


California State Water Project

Watershed Sanitary Survey

2011 Update



Prepared for The State Water Project Contractors Authority
and the California Department of Water Resources

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June 2012

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ACKNOWLEDGMENTS

The State Water Project Watershed Sanitary Survey 2011 Update was prepared under the direction of the State Water Project Contractors Authority and the Department of Water Resources. The Sanitary Survey Subcommittee assisted with development of the scope of work for the 2011 Update, provided data and information to the consultant team, and reviewed various drafts of the report. The consultant team appreciates the assistance of the subcommittee members.

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Cover photos courtesy of Scott Archibald, Richard Battson, and DWR.

ACRONYMS AND ABBREVIATIONS

AB	Assembly Bill
ACL	administrative civil liability
ACWA	Association of California Water Agencies
ACWD	Alameda County Water District
ADI	acceptable daily intake
acre feet/year	acre-feet per year
ANPR	Advanced Notice of Proposed Rulemaking
Arvin-Edison	Arvin-Edison Water Storage District
AVEK	Antelope Valley East Kern Water Agency
AwwaRF	American Water Works Association Research Foundation
BAER	Burn Area Emergency Rehabilitation
Banks	H.O. Banks Delta Pumping Plant
Basin Plan	Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
BDCP	Bay Delta Conservation Program
BMP	Best Management Practice
Boating and Waterways	California Department of Boating and Waterways
BOD	biochemical oxygen demand
BSPP	Barker Slough Pumping Plant
$CaCO_3$	calcium carbonate
CALFED	California Bay-Delta Program
Caltrans	California Department of Transportation
CDEC	California Data Exchange Center
CCL	Contaminant Candidate List
CCWA	Central Coast Water Authority
CCWD	Contra Costa Water District
CDPH	California Department of Public Health
CEC	constituents of emerging concern
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CIWQS	California integrated
CLAWA	Crestline Lake Arrowhead Water Agency
CLWA	Castaic Lake Water Agency
Coastal Commission	California Coastal Commission
Conservancy	Sacramento-San Joaquin Delta Conservancy
CSD	Crestline Sanitation District
CSO	combined sewer overflow
CSS	combined sanitary sewer
CTR	California Toxics Rule
CUWA	California Urban Water Agencies
CVC	Cross Valley Canal

CVP	Central Valley Project
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWA	Clean Water Act
CWTP	combined wastewater treatment plant
DBCP	1,2-dibromo-3-chloropropane
DBP	disinfection byproduct
D/DBP	disinfectants/disinfection byproducts
DEET	N,N-Diethyl-meta-toluamide
Delta	Sacramento-San Joaquin Delta
Devil Canyon	Devil Canyon Afterbay
DHCCP	Delta Habitat Conservation and Conveyance Program
DLR	detection limit for purposes of reporting
DMC	Delta-Mendota Canal
DO	dissolved oxygen
DOC	dissolved organic carbon
DOM	dissolved organic matter
DPC	Delta Protection Commission
DSM2	Delta Simulation Model 2
DV Check 7	Del Valle Check 7
DWEL	drinking water equivalent level
DWR	California Department of Water Resources
EBRPD	East Bay Regional Parks District
EC	electrical conductivity
E. coli	*Escherichia coli*
EDC	endocrine disrupting chemical
EEDC	estrogenic endocrine disrupting chemical
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ERP	Ecosystem Restoration Program
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
HAA	haloacetic acids
HAAFP	haolacetic acid formation potential
HAA5	five haloacetic acids
HORB	head of Old River barrier
IDSE	Initial Distribution System Evaluation
IEP	Interagency Ecological Program
IESWTR	Interim Enhanced Surface Water Treatment Rule
ILRP	Irrigated Lands Regulatory Program
ISB	Independent Science Board
KWB	Kern Water Bank

LACDPR	Los Angeles County Department of Parks and Recreation
LID	low impact development
LRAA	locational running annual average
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
KCWA	Kern County Water Agency
Kern	Kern Water Bank Authority
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MEP	Maximum Extent Practicable
mgd	million gallons per day
M&I	Municipal and Industrial
MIB	2- methylisoborneol
MIEX®	Magnetic Ion Exchange Resin
MOU	Memorandum of Understanding
MRDL	Maximum Residual Disinfectant Level
MRL	minimum reporting level
MRP	monitoring and reporting program
MS4	municipal separate storm sewer system
MSD	marine sanitation device
MTBE	methyl tertiary-butyl ether
MWDSC	Metropolitan Water District of Southern California
MWQI	Municipal Water Quality Investigations
N	nitrogen
Napa County	Napa County Flood Control and Water Conservation District
NBA	North Bay Aqueduct
NBR	North Bay Regional
NDEA	N-nitrosodiethylamine
NDMA	N-nitrosodimethylamine
NDN	nitrification/denitrification
NDPA	N-nitrosodi-n-propylamine
NMFS	National Marine Fisheries Society
NNE	nutrient numeric endpoint
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
NWIS	National Water Information System
NWRI	National Water Research Institute
OCAP	Operations Criteria and Plan
OEHHA	California Office of Environmental Health Hazard Assessment
OMR	Old and Middle rivers
O&M	DWR's Division of Operations and Maintenance
P	phosphorus
Pacheco	Pacheco Pumping Plant

Parks and Recreation	California Department of Parks and Recreation
Palmdale	Palmdale Water District
PCB	polychlorinated biphenyl
PCP	personal care product
PCE	tetrachloroethylene
PFC	perfluorocarbons
PG&E	Pacific Gas & Electric Company
PhACs	pharmaceuticals and pharmaceutically active chemicals
PHG	Public Health Goal
POC	particulate organic carbon
PPCPs	pharmaceuticals and personal care products
PPWTP	Polonio Pass Water Treatment Plant
RAA	running annual average
Reclamation	U.S. Bureau of Reclamation
Regional Water Board	California Regional Water Quality Control Board
RO	reverse osmosis
ROA	restoration opportunity areas
RPA	Reasonable and Prudent Alternative
SB	Senate Bill
SBA	South Bay Aqueduct
SCVWD	Santa Clara Valley Water District
SCWA	Solano County Water Agency
SDWA	Safe Drinking Water Act
Semitropic	Semitropic Water Storage District
SID	Solano Irrigation District
SRA	State Recreation Area
SRCSD	Sacramento Regional County Sanitation District
SRT	solids retention time
SRWTP	Sacramento Regional Wastewater Treatment Plant
SSMP	Sewer System Management Plans
SSO	sanitary sewer overflow
State Water Board	California State Water Resources Control Board
SUVA	specific ultraviolet light absorbance
SWC	State Water Contractors
SWP	State Water Project
SWPCA	State Water Project Contractors Authority
SWTR	Surface Water Treatment Rule
TCDD	dioxins
TCE	trichloroethylene
TCR	Total Coliform Rule
TDS	total dissolved solids
Terminal Tank	Santa Clara Terminal Reservoir
THM	trihalomethane

THMFP	Trihalomethane Formation Potential
TID	Turlock Irrigation District
TKN	total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
T&O	taste and odor
TOC	total organic carbon
TSS	total suspended solids
TTHM	total trihalomethanes
UC Berkeley	University of California, Berkeley
UC Davis	University of California, Davis
UCMR	Unregulated Contaminant Monitoring Rule
ULPRO	ultra-low pressure reverse osmosis
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UV	ultraviolet light
VAMP	Vernalis Adaptive Management Plan
VOC	volatile organic compounds
Vtg	vitellogenin
WARMF	Watershed Analysis and Risk Management Framework
Westlands	Westlands Water District
WET	whole effluent toxicity
Wheeler Ridge	Wheeler Ridge-Maricopa Water Storage District
WPPP	Watershed Protection Program Plan
WTP	water treatment plant
WTP2	Water Treatment Plant No. 2
WWCF	wastewater control facility
WWTP	wastewater treatment plant
Zone 7 Water Agency	Zone 7 Water Agency of the Alameda County Water Conservation and Flood Control District

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

The State Water Project (SWP) provides drinking water to approximately two-thirds of California's population and is the nation's largest state-built water development project. The SWP extends from the mountains of Plumas County in the Feather River watershed to Lake Perris in Riverside County. **Figure ES-1** shows the major features of the SWP. Four previous SWP watershed sanitary surveys were completed in 1990, 1996, 2001, and 2006, so the contaminant sources and water quality issues have been well documented. The California State Water Project Watershed Sanitary Survey, 2011 Update (2011 Update) focuses on evaluating the sources of the water quality problems that the SWP Contractors face and recommending actions that they can take to protect source water quality.

SYSTEM ENVIRONMENT

The System Environment chapter contains a discussion of drinking water regulations and source water protection regulations. This chapter also contains a discussion of the potential water quality implications of the biological opinion issued by the U. S. Fish and Wildlife Service (USFWS) to protect delta smelt and the biological opinion issued by the National Marine Fisheries Service (NMFS) to protect Chinook salmon, several other anadromous fish, and killer whales. The various programs aimed at restoring the Sacramento-San Joaquin Delta (Delta) ecosystem while enhancing water supply reliability are also discussed. Key findings and recommendations from the System Environment chapter are presented in the following paragraphs of this section.

DRINKING WATER REGULATIONS

The U.S. Environmental Protection Agency (USEPA) finalized a number of key drinking water regulations in the last five years, including the Stage 2 Disinfectants and Disinfection Byproducts Rule and the Long Term 2 Enhanced Surface Water Treatment Rule. Key federal regulations that are being developed are:

- The Unregulated Contaminant Monitoring Rule 3 – This rule is scheduled to be finalized in 2012.
- The USEPA Health Effects Assessments – Health effects assessments are being completed for acrylamide, trichloroethylene, and tetrachloroethylene.
- USEPA Drinking Water Strategy – In February 2011, USEPA announced that it will move forward with development of regulatory standards for a group of 16 carcinogenic volatile organic compounds. The USEPA also announced that the second group of contaminants to be addressed will be nitrosamine disinfection byproducts.

- Perchlorate – In February 2011, USEPA announced that it will develop a regulation for perchlorate under the Safe Drinking Water Act. A proposed rule is expected in early 2013 with a final rule by mid-2014.

Figure ES-1. The State Water Project

In the last five years, the California Department of Public Health (CDPH) reduced the arsenic MCL from 50 to 10 µg/L and the Office of Environmental Health Hazard Assessment (OEHHA) published a chromium (VI) Public Health Goal (PHG). Key California regulations that are being developed are:

- Perchlorate – OEHHA proposed a revised PHG of 1 µg/L in January 2011. OEHHA published the results of an external peer review in November 2011 and is currently developing a revised draft PHG for public review. OEHHA currently does not have a schedule for issuing the final PHG.

- Chromium (VI) – OEHHA released the final PHG of 0.02 µg/L in July 2011. CDPH will establish a Maximum Contaminant Level (MCL) in the next several years.

- Total Trihalomethanes (TTHM) – OEHHA issued a draft PHG of 0.8 µg/L for TTHM in September 2010. OEHHA is in the process of establishing the final PHG but does not yet have a schedule for completing the process.

SOURCE WATER PROTECTION REGULATIONS

Source water protection is a key component of the multi-barrier approach to protecting drinking water quality. California has adopted many regulations to protect source water quality and there are several source water protection regulations that are under development. Key regulations that are being developed are:

- Industrial Stormwater General Permit – The State Water Resources Control Board (State Water Board) has proposed changes to the Industrial Stormwater General Permit. The State Water Board staff is responding to comments submitted in April 2011.

- Irrigated Lands Regulatory Program – The Central Valley Regional Water Quality Control Board (Central Valley Regional Water Board) is developing a long-term regulatory program to replace the interim program.

- Proposed Statewide Nutrient Policy – The State Water Board is developing a new regulatory program for nutrients in inland surface waters.

- Total Maximum Daily Loads (TMDLs) – The Central Valley Regional Water Board is currently developing mercury and DO TMDLs and a Central Valley TMDL for diazinon and chlorpyrifos The board is planning to work on a Central Valley TMDL for pyrethroid pesticides in the near future.

- Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) – This is a multi-year effort to address salt, boron, and nitrate in the Central Valley.

- Central Valley Drinking Water Policy – This is a multi-year effort to develop a policy to protect source water quality for key drinking water constituents. The Drinking Water Policy is currently under development and will be considered by the Central Valley Regional Water Board in July 2013.

BIOLOGICAL OPINIONS

USFWS is required to issue biological opinions on projects that have the potential to impact federally listed threatened and endangered species. Similarly, NMFS is required to issue biological opinions on projects that have the potential to impact federally listed marine and anadromous fish species. Biological opinions have been issued for delta smelt by the USFWS and for winter-run and spring-run Chinook salmon, steelhead, green sturgeon, and killer whales by NMFS. The biological opinions were challenged by the State Water Contractors and other water organizations and were revised and challenged again. Both USFWS and NMFS are currently revising the biological opinions.

POLICY SETTING

In the last five years, there have been numerous activities and programs aimed at restoring the Bay-Delta ecosystem and improving water supply reliability. The key ongoing activities that address water quality or could impact water quality in the Delta are:

- The Delta Stewardship Council's Delta Plan – The Delta Plan is scheduled for adoption in the fall of 2012.

- The Delta Conservancy's Strategic Plan – The Strategic Plan is scheduled for completion by early 2013.

- The Bay Delta Conservation Plan (BDCP) – A public review draft BDCP is expected to be completed by September 2012. Following a public review period, a final BDCP will be prepared. The impacts of the plan on environmental and drinking water quality will be evaluated in the Environmental Impact Report/Environmental Impact Statement (EIR/EIS) which is on the same schedule as the BDCP.

- USEPA Advanced Notice of Proposed Rulemaking (ANPR) – USEPA Region 9 issued an ANPR on February 10, 2011. This ANPR initiates an assessment of the effectiveness of current programs designed to protect ecosystem water quality and aquatic species habitat in the Bay Delta Estuary. USEPA expects to release a synthesis report in the spring of 2012 and then determine if new regulations are needed.

- San Joaquin River Restoration Program – The effort to restore the San Joaquin River involves restoring flows to about 60 miles of dry river bed and significant improvements to channels, levees, and fish passages. There have not been any studies done on the impact of the increased flows on water quality in the San Joaquin River and at the Delta pumping plants.

- Delta Wetlands Project – The Delta Wetlands Project involves creating storage reservoirs on Webb Tract and Bacon Island and creating wetlands and wildlife habitat on Bouldin Island and Holland Tract in the central Delta. The Final EIR on the project was certified in September 2011. Delta Wetlands Properties is currently pursuing a water right permit with the State Water Board.

WATER QUALITY IN THE WATERSHEDS AND THE STATE WATER PROJECT

Ten chapters of the report address water quality constituents having the capacity to cause drinking water standards to be violated or to reduce the quality of drinking water supplies conveyed through the SWP. Although there are potentially numerous constituents in drinking water sources, the key water quality challenges facing the SWP Contractors that treat water from the SWP are balancing the formation of disinfection by-products, due to high concentrations of organic carbon and bromide in the source water, with removing and inactivating pathogens such as *Giardia* and *Cryptosporidium*; high nutrient concentrations that lead to algal blooms, taste and odor problems, and operational problems; and high levels of total dissolved solids that create challenges with blending, groundwater recharge, and wastewater recycling. The water quality chapters are organized as follows:

- Chapter 3 – Water Quality Background and Summary
- Chapter 4 – Organic Carbon
- Chapter 5 – Salinity
- Chapter 6 – Bromide
- Chapter 7 – Nutrients
- Chapter 8 – Taste and Odor Incidents and Algal Toxins
- Chapter 9 – Turbidity
- Chapter 10 – Pathogens
- Chapter 11 – Organic Chemicals and Trace Elements
- Chapter 12 – Constituents of Emerging Concern

The Department of Water Resources (DWR) Municipal Water Quality Investigations (MWQI) Program and the Division of Operations and Maintenance (O&M) conduct a comprehensive water quality monitoring program of the Delta and the SWP facilities. The long period of record at many locations allows the data to be analyzed for spatial trends, long-term trends, and seasonal trends. Most of the data has been entered into DWR's Water Data Library. This online database is a valuable tool that provides easy access to the data shortly after it has been collected.

WATER QUALITY TRENDS

All available water quality data at a number of locations in the watersheds, the Delta, and along the SWP facilities were evaluated for the 2011 Update. The organic carbon, salinity, bromide, nutrient, and turbidity data were evaluated to determine if there are long-term trends, spatial trends, and differences between wet and dry years.

Long-term Trends

There are no apparent long-term trends in the water quality data at any of the locations evaluated for this project. In 2009, MWQI staff conducted a long-term trend analysis for the Sacramento River at Hood (Hood), the San Joaquin River at Vernalis (Vernalis), and the Harvey O. Banks Delta Pumping Plant (Banks). Trends were analyzed for the entire period of record through 2008 at each location and for the 1999 to 2008 period. Different results were obtained for the different periods of time. For example, the analysis showed a declining trend in dissolved organic carbon (DOC) at all three locations during the longer period and an increasing trend at Hood and Vernalis and no trend at Banks during the more recent period. This analysis showed that trends are very much a function of the hydrology of the system during the starting and ending points of the analysis. Another total organic carbon (TOC) trend analysis conducted at Banks between 1990 and 2003 by O&M staff reached the same conclusion. O&M staff conducted an assessment of long-term salinity trends at Banks using data from 1970 to 2002 and concluded that the salinity in SWP exports has neither increased nor decreased over that period. Visual inspection of time series graphs for a number of other constituents and locations also shows that water quality trends can be explained by evaluating the hydrologic conditions at the start and end of the trend analysis period.

Spatial Trends

The data were analyzed to determine if water quality changes as the water flows down the Governor Edmund G. Brown California Aqueduct (California Aqueduct) and is stored in reservoirs. Factors that could potentially affect water quality include:

- North Bay Aqueduct (NBA) – The NBA is an enclosed pipeline so water quality should not change between Barker Slough and the water treatment plant intakes.

- Banks to South Bay Aqueduct (SBA) Terminal Tank – Water from Lake Del Valle enters the SBA below Del Valle Check 7 (DV Check 7). This primarily affects SBA water quality in the fall months when releases are made to the SBA.

- Banks to O'Neill Forebay – There are no inputs to the California Aqueduct in this reach.

- O'Neill Forebay and San Luis Reservoir – Water from the Delta-Mendota Canal (DMC) mixes with water from the California Aqueduct in O'Neill Forebay. Storage in San Luis Reservoir and the timing of filling and releases from the reservoir can potentially impact water quality.

- San Luis Canal Reach of the California Aqueduct – Local streams that run eastward from the Coastal Range Mountains bisect the aqueduct at various points. During storms, water from some of these streams enters the aqueduct.

- Coastal Branch of the California Aqueduct – The Coastal Branch is 115 miles long; the first 15 miles are open aqueduct and the remainder is a pipeline. No drainage enters the open canal section.

- California Aqueduct between Check 21 and Check 41 – This reach of the aqueduct is used to convey both surface water and groundwater non-Project inflows acquired through transfers and exchanges among local agencies. The quality of the non-Project inflows can affect the quality of the water in the aqueduct. This topic is addressed in Chapter 14.

- West Branch of the California Aqueduct – Pyramid and Castaic lakes provide almost 500,000 acre-feet of storage, which greatly reduces the fluctuations in water quality seen in the aqueduct. Natural inflow from the watersheds of the reservoirs can affect water quality during substantial storm events.

- East Branch of the California Aqueduct – Silverwood Lake has a capacity of only 74,970 acre-feet and does not moderate water quality the way the West Branch reservoirs do. Natural inflow from its watershed can affect water quality at times.

This analysis included an evaluation of all of the data at each monitoring location. The data collected during comparable periods of time at all locations were analyzed to draw conclusions about spatial trends. The data were statistically analyzed using the non-parametric Mann-Whitney test which determines if the data sets being compared are statistically different. The median concentrations are representative of the entire data set. The key findings are:

- Median TOC concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct when data collected during comparable periods of time are aggregated and analyzed. The median TOC concentrations along the aqueduct range from 3.0 to 3.2 mg/L. San Luis Reservoir and Castaic Lake have less variability in TOC concentrations than the aqueduct due to the dampening effect of reservoir mixing. The dampening effect is not seen in Silverwood Lake on the East Branch due to its limited hydraulic residence time. When examined on a finer time scale, differences in TOC occur between O'Neill Forebay Outlet and Check 21. The peak concentrations of TOC at Check 21 occurred approximately one month later than at O'Neill Forebay Outlet in 2008, 2009, and 2010 and the peak concentrations were about 1 mg/L lower at Check 21. The shift in the timing of the peak is likely due to low flows in the aqueduct during this period. The lower TOC concentrations at Check 21 compared to O'Neill Forebay Outlet during the 2007 to 2010 period are inexplicable. A small amount of groundwater (12,581 acre-feet) was pumped into this reach of the aqueduct by Westlands Water District (Westlands) in the summer of 2008, but that does not explain the differences during the spring of 2008, 2009, and 2010. Changes in TOC concentrations are apparent in the aqueduct during periods when non-Project inflows are introduced between Checks 21 and 41.

- Although there are no apparent differences in median TOC concentrations when all available data are aggregated, the quality of organic carbon changes. Water in San Luis Reservoir has a greater propensity to form disinfection byproducts during the spring and summer months. This is the period when most water is released from the reservoir and flows south in the California Aqueduct.

- Changes to electrical conductivity (EC) in the California Aqueduct and SWP reservoirs are complex. There is a statistically significant increase of 63 µS/cm between Banks and O'Neill Forebay Outlet due to storage in San Luis Reservoir and to mixing with water from the more saline DMC in O'Neill Forebay. However, there is not a significant change in EC between O'Neill Forebay Outlet and Check 21. There is a statistically significant decrease in EC between Check 21 and Check 41 of 16 µS/cm. This is likely due to non-Project inflows of lower EC water in recent years. The median EC at Castaic Lake Outlet (Castaic Outlet) is 57 µS/cm higher than at Check 41 but there is no significant change between Check 41 and Devil Canyon Afterbay (Devil Canyon).

- There is a statistically significant increase in bromide concentrations between Banks (median of 0.18 mg/L) and O'Neill Forebay Outlet (median of 0.22 mg/L) due to the release of water from San Luis Reservoir that has high bromide concentrations (median of 0.25 mg/L). Bromide does not change significantly between O'Neill Forebay Outlet and Check 21. The median bromide concentration of 0.21 mg/L at Check 41 is not statistically different from the median bromide concentration of 0.22 mg/L at Check 21. However, during periods when non-Project inflows are introduced to the aqueduct, the bromide concentrations at Check 41 are lower than the concentrations at Check 21. The median bromide concentration at Castaic Outlet of 0.21 mg/L is the same as at Check 41. The median bromide concentration at Devil Canyon of 0.19 mg/L is not statistically different from the median bromide concentration of 0.21 mg/L at Check 41.

- Turbidity levels are quite variable as water moves down the aqueduct but the impact of settling in reservoirs is quite apparent in that median turbidity levels in the reservoirs are 1 to 2 NTU.

- Nutrient concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct. Median total nitrogen (total N) concentrations are about 1.0 mg/L and median total phosphorus (total P) concentrations are about 0.1 mg/L throughout the system. Nutrient concentrations are substantially lower in Castaic Lake and Lake Perris.

Wet Year and Dry Year Trends

The data were analyzed to determine if there are water quality differences between wet years and dry years. Wet years are defined as those that are classified by DWR as wet and above normal. Dry years are defined as those that are classified as below normal, dry, and critical.

- There are no statistically significant differences between median TOC concentrations in dry years and wet years at many of the locations along the aqueduct.

- EC levels during dry years are statistically significantly higher than EC levels during wet years at all locations except Barker Slough and Castaic Outlet. There were no statistically significant differences between year types at these two locations. The higher levels during dry years are due to less dilution of agricultural drainage, urban runoff, and wastewater discharged to the rivers and Delta during low flow periods and to seawater intrusion in the Delta during periods of low Delta outflow.

- Bromide concentrations during dry years are statistically significantly higher than bromide concentrations during wet years at all locations except Barker Slough. There were no significant differences between year types at this location. The median bromide concentrations during dry years are 50 to 100 percent higher than the median concentrations during wet years. This is due primarily to seawater intrusion in the Delta during periods of low Delta outflow.

- Turbidity levels are statistically significantly lower during dry years than wet years at most locations that were included in this analysis. At several locations, including San Luis Reservoir and Castaic Lake, there was no significant difference between dry and wet years.

- Comparison of nutrient concentrations in dry years and wet years does not produce a consistent pattern throughout the system. At many locations, there are no differences between dry and wet years. At Hood and Vernalis, total P concentrations are not statistically different between dry years and wet years but total N concentrations are statistically significantly higher during dry years. This may be due to the greater influence of the Sacramento Regional Wastewater Treatment Plant at Hood and to agricultural drainage at Vernalis. At Pacheco Pumping Plant in San Luis Reservoir (Pacheco), both total N and total P are statistically significantly lower in dry years. This is likely due to algal uptake and settling in the reservoir since samples are collected in the epilimnion of the reservoir more frequently during dry years when water levels are lower. The pattern at Castaic Lake is different with both total N and total P being statistically significantly higher in dry years. Check 41 and Devil Canyon show the same pattern of higher total N concentrations in dry years and lower total P concentrations in dry years. This may be related to non-Project inflows that occur more frequently in dry years.

- Median total P concentrations in dry years and wet years are the same at most locations. Dry year total P medians are statistically significantly lower than wet year medians at Pacheco, Check 41, Castaic, and Devil Canyon. Dry year total N medians are statistically significantly higher than wet year medians at about half of the locations and the same at the other locations.

TASTE AND ODOR INCIDENTS AND ALGAL TOXINS

Monitoring of 2-methylisoborneol (MIB) and geosmin, the two compounds most often responsible for taste and odor (T&O) problems, was initiated at a number of locations in the SWP between 2001 and 2005. Monitoring was initiated for the NBA in 2009. The samples are quickly analyzed and email reports are sent to the SWP Contractors alerting them to potential T&O problems.

- The NBA Contractors experienced a severe T&O episode in February 2009 that resulted in numerous customer complaints when geosmin concentrations quickly increased to over 300 ng/L. The likely T&O producer was *Aphanizomenon gracile*. The NBA had to be shut down for over six weeks, resulting in a significant loss of Delta water for the NBA Contractors. The Solano County Water Agency works with DWR to monitor T&O compounds and to periodically treat Campbell Lake, a small impoundment upstream of the Barker Slough Pumping Plant. The combination of monitoring to detect problems and treatments has been effective since the NBA users have had no further customer complaints.

- Problematic levels of MIB and geosmin occur in the Delta, along the California Aqueduct, and in southern California reservoirs. MIB and geosmin peaks in excess of 10 ng/L have occurred at Clifton Court Forebay (Clifton Court) every summer since monitoring was initiated in 2003. Geosmin concentrations have exceeded 10 ng/L every year and MIB concentrations have exceeded 10 ng/L in five of the ten years that monitoring has been conducted at Banks.

- The peak levels of MIB and geosmin at Banks are quickly transported to the SBA. MIB and geosmin concentrations at DV Check 7 exceeded 10 ng/L every summer between 2003 and 2007 and again in 2010. MIB from the Delta is transported down the California Aqueduct to O'Neill Forebay Outlet but the concentrations decrease with distance down the aqueduct. Castaic Lake has extremely high levels of geosmin every summer (up to 830 ng/L) and occasional MIB peaks greater than 10 ng/L. Silverwood Lake has peaks of both compounds that exceed 10 ng/L but do not reach the high levels found in Castaic Lake.

DWR has monitored *Microcystis aeruginosa* blooms for their ecological consequences for a number of years. Monitoring for microcystins in drinking water supplies started in 2006.

- *M. aeruginosa* blooms have occurred routinely in the summer months in the Delta since 1999. While blooms are found throughout the Delta, the highest cell densities are routinely found in the south Delta in the Old River and the Middle River.

- DWR conducted cyanotoxin monitoring at various locations in the SWP for four years. In 2007, microcystin-LR was detected at all locations that were monitored, except Barker Slough. It was below the reportable limit of 1 µg/L.

PATHOGENS

All SWP Contractors have completed their Long Term 2 Enhanced Surface Water Treatment Rule monitoring and all have been classified in Bin 1, meaning *Cryptosporidium* levels are low (running annual average of less than 0.075 oocysts/L), so no additional action related to *Cryptosporidium* is required at this time. An evaluation of the total coliform, fecal coliform, and *E. coli* data indicates that 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus removal and inactivation is the appropriate level of treatment for all SWP Contractors.

There were limitations in conducting statistical analysis of the coliform data at some sampling locations due to peak values being reported as greater than an upper limit, rather than being enumerated. This is due to insufficient dilution of the samples.

CONSTITUENTS OF EMERGING CONCERN

Studies on the occurrence, fate, and transport; health effects; analytical methods; and removal of constituents of emerging concern (CECs) in drinking water and wastewater have been completed in the last five years. The five most frequently detected chemicals in surface water in a recent nationwide study were cholesterol, metolachlor, cotinine, β-sitosterol, and 1,7-dimethylxanthine. Another study showed the five most frequently detected chemicals in surface waters were sulfamethoxazole, carbamazepine, atrazine, phenytoin, and meprobamate.

In 2010, the National Water Research Institute (NWRI), Metropolitan Water District of Southern California (MWDSC), and Orange County Water District completed a source, fate, and transport study of endocrine disrupting compounds (EDCs) and pharmaceuticals and personal care products (PPCPs) that included eleven sampling sites associated with the SWP. Of the 49 PPCPs and organic wastewater contaminants analyzed, 21 analytes were detected at or above the minimum reporting level, whereas the other 28 were not detected at any of the locations with the existing minimum reporting levels. The six most frequently detected CECs were carbamazepine, diuron, sulfamethoxazole, caffeine, primidone, and tris (2-chloroethyl) phosphate (TCEP). The highest concentrations of many of the most frequently detected compounds were found in samples from the San Joaquin River at Holt Road, just downstream of the Stockton Regional Wastewater Control Facility. Certain PPCPs (carbamazepine, primidone, gemfibrozil, and sulfamethoxazole) are highly attenuated as water moves downstream along the California Aqueduct. However, detectable levels of some PPCPs were found at terminal reservoirs in southern California. The NWRI study concluded there is no evidence of human health risk from low levels of the commonly detected EDCs and PPCPs in drinking water or drinking water supplies; however, more toxicological studies are needed.

MWDSC and DWR completed a two-year study in April 2010 of the sources and occurrence of N-nitrosodimethylamine (NDMA), other nitrosamines, and their precursors in the Delta. The only instantaneous nitrosamine detected was NDMA, once at the Mossdale sampling location at 4.2 ng/L, and once at the Vernalis sampling location at 2.5 ng/L. NDMA formation potential concentrations were generally two to four times higher downstream of the Stockton and Sacramento wastewater treatment plants. The second phase of this study began in early 2011.

The State Water Board convened a CEC Science Advisory Panel to develop guidance for the establishment of monitoring programs to assess potential CEC threats from water recycling activities. The final report identified four indicator compounds based on their toxicological relevance for groundwater recharge projects: NDMA, 17 beta-estradiol, caffeine, and triclosan. Four additional CECs were identified as viable performance indicators (N,N-Diethyl-meta-toluamide (DEET), gemfibrozil, iopromide, and sucralose).

KEY WATER QUALITY VULNERABILITIES OF THE SACRAMENTO-SAN JOAQUIN DELTA

Chapter 13 contains a discussion of the key water quality vulnerabilities of the Delta. The key vulnerabilities and contaminant sources throughout the watershed have been documented in previous updates. The CDPH, SWP Contractors, and DWR identified the Delta vulnerabilities to be addressed in the 2011 Update. The key findings for each of the specific topics discussed in Chapter 13 are presented in the following paragraphs of this section.

WASTEWATER TREATMENT PLANTS

There are 12 wastewater treatment plants that discharge directly to the Delta and many others that discharge to tributaries of the Delta. Wastewater treatment plants in the SWP watershed currently discharge 346 million gallons per day (mgd) based on average dry weather flow. The current average dry weather flow design capacity of wastewater treatment plants in the Central Valley is 560 mgd, indicating that wastewater agencies are planning for growth and increased volumes of wastewater.

The DWR Modeling Section has recently developed a fingerprint that includes wastewater volumes from three of the largest treatment plants that discharge to the Delta. These three wastewater plants represent 82 percent of the wastewater volume discharged to the Delta so the fingerprints are a good estimation of the overall percent of wastewater at Delta pumping plants. The wastewater contribution at Clifton Court and the C.W. "Bill" Jones Pumping Plant (Jones) ranges from zero to about three percent.

Regulatory management of wastewater dischargers has increased significantly through implementation of more stringent National Pollutant Discharge Elimination System (NPDES) permit effluent limits and special study requirements. Most wastewater dischargers have upgraded to tertiary treatment and several other facilities are required to upgrade within the next ten years.

There are limited data on the concentrations of key drinking water constituents in wastewater effluent because NPDES monitoring programs do not include many of the key drinking water constituents.

There were few spill events at the wastewater treatment plants, but numerous collection system failures resulted in discharges to receiving waters. Most were related to sewer line blockage or failure.

URBAN RUNOFF

Urban runoff from Sacramento, Stockton, eastern Contra Costa County, and a number of small communities is discharged to the Delta. A number of other communities discharge urban runoff to Delta tributaries.

Urban runoff in the Central Valley and Delta is regulated by the Central Valley Regional Water Board through Municipal Separate Storm Sewer System NPDES permits. These permits require large (greater than 250,000 population) and medium (100,000 to 250,000 population) municipalities (designated as Phase I permittees) to develop stormwater management plans and conduct monitoring of stormwater discharges and receiving waters. Small communities (less than 100,000 population) are Phase II permittees. They are required to develop management plans but historically did not have to conduct monitoring. Monitoring may be required when the new Phase II permit is issued later this year. The permits require the communities to implement best management practices (BMPs) and conduct special studies. The permits for the larger Phase I permittees require low impact development for new development, which involves designing and maintaining facilities to manage urban runoff onsite to maintain runoff volumes at pre-development levels.

Urban runoff levels of bacteria, nutrients, and organic carbon are much higher than the receiving waters. Generally, these constituents are seen at higher levels during wet weather events.

The stormwater permits do not contain effluent limitations for specific water quality constituents but do require municipalities to reduce urban runoff pollution to the maximum extent practicable through implementation of BMPs. There are limited data on the effectiveness of BMPs in reducing drinking water constituents of concern, such as organic carbon, nutrients, and pathogens. Based on the limited studies that have been conducted, retention and detention ponds seem most effective at reducing drinking water constituents of concern. Data from a new retention basin in Sacramento support this finding.

DELTA LAND CONVERSIONS

There are a number of habitat restoration projects that are underway or being planned in the Delta. Conversion of agricultural lands to tidal marsh is called for by the Ecosystem Restoration Program's Conservation Strategy for Sacramento-San Joaquin Delta Ecological Management Zone and by the BDCP. Other ecosystem restoration projects may occur through the Sacramento-San Joaquin Delta Conservancy, and the Delta Wetlands project (discussed in Chapter 2). DWR currently has three habitat restoration projects underway.

There is consensus that DOC production will increase as a result of converting agricultural land into tidal wetlands. Recent studies have also shown that an expansion of wetlands has the potential for raising Delta dissolved organic matter concentrations in spring and early summer. Therefore, restoration may shift the overall DOC peak towards spring and summer, later than the current winter peak. This temporal shift in DOC loading may affect the overall loading to drinking water since more water is typically pumped during the spring and summer than during the winter.

Conversion of the Delta's traditional cultivated fields to managed wetlands or rice crops shows potential for stopping and reversing the effects of subsidence as well as potentially serving as a means of carbon sequestration. DWR and the U.S. Geological Survey (USGS) are jointly working on two major types of pilot projects on Delta islands to assess their effectiveness for subsidence reversal and carbon sequestration. These projects are part of the DWR Interim Delta Actions to continue incremental improvements in the Delta until a long-term solution is in place. These projects include managed wetlands and rice cultivation, both of which include flooding Delta islands.

Studies conducted to date indicate that there is great opportunity for subsidence reversal and carbon capture through wetlands and rice cultivation in the Delta. It is still uncertain if widespread implementation of these projects will occur in the Delta. The studies have included evaluation of the potential impacts to receiving waters, in particular the contribution of DOC. Wetlands and rice cultivation have been shown to both contribute elevated amounts of DOC in the drainages, particularly in the seepage flows through shallow groundwater. The highest loading of DOC from both wetlands and rice occurred during the summer months. Additional studies on the managed wetlands and rice crops will further examine the amount, extent, and potential factors influencing the transport of DOC to receiving waters.

RECREATIONAL USE OF THE DELTA

The Delta Protection Commission has estimated that there are over 12 million visitors to the Delta annually, including about 500,000 boaters. This includes shoreline recreation (picnicking, hiking, camping, and hunting), boating, fishing, water-skiing, and other recreational activities along the Delta's 57,000 acres of navigable waterways. All of these activities have the potential to impact water quality in the Delta. Recreational use of the Delta is projected to increase in the future as population increases. Recreational users may not be aware of the significance of the Delta as a drinking water source.

The California Department of Parks and Recreation prepared a Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh in May 2011. This plan will be included with the Delta Plan that will be finalized in the fall of 2012. The plan calls for creation of wildlife habitat and passive recreational facilities at Barker Slough, creation of an upland recreation area in the South Delta, possibly in the Old River area, development of floating campsites/day use areas and expanded waterfowl hunting programs (boat-in and longer-term), and potentially increasing the recreational use of SWP facilities.

There are a number of boater education programs that provide information on boating safety, proper disposal of hazardous wastes, and proper sewage handling facilities, but their effectiveness is uncertain. Although there are numerous pumpout and restroom facilities located throughout the Delta, it is uncertain how frequently they are used.

Vessel abandonment is a significant problem in the Delta which has direct impacts on source water quality. There are three key state programs that address the issue of abandoned vessels; however, two of these programs require local agencies to provide ten percent matching funds. Many local agencies cannot provide the matching funds due to budget constraints.

KEY WATER QUALITY VULNERABILITIES OF THE STATE WATER PROJECT

Chapter 14 contains a discussion of the key water quality vulnerabilities of the SWP. The CDPH, SWP Contractors, and DWR identified the SWP vulnerabilities to be addressed in the 2011 Update. The key findings for each of the specific topics discussed in Chapter 14 are presented in this section.

NORTH BAY AQUEDUCT

The NBA Contractors have taken a multifaceted approach to improving the quality of water delivered to their customers. They have conducted studies in conjunction with MWQI on the water quality of the Barker Slough watershed, installed real-time monitoring equipment to provide advanced warning of water quality problems, installed fencing and alternative water supplies to exclude cattle from Barker Slough, evaluated the impacts of Campbell Lake operations on Barker Slough water quality, and conducted hydrodynamic modeling of the watershed to better understand the sources of water at the Barker Slough watershed under varying hydrologic conditions. In addition, the NBA Contractors evaluated treatment options and water exchanges as methods of improving water quality. The NBA Contractors are currently pursuing an alternate intake on the Sacramento River. The alternate intake would be operated in conjunction with the existing intake at Barker Slough to provide operational flexibility and improve water quality.

CLIFTON COURT FOREBAY

While developing the scope of work for the 2006 Update, the SBA Contractors expressed concerns that sedimentation of Clifton Court Forebay has resulted in a shallow water body that encourages algal and vascular plant growth that result in T&O problems. The 2006 Update contains an analysis of real-time water quality monitoring data that could potentially be used to detect algal blooms. The scope of work for the 2011 Update did not include any further analysis of the impact of sedimentation in Clifton Court on algal growth and T&O problems or of the ability of monitoring equipment to detect algal blooms. The status of action items from the 2006 Update was reviewed.

