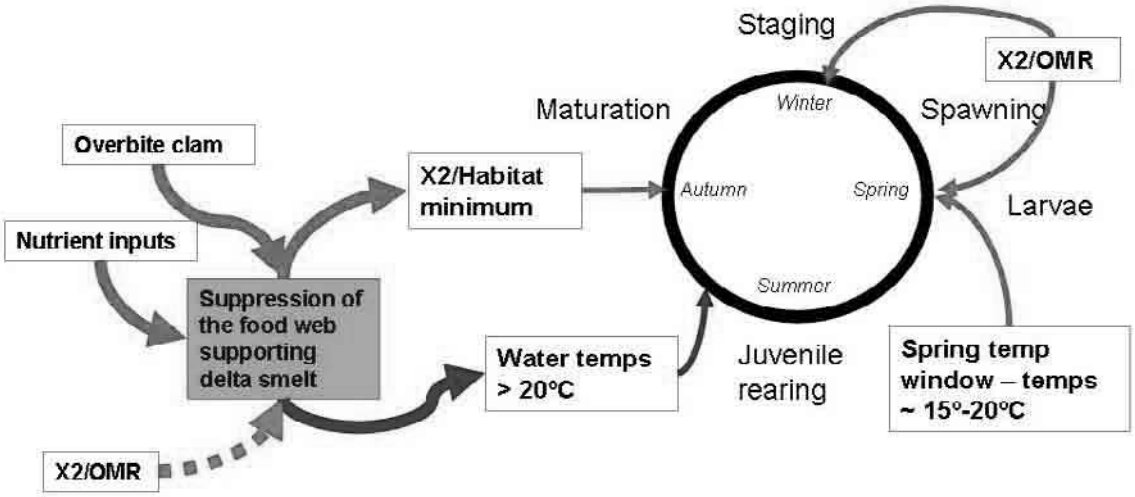


Figure S-3 Lifecycle Conceptual Model For Delta Smelt. The Larger the Arrow Size, the Stronger the Influence on the Process Box

Delta smelt are weakly anadromous and undergo a spawning migration from brackish water to freshwater annually (Moyle 2002). In early winter, mature delta smelt migrate from brackish, downstream rearing areas in and around Suisun Bay and the confluence of the Sacramento and San Joaquin rivers upstream to freshwater spawning areas in the Delta. Delta smelt historically have also spawned in the freshwater reaches of Suisun Marsh. In winters featuring high Delta outflow, the spawning range of delta smelt shifts west to include the Napa River (Hobbs et al. 2007).

The upstream migration of delta smelt, which ends with their dispersal into river channels and sloughs in the Delta (Radtke 1966; Moyle 1976, 2002; Wang 1991), seems to be triggered or cued by abrupt changes in flow and turbidity associated with the first flush of winter precipitation (Grimaldo et al, accepted manuscript) but can also occur after very high flood flows have receded. Grimaldo et al (accepted manuscript) noted salvage often occurred when total inflows exceeded over 25,000 cfs or when turbidity elevated above 12 NTU (CCF station). Delta smelt spawning may occur from mid-winter through spring; most spawning occurs when water temperatures range from about 12^0C to 18^0C (Moyle 2002). Most adult delta smelt die after spawning (Moyle 2002). However, some fraction of the population may hold over as two-year-old fish and spawn in the subsequent year.

During and after a variable period of larval development, the young fish migrate downstream until they reach the low-salinity zone (LSZ) (indexed as X2) where they reside until the following winter (Moyle 2002). The location of the delta smelt population follows changes in the location of the LSZ which depends primarily on delta outflow.

Biology and Life History

Spawning

Adult delta smelt spawn during the late winter and spring months, with most spawning occurring during April through mid-May (Moyle 2002). Spawning occurs primarily in sloughs and shallow edge areas in the Delta. Delta smelt spawning has also been recorded in Suisun Marsh and the Napa River (Moyle 2002). Most spawning occurs at temperatures between 12-18°C. Although spawning may occur at temperatures up to 22°C, hatching success of the larvae is very low (Bennett 2005).

Fecundity of females ranges from about 1,200 to 2,600 eggs, and is correlated with female size (Moyle 2002). Moyle et al. (1992) considered delta smelt fecundity to be "relatively low." However, based on Winemiller and Rose (1992), delta smelt fecundity is fairly high for a fish its size. In captivity, females survive after spawning and develop a second clutch of eggs (Mager et al. 2004); field collections of ovaries containing eggs of different size and stage indicate that this also occurs in the wild (Adib-samii 2008). Captive delta smelt can spawn up to 4-5 times. While most adults do not survive to spawn a second season, a few (<5 percent) do (Moyle 2002; Bennett 2005). Those that do survive are typically larger (90-110 mm SL) females that may contribute disproportionately to the population's egg supply (Moyle 2002 and references therein). Two-year-old females may have 3-6 times as many ova as first year spawners.

Most of what is known about delta smelt spawning habitat in the wild is inferred from the location of spent females and young larvae captured in the SKT and 20-mm survey, respectively. In the laboratory, delta smelt spawned at night (Baskerville-Bridges et al. 2000; Mager et al. 2004). Other smelts, including marine beach spawning species and estuarine populations and the landlocked Lake Washington longfin smelt, are secretive spawners, entering spawning areas during the night and leaving before dawn. If this behavior is exhibited by delta smelt, then delta smelt distribution based on the SKT, which is conducted during daylight hours in offshore habitats, may reflect general regions of spawning activity, but not actual spawning sites.

Delta smelt spawning has only been directly observed in the laboratory and eggs have not been found in the wild. Consequently, what is known about the mechanics of delta smelt spawning is derived from laboratory observations and observations of related smelt species. Delta smelt eggs are 1 mm diameter and are adhesive and negatively buoyant (Moyle 1976, 2002; Mager et al. 2004; Wang 1986, 2007). Laboratory observations indicate that delta smelt are broadcast spawners, discharging eggs and milt close to the

bottom over substrates of sand and/or pebble in current (DWR and Reclamation 1994; Brown and Kimmerer 2002; Lindberg et al. 2003; Wang 2007).

The eggs of surf smelts and other beach spawning smelts adhere to sand particles, which keeps them negatively buoyant but not immobile, as the sand may move ("tumble") with water currents and turbulence (Hay 2007; slideshow available at http://www.science.calwater.ca.gov/pdf/workshops/workshop_smelt_presentation_Hay_111508.pdf). It is not known whether delta smelt eggs "tumble incubate" in the wild, but tumbling of eggs may moderately disperse them, which might reduce predation risk within a localized area.

Presence of newly hatched larvae likely indicates regions where spawning has occurred. The 20-mm trawl has captured small (~5 mm Standard Length [SL]) larvae in Cache Slough, the lower Sacramento River, San Joaquin River, and at the confluence of these two rivers (e.g., 20-mm trawl survey 1 in 2005). Larger larvae and juveniles (size > 23 mm SL), which are more efficiently sampled by the 20-mm trawl gear, have been captured in Cache Slough (Sacramento River) and the Sacramento Deep Water Channel in July (e.g. 20-mm trawl survey 9 in 2008). Because they are small fish inhabiting pelagic habitats with strong tidal and river currents, delta smelt larval distribution depends on both the spawning area from which they originate and the effect of transport processes caused by flows. Larval distribution is further affected by water salinity and temperature. Hydrodynamic simulations reveal that tidal action and other factors may cause substantial mixing of water with variable salinity and temperature among regions of the Delta (Monson et al 2007). This could result in rapid dispersion of larvae away from spawning sites.

Sampling of larval delta smelt in the Bay-Delta in 1989 and 1990 suggested that spawning occurred in the Sacramento River; in Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs; in the San Joaquin River adjacent to Bradford Island and Fisherman's Cut; and possibly other areas (Wang 1991). However, in recent years, the densest concentrations of both spawners and larvae have been recorded in the Cache Slough/Sacramento Deepwater Ship Channel complex in the North Delta. Some delta smelt spawning occurs in Napa River, Suisun Bay and Suisun Marsh during wetter years (Sweetnam 1999; Wang 1991; Hobbs et al. 2007). Early stage larval delta smelt have also been recorded in Montezuma Slough near Suisun Bay (Wang 1986).

Larval Development

Mager et al. (2004) reported that embryonic development to hatching takes 11-13 days at 14-16º C for delta smelt, and Baskerville-Bridges et al. (2000) reported hatching of delta smelt eggs after 8-10 days at temperatures between 15-17º C. Lindberg et al. (2003) reported high hatching rates of delta smelt eggs in the laboratory at 15º C, and Wang (2007) reported high hatching rates at temperatures between 14-17º C. Bennett (2005) showed hatching success peaks near 15º C. Swim bladder inflation occurring at 60-70 days post-hatch at 16-17º C (Mager et al. 2004).

At hatching and during the succeeding three days, larvae are buoyant, swim actively near the water surface, and do not react to bright direct light (Mager et al. 2004). As

development continues, newly hatched delta smelt become semi-buoyant and sink in stagnant water. However, larvae are unlikely to encounter stagnant water in the wild.

In the laboratory, a turbid environment (>25 Nephelometric Turbidity Units [NTU]) was necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004). Successful feeding seems to depend on a high density of food organisms and turbidity, and increases with stronger light conditions (Baskerville-Bridges *et al.* 2000; Mager et al. 2004; Baskerville-Bridges *et al.* 2004).

Growth rates of wild-caught delta smelt larvae are faster than laboratory-cultured individuals. Mager et al. (2004) reported growth rates of captive-raised delta smelt reared at near-optimum temperatures (16ºC-17ºC). Their fish were about 12 mm long after 40 days and about 20 mm long after 70 days. In contrast, analyses of otoliths indicated that wild delta smelt larvae were 15-25 mm, or nearly twice as long at 40 days of age (Bennett 2005). By 70 days, most wild fish were 30-40 mm long and beyond the larval stage. This suggests there is strong selective pressure for rapid larval growth in nature, a situation that is typical for fish in general (Houde 1987).

Laboratory-cultured delta smelt larvae have generally been fed rotifers at first-feeding (Baskerville-Bridges et al. 2004; Mager et al. 2004). However, rotifers rarely occur in the guts of wild delta smelt larvae (Nobriga 2002). The most common first prey of wild delta smelt larvae is the larval stages of several copepod species. These copepod 'nauplii' are larger and have more calories than rotifers. This difference in diet may enable the faster growth rates observed in wild-caught larvae.

The food available to larval fishes is constrained by mouth gape and status of fin development. Larval delta smelt cannot capture as many kinds of prey as larger individuals, but all life stages have small gapes that limit their range of potential prey. Prey availability is also constrained by habitat use, which affects what types of prey are encountered. Larval delta smelt are visual feeders. They find and select individual prey organisms and their ability to see prey in the water is enhanced by turbidity (Baskerville-Bridges et al. 2004). Thus, delta smelt diets are largely comprised of small crustacea that inhabit the estuary's turbid, low-salinity, open-water habitats (i.e., zooplankton). Larval delta smelt have particularly restricted diets (Nobriga 2002). They do not feed on the full array of zooplankton with which they co-occur; they mainly consume three copepods, *Eurytemora affinis*, *Pseudodiaptomus forbesi*, and freshwater species of the family Cyclopidae. Further, the diets of first-feeding delta smelt larvae are largely restricted to the larval stages of these copepods; older, larger life stages of the copepods are increasingly targeted as the delta smelt larvae grow, their gape increases, and they become stronger swimmers.

The triggers for and duration of delta smelt larval movement from spawning areas to rearing areas are not known. Hay (2007) noted that eulachon larvae are probably flushed into estuaries from upstream spawning areas within the first day after hatching, but downstream movement of delta smelt larvae occurs much later. Most larvae gradually move downstream toward the two parts per thousand (ppt) isohaline (X2). X2 is scaled as the distance in kilometers from the Golden Gate Bridge (Jassby et al. 1995). It is a

physical attribute of the Bay-Delta that is used as a habitat indicator and as a regulatory standard in the SWRCB D-1641, as described in the project description.

At all life stages, delta smelt are found in greatest abundance in the water column and usually not in close association with the shoreline. They inhabit open, surface waters of the Delta and Suisun Bay, where they presumably aggregate in loose schools where conditions are favorable (Moyle 2002). In years of moderate to high Delta outflow (above normal to wet WYs), delta smelt larvae are abundant in the Napa River, Suisun Bay and Montezuma Slough, but the degree to which these larvae are produced by locally spawning fish but the degree to which they originate upstream and are transported by tidal currents to the bay and marsh is uncertain.

Juveniles

Young-of-the-year delta smelt rear in the LSZ from late spring through fall and early winter. Once in the rearing area growth is rapid, and juvenile fish are 40-50 mm SL long by early August (Erkkila *et al.* 1950; Ganssle 1966; Radtke 1966). They reach adult size (55-70 mm SL) by early fall (Moyle 2002). Delta smelt growth during the fall months slows considerably (only 3-9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila *et al.* 1950; Radtke 1966).

Nobriga et al. (2008) found that delta smelt capture probabilities in the TNS are highest at specific conductance levels of 1,000 to 5,000 $\mu S\ cm^{-1}$ (approximately 0.6 to 3.0 practical salinity unit [psu]). Similarly, Feyrer et al. (2007) found a decreasing relationship between abundance of delta smelt in the FMWT and specific conductance during September through December. The location of the LSZ and changes in delta smelt habitat quality in the San Francisco Estuary can be indexed by changes in X2 (see effects section). The LSZ historically had the highest primary productivity and is where zooplankton populations (on which delta smelt feed) were historically most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). However, this has not always been true since the invasion of the overbite clam (Kimmerer and Orsi 1996). The abundance of many local aquatic species has tended to increase in years when winter-spring outflow was high and X2 was pushed seaward (Jassby et al. 1995), implying that the quantity and quality (overall suitability) of estuarine habitat increases in years when outflows are high. However, delta smelt is not one of the species whose abundance has statistically covaried with winter-spring freshwater flows (Stevens and Miller 1983; Moyle et al. 1992; Kimmerer 2002; Bennett 2005). As presented in this biological opinion, there is evidence that X2 in the fall influences delta smelt population dynamics.

Delta smelt seem to prefer water with high turbidity, based on a negative correlation between the frequency of delta smelt occurrence in survey trawls during summer, fall and early winter and water clarity. For example, the likelihood of delta smelt occurrence in trawls at a given sampling station decreases with increasing Secchi depth at the stations (Feyrer et al. 2007, Nobriga et al. 2008). This is very consistent with behavioral observations of captive delta smelt (Nobriga and Herbold 2008). Few daylight trawls catch delta smelt at Secchi depths over one half meter and capture probabilities for delta smelt are highest at 0.40 m depth or less. The delta smelt's preference for turbid water

may be related to increased foraging efficiency (Baskerville-Bridges et al. 2004) and reduced risk of predation.

Temperature also affects delta smelt distribution. Swanson and Cech (1995) and Swanson et al. (2000) indicate delta smelt tolerate temperatures (<8° C to >25° C), however warmer water temperatures >25° C restrict their distribution more than colder water temperatures (Nobriga and Herbold 2008). Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures are usually less than 25° C in summer (Nobriga et al. 2008).

Foraging Ecology

Delta smelt feed primarily on small planktonic crustaceans, and occasionally on insect larvae (Moyle 2002). Juvenile-stage delta smelt prey upon copepods, cladocerans, amphipods, and insect larvae (Moyle 2002). Historically, the main prey of delta smelt was the euryhaline copepod *Eurytemora affinis* and the euryhaline mysid *Neomysis mercedis*. The slightly larger *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the Bay-Delta, especially in summer, when it replaces *E. affinis* in the plankton community (Moyle 2002). Another smaller copepod, *Limnoithona tetraspina*, which was introduced into the Bay-Delta in the mid-1990s, is now one of the most abundant copepods in the LSZ, but not abundant in delta smelt diets. *Acartiella sinensis*, a calanoid copepod species that invaded the Delta at the same time as *L. tetraspina*, also occurs at high densities in Suisun Bay and in the western Delta over the last decade. Delta smelt eat these newer copepods, but *Pseudodiaptomus* remains a dominant prey (Baxter et al. 2008).

River flows influence estuarine salinity gradients and water residence times and thereby affect both habitat suitability for benthos and the transport of pelagic plankton upon which delta smelt feed. High tributary flow leads to lower residence time of water in the Delta, which generally results in lower plankton biomass (Kimmerer 2004). In contrast, higher residence times, which result from low tributary flows, can result in higher plankton biomass but water diversions, overbite clam grazing (Jassby et al. 2002) and possibly contaminants (Baxter et al. 2008) remove a lot of plankton biomass when residence times are high. These factors all affect food availability for planktivorous fishes that utilize the zooplankton in Delta channels. Delta smelt cannot occupy much of the Delta anymore during the summer (Nobriga et al. 2008). Thus, there is the potential for mismatches between regions of high zooplankton abundance in the Delta and delta smelt distribution now that the overbite clam has decimated LSZ zooplankton densities (see effects section).

The delta smelt compete with and are prey for several native and introduced fish species in the Delta. The introduced inland silverside may prey on delta smelt eggs and/or larvae and compete for copepod prey (Bennett and Moyle 1996; Bennett 2005). Young striped bass also use the LSZ for rearing and may compete for copepod prey and eat delta smelt. Centrarchid fishes and coded wire tagged Chinook salmon smolts released in the Delta for survival experiments since the early 1980s may potentially also prey on larval delta smelt (Brandes and McLain 2001; Nobriga and Chotkowski 2000). Studies during the

early 1960s found delta smelt were only an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). However, delta smelt were a comparatively rare fish even then, so it is not surprising they were a rare prey. Striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did, following severe declines in the abundance of mysid shrimp (Feyrer et al. 2003). Nobriga and Feyrer (in press) showed that inland silverside, which is similar in size to delta smelt, was only eaten by subadult striped bass less than 400 mm fork length. While largemouth bass are not pelagic, they have been shown to consume some pelagic fishes (Nobriga and Feyrer 2007).

Habitat

The existing physical appearance and hydrodynamics of the Delta have changed substantially from the environment in which native fish species like delta smelt evolved. The Delta once consisted of tidal marshes with networks of diffuse dendritic channels connected to floodplains of wetlands and upland areas (Moyle 2002). The in-Delta channels were further connected to drainages of larger and smaller rivers and creeks entering the Delta from the upland areas. In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin Rivers were highly seasonal and more strongly and reliably affected by precipitation patterns than they are today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of the Delta aquatic ecosystem was greater in the past than it is today (Kimmerer 2002b). For instance, in the early 1900s, the location of maximum salinity intrusion into the Delta during dry periods varied from Chipps Island in the lower Delta to Stockton along the San Joaquin River and Merritt Island in the Sacramento River (DWR Delta Overview). Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows (Knowles 2002), though Delta outflows have been tightly constrained during late summer-fall for several decades (see Effects section).

Channelization, conversion of Delta islands to agriculture, and water operations have substantially changed the physical appearance, water salinity, water clarity, and hydrology of the Delta. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996, Feyrer et al. 2007). Wang (1991) noted in a 1989 and 1990 study of delta smelt larval distribution that, in general, the San Joaquin River was used more intensively for spawning than the Sacramento River. Though not restricting spawning *per se*, based on particle tracking modeling, export of water by the CVP and SWP would usually restrict reproductive success of spawners in the San Joaquin River by entraining most larvae during downstream transport from spawning sites to rearing areas (Kimmerer and Nobriga 2008). There is one, non-wet year exception to this generalization: in 2008, delta smelt entrainment was managed under a unique system of restrictions imposed by the Court in NRDC v Kempthorne. In 2008, CVP/SWP operations were constrained in accordance with recommendations formulated by the Service expressly to limit entrainment of delta smelt from the Central Delta.

Persistent confinement of the spawning population of delta smelt to the Sacramento River increases the likelihood that a substantial portion of the spawners will be affected by a catastrophic event or localized chronic threat. For instance, large volumes of highly concentrated ammonia released into the Sacramento River from the Sacramento Regional County Sanitation District may affect embryo survival or inhibit prey production. Further, agricultural fields in the Yolo Bypass and surrounding areas are regularly sprayed by pesticides, and water samples taken from Cache Slough sometimes exhibited toxicity to Hyalella azteca (Werner et al. 2008). The thresholds of toxicity for delta smelt for most of the known contaminants have not been determined, but the exposure to a combination of different compounds increases the likelihood of adverse effects. The extent to which delta smelt larvae are exposed to contaminants varies with flow entering the Delta. Flow pulses during spawning increase exposure to many pesticides (Kuivila and Moon 2004) but decrease ammonia concentrations entering the Delta from wastewater treatment plants.

The distribution of juvenile delta smelt has also changed over the last several decades. During the years 1970 through 1978, delta smelt catches in the TNS survey declined rapidly to zero in the Central and South Delta and have remained near zero since. A similar shift in FMWT catches occurred after 1981 (Arthur et al. 1996). This portion of the Delta has also had a long-term trend increase in water clarity during July through December (Arthur et al. 1996; Feyrer et al. 2007; Nobriga et al. 2008).

The position of the LSZ where delta smelt rear has also changed over the years. Summer and fall environmental quality has decreased overall in the Delta because outflows are lower and water transparency is higher. These changes may be due to increased upstream water diversions for flooding rice fields (Kawakami et. al. 2008). The confluence of the Sacramento and San Joaquin rivers has, as a result, become increasingly important as a rearing location for delta smelt, with physical environmental conditions constricting the species range to a relatively narrow area (Feyrer et al. 2007; Nobriga et al. 2008). This has increased the likelihood that most of the juvenile population is exposed to chronic and cyclic environmental stressors, or catastrophic events. For instance, all seven delta smelt collected during the September 2007 FMWT survey were captured at statistically significantly higher salinities than what would be expected based upon historical distribution data generated by Feyrer et al. (2007). During the same year, the annual bloom of toxic cyanobacteria (*Microcystis aeruginosa*) spread far downstream to the west Delta and beyond during the summer (Peggy Lehman, pers comm). This has been suggested as an explanation for the anomaly in the distribution of delta smelt relative to water salinity levels (Reclamation 2008).

Delta Smelt Population Dynamics and Abundance Trends

The FMWT provides the best available long-term index of the relative abundance of delta smelt (Moyle et al. 1992; Sweetnam 1999). The indices derived from these surveys closely mirror trends in catch per unit effort (Kimmerer and Nobriga 2005), but do not at present support statistically reliable population abundance estimates, though substantial progress has recently been made (Newman 2008). FMWT derived data are generally

accepted as providing a reasonable basis for detecting and roughly scaling interannual trends in delta smelt abundance.

The FMWT derived indices have ranged from a low of 27 in 2005 to 1,653 in 1970 (Figure S-5). For comparison, TNS-derived indices have ranged from a low of 0.3 in 2005 to a high of 62.5 in 1978 (Figure S-4). Although the peak high and low values have occurred in different year, the TNS and FMWT indices show a similar pattern of delta smelt relative abundance; higher prior to the mid-1980s and very low in the past seven years.

From 1969-1981, the mean delta smelt TNS and FMWT indices were 22.5 and 894, respectively. Both indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle et al. 1992). From 1982-1992, the mean delta smelt TNS and FMWT indices dropped to 3.2 and 272 respectively. The population rebounded somewhat in the mid-1990s (Sweetnam 1999); the mean TNS and FMWT indices were 7.1 and 529, respectively, during the 1993-2002 period. However, delta smelt numbers have trended precipitously downward since about 2000.

Figure S-4. TNS abundance indices for delta smelt.

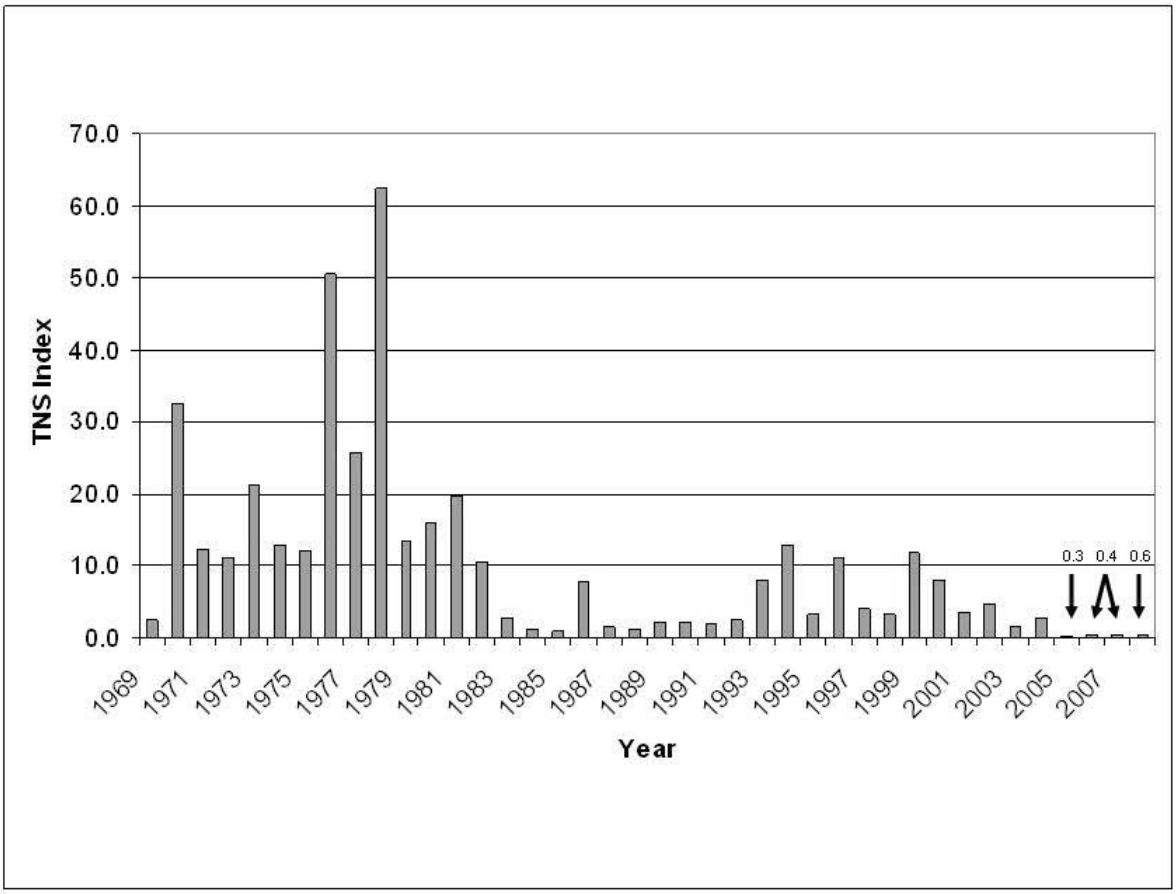
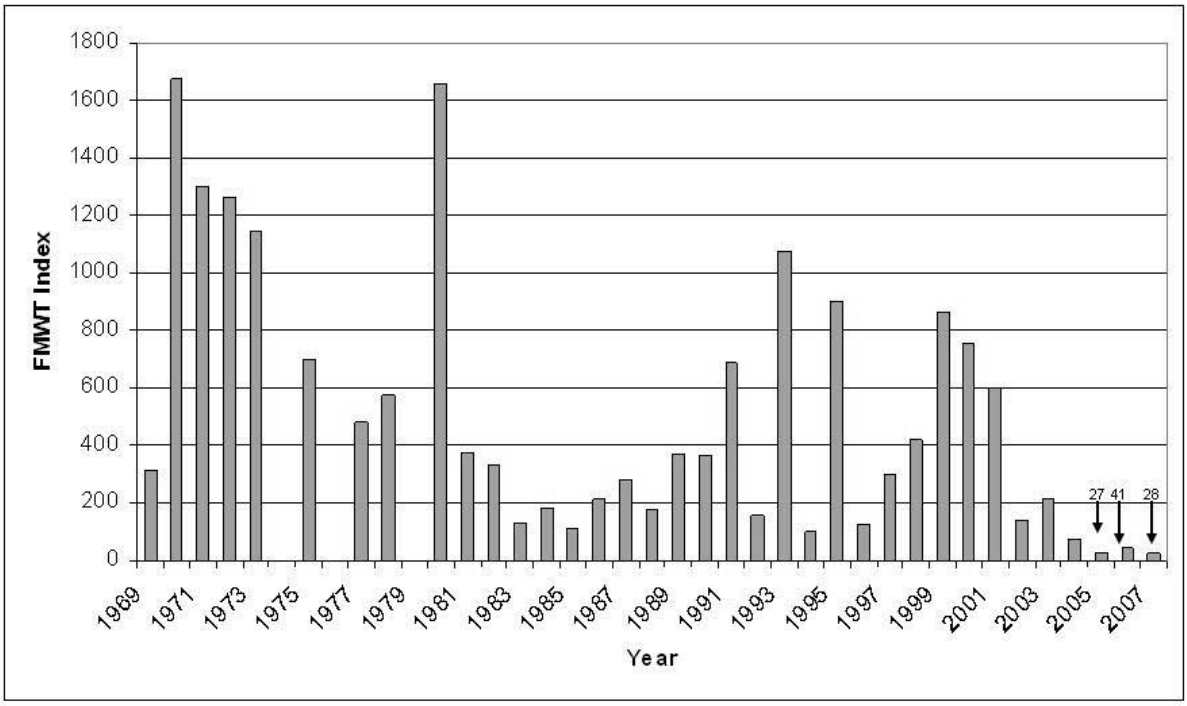


Figure S-4. FMWT abundance indices for delta smelt.



Currently, the delta smelt population indices are two orders of magnitude smaller than historical highs (Figures S-4 and S-5) and recent population abundance estimates are up to three orders of magnitude below historical highs (Newman 2008). After 1999 both the FMWT and the TNS population indices showed declines, and from 2000 through 2007 the median FMWT index was 106.5. The lowest FMWT abundance indices ever obtained were recorded during 2004-2007 (74, 27, 41, and 28, respectively; Figure S-5). The median TNS index during the period from 2000 through 2008 fell similarly to 1.6, and has also dropped to its lowest levels during the last four years with indexes of 0.3, 0.4, 0.4, and 0.6 during 2005 through 2008, respectively (Figure S-4). It is highly unlikely that the indices from 2004-2007 can be considered statistically different from one another (see Sommer et al. 2007), but they are very likely lower than at any time prior in the period of record.

The total number of delta smelt collected in the 20-mm Survey decreased substantially during the years from 2002 to 2008 (4917 to 587 fish) compared to the period 1995 through 2001 (98 to 1084 fish) (Figure S-6). Similarly, the number of delta smelt caught in the SKT has decreased steadily since the survey started in 2002 (Figure S-6)

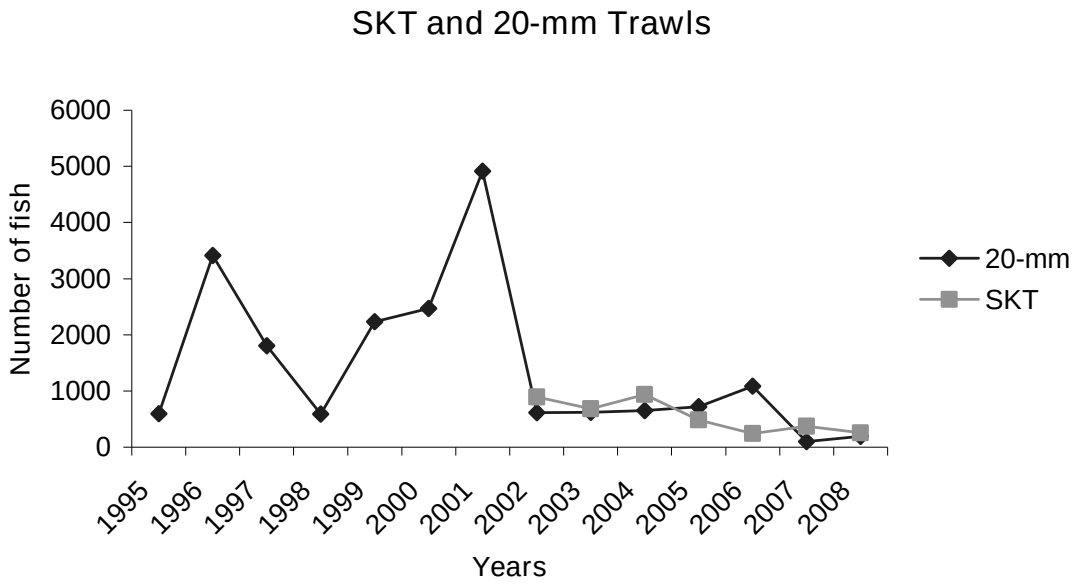


Figure S-6. Number of fish collected in the Spring Kodiak Trawl and the 20-mm surveys. Only the eight first 20-mm trawl surveys are included and only data from the four first full surveys of the SKT. SKT data from DFG at http://www.delta.dfg.ca.gov/ and 20-mm trawl catch data provided by DFG.

Since about 2002, delta smelt is one of four pelagic fish species subject to what has been termed the Pelagic Organism Decline or POD (Sommer et al. 2007). The POD denotes the sudden, overlapping declines of San Francisco Estuary pelagic fishes first recognized in data collected from 2002-2004. The POD species include delta smelt, longfin smelt, threadfin shad (*Dorosoma petenense*), and (age-0) striped bass (*Morone saxatillis*), which together account for the bulk of the resident pelagic fish biomass in the tidal water upstream of X2. The year 2002 is often recognized as the start of the POD because of the striking declines of three of the four POD species between 2001 and 2002; however, statistical review of the data (e.g., Manly and Chotkowski 2006) has revealed that for at least delta smelt, the POD downtrend really began earlier (around 1999). Post-2001 abundance indices for the POD species have included record lows for all but threadfin shad. The causes of the POD and earlier declines are not fully understood, but appear to be layered and multifactorial (Baxter et al. 2008). Several analyses have concluded that the shift in pelagic fish species abundance in the early 1980s was caused by a decrease in habitat carrying capacity or production potential (Moyle et al. 1992, Bennett 2005; Feyrer et al. 2007).

There is some evidence that the recruitment of delta smelt may have sometimes responded to springtime flow variation (Herbold et al. 1992; Kimmerer 2002). However, the weight of evidence suggests that delta smelt abundance does not (statistically)

respond to springtime flow like the abundance of the species mentioned above (Stevens and Miller 1983; Jassby et al. 1995; Bennett 2005). The number of days of suitable spawning temperature during spring is correlated with subsequent abundance indices in the autumn (Bennett 2005). This is evidence that cool springs, which allow for multiple larval cohorts, can contribute to population resilience. However, these relationships do not explain a large proportion of variance in autumn abundance. Depending on which abundance index is used, the r^2 are 0.24-0.29.

The relationship between numbers of spawning fish and the numbers of young subsequently recruiting to the adult population is known as a stock-recruit relationship. Analysis of stock-recruit relationships using delta smelt survey data indicate that a weak density dependent effect has occurred during late summer/fall (Bennett 2005, Reclamation 2008), suggesting that delta smelt year-class strength has often been set during late summer and fall. This is supported by studies suggesting that the delta smelt is food limited (Bennett 2005; IEP 2005) and evidence for density dependent mortality has been presented by Brown and Kimmerer (2001). However, the number of days during the spring that water temperature remained between 15 ºC and 20 ºC, with a density-dependence term to correct for the saturating TNS-FMWT relationship (described above), predicts FMWT indices fairly well ($r^2 \approx 0.70$; $p < 0.05$; Bennett, unpublished presentation at the 2003 CALFED Science Conference). This result shows that of the quantity of young delta smelt produced also contributes to future spawner abundance. Bennett (2005) analyzed the relationship between delta smelt spawner population and spawner recruits using data before and after the 1980s decline. He concluded that density dependence pre-1982 may have occurred at FMWT values of 600 to 800 and at FMWT values of 400 to 500 for the period 1982 through 2002.

Bennett (2005) also conducted extensive stock-recruit analyses using the TNS and FMWT indices. He provided statistical evidence that survival from summer to fall is nonlinear (= density-dependent). He also noted that carrying capacity had declined. Bennett (2005) surmised that density-dependence and lower carrying capacity during the summer and fall could happen in a small population if habitat space was smaller than it was historically. This hypothesis was recently demonstrated to be true (Feyrer et al. 2007). Reduced Delta outflow during autumn has led to higher salinity in Suisun Bay and the Western Delta while the proliferation of submerged vegetation has reduced turbidity in the South Delta. Together, these mechanisms have led to a long-term decline in habitat suitability for delta smelt. High summer water temperatures also limit delta smelt distribution (Nobriga et al. 2008) and impair health (Bennett et al. 2008).

A minimum amount of suitable habitat during summer-autumn may interact with a suppressed pelagic food web to create a bottleneck for delta smelt (Bennett 2005; Feyrer et al. 2007; Bennett et al. 2008). Prior to the overbite clam invasion, the relative abundance of maturing adults collected during autumn was unrelated to the relative abundance of juveniles recruiting the following summer (i.e., the stock-recruit relationship was density-vague). Since the overbite clam became established, autumn relative abundance explains 40 percent of the variability in subsequent juvenile abundance (Feyrer et al. 2007). When autumn salinity is factored in, 60 percent of the variance in subsequent juvenile abundance is accounted for statistically.

Since 2000, the stock-recruit relationship for delta smelt has been stronger still ($r^2 = 0.88$ without autumn habitat metrics factored in; Baxter et al. 2008). This has led to speculation about Allee effects. Allee effects occur when reproductive output per fish declines at low population levels (Allee 1931, Berec et al. 2006). Below a certain threshold the individuals in a population can no longer reproduce rapidly enough to replace themselves and the population spirals to extinction. For delta smelt, possible mechanisms for Allee effects include mechanisms directly related to reproduction and genetic fitness such as difficulty finding enough males to maximize egg fertilization during spawning (e.g., Purchase et al. 2007). Genetic problems arising from small population sizes like inbreeding and genetic drift also can contribute to Allee effects, but genetic bottlenecks occur after demographic problems like the example of finding enough mates (Lande 1988). Other mechanisms related to survival such as increased vulnerability to predation are also possible based on studies of other species.

These data provide evidence that factors affecting juvenile delta smelt during summer-autumn are also impairing delta smelt reproductive success. Thus, the interaction of warm summer water temperatures, suppression of the food web supporting delta smelt, and spatially restricted suitable habitat during autumn affect delta smelt health and ultimately survival and realized fecundity (Figure S-3).

Another possible contributing driver of reduced delta smelt survival, health, fecundity, and resilience that occurs during winter is the "Big Mama Hypothesis" (Bill Bennett, UC Davis, pers. comm. and various oral presentations). As a result of his synthesis of a variety of studies, Bennett proposed that the largest delta smelt (whether the fastest growing age-1 fish or fish that manage to spawn at age-2) could have a large influence on population trends. Delta smelt larvae spawned in the South Delta have high risk of entrainment under most hydrologic conditions (Kimmerer 2008), but water temperatures often warm earlier in the South Delta than the Sacramento River (Nobriga and Herbold 2008). Thus, delta smelt spawning often starts and ends earlier in the Central and South Delta than elsewhere. This differential warming may contribute to the "Big Mama Hypothesis" by causing the earliest ripening females to spawn disproportionately in the South Delta, putting their offspring at high risk of entrainment. Although water diversion strategies have been changed to better protect the 'average' larva, the resilience historically provided by variable spawn timing may be reduced by water diversions and other factors that covary with Delta inflows and outflows.

Substantial increases in winter salvage at Banks and Jones that occurred contemporaneously with recent declines in delta smelt and other POD species (Kimmerer 2008, Grimaldo et al. accepted manuscript) support the interpretation that entrainment played a role in the POD-era depression of delta smelt numbers. Increased winter entrainment of delta smelt represents a loss of pre-spawning adults and all their potential progeny (Sommer et al. 2007). Note that winter salvage levels subsequently decreased to very low levels for all POD species during the winters of 2005-2006 and 2006-2007, possibly due to the very low population sizes during those periods. Reduced pumping for protection of delta smelt also substantially reduced OMR flow towards the pumps and subsequently reduced number of delta smelt entrained during the winters of 2006-2007 and 2007-2008.

The hydrologic and statistical analyses of relationships between OMR flows and salvage suggest a reasonable mechanism by which winter entrainment increased with increased exports during the POD years; however, entrainment is not a substantial source of mortality every year. Manly and Chotkowski (2006; IEP 2005) found that monthly or semi-monthly measures of exports or Old and Middle rivers flow had a reliable, statistically significant effect on delta smelt abundance; however, individually they explained a small portion (no more than a few percent) of the variability in the fall abundance index of delta smelt across the entire survey area and time period. Kimmerer (2008) addressed delta smelt entrainment by means of particle tracking, and estimated historical entrainment rates for larvae and juvenile delta smelt to be as high as 40 percent; however, he concluded that non-entrainment mortality in the summer had effects on FMWT delta smelt numbers. Hence, there are other factors that often mask the effect of entrainment loss on delta smelt fall abundance in these analyses. Among them, availability and quality of summer and fall habitat (see Effects section) are clearly affected by CVP/SWP operations.

We conclude that entrainment and habitat availability/quality jointly contribute to downward pressure on spawner recruitment in and one or both of these general mechanisms is operating throughout the year. The intensity of constraints of the other threats affecting the delta smelt carrying capacity varies between years, and the importance of contributing stressors changes as outflow, export operations, weather, and the abundances of other ecosystem elements vary. For instance, Bennett (2005) noted that seasonally low outflow and warmer water temperatures may concentrate delta smelt and other planktivorous fishes into relatively small patches of habitat during late summer. This would increase competition and limit food availability during low outflow. Higher outflow that expands and moves delta smelt habitat downstream of the Delta is expected to improve conditions for delta smelt (Feyrer et al. 2007). The high proportion of the delta smelt population that has been entrained during some years (Kimmerer 2008) would be expected to reduce the ability of delta smelt to respond to the improved conditions, thereby limiting the potential for increased spawner recruitment. Further, the smaller sizes of maturing adults during fall may have affected delta smelt fecundity (Bennett, 2005). This would further reduce the species' ability to respond to years with improved conditions.

Factors Affecting the Species

Water Diversions and Reservoir Operations

Banks and Jones Export Facilities

In 1951, the Tracy Pumping Plant (now referred to as the Jones Pumping Plant), with a capacity of 4,600 cfs, was completed along with the Delta Mendota Canal which conveys water from the Jones Pumping Plant (Jones) for use in the San Joaquin Valley. Simultaneously, Reclamation also constructed the Delta Cross Channel to aid in transferring water from the Sacramento River across the Delta to the Jones Pumping Plant. From its inception and formulation, the CVP (inclusive of upstream reservoirs, river and Delta conveyance, the Jones Pumping Plant, Delta-Mendota Canal, and San

Luis Reservoir) was intended to function as an integrated system to deliver and export water, not as a grouping of separate or independent units.

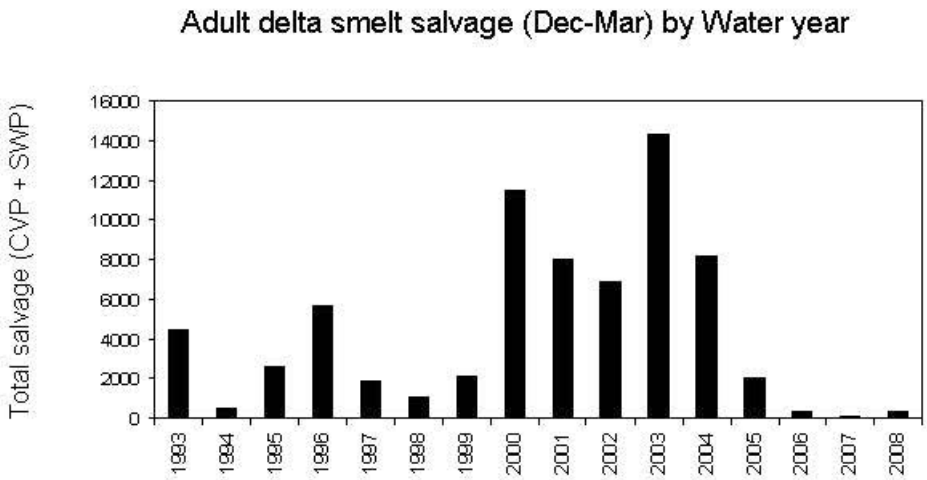
In 1968 the first stage of the Banks Pumping Plant for the SWP was completed with seven units having a combined capacity of 6,400 cfs. In 1973, the California Aqueduct was completed. In 1974 Clifton Court Forebay was completed. In 1991 an additional four pumping units were added, increasing Banks Pumping plant capacity to 10,300 cfs. However, this diversion rate has historically been restricted to 6,680 cfs as a three-day average inflow to Clifton Court Forebay, although between December 15 and March 15, when the San Joaquin River is above 1,000 cfs, pumping in excess of 6680 at a rate equal to one-third of the San Joaquin River flow at Vernalis has historically been permissible. Furthermore, under the EWA, the SWP has been permitted to pump an additional 500 cfs between July 1 and September 30 to offset water costs associated with fisheries actions making the summer limit effectively 7,180 cfs. The Army Corps of Engineers' permit for increased pumping at Banks expired and is no longer authorized. The completion and operation of the Jones and Banks pumping plants have increased Delta water exports (Figure P-18).

Export of water from the Delta has long been recognized to have multiple effects on the estuarine ecosystem upon which species such as the delta smelt depend (Stevens and Miller 1983; Arthur et al. 1996; Bennett and Moyle 1996). In general, water is conveyed to Jones and Banks via the Old and Middle River channels resulting in a net (over a tidal cycle or tidal cycles) flow towards Jones and Banks. When combined water export exceeds San Joaquin River inflows, the additional water is drawn from the Sacramento River through the Delta Cross Channel, Georgina Slough, and Three-Mile Slough. At high pumping rates, net San Joaquin River flow is toward Banks and Jones (Arthur et al. 1996). Combined flow in the Old and Middle Rivers is measured as "OMR" flows while flow in the San Joaquin River at Jersey Island is calculated as "Qwest" (Dayflow at http://www.iep.ca.gov/dayflow/). Flow towards the pumps is characterized as negative flow for both measurements. Further, OMR flow towards the pumps is increased seasonally by installation of the South Delta Temporary Barriers. In particular, the Head of Old River barrier reduces flow from the San Joaquin River downstream into Old River so more water is drawn from the Central Delta via Old and Middle Rivers.

Because large volumes of water are drawn from the Estuary, water exports and fish entrainment at Jones and Banks are among the best-studied sources of fish mortality in the San Francisco Estuary (Sommer et al. 2007). As described in the Project Description, the Tracy Fish Collection Facility (CVP) and the Skinner Fish Facility (SWP) serve to reduce the mortality of fish entrained at Jones and Banks. The export facilities are known to entrain all species of fish inhabiting the Delta (Brown et al. 1996), and are of particular concern in dry years, when the distribution of young striped bass, delta smelt, and longfin smelt shift upstream, closer to the diversions (Stevens et al. 1985; Sommer et al. 1997). As an indication of the magnitude of entrainment effects caused by Banks and Jones, approximately 110 million fish were salvaged at the Skinner Fish Facility screens and returned to the Delta over a 15-year period (Brown et al. 1996). However, this number greatly underestimates the actual number of fish entrained. It does not include losses through the guidance louvers at either facility. For Banks in particular, it does not

account for high rates of predation on fish in CCF (Gingras 1997). Fish less than 30 mm forklength (FL) are not efficiently collected by the fish screens (Kimmerer 2008).

The entrainment of adult delta smelt at Jones and Banks occurs mainly during their upstream spawning migration between December and April (Figure S-7). Entrainment risk depends on the location of the fish relative to the export facilities and the level of exports (Grimaldo et al. accepted manuscript). The spawning distribution of adult delta smelt varies widely among years. In some years a large proportion of the adult population migrates to the Central and South Delta, placing both spawners and their progeny in relatively close proximity to the export pumps and increasing entrainment risk. In other years, the bulk of adults migrate to the North Delta, reducing entrainment risk. In very wet periods, some spawning occurs west of the Delta.



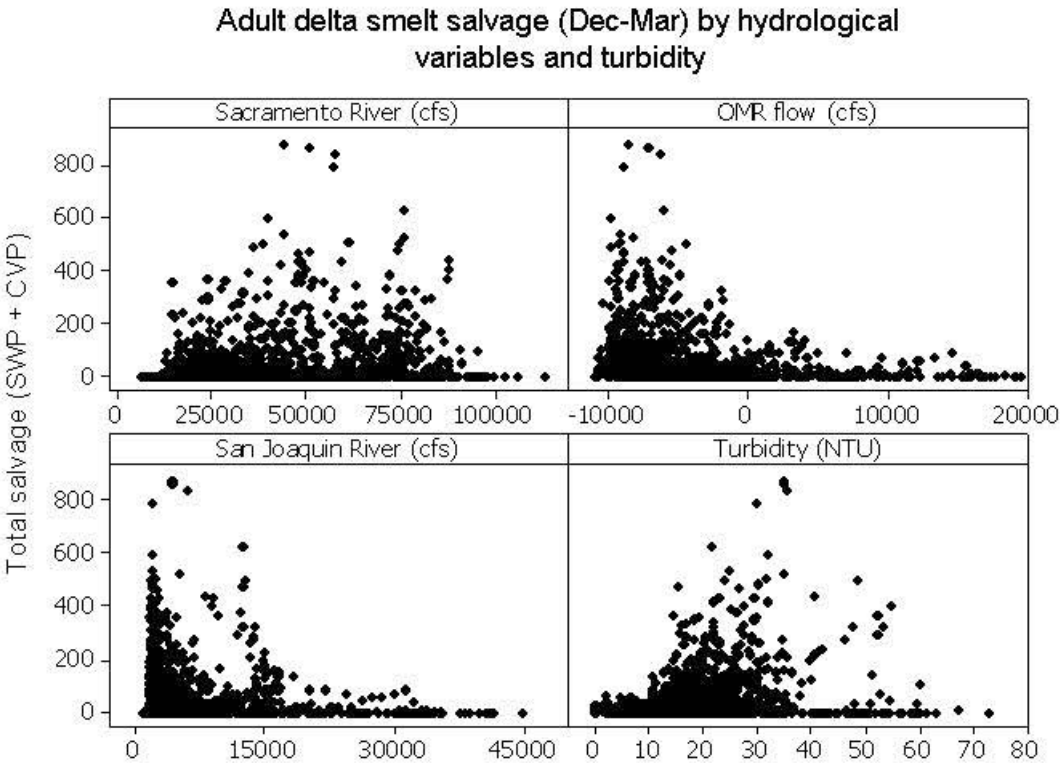


Figure S-7, Adult delta smelt salvage December through March by WY and by hydrological variables and turbidity

The CVP and SWP water operations are thought to have a minor impact on delta smelt eggs because they remain attached to substrates or at least strongly negatively buoyant due to attached sand grains (see Spawning section above). Shortly after hatching, larvae become subject to flow-mediated transport, and are vulnerable to entrainment. However, delta smelt and other fish are not officially counted at Banks or Jones unless they are 20 mm or greater in total length and transitioning to the juvenile stage. Juvenile delta smelt are vulnerable to entrainment and are counted in salvage operations once they reach 20-25 mm in length, but the fish facilities remain inefficient collectors of delta smelt until they surpass 30 mm in length (Kimmerer 2008). Most salvage of juvenile delta smelt occurs from April-July with a peak in May-June (Grimaldo et al, accepted manuscript).

High winter entrainment has been suspected as a contributing cause of both the early 1980s (Moyle et al. 1992) and the POD-era declines of delta smelt (Baxter et al. 2008). To address the increases in winter salvage during 2002-2004, three key issues were evaluated. First, there was an increase in exports during winter as compared to previous years, attributable to the SWP (Figure P-17). Second, the proportion of tributary inflows shifted. Specifically, San Joaquin River inflow decreased as a fraction of total inflow around 2000, while Sacramento River inflow increased (Figure 7-12, Reclamation 2008).

Overall, these operational changes may have contributed to a shift in Delta hydrodynamics that increased fish entrainment. The hydrodynamic change can be indexed using tidally averaged net flows through OMR that integrate changes in inflow, exports, and barrier operations (Monsen et al. 2007, Peter Smith, USGS, unpublished data). Several analyses have revealed strong, non-linear inverse relationships between net OMR flow and winter salvage of delta smelt at the Banks and Jones (Fig. 7-6 in Reclamation 2008; P. Smith, unpublished data; Grimaldo et al accepted manuscript; Kimmerer 2008) (See Figure S-8). While the specific details of these relationships vary by species and life stage, net OMR flow generally works very well as a binary switch: negative OMR is associated with some degree of entrainment, while positive OMR is usually associated with no, or very low, entrainment. Particle tracking modeling (PTM) also shows that entrainment of particles and residence time is highly related to the absolute magnitude of negative OMR flows, and that the zone of influence of the pumps increases as OMR becomes more negative. The rapid increase in the extent of the zone of entrainment at high negative OMR likely accounts for the faster-than-linear increase in entrainment as OMR becomes more negative. Adult delta smelt do not behave as passive particles, but they still use tidal flows to seek suitable staging habitats prior to spawning. When the water being exported is suitable staging habitat, for instance, when turbidity is > 12 NTU, delta smelt do not have a reason to avoid net southward transport toward the pumps so the OMR/entrainment relationship reinforces that tidally averaged net flow is an important determinant of the migratory outcome for delta smelt.

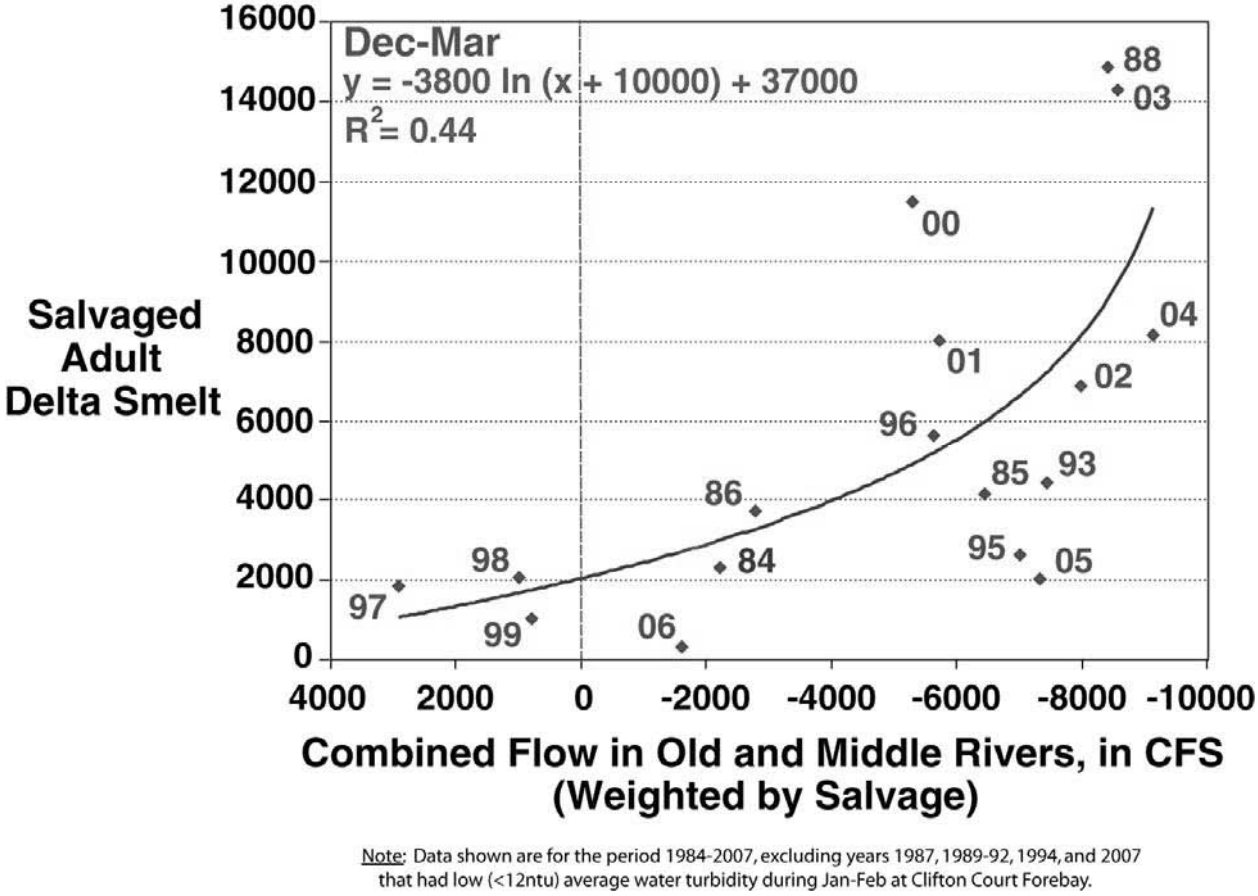


Figure S-8 – Relationship for the total number of adult delta smelt salvaged at the State and Federal fish facilities in the south Delta during the winter months of December through March with the combined, tidally averaged flow in Old and Middle Rivers near Bacon Island (***AVG_OMR$_i$***).

PTM that simulates water movement using particles injected at various stations in the Delta gives a fairly good representation of the relative likelihood of larval and juvenile delta smelt entrainment (Kimmerer 2008; Kimmerer and Nobriga 2008). Predicted entrainment is high for the San Joaquin River region given recent winter and spring operations. Depending on Delta conditions, up to 70 percent of small organisms in the Old River south of Franks Tract would be entrained within 30 days at moderate flows in San Joaquin River and an OMR of negative 3,000 cfs (SWG notes 2008). Ten to twenty percent of larval delta smelt located in the San Joaquin River at Fisherman's Cut would be expected to be entrained during the same period and OMR flows. This percentage increases to about 30 percent if OMR net flow is negative 5,000 cfs (DWR March 4, 2008, PTM runs: http://www.fws.gov/sacramento/).

Larvae are not currently sampled effectively at the fish-screening facilities and very small larvae (< 15-20 mm) are not sampled well by IEP either. Kimmerer and Nobriga (2008) and Kimmerer (2008) addressed larval delta smelt entrainment by coupling PTM with 20-mm survey results to estimate historical larval entrainment. These approaches suggest

that larval entrainment losses could exceed 50 percent of the population if low flow and high export conditions coincide with a spawning distribution that includes the San Joaquin River. Although this does not occur every year, the effect of larval entrainment is substantial when it does. Since delta smelt are an annual fish, one year with distribution within the footprint of entrainment by the pumps can lead to a serve reduction in that year's production. In order to minimize the entrainment of undetected larval delta smelt, export reductions have recently focused on the time period when larval smelt are thought to be in the South Delta (based on adult distributions) to proactively protect these fish.

Salvage of delta smelt has historically been greatest in drier years when a high proportion of young of the year (YOY) rear in the Delta (Moyle et al. 1992; Reclamation and DWR 1994; and Sommer et al. 1997). In recent years however, salvage also has been high in moderately wet conditions (Nobriga et al. 2000; 2001; Grimaldo et al., accepted manuscript: springs of 1996, 1999, and 2000) even though a large fraction of the population was downstream of the Sacramento-San Joaquin River confluence. Nobriga et al. (2000; 2001) attributed recent high wet year salvage to a change in operations for the VAMP that began in 1996. The VAMP provides a San Joaquin River pulse flow from mid-April to mid-May each year that probably improves rearing conditions for delta smelt larvae and also slows the entrainment of fish rearing in the Delta. The high salvage events may have resulted from smelt that historically would have been entrained as larvae and therefore not counted at the fish salvage facilities growing to a salvageable size before being entrained. However, a more recent analysis provides an additional explanation. Delta smelt salvage in 1996, 1999, and 2000 was not outside of the expected historical range when three factors are taken into account, (1) delta smelt distribution as indexed by X2, and (2) delta smelt abundance as indexed by the TNS. Herbold, B. et al. (unpublished: http://198.31.87.66/pdf/ewa/EWA_Herbold_historical_patterns_113005.pdf) showed that salvage during 2003 through 2005 was relatively high compared to previous years given the low abundance indicated by the FMWT index (Figure S-9). Therefore, it is uncertain that operations changes for VAMP have influenced delta smelt salvage dynamics as suggested by Nobriga et al. (2000). In addition, assets from the EWA are often used during this time of year to further reduce delta smelt entrainment, though the temporary export curtailments from EWA have not likely decreased delta smelt entrainment by more than a few percent (Brown et al. 2008). Although the population level benefits of these actions are ultimately sometimes minor, they have been successful at keeping delta smelt salvage under the limits set in the Service's OCAP biological opinions (Brown and Kimmerer 2002).

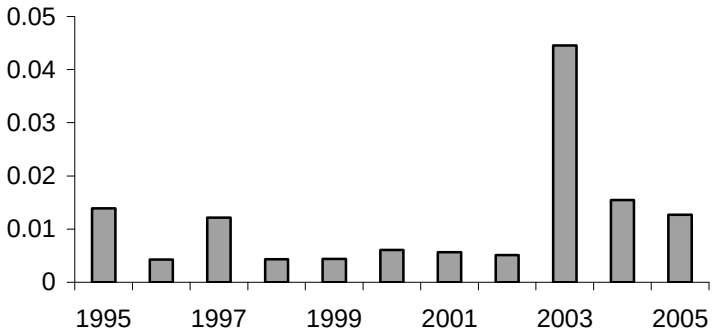


Figure S-9. Ratio of salvage density to the previous FMWT index.

In 2007 and 2008, CVP and SWP implemented actions to reduce entrainment at the pumps, including maintaining higher (less negative) OMR flows (Smelt Working Group Notes and Water Operations Management Team Notes at http://www.fws.gov/). During these two years estimated number of delta smelt salvaged decreased considerably. Estimated adult salvage was 60 and 350 in 2007 and 2008, respectively. Total (adults and young-of-the-year) estimated salvage was 2,327 and 2,038 delta smelt, respectively. These were down from a high of 14,338 in 2003.

Environmental Water Account

The EWA, as described in the Project Description, was established in 2000. The EWA agencies acquired assets and determined how the assets should be used to benefit the at-risk native fish species of the Bay-Delta estuary. The EWA reduced diversions of water at Banks and Jones when listed fish species were present in the Delta and prevented the uncompensated loss of water to SWP and CVP contractors. Typically the EWA replaced water lost due to curtailment of pumping by purchase of surface or groundwater supplies from willing sellers and by taking advantage of regulatory flexibility and certain operational assets. These assets were moved through the Delta during the summer and fall, when entrainment effects to listed fish were minimal.

Generally, under past actions, the EWA has reduced water exports out of the Delta during the winter and spring and increased exports during the summer and early winter. These actions reduced entrainment at the facilities, but only by modest amounts (Brown et al. 2008). The movement of water in the summer and fall may have negatively influenced habitat suitability and prey availability (see effects section).

500 cfs Diversion at Banks

This operation allowed the maximum allowable daily diversion rate into CCF during the months of July, August, and September to increase from 13,870 AF to 14,860 AF and three-day average diversions from 13,250 AF to 14,240 AF. The increase in diversions was permitted by the U.S. Army Corps of Engineers and has been in place since 2000.

The current permit expired on September 30, 2008 and DWR is currently seeking an extension.

The purpose of this diversion increase into CCF was for the SWP to recover export reductions made due to the ESA or other actions like the EWA taken to benefit fisheries resources. This increased capacity allowed EWA assets to be moved through the Delta during the summer, when entrainment of listed species was minimal. This additional diversion rate was included as part of the EWA operating principles. This additional pumping occurred during the summer and likely did not result in much direct entrainment of delta smelt, but did likely result in entrainment of food for delta smelt, such as *Pseudodiaptomus* and contributed to lower habitat suitability as summer-fall export to inflow ratios increased to high levels regardless of preceding winter-spring flows.

CVP/SWP Actions Taken since the 2005 OCAP Biological Opinion was Issued

After the issuance of the 2005 biological opinion, the SWG used the DSRAM (Attachment A) to provide guidance for when the group needed to meet to analyze the most recent real-time delta smelt abundance and distribution data. Using the latest data, the SWG then determined if a recommendation to the Service to protect delta smelt from excessive entrainment was warranted. For the 2006 WY, a wet WY, based on the Service's recommendations, the Projects reduced exports to protect delta smelt by operating to an E/I ratio limit. The export curtailment operated to an E/I ratio of 15 percent beginning January 3 until February 21, 2006, when the E/I was expected to increase above 20 percent due to wet hydrologic conditions. No further actions were taken to protect fish that season as the E/I ratio was maintained at about 10 percent because of high spring flows. VAMP was implemented in May 2006, although the HORB was not installed due to high flows on the San Joaquin River.

For the 2007 WY, a dry year, the Service recommended a winter pulse flow increasing OMR flows to a daily average of negative 3500 cfs or if there were not Sacramento River flows above 25,000 cfs for three days, to moderate OMR to a range of negative 5000 cfs to negative 3500 cfs until February 15th . This action was implemented by the Projects, but since the Sacramento River never achieved 25,000 cfs for three days, the Projects operated to not exceed a 5-day average OMR flow of negative 4,000 cfs starting on January 15. To protect pre-spawning adult delta smelt from becoming entrained and based on the Service's recommendation, the Projects maintained OMR above negative 4,000 cfs and on March 13 the Project operated to a 5-day average OMR of negative 5,000 cfs.

To protect larval and juvenile delta smelt from entrainment the Projects operated the export facilities to achieve a non-negative daily net OMR flow. The Projects implemented the following actions: reduced combined Banks and Jones exports from 1,500 cfs to combined 1,200 cfs (850 cfs at the CVP and 350 cfs at the SWP) and evaluated increasing New Melones releases to 1,500 cfs for steelhead emigration. VAMP was then implemented and the HORB was removed on May15. The South Delta agricultural barriers maintained their flap gates in the open position and Reclamation increased exports from 850 cfs to 1,200 cfs on June 13 while DWR maintained an export level of 400 cfs.

Water Year 2008 Interim Remedial Order Following Summary Judgment and Evidentiary Hearing (Wanger Order)

For the 2008 WY, a dry WY, the Service, Reclamation and DWR implemented the direction contained in the Wanger Order.

A modified Adaptive Process was used during 2008. The SWG continued to use the DSRAM to identify the most recent delta smelt data and to help and provide a framework for the level of protection needed to protect delta smelt from entrainment. The SWG provided guidance to the Service, who then made a recommendation to WOMT. If WOMT did not agree to the Service's determination, WOMT would develop a counter proposal which was then sent back to Service, who would decide if WOMT's action was adequate to protect delta smelt or if the Service's original determination should be implemented instead.

For 2008, the fist action to protect delta smelt was a 10-day winter pulse flow that was implemented based on a turbidity trigger. The turbidity trigger was exceeded on December 25 and by December 28, the CVP and SWP began to operate such that a daily OMR flow would not be more negative than 2,000 cfs. This action was completed on January 6, 2008.

Second, OMR flow was limited to provide a net daily upstream OMR flow not to exceed 5,000 cfs to protect pre-spawning adult delta smelt from entrainment. This flow was calculated based on a 7-day running average. On January 7, 2008, immediately following the termination of the 10-day winter pulse flow, the CVP and SWP started to operate to achieve an average net upstream flow in OMR not to exceed 5,000 cfs over a 7-day running average period.

Next, OMR was limited to provide a net daily net upstream OMR flow of 750 to 5000 cfs to protect larval and juvenile delta smelt. These flows were determined by the Service, in consultation with Reclamation and DWR, on a weekly basis and were based upon the best available scientific and commercial information concerning delta smelt distribution and abundance. The Service used a control point method using PTM to limit predicted entrainment at Station 815 to 1 percent. When delta smelt abundances are low (the 2007 delta smelt FMWT Index was 28), the control point method is an appropriate method to protect delta smelt from entrainment at Banks and Jones. This is due in part because when delta smelt abundance is low, an accurate delta smelt distribution may not be determined from survey results. The control point method also sets a limit of entrainment from the Central Delta and it does not need distributional data to be protective. The CVP and SWP maintained OMR flow between -2000 and -3000 cfs, with an OMR flow agreed upon each week until June 20 (details on the OMR flow for each week can be found on the Sacramento Fish and Wildlife's website at http://www.fws.gov/sacramento/Delta_popup.htm). The CVP and SWP also implemented VAMP during this period, with San Joaquin River flows of 3,000 cfs and 1,500 cfs export flows. The HORB was not installed in 2008 and the SDTB maintained their flap gates in the open position.

Water Transfers

As described in the Project Description, purchasers of water for transfers have included Reclamation, DWR, SWP contractors, CVP contractors, other State and Federal agencies, or other parties. To date, transfers requiring export from the Delta have been done at times when pumping and conveyance capacity at Banks or Jones is available to move the water. Exports for transfers can not infringe upon the capability of the Projects to comply with the terms of SWQCP D-1641 and the existing biological opinions. Parties to the transfer are responsible for providing for any incremental changes in flows required to protect Delta water quality standards. All transfers have been in accordance with all existing regulations and requirements. Recent transfer amounts were 1,000 TAF in 2001-02, 608 TAF in 2002-03, 700 TAF in 2003-04, and 851 TAF in 2004-05 (DWR website: http://www.watertransfers.water.ca.gov). Generally, water transfers occur in the summer (July-September), when entrainment of listed fish is minimized. Most transfers have occurred at Banks because reliable capacity is generally only available at Jones in the driest 20 percent of years.

Article 21 and changes to Water Deliveries to Southern California

Changes in pumping in accordance with Article 21 and the associated changes in water deliveries have lead to recent increases in SWP water exports from the Delta. Article 21 deliveries are made when San Luis Reservoir is physically full or projected to be full and may result in export levels that are higher than if Article 21 was not employed. Recent changes in how Article 21 is invoked and used have increased the amount of Article 21 and Table A SWP water that has been pumped from the Delta.

Diamond Valley Lake was completed in 1999 and provided Metropolitan Water District of Southern California (MWDSC) an additional location for water storage in Southern California. Diamond Valley Lake holds 800,000 acre-feet of water, which makes it the largest reservoir in Southern California. MWDSC began filling the reservoir in November 1999 and the lake was filled by early 2002. Another factor involving water deliveries in southern California that changed Delta diversions is the Quantification Settlement Agreement (QSA) signed in 2003, which resulted in a decrease in the amount of Colorado River water available to California.

Since 1999, MWDSC was filling Diamond Valley Lake and adding water to groundwater storage programs. Generally, in wetter years, demand for imported water decreases because local sources are augmented and local rainfall reduces irrigation demands. However, with the increased storage capacity in Southern California, the recent wet years did not result in lower exports from the Delta or the Colorado River. Table P-12 illustrates the demands for imported water during the recent wet years and the effect of reduced Colorado River diversions under the QSA on MWDSC deliveries from the Delta.

Vernalis Adaptive Management Plan

As described in the project description, VAMP was initiated in 2000 as part of the SWRCB D- 1641. VAMP schedules and maintains pulse flows in the San Joaquin River and reduced exports at Banks and Jones for a one month period, typically from April 15-May 15 (May 1-31 in 2005/06). Tagged salmon smolts released in the San Joaquin River are monitored as they move through the Delta in order to determine their fate. While

VAMP-related studies attempt to limit CVP and SWP impacts to salmonids, the associated reduction in exports reduces the upstream flows that occur in the South and Central Delta. This reduction limits the southward draw of water from the Central Delta, and thus reduces the Projects' entrainment of delta smelt.

Based on Bennett's unpublished analysis, reduced spring exports resulting from VAMP have selectively enhanced the survival of delta smelt larvae spawned in the Central Delta that emerge during VAMP by reducing their entrainment. Initial otolith studies by Bennett's lab suggest that these spring-spawned fish dominate subsequent recruitment to adult life stages. By contrast, delta smelt spawned prior to and after the VAMP have been poorly-represented in the adult stock in recent years. The data suggests that the differential fate of early, middle and late cohorts affects sizes of delta smelt in fall because the later cohorts have a shorter growing season. These findings suggest that direct entrainment of larvae and juvenile delta smelt during the spring are relevant to population dynamics.

Other SWP/CVP Facilities

North Bay Aqueduct

The North Bay Aqueduct (NBA) diverts Sacramento River water from Barker Slough through Lindsay Slough. The 1995 OCAP biological opinion included monitoring delta smelt at the three stations in Barker Slough and the surrounding areas on a "recent-time" (within 72 hours) basis, and the posting of delta smelt information on the internet so that interested parties can use the information for water management decisions.

DWR contracted with DFG for the monitoring from 1995-2004 to estimate and evaluate larval delta smelt loss at the NBA due to entrainment, and to monitor the abundance and distribution of larval delta smelt in the Cache Slough complex and near Prospect Island. The sampling season for this monitoring was mid-February to mid-July with high priority stations (Barker and Lindsey Sloughs) sampled every two days and the remaining stations (Cache and Miner sloughs, and the Sacramento Deep Water Channel) sampled every four days.

NBA pumping was regulated by a weighted mean of the actual catch of delta smelt at the three Barker Slough stations. The weight assigned to each station was dependent on its proximity to the NBA intake. Station 721 had a 50 percent weighting, 727 had a 30 percent weighting and station 720 had a 20 percent weighting. As stated in the Service's 1995 OCAP biological opinion, the diversions at NBA were restricted to a 5-day running average of 65 cfs for five days when delta smelt were detected. In mathematical terms, the NBA restrictions were in place when the following equation was true:

$$0.5*(\text{Catch at } 721) + 0.3*(\text{Catch at } 727) + 0.2*(\text{Catch at } 720) >= 1.0$$

An entrainment estimate was then calculated as the weighted mean density of delta smelt multiplied by the total water exported for the sampling day and the day after. Based on this method, estimated annual entrainment of delta smelt at NBA was as follows: 1995 = 375; 1996 = 12,817; 1997 = 18,964; 1998 = 1,139; 1999 = 1,578; 2000 = 10,650; 2001 = 32,323; 2002 = 10,814; 2003 = 9,978; and 2004 = 8,246. However, a study of a fish

screen in Horseshoe Bend built to delta smelt standards excluded 99.7 percent of fish from entrainment even though most of these were only 15-25 mm long (Nobriga et al. 2004). Thus, the fish screen at NBA may protect many of the delta smelt larvae that do hatch and rear in Barker Slough, so actual entrainment was probably lower.

In the Service's 2005 OCAP biological opinion, a broader larval smelt survey was included in the Project Description in lieu of the NBA monitoring. This change was suggested due to the low numbers of delta smelt caught in the NBA monitoring and it was thought that a broader sampling effort would be more helpful in determining where larval delta smelt are located. This broader monitoring effort was conducted during the spring of 2006, and used a surface boom tow at the existing 20-mm survey stations. The sampling was successful, and helped show that larval delta smelt could be caught in the Delta. However, this monitoring was not continued after 2006. Starting in 2009, an expanded larval survey in the Delta will be conducted. As discussed above, the number of delta smelt entrained at the NBA is unknown, but it may be low so long as the fish screen is maintained properly. There may be years, however, that large numbers of delta smelt are in the Cache Slough complex and could be subject the entrainment at the NBA.

Contra Costa Water District (CCWD)

CCWD diverts water from the Delta for irrigation and municipal and industrial uses in the Bay Area. CCWD's system includes intake facilities at Mallard Slough, Rock Slough, and Old River near State Route 4; the Contra Costa Canal and shortcut pipeline; and the Los Vaqueros Reservoir as described in the Project Description. The total diversion by CCWD is approximately 127 TAF per year. Most CCWD diversions are made through facilities that are screened; the Old River (80 percent of CCWD diversions) and Mallard Slough (3 percent of CCWD diversions) facilities have fish screens to protect delta smelt. However, the fish screens on these facilities may not protect larval fish from becoming entrained. For that reason, in part, there are also no-fill and no-diversion periods at the CCWD facilities.

Before 1998, the Rock Slough Intake was CCWD's primary diversion point. It has been used less since 1998 when Los Vaqueros Reservoir and the Old River Pumping Plant began operating and now only accounts for 17 percent of CCWD's diversions. To date, the Rock Slough Intake is not screened. Reclamation, as described in the Project Description, is responsible for constructing a fish screen at this facility under the authority of the CVPIA. Reclamation has received an extension for construction of the screen until 2008 and is seeking a further extension until 2013. The diversion at the Rock Slough Intake headworks structure is currently sampled with a sieve net three times per week from January through June and twice per week from July through December. A plankton net is fished at the headworks structure twice per week during times when larval delta smelt could be present in the area (generally March through June). A sieve net is fished at Pumping Plant #1 two times per week from the time the first Sacramento River winter-run Chinook salmon is collected at the Jones and Banks (generally January or February) through June. The numbers of delta smelt entrained by the facility since 1998 have been extremely low, with only a single fish observed in February 2005 (Reclamation 2008).

Other Delta Diversions and Facilities

In 2006, the Service issued a biological opinion on the construction and operation of the Stockton Delta Water Supply Facility located on Empire Tract along the San Joaquin River. This facility is expected to be completed and online by 2010. The maximum diversion rate for this facility will be 101 AF per day. Fish screens and pumping restrictions in the spring are expected to considerably limit entrainment of delta smelt. However, limited pumping will occur during the spring and the fish screens are not expected to fully exclude fish smaller than 20 mm TL, so delta smelt may be entrained at this facility.

There are 2,209 known agricultural diversions in the Delta and an additional 366 diversions in Suisun Marsh used for enhancement of waterfowl habitat (Herren and Kawasaki 2001). The vast majority of these diversions do not have fish screens to protect fish from entrainment. It has been recognized for many years that delta smelt are entrained in these diversions (Hallock and Van Woert 1959). Determining the effect of this entrainment has been limited because previous studies either (1) did not quantify the volumes of water diverted (Hallock and Van Woert 1959, Pickard et al. 1982) or (2) did not sample at times when, or locations where, delta smelt were abundant (Spaar 1994, Cook and Buffaloe 1998). Delta smelt primarily occur in large open-water habitats, but early life stages move downstream through Delta channels where irrigation diversions are concentrated (Herren and Kawasaki 2001). At smaller spatial scales, delta smelt distribution can be influenced by tidal and diel cycles (Bennett et al. 2002), which also may influence vulnerability to shore-based diversions.