SOUTH BAY AQUEDUCT

The SBA Contractors have engaged in a number of activities to improve water supply reliability and water quality of the SBA. The SBA Improvement and Enlargement Program is nearing completion. The Watershed Protection Program Plan was completed in 2008 and the SBA Contractors conducted several workshops and developed public education materials on protecting drinking water quality in Bethany Reservoir and Lake Del Valle. The SBA Contractors previously expressed concern over a proposed trail along the SBA but that project does not currently have funding and appears to not be of any immediate concern.

Cattle grazing in the Bethany Reservoir watershed remains a major concern. DWR leases a 115-acre parcel on the southwestern shoreline that drains to Bethany Reservoir and two parcels on the northeast side, most of which do not drain to the reservoir. The leases require that good grazing practices be used so the property is not over-grazed and allow DWR to inspect the property to determine if the land is being over-grazed. The leases also require that fences be constructed and maintained to prevent cattle from entering the property of adjacent property owners but there are no requirements for fencing to keep cattle out of Bethany Reservoir. Stormwater monitoring conducted by the SBA Contractors showed that the Bethany Headlands drainage on the western side of Bethany Reservoir contained high levels of *Giardia* and *Cryptosporidium* relative to other sources of water to the SBA. Cattle are the likely source of these pathogens because cattle grazing is the primary use of this land and cattle are known carriers of these pathogens.

DELTA-MENDOTA CANAL/CALIFORNIA AQUEDUCT INTERTIE

Construction was completed on an intertie between the California Aqueduct and the DMC in April 2012. The intertie will allow water pumped at the Jones Pumping Plant to be conveyed in the California Aqueduct to O'Neill Forebay. The Central Valley Project (CVP) water reaching O'Neill Forebay may be pumped into San Luis Reservoir, released to the San Luis Canal and the Dos Amigos Pumping Plant, or released through the O'Neill Pump-Generating Plant to the lower DMC and Mendota Pool.

The Final EIS did not evaluate the impacts on the quality of water in the California Aqueduct, O'Neill Forebay, or San Luis Reservoir as a result of the intertie. The intertie will be operated mainly between September and March when EC levels and bromide concentrations are highest in the South Delta. However, the volume of water pumped from the DMC into the California Aqueduct (maximum of 467 cubic feet per second) is relatively small compared to the flows in the California Aqueduct so there may not be a change in EC or bromide levels.

SAN LUIS RESERVOIR

The U.S. Bureau of Reclamation (Reclamation), Santa Clara Valley Water District, and San Luis and Delta-Mendota Water Authority have conducted a number of studies and held public scoping meetings for the San Luis Low Point Improvement Project. The three agencies are currently preparing a Feasibility Report and companion EIS/EIR which will present three alternatives: 1) Lower San Felipe Intake Comprehensive Plan, 2) Pacheco Reservoir Comprehensive Plan, and 3) the Combination Comprehensive Plan. It is anticipated that the Feasibility Report and Draft EIS/EIR will be completed in July 2012 and the Final EIS/EIR will be completed in January 2013.

The State Water Project Contractors Authority, MWQI, and O&M are currently addressing cattle grazing in the Cottonwood Bay area of the San Luis Reservoir. Efforts are underway to coordinate among the cattle owner, the land owner (Reclamation) and the San Luis Field Division to prevent the cattle from accessing the water.

COASTAL BRANCH

Over the last five years, the Central Coast Water Authority (CCWA) has implemented a number of measures to address T&O issues that may be attributed to sediment accumulation in the Coastal Branch forebays and canals. These measures include: 1) cooperating with and encouraging O&M to implement a routine sediment removal program from the open channel canal, forebays, and storage tanks, 2) implementing an MIB Monitoring Program/Response Plan at the Polonio Pass Water Treatment Plant (PPWTP) influent; Devil's Den, Bluestone, and Polonio Pass pumping plant forebays; and selected canal locations, 3) conducting an experiment using the SolarBee to evaluate its effectiveness in minimizing sediment accumulation and prevention of blue-green algae blooms in a pumping plant forebay, and 4) investigating alternative theories that may explain the high MIB levels.

Sediment accumulation in the pumping plant forebays is still occurring and remains a concern despite an active sediment removal program developed by O&M. In addition, elevated ammonia levels are routinely observed in the PPWTP influent just prior to the O&M annual winter shutdown, as water levels in the canal are reduced.

Through the examination of sediment removal records and water quality sampling along the Coastal Branch over the past five years, CCWA staff has not been able to confirm that greater amounts of sediment will lead to greater T&O incidents. However, there have been no major sustained T&O incidents from 2006 to 2010 at either Banks or the PPWTP.

NON-PROJECT INFLOWS

Non-Project inflows introduced into the California Aqueduct totaled 1,490,164 acre-feet from 2006 to 2010, which is a substantial increase from the 360,000 acre-feet previously introduced from 2001 to 2005. During certain months in the 2006 to 2010 period, inflows contributed a substantial percentage of the aqueduct flow. In February 2009, inflows contributed 87 percent of the flow at Check 29, and 92 percent of the flow at Check 41. This is an increase over the 2001 to 2005 period, as the highest monthly percentage at Check 41 was 40 percent.

Groundwater quality data from the resultant blend of participating wells for each project proponent, prior to entering the California Aqueduct, were examined. Based on the available data, Semitropic Water Storage District (Semitropic) inflows had the highest arsenic concentrations, with the majority of samples exceeding the drinking water MCL of 10 µg/L. Although conditions were placed on Semitropic's 2007 project proposal to "attempt to achieve an arsenic concentration of 10 µg/L or less in its pump-in water through full use of its resources," this was not achieved. Although one of the conditions placed on Semitropic is stated as above, it should be noted that the Semitropic inflow was actually evaluated as one component of the Kern program that also included Kern Water Bank, Kern County Water Agency, and the Wheeler Ridge-Maricopa Water Storage District. As such, the weighted average of all of the Kern program inflows was evaluated by the Facilitation Group and could not exceed any drinking water MCLs. Therefore, Semitropic was allowed to pump-in water with arsenic concentrations greater than 10 µg/L as long as the weighted average of other Kern inflows and Semitropic inflows was less than 10 µg/L. Semitropic also had the highest medians for bromide, total dissolved solids (TDS), and sulfate. The highest median for nitrate (10.3 mg/L) was measured at the Arvin-Edison Water Storage District inflow location, but it was well below the MCL of 45 mg/L.

Modeling results from the Kern County Water Agency Aqueduct Blending Model were also compared to grab samples taken along the aqueduct. The model predicts arsenic, DOC, and TDS concentrations fairly close to measured water quality at Check 29 and Check 41. The model tends to predict lower bromide concentrations and higher chromium and nitrate concentrations compared to measured water quality at both Check 29 and Check 41. This is because modeled results use long-term averages as the background concentrations at O'Neill Forebay Outlet, yet the actual water quality at this location may vary higher or lower from the long-term average. Overall, the Aqueduct Blending Model has become a useful tool in managing the non-Project inflows and assessing downstream water quality impacts.

The introduction of non-Project inflows has generally decreased the concentrations of bromide and DOC and increased the concentrations of nitrate and arsenic in the California Aqueduct downstream of the inflows. Specifically, there were eleven months when arsenic levels were measured at or above 5 µg/L at Check 29 and Check 41. Notably, arsenic levels were 6 µg/L for two consecutive months in February and March 2009 at Check 41. The percent of inflow volumes was high during this time period, averaging 83 percent in January 2009, 92 percent in February 2009, and 68 percent in March 2009. In addition, there were six non-consecutive months when the change in arsenic concentration from upstream to downstream of the Semitropic inflows was greater than 2 µg/L. This is notable as one of the conditions placed on Semitropic in 2007 was "Semitropic will operate its inflow program to achieve an increase in downstream arsenic concentrations of no more than 2 µg/L over background levels in the California Aqueduct." Further information is provided in Chapter 14. Only slight changes were observed for TDS and sulfate.

Semitropic constructed a demonstration facility to remove arsenic from groundwater. The demonstration facility was operated from November 2007 to November 2009 and treated a total of 61,665 acre-feet at a cost of $1.8 million.

Westlands was approved to convey their groundwater on a one-time basis from June to September 2008 by a Governor's Executive Order addressing the drought. During this period, Westlands pumped 12,581 acre-feet of groundwater into the San Luis Canal portion of the California Aqueduct. The Governor's Executive Order bypassed water quality testing requirements that were specified in the contract between DWR and Westlands, so Westlands was allowed to begin pumping groundwater prior to any evaluation. According to DWR, two wells were shut down based on high levels of TDS and sulfate found after the wells were placed into service. Therefore, some unacceptable water was introduced into the San Luis Canal portion of the California Aqueduct during this four-month period.

SUBSIDENCE ALONG THE AQUEDUCT

There has been renewed interest in subsidence in the San Joaquin Valley due to increased groundwater pumping, caused by a reduction of available imported surface water deliveries due to drought and fish-protection measures. In 2007, there was a 150 foot decline in groundwater elevation, which caused subsidence. Damage to the SWP due to subsidence has occurred at the turnout structures, check sites, canal lining, and bridges. The worst subsidence damage has occurred within the jurisdiction of the San Luis Field Division near Coalinga.

USGS is currently conducting a study on behalf of DWR to better understand the occurrence of land subsidence along the California Aqueduct. The study is focused on the Westlands area and will determine the location and extent of changes in land surface elevation along the California

Aqueduct. A similar study is being conducted for the CVP, and both projects are expected to be completed in September 2012. USGS hopes to define a groundwater level that will prevent/manage future subsidence.

PYRAMID LAKE

Pacific Pipeline Systems LLC (responsible party) has completed repairs and relocations of Line 63 which was damaged and resulted in a March 2005 oil spill. They have increased ground and aerial inspection of the pipeline after rain events, and conducted emergency training exercises. Pacific Pipeline Systems was also required to pay a $1.3 million civil penalty and is currently completing additional specific actions to relocate or improve resistance to movement for Line 63.

The Upper Piru Creek portion of the Pyramid Lake watershed was impacted by the Day Fire which began on September 4, 2006 and was contained on October 2, 2006. The majority of the burn area tributary to Pyramid Lake burned at a low intensity. Although sediment loading and runoff was predicted to increase post-fire, ash and debris flow did not occur due to moderate rains that winter. According to MWDSC staff, there were no changes to influent water quality at the Jensen Water Treatment Plant as a result of the fire.

CASTAIC LAKE

MWDSC has completed necessary best management practices to discourage gull roosting on the lake. Two pilot scale gull management exercises were conducted in 2007 with limited success. A brochure was developed by MWDSC and distributed at the Castaic Lake Recreation Area to discourage gull feeding by the general public. Monthly average *E. coli* levels at the Jensen Water Treatment Plant have declined since 2002.

On April 22, 2008, a 5,000 gallon sewage spill originated from the Warm Springs Rehabilitation Center in Castaic, California. The wastewater pump station experienced an electrical failure and wastewater spilled in front of the pump station. The Los Angeles County Health Department determined that the sewage did not enter Castaic Lake or any tributaries to the lake. *Cryptosporidium* and *Giardia* were not detected in samples collected by MWDSC and *E. coli* and fecal coliforms were either not detected or were present at low levels in samples analyzed by Castaic Lake Water Agency.

HESPERIA MASTER DRAINAGE PLAN

Urban runoff from the City of Hesperia is discharged to the California Aqueduct through 45 drop inlets. This issue was identified in the 1990 SWP Watershed Sanitary Survey and has still not been resolved. The San Bernardino County Flood Control District has developed a plan to address local drainage concerns but does not plan to address the discharge of urban runoff into the aqueduct unless DWR agrees to help fund the project.

Continuous turbidity and EC data measured at Check 66, which is downstream of the City of Hesperia, were analyzed to determine if levels increased during periods of heavy rainfall. Based on the current amount of development in the watershed, flow through the drop inlets is likely impacting downstream water quality only under extreme storm conditions.

SILVERWOOD LAKE

There were no incidents such as wastewater spills, sewer line breakages, fires, or high runoff events in the Silverwood Lake watershed during the study period. There were no high turbidity events in the source water, with the exception of one day in January 2006, and three days in January 2010 when turbidities reached 20 NTU. Other than these two time periods, turbidity was less than 10 NTU.

LAKE PERRIS

Since the 2006 Update was completed, use of Lake Perris by MWDSC has been reduced due to regulatory restrictions on pumping from the Delta and limitations to protect recreation and endangered species due to the Lake Perris drawdown. Lake Perris has been lowered by 25 feet below the normal maximum level to mitigate seismic risk while a permanent solution is being determined by DWR. Although MWDSC was proceeding with the procurement of a hypolimnetic oxygenation system and the design of voluntary swimming alternatives (i.e. swim lagoons, water play areas and other water features), MWDSC does not currently view Lake Perris as a reliable enough source of SWP supply to justify the cost to construct these facilities. As such, MWDSC has discontinued their efforts to implement these projects.

In January 2010, DWR prepared a Draft EIR for the Perris Dam Remediation Program to address seismic hazard. The Draft EIR evaluated the following dam remediation alternatives: 1) increased dam capacity alternative (above 1,588 feet), 2) normal dam capacity (at 1,588 feet), 3) reduced dam capacity alternative (at 1,563 feet), 4) recreation alternative (at 1,542 feet), 5) dam decommissioning alternative (draining the lake), and 6) no project alternative. The Final EIR was completed in September 2011. In the Final EIR, DWR concluded that the recreation alternative is the environmentally superior dam remediation alternative.

MWDSC, Coachella Valley Water District, and Desert Water Agency submitted comment letters on the Draft EIR, and commented that there was an inadequate range of alternatives considered, and that a more detailed analysis of possible alternatives should have been conducted. These agencies are in the process of reviewing the Final EIR.

Recreational attendance at the Lake Perris State Recreation Area has declined since the drawdown of the lake in 2005. However, attendance increased by 40,000 visitors from 2010 to 2011. The maximum number of allowable boats on the lake has been reduced from 500 to 250 for safety reasons. There were eleven beach closures from 2005 to 2010 due to *E. coli* levels exceeding standards for recreational usage.

STATE WATER PROJECT FACILITY OPERATIONS VULNERABILIITIES

Chapter 15 contains a discussion of the key operational vulnerabilities of the SWP. The CDPH, SWP Contractors, and DWR identified the operational vulnerabilities to be addressed in the 2011 Update. The key findings for each of the specific topics discussed in Chapter 15 are presented in this section.

BIOLOGICAL OPINIONS

Both the USFWS and NMFS biological opinions require exports to be limited to reduce reverse flows in the Old and Middle rivers between December and June. The intent of this action is to prevent entrainment of delta smelt at the export pumps. The other action with the potential to impact water quality is the requirement to increase Delta outflow in wet and above normal years during the fall months to move the low salinity zone near Suisun Marsh, which is thought to improve delta smelt survival. While modeling studies have been conducted to examine the impacts of the biological opinions on water supply, there have not been any modeling studies to evaluate the impacts on drinking water quality. The impacts of the Wanger Interim Remedial Order on drinking water quality were modeled. Historical data were examined and the results of the modeling studies on the Wanger Interim Remedial Order were reviewed in an attempt to determine if any conclusions could be drawn on the likely impacts of the biological opinions. Delta hydrology is extremely variable, Delta operations are highly complex, and the operations rules to comply with the actions in the biological opinions will change the way the Delta has historically been operated. It is not possible to reach firm conclusions on the impacts of the biological opinions without conducting modeling studies; however, it appears that the greater influence of the San Joaquin River during the periods that Old River and Middle River reverse flows are regulated will result in higher levels of TOC, DOC, EC, and bromide at the south Delta pumping plants. Shifting exports to the July to September period may result in more water with lower TOC and possibly EC being exported. Bromide concentrations may be lower in July but would increase to high levels by September. Increased fall Delta outflow, in the range that would likely occur in September, does not appear to have any impact on drinking water quality at the pumping plants.

HEAD OF OLD RIVER BARRIER

The head of Old River barrier (HORB) is installed to keep migrating salmon in the San Joaquin River and to prevent them from entering the Old River and being drawn towards agricultural diversions and the south Delta pumping plants. Historically the HORB was a 200-foot long barrier constructed by placing rock in the main channel bed along with overflow weirs and gated culverts. The physical barrier effectively blocks most flow from the San Joaquin River into the Old River. As a result of the delta smelt biological opinion, participants in the Vernalis Adaptive Management Plan suggested testing a non-physical barrier as an alternative to the rock barrier, since the physical barrier may have adverse impacts on delta smelt. A non-physical barrier was installed in the Old River in the spring of 2009 as an experimental project to determine if migrating salmon and steelhead would avoid the barrier and stay in the San Joaquin River rather than entering the Old River.

Modeling studies using the Delta Simulation Model 2 (DSM2) have shown that the physical barrier prevents the San Joaquin River from entering the Old River when it is in place. There have not been any studies on the impacts on water quality of replacing the physical barrier with a non-physical barrier. It would seem logical that the San Joaquin River would have a greater influence on water quality at the south Delta pumping plants with a non-physical barrier. Water quality data were compared for two relatively dry periods: 2002 to 2004 when the physical barrier was in place and 2008 to 2010 when there was no physical barrier. The Delta hydrodynamics are too complex to draw any conclusions from the examination of these limited data.

IMPACTS OF DROUGHT ON WATER QUALITY

The water quality impacts of dry years at the Barker Slough and Banks Pumping Plants were evaluated. These two locations were selected because they reflect the quality of water pumped from the north and south Delta in different year types.

When examined on a monthly basis, there are few significant differences between wet and dry year monthly medians at Barker Slough for TOC, bromide, and nutrients. During dry years, EC levels are higher during the wet months of January through April and turbidity levels are lower during the December to April period.

When examined on a monthly basis, the substantial impact of dry years on EC and bromide is evident at Banks. During dry years, EC and bromide are statistically significantly higher in the summer months, when exports are highest, and in the winter months. Turbidity levels are statistically significantly lower during the summer months of dry years. TOC concentrations are higher during a few months of dry years and lower during other months, with no clear pattern. Nutrient concentrations are not significantly different between dry years and wet years.

FINDINGS AND RECOMMENDATIONS

Chapter 16 contains a discussion of the key findings from the System Environment, Water Quality, and Vulnerabilities chapters. The recommendations presented in this chapter are draft potential actions for consideration by the SWP Contractors, CDPH and the DWR MWQI Program and O&M Division. These agencies will work with the consulting team to rank the draft recommendations and determine if, and how, they will be implemented. An Action Plan will be developed by September 2012 that describes each action in more detail, identifies the responsible entity, and lays out the schedule for implementation.

CHAPTER 1 INTRODUCTION

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CHAPTER 1 INTRODUCTION

The State Water Project (SWP) provides drinking water to approximately two-thirds of California's population and is the nation's largest state-built water development project. The SWP extends from the mountains of Plumas County in the Feather River watershed to Lake Perris in Riverside County. It is linked with the Central Valley Project that extends from southern Oregon in the Sacramento River watershed to the Mendota Pool. The watershed of the SWP is vast; encompassing the 27,000-square-mile Sacramento River and 13,000-square-mile San Joaquin River watersheds and at times, the 13,000-square-mile Tulare Basin watershed. There are numerous activities in the watershed that can affect drinking water quality. In addition, the watersheds of Del Valle, San Luis, Pyramid, Castaic, Silverwood, and Perris reservoirs contribute potential contaminants to the SWP system. There are also a few locations along the Governor Edmund G. Brown California Aqueduct (California Aqueduct) where Coastal Range drainage enters the system during flood events. Groundwater and surface water from other sources are introduced to the California Aqueduct as a means of supplementing water supplies. The Barker Slough watershed influences water quality for the North Bay Aqueduct (NBA), possibly to a greater extent than any other local watershed within the SWP. With a watershed of this size and complexity, the SWP Watershed Sanitary Survey is, by necessity, more complex than sanitary surveys completed for smaller watersheds.

HISTORY OF THE SWP SANITARY SURVEY

The California SWP Watershed Sanitary Survey, 2011 Update (2011 Update) is the fifth sanitary survey of the SWP. The 1990 Sanitary Survey of the SWP was the first sanitary survey conducted in the state for the California Department of Health Services, the predecessor of the California Department of Public Health (CDPH), to comply with the Surface Water Treatment Rule requirement for a watershed sanitary survey (Brown and Caldwell, 1990). There was no guidance on how to conduct a sanitary survey so the SWP Contractors worked closely with CDPH, the California Department of Water Resources (DWR) and the consultant team to develop the scope. The 1990 Sanitary Survey focused on reviewing available water quality data and providing an inventory of contaminant sources in the Sacramento, San Joaquin, and Tulare watersheds and along the aqueducts, with minimal effort on the contaminant sources in the SWP reservoir watersheds. The SWP Sanitary Action Committee, formed to follow up on the recommendations contained in the 1990 Sanitary Survey, produced the SWP Sanitary Survey Action Plan (State Water Contractors, 1994). A number of the recommendations from the 1990 Sanitary Survey were addressed between 1990 and 1996.

The 1996 Update focused on the recommendations from the 1990 Sanitary Survey and major changes in the watersheds between 1990 and 1996 (DWR, 1996). In addition, the 1996 Update provided more details on contaminant sources in the watersheds of Del Valle, San Luis, Pyramid, Castaic, Silverwood, and Perris reservoirs; the NBA Barker Slough watershed; and the open canal section of the Coastal Branch.

The 2001 Update provided more details on contaminant sources in the watersheds of the SWP reservoirs and along the aqueducts (DWR, 2001). It also contained a detailed analysis of indicator organism and pathogen data from the SWP. A major objective of the 2001 Update was to provide the SWP Contractors with information needed to comply with the CDPH Drinking Water Source Assessment Program requirements.

Rather than simply updating all of the information from the previous three sanitary surveys, the 2006 Update provided an opportunity to concentrate on the key water quality issues that challenge the SWP Contractors (Archibald Consulting et al., 2007). CDPH requested that the 2006 Update address the Jones Tract levee failure and emergency response procedures, efforts to coordinate pathogen monitoring in response to the Long Term 2 Enhanced Surface Water Treatment Rule, and a review of significant changes to the watersheds and their impacts on water quality. The SWP Contractors developed the State Water Project Action Plan (State Water Project Contractors Authority, 2007), which identified priorities and courses of action for following up on the recommendations from the 2006 Update.

SCOPE AND OBJECTIVES OF 2011 UPDATE

The SWP Contractors, DWR, and CDPH formed a Sanitary Survey Subcommittee to develop the scope of work for the 2011 Update. CDPH requested that the 2011 Update include a discussion of the impacts of the biological opinions and drought on water quality, the impacts of non-Project inflows on water quality, subsidence along the aqueduct, a review of the security and emergency response measures in place for the SWP, and a discussion of the monitoring conducted to comply with the Long-Term 2 Enhanced Surface Water Treatment Rule. CDPH also requested that the findings of the 2011 Update be included or considered in the next update of the California Water Plan. DWR subsequently determined that the discussion of security and emergency response measures in place for the SWP would be prepared by DWR staff and transmitted under a separate cover to CDPH, rather than included in the 2011 Update. The Sanitary Survey Subcommittee determined that the issues addressed in the 2006 Update should be revisited to update the information from the 2006 report. The subcommittee also identified some new issues to be addressed in the 2011 Update, including habitat restoration and carbon sequestration projects in the Sacramento-San Joaquin Delta (Delta) and the intertie between the California Aqueduct and the Delta-Mendota Canal. Another key aspect of the 2011 Update is that all available water quality data collected on the Delta and SWP facilities were analyzed instead of only the last five to ten years of data.

The 2011 Update focuses on evaluating the sources of the water quality problems that the SWP Contractors face. Actions that the SWP Contractors, DWR, and CDPH can take to protect SWP source water quality are recommended. The objectives of the 2011 Update are to:

- Satisfy the CDPH requirements to update the sanitary survey every five years.
- Highlight and focus on the SWP Contractors' key source water quality issues.
- Conduct an analysis of all of the water quality data that has been gathered on the Delta and the SWP facilities to identify spatial and long-term trends.

- Develop an Action Plan to guide DWR's, CDPH's and the SWP Contractors' efforts to protect and improve water quality for the next five years.

REPORT ORGANIZATION

This report is organized in the following manner:

Chapter 1 – Introduction

Chapter 2 – System Environment

This chapter contains a discussion of changes in drinking water and source water protection regulations during the five years since the 2006 Update was prepared. A summary of the various programs aimed at restoring the Delta ecosystem and improving water supply reliability is also included.

Chapters 3 through 12 – Water Quality in the Watersheds and the State Water Project

These chapters address concerns over water quality constituents having the capacity to cause drinking water standards to be violated or to reduce the quality of drinking water supplies conveyed through the SWP. Although there are potentially numerous constituents in drinking water sources, the key water quality challenges facing the SWP Contractors that treat water from the SWP are balancing the formation of disinfection by-products, due to high concentrations of organic carbon and bromide in the source water, with removing and inactivating pathogens such as *Giardia* and *Cryptosporidium*; high nutrient concentrations that lead to algal blooms, taste and odor problems, and operational problems; and high levels of total dissolved solids that create challenges with blending, groundwater recharge, and wastewater recycling. The water quality chapters are organized as follows:

- Chapter 3 – Water Quality Background and Summary
- Chapter 4 – Organic Carbon
- Chapter 5 – Salinity
- Chapter 6 – Bromide
- Chapter 7 – Nutrients
- Chapter 8 – Taste and Odor Incidents and Algal Toxins
- Chapter 9 – Turbidity
- Chapter 10 – Pathogens
- Chapter 11 – Organic Chemicals and Trace Elements
- Chapter 12 – Constituents of Emerging Concern

Chapter 13 - Key Water Quality Vulnerabilities of the Sacramento – San Joaquin Delta

The key Delta contaminant sources that are addressed in this chapter are increased wastewater and urban runoff as a result of urbanization of the Central Valley, land use changes due to ecosystem restoration activities in the Delta, agricultural crop changes in the Delta, and recreational usage of the Delta.

Chapter 14 – Key Water Quality Vulnerabilities of the State Water Project

Previous sanitary surveys of the SWP have documented the potential contaminant sources in the watersheds. As a result, the SWP Contractors have initiated a number of programs to improve water quality. This chapter contains a discussion of recent activities affecting water quality and the efforts to improve water quality in the NBA, the South Bay Aqueduct, along the California Aqueduct and in the watersheds of the storage reservoirs.

Chapter 15 – State Water Project Facility Operations Vulnerabilities

The SWP Facility Operations Vulnerabilities chapter contains a discussion of how operational changes in the Delta and drought have affected water quality exported from the Delta to the SWP Contractors.

Chapter 16 – Findings and Recommendations

Key findings from the previous chapters and recommended actions are described in this chapter.

ACTION PLAN

Each chapter of the report lists potential actions that DWR, CDPH, and the SWP Contractors can take to improve water quality. The Sanitary Survey Subcommittee will consider these actions and develop an Action Plan that will be a separate companion document to the 2011 Update. The Action Plan will be a living document that will be updated as progress is made. The Action Plan will then be able to guide development of the scope of work for the next update of the sanitary survey.

REFERENCES

Archibald Consulting, Richard Woodard Water Quality Consultants, and Palencia Consulting Engineers. 2007. California State Water Project Watershed Sanitary Survey 2006 Update. Prepared for the State Water Project Contractors Authority.

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CHAPTER 2 SYSTEM ENVIRONMENT

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FIGURES

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CHAPTER 2 SYSTEM ENVIRONMENT

This chapter contains a discussion of changes in drinking water and source water protection regulations during the five years since the California State Water Project Watershed Sanitary Survey 2006 Update (2006 Update) was prepared. A discussion of the biological opinions and the numerous programs aimed at restoring the Sacramento-San Joaquin Delta (Delta) ecosystem and water supply reliability are also included.

REGULATORY SETTING

There have been a number of changes to drinking water and source water protection regulations since the 2006 Update was completed. **Table 2-1** lists the regulations that are discussed in this chapter.

Table 2-1. Regulations Discussed in this Chapter

DRINKING WATER REGULATIONS	
Federal Regulations	**California Regulations**
Stage 1 Disinfectants and Disinfection Byproducts Rule	Review of Maximum Contaminant Levels
Stage 2 Disinfectants and Disinfection Byproducts Rule	Perchlorate
Interim Enhanced Surface Water Treatment Rule	Chromium (VI)
Long Term 2 Enhanced Surface Water Treatment Rule	Total Trihalomethanes
Arsenic Rule	Notification and Response Levels
Unregulated Contaminant Program	
Revised Total Coliform Rule	
Six-Year Review	
New Drinking Water Strategy	
SOURCE WATER PROTECTION REGULATIONS	
State Plans and Policies	**Central Valley Plans and Policies**
San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan	Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
Antidegradation Policy	Total Maximum Daily Loads
Sources of Drinking Water Policy	Wastewater Discharges
Policy for Implementation of Toxic Standards for Inland Surface Waters, Enclosed Bays, and Estuaries	Urban Runoff
Recycled Water Policy	Agricultural Discharges
Aquatic Pesticides	Confined Animal Facilities
Proposed Policy for Nutrients	Central Valley Salinity Alternatives for Long-Term Sustainability
	Central Valley Drinking Water Policy

DRINKING WATER REGULATIONS

The U.S. Environmental Protection Agency (USEPA) is responsible for implementing the Safe Drinking Water Act (SDWA). Congress passed the SDWA in 1974 and significantly amended it in 1986 and 1996. The California Department of Public Health (CDPH) is responsible for implementing the federal regulations and for developing regulations specific to protection of drinking water supplies in California. The California Office of Environmental Health Hazard Assessment (OEHHA) is responsible for establishing Public Health Goals (PHGs) in California. A PHG is the level of a contaminant in drinking water that does not pose a significant risk to public health. CDPH is required to adopt Maximum Contaminant Levels (MCLs) that are at least as stringent as the federal MCLs established by USEPA and are as close to the PHGs as is economically and technically feasible. These are published in the California Code of Regulations, Title 22 – Social Security, Division 4 – Environmental Health (Title 22).

Several major rules have been implemented or promulgated and a number of MCLs, PHGs, and notification levels have been revised in the last five years. The highlights of the changes are discussed in this chapter. **Table 2-2** contains a list of contaminants for which revised or new MCLs and/or PHGs have been established since the 2006 Update was prepared.

Federal Regulations

CDPH has adopted and implemented a number of federal rules in the last five years that have significantly affected the State Water Project (SWP) Contractors who treat water from the Delta. Some were adopted directly from the federal regulations, while others were developed with expanded requirements.

Stage 1 Disinfectants and Disinfection Byproducts Rule

The Stage 1 Disinfectants and Disinfection Byproducts (D/DBP) Rule was promulgated by USEPA on December 16, 1998, along with the Interim Enhanced Surface Water Treatment Rule (IESWTR). CDPH incorporated the provisions of this rule into Title 22 in 2006 (Chapter 15.5), with limited variation from the federal statute. The Stage 1 D/DBP Rule applies to public water systems that are community water systems or non-transient non-community water systems. Large water systems were required to comply with the provisions of this rule by January 2002.

Table 2-2. New or Revised Maximum Contaminant Levels and Public Health Goals

Contaminant	CA MCL (mg/L)	Date CA MCL Established	PHG (mg/L)	Date PHG Established
Inorganics				
Arsenic	0.010	2008[b]	0.000004	2004[a]
Copper	1.0/1.3	1977/1995[c]	0.3	2008[b]
Lead	0.015	1995[d]	0.0002	2009[b]
Perchlorate	0.006	2007[a]	0.006	2004[a]
Selenium	0.05	1994	0.03	2010[a]
Volatile Organic Chemicals)				
1,2-Dichlorobenzene	0.6	1994	0.6	2009[b]
1,3-Dichloropropene	0.0005	1989	0.0002	2006[b]
Trichloroethylene	0.005	1989	0.0017	2009[b]
1,2,3-Trichloropropane	none	N/A	0.0000007	2009[b]
Styrene	0.1	1994	0.0005	2010[a]
Synthetic Organic Chemicals				
2,4-Dichlorophenoxyacetic acid (2,4-D)	0.07	1994	0.02	2009[b]
Bentazon	0.018	1989	0.2	2009[b]
Benzo (a) pyrene	0.0002	1994	0.000007	2010[b]
Chlordane	0.0001	1990	0.00003	2006[b]
Dalapon	0.2	1994	0.79	2009[b]
Dinoseb	0.007	1994	0.014	2010[b]
Endrin	0.002	1994	0.0018	2008[b]
Glyphosate	0.7	1990	0.9	2007[b]
Methoxychlor	0.03	2003	0.00009	2010[b]
Molinate	0.02	1989	0.001	2008[a]
Oxamyl	0.05	2003	0.026	2009[b]
Pentachlorophenol	0.001	1994	0.0003	2009[b]
Polychlorinated biphenyls	0.0005	1994	0.00009	2007[a]
2,3,7,8-TCDD (Dioxin)	$3x10^{-8}$	1994	$5x10^{-11}$	2010[a]
Disinfection Byproducts				
Bromate	0.010	2006[a]	0.0001	2009[a]
Chlorite	1.0	2006[a]	0.05	2009[a]

[a] Represents new MCL or PHG since 2006
[b] Represents revised MCL or PHG since 2006
[c] Represents secondary MCL and Regulatory Action Level
[d] Represents Regulatory Action Level

The Stage 1 D/DBP Rule requires water systems to comply with a combination of new MCLs, maximum residual disinfectant levels, and a treatment technique to improve control of disinfectants and disinfection byproducts. The total trihalomethanes (TTHM) MCL was reduced from 0.10 to 0.080 mg/L and a 0.060 mg/L MCL was established for the sum of five haloacetic acids (HAA5). In addition, MCLs were established for chlorite (1.0 mg/L) for plants using chlorine dioxide and bromate (0.010 mg/L) for plants using ozone. Compliance with the TTHM and HAA5 MCLs is based on the running annual average (RAA) of quarterly averages of all distribution system samples. (This is being replaced by the locational running annual average [LRAA] regulated in the Stage 2 D/DBP Rule and discussed below).

Under Step 1 of the Stage 1 D/DBP rule, systems using surface water and conventional filtration must remove specific amounts of total organic carbon (TOC) prior to adding disinfectants by implementing a treatment technique, either enhanced coagulation or enhanced softening. The percent removal required depends on the source water TOC and alkalinity. **Table 2-3** provides a summary of the removal requirements. TOC removal compliance is based on the RAA, calculated quarterly, of monthly removal ratios. The removal ratio is the ratio of the removal achieved divided by the removal required. The RAA of the removal ratios needs to equal or exceed 1.00.

Table 2-3. Stage 1 D/DBP Rule Step 1 Percent TOC Removal Requirements

TOC (mg/L)	Alkalinity (mg/L as $CaCO_3$)		
	0 – 60	> 60 – 120	> 120
> 2.0 – 4.0	35.0%	25.0%	15.0%
> 4.0 – 8.0	45.0%	35.0%	25.0%
> 8.0	50.0%	40.0%	30.0%

Systems that cannot achieve the Step 1 TOC removal requirements must apply to CDPH for approval of alternative minimum TOC (Step 2) removal requirements. The application must include bench- or pilot-scale testing to establish the minimum TOC removal required by the system. The alternate enhanced coagulation level is defined as coagulation at a coagulant dose and pH in bench- or pilot-scale testing such that an incremental addition of 10 mg/L of alum (or equivalent amount of ferric salt) results in a TOC removal of 0.3 mg/L or less. The percent removal of TOC at this point on the "TOC removal versus coagulant dose" curve is then defined as the minimum TOC removal required for the system. If the TOC removal is consistently less than 0.3 mg/L of TOC per 10 mg/L of incremental alum dose at all dosages of alum (or equivalent addition of iron coagulant), the water is deemed to contain TOC not amenable to enhanced coagulation. The system may then apply to CDPH for a waiver of enhanced coagulation requirements.

If any of the following conditions are met during a month, systems may assign a monthly value of 1.0 when determining compliance with the TOC removal requirements:

- Source water TOC level is less than 2.0 mg/L
- Treated water TOC level is less than 2.0 mg/L

- A system practicing softening removes at least 10 mg/L as $CaCO_3$ of magnesium hardness
- Source water specific ultraviolet absorbance (SUVA), prior to any treatment, is less than or equal to 2.0 L/mg-m
- Finished water SUVA is less than or equal to 2.0 L/mg-m
- A system practicing enhanced softening lowers alkalinity below 60 mg/L as $CaCO_3$

The USEPA has also provided alternative compliance criteria from the treatment technique requirements for systems practicing enhanced coagulation or enhanced softening. Water systems are not required to achieve the specified Step 1 TOC removals provided one of the following conditions is met:

- Source water TOC is less than 2.0 mg/L.
- Treated water TOC is less than 2.0 mg/L.
- Source water TOC is less than 4.0 mg/L, source water alkalinity is greater than 60 mg/L, and distribution system TTHM is no greater than 0.040 mg/L and HAA5 is no greater than 0.030 mg/L.
- Distribution system TTHM is no greater than 0.040 mg/L and HAA5 is no greater than 0.030 mg/L and, only chlorine is used for primary disinfection and distribution system residual.
- Source water SUVA, prior to any treatment, is less than or equal to 2.0 L/mg-m.
- Treated water SUVA is less than or equal to 2.0 L/mg-m.

In addition, systems practicing enhanced softening are not required to achieve the Step 1 TOC removals provided one of the following two conditions is met:

- Treated water alkalinity is less than 60 mg/L as $CaCO_3$
- At least 10 mg/L as $CaCO_3$ of magnesium hardness is removed

Stage 2 Disinfectants and Disinfection Byproducts Rule

The Stage 2 D/DBP Rule was promulgated by USEPA on January 4, 2006, along with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). CDPH is beginning to incorporate the provisions of the Stage 2 D/DBP Rule into Title 22. A draft regulation was published in September 2010. This rule applies to all community and non-transient non-community water systems that use disinfectants other than ultraviolet (UV) light. The rule retains the MCLs for TTHM, HAA5, chlorite, and bromate established in the Stage 1 D/DBP Rule but requires compliance at every monitoring location in the distribution system. The rule requires an Initial Distribution System Evaluation (IDSE) be conducted to identify the locations in the distribution system that have the highest concentrations of TTHM and HAA5 as well as confirm the long-term monitoring locations. The SWP Contractors have completed their IDSEs. Compliance with the Stage 2 D/DBP Rule will be based on calculating a LRAA, where compliance means maintaining the LRAA at each compliance monitoring location in the distribution system at or below 0.080 mg/L for TTHMs and 0.060 mg/L for HAA5.

Monitoring for the LRAA will occur at long-term monitoring locations identified in the IDSE report at specific frequencies, based on population served. For systems serving more than 100,000 people or part of a combined distribution system with another large system, monitoring must start by April 1, 2012 and compliance with the Stage 2 MCLs must be achieved one year after monitoring is started. Systems serving between 50,000 and 99,999 must start by October 1, 2012 and systems serving between 10,000 and 49,999 must start by October 1, 2013. Systems serving fewer than 10,000 people must begin either October 1, 2013 (if *Cryptosporidium* monitoring is not required) or October 1, 2014 (if *Cryptosporidium* monitoring is required). If capital improvements are needed to meet the MCLs, CDPH may allow an additional 24 months before compliance is required.

Interim Enhanced Surface Water Treatment Rule

The IESWTR was promulgated by USEPA on December 16, 1998. Public water systems that use surface water or groundwater under the direct influence of surface water and serve at least 10,000 people were required to comply with the provisions of this rule by January 2002. CDPH incorporated this regulation into Title 22 in December 2007, and it was effective in January 2008. The state rule contains additional monitoring and reporting requirements. This rule established a Maximum Contaminant Level Goal (MCLG) for *Cryptosporidium* of zero and established a treatment technique requirement of 2-log (99 percent) removal of *Cryptosporidium*. The rule provides that systems with conventional or direct filtration water treatment plants are granted the 2-log removal credit, provided the new enhanced turbidity requirements are met. Turbidity must be continuously monitored for all filters and the combined filter effluent turbidity must be less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95 percent of measurements taken each month, and never exceed 1 NTU. CDPH requires continuous monitoring of the filter effluent with 15-minute recordings and has set other specific turbidity limitations on the combined filter effluent, as well as reporting thresholds on the individual filter effluent, based on the more frequent recordings.