In the early 1980s, delta smelt were commonly entrained in the Roaring River diversion in Suisun Marsh (Pickard et al. 1982), suggesting that it and similar diversions can adversely affect delta smelt. However, delta smelt may not be especially vulnerable to many Delta agricultural diversions for several reasons. First, adult delta smelt move into the Delta to spawn during winter-early spring when agricultural diversion operations are at a minimum. Second, larval delta smelt only occur transiently in most of the Delta and now avoid the South Delta during summer when diversion demand peaks. Third, Nobriga et al. (2004) examined delta smelt entrainment at an agricultural diversion in Horseshoe Bend during July 2000 and 2001, when much of the YOY population was rearing within one tidal excursion of the diversion. Delta smelt entrainment was an order of magnitude lower than density estimates from the DFG 20-mm Survey. Low entrainment was attributed to the offshore distribution of delta smelt, and the extremely small hydrodynamic influence of the diversion relative to the channel it was in. Because Delta agricultural diversions are typically close to shore and probably take small amounts of water relative to what is in the channels they draw water from, delta smelt vulnerability may be low despite their small size and their poor performance near simulated fish screens in laboratory settings (Swanson et al. 1998; White et al. 2007).

The impact on fish populations of individual diversions is likely highly variable and depends upon size, location, and operations (Moyle and Israel 2005). Given that few studies have evaluated the effectiveness of screens in preventing losses of fish, much less declines in fish populations, further research is needed to examine the likely population-level effects of delta smelt mortality attributed to agricultural diversions (Nobriga et al.

2004; Moyle and Israel 2005). Note however, that most of the irrigation diversions are in the Delta, so low flow conditions that compel delta smelt to rear in the Delta fundamentally mediate loss to these irrigation diversions. PTM evidence for this covariation of Delta hydrodynamics and cumulative loss to irrigation diversions was provided by Kimmerer and Nobriga (2008).

Delta Power Plants

There are two major power plants located near the confluence of the Sacramento and San Joaquin Rivers. The upstream-most facility is commonly referred to as the Contra Costa Power Plant while the downstream-most facility is commonly referred to as the Pittsburg Power Plant. Both facilities are located in the low salinity rearing habitats of delta smelt. The following assessment of the Contra Costa and Pittsburg Power Plants comes from information collected by Matica and Sommer (2005).

The Contra Costa Power Plant is located 2.5 miles upstream from the city of Antioch. The first units were operational in June 1951. By 1975, with expansions, the power plant incorporated 7 main power-generating units and 3 smaller house units. In 1995, Units 1-5 were decommissioned. When all units were operating, the cooling water flows into Units 1-5 and Units 6-7 were up to 946 and 681 cfs, respectively. Cooling water was diverted by two separate intake arrangements. Water for Units 1-5 was taken from near the river bottom 410 feet offshore and for Units 6-7 from a shoreline intake system. Water was carried at 3.8 ft/sec to five recessed onshore traveling trash screens, with 3/8-inch square-opening wire mesh. Calculated screen approach velocities averaged about 1.3 ft/sec with velocities of 2.0 ft/sec through the mesh. Discharge canals return the heated water to the river. For Units 1-5 water was returned 750 ft west of its uptake and for Units 6-7 it is returned 750 ft east of its uptake. Under normal full-load operation the temperature of the discharge water was raised a mean of 16.2 °F and at peak loads the maximum differential between intake and discharge temperature was 21 °F, creating a thermal plume, concentrated near the surface and shoreline, extending over an area of approximately 100 acres.

The Pittsburg Power Plant is located on the south shore of Suisun Bay just west of Pittsburg. This steam generation plant consists of 7 power generating units. Construction began in 1953 and the 7 units were commissioned in 3 phases: Units 1-4 in 1954; Units 5 and 6 in 1960; and Unit 7 in 1961. Units 1-6 withdraw and return cooling water to Suisun Bay. Their intake structures are located on the shoreline about 1,000 feet to the west of the discharge structure. Discharge is located 10-30 feet offshore in about 10 feet of water. Total cooling water flow for Units 1-6 when all pumps are running is 1,612 cfs. Entrainment effects may occur at the plants from large pressure decreases across the condenser at both power plants, and impingement on fish screens.

Overall, the total maximum non-consumptive intake of cooling water for the two facilities is 3,240 cfs, which can exceed 10 percent of the total net outflow of the Sacramento and San Joaquin rivers, depending on hydrology. However, pumping rates are often significantly lower under normal operation. Potential impacts to aquatic species include chemical and thermal pollution, and entrainment. Chemical impacts may occur as a result of chlorination for control of "condenser slime", which was historically

conducted weekly. This treatment at Contra Costa Power Plant consumed a little over 1 ton of chlorine a month, or 13 tons per year. The discharge water was not historically dechlorinated or subject to regular monitoring for residual chlorine.

Thermal pollution represents an additional concern for aquatic species. Temperature objectives set by the California Regional Water Quality Control Board include: "No discharge shall cause a surface water temperature rise greater than 4 ºF above the natural temperature of the receiving water at any time or place"; and "The maximum temperature of thermal waste discharge shall not exceed 86 ºF." Both plants discharge water at temperatures in excess of 86 °F 10 percent of the time, and surface water temperature plumes in the receiving water at each plant exceed +4 °F for areas up to 100 acres. The previous owner of these two plants, Pacific Gas and Electric (PG&E), sought and received exemptions to the above limitations.

In 1951, DFG recognized the power plants presented a potential issue for the salmon and striped bass resources of the area as both plants were originally equipped with inefficient fish barriers. At the time, DFG estimated that as many as 19 million small striped bass might pass through the Contra Costa plant and be killed each year between April and mid-August. As a result of these concerns, DFG and PG&E conducted a monitoring study to evaluate entrainment. In 1979, consultants estimated the total average annual entrainment to be 86 million smelt (delta smelt and longfin smelt not differentiated). The total average annual impingement was estimated to be 178,000 smelt. It's unclear whether these numbers are relevant to current entrainment trends. Further, power plant operations have been reduced such that the plants only operate to meet peak power needs. The current owner of the power plants, Mirant, is currently undergoing a monitoring program that is sampling entrainment and impingement at the Contra Costa and Pittsburg powerplants to compile more recent information on how many delta smelt are affected by the two plants.

Delta Cross Channel

When the DCC is open, water flows from the Sacramento River through the cross channel to channels of the lower Mokelumne and San Joaquin Rivers toward the Central Delta. The closures for salmonid protection, as described in the Project Description, are likely to create more natural hydrologies in the Delta, by keeping Sacramento River flows in the Sacramento River and in Georgiana Slough, which may provide flow cues for migrating adult delta smelt. Larval and juvenile delta smelt are probably not strongly affected by the DCC if it is closed or open. Previous PTM modeling done for the SWG has shown that having the DCC open or closed does not significantly affect flows in the Central Delta (Kimmerer and Nobriga 2008). There could be times, however, when the DCC closure affects delta smelt by generating flows that draw them into the South Delta.

South Delta Temporary Barriers

The SDTB was initiated by DWR in 1991. The U.S. Army Corps of Engineers (Corps) permit extensions for this project were granted in 1996 and again in 2001, when DWR obtained permits to extend the Project through 2007. The Service has approved the extension of the permits through 2008. Continued coverage by Service for the SDTB will

be assessed in this biological opinion for the operational effects and under a separate Section 7 consultation for the construction and demolition effects.

Under the Service's 2001 biological opinion for the SDTB, operation of the barriers at Middle River and Old River near Tracy can begin May 15 or as early as April 15 if the spring barrier at the head of Old River is in place. From May 16 to May 31 (if the barrier at the head of Old River is removed) the tide gates are tied open in the barriers in Middle River and Old River near Tracy. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

During the spring, the HORB is designed to reduce the number of out-migrating salmon smolts entering Old River. During the fall, this barrier is designed to improve flow and DO conditions in the San Joaquin River for the immigration of adult fall-run Chinook salmon. The HORB is typically in place from April 15 to May 15 in the spring, and from early September to late November in the fall. Installation and operation of the barrier also depends on San Joaquin River flow conditions.

The SDTB cause changes in the hydraulics of the Delta that affect fish. The SDTB cause hydrodynamic changes within the interior of the Delta. When the HORB is in place, most water flow is effectively blocked from entering Old River. This, in turn, increases the flow to the west in Turner and Columbia cuts, two major Central Delta channels that flow toward Banks and Jones.

Susiun Marsh Salinity Control Gates

When Delta outflow is low to moderate and the SMSCG are not operating, tidal flow past the gates is approximately +/- 5,000-6,000 cfs while the net flow is near zero. When these gates are operated, flood tide flows are arrested while ebb tide flows remain in the range of 5,000-6,000 cfs. The net flow moves into Suisun Marsh via Montezuma Slough at approximately 2,500-2,800 cfs. The Army Corps of Engineers permit for operating the SMSCG requires that it be operated between October and May only when needed to meet Suisun Marsh salinity standards set forth in SWRCB D-1641. Historically, the gates have been operated as early as October 1, while in some years (e.g., 1996) the gates were not operated at all. When the channel water salinity decreases sufficiently below the salinity standards, or at the end of the control season, the flashboards are removed and the gates are raised to allow unrestricted fish movement through Montezuma Slough.

The approximately 2,800 cfs net flow induced by SMSCG operation is effective at repelling the salinity in Montezuma Slough. Salinity is reduced by roughly one-hundred percent at Beldons Landing, and lesser amounts further west along Montezuma Slough. At the same time, the salinity field in Suisun Bay moves upstream as net Delta outflow is reduced by SMSCG operation. Net outflow through Carquinez Strait is not demonstratably affected.

It is important to note that historical gate operations (1988-2002) were much more frequent than recent and current operations (2006-May 2008). Operational frequency is affected by many factors (e.g., hydrologic conditions, weather, Delta outflow, tide, fishery considerations, etc). The gates have also been operated for scientific studies.

Salmon passage studies between 1998 and 2003 increased the number of operating days by up to 14 to meet study requirements. After discussions with NMFS based on study findings, the boat lock portion of the gates are now held open at all times during SMSCG operation to allow for continuous salmon passage opportunity. With increased understanding of the effectiveness of the gates in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operation since 2006. Despite very low outflow in the fall of the two most recent WYs, gate operation was not required at all in fall of 2007 and was limited to 17 days in the winter 2008. When the SMSCG are operated or closed frequently, delta smelt may become trapped behind the gates in Montezuma Slough, which may prevent delta smelt from migrating upstream into the Delta to spawn. Salinity changes in Montezuma Slough could also affect delta smelt by changing or masking flow cues in the Delta which delta smelt use to migrate. However, the recent reduced operations likely have resulted in few adverse effects to delta smelt, since the reduced closures have minimized the migration blockage and salinity changes.

Upstream Diversion and Reservoir Operations

Construction and operation of reservoirs and water delivery systems upstream of the Delta, including CVP and SWP reservoirs, have changed the historical timing and quantity of flows through the Delta. The past and current operations of upstream diversions and reservoirs combined with the Delta water diversions affect the net Delta outflow and the location of the LSZ.

Delta smelt lives its entire life in the tidally-influenced fresh- and brackish waters of the San Francisco Estuary (Moyle 2002). It is an open-water species and does not associate strongly with structure. It may use nearshore habitats for spawning, but free-swimming life stages mainly occupy offshore waters. Thus, the population is strongly influenced by river flows because the quantity of fresh water flowing through the estuary changes the amount and location of suitable low-salinity, open-water habitat (Feyrer et al. 2007; Nobriga and Herbold 2008). Outflow plays a prominent role in delta smelt population dynamics year-round (Nobriga and Herbold 2008). X2 is an indicator of delta outflow (Jassby et al. 1995) and a useful metric by which to determine effects on delta smelt distribution and habitat suitability.

Trinity River

The Trinity River Division includes facilities to divert water to the Sacramento River Basin. The mean annual inflow to Trinity Lake from the Trinity River is about 1.2 MAF per year. Historically, an average of about two-thirds of the annual inflow has been diverted to the Sacramento River Basin (1991-2003).

Diversion of Trinity water to the Sacramento Basin provides limited water supply and hydroelectric power generation for the CVP and assists in water temperature control in the Trinity River and upper Sacramento River. The seasonal timing of Trinity exports is a result of determining how to make best use of a limited volume of Trinity export (in concert with releases from Shasta) to help conserve cold water pools and meet

temperature objectives on the upper Sacramento and Trinity rivers, as well as power production economics.

The diversions from the Trinity River have been reduced in recent years after the Trinity River Main-stem Fishery Restoration ROD, dated December 19, 2000, which mandated 368,600 to 815,000 AF is allocated annually for Trinity River flows. This amount is scheduled in coordination with the Service to best meet habitat, temperature, and sediment transport objectives in the Trinity Basin. These higher flows in the Trinity River system mean less water diverted to the Sacramento River. This reduced water results in less flexibility in releases for Sacramento River flows and can result in increased releases from Shasta Lake.

Seasonal Life History of Delta Smelt

Winter (December-February)

Adult delta smelt are generally distributed in low salinity habitats of the greater Suisun Bay region and the Sacramento and San Joaquin River confluence during fall. Variation in outflow appears to initiate their migration from Suisun Bay upstream to freshwater habitats for spawning. This is because initial catches upstream normally occur in close association with increased turbidity associated with the first strong flow pulse of the winter (Grimaldo et al. accepted manuscript). As a result, entrainment of adult delta smelt at Banks and Jones is also closely associated with factors controlled by outflow or X2 (Grimaldo et al. accepted manuscript). Specifically, salvage of adult delta smelt is significantly negatively associated with flows in OMR flows, and when the flows are highly negative the starting location of the fish indexed by X2 the month prior to entrainment also has an effect (Grimaldo et al. accepted manuscript).
Outflow during winter also affects the entrainment of early-spawned larvae when their distribution is within the hydrodynamic zone affected by pumping operations (Kimmerer 2008). Winter outflow also affects the distribution of spawning fish in major regions. For example, the Napa River is used for spawning only in years when outflow is sufficient to connect the Napa River with low salinity habitat in the estuary (Hobbs et al. 2007).

Spring (March-May)

During spring, YOY delta smelt generally move from upstream spawning locations downstream into low salinity rearing habitats. There is some evidence that recruitment variability of delta smelt may have sometimes responded to springtime flow variation (Herbold et al. 1992; Kimmerer 2002). For example, the number of days X2 is in Suisun Bay during spring is weakly positively correlated with abundance as measured by the FMWT index. However, the weight of evidence suggests that delta smelt abundance does not statistically respond to springtime flow in a similar manner to other species for which the spring X2 requirements were developed (Stevens and Miller 1983; Jassby et al. 1995; Bennett 2005).

However, studies have demonstrated that outflow has a strong effect on the distribution of YOY delta smelt (Dege and Brown 2004) and that it therefore also ultimately influences entrainment at Jones and Banks (Kimmerer 2008). Dege and Brown (2004) found that X2 had a strong influence on the geographic distribution of delta smelt, but distribution with respect to X2 was not affected, indicating that distribution is closely associated with habitat conditions proximal to X2. YOY delta smelt are consistently located just upstream of X2 in freshwater until they become juveniles and enter the low salinity habitats of Suisun Bay later in the year.

Outflow affects the entrainment of YOY delta smelt at the Jones and Banks facilities in several ways. First, because outflow affects adult spawning migration and juvenile distribution, it affects their position relative to the hydrodynamic influence of the diversions (Kimmerer 2008). Second, OMR is the best predictor of salvage and entrainment for adult delta smelt and it is also relevant to larval and juvenile entrainment when considered in the context of X2 (see effects section). In general, the more water that is exported relative to that which is dedicated to outflow enhances negative flows in OMR flow towards the diversions, which in turn increases salvage (Baxter et al. 2008; Kimmerer 2008; Grimaldo et al accepted manuscript).

Summer (June-August)

Summer represents a primary growing season for delta smelt while they are distributed in low salinity habitats of the estuary. X2 affects delta smelt distribution during summer (Sweetnam 1999). Food supply and habitat suitability are currently believed to be important factors for delta smelt during summer (Bennett 2005; Baxter et al. 2008; Nobriga and Herbold 2008). The CVP/SWP affect summer habitat suitability and might affect summer prey co-occurrence through their effect on Delta hydrodynamics.

Fall

During fall, delta smelt are typically fully distributed in low salinity rearing habitats located around the confluence of the Sacramento and San Joaquin Rivers. Suitable abiotic habitat for delta smelt during fall has been defined as relatively turbid water (Secchi depths < 1.0 m) with a salinity of approximately 0.6-3.0 psu (Feyrer et al. 2007). The amount of suitable abiotic habitat available for delta smelt, measured as hectares of surface area, is negatively related to X2 (see effects section). The average X2 during fall has exhibited a long-term increasing trend (movement further upstream), which has resulted in a corresponding reduction the amount and location of suitable abiotic habitat (Feyrer et al. 2007, 2008).

The available data provide evidence to suggest that the amount of suitable abiotic habitat available for delta smelt during fall affects the population in a measurable way. There is a statistically significant stock-recruit relationship for delta smelt in which pre-adult abundance measured by the FMWT positively affects the abundance of juveniles the following year in the TNS (Bennett 2005; Feyrer et al. 2007). Incorporating suitable abiotic habitat into the stock-recruit model as a covariate improves the model by

increasing the amount of variability explained by 43 percent, r-squared values improved from 46 percent to 66 percent (Feyrer et al. 2007).

It is likely that changes in X2 and the corresponding amount of suitable abiotic habitat are important to the long-term decline of delta smelt but may have been of lesser importance in the more recent POD. Over the long-term, the amount of suitable abiotic habitat for delta smelt during fall has decreased anywhere from 28 percent to 78 percent, depending on the specific habitat definitions that are considered (Feyrer et al. 2008). The majority of this habitat loss has occurred along the periphery, limiting the distribution of delta smelt mainly to a core region in the vicinity of the confluence of the Sacramento and San Joaquin Rivers (Feyrer et al. 2007). Concurrently, delta smelt abundance as measured by the FMWT decreased by 63 percent. This correspondence and the significant stock-recruit relationship with the habitat covariate strongly suggest that delta smelt have been negatively affected by long-term changes in X2 and habitat. However, at the onset of the POD, delta smelt abundance and suitable abiotic habitat had already declined to a point where it was unlikely that Feyrer's two variable definition of habitat was the primary limiting factor constraining the population.

Nevertheless, X2 (Figure S-10) and inflow-corrected X2 (Figure S-11) during fall in the years following the POD (2000-2005) was several km upstream compared to that for the pre-pod years (1995-1999). This suggests that operations in the Delta have exported more water relative to inflow, which has had a negative effect on X2 by moving it upstream. This is confirmed by a long-term positive trend in the E:I ratio for all months from June through December (Figure S-12). In fact, long-term trends in X2 (Figure S-13), inflow-corrected X2 Figure S-14), and the E:I ratio (Figure S-12) indicate this pattern has been in effect for many years and likely one of the factors responsible for the long-term decline in habitat suitability for delta smelt.

Figure S-10. X2 in years preceding and immediately following the Pelagic Organism Decline.

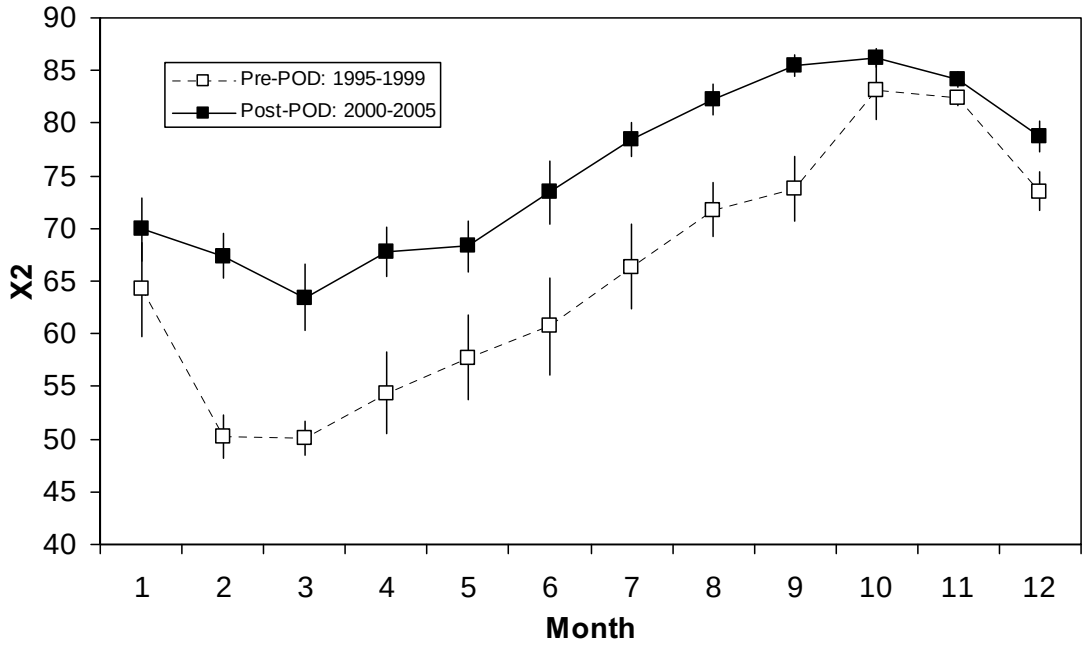


Figure S-11. Inflow-corrected X2 in years preceding and immediately following the Pelagic Organism Decline.

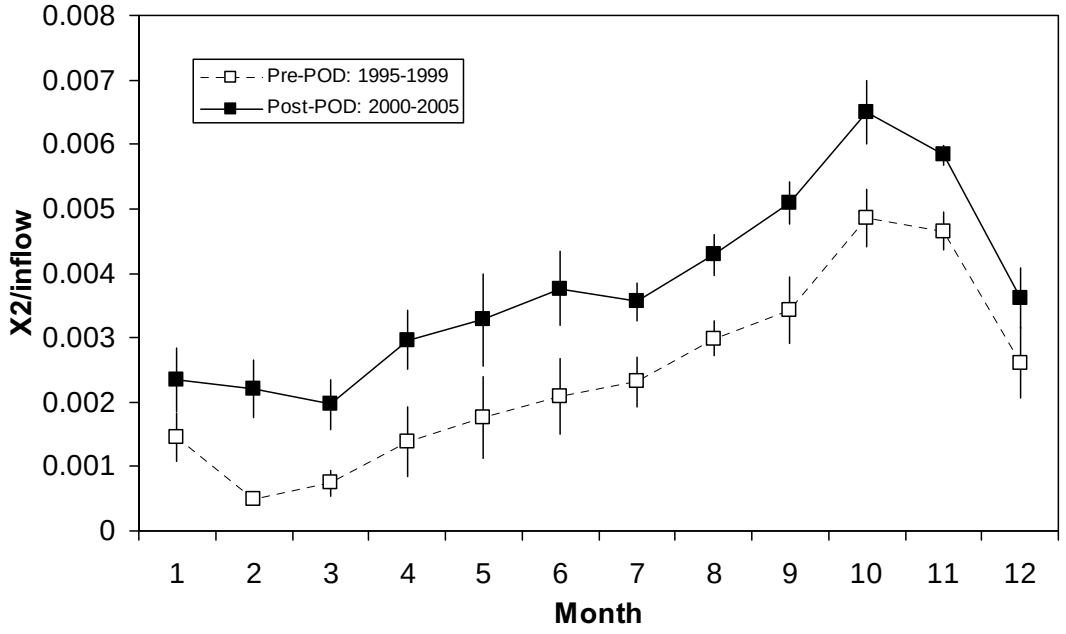


Figure S-12. Monthly time trends of the ratio of project exports to Delta inflow.

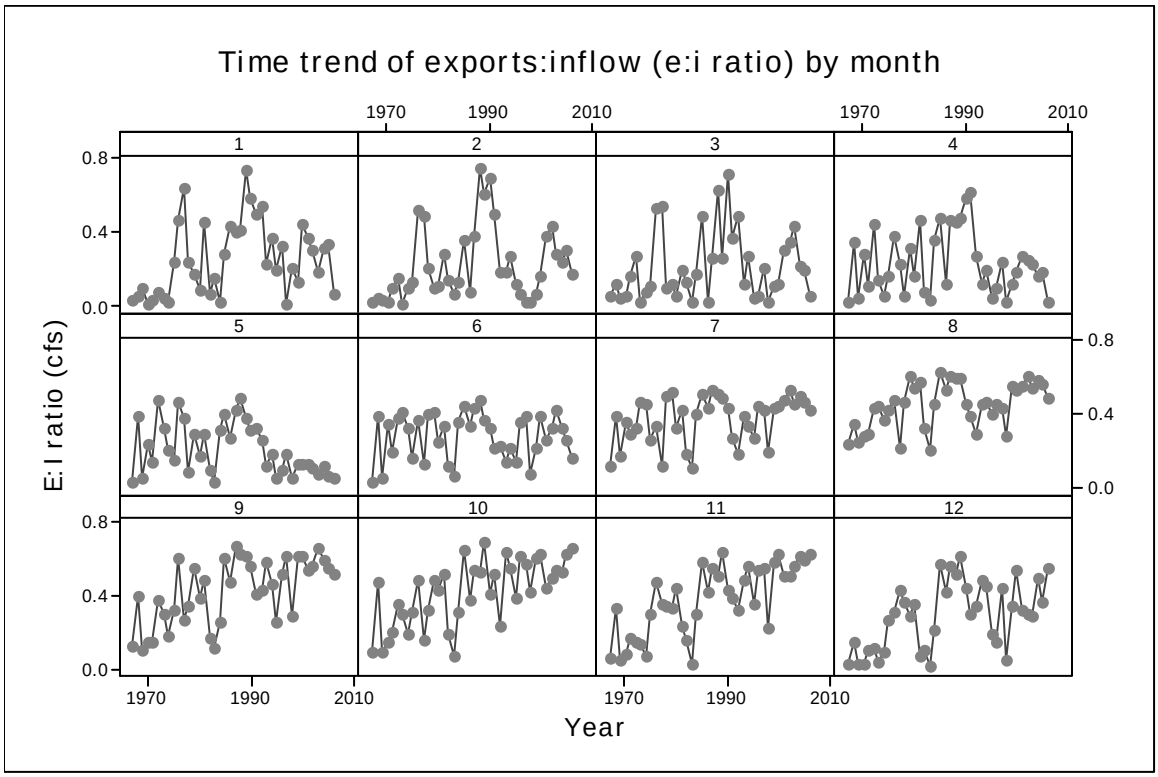


Figure S-13. Monthly time trends of X2.

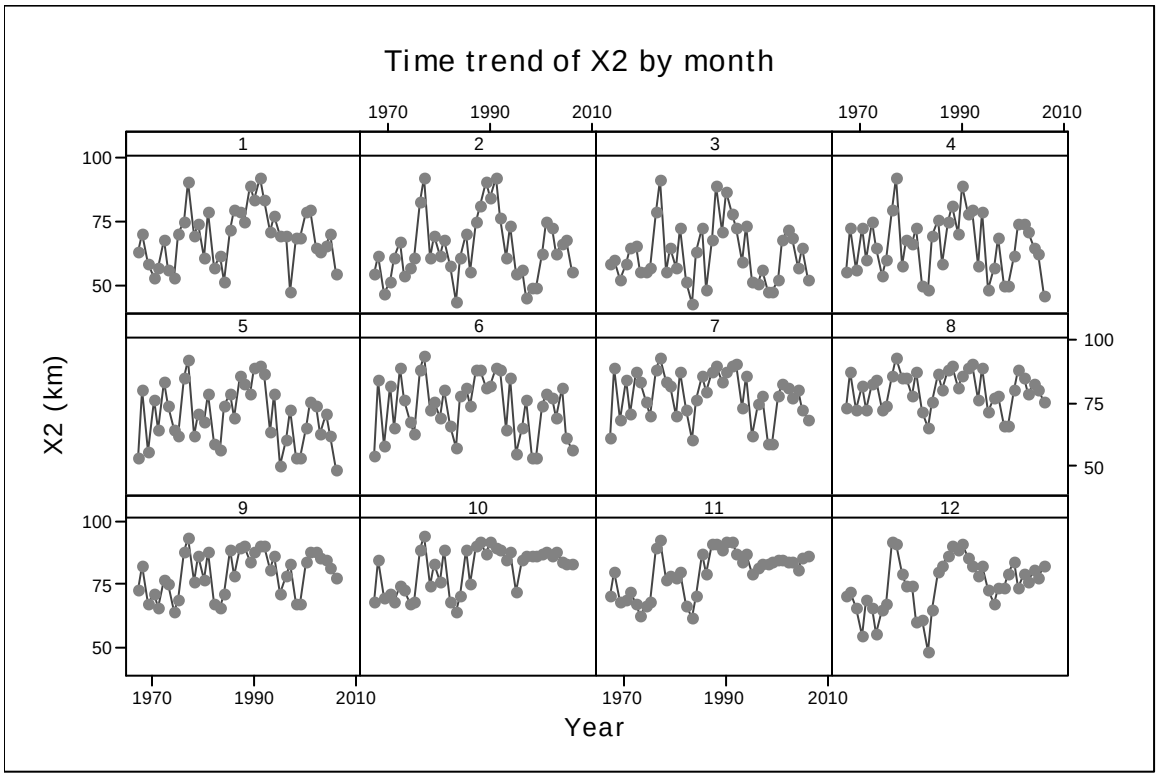
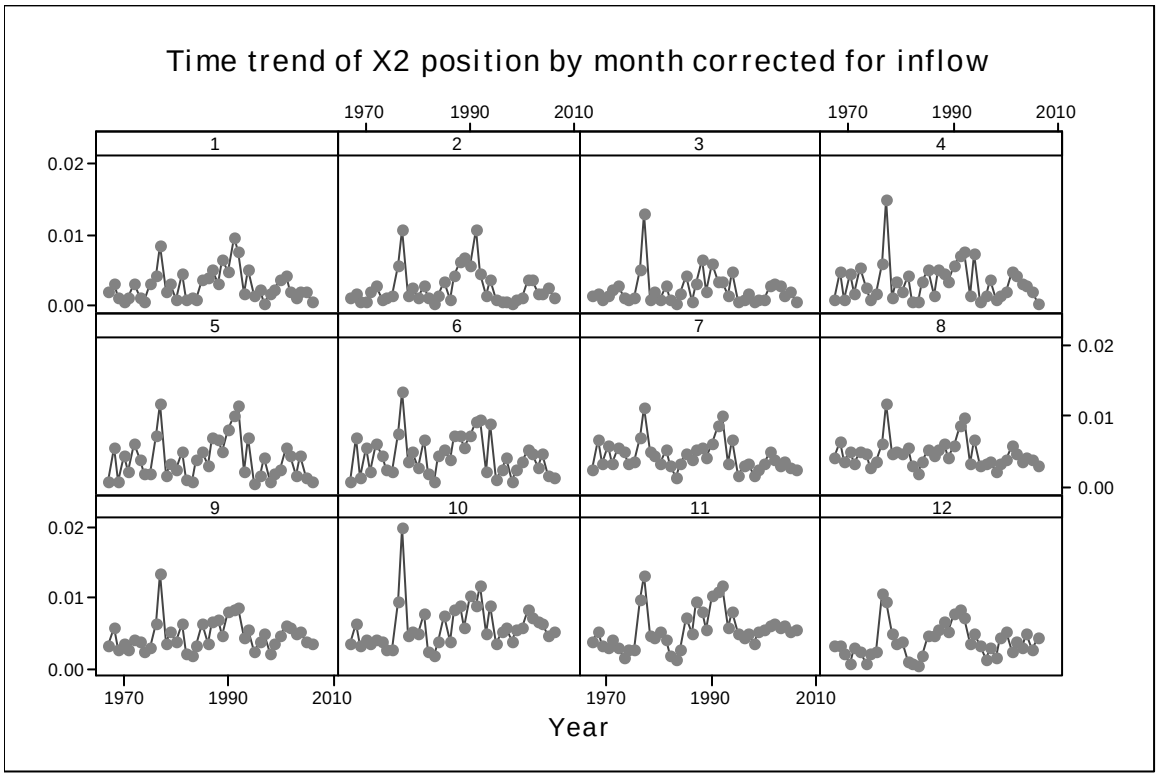


Figure S-14. Monthly time trends of inflow-corrected X2.



Other Stressors

Aquatic Macrophytes

In the last two decades, the interior Delta has been extensively colonized by submerged aquatic vegetation. The dominant submerged aquatic vegetation is *Egeria densa*, a non-native from South America that thrives under warm water conditions. Research suggests that *Egeria densa* has altered fish community dynamics in the Delta, including increasing habitat for centrarchid fishes including largemouth bass (Nobriga et al. 2005; Brown and Michniuk 2007), reducing habitat for native fishes (Brown 2003; Nobriga et al. 2005; Brown and Michniuk 2007), and supporting a food web pathway for centrarchids and other littoral fishes (Grimaldo et al in review). *Egeria densa* has increased its surface area coverage by up to 10 percent per year depending on hydrologic conditions and water temperature (Erin Hestir personal communication University of California Davis).

Egeria densa and other non-native submerged aquatic vegetation (e.g., *Myriophyllum spicatum*) can affect delta smelt in direct and indirect ways. Directly, submerged aquatic vegetation can overwhelm littoral habitats (inter-tidal shoals and beaches) where delta smelt may spawn making them unsuitable for spawning. Indirectly, submerged aquatic

vegetation decreases turbidity (by trapping suspended sediment) which has contributed to a decrease in both juvenile and adult smelt habitat (Feyrer et al. 2007; Nobriga et al. 2008). Increased water transparency may delay feeding and may also make delta smelt more susceptible to predation pressure.

Predators

Delta smelt is a rare fish and has been a rare fish (compared to other species) for at least the past several decades (Nobriga and Herbold 2008). Therefore, it has also been rare in examinations of predator stomach contents. Delta smelt were occasional prey fish for striped bass, black crappie and white catfish in the early 1960s (Turner and Kelley 1966) but went undetected in a recent study of predator stomach contents (Nobriga and Feyrer 2007). Striped bass are likely the primary predator of juvenile and adult delta smelt given their spatial overlap in pelagic habitats. Despite major declines in age-0 abundance, there remains much more biomass of striped bass in the upper estuary than delta smelt. This means it is not possible for delta smelt to support any significant proportion of the striped bass population. It is unknown whether incidental predation by striped bass (and other lesser predators) represents a substantial source of mortality for delta smelt.

Delta smelt may experience high predation mortality around water diversions where smelt are entrained and predators aggregate. The eggs and newly-hatched larvae of delta smelt are thought to be prey for inland silversides in littoral habitats (Bennett 2005). Other potential predators of eggs and larvae of smelt in littoral habitats are yellowfin goby, centrarchids, and Chinook salmon.

The Delta-wide increase in water transparency may have intensified predation pressures on delta smelt and other pelagic fishes in recent years. It is widely documented that pelagic fishes, including many smelt species, experience lower predation risks under turbid water conditions (Thetmeyer and Kils 1995; Utne-Palm 2002; Horpilla et al. 2004). There has been limited research to address predation of pelagic fishes in offshore habitats. Stevens (1966) examined diets of striped bass in pelagic habitats, finding that they varied by geographical area and prey abundance but no information was provided on the physical variables that may have influenced predation rates. Research is underway to determine the specific factors responsible for increased water transparency in the Delta (David Schoelhammer, personal communication, University of California at Davis) but recent findings suggest the trend is related to the submerged aquatic vegetation invasion in recent years.

Competition

It has been hypothesized that delta smelt are adversely affected by competition from other introduced fish species that use overlapping habitats, including inland silversides, (Bennett and Moyle 1995) striped bass, and wakasagi (Sweetnam 1999). Laboratory studies show that delta smelt growth is inhibited when reared with inland silversides (Bennett 2005) but there is no empirical evidence to support the conclusion that competition between these species is a factor that influences the abundance of delta smelt in the wild. There is some speculation that the overbite clam competes with delta smelt for copepod nauplii (Nobriga and Herbold 2008). It is unknown how intensively overbite clam grazing and delta smelt directly compete for food, but overbite clam consumption of

shared prey resources does have other ecosystem consequences that appear to have affected delta smelt indirectly.

Delta Smelt Feeding

The DRERIP conceptual model for delta smelt (summarized in figure S-3) provides a thorough summary of delta smelt feeding behavior (Nobriga and Herbold 2008), much of which is described in this section and the Delta food web section. Delta smelt are visual feeders that select prey individually rather than by filtering-feeding. Juvenile and adult smelt primarily eat copepods, but they are also known to prey on cladocerans, mysids, amphipods, and larval fish (Moyle et al. 1992; Lott 1998; Feyrer et al. 2003). During the 1970s and 1980s, delta smelt diets were dominated by *Eurytemora affinis*, *Neomysis mercedis*, and *Bosmina longirostus* (Moyle et al. 1992; Feyrer et al. 2003), however, none of these are important prey now (Steve Slater personal communication California Department of Fish and Game). When delta smelt diets were examined again between 1988 and 1996, they were consistently dominated by the copepod *Pseudodiaptomus forbesi*, which was introduced and became abundant following the overbite clam invasion (Lott 1998). *Pseudodiaptomus forbesi* was introduced into the San Francisco Bay-Delta in 1988 and became a significant part of the summertime zooplankton assemblage and is now an important prey item for Delta smelt and other small fishes (Kimmerer and Orsi 1996; Nobriga 2002; Hobbs et al. 2006; Bryant and Arnold 2007). Recent diet studies have shown that *Pseudodiaptomus forbesi* (all lifestages) remains an important prey for juvenile delta smelt during summer, but that several other copepods introduced into the system in the mid-1990s, are also frequently being eaten (Steven Slater unpublished data California Department of Fish and Game).

Delta Food Web

Suisun Bay Region

Following the introduction of the overbite clam into the lower Estuary in 1986, a dramatic decline in primary production in the Estuary was documented (Alpine and Cloern 1992; Jassby et al 2002). The overbite clam is a highly efficient grazer with a wide salinity range. It does not encroach into freshwater but its grazing effect does, presumably due to tides (Jassby et al. 2002). With a high metabolism, the overbite clam has been able to reduced standing stocks of phytoplankton to fractions of historic levels. As a consequence, many zooplankton and fish species experienced sharp declines in abundance (Kimmerer and Orsi 1996, Kimmerer 2002, Kimmerer 2007). Clam grazing on copepod nauplii also may affect copepods directly. Despite its impact on the estuarine pelagic food web, to date, there is no direct evidence linking the effects of overbite clam grazing to adverse effects to delta smelt (Kimmerer 2002; Bennett 2005). It has been noted that delta smelt fork lengths have decreased since 1990, but it is uncertain whether this is a direct consequence of the overbite clam. The Feyrer (2007) effect of fall habitat assumes delta smelt have been chronically food-limited since the overbite clam invasion.

There have been two notable zooplankton introductions into the estuarine food web in recent years that have the potential to adversely affect delta smelt trophic dynamics. In the mid 1990s, the estuary was invaded by *Limnoithona tetraspina* and *Acartiella*

sinensis, both which originated from Asia and are believed to have been introduced via ballast water. *Limnoithona tetraspina* is now the most abundant copepod in the LSZ but evidence suggests that it is not an important food item for delta smelt and other pelagic fishes because of its small size, generally sedentary behavior, and predator-avoidance capability (Bouley and Kimmerer 2006). The consequences of these copepod invasions on the diet of delta smelt feeding remains unknown, but the likely effect is fewer calories per unit when delta smelt prey on *Limnoithona tetraspina*. Experimental studies are currently under way to determine the feeding dynamics of delta smelt on the newly introduced invaders in relation to the current zooplankton fauna of the Delta/Estuary (Lindsay Sullivan RTC 2008 CALFED Science Conference Presentation).

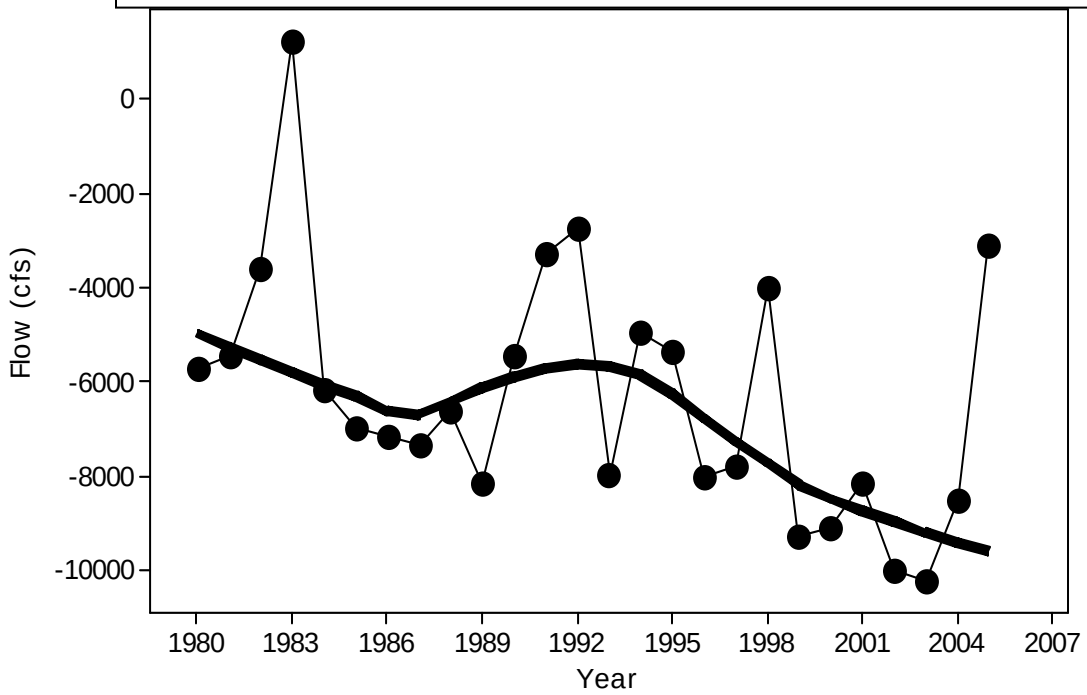
Delta

Water diversions represent one of the major factors controlling lower trophic level production in the Delta (Jassby et al. 2002). Water diversions directly entrain zooplankton and phytoplankton biomass which might impact food availability to delta smelt. Entrainment impacts to lower trophic level production are of concern during the spring and summer when newly hatched delta smelt larvae and juveniles are vulnerable to starvation and thermal stress; food limitation may lead to disease, poor growth, or death (Bennett 2005; Bennett et al. 2008).

Water diversions can also influence the residence time of water in the Eastern and Central Delta that can greatly influence phytoplankton production (Jassby 2005). Low export conditions can result in a doubling of primary production in the Eastern Delta. However, during periods of high exports, such as the summer (Figure S-15), much of the lower trophic level production is entrained rather than dispersed downstream to Suisun Bay. Summer entrainment of phytoplankton and zooplankton could therefore adversely affect delta smelt if food supplies are not transported to the LSZ. Preliminary evidence shows that the abundance of *Pseudodiaptomus forbesi*, a dominant prey of delta smelt in the summer, has steadily declined in the lower Estuary since 1995, while its numbers have increased in the South Delta (Figure 7-19 in the biological assessment; Kimmerer et al. in prep.). This copepod has blooms that originate in the Delta. Thus, its availability to delta smelt rearing to the west of the summer blooms may be impaired by high export to inflow ratios.

As stated above, clam grazing represents another major factor influencing primary and secondary production in the Delta. In the Western Delta, the food web may be compromised by overgrazing effects of the overbite clam (Kimmerer and Orsi 1996, Jassby et al. 2002). Within the Central Delta, grazing by the introduced river clam (*Corbicula fluminea*) can deplete resident phytoplankton biomass, especially in flooded island areas (Lucas et al 2002; Lopez et al 2006). Given that the food web supporting delta smelt depends on phytoplankton, these effects are likely to adversely affect its survival and reproduction by limiting food resources.

Figure S-15 Combined OMR flow (June-August)



Microcystis

Large blooms of toxic blue-green alga, *Microcystis aeruginosa*, were first detected in the Delta during the summer of 1999 (Lehman et al. 2005). Since then, *M. aeruginosa* has bloomed each year, forming large colonies throughout most of the Delta and increasingly down into eastern Suisun Bay. Blooms typically occur between late spring and early fall (peak in the summer) when temperatures are above 20 ^{o}C. *Microcystis aeruginosa* can produce natural toxins that pose animal and human health risks if contacted or ingested directly. Preliminary evidence indicates that the toxins produced by local blooms are not toxic to fishes at current concentrations. However, it appears that *M. aeruginosa* is toxic to copepods that delta smelt eat (Ali Ger 2008 CALFED Science Conference). In addition, *M. aeruginosa* could out-compete diatoms for light and nutrients. Diatoms are a rich food source for zooplankton in the Delta (Mueller-Solger et al. 2002). Studies are underway to determine if zooplankton production is compromised during *M. aerguinosa* blooms to an extent that is likely to adversely affect delta smelt. *Microcystis* blooms may also decrease dissolved oxygen to lethal levels for fish (Saiki et al. 1998), although delta smelt do not strongly overlap the densest *Microcystis* concentrations, so dissolved oxygen is not likely a problem. *Microcystis* blooms are a symptom of eutrophication and high ammonia to nitrate ratios in the water.

Contaminants

Contaminants can change ecosystem functions and productivity through numerous pathways. However, contaminant loading and its ecosystem effects within the Delta are not well understood. Although a number of contaminant issues were first investigated

during the POD years, concern over contaminants in the Delta is not new. There are long-standing concerns related to mercury and selenium levels in the watershed, Delta, and San Francisco Bay (Linville et al. 2002; Davis et al. 2003). Phytoplankton growth rate may, at times, be inhibited by high concentrations of herbicides (Edmunds et al. 1999). New evidence indicates that phytoplankton growth rate is chronically inhibited by ammonium concentrations in and upstream of Suisun Bay (Wilkerson et al. 2006, Dugdale et al. 2007). Contaminant-related toxicity to invertebrates has been noted in water and sediments from the Delta and associated watersheds (e.g., Kuivila and Foe 1995, Giddings 2000, Werner et al. 2000, Weston et al. 2004). Undiluted drainwater from agricultural drains in the San Joaquin River watershed can be acutely toxic (quickly lethal) to fish and have chronic effects on growth (Saiki et al. 1992). Evidence for mortality of young striped bass due to discharge of agricultural drainage water containing rice herbicides into the Sacramento River (Bailey et al. 1994) led to new regulations for water discharges. Bioassays using caged Sacramento sucker (*Catostomus occidentalis*) have revealed deoxyribonucleic acid strand breakage associated with runoff events in the watershed and Delta (Whitehead et al. 2004). Kuivila and Moon (2004) found that peak densities of larval and juvenile delta smelt sometimes coincided in time and space with elevated concentrations of dissolved pesticides in the spring. These periods of co-occurrence lasted for up to 2-3 weeks, but concentrations of individual pesticides were low and much less than would be expected to cause acute mortality. However, the effects of exposure to the complex mixtures of pesticides actually present are unknown.

The POD investigators initiated several studies beginning in 2005 to address the possible role of contaminants and disease in the declines of Delta fish and other aquatic species. Their primary study consists of twice-monthly monitoring of ambient water toxicity at fifteen sites in the Delta and Suisun Bay. In 2005 and 2006, standard bioassays using the amphipod *Hyalella azteca* had low (<5 percent) frequency of occurrence of toxicity (Werner et al. 2008). However, preliminary results from 2007, a dry year, suggest the incidence of toxic events was higher than in the previous (wetter) years. Parallel testing with the addition of piperonyl butoxide, an enzyme inhibitor, indicated that both organophosphate and pyrethroid pesticides may have contributed to the pulses of toxicity. Most of the tests that were positive for *H. azteca* toxicity have come from water samples from the lower Sacramento River. Pyrethroids are of particular interest because use of these insecticides has increased within the Delta watershed (Ameg et al. 2005, Oros and Werner 2005) as use of some organophosphate insecticides has declined. Toxicity of sediment-bound pyrethroids to macroinvertebrates has also been observed in small, agriculture-dominated watersheds tributary to the Delta (Weston et al. 2004, 2005). The association of delta smelt spawning with turbid winter runoff and the association of pesticides including pyrethroids with sediment is of potential concern.

In conjunction with the POD investigation, larval delta smelt bioassays were conducted simultaneously with a subset of the invertebrate bioassays. The water samples for these tests were collected from six sites within the Delta during May-August of 2006 and 2007. Results from 2006 indicate that delta smelt are highly sensitive to high levels of ammonia, low turbidity, and low salinity. There is some preliminary indication that reduced survival may be due to disease organisms (Werner et al. 2008). No significant mortality of larval delta smelt was found in the 2006 bioassays, but there were two

instances of significant mortality in June and July of 2007. In both cases, the water samples were collected from sites along the Sacramento River and had relatively low turbidity and salinity levels and moderate levels of ammonia. It is also important to note that no significant *H. azteca* mortality was detected in these water samples. While the *H. azteca* tests are very useful for detecting biologically relevant levels of water column toxicity for zooplankton, interpretation of the *H. azteca* test results with respect to fish should proceed with great caution. The relevance of the bioassay results to field conditions remains to be determined.

The POD investigations into potential contaminant effects also include the use of biomarkers that have been used previously to evaluate toxic effects on POD fishes (Bennett et al. 1995, Bennett 2005). The results to date have been mixed. Histopathological and viral evaluation of young longfin smelt collected in 2006 indicated no histological abnormalities associated with exposure to toxics or disease (Foott et al. 2006). There was also no evidence of viral infections or high parasite loads. Similarly, young threadfin shad showed no histological evidence of contaminant effects or of viral infections (Foott et al. 2006). Parasites were noted in threadfin shad gills at a high frequency but the infections were not considered severe. Both longfin smelt and threadfin shad were considered healthy in 2006. Adult delta smelt collected from the Delta during the winter of 2005 also were considered healthy, showing little histopathological evidence for starvation or disease (Teh et al., unpublished data). However, there was some evidence of low frequency endocrine disruption. In 2005, 9 of 144 (6 percent) of adult delta smelt males sampled were intersex, having immature oocytes in their testes (Teh et al., unpublished data).

In contrast, preliminary histopathological analyses have found evidence of significant disease in other species and for POD species collected from other areas of the estuary. Massive intestinal infections with an unidentified myxosporean were found in yellowfin goby *Acanthogobius flavimanus* collected from Suisun Marsh. Severe viral infection was also found in inland silverside and juvenile delta smelt collected from Suisun Bay during summer 2005. Lastly, preliminary evidence suggests that contaminants and disease may impair survival of age-0 striped bass. Baxter et al. 2008 found high occurrence and severity of parasitic infections, inflammatory conditions, and muscle degeneration in young striped bass collected in 2005; levels were lower in 2006. Several biomarkers of contaminant exposure including P450 activity (i.e., detoxification enzymes in liver), acetylcholinesterase activity (i.e., enzyme activity in brain), and vitellogenin induction (i.e., presence of egg yolk protein in blood of males) were also reported from striped bass collected in 2006 (Ostrach 2008).

Climate Change

There is currently no quantitative analysis of how ongoing climate change is currently affecting delta smelt and the Delta ecosystem. Climate change could have caused shifts in the timing of flows and water temperatures in the Delta which could lead to a change in the timing of migration of adult and juvenile delta smelt.

Summary of Delta Smelt Status and Environmental Baseline

Given the long list of stressors discussed, the rangewide status of the delta smelt is currently declining and abundance levels are the lowest ever recorded. This abundance trend has been influenced by multiple factors, some of which are affected or controlled by CVP and SWP operations and others that are not. Although it is becoming increasingly clear that the long-term decline of the delta smelt was very strongly affected by ecosystem changes caused by non-indigenous species invasions and other factors influenced, but not controlled by CVP and SWP operations, The CVP and SWP have played an important direct role in that decline, especially in terms of entrainment and habitat-related impacts that add increments of additional mortality to the stressed delta smelt population. Further, past CVP and SWP operations have played an indirect role in the decline of the delta smelt by creating an altered environment in the Delta that has fostered both the establishment of non-indigenous species and habitat conditions that exacerbate their adverse influence on delta smelt population dynamics. Past CVP and SWP operations have been a primary factor influencing delta smelt abiotic and biotic habitat suitability, health, and mortality.

Survival and Recovery Needs of Delta Smelt

Based on the above discussion of the current condition of the delta smelt, the factors responsible for that condition, and the final *Recovery Plan for the Delta Smelt* (Service 1995), the Service has identified the following survival and recovery needs for this species:

- Increase the abundance of the adult population and the potential for recruitment of juveniles into the adult population.

- Increase the quality and quantity of spawning, rearing, and migratory habitat with respect to turbidity, temperature, salinity, freshwater flow, and adequate prey availability by mimicking natural (i.e., pre-water development) water and sediment transport processes in the San Francisco Bay-Delta watershed to enhance reproduction and increase survival of adults and juveniles.

- Reduce levels of contaminants and other pollutants in smelt habitat to increase health, fecundity and survival of adults and juveniles.

- Reduce delta smelt exposure to disease and toxic algal blooms to increase health, fecundity and survival of adults and juveniles.

- Reduce entrainment of adult, larval, and juvenile delta smelt at CVP-SWP pumping facilities, over and above reductions achieved under the Vernalis Adaptive Management Plan and the Environmental Water Account, to increase

the abundance of the spawning adult population and the potential for recruitment of juveniles into the adult population. Best available information indicates that delta smelt entrainment at CVP-SWP pumping facilities can be substantially reduced by maintaining a positive flow in the Old and Middle rivers. Entrainment reduction at other water diversion-related structures within the Bay-Delta where delta smelt adults or juveniles are known or likely to be entrained might also be needed to increase the adult population and the potential for recruitment of juveniles into the adult population, but there are secondary to reducing Banks and Jones entrainment.

- Restore the structure of the food web in the Bay-Delta to a condition that enhances diatom-based pelagic food chains in the LSZ.

- Maximize the resilience of the delta smelt population to the adverse effects of ongoing climate change. Achieving the above conditions should help with this need. In general, the management of CVP-SWP water storage and delivery facilities could have an important role to play in tempering the adverse effects of climate change on the Bay-Delta ecosystem upon which the delta smelt depends.

Delta Smelt Critical Habitat

The action area for this consultation covers nearly the entire range of delta smelt critical habitat. For that reason, the Status of Critical Habitat and Environmental Baseline sections are combined into one section in this document.

The Service designated critical habitat for the delta smelt on December 19, 1994 (59 FR 65256). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (USFWS 1994).

Description of the Primary Constituent Elements

In designating critical habitat for the delta smelt, the Service identified the following primary constituent elements essential to the conservation of the species:

1. “Physical habitat” is defined as the structural components of habitat. Because delta smelt is a pelagic fish, spawning substrate is the only known important structural component of habitat. It is possible that depth variation is an important structural characteristic of pelagic habitat that helps fish maintain position within the estuary’s LSZ (Bennett et al. 2002).

2. "Water" is defined as water of suitable quality to support various delta smelt life stages with the abiotic elements that allow for survival and reproduction. Delta smelt inhabit open waters of the Delta and Suisun Bay. Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for delta smelt and are discussed in detail in the Status of the Species/Environmental Baseline section, above. Factors such as high entrainment risk and contaminant exposure can degrade this PCE even when the basic water quality is consistent with suitable habitat.

3. "River flow" is defined as transport flow to facilitate spawning migrations and transport of offspring to LSZ rearing habitats. River flow includes both inflow to and outflow from the Delta, both of which influence the movement of migrating adult, larval, and juvenile delta smelt. Inflow, outflow, and OMR influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at Banks and Jones (refer to Status of the Species/Environmental Baseline section, above). River flow interacts with the fourth primary constituent element, salinity, by influencing the extent and location of the highly productive LSZ where delta smelt rear.

4. "Salinity" is defined as the LSZ nursery habitat. The LSZ is where freshwater transitions into brackish water; the LSZ is defined as 0.5-6.0 psu (parts per thousand salinity; Kimmerer 2004). The 2 psu isohaline is a specific point within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby et al. 1995). By local convention the location of the LSZ is described in terms of the distance from the 2 psu isohaline to the Golden Gate Bridge (X2); X2 is an indicator of habitat suitability for many San Francisco Estuary organisms and is associated with variance in abundance of diverse components of the ecosystem (Jassby et al. 1995; Kimmerer 2002). The LSZ expands and moves downstream when river flows into the estuary are high. Similarly, it contracts and moves upstream when river flows are low.

   During the past 40 years, monthly average X2 has varied from as far downstream as San Pablo Bay (45 km) to as far upstream as Rio Vista on the Sacramento River (95 km). At all times of year, the location of X2 influences both the area and quality of habitat available for delta smelt to successfully complete their life cycle (see Biology and Life History section above). In general, delta smelt habitat quality and surface area are greater when X2 is located in Suisun Bay. Both habitat quality and quantity diminish the more frequently and further the LSZ moves upstream, toward the confluence.

Conservation Role of Delta Smelt Critical Habitat

The Service's primary objective in designating critical habitat was to identify the key components of delta smelt habitat that support successful spawning, larval and juvenile transport, rearing, and adult migration. Delta smelt are endemic to the Bay-Delta and the vast majority only live one year. Thus, regardless of annual hydrology, the Delta must

provide suitable habitat all year, every year. Different regions of the Delta provide different habitat conditions for different life stages, but those habitat conditions must be present when needed, and have sufficient connectivity to provide migratory pathways and the flow of energy, materials and organisms among the habitat components. The entire Delta and Suisun Bay are designated as critical habitat; over the course of a year, the entire habitat is occupied.

Overview of Delta Smelt Habitat Requirements and the Primary Constituent Elements

As previously described in the Status of the Species/Environmental Baseline section, Delta smelt live their entire lives in the tidally-influenced fresh- and brackish waters of the San Francisco Estuary (Moyle 2002). Delta smelt are an open-water, or pelagic, species. They do not associate strongly with structure. They may use nearshore habitats for spawning (PCE #1), but free-swimming life stages mainly occupy offshore waters (PCE #2). Thus, the distribution of the population is strongly influenced by river flows through the estuary (PCE #3) because the quantity of fresh water flowing through the estuary changes the amount and location of suitable low-salinity, open-water habitat (PCE #4). This is true for all life stages. During periods of high river flow into the estuary, delta smelt distribution can transiently extend as far west as the Napa River and San Pablo Bay. Delta smelt distribution is highly constricted near the Sacramento-San Joaquin river confluence during periods of low river flow into the estuary (Feyrer et al. 2007).

In the 1994 designation of critical habitat, the best available science held that the delta smelt population was responding to variation in spring X2. In the intervening 14 years, the scientific understanding of delta smelt habitat has improved. The current understanding is that X2 and OMR both must be considered to manage entrainment and that X2 indexes important habitat characteristics throughout the year.

Conservation Function of Primary Constituent Elements by Life History Stage

The conservation function and important attributes of each constituent element in each life stage are further described below.

Spawning

Spawning delta smelt require all four PCEs, but spawners and embryos are the only life stages of delta smelt that are known to require specific structural components of habitat (PCE # 1; see Biology and Life History section). Spawning delta smelt require sandy or small gravel substrates for egg deposition. Migrating, staging, and spawning delta smelt also require low-salinity and freshwater habitats, turbidity, and water temperatures less than 20ºC (68ºF) (attributes of PCE #2 and #4 for spawning). The developing embryos likewise may remain associated with sandy substrate until they hatch. Hatching success is only about 20 percent at 20ºC in the laboratory and declines to zero at higher temperatures (Bennett 2005).

Laboratory observations indicate that delta smelt are broadcast spawners, discharging eggs and milt close to the bottom over substrates of sand or pebble (DWR and Reclamation 1994; Lindberg et al. 2003; Wang 2007). Rather than stick to immobile substrates, the adhesive eggs might adhere to sand particles, which keeps them negatively buoyant but not immobile (Hay 2007).

Spawning occurs primarily during April through mid-May (Moyle 2002) in sloughs and shallow edge areas in the Delta. Spawning also has been recorded in Suisun Marsh and the Napa River (Hobbs et al. 2007). Historically, delta smelt ranged as far up the San Joaquin River as Mossdale, indicating that areas of the lower San Joaquin and its tributaries support conditions appropriate for spawning. Little data exists on delta smelt spawning activity in the lower San Joaquin region. Larval and young juvenile delta smelt collected at South Delta stations in DFG's 20-mm Survey, indicate that appropriate spawning conditions exist there. However, the few delta smelt that are collected in the lower San Joaquin region is a likely indicator that changes in flow patterns entrain spawning adults and newly-hatched larvae into water diversions (Moyle et al 1992).

Once the eggs have hatched, larval distribution depends on both the spawning area from which they originate (PCE#1 and PCE#2) and the effect of Delta hydrodynamics on transport (PCE#3). Larval distribution is further affected by salinity and temperature (attributes of PCE#4 and #3). Tidal action and other factors may cause substantial mixing of water with variable salinity and temperature among regions of the Delta (Monson et al. 2007), which in some cases might result in rapid dispersal of larvae away from spawning sites.

In the laboratory, a turbid environment (>25 NTU) was necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004) (attribute of PCE#2). Successful feeding depends on a high density of food organisms and turbidity. The ability of delta smelt larvae to see prey in the water is enhanced by turbidity (Baskerville-Bridges et al. 2004). Their diet is comprised of small planktonic crustaceans that inhabit the estuary's turbid, low-salinity, open-water habitats (attribute of PCE#2).

Larval and Juvenile Transport

Delta smelt larvae require PCEs # 2-4. The distribution of delta smelt larvae follows that of the spawners; larvae emerge near where they are spawned. Thus, they are distributed more widely during high outflow periods. Delta smelt larvae mainly inhabit tidal freshwater at temperatures between 10ºC-20ºC (Bennett 2005). The center of distribution for delta smelt larvae < 20 mm is usually 5-20 km upstream of X2, but larvae move closer to X2 as the spring progresses into summer (Dege and Brown 2004). The primary influences the water projects have on larval delta smelt critical habitat are that they influence water quality, the extent of the LSZ, and larval transport via capture of runoff in reservoirs and subsequent manipulation of Delta inflows and exports that affect OMR flows, and resultant Delta outflows that affect X2.

Changes to delta smelt larval and juvenile transport attributable to the SWP and CVP include water diversions that create net reverse flows in the Delta that entrain larval and

juvenile delta smelt; permanent and temporary barrier installations and operation that change Delta hydrology and salinity and increase entrainment risk; and diminished river inflows that seasonally bring the LSZ into the Delta for increasingly longer periods of time, resulting in lower quality and quantity of rearing habitat.

Juvenile Rearing

Rearing juvenile delta smelt mainly require PCEs # 2 and # 4. Juvenile delta smelt are most abundant in the LSZ, specifically at the upstream edge of the LSZ where salinity is < 3 psu, water transparency is low (Secchi disk depth < 0.5 m), and water temperatures are cool (< 24ºC) (Feyrer et al. 2007; Nobriga et al. 2008). Because high freshwater inflows that push X_2 well into Suisun Bay are not sustained through the juvenile stage (July-December), many juvenile delta smelt rear near the Sacramento-San Joaquin river confluence. This reflects a long-term change in distribution. During surveys in the latter 1940s, juvenile delta smelt reared throughout the Delta during summer (Erkkila 1950). Currently, young delta smelt rear throughout the Delta into June or the first week of July, but thereafter, distribution shifts to the Sacramento-San Joaquin river confluence where water temperatures are cooler and water transparencies are lower (Feyrer et al. 2007; Nobriga et al. 2008). Note that this change in distribution has often been mischaracterized as a migration into brackish water.

- The primary influences the water projects have on juvenile delta smelt critical habitat are that they influence water quality, the extent of the LSZ, and early summer (June) transport via capture of runoff in reservoirs and subsequent manipulation of Delta inflows and exports that affect OMR flows, and resultant Delta outflows that affect X2. The projects are the primary influence on freshwater inflows and outflows during the juvenile stage. The SWP and CVP control almost all Delta inflow during summer-fall. The primary effects these highly controlled flows have on juvenile delta smelt are a possible impact on summertime prey availability in the LSZ and a strong effect on the extent of the LSZ and dilution flows and thus, habitat suitability during fall (see Effects section).

- Estuarine turbidity varies with Delta outflow and it is higher during periods of high outflow (Kimmerer 2004). The interannual variation in peak flows to the estuary is not always controlled by the projects, so they have little effect on interannual variation in estuary turbidity during delta smelt's spawning season. The CVP/SWP have had a long-term influence on turbidity in the estuary because project dams have retained sediment originating in project tributaries, especially in the Sacramento River basin (Wright and Schoelhamer 2004). However, the CVP/SWP have not been shown to have influenced shorter-term decreases in turbidity due to the proliferation of aquatic plants like *Egeria densa*.

- The water projects have little if any ability to affect water temperatures in the Estuary (Kimmerer 2004). Estuarine and Delta water temperatures are driven by air temperature. Water temperatures at Freeport can be cooled up to about 3ºC by high Sacramento River flows, but only by very high river flows that cannot be sustained by the projects. Note also that the cooling effect of the Sacramento

River is not visible in data from the west Delta at Antioch (Kimmerer 2004) so the area of influence is limited.

Adult Migration

Successful delta smelt adult migration habitat is characterized by conditions that attract migrating adult delta smelt, attributes of PCE #2, #3, and #4, and that help them migrate to spawning habitats (PCE #3). Delta smelt are weakly anadromous and move from the LSZ into freshwater to spawn, beginning in late fall or early winter and likely extending at least though May (see Delta Smelt Life Cycle section in the Status and Baseline). Although the physiological trigger for the movement of delta smelt up the Estuary is unknown, movement is associated with pulses of freshwater inflow, which are cool, less saline and turbid (attributes of PCE #2 and #4 for adult migration). As they migrate, delta smelt increase their vulnerability to entrainment if they move closer to Banks and Jones (Grimaldo et al accepted manuscript). Analyses indicate that delta smelt become less vulnerable to entrainment when reverse flows in the Delta are minimized. Inflows in early winter must be of sufficient magnitude to provide the cool, fresh and highly turbid conditions needed to attract migrating adults and of sufficient duration to allow connectivity with the Sacramento and San Joaquin river channels and their associated tributaries, including Cache and Montezuma sloughs and their tributaries (attributes of PCE #2 for adult migration). These areas are vulnerable to physical disturbance and flow disruption during migratory periods. Once adults have moved into the Delta, freshwater inflows must remain of sufficient magnitude to minimize their vulnerability to entrainment.

Changes to delta smelt adult migration habitat include water diversions that have increased net negative OMR flows that entrain migrating adult smelt and reservoir operations that reduce seasonal inflow that provides flow and turbidity cues for migration. In addition, the proliferation of nonnative aquatic plants that trap sediment has reduced overall turbidity and may have increased the deposition of fine sediments in historical spawning habitats.

Current Condition of Delta Smelt Critical Habitat and Factors that Contribute to that Condition

As stated in the previous section on the status of the delta smelt, the physical appearance, salinity, water clarity, and hydrology of the Delta have been modified significantly by channelization, conversion of Delta islands to agriculture, and water operations. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996, Baxter et al. 2008).

In general, the CVP/SWP operations have decreased springtime flows (PCE #3) relative to the natural hydrograph, as reservoir operations change over from flood management to water storage (Kimmerer 2004). Further, summer and early fall inflows (PCE #2, #3, and #4) may be increased over the natural hydrograph as reservoirs release stored water to support export operations. Changes in inflow affect the location of the historically highly-productive LSZ, affecting habitat volume and quality (effect on PCE #2, #3 and

#4). The combined influence of these changes since the 1980s and earlier has had the effect of distributing delta smelt narrowly and in areas with high risk of mortality from many known sources (e.g., entrainment in water diversions large and small) and plausible sources (intensified predation loss, sublethal contaminant exposure, etc.) (combined effect on the condition of PCE #2, #3, and #4). Second, a more upstream distribution of maturing adult delta smelt places them at greater vulnerability to entrainment by CVP and SWP export operations once they begin their spawning migration (Grimaldo et al, accepted manuscript) (combined effect on the condition of PCE #2, #3, and #4).

PCE #1 - Physical Habitat for Spawning

We are aware of no conditions attributable to SWP and CVP operations that limit the availability of spawning substrate.

Routine dredging of various Delta channels to facilitate shipping periodically may disrupt or eliminate spawning substrate availability, but is not known to substantially modify location, extent, or quality of available spawning substrate (PCE #1) for delta smelt.

Nonnative submerged aquatic vegetation, particularly *Egeria densa*, overwhelms littoral habitats (inter-tidal shoals and beaches) where delta smelt spawn, possibly making them unsuitable for spawning.

The cumulative effects of locally small or isolated losses or degradations of physical habitat associated with construction and maintenance of water conveyance facilities, together with increasing exposure in physical habitat to chemical pollutants from other sources, and the increase of nonnative submerged aquatic vegetation likely have reduced both the quality and extent of physical habitat. Overall, this primary constituent element remains capable of fulfilling its intended conservation function, but the trend is downward and will likely remain so unless ways are found to control *Egeria*.

PCE #2 - Water for All Life Stages (Suitable Quality)

The condition of PCE #2 has been substantially reduced. Pelagic habitat in the Delta has been highly altered and degraded by many factors discussed in the Baseline and Effects Sections. The historic Delta consisted primarily of tidal freshwater marshes, tributary river channels and their associated floodplains, and sloughs. The current Delta has little (< 1 percent) of its historic intertidal marsh habitat, its patterns of sloughs and channels have been modified, changing its hydrodynamic characteristics, and the pattern and quantity and inflow to, through and out of the estuary has been altered. When compared to estuaries around the world, the Delta is unique in its low levels of productivity (Clipperton and Kratville, in review). Current conditions for larval and juvenile transport, rearing, and adult migration in particular have been modified to an extent that this primary constituent element is substantially impaired in its ability to fulfill its conservation function at least seasonally in all water year-types. Special management is needed to address the degraded condition of this primary constituent element. Many factors that have contributed to the current condition are described below.

Factors that Impair/Degrade the Function of PCE #2

CVP and SWP

Operations of the Banks and Jones (inclusive of 500 cfs diversion at Banks, Article 21, upstream diversion and reservoir operations, North Bay Aqueduct, South Delta Temporary Barriers and Permanent Operable Gates, pumping plants water transfers) have diminished the ability of PCE #2 to fulfill its intended conservation purpose. Disconnecting inflow and outflow via water exports in the South Delta probably represents the single largest stressor for this primary constituent element. The manipulation of inflow and outflow with a goal of maintaining "balanced conditions" also has adversely affected the functionality of the other primary constituent elements and is discussed in more detail under each of the primary constituent elements. Though not restricting spawning *per se*, export of water by the CVP and SWP has usually restricted reproductive success of spawners in the San Joaquin River portion of the Delta as many adults and most larvae have been entrained and lost during transport to and from spawning sites to rearing areas (see Effects Section). Persistent confinement of the effective spawning population of delta smelt to the Sacramento River increases the likelihood that a substantial portion of the spawning population could be adversely affected by catastrophic event or localized chronic threat, such as localized contaminant releases.

The additional interaction of PCE #2 with salinity, PCE #4, has resulted in a lengthening seasonal shift in the distribution of delta smelt to areas that are generally upstream of where they once occurred. See additional discussion below in the section on Rearing.

Preliminary evidence shows that the abundance of *Pseudodiaptomus forbesi*, a dominant prey of delta smelt in the summer, has steadily declined in the lower Estuary since 1995, while its numbers have increased in the Southern Delta (Kimmerer et al. in prep.). This copepod has blooms that originate in the Delta. Its availability to delta smelt rearing to the west of the summer blooms may be impaired by pumping at Banks and Jones.

The operation of upstream diversions and reservoirs can, depending on how they are managed, substantially influence the pelagic environment in the Delta by controlling timing and volume of releases. Over time, the operation of project dams and diversions has had the additional effect of making water in the Delta more clear by trapping sediment behind dams and diverting sediment that otherwise would be transported to the Delta (effect on the condition of PCE #2). Delta smelt seem to prefer water with high turbidity (see Baseline Section). In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin River was highly seasonal and more strongly and reliably affected by precipitation that it is today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of Delta water was larger then than now (Kimmerer 2002b). Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows, but through time more and more of the summer-fall inflow and been exported, reducing outflows.

Aquatic Macrophytes

As stated in the Status and Baseline Section, research suggests that the nonnative South American aquatic plant *Egeria densa* has altered fish community dynamics in the Delta. In addition to the above-mentioned effect of overwhelming spawning habitat (PCE #1), *Egeria* and other submerged aquatic vegetation decreases turbidity by trapping suspended sediment, thereby decreasing juvenile and adult smelt habitat (Feyrer et al. 2007; Nobriga et al. 2008). Increased water transparency may also make delta smelt more susceptible to predation. It appears that aquatic macrophytes may have a role in degrading pelagic habitat to the extent that the Delta's ability to fulfill its intended conservation purpose continues to diminish. *Egeria* has the additional effect of decreasing turbidity, described above as important to successful feeding of newly-hatched larval delta smelt. However, there is still enough turbidity in the Central and South Delta to initiate larval feeding responses because larvae collected in the South Delta have comparatively high growth rates. So while *Egeria* may reduce or eliminate the extent and quality of spawning habitat for delta smelt, it is not at this time considered to have detectable effects on spawning or early feeding success.

Contaminants

While contaminants are thought to reduce habitat quality and thus reduce the ability of PCE #2 to fulfill its intended conservation function, contaminant loading and its ecosystem effects within the Delta are still not well understood. There are long-standing concerns related to methyl mercury and selenium levels in the watershed, Delta, and San Francisco Bay (Linville et al. 2002; Davis et al. 2003). There is evidence that contaminants may inhibit phytoplankton growth rates at times (Wilkerson et al. 2006; Dugdale et al. 2007). Pulses of sediment-bound pesticides can co-occur in space and time with delta smelt reproduction (Kuivila and Moon 2004). There is also recent evidence of low frequency of intersex delta smelt suggesting exposure to estrogenic chemicals (Teh 2008).

Nonnative Species

Within the Delta, grazing by the introduced clams *Corbula amurensis* and *Corbicula fluminea* can deplete resident phytoplankton biomass (Jassby et al. 2002; Lucas et al. 2002; Lopez et al. 2006). The former has had a demonstrable effect on phytoplankton standing stock and zooplankton abundance throughout the estuary (Kimmerer and Orsi 1996), but the effect of the latter is mainly limited to freshwater flooded island areas (Lucas et al. 2002; Lopez et al. 2006). Given that phytoplankton help support the production of prey items eaten by delta smelt, these nonnative species are likely to adversely affect the ability of PCE #2 to fulfill its intended conservation function, which results in degraded condition.

PCE #3 - River Flow for Larval and Juvenile Transport, Rearing, and Adult Migration

Management of Delta inflows results in conditions for river flow that frequently do not meet the intended conservation function of this primary constituent element in certain

WYs. PCE #3 is probably the most significantly degraded of all the PCEs, and requires the most intensive management in order for it to continue to fulfill its intended conservation role. The primary factors that have contributed to this condition are discussed below.

Factors that Impair/Degrade the Function of PCE #3

CVP and SWP

Operations of the CVP and SWP manipulate inflows, outflows and OMR flows. This probably represents the single largest stressor for PCE #3. Banks and Jones entrain delta smelt and delta smelt food items, thereby affecting the quality of PCE #2 as well. While tides and climate affect flow into and within the Delta, Banks and Jones are the single most prominent factor in determining whether transport flows are sufficient to allow larval and juvenile delta smelt to move out of the Central and South Delta before water temperatures reach lethal levels. Baseline operation of the CVP/SWP represents a downward trend in the ability of this primary constituent element to fulfill its intended conservation function.

Management of Article 21 water at the SWP has changed since 2000. The result is more water exported than historically during the late fall and winter months, and increasing SWP exports overall relative to historic conditions (Table P-12). This additional pumping has contributed to the downward trend in the ability of PCE #3 to meet its intended conservation function by increasing the entrainment risk of adults migrating upstream to spawn.

Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows. Reservoir operations have played a significant role in modifying conditions in the Delta to the extent that this primary constituent element is unable to fulfill its intended conservation purpose in most years. The SWRCB D-1641 has helped provide Delta outflow during the spring, but outflows are reduced during other times by increased pumping at Jones and Banks.

Environmental Water Account

Implementation of the EWA provided brief export cutbacks in winter and spring, but also increased exports during early winter and summer, and it contributed to increased exports in summer and fall to levels that would not have occurred if EWA assets had not been purchased. This may have negatively affected habitat suitability and prey availability for delta smelt (see Effects Section). So while EWA was intended to moderate effects of CVP and SWP operations, its ability to do so measured over time was small (Brown et al. 2008). While EWA may have provided short-term transport opportunities in the early part of the year, it contributed to low outflows during other times of the year, which diminished the ability of this primary constituent element to fulfill its intended conservation purpose.

Special Management for PCE #3

Vernalis Adaptive Management Plan

VAMP represents one of the management measures that has been applied to CVP and SWP operations to assist this primary constituent element in fulfilling its intended conservation role. VAMP flows are thought to have selectively enhanced survival of delta smelt larvae that emerge in the Central Delta during VAMP by reducing entrainment. VAMP has enhanced the ability of this primary constituent element to fulfill its intended conservation purpose for 31 days each year.

PCE #4 - Salinity for Rearing

Summer and fall environmental quality, represented by PCE #4, has decreased overall in the Delta, but less so for the Sacramento River-San Joaquin River confluence. The rivers' confluence has, as a result, become increasingly important as a rearing location, as delta smelt's range has been restricted to an increasingly small area (Feyrer et al. 2007; Nobriga et al. 2008). This has increased the likelihood that juvenile and maturing adult delta smelt are exposed to chronic and cyclic environmental stressors, or localized catastrophic events. The many changes imposed on the Delta have had the effect of concentrating the distribution of delta smelt to an area that is generally upstream of where they once were. This upstream location of rearing habitat has reduced habitat quantity and quality, making larval and juvenile delta smelt more susceptible to marginal water temperatures, cyanobacterium blooms, and other habitat-related effects.

Delta smelt cannot occupy much of the Delta anymore during the summer (Nobriga et al. 2008). Thus, there is the potential for mismatches between regions of high zooplankton abundance in the Delta and delta smelt distribution now that the overbite clam has decimated historical delta smelt prey in the LSZ. A minimum amount of suitable habitat during summer-autumn may interact with a suppressed pelagic food web to create a bottleneck for delta smelt (Bennett 2005; Feyrer et al. 2007; Bennett et al. 2008). As discussed in the preceding section on Population Dynamics-Abundance Trends, there is evidence that factors affecting juvenile delta smelt during summer-autumn are strongly impairing delta smelt reproductive success. The interaction of warm summer water temperatures, suppression of the food web supporting delta smelt, and spatially restricted suitable habitat during autumn all affect delta smelt health and ultimately survival and realized fecundity. The preceding factors have contributed to the current condition of seasonally low outflow and the inability of PCE #4 to fulfill its intended conservation purpose in most years.

Factors that Impair/Degrade the Function of PCE #4

CVP and SWP

Operations of the CVP and SWP pumping plants manipulate outflow and represent probably the single largest factor affecting the condition of this primary constituent

element. The facilities entrain delta smelt and delta smelt food items. While tides and climate affect flow into and within the Delta, the export facilities are the single most prominent factor in determining whether transport flows for migrating larvae, juveniles, and adults are sufficient to move fish out of the Central Delta before water temperatures reach lethal levels, are sufficient to maintain rearing habitat at a more downstream position where smelt also are not at risk of entrainment from export facilities, and are sufficient to cue adults to migrate to upstream spawning habitat without being entrained at the export facilities. Baseline operation of these facilities represents a downward trend in the ability of this primary constituent element to fulfill its intended conservation purpose with the possible exception of specific actions taken recently, the results of which, however, remain uncertain.

Management of Article 21 water at the SWP has changed since 2000. The result is more water exported than historically during the late fall and winter months when Article 21 water normally is moved, and increasing SWP exports overall relative to historic conditions. This additional pumping has contributed considerably to the downward trend in the ability of this primary constituent element to meet its intended conservation purpose.

Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage and in some years may increase late summer and fall inflows. Reservoir operations have played a significant role in modifying conditions in the Delta to the extent that this primary constituent element is unable to fulfill its intended conservation purpose in most years.

Environmental Water Account

Implementation of the EWA provided brief export cutbacks in winter and spring, but also increased exports during early winter and summer, and it contributed to increased exports in summer and fall to levels that would not have occurred if EWA assets had not been purchased. This may have negatively affected habitat suitability and prey availability for delta smelt (see Effects Section). So while EWA was intended to moderate effects of CVP and SWP operations, its ability to do so measured over time was small (Brown et al. 2008). While EWA may have provided short-term transport opportunities in the early part of the year, it contributed to low outflows during other times of the year, which diminished the ability of this primary constituent element to fulfill its intended conservation purpose.

Other Factors that May Influence the Condition of PCE #4

Aquatic Macrophytes

As stated in the preceding section on Other Stressors, research suggests that the nonnative South American aquatic plant *Egeria densa* has altered fish community dynamics in the Delta. However, we are not aware of evidence that aquatic macrophytes such as *Egeria*,

affect flows. Thus, this factor is considered to have no influence on the current condition of PCE #4

Nonnative Species

A dramatic decline in primary production in the Estuary was documented following the introduction of the overbite clam into the lower Estuary in 1986 (Alpine and Cloern 1992; Jassby et al 2002).

In the Western Delta, the food web may be compromised by overgrazing by overbite clam that can suppress phytoplankton biomass, and the abundance of delta smelt's prey (Kimmerer and Orsi 1996, Jassby et al 2002). The chronic low outflow conditions during summer and fall may increase the reproductive success and upstream range of overbite clam.

Climate Change

There are currently no published analyses of how ongoing climate change has affected the current condition of any of the primary constituent elements of delta smelt critical habitat. Climate change could have caused shifts in the timing of flows and water temperatures in the Delta which could lead to a change in the timing of migration of adult and juvenile delta smelt.

Effects of the Proposed Action

Introduction

The Status of the Species/Environmental Baseline section of this document described the multitude of factors that affect delta smelt population dynamics including predation, contaminants, introduced species, entrainment, habitat suitability, food supply, aquatic macrophytes, and *microcystis*. The extent to which these factors adversely affect delta smelt is related to hydrodynamic conditions in the Delta, which in turn are controlled to a large extent by CVP and SWP operations. Other sources of water diversion (NBA, CCWD, local agricultural diversions, power plants) adversely affect delta smelt largely through entrainment (see following discussion), but when taken together do not control hydrodynamic conditions throughout the Delta to any degree that approaches the influence of the Banks and Jones export facilities. So while many of the other stressors that have been identified as adversely affecting delta smelt were not caused by CVP and SWP operations, the likelihood and extent to which they adversely affect delta smelt is highly influenced by how the CVP/SWP are operated in the context of annual and seasonal hydrologic conditions. While research indicates that there is no single primary driver of delta smelt population dynamics, hydrodynamic conditions driven or influenced by CVP/SWP operations in turn influence the dynamics of delta smelt interaction with these other stressors (Bennett and Moyle 1996).

The following analysis focuses on the subset of factors that is affected or controlled by CVP/SWP operations, and includes a discussion of other factors to the extent they modulate or otherwise affect the CVP/SWP-related factors affecting delta smelt. Although it is becoming increasingly clear that the long-term decline of delta smelt has been affected by ecosystem changes caused by non-indigenous species invasions and other non-CVP/SWP factors, the CVP and SWP have played an important direct role in that decline. The CVP and SWP have also played an indirect role in the delta smelt's decline by creating an altered environment in the Delta that has fostered the establishment of non-indigenous species and exacerbates these and other stressors that are adversely impacting delta smelt. This analysis and others show that every day the system is in balanced conditions, the CVP and SWP are a primary driver of delta smelt abiotic and biotic habitat suitability, health, and mortality. However, the Service is relying on the findings of Bennett and Moyle (1996) and Bennett (2005), and the consensus emerging from the POD investigation (Sommer et al. 2007, Baxter et al. 2008), by assuming that delta smelt abundance trends have been driven by multiple factors, some of which are affected or controlled by CVP/SWP operations and others that are not. The decline of delta smelt cannot be explained solely by the effects of CVP/SWP operations.

This analysis of the effects of proposed CVP/SWP operations on delta smelt differs from the 2005 biological opinion in that it analyzes CVP/SWP-related effects in the context of a life-cycle model for delta smelt (Table E-1). In the following discussion, the effects of proposed CVP/SWP operations on delta smelt are organized in a seasonal context from winter through fall over the course of the annual delta smelt life cycle. Although all types of effects are covered, there is a specific focus on three major seasonally-occurring categories of effects: entrainment of delta smelt, habitat restriction, and entrainment of *Pseudodiaptomus forbesi*, the primary prey of delta smelt during summer-fall.

The following analysis assumes that the proposed CVP/SWP operations affect delta smelt throughout the year either directly through entrainment or indirectly through influences on its food supply and habitat suitability. During December-June, when delta smelt are commonly entrained at Banks and Jones, their habitat and co-occurring food supply also are being entrained, so CVP/SWP-related effects on habitat and food supply are only examined explicitly during July-December when delta smelt entrainment is rare. Delta smelt entrainment is rare from about mid-July through mid-December each year mainly because environmental conditions in the San Joaquin River and its distributaries are not appropriate to support delta smelt. The water is too warm and clear, so delta smelt actively avoid the Central and South Delta during summer and fall (Feyrer et al. 2007; Nobriga et al. 2008).

Our analysis also assumes that any of these three major categories of effects described above will adversely affect delta smelt, either alone or in combinations. This approach is also consistent with Rose (2000), who used several different individual-based models to show how multiple interacting stressors can result in fish population declines that would not be readily discernable using linear regression-based approaches.

Table E-1. The distribution of three categories of effects caused by proposed CVP/SWP operations over the life cycle of delta smelt.

Season	Delta smelt entrainment	Pseudodiaptomus entrainment/retention	Habitat suitability
Winter	X (adults)[a]		
Spring	X (larvae/juveniles)[b]		
Summer		X[c]	
Fall			X[d]

[a] Historical hydrodynamic data are DAYFLOW 1967-2007; OMR was measured 1993-2007 and estimated using regression on DAYFLOW variables by Cathy Ruhl (USGS) for 1967-1992; historical delta smelt salvage data are 1993-2007, the period when the data are considered most reliable.
[b] Historical hydrodynamic data are DAYFLOW 1967-2007 (except OMR as noted in the previous footnote); direct estimates of larval-juvenile entrainment are 1995-2005. (Kimmerer 2008); Entrainment was estimated statistically for 1967-1994 and 2006-2007
[c] Historical hydrodynamic data (DAYFLOW; except OMR 1988-1992, see footnote a) and Pseudodiaptomus density data (IEP monitoring) are 1988-2006 because Pseudodiaptomus was introduced in 1988.
[d] Historical hydrodynamic data are DAYFLOW 1967-2007.

Data and Models used in the Analysis

This analysis of the effects of proposed CVP and SWP operations on the delta smelt and its critical habitat uses a combination of available tools and data, including the CALSIM II model outputs provided in the appendices of Reclamation's 2008 biological assessment, historical hydrologic data provided in the DAYFLOW database, statistical summaries derived from 936 unique 90-day particle tracking simulations published by Kimmerer and Nobriga (2008), and statistical summaries and derivative analyses of hydrodynamic and fisheries data published by Feyrer et al. (2007), Kimmerer (2008), and Grimaldo et al. (accepted manuscript).

The biological assessment suggested using CALSIM II study 7.0 as the current baseline, and 6.1 as the historical baseline but the CALSIM monthly simulation model does not capture a precise Delta operation. When Study 6.1 was modeled, changes were expected between Study 6.1 and Studies 7.0 and 7.1 but the results in the August 2008 biological assessment were nearly identical (which differed from the May 2008 biological assessment model outputs where there had been a difference between those study runs). On page 9-32 of the 2008 biological assessment there is discussion of the various studies, including study 6.1 taken from the text: "Study 6.1 – This study represents the previous

OCAP biological assessment 2004 assumptions also within the new CALSIM II model framework. Conditions for water demands, facilities, and water project-operational policy are duplicated, to the extent possible, to Study 3a, but this is simulated only through the CVPIA (b)(2) step. This study is identical to Study 6.0 in the OCAP biological assessment May 2008 issue and is included to emulate pre-POD conditions. Study 6.1 is an imperfect representation of the pre-POD and supplemental analysis should be evaluated to compensate for this modeling limitation (discussed in Chapter 13: CVP and SWP Delta Effects). " The modeling done in the 2004 OCAP biological assessment is shown in Table E-2.

Table E-2. Summary of assumptions in the 2004 OCAP CALSIM II runs.

	Level of Development	Article 21	Refuge Deliveries	Trinity Required Flows	D1485	Winter-Run B.O.	D1641	CVPIA 3406 (b)(2)	EWA
Study A D1485 (1991)	2001		Historical Level 2	340,000 af/yr	X				
Study B D1485 w/ Refuge Firm Level 2 (1992)	Same as above		Firm Level 2	Same as above	X				
Study C D1485 w/ Refuge Firm Level 2, and Winter Run B.O. (1993)	Same as above		Same as above	Same as above	X	X			
Study D D1641 (1994)	Same as above		Same as above	Same as above		X	X		
Study 1 D1641 w/ CVPIA 3406 (b)(2) (1997)	Same as above	X	Same as above	Same as above		X	X	X	
Study 3 Today CVPIA 3406 (b)(2) with EWA (2004)	Same as above	X	Same as above	369,000-453,000 af/yr		X	X	X	X

A number of CALSIM II model updates and changes in assumptions have been revised from the 2004 biological assessment to the 2008 biological assessment. A summary of these changes are provided the Table E-3.

Table E-3. Changes in CALSIM II model updates and assumptions from 2004 to 2008.

Major Model updates		
Area	**2004 BA**	**2008 BA**
Hydrology	73 years (1922-1994)	82 years (1922-2003)
San Joaquin River	Derived from older logic	Water Quality and hydrology Updated
Yuba	Timeseries from DWR's HEC-5 external model	Timeseries from updated, YCWA external model

Colusa Basin	Colusa Basin within Hydrology	Improved Hydrology and more explicit operation
Sacramento River Hydrology	No explicit rice decomposition, within hydrology	Included Rice Decomposition water
State Project	Assumed variable Table A demand and some Article 21	Updated 3 pattern with Article 56 and more accurate Table A and Article 21 split
ANN – Delta Salinity Estimate	2004 version of ANN	Training of ANN improved between DSM2 by including tidal energy and now using DSM2 trained X2
Level of Development	Current 2001 & Future 2020	Current 2005 & Future 2030
Major Assumptions	**2004 BA**	**2008 BA**
American River Demands	Future demands based on Water Forum assumptions	Future demands based on full contract amounts
State Demands	Future Table A 3.3-4.1 MAF and Article 21 demand 134 TAF/month (Dec-Mar)	Future Full Table A (4.2 MAF) and Article 21 demand 314 TAF/month (Dec-Mar)
EWA	Future with Full EWA and different logic for assets, debts, and actions	Future with Limited EWA with updated more explicit asset, debt, and action logic
Refuge	Firm Level 2	Recent Historic (existing), Firm Level 2 (future)
San Joaquin River	Fixed Annual demands	Updated land based demand
Trinity Note	Flows 340 TAF in current or 369-453 TAF and 369-815 in ROD for future	Trinity current level is 369-815 from the ROD

The inaccuracies in CALSIM lead us to use actual data to develop an empirical baseline. We also developed historical time series data for hydrologic variables used in this effects analysis based on the DAYFLOW database (http://iep.water.ca.gov/dayflow/index.html) and OMR data obtained from USGS. We calculated monthly or multiple month averages or medians based on these daily hydrology data sets. The historical time series are intended to show where changes in water project operations have caused or contributed to changed Delta hydrology and to serve as an empirical baseline of SWP and CVP operations for comparison to proposed futures modeled using CALSIM II. We used WYs 1967-2007 as the "historical" period for all hydrologic variables. Note that OMR has only been measured empirically since 1987. The OMR data for 1981-1986 were estimated by Ruhl et al. (2006). The OMR flows for 1967-1980 were estimated using DAYFLOW variables with the following equation: (-600) – (0.0065*EAST) – (0.851*EXPORT) + (0.506*SJR). The equation used by Ruhl et al. (2006) did not

include the "EAST" term accounting for flows from the Delta's east side tributaries. Note however that the r^2 between the Ruhl equation and the one including the "EAST" term is 0.99.

The CALSIM II model is a mathematical simulation model developed for statewide water planning. It has the ability to estimate water supply, streamflows, and Delta water export capability, keeping within "rules" such as water quality standards that limit model outputs to plausibly achievable system operations. CALSIM II is DWR's and Reclamation's official SWP and CVP planning tool. The CALSIM II model is applied to the SWP, the CVP, and the Sacramento and San Joaquin Delta. The model is used to evaluate the performance of the CVP and SWP systems for: existing or future levels of land development, potential future facilities, and current or alternative operational policies and regulatory environments. Key model output includes reservoir storage levels, instream river flow, water delivery, Delta exports and conditions, biological indicators such as X2, and operational and regulatory metrics.

CALSIM II simulates 82 years of hydrology for the Central Valley region spanning WYs 1922-2003. The model employs an optimization algorithm to find ways to move water through the SWP and CVP in order to meet assumed water demands on a monthly time step. The movement of water in the system is governed by an internal weighting structure that ensures regulatory and operational priorities are met. The Delta is also represented in CALSIM II by DWR's Artificial Neural Network (ANN), which simulates flow and salinity relationships. Delta flow and electrical conductivity are output for key regulatory locations. Details of the level of land development (demands) and hydrology are discussed in Appendix D of the biological assessment (Reclamation 2008), as are details of how the model simulates flexible operations like (b)(2) and EWA allocations. Most of the model data used in this analysis were direct output from CALSIM II simulations for the biological assessment. However, certain Delta flow indicators, most notably OMR flows, were estimated by inputting CALSIM II outputs into the DSM-2 HYDRO model, which can predict OMR based on the hydrologic data output by CALSIM II.

This effects analysis analyzes outputs from the following subset of studies presented in the biological assessment: 7.0, 7.1, 8.0, and 9.0-9.5.

Study 7.0 was the model run that Reclamation and DWR thought best represented current operations, and was thus intended as a "current baseline." However, due to limitations of CALSIM II to accurately model actual operations, we also used the 1967-2007 DAYFLOW summaries described above to compare against CALSIM II outputs. Study 7.0 modeled represents a 2005 level of development with (b)(2) allocations and a full EWA. The full EWA was represented in the CALSIM II framework as up to 50,000 acre-feet of water export reductions during December-February, the VAMP pulse flow, and export reductions following VAMP (mid-May into June) when CALSIM II predicted the EWA had surplus water (i.e., collateral exceeded debt).

Study 7.1 also represents a 2005 level of development with (b)(2) allocations, but with a limited EWA, which as described in the Project Description above consists mainly of

water provided under the Yuba Accord. In the limited EWA, there were no export reductions in February and June, but export reductions were possible during December to January and late May. The VAMP pulse flow was modeled in the same way as in the full EWA.

Study 8.0 estimates SWP and CVP operations with a 2030 level of development, (b)(2) allocations and the limited EWA. Note that the 2030 level asked CALSIM II to try to provide 100 percent of the CVP's contract demand and 100 percent of the SWP's Table A contract demand, in all WY types but deliveries are shorted based on hydrology.

Study 9.0 represents a future condition to serve as a basis of comparison of the effects of climate change to sea level rise for the sensitivity evaluation. Neither (b)(2) actions or EWA were added to these steps.

Study 9.1 represents a future scenario in which sea level is assumed to be one foot higher than present, resulting in a four-inch higher tidal elevation at Martinez, California.

Studies 9.2-9.5 represent 'bookends' of climate change scenarios with the 2030 level of development. These bookends cannot be summarized simply except in qualitative terms. The bookends represent 10th and 90th percentiles of predicted changes in precipitation and temperature for the period 2010 to 2030 relative to 1971 to 2000 conditions. Generally, climate change models outputs indicate that the Central Valley will be warmer in the future, but are indeterminate as to whether precipitation will increase or decrease (e.g., Dettinger 2005). Thus, the climate change bookends include drier and wetter possibilities, but do not include cooler futures relative to current conditions. Thus, the temperature bookends can be called 'less warming' and 'more warming' or 'warmer' and 'warmer still'. Study 9.2 is a wetter and warmer simulation, 9.3 is a wetter and warmer still simulation, 9.4 is a drier and warmer simulation, and 9.5 is a drier and warmer still simulation. These climate change scenarios were not intended to be directly compared to studies 7.0-8.0. However, for simplicity all model output summaries were plotted together.

Study 9.5 represents the "worst-case scenario" among all simulations presented in the biological assessment because drier conditions are expected to result in more frequent conflicts over limited water resources. Further, springtime water temperatures influence the length of the spawning season for delta smelt (Bennett 2005) and summertime water temperature conditions already can be marginal for delta smelt (e.g., Nobriga et al. 2008). For those reasons, all warmer future scenarios are expected to further stress delta smelt, but the warmer still scenarios have the highest potential for detrimental effects.

Effects Analysis Methods

The effects analyses range from qualitative descriptions and conceptual models of project effects to quantitative analyses. The effects of Banks and Jones pumping on adult delta smelt entrainment, larval-juvenile delta smelt entrainment, and fall habitat suitability and its predicted effect on the summer townet survey abundance index are quantitatively

analyzed. The remainder of proposed action elements and effects are not analyzed quantitatively because data are not available to do so or it is the opinion of the FWS that they have minor effects on delta smelt. For maximum clarity, analytical details are provided in the relevant sections.

Migrating and Spawning Adults (~ December through March)

Water Diversions and Reservoir Operations

Upstream Reservoirs and Diversions

The following CVP/SWP project elements are included in the modeling results and are not specifically discussed in this analysis, rather the effects of these project elements are included in the "Adult Entrainment Effects" and the "Habitat Suitability Effects" sections below: Trinity River Operations, Whiskeytown Operations, Clear Creek Operations, Shasta Lake and Keswick Dam Operations, Red Bluff Diversion Dam Operations, Oroville Dam and Feather River Operations, Folsom and Nimbus Dam Operations, New Melones Reservoir Operations, and Freeport Diversion Operations.

Banks and Jones Pumping Plants

Entrainment

The entrainment of delta smelt into the Banks and Jones pumping plants is a direct effect of SWP and CVP operations. See Brown et al. (1996) for a description of fish salvage operations. Total entrainment is calculated based upon estimates of the number of fish salvaged (Kimmerer 2008). However, these estimates are indices - most entrained fish are not observed (Table E-4), so most of the fish are not salvaged and therefore do not survive. Many, if not most, of the entrained delta smelt likely die due (Bennett 2005). Recent studies also indicate that delta smelt predation and mortality across CCF may be high (Castillo et al. 2008). Additional studies will further explore this issue. The effects of NBA and CCWD operations on delta smelt are presented separately below.

Table E-4. Factors affecting delta smelt entrainment and salvage.

	Adults	Larvae < 20 mm	Larvae > 20 mm and juveniles
Predation prior to encountering fish salvage facilities	unquantified	unquantified	unquantified
Louver efficiency (based on Kimmerer 2008)	Limited data indicate an efficiency of about 13 percent for the CVP facility; no equivalent data are available for the SWP facility	~ 0 percent	Likely < 13 percent at any size; << 13 percent at less than 30 mm
Collection screens efficiency	~ 100 percent	~ 0 percent	< 100 percent until at least 30 mm
Identification protocols	Identified from subsamples, then expanded in salvage estimates	Not identified	Identified from subsamples, then expanded in salvage estimates
Fish survival after Handling, trucking and release back into the Delta	Study in progress	0 percent	Study in progress

The population-level effects of delta smelt entrainment vary; delta smelt entrainment can best be characterized as a sporadically significant influence on population dynamics. Kimmerer (2008) estimated that annual entrainment of the delta smelt population (adults and their progeny combined) ranged from approximately 10 percent to 60 percent per year from 2002-2006. Major population declines during the early 1980s (Moyle et al. 1992) and during the recent POD years (Sommer et al. 2007) were both associated with hydrodynamic conditions that greatly increased delta smelt entrainment losses as indexed by numbers of fish salvaged. However, currently published analyses of long-term associations between delta smelt salvage and subsequent abundance do not support the hypothesis that entrainment is driving population dynamics year in and year out (Bennett 2005; Manly and Chotkowski 2006; Kimmerer 2008).

Adult Entrainment

Adult delta smelt have been salvaged at Banks and Jones as early in the WY as November and as late as June, but most of the recent historical salvage has occurred between mid-December and March (www.delta.dfg.ca.gov). Delta smelt salvage usually occurs in a prolonged event that has one major peak. This is evidence that the maturing population makes a spawning migration into the Delta. The migration is cued by pulses of freshwater flow into the estuary, otherwise known as “first flush” events (Grimaldo et al. accepted manuscript). The physiological mechanism that cues migration is unknown

but salvage of adults typically begins when turbidities elevate over 12 NTU (Clifton Court Forebay Station) and total Delta inflow generally increases to over 25,000 cfs. During extreme flow events (total inflow > 100,000 cfs), delta smelt spawn downstream of the Delta and in critically dry years they often spawn in the North Delta.

Annual winter salvage is best explained by OMR flow, whereby salvage increases with reverse OMR flow (Figure E-1). Kimmerer (2008) calculated that entrainment losses of adult delta smelt in the winter removed 1 to 50 percent of the estimated population and were proportional to OMR flow, though the high entrainment case might overstate actual entrainment. Given there are demonstrated relationships between smelt entrainment and salvage with OMR flows (Kimmerer 2008; Grimaldo et al. accepted manuscript), this effects analysis evaluates the proposed action operations by comparing the long-term trends in OMR flows to OMR flows in the CALSIM II modeling presented in the biological assessment. For both approaches, predictions of salvage and total entrainment losses were made using OMR flow since it was the best explanatory variable of each. The effects of proposed operations were determined by comparing actual salvage and entrainment losses with predictions of these parameters under modeled OMR flows. As was done in the biological assessment (Reclamation 2008, Chapter 13), we have not attempted to separate the effects of SWP and CVP. The hydrodynamic effects of pumping that cause reverse OMR flow result from the combined action of both facilities.

The salvage and adult effects analysis was determined for each December to March period (i.e., winter period). We defined the December to March period to be consistent with recent analyses (Kimmerer 2008, Grimaldo et al. accepted manuscript) as this is the period when the majority of adults migrate upstream to spawn And therefore vulnerable to export operations. We compared salvage and population losses over the full winter period and not on a month-by-month basis to account for the cumulative effects of the proposed operations on the adult life stage of delta smelt.

OMR Flows

Overall, there has been a downward trend in average winter OMR flows in these years (Figure E-2a). In contrast, winter total inflows have remained constant (Figure E-2b). The increase in negative OMR flow is mostly driven by a steady increase in winter exports over the last four decades (Figure E-2c). The modeling results show OMR flows much more negative than historic years for all WY types except for critical dry years (Figure E-3).

Salvage and Entrainment Loss Predictions

Salvage loss estimates were derived from the linear model from Grimaldo et al. (accepted manuscript). In that paper, the authors identified that OMR flow was the best explanatory variable of salvage between 1993 and 2005. The equation from this relationship (salvage = 3757 – 0.4657*OMR flow; adjusted $R^2 = 0.31$) was used to generate salvage for the proposed action operations by WY type (Table E-5b). Predicted

salvage numbers are not reported since it is unknown how the population size will vary in future years. Instead, the predicted percentage increase or decrease in salvage are reported as a more meaningful method to assess effects of proposed operations on salvage given an OMR value.

To quantitatively predict population losses of delta smelt, a suite of hydrodynamic variables were explored with adult entrainment loss estimates from Kimmerer (2008; Kimmerer (2008) calculated adult entrainment losses (Dec-Mar) using Kodiak trawl data for 2002-2005 and FMWT (November-December) for 1995-2005. For this analysis, the adult entrainment estimates from the FMWT estimates were used since they encompass a longer period by which to explore meaningful relationships. The model that explained adult entrainment losses (Dec-Mar) was the following: adult entrainment loss = 6.243 – 0.000957*OMR Flow (Dec-Mar). The adjusted R^2 for this model was 0.36. For comparative analyses, predictions of population losses from 1967-1994 were generated from this equation, (Figure E-4) whereby loss estimates from 1995-2006 were taken from Kimmerer (2008). Note much of the variability in both the salvage and population loss model is left unexplained but the predictions in the models do follow the trend that salvage and population losses increase as OMR flows decrease. In part, the variation is not captured because adult salvage and entrainment is not solely explained by OMR flows. Entrainment is also related to the number of adults that migrate into the vicinity of Banks and Jones. Although WY type may sometimes affect the spawning distribution (Sweetnam 1999), there is wide, apparently random variation in the use of the Central and South Delta by spawning delta smelt. For example, there are years when a greater proportion of the smelt population moves into the vicinity of the export facilities, which may lead to larger salvage and population loss. Leaving aside differences due to spawning migration variability, the approach used here provides expected salvage and entrainment losses given an OMR flow. The percent differences between historic winter salvage and predicted winter salvage from modeled studies were examined for each WY.

Predicted Salvage and Entrainment

The median OMR flows from the CALSIM II modeled scenarios were more negative than historic OMR flow for all WY types except critically dry years (Figure E-3; see Table E-5b for all differences). Overall, proposed OMR flows are likely to generate increases in population losses compared to historic years (Figure E-5 and Figure E-6). For example, the frequency of years when population losses are less than 10 percent from most modeled studies (except studies 7.0 and 8.0) is less than 24 percent compared to historic estimates that only exceed 10 percent in approximately half of the years.

The most pronounced differences occur during wet years, where median OMR flows are projected to be approximately 400 to 600 percent (-7100 to -3678 cfs) higher than historical wet years (-1032 cfs). Generally, wet years are marked by low salvage and population losses. However, the proposed operations during wet year are predicted to cause up to a 65 percent increase in smelt salvage and lower probability that population losses will be below 10 percent.

The proposed operation conditions likely to have the greatest impact on delta smelt are those modeled during above normal WYs. The modeled OMR flows for the above normal WYs ranged between -8155 and -6242 cfs, a 33 to 57 percent decrease from the historic median of -5178 cfs. Though the predicted salvage would only be about 15-20 percent higher than historic salvage during these years (Table E-5c), the modeled OMR flows in these years would increase population losses compared to historic years.

In below normal and dry WYs, proposed OMR flows are also modeled to decrease from historic medians. Predicted salvage levels are likely to increase between 2 and 44 percent. More importantly, the modeled median flows from all studies in these WY types range between -5747 and -7438 cfs. Modeled OMR flows at these levels are predicted to increase salvage and increase the population losses from historic levels as well.

During critically dry years, the median OMR flows for studies 7.0, 7.1, 8.0, 9.1, 9.4, and 9.5 are less than -5,000 cfs. These studies have predicted salvage lower than historic salvage and are not likely to generate larger population losses compared to historic years. The models might overestimate salvage during critical dry years when smelt are unlikely to migrate towards the Central Delta due to lack of turbidity or first flush. Thus, the effects of critical dry operations on delta smelt take are probably small and lower than estimated.

In summary, adult entrainment is likely to be higher than it has been in the past under most operating scenarios, resulting in lower potential production of early life history stages in the spring in some years. While the largest predicted effects occur in Wet and Above Normal WYs, there are also likely adverse effects in Below Normal and Dry WYs. Only Critically Dry WYs are generally predicted to have lower entrainment than what has occurred in the recent past.

Table E-5a. Historic and CALSIM II modeled median winter (Dec-Mar) OMR flows by water year type

Water year type	Historic	7	7.1	8	9	9.1	9.2	9.3	9.4	9.5
Wet	-1033	-5256	-5498	-5699	-5684	-5500	-3999	-3678	-7066	-6100
Above Normal	-5178	-7209	-7923	-8073	-8156	-7595	-6863	-6934	-7861	-7723
Below Normal	-2405	-6461	-7208	-7009	-6599	-6420	-5647	-6736	-6721	-6343
Dry	-5509	-6443	-6931	-6692	-6620	-6353	-6831	-7438	-5785	-5760
Critical	-5037	-4547	-4931	-4980	-5051	-4588	-5320	-5194	-4260	-3845

Table E-5b. Winter OMR Flow percent difference from historic median value to CALSIM II model median value

Water year type	7	7.1	8	9	9.1	9.2	9.3	9.4	9.5
Wet	408.92%	432.37%	451.84%	450.36%	432.50%	287.16%	256.13%	584.15%	490.63%
Above Normal	39.21%	53.01%	55.90%	57.49%	46.67%	32.53%	33.91%	51.80%	49.13%
Below Normal	168.62%	199.68%	191.41%	174.35%	166.90%	134.75%	180.05%	179.42%	163.72%
Dry	16.95%	25.81%	21.48%	20.17%	15.32%	24.01%	35.02%	5.01%	4.57%
Critical	-9.74%	-2.12%	-1.14%	0.27%	-8.92%	5.61%	3.11%	-15.44%	-23.68%

Table E-5c. Percent difference from historic median salvage to predicted salvage based on Dec-Mar OMR flows from CALSIM II studies

Water year type	Study 7	Study 7.1	Study 8	Study 9	Study 9.1	Study 9.2	Study 9.3	Study 9.4	Study 9.5
Wet	45.64%	48.26%	50.43%	50.26%	48.27%	32.05%	28.59%	65.20%	54.76%
Above Normal	15.15%	20.49%	21.60%	22.22%	18.04%	12.57%	13.10%	20.02%	18.99%
Below Normal	38.17%	45.20%	43.33%	39.46%	37.78%	30.50%	40.76%	40.61%	37.06%
Dry	6.80%	10.36%	8.62%	8.09%	6.15%	9.63%	14.05%	2.01%	1.83%
Critical	-3.70%	-0.81%	-0.43%	0.10%	-3.39%	2.13%	1.18%	-5.87%	-9.00%

Article 21

The analysis of Banks Article 21 pumping is qualitative because the CALSIM II modeling, as shown in the biological assessment, does not simulate two major South of the Delta storage facilities, the Kern Water Bank and Diamond Valley Lake. Both of these facilities have been used to store water moved under Article 21. As such, the full effects of Article 21 pumping is underestimated by the modeling. The modeling assumptions assume that Article 21 water demand would be 314 TAF for each month December through March and up to 214 TAF per month in all other months. As shown in Figure P-17 and Table P-12, there has been an increase in SWP pumping corresponding to an increase of the use of Article 21. This increased pumping at the SWP from the year 2000 to present corresponds to the recent declines in the delta smelt population, currently being studied by the IEP. This pumping is included in the exports at Banks, so Article 21 effects to delta smelt are included in the adult entrainment, larval-juvenile entrainment, and fall habitat effects sections. However, as described above, the modeling underestimates these effects and the amounts of water that would be moved to south of Delta storage facilities. The previous section showed that the proposed action would result in increased adult entrainment during winter. As shown below, Article 21 pumping in the fall contributes to habitat degradation and Article 21 pumping in the spring (if it occurred) would contribute to higher larval-juvenile entrainment than what occurred from 1995-2007.

The export of Article 21 appears to be one of the factors that increase entrainment in the months of December through March, demonstrated by the large increases of pumping at Banks. The highest amounts of Article 21 water are pumped in the months when adult delta smelt entrainment is also highest.

The Service is concerned with the WY type in which Article 21 water is pumped. In the 2004 OCAP biological assessment and the Service's 2005 biological opinion, Article 21 pumping was only assumed to occur during wet and above normal WYs. In the modeling for the 2004 biological assessment, Article 21 was assumed to be 50 TAF/month for MWDSC in December through March and up to 84 TAF/month for other water users for a total of 134 TAF/month from December through March. The 2005 biological opinion stated this would be an infrequent occurrence. However, from 2004 to 2007, Article 21 has been used in more than in the wet years. In 2004, a below normal WY when Article 21 should not have been pumped according to the 2005 biological opinion, 209 TAF (which was higher than the maximum assumed amount of 134 TAF) of Article 21 was pumped in March. The maximum assumed Article 21 pumping from the biological opinion was also exceeded in 2005 (167 TAF in February, 219 TAF in March and 147 TAF in April) and 2006 (260 TAF in February and 184 TAF in March).

The effects of pumping of Article 21 water to adult delta smelt would be most severe during below normal and dry years. Even though Article 21 may not be called often in these water types, San Luis Reservoir can be filled in dryer years (for example if the preceding year was wet). It is during these types of years that the increased pumping

associated with Article 21 would have the most detrimental effects to delta smelt and significant adult entrainment may occur.

DMC-CA Intertie

As described in the Project Description, the DMC-CA Intertie would provide operational flexibility between the DMC and the CA. CALSIM II-modeling results show that the Jones pumping plant capacity increases from 4,200 cfs in Study 7.0 to 4,600 cfs in Study 8.0. While the specific effects of the intertie on delta smelt cannot be analytically distinguished, the increased capacity of the Jones pumping plant is included in the adult entrainment effects discussion above and can result in higher entrainment of adult, larval and juvenile delta smelt at Jones. In addition, increased pumping at Jones can have indirect effects to delta smelt by entraining their food source and reducing their available habitat, as discussed below in the habitat suitability section.

NBA Diversion

North Bay Aqueduct diversions have had no clear trend in most months since 2000 (Source: Dayflow), though annualized average NBA pumping was higher (83 cfs) in WY 2007 than in any previous year. Seasonal pumping rates during 2005-2007 were 109 cfs in Summer (Jun-Aug), 94 in Fall (Sep-Nov), 39 in Winter (Dec-Feb), and 36 in Spring (Mar-May). These recent historical numbers are substantially below values produced by CALSIMII Study 7.0 in the Winter and Spring months. For example, the 2005-2007 December pumping rate of 52 cfs is 44 percent of the Study 7.0 December pumping rate (116 cfs); the historical April pumping rate during the same period was 31 cfs, or 23 percent of the Study 7.0 rate of 133 cfs. Because some of these differences are large, the actual historical values are discussed in each seasonal subsection below.

Modeled North Bay Aqueduct diversions are highest during the winter months. The diversion rate for study 8 in December (142 cfs) was higher than diversion rate for studies 7.0 (116 cfs). The actual average December through February pumping in 2005-2007 was 39 cfs. The SCWA hydrodynamic modeling of NBA diversions indicates that the majority of water diverted under historical pumping rates originates from Campbell Lake and Calhoun Cut during the winter. As previously mentioned, delta smelt migrate up into the Delta during the winter months. Modeled diversion rates in Studies 7.0 and 8.0 for the winter months may create hydrodynamic conditions that entrain substantial numbers of delta smelt into Barker Slough if delta smelt are present in that region.

In some years, delta smelt will begin spawning in February when temperatures reach about 12 ^{o}C (Bennett 2005). In some years, delta smelt larvae may be entrained at the NBA diversions. However since the majority of water diverted originates from Campbell Lake during the winter under historical pumping conditions, these effects were likely minimal. During years when the Yolo Bypass floods, the entrainment risk of larvae into the NBA was also probably extremely localized under historical pumping conditions because of a hydrodynamic “plug” that forms between Barker and Lindsay sloughs with

Cache Slough. When this happens, hydrodynamic mixing between Cache Slough and Lindsay/Barker sloughs decreases, causing spikes in turbidity and organic carbon in Barker and Lindsay Sloughs (DWR, North Bay Aqueduct Water Quality Report). Entrainment vulnerability would be greatest during dry years when the NBA diversions entrain a large portion of water from Barker and Lindsay Sloughs and are often years when delta smelt will spawn in the North Delta (Sweetnam 1999). This vulnerability could be higher under pumping rates associated with Studies 7.0 and 8.0. The fish screen at the NBA diversion was designed to exclude delta smelt larger than 25 mm. However, a study of a fish screen in Horseshoe Bend built to delta smelt standards excluded 99.7 percent of fish from entrainment even though most of these were only 15-25 mm long (Nobriga et al. 2004). On that basis, the fish screen at NBA may protect many, if not most, of the delta smelt larvae that do hatch and rear in Barker Slough.

CCWD Diversions

As described in the Project Description, CCWD diverts water from three different intakes in the Delta. All CCWD facilities are subject to no-fill and no-diversion periods to protect delta smelt from entrainment. With implementation of proposed CVP/SWP operations, water demands of the CCWD are anticipated to increase from 135 TAF/year in study 7.0 to 195 TAF/year in study 8.0.

Old River intake

CCWD currently diverts water using the Old River intake for its supplies directly from the Delta. In addition, when salinity is low enough, Los Vaqueros Reservoir is filled at a rate of up to 200 cfs from the Old River Intake. However, since this facility is fully screened to meet delta smelt fish screening criteria, adult entrainment is not a concern. Diversion from this facility may affect OMR flows.

Rock Slough

The Rock Slough Intake is presently unscreened. As described in the Project Description, Reclamation is required to screen this diversion and is seeking an extension for the completion of the fish screen.

Catches of delta smelt at the Rock Slough diversion are low based on sampling conducted using a sieve net three times per week from January through June and twice per week from July through December and using a plankton net at the headworks structure twice per week during times when larval delta smelt could be present in the area (generally March through June). The numbers of delta smelt entrained by the facility since 1998 have been extremely low based on this monitoring, with only a single fish taken in February 2005. Most water diversions at the Rock Slough intake now occur during the summer months, so adult delta smelt entrainment is not likely to be high. In addition, Rock Slough is a dead-end slough with poor habitat for delta smelt, so the numbers of delta smelt using Rock Slough are usually low.

Alternative Intake

Total entrainment at CCWD's facilities is likely to be reduced when the CCWD's Alternative Intake Project is completed. This diversion is going to be screened according to delta smelt fish screening criteria and will likely reduce diversions from the unscreened Rock Slough diversion. Because the Alternative Intake diversion is fully screened, adult delta smelt entrainment is not likely to be high. Diversion from this facility may affect OMR flows.

Suisun Marsh Salinity Control Gates

The SMSCG are generally operated, as needed, from September through May to meet State salinity standards in the marsh. The number of days the SMSCG are operated in any given year varies. Historically, the SMSCG were operated 60-120 days between October and May (for the period 1988-2004). With an increased understanding of the effectiveness of the SMSCG in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operations. In 2006 and 2007, the gates were operated periodically between 10-20 days annually. It is expected that this level of operational frequency (10-20 days per year) will continue in the future.

It is possible for delta smelt and other fishes to be entrained behind the SMSCG in Montezuma Slough and Suisun Marsh when the SMSCG is closed. Fish may enter Montezuma Slough from the Sacramento River when the gates are open to draw freshwater into the marsh and then may not be able to move back out when the gates are closed. It is not known whether this harms delta smelt in any way, but they could be exposed to predators hovering around the SMSCG or they could have an increased risk of exposure to water diversions in the marsh (Culberson et al. 2004). It is possible that if delta smelt are indeed entrained into Montezuma Slough and Suisun Marsh that they may be more vulnerable to water diversion such as DWR's MIDS. Entrainment into MIDS from the Sacramento River may be unlikely based on particle tracking studies that have demonstrated low entrainment vulnerability for particles released at random locations throughout Suisun Marsh (3.7 percent), and almost no vulnerability (<0.1 percent) to particles released at Rio Vista (Culberson et al. 2004). Moreover, fish entrainment monitoring at MIDS showed very low entrainment of delta smelt (one larva in 2.3 million m^3 of water sampled over a two-year period) because salinity in Suisun Slough was usually too high for delta smelt when the MIDS diversion needed to operate (Enos et al. 2007). The degree to which movement of delta smelt around the LSZ is constrained by opening and closing the SMSCG is also unknown.

Indirectly, operations of the SMSCG may influence delta smelt habitat suitability and entrainment vulnerability. When the SMSCG are opened, the draw of freshwater into the marsh effectively moves the Suisun Bay salinity field upstream. In some years, the salinity field indexed by X2 may be shifted as far as 3 km upstream. Thus, depending on the tidal conditions during and after gate operations, X2 may be transported upstream nominally about 20 days per year. The consequence of this shift decreases the extent of delta smelt habitat and moves the distribution of delta smelt upstream (Feyrer et al. 2007; see delta smelt habitat effects section below for further discussion). Because juvenile

delta smelt production decreases when X2 moves upstream during the fall (Feyrer et al. 2007), any attributable shift in X2 between September to November (December during low outflow years) caused by operation of the SMSCG can be a concern. However, a 3-km shift in X2 happening 20 days per year is far less significant than the 10-20 km shifts that have occurred for up to 120 or more days per year during late summer through early winter due to South Delta diversions (see habitat effects section below).

During January through March, most delta smelt move into spawning areas in the Delta. Grimaldo et al (accepted manuscript) found that prior to spawning entrainment vulnerability of adult delta smelt increased at the SWP and CVP when X2 was upstream of 80 km. Thus, any upstream shift in X2 from SMSCG operations may influence entrainment of delta smelt at the CVP and SWP, especially during years of low outflow or periods of high CVP/SWP exports. However, between January and June the SWP and CVP operate to meet the X2 standards in SWRCB D-1641, thus the effects of the SMSCG on X2 during this period are negligible. Therefore, SMSCG operations from January to May are not likely to affect delta smelt entrainment vulnerability. In addition, because delta smelt move upstream between December and March, operations of the SMSCG are unlikely to adversely affect delta smelt habitat suitability during this period.

Larval and Juvenile Delta Smelt (~ March-June)

Water Diversions and Reservoir Operations

Banks and Jones

As stated previously, larval and juvenile delta smelt are free-swimming and pelagic; they do not associate strongly with structure or shorelines. Delta smelt use a variety of swimming behaviors to maintain position within suitable habitats – even in regions of strong tidal currents and net seaward flows (Bennett et al. 2002). Since the water exported during spring and early summer (mainly March-June) from the Central and South Delta is suitable habitat, young delta smelt do not have a cue to abandon areas where water is flowing toward Banks and Jones. Combinations of Delta inflows and export flows or variables like Delta outflow and OMR are good predictors of larval and young juvenile delta smelt entrainment (Kimmerer 2008). This effects analysis evaluates the proposed action operations by exploring long-term trends in Delta outflow, or X2, and OMR flows during March-June and comparing these to hydrodynamic conditions expected based on CALSIM II modeling presented in the biological assessment. The analysis uses the larval-juvenile entrainment estimates provided by Kimmerer (2008) and flow and export projections from the biological assessment to estimate the annual percentages of the larval/juvenile delta smelt population expected to be entrained.

This section examines the effects of entrainment on larval and juvenile delta smelt during the months of March-June. The analysis is based on comparison of historical (1967-2007) OMR and X2 to the proposed action's predictions of these variables provided in the biological assessment for studies 7.0, 7.1, 8.0, and 9.0-9.5. The hydrologic data are

examined in light of recent estimates of larval/juvenile delta smelt entrainment (Kimmerer 2008) that are reproduced well by Delta outflow (or X2) and OMR (Figure E-7). All analyses examine two sets of spring months; March-June, which encompasses most of the spawning season and April-May, which encompasses the empirical hatch dates of most fish surviving to the fall in recent years (Hobbs and Bennett, 2008). The reason for using two spring averaging periods was to demonstrate that the conclusions are robust with regard to choice of averaging period; the predicted entrainment is very similar.

Kimmerer (2008) proposed a method for estimating the percentage of the larval-juvenile delta smelt population entrained at Banks and Jones each year. These estimates were based on a combination of larval distribution data from the 20-mm survey, estimates of net efficiency in this survey, estimates of larval mortality rates, estimates of spawn timing, particle tracking simulations from DWR's DSM-2 particle tracking model, and estimates of Banks and Jones salvage efficiency for larvae of various sizes. Kimmerer estimated larval-juvenile entrainment for 1995-2005. We used Kimmerer's entrainment estimates to develop multiple regression models to predict the proportion of the larval-juvenile delta smelt population entrained based on a combination of X2 and OMR. Using Kimmerer's method, larval-juvenile is predicted to be 0 during periods of very high outflow. For instance, Kimmerer predicted entrainment loss was 0 percent in 1995 and 1998. For simplicity, we estimated the relationship between X2, OMR, and larval-juvenile entrainment without 1995 and 1998 in the model because the relationship between these variables is linear when only years that had entrainment higher than 0 were modeled. As mentioned above, we developed two separate models, one for the March-June averaging period and one for the April-May averaging period. The reason for using two spring averaging periods was to demonstrate that the conclusions are robust with regard to choice of averaging period; the predicted entrainment is very similar. The equations are: March-June percent entrainment = (0.00933*March-June X2) - (0.0000207*March-June OMR) – 0.556 and April-May percent entrainment = (0.00839*April-May X2) - (0.000029*April-May OMR) – 0.487. The adjusted R^2 on these equations are 0.90 and 0.87, respectively. These equations were used to predict historical springtime entrainment (1967-1994 and 2006-2007). We also used the above-mentioned regression equations to predict larval-juvenile entrainment based on the hydrologic predictions provided in the biological assessment. We used these estimates to compare historical entrainment effects predicted from the CALSIM II studies. Because the equations were based only on data that had non-zero entrainment, they predict entrainment proportions are negative during periods of very high outflow. The negative entrainment predictions were changed to 0 percent before summary analysis.

Historical Data (1967-2007)

Combined Old and Middle River Flow

There has been no clear long term trend in OMR for either the March-June or April-May averaging periods (Figures E-8 and E-9). Since the early 1990s, minimum OMR flows during April-May have been higher (less negative) than 1967-1990 (Figure E-9).

Delta Outflow

Delta outflows generally declined from 1967-1990, but Delta outflows have generally been higher and comparable to 1970s levels since 1990. This is true for both the March-June and April-May averaging periods (Figures E-10 and E-11). Since the early 1990s, minimum Delta outflows flows during April-May have usually been slightly higher than 1967-1990. This is likely due to the combination of the X2 standard and the VAMP pulse flow.

Predicted entrainment

Predicted entrainment is a function of both X2 and OMR, therefore higher flows and lower exports translate into lower entrainment of delta smelt. Predicted larval-juvenile entrainment was often higher prior to the implementation of the X2 standard in 1995 than it has been since (Figure E-16). The predictions for entrainment range from 0 to about 40 percent for 1967-1994 and 0 to about 30 percent for 1995-2007. However, the upper confidence limits reach substantially higher levels, ranging from 0 to about 65 percent between 1967 and 1994 and 0 to about 40 percent during 1995-2007. The effect of the X2 standard on larval-juvenile entrainment can be seen in Figure E-17. The frequency of years in which 0 percent-10 percent of the larval-juvenile population was estimated to have been entrained was similar between 1967-1994 and 1995-2005 because very high spring outflows have always pushed X2 far downstream resulting in delta smelt distributions distant from the influence of Banks and Jones. However, there are substantial differences between the 1967-1994 and 1995-2005 time periods in terms of how frequently larger percentages of the larval-juvenile population were entrained. For instance, it is estimated that less than 20 percent of the larval-juvenile population was entrained in 67 percent of years from 1995-2005, but only 44 percent of years from 1967-1994 (Figure E-17). Further, predicted entrainment sometimes exceeded 30 percent

during 1967-1994, but was never that high during 1995-2005. Note that we did not attempt to carry the confidence limits on entrainment estimates through these calculations. See Figure E-16 for estimates of the confidence intervals.

Proposed Action

Combined Old and Middle River Flow

The biological assessment proposes that Banks and Jones pumping will cause March-June OMR flows to be more negative than 1967-2007 in wet and above normal years and will cause April-May OMR flows to be more negative than 1967-2007 wet years (Figures E-12 and E-13). It is also anticipated there will be less variation in OMR during wet and above normal years than there was historically. The predicted OMR flows are predicted to be higher (hovering near 0 cfs on average) in dry and critical years. This is true for both averaging periods. These patterns do not change in the climate change scenarios (Studies 9.0-9.5).

X2

Most of the projected operations result in average March-June and average April-May X2 that are further downstream than 1967-2007 averages (Figures E-14 and E-15). As stated previously, this is likely due to the full implementation of the X2 standard and VAMP export reduction in projected operations. The exception is wet years. In wet years, projected X2 is generally very similar to historical in both averaging periods except that the boxplots indicate no occurrences of X2 further downstream than 50 km. This is probably due to the proposed decreases in wet year OMR flows (Figures E-8 and E-9). The climate change scenarios predict April and May X2 will be further downstream in dry and critical years, but the differences are modest (< 5 km) and again likely due primarily to the modeling assumptions of meeting the X2 standard and providing an export reduction during VAMP.

Effects of Forecasted Operations

Note that we did not attempt to carry the confidence limits on entrainment estimates through these calculations. See Figure E-16 for estimates of the uncertainty surrounding the following. The biological assessment's assumptions of a continued X2 standard and an EWA-related export reduction during April-May, keep the frequency of years with larval-juvenile entrainment higher than 20 percent consistent with 1995-2005 expectations regardless of operational assumptions (Figure E-18). However, the proposed action will decrease the frequency of years in which estimated entrainment is ≤ 15 percent. Thus, over a given span of years, the project as proposed will increase larval-juvenile entrainment relative to 1995-2005 levels. This will have an adverse effect on delta smelt based on their current low population levels.

Article 21

The effects from Article 21 on larval and juvenile delta smelt would be similar to those described for adult delta smelt (See previous effects discussion on Article 21 in the adult delta smelt section). While Article 21 pumping during March through June is usually lower than in the winter, larval and juvenile delta smelt could become entrained during March through June when Article 21 pumping is occurring.

VAMP

VAMP, as described in the Project Description and the Status of the Species and Environmental Baseline section, has beneficial effects to larval and juvenile delta smelt because it simultaneously provides a pulse flow on the San Joaquin River and an export reduction at Banks and Jones. This combination has provided 31 days of improved transport flows in the Central Delta since 2000. Also as discussed above in the Status of the Species/Environmental Baseline section, Bennett (unpublished analysis) found that most delta smelt that survived to be pre-adults in the FMWT hatched during VAMP. The Service considers this evidence that VAMP has selectively enhanced the survival of delta smelt larvae that emerge during the flow pulse and export reduction by reducing the entrainment of larvae from the Central Delta.

VAMP is an experiment, and it is only projected to continue until 2009. As described in the Project Description, after VAMP ends, Reclamation has committed to maintaining the export curtailment portion of VAMP. However, since VAMP also contains a San Joaquin River flow component, which would not be continued past 2009, maintaining only the export curtailment is not expected to provide the same benefits to larval and juvenile delta smelt as the complete VAMP experiment. In order for delta smelt spawned in the Central Delta during the VAMP period to survive to the fall, the export curtailments and the VAMP flows would be needed.

According to the Project Description, DWR proposes to continue the export reductions at Banks as long as there are assets available from the Yuba Accord Water Transfer to compensate the SWP for lost pumping. Because the export reductions may cost more than the Yuba Accord provides, the export curtailments at Banks may be smaller and therefore provide less benefit to larval and juvenile delta smelt. Also, as mentioned above, the export reductions at Jones and Banks are only part of VAMP, and the San Joaquin River (i.e., Vernalis) flow pulse is also important for protection of delta smelt from entrainment.

Therefore, the reduced protections during VAMP by only providing the export curtailment portion of VAMP and not the San Joaquin River flow component is likely to adversely effect delta smelt. Larval and juvenile delta smelt in the Central and South Delta would be protected from entrainment at Banks and Jones during this period, but the lack of San Joaquin River flow would not help them to move to the Western Delta and

Suisun Bay. Without the flow component, the larval and juvenile delta smelt would remain in the Central and South Delta, where they could be exposed to lethal water temperatures, entrainment at Banks and Jones after the VAMP export curtailment period, or succumb to predation or m*icrocystis* blooms.

Intertie

The effects from the intertie on larval and juvenile delta smelt would be similar to those described for adult delta smelt. See previous effects discussion on the intertie in the adult delta smelt section.

NBA Diversion

The differences in NBA diversions during the spring were as follows: For April, study 8.0 had a diversion rate of 145 cfs, which is approximately 10 percent higher than the April diversion rates in studies 7.0 (133 cfs) (Chapter 12). For May, study 8.0 also had a diversion rate of 145 cfs, which is approximately 25 percent higher than the May diversion rates in studies 7.0 (116 cfs). For June, study 8.0 assumed a diversion rate of 148 cfs, about 18 percent higher than the June diversion rates in studies 7.0 (126 cfs) The actual average March through May pumping in 2005-2007 was 36 cfs. Overall, spring represents the period of greatest entrainment risk for delta smelt larvae at the NBA, especially in dry years when delta smelt spawn in the North Delta (http://www.delta.dfg.ca.gov/data/NBA/). Entrainment risk at the pumping rates modeled in Studies 7.0 and 8.0 could be substantially higher than risks that existed under historical pumping rates. As described above, based on Nobriga et al. 2004, the fish screen at NBA may protect many, if not most of the delta smelt larvae that hatch and rear in Barker Slough. However, as the NBA diversions increase, as proposed in study 8.0, the small effect of the NBA diversion may become more significant.

CCWD Diversions

Old River Intake

In addition to the Old River diversion being screened to protect adult delta smelt, all CCWD diversions implement fishery protection measures to minimize larval delta smelt from becoming entrained at CCWD facilities. These measures consist of a 75-day period during which CCWD does not fill Los Vaqueros Reservoir and a concurrent 30-day period during which CCWD halts all diversions from the Delta, provided that Los Vaqueros Reservoir storage is above emergency levels. The default dates for the no-fill and no-diversion periods are March 15 through May 31 and April 1 through April 30, respectively; the Service, NMFS and DFG can change these dates to best protect the subject species. Larval fish may occur at this facility outside of the no-fill and no-diversion periods, and may be subject to entrainment. However, larval fish monitoring behind the screens has shown very few larval fish become entrained (Reclamation 2008) and, as stated above for the NBA, the fish screens at this facility may protect fish smaller

than intended by the screens' designs. Diversion from this facility may affect OMR flows.

Rock Slough

Although most water diversions at the Rock Slough intake now occur during the summer months, the Rock Slough diversion is also subject to the no-fill and no-diversion periods that all CCWD diversions are operated under. Like the Old River diversion, larval delta smelt may occur at this facility outside of the no-fill and no-diversion periods, and may be subject to entrainment. Since the Rock Slough diversion is not screened, larval fish entrainment at this facility may be a concern. However, larval fish monitoring behind the headworks has not shown that large numbers of larval fish become entrained (Reclamation 2008).

Alternative Intake

Like the Old River diversion, the Alternative intake is screened to protect adult delta smelt from entrainment. Since larval smelt are not protected by these fish screens, the Alternative intake is also proposed to operate in accordance with the no-fill and no-diversion periods to minimize larval fish from entrainment. Like the other two CCWD diversions discussed above, larval delta smelt may occur at this facility outside of the no-fill and no-diversion periods, and may be subject to entrainment. Larval fish may also become entrained at this facility, but as stated above for the NBA, the fish screens at this facility may protect fish smaller than intended by the screens' designs. Diversion from this facility may affect OMR flows.

South Delta Temporary Barriers

Hydrodynamic Effects

The TBP does not alter total Delta outflow, or the position of X2. However, the TBP causes changes in the hydraulics of the Delta, which may affect delta smelt. The HORB blocks San Joaquin River flow, which prevents it from entering Old River at that point. This situation increases the flow toward Banks and Jones from Turner and Columbia cuts, which can increase the predicted entrainment risk for particles in the East and Central Delta by up to about 10 percent (Kimmerer and Nobriga 2008). In most instances, net flow is directed towards the Banks and Jones pumps and local agricultural diversions. Computer simulations have shown that placement of the barriers changes South Delta hydrodynamics, increasing Central Delta flows toward the export facilities (Reclamation 2008). In years with substantial numbers of adult delta smelt moving into the Central Delta, increases in negative OMR flow caused by installation of the SDTBs can increase entrainment. The directional flow towards the Banks and Jones increases the vulnerability of fish to entrainment. Larval and juvenile delta smelt are especially susceptible to these flows.

The varying proposed operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables limit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. In 1996, the installation of the spring HORB caused a sharp reversal of net flow in the South Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage (Nobriga et al. 2000). This observation indicates that short-term salvage can significantly increase when the HORB is installed in such a manner that it causes a sharp change or reversal of positive net daily flow in the South and Central Delta. The physical presence of the TBP may attract piscivorous fishes and influence predation on delta smelt. However, past studies by the DFG TBP Fish Monitoring Program indicated that such predation is negligible (DWR 2000a).

Vulnerability to Local Agricultural Diversions

Fish that may become trapped upstream of the TBP agricultural barriers may suffer increased vulnerability to local agricultural diversions. However, the risk of entrainment (Kimmerer and Nobriga 2008) or death from unsuitable water quality (as inferred from lack of delta smelt occurrence in the South Delta during summer; see Nobriga et al. 2008) is so high for delta smelt trapped in the South Delta that loss to irrigation diversions in this region is likely to be negligible.

Effects to Potential Fish Prey Items

The extent to which the distribution and abundance of delta smelt prey organisms is influenced by the conditions created by the TBP is difficult to determine. Because the TBP does not influence X2, organisms that exhibit a strong abundance-X2 relationship (e.g., mysid shrimp) (Jassby et al.1995), are not likely to be affected. However, the barriers might influence the flux of *Pseudodiaptomus* from the Delta to the LSZ.

South Delta Permanent Operable Gates

Hydrodynamic Effects

As described in the Project Description, the South Delta Permanent Operable Gates (Operable Gates) are expected to be constructed in late 2012. The Operable Gates are expected to operate during similar time periods as the TBP, with the gate closing starting in April and operating thorough the winter. The Head of Old River Gate would operate in April and May and in the fall.

The effects of the Operable Gates on larval and juvenile delta smelt are expected to be similar to those caused by the TBP. The Operable Gates will open daily to maintain water levels at 0.0 foot mean sea level in Old River near the Jones pumping plant, and these daily openings would provide passage for delta smelt. Like the TBP, the operations of the Operable Gates are not expected to decrease Delta outflows, but the risk of larval and juvenile delta smelt entrainment at Banks and Jones is expected to remain about the same as with the TBP. Also, OMR flows would be affected by the Operable Gates and

may result in more negative OMR flows which could increase the risk of larval and juvenile delta smelt entrainment.

If the Operable Gates are operated during periods when the TBP have not been installed, additional effects to delta smelt could occur. For example, if the Operable Gates are closed during the winter (December through March), flow cues from the San Joaquin River may be disrupted and may affect adult delta smelt migration into the Delta. Also, if the Operable Gates are closed during this period, the available habitat for delta smelt would be reduced. The South Delta can be suitable habitat for delta smelt in some years; if this habitat is inaccessible to the delta smelt due to the Operable Gates being closed, adverse effects to the delta smelt and their habitat would occur.

Vulnerability to Local Agricultural Diversions

Under the proposed operations of the Operable Gates, delta smelt are likely to be affected in a manner similar to that caused by operation of the TBP, although delta smelt may be less susceptible to entrainment at local agricultural diversion since the Operable Gates are likely to be opened more often. As discussed above, the risk of entrainment or death from unsuitable water quality is so high for delta smelt trapped in the South Delta that loss to irrigation diversions in this region is likely to be negligible.

Effects to Potential Fish Prey Items

Under the proposed operations of the Operable Gates, delta smelt are likely to be affected in a manner similar to that caused by operation of the TBP, although delta smelt may be less affected because the Operable Gates will be open more than the TBP.

Suisun Marsh Salinity Control Gates

The effects from the SMSCG on larval and juvenile delta smelt would be similar to those described for adult delta smelt. See previous effects discussion on the SMSCG in the adult delta smelt section.

American River Demands

Based on CALSIM II model study 8.0 results, total American River Division annual demands on the American and Sacramento rivers are estimated to increase from about 324,000 acre-feet in 2005 to 605,000 acre-feet in 2030, without the Freeport Regional Water Project maximum of 133,000 acre-feet during drier years. These increases in demands and diversions are included in the modeling results. The effects of these demands on delta smelt are discussed below in the section dealing with the effects of CVP/SWP operation on habitat suitability.

Delta Cross Channel

The DCC will be closed for fishery protection as described in the Project Description. This action is not expected to change in the future. The effects of the DCC on Delta hydrodynamics are included in the CALSIM II modeling results and are discussed below in the section dealing with the effects of CVP/SWP operation on habitat suitability.

Juveniles and Adults (~ July-December)

Entrainment of *Pseudodiaptomus forbesi* (June-September)

Historically, the diet of juvenile delta smelt during summer was dominated by the copepod *Eurytemora affinis* and the mysid shrimp *Neomysis mercedis* (Moyle et al. 1992; Feyrer et al. 2003). These prey bloomed from within the estuary's LSZ and were decimated by the overbite clam *Corbula amurensis* (Kimmerer and Orsi 1996), so delta smelt switched their diet to other prey. *Pseudodiaptomus forbesi* has been the dominant summertime prey for delta smelt since it was introduced into the estuary in 1988 (Lott 1998; Nobriga 2002; Hobbs et al. 2006). Unlike *Eurytemora* and *Neomysis*, *Pseudodiaptomus* blooms originate in the freshwater Delta (John Durand San Francisco State University, oral presentation at 2006 CALFED Science Conference). This freshwater reproductive strategy provides a refuge from overbite clam grazing, but *Pseudodiaptomus* has to be transported to the LSZ during summer to co-occur with most of the delta smelt population. This might make *Pseudodiaptomus* more vulnerable to pumping effects from the export facilities than *Eurytemora* and *Neomysis* were. By extension, the projects might have more effect on the food supply available to delta smelt than they did before the overbite clam changed the LSZ food web. As evidence for this hypothesis, the IEP Environmental Monitoring Program zooplankton data show the summertime density of *Pseudodiaptomus* is generally higher in the South Delta than in Suisun Bay. The ratio of South Delta *Pseudodiaptomus* density to Suisun Bay *Pseudodiaptomus* density was greater than one in 73 percent of the collections from June-September 1988-2006. The average value of this ratio is 22, meaning that on average summer *Pseudodiaptomus* density has been 22 times higher in the South Delta than Suisun Bay. Densities in the two regions are not correlated ($P > 0.30$). This demonstrates that the presence of high copepod densities in the South Delta which delta smelt do not occupy during summer months, do not necessarily occur simultaneously in the LSZ where delta smelt rear.

There is statistical evidence suggesting that the co-occurrence of delta smelt and *Pseudodiaptomus forbesi* has a strong statistical influence on the survival of young delta smelt from summer to fall (Miller 2007). In addition, recent histopathological evaluations of delta smelt have shown possible evidence of food limitation in delta smelt during the summer (Bennett 2005; Bennett et al. 2008). However, the glycogen depletion of the delta smelt livers reported in these studies can also arise from thermal stress due to high summer water temperatures (Bennett et al. 2008).

Water Transfers

Water transfers would increase Delta exports by 0 to 360,000 acre-feet (af) in most years (the wettest 80 percent of years) and by up to 600,000 AF in Critical and some Dry years (approximately the driest 20 percent years). Most transfers will occur at Banks (SWP) because reliable capacity is not likely to be available at Jones except in the driest 20 percent of years. Although transfers can occur at any time of year, the exports for transfers described in this assessment would occur only in the months July-September. Delta smelt are rarely present in the Delta in these months, so no increase in salvage due to water transfers during these months is anticipated, but as described above, these transfers might affect delta smelt prey availability.

Post-processing of Model Data for Transfers

This section shows results from post-processed available pumping capacity at Banks and Jones for the Study 8.0 . Results from the Existing Conditions CVP-OCAP study alternatives do not differ greatly from those of Study 8.0, and produce similar characteristics and tendencies regarding the opportunities for transfers over the range of study years. The assumptions for the calculations are:

- Capacities are for the Late-Summer period July through September total.

- The pumping capacity calculated is up to the allowable E:I ratio and is limited by either the total physical or permitted capacity, and does not include restrictions due to ANN salinity requirements with consideration of carriage water costs.

- The quantities displayed on the graph do not include the additional 500 cfs of pumping capacity at Banks (up to 7,180 cfs) that is proposed to offset reductions previously taken for fish protection. This could provide up to a maximum about 90 TAF of additional capacity for the July-September period, although 60 TAF is a better estimate of the practical maximum available from that 500 cfs of capacity, allowing for some operations contingencies.

- Figure 13-59 and Figure 13-60 in the biological assessment show the available export capacity from Study 8.0 (Future Conditions-2030) at Banks and Jones, respectively, with the 40-30-30 WY type on the x-axis and the WY labeled on the bars. The SWP allocation or the CVP south of Delta Agriculture allocation is the allocation from CALSIM II output from the WY.

From Figure 13-59 of the biological assessment, Banks will have the most ability to move water for transfers in Critical and certain Dry years (driest 20 percent of study years) which generally have the lowest water supply allocations, and reflect years when transfers may be higher to augment water supply to export contractors. For all other study years (generally the wettest 80 percent) the available capacity at Banks for transfer

ranges from about 0 to 500 TAF (not including the additional 60 TAF accruing from the proposed permitted increase of 500 cfs at Banks. But, over the course of the three months July-September other operations constraints on pumping and occasional contingencies would tend to reduce capacity for transfers. In consideration of those factors, proposed transfers would be up to 360 TAF in most years when capacity is limiting. In Critical and some Dry years, when capacity would not be a limiting factor, exports for transfers could be up to 600 TAF (at Banks and Jones combined). Transfers at Jones (Figure 13-60 of the biological assessment) are probably most likely to occur only in the driest of years (Critical years and some Dry years) when there is available capacity and low allocations.

Limitations

The analysis of transfer capacity available derived from the CALSIM II study results shows the capacity at the export pumps and does not reflect the amount of water available from willing sellers or the ability to move through the Delta. The available capacity for transfer at Banks and Jones is a calculated quantity that should be viewed as an indicator, rather than a precise estimate. It is calculated by subtracting the respective project pumping each month from that project's maximum pumping capacity. That quantity may be further reduced to ensure compliance with the Export/Inflow ratio required. In actual operations, other contingencies may further reduce or limit available capacity for transfers: for example, maintenance outages, changing Delta outflow requirements, limitations on upstream operations, water level protection criteria in the South Delta, and fishery protection criteria. For this reason, the available capacity should be treated as an indicator of the maximum available for use in transfers under the assumed study conditions.

Proposed Exports for Transfers

In consideration of the estimated available capacity for transfers, and in recognition of the many other operations contingencies and constraints that might limit actual use of available capacity, for this assessment proposed exports for transfers (months July-September only) are as follows:

Water Year Type	Maximum Amount of Transfer
Critical	up to 600 kaf
Consecutive Dry	up to 600 kaf
Dry after Critical	up to 600 kaf
All other Years	up to 360 kaf

Therefore, effects of water transfers are not expected to have direct entrainment effects to adult delta smelt since the proposed transfer window is a time when delta smelt are distributed the western Delta. However, water transfers could have adverse effects to

delta smelt habitat or food items by increased pumping during the summer or fall. These habitat effects are captured in CALSIM II modeling and the Habitat Suitability Section.

JPOD

JPOD, as described in the Project Description and included in the SWRCB's D-1641, gives Reclamation and DWR the ability to use/exchange each Project's diversion capacity capabilities to enhance the beneficial uses of both Projects. There are a number of requirements outlined in D-1641 that restrict JPOD to protect Delta water quality and fisheries resources. The effects of JPOD are included in the CALSIM II modeling results and in the habitat suitability section.

500 cfs at Banks

Under the 500 cfs increased diversion, the maximum allowable daily diversion rate into CCF during the months of July, August, and September would increase from 13,870 AF up to 14,860 AF and three-day average diversions would increase from 13,250 AF up to 14,240 AF. This increased diversion over the three-month period would result in an amount not to exceed 90,000 AF each year. Maximum average monthly SWP exports during the three-month period from Banks Pumping Plant would increase to 7,180 cfs. Variations to hydrologic conditions coupled with regulatory requirements may limit the ability of the SWP to fully utilize the proposed increased diversion rate. Also, facility capabilities may limit the ability of the SWP to fully utilize the proposed increased diversion rate. This increased pumping may reduce the suitable habitat available for delta smelt and may result in entrainment of *Pseudodiaptomus* as described above.

NBA Diversion

The summer pumping rates of NBA diversions in study 7.0 (average rate was 115 cfs) was 18 percent lower than study 8.0 (average 135 cfs) (Chapter 12). The actual average June-August pumping in 2005-2007 was 109 cfs. Hydrodynamic modeling results from the Solano County Water Agency (SCWA) indicate that at recent (post-2004) actual pumping rates, the major water source pumped by the NBA during normal water years is Campbell Lake, a small non-tidal lake north of Barker Slough that receives local drainage. Thus under most summer-time conditions the entrainment effects are likely to have been low, especially since delta smelt move downstream by July (Nobriga et al. 2008). In dry seasons and at higher pumping rates described in Study 7 and the future Studies, the NBA entrains water from Barker and Lindsay sloughs (SCWA), indicating a potential entrainment risk for delta smelt. Historically, delta smelt densities have been low in Barker and Lindsay sloughs, but the modeling data suggest that delta smelt could exhibit some level of entrainment vulnerability. North Bay aqueduct diversions are

lowest in the fall (Chapter 12), averaging 101 cfs in study 7.0, and 123 in study 8.0. The actual average September through November pumping in 2005-2007 was 94 cfs. As discussed previously, delta smelt reside in the Suisun Bay to Sherman Island region during the fall months and are not likely to be entrained. Thus, there are no expected direct effects of the NBA on delta during this period. Because pumping rates are low and the hydrodynamic models indicate only a small percentage of water entrained enters from Barker Slough, it is unlikely the NBA has any measurable indirect effects during this period.

CCWD Diversions

The effects of CCWD diversions on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on effects of CCWD diversions in the larval and juvenile delta smelt section.

Temporary Agricultural Barriers

The effects of the TBP on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on effects of the TBP in the larval and juvenile delta smelt section.

Permanent Operable Gates

The effects of the permanent gates on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on the effects of the permanent operable gates in the larval and juvenile delta smelt section.

American River Demands

The effects of increased American River demands on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on increased American River demands in the larval and juvenile delta smelt section.

Delta Cross Channel

The effects DCC operations on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on the effects of the DCC in the larval and juvenile delta smelt section.

Entrainment Effects

Water Diversions and Reservoir Operations

Banks and Jones

Entrainment effects during July through November are not expected to be significant. Delta smelt are not present during this time of year, so direct entrainment during this time of year is not likely a concern.

Intertie

The effects the intertie on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on the effects of the intertie in the larval and juvenile delta smelt section.

Suisun Marsh Salinity Control Gates

The effects of the SMSCG on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on the effects of the SMSCG in the larval and juvenile delta smelt section.

Habitat Suitability (Sept-Dec)

All fishes depend on healthy suitable habitats to survive and reproduce. Because the upper San Francisco Estuary constitutes the sole habitat for delta smelt, a healthy suitable estuary and delta are critical to the long-term health and persistence of the species. The biological assessment and the Baseline section of this biological opinion provide details on the habitat requirements for the different life stages of delta smelt. This element of the Effects Analysis covers the effects of habitat for delta smelt during the fall months of September through December. During this time period, delta smelt are maturing pre-adults that rely heavily on suitable habitat conditions in the low salinity portion of the estuary. Suitable habitat for delta smelt during this time period can be briefly defined as the abiotic and biotic components of habitat that allow delta smelt to survive and grow to adulthood. Biotic components of habitat include suitable amounts of food resources and sufficiently low predation pressures. Abiotic components of habitat include the physical characteristics of water quality parameters, especially salinity and turbidity.

Interactions between the amount or area of suitable abiotic habitat available for delta smelt and the biotic components of habitat can have great consequences on density-dependent effects on population dynamics. Density-dependence is a fundamental concept in fish population dynamics. Compensatory density-dependence is a negative feedback on population size and therefore tends to stabilize the population (Rose et al. 2001). Depensatory density-dependence is a positive feedback on the population and

therefore tends to destabilize the population (Liermann and Hilborn 2001). Both of these mechanisms are important in delta smelt population dynamics. Compensatory density-dependence has been statistically detected in delta smelt at high population levels (Bennett 2005). However, the current record low levels of abundance of delta smelt make the species extremely vulnerable to the effects of depensatory density-dependence (Baxter et al. 2008).

Depensatory density-dependence can manifest in four ways: decreased probability of fertilization, impaired group dynamics, conditioning of the environment, and predator saturation (Liermann and Hilborn 2001). Patterns in the stock-recruit relationship since 2000 suggest that impaired group dynamics and the probability of fertilization are likely to be currently affecting the delta smelt population (Allee effects; Baxter et al. 2008). As discussed below, there is substantial evidence to suggest that delta smelt is vulnerable to environmental conditioning and predator saturation because the amount of suitable abiotic habitat for maturing pre-adult delta smelt has been seriously depleted and stabilized by CVP/SWP operations. The fact that delta smelt are subject to the effects of all four elements of depensatory density-dependence creates a situation where it might be extremely difficult for the population to recover under the present environmental conditions in the Estuary.

The Service's examination of habitat suitability during fall is derived from published literature and unpublished information linking X2 to the amount of suitable abiotic habitat for delta smelt (Feyrer et al 2007, 2008). Under balanced conditions, CVP/SWP operations control the position of X2 and therefore are a primary driver of delta smelt habitat suitability. As a result, this analysis relies on the effects of proposed CVP/SWP operations on fall X2, how that affects the surface area of suitable abiotic habitat for delta smelt, and finally how that affects delta smelt abundance given current delta smelt population dynamics. Supporting background material on the effect of fall X2 on the amount of suitable abiotic habitat and delta smelt abundance is available in Feyrer et al. (2007, 2008).

During the fall, when delta smelt are nearing adulthood, the amount of suitable abiotic habitat for delta smelt is positively associated with X2. This results from the effects of Delta outflow on salinity distribution throughout the Estuary. Fall X2 also has a measurable effect on recruitment of juveniles the following summer in that it has been a significant covariate in delta smelt's stock-recruit relationship since the invasion of the overbite clam. Potential mechanisms for the observed effect are two-fold. First, positioning X2 seaward during fall provides a larger habitat area which presumably lessens the likelihood of density-dependent effects (e.g., food availability) on the delta smelt population. Second, a more confined distribution may increase the impact of stochastic events that increase mortality rates of delta smelt. For delta smelt, this includes predation and anthropogenic effects such as contaminants and entrainment (Sommer et al. 2007).

This evaluation of habitat suitability considered three specific elements: X2, total area of suitable abiotic habitat, and the predicted effect on delta smelt abundance the following

summer. Effects of proposed CVP/SWP operations were determined by comparing X2, the area of suitable abiotic habitat, and the effect of these two variables on delta smelt abundance across the operational scenarios characterized by the CALSIM II model runs, and also as they compare to actual historic values from 1967 to the present. The modeled scenarios include: Study 7.0, Study 7.1, Study 8.0, and Studies 9.0-9.5. This section concludes with additional observations of the historic and modeled data with a discussion of the potential underlying mechanisms.