Long Term 2 Enhanced Surface Water Treatment Rule

USEPA promulgated the LT2ESWTR on January 5, 2006 to provide additional *Cryptosporidium* protection for drinking water consumers supplied from surface water sources. CDPH has started the process to incorporate the provisions of the LT2ESWTR into Title 22. This regulation requires public water systems using surface water sources to conduct source water monitoring to determine if additional action is needed to reduce *Cryptosporidium*. Filtered systems are not required to conduct source water monitoring if the system provides a total of at least 5.5-log of treatment for *Cryptosporidium*. Public water systems serving at least 10,000 people are required to sample their source water for *Cryptosporidium*, *E. coli*, and turbidity at least monthly for 24 months. The SWP Contractors have completed this monitoring and met all of the sampling and analytical requirements of the LT2ESWTR. A second round of source water monitoring is required by all systems and must begin six years after initial bin classification. Final compliance dates vary based on system size and range from April 2015 (for large systems) through October 2017 (for small systems).

Filtered water systems are classified in one of four bins based on their monitoring results, as shown in **Table 2-4**. Systems can select from a wide range of treatment and management strategies in the microbial toolbox to meet their additional treatment requirements. The microbial toolbox contains various methods of achieving the additional treatment requirements including watershed management, pretreatment, additional treatment, and optimizing existing treatment processes. **Table 2-5** provides a summary of the treatment requirements by bin classification and filtration treatment type. Conventional filtration systems classified in Bins 2, 3 and 4 must provide 1.0 to 2.5-log additional action for *Cryptosporidium*. Systems will select from a wide range of treatment and management strategies in the "microbial toolbox" to meet their additional action requirements. Systems classified in Bin 3 and Bin 4 must achieve at least 1 log of additional treatment using either one or a combination of the following: bag filters, bank filtration, cartridge filters, chlorine dioxide, membranes, ozone, or UV light. SWP *Cryptosporidium* monitoring results are discussed in Chapter 3.

Table 2-4. LT2ESWTR Bin Classification and Action Requirements

Bin Classification	Maximum Running Annual Average (oocysts/L)	Action Required (log reduction)
1	< 0.075	none
2	0.075 to < 1.0	1
3	1.0 to < 3.0	2
4	≥ 3.0	2.5

Table 2-5. Treatment Requirements by Bin Classification

Bin Classification	Filtration Treatment			
	Conventional filtration (including softening)	Direct Filtration	Slow Sand or Diatomaceous Earth Filtration	Alternative Filtration Technology
Bin 1	No additional treatment	No additional treatment	No additional treatment	No additional treatment
Bin 2	1-log	1.5-log	1-log	As determined by state
Bin 3	2-log[a]	2.5-log[a]	2-log[a]	As determined by state[a]
Bin 4	2.5-log[a]	3-log[a]	2.5-log[a]	As determined by state[a]

[a]Systems must achieve at least 1-log through ozone, chlorine dioxide, UV, membranes, bag/cartridge filters, or bank filtration.

Arsenic Rule

The Final Arsenic Rule was promulgated by USEPA on January 22, 2001. The rule applies to community and non-transient non-community water systems and sets an MCLG of 0 mg/L and an MCL of 0.010 mg/L for arsenic. The federal MCL was in effect in California beginning January 2006. OEHHA developed a PHG for arsenic of 0.004 µg/L in 2004, based on lung and urinary bladder cancer risk. CDPH adopted a revised MCL for arsenic at the same level as the USEPA, 0.010 mg/L, on November 28, 2008. The level of the arsenic MCL is important to the SWP due to the storage of surplus supplies in groundwater basins and subsequent extraction of the groundwater and conveyance in the California Aqueduct. Due to naturally occurring arsenic, groundwater in the southern San Joaquin Valley exceeds the federal MCL in some cases. The impact of groundwater inflows on water quality in the California Aqueduct is discussed in Chapter 14.

Unregulated Contaminant Program

The USEPA implements two programs to evaluate unregulated contaminants to determine if they require regulation in drinking water. The first program is the Contaminant Candidate List (CCL), which was promulgated as part of the 1996 SDWA Amendments. This provides a list of chemical and microbial contaminants that may require possible future regulation. This list is required to be updated every five years by the USEPA. At least five constituents must be selected for evaluation and then the USEPA will provide regulatory determinations for the selected constituents. The second program is the Unregulated Contaminant Monitoring Program which identifies unregulated contaminants for which insufficient data exist. These contaminants must be monitored by public water systems throughout the country. This is a tiered monitoring program. These data are used to support the regulatory determinations in the CCL process.

The first CCL (CCL1) was published in 1998. Nine constituents were selected for evaluation and in 2003 the USEPA determined that none required regulation. The second CCL (CCL2) consisted of those constituents remaining on CCL1, including 42 chemical and 9 microbial constituents. The USEPA selected 11 of these constituents for evaluation and determined in 2007 that none required regulation. However, it was determined that more information was needed for perchlorate and methyl tert-butyl ether (MTBE). In February 2011 the USEPA determined that perchlorate warrants regulation in drinking water. A proposed rule is expected in early 2013, with a final by mid-2014. A revised risk assessment for MTBE is expected in 2011 and a regulatory determination will be made after that. The third CCL (CCL3) included a newly developed list of 104 chemicals, or chemical groups, and 12 microbial contaminants. It was published in 2009. No regulatory determinations have been made yet.

The first Unregulated Contaminant Monitoring Regulation (UCMR) was published by the USEPA in 1999 and included 26 contaminants. The regulation included 12 contaminants on List 1 (Assessment Monitoring) and 14 contaminants on List 2 (Screening Survey). The Assessment Monitoring was conducted by all large public water systems serving more than 10,000 people, and 800 representative small public water systems serving 10,000 or fewer people. Assessment Monitoring was conducted by each system over a 12-month period between 2001 and 2003. The Screening Survey monitoring was conducted by a randomly selected set of 300 large and small public water systems. Screening Survey monitoring for chemical contaminants was conducted in

2001 at selected small systems and in 2002 at selected large systems. Screening Survey monitoring for the List 2 microorganism, *Aeromonas*, was conducted in 2003 for both large and small selected systems.

The second UCMR was published by the USEPA in 2007. The Assessment Monitoring (List 1) had 10 contaminants and the Screening Survey (List 2) had 15 contaminants, which included six nitrosamines. Similar to the first UCMR, Assessment Monitoring was conducted by public water systems serving more than 10,000 people and a representative sample of 800 public water systems serving 10,000 or fewer people. The Screening Survey was conducted by all public water systems serving more than 100,000 people, 320 selected systems serving 10,001 to 100,000 people, and 480 selected systems serving 10,000 or fewer people. Samples were collected quarterly between January 2008 and December 2010 at the entry point of the distribution system. The six nitrosamines were also analyzed in samples from the part of the distribution system that had maximum residence time.

The proposed third UCMR was published in the Federal Register in March 2011. It includes Assessment Monitoring (List 1) and Pre-screen Testing (List 3). Screening Survey monitoring (List 2) is not proposed. All public water systems serving more than 10,000 people, and a representative sample of 800 systems serving 10,000 or fewer people, would be required to conduct Assessment Monitoring for 28 List 1 chemicals during a continuous 12-month period from January 2013 through December 2015. In addition, a targeted group of 800 systems serving 1,000 or fewer people would be required to conduct Pre-Screen Testing for two List 3 viruses during a 12-month period from January 2013 through December 2015. Comments were due on May 2, 2011. The final rule is expected in 2012.

Revised Total Coliform Rule

The USEPA conducted a review of 69 existing drinking water regulations in April 2002. The USEPA determined that only the Total Coliform Rule (TCR) was a candidate for revision. The USEPA developed nine white papers on the most critical subjects. USEPA, along with the American Water Works Association, prepared a series of ten TCR issue papers. USEPA used the papers as information sources for discussions of distribution system water quality issues with the drinking water community, experts, and stakeholders.

The USEPA met in January 2007 to seek information and analytical approaches for characterizing risks posed by the distribution system and then established the TCR Distribution System Advisory Committee under the Federal Advisory Committee Act to provide advice and recommendations on how best to utilize available information for potential revisions to the TCR and to address public health risks from contamination of distribution systems. The USEPA and the TCR Distribution System Advisory Committee published an Agreement in Principle in September 2008. This agreement provides the regulatory framework for an updated TCR. The USEPA published Proposed Revisions to the TCR in July 2010.

Some of the key topics in the Proposed Revisions to the TCR include:

- Applies to Community Water Systems and Non-community Water Systems.
- Establishes MCLG and MCL of zero for *E. coli*.
- Removes MCLG and MCL of zero for total coliform.
- Total coliform serves as an indicator of potential contamination into the distribution system. If detected, assessments must be conducted to determine if any sanitary defects exist and defects must be corrected.
- *E. coli* MCL violation results in requirement to conduct an assessment and correct any sanitary defects found.
- Revision of routine and repeat monitoring requirements to match newer Groundwater Rule requirements (related to water quality and system performance).
- Increased flexibility in repeat monitoring for total coliform positive to better increase options for verifying and identifying extent of fecal contamination.

A final rule is expected in the fall of 2012. Compliance would be mandated within three years of promulgation and CDPH would assume primacy by adopting a state version of this rule.

Six-Year Review

In March 2010, the USEPA published its Six Year Review of the National Primary Drinking Water Regulations. This is an assessment of the existing 71 standards to determine if any of the current standards are in need of a detailed analysis for possible regulatory revision. The USEPA determined that 67 of the 71 existing standards do not need to be revised. Four constituents; acrylamide, epichlorohydrin, trichloroethylene (TCE), and tetrachloroethylene (PCE), are all candidates for possible regulatory revision. This will initiate a process for detailed analyses in four categories to determine if the current standards should be revised. The analyses include:

- Health effects assessment
- Analytical and treatability feasibility assessment
- Occurrence assessment
- Cost and benefit assessment

There are health assessments in progress for acrylamide, TCE, and PCE, one has not yet been initiated for epichlorohydrin. When the analyses are completed a regulatory revision determination will be made for each constituent. This will likely take quite a few years to complete.

New Drinking Water Strategy

In March 2010, the USEPA announced that it would be implementing a new regulatory strategy for drinking water. There are four major components to the strategy:

- Regulate contaminants as groups
- Foster development of new drinking water treatment technologies
- Use authority of multiple statutes to protect drinking water
- Partner with states to share data

In the fall of 2010, the USEPA worked with the drinking water community to solicit input on the key groups of water quality constituents which may be appropriate for regulation. Nine groups of constituents were identified:

- Ready for regulatory consideration – carcinogenic volatile organic compounds (VOCs), nitrosamines, and DBPs from chlorination.

- Future consideration with data gaps – perfluoronated compounds, organophosphates, and carbamates.

- Long-term consideration with significant gaps and other issues – triazines, chloroacetanilides, and cyanotoxins.

In February 2011, the USEPA announced that it will move forward with development of regulatory standards for a group of carcinogenic VOCs. These are largely industrial contaminants and include 16 VOCs, eight of which are already regulated. This includes TCE and PCE, as recommended by the Six-Year Review process. The USEPA also announced nitrosamine DBPs will be evaluated for possible regulation in the near-term as part of the CCL Regulatory Determination process. Data from the second UCMR indicate that these compounds are frequently being found in public water systems.

California Regulations

This discussion focuses on changes in California drinking water regulations that were initiated by specific concerns in the state and not required by promulgation of new federal regulations.

Review of Maximum Contaminant Levels

CDPH is required to review its MCLs at least once every five years to ensure that California MCLs are at least as stringent as federal MCLs and to determine if the MCLs are as close to the PHGs as is technically and economically feasible. In 2006 CDPH revised the arsenic MCL reducing it from 50 µg/L to 10 µg/L. In 2011 CDPH conducted a screening level review of all contaminants for which PHGs had been established by 2010 (86 total) and a detailed review of 18 contaminants. The contaminants that received detailed review are listed in **Table 2-6**.

Table 2-6. Contaminants Reviewed in 2011

Inorganic Chemicals	Volatile Organic Chemicals	Synthetic Organic Chemicals
Beryllium	Benzene	1,2-Dibromo-3-chloropropane (DBCP)
Cadmium	Carbon tetrachloride	Ethylene dibromide
Mercury	1,1-Dichloroethane	
Nickel	1,2-Dichloropropane	
Selenium	1,3-Dichloropropene	
Thallium	Styrene	
	Tetrachloroethylene (PCE)	
	1,1,2-Trichloroethane	
	Trichloroethylene (TCE)	
	Vinyl chloride	

This list was developed by eliminating any contaminant that has an MCL lower than the PHG, eliminating contaminants that had not been detected at or above the detection limit for purposes of reporting (DLR) in at least one drinking water source between 2006 and 2009, and eliminating those with recently revised MCLs. The DLR is the level at which CDPH is confident about the quantity of contaminant being reported by analytical laboratories. CDPH did not recommend revision of most of the MCLs due primarily to a lack of information on changes in treatment techniques, no new public health risk information, few detections in drinking water sources, and the inability to set an MCL below the DLR. CDPH acknowledged that PCE and TCE were frequently detected in drinking water sources. CDPH intends to examine the PCE detections, as resources allow, and to develop a cost benefit analysis of possible MCL revisions. This will likely be done in conjunction with an analysis of TCE. CDPH has identified styrene for further review of the MCL based on new risk to public health by the cancer-based PHG, as resources allow. CDPH previously considered DBCP as a candidate for possible MCL revision but concluded that reduction of the current MCL would not be economically feasible.

Perchlorate

Perchlorate interferes with iodide uptake by the thyroid gland. Iodide is a key component of thyroid hormone, which is required for a variety of basic human physiological functions. By blocking iodide uptake, perchlorate can potentially cause a decreased production of this hormone. Perchlorate has been found in groundwater wells throughout the state and in the Colorado River. OEHHA published a final PHG for perchlorate of 6 µg/L in March 2004. CDPH subsequently published a final MCL of 6 µg/L in July 2007. OEHHA proposed a revised PHG of 1 µg/L in January 2011. The primary difference between the 2004 PHG and the proposed PHG is that the 2004 PHG focused on pregnant women and their fetuses as the primary susceptible population, whereas the proposed PHG focuses on infants. Exposure to perchlorate can affect infant brain development, growth, and other body functions. Comments on the draft PHG were due on February 23, 2011. OEHHA published the results of an external peer review in November 2011 and is currently developing a revised draft PHG for public review.

On February 11, 2011, USEPA announced that it will develop a regulation for perchlorate under the SDWA. This announcement reversed a 2008 decision to not regulate perchlorate. A proposed rule is expected in February 2013 with a final rule by August 2014.

Chromium (VI)

Chromium (VI), or hexavalent chromium, causes acute gastritis when ingested in high doses and is an established human lung carcinogen when inhaled. Chromium (VI) has been found in groundwater supplies in California. Chromium (VI) is currently regulated as part of the 50 µg/L MCL for total chromium. OEHHA recommended a PHG for chromium (VI) of 0.2 µg/L in a 2005 "pre-release" draft. In 2008, the National Toxicology Program finalized a two-year drinking water study of Cr (VI) that reported intestinal tumors in mice and oral cavity tumors in rats. After reviewing the results of the National Toxicology Program study, OEHHA proposed a new PHG of 0.06 µg/L in August 2009. An external scientific peer review was conducted. In December 2010, OEHHA published a second draft of the proposed PHG reducing it to 0.02 µg/L. The lower PHG is based on early-in-life exposures for cancer potency. Comments on the draft PHG were due on February 15, 2011. OEHHA published the final PHG of 0.02 µg/L in July 2011. CDPH is developing an MCL with a draft expected in 2014 and a final in 2015.

Assembly Bill (AB) 403, as introduced in February 2011, resets the current January 1, 2004 deadline by which CDPH is required to establish an MCL for hexavalent chromium, to January 1, 2013. In addition, the introduced version of AB 403 made the MCL equivalent to the PHG if CDPH fails to meet the new deadline. The bill was amended to remove the above provisions and, in its current form, merely requires CDPH to post its progress toward establishing the MCL on its website and makes the adoption of the MCL subject to the 90-day expedited review process at the Department of Finance. AB 403 passed both the Assembly and the Senate and returned to the Assembly for concurrence in a technical amendment made in the Senate. The author chose to place the bill on the Assembly Inactive File, from which it can be removed and acted upon any time before the end of the 2012 legislative year, which typically would occur at the end of August.

In a parallel effort, the USEPA is now recommending that water systems conduct enhanced monitoring for hexavalent chromium. For surface water supplies this includes quarterly sampling of the raw water, the entry point to the distribution system, and locations in the distribution system.

Total Trihalomethanes

Trihalomethanes are carcinogenic byproducts formed in treated drinking water when organic matter and bromide in the source water react with chlorine in the disinfection process. As discussed previously, USEPA has established an MCL of 80 µg/L for TTHM. OEHHA issued a draft PHG of 0.8 µg/L for TTHM in September 2010. Health protective values were established for each of the four THM species (chloroform – 1 µg/L, bromodichloromethane – 0.4 µg/L dibromochloromethane – 0.7 µg/L, and bromoform – 5 µg/L). The proposed PHG is based on the health protective values and the mean concentrations of the four individual THM species in California drinking water. Comments were due on the proposed PHG by October 11, 2010. OEHHA is in the process of establishing the final PHG.

Notification and Response Levels

CDPH has established health based notification levels for contaminants that have no MCLs but are thought to pose a risk to drinking water supplies. Notification levels have been established in response to detection in drinking water supplies or in anticipation of possible contamination. Chemicals for which notification levels are established may eventually be regulated by MCLs. To date, 39 of the 93 chemicals for which notification levels have been established, are now regulated by MCLs. Of the remaining 54 chemicals, 30 currently have notification levels, as shown in **Table 2-7**, and 24 are chemicals with archived advisory levels, as shown in **Table 2-8**. Notification levels are calculated using standard risk assessment procedures. If a chemical is present in a water supply at a concentration that exceeds the notification level, the water system must inform the local governing bodies. CDPH recommends these detects be reported in the annual Consumer Confidence Report by the water system. If a chemical is present at the response level concentration, CDPH recommends taking the source out of service. If the drinking water system does not take the source out of service, more extensive public notification is required. The same action is required for archived advisory levels.

Potential Actions

Individual SWP Contractors and CDPH should Keep MWQI Informed of Regulatory Developments that may Impact the MWQI Monitoring Program or Lead to Special Studies.

Individual SWP Contractors, CDPH, and water organizations such as ACWA and CUWA track regulatory development for their members. While there is no need for SWPCA to track the pending regulations, individual SWP Contractors and CDPH should keep MWQI apprised of any developments that could impact the monitoring program or special studies.

Table 2-7. Notification and Response Levels

Contaminant	Notification Level (mg/L)	Response Level (mg/L)
Boron	1	10
n-Butylbenzene	0.26	2.6
sec-Butylbenzene	0.26	2.6
tert-Butylbenzene	0.26	2.6
Carbon disulfide	0.16	1.6
Chlorate	0.8	8
2-Chlorotoluene	0.14	1.4
4-Chlorotoluene	0.14	1.4
Diazinon	0.0012	0.012
Dichlorodifluoromethane (Freon 12)	1	10
1,4-Dioxane	0.001	0.035
Ethylene glycol	14	140
Formaldehyde	0.1	1
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	0.35	3.5
Isopropylbenzene	0.77	7.7
Manganese	0.5	5
Methyl isobutyl ketone (MIBK)	0.12	1.2
Naphthalene	0.017	0.17
N-Nitrosodiethylamine (NDEA)	0.00001	0.0001
N-Nitrosodimethylamine (NDMA)	0.00001	0.0003
N-Nitrosodi-n-propylamine (NDPA)	0.00001	0.0005
Propachlor	0.09	0.9
n-Propylbenzene	0.26	2.6
Hexahydro-1,3,5-trinitro-1,3,5triazine (RDX)	0.0003	0.03
Tertiary butyl alcohol (TBA)	0.012	1.2
1,2,3-Trichloropropane	0.000005	0.0005
1,2,4-Trimethylbenzene	0.33	3.3
1,3,5-Trimethylbenzene	0.33	3.3
2,4,6-Trinitrotoluene (TNT)	0.001	0.1
Vanadium	0.05	0.5

Table 2-8. Archived Advisory and Response Levels

Chemical	Archived Advisory Level (mg/L)	Response Level (mg/L)
Aldicarb	0.007	0.07
Aldrin	0.000002	0.0002
Baygon	0.03	0.3
a-Benzene Hexachloride	0.000015	0.0015
b-Benzene Hexachloride	0.000025	0.0025
Captan	0.015	1.5
Carbaryl	0.7	7
Chloropicrin	0.05	0.5
Chlorpropham (CIPC)	1.2	12
1,3-Dichlorobenzene	0.6	6
Dieldrin	0.000002	0.0002
Dimethoate	0.001	0.01
2,4-Dimethylphenol	0.1	1
Diphenamide	0.2	2
Ethion	0.004	0.04
Malathion	0.16	1.6
N-Methyl dithiocarbamate (Metam sodium)	0.00019	0.019
Methylisothiocyanate	0.19	1.9
Methyl parathion	0.002	0.02
Parathion	0.04	0.4
Pentachloronitrobenzene	0.02	0.2
Phenol	4.2	42
2,3,5,6-Tetrachloroterephthalate	3.5	35
Trithion	0.007	0.07

SOURCE WATER PROTECTION REGULATIONS

Protection of source water quality is a key component of the multiple barrier approach to providing safe drinking water to customers. The Dickey Water Pollution Act of 1949 created the State Water Pollution Control Board and nine Regional Water Boards. In the early 1960s this was renamed the State Water Quality Control Board. In 1967, the legislature recognized the overlap of the water pollution and water rights activities and merged the State Water Quality Control Board with the State Water Rights Board to make the State Water Resources Control Board (State Water Board). The California State Legislature passed the Porter- Cologne Water Quality Control Act in 1969 to protect water quality throughout the state. In 1972 Congress passed the Federal Water Pollution Control Act (now known as the Clean Water Act [CWA]). The State Water Board and the nine Regional Water Boards are charged with implementing both the federal and state water quality regulations. The Central Valley Regional Water Quality Control Board (Central Valley Regional Water Board) is responsible for protecting water quality in the Sacramento and San Joaquin basins, the source waters for the SWP, and in the Tulare Basin, which occasionally provides water to the SWP. The State Water Board adopts Water Quality Control Plans and Water Quality Policies to protect water quality throughout the state. Key plans and policies that protect drinking water source quality and recent changes in source water protection are discussed in this section.

State Plans and Policies

The State Water Board adopted the San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan (Bay-Delta Water Quality Control Plan). In addition, there are several policies that have been adopted by the State Water Board that must be implemented in the Sacramento and San Joaquin basins by the Central Valley Regional Water Board.

San Francisco Bay/Sacramento-San Joaquin Delta Water Quality Control Plan

The original Bay Delta Water Quality Control Plan was adopted in 1978, revised in 1991, and then substantially revised in 1995. The water quality and flow objectives for the Delta were substantially changed in the 1995 Plan. The State Water Board adopted Water Rights Decision 1641 to implement the objectives. The State Water Board made minor revisions to the 1995 Plan and adopted a new plan in 2006.

The Bay Delta Water Quality Control Plan establishes water quality control measures that protect the beneficial uses of San Francisco Bay and the Delta, that require control of salinity (caused by seawater intrusion, municipal discharges, and agricultural drainage) and water project operations (flows and diversions). The plan contains specific numeric standards for Delta inflow and outflow, and standards for chloride and electrical conductance (EC) at various locations in the Delta. The California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) are responsible for meeting the flow objectives; salinity objectives are met through a combination of flow and salinity control measures.

The State Water Board initiated its periodic review of the 2006 Bay-Delta Plan in August 2008, by issuing a notice of a public workshop to receive comments on potential modifications of the Bay-Delta Plan. The workshop was held in October 2008. In February 2009, the State Water Board issued a Notice of Preparation for the update of the Bay-Delta Plan, indicating that the update would be conducted in four phases:

- Bay-Delta Plan review and update of the San Joaquin River flow and southern Delta salinity objectives and their program of implementation
- Amendment of water rights and other measures to implement the San Joaquin River flow and southern Delta salinity objectives
- Review and update of other components of the Bay-Delta Plan and their program of implementation
- Amendment of water rights and other measures to implement other components of the Bay-Delta Plan

As discussed in the Policy Setting of this chapter, the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act) was approved by the legislature and signed by Governor Schwarzenegger in November 2009. This Act mandated that the State Water Board approve new flow criteria by August 2010 for the Delta ecosystem that are necessary to protect public trust resources.

The San Joaquin River flows and southern Delta salinity objectives and the comprehensive review of other elements of the Bay-Delta Plan are discussed in the following sections.

San Joaquin River Flows and Southern Delta Salinity Objectives

The State Water Board held a number of public workshops from 2009 to 2011 and issued a report on salt tolerance of crops in the southern Delta (Hoffman, 2010) and a draft and final technical report providing the scientific information that will be considered in developing the objectives (State Water Board, 2010 and 2011). The final technical report contains the proposed basin plan amendment language. The existing numeric San Joaquin River flow objectives at Vernalis are proposed to be replaced by a narrative objective that calls for flows to be maintained at levels that support viable fish populations migrating through the Delta and that more closely mimic the natural hydrograph. The State Water Board proposed minor changes to the southern Delta salinity standards that will be further refined before the final proposal is released and proposed a new narrative objective to maintain water levels and circulation conditions to protect agricultural beneficial uses. The State Board requested that an external peer review be conducted of both the crop salt tolerance report (Hoffman, 2010) and the final technical report (State Water Board, 2011). Five peer reviewers were identified and they completed their reviews in mid-November 2011.

The State Board released the technical and economic appendices on February 24, 2012 and will release the draft environmental documents in the spring of 2012. The environmental documents will contain the basin plan amendment language that will be submitted to the State Water Board at an adoption hearing. The San Joaquin River flow objectives and south Delta salinity standards will be completed by the fall of 2012

Comprehensive Review of Other Elements of the Bay-Delta Plan

In August 2009, the State Water Board published a Staff Report on the Periodic Review of the 2006 Plan. Staff recommended further review in the basin planning process of the following:

- Delta outflow objectives
- Export/inflow objectives
- Delta Cross Channel gate closure objectives
- Suisun Marsh objectives
- Reverse flow objectives
- Floodplain habitat flow objectives
- Changes to the monitoring and special studies program
- Other changes to the program of implementation

The State Water Board staff has indicated they will also consider the flow criteria in the comprehensive review of the Bay-Delta Plan.
The State Water Board issued a supplemental Notice of Preparation on January 24, 2012 seeking public input on the issues to address in the comprehensive review. The State Water Board held an informational item on February 21, 2012 to receive comments on the schedule for updating the Bay-Delta Plan. A series of scoping meetings will be held during the summer and fall of 2012. The comprehensive review will be completed by the summer of 2013.

Antidegradation Policy

In 1968 the State Water Board adopted Resolution No. 68-16, *"Statement of Policy With Respect to Maintaining High Quality of Waters in California,"* known as the Antidegradation Policy. Under the Antidegradation Policy, whenever the existing quality of water is better than that needed to protect existing and probable future beneficial uses, such existing high quality is to be maintained until it is demonstrated to the state that any change in water quality will be consistent with the maximum benefit to the people of the state; will not unreasonably affect present or probable future beneficial uses; and will not result in water quality less than prescribed in state policies. The effect of this policy is to define a range of water quality between natural background levels and water quality objectives that must be maintained. The policy also specifies that discharges of waste to existing high quality waters are required to use "best practicable treatment or control" to protect the high quality water.

In November 2008 the State Water Board initiated a review of the Antidegradation Policy. This included a public meeting and submittal of comments on the policy. Over 30 comments were received and staff has yet to publish a response or summary of those comments. Eventually staff will prepare a recommendation to the State Water Board, but at this time the work has been delayed due to petitions.

Sources of Drinking Water Policy

In 1988 the State Water Board adopted Resolution No. 88-63, *Adoption of Policy Entitled "Sources of Drinking Water."* This policy specifies that, except under specifically defined circumstances, all surface water and groundwater of the state are to be protected as existing or potential sources of municipal and domestic supply, unless this beneficial use is explicitly excluded in a Water Quality Control Plan. The policy lists the following circumstances under which surface waters may be excluded from the municipal and domestic supply beneficial use:

- Waters with total dissolved solids (TDS) concentrations greater than 3,000 mg/L.
- Water with contamination, unrelated to a specific pollution incident, which cannot reasonably be treated for domestic use.
- Water in systems designed to collect or treat municipal or industrial wastewater, process water, mining wastes, or stormwater runoff.
- Water in systems designed for the primary purpose of conveying or holding agricultural drainage.

This policy was amended by the State Water Board in February 2006 (Resolution No. 2006-0008) to add a site-specific exclusion for Old Alamo Creek, which receives effluent from the City of Vacaville's wastewater treatment plant.

Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California

USEPA promulgated water quality criteria for toxic contaminants in the National Toxics Rule in 1992 and the California Toxics Rule (CTR) in 2000. The CTR covers 127 priority pollutants and includes criteria for the protection of human health and aquatic life. The human health criteria are derived for drinking water sources considering exposure from consumption of both water and fish that had lived in the water. The *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California*, adopted by the State Water Board in March 2000, establishes state policy implementing numeric toxic pollutant criteria and objectives for inland surface waters and enclosed bays and estuaries. This was amended by the State Water Board in February 2005 (Resolution No. 2005-0019) to include the following changes:

- Allow water effects ratios to be established in individual National Pollutant Discharge Elimination System (NPDES) permits, rather than in the basin planning process as currently required.
- Eliminate the reasonable potential trigger for situations where ambient background pollutant concentrations are greater than a priority pollutant objective or criterion.
- Make non-regulatory language corrections to improve clarity.
- Add mutual water companies to section 5.3 (exceptions).

Some of the human health criteria in the CTR are more stringent than drinking water MCLs because economics and treatment feasibility are not considered. For example, the CTR requires compliance with individual trihalomethane criteria, listed in **Table 2-9**. Similarly, the criterion for N-Nitrosodimethylamine (NDMA) is 0.00069 µg/L, which is well below the drinking water notification level and method detection limit. The result is that some dischargers, particularly those that discharge to effluent dominated waterways, have to discharge water with lower concentrations of trihalomethanes than required in drinking water. This policy has ramifications for water providers implementing recycled water programs and groundwater recharge programs.

Table 2-9. California Toxics Rule Criteria and Maximum Contaminant Levels for Trihalomethanes

THM Species[a]	Criterion (µg/L)	MCL (µg/L)
Bromodichloromethane	0.56	-
Dibromochloromethane	0.401	-
Bromoform	4.3	-
TTHM	-	80

[a] The CTR did not establish a criterion for chloroform.

Recycled Water Policy

In February 2009 the State Water Board adopted the Recycled Water Policy. The purpose of the Policy is to increase the use of recycled water from wastewater sources, while still implementing state and federal water quality laws. Four goals were adopted, including;

- Increase recycled water use over 2002 levels by at least one million acre-feet per year (acre-feet/year) by 2020 and by at least two million acre-feet/year by 2030.

- Increase stormwater use over 2007 levels by at least 500,000 acre-feet/year by 2020 and by at least one million acre-feet/year by 2030.

- Increase water conservation in urban and industrial uses over 2007 levels by at least 20 percent by 2020.

- Substitute as much recycled water for potable water as possible by 2030.

In addition, three mandates were identified, contingent upon the availability of sufficient capital funding, including:

- Increase use of recycled water by 200,000 acre-feet/year by 2020 and an additional 300,000 acre-feet/year by 2030. This will be reviewed and revised in 2012 and 2016.

- Agencies producing recycled water shall make it available to water purveyors on reasonable terms and conditions.

- It will be considered a waste and an unreasonable use of water for water purveyors not to use recycled water when it is available.

The Policy clearly identifies the roles of the State Water Board, Regional Boards, CDPH, and DWR in the jurisdiction over the use of recycled water and provides information on specific criteria to be used by the State Water Board and Regional Boards to issue permits for recycled water projects. All projects must meet state and federal water quality laws. The policy has been designed to allow for streamlining of the permitting requirements and increasing statewide consistency in permits. Some of the key specific requirements of the Policy include; development of salt and nutrient management plans for all groundwater basins/sub-basins in the State by 2014, permitting of landscape irrigation projects, permitting of groundwater recharge projects, compliance with the Antidegradation Policy (Resolution No. 68-16), evaluation of constituents of emerging concern (CECs), and incentives for use.

The State Water Board convened a Science Advisory Panel to provide monitoring strategies for CECs in recycled water and a Final Report was published in June 2010. This report provided information needed to develop monitoring plans to assess the potential threats to groundwater from recycled water use via surface spreading and direct injection. This included a conceptual framework to select CECs to monitor, provided an immediate list based on currently available information, a sample plan design and data analysis suggestions, as well as priorities for improvements in the CEC investigations. In November 2010, a Staff Report was published which provided the recommendations for CEC monitoring of recycled water projects. This included monitoring of four health-based constituents (NDMA, 17 beta-estradiol, caffeine, and triclosan), four performance-based constituents (gemfibrozil, iopromide, sucralose, and N,N-Diethyl-meta-toluamide [DEET]), four surrogates (ammonia, dissolved organic carbon [DOC], EC, and turbidity), as well as 15 additional chemical constituents at the request of CDPH.

Aquatic Pesticides

The use of selected aquatic pesticides, applied directly to water, is regulated under four Statewide General NPDES Permits.

- Weed Control – Discharge of Aquatic Pesticides for Aquatic Weed Control in Waters of the U.S. (WQO-2004-0009-DWQ) was adopted by the State Water Board in May 2004, with minor modifications in June 2006. This Permit includes coverage for discharges containing 2,4-Dichlorophenoxyacetic acid (2,4-D), acrolein, copper, diquat, endothall, fluridone, glyphosate, imazapyr, sodium carbonate peroxyhydrate, and triclopyr. This permit expired in May 2009, but remains in effect until a new permit is adopted.

- Vector Control – Biological and Residual Pesticide Discharges to Waters of the U.S. from Vector Control Applications (Water Quality Order No. 2011-0002-DWQ) was adopted by the State Water Board in March 2011. This General Permit covers the direct and spray application of larvicides (monomolecular films, methoprene, *Bacillus thuringiensis* subspecies *isralensis*, *Bacillus sphaericus*, temephos, petroleum distillates, and spinosad) and adulticides (malathion, naled, pyrethrin, permethrin, resmethrin, sumithrin, prallethrin, piepronyl butoxide, etofenprox, and N-octyl bicycloheptene dicarboximide) currently registered in California for use for vector control.

- Aquatic Animal Invasive Species Control – Residual Pesticide Discharges to Waters of the U.S. from Aquatic Animal Invasive Species Control Applications (Water Quality Order No. 2011-0003-DWQ) was adopted by the State Water Board in March 2011. Users of products containing sodium hypochlorite (used for control of aquatic mollusks) are required to obtain coverage under this General Permit prior to application. The applicant is required to prepare an Aquatic Pesticide Application Plan which identifies best management practices (BMPs) including compliance with all pesticide label instructions.

- Spray Applications – Biological and Residual Pesticide Discharges to Waters of the U.S. from Spray Applications (Water Quality Order No. 2011-0004-DWQ) was adopted by the State Water Board in March 2011. This General Permit covers spray application activities of the California Department of Food and Agriculture and the U.S. Forest Service for discharges containing acetaminiprid, aminopyralid, Bacillus thuringiensis kurstaki (Btk), carbaryl, chlorsulfuron, clopyralid, cyfluthrin, dinotefuran, glyphosate, imazapyr, imidacloprid, malathion, naled, nuclear polyhedrosis virus, pheromone, pyrethrins, Spinosad A and D, tricholpyr butoxyethyl ester and triclopyr triethylamine salt.

In November 2006, USEPA adopted a final regulation that adds pesticide application at, on, or near waters of the U.S. to the list of discharges that do not require NPDES permits. In January 2009 the Sixth Circuit Court determined that the USEPA Final Rule is not a reasonable interpretation of the CWA and vacated the Final Rule. In June 2009, the Sixth Circuit granted a motion for a two-year stay of the lawsuit, and the USEPA exemption remained in effect until April 9, 2011 to allow time for USEPA and state agencies to develop new NPDES permits to cover the pesticide applications included in the decision. On March 28, 2011, USEPA's request to extend the stay was granted until October 31, 2011.

On October 31, 2011, USEPA issued a final NPDES Pesticide General Permit for discharges of pesticide applications to U.S. waters. The final permit covers operators who apply pesticides that result in discharges from the following uses: (1) mosquito and other flying insect pest control; (2) weed and algae control; (3) animal pest control; and (4) forest canopy pest control. This general permit provides coverage to areas where USEPA is the permitting authority. It does not apply in most areas of California since the State Water Board has issued general permits covering these activities. It does apply on tribal lands which are under USEPA's jurisdiction.

In addition, H.R. 872, the Reducing Regulatory Burdens Act of 2011 was introduced in March 2011. This bill prohibits the USEPA or any state from requiring an NPDES permit for a discharge from a point source of a pesticide, or residue of a pesticide, regulated by the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). H.R. 872 passed the House of Representatives on March 31, 2011 and was approved by the Senate Agriculture, Nutrition, & Forestry Committee on June 21, 2011. The bill has been on the Senate Legislative Calendar since June 21, 2011. If this bill becomes law, it could obviate the need for NPDES permits for aquatic pesticides since FIFRA requirements would supersede those in the CWA.

Proposed Policy for Nutrients for Inland Surface Waters of the State of California

In October 2011, the State Water Board convened a California Environmental Quality Act scoping meeting on a proposed Statewide Nutrient Policy for Inland Surface Waters. The policy will include water quality objectives and establish control strategies for nutrients. The purpose of this meeting was to solicit early public consultation on the policy development, outline the environmental considerations of nutrients, and present the alternatives for developing objectives, implementation, and monitoring.

Currently, the options include no action, adopting the USEPA Recommended Nutrient Criteria, or adopting a Statewide Nutrient Policy based on the Nutrient Numeric Endpoint (NNE) Approach. The NNE Approach evaluates the relative risk of the nutrients causing eutrophication to the beneficial uses and allows for more site-specific objectives/translators to be developed. The State Water Board has identified the State Nutrient Policy using the NNE Approach as their preferred option. Comments from the scoping meeting were due in November 2011 and staff is working on preparation of a Public Draft Policy. This is expected to be ready for public review in the second half of 2012 and presented to the State Water Board in the fall 2012. Adoption of a final Nutrient Policy is expected in 2013.

Central Valley Plans and Programs

The Central Valley Regional Water Board is responsible for protecting water quality in the Sacramento, San Joaquin, and Tulare basins. In the last five years, point source dischargers have continued to face increasingly stringent regulations and more prescriptive NPDES permits. The Central Valley Regional Water Board has also continued to focus on regulating nonpoint source discharges.

Water Quality Control Plan for the Sacramento River and San Joaquin River Basins

The Central Valley Regional Water Board adopted the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) in 1975, and has periodically updated the plan. The Basin Plan designates beneficial uses and water quality objectives for waters of the Sacramento and San Joaquin basins and contains an implementation plan for achieving the water quality objectives. Water quality standards consist of both the beneficial use and the water quality objectives (water quality criteria in the federal regulations) to protect the use. To protect both existing and potential future beneficial uses, water quality standards normally apply throughout the bodies of surface water and groundwater for which they were established rather than at points of current water use or withdrawal. The Basin Plan designates many waterways in the Sacramento and San Joaquin basins with the municipal and domestic supply (MUN) beneficial use. Due to the large number of small streams and creeks that flow into major waterways in the Sacramento and San Joaquin basins, it is not possible to designate specific beneficial uses for each waterway. The Central Valley Regional Water Board relies on the Sources of Drinking Water Policy and the Tributary Statement to establish the MUN beneficial use for waterways not specifically mentioned in the Basin Plan. The Tributary Statement simply states that beneficial uses of any specifically identified water body generally apply to its tributary streams. The Central Valley Regional Water Board applied the Sources of Drinking Water Policy to all water bodies that are not specifically listed in the Basin Plan. This includes small tributaries, effluent dominated waterways, agricultural dominated waterways, and agricultural drains.

The Basin Plan for the Sacramento and San Joaquin basins contains both numeric and narrative water quality objectives to protect the MUN beneficial use, as well as other beneficial uses. Numeric objectives are established for bacteria, EC, TDS, turbidity, dissolved oxygen (DO), pH, pesticides, temperature, and trace elements. Many of the numeric objectives are specific to individual waterbodies and were established to protect aquatic life. The fecal coliform bacteria objectives were established to protect contact recreational use, rather than MUN. The fecal coliform objective is a 30-day geometric mean of 200 MPN/100 ml and no more than 10 percent of the samples in a 30-day period can exceed 400 MPN/100ml. MCLs established by CDPH are incorporated into the Basin Plan as numeric objectives for the protection of the MUN beneficial use. The narrative water quality objectives are listed below:

- Chemical Constituents – Waters shall not contain chemical constituents in concentrations that adversely affect beneficial uses.
- Taste and Odor – Water shall not contain taste or odor-producing substances in concentrations that impart undesirable tastes or odors to domestic or municipal water

supplies or to fish flesh or other edible products of aquatic origin, or that cause nuisance or otherwise adversely affect beneficial uses.

- Sediment – The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

- Suspended Material – Water shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.

- Toxicity – All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effects of multiple substances.

Under current regulations, once water quality objectives are adopted into an approved Basin Plan, the Central Valley Regional Water Board is responsible for ensuring compliance with the objectives through adoption of discharge permits and implementation of other water quality control programs. Point source discharges to surface waters, such as wastewater treatment plants and industries, are regulated under NPDES permits. NPDES permits, excluding stormwater permits, normally include effluent and receiving water limits to protect the beneficial uses of the receiving water. Urban runoff dischargers are also required to obtain NPDES permits, but they are not assigned effluent limitations. Urban runoff permits require the discharger to implement BMPs to reduce pollutant loadings to the maximum extent practicable.

The Central Valley Regional Water Board regulates nonpoint source discharges through waste discharge requirements, conditional waivers, or discharge prohibitions. Nonpoint source regulation typically entails discharger implementation of BMPs to control pollutant sources. Agricultural discharges are currently regulated as an interim program under a conditional waiver, but will soon be converted to a long-term program. More detail on the specifics of these control programs is provided in the following sections.

Section 303(d) of the Clean Water Act requires the identification of waterbodies that do not meet, or are not expected to meet, water quality standards (i.e., impaired waterbodies). These are then prioritized in the 303(d) List. A total maximum daily load (TMDL) must be developed for each listing. In 2008, California began integrating the 303(d) List of Impaired Waters and the 305(b) Water Quality Assessment Report into a single report (Integrated Report). The California 2008-2010 Integrated Report was approved by the State Water Board in August 2010 and approved by USEPA in October 2011. This Integrated Report can be viewed through an interactive map on the State Water Board website.

<u>Total Maximum Daily Loads</u>

The Clean Water Act section 303(d) requires that states develop a list of waters that are not attaining water quality standards and that they develop TMDLs for each constituent that results in the exceedance of a standard. The TMDLs generally consist of a maximum allowable load of a water quality constituent that will allow the water quality standard to be met. The load is allocated to both point and non-point sources contributing to the water quality standard exceedance. TMDLs have been established for cadmium, copper, zinc, diazinon, chlorpyrifos, nutrients, and mercury in various reaches of the Sacramento River Basin. In the San Joaquin Basin, TMDLs have been established for DO, selenium, diazinon, chlorpyrifos, salt, boron, and pathogens. The Central Valley Regional Water Board is currently developing additional mercury and DO TMDLs, a Central Valley TMDL for diazinon and chlorpyrifos and is planning to work on a Central Valley TMDL for pyrethroid pesticides in the near future. The TMDLs for drinking water constituents addressed in this sanitary survey are briefly described.

San Joaquin River Salt and Boron TMDL

The Central Valley Regional Water Board adopted a TMDL for salt and boron in the San Joaquin River in 2004. The TMDL was adopted by the State Water Board in 2005 and by the USEPA in February 2007. This TMDL requires that the existing water quality objectives for EC of 700 µS/cm during the irrigation season and 1,000 µS/cm during the non-irrigation season be met in the San Joaquin River at Vernalis. The San Joaquin River Water Quality Management Group, consisting of stakeholders in the San Joaquin Basin, is working cooperatively to meet the water quality objectives.

A Management Agency Agreement was signed between Reclamation and the Central Valley Regional Water Board in December 2008 to address salt loads from the Delta Mendota Canal. A Salinity Management Plan was prepared at that time and was subsequently updated in November 2010. The Action Plan focuses on providing flows to the system, reducing salt load to the river, and facilitating mitigation.

Clear Lake Nutrient TMDL

Clear Lake drains to the Yolo Bypass, which flows into the Sacramento River in the western Delta. Blue-green algae (cyanobacteria) blooms have impaired Clear Lake for a number of years. The Central Valley Regional Water Board adopted a TMDL in June 2006 that limits the phosphorus load and establishes a target of 73 µg/L of chlorophyll a in Clear Lake. This was adopted by the State Water Board in April 2007 and by the USEPA in September 2007.

In 2008 the responsible parties identified in the TMDL developed a Workplan and Monitoring Plan. This lists BMPs for each contributing source and provides a monitoring program to track progress. Most of the BMPs are implemented through other regulatory programs, such as the Irrigated Lands Program for agricultural contribution and NPDES permits for wastewater and stormwater discharges. An update on the program is scheduled to be provided to the Regional Board by staff in the fall of 2012.

Stockton Urban Water Bodies Pathogen TMDL

The TMDL addresses pathogen impairment in Five Mile Slough, Lower Calaveras River, Mormon Slough, Mosher Slough, Smith Canal, and Walker Slough. Implementation of this TMDL is conducted through the City of Stockton’s MS4 Permit (Order No. R5-2007-0173) and associated Pathogen Plan. The TMDL was adopted by the Central Valley Regional Water Board in March 2008. It was subsequently adopted by the State Water Board in April 2008 and

approved by the USEPA in May 2008. The TMDL sets numeric limits for fecal coliform and *E. coli*, in accordance with body contact objectives.
Implementation of the TMDL is conducted through the City of Stockton's Urban Runoff Permit and associated Pathogen Plan (see discussion in Chapter 13).

Wastewater Discharges

Municipal and industrial wastewater dischargers are required to obtain NPDES permits and the permits are reviewed and readopted by the Central Valley Regional Water Board every five years or whenever there is a proposed change in discharge quality or quantity that is not included within the existing permit. As described previously, the beneficial uses and receiving water objectives to protect those uses are established in the Basin Plan. The Central Valley Regional Water Board establishes effluent limitations for wastewater dischargers based on the beneficial uses and the water quality objectives of the water body that receives the discharge and the state's antidegradation policy. There are specific steps necessary to determine whether a discharge permit needs a limit for a constituent and if so, what the limit should be. To determine a permit limit the Central Valley Regional Water Board determines whether a discharge has a reasonable potential to cause or contribute to an exceedance of a receiving water objective for a particular constituent or parameter, identifies the water quality objectives for the protection of the beneficial uses that have been designated for the receiving water body, and selects criteria (numerical water quality objectives or water quality goals that implement a narrative objective).
The permit limit derivation procedures take into account acute and chronic aquatic life toxicity effects, human health effects, dilution, ambient background concentrations and antidegradation requirements. For drinking water constituents, if a discharge has the reasonable potential to cause an excursion above an existing objective or MCL, then the discharge permit will include a limit and requirements for monitoring that constituent. However, this process does not apply to constituents for which objectives do not already exist (for example, TOC and pathogens). If a discharge is to an ephemeral stream or a stream that the Central Valley Regional Water Board determines does not have any assimilative capacity for a contaminant, the discharger must meet the receiving water quality objectives in the effluent. If there is dilution capacity available in the receiving water, the Central Valley Regional Water Board may establish effluent limitations that allow for a mixing zone and dilution of the effluent in the receiving water.

To provide a consistent, statewide regulatory approach to address sanitary sewer overflows (SSOs), the State Water Board adopted Statewide General Waste Discharge Requirements for Sanitary Sewer Systems, Water Quality Order No. 2006-0003 (Sanitary Sewer Order) on May 2, 2006. The Sanitary Sewer Order requires public agencies that own or operate sanitary sewer systems to develop and implement sewer system management plans (SSMPs) and report all SSOs to the State Water Board's online SSO database.

The Sanitary Sewer Order requires the owners and operators of sanitary sewer systems to take all feasible steps to eliminate SSOs and to develop and implement a system-specific SSMP. SSMPs must include provisions to provide proper operation and maintenance while considering risk management and cost. The SSMP must contain a spill response plan that establishes standard procedures for immediate response to an SSO in a manner designed to minimize water quality impacts and potential nuisance conditions. The SSMPs must be updated every five years.

A key requirement of the Sanitary Sewer Order is that SSOs must be entered into the State Water Board's SSO online database. Wastewater spills greater than 1,000 gallons, all wastewater spills that enter waters of the state, and spills that occur where public contact is likely, regardless of the volume are classified as Category 1 SSOs. Category 1 SSOs must be reported to the SSO database as soon as possible but no later than three business days after the SSO is detected. The Sanitary Sewer Order contains other requirements for reporting of SSOs that do not reach surface waters and for monthly reporting if no SSOs occurred. If spills are not reported, this is considered a violation of the California Water Code and it is grounds for enforcement action. Reporting began in September 2007. This process simplifies the ability of water purveyors to identify spills of interest and obtain specific information about a spill using the State Water Board California Integrated Water Quality System website.

In August 2008 the Central Valley Regional Water Board issued Spill Reporting Procedures for wastewater treatment plant spills. This was issued to ensure consistency in notification procedures with the State Water Board Order for Sanitary Sewer Systems (see discussion above). This requires facilities to notify the California Office of Emergency Services, the local health department, and the Central Valley Regional Water Board within two hours of a spill or discharge. Wastewater spills greater than 1,000 gallons, all wastewater spills that enter waters of the state (surface and groundwater), and spills that occur where public contact is likely, regardless of the volume, must be reported to the Central Valley Regional Water Board. This notification must be made by telephone as soon as notification is possible, but should not impede the cleanup or other emergency measures required. The notification must occur within 24 hours of detection of the spill. In addition to oral notification, a written report must be submitted to the Central Valley Regional Water Board within five days of the spill.

More detail on wastewater discharges in the Sacramento and San Joaquin basins is provided in Chapter 13.

Urban Runoff

In 1972, The Federal Water Pollution Control Act (now referred to as the CWA) was amended to provide that the discharge of pollutants to waters of the United States from any point source is unlawful, unless the discharge is in compliance with an NPDES permit. The 1987 amendments to the CWA added section 402(p) which directs that stormwater discharges are point source discharges and establishes a framework for regulating municipal and industrial stormwater discharges under the NPDES program. On November 16, 1990, the USEPA promulgated final regulations that established the stormwater permit requirements. The regulations addressed municipal stormwater and also specified a requirement for stormwater permits from 10 categories of industry, as well as construction activities greater than one acre.

Stormwater permits are required for discharges from a municipal separate storm sewer system (MS4). The USEPA developed its stormwater regulation in two phases. The Phase I regulation was promulgated in 1990 for cities or contiguous unincorporated urban areas with populations greater than 100,000. The Phase II regulation was promulgated in 1999 for cities and other contiguous areas with populations less than 100,000. USEPA defined MS4 to include road systems owned by states which are in an area with a population greater than 100,000.

Municipal urban runoff in the Central Valley and most of the Delta is regulated by the Central Valley Regional Water Board through MS4 permits. The San Francisco Bay Regional Water Board has jurisdiction over eastern Contra Costa County. Both the Phase I and Phase II stormwater regulations require municipalities to reduce urban runoff pollution to the maximum extent practicable through implementation of BMPs. Management programs must include public education, pollution prevention and good housekeeping for municipal operations, implementation of new development BMPs, erosion and sediment control at construction sites, and control of illicit discharges. Phase I programs must also include control programs for industrial sites. Both the Phase I and II regulations provide the regulated municipalities with the flexibility to make their own selection of BMPs in designing their individual programs. Phase 1 permits are issued to individual permittees or to groups of permittees in contiguous areas. The Phase 1 MS4 permits issued to cities and counties in the Delta are described in Chapter 14.

The Phase II program is governed by a General Permit from the State Water Board which expired in 2008, but remains in effect until a new General Permit is adopted. In June 2011 the State Water Board issued a draft order. There are several major changes to the permit, including; compliance tiers with specific BMPs and management measures, waiver certification, new program management requirements and industrial/commercial inspection program, trash reduction programs, water quality monitoring and BMP assessment, and program effectiveness assessments. Public comments were due on September 8, 2011. The State Water Board will issue a revised draft permit in the spring of 2012 and the permit will be considered for adoption by the State Water Board in the late spring or early summer of 2012 (Personal Communication, Christine Sotelo, State Water Board).

The State Water Board has issued general NPDES permits for stormwater discharges from construction sites greater than one acre in size (Construction General Permit) and for industrial discharges (Industrial General Permit). These two permits require that the permittees prepare stormwater pollution prevention plans that identify BMPs to be implemented to control stormwater runoff. The Construction General Permit was renewed in 2009 and contained significant changes, including technology based numeric action levels and numeric effluent limits for pH and turbidity, a shift to risk-based permitting, a requirement that the Stormwater Pollution Prevention Plan be prepared by a qualified developer, a requirement for a sediment monitoring plan if the site discharges to a waterbody listed on the 303(d) list for sediment, a requirement for post-construction stormwater runoff reduction, additional monitoring and reporting requirements, and training and action plans. The Industrial General Permit is in the process of being renewed and is expected to include minimum BMPs, enhanced procedures and reporting, and increased monitoring requirements. The draft permit was issued in January 2011 and comments were due by April 29, 2011.

The State Water Board has also issued a statewide permit for the California Department of Transportation (Caltrans). This permit regulates stormwater discharges from all Caltrans properties, facilities, and activities.

More detail on municipal stormwater dischargers in the Sacramento and San Joaquin basins is provided in Chapter 4.

Agricultural Discharges

The Central Valley has about seven and a half million acres of cropland, with over six and a half million of those acres irrigated. Approximately one-third of the acreage is in the Sacramento Valley, while the remaining two-thirds are in the San Joaquin Valley (including the Tulare Lake Basin). The Tulare Lake Basin includes nearly 25 percent of the total irrigated acreage but only contributes to the San Joaquin Valley during flood conditions.

There are two main regulatory programs related to irrigated agriculture in the watershed, the Rice Pesticides Program and the Irrigated Lands Regulatory Program. The Rice Pesticides Program focuses on five rice pesticides while the Irrigated Lands Regulatory Program covers a wider array of constituents. Both programs have significantly increased the regulatory oversight of agricultural discharges in the Central Valley and contributed to a much better understanding of the actual water quality threats and how those threats can be mitigated.

Rice Pesticides Program

The purpose of the Rice Pesticides Program is to reduce discharges of specified rice pesticides (molinate, carbofuran, thiobencarb, malathion, and methyl parathion) into surface waters leading to the Sacramento River, only one of which (thiobencarb) is still heavily used for rice. Carbofuran and molinate are no longer allowed for use on rice, while malathion and methyl parathion have been replaced by newer pesticides which are not covered in this program. They are regulated through the Irrigated Lands Regulatory Program discussed below. In 1990 the Central Valley Regional Water Board established performance goals for carbofuran (0.4 µg/L), malathion (0.1 µg/L), methyl parathion (0.13 µg/L), molinate (10 µg/L), and thiobencarb (1.5 µg/L) in the Basin Plan In addition, there are water quality objectives for these constituents set at their primary or secondary MCLs for drinking water. The Rice Pesticides Program began in 1983 to address fish toxicity and drinking water taste concerns. It is now jointly administered by the Central Valley Regional Water Board and the California Department of Pesticide Regulation. The Department of Pesticide Regulation provides permit conditions for the County Agricultural Commissioners who issue permits and conduct field work. This program prohibits discharge of rice field drainage unless specific management practices are implemented including; holding water on fields to allow for pesticide dissipation, seepage management, and aerial drift control.

Irrigated Lands Regulatory Program

Other discharges of irrigation water and stormwater runoff from agricultural fields were largely unregulated until the Central Valley Regional Water Board adopted the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands (Conditional Waiver) in December 2002. In response to numerous complaints about the process used to adopt the Conditional Waiver in 2002, the Central Valley Regional Water Board staff worked with stakeholders to revise the program and the Central Valley Regional Water Board rescinded the December 2002 order and adopted the Irrigated Lands Regulatory Program (ILRP) in July 2003. This was developed as an interim program until a long-term program could be developed. In June 2006, the Central Valley Regional Water Board adopted a new waiver that maintained many of the elements of the 2003 Conditional Waiver. The Conditional Waiver required all irrigated agriculture, including rice, row crops, field crops, tree crops, commercial nurseries, managed wetlands, and pastureland, to develop a monitoring program to assess the sources and impacts of discharges from irrigated lands, and to determine if reduction strategies needed to be implemented. Dischargers have the option of obtaining individual permits or joining a coalition. The Conditional Waiver expired in June 2011. The Central Valley Regional Water Board did not adopt a long-term regulatory program at their June 2011 meeting. The Board adopted the Programmatic Environmental Impact Report (EIR) and required staff to begin development of new orders for the existing Coalition Groups, as well as an Individual Order. The Board also approved an extension through June 2013 to complete development of these orders. The key components of the Conditional Waiver and the proposed long-term regulatory program are discussed in the following paragraphs.

Coalition Groups - Although several large irrigation districts opted to apply for individual waivers, most growers joined coalition groups. There are eight coalition groups that cover agricultural areas of the Central Valley and one commodity specific (rice) coalition group.

- California Rice Commission
- East San Joaquin Water Quality Coalition
- Goose Lake Water Quality Coalition
- Pleasant Valley Water Quality Coalition
- Sacramento Valley Water Quality Coalition
- San Joaquin County & Delta Water Quality Coalition
- Southern San Joaquin Valley Water Quality Coalition
- Westlands Water District
- Westside San Joaquin River Watershed Coalition

The five irrigation districts which hold individual discharge orders are; Merced, Modesto, Oakdale, South San Joaquin, and Turlock irrigation districts.

Monitoring Program – The Conditional Waiver Program requires coalition groups to monitor agricultural drainage for a variety of constituents. The constituents vary according to agriculture type and pesticides used and can include TOC, TDS, nutrients, and bacteria. Sampling also varies and is typically conducted during the irrigation season and during storm events. A Monitoring and Reporting Program (MRP) plan must be developed by each coalition group or individual discharger. These must be submitted to and approved by the Central Valley Regional Water Board. Three Coalition-specific MRP Orders have been adopted; the California Rice Commission, the Sacramento Valley Water Quality Coalition, and the Westside San Joaquin River Watershed Coalition. All entities are required to submit periodic monitoring reports to the Central Valley Regional Water Board.

Water Quality Exceedances – The Conditional Waiver Program requires agricultural dischargers to meet water quality objectives in receiving waters but the Waiver states that the Central Valley Regional Water Board does not expect that all applicable water quality standards will be achieved in the five-year period covered by the Conditional Waiver. They do expect that compliance with the requirements of the Conditional Waiver will lead to actions on the part of the agricultural community that will lead to achieving water quality objectives. When a water quality objective is exceeded, the coalition group is required to file various reports with the Central Valley Regional Water Board.

Water Quality Management Plans – Dischargers must prepare and implement Management Plans when a water quality objective has been exceeded more than once in three years. These have been prepared throughout the Central Valley for constituents ranging from toxicity to bacteria to pesticides. The management plan must evaluate the effectiveness of existing management practices in achieving applicable water quality objectives, identify additional actions, including different or additional management practices or education outreach that the coalition group and/or its participants propose to implement to achieve applicable water quality objectives, and identify how the effectiveness of those additional actions will be evaluated.

Long-term Program – In 2006 the Central Valley Regional Water Board began the process of developing a long-term ILRP. This included development of an Existing Conditions Report, which served as a foundation to develop alternatives for a long-term water quality regulatory program to address discharges from irrigated agriculture. An Advisory Workgroup was formed in 2008 to begin development of the form and content of the long-term program. This resulted in development of a Long-Term ILRP Alternatives Document, which presented five alternatives to move forward in the process. In 2010, the Central Valley Regional Water Board began General Stakeholder meetings to inform the public of the current status, provide a "Straw Proposal" of how the long-term program will be presented, and begin to receive comments. A Draft Programmatic EIR was published in July 2010. In February 2011, the Central Valley Regional Water Board published a Recommended Framework for the Long-Term Program. The focus of the Framework is to classify areas into tiers that have varying levels of water quality threats and corresponding levels of management and monitoring requirements. The Framework was not formally adopted by the Central Valley Regional Water Board, but the work is expected to be used in development of specific orders. The program is also being expanded to include discharges to groundwater.

Confined Animal Facilities

Confined animal facilities are defined as any place where cattle, calves, sheep, swine, horses, mules, goats, fowl, or other domestic animals are corralled, penned, tethered, or otherwise enclosed or held and where feeding is by means other than grazing. Historically, dairies were required to confine all waste, wash water, and storm runoff that contacts animal waste on site. Under Section 15 of the California Code of Regulation; discharge to receiving waters was prohibited. Some of the very large dairies and dairies with known problems were required to obtain individual permits under the Central Valley Regional Water Board's Waste Discharge Requirements Program, which covers discharges to land.

As part of a new regulatory process, the Central Valley Regional Water Board requested each existing milk cow dairy to submit a Report of Waste Discharge by October 2005. The Central Valley Regional Water Board reports that there was 100 percent compliance with this submittal. In May 2007, the Central Valley Regional Water Board adopted Order No. R5-2007-0035 Waste Discharge Requirements for Existing Milk Cow Dairies (General Order). This covered all dairies that submitted Reports of Waste Discharge in 2005. This includes over 1,500 dairies in the Central Valley; the majority of these are located in the San Joaquin Valley.

The General Order defines dairy waste as "manure, leachate, process wastewater, and any water, precipitation or rainfall runoff that comes into contact with raw materials, products, or byproducts such as manure, compost piles, feed, silage, milk, or bedding." Waste generated at dairies is stored dry in piles or in liquid form in waste retention ponds. The wastes are then applied to cropland or transported off-site for utilization on cropland as a nutrient source. Dairy wastes contain high concentrations of nutrients (organic nitrogen, ammonia, phosphorus, and potassium), organic carbon, salts, and pathogens. Although the waste materials provide nutrients to crops, they can create nuisance conditions if improperly managed or cause degradation of surface waters and groundwater.

Discharge Prohibitions and Monitoring Requirements

The General Order requires protection of both surface water and groundwater quality. To protect surface water quality, the General Order prohibits discharges of: (1) waste and/or stormwater to surface water from the production area, (2) wastewater to surface water during or following application to cropland, and (3) stormwater to surface water from the land application area where manure or process wastewater has been applied, unless the land application has been managed consistent with a certified nutrient management plan. Owners are required to design detention basins large enough to retain waste and stormwater on-site for a 25-year, 24-hour event. In addition, animals are prohibited from entering surface water within the confinement areas. To protect groundwater quality, the General Order requires: (1) management of manure to prevent leaching of nutrients to groundwater, (2) reconstruction of waste storage ponds that have impacted groundwater quality, and (3) elimination of cross connections that would allow backflow of wastewater into a water supply or irrigation well. The General Order also prohibits discharges that cause or contribute to exceedances of water quality objectives in surface water and groundwater. The General Order requires monitoring of discharges, surface water, groundwater, stormwater, and tailwater for general physical characteristics, nutrients, TDS, and bacteria.

Reports

The General Order requires each dairy to submit an initial Existing Conditions Report and then annual reports demonstrating that they are taking specific steps toward complying with all terms and conditions of the General Order within five years. Each dairy must also submit a waste management plan by 2011, a nutrient management plan if they apply manure to land by 2012, and a salinity report. These reports must demonstrate that they have adequate waste containment to prevent discharges to surface water, have adequate flood protection to comply with state regulations, can operate and maintain their facilities in compliance with the General Order, and can manage their waste applications to land application areas in a manner that will minimize or eliminate the transport of nutrients to surface water.

Compliance

Contact with Central Valley Regional Water Board staff in Redding and Sacramento indicates substantial compliance with the new order. Inspections have been completed for almost all of the facilities, including storm-related inspections. Most of the dairies are pasture-based, meaning that cattle move from barns to fields, and most are smaller, older facilities. In addition, there are several permitted facilities which have ceased operating, but have not yet completed the closure plans to close their permits.

The Dairy Quality Assurance Program

Owners will receive a 50 percent fee reduction if they complete certification through the Dairy Quality Assurance Program. The Dairy Quality Assurance Program was formed in late 1996 as a voluntary program, sponsored by the State Water Board, the California Department of Food and Agriculture, and the University of California Cooperative Extension, to assist dairy owners in complying with regulations and improving sanitary conditions at dairies. The program core components include:

- Attendance of a six hour education short course on farm management.
- Development of an individual Farm Management Plan.
- Third party evaluation, conducted by California Department of Food and Agriculture inspectors who have received additional training from the University of California, Davis and the Central Valley Regional Water Board.

Once a dairy operator completes all three of these components, a certification is issued. To date, over 1,800 dairies have been certified in the Central Valley region.

Central Valley Salinity Alternatives for Long-Term Sustainability

The Central Valley Regional Water Board, the State Water Board, and the Central Valley Salinity Coalition are working collaboratively on the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) project. The Coalition was formed in July 2008 to organize, facilitate, and fund efforts needed to achieve the goals of the CV-SALTS initiative. The goal of this effort is to develop a comprehensive salinity and nitrate management program for the Central Valley. This effort was initiated in January 2006 and a background report on the salinity issues in the Central Valley was prepared in May 2006 (Central Valley Regional Water Board, 2006). The scope of the initiative includes salinity, namely salt and boron, as well as nitrate. This includes impacts to both surface water and groundwater. The work focuses on studies to assess sources of salinity, strategies for reduction, development of key tolerance information, as well as public outreach to identify all salinity concerns.

Development of the Basin Plan Amendment for salt and boron on the San Joaquin River upstream of Vernalis has been assigned to the CV-SALTS initiative. The Lower San Joaquin River Committee was created to review information and develop recommendations for this basin planning effort.

Central Valley Drinking Water Policy

In the 1990s, California Urban Water Agencies (CUWA) recognized that many of the constituents of concern to drinking water suppliers are not included as objectives in the Basin Plan (disinfection byproduct precursors, pathogens, nutrients) or the current objectives are not based on drinking water concerns (salinity, chloride). As a result, there is limited ability to require dischargers to monitor or control these constituents. In addition, since there are no objectives for these constituents, drinking water constituents are not considered when the Central Valley Regional Water Board develops recommendations to the State Water Board for its list of impaired water bodies (303d list) which triggers the development of TMDLs. As discussed in Chapter 4, the population of the Central Valley is rapidly increasing so there are concerns that water quality will degrade without a regulatory mechanism to control discharges of the drinking water constituents. CUWA worked with the Central Valley Regional Water Board and the California Bay Delta Program (CALFED) to include the development of a drinking water policy for the Central Valley in the CALFED Record of Decision. As a result, the Central Valley Regional Water Board is engaged in a multi-year effort to develop a policy for protecting source water for the beneficial use of drinking water.

In 2002, the Central Valley Drinking Water Policy Work Group was formed to help Central Valley Regional Water Board staff develop and implement a work plan that describes the technical studies needed to develop a drinking water policy for the Central Valley. The Work Group consists of stakeholders representing drinking water, wastewater, agricultural, urban runoff, and public interests. The drinking water policy work plan lays out a comprehensive watershed-based strategy for identifying contaminant sources and cost-effective control strategies. The technical studies needed to support the policy were completed by May 2011, and the Work Group completed a report summarizing the findings from the technical work in February 2012. Highlights of the technical work include:

- DBP precursors (organic carbon and bromide), salinity, nutrients, pathogens (*Giardia* and *Cryptosporidium*) and fecal indicator bacteria were identified as the priority drinking water constituents of concern.

- Conceptual models were developed for organic carbon, nutrients salinity, and pathogens.

- A review of plans, policies, and objectives established in other states and countries was conducted. There is no comparable process for adoption of drinking water constituent objectives.

- The Work Group identified three major sources of the priority water quality constituents: wastewater treatment plants (publically owned treatment works or POTWs), urban runoff, and irrigated agriculture.

- A report was prepared on wastewater treatment plants in the Central Valley including current treatment and planned future treatment. Three future (2030) wastewater treatment scenarios were developed.

- A literature review was conducted to evaluate urban runoff management practices to determine their effectiveness in removing drinking water constituents. Three future (2030) urban runoff scenarios were developed.

- The future scenarios for wastewater and urban runoff included the Planned Future, which projected the current regulatory requirements forward to 2030 with modified land use and population; the Plausible Future, which included more stringent, yet plausible, regulatory requirements; and the Outer Boundary Future, which projected "limit of technology" regulatory requirements.

- For agriculture, current loads were calculated but future scenarios included arbitrary reductions in loads because information was not available on load reductions that could be achieved by implementing management practices.

- The source evaluations indicated that the combined loads of drinking water constituents of concern from wastewater treatment plants, urban runoff, and irrigated agriculture will likely decrease in the future as a result of changing land use and regulatory actions already taken by the Central Valley Regional Water Board.

The Watershed Analysis Risk Management Framework (WARMF) analytical model for the San Joaquin watershed was refined, and a model was developed for the Sacramento watershed. Agricultural land use was refined to include more crop types than in the original WARMF model. Due to schedule and budget constraints, the WARMF model wasn't fully calibrated.

- The output from the WARMF models was used to run the Delta Simulation Model 2 (DSM2) for DOC, EC, and nutrients to evaluate the impact at the Delta pumping plants of changes as a result of the potential future scenarios. Due to the calibration problem with WARMF, the DSM2 results are not considered reliable.

- An analysis was conducted of water treatment needs for the upper Sacramento River watershed, the Delta, and the east and west branches of the California Aqueduct using the USEPA Water Treatment Plant Model. Plausible Future and Outer Boundary Future regulatory scenarios were developed.

- The Water Treatment Plant model was used to evaluate water treatment needs under the future drinking water regulatory scenarios. In the Plausible Future regulatory scenario, the model predicted that water treatment upgrades would be needed for water treatment plants treating water from the upper watershed (Sacramento River), the Delta, and at some locations along the California Aqueduct.

The Record of Decision called for development of the policy by the end of 2004, which was an unrealistic deadline given the amount of technical work to be completed and the timeframe for adopting a Basin Plan amendment. In July 2004, the Central Valley Regional Water Board adopted a resolution supporting the need for the policy. In July 2010, the Central Valley Regional Water Board adopted a resolution reaffirming support for development of the policy and requiring an outline of the policy by July 2011 and a final policy for Board consideration by July 2013. The Work Group is currently working on drafting a policy that will include a narrative water quality objective for pathogens and an explanation of how organic carbon will be considered under the existing chemical constituents narrative objective. Salinity is being addressed by the CV-SALTS process and nutrients are being addressed by the State Water Board's Nutrient Numeric Endpoint process.

Potential Actions

MWQI and CDPH should Participate in Regulatory Development and Provide Comment Letters on Source Water Protection Programs and Regulations, when Feasible.

Individual SWP Contractors and water organizations such as ACWA and CUWA track regulatory development for their members. While there is no need for SWPCA to track the pending regulations, SWPCA, MWQI, and CDPH staff should lend support to organizations such as CUWA. CUWA has historically notified MWQI and CDPH when critical permits and regulatory programs are being developed in which MWQI and CDPH staff can contribute based on their knowledge of drinking water issues, the Delta, and the SWP watershed. MWQI and CDPH should continue to participate in these processes, when feasible.

BIOLOGICAL OPINIONS

The U.S. Fish and Wildlife Service (USFWS) is required to issue biological opinions on projects that have the potential to impact federally listed threatened and endangered species. Similarly, the National Marine Fisheries Service (NMFS) is required to issue biological opinions on projects that have the potential to impact federally listed marine and anadromous fish species. Until 2004, a 1995 delta smelt biological opinion and a 1993 winter-run Chinook salmon biological opinion governed limitations on Delta exports. A proposed change in coordinated operation of the SWP and Central Valley Project (CVP) in 2004 (including increased Delta exports) resulted in the need to develop updated biological opinions.

U.S. Fish and Wildlife Service Delta Smelt Biological Opinion

The delta smelt was listed as a threatened species under the federal Endangered Species Act and the California Endangered Species Act in 1993. In 2010, the California Fish and Game Commission listed the delta smelt as an endangered species. There has been a significant decline in delta smelt abundance since 2000. The USFWS issued the biological opinion on the Long-term Operations Criteria and Plan (OCAP) for coordinated operations of the SWP and CVP in 2005 concluding that the Delta pumping plants posed no threat to delta smelt. The Natural Resources Defense Council and other environmental groups disagreed and filed suit later that year. In May 2007, U.S. District Judge Oliver Wanger invalidated the biological opinion and ordered the USFWS to rewrite it by September 15, 2008. This order, known as the Wanger Decision, also established flow conditions on Old and Middle rivers to limit the take of delta smelt at the south Delta pumping plants. The revised biological opinion was issued on December 15, 2008, concluding that the pumps were likely to jeopardize the federally protected delta smelt. The biological opinion included a Reasonable and Prudent Alternative (RPA) designed to allow the projects to continue operating without causing jeopardy to the delta smelt or adversely affecting its critical habitat. The RPA included operational components designed to reduce entrainment of delta smelt during critical times of the year by limiting water exports at the south Delta pumping plants. This resulted in major water supply impacts. Water users challenged the plan in the spring of 2009 claiming it relied on poor science and targeted Delta pumping when other Delta issues such as contaminants, unscreened agricultural diversions, and invasive species were also harming delta smelt. In December 2010, Judge Wanger overturned major portions of the biological opinion, finding that restrictions on Delta pumping required under the plan were not adequately justified. In March 2011, Judge Wanger issued a final written judgment that required the USFWS to revise the biological opinion by October 1, 2011. The judgment also includes interim flow requirements for Old and Middle rivers to protect delta smelt through June 30, 2011 and allows water contractors and environmental organizations to participate in weekly meetings with federal agencies to review Delta conditions and determine if pumping should be limited. The deadline for the final biological opinion was extended to December 1, 2013 in May 2011.

National Marine Fisheries Service Biological Opinion for Salmon and other Listed Species

Due to the proposed change in coordinated operation of the SWP and CVP in 2004, NMFS issued a biological opinion which initially found no jeopardy to listed species. This biological opinion was voluntarily withdrawn and rewritten. In June 2009, NMFS released a biological opinion on OCAP that covers winter-run and spring-run Chinook salmon, steelhead, green sturgeon, and killer whales, concluding that the operations of the SWP and CVP are jeopardizing these species. Killer whales are included because salmon are one of their food sources. The RPA contains a suite of actions for the Sacramento, American, and Stanislaus rivers including requirements to release adequate flows of cold water from the major dams, restoration of floodplain habitat, and restoration of spawning habitat. Actions required in the Delta include modification of Delta Cross Channel operations, controls on negative flows in Old and Middle rivers, restrictions on pumping, and improvements to fish screening and salvage operations. In August 2009 the State Water Contractors requested that the biological opinion for salmon be overturned. Judge Wanger ruled in September 2011 that the biological opinion was arbitrary, capricious, and unlawful and remanded it to NMFS. The deadline for completion of a revised biological opinion is February 2016. In January 2012, NMFS, DWR, and other public agencies entered into an agreement on SWP and CVP operations between April and May 2012 and scientific studies to be conducted to evaluate the effects of project operations on salmonids.

OCAP Integrated Annual Review Workshop

The NMFS RPA requires the Bureau of Reclamation and NMFS to work with the Delta Science program to host a workshop by November 30 of each year to review the prior water year's operations and to determine whether any measures prescribed in the RPA should be altered. Under direction from the Secretaries of Commerce and Interior the review was expanded to include implementation of the USFWS delta smelt actions. Since the OCAP biological opinions were issued, NMFS, USFWS, and other agencies have been conducting research and monitoring to determine the effectiveness of the RPA actions. The Delta Science Program assembled an independent review panel of national experts to review the findings of the research and monitoring in November 2010. The panel issued their report in December 2010, commenting on many specific actions and recommending that biological models be developed to link the physical actions required by the RPA to biological targets. Another independent review was conducted in November 2011 and the report was issued in December 2011. The panel concluded that most of the RPA actions that would have constrained water exports under drier conditions were neither triggered nor applied in Water Year 2011 because it was classified as wet in both the Sacramento and San Joaquin watersheds. The panel also concluded that after two years of operating under the RPA actions, conclusions could not be drawn on their effectiveness in restoring fish populations.

Potential Water Quality Impacts

The water quality impacts of the biological opinions have not been evaluated with modeling studies (Personal Communication, Tara Smith, DWR). Chapter 15 contains a qualitative discussion of the potential impacts on water quality.

Potential Actions

None

The SWC has historically taken the lead on tracking and responding to the biological opinions. There is no need for SWPCA or MWQI to track and comment on the revised biological opinions when they are reissued by USFWS and NMFS.

POLICY SETTING

The Delta provides drinking water for over 25 million Californians in the San Francisco Bay Area, the Central Coast, and Southern California. Federal regulatory actions to protect threatened and endangered fish have made water supplies increasingly unreliable. This section contains a description of the major programs aimed at restoring the Bay-Delta ecosystem and improving water supply reliability.

CALFED

A number of state and federal agencies signed an agreement in June 1994 to coordinate their actions to meet water quality standards to protect the Delta, coordinate the operation of the SWP and CVP more closely with environmental mandates, and develop a process to establish a long-term Bay-Delta solution to restore the ecosystem health of the Delta while improving water supply reliability, water quality, and levee stability. This agreement laid the foundation for the Bay-Delta Accord and CALFED. The CALFED Program was described in the 2006 Update with an emphasis on the Water Quality Program. Subsequent to completion of the 2006 Update, CALFED issued the CALFED Bay-Delta Program Performance Assessment in June 2007. The Water Quality Program was ranked poorly with “low progress” during the seven years of the CALFED Program due largely to a lack of sufficient funding. In 2006, the Little Hoover Commission issued a report declaring that CALFED was essentially a failure. The CALFED Program was disbanded and a few years later, its authorizing statute was formally repealed.

DELTA VISION PROCESS

Governor Arnold Schwarzenegger issued Executive Order S-17-06 in September 2006 to form the Delta Vision process to “develop a durable vision for sustainable management of the Delta” that can “restore and maintain identified functions and values that are determined to be important to the environmental quality of the Delta and the economic and social well being of the people of the state." The Executive Order established the seven-member independent Blue Ribbon Task Force and charged them with developing a vision to repair the ecological damage to the Delta in 2007 and then prepare a strategic plan to sustain the Delta in future decades while ensuring a reliable water supply for Californians who depend on water from the Delta. The Executive Order also established the five-member Delta Vision Committee consisting of the Secretaries of Resources; California Environmental Protection Agency; the Business, Transportation, and Housing Agency; and the Department of Food and Agriculture; and the president of the Public Utilities Commission. The Delta Vision Committee was charged with reporting to the Governor about the vision and strategic plan in late 2008.