X2

The first step of the evaluation examined the effect of proposed CVP/SWP operations on X2 (km) during fall, as determined by the CALSIM II model results. These model results are presented in a monthly time step and are provided in the appendices to the biological assessment. In order to be consistent with previous analyses (Feyrer 2007, 2008), X2 during the fall was calculated as the average of the monthly X2 values from September through December obtained from the CALSIM II model results. The data were also differentiated by WY type according to that of the previous spring.

The median X2 across the CALSIM II modeled scenarios were 10-15 percent further upstream than actual historic X2 (Figure E-19). Median historic fall X2 was 79km, while median values for the CALSIM II modeled scenarios ranged from 87 to 91km. The CALSIM II modeled scenarios all had an upper range of X2 at about 90km. The consistent upper cap on X2 shows that water quality requirements for the Delta ultimately constrain the upper limit of X2 in the simulations. These results were also consistent across WY types (Figure E-19) with the differences becoming much more pronounced as years became drier. Thus, the proposed action operations will affect X2 by shifting it upstream in all years, and the effect is exacerbated in drier years.

Area of Suitable Abiotic Habitat

The second step of the evaluation used the modeled X2 to estimate the total surface area of suitable abiotic habitat available for delta smelt. Feyrer et al. (2008) examined three different definitions of habitat suitability for delta smelt that were subsequently used to generate the hectares (ha) of suitable abiotic habitat. The three habitat criteria examined by Feyrer et al. (2008) were based on the statistical probability of delta smelt occurring in a sample due to water salinity and clarity characteristics at the time of sampling. The probabilities of occurrence they examined and compared were $\geq$ 10 percent, $\geq$ 25 percent, and $\geq$ 40 percent. This evaluation applied their intermediate definition of 25 percent to avoid potentially over- or under-estimating the effect. The quantitative model relating X2 to area of suitable abiotic habitat is presented in Figure E-20.

The median amounts of suitable abiotic habitat based upon X2 values generated across the CALSIM II modeled scenarios were 49-57 percent smaller than that predicted by actual historic X2 (Figure E-21). The median historic amount of suitable abiotic habitat was 9,164 ha, while median values for the CALSIM II modeled scenarios ranged from 3,995 to 4,631 ha. These results were also consistent across WY types (Figure E-21),

with the differences becoming much more pronounced in drier years. Thus, the proposed action operations affect the amount of suitable abiotic habitat by decreasing it as a result of moving X2 upstream, and the effect is exacerbated in drier years.

Effect on Delta Smelt Abundance

The third step of the evaluation was to use the modeled X2 to estimate the effect on delta smelt abundance. The model relating X2 to delta smelt abundance was updated from that developed by Feyrer et al. (2008) by adding the most recent year of available data (Figure E-22). This model incorporates X2 as a covariate in the standard stock-recruit (FMWT index-TNS index the following year; Bennett (2005)) relationship for delta smelt. The model is based on data available since 1987 and therefore represents current delta smelt population dynamics (Feyrer et al. 2007). Note that although the regression model is highly significant and explains 56 percent of the variability in the data set, the residuals are not normally distributed. The pattern of the residuals suggests that some type of transformation of the data would help to define a better fitting model (Figure E-22). This analysis did not explore different data transformations. For generating predictions, the FMWT values in the model were held constant at 280, the median value over which the model was built. This was done for all iterations in order to make the results comparable across the scenarios examined. In plots that show "historic" TNS categories, the values are those predicted with the model using actual historic X2 values from 1967 to the present. This approach was necessary in order to examine the likely effects of the different scenarios on present-day delta smelt population dynamics.

The median values for the predicted TNS index based upon X2 values generated across the CALSIM II modeled scenarios were 60-80 percent smaller than those predicted from actual historic X2 (Figure E-23). The median value for the TNS index predicted based upon historic X2 was 5, while median values predicted from X2 values generated from the CALSIM II modeled scenarios ranged from 1 to 2. These results were also consistent across WY types (Figure E-23) with the differences becoming much more pronounced as years became drier. Thus, the proposed action operations are likely to negatively affect the abundance of delta smelt.

Additional Long-term Trends and Potential Mechanisms

There has been a long-term shift upstream for actual X2 during fall that is associated with a similar upstream shift in the E:I ratio (Figure E-24). X2 is largely determined by Delta outflow, which in turn is largely determined by the difference between total delta inflow and the total amount of water exported, commonly referred to as the E:I ratio. During fall, the E:I ratio directly affects X2, slightly less so when the E:I ratio reaches approximately 0.45 (Figure E-24). The leveling off is due to the need to meet D-1641 salinity standards. Thus, the long-term positive trend in X2 and the associated negative affects on area of suitable abiotic habitat and predicted delta smelt abundance appear to be related to the long-term positive trend in E:I ratio. X2 in the time series for each of the

CALSIM II model runs is even greater than the peak of the actual historic values (Figure E-25). Based on the proposed operations, the upstream X2 shift will persist.

While the above results demonstrate the likely effects of project operations on X2 averaged over the fall period, the modeling scenarios indicate that X2 in individual months will vary by WY type classification and by the specific modeling scenario (Figure E-26). In wetter years of Studies 7.0, 7.1, and 8.0 (wet and above average WY types), X2 tends to diverge from historic conditions in that it shifts upstream in September, October, and November, and shifts downstream in December. This pattern is much less pronounced in the climate change scenarios, Studies 9.0-9.5. In all model studies there is also a general decrease in interannual variability across all of the months. In drier years (below normal to critical WY types), the model scenarios indicate that for all months X2 will generally be shifted upstream and that much of the interannual historic variability will be lost.

The effects of project operations outlined above on X2 during the fall months have considerably altered the hydrodynamics of the estuary in two important ways other than which have already been described. First, the long-term upstream shift in fall X2 has created a situation where all fall seasons regardless of WY type now resemble dry or critical years (Figure E-27). In other words, all fall seasons have now been converted into uniform, low flow periods. Second, the effects have also manifested in a divergence between X2 during fall and X2 during the previous spring (April-July spring averaging period), and the modeling studies indicate this condition will persist in the future (Figure E-28).

Combined, these effects of project operations on X2 will have significant adverse direct and indirect effects on delta smelt. Directly, these changes will substantially decrease the amount of suitable abiotic habitat for delta smelt, which in turn has the possibility of affecting delta smelt abundance through the depensatory density-dependant mechanisms outlined above. Because current abundance estimates are at such historic low levels, depensatory density-dependence can be a serious threat to delta smelt despite the fact that the population may not be perceived to be habitat limited. It is clear from published research that delta smelt has become increasingly habitat limited over time and that this has contributed to the population declining to record-low abundance levels (Bennett 2005; Baxter et al. 2008; Feyrer et al. 2007, 2008; Nobriga et al. 2008). Therefore, the continued loss and constriction of habitat proposed under future project operations significantly threatens the ability of a self-sustaining delta smelt population to recover and persist in the Estuary at abundance levels higher than the current record-lows.

Indirectly, changes such as the extremely stable low outflow conditions resembling dry or critical years proposed for the fall across all WY types will likely a) contribute to higher water toxicity (Werner et al. 2008) because the proposed flows are always low in all WY types, b) contribute to the potential suppression of phytoplankton production by ammonia entering the system from wastewater treatment plants (Wilkerson et al. 2006; Dugdale et al. 2007) because diluting flows are minimal, c) increase the reproductive success of overbite clams allowing them to establish year-round populations further east because

salinity is consistently high with low variability (Jan Thompson, USGS, unpublished data), d) correspond with high E:I ratios resulting in elevated entrainment of lower trophic levels, e) increase the frequency with which delta smelt encounter unscreened agricultural irrigation diversions in the Delta (Kimmerer and Nobriga 2008) because the eastward movement of X2 will shift the distribution of delta smelt upstream, and provide environmental conditions for nonnative fishes that thrive in stable conditions (Nobriga et al. 2005). Although there is no single driver of delta smelt population dynamics (Baxter et al. 2008), these indirect effects will exacerbate any direct effects on delta smelt and hinder the ability of the population to recover and maintain higher levels of abundance in the future (Bennett and Moyle 1996; Bennett 2005; Feyrer et al. 2007).

American River Demands

The effects of increased American River demands on delta smelt during the summer and fall would be similar to those described for larval and juvenile delta smelt. See previous effects discussion on the effects of increased American River demands in the larval and juvenile delta smelt section.

Komeen Treatment

The Department of Boating and Waterways (DBW) prepared an Environmental Impact Report (2001) for a two-year Komeen research trial in the Delta. They determined there were potential effects to fish from Komeen treatment despite uncertainty as to the likelihood of occurrence. Uncertainties exist as to the direct impact that Komeen and Komeen residues may have on fish species. “The target concentration of Komeen is lower than that expected to result in mortality to most fish species, including delta smelt.” However, there is evidence that, at target concentrations, Komeen could adversely impact some fish species. The possibility exists that Komeen concentrations could be lethal to some fish species, especially during the first nine hours following application. Although no tests have examined the toxicity of Komeen to Chinook salmon, LC50 data for rainbow trout suggest that salmonids would not be affected by use of Komeen at the concentrations proposed for the research trials. No tests have been conducted to determine the effect of Komeen on splittail, green sturgeon, pacific lamprey or river lamprey.” (DBW, 2001) or delta smelt.

In 2005, no fish mortality or stressed fish were reported during or after the treatment. The contractor, Clean Lakes, Inc was looking for dead fish during the Komeen application. In addition, no fish mortality was reported in any of the previous Komeen or Nautique applications. In 2005, catfish were observed feeding in the treatment zone at about 3 PM on the day of the application (Scott Schuler, SePro). No dead fish were observed. DWR complied with the NPDES permit that requires visual monitoring assessment. Due to the uncertainty of the impact of Komeen on fish that may be in the Forebay, we will assume that all delta smelt in the Forebay at the time of application are taken. The daily loss values vary greatly within treatments, between months and between years. Figure E-29 illustrates the presence of delta smelt in the Forebay during treatments. There are no loss

estimates for delta smelt, so the relationship between salvage and true loss of delta smelt in the Forebay in unknown. However, since the treatments will only be during July and August, delta smelt are not expected to be present in the Forebay during this time, so adverse effects to delta smelt are unlikely.

Effects to Delta Smelt Critical Habitat

Primary Constituent Elements

Due to the interrelationship between the PCEs and the intended conservation role they serve for different delta smelt life stages, some effects are similar and overlap across the PCEs. For instance, Delta outflow determines the extent and location of the LSZ and the areas of physical habitat delta smelt are able to utilize at all times of the year. Therefore, many of the effects described below for the PCEs are difficult to separate so some effects are repeated for multiple PCEs.

Spawning Habitat

PCE 1 – Physical Habitat

Delta smelt require physical habitat only during spawning. The major impact to spawning habitat from the CVP/SWP projects would be from dredging proposed as part of construction of the South Delta Improvements Program Stage 1. However, any dredging activities will be covered through a separate section 7 consultation. Upstream reservoirs such as Shasta, Folsom and Oroville Dams reduce gravel and sediment recruitment into the rivers and estuary. However, this impact is expected to remain relatively unchanged for delta smelt. The TBP will impact the physical habitat during the construction of the barriers which again is not covered within this biological opinion.

PCE 2 – Water

As described in the Effects Section, the CVP/SWP alter the hydrologic conditions within spawning habitat throughout the spawning period for delta smelt by impacting various abiotic factors including the distributions of turbidity, food, and contaminants. Article 21, DMC-CA Intertie, NBA, and CCWD Diversions effects are included within the affects of the CVP/SWP. The TBP and the SMSCG modify circulation within the Delta and Suisun Marsh which may have a small impact on delta smelt spawning habitat. The South Delta Permanent Operable Gates should have less of an impact than the TBP if operated only within the time period, as described in the Project Description.

PCE 3 – River Flow

The CVP and SWP, as analyzed in the Effects Section, directly influence the location and the amount of suitable spawning habitat, especially in drier WYs . Further, through upstream depletions and alteration of river flows, the CVP/SWP has played a role in altering the environment of the Delta. This has resulted in adverse effects to delta smelt spawning habitat availability and may mobilize contaminants. The contaminant effects may be generated or diluted by flow depending on the amount of flow, the type of contaminant, the time of the year, and relative concentrations.

Article 21 has increased in total volume recently (see Baseline section). This increase of pumping for Article 21 has occurred in December through March which coincides with the spawning of delta smelt. The DMC-CA Intertie, NBA, and CCWD Diversions are smaller diversions that are captured within the effects of the CVP/SWP. As described in the Project Description, CCWD operations are managed for fishery concerns during the spawning and rearing period for delta smelt through the no-fill and no-diversion requirements.

PCE 4 – Salinity

The LSZ expands and moves downstream when river flows are high. By capturing river flows, reservoirs can contribute to upstream movement of the LSZ which reduces habitat quality and quantity. Banks and Jones pumping likewise can result in upstream movement of the LSZ. Model results in the biological assessment show that in the future the location of the LSZ will generally be further upstream than occurred historically. This will result in a reduction in the amount and quality of spawning habitat available to delta smelt. These changes are primarily due to proposed future increases in upstream depletions and changes to reservoir operations and export pumping from the CVP/SWP.

Habitat quality will continue to be adversely affected by contaminants and increasing numbers of non-native invasive species.

Larval and Juvenile Transport

PCE 1 – Physical Habitat

Physical habitat is needed only during the spawning season and is not associated with larval and juvenile transport.

PCE 2 – Water

As described in the Effects Section, the CVP/SWP alter the hydrologic conditions within

spawning habitat throughout the spawning period for delta smelt by impacting various abiotic factors including distributions of turbidity, food, and contaminants. Article 21, DMC-CA Intertie, NBA, and CCWD Diversions effects are included within the effects of the CVP/SWP. The TBP and the SMSCG modify circulation within the Delta and Suisun Marsh which may have a small impact on delta smelt spawning habitat. The South Delta Permanent Operable Gates should have less of an impact than the TBP if operated only within the time period, as described in the Project Description.

PCE 3 – River Flows

The CVP/SWP, as analyzed in the Effects Section, directly influence river flows especially in years when releases from CVP/SWP reservoirs make up a higher percentage flows into the Delta from the Sacramento River.

In addition, pumping at Banks and Jones can alter flows within the Delta. This results in a corresponding alteration of larval and juvenile transport. Instead of tidal and downstream transport within suitable rearing areas, operations result in upstream transport that entrains delta smelt. Since the water exported during the spring and early summer (mainly March-June) from the Central and South Delta is suitable habitat, the effect of the action results in loss of suitable habitat. Unfortunately, young delta smelt do not have a cue to abandon areas where water is flowing toward Banks and Jones.

Reservoir releases and export reductions during VAMP have resulted in enhanced survival of delta smelt. However, the future of VAMP is uncertain.

The TBP increases the flux of delta smelt into the zone of entrainment. As described in the Effects Section, significant entrainment of delta smelt has occurred when the TBP operates coincident with high export levels. The South Delta Permanent Operable Gates should have less impact than the TBP if operated only within the time period specified in the Project Description (April 15-May 15 for the HOR Gate and April 15-November 30 for the flow control gates). The SMSCG can alter flows that interrupt the transport of larval and juvenile delta smelt in Montezuma Slough and Suisun Marsh when the SMSCG is closed.

PCE 4 – Salinity

As described previously, the CVP/SWP alters the location of the LSZ by modifying both the Sacramento and San Joaquin river flows which reduces habitat quality and quantity. Model results in the biological assessment show the location of the LSZ will be further upstream in the future than occurred historically. This will result in less suitable habitat for larval and juvenile delta smelt. These changes are primarily due to proposed future increases in upstream depletions and changes to reservoir operations. In addition, habitat quality will continue to be adversely affected by many associated factors like non-native invasive species and contaminants. The SMSCG, when in operation, modifies the salinity within Suisun Marsh and when in operation, there can be upstream movement of X2.

However, the SMSCG have been operated less frequently in recent years.

Rearing Habitat

PCE 1 – Physical Habitat

Physical habitat is needed only during the spawning season and is not associated with rearing habitat.

PCE 2 – Water

As described in the Effects Section, the CVP/SWP alter the hydrologic conditions within rearing habitat throughout the spawning period for delta smelt by impacting various abiotic factors including distributions of turbidity, food, and contaminants. Article 21, DMC-CA Intertie, NBA, and CCWD Diversions effects are included within the effects of the CVP/SWP. As described in the Project Description, CCWD operations are managed during the spawning and rearing period for delta smelt through the no-fill and no-diversion requirements. The TBP and the Suisun Marsh Salinity Control Gates modify circulation within the Delta and Suisun Marsh which may have a small adverse impact on delta smelt rearing habitat. The South Delta Permanent Operable Gates should have less of an adverse impact than the TBP if operated only within the time period (April 15-May 15 for the HOR Gate and April 15-November 30 for the flow control gates), as described in the Project Description.

PCE 3 – River Flows

The CVP and SWP, as analyzed in the Effects Section, directly influence river flows.

Pumping at Banks and Jones alters flows within the Delta. As described in the Effects Section, negative flows can result in an increase risk of entrainment when rearing habitat includes the South Delta. In addition, when rearing habitat includes the Central and South Delta, as temperatures increase in May and June, altered river flows can further degrade rearing habitat suitability. Rearing habitat in the South Delta may also be impacted indirectly through increases in contaminant concentrations and entrainment of zooplankton.

The TBP alter flows within rivers and channels which can increase the risk of entrainment. As described in the Effects Section, in the past with operation of the TBP and with high export levels, significant spikes in delta smelt entrainment have occurred at Jones and Banks. The South Delta Permanent Operable Gates should have less impact than the TBP if operated only within the time period (April15-May 15 for the HOR Gate and April 15-November 30 for the flow control gates), as described in the Project Description. The SMSCG can alter flows that interrupt and alter flows in Montezuma

Slough and Suisun Marsh when the SMSCG is closed.

PCE 4 – Salinity

As stated previously, the CVP/SWP alters the extent and location of the LSZ by modifying both the Sacramento and San Joaquin river flows which reduces habitat quality and quantity. Model results in the biological assessment show that in the future the location of the LSZ will be further upstream in the future than occurred historically. This will result in less suitable habitat for larval and juvenile delta smelt. These changes are primarily due to proposed future increases in upstream depletions and changes to reservoir operations and exports at Banks and Jones. In addition, habitat quality will continue to be adversely affected by mobilizing and concentrating contaminants within the Delta and creating hydrologic conditions that favor non-native invasive species over native species. The SMSCG, when in operation, modifies the salinity within Suisun Marsh and when the SMSCG is in operation there can be upstream movement of X2. However, the Gates have been operated less frequently in recent years.

Adult Migration

PCE 1 – Physical Habitat

Physical habitat is needed only during the spawning season and is not associated with adult migration per se.

PCE 2 – Water

As described previously, the CVP/SWP alters Delta hydrodynamics in ways that adversely affect delta smelt migration. Article 21, DMC-CA Intertie, NBA, and CCWD Diversions effects are included within the affects of the CVP/SWP. The TBP and the SMSCG modify circulation within the Delta and Suisun Marsh which may have a small impact on delta smelt migration. The South Delta Permanent Operable Gates should have less of an impact than the TBP if operated only within the time period, as described in the Project Description.

PCE 3 – River Flows

The CVP and SWP, as analyzed in the Effects Section, directly influence river flows especially during low flow periods when releases from CVP and SWP reservoirs make up a higher percentage of river flows into the Delta from the Sacramento River.

River flows in combination with an increase in turbidity cues the upstream migration of delta smelt for spawning.

In addition, Banks and Jones can alter flows within rivers and channels within the Delta. These alterations can interrupt the migration of pre-spawning and spawning adult delta smelt resulting in entrainment of delta smelt. As described in the Effects Section, adult entrainment is likely to be higher than it has been in the past under most operating scenarios, resulting in lower potential production of larval and juvenile delta smelt.

The South Delta Permanent Operable Gates would only have adverse effect to adult migration if they are operated during the winter months. The SMSCG can alter flows that interrupt movements of adult delta smelt in Montezuma Slough and Suisun Marsh when the gate is closed.

PCE 4 – Salinity

The CVP/SWP alters the location of the LSZ by modifying both the Sacramento and San Joaquin river flows which reduces habitat quality and quantity. Model results in the biological assessment show that in the future the location of the LSZ will be further upstream than occurred historically. This will result in less suitable habitat for pre-spawning and spawning delta smelt. These changes are primarily due to the proposed future increases in upstream depletions and changes to reservoir operations. The SMSCG, when in operation, modifies the salinity within Suisun Marsh and when the Gates is in operation there can be upstream movement of X2. However, the Gates have been operated less frequently in recent years.

Summary of Effects of the Action on Delta Smelt Critical Habitat

Implementation of the proposed action, primarily the volume of diversions at Banks and Jones relative to proposed Delta inflows, will prevent critical habitat from serving its intended conservation role. It is imperative that suitable habitat conditions, as defined by the co-occurring PCEs, immediately be provided over the designated critical habitat. This is based on the extremely low numbers of delta smelt; their annual life cycle, and the fact that delta smelt spend their entire life within the influence of the CVP/SWP. The proposed actions only provide as conservation measures VAMP and flows from the Yuba Water Accord (identified in the Project Description as “limited EWA”). In the past, VAMP has benefited delta smelt. However, equivalent flows may not be provided in all WYs.

Cumulative Effects

Cumulative effects include the effects of future State, Tribal, local, or private actions that are reasonably certain to occur in the area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section, because they require separate consultation pursuant to section 7 of the Act.

On-going non-Federal diversions of water within the action area (e.g., municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands) are not likely to entrain very many delta smelt based on the results of a study by Nobriga et al. (2004). Nobriga et al. reasoned that the littoral location and low-flow operational characteristics of these diversions reduced their risk of entraining delta smelt. A study of the Morrow Island Distribution System by DWR produced similar results, with one demersal species and one species that associates with structural environmental features together accounting for 97-98 percent of entrainment; only one delta smelt was observed to be entrained during the two years of the study (DWR 2007).

State or local levee maintenance may also destroy or adversely affect delta smelt spawning or rearing habitat and interfere with natural, long term spawning habitat-maintaining processes. Operation of flow-through cooling systems on the Mirant electrical power generating plants that draw water from and discharge into the action area may also adversely affect delta smelt in the form of entrainment and locally increased water temperatures.

Adverse effects to delta smelt and its critical habitat may result from point and non-point source chemical contaminant discharges within the action area. These contaminants include, but are not limited to ammonia and free ammonium ion, numerous pesticides and herbicides, and oil and gasoline product discharges. Oil and gasoline product discharges may be introduced into Delta waterways from shipping and boating activities and from urban activities and runoff. Implicated as potential stressors of delta smelt, these contaminants may adversely affect fish reproductive success and survival rates.

Two wastewater treatment plants (one located on the Sacramento River near Freeport and the other on the San Joaquin River near Stockton) have received special attention because of their discharge of ammonia. The Sacramento Regional County Sanitation District (SRCSD) wastewater treatment facility near Freeport discharges more than 500,000 cubic meters of treated wastewater containing more than 10 tons of ammonia into the Sacramento River each day (http://www.sacbee.com/378/story/979721.html). Preliminary studies commissioned by the IEP POD investigation and the Central Valley Regional Water Quality Control Board are evaluating the potential for elevated levels of Sacramento River ammonia associated with the discharge to adversely affect delta smelt and the Delta ecosystem. The Freeport location of the SRCSD discharge places it upstream of the confluence of Cache Slough and the mainstem Sacramento River, a location just upstream of where delta smelt have been observed to congregate in recent years during the spawning season. The potential for exposure of a substantial fraction of delta smelt spawners to elevated ammonia levels has heightened the importance of this investigation. Ammonia discharge concerns have also been expressed with respect to the City of Stockton Regional Water Quality Control Plant, but its remoteness from the parts of the Estuary frequented by delta smelt and its recent upgrades suggest that it is more a potential issue for migrating salmonids than for delta smelt.

Other future, non-Federal actions within the action area that are likely to occur and may adversely affect delta smelt and its critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; construction and maintenance of golf

courses that reduce habitat and introduce pesticides and herbicides into the aquatic environment; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; agricultural activities, including burning or removal of vegetation on levees that reduce riparian and wetland habitats that contribute to the quality of habitat used by delta smelt; and livestock grazing activities that may degrade or reduce riparian and wetland habitats that contribute to the quantity and quality of habitat used by delta smelt.

Future actions that implement planning efforts such as the Bay-Delta Conservation Plan or the Governor's Delta Vision may have adverse effects to delta smelt or its critical habitat, but these projects would have a federal nexus and would be the subject of future ESA consultations, as appropriate.

Figures referenced in the Effects Section

Figure E-1. Relationship between average December-March flow in Old and Middle rivers and the salvage of delta smelt in the same averaging period.

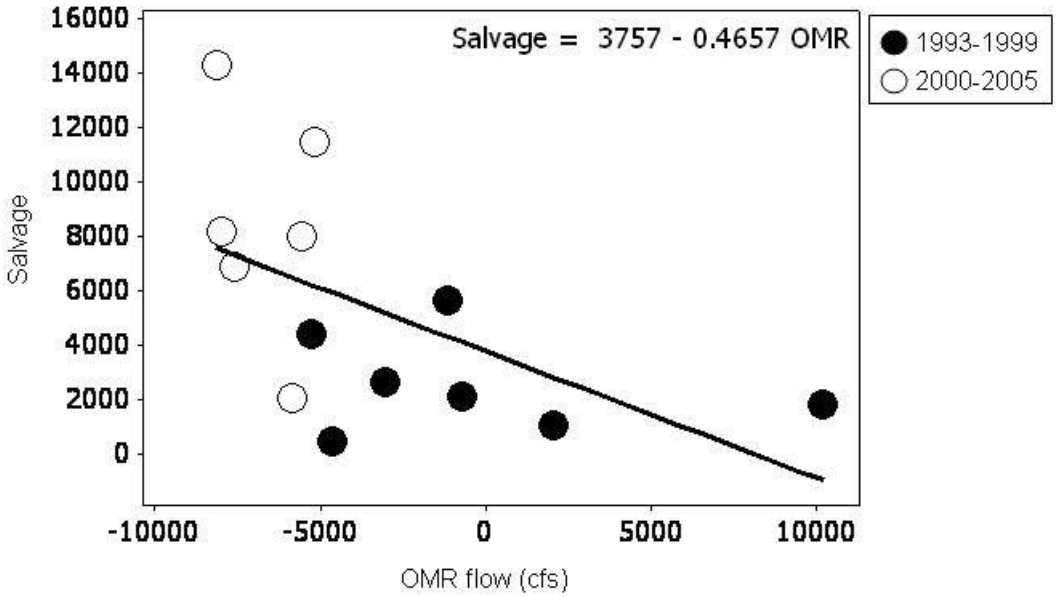


Figure E-2. Average winter (Dec-Mar) OMR flow (A), total Delta inflow (B), and combined SWP/CVP exports (C) by year. The data were fitted with lowess splines to show trends.

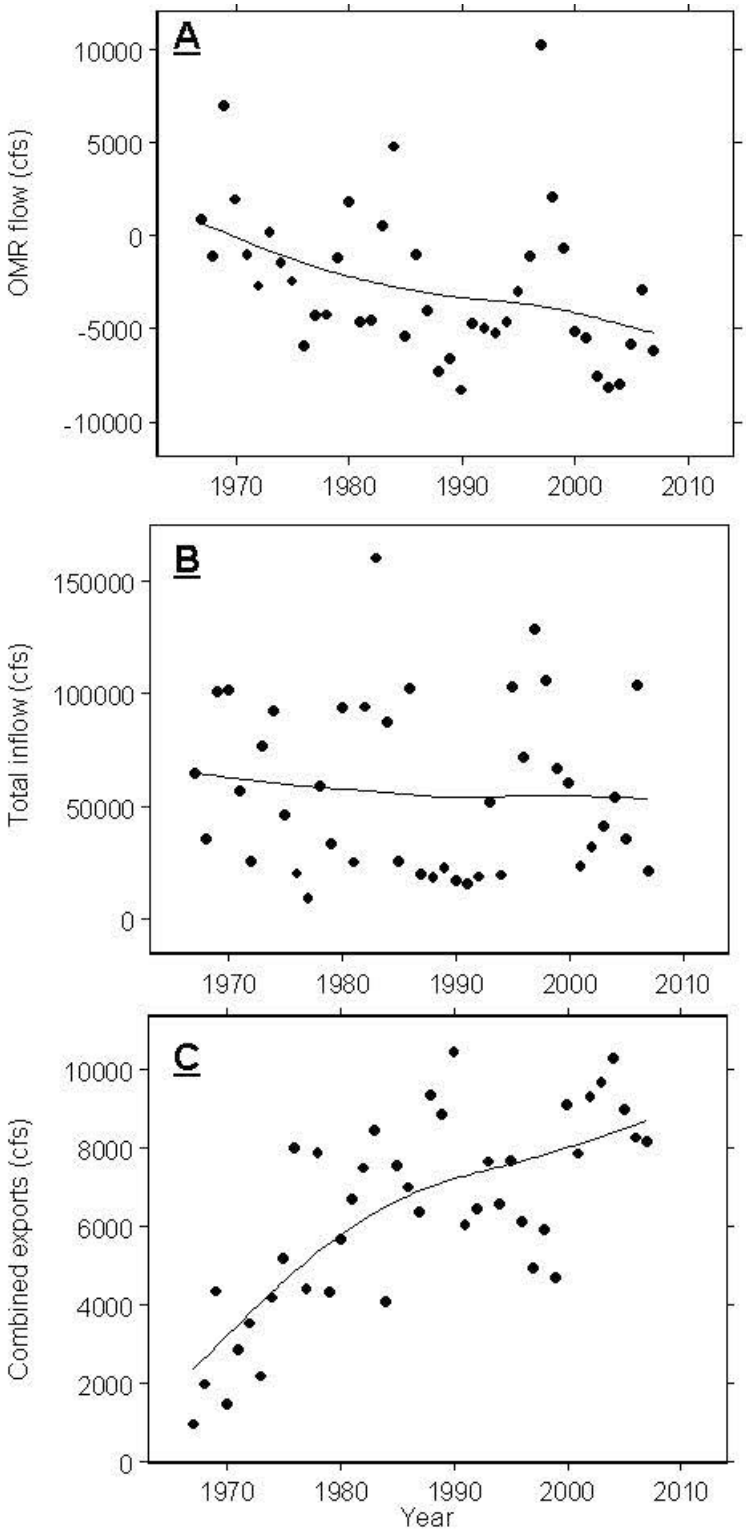


Figure E-3. Boxplot summary of CALSIM II operations study outputs of average winter (Dec-Mar) OMR flow for five water year types and the actual historic data (1967-2007). The boxes depict the interquartile range which is the distance between the 25th and 75th percentiles.

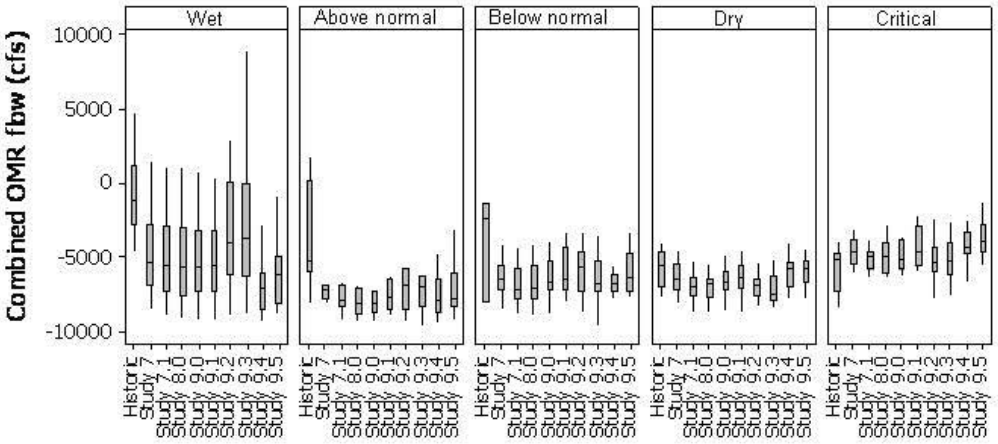


Figure E-4. Time series of estimated percentages (with 95 percent error bars) of the adult delta smelt population entrained in the SWP and CVP South Delta water export diversion facilities estimated from Kimmerer (2008). OMR flow is plotted on the secondary y-axis.

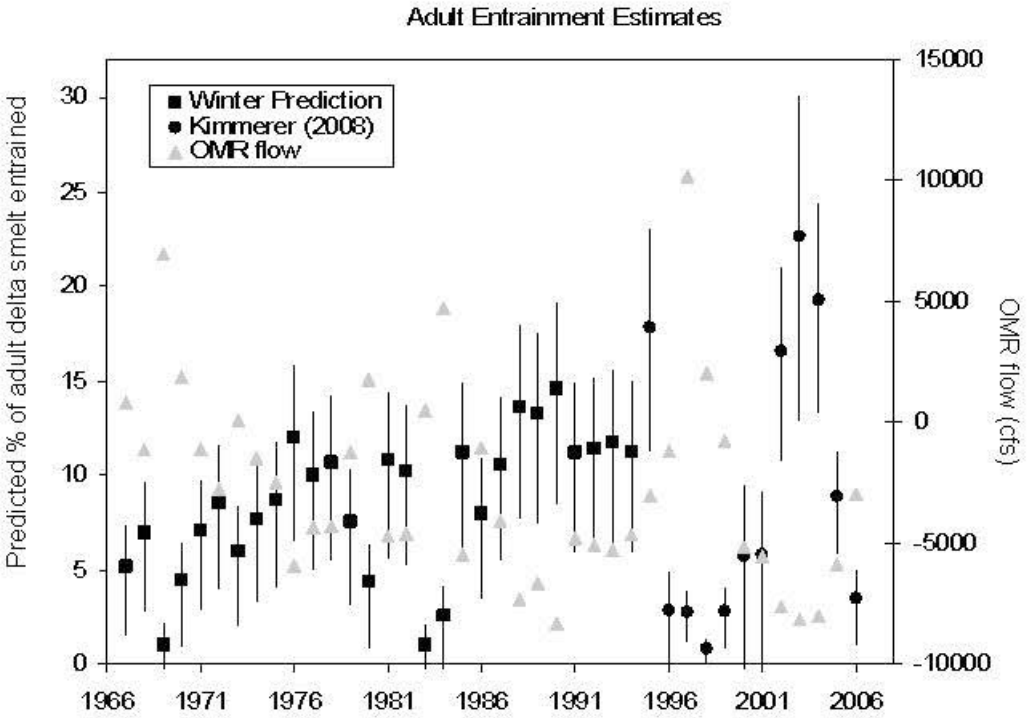


Figure E-5. Frequency distribution of predicted adult delta smelt entrained at Banks and Jones for predicted estimates from historic data (1967-1994), actual estimates from Kimmerer (2008) for years 1995-2006, and those estimated from CALSIM II model data by study.

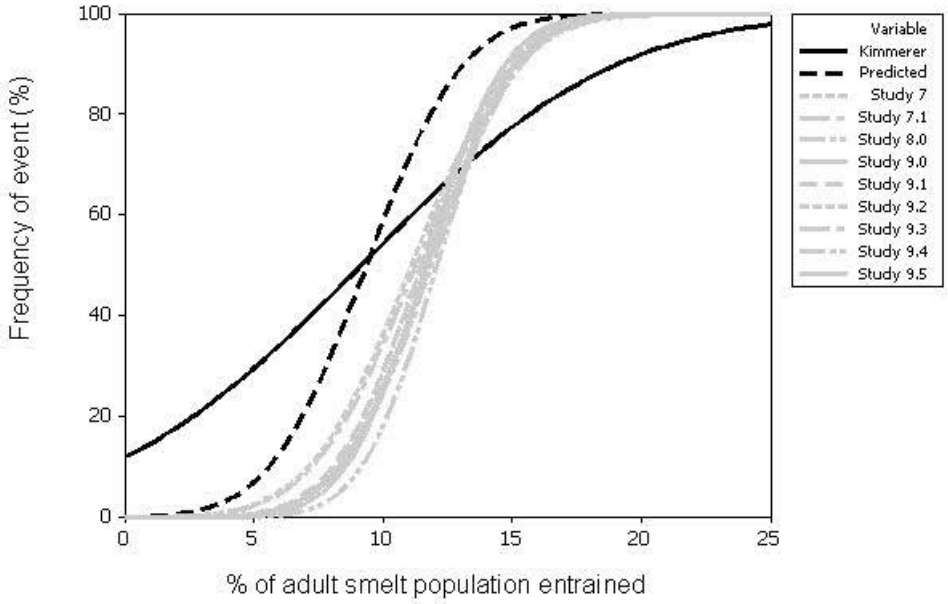


Figure E-6. Same as E-5 but by water year type. Kimmerer (2008) estimates did not include below normal or critical dry water year types.

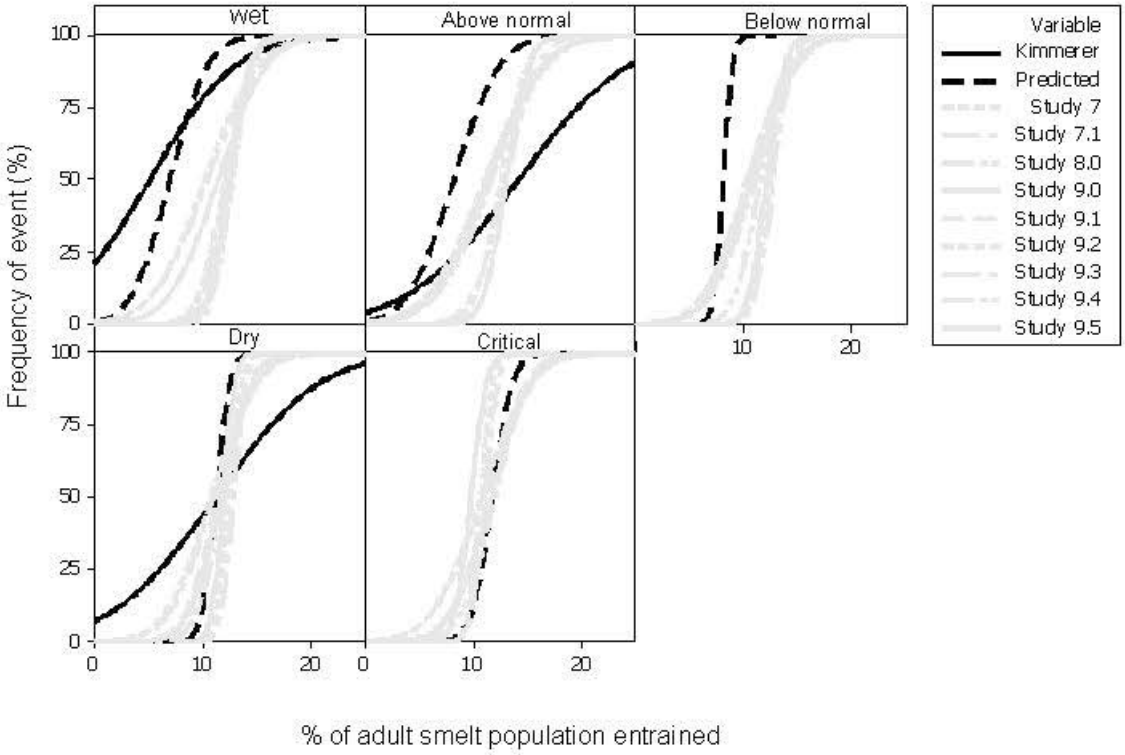


Figure E-7. Scatterplot of average flow in Old and Middle rivers (upper panel = March – June; lower panel = April – May) and the percentage of the larval and juvenile delta smelt population entrained in the SWP and CVP export pumps. The entrainment estimates were taken from Kimmerer (2008). The bubble sizes are scaled to the average Delta outflow for the same averaging periods as the OMR flows.

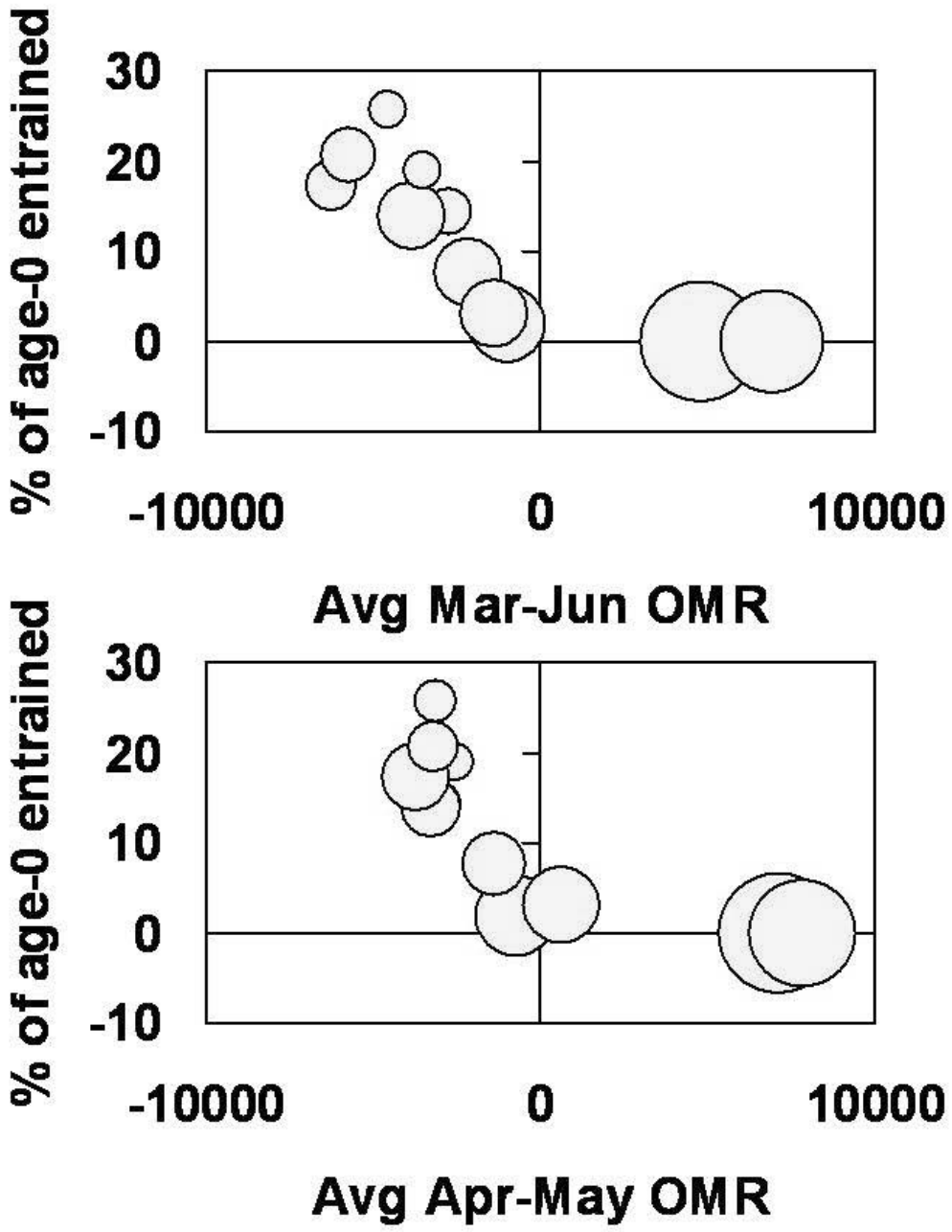


Figure E-8. Time trend in average March – June flow Old and Middle river flow, 1967-2007. Data for 1980-2006 are empirical data based on ADCP measurements. Data for 1967-1979 and 2007 are estimated as described in the text. The spline is a LOWESS regression
line.

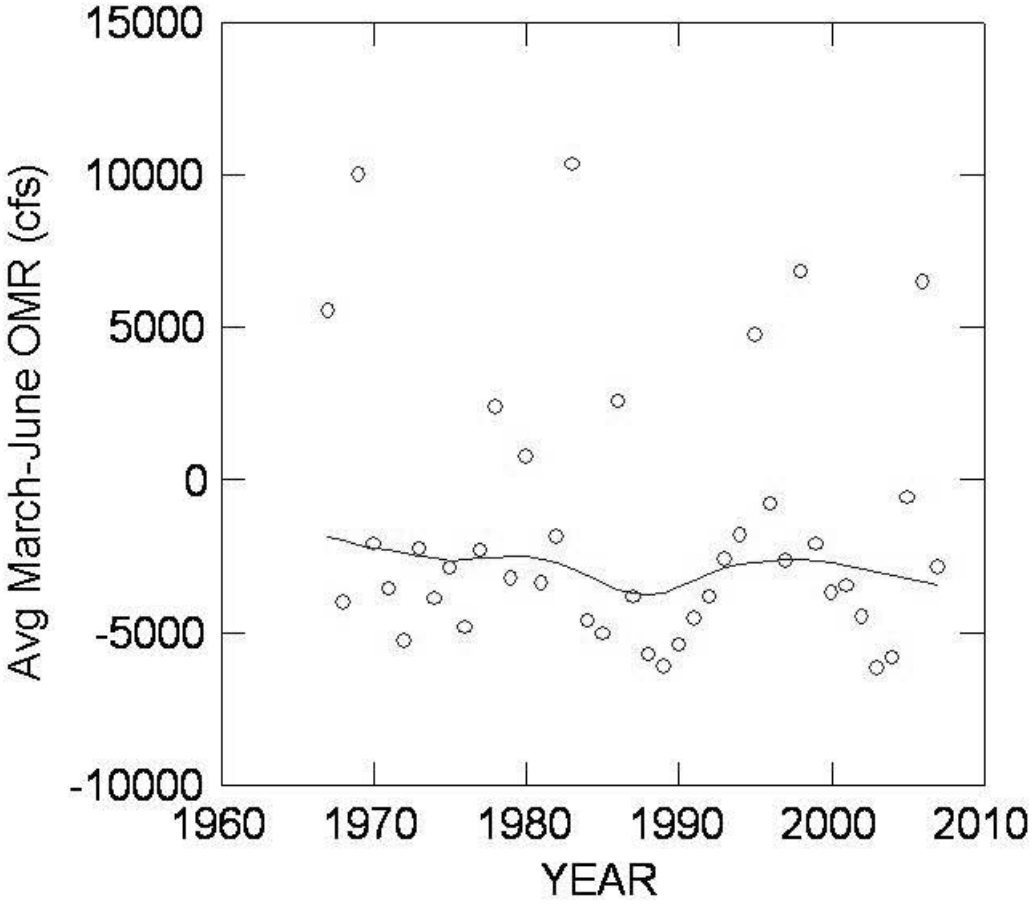


Figure E-9. Time trend in average April-May OMR flow, 1967-2007. Data for 1980-2006 are empirical data based on ADCP measurements. Data for 1967-1979 and 2007 are estimated as described in the text. The spline is a LOWESS regression line.

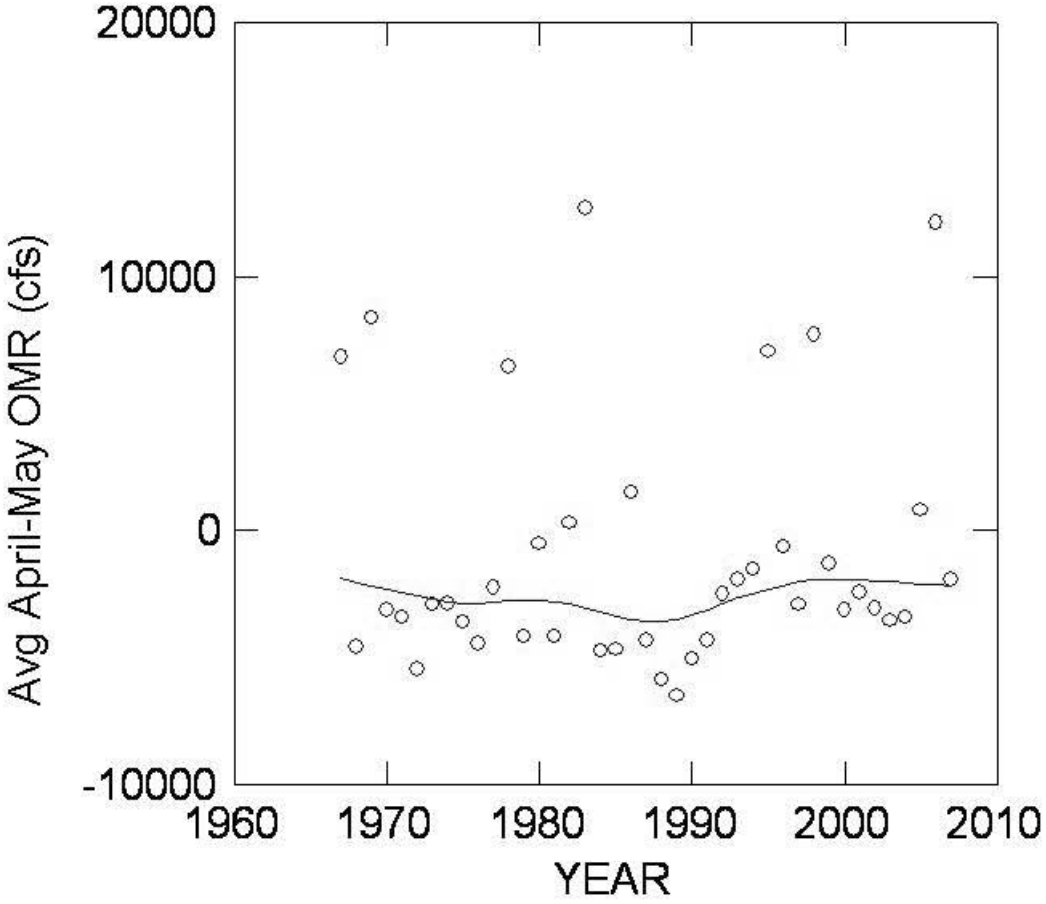


Figure E-10. Time trend in average March – June Delta outflow, 1967-2007. The spline is a LOWESS regression line.

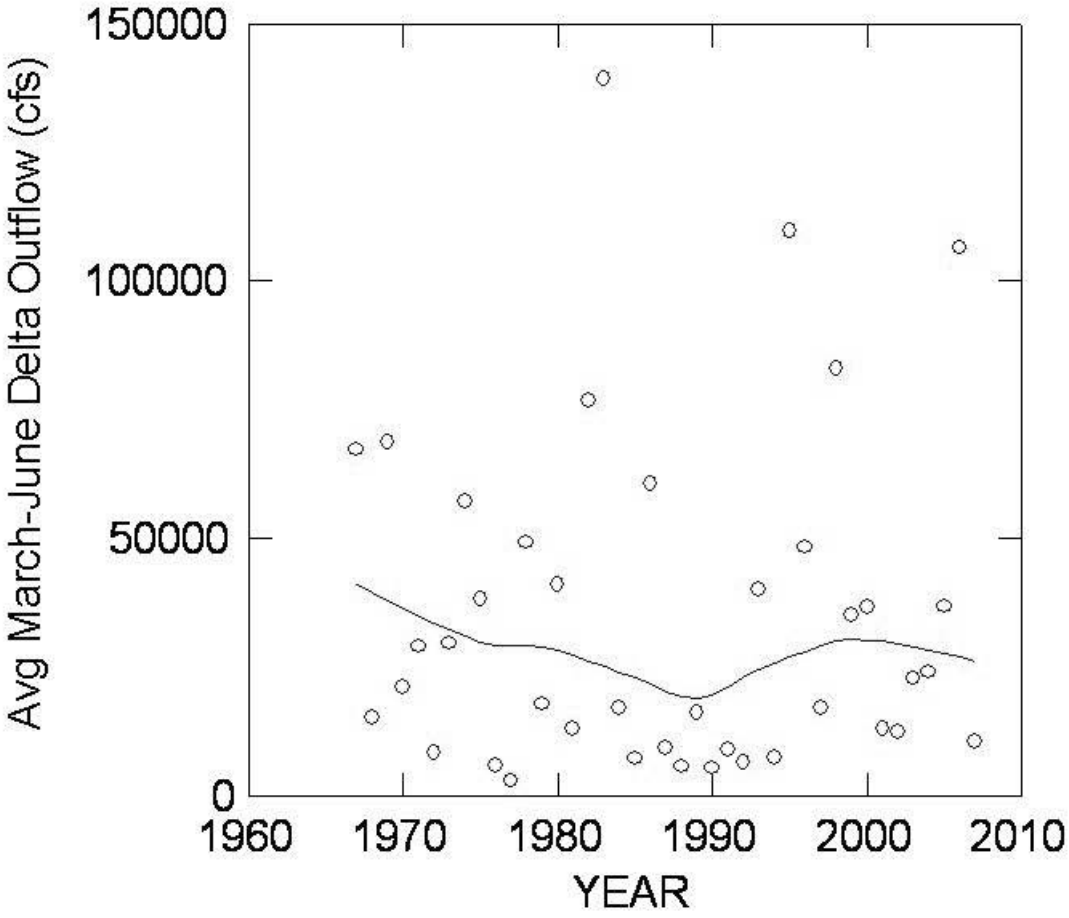


Figure E-11. Time trend in average April - May Delta outflow, 1967-2007. The spline is a LOWESS regression line.

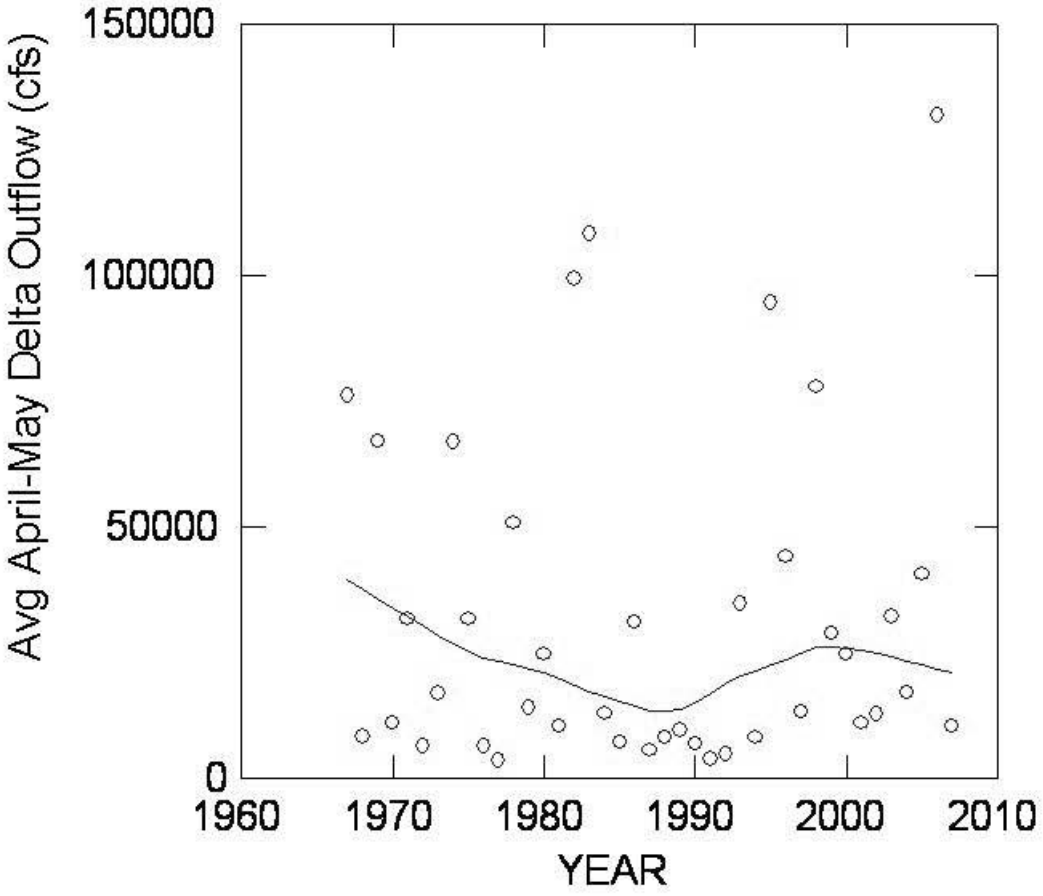


Figure E-12. Boxplot summary of CALSIM II operations study outputs of average March – June flows in Old and Middle rivers for five WY types. The boxes depict the interquartile range which is the distance between the 25th and 75th percentiles. The lines within the boxes show the medians, more extreme values are shown by the lines and asterisks. "Actual" is estimated and measured OMR flows from 1967-2007.

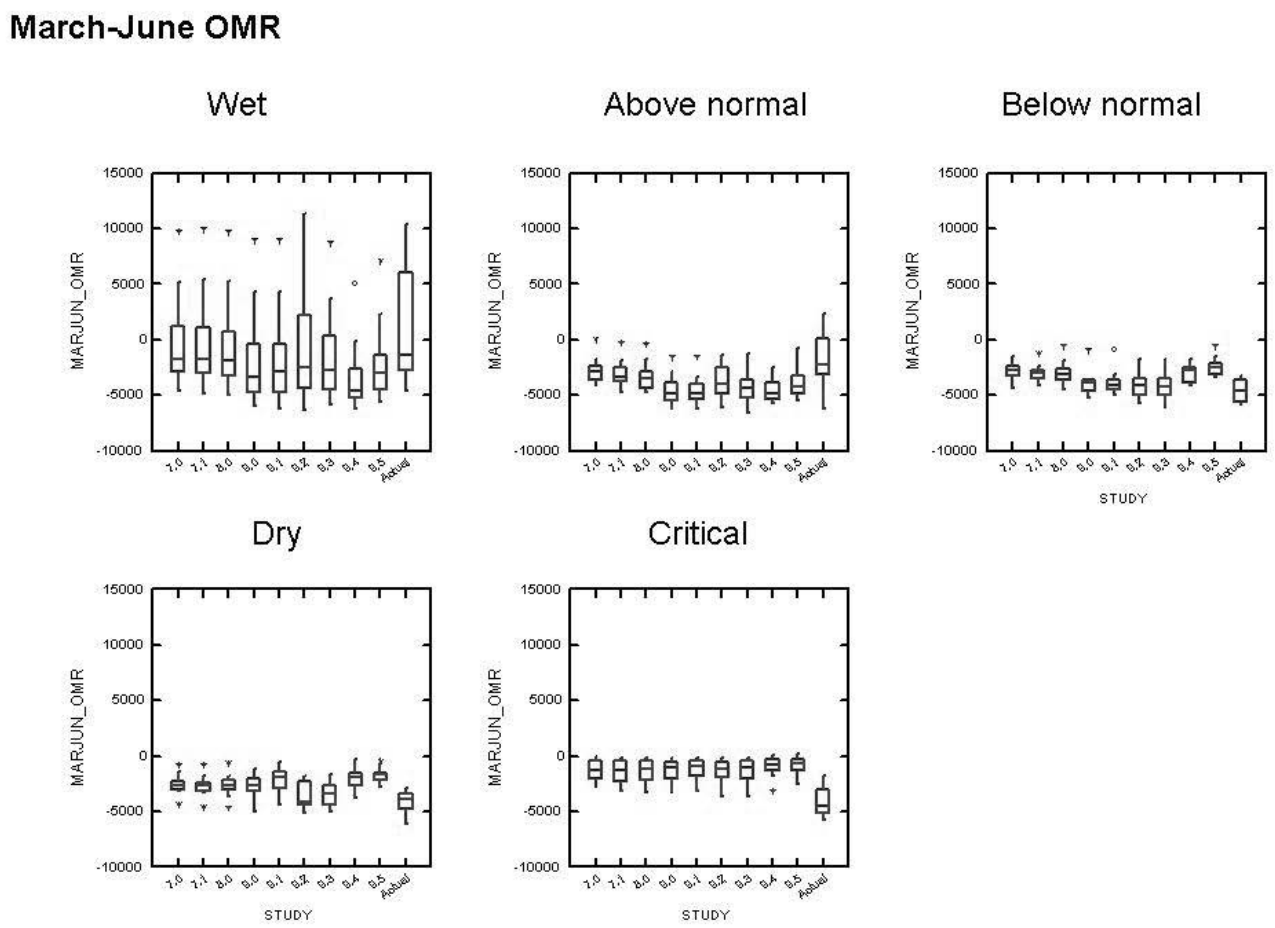


Figure E-13. Boxplot summary of CALSIM II operations study outputs of average April – May flows in Old and Middle rivers for five WY types. The boxes depict the interquartile range which is the distance between the 25th and 75th percentiles. The lines within the boxes show the medians, more extreme values are shown by the lines and asterisks. "Actual" is estimated and measured OMR flows from 1967-2007.

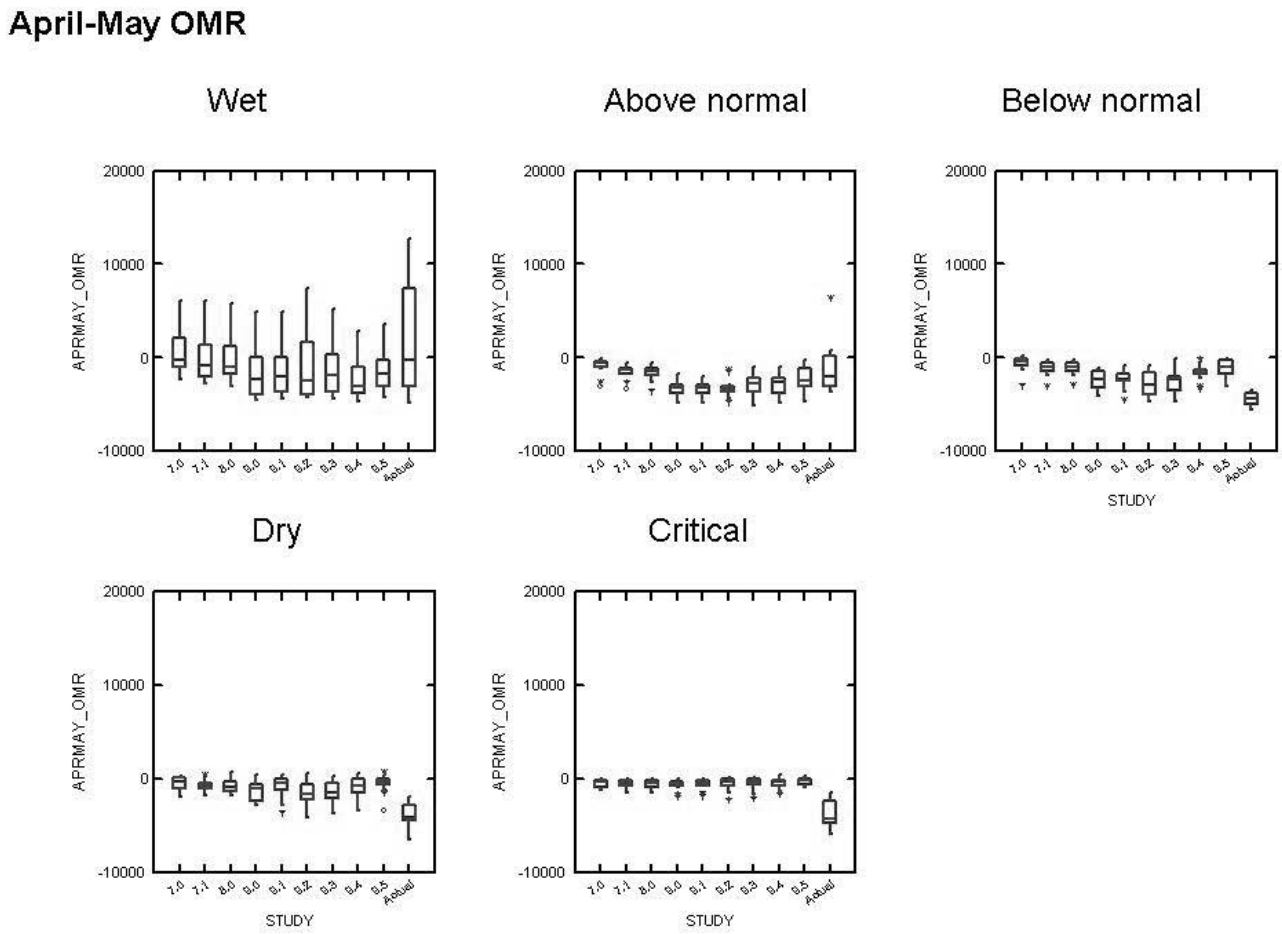


Figure E-14. Boxplot summary of CALSIM II operations study outputs of average March – June X2 positions for five WY types. The boxes depict the interquartile range which is the distance between the 25th and 75th percentiles. The lines within the boxes show the medians, more extreme values are shown by the lines and asterisks. "Actual" is X2 from 1967-2007.

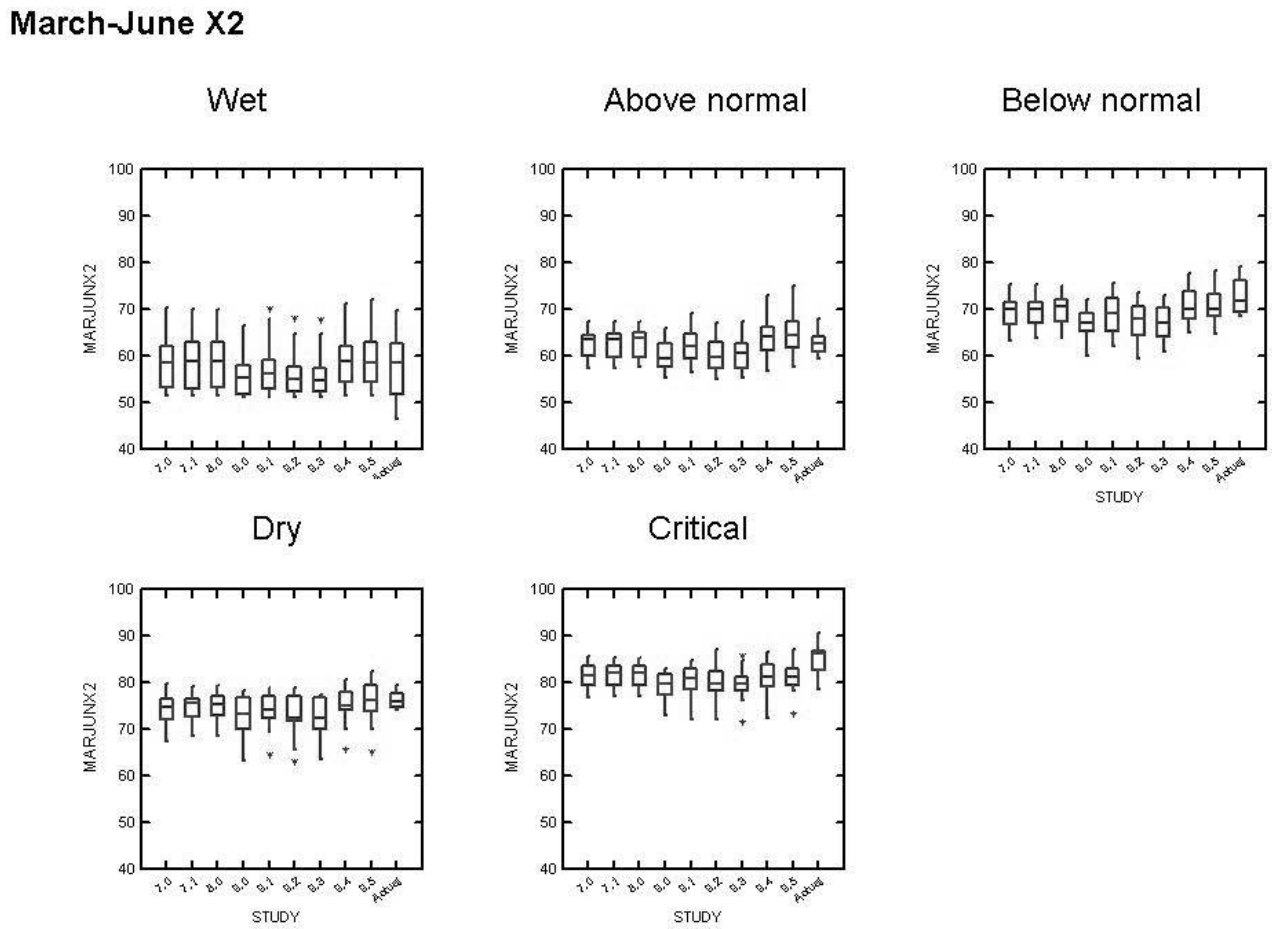


Figure E-15. Boxplot summary of CALSIM II operations study outputs of average April – May X2 positions for five WY types. The boxes depict the interquartile range which is the distance between the 25th and 75th percentiles. The lines within the boxes show the medians, more extreme values are shown by the lines and asterisks. "Actual" is X2 from 1967-2007.

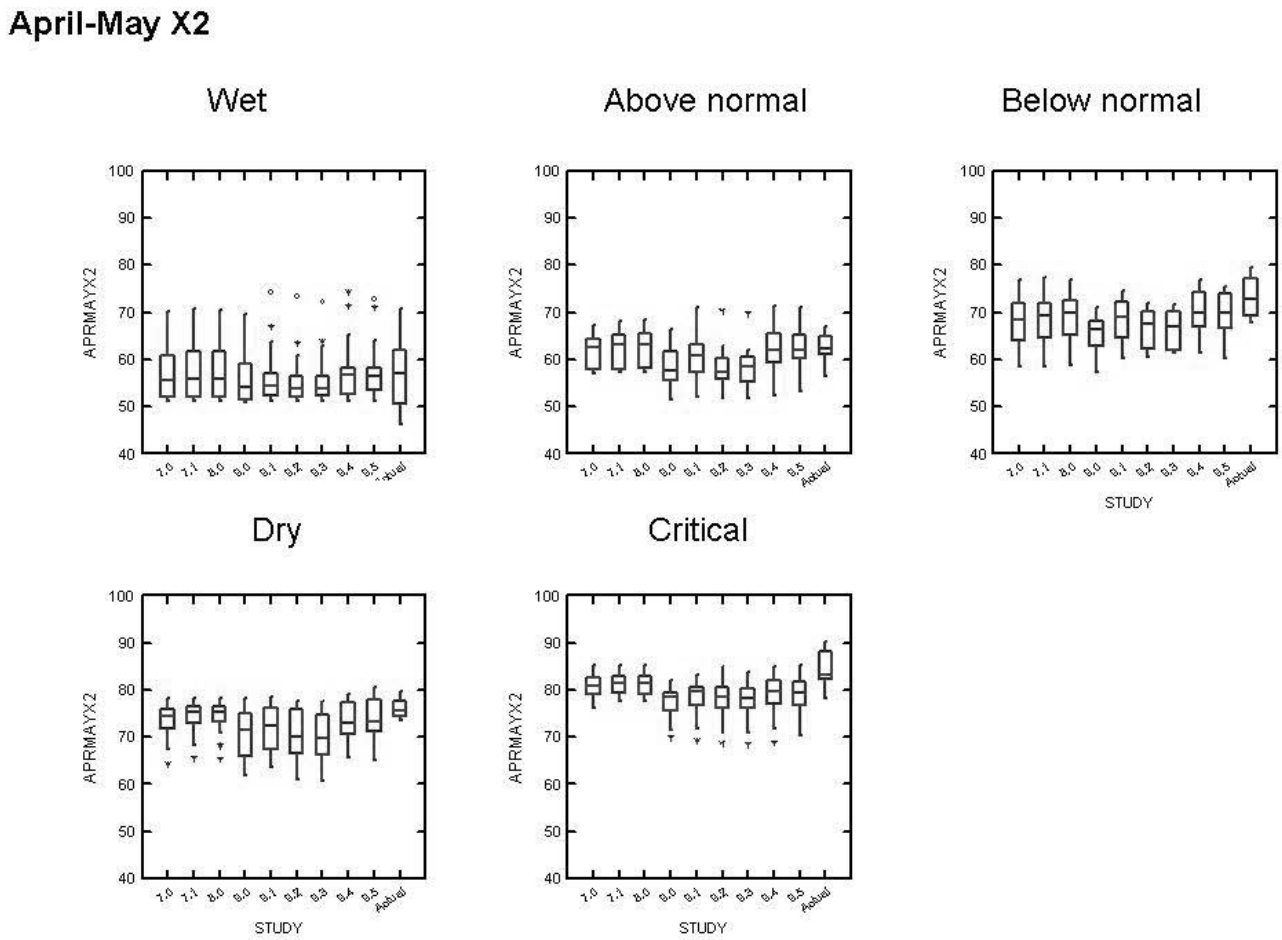


Figure E-16. Time series of estimated percentages of the larval-juvenile delta smelt population entrained in the SWP and CVP South Delta water export diversion facilities. Error bars were estimated by linear regression of Kimmerer's (2008) entrainment estimates versus the upper and lower 95 percent confidence intervals of the estimates.

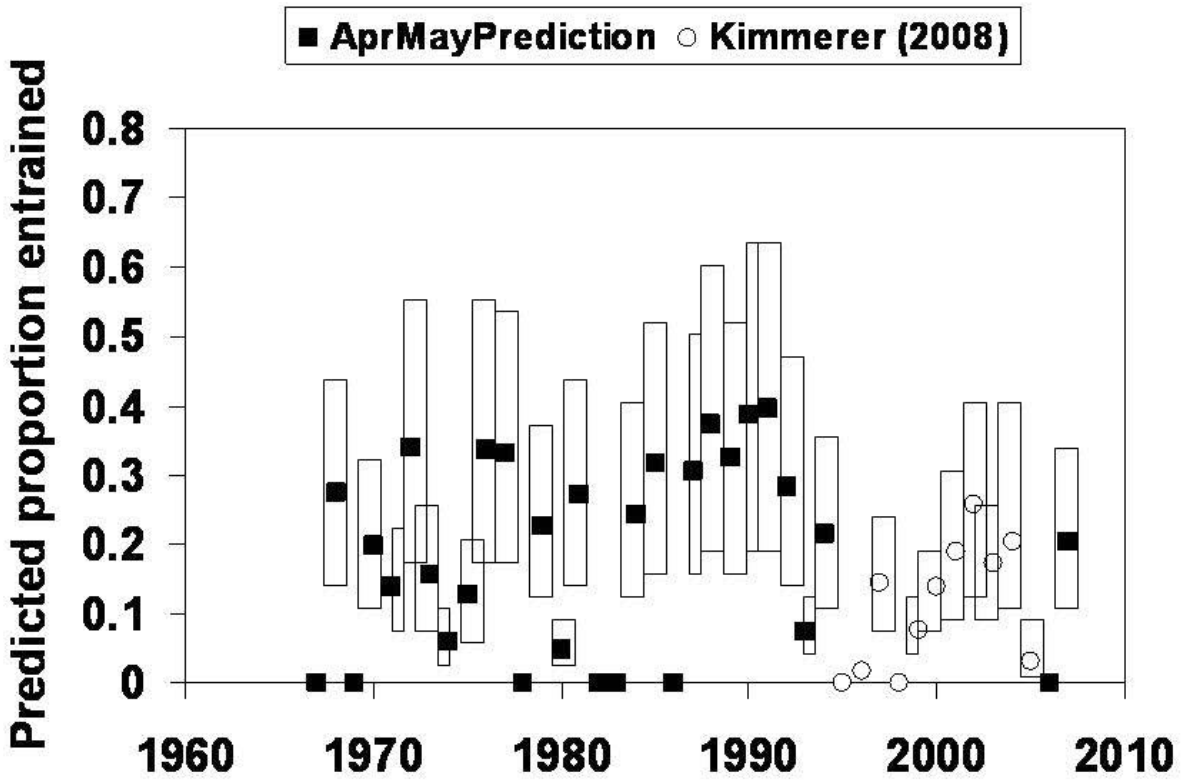


Figure E-17. Frequency distribution of estimated proportions of larval-juvenile delta smelt entrained at Banks and Jones for 1967-1994 and 1995-2007. The data were extrapolated to an 82-year period to make them comparable to the CALSIM II outputs in the biological assessment.

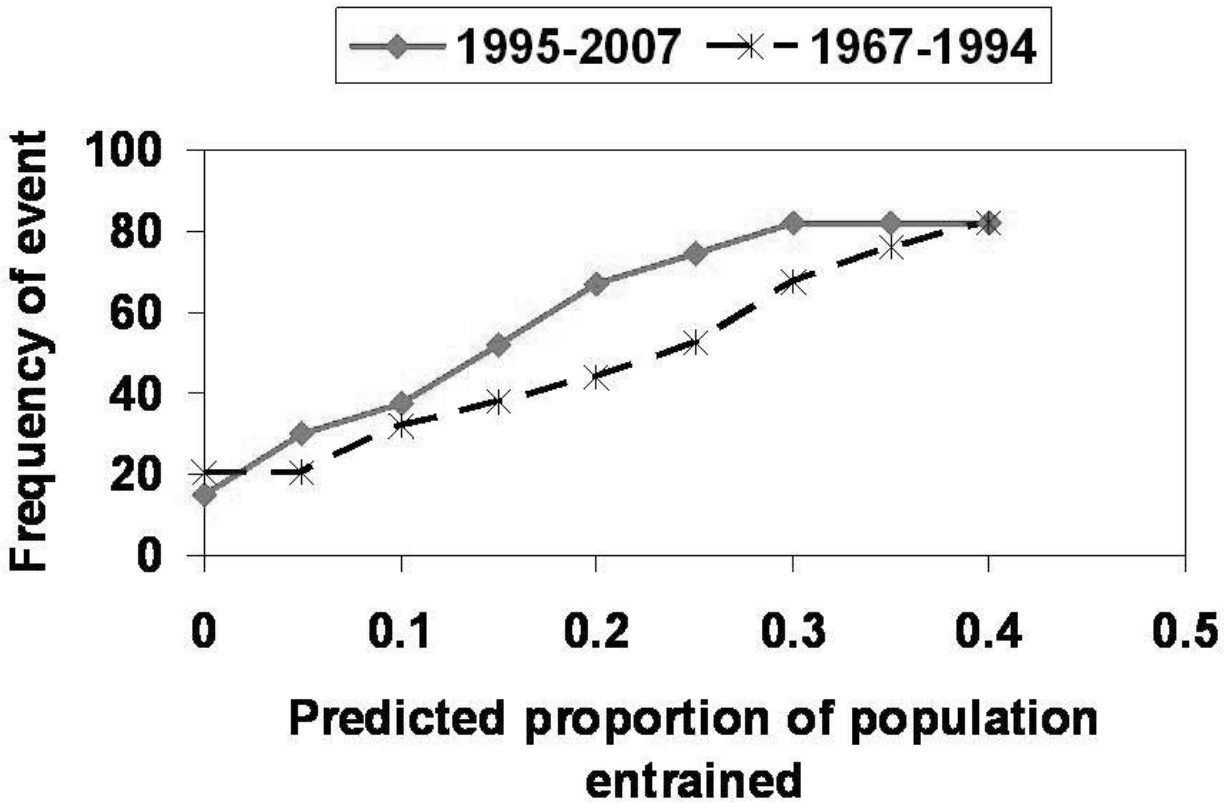


Figure E-18. Same as Figure 17, but including estimates based on X2 and OMR summaries from studies 7.0, 7.1, 8.0, 9.0-9.5 from the biological assessment.