Delta Vision

The Blue Ribbon Task Force received input from the Stakeholder Coordination Group, the Delta Vision Science Advisors, and numerous stakeholders who attended Task Force meetings. The Task Force released the final Delta Vision report in November 2007. The Delta Vision contains twelve integrated and linked recommendations with the first being, "The Delta ecosystem and a reliable water supply for California are the primary, co-equal goals for sustainable management of the Delta." The focus of the Delta Vision was on improving the Delta ecosystem, sustaining the Delta as a unique resource, and improving water supply reliability. Drinking water quality was briefly mentioned as one of the factors to consider in evaluating conveyance alternatives.

Delta Vision Strategic Plan

The Delta Vision Blue Ribbon Task Force expanded the stakeholder process and formed four workgroups of stakeholders (California Delta, Delta Ecosystem as Part of a Healthy Estuary, Water Supply and Reliability, and Governance and Finance) and formed the Delta Vision Scenario Assessment Team to provide information and assist in development of ideas for inclusion in the Delta Vision Strategic Plan. The final Strategic Plan was released in October 2008. The Strategic Plan contains seven goals with numerous strategies and actions to achieve those goals. The following paragraphs focus on the aspects of the Strategic Plan that address or could potentially impact drinking water quality.

Delta Vision Recommendations
1. The Delta ecosystem and a reliable water supply for California are the primary, co-equal goals for sustainable management of the Delta.
2. The California Delta is a unique and valued area, warranting recognition and special legal status from the State of California.
3. The Delta ecosystem must function as an integral part of a healthy estuary.
4. California's water supply is limited and must be managed with significantly higher efficiency to be adequate for its future population, growing economy, and vital environment.
5. The foundation for policymaking about California water resources must be the longstanding constitutional principles of "reasonable use" and "public trust;" these principles are particularly important and applicable to the Delta.
6. The goals of conservation, efficiency, and sustainable use must drive California water policies.
7. A revitalized Delta ecosystem will require reduced diversions – or changes in patterns and timing of those diversions upstream, within the Delta, and exported from the Delta – at critical times.
8. New facilities for conveyance and storage, and better linkage between the two, are needed to better manage California's water resources for both the estuary and exports.
9. Major investments in the California Delta and the statewide water management system must integrate and be consistent with specific policies in this vision. In particular, these strategic investments must strengthen selected levees, improve floodplain management, and improve water circulation and quality.
10. The current boundaries and governance system of the Delta must be changed. It is essential to have an independent body with authority to achieve the co-equal goals of ecosystem revitalization and adequate water supply for California – while also recognizing the importance of the Delta as a unique and valued area. This body must have secure funding and the ability to approve spending, planning, and water export levels.
11. Discouraging inappropriate urbanization of the Delta is critical both to preserve the Delta's unique character and to ensure adequate public safety.
12. Institutions and policies for the Delta should be designed for resiliency and adaptation.

Delta Vision Strategic Plan Goals
1. Legally acknowledge the co-equal goals of restoring the Delta ecosystem and creating a more reliable water supply for California
2. Recognize and enhance the unique cultural, recreational, and agricultural values of the California Delta as an evolving place, an action critical to achieving the co-equal goals.
3. Restore the Delta ecosystem as the heart of a healthy estuary.
4. Promote statewide water conservation, efficiency, and sustainable use.
5. Build facilities to improve the existing water conveyance system and expand statewide storage, and operate both to achieve the co-equal goals.
6. Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and strategic levee investments.
7. Establish a new governance structure with the authority, responsibility, accountability, science support, and secure funding to achieve these goals.

Actions that could Improve Delta Drinking Water Quality

One of the strategies to implement Goal 3 – Restore the Delta ecosystem as the heart of a healthy estuary – is to improve water quality to meet drinking water, agriculture, and ecosystem long-term goals. This strategy contains two actions that could potentially improve drinking water quality and one action that would result in improved monitoring of water quality. The actions and the responses to the actions are briefly summarized in this section.

- Require the Central Valley Regional Water Board to conduct three actions:
  - Immediately re-evaluate wastewater treatment plant discharges into Delta waterways and upstream rivers and set discharge requirements at levels that are fully protective of human health and ecosystem needs – As described in more detail in Chapter 4, the Central Valley Regional Water Board has continued to follow existing state regulations in adopting permits for wastewater treatment plants. A number of wastewater dischargers have been issued discharge permits that require tertiary treatment.
  - Adopt by 2010 a long-term program to regulate discharges from irrigated agricultural lands – As described in the Source Water Protection section, the Central Valley Regional Water Board held a public hearing on the Long-term ILRP in April 2011 and will hold another hearing in June 2011.
  - Review by 2012 the impacts of urban runoff on Delta water quality and adopt a plan to reduce or eliminate those impacts – The Central Valley Regional Water Board has continued to issue permits for urban runoff but was not given a mandate or funding to develop a plan to reduce or eliminate the impacts of urban runoff.
- Relocate as many Delta drinking water intakes as feasible away from sensitive habitats and to channels where water quality is higher – The BDCP section contains a description of the effort to improve water quality for SWP Contractors who take water from the south Delta. Chapter 4 contains a description of the activities undertaken by the North Bay Aqueduct Contractors to pursue an alternate intake on the Sacramento River.
- Begin comprehensive monitoring of water quality and Delta fish and wildlife health in 2009 – The Central Valley Regional Water Board and the State Water Board have initiated the Delta Regional Monitoring Program. Efforts to date have been largely aimed at developing information on the different entities that are currently conducting Delta monitoring programs and on communicating with stakeholders about the need for a regional approach.

Goal 5 calls for a dual conveyance system to improve water supply reliability and ecosystem health. The dual conveyance system would consist of existing through-Delta facilities and an isolated facility that would divert water from the Sacramento River and convey it to the south Delta export pumps. A dual conveyance facility could improve water quality exported from the Delta by taking more high quality water from the Sacramento River. This would be highly dependent on the volume of Sacramento River water diverted, the timing of the diversions, and the locations of the diversion structures. The impact of the Sacramento Regional Wastewater Treatment Plant discharge would need to be considered if an intake is located near Freeport.

Actions that could Degrade Delta Drinking Water Quality

Goal 3 – Restore the Delta ecosystem as the heart of a healthy estuary – contains a number of strategies and actions that call for habitat restoration in the Delta, although there are no specific areas or types of habitat identified. As described later in Chapter 14, habitat restoration could potentially increase organic carbon concentrations at Delta pumping plants. The Strategic Plan addresses this potential impact by calling for the relocation of drinking water intakes.

2009 COMPREHENSIVE WATER PACKAGE

In November 2009, the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act), consisting of four legislative bills and a supporting bond bill, was approved by the legislature and signed by Governor Schwarzenegger. The legislation establishes the governmental framework to achieve the co-equal goals of providing a more reliable water supply to California and restoring and enhancing the Delta ecosystem. The package includes requirements to improve the management of our water resources by monitoring groundwater basins, developing agricultural water management plans, reducing statewide per capita water consumption 20 percent by 2020, and reporting water diversions and uses in the Delta. It also appropriates $250 million for grants and expenditures for projects to reduce dependence on the Delta. The bond bill was originally scheduled for the November 2010 ballot but it was postponed. It is unclear at this time if it will be on the November 2012 ballot. If enacted, it would provide funding for California's aging water infrastructure and for projects and programs to improve the ecosystem and water supply reliability for California.

DELTA STEWARDSHIP COUNCIL

The Delta Stewardship Council was established on February 3, 2010 by Senate Bill (SB) 1 (Simitian) – Chapter 5 of the Seventh Extraordinary Session of 2009 (SBX7 1), and is considered the successor entity to the California Bay-Delta Authority and the CALFED Program. The Council's mission is to achieve the state's "co-equal" goals of 1) enhancing the reliability of the water supply for California and 2) protecting, restoring, and enhancing the Delta ecosystem. These goals are to be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

Council Membership

The Delta Stewardship Council consists of seven members with diverse expertise intended to provide a broad statewide perspective. The Governor appointed four members, the Senate and Assembly appointed one each, and the seventh member is the Chairperson of the Delta Protection Commission.

Council Responsibilities

The Council is responsible for carrying out the following tasks:

- Developing a sustainable management plan for the Delta (Delta Plan).
- Developing performance measures to access and track progress and changes to the health of the Delta ecosystem, fisheries, and water supply reliability.
- Determining, on appeal, if a state or local agency's project in the Delta is consistent with the Delta Plan.
- Determining, on appeal, whether the BDCP meets statutory criteria in the Delta Reform Act for inclusion in the Delta Plan.

The Delta Plan

To achieve the co-equal goals, a legally enforceable Delta Plan is intended to guide state and local agency activities related to the Delta. The Council intends to develop and implement a strategy to appropriately engage participation by federal and state agencies with responsibilities in the Delta and develop a scientific program to manage the Delta through the Delta Science Program and the Delta Independent Science Board. To achieve the co-equal goals, the Delta Plan must reflect the following state policy objectives:

- Manage the Delta's water and environmental resources and the state's water resources over the long-term.
- Protect and enhance the unique cultural, recreational, and agricultural values of the Delta as an evolving place.
- Restore the Delta ecosystem, including its fisheries and wildlife, as the heart of a healthy estuary and wetland ecosystem.
- Promote statewide water conservation, water use efficiency, and sustainable water use.
- Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.
- Improve the water conveyance system and expand statewide water storage.
- Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and investments in flood protection.
- Establish a new governance structure with the authority, responsibility, accountability, scientific support, and adequate and secure funding to achieve these objectives.

The Delta Plan is intended to lay out the initial roadmap on how to achieve the co-equal goals and inherent objectives in the years to come. It will specify the regulatory policies and recommendations that will guide implementation of the Delta Plan over the next five years and beyond. The Final Staff Draft was released in May 2012 and the Draft EIR on the Delta Plan was released in November 2011. The Council will adopt the Delta Plan in the fall of 2012. When the Delta Plan is completed, state and local agencies proposing actions or projects within the Delta will need to certify for the Delta Stewardship Council that those efforts are consistent with the Delta Plan.

The following paragraphs focus on the aspects of the Delta Plan that address or could potentially impact drinking water quality:

Actions that could Improve Delta Drinking Water Quality

The Delta Plan contains twelve recommendations to improve water quality. Four of these have the most potential to improve Delta drinking water quality.

- The Central Valley Regional Water Board should complete the Central Valley Drinking Water Policy by July 2013. As described previously, the Central Valley Regional Water Board is working on this policy and expects to complete it by July 2013.

- DWR should complete the North Bay Aqueduct Alternative Intake Project EIR by July 1, 2012, and begin construction as soon as possible thereafter. The status of this project is discussed in Chapter 14.

- The State Water Board should complete the Proposed Policy for Nutrients for Inland Surface Waters of the State of California by January 1, 2014. The State Water Board and the San Francisco and Central Valley Regional Water Boards should develop and adopt nutrient objectives for the Delta and Suisun Marsh by January 1, 2018.

- The Central Valley Regional Water Board should require entities that discharge wastewater treatment plant effluent or urban runoff to Delta waters to evaluate whether all or a portion of the discharge can be recycled, otherwise used, or treated to reduce contaminant loads to the Delta by January 1, 2014.

Actions that could Degrade Delta Drinking Water Quality

The Delta Plan contains policies and recommendations that call for habitat restoration in the Delta and restoration of a more natural flow regime. As discussed previously in the Delta Vision strategic plan section, habitat restoration projects could potentially increase the loads of organic carbon and shift the timing of release of organic carbon to Delta waterways. This topic is discussed in more detail in Chapter 13. Restoring a more natural flow regime would mean that reservoir releases would increase in the winter, spring, and fall to reduce salinity in the Delta. Higher salinity water would be present in the Delta during the summer months. The impact of this action on exported water quality would depend to a large extent on when water is pumped from the Delta.

THE SACRAMENTO-SAN JOAQUIN DELTA CONSERVANCY

The Sacramento-San Joaquin Delta Conservancy (Conservancy) was created by SBX7 1. The Conservancy's mission is to support efforts that advance both environmental protection and the economic well-being of Delta residents in a complementary manner. The Conservancy is the state's primary agency for implementing ecosystem restoration in the Delta.

The Delta Conservancy Board

The Conservancy is governed by a board consisting of 11 voting member and two non-voting members. The voting members include the Secretary of the Natural Resources Agency, the state Director of Finance, representatives appointed by the Boards of Supervisors of the Counties of Sacramento, San Joaquin, Solano, and Yolo, two members appointed by the Governor, and one member each appointed by the Senate Rules Committee and the Assembly Speaker. The two non-voting members are a State Senator and Assemblymember, both of whom represent districts that encompass a portion of the Delta.

The Board is advised by ten liaisons from the USFWS, NMFS, Reclamation, the U.S. Army Corps of Engineers, the San Francisco Bay Conservation and Development Commission, the State Coastal Conservancy, the Suisun Resource Conservation District, the Central Valley Flood Protection Board, the Yolo Basin Foundation, and the Delta Protection Commission.

Conservancy Activities

The Conservancy supports efforts to: 1) protect and enhance habitat and habitat restoration; 2) protect and preserve Delta agriculture and working landscapes; 3) increase opportunities for tourism and recreation in the Delta; 4) promote Delta legacy communities and economic vitality in the Delta; 5) increase the Delta's resilience to the effects of natural disasters such as earthquakes and floods; 6) protect and improve water quality; 7) assist the Delta regional economy; 8) identify priority projects and initiatives for which funding is needed; 9) protect, conserve, and restore the region's physical, agricultural, cultural, historical, and living resources; 10) help local agencies in the Delta implement their habitat conservation plans and natural community conservation plans; 11) facilitate take protection and safe harbor agreements for adjacent landowners and local public agencies under federal and state endangered species and habitat conservation laws; and 12) promote environmental education through grant funding.

In early 2011, the Conservancy completed a final draft of its Interim Strategic Plan that lays out its vision, mission, and proposed goals, objectives, and near-term strategies. The Conservancy expects to complete a final Strategic Plan by early 2013.

DELTA SCIENCE PROGRAM AND DELTA INDEPENDENT SCIENCE BOARD

The Delta Science Program (formerly CALFED Science Program) was established to provide the best possible scientific information needed for water and environmental decision-making in the Bay-Delta system. The Delta Science Program funds research through grants and fellowships, facilitates peer review of documents and programs, and communicates scientific information to policy-makers, scientists, and the public through newsletters, workshops, and the San Francisco Estuary & Watershed Science journal.

SBX7 1 established the Delta Independent Science Board (ISB) and required the Delta Stewardship Council to appoint the scientists to sit on this board. The Council appointed ten nationally and internationally prominent scientists in June 2010. The Delta ISB reports to the Council and provides oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta. In addition, the Delta ISB will conduct independent peer reviews of BDCP work products.

DELTA PROTECTION COMMISSION

The Delta Protection Commission (DPC) was established by the Johnston-Baker-Andal-Boatwright Delta Protection Act of 1992. SBX7 1 reduced the number of commissioners from 23 to 15 and established new responsibilities for the DPC. The DPC's primary mission is to act as an appeal and review agency to enhance the orderly development of resources within defined core areas of the Delta. The DPC also works to improve flood protection in the Delta and pursues projects designed to enhance the agricultural, habitat, marine, and recreational resources of the Delta. DPC commission members represent Delta-area reclamation and water agencies, counties, and residents/landowners, plus regional councils of government, relevant state agencies, and ex-officio members from the California State Senate and Assembly.

Responsibilities

The DPC acts as an appeal entity to land use decisions involving projects located in a defined "Primary Zone" of the Delta. The commission also reviews projects located in a defined "Secondary Zone" that may impact the Primary Zone. Its diverse membership is intended to provide stakeholder representation in the areas of agriculture, habitat, recreation, and water.

The DPC developed and adopted a Land Use and Resource Management Plan in 1995 and updated the Management Plan in 2009. Delta-area agency General Plans must, among other things, be consistent with the Management Plan.

Projects

In addition to its project review responsibilities, the DPC participates in other Delta-related strategic planning, administers the planning process for development of the "Great California Delta Trail," a network of hiking trails through all five county regions of the Delta, and is seeking a National Heritage designation for the Delta.

Primary Zone Study

SBX7 1 requires the DPC to develop recommendations for expanding the Primary Zone of the Delta to enhance the commission's ability to protect Delta resources. Although the Primary Zone Study, approved by the DPC in December 2010, recommended specific Primary Zone and Secondary Zone boundary changes to the DPC, the commission deferred formal recommendations until a companion Economic Sustainability Plan is completed. A Public

Review Draft Economic Sustainability Plan was released for public comment in October 2011. The report has not yet been finalized.

Abandoned Vessel Removal

The DPC takes an active role, along with county, regional and state agencies, in abating the nuisance caused by vessels, both private and commercial, abandoned in the Delta. These abandoned vessels pose navigational hazards and can release hazardous materials into the Delta environment. The Abandoned Watercraft Abatement Program, administered by the Department of Boating and Waterways, helps both the DPC and the five counties in which the Delta is located to identify, secure and remove as many vessels as funding and personnel resources permit.

FLOW CRITERIA FOR THE DELTA ECOSYSTEM

In accordance with the Delta Reform Act of 2009, the State Water Board approved new flow criteria in August 2010 for the Delta ecosystem that are necessary to protect public trust resources. The flow criteria report will inform planning decisions for the Delta Stewardship Council’s Delta Plan and the BDCP. Under the circumstances analyzed in the report, the State Water Board found that current flows are insufficient to support native Delta fishes and that there is sufficient scientific information to support the need for increased flows to protect public trust resources. To achieve the goal of halting the population decline and increasing the populations of native fish species, as well as species of commercial and recreational importance, the report includes criteria for percentages of natural or unimpaired flows that provide fisheries protection under existing conditions. The report also summarizes other issues and concepts including: increased fall Delta outflow in wet and above normal years; fall pulse flows on the Sacramento and San Joaquin rivers; and flow criteria in the Delta to help protect fish from mortality in the central and southern Delta resulting from operations of the south Delta pumping plants.

The flow criteria are currently for planning purposes only and do not have any regulatory or adjudicatory effect. In the State Water Board’s development of Delta flow objectives with regulatory effect, it must ensure the reasonable protection of beneficial uses, which may entail balancing of competing beneficial uses of water, including municipal and industrial uses, agricultural uses, and other environmental uses. The State Water Board’s evaluation will include an analysis of the effect of any changed flow objectives on the environment in the watersheds in which Delta flows originate, the Delta, and the areas in which Delta water is used. It will also include an analysis of the economic impacts that result from changed flow objectives.

In the future, if DWR and/or Reclamation ask the State Water Board to amend the water right permits for the SWP and/or the CVP to move the authorized points of diversion for the projects from the southern Delta to the Sacramento River, Water Code section 85086 directs the State Water Board to include in any order approving a change in the point of the diversion of the projects appropriate Delta flow criteria. At that time, the State Water Board will determine appropriate permit terms and conditions. That decision will take into consideration the flow criteria needed to protect public trust resources, but will also take many other factors into consideration, including any newly developed scientific information, habitat conditions at the time, and other policies of the State, including the relative benefit to be derived from all beneficial uses of water.

BAY DELTA CONSERVATION PLAN

The BDCP is being prepared through a collaboration of state and federal agencies, water agencies, environmental organizations, and other interested parties with the goal of protecting and restoring the ecological health of the Delta and providing a more reliable water supply. The BDCP is being developed in compliance with the federal Endangered Species Act and the California Natural Communities Conservation Planning Act. When completed, the BDCP will provide the basis for the issuance of endangered species permits for the operation of the state and federal water projects. The goal of the BDCP is to promote the recovery of endangered, threatened, and sensitive species and their habitats in the Delta in a way that also improves the reliability of water supplies exported from the Delta. The plan will be implemented over the next 50 years.

Starting in December 2011, various working draft chapters of the BDCP and EIR/EIS have been released for public review. The formal draft BDCP and EIR/EIS were scheduled to be released on June 29, 2012 and the final documents were scheduled for the end of 2012. On May 3, 2012, the Secretary for Natural Resources announced that there was a delay in the schedule. At this time, the draft documents are scheduled for release in September 2012. The Final Staff Draft of the Delta Plan calls for completion of the BDCP and acquisition of incidental take permits by December 31, 2014. Key aspects of the plan include:

- Water Facilities and Operations – The plan calls for up to five new intakes on the Sacramento River between Clarksburg and Walnut Grove that would divert up to 15,000 cfs. The working draft of Chapter 4 of the BDCP states that a decision has not been made on whether water will be conveyed in a pipeline/tunnel or a canal to the south Delta pumping plants. Water would also be conveyed through the Delta with the existing facilities. This is being referred to as the dual conveyance alternative. These facilities would allow the water operations to be better aligned with natural seasonal flow patterns and would reduce the impacts of diverting water at the South Delta pumping plants. The dual conveyance operating criteria are still being discussed. Construction of the new intake facilities and conveyance structures will take at least ten years.

- Aquatic and Terrestrial Species Habitat – The plan covers 11 fish species and 52 sensitive wildlife and plant species and identifies conservation measures to help in their recovery. There are numerous conservation measures that have been identified, including reconnecting floodplains and developing up to 65,000 acres of freshwater and brackish tidal habitat. Up to 5,000 acres of freshwater tidal habitat would be created in the south Delta.

- Other Stressors Reduction – The plan calls for reducing the adverse effects of toxic substances and invasive species on the covered species.

- Adaptive Management Decision Making Process – This would provide a mechanism to make adjustments to conservation measures based on new scientific information.

- Governance – The primary responsibility for plan implementation would lie with the BDCP Implementation Office. Oversight of plan implementation would be conducted by the BDCP Implementation Board, comprised of permitting agencies, permittees, and supporting organizations including non-governmental organizations and the Delta Conservancy. A BDCP Stakeholder Committee would also be established to provide input on implementation issues.

The plan contains actions that could improve drinking water quality by drawing water from the Sacramento River and actions that could harm water quality, such as the restoration of tidal marshes. The impacts of the plan on water quality will be evaluated in the Environmental Impact Report/Environmental Impact Statement (EIR/EIS). A preliminary draft of the Water Quality Chapter was released on February 29, 2012. A few of the key conclusions with respect to the dual conveyance with a tunnel and five intakes on the Sacramento River alternative are:

- Organic Carbon
  - Barker Slough – Not discussed.
  - South Delta Export Locations – Long-term average DOC would decrease by 0.4 mg/L at both pumping plants.
- Bromide
  - Barker Slough – Modeled long-term concentrations of bromide would increase from 51 µg/l to 71 µg/L. The predicted increases in bromide concentrations at Barker Slough may necessitate changes in treatment plant operations or treatment plant facilities. This is judged to be a significant impact and the report calls for mitigating this impact by relocating the NBA intake.
  - South Delta Export Locations – At the Banks and Jones pumping plants long-term bromide concentrations would decrease by 37 percent.
- EC
  - Barker Slough – Not discussed.
  - South Delta Export Locations – Average EC levels would decrease by 22 percent at Banks and by 19 percent at Jones.
- Pathogens
  - Barker Slough – Not discussed
  - South Delta Export Locations – No impacts on bin/treatment levels.

DELTA HABITAT CONSERVATION AND CONVEYANCE PROGRAM

The Delta Habitat Conservation and Conveyance Program (DHCCP) is a partnership between DWR and Reclamation to evaluate the ecosystem restoration and water conveyance alternative identified by the BDCP along with other conveyance alternatives. DHCCP will also develop engineering options for habitat restoration, other stressors, and water conveyance. DHCCP will prepare the EIR/EIS on the BDCP. The state and federal lead agencies for the EIR/EIS are DWR, Reclamation, USFWS, and NMFS. The EIR/EIS is being developed in cooperation with the Department of Fish and Game, USEPA, and the U.S. Army Corps of Engineers. The draft Delta EIR/EIS is scheduled to be completed by mid-2012 and a final EIR/EIS is scheduled for completion in late 2012.

USEPA ADVANCED NOTICE OF PROPOSED RULEMAKING

The USEPA Region 9 issued an Advance Notice of Proposed Rulemaking (ANPR) on February 10, 2011. This ANPR initiates an assessment of the effectiveness of current programs designed to protect ecosystem water quality and aquatic species habitat in the Bay Delta Estuary. The ANPR does not address drinking water quality issues. Through the ANPR, USEPA solicited public input on how ecosystem water quality and aquatic resource protection goals can be achieved in the Bay Delta Estuary. USEPA expects to release a synthesis report in the spring of 2012 and then determine if new regulations are needed (Personal Communication, Erin Foresman, USEPA).

SAN JOAQUIN RIVER RESTORATION PROGRAM

The San Joaquin River was dammed in 1942 and most of the water was diverted to farms and cities on the east side of the San Joaquin Valley. This resulted in a 60 mile stretch of the river essentially drying up and cut off Chinook salmon from their historic spawning grounds. A coalition led by the Natural Resources Defense Council filed a lawsuit in 1988 challenging the U.S. Department of the Interior’s intention to renew the Friant Division 40-year water service contracts without the preparation of an EIS. The complaint was expanded to include other claims, including a claim under the federal Endangered Species Act and a claim that operation of Friant Dam violated a California Fish and Game Code section that requires dams to release sufficient water to keep fish in good condition below the dam. This latter claim became the focus of the litigation, with all claims resolved by the settlement.

The San Joaquin River Restoration Program resulted from a September 2006 settlement of the 18-year-old lawsuit regarding sufficient fish habitat on the San Joaquin River below Friant Dam. The parties to the settlement are the U.S. Departments of the Interior and Commerce, the Natural Resources Defense Council, and the Friant Water Users Authority. The programs’s goals are to restore and maintain fish populations in “good condition” in the main stem of the San Joaquin River between Friant Dam and the confluence of the Merced River, while reducing or avoiding adverse water supply impacts to all the Friant Division long-term contractors that may result from the interim flows and restoration flows required by the settlement. The effort to restore the San Joaquin River covers 153 miles and involves not only restoring flows to about 60 miles of dry river bed, but also requires significant improvements to channels, levees, and fish passages. Funds for the project come from water users, state bond initiatives and federal authorizations.

The settlement requires specific water releases from Friant Dam to meet the various life stage needs for spring- run and fall-run Chinook salmon. In addition to a base volume equal to the average Friant Dam release of 116,741 acre-feet/year, the settlement requires approximately 247,000 acre-feet/year in most dry years and about 555,000 acre-feet/year in wet years. The first interim restoration flows were released from Friant Dam in October 2009. Flows will be gradually increased with full restoration flows scheduled to begin by January 1, 2014. Chinook salmon will be reintroduced by the end of 2012.

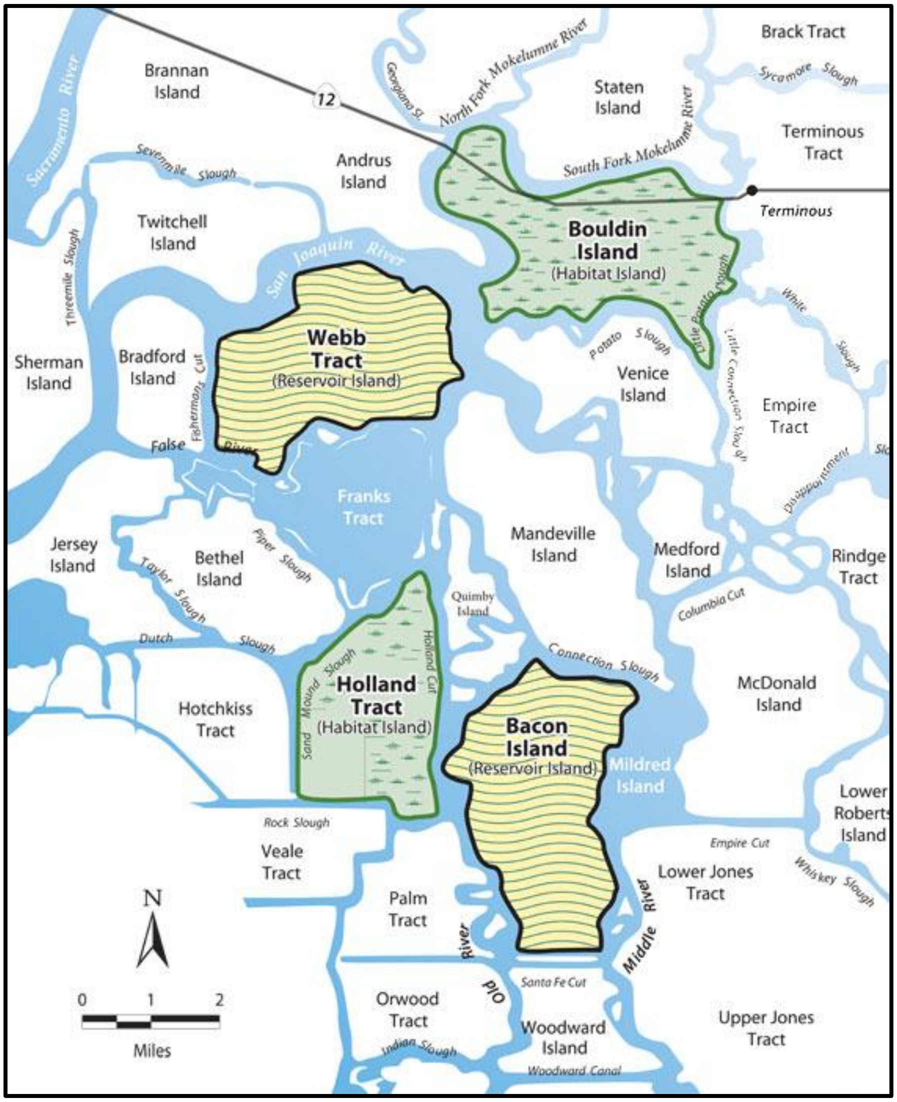
In addition to the direct benefits of restoring a sustainable flow on the San Joaquin River and providing planning certainty for the farms that rely on Friant water, other benefits will likely result from the SJRRP, including enhanced downstream water quality and increased recreational opportunities. There have not been any studies done on the impact of the increased flows on water quality in the San Joaquin River and at the Delta pumping plants.

DELTA WETLANDS PROJECT

The Delta Wetlands Project involves creating storage reservoirs on Webb Tract and Bacon Island and creating wetland and wildlife habitat on Bouldin Island and Holland Tract in the central Delta. Figure 3-1 shows the location of the islands. This project was initiated in 1987 and has been through several iterations and environmental review processes. The currently proposed project is a partnership between Delta Wetlands and Semitropic Water Storage District. During wet months (December to March) surplus water will be stored on the reservoir islands. During dry summer months, stored water will be released into the Delta and pumped to customers in Southern California. Water stored during wet years will be pumped to Semitropic Water Storage District and the Antelope Valley Water Bank, which is south of the Tehachapi Mountains and stored in groundwater banks for use in dry years. The two reservoir islands will have a combined capacity to store 215,000 acre-feet of water and will be able to deliver about 160,000 acre-feet of water each year. The final EIR assessing the impacts of diverting and storing the water and the storage of the water in groundwater banks was certified in September 2011. Delta Wetlands is currently working with the State Water Board to draft a new water rights permit.

The SWP Contractors and CUWA have expressed concern since the project was first proposed that storing water on Delta islands with peat soils could result in high organic carbon concentrations and other impacts on water quality at the Delta pumping plants. CUWA entered into a settlement agreement with Delta Wetlands Properties in 2000 that included a Water Quality Management Plan. The Water Quality Management plan focused on salinity and disinfection byproduct precursors (organic carbon and bromide). CUWA and Delta Wetlands plan to revise the Water Quality Management Plan to address other constituents of concern.

Figure 2-1. Proposed Delta Wetlands Project



Source: Delta Wetlands

POTENTIAL ACTIONS

SWPCA and MWQI should Continue to Track Projects that could Impact Delta Water Quality.

SWPCA and MWQI have historically tracked projects that could impact Delta water quality and have provided comments to the appropriate regulatory agency. This effort should continue. High priority activities with the most potential to impact water quality include the BDCP and the Delta Wetlands Project.

SWPCA and MWQI should Review the Draft BDCP EIR/EIS and Submit Comments on the Water Quality Section and Appendices.

The draft BDCP EIR/EIS is scheduled to be released in September 2012. SWPCA and MWQI should review these documents and submit comments on the water quality sections to ensure that the impacts on drinking water quality have been adequately addressed.

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Personal Communication

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Sotelo, Christine, State Water Resources Control Board. Email on February 23, 2012.

CHAPTER 3 WATER QUALITY BACKGROUND AND SUMMARY

CONTENTS

FIGURES

TABLES

CHAPTER 3 WATER QUALITY BACKGROUND AND SUMMARY

Chapters 4 to 11 contains detailed descriptions of water quality conditions in the Sacramento-San Joaquin Delta (Delta) and the State Water Project (SWP). Chapter 12 contains a description of the latest research on constituents of emerging concern. This chapter provides the background on the SWP needed to understand the water quality chapters and it provides a summary of the more detailed information that is in the following chapters. This chapter is organized to cover the following topics:

- The SWP – This section provides a brief overview of the major facilities of the SWP.

- Hydrology and SWP Operations – The hydrologic conditions in the Sacramento and San Joaquin basins and the Delta area discussed in this section. Key aspects of SWP operations that affect water quality are also described.

- Water Quality Data – The sources of water quality data and the locations that are included in the data analysis in Chapters 4 through 11 are discussed in this section.

- Summary of Water Quality in the Watersheds and the SWP – This section contains a summary of the findings for each constituent that is discussed in subsequent chapters. The following chapters are organized as follows:

    - Chapter 4 – Organic Carbon
    - Chapter 5 – Salinity
    - Chapter 6 – Bromide
    - Chapter 7 – Nutrients
    - Chapter 8 – Taste and Odor Incidents and Algal Toxins
    - Chapter 9 – Turbidity
    - Chapter 10 – Pathogens
    - Chapter 11 – Organic Chemicals and Trace Elements
    - Chapter 12 – Constituents of Emerging Concern

- Status of Action Items – This section contains a discussion of the water quality action items in the 2007 State Water Project Action Plan and progress made in the last five years on completing those actions.

- Potential Actions – The SWP Contractors will develop the 2012 State Water Project Action Plan upon completion of this watershed sanitary survey. Potential actions have been identified as a starting point for the Action Plan.

THE STATE WATER PROJECT

The SWP extends from the mountains of Plumas County in the Feather River watershed to Lake Perris in Riverside County. **Figure 3-1** shows the major features of the SWP. Water is delivered to Plumas County Flood Control and Water Conservation District upstream of Lake Oroville. The City of Yuba City and Butte County receive SWP water from Lake Oroville. The Sacramento and San Joaquin rivers are the two major rivers providing water to the Delta, the source of water for most SWP Contractors. **Figure 3-2** shows the Delta and the key water quality monitoring locations in the Delta and the tributaries to the Delta.

Water from the north Delta is pumped into the North Bay Aqueduct (NBA) at the Barker Slough Pumping Plant, as shown in **Figure 3-3**. Barker Slough is a tidally influenced dead-end slough which is tributary to Lindsey Slough. Lindsey Slough is tributary to the Sacramento River. The pumping plant draws water from both the upstream Barker Slough watershed and from the Sacramento River, via Lindsey Slough. Other local sloughs may also contribute water to the NBA. The NBA pipeline extends 21 miles from Barker Slough to Cordelia Forebay (Cordelia) and Pumping Plant, and then 7 miles to its terminus at two 5-million gallon terminal tanks. The NBA serves as a municipal water supply source for a number of municipalities in Solano and Napa counties. The Solano County Water Agency (SCWA) and the Napa County Flood Control and Water Conservation District (Napa County) are wholesale buyers of water from the SWP. SCWA delivers water to Travis Air Force Base and the cities of Benicia, Fairfield, Vacaville, and Vallejo. Napa County delivers water to the cities of Napa, and American Canyon.

In the southern Delta, water enters SWP facilities at Clifton Court Forebay (Clifton Court), and flows across the forebay about 3 miles to the H.O. Banks Delta Pumping Plant (Banks), from which the water flows southward in the Governor Edmund G. Brown California Aqueduct (California Aqueduct). Water is diverted into the South Bay Aqueduct (SBA) at Bethany Reservoir, 1.2 miles downstream from Banks. **Figure 3-4** is a map showing the locations of the SBA facilities. The SBA consists of about 11 miles of open aqueduct followed by about 34 miles of pipeline and tunnel serving East and South Bay communities through the Zone 7 Water Agency of the Alameda County Flood Control and Water Conservation District (Zone 7 Water Agency), Alameda County Water District (ACWD), and Santa Clara Valley Water District (SCVWD). Water from the SBA can be pumped into or released from Lake Del Valle at the Del Valle Pumping Plant. Lake Del Valle has a nominal capacity of 77,110 acre-feet, with 40,000 acre-feet for water supply. The terminus of the SBA is the Santa Clara Terminal Reservoir (Terminal Tank).

Figure 3-1. The State Water Project

Figure 3-2. Delta Features and Monitoring Locations

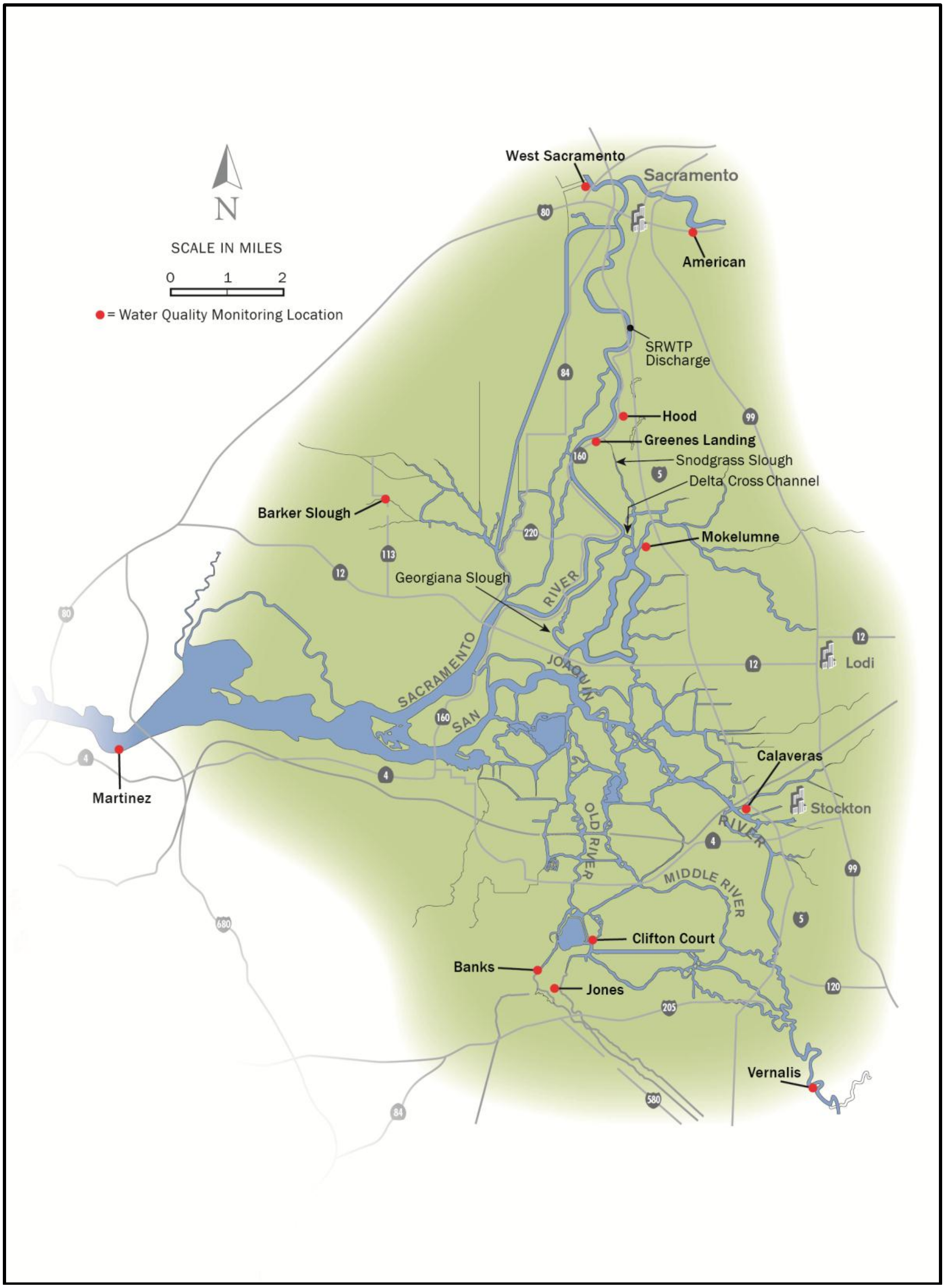


Figure 3-3. The North Bay Aqueduct

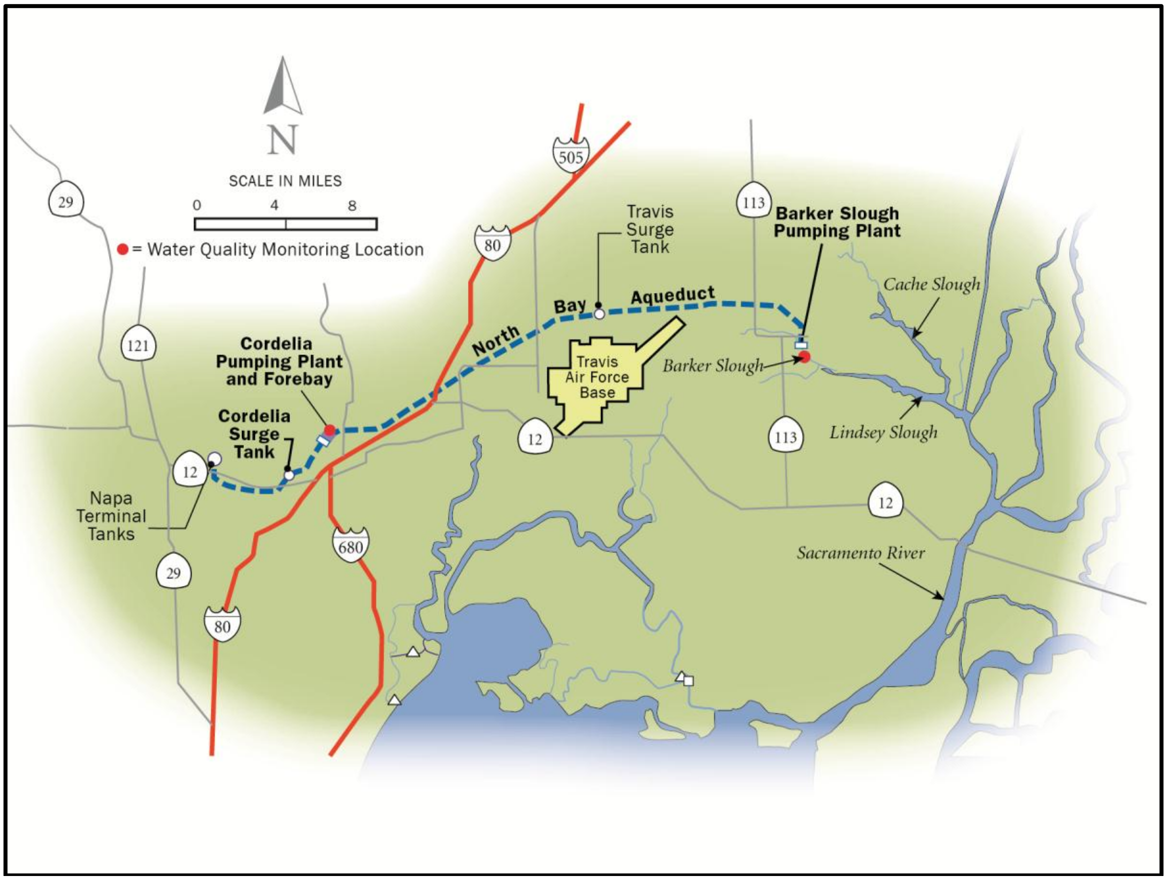
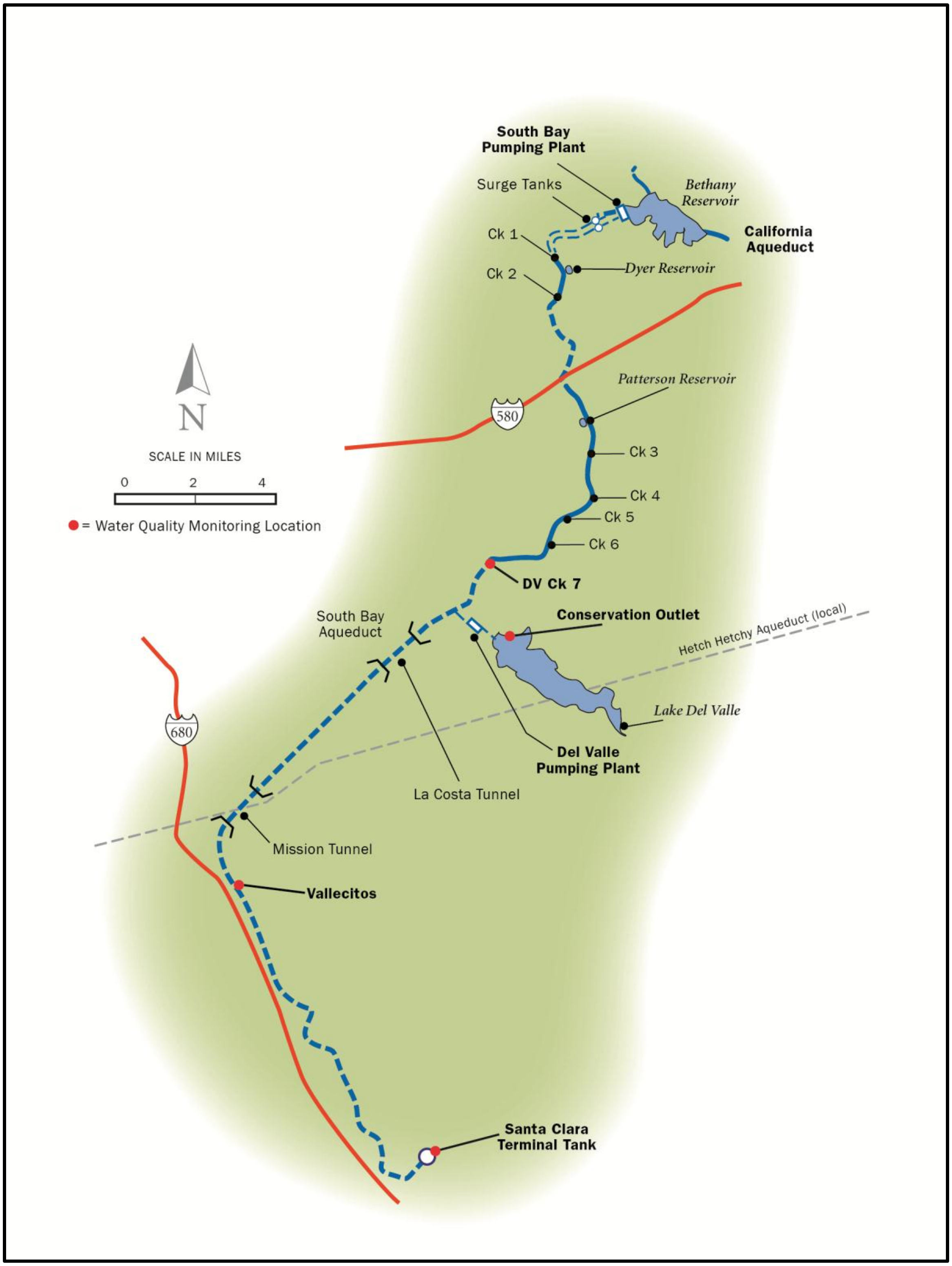


Figure 3-4. The South Bay Aqueduct



From Bethany Reservoir, water flows in the California Aqueduct about 59 miles to O'Neill Forebay, as shown in **Figure 3-5**. The forebay is the start of the San Luis Joint-Use Facilities, which serve both SWP and federal Central Valley Project (CVP) customers. CVP water is pumped into O'Neill Forebay from the Delta-Mendota Canal (DMC). The DMC conveys water from the C.W. "Bill" Jones Pumping Plant (Jones) to, and beyond, O'Neill Forebay. The O'Neill Pump-Generation Plant (O'Neill Intake), located on the northeast side of O'Neill Forebay, enables water to flow between the forebay and the DMC. San Luis Reservoir is connected to O'Neill Forebay through an intake channel located on the southwest side of the forebay. **Figure 3-6** is a location map that shows these features. Water in O'Neill Forebay can be pumped into San Luis Reservoir by the William R. Gianelli Pumping-Generating Plant (Gianelli) or released from the reservoir to the forebay to generate power. San Luis Reservoir, with a capacity of 2.03 million acre-feet, is jointly owned by the SWP and CVP, with 1.06 million acre-feet being the state's share. An intake on the west side of the reservoir provides drinking water supplies to SCVWD. Water enters SCVWD facilities at Pacheco Pumping Plant (Pacheco), from which it is pumped by tunnel and pipeline to water treatment and ground water recharge facilities in the Santa Clara Valley.

Water released from the reservoir co-mingles in O'Neill Forebay with water delivered to the forebay by the California Aqueduct and the DMC, and exits the forebay at O'Neill Forebay Outlet, located on the southeast side of the forebay. O'Neill Forebay Outlet is the inception of the San Luis Canal reach of the California Aqueduct, as shown in **Figure 3-7**. The San Luis Canal extends about 100 miles to Check 21, near Kettleman City. The San Luis Canal reach of the aqueduct serves mostly agricultural CVP customers and conveys SWP waters to points south. Unlike the remainder of the California Aqueduct, which was constructed by the state, the San Luis Canal reach was federally constructed and was designed to allow drainage from adjacent land to enter the aqueduct. Local streams that run eastward from the Coastal Range mountains bisect the aqueduct at various points. During storms, water from some of these streams enters the aqueduct. This is generally not the case for the other reaches of the aqueduct.

The junction with the Coastal Branch of the aqueduct is located 185 miles downstream of Banks and about 12 miles south of Check 21. The Coastal Branch provides drinking water supplies to central California coastal communities through the Central Coast Water Authority (CCWA) and the San Luis Obispo County Flood Control and Water Conservation District. **Figure 3-8** is a map showing locations of these facilities. The Coastal Branch is 115 miles long; the first 15 miles are open aqueduct and the remainder is a pipeline.

Figure 3-5. California Aqueduct between Banks Pumping Plant and San Luis Reservoir

Figure 3-6. O'Neill Forebay and San Luis Reservoir

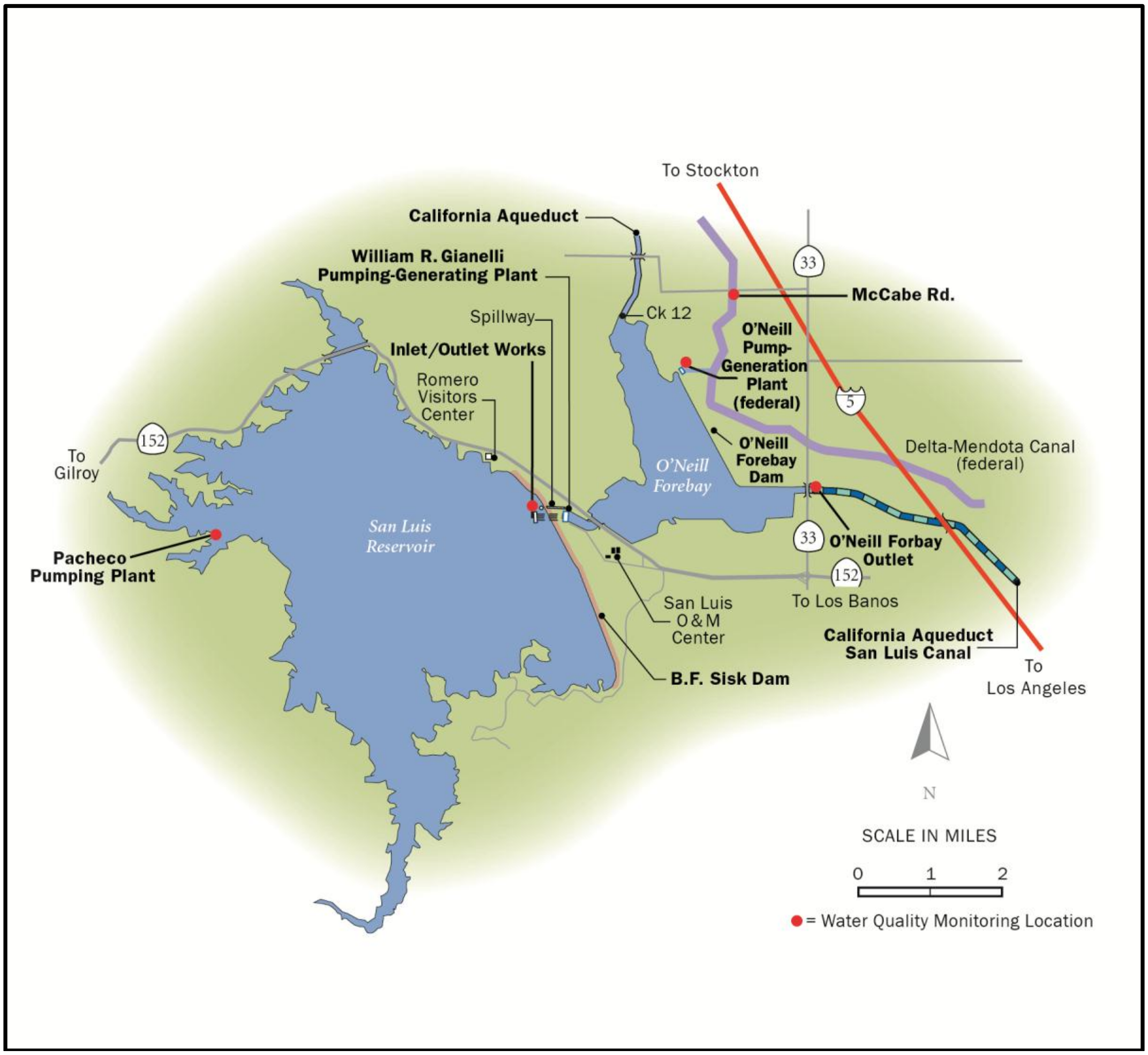
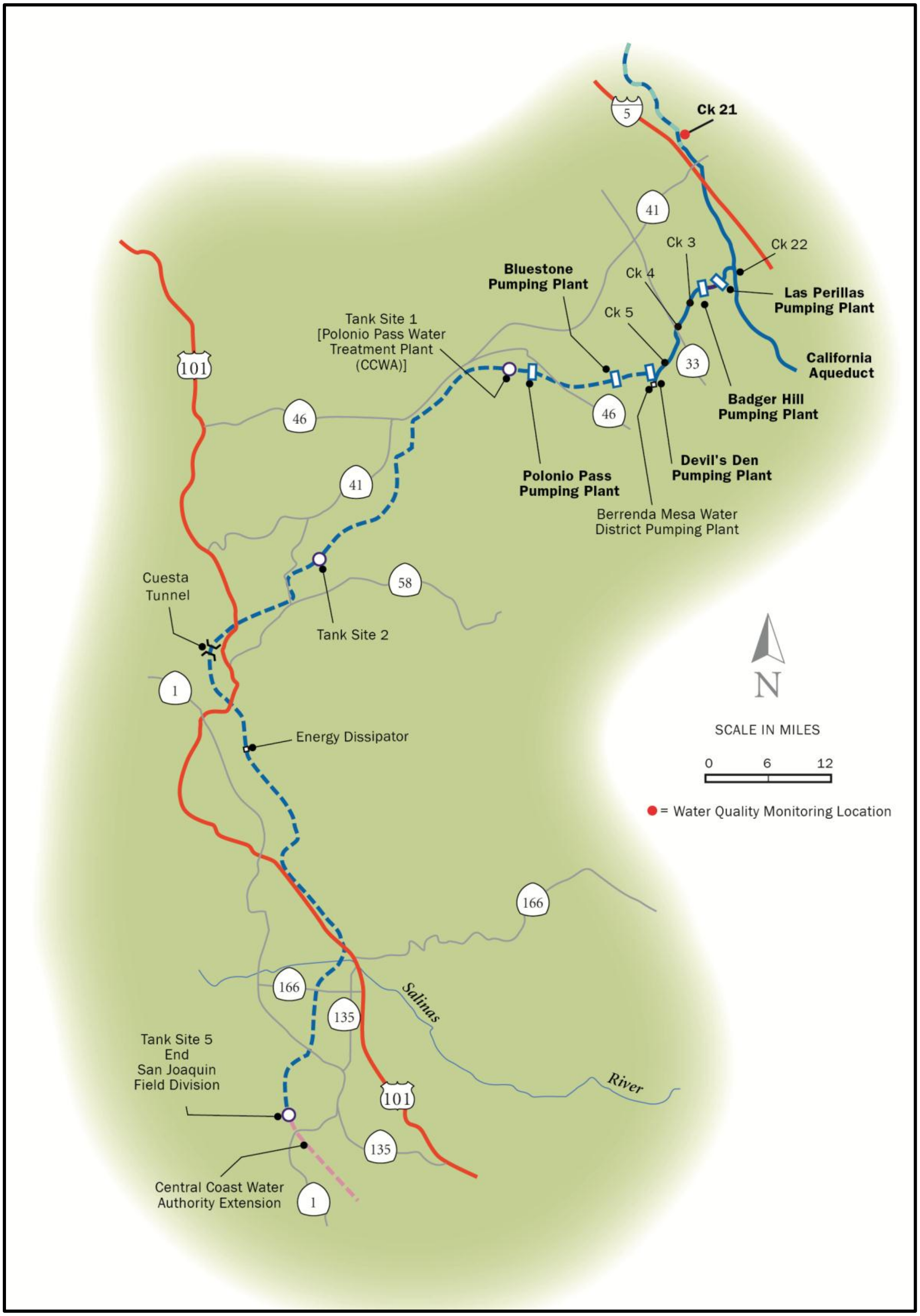


Figure 3-7. San Luis Canal Reach of the California Aqueduct

Figure 3-8. The Coastal Branch of the California Aqueduct



From the junction with the Coastal Branch, water continues southward in the California Aqueduct as shown in **Figure 3-9**, providing water to both agricultural and drinking water customers in the service area of Kern County Water Agency (KCWA). The Kern River Intertie is designed to permit Kern River water to enter the aqueduct during periods of high flow. Due to increasingly scarce California water supplies, the SWP is used to convey both surface water and groundwater acquired through transfers and exchanges among local agencies. Most of the non-Project water enters the aqueduct between Check 21 and Check 41. The water quality impacts of these non-Project inflows are examined in Chapter 14. Edmonston Pumping Plant is at the northern foot of the Tehachapi Mountains. This facility lifts SWP water about 2000 feet by multi-stage pumps through tunnels to Check 41, located on the south side of the Tehachapi Mountains. About a mile downstream, the California Aqueduct divides into the West and East Branches. The West Branch flows 14 miles to Pyramid Lake, then another 17 miles to the outlet of Castaic Lake, the drinking water supply intake of the Metropolitan Water District of Southern California (MWDSC) and Castaic Lake Water Agency (CLWA). Pyramid Lake has a capacity of 171,200 acre-feet and Castaic Lake has a capacity of 323,700 acre-feet. **Figure 3-10** is a map showing locations of West Branch features.

From the bifurcation of the East and West Branches, water flows in the East Branch to high desert communities in the Antelope Valley served by the Antelope Valley East Kern Water Agency (AVEK) and the Palmdale Water District (Palmdale). **Figure 3-11** is a map showing East Branch features. As in the southern San Joaquin Valley, groundwater from the local area has occasionally been allowed into the aqueduct to alleviate drought emergencies. On the East Branch near Hesperia, surface water drainage from part of that city enters the aqueduct during storm events. The inlet to Silverwood Lake is located on the north side of the reservoir near Check 66. Silverwood Lake has a capacity of 74,970 acre-feet and serves as a drinking water supply for the Crestline-Lake Arrowhead Water District (CLAWA). Water is drawn from the south side of the reservoir and flows through the Devil Canyon Powerplant to the two Devil Canyon afterbays. Drinking water supplies are delivered to MWDSC and San Bernardino Valley Municipal Water District from this point, and water is also transported via the Santa Ana Pipeline to Lake Perris, which is the terminus of the East Branch. MWDSC routinely takes a small amount of water from Lake Perris.

Figure 3-9. California Aqueduct between Check 21 and Check 41

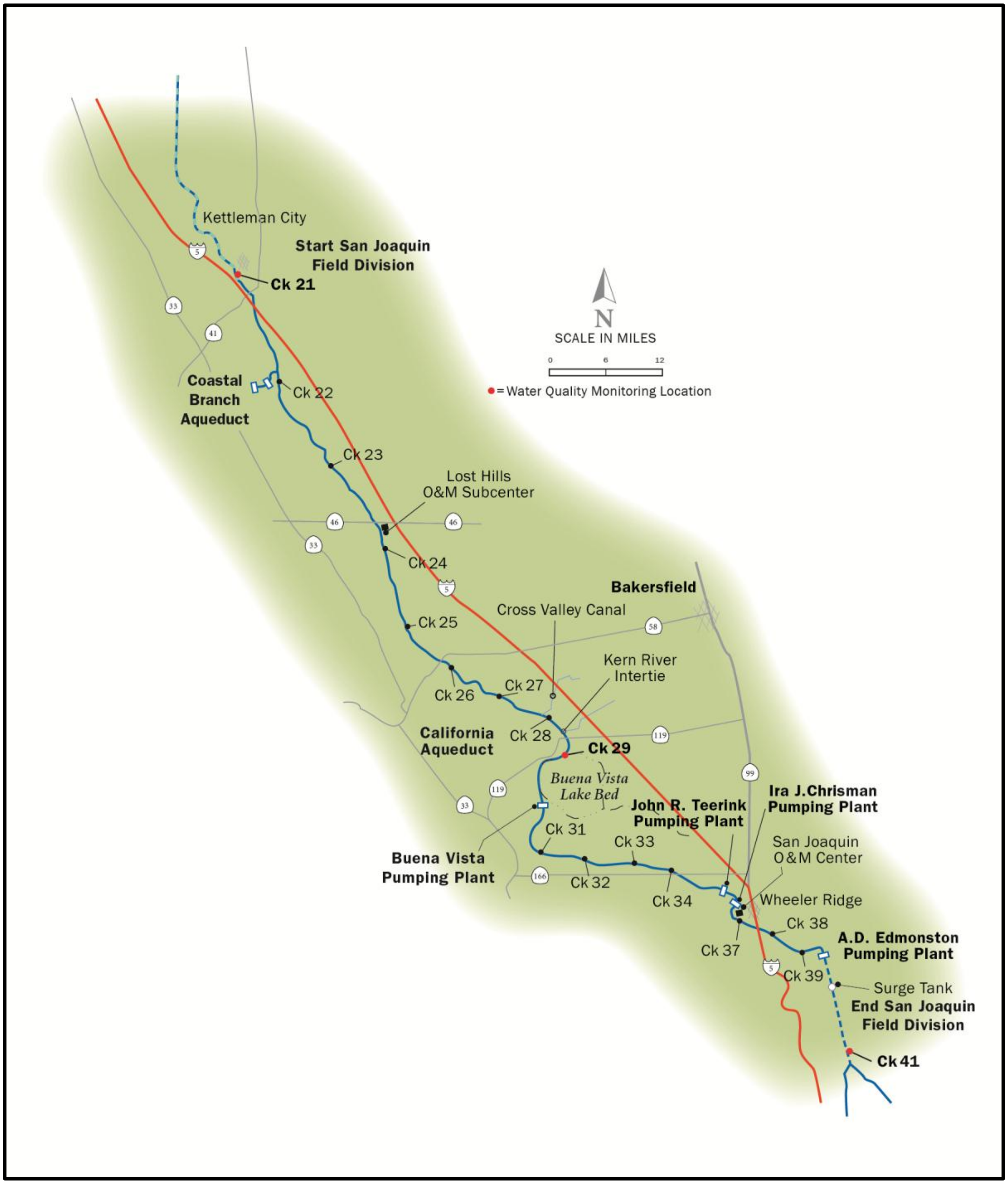


Figure 3-10. The West Branch of the California Aqueduct

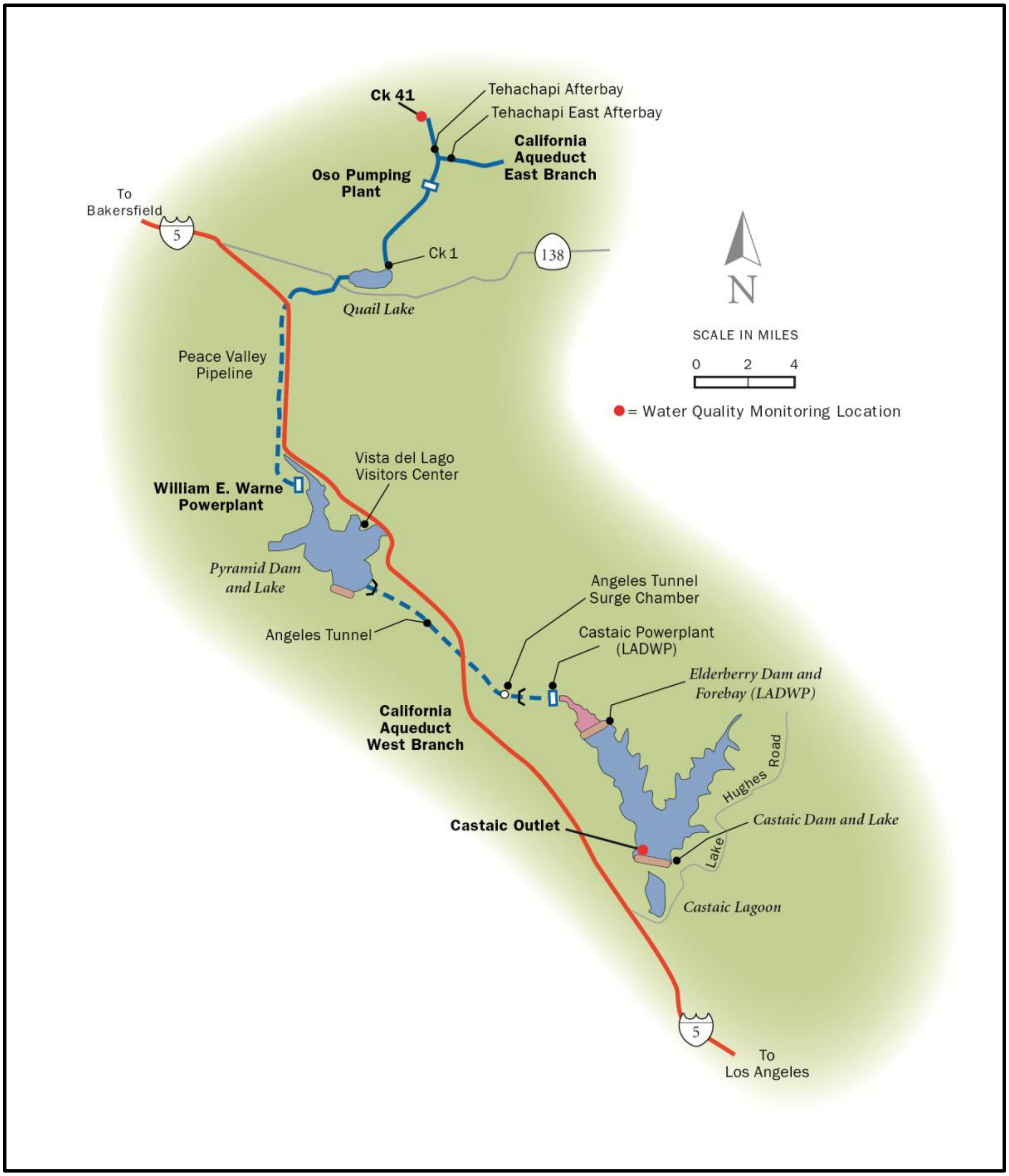
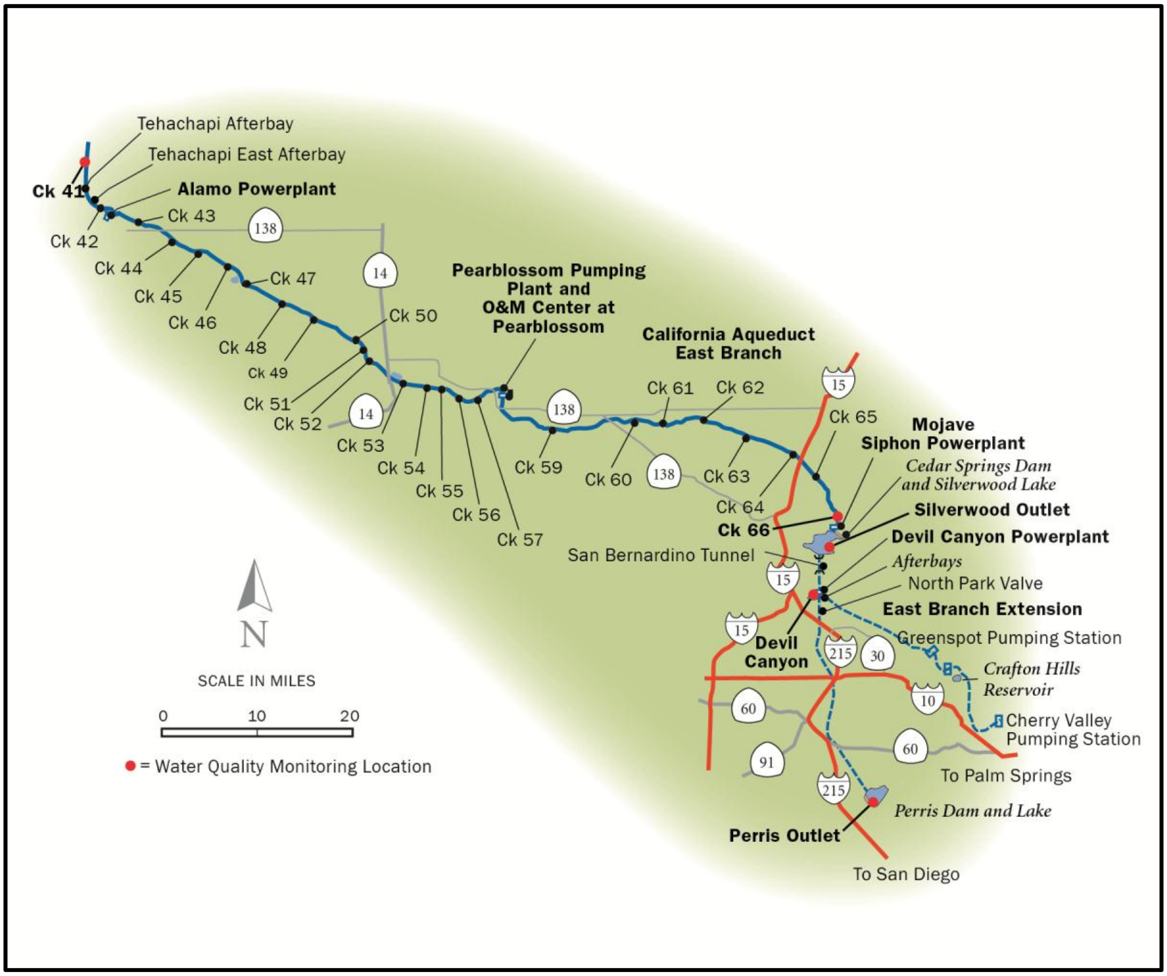


Figure 3-11. The East Branch of the California Aqueduct



HYDROLOGY AND OPERATIONS

The Delta is located at the confluence of the Sacramento and San Joaquin rivers and San Francisco Bay. Water quality at the SWP export locations is greatly affected by hydrologic conditions in the Sacramento and San Joaquin basins, operations of reservoirs, and operations of the Delta Cross Channel and barriers in the South Delta. The water quality of water delivered to SWP Contractors south of the Delta is also affected by the timing of diversions and the operations of reservoirs south of the Delta. A brief overview of Delta hydrology and SWP operations is provided in this section to place the water quality discussion that follows in the proper context.

DELTA HYDROLOGY AND OPERATIONS

Delta Inflow

The two major sources of freshwater inflow to the Delta are the Sacramento and San Joaquin rivers. Additional flows come from the eastside tributaries: the Mokelumne, Calaveras, and Cosumnes rivers. The Sacramento River provides approximately 75 to 85 percent of the freshwater flow to the Delta and the San Joaquin River provides about 10 to 15 percent of the flow. Daily flows measured at Freeport on the Sacramento River are shown in **Figure 3-12** for the period of October 1980 through December 2010. This period of record was selected because all available water quality data are discussed in this chapter and water quality data are available from the early 1980s at some locations. During extremely wet years, Sacramento River flows can exceed 100,000 cubic feet per second (cfs) at Freeport. Freeport is downstream of the Sacramento urban area, as shown previously on **Figure 3-2**. To prevent flooding in the Sacramento urban area, high flows on the Sacramento River are diverted into the Yolo Bypass at Fremont Weir, upstream of Sacramento. **Figure 3-13** presents all available flow data for the Yolo Bypass at Fremont Weir. During this time period (1996 to 2010), flows peaked at 326,000 cfs during the wet year of 1997.

Figure 3-14 indicates that the flows in the San Joaquin River at Vernalis are substantially lower than flows in the Sacramento River. Peak flows can exceed 50,000 cfs but flows are normally much lower. The Vernalis Adaptive Mangement Plan (VAMP) is designed to improve the survival of salmon smolts migrating down the San Joaquin River in the spring. Flows are increased on the San Joaquin River between April 15 and May 15 of each year by releasing water from reservoirs on the Merced, Stanislaus, and Tuolumne rivers. Combined exports at the Banks and Jones pumping plants are reduced to 1,500 cfs.

Flows on the Sacramento and San Joaquin rivers are highly managed. CVP and SWP reservoirs on the rivers and their tributaries attenuate the highly variable natural flows, capturing high volume flows during short winter and spring periods and releasing water throughout the year. The California Department of Water Resources (DWR) classifies each water year based on the amount of unimpaired runoff that would have occurred in the watershed unaltered by water diversions, storage, exports, and imports. **Table 3-1** presents the water year classifications for the Sacramento and San Joaquin basins between 1980 and 2010. This table illustrates that there are multi-year dry periods and multi-year wet periods.