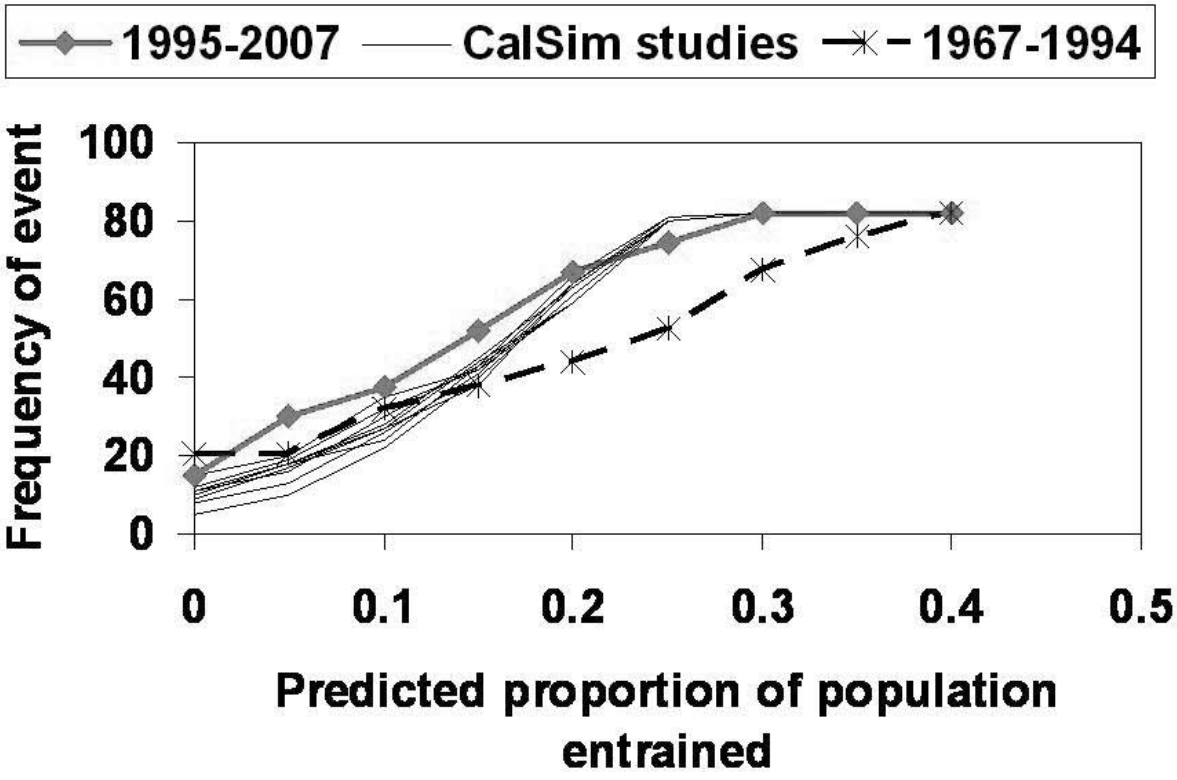


Figure E-19. X2 (km) during September to December based on historic data and CALSIM II model results. The center line in the box is the median and the outer box boundaries are the first and third quartiles.

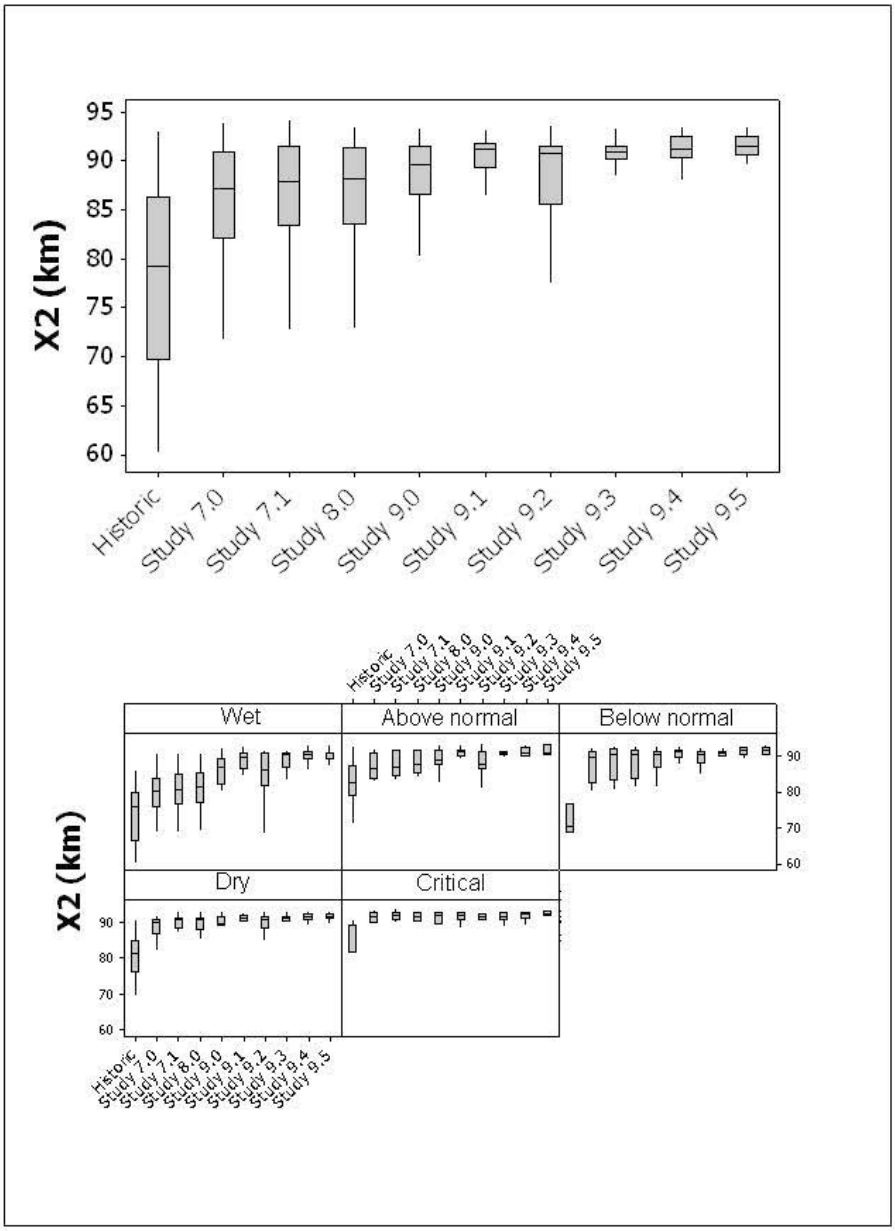
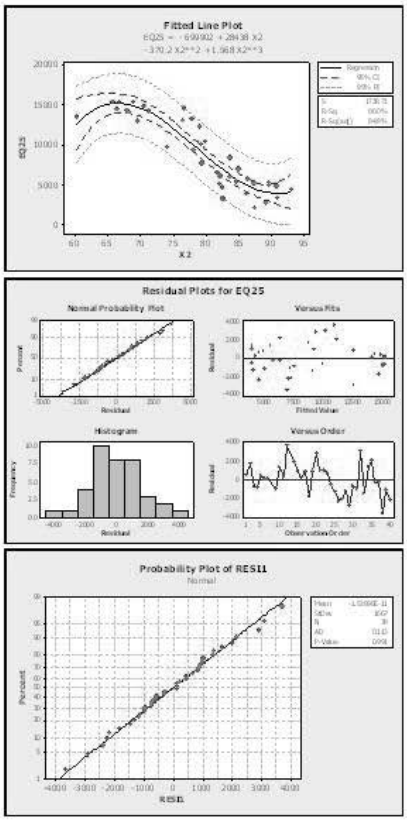


Figure E-20. Summary statistics for the model relating the effect of X2 on the area of suitable abiotic habitat (ha) for delta smelt during September to December.



The regression equation is
EQ25 = - 699902 + 28438 X2 - 370.2 X2**2 + 1.568 X2**3

S = 1738.71 R-Sq = 86.0% R-Sq(adj) = 84.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	630739911	210246637	69.55	0.000
Error	34	102786267	3023126		
Total	37	733526178			

Sequential Analysis of Variance

Source	DF	SS	F	P
Linear	1	582964214	139.39	0.000
Quadratic	1	6071691	1.47	0.233
Cubic	1	41704006	13.79	0.001

Figure E-21. Area of suitable abiotic habitat (ha) during September to December) based on historic data and CALSIM II model results for X2. The center line in the box is the median and the outer box boundaries are the first and third quartiles..

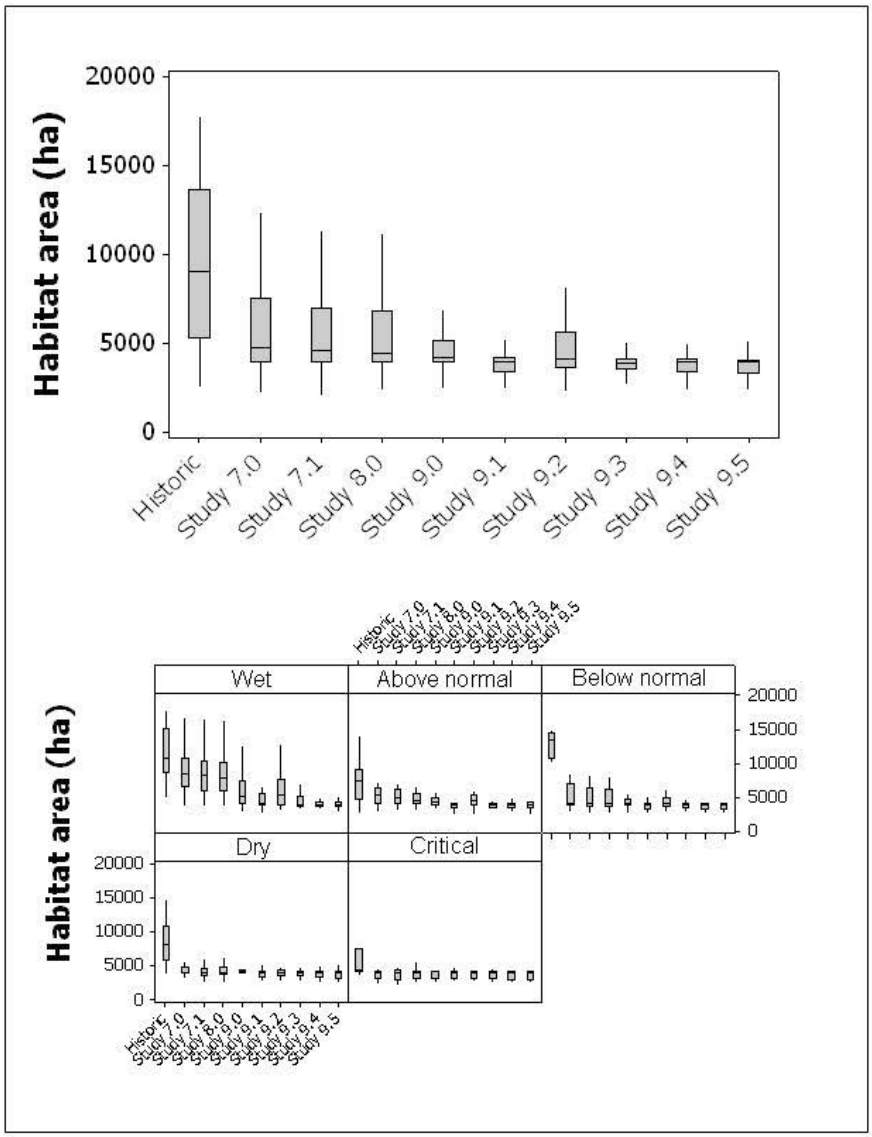
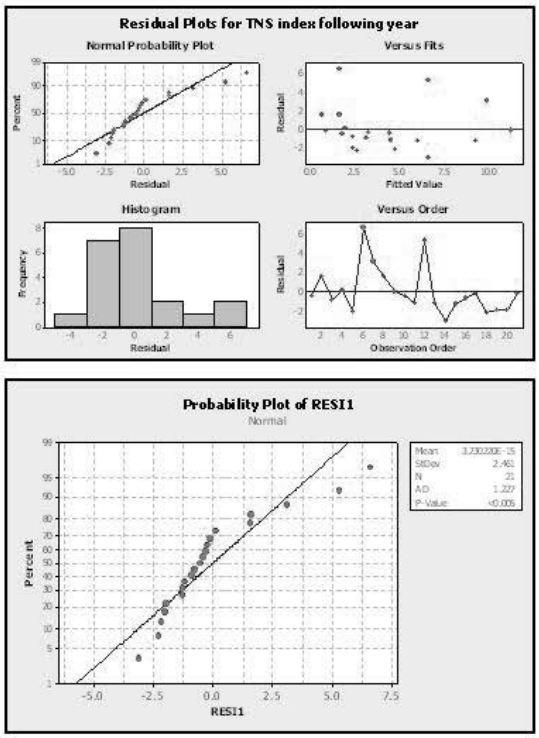


Figure E-22. Summary statistics for the stock-recruit model for delta smelt that incorporates X2 position during September to December as a covariate.



The regression equation is
TNS index following year = 29.1 + 0.00708 FMT index - 0.328 X2

Predictor	Coef	SE Coef	T	P
Constant	29.12	11.63	2.50	0.022
FMT index	0.007078	0.001886	3.75	0.001
X2	-0.3277	0.1354	-2.42	0.026

S = 2.59377 R-Sq = 60.6% R-Sq(adj) = 56.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	186.134	93.067	13.83	0.000
Residual Error	18	121.097	6.728		
Total	20	307.231			

Source	DF	Seq SS
FMT index	1	146.751
X2	1	39.383

Figure E-23. Predicted Summer Townet Index for delta smelt based on historic and CALSIM II-modeled values of X2 position. The center line in the box is the median and the outer box boundaries are the first and third quartiles.

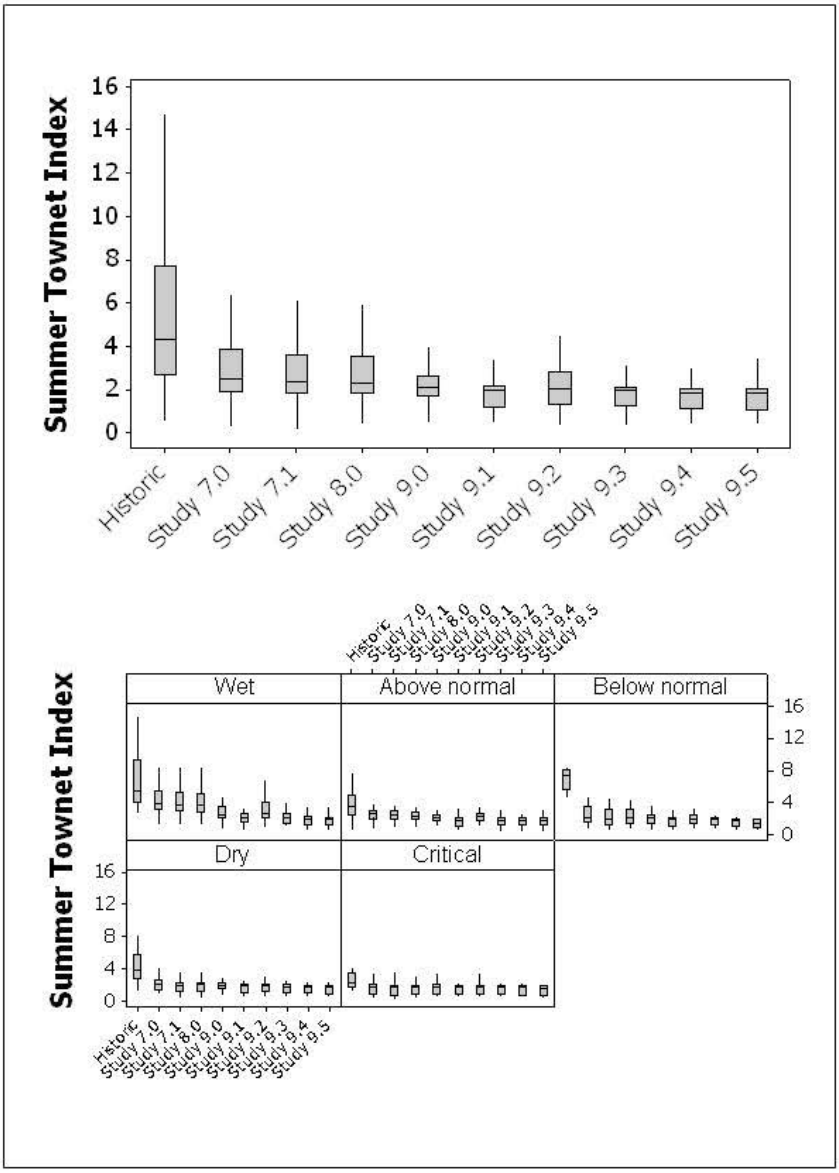


Figure E-24. Time series of historic X2 and E:I ratio for fall (September-December) in the upper panels and their relationship in the lower panel.

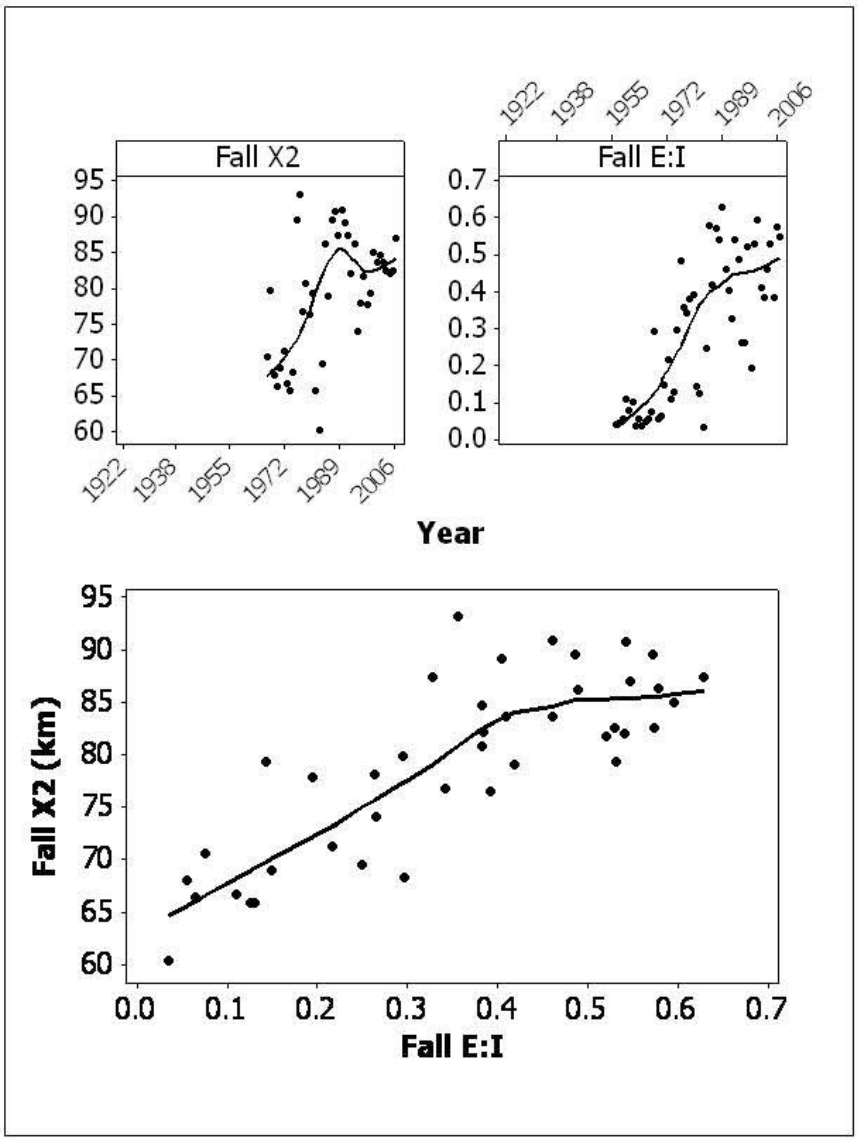


Figure E-25. Smoothed trend lines for the time series of historic and CALSIM II-modeled fall X2.

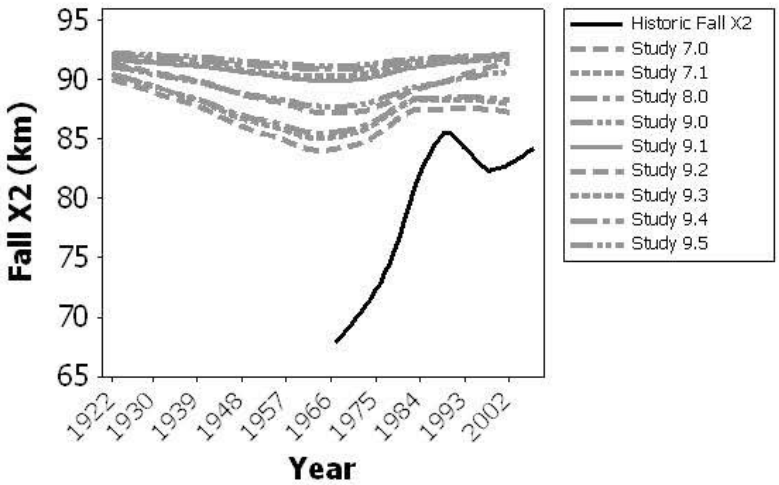


Figure E-26. X2 (km) during individual fall months for historic data and CALSIM II model results. The center line in the box is the median and the outer box boundaries are the first and third quartiles.

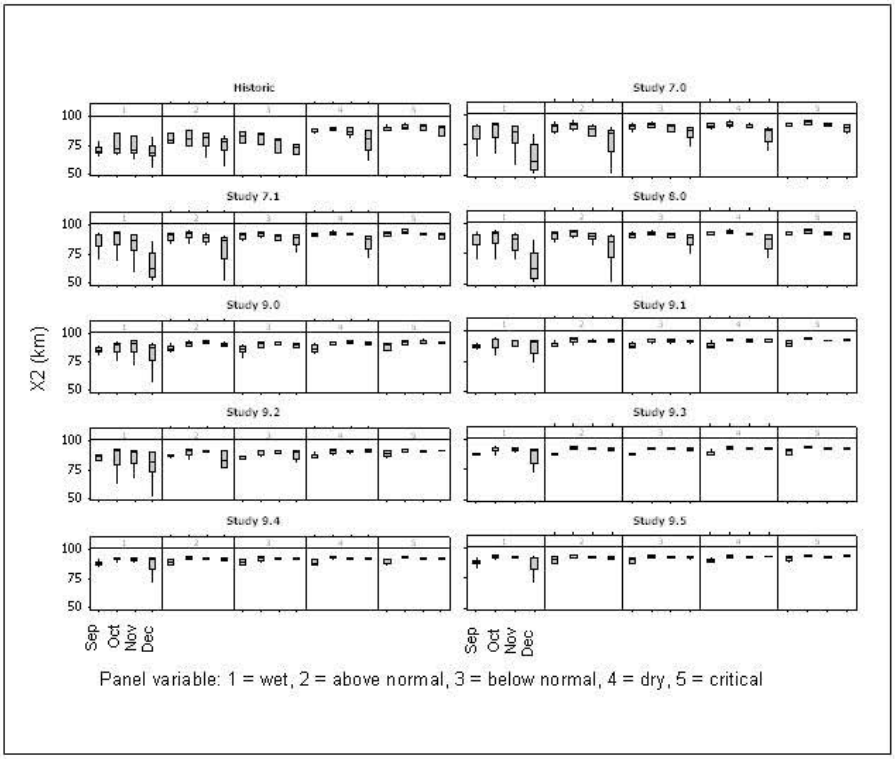


Figure E-27. Time series of fall X2 (September-December) with years noted by WY type for the previous spring.

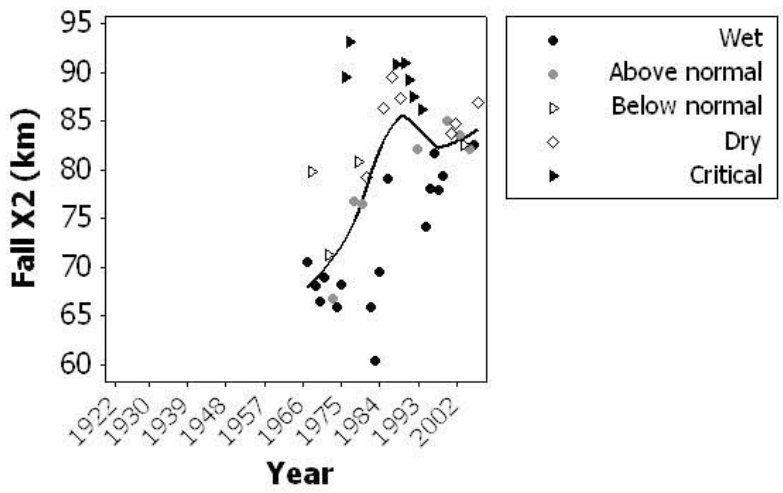


Figure E-28. Top panel: Time series of fall (September-December) and spring (April-July) X2. Lower panel: Smoothed time series of the difference between fall and spring X2 based on historic data and the CALSIM II model results.

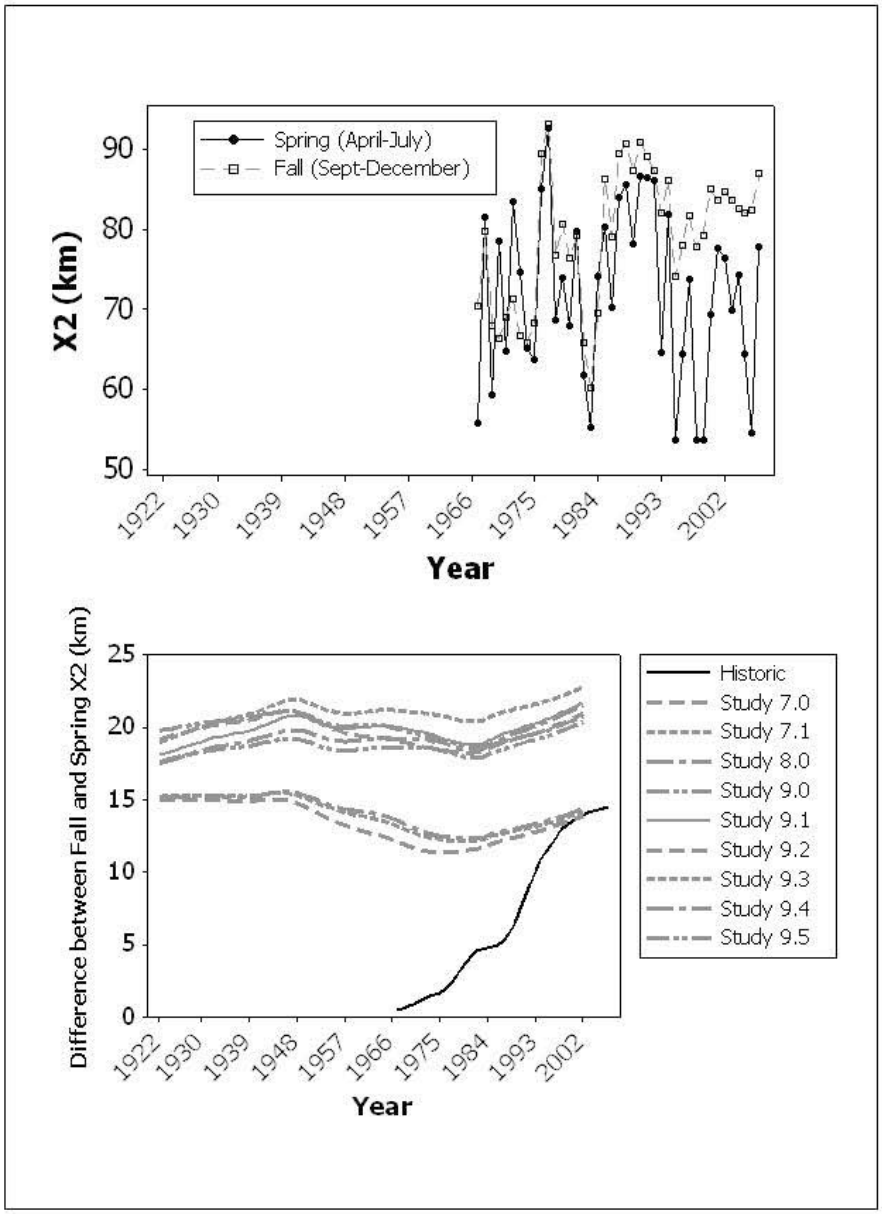
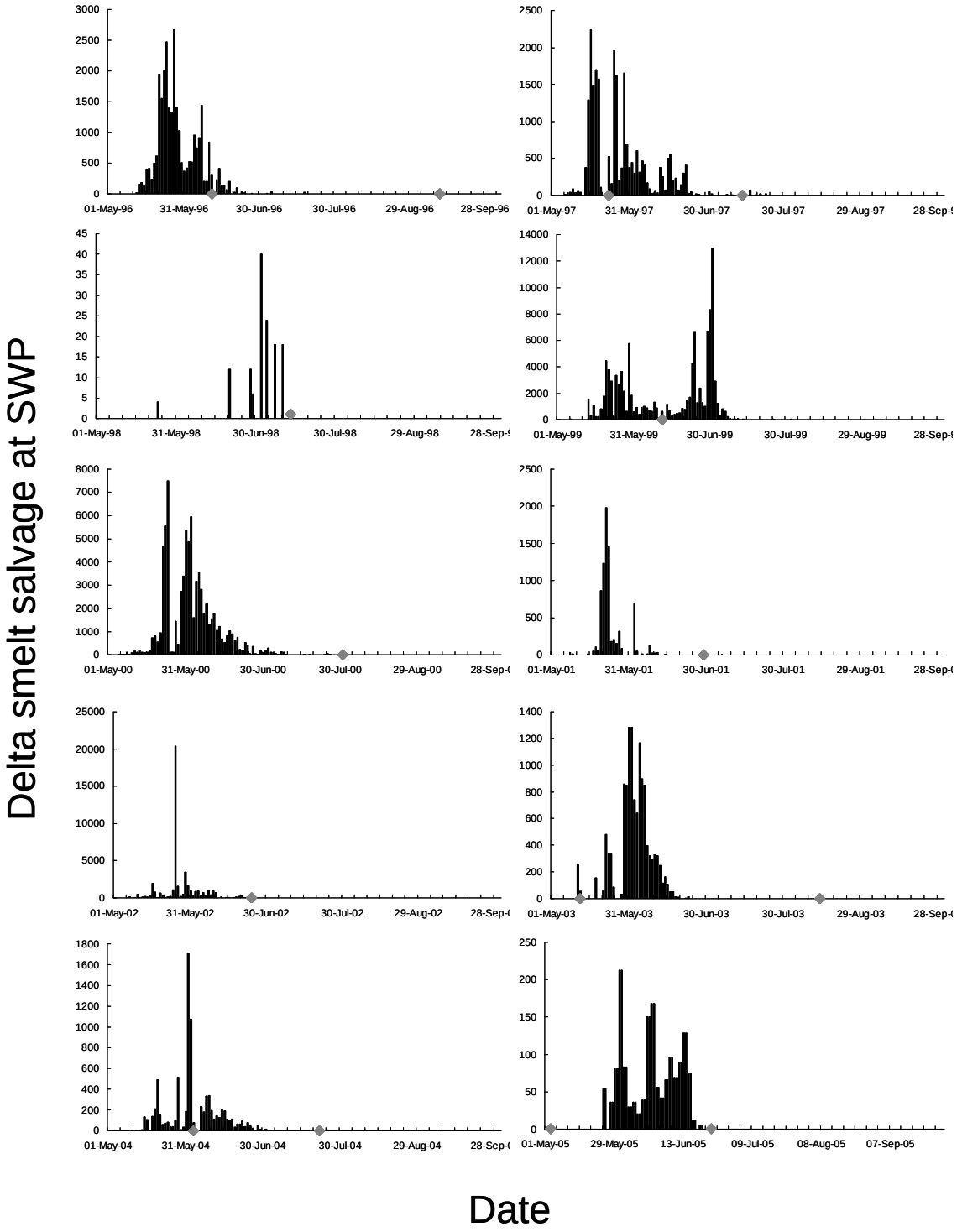


Figure E-29. May-September delta smelt salvage at the SWP Banks Pumping Plant, 1996-2005, with the start and end dates of Komeen or Nautique aquatic weed treatment indicated by the red diamonds.



Conclusion

Delta Smelt

After reviewing the current status of the delta smelt, the effects of the proposed action and the cumulative effects, it is the Service's biological opinion that the coordinated operations of the CVP and SWP, as proposed, are likely to jeopardize the continued existence of the delta smelt. The Service reached this conclusion based on the following findings, the basis for which is presented in the preceding *Status of the Species/Environmental Baseline*, *Effects of the Action*, and *Cumulative Effects* sections of this document.

1. Diversions of water from the Delta have increased since 1967 when the SWP began operation in conjunction with the CVP. Past and present CVP/SWP operations have significantly altered hydro-dynamics throughout the Bay-Delta ecosystem. This alteration has resulted in numerous direct and indirect adverse effects on the delta smelt, including: (a) entrainment of migrating adults, larvae, and juveniles caused by pumping at the Banks and Jones water export facilities; (b) a reduction in the extent of available rearing and foraging habitat caused by CVP/SWP export of high proportions of Delta inflows that causes net negative flows in the South and Central Delta; and (c) a reduction in the frequency, duration and magnitude of high Delta outflows that has altered the location of the LSZ, which is a crucial component of the delta smelt's habitat, and may have facilitated the invasion of dense populations of exotic species that have significantly changed delta smelt prey dynamics. Increased pumping at the Banks and Jones export facilities (see Table P-12 and Figure P-17 in the biological assessment) corresponds to the decline of the delta smelt population during the period both prior to and following its listing under the Act.

2. The delta smelt is currently at its lowest level of abundance since monitoring began in 1967. A significant decline in the abundance of the delta smelt and other pelagic fish species began in about the year 2000 in conjunction with the POD. Since 2004, the FMWT index has varied from 26 to 74, but at such low levels that true differences in population abundance cannot be determined. On that basis, the Service concludes that resilience of the delta smelt population is currently at or near its lowest level since abundance monitoring began in 1967.

3. Under the proposed CVP/SWP operations, inflows to the Delta are likely to be further reduced, as water demands upstream of the Delta increase, most notably on the American River. Additionally, in Modeling Study 8.0, exports at the Banks and Jones export facilities are projected to increase over Study 7.0. These effects are likely to cause increased relative entrainment of adult delta smelt in the winter and spring, and of larval and juvenile delta smelt in the spring. OMR flows are expected to become more negative as a result of the proposed action. This is expected to result in higher entrainment of delta smelt, as well as affect the transport of larval and juvenile delta smelt into essential

rearing habitat in the Central and South Delta. The full suite of proposed operations will reduce Delta outflows, resulting in chronically lower suitability of delta smelt habitat.

4. Other baseline stressors will continue to adversely affect the delta smelt, such as contaminants, microcystis, aquatic macrophytes, and invasive species. Available information is inconclusive regarding the extent, magnitude and pathways by which delta smelt may be affected by these stressors independent of CVP/SWP operations. However, the operation of the CVP/SWP, as proposed, is likely to reduce or preclude seasonal flushing flows, substantially reduce the natural frequency of upstream and downstream movement of the LSZ, and lengthen upstream shifts of the LSZ to an extent that may increase the magnitude and frequency of adverse effects to the delta smelt from these stressors.

5. To survive and recover, delta smelt need:

(a) a substantially more abundant adult population;

(b) an increase in the quality and quantity of its spawning, rearing, and migratory habitat with respect to turbidity, temperature, salinity, escape cover, freshwater flow, and prey availability as a result of active or passive management of water and sediment processes in the San Francisco Bay-Delta ecosystem that mimics more natural (i.e., pre-water development) conditions. Improved habitat quality within the Bay-Delta should enhance the reproduction of adult delta smelt and increase the survival of both adults and juveniles;

(c) a reduction in the levels of contaminants and other pollutants within its habitat to increase survival of adults, larvae and juveniles;

(d) a reduction in exposure to disease and toxic algal blooms to increase survival of adults, larvae, and juveniles; a reduction in entrainment of adult and juvenile delta smelt at CVP/SWP pumping facilities, over and above reductions achieved under the VAMP and the EWA, to increase the abundance of the spawning adult population and the potential for recruitment of juveniles into the adult population;

(e) a reduction in entrainment at other water diversion-related structures within the Bay-Delta where delta smelt adults, larvae, or juveniles are known or are likely to be entrained to increase the adult population and the potential for recruitment of juveniles into the adult population;

(f) restoration of the structure of the food web in the Bay-Delta to a condition that more closely mimics the natural environment to increase survival of adults and juveniles; and

(g) to maximize its population resilience in the face of the potential adverse effects of ongoing climate change that are occurring in Bay-Delta ecosystem.

Relative to these survival and recovery needs, the effects of the proposed action are likely to: decrease the abundance of delta smelt; decrease the quality and quantity of its habitat; maintain or increase high levels of entrainment; contribute to a degraded food web in the Delta; and reduce the population resilience of delta smelt.

6. On the basis of findings (1)-(5) above, the Service concludes that the effects of the proposed action, taken together with cumulative effects, are likely to appreciably reduce the likelihood of both the survival and recovery of delta smelt in the wild by reducing its reproduction, abundance, and distribution.

Delta Smelt Critical Habitat

After reviewing the current status of delta smelt critical habitat, the effects of the proposed action and the cumulative effects, it is the Service's biological opinion that the coordinated operations of the CVP and SWP, as proposed, are likely to adversely modify delta smelt critical habitat. The Service reached this conclusion based on the following findings, the basis for which is presented in the preceding *Status of Critical Habitat/Environmental Baseline, Effects of the Action, and Cumulative Effects* sections of this document.

1. The conservation role of delta smelt critical habitat is to provide migration, spawning and rearing habitat conditions necessary for successful delta smelt recruitment at levels that will provide for the conservation of the species. Appropriate physical habitat (PCE 1), water (PCE 2), river flows (PCE 3), and salinity (PCE 4) are essential for successful delta smelt spawning and survival.

2. The past and present operations of the CVP/SWP have degraded these habitat elements (particularly PCEs 2-4) to the extent that their co-occurrence at the appropriate places and times is insufficient to support successful delta smelt recruitment at levels that will provide for the species' conservation.

3. Implementation of the proposed action is expected to perpetuate the very limited co-occurrence of PCEs at appropriate places and times by: (a) altering hydrologic conditions in a manner that adversely affects the distribution of abiotic factors such as turbidity and contaminants; (b) altering river flows to an extent that increases delta smelt entrainment at Banks and Jones, as well as reduces habitat suitability in the Central and South Delta; and (c) altering the natural pattern of seasonal upstream movement of the LSZ to an extent that is likely to reduce available habitat for the delta smelt within areas designated as critical habitat.

The proposed action does include a provision for VAMP to address augmentation of river flow but future implementation of this provision is not well defined, making its beneficial effects on the PCEs of delta smelt critical habitat uncertain.

4. On the basis of findings (1)-(3) above, the Service concludes that implementation of the proposed action is likely to prevent delta smelt critical habitat from serving its intended conservation role.

Reasonable and Prudent Alternative

The regulations (50 CFR 402.02) implementing section 7 of the Act define reasonable and prudent alternatives (RPA) as alternative actions, identified during formal consultation, that: 1) can be implemented in a manner consistent with the intended purpose of the action; 2) can be implemented consistent with the scope of the action agency's (i.e.Reclamation's) legal authority and jurisdiction; 3) are economically and technologically feasible; and, 4) would, the Service believes, avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.

The Service has developed the following RPA that includes four components to be implemented using an adaptive approach within specific constraints. The fifth component includes monitoring and reporting requirements. The components presented below are based on the best available scientific information regarding what is necessary to adequately provide for successful delta smelt migration and spawning, and larval and juvenile survival, growth, rearing, and recruitment within the Bay-Delta.

The specific flow requirements, action triggers and monitoring stations prescribed in the RPA will be continuously monitored and evaluated consistent with the adaptive process. As new information becomes available, these action triggers may be modified without necessarily requiring re-consultation on the overall proposed action.

The following actions are necessary to ensure that implementation of the long term operations of the CVP/SWP does not appreciably reduce the likelihood of both the survival and recovery of the delta smelt and does not preclude the intended conservation role of its critical habitat through: 1) preventing/reducing entrainment of delta smelt at Jones and Banks; 2) providing adequate habitat conditions that will allow the adult delta smelt to successfully migrate and spawn in the Bay-Delta; 3) providing adequate habitat conditions that will allow larvae and juvenile delta smelt to rear; and 4) providing suitable habitat conditions that will allow successful recruitment of juvenile delta smelt to adulthood. In addition, it is essential to monitor delta smelt abundance and distribution through continued sampling programs through the IEP.

Detailed descriptions of the adaptive process, its framework, and the rationale for each of the RPA components are presented in Attachment B of this biological opinion.

Process for Determining Specific Actions within Components 1 and 2

1. Within one day after the SWG recommends an action should be initiated, changed, suspended or terminated, the SWG shall provide to the Service a written recommendation and a biological justification. The SWG shall use the process described in Attachments A and B to provide a framework for their recommendations. The Service shall determine whether the proposed action should be implemented, modified, or terminated; and the OMR flow needed to achieve the protection. The Service shall present this information to the WOMT.

2. The WOMT shall either concur with the recommendation or provide a written alternative to the recommendation to the Service within one calendar day. The Service shall then make a final determination on the proposed action to be implemented, which shall be documented and posted on the Sacramento Fish and Wildlife Service's webpage.

3. Once the Service makes a final determination to initiate a new action, it shall be implemented within two calendar days by Reclamation and DWR, and shall remain in effect until the need for the action ends or the OMR flow is changed, as determined by the Service, consistent with the RPA and described within Attachment B. Data demonstrating the implementation of the action shall be provided by Reclamation to the Service on a weekly basis.

4. If the Service determines that an OMR flow change is required while an action is ongoing, Reclamation and DWR shall adjust operations to manage to the new OMR flow within two days of receipt of the Service's determination. This new OMR flow shall be used until it is adjusted or the action is changed or terminated based on new information, as described in the RPA and Attachment B.

RPA Component 1: Protection of the Adult Delta Smelt Life Stage

Delta smelt are entrained at the fish facilities each year. These actions are designed to reduce the delta smelt entrainment losses. The objective of Component 1 (Actions 1 and 2 in Attachment B) is to reduce entrainment of pre-spawning adult delta smelt during December to March by controlling OMR flows during vulnerable periods. Action 1 is designed to protect upmigrating delta smelt. Action 2 is designed to protect adult delta smelt that have migrated upstream and are residing in the Delta prior to spawning. Overall, RPA Component 1 will increase the suitability of spawning habitat for delta smelt by decreasing the amount of Delta habitat affected by the projects' export pumping plants' operations prior to, and during, the critical spawning period.

Beginning in December of each year, the Service shall review data on flow, turbidity, salvage, and other parameters that have historically predicted the timing of delta smelt migration into the Delta. On an ongoing basis, and consistent with the parameters outlined below and in Attachment B, the SWG shall recommend to the Service OMR flows that are expected to minimize entrainment of adult delta smelt. Throughout the

implementation of RPA Component 1, the Service will make the final determination as to OMR flows required to protect delta smelt.

OMR flow requirements given below are based on the following understanding: Where a 14-day running average is established, the average daily OMR flow must be no more negative than the required OMR flow. Where a 5-day running average is given, the daily average shall be no more than 25 percent more negative than the requirement. The daily OMR flows used to compute both the 14-day and the 5-day averages shall be the "tidally filtered" values reported by USGS.

Low-entrainment risk period: delta smelt salvage has historically been low between December 1 and December 19, even during periods when first flush conditions (i.e., elevated river inflow and turbidity) occurred. During the low-entrainment risk period, the SWG shall determine if the information generated by physical (i.e. turbidity and river inflow) and biological (e.g., salvage, DFG trawls) monitoring indicates that delta smelt are vulnerable to entrainment or are likely to migrate into a region where future entrainment events may occur. If this occurs, the Service shall require initiation of Action 1 as described in Attachment B. Action 1 shall require the Projects to maintain OMR flows no more negative than -2,000 cfs (14-day average) with a simultaneous 5-day running average flow no more negative than -2,500 cfs to protect adult delta smelt for 14 days.

High-entrainment risk period: delta smelt have historically been entrained when first flush conditions occur in late December. In order to prevent or minimize such entrainment, Action 1 shall be initiated on or after December 20 if the 3 day average turbidity at Prisoner's Point, Holland Cut, and Victoria Canal exceeds 12 NTU, or if there are three days of delta smelt salvage at either facility or if the cumulative daily salvage count is above the risk threshold based upon the "daily salvage index" approach described in Attachment B. Action 1 shall require the Projects to maintain OMR flows no more negative than -2,000 cfs (14-day running average) with a simultaneous 5-day running average flow no more negative than -2,500 cfs to protect adult delta smelt for 14 days. However, the SWG can recommend a delayed start or interruption based on other conditions such as delta inflow that may affect vulnerability to entrainment.

Winter protection period: recent analyses indicate that cumulative adult entrainment and salvage are lower when OMR flows are no more negative than -5,000 cfs in the December through March period. Action 2 shall commence immediately after Action 1 ends. If Action 1 is not implemented, the SWG may recommend a start date for the implementation of Action 2 to protect adult delta smelt. OMR flows under Action 2 shall be in the range of -3,500 to -5,000 when turbidity and salvage are low. Based on historic conditions, OMR flow would generally be expected to be in the range of -2,000 cfs to -3,500 cfs given recent salvage events. However, at times when turbidity and flow conditions in the Delta may result in increased salvage, the range may be between -1,250 to -2,000 cfs. During the implementation of Action, the maximum negative flow for OMR shall be determined based on the criteria outlined in Attachment B. The OMR flow shall be based on a 14-day running average with simultaneous 5-day running average

within 25 percent of the required OMR flow. The action may be suspended temporarily if the three day flow average is greater than or equal to 90,000 cfs at the Sacramento River at Rio Vista and 10,000 cfs at the San Joaquin River at Vernalis, because there is low likelihood that delta smelt will be entrained during such high inflow conditions. Suspension of this action due to high flow will end when flow drops below the 90,000 cfs and 10,000 cfs threshold. Action 2 ends when spawning begins as defined for Action 3 implementation (Component 2).

RPA Component 2: Protection of Larval and Juvenile Delta Smelt

Delta smelt larvae and juveniles are susceptible to direct mortality by entrainment. Hydrologic conditions resulting from CVP/SWP operations increase the risk of that entrainment. The objective of this RPA component (which corresponds to Action 3 in Attachment B), is to improve flow conditions in the Central and South Delta so that larval and juvenile delta smelt can successfully rear in the Central Delta and move downstream when appropriate.

Upon completion of RPA Component 1 or when Delta water temperatures reach 12˚C (based on a 3-station average of daily average water temperature at Mossdale, Antioch, and Rio Vista) or when a spent female delta smelt is detected in the trawls or at the salvage facilities, the projects shall operate to maintain OMR flows no more negative than -1,250 to -5000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable 14-day OMR flow requirement. Depending on the extant conditions, the SWG shall make recommendations for the specific OMR flows within this range from the onset of implementing RPA Component 2 through its termination. The Service shall make the final determination regarding specific OMR flows. This action shall end June 30 or when the 3-day mean water temperature at Clifton Court Forebay reaches 25° C, whichever occurs earlier.

The Spring HORB shall be installed only if the Service determines delta smelt entrainment is not a concern (Action 5 from Attachment B).

RPA Component 3: Improve Habitat for Delta Smelt Growth and Rearing

The objective of this component is to improve fall habitat for delta smelt through increasing Delta outflow during fall. Increase in fall habitat quality and quantity will both benefit delta smelt.

Subject to adaptive management as described below and in Action 4 in Attachment B, during September and October in years when the preceeding precipitation and runoff period was wet or above normal as defined by the Sacramento Basin 40-30-30 index, Reclamation and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater (more eastward) than 74 km (from the Golden Gate) in Wet WYs and 81 km in Above Normal WYs. The monthly X2 target will be separately achieved for the months of September and October. During any November when the preceding

water year was wet or above normal as defined by the Sacramento Basin 40-30-30 index, all inflow into CVP/SWP reservoirs in the Sacramento Basin shall be added to reservoir releases in November to provide an additional increment of outflow from the Delta to augment Delta outflow up to the fall X2 of 74 km for Wet WYs or 81 km for Above Normal WYs, respectively. In the event there is an increase in storage during any November this action applies, the increase in reservoir storage shall be released in December to augment the December outflow requirements in SWRCB D-1641.

Given the nature of this Action and to align its management more closely with the general plan described by the independent review team and developed by Walters (1997), the Service shall oversee and direct the implementation of a formal adaptive management process. The adaptive management process shall include the elements as described in Attachment B. This adaptive management program shall be reviewed and approved by the Service in addition to other studies that are required for delta smelt. In accordance with the adaptive management plan, the Service will review new scientific information when provided and may make changes to the action when the best available scientific information warrants. For example, there may be other ways to achieve the biological goals of this action, such as a Delta outflow target, that will be evaluated as part of the study. This action may be modified by the Service consistent with the intention of this action based on information provided by the adaptive management program in consideration of the needs of other listed species. Other CVP/SWP obligations may also be considered.

The adaptive management program shall have specific implementation deadlines. The creation of the delta smelt habitat study group, initial habitat conceptual model review, formulation of performance measures, implementation of performance evaluation, and peer review of the performance measures and evaluation that are described in steps (1) through (3) of Attachment B shall be completed before September 2009. Additional studies addressing elements of the habitat conceptual model shall be formulated as soon as possible, promptly implemented, and reported as soon as complete.

The Service shall conduct a comprehensive review of the outcomes of the Action and the effectiveness of the adaptive management program ten years from the signing of the biological opinion, or sooner if circumstances warrant. This review shall entail an independent peer review of the Action. The purposes of the review shall be to evaluate the overall benefits of the Action and to evaluate the effectiveness of the adaptive management program. At the end of 10 years or sooner, this action, based on the peer review and Service determination as to its efficacy shall either be continued, modified or terminated.

RPA Component 4: Habitat Restoration

This component of the RPA (Action 6 of Attachment B) is intended to provide benefits to delta smelt habitat to supplement the benefits resulting from the flow actions described above. DWR shall implement a program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh. These actions

may require separate ESA consultations for their effects on federally listed species. The restoration efforts shall begin within 12 months of signature of this biological opinion and be completed by DWR (the applicant) within 10 years. The restoration sites and plans shall be reviewed and approved by the Service and be appropriate to improve habitat conditions for delta smelt. Management plans shall be developed for each restoration site with an endowment or other secure financial assurance and easement in place held by a third-party or DFG and approved by the Service. The endowment or other secure financial assurance shall be sufficient to fund the monitoring effort and operation and maintenance of the restoration site.

An overall monitoring program shall be developed to focus on the effectiveness of the restoration actions and provided to the Service for review within six months of signature of this biological opinion. The applicant shall finalize the establishment of the funding for the restoration plan within 120 days of final approval of the restoration program by the Service. There is a separate planning effort in Suisun Marsh where the Service is a co-lead with Reclamation on preparation of an Environmental Impact Statement. Restoration actions in Suisun Marsh shall be based on the Suisun Marsh Plan that is currently under development.

RPA Component 5: Monitoring and Reporting

Reclamation and DWR shall ensure that information is gathered and reported to ensure:
1) proper implementation of these actions,
2) that the physical results of these actions are achieved, and
3) that information is gathered to evaluate the effectiveness of these actions on the targeted life stages of delta smelt so that the actions can be refined, if needed.

Essential information to evaluate these actions (and the Incidental Take Statement) includes sampling of the FMWT, Spring Kodiak Trawl, 20-mm Survey, TNS and the Environmental Monitoring Program of the IEP. This information shall be provided to the Service within 14 days of collection. Additional monitoring and research will likely be required, as defined by the adaptive management process.

Information on salvage at Banks and Jones is both an essential trigger for some of these actions and an important performance measure of their effectiveness. In addition, information on OMR flows and concurrent measures of delta smelt distribution and salvage are essential to ensure that actions are implemented effectively. Such information shall be included in an annual report for the WY (October 1 to September 30) to the Service, provided no later than October 15 of each year, starting in 2010.

Reclamation shall implement the RPA based on performance standards, monitoring and evaluation of results from the actions undertaken and adaptive management as described in RPA component 3. RPA component 3 has a robust adaptive management component that requires a separate analysis apart from those required under this component. Some of the data needed for these performance measures are already being collected such as the FMWT abundances and salvage patterns. However, more information on the effect of

these actions on smelt survival and the interactions of project operations with other stressors on delta smelt health, fecundity and survival is needed. This information may provide justificationfor refining these actions to better address the needs of delta smelt. Studies like those of the IEP's POD workteam have provided much useful information on the needs of delta smelt and the stressors affecting them that was integral in the development of these actions.

Avoidance of Jeopardy and Adverse Modification

The conservation needs of the delta smelt at this time are primarily associated with: (1) protective measures for pre-spawning adult delta smelt; (2) improvement of flow conditions in the Central and South Delta so that larval and juvenile delta smelt can successfully rear and move downstream with a minimum entrainment risk; and (3) restoration and enhancement of habitat availability and quality that improves growth and survival of delta smelt.

The RPA components described above and in Attachment B specifically address the above factors to the extent provided by the regulatory criteria that define a RPA. Implementation of this RPA will increase the likelihood that delta smelt habitat conditions and attributes for migration, spawning, recruitment, growth, and survival will be provided during the term of the proposed action. For these reasons, the Service finds that implementation of the RPA described above is likely to avoid jeopardy to the delta smelt and adverse modification of its critical habitat.

Incidental Take Statement

Introduction

Section 9 of the Act and Federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering. Harm is defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by impairing behavioral patterns including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be a prohibited taking under the Act, provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are nondiscretionary and must be implemented by Reclamation, working with DWR under the COA and other interagency agreements, in order for the exemption in section 7(o)(2) to apply. Reclamation has a continuing duty to regulate the activities that are covered by this Incidental Take Statement for the life of the proposed action. If Reclamation fails to assume and implement the RPA and terms and conditions or is unable to ensure that DWR adheres to the RPA and terms and conditions of this Incidental Take Statement while jointly operating under the COA and other interagency agreements, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impacts of incidental take, Reclamation must report the progress of the action and its impacts on the delta smelt to the Service as specified in this Incidental Take Statement. [50 CFR §402.14(i)(3)]

The Service developed the following Incidental Take Statement based on the premise that the RPA will be implemented. A detailed description of the rational for the development of the incidental take statement is in Attachment C. This Incidental Take Statement assumes full implementation of the RPA.

Form of Take Anticipated

The Service anticipates that take of the delta smelt is likely to occur in the form of kill, capture (via salvage), wound, harm, and harass as a result of CVP/SWP operations within the action area, inclusive of activities at the NBA and at CCWD facilities, and in conjunction with studies to determine screening criteria and to improve delta smelt handling and survival in the salvage process. The above forms of take will result in the injury or death of delta smelt. This Incidental Take Statement addresses all of the above.

Amount or Extent of Take

Take of Delta Smelt at the NBA and CCWD Facilities

The Service anticipates that incidental take of delta smelt at the NBA and at the CCWD diversions will be difficult to detect since no monitoring program samples for entrainment at these facilities on a regular basis. Incidental take is not expected to be high since the other diversions have fish screens and the unscreened Rock Slough diversion is at a dead end slough where delta smelt are not usually present. Due to the difficulty in quantifying the number of delta smelt that will be taken as a result of the proposed action, the Service is quantifying incidental take for the NBA and the CCWD diversion to be all delta smelt inhabiting the water diverted at these facilities under the conditions of 71 TAF per year at the NBA and 195 TAF at the CCWD diversions.

Take of Adult Delta Smelt

The Service anticipates that take of adult delta smelt via entrainment will be minimized when OMR flows are limited to -2,000 cfs during the first winter flush when adult smelt move within the zone of entrainment. OMR flows held between -1,250 and -5,000 cfs following the first flush until the onset of spawning will protect later delta smelt migrants and spawners. During frequent intervals within the timeframe for RPA Component 1, the SWG shall provide specific OMR flow recommendations to the Service; and the Service

shall then determine flow requirements using the adaptive process as described in the RPA.

To estimate take with implementation of the RPA, the Service scaled projected salvage to abundance using the estimates provided by the prior year's FMWT Index (further details on the methods used in developing the Incidental Take Statement can be found in Attachment C). The segregation of year types is based upon descriptive statistics comprising quartiles, as expressed in Figure C-1 of Attachment C, and quantified following the approach described below.

The Cumulative Salvage Index (CSI) is calculated as the total year's adult salvage (the aggregate number for expanded salvage at both the Banks and Jones export facilities for the period December through March) divided by the previous year's FMWT Index. Water years 2006 to 2008 were years in which salvage, negative OMR flows, and delta smelt abundance were all lower relative to the historic values. The Service therefore believes these years within the historic dataset best approximate expected salvage under RPA Component 1.

The average CSI value for WYs 2006 to 2008 was 7.25. Projecting this average rate of salvage to the years in which CVP/SWP operations will be conducted within the sideboards established by the RPA would yield estimates of salvage at 7.25 times the prior year's FMWT Index. The Service used this estimator to predict incidental take levels of adult delta smelt during each year that the RPA's will be in effect. This value, which can be calculated upon release of the final FMWT Index within the current water year, is regarded as the incidental take for adult delta smelt under the RPA.

Incidental Take: Cumulative Expanded Salvage = 7.25 * Prior Year's FMWT Index

Delta smelt abundance is critically low, and without habitat quality conditions to appreciably improve juvenile growth and rearing from recent historic levels, is expected to remain so for the foreseeable future. The current population cannot tolerate direct mortality through adult entrainment at levels approaching even "moderate" take as observed through the historic record of recent decades. The method utilized herein to calculate take contains uncertainty within the estimates, and this fact translates into population-level risk. Further, there is a recognized need to provide a quantitative framework so that the Service and CVP/SWP operators have a common analytical methodology for reference and to further guide the adaptive process.

Therefore, the Service is also providing a Concern Level estimate, meant to indicate salvage levels approaching the take threshold, and help guide implementation of the RPA. Reaching this expanded salvage figure within a given season may require that OMR flows be set to a more restrictive level, unless available data indicate some greater level of exports is possible without increasing entrainment (e.g., there is strong reason to presume the pre-spawning migration has passed). Throughout the water year, as the SWG convenes and reviews daily salvage data, reaching the Concern Level for adult salvage requires an immediate specific recommendation to the Service.

The Service believes this Concern Level value should trigger at 75 percent of the calculated adult incidental take, as an indicator that operations may need to be more constrained to avoid exceeding the incidental take.

Concern Level: Cumulative Expanded Salvage = 5.43 * Prior Year's FMWT Index

Table IT-1 lists threshold levels of concern and incidental take for a range of potential FMWT indices. This table is intended to be used as a reference to discern levels of salvage reflecting the range of expected adult delta smelt mortality with implementation of the RPA, and as an indicator of adult delta smelt salvage levels that constitutes an increasing adverse effect to the delta smelt population due to CVP/SWP operations.

Table IT-1: Incidental Take Expanded Salvage Numbers by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	11	15	66	359	479	220	1197	1596	550	2992	3989
4	22	29	72	392	522	240	1305	1741	560	3046	4061
6	33	44	78	424	566	260	1414	1886	570	3100	4134
8	44	58	84	457	609	280	1523	2031	580	3155	4206
10	54	73	90	490	653	300	1632	2176	590	3209	4279
12	65	87	96	522	696	320	1741	2321	600	3264	4351
14	76	102	100	544	725	340	1849	2466	620	3372	4496
16	87	116	102	555	740	360	1958	2611	640	3481	4642
18	98	131	104	566	754	380	2067	2756	660	3590	4787
20	109	145	106	577	769	400	2176	2901	680	3699	4932
22	120	160	108	587	783	420	2285	3046	700	3808	5077
24	131	174	110	598	798	460	2502	3336	720	3916	5222
26	141	189	120	653	870	480	2611	3481	740	4025	5367
28	152	203	130	707	943	500	2720	3626	760	4134	5512
30	163	218	140	762	1015	502	2731	3641	780	4243	5657
34	185	247	150	816	1088	504	2741	3655	800	4351	5802
38	207	276	160	870	1160	506	2752	3670	840	4569	6092
42	228	305	170	925	1233	510	2774	3699	880	4787	6382
48	261	348	180	979	1305	520	2828	3771	920	5004	6672
54	294	392	190	1033	1378	530	2883	3844	960	5222	6962
60	326	435	200	1088	1450	540	2937	3916	1000	5439	7252

Take of Larval and Juvenile Delta Smelt

The Service has largely followed the methodology for estimating incidental take of larval delta smelt similar to that utilized for adults. Specifically, an average of the last four years (2005-2008) cumulative larval/juvenile salvage by month (April through July) was calculated. This can be summarizes as a Juvenile Salvage Index (JSI), calculated as:

Monthly Juvenile Salvage Index = cumulative seasonal ≥ 20 mm salvage by month end divided by current WY FMWT Index

The mean values from 2005-2008 were used as an estimate of take under the RPA. The reason for selecting this span of years is that the apparent abundance of delta smelt since 2005 as indexed by the 20-mm Survey and the TNS is the lowest on record. It was necessary to separate out this abundance variable, but also to account for other poorly understood factors relating salvage to OMR, distribution, and the extant conditions. On a monthly basis (cumulative salvage across the spring), this estimate represents a concern level where entrainment has reached high enough numbers to indicate the need for more protective OMR restrictions. The cumulative salvage figures in the Incidental Take Statement reflect totals beginning with the first seasonal juvenile salvage through the end of the current month (i.e., prior month totals are added to the succeeding month's values). The tables provided cover the full month to the final day of the applicable calendar month.

Concern Level = Monthly JSI 2005-2008 mean * Current WY FMWT

The last four years average monthly cumulative salvage was used to calculate the concern level for larval/juvenile smelt, as opposed to the incidental take under the RPA. It is acknowledged that salvage across years will be variable, as distribution, spawning success, prior entrainment of adults, enhanced survival of <20mm larval delta smelt under the RPA, and extant natural conditions determine. As mentioned above, this constrains predictability of take using this methodology, and is less reliable overall as the method used for adults. Also, it is believed that individuals of the larval/juvenile lifestage are less demographically significant than adults. Given these considerations, the incidental take estimate for ≥ 20 mm larval/juvenile delta smelt under the RPA will be above the four year average by 50 percent.

Larval/Juvenile Incidental Take = 1.5 * Concern Level

Lookup tables relating (current WY) FMWT to concern level and incidental take for cumulative salvage by month appears in Table IT-2 through IT-5, below.

Table IT-2: April Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	1	1	102	30	45	502	147	221
4	1	2	104	30	46	504	148	222
6	2	3	106	31	47	506	148	223
8	2	4	108	32	47	510	150	224
10	3	4	110	32	48	520	152	229
12	4	5	120	35	53	530	155	233
14	4	6	130	38	57	540	158	237
16	5	7	140	41	62	550	161	242
18	5	8	150	44	66	560	164	246
20	6	9	160	47	70	570	167	251
22	6	10	170	50	75	580	170	255
24	7	11	180	53	79	590	173	259
26	8	11	190	56	84	600	176	264
28	8	12	200	59	88	620	182	273
30	9	13	220	64	97	640	188	281
34	10	15	240	70	106	660	193	290
38	11	17	260	76	114	680	199	299
42	12	18	280	82	123	700	205	308
48	14	21	300	88	132	720	211	317
54	16	24	320	94	141	740	217	325
60	18	26	340	100	150	760	223	334
66	19	29	360	106	158	780	229	343
72	21	32	380	111	167	800	235	352
78	23	34	400	117	176	840	246	369
84	25	37	420	123	185	880	258	387
90	26	40	460	135	202	920	270	405
96	28	42	480	141	211	960	281	422
100	29	44	500	147	220	1000	293	440

Table IT-3: May Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	26	39	102	1329	1994	502	6543	9815
4	52	78	104	1356	2033	504	6569	9854
6	78	117	106	1382	2072	506	6595	9893
8	104	156	108	1408	2112	510	6647	9971
10	130	196	110	1434	2151	520	6778	10167
12	156	235	120	1564	2346	530	6908	10362
14	182	274	130	1694	2542	540	7038	10558
16	209	313	140	1825	2737	550	7169	10753
18	235	352	150	1955	2933	560	7299	10949
20	261	391	160	2085	3128	570	7429	11144
22	287	430	170	2216	3324	580	7560	11340
24	313	469	180	2346	3519	590	7690	11535
26	339	508	190	2476	3715	600	7821	11731
28	365	547	200	2607	3910	620	8081	12122
30	391	587	220	2868	4301	640	8342	12513
34	443	665	240	3128	4692	660	8603	12904
38	495	743	260	3389	5083	680	8863	13295
42	547	821	280	3650	5474	700	9124	13686
48	626	938	300	3910	5865	720	9385	14077
54	704	1056	320	4171	6256	740	9645	14468
60	782	1173	340	4432	6647	760	9906	14859
66	860	1290	360	4692	7038	780	10167	15250
72	938	1408	380	4953	7429	800	10427	15641
78	1017	1525	400	5214	7821	840	10949	16423
84	1095	1642	420	5474	8212	880	11470	17205
90	1173	1760	460	5996	8994	920	11991	17987
96	1251	1877	480	6256	9385	960	12513	18769
100	1303	1955	500	6517	9776	1000	13034	19551

Table IT-4: June Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	66	99	102	3369	5053	502	16578	24868
4	132	198	104	3435	5152	504	16644	24967
6	198	297	106	3501	5251	506	16711	25066
8	264	396	108	3567	5350	510	16843	25264
10	330	495	110	3633	5449	520	17173	25759
12	396	594	120	3963	5944	530	17503	26255
14	462	694	130	4293	6440	540	17833	26750
16	528	793	140	4623	6935	550	18164	27245
18	594	892	150	4954	7431	560	18494	27741
20	660	991	160	5284	7926	570	18824	28236
22	727	1090	170	5614	8421	580	19154	28732
24	793	1189	180	5944	8917	590	19485	29227
26	859	1288	190	6275	9412	600	19815	29722
28	925	1387	200	6605	9907	620	20475	30713
30	991	1486	220	7265	10898	640	21136	31704
34	1123	1684	240	7926	11889	660	21796	32695
38	1255	1882	260	8586	12880	680	22457	33685
42	1387	2081	280	9247	13870	700	23117	34676
48	1585	2378	300	9907	14861	720	23778	35667
54	1783	2675	320	10568	15852	740	24438	36657
60	1981	2972	340	11228	16843	760	25099	37648
66	2180	3269	360	11889	17833	780	25759	38639
72	2378	3567	380	12549	18824	800	26420	39630
78	2576	3864	400	13210	19815	840	27741	41611
84	2774	4161	420	13870	20806	880	29062	43593
90	2972	4458	460	15191	22787	920	30383	45574
96	3170	4756	480	15852	23778	960	31704	47556
100	3302	4954	500	16512	24769	1000	33025	49537

Table IT-5: July Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	75	112	102	3822	5732	502	18808	28213
4	150	225	104	3897	5845	504	18883	28325
6	225	337	106	3971	5957	506	18958	28437
8	300	450	108	4046	6070	510	19108	28662
10	375	562	110	4121	6182	520	19483	29224
12	450	674	120	4496	6744	530	19857	29786
14	525	787	130	4871	7306	540	20232	30348
16	599	899	140	5245	7868	550	20607	30910
18	674	1012	150	5620	8430	560	20981	31472
20	749	1124	160	5995	8992	570	21356	32034
22	824	1236	170	6369	9554	580	21731	32596
24	899	1349	180	6744	10116	590	22105	33158
26	974	1461	190	7119	10678	600	22480	33720
28	1049	1574	200	7493	11240	620	23229	34844
30	1124	1686	220	8243	12364	640	23979	35968
34	1274	1911	240	8992	13488	660	24728	37092
38	1424	2136	260	9741	14612	680	25477	38216
42	1574	2360	280	10491	15736	700	26227	39340
48	1798	2698	300	11240	16860	720	26976	40464
54	2023	3035	320	11989	17984	740	27725	41588
60	2248	3372	340	12739	19108	760	28475	42712
66	2473	3709	360	13488	20232	780	29224	43836
72	2698	4046	380	14237	21356	800	29973	44960
78	2922	4384	400	14987	22480	840	31472	47208
84	3147	4721	420	15736	23604	880	32971	49456
90	3372	5058	460	17235	25852	920	34469	51704
96	3597	5395	480	17984	26976	960	35968	53952
100	3747	5620	500	18733	28100	1000	37467	56200

Effect of the Take

The Service determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat when the RPA is implemented.

Reasonable and Prudent Measures

The following reasonable and prudent measures are necessary and appropriate to minimize the effect of the proposed action on the delta smelt:

1. Minimize adverse effects of the operations of the Permanent Operable Gates.

2. Minimize adverse effects of operations of the NBA.

3. Obtain real time data on the abundance and distribution of delta smelt in the Bay-Delta.

4. Minimize adverse effects of Banks and Jones on delta smelt.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, Reclamation shall ensure compliance with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are nondiscretionary.

The following Term and Condition implements Reasonable and Prudent Measures one (1):

1. The Service shall have the final decision on the operations of the Permanent Gates. The members of the GORT can provide suggestions to operate the gates, but the ultimate decision on how to operate the gates to protect delta smelt will be made by the Service.

The following Term and Condition implements Reasonable and Prudent Measures two (2):

1. Annual evaluations shall be conducted for the fish screens at the NBA diversion during January through June. A proposed evaluation study shall be submitted to the Service for approval within 3 months of the issuance of this biological opinion. The evaluation shall monitor fish entrained and impinged on the fish screen, the screen approach velocities, cleanliness of the screen and any other pertinent criteria needed to determine the effectiveness of the fish screen.

The following Terms and Conditions implement Reasonable and Prudent Measures three (3):

1. During the months of December through July, when water is being diverted, Reclamation and DWR shall ensure that the frequency of sampling for delta smelt at Banks and Jones will be at least 25 percent of the time.

2. Reclamation and DWR shall develop a methodology for quantitative larval monitoring at Banks and Jones to help refine the triggers for the Actions in the RPA. An interim plan shall be submitted to the Service for approval within 30 days of the issuance of this biological opinion so the monitoring can be implemented this year. A more detailed plan shall be developed and approved by the Service within one year.

The following Term and Condition implements Reasonable and Prudent Measures four (4):

1. Reclamation will develop within 30 days a methodology for dealing with transitions in operations after changes in OMR flow requirements.

Monitoring Requirements

Monitoring requirements in accordance with section 402.14(i)(3) of the implementing regulations for section 7 of the Act have been included as part of the RPA and must be implemented by Reclamation and DWR.

Reporting Requirements

Reclamation or DWR shall immediately report to the Service any information about take or suspected take of federally-listed species not authorized in this biological opinion. Reclamation or DWR must notify the Service within 24 hours of receiving such information. Notification must include the date, time, and location of the incident or of the finding of a dead or injured delta smelt. Any killed delta smelt that have been taken should be properly preserved in accordance with Natural History Museum of Los Angeles County policy of accessioning (10 percent formalin in quart jar or freezing). Information concerning how the fish was taken, length of the interval between death and preservation, the water temperature and outflow/tide conditions, and any other relevant information should be written on 100 percent rag content paper with permanent ink and included in the container with the specimen. The Service contact persons are Chris Nagano, Deputy Assistant Field Supervisor, at telephone (916) 414-6600, and Dan Crum, Resident Agent-in-Charge of the Service's Law Enforcement Division at telephone (916) 414-6660.

Conservation Recommendations

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities that can be implemented to further the purposes of the Act, such as preservation of endangered species habitat, implementation of recovery actions, or development of information and data bases.

The Service requests notification of the implementation of any conservation recommendations in order to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats. We propose the following conservation recommendations:

1. The Service recommends that Reclamation and DWR develop and implement restoration measures consistent with the current Delta Native Species Recovery Plan.

2. The Service recommends that Reclamation and DWR develop procedures that minimize the effects of all other in-water activities that it conducts within the action area on delta smelt.

3. The Service recommends Reclamation work with willing partners to establish and maintain a diverse population of delta smelt for refuge and research purposes, managed to ensure adequate genetic diversity.

To be kept informed of actions minimizing or avoiding adverse effects or benefiting listed and proposed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

Reinitiation-Closing Statement

If the Sacramento Valley Water Year Type Index (40-30-30) February 1 50 percent exceedence forecast indicates that the water year will be a second consecutive (or more) dry or critically dry year, Reclamation shall reinitiate consultation with the Service. In order to allow the CVP/SWP to provide health and safety needs, critical refuge supplies, and obligation to senior water rights holders, the combined CVP/SWP export rates will not be required to drop below 1,500 cfs in these circumstances. However, in the unlikely event that salvage approaches the incidental take limit at these low export levels, the Service shall assess the on-going risk to delta smelt and will determine if additional reductions in pumping or other actions are necessary to further minimize effects.

If the subsequent 40-30-30 March 1 50 percent forecast indicates that the water year will no longer be a second consecutive (or more) dry or critically dry year, project operations may resume as described in the RPA. However, if subsequent April or May 75 percent exceedence forecasts move back to a critically dry year, reinitiation will again commence. Forecasts wetter than dry shall result in implementation of actions as described in the RPA.

This concludes formal consultation on the proposed coordinated operations of the CVP and SWP in California. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Reclamation involvement or control over the

action has been maintained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the CVP/SWP that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the CVP/SWP is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the CVP/SWP. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease, pending reinitiation.

If you have questions concerning this biological opinion, please contact Ryan Olah, Steven Detwiler, or Cay C. Goude or Susan Moore of our Sacramento Fish and Wildlife Office at the letterhead address or at telephone (916) 414-6600.

Cc: California Department of Water Resources, Sacramento, CA

California Department of Fish and Game, Sacramento and Yountville, CA

National Marine Fisheries Service, Sacramento, CA

Literature Cited

Arthur, J. F., M. D. Ball, and S. Y. Baughman. 1996. Summary of federal and State water project impacts in the San Francisco Bay-Delta estuary, California. Pages 445-495 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Adib-Samii 2008. Personal communication via e-mail with Victoria Poage, USFWS, re: water temperature thresholds for collection of delta smelt in routine survey sampling, October 8, 2008

Alpine, A. E., and J. E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37: 946-955.

Amweg, E.L., D.P. Weston, & N.M. Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environmental Toxicology and Chemistry 24:966–972.

Bailey, H. C., C. Alexander, C. DiGiorgio, M. Miller, S. I. Doroshov, and D. E. Hinton. 1994. The effect of agricultural discharge on striped bass (Morone saxatilis) in California's Sacramento-San Joaquin drainage. Ecotoxicology 3: 123-142.

Baskerville-Bridges, B., J.C. Lindberg and S.I. Doroshov. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. Pages 219-228 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. (available at: http://www/science.calwater.ca.gov/pdf/workshops/POD/IEP_POD_2007_synthesis_report_031408.pdf)

Bennett, WA, Moyle, PB. 1996. Where have all the fishes gone? Interactive factors producing fish declines. Pages 519-541 in Hollibaugh, JT, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science. San Francisco, CA.

Bennett, WA, Kimmerer, WJ, Burau, JR. 2002. Plasticity in vertical migration by native and exotic fishes in a dynamic low-salinity zone. Limnology and Oceanography 47:1496-1507.

Bennett, W.A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science [Internet] 3(2) http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1

Bennett, WA, Hobbs, JA, Teh, S. 2008. Interplay of environmental forcing and growth-selective mortality in the poor year-class success of delta smelt in 2005. Final Report to the Interagency Ecological Program.

Brandes, P.L. and J.S. McClain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. *In* R.L. Brown (ed.), Contributions to the biology of Central Valley salmonids. Fish Bulletin 179, pp 39-137

Bouley, P. and W. J. Kimmerer 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324: 219-228.

Brown, R., S. Greene, P. Coulston, and S. Barrow. 1996. An evaluation of the effectiveness of fish salvage operations at the intake of the California Aqueduct, 1979-1993. Pages 497-518 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Brown, L.R. 2003. Will tidal wetland restoration enhance populations of native fishes? San Francisco and Watershed Science 1: http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art2.