Figure 3-12. Flow in the Sacramento River at Freeport

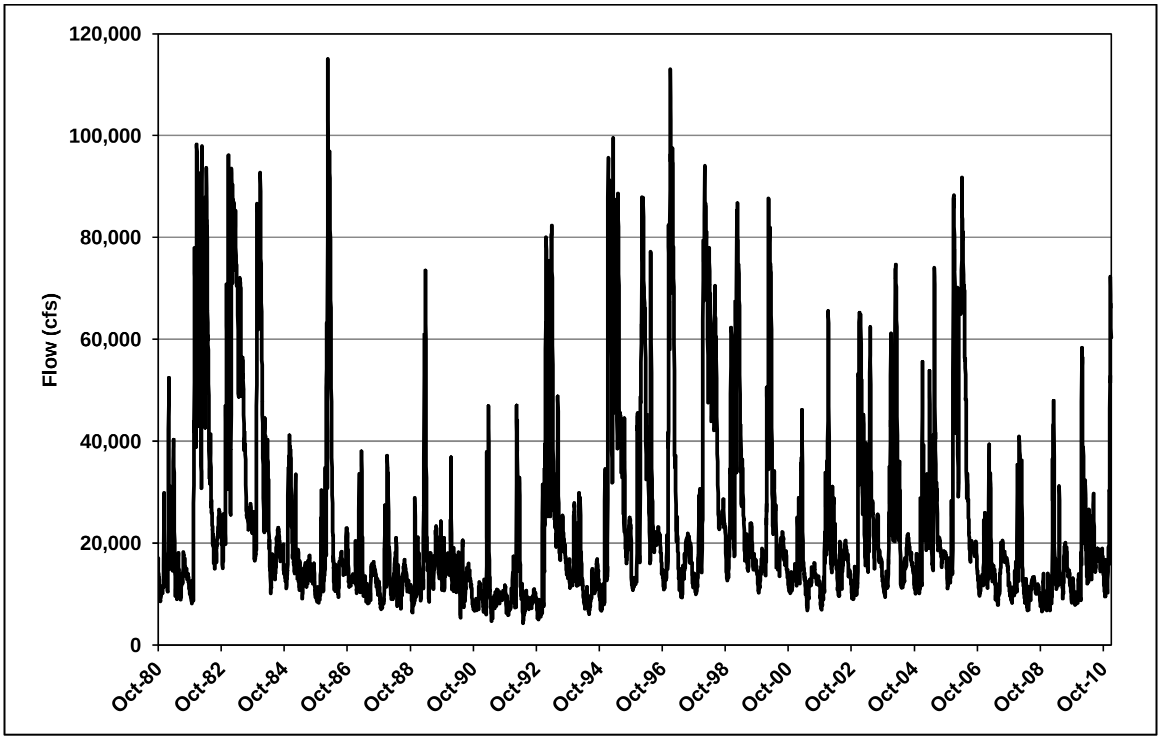


Figure 3-13. Flow in the Yolo Bypass at Fremont Weir

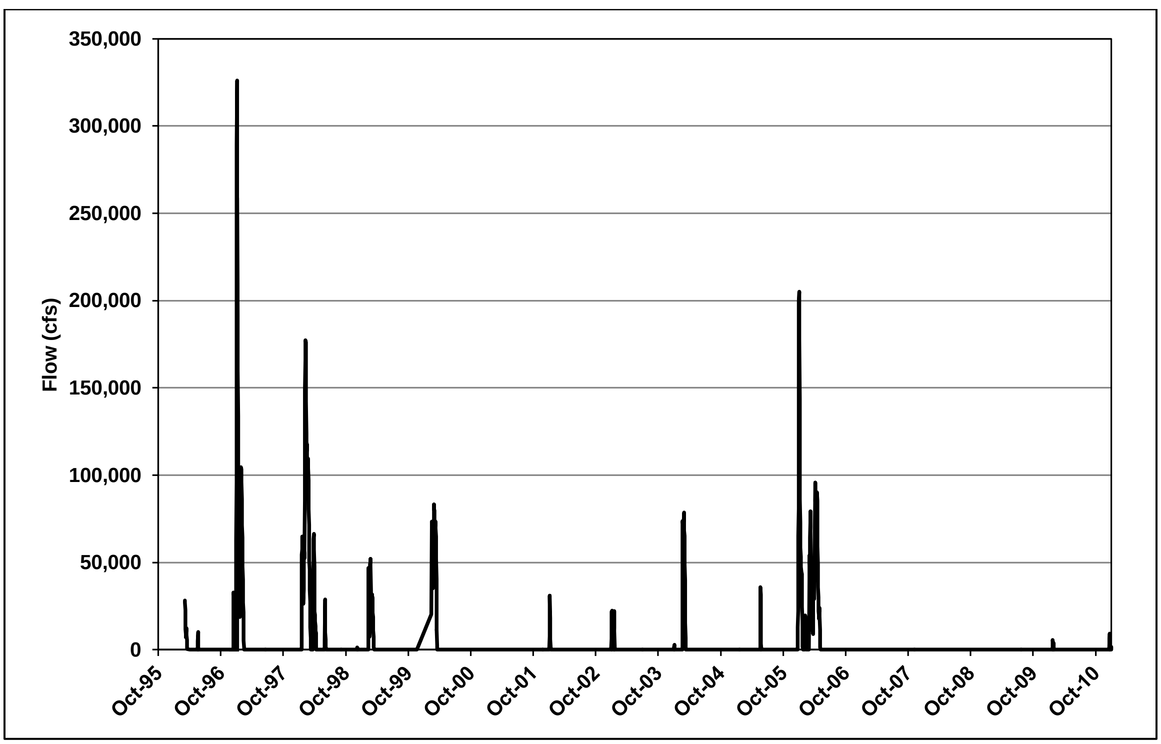


Figure 3-14. Flow in the San Joaquin River at Vernalis

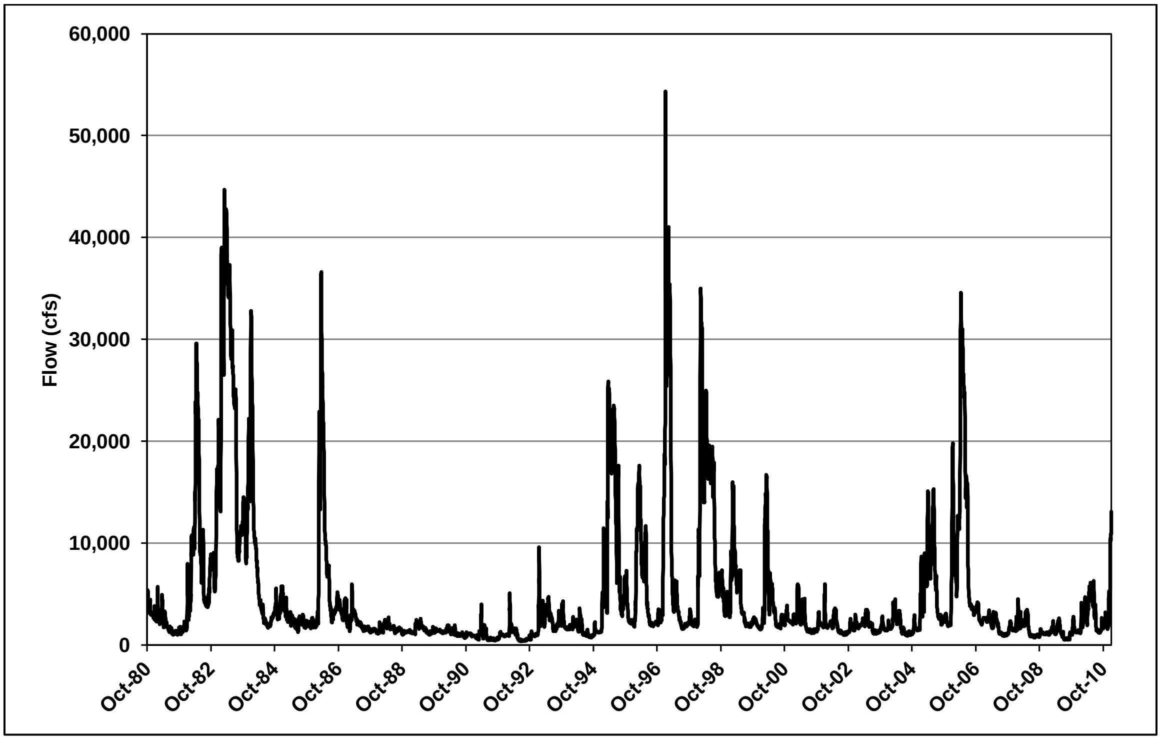


Table 3-1. Water Year Classifications

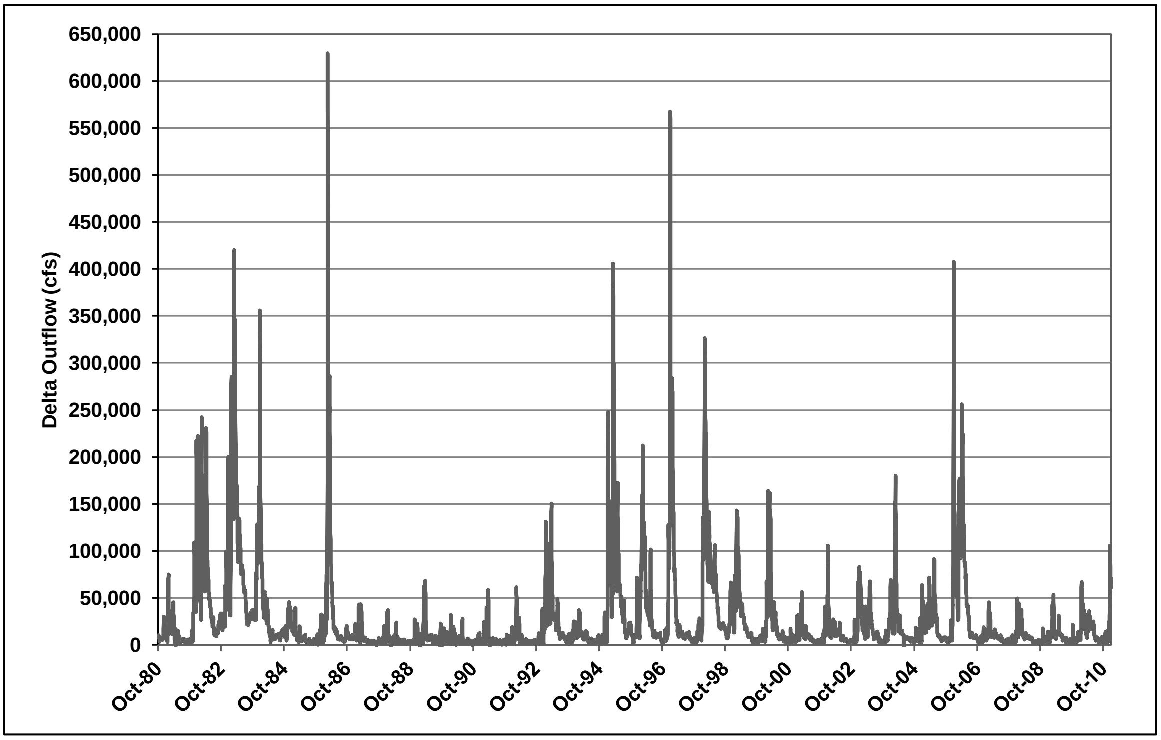
Water Year	Sacramento Basin	San Joaquin Basin
1980	Above Normal	Wet
1981	Dry	Dry
1982	Wet	Wet
1983	Wet	Wet
1984	Wet	Above Normal
1985	Dry	Dry
1986	Wet	Wet
1987	Dry	Critical
1988	Critical	Critical
1989	Dry	Critical
1990	Critical	Critical
1991	Critical	Critical
1992	Critical	Critical
1993	Above Normal	Wet
1994	Critical	Critical
1995	Wet	Wet
1996	Wet	Wet
1997	Wet	Wet
1998	Wet	Wet
1999	Wet	Above Normal
2000	Above Normal	Above Normal
2001	Dry	Dry
2002	Dry	Dry
2003	Above Normal	Below Normal
2004	Below Normal	Dry
2005	Above Normal	Wet
2006	Wet	Wet
2007	Dry	Critical
2008	Critical	Critical
2009	Dry	Below Normal
2010	Below Normal	Above Normal

Source: http://cdec.water.ca.gov/cgi-progs/iodir/wsihist

Delta Outflow Index

Delta outflow, inflow that is not exported at the SWP and CVP pumps or diverted for use within the Delta, is the primary factor controlling salinity in the Delta. Except under conditions of high winter runoff, Delta outflow is dominated by tidal ebb and flood. Over the tidal cycle, flows move downstream toward San Francisco Bay during ebb tides and move upstream during flood tides. Freshwater flows provide a barrier against seawater intrusion. When Delta outflow is low, seawater can intrude further into the Delta, increasing salinity and bromide concentrations at the export locations. **Figure 3-15** shows the variable and seasonal nature of Delta outflow.

Figure 3-15. Delta Outflow Index

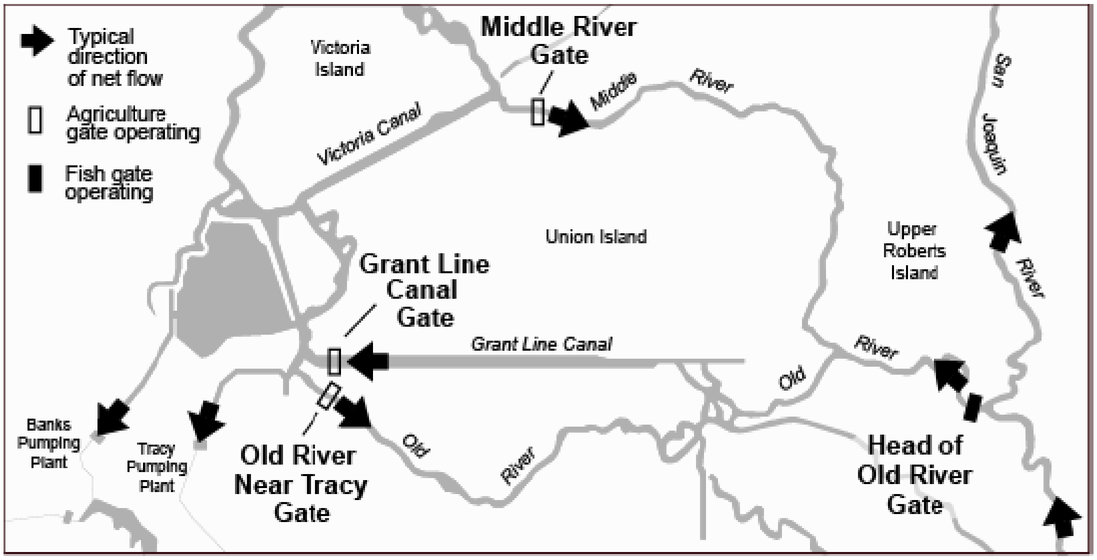


Delta Operations

Water from the Sacramento River flows into the central Delta via Georgiana Slough and the Delta Cross Channel, which connects the Sacramento River to the Mokelumne River via Snodgrass Slough (**see Figure 3-2**). The Delta Cross Channel is operated by the U.S. Bureau of Reclamation (Reclamation). The Cross Channel operations are determined by several factors, including fish migration, Delta water quality, and flow in the Sacramento River. The Cross Channel is generally closed between January and mid-June, open between mid-June and October, and closed in November and December. Flows of Sacramento River water through the Delta Cross Channel improve central Delta water quality by increasing the flow of higher quality (lower salinity, lower organic carbon) Sacramento River water into the central and southern Delta. The relative impact of the Delta Cross Channel operations on water quality at the south Delta pumping plants is governed by pumping rates and flows on the San Joaquin River.

DWR installs temporary rock barriers in south Delta channels (Old River near Tracy, Grant Line Canal, and Middle River) to enhance water levels and improve circulation in the south Delta for agricultural diversions. These barriers are generally in place during the irrigation season of June to October. Another temporary barrier is installed in the spring (mid-April to mid-June) at the head of Old River to aid salmon migration down the San Joaquin River. This barrier is also installed in the fall, if needed, to aid salmon migrating up the San Joaquin River to spawn. **Figure 3-16** shows the locations of the temporary barriers. These barriers divert San Joaquin River water to the central Delta where it can be mixed with Sacramento and Mokelumne river water before entering the south Delta pumping plants. The degree of water quality improvement by mixing with Sacramento River water is dependent on the rate of pumping, which is controlled by the amount of reverse flow permitted on the Old and Middle rivers.

Figure 3-16. South Delta Temporary Barriers



Source: DWR 2006. Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun March.

Sources of Water at South Delta Pumping Plants

DWR uses results from the Delta Simulation Model 2 (DSM2) to identify the contributing sources of water volume, electrical conductivity (EC), and dissolved organic carbon (DOC) at each of the Delta intakes; this technique is known as fingerprinting. The fingerprinting technique has been described by DWR (DWR, 2005a). The volumetric fingerprint, which shows the relative volumes of water from various sources at Clifton Court, is shown in **Figure 3-17**. This figure shows that the Sacramento River is the predominant source of water for the SWP at Clifton Court; however, during wet and above normal years in the San Joaquin Basin and at other times when flow in the San Joaquin River is relatively high, the San Joaquin River contributes more water to the SWP. During the 1991 to 2010 period, the Sacramento River contributed an average of 58 percent of the water at Banks, the San Joaquin River contributed 27 percent, and the eastside streams (Cosumnes, Mokelumne, and Calaveras rivers) contributed 5 percent. The remaining water came from seawater intrusion and agricultural drains, as described below. The volumetric fingerprint for Jones is shown in **Figure 3-18**. This figure clearly shows the greater influence of the San Joaquin River at Jones. During the 1991 to 2010 period, the Sacramento and San Joaquin rivers each contributed an average of 44 percent of the water at Jones and the eastside streams contributed 4 percent. The remaining water came from seawater intrusion and agricultural drains.

Figure 3-17. Volumetric Fingerprint at Clifton Court

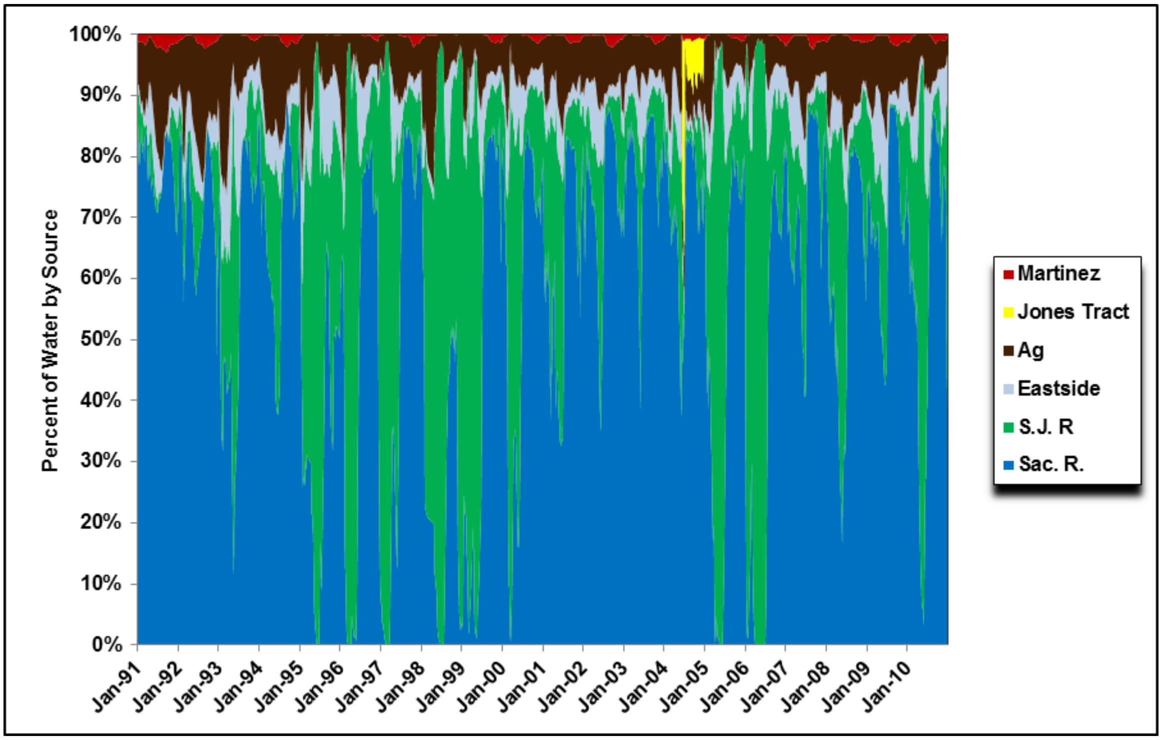
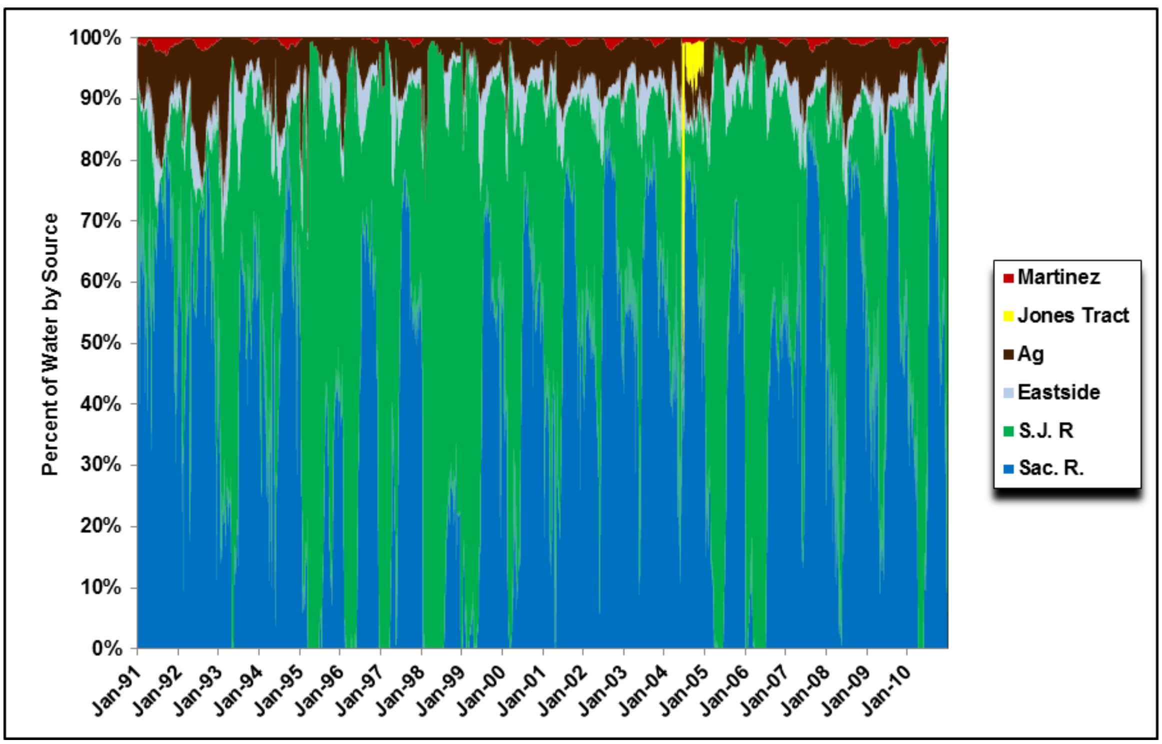


Figure 3-18. Volumetric Fingerprint at Jones



Seawater intrusion is represented on the fingerprints as “Martinez”; Martinez represents the western boundary of the Delta in the DSM2 model. Seawater intrusion is most significant during the fall months, when river flows are minimal. During the fall months of critically dry years, the Martinez water volume can sometimes be 2 to 3 percent of the total volume at both pumping plants. However, since the water at Martinez is heavily influenced by seawater intrusion, that small volume can contribute significant salinity and bromide, as described later in this chapter.

Drainage from Delta islands also contributes an average of 8.7 percent of the water volume at Clifton Court and 7.2 percent at Jones. During the 1991 to 2010 period, the maximum contribution of water volume from agricultural drains was 26 percent at Clifton Court and 34 percent at Jones. Agricultural drains contribute the greatest percent of water during the January through April period. As discussed later in this chapter, due to the high concentrations of DOC in agricultural drainage, this is a significant source of organic carbon at both pumping plants.

On June 3, 2004, a levee failed on Upper Jones Tract, resulting in flooding of both Upper and Lower Jones tracts. The fingerprints show the estimated percentage of water volume at Clifton Court and Jones that came from the flooded island, initially as the island was opened to the adjacent Delta channel and subject to tidal flow, then later as water was pumped from the island into Delta channels after the levee break had been repaired.

STATE WATER PROJECT OPERATIONS

Information is presented in this section on pumping at the major pumping plants supplying water to the NBA, SBA, and California Aqueduct and on releases from Lake Del Valle to the SBA and San Luis Reservoir to the California Aqueduct. The period of 1998 to 2010 was selected because between 1998 and 2006, diversions at the Banks Pumping Plant were governed by the 1995 Bay-Delta Plan (D-1641). The Bay-Delta Plan established new water quality objectives for the Delta that resulted in lower diversions of water from the Delta in the spring and higher diversions in the fall, starting in 1998. Delta operations changed again in 2007 when DWR voluntarily reduced exports in the spring to reduce entrainment of delta smelt. As discussed in Chapter 2, biological opinions issued by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) and court orders (the Wanger Decision) changed operations at the south Delta pumping plants beginning in 2008. The impacts of the Wanger Decision and the biological opinions on operations and water quality are discussed in Chapter 15.

North Bay Aqueduct

Water is pumped into the NBA via the Barker Slough Pumping Plant. **Figure 3-19** presents annual pumping at the Barker Slough Pumping Plant for the 1998 to 2010 period. The data for 1998 to 2009 were taken from the SWP Annual Report of Operations prepared by DWR. The 2010 report is not available so daily pumping was downloaded from the California Data Exchange Center (CDEC) for 2010. **Figure 3-19** shows pumped volumes ranged from about 36,000 acre-feet in 1998 to almost 60,000 acre-feet in 2007. **Figure 3-20** presents the average monthly pumping for the 1998 to 2010 period. This figure shows that pumping during the months of January to April is minimal and pumping is relatively high for the remaining months.

Figure 3-19. Annual Pumping at the Barker Slough Pumping Plant

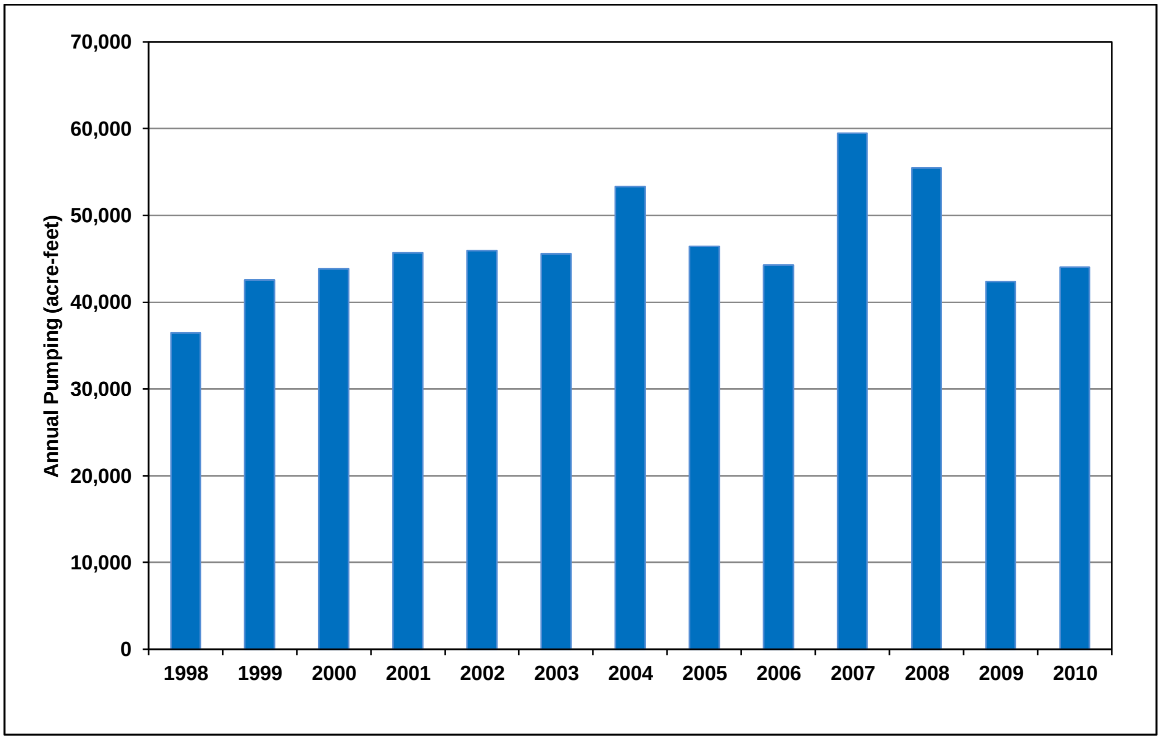
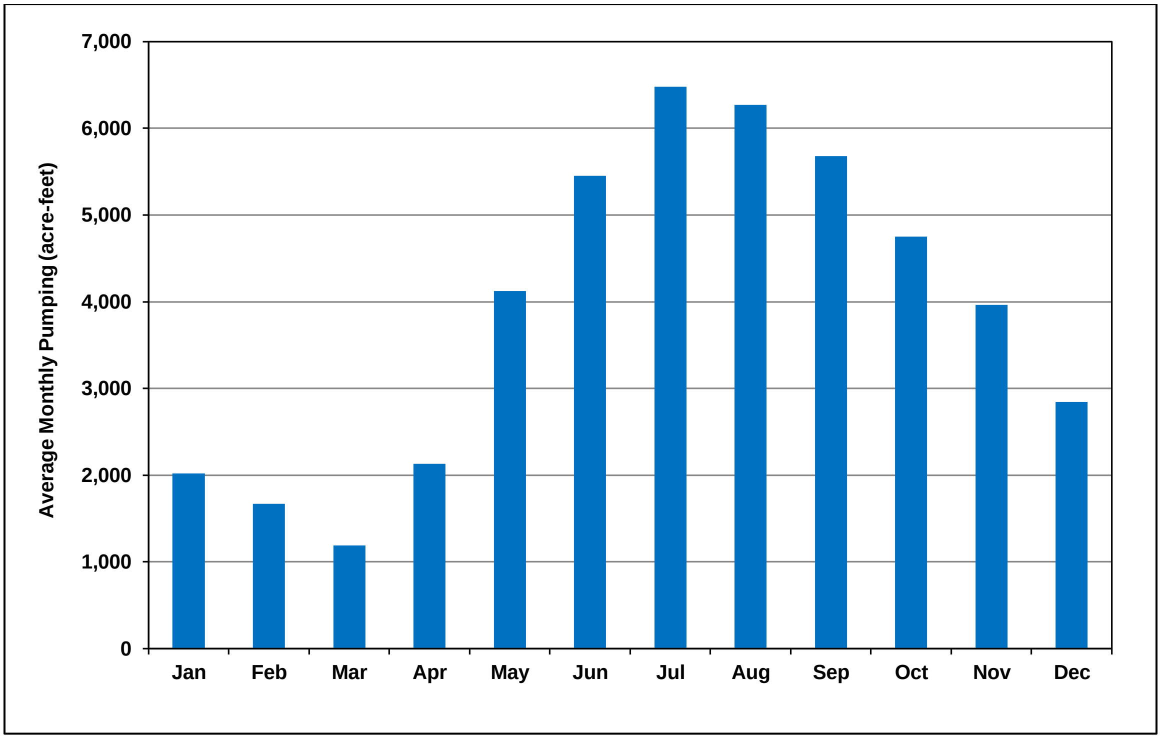


Figure 3-20. Average Monthly Pumping at the Barker Slough Pumping Plant (1998 to 2010)



Banks Pumping Plant

Water is pumped into the California Aqueduct via the Banks Pumping Plant. **Figure 3-21** presents the annual pumping at Banks for the 1998 to 2010 period. The data for 1998 to 2009 were taken from the SWP Annual Report of Operations prepared by DWR. The 2010 report is not available so daily pumping was downloaded from CDEC for 2010. **Figure 3-21** shows pumped volumes ranged from 1.2 million acre-feet in 2008 to over 4 million acre-feet in 2005. As discussed previously, pumping operations changed starting in 2007. **Figure 3-22** presents the average monthly pumping from 1998 to 2006 and from 2007 to 2010. This figure shows that pumping is highest in the summer months and lowest in the April to June period. Pumping during the 2007 to 2010 period was lower in all months of the year compared to the previous period, with the greatest reduction in June. It is difficult to separate the impacts of the biological opinions from the impacts of hydrology. The 1998 to 2006 period had more wet years than dry years, whereas the later period was predominantly dry. This issue is discussed in more detail in Chapter 15.

South Bay Aqueduct

As discussed previously, water is pumped from Bethany Reservoir via the South Bay Pumping Plant into the SBA. **Figure 3-23** presents annual pumping at the South Bay Pumping Plant for the 1998 to 2009 period. These data come from the SWP Annual Report of Operations prepared by DWR. The 2010 report is not available and SBA pumping is not available on CDEC. **Figure 3-23** shows a large range in pumped volumes with less than 80,000 acre-feet pumped in 1998 to almost 160,000 acre-feet pumped in 2007. **Figure 3-24** presents the average monthly pumping from 1998 to 2006 and from 2007 to 2009. This figure shows that the least amount of water is pumped into the SBA during the winter months and the most is pumped in during the summer months. Unlike Banks, there has been more pumping during most months in the last few years than during the 1998 to 2006 period. Lake Del Valle is the other source of water for the SBA Contractors. Lake Del Valle receives natural inflows from its watershed and Delta water pumped into it at the Del Valle Pumping Plant. **Figure 3-25** presents the average monthly pumping at the South Bay Pumping Plant and average monthly releases from Lake Del Valle for the 1998 to 2009 period. During most months of the year there are minimal releases from Lake Del Valle so ACWD and SCVWD are receiving primarily water from the Delta. Water is released from Lake Del Valle primarily from September to November and can represent a large portion of the water that ACWD and SCVWD receive during these months, particularly in November.

Figure 3-21. Annual Pumping at the Banks Pumping Plant

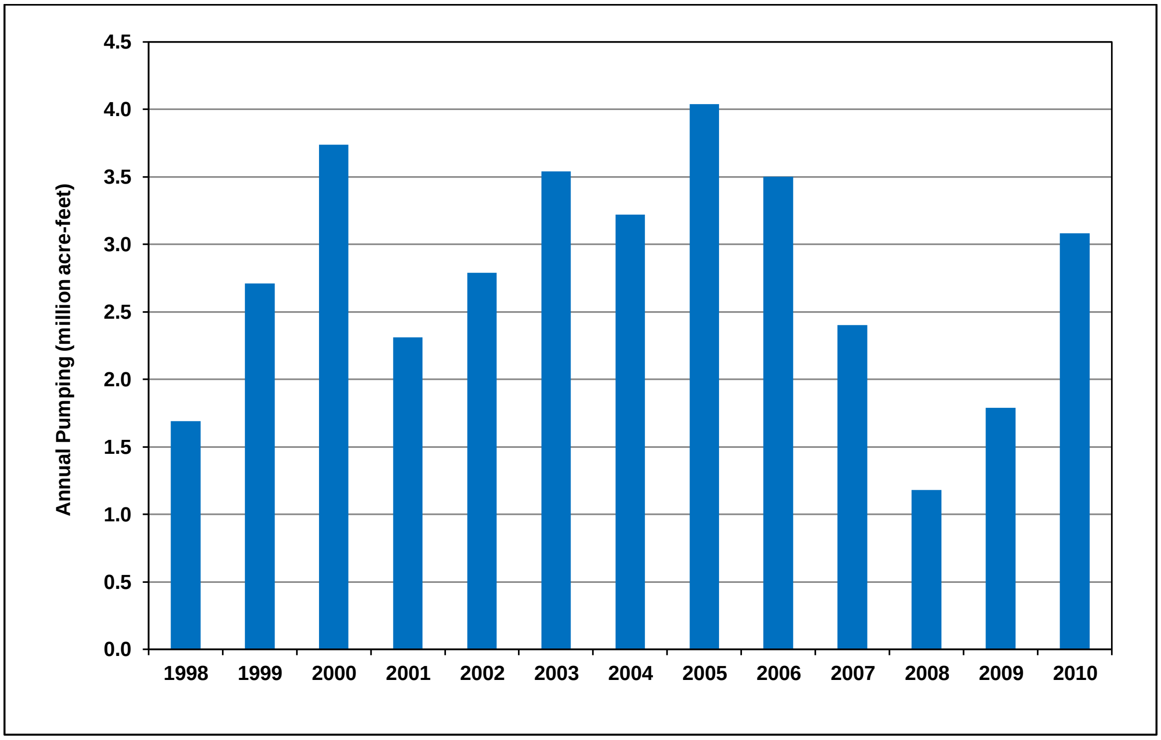


Figure 3-22. Average Monthly Pumping at the Banks Pumping Plant

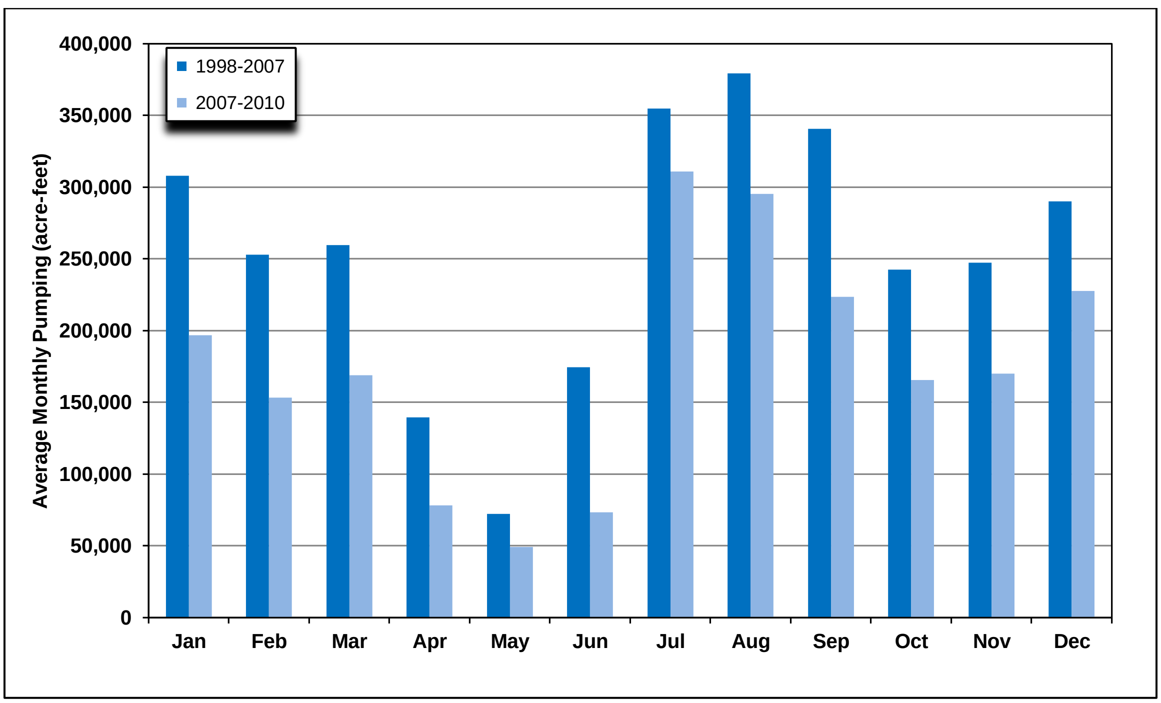


Figure 3-23. Annual Pumping at the South Bay Pumping Plant

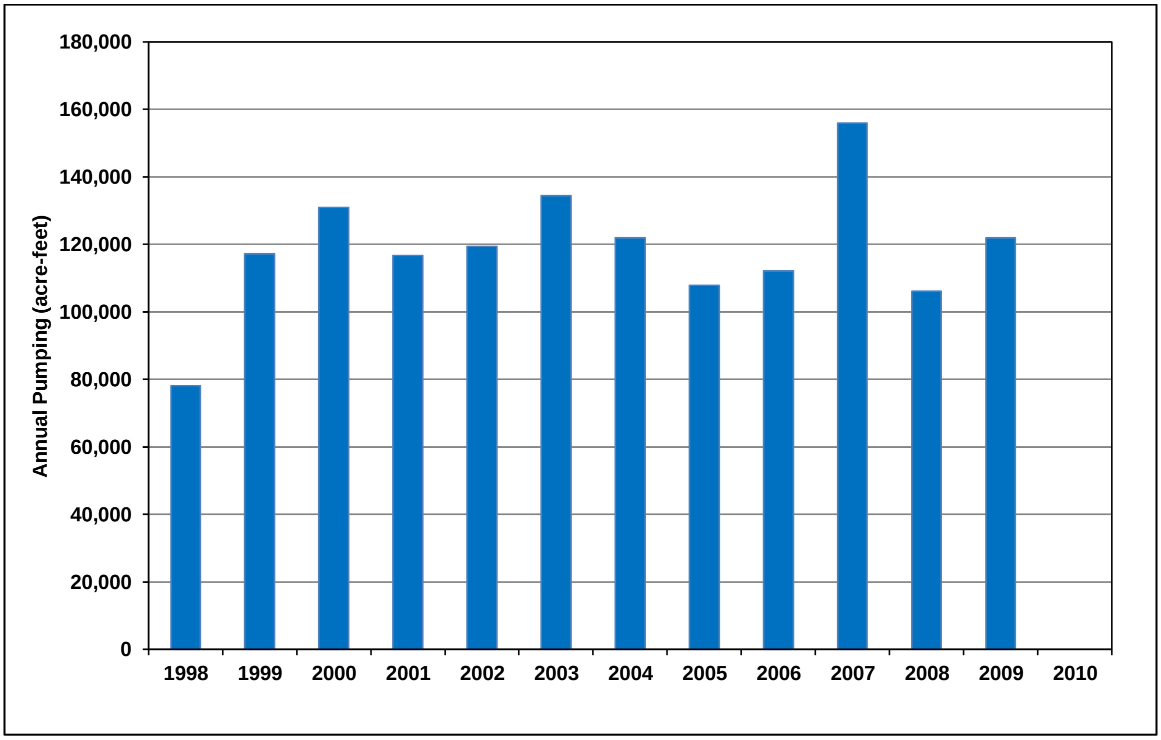


Figure 3-24. Average Monthly Pumping at the South Bay Pumping Plant

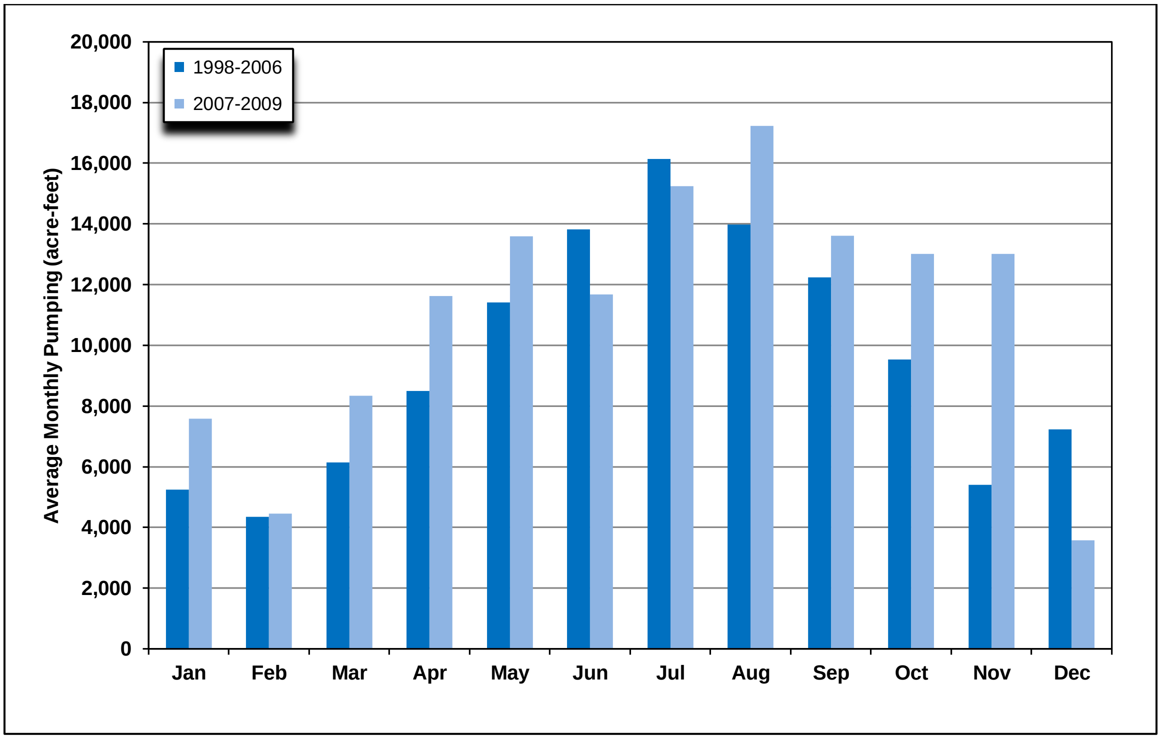
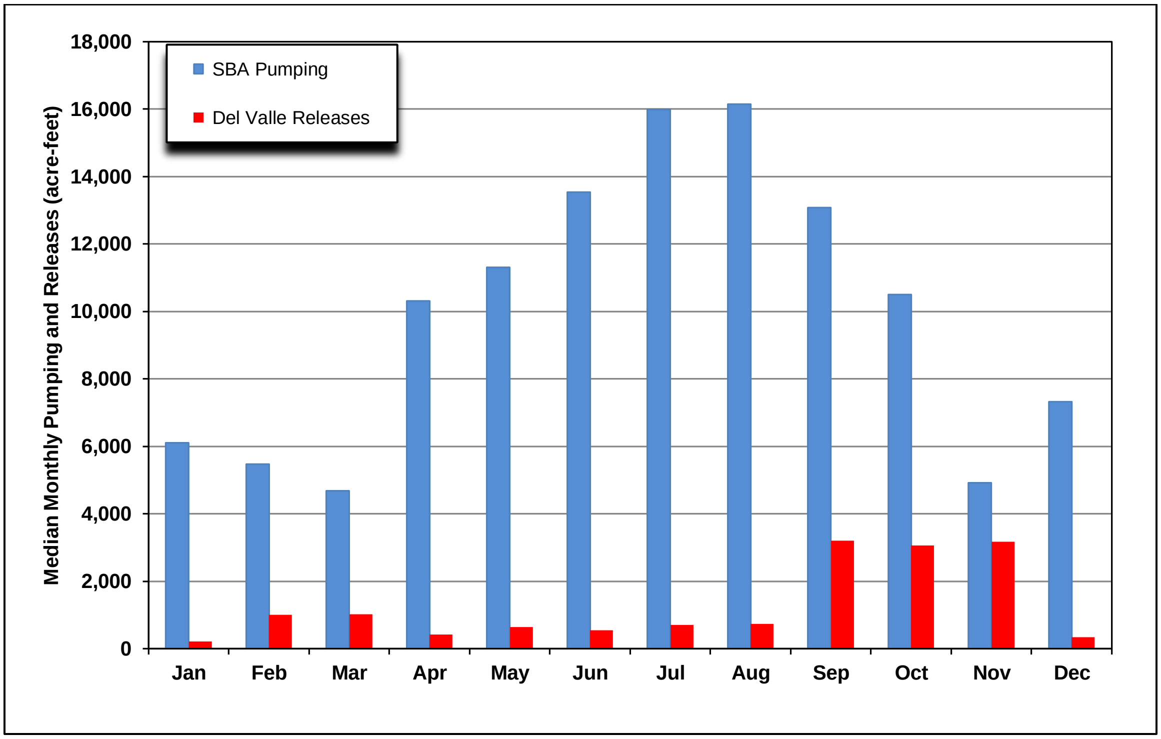