Brown, L. R., W. Kimmerer, and R. Brown. 2008. Managing water to protect fish: a review of California's Environmental Water Account, 2001-2005. Environmental Management DOI 10.1007/s00267-008-9213-4 http://www.springerlink.com/content/u4022223x2181287/fulltext.pdf

Brown, R.L. and W.J. Kimmerer. 2001. Environmental and institutional background for CALFED's Environmental Water Account. CALFED Bay-Delta Program, Sacramento, California

Brown, R.L. & W. Kimmerer. 2002. Delta smelt and CALFED's Environmental Water Account: A summary of the 2002 delta smelt workshop. Prepared for the CALFED Science Program, October 2002.

Brown, LR, Michniuk, D. 2007. Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. Estuaries and Coasts 30:186-200.

Bryant, ME, Arnold, JD. 2007. Diets of age-0 striped bass in the San Francisco Estuary, 1973-2002. California Fish and Game 93:1-22.

California Department of Fish and Game. 2008a. ttp://www.delta.dfg.ca.gov/data/20mm/

California Department of Fish and Game. 2008b. Spring Kodiak Trawl Survey. http://www.delta.dfg.ca.gov/data/skt/

California Department of Fish and Game. 2008c. Summer Tow Net Survey. http://www.delta.dfg.ca.gov/data/townet/

Castillo, G., Morinaka, J., Baskerville-Bridges, B., Lindberg, J., Fujimura, R., Dubois, J., Tigan, G., Poage, V. 2008. Pilot Mark-Recapture Study to Estimate Delta Smelt Pre-screen Loss and Salvage Efficiency. 2008 CALFED Science Conference Presentation

Cook and Buffaloe 1998. – Determining the effect of earlier entrainment has been limited because previous studies either (1) did not quantify the volumes of water diverted (Hallock and Van Woert 1959, Pickard et al. 1982) or (2) did not sample at times when, or locations where, delta smelt were abundant

Culberson, S.D., C.B. Harrison. C. Enright and M.L. Nobriga. 2004. Sensitivity of larval fish transport to location, timing, and behavior using a particle tracking model in Suisun Marsh, California. Pages 257-267 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA

Davis, J.A., D. Yee, J.N. Collins, S.E. Schwarzbach, & S.N. Luoma. 2003. Potential for Increased Mercury Accumulation in the Estuary Food Web. San Francisco Estuary and Watershed Science. Vol. 1.

Dege, M. and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. Am. Fish. Soc. Symposium 39: 49-65

Dettinger, MD. 2005. From climate-change spaghetti to climate-change distributions for 21st Century California. San Francisco Estuary and Watershed Science 3:http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4.

Dugdale, RC, Wilkerson, FP, Hogue, VE, Marchi, A. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal, and Shelf Science 73:17-29.

Durand J. San Francisco State University, oral presentation at 2006 CALFED Science Conference

DWR Delta Overview. http://baydeltaoffice.water.ca.gov/sdbtbp/deltaoverview/delta_overview.pdf

DWR and Reclamation (California Department of Water Resources and U.S. Bureau of Reclamation). 1994. Biological Assessment — Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail. Prepared for U.S. Fish and Wildlife Service, Sacramento, CA. 230 p.

DWR. 1994. Temporary Barriers Project Fishery, Water Quality, and Vegetation Monitoring, 1993. Submitted to U.S. Army Corps of Engineers for permit requirements. 169 pp. plus appendixes.

DWR. 2000a. Benchmark Studies Assumptions, (Draft), Sacramento, CA, Sept. 2000.

DWR 2007. Morrow Island Distribution System fish entrainment study. Interim data summary report, Division of Environmental Services, Sacramento, CA.

Edmunds, J.L., K.M. Kuivila, B.E. Cole, & J.E. Cloern. 1999. Do herbicides impair phytoplankton primary production in the Sacramento-San Joaquin River Delta? In: USGS Toxic Substances Hydrology Program Technical Meeting Proceedings, Charleston, SC, March 8-12, 1999.

Edwards, G.W., K. Urquhart , & T. Tillman. 1996. Adult salmon migration monitoring during the various operational phases of the Suisun Marsh Salinity Control Gates, September–November 1994. Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 50. 27 p.

Enos, C, Sutherland, J, Nobriga, M. 2007. Results of a two year fish entrainment study at Morrow Island Distribution System in Suisun Marsh. Interagency Ecological Program Newsletter 20(1):10-19.

Feyrer, F, Herbold, B, Matern, SA, Moyle, PB. 2003. Dietary shifts in a stressed fish assemblage: consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277-288.

Feyrer, F, Nobriga, ML, Sommer, TR. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723-734.

Feyrer, F, Newman, K, Nobriga, ML, Sommer, TR. 2008. Modeling the effects of water management actions on suitable habitat and abundance of a critically imperiled estuarine fish (delta smelt *Hypomesus transpacificus*). Manuscript in preparation.

Foott, J. S., K. True, & R. Stone. 2006. Histological evaluation and viral survey of juvenile longfin smelt, (*Spirinchus thaleichthys*) and threadfin shad (*Dorosoma petenense*) collected in the Sacramento-San Joaquin River Delta, April-October 2006. California Nevada Fish Health Center

Giddings, J.M., L.W. Hall, Jr, & K.R. Solomon. 2000. Ecological risks of diazinon from agricultural use in the Sacramento - San Joaquin River Basins, California. Risk Analysis 20:545–572.

Grimaldo, LF, Sommer, T, Van Ark, N, Jones, G, Holland, E, Moyle, P, Smith, P, Herbold, B. Factors affecting fish entrainment into massive water diversions in a freshwater tidal estuary: can fish losses be managed? North American Journal of Fisheries Management: accepted manuscript

Grimaldo, L.F., A. R. Stewart, and W. Kimmerer. Dietary segregation of pelagic and littoral fish assemblages in a highly modified tidal freshwater estuary. In review Marine and Coastal Fisheries

Hallock, RJ, Van Woert, W. 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin rivers. California Fish and Game 45: 227-521.

Hobbs, JA, Bennett, WA, Burton, J. 2006. Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco Estuary. Journal of Fish Biology 69: 907-922.

Hobbs, JA, Bennett, WA, Burton, J, Gras, M. 2007. Classification of larval and adult delta smelt to nursery areas by use of trace elemental fingerprinting. Transactions of the American Fisheries Society 136:518-527.

Horppila, *J., A.* Liljendahl-Nurminen and T. Malinen. 2004. Effects of clay turbidity and light on the predator–prey interaction between smelts and chaoborids. Can. J. Fish. Aquat. Sci. 61: 1862-1870

Herren, JR, Kawasaki, SS. 2001. Inventory of water diversions in four geographic areas in California's Central Valley. California Department of Fish and Game Fish Bulletin 179(vol.2):343-355.

Jassby, A. D., J. E. Cloern, and T. M. Powell. 1993. Organic carbon sources and sinks in San Francisco Bay: variability induced by river flow. Mar. Ecol. Prog. Ser. 95: 39-54.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecol. Appl. 5(1): 272-289

Jassby, AD, Cloern, JE, Cole, BE. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography 47:698-712.

Jassby, A.D., A.B. Mueller-Solger and M. Vaysierres. 2005. Subregions of the

Sacramento-San Joaquin Delta: identification and use. Interagency Ecological Program Newsletter 18(2): 46-56

Kawakami, B.T., Denton, R.A., Gartrell, G. 2008. Investigation of the Basis for Increases in Delta Fall Salinity. CALFED Sceince Conference Poster Presentation.

Kimmerer, WJ, Orsi, JJ. 1996. Causes of long-term declines in zooplankton in the San Francisco Bay estuary since 1987. Pages 403-424 in J. T. Hollibaugh (editor) San Francisco Bay: the ecosystem. AAAS, San Francisco, CA.

Kimmerer, W.J. 2002. Physical, biological and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25: 1275-1290

Kimmerer, W. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological processes. San Francisco Estuary and Watershed Science [Internet] 2(1) http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1

Kimmerer, W. and M. Nobriga 2005. Development of bootstrapped confidence intervals for the IEP fish abundance indices. Interagency Ecological Program Newsletter 18(2): 68-75.

Kimmerer, W.J. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entraiment in water diversioins in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] Vol. 6, Issue 2 (June 2008), Article 2 http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art2

Kimmerer, W.J. and M.L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science [online serial] Vol. 6, Issue 2 (February 2008), Article 4 http://repositories.cdlib.org/jmie/sfews/vol6/iss1/art4

Kimmerer, W.J. in prep Draft report on Tasl 4: Modeling. Report to the CALFED Ecosystem Restoration Program, Contract ERP-02-P19. Submitted June 12, 2008

Knutson, A.C. Jr and J.J. Orsi. 1983. Factors regulating abundance and distribution of the shrimp *Neomysis mercedis* in the Sacramento-San Joaquin Estuary. T. Am. Fish. Soc. 112: 476-485

Kuivila, K. M., and C. G. Foe 1995. Concentrations, transport, and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environmental Toxicology and Chemistry 14: 1141-1150.

Kuivila, KM, Moon, GE. 2004. Potential exposure of larval and juvenile delta smelt to dissolved pesticides in the Sacramento-San Joaquin Delta, California. American Fisheries Society Symposium 39:229-242.

Lehman, PW, Boyer, G, Hall, C, Waller, S, Gehrts, K. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia 541:87-99.

Lehman, PW, Boyer, G, Satchwell, M, Waller, S. 2008. The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. Hydrobiologia 600:187-204.

Lehman, P. W., T. Sommer and L. Rivard, 2008. The influence of floodplain habitat on the quantity of riverine phytoplankton carbon produced during the flood season in San Francisco Estuary. Aquatic Ecology 42: 363-378.

Liermann, M. and R. Hilborn. 2001. Depensation, evidence, models and implications. Fish and Fisheries 2:33-58.

Lindberg, Joan C., B. Baskerville-Bridges, and S.I. Doroshov. 2003. "Two Reproductive Concerns Tested in Captive Delta Smelt, *Hypomesus transpacificus*, 2002: I. Effect of substrate and water velocity on spawning behavior.

Linville, R.G., S.N. Luoma, L. Cutter, & G.A. Cutter. 2002. Increased selenium threat as a result of invasion of the exotic bivalve *Potamocorbula amurensis* into the San Francisco Bay-Delta. Aquatic Toxicology 57: 51-64.

Lopez , C. B., Cloern, J.E., Schraga, T.S., Little, A.J., Lucas, L.V., Thompson, J.K., and Burau, J.R., 2006, Ecological values of shallow-water habitats: implications for restoration of disturbed ecosystems, Ecosystems 9: 422-440.

Lott, J. 1998. Feeding habits of juvenile and adult delta smelt from the Sacramento-San Joaquin River Estuary. Interagency Ecological Program Newsletter 11(1):14-19 (available at http://iep.water.ca.gov/report/newsletter/)

Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. 2007. Envisioning Futures for the Sacramento-San Joaquin Delta. San Francisco, CA: Public Policy Institute of California.

Mager RC. 1996. Gametogenesis, Reproduction and Artificial Propogation of Delta Smelt, *Hypomesus transpacificus.* [Dissertation] Davis: University of California, Davis. 115 pages.

Mager, R.C., S.I. Doroshov, J.P. Van Eenennaam and R.L. Brown. 2004. Early life stages of delta smelt. Pages 169-180 *in* F. Feyrer, L.R. Brown, R.L. Brown and J.J. Orsi, eds. Early fife history of fishes in the San Francisco Estuary and watershed. Am. Fish. Soc. Symp. 39, Bethesda, MD, USA

Manly, B.F.J. and M. Chotkowski. 2006. Two new methods for regime change analyses.

Arch. Hydrobiol. 167(1-4): 593-607

Monson, N.E., J.E. Cloern and J.R. Burau. 2007. Effects of flow diversion on water and habitat quality: examples from California's highly manipulated Sacramento-San Joaquin

Moyle, P.B. 2002. Inland fishes of California. University of California Press, Berkeley and Los Angeles, California

Moyle, PB, Herbold, B, Stevens, DE, Miller LW. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67-77.

Moyle, P. B. 1976. Inland fishes of California. University of California Press. Berkeley, CA.

Moyle, PB, Herbold, B, Stevens, DE, Miller LW. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67-77.

Moyle, PB, Israel, JA. 2005. Untested assumptions: effectiveness of screening diversions for conservation of fish populations. Fisheries 30(5):20-28.

Miller, BJ. 2007. Declaration of William J. (B.J.) Miller, Ph.D. Regarding Interim Injunctive Relief, July 23, 2007, Proceedings of Natural Resources Defense Council, et al. v. Kempthorne, et al., Case No. 05 CV-01207 OWW (E.D. Cal.)

Mueller-Solger, A.B., Jassby, A.D., Mueller-Navarra, D.C. 2002. Nutritional quality of food resources for zooplankton (Daphnia) in a tidal freshwater system (Sacramento?San Joaquin River Delta), Limnol. Oceanogr. 47(5), 2002, 1468-1476.

Newman KB. 2008. Sample design-based methodology for estimating delta smelt abundance. San Francisco Estuary and Watershed Science 6(3): article 3. Available from: http://repositories.cdlib.org/jmie/sfews/vol6/iss3/art3

Nobriga, M, Hymanson, Z, Oltmann, R. 2000. Environmental factors influencing the distribution and salvage of young delta smelt: a comparison of factors occurring in 1996 and 1999. Interagency Ecological Program Newsletter 13(2):55-65. Available online at http://www.iep.ca.gov/report/newsletter/2000spring/IEPNewsletter_Spring2000.pdf

Nobriga, M. and M. Chotkowski 2000. Recent historical evidence of centrarchid increases and tule perch decrease in the Delta. Interagency Ecological Program Newsletter 13(1):23-27. Available online at http://www.iep.ca.gov/report/newsletter

Nobriga, M. L. and F. Feyrer (in press). Diet composition of San Francisco Estuary striped bass: does trophic adaptability have its limits? Environmental Biology of Fishes. In press.

Nobriga, ML. 2002. Larval delta smelt diet composition and feeding incidence: environmental and ontogenetic influences. California Fish and Game 88:149-164.

Nobriga, Matthew L, , Z Matica, and Z.P. Hymanson 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison among Open-Water Fishes. Pages 281-295 in F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Nobriga, ML, Feyrer, F, Baxter, RD, Chotkowski, M. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies and biomass. Estuaries 28:776-785.

Nobriga, M.L., & F. Feyrer. 2007. Shallow-water piscivore-prey dynamics in California's Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 5:http://repositories.cdlib.org/jmie/sfews/vol5/iss2/art4.

Nobriga, M. and B. Herbold. 2008. Conceptual model for delta smelt (*Hypomesus transpacificus*) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP)

Nobriga, ML, Sommer, TR, Feyrer, F, Fleming, K. 2008. Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*. San Francisco Estuary and Watershed Science 6: http//repositories.cdlib.org/ jmie/sfews/vol6/iss1/art1.

Odum, W. E. 1988. Comparative ecology of tidal freshwater and salt marshes. Ann. Rev. Ecol. Syst. 19:147-176.

Ostrach, D. 2008. Multiple stressors and their effects on the striped bass population in the San Francisco estuary. Presented at Interagency Ecological Program 2008 Annual Workshop, Pacific Grove, CA, February 26-29, 2008.

Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon, in Ecological studies of the Sacramento-San Joaquin Delta, Part II. In: S.L. Turner & D.W. Kelley (Eds.), Ecological Studies of the Sacramento–San Joaquin Estuary, pp. 115-129. California Department of Fish and Game Fish Bulletin 136.

Reclamation 2008. OCAP Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project.

Rose, KA. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? Ecological Applications 10:367-385.

Rose, KA., J.H. Cowan, K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding, and prognosis. Fish and Fisheries 2: 293-327.

Ruhl, C.A., P.E. Smith, J.J. Simi and J.R. Burau. 2006. The pelagic organism decline and long-term trends in Sacramento-San Joaquin Delta hydrodynamics. Presentation at the 4th Biennial 2006 CALFED Science Conference, October 23-25, 2006, Sacramento, California

Saiki, MK, Jennings, MR, Wiedmeyer, RH. 1992. Toxicity of agricultural subsurface drainwater from the San Joaquin River, California, to juvenile Chinook salmon and striped bass. Transactions of the American Fisheries Society 121:78-93.

Saiki, M.K. 1998. An ecological assessment of the Grassland Bypass Project on fishes inhabiting the Grassland Water District, California. Final report submitted to U.S. Fish and Wildlife Service, Sacramento, CA. 72 pp.

Slater Steven unpublished data California Department of Fish and Game

Sommer, T. R., R. Baxter, and B. Herbold. 1997. Resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126: 961-976.

Spaar, S. 1994. Delta agricultural diversion evaluation1992 pilot study. California Department of Water Resources, Interagency Ecological Program Technical Report 3, Sacramento, California

Sobczak, W. V., J. E. Cloern, A. D. Jassby, and A. B. Muller-Solger. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. Proceedings of the National Academy of Sciences 99, no. 12: 8101-8105.

Sommer, T.R., W.C. Harrell, A. Mueller-Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14:247-261.

Sommer, T, Armor, C, Baxter, R, Breuer, R, Brown, L, Chotkowski, M, Culberson, S, Feyrer, F, Gingras, M, Herbold, B, Kimmerer, W, Mueller-Solger, A, Nobriga, M, Souza, K. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32(6):270-277.

Stevens, DE, Miller, LW. 1983. Effects of river flow on abundance of young Chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin river system. North American Journal of Fisheries Management 3:425-437.

Sullivan et al., unpublished information

Swanson, C. and J.J. Cech Jr. 1995. Environmental tolerances and requirements of the delta smelt, *Hypomesus transpacificus*. Final Report. California Department of Water Resources Contracts B-59499 and B-58959. Davis, California. July 20, 1995

Swanson, C, Young, PS, Cech, JJ, Jr. 1998. Swimming performance of delta smelt: maximum performance, and behavioral and kinematic limitations on swimming at submaximal velocities. Journal of Experimental Biology 201:333-345.

Swanson, C., T. Reid, P.S. Young and J. Cech Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123: 384-390

Sweetnam, DA. 1999. Status of delta smelt in the Sacramento-San Joaquin Estuary. California Fish and Game 85:22-27.

Thetmeyer. H. and U. Kils. 1995. To see and not be seen: the visibility of predator and prey with respect to feeding behaviour. Mar. Ecol. Prog. Ser. 126: 1-8

Tillman, T., G.W. Edwards, K. Urquhart. 1996. Adult salmon migration monitoring during the various operational phases of the Suisun Marsh Salinity Control Gates in Montezuma Slough, August–October 1993. Stockton (CA): California Department of Fish and Game, Bay-Delta and Special Water Projects Division. 35 p.

Trenham, P.C., H.B. Shaffer and P.B. Moyle. 1998. Biochemical identification and assessment of population subdivision in morphometrically similar native and invading smelt species (*Hypomesus*) in the Sacramento-San Joaquin Estuary, California. T. Am. Fish. Soc. 127: 417-424

Turner, J. L. and H. K. Chadwick 1972. Distribution and abundance of young-of-the-year striped bass, Morone saxatilis, in relation to river flow in the Sacramento-San Joaquin estuary. Transactions of the American Fisheries Society 101: 442-452.

Turner, JL, Kelley, DW (editors). 1966. Ecological studies of the Sacramento-San Joaquin Delta, part II, fishes of the Delta. California Department of Fish and Game Fish Bulletin 136.

Utne-Palm, A.C. and J.E. Stiansen. Effect of larval ontogeny, turbulence and light on prey attack rate and swimming activity in herring larvae. J. Exper. Mar. Biol. Ecol. 268(2): 147-170

U.S. Fish and Wildlife Service. 1996. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology [online]1(2):1. Available from the Internet. URL: http://www.consecol.org/vol1/iss2/art1/

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: a guide to the early life stages. Interagency Ecological Studies Program Technical Report 9. Sacramento

Wang, J.C.S. 1991. Early life stages and early life history of the delta smelt, *Hypomesus transpacificus*, in the Sacramento-San Joaquin Estuary, with comparison of early life stages of the longfin smelt, *Spirinchus thaleichthys*. Interagency Ecological Studies Program Technical Report 28, August 1991

Wang, JCS. 2007. Spawning, early life stages, and early life histories of the Osmerids found in the Sacramento-San Joaquin Delta of California. Tracy Fish Facilities Studies California Volume 38. U.S. Bureau of Reclamation, Mid-Pacific Region.

Werner, I., L.A. Deanovic, V. Conner, V. de Vlaming, H.C. Bailey and D.E. Hinton. 2000. Insecticide-caused toxicity to *Ceriodaphnia dubia* (Cladocera) in the Sacramento-San Joaquin River Delta, California, USA. Environ. Tox. Chem. 19(1): 215-227

Werner, I, Deanovic, L, Markiewicz, D, Stillway, M, Offer, N, Connon, R, Brander, S. 2008. Pelagic organism decline (POD): Acute and chronic invertebrate and fish toxicity testing in the Sacramento-San Joaquin Delta, 2006-2007. Final report to the Interagency Ecological Program, April 30, 2008.

Weston, D.P, R.W. Holmes, J. You, & M.J. Lydy. 2005. Aquatic toxicity due to residential use of pyrethroid insecticides. Environmental Science and Technology 39: 9778-9784.

Weston, D.P., J. You, & M.J. Lydy. 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. Environmental Science and Technology 38: 2752-2759.

Whitehead, A., K.M. Kuivila, J.L. Orlando, S. Kotelevtsev, & S.L. Anderson. 2004. Genotoxicity in native fish associated with agricultural runoff events. Environmental Toxicology and Chemistry: 23:2868–2877

Wilkerson, FP, Dugdale, RC, Hogue, VE, Marchi, A. 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay. Estuaries and Coasts 29:401-416.

Winemiller, KO, Rose, KA. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196-2218.

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Attachment A-Delta Smelt Risk Assessment Matrix

Triggers	December	January	February	March	April	May	June	July
Life Stage	Adults	Adults	Adults	Adults and larvae	Adults and larvae	Larvae and juveniles	Larvae and juveniles	Juveniles
Previous Year's Fall Midwater Trawl Recovery Index (1)	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74	Index below 74
Risk of Entrainment (2)				X2 upstream of Chipps Island and temps are ≥ 12°	X2 upstream of Chipps Island and temps are between 12° and 18°C	X2 upstream of Chipps Island and mean delta-wide temps <18°C and south delta temps below 28°C	X2 upstream of Chipps Island and temps are below 28°C	X2 upstream of Chipps Island and temps are below 28°C
Duration of Spawning period (number of days temperatures are between 12 and 18°C) (3)					39 days or less by April 15	50 days or less by May 1		
Spawning Stage as determined by spring Kodiak trawl and/or salvage (4)			Presence of Adults at spawning stage ≥ 4	Adult spawning stage ≥ 4	Adult spawning stage ≥ 4			
smelt distribution (5)	See footnote #5	See footnote #5	See footnote #5	See footnote #5 or negative 20mm centroid or low juvenile abundance	Negative 20mm centroid or low juvenile abundance	Negative 20mm centroid or low juvenile abundance	Negative 20mm/summer townet centroid or low juvenile abundance	Negative 20mm/summer townet centroid or low juvenile abundance
Salvage Trigger (6)	Adult concern level calculation	Adult concern level calculation	Adult concern level calculation	Adult concern level calculation		If salvage is above zero	If salvage is above zero	

Delta Smelt Risk Assessment Matrix (DSRAM) **May 2008**

Tools for Change (7)	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**
Export reduction at one or both facilities	X	X	X	X	X	X	X	X
Change in barrier operations						X	X	X
Change in San Joaquin River flows				X	X	X	X	X
Change position of cross channel gates						X	X	

Delta Smelt Risk Assessment Matrix Footnotes

1 The Recovery index is calculated from a subset of the September and October Fall Midwater Trawl sampling (http://www.delta.dfg.ca.gov/). The number in the matrix, 74, is the median value for the 1980-2002 Recovery Index (Figure 1)

2 The temperature range of 12 to 18 °C is the range in which most successful delta smelt spawning occurs. This has been analyzed by using observed cohorts entering the 20-mm Survey length frequency graphs (1996-02). Cohorts were defined by having a noticeable peak or signal and occurring over three or more surveys during the rearing season. Temperature data from DWR's CDEC web site was compiled using three stations representing the South Delta (Mossdale), confluence (Antioch), and North Delta (Rio Vista). Spawning dates for each cohort was back-calculated by applying an average daily growth rate (wild fish) of 0.45 mm/day (Bennett, DFG pers. comm.) and egg incubation period of 8-14 days (Baskerville-Bridges, Lindberg pers. comm.)(Mager et al. 2004) from the median value of the analyzed cohort. Each spawning event was then plotted against temperature over time (Figure 2). While spawning does occur outside of the 12-18 °C range, larval survival is most likely reduced when temperatures are either below (DFG pers. comm.) or above this range (Baskerville-Bridges & DFG pers. comm.).

Critical thermal maxima for delta smelt was reached at 25.4 °C in the laboratory (Swanson et al., 2000); however, in 2007 delta smelt were observed in the delta and in salvage at temperatures up to about 28 °C.

Websites for the temperature data: http://cdec.water.ca.gov/cgi-progs/queryF?MSD
http://cdec.water.ca.gov/cgi-progs/queryF?ANH
http://cdec.water.ca.gov/cgi-progs/queryF?RIV

Mager RC, Doroshov SI, Van Eenennaam JP, and Brown RL. 2004. Early Life Stages of Delta Smelt. American Fisheries Society Symposium 39:169-180.

Swanson C, Reid T, Young PS, and Cech JJ. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced Wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123:384-390.

3 Figure 3: The working hypothesis for delta smelt is that spawning only occurs when temperatures are suitable during the winter and spring. In years with few days having suitable spawning temperatures, the spawning "window" is limited, so the species produces fewer cohorts of young smelt. Few cohorts increase the risk that mortality sources such as entrainment may have population level effects.

The figures below were used to help define years when there were relatively days with suitable temperatures. For April 15 and May 1, the figures show the cumulative spawning days for each year during 1984-2002. The cumulative spawning days for each year were calculated based on the number of days that the mean water temperature for three Delta stations (Antioch; Mossdale and Rio Vista) was in the 12 - 18 °C range starting on February 1. The results are plotted in terms of the ranks to identify the lower quartile. In other words, years in the lower quartile represent examples of years with relatively few spawning days.

4 The adult spawning stage is determined by the Spring Kodiak Trawl and/or fish salvaged at the pumping facilities (http://www.delta.dfg.ca.gov/). A stage greater than or equal to 4 indicates female delta smelt are ripe and ready to spawn or have already spawned (Mager 1996).

Mager RC. 1996. Gametogenesis, Reproduction and Artificial Propogation of Delta Smelt, *Hypomesus transpacificus.* [Dissertation] Davis: University of California, Davis. 115 pages. Published.

5 The spring kodiak trawl will be used to help generally determine the distribution of adult smelt. However, since the spring kodiak trawl is not intended to be a survey for abundance or distributions, no definitive trigger for concern can be determined at this time.

Juveniles (March-July) – distribution of juvenile delta smelt where the centroid is located upstream (negative) or downstream (positive) of the Sacramento-San Joaquin River confluence (Figure 4). The 20-mm Survey (or Summer Townet Survey) centroid is calculated by multiplying the observed delta smelt station CPUE (fish/10,000 m3) by a distance parameter in km from the confluence. The summed result (summed over a survey) is divided by the survey CPUE which gives the survey centroid position (Figure 5)

Low juvenile abundance will also be a trigger. Abundance (total cumulative count) will be monitored throughout the sampling season with low values based upon median values of historic cumulative 20-mm Survey catch (1995-2003). Each survey within a season has a median value associated with it and when catch is equal to or below that value, concern is high (Table 1).

6 Salvage trigger: the salvage trigger for December through March is determined by calculating the ratio of adult salvage to the fall MWT index. This ratio will increase as fish are salvaged during the winter months. If the ratio exceeds the median of what was observed during December-March 1980-2002, then the trigger was met (see Figure 6 for more explanation of the calculation)

During May and June, if delta smelt salvage at the salvage facilities is greater than zero, then the working group will meet. This is because May and June are the peak of smelt salvage and salvage densities cannot be predicted. Therefore,

during these two months, the SWG will meet proactively to protect these fish by looking at relevant information such as salvage, Delta temperatures, Delta hydrology and smelt distributions.

7 The tools for change are actions that the working group can recommend to the DAT and WOMT group to help protect delta smelt. Exports may be reduced at one or both of the South Delta export facilities and a proposed duration of the reduction would be recommended by the working group. Export reductions and changes in San Joaquin River flows may be covered by (b)(2) or EWA assets. Details of past fish actions can be found at the CALFED Ops website: http://wwwoco.water.ca.gov/calfedops/index.html; >Operations [year]

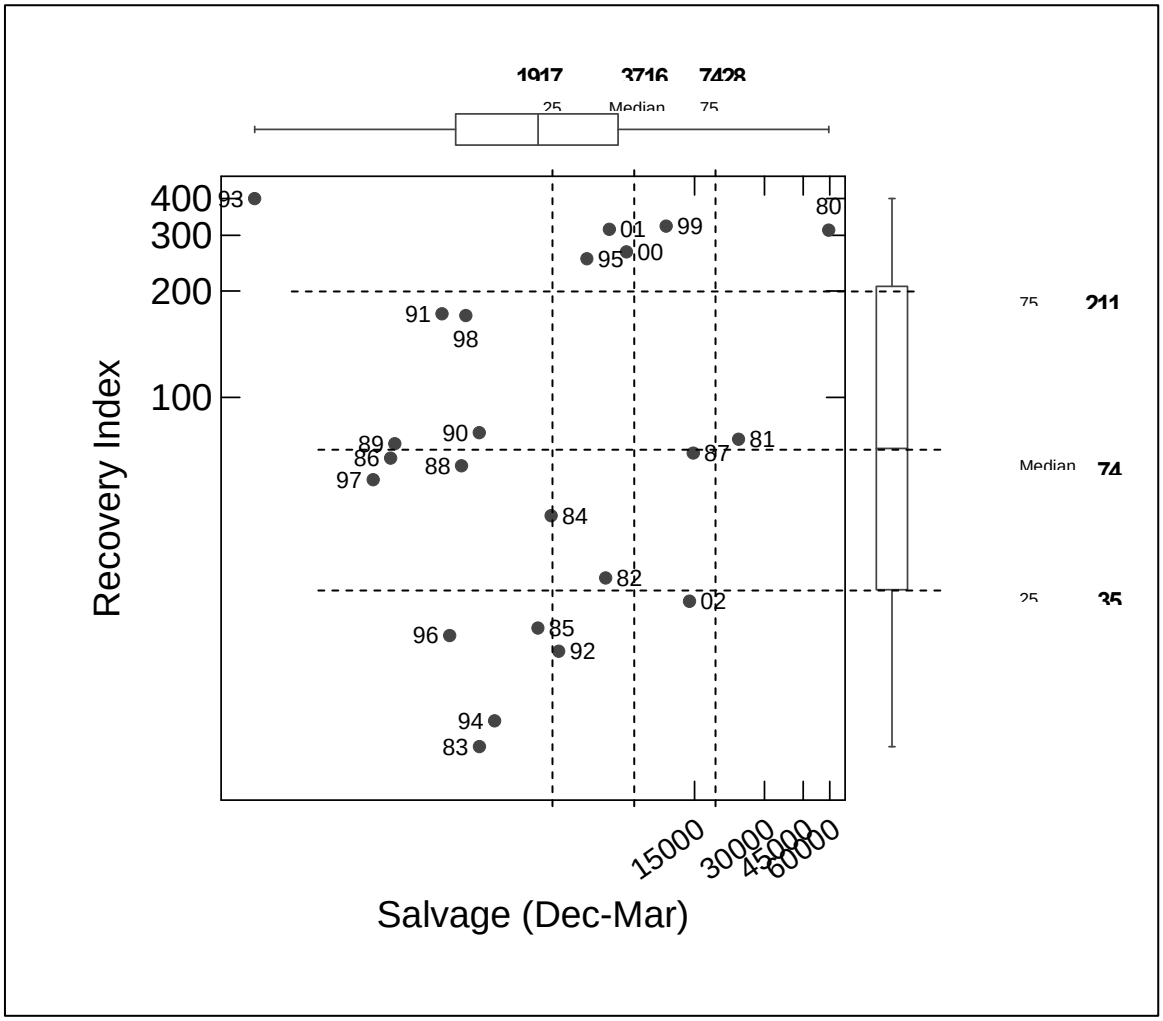


Figure 1 1980-2002 Recovery Index

Figure 1 points are labeled with the year representing the recovery index.
The winter salvage is for this analysis starts in December of the recovery index year and carries through March of the following year.

Figure 2 shows the successful delta smelt spawning periods (black bars) and start and end of spawning season (yellow bars) determined by the 20-mm Survey catch results (1996-2002). Temperature data (^{o}C) was compiled from CDEC using mean daily temperatures from the South Delta (Mossdale), North Delta (Rio Vista), and confluence (Antioch).

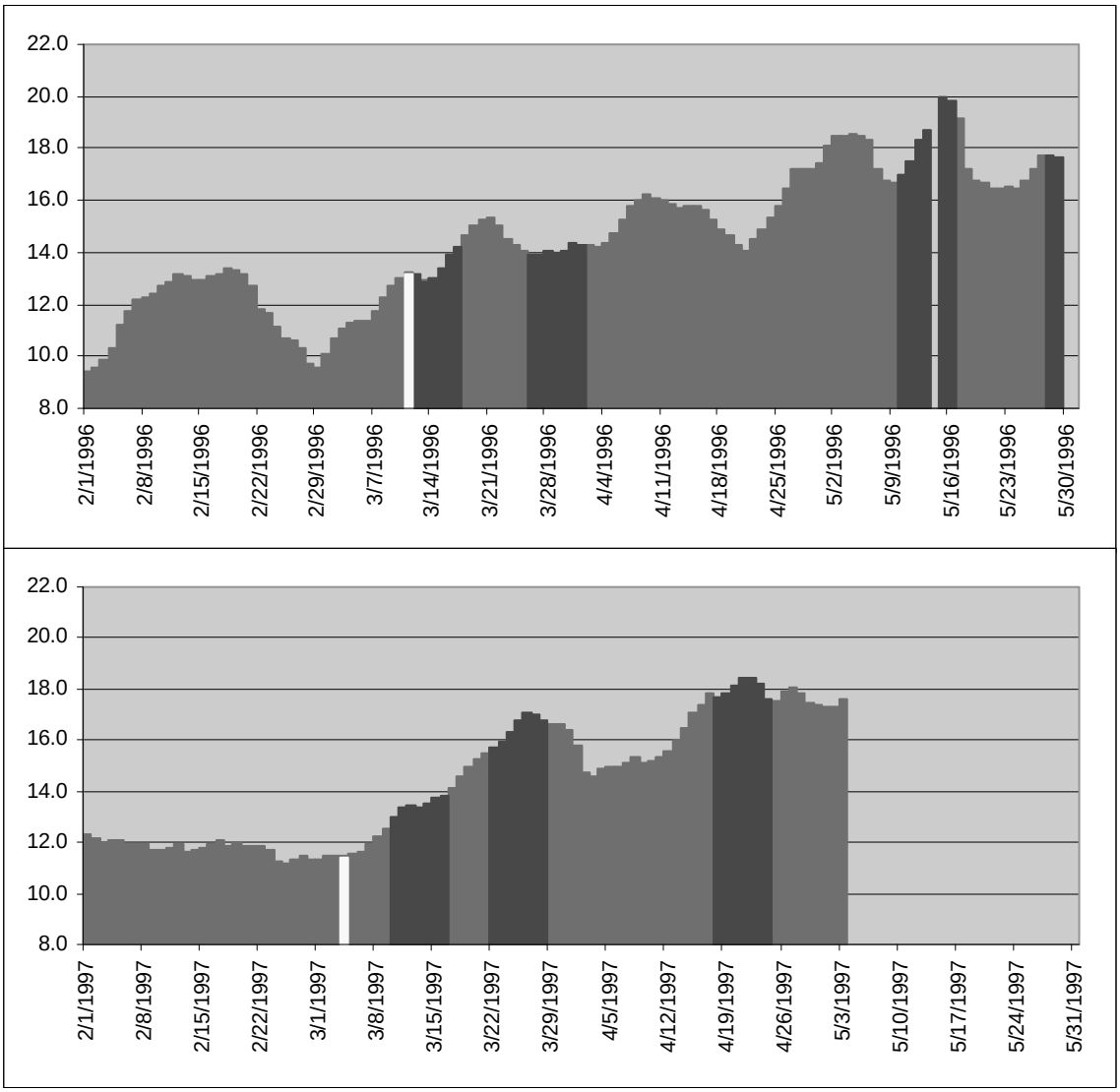
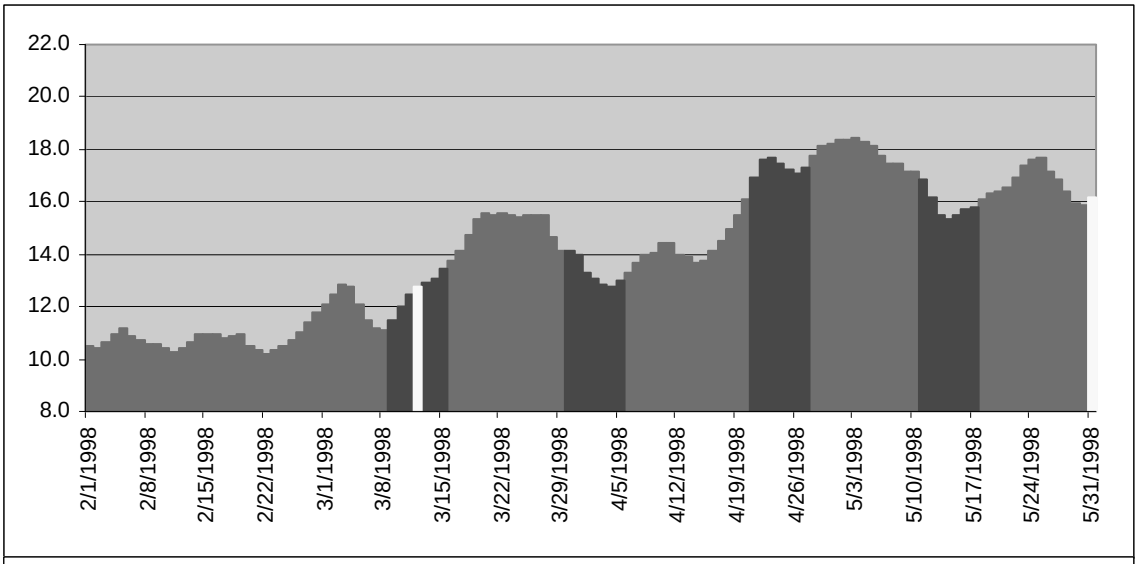


Figure 2 Successful delta smelt spawning periods


22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
2/1/1998
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2/15/1998
2/22/1998
3/1/1998
3/8/1998
3/15/1998
3/22/1998
3/29/1998
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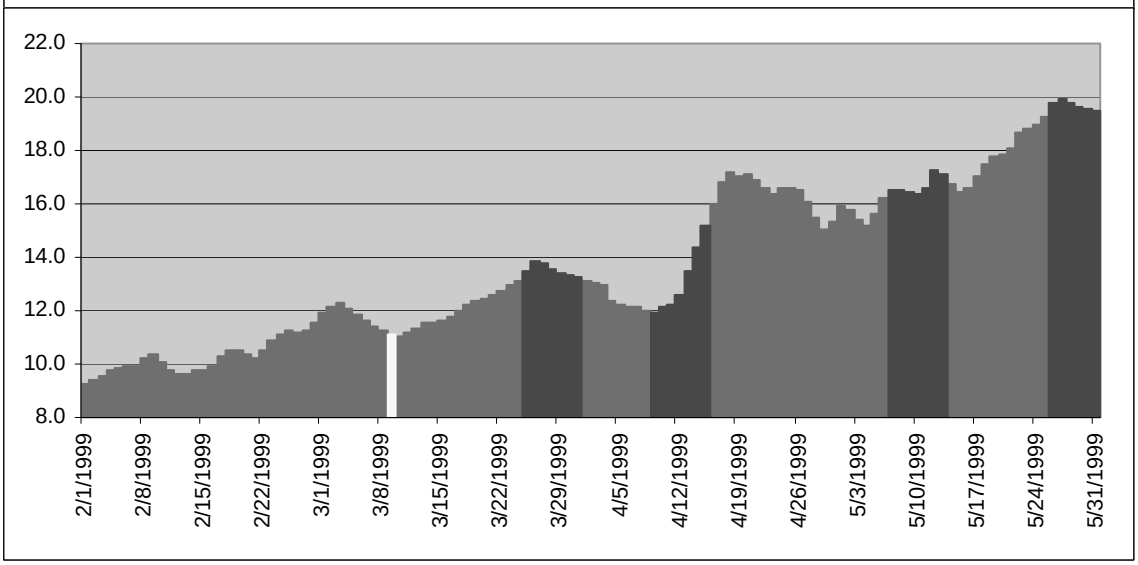
22.0
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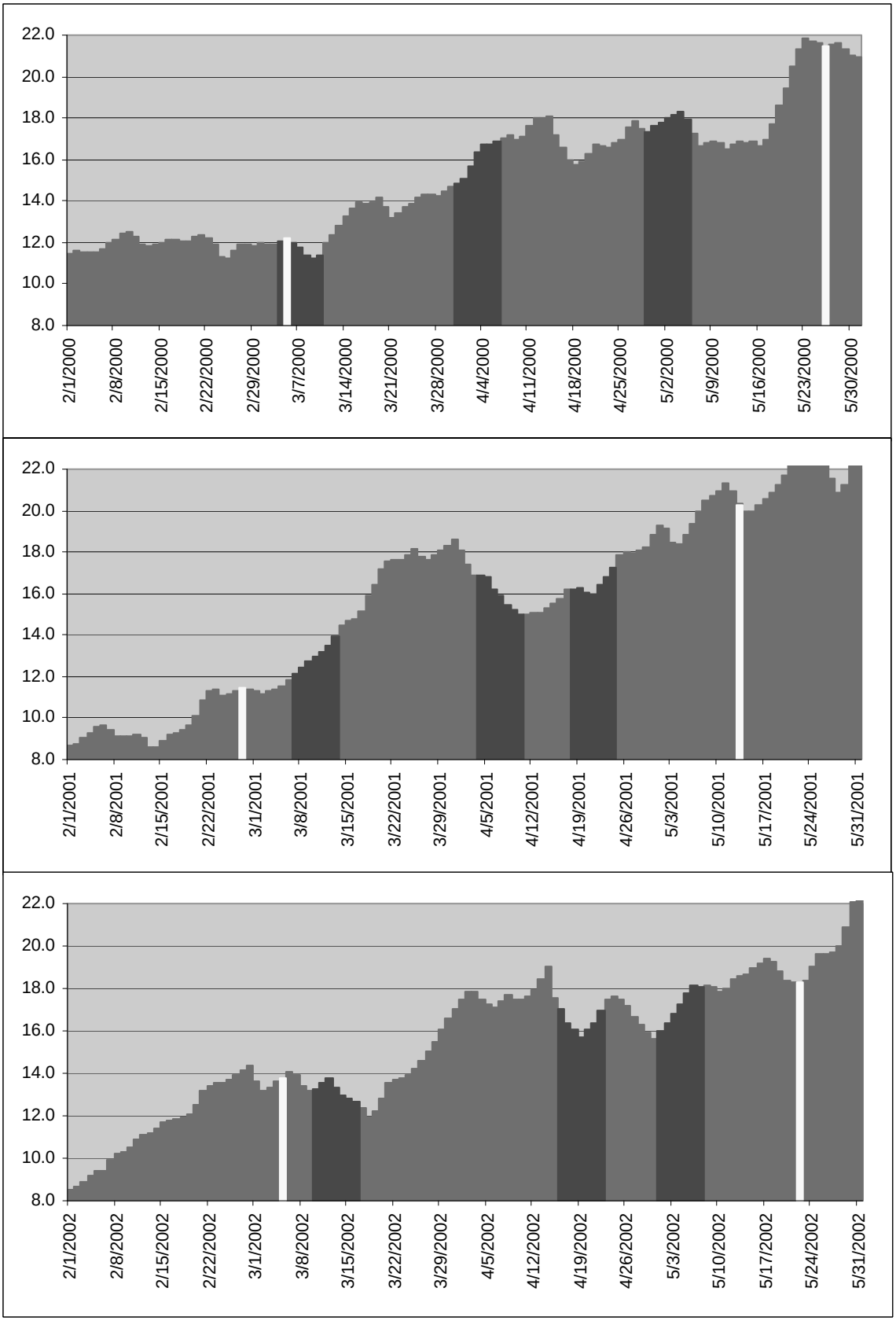
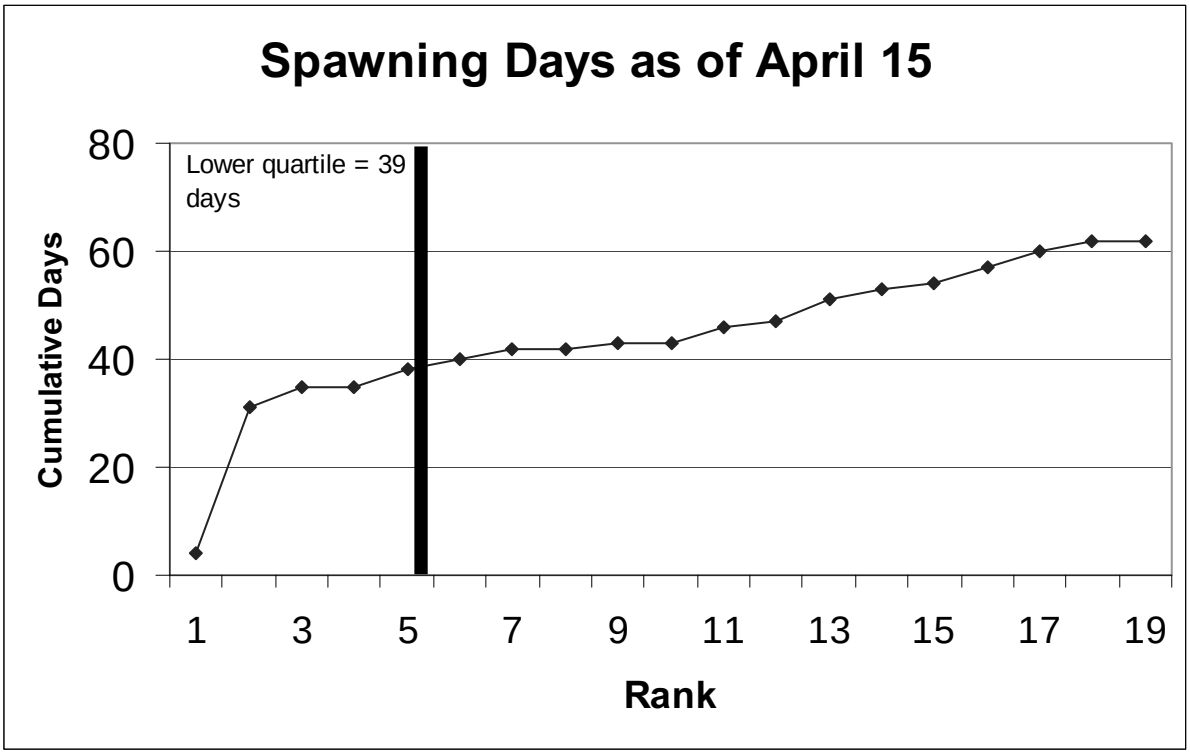


Figure 2 cont.



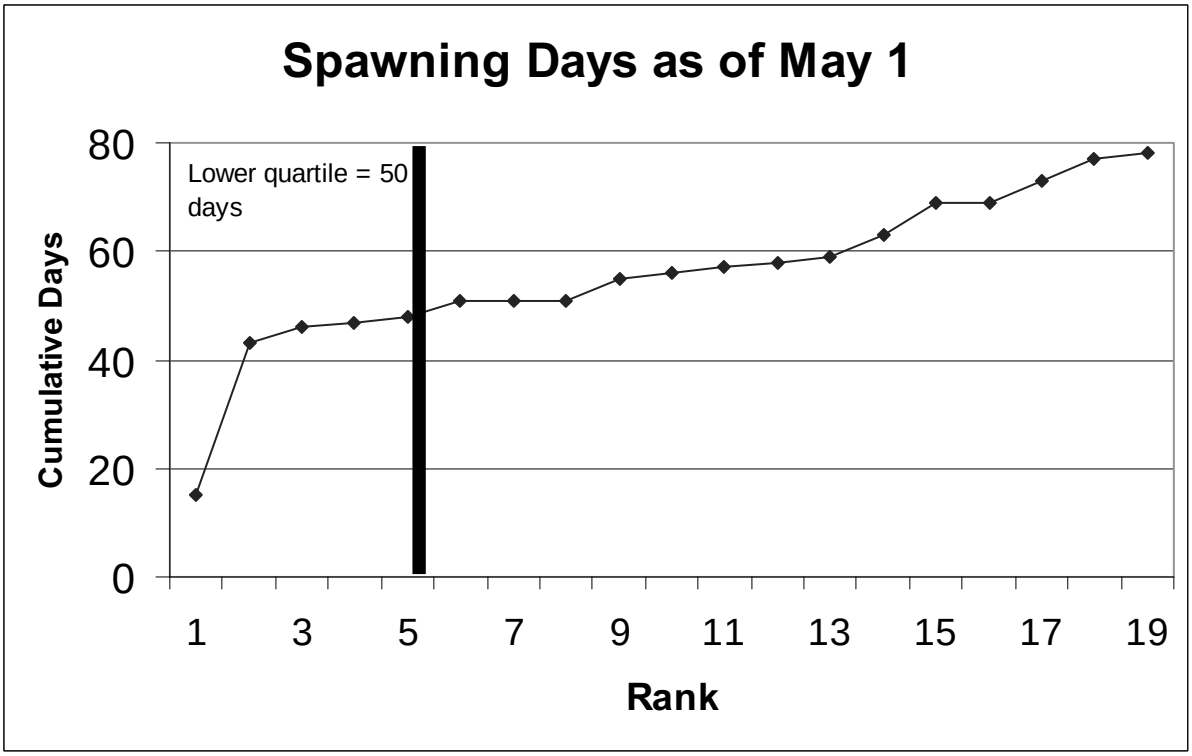


Figure 3 Delta smelt spawning days

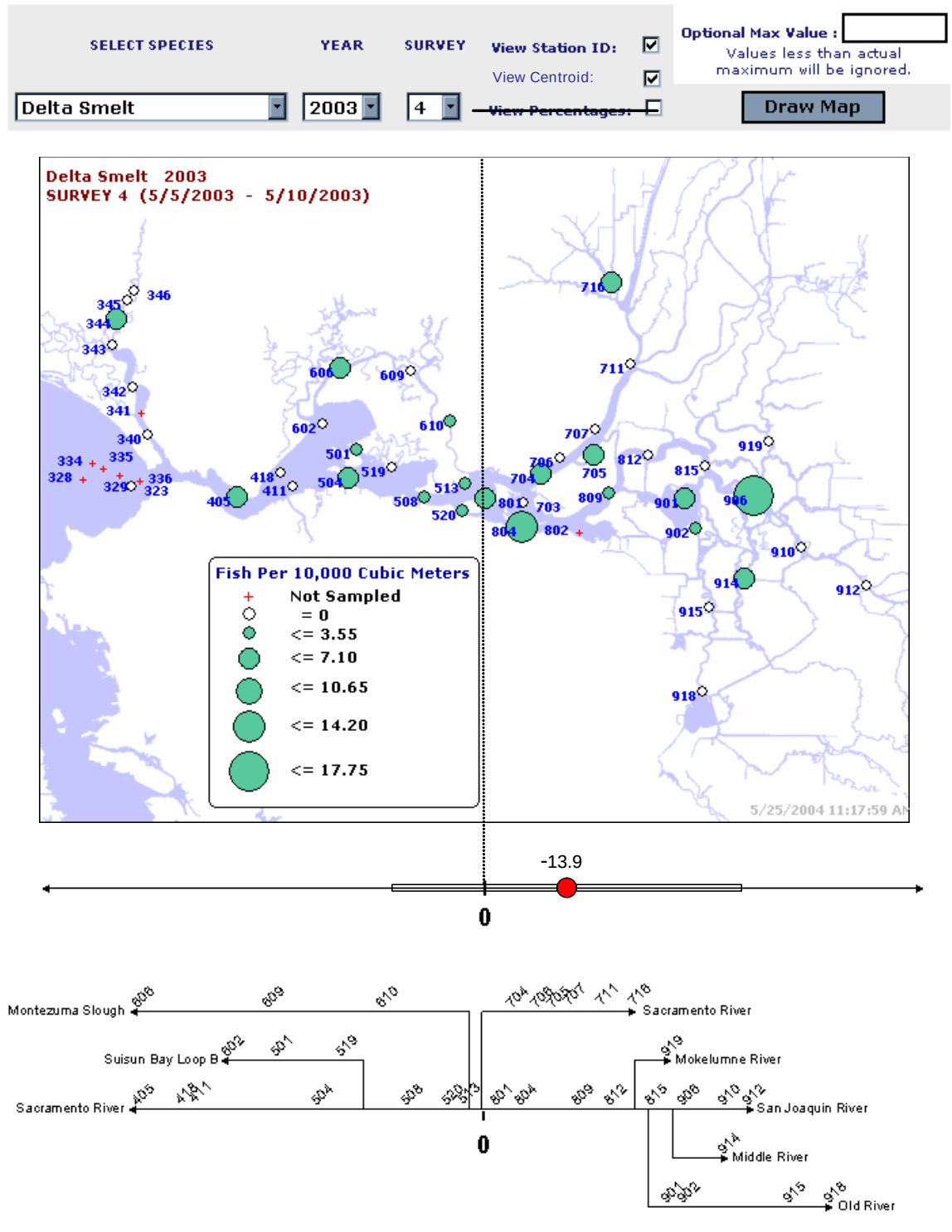


Figure 4 A 20-mm Survey delta smelt bubble plot map with calculated centroid position from the confluence of Sacramento-San Joaquin Rivers with one standard deviation.

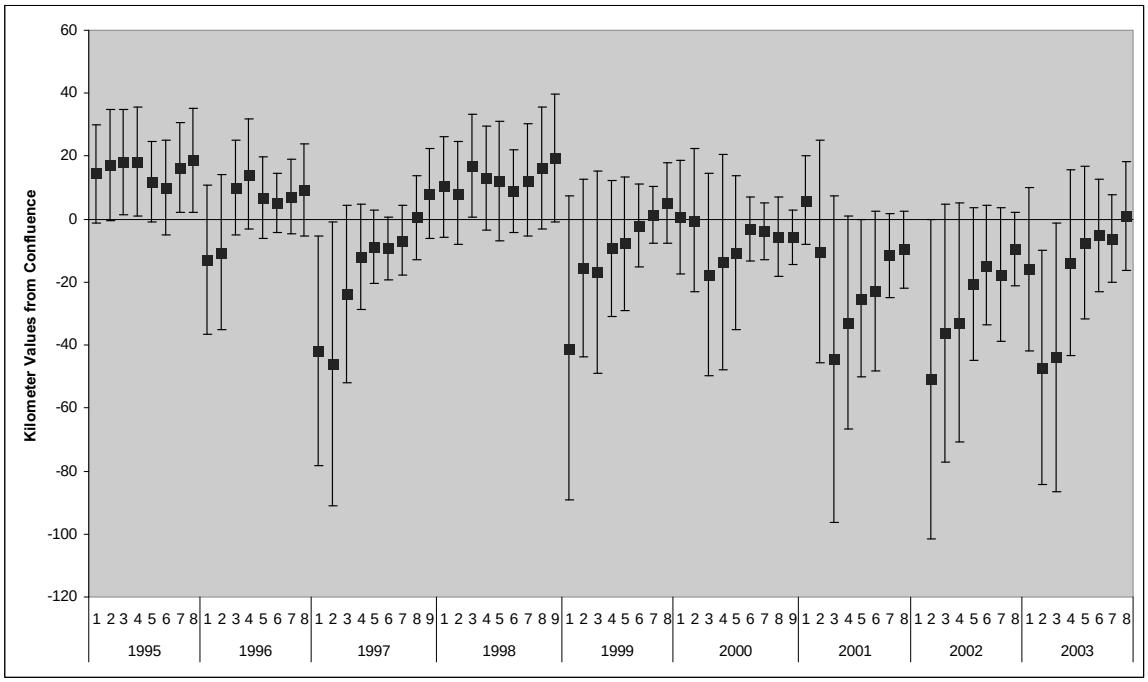


Figure 5 Historic juvenile centroid position (20-mm Survey) with one standard deviation.

Table 6 Lower quartile values of cumulative catch from the 20-mm Survey. When cumulative catch per survey during a season is at or below the calculated value, concern is high.

	survey 1	survey 2	survey 3	survey 4	survey 5	survey 6	survey 7	survey 8
lower quartile	12	40	144	188	346	500	924	1019

In Figure 7**,** the objective is to quantify a level of concern for adult delta smelt during the winter, that is based upon not only the number of fish salvaged but also accounts for the overall abundance of smelt. Whatever quantifier we select should reflect that when the abundance is low and salvage is high concern is high and conversely, when abundance is high and salvage is low that concern is low.

Below is a Quantile plot of the ratio of winter salvage to MWT index (ln (winter salvage/MWT index)). Winter salvage is defined as the total salvage from December through March. In the figure below, the size of the bubbles is proportional to the log of the fall midwater trawl just to give some indication of relative abundance. The resulting quartiles of the ratio are as follows:

25th percentile =: 2.950; 50th percentile = 3.575; 75th percentile = 5.029.

If we were to use this approach to calculate winter concern levels and use the median value, then all years above the 1999 point in the graph would have been years of concern. In other words, these are the years in which we may have recommended some protection. Comparing it to the protection afforded adult delta smelt in the winter by the 1995 biological opinion ("red light" was, or would have been reached in the following winters of 1980, 1981, 1982, 1984 and 1999) .

If the median was selected as the measure of concern it would be calculated by:

concern level = anti ln(3.575)* MWT recovery index

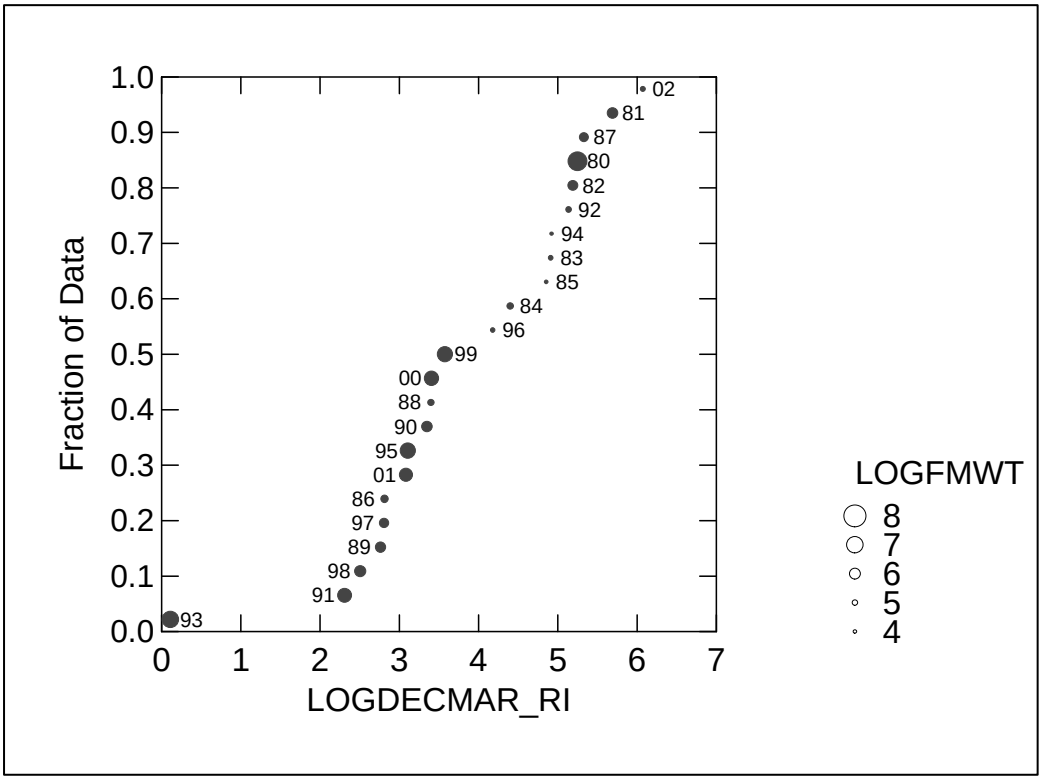


Figure 7 Quantile plot of the ratio of winter salvage to MWT recovery index

The goal for the DSRAM is to avoid the upper quartile of the above graph, in general, to avoid high salvage events when the MWT recovery index is low. Actions would be taken prior to salvage events and ideally, high salvage events would not occur.

Attachment B, Supplemental Information related to the Reasonable and Prudent Alternative

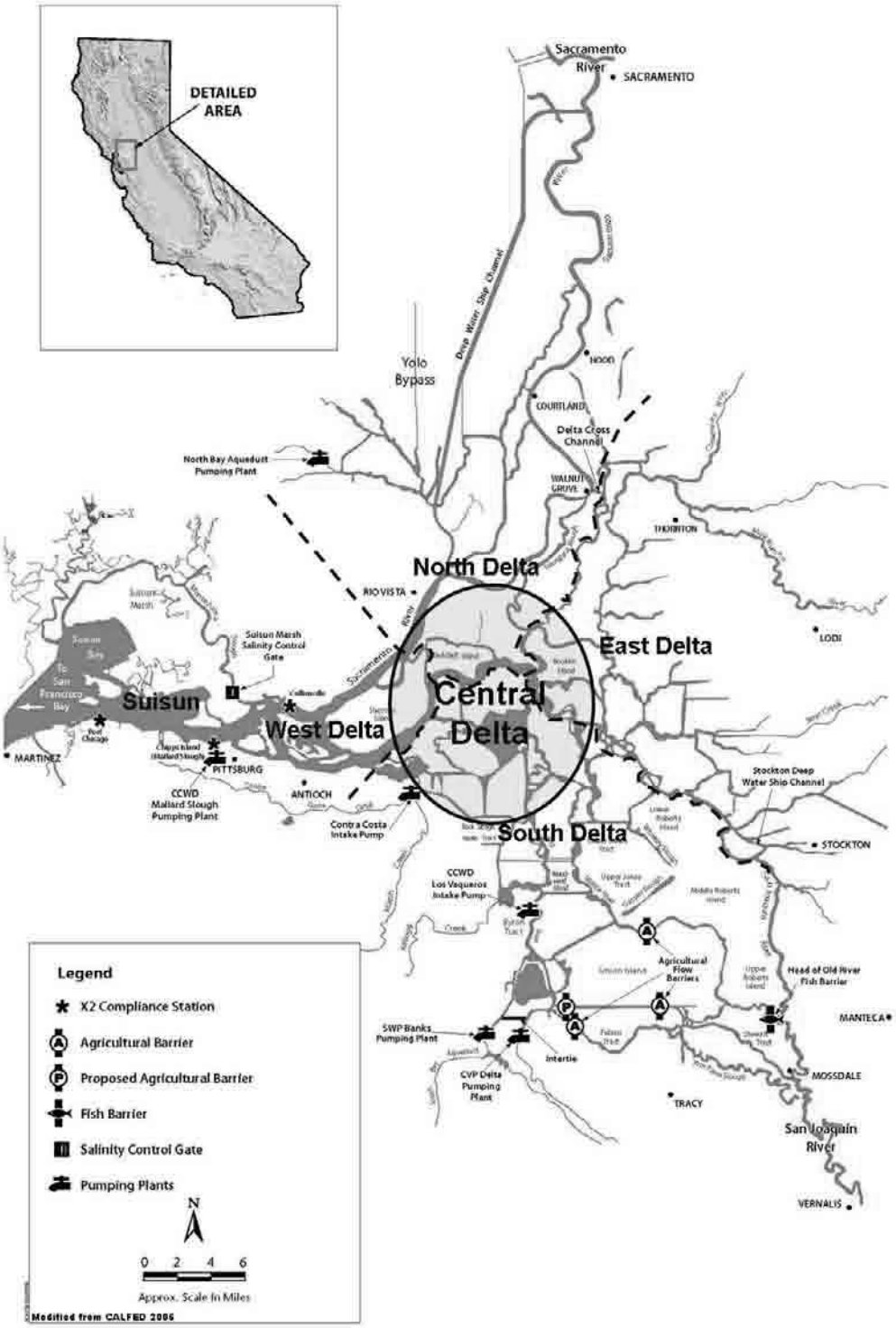
There are three major factors related to operations of the CVP/SWP affecting delta smelt population resilience and long-term viability. It is also recognized that the hydrologic changes from the CVP/SWP result in ecological conditions that influence delta smelt interactions with other stressors within the Delta. The following actions were developed to counter these adverse effects based upon the Baseline and Effects section of the biological opinion.

These three factors are: 1) direct mortality associated with entrainment of pre-spawning adult delta smelt by CVP/SWP operations; 2) direct mortality of larval and early juvenile delta smelt associated with entrainment by CVP/SWP operations; and, 3) indirect mortality and reduced fitness through reductions to and degradation of Delta habitats by CVP/SWP operations, with the fall as a particular concern. The actions below address these factors and will ameliorate the adverse effects that are brought about from the hydrologic modifications that influence delta smelt interactions with other stressors in the Delta.

The metric for monitoring direct mortality of delta smelt is salvage at Banks and Jones during pumping operations. However, this metric alone cannot be used to trigger operational changes in CVP/SWP to prevent entrainment. This is because the combination of tidal cycles, hydrologic and meteorological events, and CVP/SWP operations can draw delta smelt into the South and Central Delta (see Map 1) where they are more susceptible to entrainment by the facilities prior to any observed delta smelt salvage. This necessitates an anticipatory strategy in order to sufficiently protect delta smelt from entrainment.

As discussed in the Baseline and Effects Sections of the biological opinion, there are other impacts to delta smelt through reduction and degradation of habitat. These effects are functional year-round, through mechanisms defined and discussed in those sections. Indirect mortality and reduced fitness of juvenile delta smelt due to degraded environmental quality (habitat suitability) in the fall impacts delta smelt. The mechanism of this impact is habitat constriction, entrainment of primary and secondary productivity leading to food-web deprivation for prey species, decreased dilution flows resulting in increased exposure to lethal and sublethal concentrations of contaminants. Additionally it results in reduced habitat variability that is expected to help control invasive species such as *Corbula* or *Microcystis* that either compete with, or directly impact survival of delta smelt. The operational criteria to restore habitat quality for rearing juveniles in the estuary are related to increasing delta outflows during fall months (September through November) of above-normal and wet WYs to improve habitat variability.

Actions 1 and 2 will reduce the direct mortality of pre-spawning adult delta smelt (Adult Entrainment). Action 3 will reduce the direct mortality of larval and juvenile delta smelt (Larval/Early Juvenile Entrainment). Action 4 will restore habitat quality for rearing juveniles in the estuary that are directly related to increasing Delta outflows during fall months (September through November) of above-normal and wet WYs to restore habitat



Map 1: Delta Regions

suitability. Action 5 describes the installation and operations of the spring temporary Head of Old River Barrier (HORB) and the temporary agricultural barriers to reduce juvenile entrainment. The detailed elements of these prescriptions, including rationale and justification, appear in subsequent sections of this document, by Action.

Delta Smelt Evaluation Team

To develop the initial actions, the Service re-evaluated the Interim Remedies for delta smelt protection as proposed in the Service's declarations of July 3, 2007 and August 3, 2007 (Cay Collette Goude 2007), and implemented in the Federal District Court's Interim Remedies Order. The Service used the CALLite operations model to evaluate different operational scenarios. Different operational parameters were run to evaluate their influence upon predicted entrainment. These parameters included export-inflow (EI) ratios, QWest, X2, and OMR flows, among others.

During these sessions, two clear patterns became evident. First, shifting operations to reduce exports during any one given month resulted in a shift in operations to increase exports in other months. Second, holding one particular parameter steady did not prevent other parameters from adapting to meet similar water supply objectives. For example, modeling Qwest to some static number still allowed considerable variability in negative OMR flows, due to the contribution of other intervening variables to Qwest, including operation of the DCC and Sacramento and San Joaquin River flows. For these reasons, the most logical operational criterion for protecting delta smelt from entrainment is controlling the magnitude of flows in the South and Central Delta towards the export facilities. This is reflected quantitatively as net negative OMR flows during the time periods when delta smelt are present and subject to entrainment.

In July 2008, the Service convened a team of experts comprising members of the Adaptive Management Planning Team (AMPT) of the ERP, technical staff from the Department of Fish and Game and the Service, and an expert hydrodynamicist to conduct evaluations of Interim Remedy actions using the evaluation process and conceptual models developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) in light of the current project description.

To the extent practicable, the DRERIP evaluation tools were used in formulating potential actions to ameliorate the anticipated effects of the proposed action. The DRERIP tools include peer reviewed ecosystem and species conceptual models for the Delta drafted by teams of experts. These models represent a compilation of the current state of scientific knowledge regarding specific ecosystems and fish species, including delta smelt.

The full DRERIP evaluation process was not applied to the potential actions for delta smelt, but elements of the process were considered and followed during the initial phases of actions development and evaluation. The nature of the task before the evaluation team finally necessitated direct involvement of technical experts in providing up-to-date

quantitative analysis and detailed evaluation exceeding the level of detail inherent in the current DRERIP conceptual models.

Role of Adaptive Process and Monitoring

As discussed in the Baseline and Effects Sections of this biological opinion, we recognize that there are multiple factors affecting delta smelt population dynamics and that not all are directly influenced by operations of the CVP/SWP. With respect to direct mortality from entrainment, the prescriptions and triggers presented in actions 1, 2, and 3 are based on historical data. Net daily OMR flows serve as a key indicator of overall Delta hydrodynamics and changing OMR flows will change a key underlying driver of future salvage. Based on the low numbers of delta smelt and therefore the difficulties in delta smelt monitoring and the uncertainty in relying on historical data, the use of an adaptive process with regulatory sideboards is essential.

It is very important that the control mechanisms used to implement the actions be functionally protective when delta smelt densities are low. Delta smelt densities are likely to remain low for the foreseeable future. When delta smelt occur at low densities, it becomes difficult to reliably infer distribution and flux towards Banks and Jones based on IEP monitoring data. In circumstances where it is difficult to reliably infer these parameters, automated control mechanisms that assume reliable distribution information are likely to fail.

The real-time monitoring of final flow prescriptions within these actions are necessary parts of the final actions. Such a strategy utilizes weekly review of the sampling data and real-time salvage data at the CVP/SWP. It utilizes the most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity, and thereby adapts to current conditions. This would provide protection to delta smelt and reduce operational constraints when the risk of delta smelt entrainment is low based on distribution and data analysis. Such a strategy would provide necessary protections while utilizing the minimum possible regulatory constraints on the project.

ACTION 1: ADULT MIGRATION AND ENTRAINMENT (FIRST FLUSH)

Objective: A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period.

Action: Limit exports so that the average daily OMR flow[6] is no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent).

Timing:

Part A: December 1 to December 20 – Based upon an examination of turbidity data from Prisoner's Point, Holland Cut, and Victoria Canal and salvage data from CVP/SWP (see below), and other parameters important to the protection of delta smelt including, but not limited to, preceding conditions of X2, FMWT, and river flows; the SWG may recommend a start date to the Service. The Service will make the final determination.

Part B: After December 20 – The action will begin if the 3 day average turbidity at Prisoner's Point, Holland Cut, and Victoria Canal exceeds 12 NTU. However the SWG can recommend a delayed start or interruption based on other conditions such as Delta inflow that may affect vulnerability to entrainment.

Triggers (Part B):

Turbidity: 3-day average of 12 NTU or greater @ *all three* stations (Prisoner's Point, Holland Cut, Victoria Canal)

OR

Salvage: Three days of delta smelt salvage after December 20 at either facility or cumulative daily salvage count that is above a risk threshold based upon the "daily salvage index" approach reflected in a daily salvage index value ≥0.5 (daily delta smelt salvage > one-half prior year FMWT index value).

The window for triggering Action 1 concludes when either offramp condition described below is met. These offramp conditions may occur without Action 1 ever being

[6] OMR Flows for this and all relevant actions will be measured at the Old River at Bacon Island and Middle River at Middle River stations, as has been established already by the Interim Order.

triggered. If this occurs, then Action 3 is triggered[7], unless the Service concludes on the basis of the totality of available information that Action 2 should be implemented instead.

Off-ramps:

Temperature: Water temperature reaches 12°C based on a three station daily mean at Mossdale, Antioch, and Rio Vista

OR

Biological: Onset of spawning (presence of spent females in SKT or at Banks or Jones).

[7] The offramp criteria for Actions 1 and 2 to protect adults from entrainment are identical to the initiation triggers for Action 3 to protect larval/juveniles from entrainment

Background

Adult delta smelt entrainment is characterized by a pulse of pre-spawning migrants entering the Central and South Delta following a "first flush" flow event in winter. This event generally involves a coincident increase in turbidity; which, along with the flows, is a cue for delta smelt migration. The interaction of these migratory cues: flow, turbidity, temperature, and season, leads to migration patterns that are difficult to predict yearly. However, historical salvage of delta smelt at Banks and Jones provides an index of entrainment that can be compared against key general predictors like flow and turbidity. Figures B-1 and B-2 below graphically depict the relationship of these variables against daily smelt salvage at Banks and Jones during two example WYs. Once the initial pulse of pre-spawning migration passes, it is believed that spawning adults moderate their movements to maintain their geographical range to a smaller area (when conditions stay favorable) and to the extent that delta smelt can control their location based on extant flow variables.

Entrainment effects upon delta smelt populations can be substantial (Kimmerer 2008). In one historically common scenario, a tight coincidence between calendar timing, sudden influx of turbid (>12 NTU) fresh water into the Delta, and high Delta exports may lead to very high salvage spikes. These events are seen within the data as high amplitude peaks in the daily adult delta smelt salvage histogram. Such events occurred in WY's 1993 and 2003, as displayed in Figures B-3 and B-4, which plot turbidity and negative OMR on visually convenient scales against total salvage. If this scenario plays out in years where there are few delta smelt, it may be difficult to detect salvage spikes even if they represent substantial proportional entrainment events.

In a second scenario there are no large salvage spikes, but chronic entrainment over a sufficient duration adds up to a relatively large cumulative salvage. Alternatively, there may be multiple entrainment spikes in years where the timing of migratory cues is diffuse or occurs in episodes. This would appear graphically as a histogram with generally low-amplitude over the duration of the entrainment period. Examples of such entrainment years would include WY 2004 and 2005, as displayed in Figures B-5, and B-6.

Total entrainment depends on precipitation patterns, ambient air temperature, controlled and uncontrolled releases from waterways feeding the Delta, specific operation of facilities such as the DCC, and condition of that year's pre-spawning cohort based on current year habitat quality. All of these factors may affect the distribution of delta smelt adults as and after they migrate into the Delta—and it is the migration into the entrainment risk zone and the area of that zone based on operational conditions at the time that determines ultimate mortality. However, the list of variables known or believed to influence delta smelt distribution during this period is not complete, and there is substantial apparently stochastic variation in adult delta smelt habitat use.

Figure B-1: 1995 WY OMR, Turbidity, Salvage

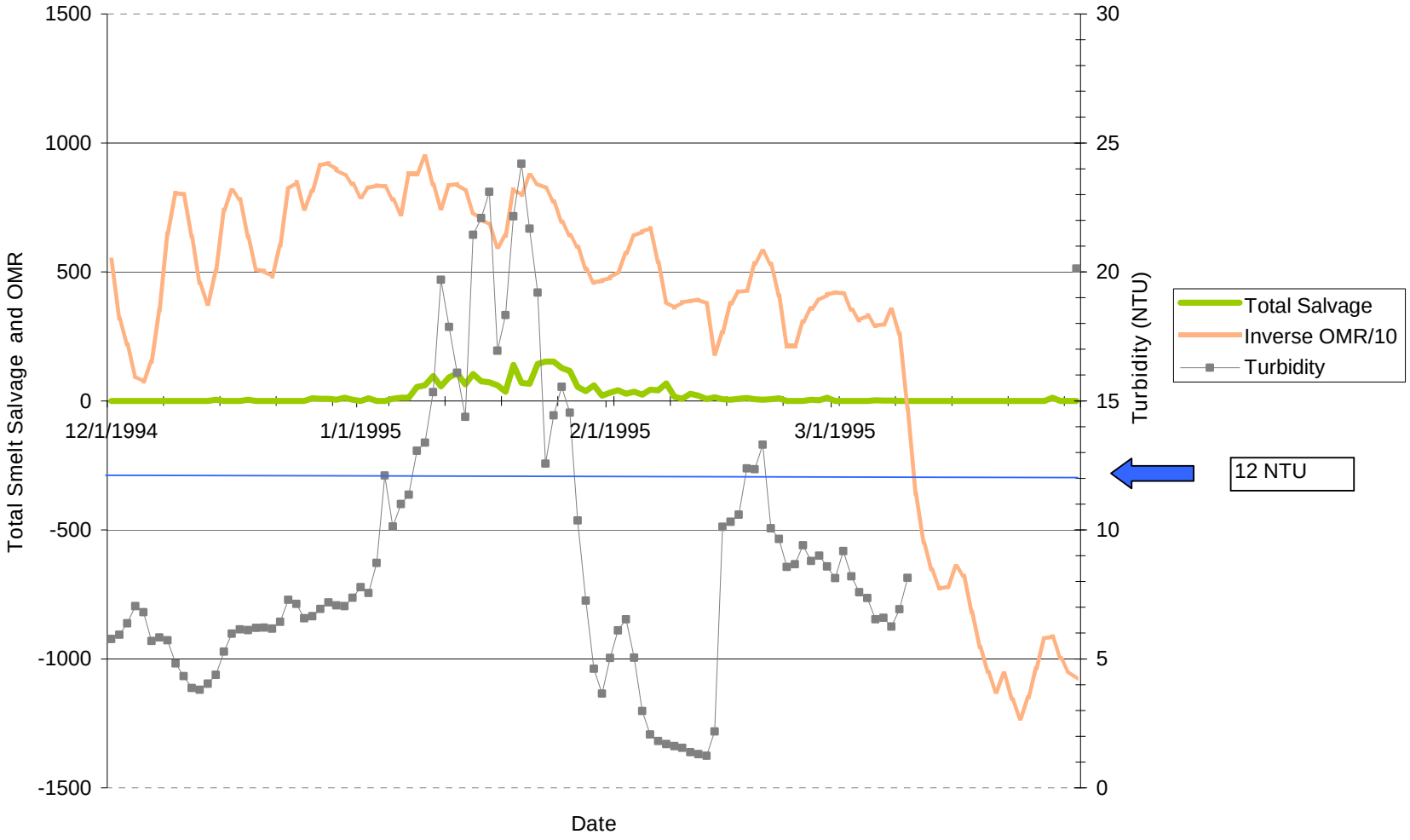


Figure B-2: 2002 WY OMR, Turbidity, Salvage

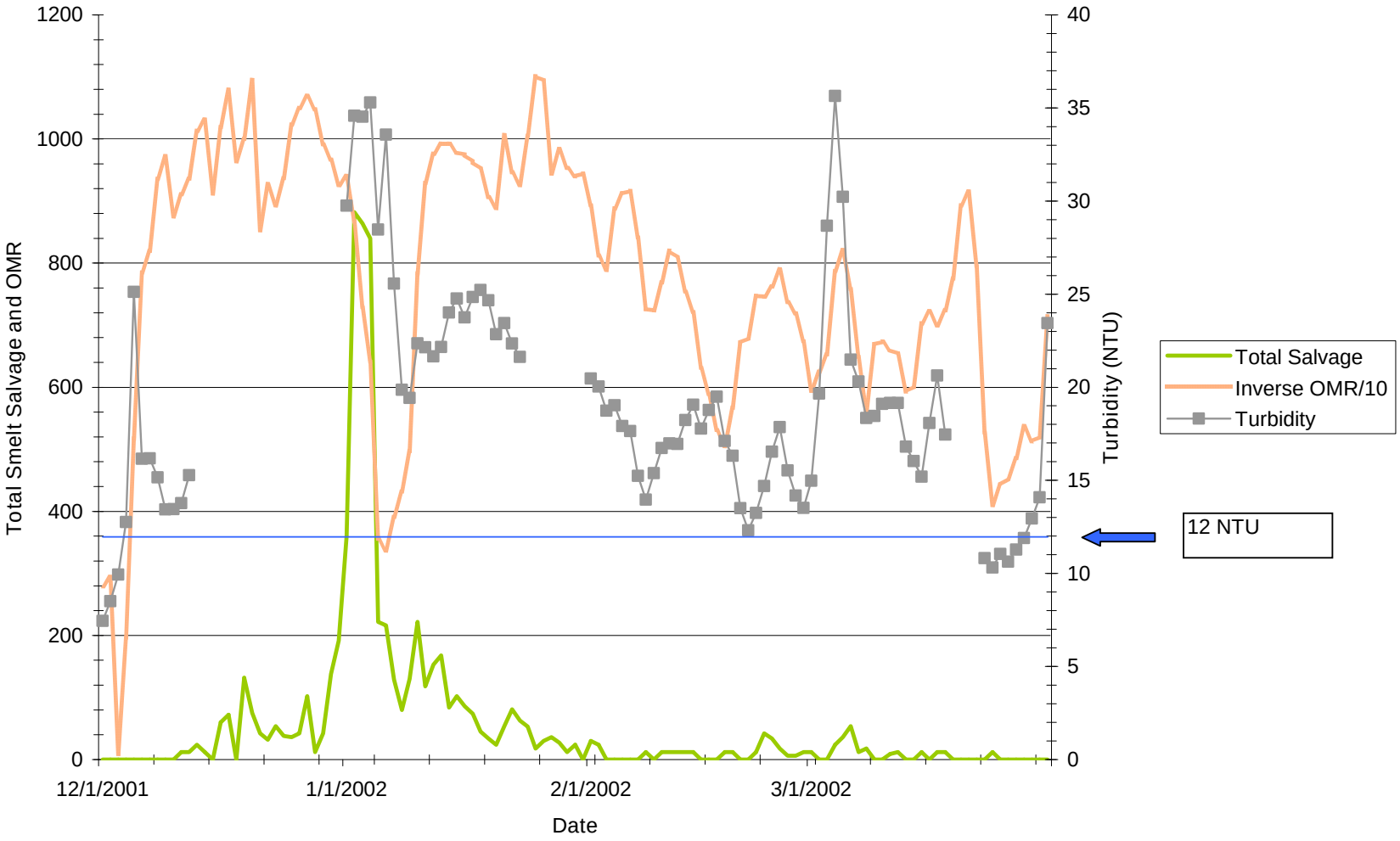


Figure B-3: 1993 WY OMR, Turbidity, Salvage

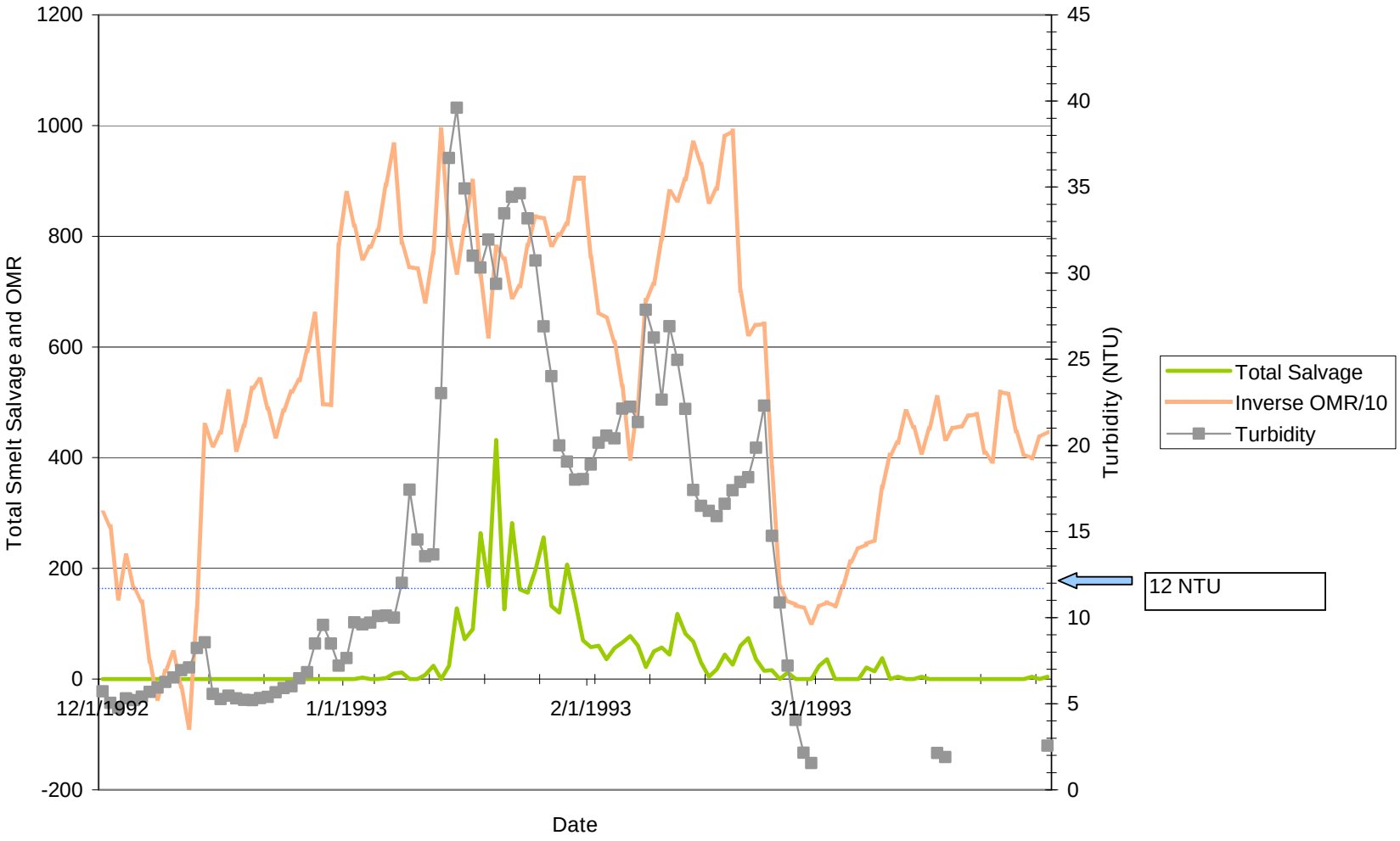


Figure B-4: 2003 WY OMR, Turbidity, Salvage

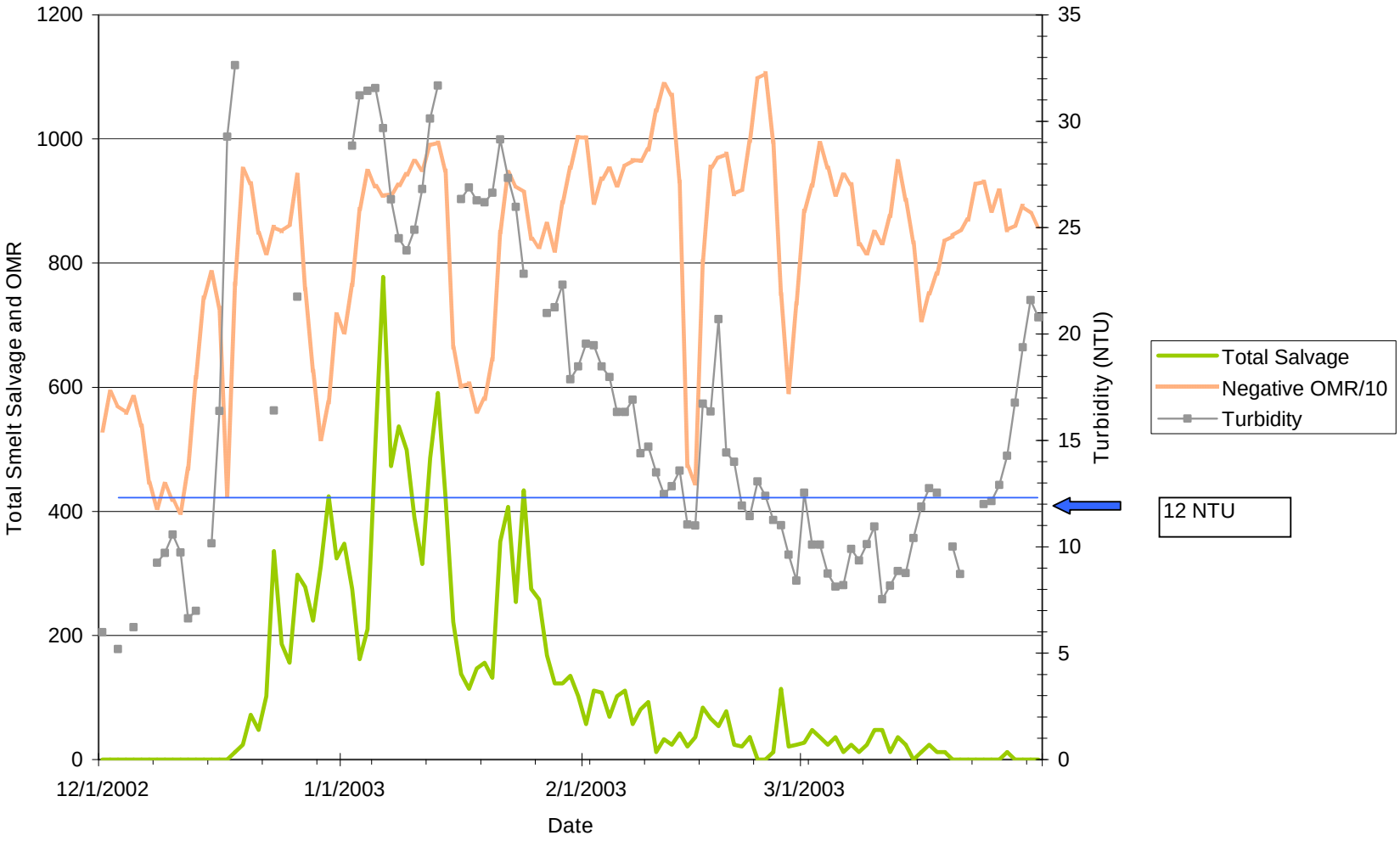


Figure B-5: 2004 WY OMR, Turbidity, Salvage

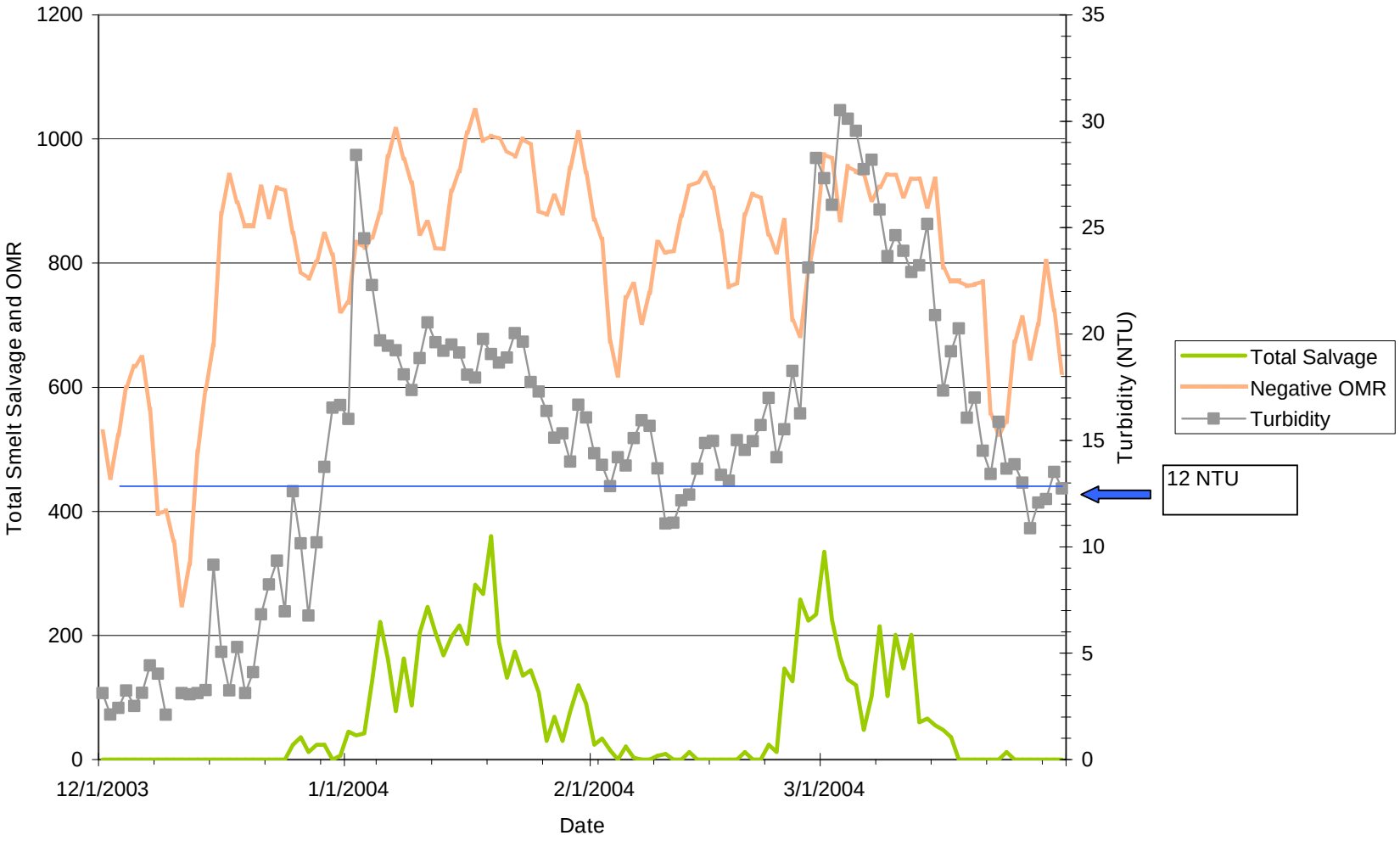
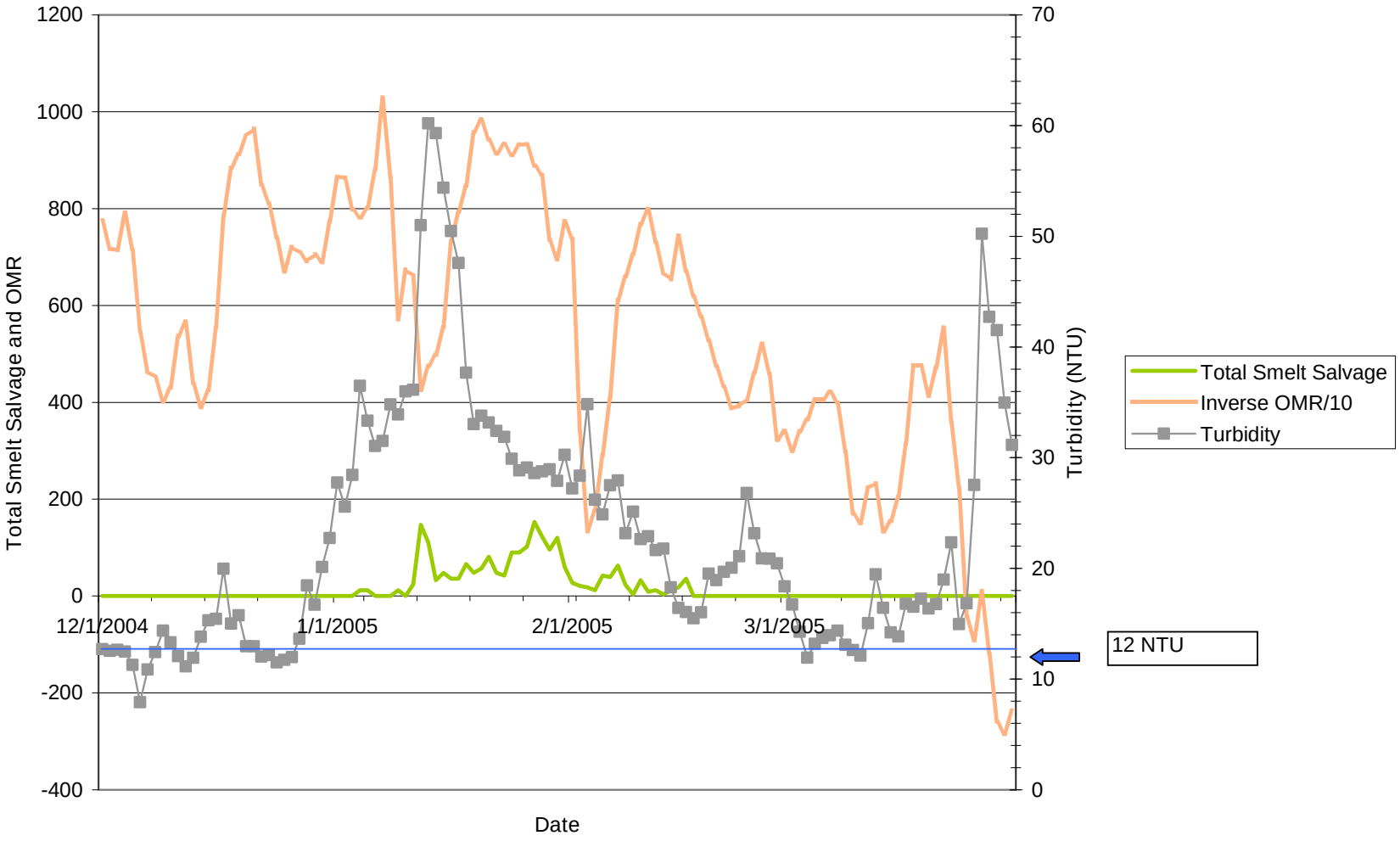


Figure B-6: 2005 WY OMR, Turbidity, Salvage



Up to fifty percent of the pre-spawning adult population has been entrained at the export facilities in recent years, depending on circumstances (Kimmerer 2008). Entrainment risk depends most importantly upon the distribution of delta smelt relative to the entrainment footprint of the CVP/SWP export facilities. Monitoring programs such as the FMWT and SKT provide a useful basis for estimating the abundance and distribution of delta smelt, despite having drawbacks (Newman 2008). The margin of error associated with abundance and distribution inferences increases at low abundances that have characterized the last several years. Abundances near the detection threshold of the sampling techniques makes it very difficult to draw reliable inferences about how many delta smelt there are, and where they are located.

To provide context to determine the magnitude of effect of pre-spawning adult direct mortality through entrainment within any given season (as measured by salvage), it is necessary to consider two important factors. First, although salvage is an index of entrainment, it is not a direct quantitative equivalent. The number of delta smelt that are actually counted at the salvage facilities represents a small percentage of the actual number entrained (See baseline section). Efficiency of sampling methodology is another consideration given the delicate tissues of the delta smelt, and this decreases inversely with fish size (adults are most accurately counted, while juvenile salvage efficiency is much lower, while <20mm smelt are mostly undetectable at the salvage facilities). Finally, although surviving individuals are held and released to the Delta, it is generally thought that they do not survive. Therefore salvage at the Banks and Jones facilities is not a good estimate of actual adult delta smelt mortality through entrainment (See baseline section).

The second factor to consider when relating salvage data to population-level significance is that the total number salvaged at the facilities does not necessarily indicate a negative impact upon the overall delta smelt population. The Salvage Index normalizes salvage to the population size based upon the previous FMWT Index:

Salvage Index = Number of Delta Smelt Salvaged ÷ Prior Year FMWT Index

Summaries of delta smelt salvage are presented by WY in Table B-2. Figures B-7 through B-11 display salvage data normalized to prior-year FMWT for the POD years (WY2002-WY2006). These plots have consistent units on the y-axis, reflecting the Salvage Index. The area under the salvage histogram reflects the total number of smelt salvaged, and this is a metric that can be related to total demographic impacts through entrainment. Review of salvage histograms within Figures B-7 through B-11 gives a sense of the magnitude of entrainment effects for all detectable lifestages of smelt through the water year.

Table B-2: Total Adult Delta Smelt Salvage by Year, including summary statistics

Year	Total Salvage	Prior Year FMWT	Cumulative Salvage Index	Peak Daily Salvage "Amplitude"	Salvage distribution	12 NTU "Trigger Date"	NTU trigger to peak salvage (days)	Total # salvaged before trigger	propn of total season salvage prior to trigger date
1993	4425	156	28.4	2.77	unimodal	10-Jan	12	27	0.0061
1994	398	1078	0.37	0.08	unimodal	4-Jan	52	100	0.25
1995	2600	102	25.5	1.49	unimodal	9-Jan	16	150	0.058
1996*	5634	899	6.27	0.52	unimodal	14-Feb	36	0	0.00
1997	1816	127	14.3	1.12	unimodal	20-Dec	80	12	0.007
1998	1027	303	3.39	0.38	bimodal	20-Dec	10 & 94	75	0.073
1999	2074	420	4.94	0.40	unimodal	14-Jan	36	20	0.0096
2000	11493	864	13.34	0.72	unimodal	23-Jan	28	482	0.042
2001	7991	756	10.6	0.49	unimodal	13-Jan	29	255	0.032
2002	6865	603	11.4	1.46	unimodal	20-Dec	14	324	0.047
2003	14323	139	103	5.60	unimodal	20-Dec	17	108	0.0075
2004	8148	210	38.8	1.71	bimodal	31-Dec	19	126	0.015
2005	2018	74	27.3	2.07	unimodal	20-Dec	39	0	0.00

* 3 NTU sensor malfunctions most of year; date evaluated as Dec 20 using total inflow > 25,000 cfs

Review of salvage data across years for which monitoring data are available indicate some patterns which led to the development of Interim Remedies Action 1; the same logic has been used to develop the present Action 1. First, salvage data during winter generally follows a unimodal distribution, with a defined salvage peak, and short duration. Occasionally, climatic conditions and operational criteria interact to produce bimodal or diffuse salvage distributions, however these year types are the exception, as summarized in Table B-2. Peak salvage usually occurs during the month of January, however this pattern does not hold during all year types, and some years even exhibit low overall adult salvage (wet WY of 1997 and 1998, or dry years with no winter first flush as in WY 1994).

Historic delta smelt salvage data and the current population status suggest a protective strategy for this period that focuses upon prevention of the attraction and subsequent entrainment of pre-spawning adults during the onset of upstream migration. While salvage itself is a useful indicator of distribution after the fact, it has serious drawbacks as a management tool when used on its own, because a large entrainment event may be inevitable by the time an increase in salvage is detected.

Figure B-7: 2002 WY Salvage Index

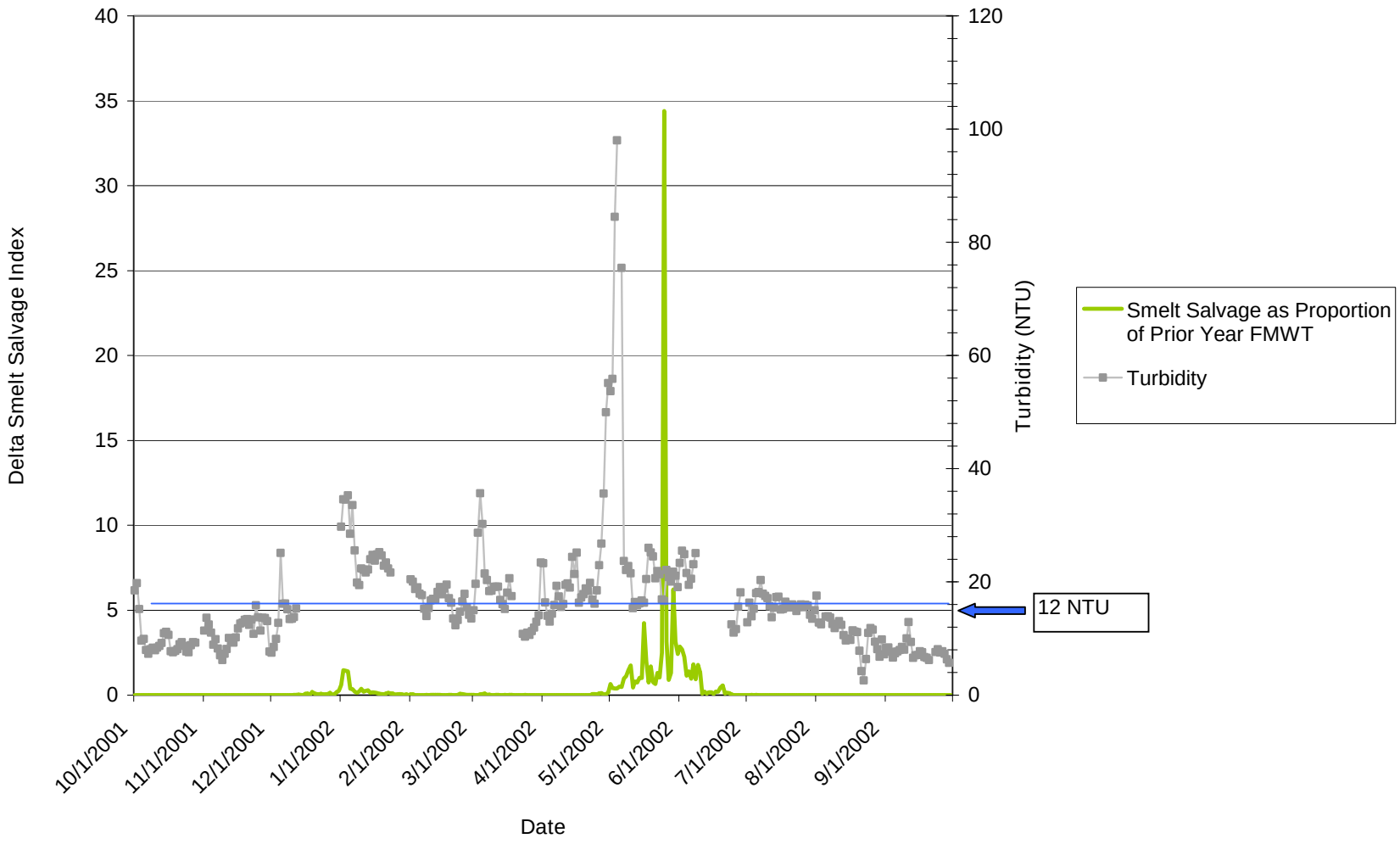


Figure B-8: 2003 WY Salvage Index

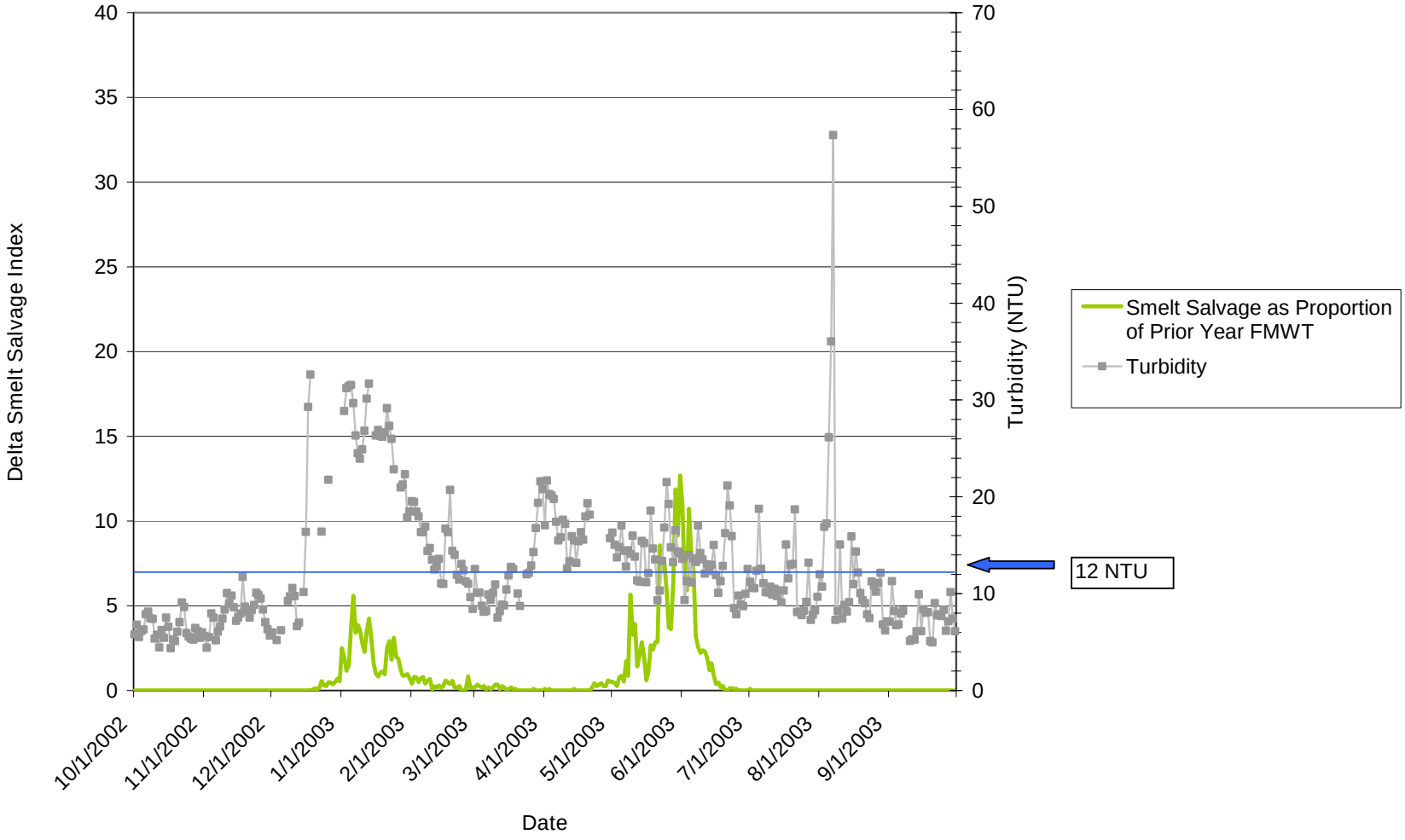


Figure B-9: 2004 WY Salvage Index

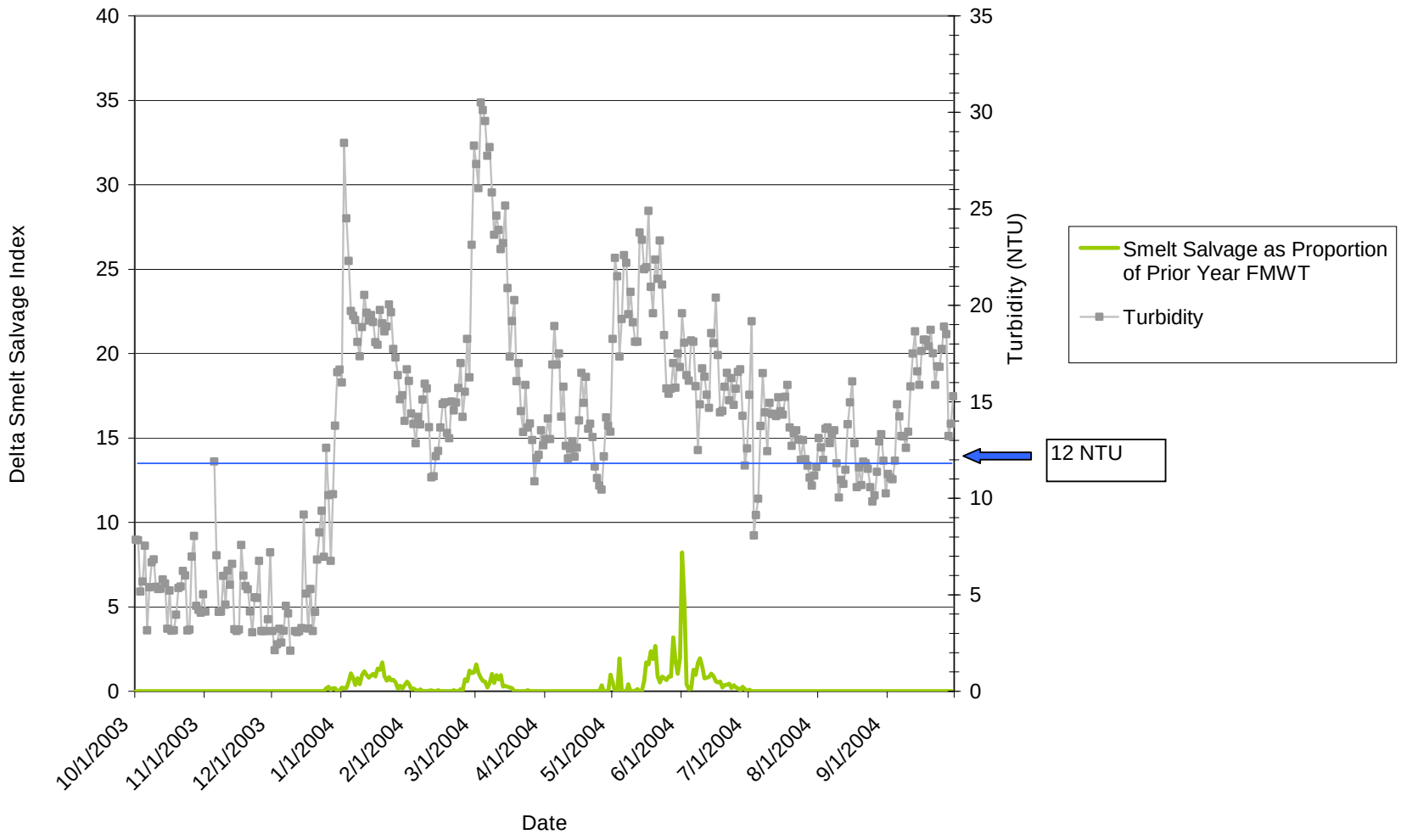


Figure B-10: 2005 WY Salvage Index

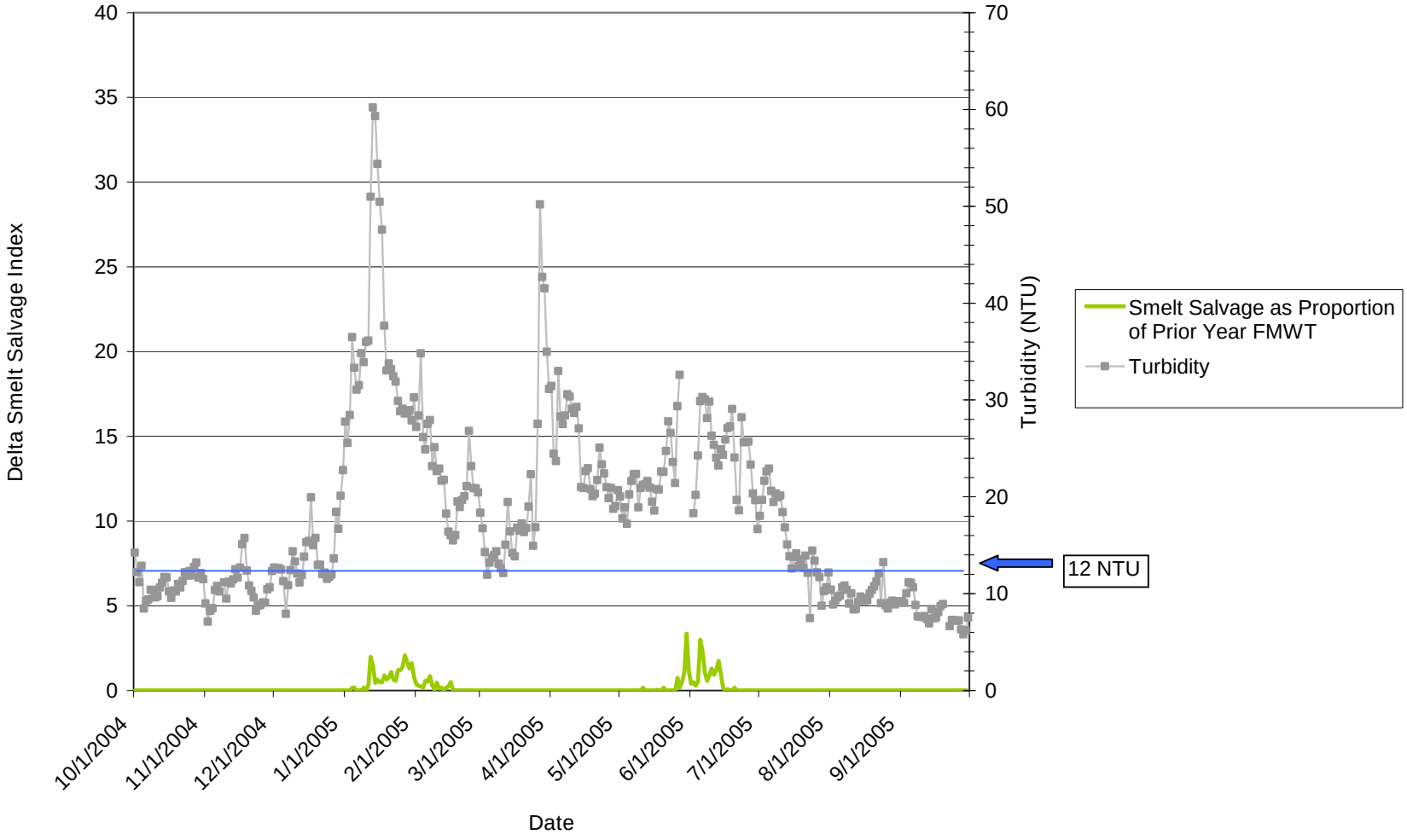
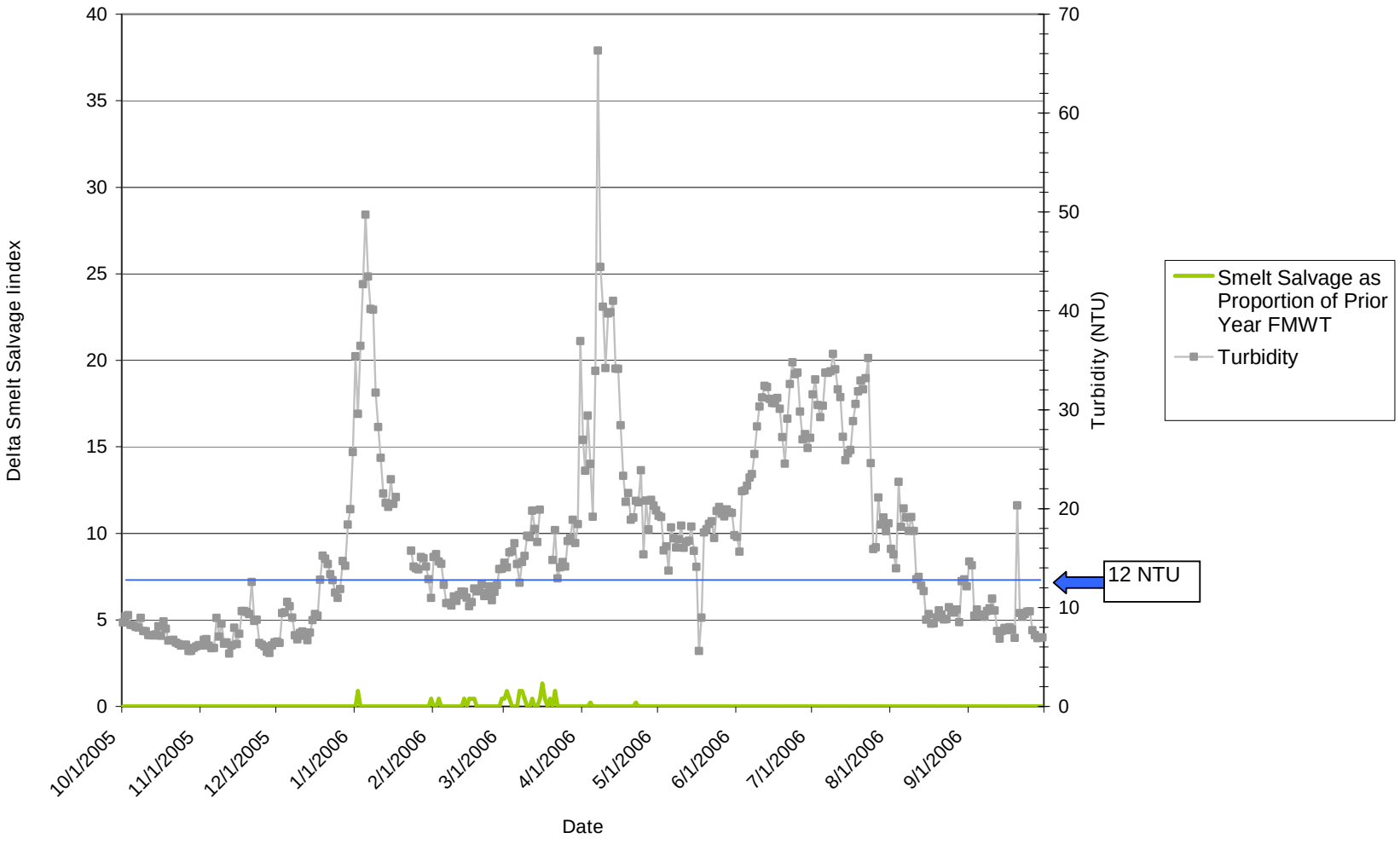


Figure B-11: 2006 WY Salvage Index



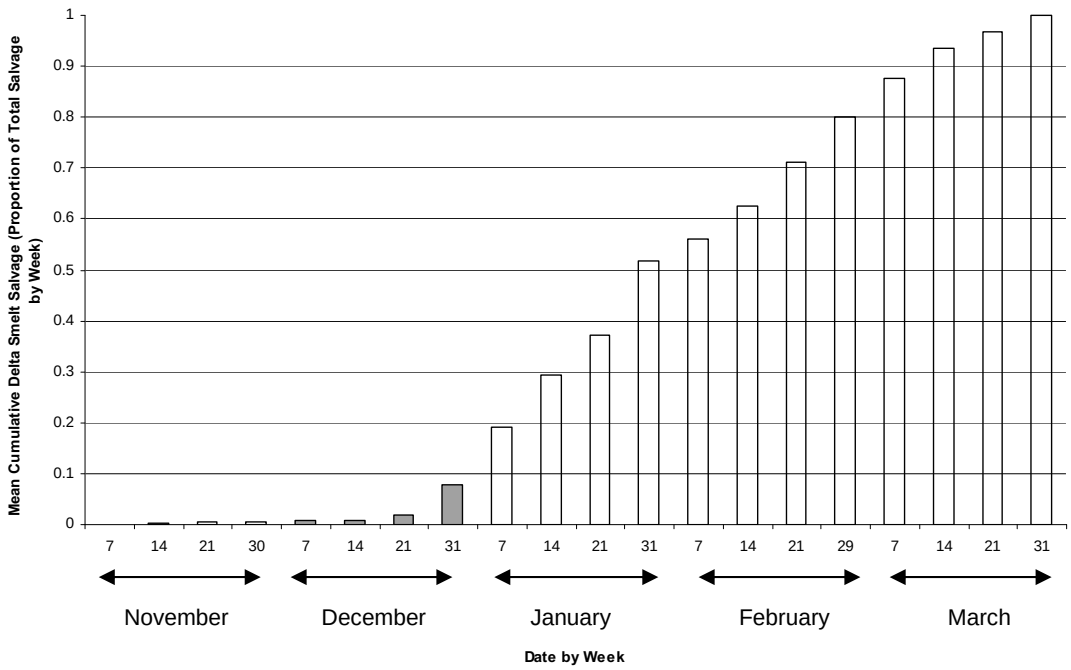
Justification for Timing of Action 1

Action 1, Part A covers the period (December 1 to December 20) when first flush salvage events were historically uncommon (Figure B-12). During this period the SWG will review conditions from week to week and may recommend to the Service that Action 1 be triggered. Part B of Action 1 (December 20 to March) covers a period when first flush salvage events have been historically more common. Part B will be triggered when turbidity increases above 12 NTU. The Service can bypass implementation of the trigger if the SWG concludes that the trigger was met by conditions (i.e., wind-induced turbidity) not likely to initiate smelt migration.

The timing of first flush salvage events is variable in any given WY. Thus, initiation of Action 1 is based on conditions (i.e., turbidity) rather than a specific month. Action 1 is therefore designed to provide flexibility and maximum protection for delta smelt. On average, about 1 percent of cumulative adult delta smelt entrainment occurs by December 21 (Figure B-12). By December 31, cumulative salvage has historically reached 3.2 percent.

Action 1 will be shifted from December 25 (as described in the Interim Remedies) to December 20 because it better reflects the period when protection will be needed. As previously mentioned, the Service will decide to initiate Action 1 before December 20 if the conditions warrant evidence smelt are migrating upstream (i.e., salvage, trawl data). Beginning in December, the SWG will review physical and biological parameters historically associated with smelt migration (i.e., precipitation, operations, turbidity, and salvage data) to make ongoing recommendations to the Service about the need to implement Action 1 at any time.

Figure B-12: Cumulative Proportional Salvage for WY 1993 to 2006 by Week



Duration of Action 1

The Interim Remedies Action 1 has been revised from ten to 14 days to incorporate coverage between spring and neap tidal cycles that may influence migration rate into the interior Delta.

Justification for the Salvage Guideline Action 1

In many years, delta smelt have been salvaged prior to when turbidity elevates above 12 NTU (Table B-2). In the case that salvage begins prior to the trigger, the decision to implement Action 1 will be based on the following: 1) magnitude of salvage scaled to the population size (Table B-2), and 2) the amplitude which represents daily salvage divided by the prior year FMWT.

The 4th column in Table B-2 lists the cumulative seasonal salvage of adult delta smelt divided by the prior year FMWT Index (the Cumulative Salvage Index). This value ranged from a minimum of 0.37 in WY 1994 to a maximum of 103 during WY 2003. The combination of peak (amplitude in the histogram or maximum daily salvage), and Cumulative Salvage Index is a general index of the magnitude of adult entrainment in a given WY.

The median value for the Cumulative Salvage Index for the years presented would be 13.3. The mean value for all years within the range presented in Table B-2 is 22.1. For peak daily salvage, the Salvage Index mean for the WY 1993 through 2005 is 1.45. The median amplitude value is 1.1. Taking these data into account, a Cumulative (seasonal) Salvage Index exceeding 7.25 appears to be indicative of an unacceptable risk threshold based on the current low numbers of delta smelt. A peak Daily Salvage Index of 1.0 is suggested as an index of daily smelt salvage at levels or maintained at existing levels that ongoing or anticipated salvage could rapidly reach unacceptable losses if exports are to increase. These values are carried forward into the prescriptions as pre-emptive triggers, and as releases from Action prescriptions to carry forward through Actions 1 and 2.

Justification for the Turbidity Criterion as a Trigger in Action 1 (Part B)

Onset of Action 1 during Part B

Turbidity associated with freshets of water is a reasonable indicator of when smelt begin to migrate upstream and become vulnerable to salvage. Though this historical trend is based on the turbidity sensor located outside the Clifton Court Forebay, there is no expectation that the relationship between increased flow and turbidity would differ from recently installed sensors identified in the Interim Remedies: Prisoners Point, Holland Cut, and Victoria Canal. It appears that the Holland Cut sensor is sensitive to localized wind conditions at times. On December 25-27, 2007, a three-day rise in turbidity at the Holland Cut monitoring station triggered Action 1. It was unlikely that a wind-associated turbidity event initiated smelt migration. Rather than rely on one of these stations to trigger Action 1 (Interim Remedies), Action 1 will be triggered when turbidities elevate over 12 NTU at all three stations. The use of three stations would better reflect a Delta-wide change in turbidity than one station which may be prone to localized conditions.

Timing and the Protectiveness of the 12 NTU criterion

If the 12 NTU threshold had been used in previous years, Action 1 would have likely provided early protection (i.e., less salvage) during most years. The degree to which it would have minimized the number of smelt entering the South Delta is unknown.

Justification for Flow Prescriptions in Action 1

Understanding the relationship between OMR flows and delta smelt salvage allows a determination of what flows will result in salvage. The OMR-Salvage analysis herein was initiated using the relationship between December to March OMR flow and salvage provided by P. Smith and provided as Figure B-13, below. Visual review of the relationship expressed in Figure B-13 indicates what appears to be a “break” in the dataset at approximately -5,000 OMR; however, the curvilinear fit to the data suggest that the break is not real and that the slope of the curve had already begun to increase by the time that OMR flows reached -5,000 cfs.

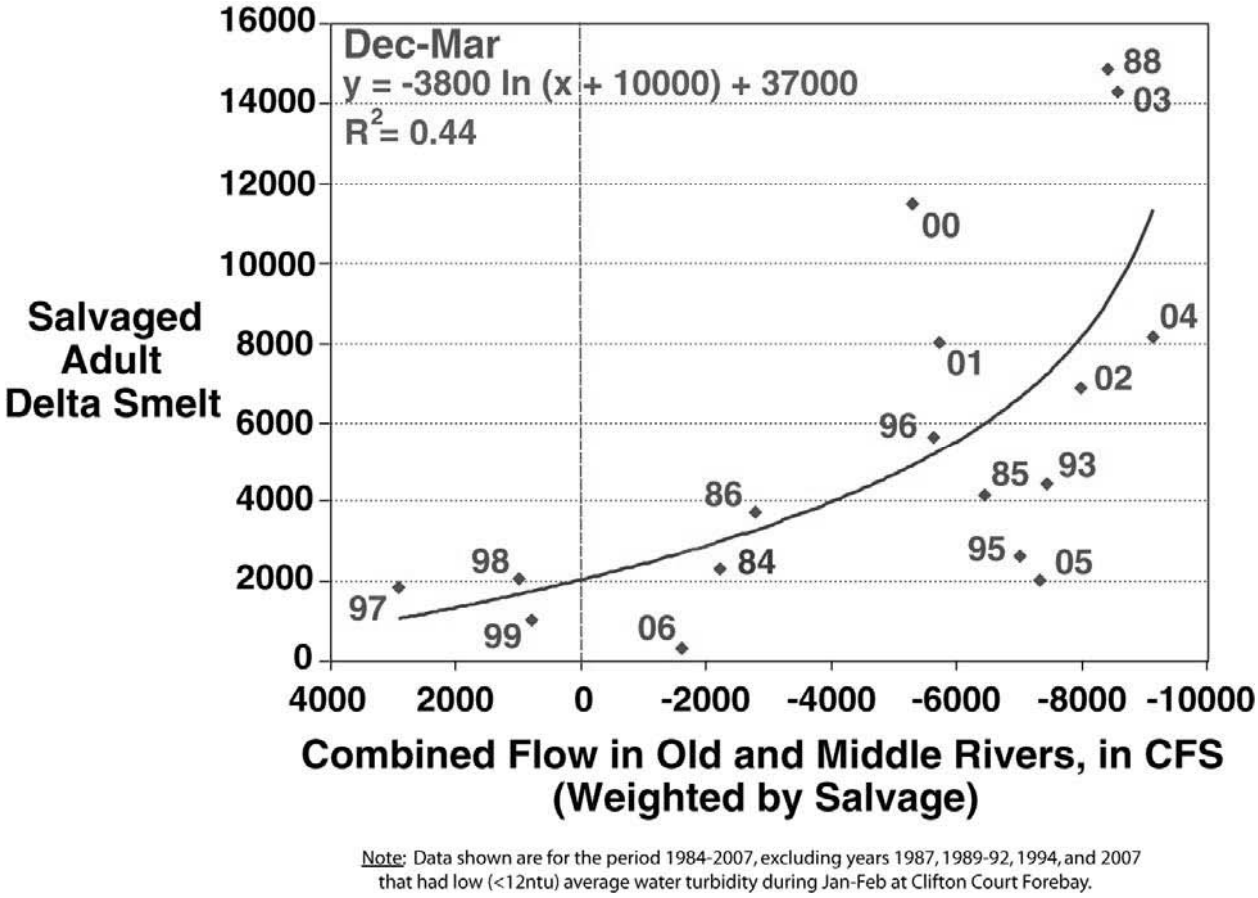


Figure B-13. OMR-Salvage relationship for adult delta smelt. (source, P. Smith). Data from this figure were the raw data used in the piecewise polynomial regression analysis.

Further, a nonlinear regression was performed on the dataset, and the resulting pseudo-R^2 value was 0.44—suggesting that although the curvilinear fit is a reasonable description of the data, other functional relationships also may be appropriate for describing the data. Fitting a different function to the data could also determine the location where salvage increased, i.e. identify the "break point" in the relationship between salvage and OMR flows. Consequently, an analysis was performed to determine if the apparent break at -5,000 cfs OMR was real. A piecewise polynomial regression, sometimes referred to as a multiphase model, was used to establish the change (break) point in the dataset.

A piecewise polynomial regression analysis with a linear-linear fit was performed using data from 1985 to 2006. The linear-linear fit was selected because it was the analysis that required the fewest parameters to be estimated relative to the amount of variation in the salvage data. Piecewise polynomial regressions were performed using Number Cruncher Statistical Systems (© Hintz, J., NCSS and PASS, Number Cruncher Statistical Systems, Kaysville UT).

The piecewise polynomial regression analysis resulted in a change point of -1162, i.e. at -1162 cfs OMR, the slope changed from 0 to positive (Figure B-14). These results indicate that there is a relatively constant amount of salvage at all flows more positive than -1162 cfs but that at flows more negative than -1162, salvage increases. The pseudo-R^2 value was 0.42, a value similar to that obtained by P. Smith in the original analysis.

To verify that there was no natural break at any other point, the analysis was performed using a linear-linear-linear fit (fitting two change points). The linear-linear-linear fit resulted in two change points, -1,500 cfs OMR and -2,930 cfs OMR. The -1,500 cfs value is again the location in the dataset at which the slope changes from 0 to positive. The pseudo-R^2 value is 0.42 indicating that this relationship is not a better description of the data. Because of the additional parameters estimated for the model, it was determined that the linear-linear-linear fit was not the best function to fit the data, and it was rejected. No formal AIC analysis was performed because of the obvious outcome.

A major assumption of this analysis is that as the population of Delta smelt declined, the number of fish at risk of entrainment remained constant. If the number of fish in the vicinity of the pumps declined, fewer fish would be entrained and more negative OMR flows would result in lower salvage. This situation would result in an overestimate, i.e. the change point would be more positive. In fact, if the residuals are examined for the relationship in Figure B-13 above, the salvage for the POD years 2002, 2004, 2005, and 2006 are all below the line. 2003 is above the line although the line is not extended to the points at the top of the figure, and these data points occur when the curve becomes almost vertical. The negative residuals could be a result of a smaller population size available for entrainment and salvage. This could be verified by normalizing the salvage data by the estimated population size based on the FMWT data.

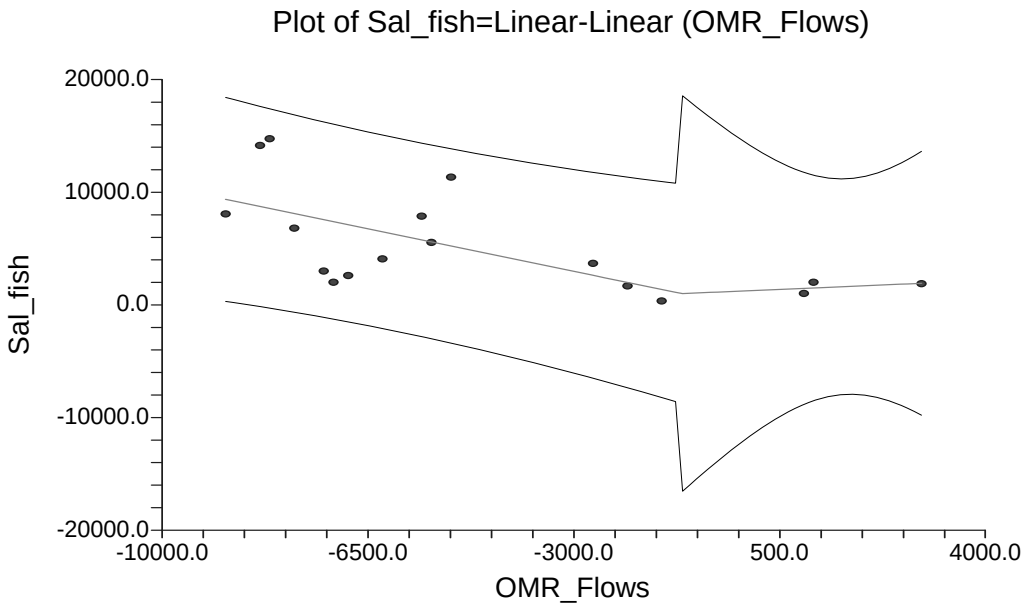


Figure B-14. Piecewise polynomial regression of OMR flows and salvage. The change point is the location at which the two regression lines meet; -1,162 cfs OMR.

The original values of OMR and salvage could have been measured with error due to a number of causes, consequently the values used in the original piecewise polynomial analysis could be slightly different than the "true" values of salvage and OMR flow. Consequently, a second analysis was undertaken to examine the effect of adding stochastic variation to the OMR and salvage values in the piecewise polynomial regression analysis. The correlation between OMR and salvage in the original dataset was -0.61 indicating that the more negative the OMR, the greater the salvage. Consequently, it was necessary to maintain the original covariance structure of the data when adding the error terms and performing the regressions. The original covariance structure of the OMR–salvage data was maintained by adding a random error term to both parameters. The random error term was added to OMR and a correlated error term was added to salvage. The expected value of the correlated errors was -0.61.

The error terms were selected from a normal distribution with a mean of 1.0 and a standard deviation of 0.25 which provided reasonable variability in the original data. Operationally this process generated a normal distribution of OMR and salvage values in which the mean of the distributions were the original data points. Additional analyses were performed with standard deviations of 0.075, 0.025, and 0.125. Smaller standard deviations in the error term resulted in estimates of the change point nearer to the original estimate of -1,162 cfs. This is to be expected as the narrower the distribution of error terms, the more likely the randomly selected values would be close to the mean of the distribution. The process was repeated one hundred times, each time a new dataset was generated and a new piecewise polynomial regression was performed. The software package @Risk (© Palisade Decision Tools) was used to perform the Monte Carlo simulations. Latin hypercube sampling was used to insure that the distributions of OMR and salvage values were sampled from across their full distributions. The parameter of

interest in the simulations was the change point, the value of the OMR flow at which the amount of salvage began to increase. Incorporating uncertainty into the analysis moved the change point to -1,800 cfs OMR, indicating that at flows above -1683, the baseline level of salvage occurred but with flows more negative than -1683, salvage increased.

Justification for Release from Prescriptions of Action 1

Temperature

The Interim Remedies prescribed regulatory release from Action 1 once mean water temperatures at Rio Vista, Antioch, and Mossdale Stations reaches 12°C. This metric is used as a surrogate to indicate time when spawning is likely to have begun based on physiological preferences.

Biological Conditions

The Interim Remedies prescribed regulatory release from Action 1 once spent females are detected in the SKT or at the salvage facilities.

Changing the Timing of the Action

If the SWG recommends a delayed start or interruption to Action 1 based on variations in conditions which may affect vulnerability to entrainment (e.g., no observed salvage and a rapid reduction in turbidity after the first week of Action 1), the Service will weigh such information and make a final determination on protective OMR flow requirements.

ACTION 2: ADULT MIGRATION AND ENTRAINMENT

Objective: An action implemented using an adaptive process to tailor protection to changing environmental conditions after Action 1. As in Action 1, the intent is to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions.

Action: The range of net daily OMR flows will be no more negative than -1,250 to -5,000 cfs. Depending on extant conditions (and the general guidelines below) specific OMR flows within this range are recommended by the SWG from the onset of Action 2 through its termination (see Adaptive Process in Introduction). The SWG would provide weekly recommendations based upon review of the sampling data, from real-time salvage data at the CVP and SWP, and utilizing most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity. The Service will make the final determination.

Timing: Beginning immediately after Action 1. Before this date (in time for operators to implement the flow requirement) the SWG will recommend specific requirement OMR flows based on salvage and on physical and biological data on an ongoing basis. If Action 1 is not implemented, the SWG may recommend a start date for the implementation of Action 2 to protect adult delta smelt.

Suspension of Action:

Flow: OMR flow requirements do not apply whenever a three day flow average is greater than or equal to 90,000 cfs in Sacramento River at Rio Vista and 10,000 cfs in San Joaquin River at Vernalis. Once such flows have abated, the OMR flow requirements of the Action are again in place.

Off-ramps:

Temperature: Water temperature reaches 12°C based on a three station daily average (Rio Vista, Antioch, Mossdale)

OR

Biological: Onset of spawning (presence of spent females in SKT or at either facility)

Adaptive Process Required Parameters:

Two scenarios span the range of circumstances likely to exist during Action 2. First, the low-entrainment risk scenario. There may be a low risk of adult entrainment because (a) there has been no discernable migration of adults into the South and Central Delta (b) the upstream migration has already occurred but turbidity is low and there is no or little evidence of ongoing adult entrainment. In this scenario, higher negative OMR flow rates as high as -5,000 cfs may be ventured as long as entrainment risk factors and salvage permit.

The second scenario, the high-entrainment risk scenario, is one in which either (a) there is evidence that upstream adult migration is currently occurring, or (b) upstream migration has already occurred and there are adult fish in the South and Central Delta and turbidity is high, increasing the risk of entrainment, or (c) there is evidence of ongoing entrainment, regardless of other risk factors. In this case, OMR flow will be set to reduce entrainment and/or the risk of entrainment as the totality of circumstances warrant.

Generally, if the available distributional information suggests that most of the delta smelt are in the North or North/Central Delta, then OMR flow can be chosen to minimize Central Delta entrainment. However, if the distributional information suggests there are delta smelt in the Central or South Delta, then OMR flow will have to be set lower to reduce entrainment of delta smelt.

The following two paragraphs describe how these action guidelines would be implemented at the start of Action 2 and at other times during Action 2.

1. OMR flow setting at initiation of Action 2

a) If salvage is zero during the final 7 days of Action 1, and three-station mean turbidity is below 15 NTU, then increase negative OMR flow to no more negative than -5,000 cfs on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable required OMR flow[8]; *UNLESS*

b) If salvage is less in the most recent three days than in the preceding three days of Action 1, and the maximum Daily Salvage Index is ≤1 during the prior 7 days, then limit exports to achieve OMR flows no

[8] Both the 14-day and the 5-day running averages will be computed using the "tidally filtered" daily average OMR flows reported by USGS.

more negative than -3,500 cfs on a 14-day running average for 7 days (or until 4 consecutive days of zero salvage or any 5 of 7 days with zero salvage), with a 5-day running average within 25 percent of the applicable required OMR flow; *OR*

c) If salvage is greater or equal in the last three days than in the preceding three days of Action 1, and maximum Daily Salvage Index ≥1 during any of those days, then continue OMR flow at no more negative than -2,000 cfs on a 14-day running average for an additional 7 days (or until 4 succeeding days of zero salvage or any 5 of 7 days zero salvage), with a simultaneous 5-day running average within 25 percent of the applicable requirement OMR; *OR*

d) If circumstances existing at the initiation of Action 2 are, in the judgment of the Service, markedly different from those anticipated in (a) through (c) above, then the OMR flow requirement in (c) will be applied and the SWG will review available data and recommend an initial flow rate to the Service.

2. OMR flow setting after initiation of Action 2

a) The SWG will review all available information and request updated entrainment simulations and/or other information, as needed, on a weekly basis to decide whether the current OMR flow requirement is appropriate or should be changed.

b) Unless OMR flow is grossly positive regardless of water project operations, due to high Delta inflows, then important variables that affect the risk of adult entrainment during Action 2 include (1) salvage or other actual entrainment indicators, (2) turbidity, (3) available monitoring results, hydrologic variables other than export pumping rates that affect OMR flow, (4) apparent population size from the preceding FMWT survey, and (5) particle tracking or other model-based entrainment risk information.

c) As described above, the risk of entrainment is generally higher when there is evidence of ongoing entrainment or turbidity is high, and these two variables are the most likely triggers of decisions to raise or lower OMR flow requirements.

d) Based on historical experience, OMR flow requirements between the limits of -2,000 cfs and -5,000 cfs are likely to be adequate in most years. The exception is years in which there appears, for whatever reasons, to be a substantial fraction of the adult spawning migrant population in the Central and/or South Delta. When this occurs, more stringent OMR limitation (possibly to no more negative than -1,250 cfs) may be required.

Background

Action 2 reflects the period when OMR prescriptions for pre-spawning adult delta smelt are still required to protect parental stock prior to reproduction, however such controls may generally be relaxed because the main pulse of fish migration has occurred and adults are holding more tightly to their selected spawning areas. Action 2 may also be needed to extend protections consistent with Action 1 in years of longer spawning migration periods or changing environmental conditions. Conditions are highly variable in any given year. Rather than provide a prescription that is protective under all circumstances, an adaptive process based on the guidelines outlined herein is warranted. This process can most efficiently and effectively provide protections utilizing analysis of all available data and seasonal conditions.

The OMR flow prescriptions set forth during Action 2 will be based upon analysis of population status in any given year, available monitoring data from the SKT, seasonal variables such as WY type, CVP and SWP reservoir storage levels, temperature, and observed salvage during Action 1. Of these, population status and real-time salvage data are expected to be the primary driving criterion.

Justification for Guidelines in Setting Prescriptions of Action 2

The SWG will apply the following criteria to set the flow prescriptions during Action 2, to be operational until the onset of Action 3.

Zero Salvage or Extended Salvage Index of Low Amplitude

a) If salvage is zero during the final 7 days of Action 1, then increase negative OMR to no more negative than -5,000 cfs on a 14-day running average, with a simultaneous 5-day running average within 25 percent of the applicable requirement OMR; *OR*

Decreasing Salvage or Salvage Index with Low Amplitude

b) If salvage is less in the last three days than in the preceding three days and the maximum daily salvage index is ≤1 during the prior 7 days, then limit exports to achieve OMR flows no more negative than -4,000 cfs on a 14-day running average for 7 more days with average OMR for the period within 25 percent of the requirement (or until 4 succeeding days of zero salvage or any 5 of 7 days zero salvage); *OR*

Rising Salvage or Salvage Index with High Amplitude

c) If salvage is greater or equal in the last three days than in the preceding three days, and maximum daily salvage index ≥1 during any of those days, then continue OMR flow at no more negative than -2000 cfs on a 14-day running average for an additional 7 days (or until 4 succeeding days of zero salvage or any

5 of 7 days zero salvage), with a simultaneous 5-day running average within 25 percent of the applicable OMR requirement.

Flow requirements will be monitored in real-time utilizing salvage data as a check on performance of the Service-recommended requirements, consistent with the objectives and numerical requirements established in the take statement (Attachment C).

Flow requirements defined within Action 2 follow the same protectiveness criterion established during Action 1, as adjusted to reflect real-time conditions and predicted entrainment risk relative to the anticipated distribution and abundance of year-class delta smelt; and reflecting their behavioral propensity to hold in their chosen spawning habitat. These are allowed to vary based upon assessment of available data as described in the adaptive process described in the Introductions to Actions section above.

Justification for Release from Prescriptions of Action 2

Flow

The Interim Remedies provided release from the prescription of Action 2 when the three day average Sacramento River flow at Freeport is greater than 80,000 cfs.
During WY 1982 and 1995, salvage was observed during periods when Sacramento River flows exceeded this criterion. During 1995, Sacramento River flows at Freeport exceeded 90,000 cfs while San Joaquin River flows approximated 5,000 cfs—salvage still occurred. This data suggests that adult delta smelt can still navigate the channels upstream at these flows. During 1997 and 1998, low salvage was observed while flows within both the Sacramento and San Joaquin rivers were high. For these reasons, it was determined that the offramp for prescriptions in Actions 1 and 2 should be Sacramento River flows at *Rio Vista* exceeding a three-day average of *90,000* cfs *and* San Joaquin River flows at Vernalis exceeding 10,000 cfs. Based on historic observations, it is predicted that salvage under these flow conditions will be minimal.

Temperature

The Interim Remedies prescribed regulatory release from Action 1 once mean water temperatures at Rio Vista, Antioch, and Mossdale Stations reaches 12°C. This metric is used as a surrogate to indicate time when spawning is likely to have begun based on physiological preferences.

Biological Conditions

The Interim Remedies prescribed regulatory release from Action 1 once spent females are detected in the SKT or at the salvage facilities.

ACTION 3: ENTRAINMENT PROTECTION OF LARVAL SMELT

Objective: Minimize the number of larval delta smelt entrained at the facilities by managing the hydrodynamics in the Central Delta flow levels pumping rates spanning a time sufficient for protection of larval delta smelt, e.g., by using a VAMP-like action. Because protective OMR flow requirements vary over time (especially between years), the action is adaptive and flexible within appropriate constraints.

Action: Net daily OMR flow will be no more negative than -1,250 to -5,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR.[9] Depending on extant conditions (and the general guidelines below) specific OMR flows within this range are recommended by the SWG from the onset of Action 3 through its termination (see adaptive process in Introduction).[10] The SWG would provide these recommendations based upon weekly review of sampling data, from real-time salvage data at the CVP/SWP, and expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity. The Service will make the final determination.

Timing: Initiate the action after reaching the triggers below, which are indicative of spawning activity and the probable presence of larval delta smelt in the South and Central Delta. Based upon daily salvage data, the SWG may recommend an earlier start to Action 3. The Service will make the final determination.

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[9] Both the 14-day and the 5-day running averages will be computed using the "tidally filtered" daily average OMR flows reported by USGS.

[10] During most conditions, it is expected that maximum negative OMR flows will range between -2000 and -3500. During certain years of higher or lower predicted entrainment risk, requirements as low as -1,250 or -5,000 will be recommended to the Service by the SWG.

Triggers:

Temperature: When temperature reaches 12°C based on a three station average at Mossdale, Antioch, and Rio Vista.

OR

Biological: Onset of spawning (presence of spent females in SKT or at either facility).

Offramps:

Temporal: June 30;

OR

Temperature: Water temperature reaches a daily average of 25°C for three consecutive days at Clifton Court Forebay.

Adaptive Process Required Parameters:

During the larval/juvenile entrainment risk period, the SWG will meet weekly to review available physical and biological data and develop a recommendation to the Service. The Service will determine the specific OMR requirement based upon the SWG recommendation and the strength of the accompanying scientific justification.

Two scenarios span the range of circumstances likely to exist during Action 3. First, the low-entrainment risk scenario. There may be a low risk of larval/juvenile entrainment because there has been no evidence of delta smelt in the South and Central Delta or larval delta smelt are not yet susceptible to entrainment. In this scenario, negative OMR flow rates as high as -5,000 cfs may occur as long as entrainment risk factors permit.

The second scenario, the high-entrainment risk scenario, is one in which either (a) there is evidence of delta smelt in the South and Central Delta from the SKT and/or 20mm survey, or (b) there is evidence of ongoing entrainment, regardless of other risk factors. In this case, OMR should be set to reduce entrainment and/or the risk of entrainment as the totality of circumstances warrant.

Usually, if the available distributional information suggests that most delta smelt are in the North or North/Central Delta, then OMR flow can be chosen to minimize Central Delta entrainment. However, if the distributional information suggests there are delta smelt in the Central or South Delta, then OMR flows will have to be set lower to reduce entrainment of these fish. If delta smelt abundance is low, distribution cannot be reliably inferred. Therefore, the adaptive process is extremely important. The SWG may recommend any specific OMR flow within the specified range above.

Action 3 is initiated when temperature reaches 12°C based on a three station average at Mossdale, Antioch, and Rio Vista, or when spent females or larva are detected;

a) Once larvae are likely to become vulnerable to entrainment, set OMR flows to no more negative than -2,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR;[11]

b) The SWG will use available physical and biological real-time monitoring data to decide whether a large fraction of the delta smelt population is in the Central Delta and therefore at risk of entrainment. If a large portion of the delta smelt population appears to be in the Central Delta, OMR flows would likely be set to no more negative than -1,250 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR; [6]

c) The SWG will use available physical and biological real-time monitoring data to decide whether the delta smelt population is at a lesser entrainment risk. In this circumstance, OMR flows would likely be set to no more negative than -3,500 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR;[6]

d) The SWG will use available physical and biological real-time monitoring data to decide whether the delta smelt population is at a low entrainment risk. In this circumstance, OMR flows to no more negative than -5,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25 percent of the applicable requirement for OMR;[6]

e) If circumstances existing at the initiation of Action 3 are, in the judgment of the Service, markedly different from those anticipated in (a) through (d) above, then the OMR flow prescription will be set to entrain no more than 1 percent of the particle entrainment at Station 815 (approximately no more than 10 percent of the cumulative population).

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[11] Both the 14-day and the 5-day running averages will be computed using the "tidally filtered" daily average OMR flows reported by USGS.

Background

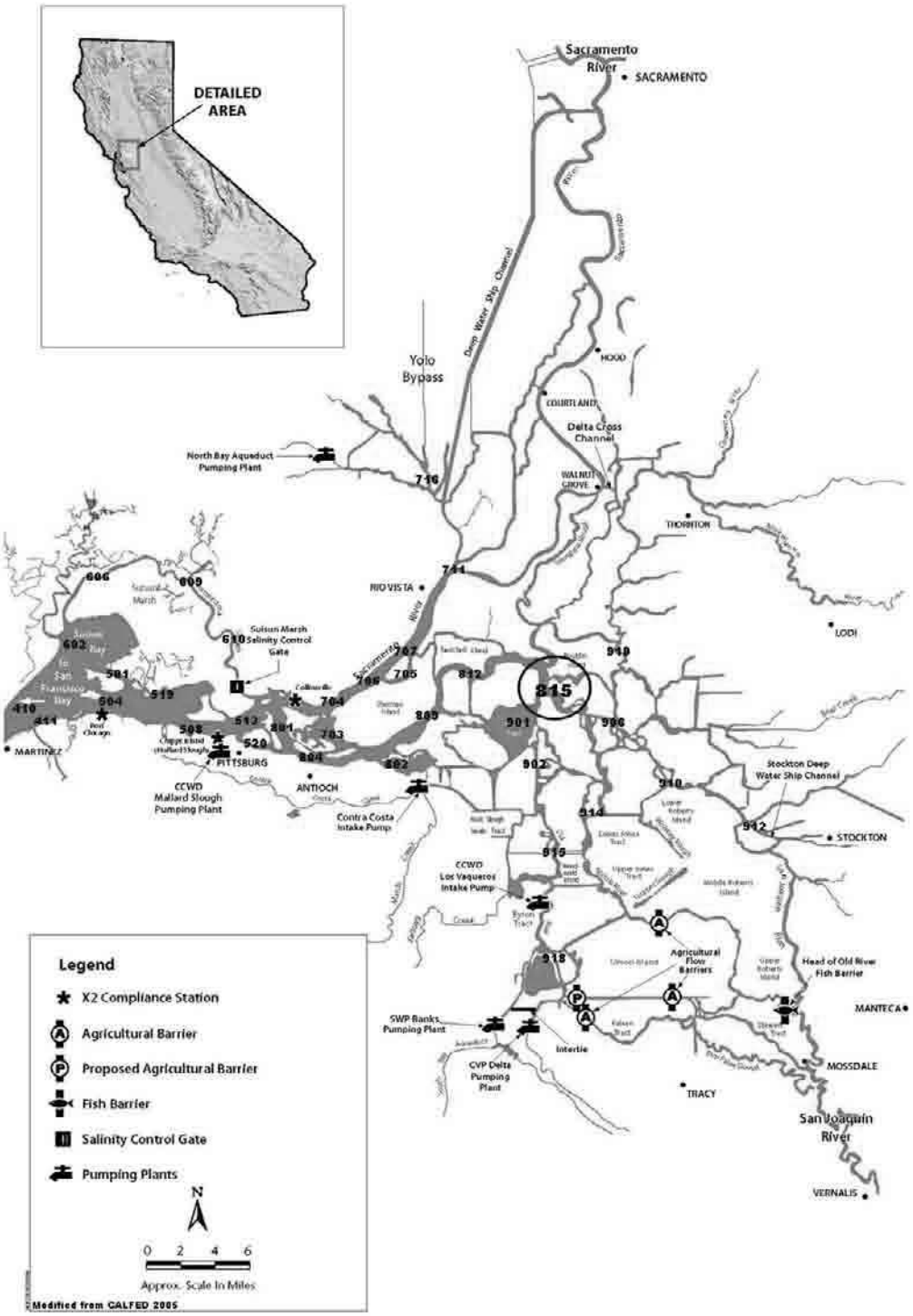
Action 3 is intended to minimize the entrainment of larval/juvenile delta smelt in the Central and South Delta. When the distribution of delta smelt is in the North or North/Central Delta, this will generally be accomplished by holding entrainment to ~1 percent of the individuals utilizing the Central and South Delta (south and east [upstream] of Station 815, see Map 2) across a 14-day particle modeling interval. Preserving larvae and juveniles that are in the Central Delta, or might be in the Central Delta in circumstances where it is difficult to ascertain the distribution of the fish, is critical to ensuring year-to-year stock-recruitment of the population and minimize the risk of localized disturbances that might adversely affect the North Delta.

In circumstances where it is known or suspected that the Central Delta or South Delta is a principal source of emerging larvae, as occurred in WY 2003, OMR restrictions might be calculated using reduction of 14-day Station 815 entrainment below 1 percent, or other methods as needed to ensure protection of the larval population in conditions of such severe vulnerability. The Action utilizes OMR restrictions to achieve the desired end, as OMR flow is a strong predictor of geographical variation in entrainment risk in the Central and North Delta. The OMR flows associated with the protectiveness criteria defined above have been derived from particle tracking modeling with the input assumptions defined below.

These protections are directly tied to presence of vulnerable larval and juvenile delta smelt within the zone of entrainment of Banks and Jones. Therefore, Action 3 must commence no later than the time when larvae are likely to become vulnerable to entrainment.

Data presented in the Effects section of this biological opinion support the conclusion that flow conditions during the VAMP (during the years in which they have been in effect) have been instrumental in protecting delta smelt progeny. Examination of the OMR flow records shows that the combination of increased San Joaquin River flows and reduced pumping during the VAMP generally resulted in OMR flows of approximately -2,000 cfs (Figure B-15).

Protection from entrainment for larval and juvenile delta smelt will be achieved using OMR prescriptions generally ranging between -2,000 to -3,500 cfs on a 14-day running average with a simultaneous 5-day average not more negative by more than 25 percent of the current OMR flow requirement. However, during certain years of unusual smelt distribution (while predicted or measured larval/juvenile delta smelt distribution are in close proximity to the zone of entrainment), maximum negative OMR flows may for a time be set as low as -1,250 cfs. Overall, the OMR flow may be set anywhere between -1,250 to -5,000 cfs on a 14-day running average with a simultaneous 5-day average (from actual daily OMR values) not more negative than the required OMR by more than 25 percent.



Map 2 Biological Monitoring Stations in the Delta

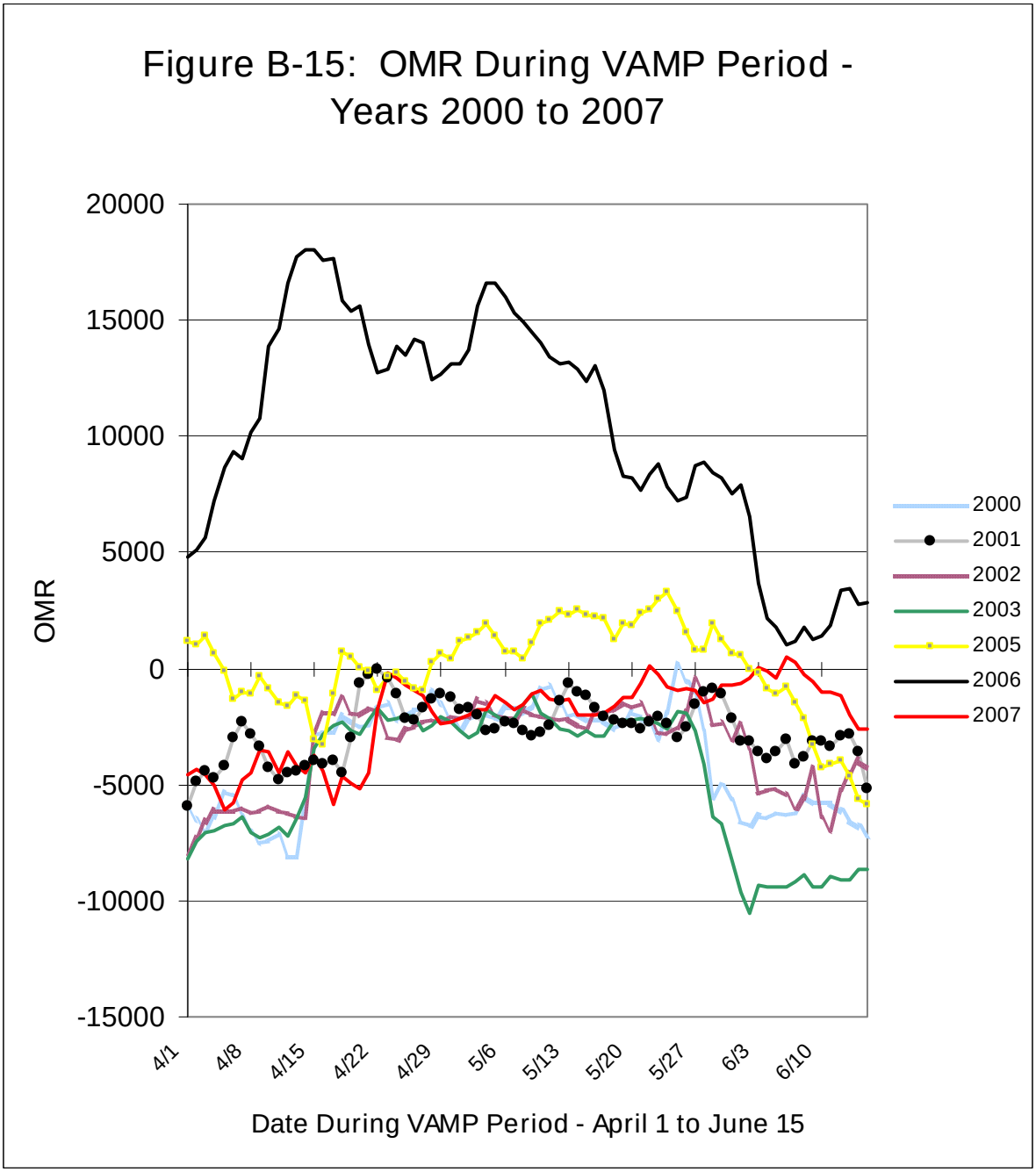


Figure B-15. OMR flows across VAMP period (usually April 15-May 15). Note that although exact VAMP conditions vary across years, the period is easily identified by OMR flows no more negative than -2000 cfs.

The following examples provide the insight on when exceptions to the ranges of OMR flows above would be used. In high risk years, when delta smelt are in the South Delta, suggesting that delta smelt are particularly sensitive to entrainment (as for example in 2003), a stricter limit on OMR flow of -1,250 cfs would be necessary to meet the defined

protectiveness criterion. Alternatively, in years when sampling indicates that it appears that most adults have spawned in the Cache Slough complex and larvae may be at reduced risk of entrainment, an OMR flow of about -3,500 cfs may be possible while still meeting the protectiveness criterion. Later in the season, as more juvenile delta smelt are found seaward and while physical conditions in the Delta become less conducive to smelt larvae, OMR flow requirements could relax further. Once conditions in the Delta are inconsistent with smelt survival (i.e. South Delta waters are too warm), the larval protections of Action 3 cease.

Justification for Timing of Action 3

The window for delta smelt spawning generally begins during February, but is variable based on seasonal conditions of flow, temperature, and physiological condition of the current year spawning cohort. Further, low adult abundances make it very difficult to discern adult spawning distribution using current monitoring methods. Lastly, protective and successful flow restrictions during the winter may reduce the discriminatory power of salvage itself as an indicator of the distribution of spawning smelt and timing to initiate Action 3.

For these reasons, it is believed that an adaptive approach using recommendations from the SWG in real-time is preferred to protective prescriptions that are applied regardless of variation or nuance in actual conditions. By monitoring a combination of these factors, along with tracking of important parameters in real time that are indicative of smelt presence and the timing of smelt spawning activity, the SWG is best situated to judge when OMR actions should be initiated or adjusted in Action 3.

During Action 3 (generally March through June 30), the SWG will recommend OMR flows to the Service. These will be based upon the best-available predictive capacity of the experts within the group given available data in real-time, and will be protective of larval/juvenile delta smelt to the criteria defined above.

Justification for Different OMR Requirements of Action 3

Analysis of the birth dates of delta smelt collected from the Summer Townet Survey (Bennett 2008) indicates that in 2005 the delta smelt found in the summer were almost entirely born during the VAMP period. Collection of spawned adults suggests that larvae were produced throughout much of the February-May period, but only the late produced young survived. Thus, we have determined that managing the hydrodynamics of the Central Delta, e.g., by providing VAMP-like conditions throughout Action 3 will be beneficial to larval and juvenile delta smelt. During most year types, these OMR requirements will range between -2,000 to -3,500 cfs.

If sampling, salvage, or any applicable and available information suggests that delta smelt are at high risk in the Central or South Delta, then the OMR will need to be as low as a 14-day running average of -1,250 cfs. If for example, based on the sampling, minimal to no salvage at the export facilities, increase in temperature, decreases in turbidity or higher

San Joaquin River inflows suggest that delta smelt larvae are at lower risk in the South and Central Delta then flows may be held to no more negative than -3,500 cfs. As temperatures rise, trawl data continue to show no fish in the Central and South Delta, and salvage does not occur, OMR flows will be allowed to become as negative as -5,000 cfs. When temperature rises and turbidity drops to levels likely to be inimical to delta smelt (> 25°C, turbidity <12 NTU), no further restrictions are needed as long as salvage remains at or close to zero.

The Influence-Exposure-Intensity-Response (IEIR) Analysis

On December 13, 2007, the Service requested the SWG to formulate a process to determine protective OMR flow recommendations for delta smelt larvae during the spring. The SWG agreed that a strict decision-tree approach was imprudent because it would be inflexible to real-time conditions. In such circumstances, where dynamic and interacting parameters determine delta smelt risk, static prescriptions tend to be imperfect moderators of such risk.

The process that has been developed is called "influence-exposure-intensity-response analysis" (IEIR Analysis). It involves four steps:

1) Particle tracking modeling of current and/or projected Delta conditions describes Banks and Jones' relevant hydrological influence at different flow rates.

2) Risk exposure of smelt larvae is determined by comparing Banks and Jones' relevant hydrological influence from the PTM results with current knowledge of smelt distribution using real-time data from surveys and salvage.

3) PTM runs are used to predict the probability of delta smelt entrainment at several OMR flow limits using "particle injection" points corresponding to 20mm survey sampling stations.

4) OMR flow recommendations are developed to reduce the projected entrainment risk to the extant delta smelt population, as estimated by the prior-year FMWT Index.

The levels of concern expressed through this analytical real-time adaptive approach have been classified into three categories: High Concern, Medium Concern and Less Concern. These correspond generally to the following realized values of key physical, operational, and biological parameters, and were applied in 2008 such as:

	Factor	***State***
•	Prior Year FMWT	<40 = High Concern; >300 = Less Concern
•	Salvage	high numbers = high concern; low numbers = less concern
•	Distribution	south = high concern; north/northwest = less concern
•	X2 Location	>80 km = high concern; <75 km = less concern

- Temperature 12°C to 25°C = high concern; >25°C = less concern

These five factors were chosen based on the following:

1. Size of spawning population: A low FMWT index indicates low abundance of potential spawners which makes population growth rate more sensitive to loss of individuals.

2. Salvage: Salvage of delta smelt indicates that larvae and juveniles are located in the Central and South Delta and are vulnerable to entrainment. Future entrainment becomes more demographically significant as cumulative entrainment numbers increase.

3. Fish Distribution: The hydrodynamic influence of Banks and Jones increases when larvae are closer to the intakes. Thus, smelt located in the Central and South Delta are exposed to greater intensity of entrainment risk than those located in the North or West Delta.

4. X2 Location: Estimating the distribution of larval smelt and their exposure to pumping effects from existing survey data includes high inherent uncertainty, with increasing magnitude at low population abundances. However, the majority of smelt larvae and juveniles are often located just inland of X2, and so an easterly X2 would indicate that the smelt are at greater risk of entrainment at Banks and Jones

5. Water Temperature: Laboratory studies of delta smelt temperature tolerance has shown increased mortality at temperatures exceeding 25°C. An average south Delta water temperature of 25°C corresponds in most years to a distribution of delta smelt juveniles towards Suisun Bay, and out of the zone of entrainment risk. Most delta smelt remaining in the San Joaquin River portion of the Delta are not expected to survive as water temperatures increase above 25°C, so their loss at salvage will not affect recruitment success.

The balance of conditions relative to level of concern within the IEIR analysis determines the foundation upon which a final flow recommendation may be based.

Application of IEIR Analysis: Further Guidelines for the Adaptive Process

In light of the experience in 2008, the IEIR is adjusted to make the following amendments.

As before, the SWG will evaluate data from the 20-mm survey and other parameters and make recommendations for specific timing of the more protective levels of OMR flows based upon real-time assessment of entrainment risk of larval smelt based upon their proximity to Banks and Jones, forecast operations, and particle tracking modeling run

results based on a control-point method using a protectiveness criterion of 1 percent per 14-day time interval salvage threshold at Station 815.

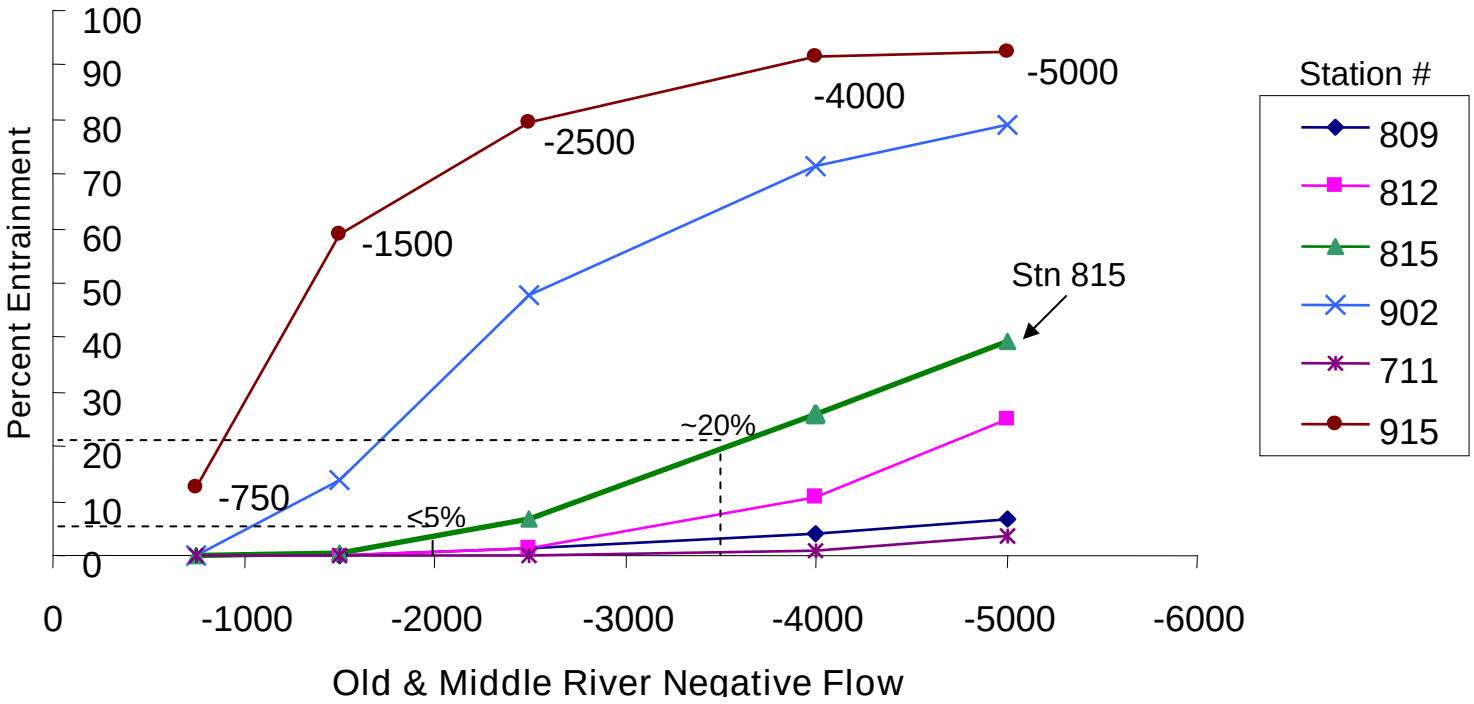
The SWG may recommend using the less stringent level of OMR restriction based on an average Recovery Index (RI) from the preceding two years exceeding 84 (the minimum for a recovery period in the Delta Native Fishes Recovery Plan, Service 1995); however, low San Joaquin River inflows, high cross-Delta flows or other conditions that degrade larval habitat in the Central Delta could preclude such relaxations. During periods of intermediate concern (recovery indices from the preceding year in excess of 239), a reduction to a shorter period of restriction to the -2000 cfs level in the larval period may be supported, if the SWG determines that a large part of the larval population would not be put at risk.

The most efficient protective measure for protecting the resilience and not precluding the recovery of the delta smelt population specific to the larval/juvenile lifestage is to prevent entrainment of fish in as large a portion of the Central Delta as is practical. Results of PTM modeling focusing on protections at station 815 (Prisoner's Point) indicates that precluding entrainment of larval/juvenile delta smelt at this station would also protect fish at station 812 (Fisherman's Cut) and other stations north and west (downstream) of station 815. While the target entrainment at station 815 would ideally also be zero, there appears to be little additional entrainment protection (less than 5 percent) at OMR flows at -750 cfs (the strictest level addressed by Interim Remedies). However, entrainment risk grows exponentially at OMR flows increasingly more negative than -2000 cfs.

Figure B-16 displays injection points for modeled particle tracking runs that were conducted in February 2008 with injection points at Stations 711, 809, 812, 815, 902, 915. This figure plots projected relationships for OMR flows by injection point, including entrainment probabilities for station 815 (over 30 days).

The results from these runs indicate an approximate <5 percent entrainment risk at OMR flow not more negative than -2000 cfs. At a requirement of -3,500 cfs OMR flow, entrainment risk at station 815 is roughly 20 percent over each 30 day interval. Assuming cumulative entrainment is additive, over a roughly four month (~120 days) interval in which Action 3 would be under effect, consistently operating at -3,500 OMR would yield a net entrainment probability placing at risk approximately 80 percent of the larval/juvenile subpopulation utilizing the South Delta at and below Station 815. If immigration of larval smelt from the Central or North Delta into the zone of entrainment during spring

Figure B-16: Pump Entrainment at Various Levels of Negative Flow at Old and Middle River Monitoring



were to occur, the population-level risk would be even greater. Such entrainment levels are potentially a significant adverse risk to delta smelt population.

Justification for Release from Prescriptions of Action 3

Calendar Date

The Interim Remedies specified the duration of Action 3 to extend to *around* June 20, or until the temperature metric below. Based upon salvage data observed during WY 2008 (see Figure B-17, above), this temporal window should be amended (extended) to June 30 in order to provide sufficient protections to late-spawned delta smelt larvae.

Temperature

When South Delta temperatures reach a daily average of 25°C for three consecutive days at Clifton Court Forebay, it is expected that conditions are no longer suitable for smelt survival. This metric is a functionally adequate predictor that viable smelt will not be present within the entrainment zone of Banks and Jones.

ACTION 4: ESTUARINE HABITAT DURING FALL

Objective: Improve fall habitat for delta smelt by managing of X2 through increasing Delta outflow during fall when the preceding water year was wetter than normal. This will help return ecological conditions of the estuary to that which occurred in the late 1990s when smelt populations were much larger. Flows provided by this action are expected to provide direct and indirect benefits to delta smelt. Both the direct and indirect benefits to delta smelt are considered equally important to minimize adverse effects.

Action: Subject to adaptive management as described below, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall target. The action will be evaluated and may be modified or terminated as determined by the Service.

Timing:

September 1 to November 30.

Triggers:

Wet and above normal WY type classification from the 1995 Water Quality Control Plan that is used to implement D-1641.

Adaptive Management of Habitat Action:

To address uncertainties about the efficiency of the Action, it will be adaptively managed under the supervision of the Service. Adaptive management is a mode of operation that provides for learning and feedback to adjust an action undertaken in the face of uncertainty. To improve the efficiency of the Action and align its management more closely with the general plan articulated in Walters (1997) and endorsed by the independent peer review of this BO, the Service will supervise the implementation of a formal adaptive management process.

According to Walters (1997), an adaptive management plan should include a clearly stated conceptual model, predictions of outcomes, a study design to determine the results of actions, a formal process for assessment and action adjustment, and a program of periodic peer review. A conceptual model that is based on the best available scientific information underlying the present Action is described in the Effects section. Expected

outcomes are described in general terms below, though there is a high degree of uncertainty about the quantitative relationship between the size of the Action described above and the expected increment in delta smelt recruitment or production.

The adaptive management plan will include the following new elements to ensure that performance measures and plans to evaluate the outcome of the Action are in place by the time it is implemented and that refinements to the Action can be developed as quickly as possible. These are listed in chronological order of implementation, but steps (2) through (6) are viewed as steps in an adaptive feedback loop that may cycle multiple times. The loop is closed when new information developed in (3) – (5) and/or Service decisions to alter the Action in (6) provide a basis for altering the conceptual model and/or study design in (2) or create a need to alter the performance measures in (3). The process will then continue from the re-entry step.

(1) Delta smelt habitat study group (HSG)

A panel of scientists will be convened by the Service to review and improve the habitat conceptual model, design performance measures for the Action, and prepare a study plan to improve scientific understanding of delta smelt habitat. Products produced by the HSG will be made publicly available by the Service.

(2) Conceptual model review and preparation of study design

In this instance, the conceptual model (summarized below and in the effects section) describes multiple mechanisms potentially contributing to the observed habitat/flow relationship that motivates the Action. Consequently, the study group will develop an improved conceptual model more clearly sorting out component mechanisms as an important goal. With the conceptual model in hand, two lines of investigation will be developed: one line will be designed to evaluate the performance of the specific Action described in Part A above, while the other will address the scientific uncertainties underlying the relationship between summer/fall habitat quality and delta smelt adult recruitment. The second line of investigation will provide new scientific information that is likely to aid in refinement of the Action in Part A.

(3) Performance evaluation of the Action

The study group will develop performance measures for the Action, and these measures will be subject to independent peer review. The study to evaluate the present Action will be implemented in accordance with its design prior to the first September following adoption of the biological opinion.

(4) Studies to elucidate the operative mechanism(s) controlling the relationship between delta smelt habitat features and quality and delta smelt production.

The HSG will develop a habitat investigation, and the plan will be subject to independent peer review. There are several potentially fruitful lines of investigation to pursue,

including studies to elucidate the precise mechanisms by which habitat affects delta smelt and studies intended to develop management tools to improve habitat. The peer review panel provided several useful suggestions in its review of the proposed actions.

(5) Peer review

Studies conducted under the guidance of the study group will be subject to independent peer review both at the design stage (when possible) and after results are obtained. Conclusions regarding the efficiency of the Action and potential alternatives will also be independently peer reviewed prior to receipt for official consideration by the Service.

(6) Service review and Action adjustment

The Service will direct all stages of the adaptive management plan, and will adjust the Action if/when circumstances and improved scientific understanding warrant. The HSG will provide technical assistance in the interpretation of results, but the Service will have ultimate responsibility for drawing conclusions regarding the advisability of any changes to the Action.

The Service will conduct a comprehensive review of the outcomes of the Action and the effectiveness of the adaptive management program ten years from the adoption of the BO, or sooner if circumstances warrant. This review will entail an independent peer review of the full history of the Action. The purposes of the review will be (1) to evaluate the overall benefits of the Action and (2) to evaluate the effectiveness of the adaptive management program.

The adaptive management program will have specific implementation deadlines. The creation of the HSG, initial habitat conceptual model review, and formulation of performance measures, implementation of performance evaluation, and peer review of the performance measures and evaluation that are described in steps (1) through (3) will be completed before the first September following adoption of the BO. This will ensure that measures required to evaluate the effectiveness of the action are in place during the first autumn after adoption. Additional studies addressing elements of the habitat conceptual model will be formulated as soon as possible, promptly implemented, and reported as soon as complete. As described above, there will also be a ten year review of the Action and its consequences.

Background

Delta outflows of as much as 20,000 cfs formerly occurred in fall months of all but drought WYs. Currently, however, fall outflows are similar to historic droughts regardless of WY type. Fall Delta outflows in wet and above normal WYs (i.e., from 1993-98) average 8,000-10,000 cfs; whereas after 1998, monthly averages have been 5,600 cfs across all WY types and monthly outflow variation has been very small. High among-month variability in Delta outflows may be important for restoring estuarine habitat conditions favoring many native species (Lund et. al. 2007).

Habitat parameters for delta smelt have been well described for both the summer and fall seasons as combinations of salinity, temperature, and turbidity. In winter and spring, temperature seems to be a dominant driver of habitat suitability both for adult spawning and for larval occurrence (Bennett 2005). Summer habitat is controlled largely by changes in turbidity due to changes in sediment supply and in the distribution of the sediment-trapping aquatic weed, *Egeria densa*. (Nobriga et al. 2008) Fall habitat (and smelt) shifts in abundance and distribution largely due to fluctuations in salinity (Feyrer et al. 2007). X2, which reflects salinity distribution in the estuary (Jassby et al. 1995), fluctuates mostly in response to fluctuations in outflow, although atmospheric conditions and barrier operations can also affect it.

X2 is strongly influenced by tidal cycles, moving twice daily up and downstream 6-10 km from its average daily location. For example, when the average daily X2 is near Sherman Island, delta smelt habitat can range from Chipps Island to Franks Tract. When the daily average X2 is centered on Browns Island, delta smelt habitat can range from Honker Bay to Big Break. The daily fluctuation in X2 around an upstream point such as Brown's Island confines the population to narrow channels, where delta smelt may be exposed to more stressors (e.g., agricultural diversions, predation) relative to a downstream X2. Adverse effects on adult delta smelt during fall may be a part of the reason that Feyrer et al. (2007) found a statistical association between fall X2 and the production of young delta smelt during the following year.

Other factors can degrade the quality of smelt habitat, principally water quality degradation. In September 2007 all collected delta smelt were found at salinities much higher than ever before. This observation was coincident with a period when their usual salinity range was heavily infested with the cyanobacterium *Microcystis aeruginosa*. *Microcystis* produces toxins in its normal life, but the concentrations of these toxins in water sharply increase when the population dies, usually in September and October (Lehman pers. comm.). In September 2008, delta smelt were in their normal salinity range and *Microcystis* were less abundant than in September 2007 (pers. comm. Randy Baxter DFG and Peggy Lehman DWR). Low flow conditions are among the factors associated with *Microcystis* blooms (Lehman et al. 2008).

Protection and restoration of habitat is an essential element in any conservation strategy where habitat has been lost or degraded. However, identifying the exact role habitat quality and volume play in the growth and survival of a species comes with some

uncertainty. In the case of fall delta smelt, habitat area is a significant covariate in its stock-recruit relationship, indicating evidence of an effect on the population. Westward and variable locations of fall habitat provide increased habitat area and moves the delta smelt population away from the risks of possible future entrainment in the Delta, and distributes it more broadly throughout the estuary.

This action is designed to increase baseline monthly outflows in the fall period of wet and above normal WYs to increase areas of habitat and move the habitat away from Delta impacts and into broader open waters west of Sherman Island; and to increase variability of monthly habitat extent by having 2-3 months above the baseline. This would be expected to distribute smelt into more diverse geographic areas, helping to reduce the risk of localized losses from future entrainment, contaminants, and predation. Finally, it may reduce the proliferation of other factors that reduce habitat suitability such as *Microcystis* and *Egeria* growth.

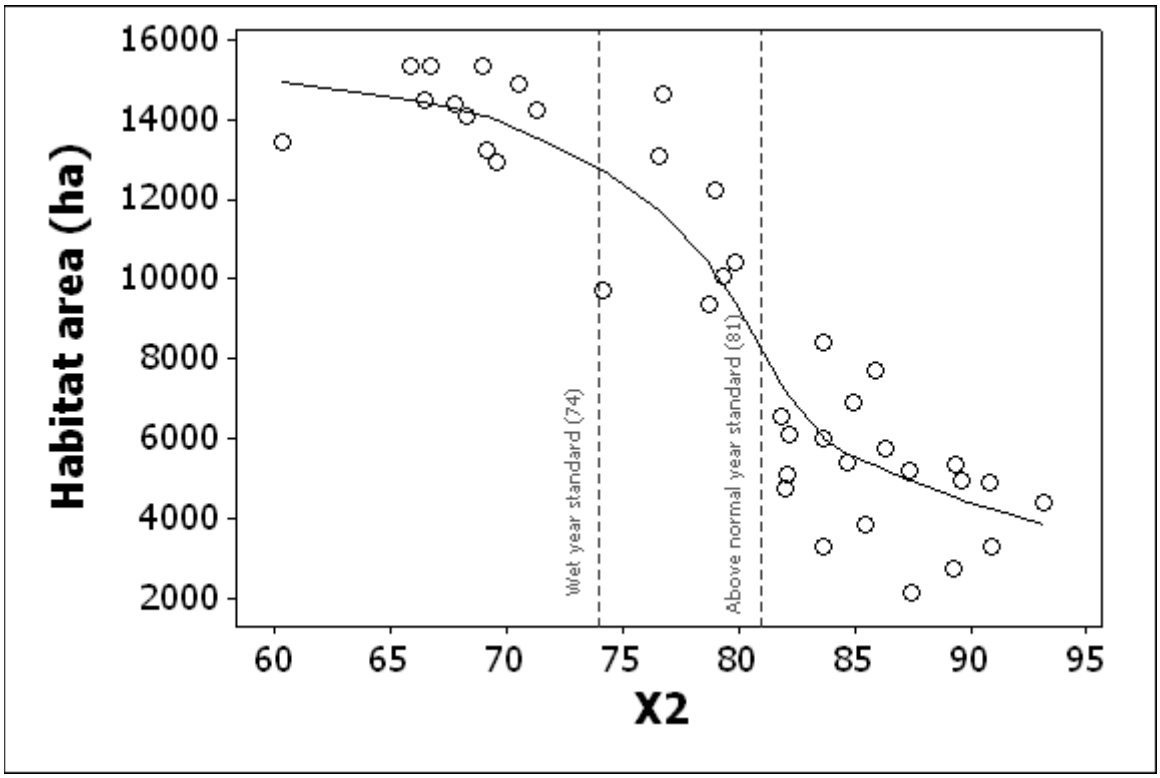
Justification:

The Effects section clearly indicates that there will be significant adverse impacts on X2, which is a surrogate indicator of habitat suitability and availability for delta smelt in all years (Figures E-19 and E-25 in Effects section). Moreover, the results of Feyrer et al. (2007) suggest that adverse effects on adult delta smelt during fall may be part of the reason that there is a statistical association between fall X2 and the production of young delta smelt during the following year. The action is focused on wet and above normal years because these are the years in which project operations have most significantly adversely affected fall (Figure E-27 in Effects section) and therefore, actions in these years are more likely to benefit delta smelt.

The action is designed to be governed by hydrologic conditions and therefore will be ecologically-based. For the purposes of implementation of this action, water year type is defined as the water year that ends in the September of the calendar year in which the action will be implemented. The standards of 74km in wet years and 81km in above normal years are designed to mitigate the effects of X2 encroachment upstream in current and proposed action operations, and provide suitable habitat area for delta smelt (Figure B-17).

The long-term trend in which all falls have Delta outflows indicative of dry or critical years matches long-term upward trends in the E:I ratio and X2 (Figure E-28 in effects

Figure B-17. Relationship between X2 and habitat area for delta smelt during fall, with standard shown for wet and above normal years.



section). The overall effect is readily observed as a substantial divergence in the difference between fall X2 and X2 the preceding spring (April-July). Given that these conditions will persist under the proposed CVP/SWP operations, the modeling also shows they may be exacerbated under various climate change scenarios (Figure E-28 in effects section).

The persistence of this significant hydrologic change to the estuary threatens the recovery and persistence of delta smelt. Outflow during fall determines the location of X2, which determines the amount of suitable abiotic habitat available to delta smelt (Feyrer et al. 2007, 2008). The long-term upstream shift in X2 during fall has caused a long-term decrease in habitat area availability for delta smelt (Feyrer et al. 2007, 2008), and the condition will persist and possibly worsen in the future. This alone is a significant adverse effect on delta smelt.

However, the problem is further complicated because there are several lines of published peer reviewed scientific research that link habitat alteration to the decline of delta smelt (Bennett 2005; Feyrer et al. 2007; Nobriga et al. 2008). An important point regarding this action is that because of the current, extremely low abundance of delta smelt, it is unlikely that habitat space is currently a limiting factor. However, it is clear that delta smelt have become increasingly habitat limited over time and that this has contributed to the population attaining record-low abundance levels (Bennett 2005; Baxter et al. 2008;

Feyrer et al. 2007, 2008; Nobriga et al. 2008). Further, as detailed in the Effects section, persistent degraded or worsened habitat conditions are likely to contribute to depensatory density-dependent effects on the delta smelt population while it is at historical low levels, and would at some point in the proposed term of this project, limit delta smelt recovery.

Therefore, the continued loss and constriction of habitat into areas of low habitat quality under the proposed action significantly threatens the ability of the delta smelt population to recover and persist in the estuary at self-sustaining levels higher than the current record-lows. While it is not yet proven why habitat quality under this constant dry-year fall X2 scenario has been degraded for rearing delta smelt, the coincidence of this pattern with sustained and significant population level losses for this lifestage (as measured in survival rates and smelt physiological condition), along with the increasing body of support ascribing the aforementioned hypothesized mechanisms of action to habitat degradation and smelt condition, and finally the current critically low level of the current population, make the implementation of a fall action essential to the maintenance of the population resilience for delta smelt. In short, the historically high variability in summer/fall survival rates does not negate the need for protection from direct mortality losses due to adult and larval/juvenile entrainment, it actually highlights the need for restoring flow variability to the Delta environment so that smelt populations can recover through allowing these essential periods of population rebound.

Monitoring Component to Assess Performance of Action 4

The Service will require that Action 4 be implemented with an adaptive management program to provide for learning and improvement of the action over time. The adaptive management program will include commissioning studies to clarify the mechanisms underlying the effects of fall habitat on the delta smelt population and should, at the least, focus on the following general study questions:

i. What is the effect of habitat area and distribution on delta smelt distribution?

ii. How does fish condition/health vary across a gradient of habitat quality?

iii. Does fish condition/health in fall affect over-winter survival?

iv. Does fish condition/health affect fecundity and egg viability?

v. Does spatio-temporal salinity variation resulting from this fall action affect *Microcystis*?

vi. Does spatio-temporal salinity variation resulting from this fall action affect *Corbula* and the benthic invertebrate community?

Given the low numbers of delta smelt currently in the estuary, a suite of surrogate species is probably required to address questions ii-iv, although question iv could be examined directly with experiments on fish from the Tracy Fish Culture Facility. It is recommended that studies designed address these research questions be coordinated and

implemented through the IEP and POD Management Teams. The research and monitoring plan will include reporting criteria, data sharing and dissemination requirements, oversight and contractual compliance elements for purposes of quality assurance and ensure the transparency and timely completion of necessary monitoring, research and assessment.

ACTION 5: TEMPORARY SPRING HEAD OF OLD RIVER BARRIER (HORB) AND THE TEMPORARY BARRIER PROJECT (TBP)

Objective: To minimize entrainment of larval and juvenile delta smelt at Banks and Jones or from being transported into the South and Central Delta, where they could later become entrained.

Action: Do not install the HORB if delta smelt entrainment is a concern. If installation of the HORB is not allowed, the agricultural barriers would be installed as described in the Project Description. If installation of the HORB is allowed, the TBP flap gates would be tied in the open position until May 15.

Timing: The timing of the action would vary depending on the conditions. The normal installation of the spring temporary HORB and the TBP is in April.

Triggers: For delta smelt, installation of the HORB will only occur when PTM results show that entrainment levels of delta smelt will not increase beyond 1 percent at Station 815 as a result of installing the HORB.

Offramps: If Action 3 ends or May 15, whichever comes first.

Justification for Action 5

The TBP change the hydraulics of the Delta, which can affect delta smelt. The HORB blocks San Joaquin River flow from entering Old River. This increases the flow toward Banks and Jones from Turner and Columbia cuts, which can increase the predicted entrainment risk of particles in the East and Central Delta by up to about 10 percent (Kimmerer and Nobriga 2008). In most instances, net flow is directed towards Banks and Jones and local agricultural diversions. Computer simulations have shown that placement of the barriers changes South Delta hydrodynamics, increasing Central Delta flows toward the export facilities (DWR 2000). In years with substantial numbers of adult delta smelt in the Central Delta, increases in negative OMR flow caused by installation of the TBP can increase entrainment. The directional flow towards Banks and Jones increases the vulnerability of fish to entrainment. Larval and juvenile delta smelt are especially susceptible to these flows.

The varying operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables limit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. In 1996, the installation of the HORB caused a sharp reversal of net flow in the South Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage (Nobriga et al. 2000). This observation indicates that short-term salvage can significantly increase when the HORB is installed in such a manner that it causes a sharp change or reversal of positive net daily flow in the South and Central Delta.

Many of these potential effects to delta smelt would be reduced by the OMR flows provided in Action 3. In order to determine if there will be adverse effects to delta smelt from the installation of the HORB, PTM will be completed during Action 3. The Service may use the control point method of maintaining an entrainment level at Banks and Jones below 1 percent at Station 815. If the PTM results show that entrainment would be higher than 1 percent during the period when the HORB would be installed, and would result in increased risk to juvenile delta smelt, then it would not be installed.

Additionally, the OMR flows provided in Action 3 or high San Joaquin River flows may provide beneficial conditions in the Delta for out-migrating salmonids and sturgeon, which would preclude the need for the HORB installation. This analysis, combined with the PTM results will provide data to help determine if listed fish would be adversely affected by the HORB. If the spring temporary HORB is not installed, the TBP would be operated as described in the Project Description.

Justification for Release from Prescriptions of Action 5

If Action 3 has ended, the entrainment concern has likely abated, and delta smelt larvae and juveniles are not likely to be present in the Central and South Delta. High flows on the San Joaquin River may also preclude the spring temporary HORB from being installed since it is not physically possible during these flows to install the HORB. The concerns for entrainment are reduced during high San Joaquin River flows.

ACTION 6: HABITAT RESTORATION

Objective: To improve habitat conditions for delta smelt by enhancing food production and availability.

Action: A program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh shall be implemented. A monitoring program shall be developed to focus on the effectiveness of the restoration program.

Timing: The restoration efforts shall begin within 12 months of signature of this biological opinion and be completed within a 10 year period.

Background

The historic Delta was a tidal wetland-floodplain system including about 350,000 acres of tidal wetland. Almost all of the historic wetlands in the Delta have been lost due to conversion to agriculture and urban development. The Delta currently supports less than 10,000 acres of tidal wetland, all of which is small and fragmented. This conversion of the Delta's wetlands beginning in the mid-nineteenth century has resulted in a landscape dominated by agricultural lands intersected by deep and comparatively uniform tidal channels.

Delta smelt feed mainly on zooplankton throughout their life cycle (Nobriga and Herbold 2008) with the copepod Pseudodiaptomus forbesi being the dominant prey item for juvenile delta smelt in the summer (Lott 1998; Nobriga 2002; Hobbs et al. 2006). Diatoms form the base of the pelagic foodweb and primary consumers (e.g. copepods) appear to be food-limited in the Delta and Suisun (Muller-Solger et al. 2002; Sobczak et al. 2002). Pelagic productivity in the Delta and Suisun Bay has been declining for several decades with a steep decline following the introduction of the overbite clam in 1986 (Kimmerer and Orsi 1996). Histopathological evaluations have provided evidence that delta smelt have been food-limited during the summer months (Bennett 2005). This finding has been corroborated by recent work on juvenile delta smelt as part of ongoing studies on the POD. Moreover, recent studies suggest a statistical association between delta smelt survival and the biomass of copepods in the estuary (Kimmerer 2008).

Overall research in other estuaries has indicated that tidal wetlands are highly productive. Although definitive studies have not been done on the type and amount of productivity in freshwater tidal wetlands of the Delta, brackish tidal wetlands of Suisun Marsh are one of the most productive habitats in northern San Francisco Bay-Delta estuary (Sobczak et al. 2002). It is likely that restored freshwater tidal wetlands in the Delta would have higher productivity than the brackish wetlands of Suisun (Odum 1988). A large portion of the production in Suisun Marsh consists of high quality phytoplankton-derived carbon (Sobczak et al. 2002) that is an important food source for zooplankton and therefore can contribute to the base of the pelagic foodweb. Modeling suggests that the tidal wetlands of Suisun currently provide about 6 percent of the organic carbon to the pelagic habitats of Suisun Bay (Jassby et al. 1993). In addition, sampling in Liberty Island shows that these freshwater tidal habitats can be a source of high-quality phytoplankton that contribute to the pelagic food web downstream (Lehman et al. 2008). Thus, restoration of large amounts of intertidal habitat in the Delta and Suisun could enhance the ecosystem's pelagic productivity.

Justification:

Since it was introduced into the estuary in 1988, the zooplankton Pseudodiaptomus forbesi has been the dominant summertime prey for delta smelt (Lott 1998; Nobriga 2002; Hobbs et al. 2006). There is evidence suggesting that the co-occurrence of delta smelt and Pseudodiaptomus forbesi has a strong influence on the survival of young delta smelt from summer to fall (Miller 2007). The Effects Section indicates that

Pseudodiaptomus distribution may be vulnerable to effects of export facilities operations and therefore, the projects have a likely effect on the food supply available to delta smelt.

The near complete loss of tidal wetlands from the Delta threatens the persistence of delta smelt by reducing productivity at the base of the pelagic foodweb. Primary production in tidal wetlands of the Northern San Francisco estuary has been shown to support high zooplankton growth (Muller-Solger et al. 2002). This action should therefore enhance the foodweb on which delta smelt depend. This action is designed to increase high quality primary and secondary production in the Delta and Suisun Marsh through an increase in tidal wetlands. Exchange of water between the tidal wetlands and surrounding channels should distribute primary and secondary production from the wetlands to adjacent pelagic habitats where delta smelt occur. This exchange should be optimized through intertidal habitat restoration designed to incorporate extensive tidal channels supported an appropriately sized vegetated marsh plain which will provide the necessary tidal prism to maintain large tidal exchange.

New evidence indicates how tidal marsh may benefit delta smelt even if they do not occur extensively within the marsh itself. Specifically, monitoring suggests this species is taking advantage of recently-created tidal marsh and open water habitat in Liberty Island. The fact that delta smelt make heavy use of habitat in the Cache Slough complex has been evident in sampling by the DFG's Spring Kodiak trawl and 20 mm surveys (www.delta.dfg.ca.gov). The Spring Kodiak trawls show that delta smelt are present in channels of the Cache Slough complex during winter and spring; the collection of larval delta smelt in subsequent 20-mm surveys indicates that these adult delta smelt eventually spawn in the vicinity. In addition, the use of Cache Slough complex by delta smelt includes habitat on Liberty Island. The island flooded in 1998 and has evolved rapidly into a system of open-water and tidal marsh habitat. Recent sampling of Liberty Island by USFWS biologists (http://www.delta.dfg.ca.gov/jfmp/libertyisland.asp) revealed that delta smelt both spawn and rear in Liberty Island. Light traps collected relatively high numbers of larval delta smelt in several locations of Liberty Island during the 2003 spawning period for this species. Moreover, subsequent beach seine sampling showed that older delta smelt were present at all ten of their sampling stations during 2002-2004 and in all seasons of the year (USFWS, unpublished data). These results are particularly striking because they were from a period when delta smelt was at record low abundance. Collection of delta smelt from shallow inshore areas using seines indicates that the fish do not occupy deeper pelagic habitat exclusively. These results seem reasonable in light of the area's consistently high turbidity (Nobriga et al. 2005; DWR, unpublished data) and zooplankton abundance (e.g. Sommer et al. 2004), both of which are important habitat characteristics for delta smelt (Bennett 2005; Feyrer et al. 2007). In any case, these data suggest that freshwater tidal wetlands can be an important habitat type to delta smelt with proper design and location.

A monitoring program shall be developed to focus on the effectiveness of the restoration program. This program shall be reviewed and modified as new information becomes available.

Attachment C: Methods Used in Developing the Incidental Take Statement

Methods Used in Developing the Incidental Take Statement

The objective adopted by the Service to minimize take of adult delta smelt through entrainment is two-fold. First, adult entrainment shall be minimized during all year types through the RPA. More critically, demographic losses from periodic episodes of high entrainment will be eliminated through implementation of the RPA. These outcomes shall be accomplished through the application of measures as defined in RPA Components 1 and 2.

Adoption of the RPA included in this biological opinion is expected to appreciably reduce the number of delta smelt salvaged during certain years. Implementation of the RPA should avoid significant mortality during those years of high entrainment. The Service believes these high salvage year events (such as in WY 2003 for adult delta smelt) resulted in mortality at levels that were demographically significant to the delta smelt population. Further, at low abundances observed in the last few years, high entrainment events (observed more frequently, for adult delta smelt in 2003, 2004, and 2005, successively) further reduces the resilience of the current delta smelt population.

The Service anticipates that take of adult delta smelt via entrainment will be minimized when OMR flows are limited to -2,000 cfs during the first winter flush when adult smelt move within the zone of entrainment. OMR flows held between -1,250 and -5,000 cfs following the first flush until the onset of spawning will protect later delta smelt migrants and spawners. During frequent intervals within the timeframe for RPA Component 1, the SWG shall provide specific OMR flow recommendations to the Service; and the Service will then determine flow requirements using the adaptive process as described in the RPA.

This approach was adopted because it reflects the most reasonable strategy to allow continued CVP/SWP operations while providing necessary protection to the delta smelt population under real-time conditions. It accounts for uncertainty of adult smelt entrainment risk resulting from variable environmental, demographic, and operational conditions; and adapts operations in response to real-time data.

The specific level of take of adult delta smelt at the CVP/SWP pumping facilities is difficult to definitively project, due to inherent uncertainties. First, the only data available from which to derive population estimates come from monitoring that is not specifically designed to assess the abundance of delta smelt. Distribution of adult smelt is highly variable between years, and is driven by factors that are both inherently difficult to predict and also not completely understood. These factors are, at best, imperfectly controlled. Additionally, salvage data (our most definitive measurement endpoint) reflects only a portion of the total mortality associated with entrainment. Losses to predation and inefficient screening are significant, but unknown. Finally, salvage itself is clearly at least partially a function of abundance. In other words, the more delta smelt there are out there, the higher the salvage numbers will be, given the same operational conditions and delta smelt distribution. In short, entrainment and the population-level

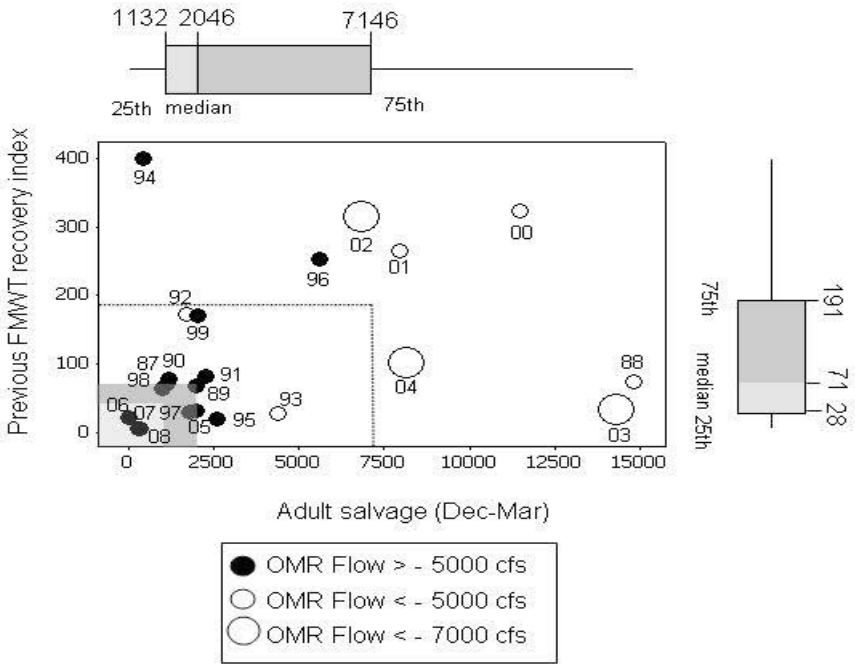
effect from direct mortality attributed to pumping is a multivariate and complex process, and this complexity defies ready predictive modeling.

The Service in past take statements has relied upon historic salvage as the most reasonable predictor of future salvage. Adult delta smelt salvage data (grouped by sorting entrainment years into quartiles by the total number salvaged between December and March) can be plotted by year and related to delta smelt population abundance and flows as shown in Figure C-1. The historic (1987-2007) median salvage levels with 25th and 75th percentiles are plotted versus the preceding FMWT Recovery Index (RI). The RI provides an indication of the status of the delta smelt population based on distributional and abundance criteria from a subset of September and October FWMT sampling data (Service 1995). A low RI indicates the delta smelt population is at a low level, whereas a high RI value (~400) indicates a larger population. Figure 1 uses 1987 to 2007 as the historic baseline dataset for this analysis because these years represent the period after which delta smelt experienced coincident declines in abundance and habitat quality (Feyrer et al. 2007), and because these are years for which salvage data are considered most reliable.

One benchmark for determining the severity of salvage is the 25th percentile (first quartile) of recent historic winter salvage of delta smelt at the CVP/SWP export facilities. For reference, the first quartile historic salvage count for 1987 through 2007 is 1,132 adult delta smelt, while the median value during this same interval is 2,046 individuals. Salvage above these levels is likely to lead to large losses of spawning delta smelt relative to the mean population size. For example, in 2003 and 2004, the projects salvaged 14,323 and 8,148 adult delta smelt respectively. These losses are disproportionately high (i.e., greater than the 75th percentile of historical salvage) for their given RI values, 33 (2003) and 101 (2004), respectively. According to Kimmerer (2008), 2003 and 2004 were years when entrainment accounted for 50 percent and 19 percent losses, respectively, of adults from the population. These are very high loss rates even by commercial fishery standards and for delta smelt, with such low population numbers, it is an even greater concern.

As presented in Figure C-1, using a rough estimate of expected future flows based on implementation of the RPA (i.e., >-5,000 cfs OMR) and when abundance indices are low (based on RI), adult salvage levels during WY's 2006, 2007, and 2008 best approximates adult salvage numbers expected in the future.

Figure C-1. Adult delta smelt salvage levels in relation to OMR flows and the FMWT RI for the period 1987-2007.



To estimate take with implementation of the RPA, the Service scaled projected salvage to abundance using the estimates provided by the prior year's FMWT Index (note that this differs somewhat from Figure C-1, which used the RI, reflecting a subset of FMWT Index data). The segregation of year types is based upon descriptive statistics comprising quartiles, as expressed above in Figure C-1, and quantified following the approach described below.

A *Cumulative Salvage Index*

The Cumulative Salvage Index (CSI) is calculated as the total year's adult salvage (the aggregate number for expanded salvage at both the Banks and Jones export facilities for the period December through March) divided by the previous year's FMWT Index. Taking all water year types together (regardless of abundance or OMR flows in a given year), the median CSI value for the period 1993 to 2008 is 12.0. The first and third quartile CSI values for this period are 6 and 26, respectively. These data are summarized below in Table C-1.

Incidental Take for Adult Entrainment (Salvage)

Water years 2006 to 2008 were years in which salvage, negative OMR flows, and delta smelt abundance were all relatively lower relative to the historic values. These are the

only three years of lower negative OMR flows which coincided with salvage values below the first quartile within the historic range and low overall adult delta smelt abundances (below first quartile FMWT Index). The corresponding CSI values are: 8.3 (2006), 0.88 (2007), and 12.6 (2008). The Service therefore believes these years within the historic dataset best approximate expected salvage under the RPA Component 1.

The mean value for adult salvage during WYs 2006 to 2008 is 247 adult delta smelt. The average CSI value for WYs 2006 to 2008 was 7.25. Projecting this average rate of salvage to the years in which CVP/SWP operations will be conducted within the sideboards established by the RPA would yield estimates of salvage at 7.25 times the prior year's FMWT Index. The Service use this estimator to predict incidental take levels of adult delta smelt during each year that the RPA's will be in effect. This value, which can be calculated upon release of the final FMWT Index within the current water year, is regarded as the incidental take for adult delta smelt under the RPA.

Incidental Take: Cumulative Expanded Salvage = 7.25 * Prior Year's FMWT Index

As indicated in Table C-1, for the entire span of WY's since 1993, this numerical salvage threshold would have been exceeded in WY's 1993, 1995, and 2003-2005.

Table C-1: Adult Salvage Summary Statistics 1993-2008

Year	FMWT Index	Adult Salvage	Cumulative Salvage Index	Take Threshold
1993	156	4425	28.4	X
1994	1078	359	0.33	
1995	102	2608	25.6	X
1996	899	5628	6.3	
1997	127	1828	14.4	
1998	303	1027	3.4	
1999	420	2074	4.9	
2000	864	11505	13.3	
2001	756	8015	10.6	
2002	603	6865	11.4	
2003	139	14338	103	X
2004	210	8058	38.4	X
2005	74	2018	27.3	X
2006	26	216	8.3	
2007	41	36	0.88	
2008	28	352	12.6	
min	26	36	0.33	
max	1078	14338	103	
mean	364	4335	19.3	
25th	95.0	860.0	5.9	
median	183	2341	12.0	
75th	641.3	7152.5	26.0	

High Concern Level for Adult Entrainment (Salvage)

Delta smelt abundance is critically low, and without habitat quality conditions to appreciably improve juvenile growth and rearing from recent historic levels, is expected

to remain so for the foreseeable future. The current population cannot tolerate direct mortality through adult entrainment at levels approaching even "moderate" take as observed through the historic record of recent decades. The method utilized herein to calculate take contains uncertainty within the estimates, and this fact translates into population-level risk. Further, there is a recognized need to provide a quantitative framework so that the Service and CVP/SWP operators have a common analytical methodology for reference and to futher guide the adaptive process.

Therefore, the Service is also providing a Concern Level estimate, meant to indicate salvage levels approaching the take threshold, and help guide implementation of the RPA. Reaching this expanded salvage figure within a given season may require that OMR flows be set to a more restrictive level, unless available data indicate some greater level of exports is possible without increasing entrainment (e.g., there is strong reason to presume the pre-spawning migration has passed). Throughout the water year, as the SWG convenes and reviews daily salvage data, reaching the Concern Level for adult salvage requires an immediate specific recommendation to the Service.

The Service believes this Concern Level value should trigger at 75 percent the adult incidental take, as an indicator that operations need to be more constrained to avoid exceeding the incidental take.

Concern Level: Cumulative Expanded Salvage = 5.43 * Prior Year's FMWT Index

The rationale for a value approaching 75 percent (as opposed to 50 percent, for example), is that the window for adult entrainment, once begun, is generally short (~1 month), and it is not expected that aggressive pumping restrictions would continue for long durations once salvage is occurring and data are available. The SWG will take timing into account during interpretation of salvage within a given season, and recommend OMR restrictions to the Service accordingly.

For reference purposes, the population level losses reported in Kimmerer (2008) appear in Table 2 compared to our CSI metric. Caution is necessary when comparing field data to take estimates from population models due to; (1) their high inherent predictive uncertainty based on broad underlying assumptions and limited monitoring methodology, (2) the crude discriminative capacity of the inherent methodology utilized within the CSI-derived risk thresholds, and (3) the paucity of available data. However, regressing the Kimmerer (2008) estimates against the CSI approach in order to make this comparison ($y = 0.4539x + 1.8905$; $r^2 = 0.9105$) yields an expected take under implementation of the RPA defined herein approximating delta smelt population level losses during the adult lifestage to around 5 percent. The concern level would roughly approximate salvage of 4 percent of the adult pre-spawning population.

Table C-2. Cumulative Salvage Index in comparison to adult take estimates in Kimmerer (2008).

Year	Estimate	Lower 95% Confidence Boundary	Upper 95% Confidence Boundary	FMWT Recovery Index	Total Salvage	CSI
2002	15	5	24	603	6865	11.4
2003	50	19	69	139	14338	103
2004	19	6	31	210	8058	38.4
2005	7	2	12	74	2018	27.3
2006	4	1	6	26	216	8.3

Table C-3 lists threshold levels of high concern and incidental take for a range of potential FMWT indices. This table is intended to be used as a reference to discern levels of salvage reflecting the range of expected adult delta smelt mortality with implementation of the RPA, and an indicator of adult delta smelt salvage levels that constitutes an increasing and adverse effect to the delta smelt population due to CVP/SWP operations.

Table C-3: Incidental Take Expanded Salvage Numbers by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	11	15	66	359	479	220	1197	1596	550	2992	3989
4	22	29	72	392	522	240	1305	1741	560	3046	4061
6	33	44	78	424	566	260	1414	1886	570	3100	4134
8	44	58	84	457	609	280	1523	2031	580	3155	4206
10	54	73	90	490	653	300	1632	2176	590	3209	4279
12	65	87	96	522	696	320	1741	2321	600	3264	4351
14	76	102	100	544	725	340	1849	2466	620	3372	4496
16	87	116	102	555	740	360	1958	2611	640	3481	4642
18	98	131	104	566	754	380	2067	2756	660	3590	4787
20	109	145	106	577	769	400	2176	2901	680	3699	4932
22	120	160	108	587	783	420	2285	3046	700	3808	5077
24	131	174	110	598	798	460	2502	3336	720	3916	5222
26	141	189	120	653	870	480	2611	3481	740	4025	5367
28	152	203	130	707	943	500	2720	3626	760	4134	5512
30	163	218	140	762	1015	502	2731	3641	780	4243	5657
34	185	247	150	816	1088	504	2741	3655	800	4351	5802
38	207	276	160	870	1160	506	2752	3670	840	4569	6092
42	228	305	170	925	1233	510	2774	3699	880	4787	6382
48	261	348	180	979	1305	520	2828	3771	920	5004	6672
54	294	392	190	1033	1378	530	2883	3844	960	5222	6962
60	326	435	200	1088	1450	540	2937	3916	1000	5439	7252

Take of Larval and Juvenile Delta Smelt

In contrast to adult delta smelt, there is no well established index of larval and juvenile abundance to reliably scale the take of this lifestage to abundance. Indices of abundance are constructed from fishery surveys performed by DFG (Figure C-2). The DFG has monitored the distribution and relative abundance of larval and post-larval delta smelt throughout their spring range since 1995. This survey is named the 20-mm survey for the size at which delta smelt are retained and readily identified by the fish salvage facilities, and provides near-real time information on larval abundance and distribution for individuals that have reached this size class. There is no established way to measure and document take of larval smelt below this size. Protection of this age class is afforded through the RPA, when setting OMR restrictions, but there is no reliable means to assess performance until later in the season when >20mm larvae are present. This should be kept in mind in light of salvage numbers, pre-emptive OMR prescriptions based on salvage predictions, and the take statement for the earlier part of the spring season (i.e., April).

Historically, as with adults, larval and juvenile delta smelt salvage has varied widely, as a function of overall abundance, distribution and Delta hydrology (Figures C-3 and C-4). This variability makes prediction of salvage of larvae and juvenile delta smelt difficult. In order for a survey to have significant predictive value, it must precede the period of entrainment with as few confounding variables (intervening factors) between the estimate and the event as possible. Larval and juvenile take cannot be scaled to either the 20-mm Survey Index or the TNS Index because both surveys overlap the period during which the salvage occurs. Further, as migration, spawning distribution and success, adult delta smelt entrainment and mortality (due to quantifiable and unquantified variables) occur between the FMWT (the parental generation) and salvage of their progeny (the following April through July); it is difficult to infer actual larval abundance reliably through the next spring. This dilutes the statistical reliability of the calculation of a larval/juvenile salvage index, corresponding to the CSI for adult delta smelt. However, review of the salvage data relative to actual OMR values within a given year does reveal that a relationship of fall parental abundance to salvage of progeny exists—enough so such that predictability does increase through scaling to current water year FMWT.

The Service has therefore largely followed the methodology for estimating incidental take of larval delta smelt similar to that utilized for adults. Specifically, an average of the last four years (2005-2008) cumulative larval/juvenile salvage by month (April through July) was calculated. This can be summarizes as a Juvenile Salvage Index (JSI), calculated as:

Monthly Juvenile Salvage Index = cumulative seasonal salvage ≥ 20 mm by month end divided by current WY FMWT Index

The mean values from 2005-2008 were used as an initial estimate of take under the RPA. The reason for selecting this span of years is that the apparent abundance of delta smelt since 2005 as indexed by the 20-mm Survey and the TNS is the lowest on record (Table

C-4). It was necessary to separate out this abundance variable, but also to account for other poorly understood factors relating salvage to OMR, distribution, and the extant conditions. In other words, the most recent conditions are our best available reflection of predicted salvage under the RPA. On a monthly basis (cumulative salvage across the spring), this estimate represents a concern level where entrainment has reached high enough numbers to indicate the need for more protective OMR restrictions. The average JSI for the last four spring seasons by month (April through July), equals: 0.29, 13.03, 33.02, and 37.47, respectively.

Concern Level = Monthly JSI 2005-2008 mean * Current WY FMWT

It was determined that the last four years average monthly cumulative salvage was sufficient as an estimate of the concern level for larval/juvenile smelt, as opposed to the incidental take under the RPA. It is acknowledged that salvage across years will be variable, as distribution, spawning success, prior entrainment of adults, enhanced survival of <20mm larval delta smelt under the RPA, and extant natural conditions determine. As mentioned above, this constrains predictability of take using this methodology, and is less reliable overall as the method used for adults. Also, it is believed that individuals of the larval/juvenile lifestage are less demographically significant than adults. Given these considerations, the incidental take estimate for ≥ 20 mm larval/juvenile delta smelt under the RPA will be above the four year average by 50 percent.

Larval/Juvenile Incidental Take = 1.5 * Concern Level

Lookup tables relating (current WY) FMWT to concern level and incidental take for cumulative salvage by month appears in Table C-5 through C-8, below.

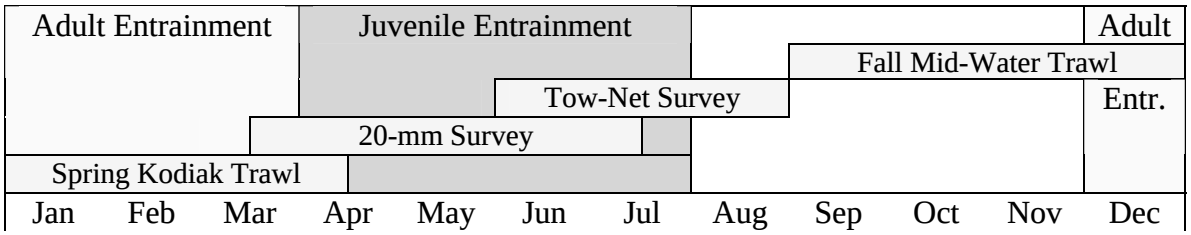


Figure C-2. Fishery surveys conducted by the California Department of Fish and Game that routinely collect delta smelt, and may be used to infer relative abundance.

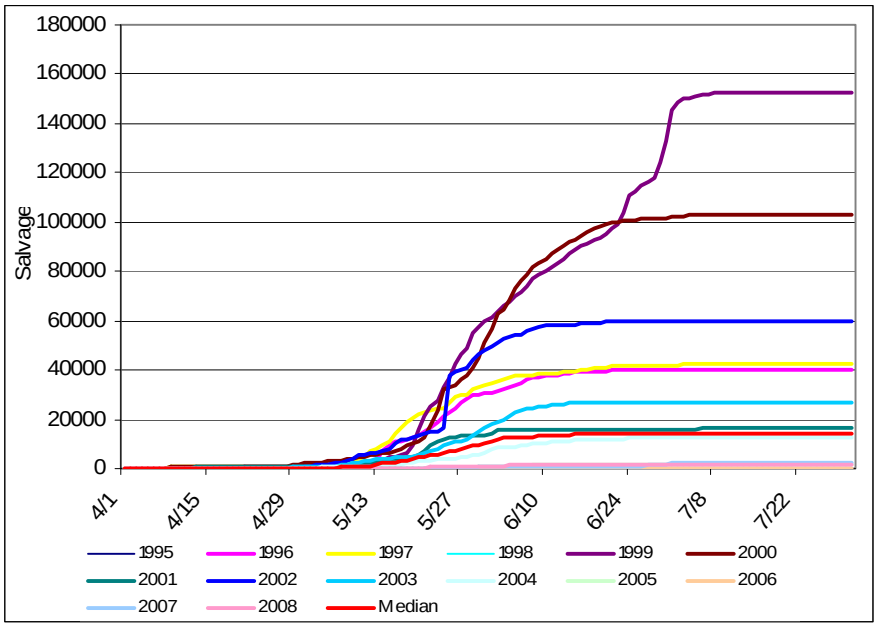


Figure C-3. Cumulative salvage of larval and juvenile delta smelt, 1995 through 2008.

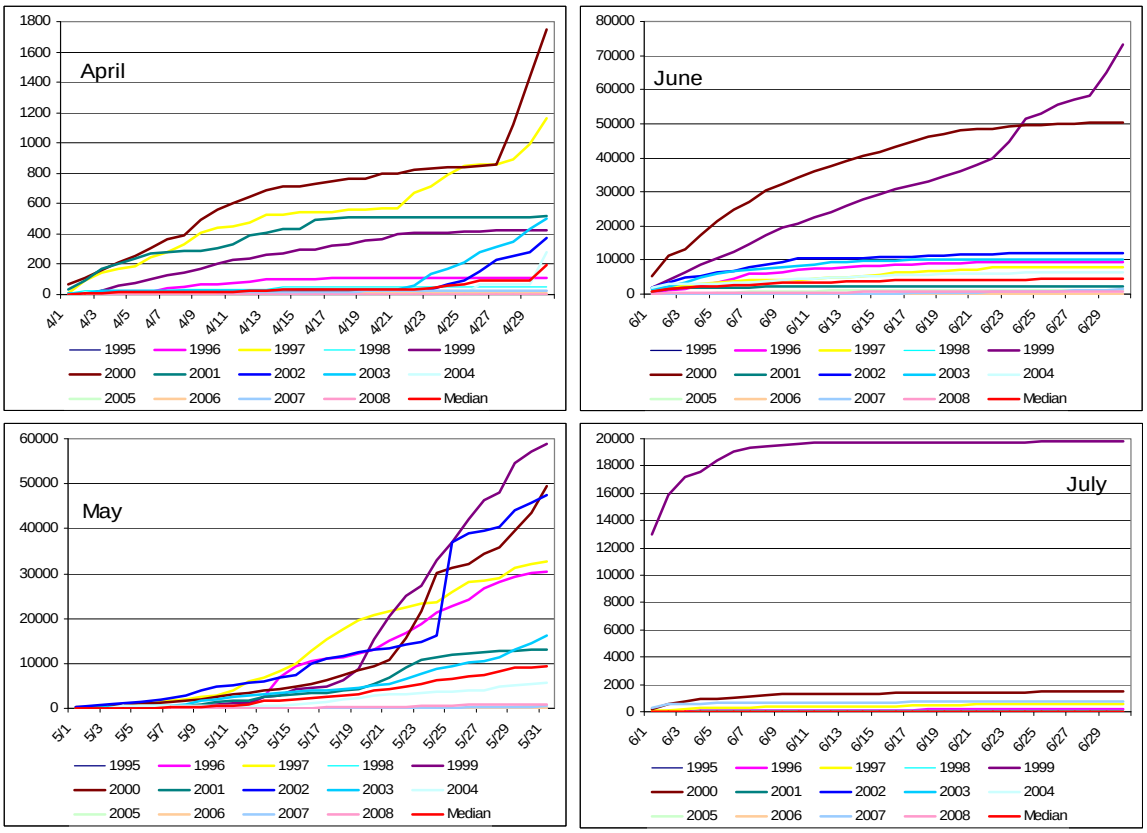


Figure C-4. Cumulative salvage of larval and juvenile delta smelt, 1995-2008, by month.

Table C-4. Larval/juvenile ≥ 20 mm delta smelt abundance and salvage statistics.

Water Year	Prior Year FMWT Index	20-mm Index	STNS	Salvage	Juvenile Salvage Index
1995	102	4.4	3.2	24	0.2
1996	899	33.9	11.1	40099	44.6
1997	127	19.3	4.0	42091	331.4
1998	303	7.7	3.3	242	0.8
1999	420	39.7	11.9	152526	363.2
2000	864	23.8	8.0	101783	117.8
2001	756	11.3	3.5	15984	21.1
2002	603	8	4.7	59652	98.9
2003	139	13.1	1.6	26220	188.6
2004	210	8.2	2.9	12441	59.2
2005	74	15.4	0.3	1734	23.4
2006	27	9.9	0.4	12	0.4
2007	41	1	0.4	2669	65.1
2008	28	2.9	0.6	1705	60.9
min	27	1	0.3	12	0.2
max	899	39.7	11.9	14213	363
mean	328	15.0	4.3	32656	98
25th	81	6.05	0.5	152526	22
median	175	10.6	3.25	1712	60
75th	557	17.3	4.3	41593	363
ITS	**April**	**May**	**June**	**July**	**Total**
Concern Level	0.29*FMWT	13.03*FMWT	33.02*FMWT	37.47*FMWT	37.47*FMWT
Incidental Take	0.44*FMWT	19.6*FMWT	49.5*FMWT	56.2*FMWT	56.2*FMWT

Table C-5: April Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	1	1	102	30	45	502	147	221
4	1	2	104	30	46	504	148	222
6	2	3	106	31	47	506	148	223
8	2	4	108	32	47	510	150	224
10	3	4	110	32	48	520	152	229
12	4	5	120	35	53	530	155	233
14	4	6	130	38	57	540	158	237
16	5	7	140	41	62	550	161	242
18	5	8	150	44	66	560	164	246
20	6	9	160	47	70	570	167	251
22	6	10	170	50	75	580	170	255
24	7	11	180	53	79	590	173	259
26	8	11	190	56	84	600	176	264
28	8	12	200	59	88	620	182	273
30	9	13	220	64	97	640	188	281
34	10	15	240	70	106	660	193	290
38	11	17	260	76	114	680	199	299
42	12	18	280	82	123	700	205	308
48	14	21	300	88	132	720	211	317
54	16	24	320	94	141	740	217	325
60	18	26	340	100	150	760	223	334
66	19	29	360	106	158	780	229	343
72	21	32	380	111	167	800	235	352
78	23	34	400	117	176	840	246	369
84	25	37	420	123	185	880	258	387
90	26	40	460	135	202	920	270	405
96	28	42	480	141	211	960	281	422
100	29	44	500	147	220	1000	293	440

Table C-6: May Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	26	39	102	1329	1994	502	6543	9815
4	52	78	104	1356	2033	504	6569	9854
6	78	117	106	1382	2072	506	6595	9893
8	104	156	108	1408	2112	510	6647	9971
10	130	196	110	1434	2151	520	6778	10167
12	156	235	120	1564	2346	530	6908	10362
14	182	274	130	1694	2542	540	7038	10558
16	209	313	140	1825	2737	550	7169	10753
18	235	352	150	1955	2933	560	7299	10949
20	261	391	160	2085	3128	570	7429	11144
22	287	430	170	2216	3324	580	7560	11340
24	313	469	180	2346	3519	590	7690	11535
26	339	508	190	2476	3715	600	7821	11731
28	365	547	200	2607	3910	620	8081	12122
30	391	587	220	2868	4301	640	8342	12513
34	443	665	240	3128	4692	660	8603	12904
38	495	743	260	3389	5083	680	8863	13295
42	547	821	280	3650	5474	700	9124	13686
48	626	938	300	3910	5865	720	9385	14077
54	704	1056	320	4171	6256	740	9645	14468
60	782	1173	340	4432	6647	760	9906	14859
66	860	1290	360	4692	7038	780	10167	15250
72	938	1408	380	4953	7429	800	10427	15641
78	1017	1525	400	5214	7821	840	10949	16423
84	1095	1642	420	5474	8212	880	11470	17205
90	1173	1760	460	5996	8994	920	11991	17987
96	1251	1877	480	6256	9385	960	12513	18769
100	1303	1955	500	6517	9776	1000	13034	19551

Table C-7: June Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	66	99	102	3369	5053	502	16578	24868
4	132	198	104	3435	5152	504	16644	24967
6	198	297	106	3501	5251	506	16711	25066
8	264	396	108	3567	5350	510	16843	25264
10	330	495	110	3633	5449	520	17173	25759
12	396	594	120	3963	5944	530	17503	26255
14	462	694	130	4293	6440	540	17833	26750
16	528	793	140	4623	6935	550	18164	27245
18	594	892	150	4954	7431	560	18494	27741
20	660	991	160	5284	7926	570	18824	28236
22	727	1090	170	5614	8421	580	19154	28732
24	793	1189	180	5944	8917	590	19485	29227
26	859	1288	190	6275	9412	600	19815	29722
28	925	1387	200	6605	9907	620	20475	30713
30	991	1486	220	7265	10898	640	21136	31704
34	1123	1684	240	7926	11889	660	21796	32695
38	1255	1882	260	8586	12880	680	22457	33685
42	1387	2081	280	9247	13870	700	23117	34676
48	1585	2378	300	9907	14861	720	23778	35667
54	1783	2675	320	10568	15852	740	24438	36657
60	1981	2972	340	11228	16843	760	25099	37648
66	2180	3269	360	11889	17833	780	25759	38639
72	2378	3567	380	12549	18824	800	26420	39630
78	2576	3864	400	13210	19815	840	27741	41611
84	2774	4161	420	13870	20806	880	29062	43593
90	2972	4458	460	15191	22787	920	30383	45574
96	3170	4756	480	15852	23778	960	31704	47556
100	3302	4954	500	16512	24769	1000	33025	49537

Table C-8: July Cumulative ≥ 20 mm Juvenile Incidental Take by FMWT Index Lookup Table

FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take	FMWT Index	Concern Level	Incidental Take
2	75	112	102	3822	5732	502	18808	28213
4	150	225	104	3897	5845	504	18883	28325
6	225	337	106	3971	5957	506	18958	28437
8	300	450	108	4046	6070	510	19108	28662
10	375	562	110	4121	6182	520	19483	29224
12	450	674	120	4496	6744	530	19857	29786
14	525	787	130	4871	7306	540	20232	30348
16	599	899	140	5245	7868	550	20607	30910
18	674	1012	150	5620	8430	560	20981	31472
20	749	1124	160	5995	8992	570	21356	32034
22	824	1236	170	6369	9554	580	21731	32596
24	899	1349	180	6744	10116	590	22105	33158
26	974	1461	190	7119	10678	600	22480	33720
28	1049	1574	200	7493	11240	620	23229	34844
30	1124	1686	220	8243	12364	640	23979	35968
34	1274	1911	240	8992	13488	660	24728	37092
38	1424	2136	260	9741	14612	680	25477	38216
42	1574	2360	280	10491	15736	700	26227	39340
48	1798	2698	300	11240	16860	720	26976	40464
54	2023	3035	320	11989	17984	740	27725	41588
60	2248	3372	340	12739	19108	760	28475	42712
66	2473	3709	360	13488	20232	780	29224	43836
72	2698	4046	380	14237	21356	800	29973	44960
78	2922	4384	400	14987	22480	840	31472	47208
84	3147	4721	420	15736	23604	880	32971	49456
90	3372	5058	460	17235	25852	920	34469	51704
96	3597	5395	480	17984	26976	960	35968	53952
100	3747	5620	500	18733	28100	1000	37467	56200