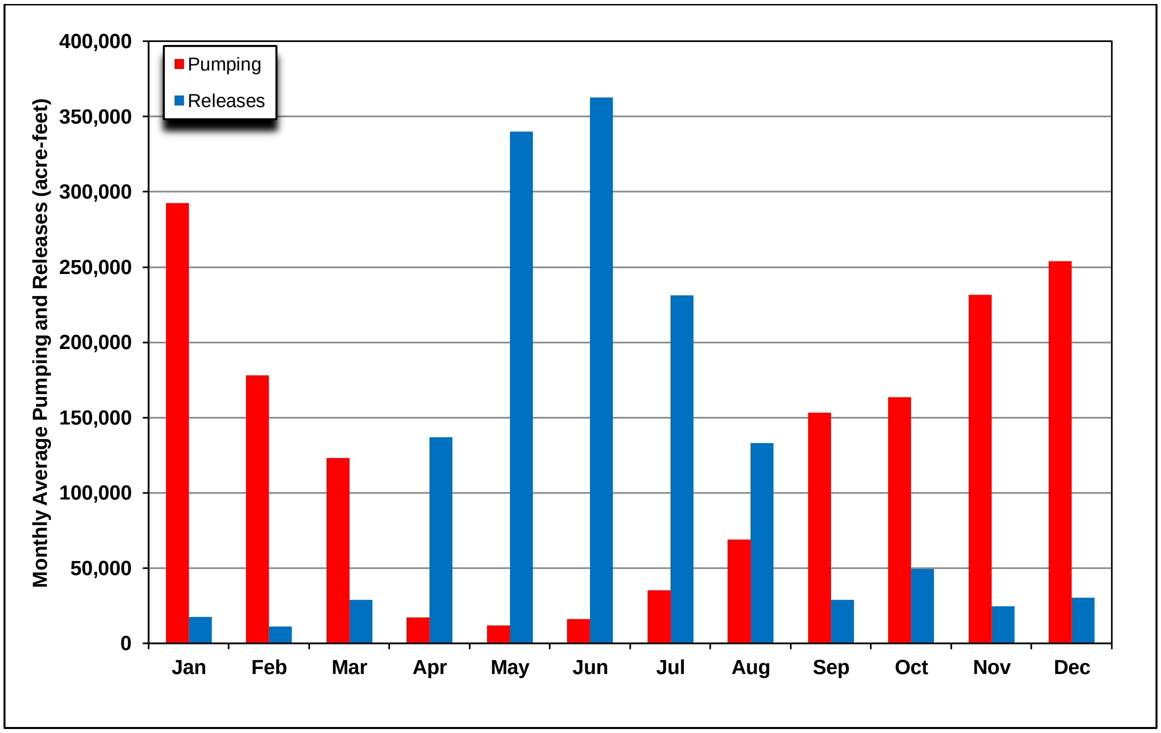
Figure 3-25. Monthly Pumping at the South Bay Pumping Plant and Releases from Lake Del Valle (1998 to 2009)



San Luis Reservoir

Water is generally pumped into San Luis Reservoir starting between the fall months and March, when supplies are available and demand for water is lowest. The stored water is released from the reservoir during the summer months when agricultural and urban demands are highest. **Figure 3-26** shows the average monthly pumping and releases from the Gianelli Pumping Plant for the 1998 to 2009 period. Data were not available for 2010.

Figure 3-26. Monthly Pumping at the Gianelli Pumping Plant and Releases from San Luis Reservoir (1998 to 2009)



WATER QUALITY DATA

DATA SOURCES

Sources of data for this chapter include flow data from the U.S. Geological Survey (USGS) and DWR, as well as discrete (grab) sample water quality data and continuous recorder (real-time) water quality data from DWR monitoring stations in the Delta and SWP. The grab sample data were obtained from DWR's Water Data Library and the real-time data were obtained from CDEC. A number of SWP Contractors provided pathogen and indicator organism data. The pathogen data provided by the Contractors generally comes from the intakes to their water treatment plants rather than at locations in the SWP that are monitored by DWR.

MONITORING LOCATIONS

Chapters 4 through 11 contain a discussion of data collected at numerous locations in the major rivers, the Delta, and the SWP, with varying periods of record. **Figure 3-2** shows the monitoring locations in the Delta and **Figures 3-3 through 3-11** show the monitoring locations along the SWP. **Table 3-2** provides a brief explanation of the monitoring locations that are referred to in the following chapters.

Table 3-2. Water Quality Monitoring Locations

Monitoring Location	Abbreviated Name	Description
The SWP Watershed		
Sacramento River at West Sacramento	West Sacramento	Sacramento River upstream of Sacramento urban area
American River	American	American River five miles upstream of confluence with Sacramento River
Sacramento River at Hood	Hood	Sacramento River inflow to the Delta
Sacramento River at Greenes Landing	Greenes Landing	Sacramento River inflow to the Delta two miles downstream of Hood. This station was replaced by Hood.
Mokelumne River at Wimpys	Mokelumne	Mokelumne River inflow to the Delta
Calaveras River at Brookside Road	Calaveras	Calaveras River inflow to the Delta
San Joaquin River near Vernalis	Vernalis	San Joaquin River inflow to the Delta
Clifton Court Forebay Inlet Structure	Clifton Court	Inlet to Clifton Court Forebay from Old River
Harvey O. Banks Delta Pumping Plant Headworks	Banks	Inception of California Aqueduct
North Bay Aqueduct		
Barker Slough Pumping Plant	Barker Slough	Inlet to North Bay Aqueduct (supplies Fairfield and Vacaville)
Cordelia Pumping Plant Forebay	Cordelia	North Bay Aqueduct (supplies Vallejo, Benicia, Napa, and American Canyon)
South Bay Aqueduct		
Del Valle Check 7	DV Check 7	SBA upstream of Lake Del Valle
Del Valle Conservation Outlet	Conservation Outlet	Outlet from Lake Del Valle to SBA
Vallecitos Turnout	Vallecitos	SBA downstream of Lake Del Valle
Santa Clara Terminal Reservoir	Terminal Tank	Terminus of the SBA at SCVWD intake
Delta-Mendota Canal		
Headworks at Jones Pumping Plant	Jones	Inception of the DMC
DMC at McCabe Road	McCabe	DMC upstream of O'Neill Forebay at McCabe Road bridge
DMC at O'Neill Intake	O'Neill Intake	DMC at milepost 70 near O'Neill Pump-Generation Plant
California Aqueduct and Reservoirs		
Pacheco Pumping Plant	Pacheco	San Luis Reservoir releases to SCVWD
Gianelli Pumping-Generating Plant	Gianelli	San Luis Reservoir releases to O'Neill Forebay and California Aqueduct
O'Neill Forebay Outlet	O'Neill Forebay Outlet	California Aqueduct at O'Neill Forebay outlet
Check 21	Check 21	California Aqueduct at end of San Luis Canal reach. Represents water quality in Coastal Branch Aqueduct.
Check 29	Check 29	California Aqueduct 3.5 miles downstream of Kern River Intertie
Check 41	Check 41	Inlet to Tehachapi Afterbay near bifurcation of East and West Branches
Check 66	Check 66	East Branch, near Silverwood Lake inlet
Castaic Lake Outlet Tower	Castaic Outlet	Outlet from Castaic Lake on the West Branch. Samples are collected in surface water at 1 meter depth.
Silverwood Lake at San Bernardino Tunnel	Silverwood Outlet	Outlet from Silverwood Lake via the San Bernardino Tunnel to Devil Canyon.
Devil Canyon Headworks and Afterbay	Devil Canyon	Devil Canyon Afterbay, intake for MWDSC's Mills WTP, and for San Bernardino Valley Municipal Water District.
Lake Perris	Perris Outlet	Outlet to Lake Perris and intake for MWDSC, terminus of East Branch.

Rather than comparing water quality conditions for the last five years (2006 to 2010) to data from the previous five years, the entire period of record at each key location is evaluated and discussed in this chapter. This approach was taken because the hydrologic conditions of the system greatly affect water quality. Comparing one five year period to the previous five year period is not meaningful if the hydrologic conditions are different. Data are presented in summary form for all locations listed in **Table 3-2**, if available, and analyzed in more detail for the following key locations, including those that are the sources of water to the Contractors' water treatment plants.

- Sacramento River at Hood (Hood) – Represents the quality of water flowing into the Delta from the Sacramento River.

- San Joaquin River at Vernalis (Vernalis) – Represents the quality of water flowing into the Delta from the San Joaquin River.

- Barker Slough Pumping Plant (Barker Slough) – Represents the quality of water entering the NBA.

- Banks Pumping Plant (Banks) – Represents the quality of water entering the California Aqueduct.

- South Bay Aqueduct Del Valle Check 7 (DV Check 7) - Represents SBA water quality upstream of releases from Lake Del Valle. Since limited data are collected downstream of this location, it is used to represent the quality of water delivered to all SBA Contractors.

- Delta-Mendota Canal at McCabe Road (McCabe) – Represents the quality of water entering O'Neill Forebay from the DMC.

- Pacheco Pumping Plant (Pacheco) – Represents the quality of water delivered to SCVWD from San Luis Reservoir. This location is also used to represent the quality of water delivered to O'Neill Forebay from San Luis Reservoir since limited data are available at Gianelli.

- California Aqueduct O'Neill Forebay Outlet – Represents the quality of water entering the California Aqueduct after mixing of water from the aqueduct, DMC, and San Luis Reservoir in O'Neill Forebay.

- California Aqueduct Check 21 (Check 21) – Represents the quality of water entering the Coastal Branch and delivered to Central Coast Water Authority and San Luis Obispo County Flood Control and Water Conservation District. This location is also used to evaluate the impacts of inflows to the aqueduct between O'Neill Forebay Outlet and Check 21.

- California Aqueduct Check 41 (Check 41) – Represents the quality of water entering the east and west branches of the aqueduct. This location is also used to evaluate the impacts of inflows to the aqueduct between Check 21 and Check 41.

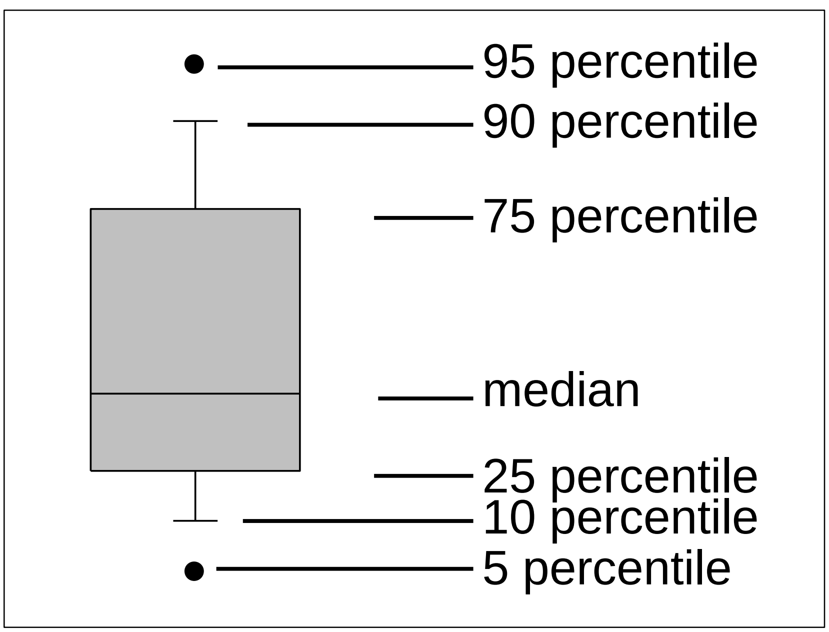
- Castaic Lake Outlet (Castaic Outlet) – This is the terminus of the west branch of the aqueduct. It represents the quality of water delivered to MWDSC and CLWA. Deliveries to the Ventura County Flood Control and Water Conservation District are made directly to the Santa Clara River.

- Devil Canyon Afterbay (Devil Canyon) and Silverwood Lake (Silverwood) – Represents the quality of water delivered to MWDSC, CLAWA, and San Bernardino Valley Municipal Water District.

DATA EVALUATION AND STATISTICAL ANALYSIS

Time series plots are presented for each of the key locations for each constituent that is discussed in the following chapters. Non-detects were set at the detection limit and included in the graphs and the statistical analyses. Box plots are also used to show data from multiple locations on one plot and to display seasonal differences at one location. **Figure 3-27** presents an explanation of the box plots. Since environmental data are not normally distributed, the non-parametric Mann-Whitney test (also called the Wilcoxon Rank-sum test) was used for comparisons of data among locations and between wet years and dry years. In this report, the *p*-value is reported whenever a statistical comparison is made. The *p*-value is a computed probability value used in combination with a prescribed level of significance (α) to determine if a test is statistically significant. The smaller the *p*-value, the stronger is the evidence supporting statistical significance. The commonly accepted α-value of 5 percent or $\alpha=0.05$ is used in this report. If the *p*-value is <0.05, the statistical test is declared significant.

Figure 3-27. Explanation of Box Plots



WATER QUALITY SUMMARY

Chapters 4 through 11 contain detailed analyses of the water quality data collected in the watersheds, the Delta, and the SWP facilities. Each of those chapters ends with a summary of the key findings from the data analysis. Those summaries are also presented in this section to provide the reader with a brief overview of water quality in the SWP.

ORGANIC CARBON

- The DOC fingerprints indicate that the San Joaquin River is the primary source of DOC at the south Delta pumping plants when flows on that river are high. During dry years, the Sacramento River has more influence on DOC concentrations at the pumping plants. Delta agricultural drainage is also a source of DOC at the pumping plants.

- Total organic carbon (TOC) concentrations are measured with both the combustion and oxidation methods at various locations in the SWP. Ngatia et al. (2010) found that the two methods were equivalent and that the field instruments were equivalent to the laboratory instruments at the 20 percent equivalence level. Organic carbon samples measured with the oxidation method were evaluated in this chapter since there is a longer period of record. The grab samples that are analyzed by the oxidation method were compared to real-time results that are analyzed by the combustion method since most of the real-time samplers use the combustion method.

- The median TOC concentration of 1.8 mg/L in the Sacramento River at Hood is not statistically significantly different from the median TOC concentration of 2.0 mg/L at West Sacramento, which is upstream of the Sacramento urban area (Mann-Whitney, p=0.3395). This is despite the fact that the high quality American River (median of 1.6 mg/L) enters the Sacramento River between these two locations. This is likely due to the fact that urban runoff and treated wastewater from the Sacramento urban area are discharged to the river between West Sacramento and Hood. The median TOC concentration of 3.3 mg/L in the San Joaquin River at Vernalis is statistically significantly higher than the median concentration of 1.8 mg/L at Hood (p=0.0000).

- TOC concentrations are much higher in the NBA than any other location in the SWP. Wet season peak concentrations are generally in the range of 14 to 20 mg/L and the median concentration is 5.5 mg/L. The local Barker Slough watershed is the source of this TOC.

- TOC concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct when data collected during comparable periods of time are aggregated and analyzed. The median TOC concentrations along the aqueduct range from 3.0 to 3.2 mg/L. San Luis Reservoir and Castaic Lake have less variability in TOC concentrations than the aqueduct due to the dampening effect of reservoir mixing. The dampening effect is not seen in Silverwood Lake on the East Branch due to its limited hydraulic residence time. Changes in TOC concentrations are apparent in the aqueduct during periods when non-Project inflows are introduced between Checks 21 and 41.

- Water agencies treating SWP water in conventional water treatment plants must remove TOC from their influent water based on the TOC and alkalinity concentrations of the water. Agencies treating NBA water typically remove 35 percent of the TOC and at times, are required to remove up to 50 percent of the TOC. The SWP Contractors treating water from the California Aqueduct in conventional water treatment plants typically have to remove 25 percent of the TOC. Alkalinity levels are often low when TOC concentrations are high, leading to the requirement to remove 35 percent of the TOC in the source water in conventional water treatment plants and to implement TOC removal in addition to ozone disinfection. On occasion, alkalinity concentrations drop below 60 mg/L when TOC concentrations exceed 4 mg/L leading to the requirement to remove 45 percent of the TOC in the source water.

- The real-time samplers at Hood, Vernalis, and Banks provide valuable information on the variability of TOC concentrations at these locations. The real-time monitoring data compare well with the grab sample data collected on the same day. The real-time data show that TOC peaks are higher than previously measured in grab samples. Peak concentrations at Hood and Vernalis are more than 3 mg/L higher than those measured in grab samples. There is a smaller difference at Banks with real-time peaks being about 1.5 mg/L higher than those measured in grab samples.

- DWR's Municipal Water Quality Investigations (MWQI) Program staff conducted a long-term trend analysis at Hood, Vernalis, and Banks (Personal Communication, Carol DiGiorgio, DWR). Trends were analyzed for the entire period of record through 2008 at each location and for the 1999 to 2008 period. Different results were obtained for the different periods of time. For example, the analysis showed a declining trend in DOC at all three locations during the longer period and an increasing trend at Hood and Vernalis and no trend at Banks during the more recent period. This analysis showed that trends are very much a function of the hydrology of the system during the starting and ending points of the analysis. Another trend analysis conducted at Banks between 1990 and 2003 by DWR O&M staff reached the same conclusion (DWR, 2005b).

- Time series graphs at all of the other key locations were visually inspected to determine if there are any discernible trends. There are no apparent long term trends at most of the locations included in this analysis. TOC concentrations have been lower at Check 41 and Castaic Outlet in recent years as a result of the substantial amount of non-Project inflows that are low in TOC. Inexplicable, the lower TOC concentrations have not been seen at Devil Canyon.

- There are no statistically significant differences between median TOC concentrations in dry years and wet years at many of the locations along the aqueduct, as shown in **Table 3-3**. Dry year concentrations are statistically significantly lower than wet year concentrations at Barker Slough, Pacheco, Check 41, and Castaic Outlet. Conversely, dry year concentrations are statistically significantly higher in the Sacramento and San Joaquin rivers. With the exception of Barker Slough, there is generally only about a 10 percent difference between dry year and wet year median concentrations of TOC at the locations where there is a statistically significant difference.

- There is a distinct seasonal pattern in TOC concentrations in the Sacramento River, the Delta, and the aqueducts. High concentrations (5 to 9 mg/L) occur during the wet season and low concentrations (2 to 3 mg/L) occur in the late summer months. Vernalis has a slightly different pattern with both winter and summer peaks. The summer peak is attributed to agricultural drainage entering the river during low flow periods. San Luis Reservoir and Castaic Lake display a different seasonal pattern. Concentrations are highest in the summer months and lowest in the winter months.

- There is a good correlation between DOC and TOC at most locations in the SWP system. DOC is generally about 85 to 95 percent of TOC and the coefficient of determination (R^2) is generally 0.9 or better. The two rivers have more particulate organic carbon and poorer R^2 values.

Table 3-3. Comparison of Dry Year and Wet Year TOC Concentrations

Location	Median TOC (mg/L)		TOC Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	1.9	1.7	0.2	11	D>W
Vernalis	3.6	3.2	0.4	11	D>W
Banks	3.2	3.2	0	0	No
Barker	4.2	5.8	-1.6	-38	D<W
DV Check 7	3.6	3.2	0.4	11	No
McCabe	3.2	3.2	0	0	No
Pacheco	3.2	3.5	-0.3	-9	D<W
O'Neill Forebay Outlet	3.2	3.5	-0.3	-9	No
Check 21	3.0	3.2	-0.2	-7	No
Check 41	2.9	3.2	-0.3	-10	D<W
Castaic Outlet	2.7	3	-0.3	-11	D<W
Devil Canyon	3	3.2	-0.2	-7	No

SALINITY

- The EC fingerprints indicate that the San Joaquin River, seawater intrusion, and Delta agricultural drainage are the primary sources of EC at the south Delta pumping plants. The San Joaquin River has a greater influence on EC at Jones than at Banks.

- The median EC at Hood (158 µS/cm) is statistically significantly lower than the median of 163 µS/cm at West Sacramento when data from the same period of record are compared (Mann-Whitney, p=0.0263). This small decrease in the median level is due to the inflow of the American River (median EC of 62 µS/cm). The decrease is lower than expected and probably due to the discharge of Sacramento area urban runoff and treated wastewater to the river. EC levels at Vernalis (median of 629 µS/cm) are substantially higher than the levels in the Sacramento River.

- EC levels in the NBA are higher and more variable than at Hood but lower than the levels at Banks. Peak EC levels are found in April with a clear indication that the local Barker Slough watershed is a contributor of salinity. The real-time results reveal a small but statistically significant decrease in EC between Barker Slough (277 µS/cm) and Cordelia (266 µS/cm) (Mann-Whitney, p=0.0000).

- The median EC at Banks (408 µS/cm) is statistically significantly lower than the median EC at Jones (451 µS/cm) due to the greater influence of the San Joaquin River at Jones (Mann-Whitney, p=0.0082). EC does not change significantly between Banks, Del Valle Check 7 (DV Check 7), and the Terminal Tank on the SBA. EC changes in the California Aqueduct and SWP reservoirs are complex. Because different periods of record are available at sampling locations, varying time periods are used to compare locations and each time period has a different median at any given location. Consequently, the changes in the aqueduct and reservoirs are described in terms of the increase or decrease in EC levels rather than by comparing medians in this summary. There is an increase of 97 µS/cm in EC between Banks and Pacheco; however the variability of EC in the reservoir is greatly reduced. The increase between Banks and Pacheco is due to evaporation in the reservoir, the timing of filling the reservoir, and the mixing of DMC water with aqueduct water in O'Neill Forebay. EC increases along the DMC by 29 µS/cm between Jones and O'Neill Intake. There is an increase of 63 µS/cm between Banks and O'Neill Forebay Outlet and no statistically significant change in EC between O'Neill Forebay Outlet and Check 21. There is a statistically significant decrease in EC between Check 21 and Check 41 of 16 µS/cm. This is likely due to the non-Project inflows of lower EC water in recent years. The median EC at Castaic Outlet is 57 µS/cm higher than at Check 41 but there is no statistically significant change between Check 41 and Devil Canyon. EC levels at Castaic Outlet are less variable than the aqueduct locations, due to the dampening effect of about 500,000 acre-feet of storage on the West Branch. The dampening effect is not seen in Silverwood Lake on the East Branch due to its limited hydraulic residence time.

- There are a number of real-time monitoring locations in the watersheds, along the California Aqueduct, and in the reservoirs. There is good correspondence between the grab sample and real-time EC data at most locations. There are differences at Vernalis, Banks, Cordelia, and Devil Canyon. The EC levels in grab samples at Cordelia are substantially higher than those measured by the real-time equipment. This warrants some investigation because there is good correspondence between the real-time data at Barker Slough and at Cordelia. Cordelia is a small forebay so it's difficult to explain why there would be such a difference between the real-time and grab sample data. The real-time data at most other locations show that peak EC levels are slightly higher than those measured in the grab samples. This is likely due to the sampling frequency, with the real-time instruments capturing peaks that occur between the days that grab samples are collected.

- DWR (2004) conducted an assessment of long-term salinity trends at Banks using data from 1970 to 2002 and concluded that the salinity in SWP exports has neither increased nor decreased over that period. Time series graphs at each key location were visually inspected to determine if there are any discernible trends. The only trends observed in the data are related to hydrology, with EC increasing during dry years and decreasing during wet years.

- EC levels during wet years are statistically significantly lower than EC levels during dry years at all locations except Barker Slough and Castaic Outlet, as shown in **Table 3-4**. The higher levels during dry years are due to less dilution of agricultural drainage, urban runoff, and treated wastewater discharged to the rivers and Delta during low flow periods and to seawater intrusion in the Delta during periods of low Delta outflow. Barker Slough is influenced more by the local watershed than by differences in Delta conditions in different year types. There is little variability in Castaic due to the dampening effects of storage.

- There are distinct seasonal patterns in EC levels but they vary between locations. On the Sacramento River, EC levels are lowest in the early summer, increase in the fall and then decrease during the spring months. On the San Joaquin River, EC levels are lowest in the spring during the VAMP flows, increase during the summer months due to agricultural drainage discharges, continue to climb during the fall due to seawater intrusion, and remain high until late winter or early spring when flow increases on the river. The seasonal pattern at Banks is similar to the Sacramento River with the lowest levels in July and the highest levels in the fall months. The pattern seen at Banks is seen at most of the other locations except below San Luis Reservoir there is a bimodal seasonal pattern with a secondary peak in EC during May and June. Large amounts of water are released from the reservoir during these months, resulting in higher EC levels in the California Aqueduct.

Table 3-4. Comparison of Dry Year and Wet Year EC Levels

Location	Median EC (µS/cm)		EC Difference (µS/cm)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	168	146	22	13	D>W
Vernalis	745	456	289	39	D>W
Banks	497	312	185	37	D>W
Barker Slough	298	283	15	5	No
DV Check 7	452	311	141	31	D>W
McCabe	516	359	157	30	D>W
Pacheco	528	499	29	5	D>W
O'Neill Forebay Outlet	524	389	135	26	D>W
Check 21	504	418	86	17	D>W
Check 41	482	381	101	21	D>W
Castaic Outlet	497	491	6	1	No
Devil Canyon	482	387	95	20	D>W

BROMIDE

- Bromide concentrations in the Sacramento River are low, often at or near the detection limit of 0.01 mg/L. Conversely, bromide concentrations are high in the San Joaquin River (median of 0.25 mg/L).

- Bromide concentrations in the NBA are higher and more variable than at Hood but substantially lower than the levels at Banks. The Barker Slough watershed is the source. The median bromide concentration (0.04 mg/L) is the same at Barker Slough and Cordelia.

- The median concentration of bromide does not change significantly between Banks, DV Check 7, and the Terminal Tank on the SBA. There is a statistically significant increase in bromide between Banks (median of 0.18 mg/L) and San Luis Reservoir (median of 0.25 mg/L) (Mann-Whitney, p=0.0002); however, the variability of bromide in the reservoir is greatly reduced. Bromide concentrations in the DMC at McCabe (median of 0.20 mg/L) are not statistically significantly different from Banks so the increase between Banks and Pacheco is attributed to evaporation in the reservoir and filling of the reservoir when bromide concentrations are high in the Delta. There is a statistically significant increase in bromide concentrations between Banks and O'Neill Forebay Outlet (median of 0.22 mg/L) but bromide does not change statistically significantly between O'Neill Forebay Outlet and Castaic Outlet and Devil Canyon. Bromide concentrations in Castaic Lake are slightly less variable than the aqueduct locations; however, the dampening effect is not seen in Silverwood Lake.

- Anion analyzers have measured bromide concentrations continuously at Banks and Vernalis for over four years. There is good correspondence between the grab sample and real-time data at these two locations. The real-time data at Banks show that bromide concentrations are occasionally higher than the levels measured in grab samples.

- Bromide concentrations are a function of the hydrology of the system. There are apparent downward trends in bromide concentrations at Vernalis and Banks that are simply due to the fact that data collection began at these two sites during the drought of the early 1990s. There is an apparent upward trend in bromide concentrations at Pacheco that is due to the fact that bromide data were first collected in 2000, which was the end of six wet years and bromide concentrations were low. There are no apparent long term trends at any of the other locations included in this analysis.

- Bromide concentrations during dry years are statistically significantly higher than bromide concentrations during wet years at all locations except Barker Slough, as shown in **Table 3-5**. There are no statistically significant differences between year types at this location. The median bromide concentrations during dry years are 50 to 100 percent higher than the median concentrations during wet years. This is due to seawater intrusion in the Delta during periods of low Delta outflow.

- There are distinct seasonal patterns in bromide concentrations but they vary between locations. At Barker Slough, bromide concentrations increase during the spring months due to groundwater and subsurface flows from the Barker Slough watershed and then decrease throughout the summer and fall months. On the San Joaquin River, concentrations decrease throughout the winter and spring months to minimum levels in May during the VAMP flows. The concentrations then increase throughout the summer, fall, and early winter months. Concentrations are low at Banks from February through May and then increase steadily throughout the summer, fall, and early winter months due to the discharge of agricultural drainage and seawater intrusion. Downstream of San Luis reservoir, bromide concentrations show the same pattern as Banks except there is a secondary peak in May and June due to the release of large amounts of water from San Luis Reservoir.

Table 3-5. Comparison of Dry Year and Wet Year Bromide Concentrations

Location	Median Bromide (mg/L)		Bromide Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	<0.01	<0.01	0	0	No
Vernalis	0.30	0.17	0.13	43	D>W
Banks	0.27	0.12	0.15	56	D>W
Barker Slough	0.04	0.04	0	0	No
DV Check 7	0.18	0.12	0.06	33	D>W
McCabe	0.24	0.13	0.11	46	D>W
Pacheco	0.26	0.23	0.03	12	D>W
O'Neill Forebay Outlet	0.27	0.16	0.11	41	D>W
Check 21	0.24	0.15	0.09	38	D>W
Check 41	0.22	0.14	0.08	36	D>W
Castaic Outlet	0.23	0.16	0.07	30	D>W
Devil Canyon	0.23	0.15	0.08	35	D>W

NUTRIENTS

- Nutrient concentrations increase considerably in the Sacramento River between West Sacramento and Hood, despite the inflow of the high quality American River, due mainly to the discharge from the Sacramento Regional Wastewater Treatment Plant. The median concentrations of total N (0.67 mg/L) and total P (0.08 mg/L) at Hood are statistically significantly higher than the median concentrations of total N (0.29 mg/L) and total P (0.05 mg/L) at West Sacramento. Total N and total P concentrations in the San Joaquin River are considerably higher and more variable than concentrations in the Sacramento River. The median total N concentration at Vernalis of 2 mg/L is the highest in the SWP system. The total P median is 0.16 mg/L, twice the level found at Hood.

- Nutrient concentrations in the NBA are higher than in the Sacramento River. The median total N concentration is 0.8 mg/L and the median total P concentration is 0.18 mg/L. The highest concentrations occur in the winter months due to the influence of runoff from the local Barker Slough watershed.

- Total N and total P concentrations in water exported from the Delta at Banks are sufficiently high to cause algal blooms in the aqueducts and downstream reservoirs.

- Nutrient concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct. Median total N concentrations are about 1.0 mg/L and median total P concentrations are about 0.1 mg/L throughout the system, with the exception of Castaic Outlet and Perris Outlet. The median concentrations are substantially lower at Castaic Outlet (total N is 0.67 mg/L and total P is 0.04 mg/L) and at Perris Outlet (total N is 0. 51 mg/L and total P is 0.03 mg/L). Algal uptake and subsequent settling of particulate matter may be responsible for the lower nutrient concentrations in the terminal reservoirs.

- There is a shorter period of record for nutrient data than for other water quality constituents such as organic carbon and EC, at many of the key locations. Time series graphs at each key location were visually inspected to determine if there are any discernible trends. Total P concentrations at DV Check 7 and along the California Aqueduct below San Luis Reservoir have been lower and less variable in the last five years. It’s not clear if this is a trend or if it is related to hydrology since four of the last five years have been dry years.

- Comparison of nutrient concentrations in dry years and wet years does not produce a consistent pattern throughout the system, as shown in **Tables 3-6 and 3-7**. At many locations there are no differences between dry and wet years. At Hood and Vernalis, total P concentrations are not statistically different between dry years and wet years but total N concentrations are statistically significantly higher during dry years. This may be due to the greater influence of the Sacramento Regional Wastewater Treatment Plant at Hood and to agricultural drainage at Vernalis. At Pacheco, both total N and total P are statistically significantly lower in dry years. This is likely due to algal uptake and settling in the reservoir since samples are collected in the epilimnion of the reservoir more frequently during dry years when water levels are lower. The pattern at Castaic Lake is different with both total N and total P being statistically significantly higher in dry years. Check 41 and Devil Canyon show the same pattern of higher total N concentrations in dry years and lower total P concentrations in dry years. This may be related to non-Project inflows that occur more frequently in dry years.

- Seasonal trends also vary throughout the system. On the Sacramento River, total N and total P concentrations are highest during the wet season of November to February. There is a secondary peak in total N concentrations in June that is likely due to the greater influence of the Sacramento Regional Wastewater Treatment Plant during periods of low flow on the river. On the San Joaquin River nutrient levels are highest from January to March and lowest in May due to VAMP flows. The concentrations of both nutrients gradually increase during the summer months due to agricultural drainage being discharged to the river. Total N concentrations are highest at Banks from January through March, decline during the summer months and gradually increase during the fall months. The total P concentrations are high in the winter months, decrease during April but then increase again in May and June before declining throughout the rest of the summer and fall. The seasonal pattern at a number of the check structures on the aqueduct is similar to the pattern at Banks except that peak levels of total P occur about one month later.

Table 3-6. Comparison of Dry Year and Wet Year Total N Concentrations

Location	Median Total N (mg/L)		Total N Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	0.74	0.60	0.14	19	D>W
Vernalis	2.2	1.8	0.40	18	D>W
Banks	0.99	0.82	0.17	17	No
Barker Slough	0.82	0.84	-0.02	-2	No
DV Check 7	0.84	0.89	-0.05	-6	No
McCabe	NA	NA			
Pacheco	0.96	1.0	-0.04	-4	D<W
O'Neill Forebay Outlet	0.99	0.98	0.01	1	No
Check 21	1.0	1.1	-0.10	-10	No
Check 41	1.1	0.97	0.13	12	D>W
Castaic Outlet	0.7	0.55	0.15	21	D>W
Devil Canyon	1.0	0.88	0.12	12	D>W

Table 3-7. Comparison of Dry Year and Wet Year Total P Concentrations

Location	Median Total P (mg/L)		Total P Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	0.09	0.08	0.01	11	No
Vernalis	0.16	0.16	0	0	No
Banks	0.10	0.10	0	0	No
Barker Slough	0.18	0.20	0.02	11	No
DV Check 7	0.09	0.10	-0.01	-11	No
McCabe	NA	NA			
Pacheco	0.09	0.10	-0.01	-11	D<W
O'Neill Forebay Outlet	0.08	0.10	-0.02	-25	No
Check 21	0.10	0.09	-0.01	-10	No
Check 41	0.08	0.10	-0.02	-25	D<W
Castaic Outlet	0.04	0.03	0.01	25	D>W
Devil Canyon	0.08	0.09	-0.01	-13	D<W

TASTE AND ODOR INCIDENTS AND ALGAL TOXINS

Taste and Odor Incidents

- Monitoring of 2-methylisoborneol (MIB) and geosmin was initiated at a number of locations in the SWP between 2001 and 2005. Monitoring was initiated on the NBA in 2009. The samples are quickly analyzed and email reports are sent to the SWP Contractors alerting them to potential taste and odor (T&O) problems.

- The NBA Contractors experienced a severe T&O episode in February 2009 that resulted in numerous customer complaints when geosmin concentrations quickly increased to over 300 ng/L. The likely T&O producer was *Aphanizomenon gracile*. The NBA had to be shut down for over six weeks, resulting in a significant loss of Delta water for the NBA Contractors. SCWA works with DWR to monitor T&O compounds and to periodically treat Campbell Lake. The combination of monitoring to detect problems and treatments has been effective since the NBA users have had no further customer complaints.

- MIB and geosmin peaks in excess of 10 ng/L have occurred at Clifton Court every summer since monitoring was initiated in 2003. MIB concentrations have exceeded 10 ng/L every year and geosmin concentrations have exceeded 10 ng/L in five of the ten years that monitoring has been conducted at Banks. Concentrations exceeding 10 ng/L can be detected by most people and result in customer complaints to drinking water providers. The highest MIB concentration measured at Banks was 74 ng/L in August 2004 and the highest geosmin concentration was 32 ng/L in September 2006. Benthic cyanobacteria are responsible for most of the T&O production in the Delta and Clifton Court.

- The peak levels of MIB and geosmin at Banks are quickly transported to the SBA. MIB and geosmin concentrations exceeded 10 ng/L every summer between 2003 and 2007 and again in 2010. The highest MIB concentration measured at DV Check 7 was 50 ng/L in July 2007 and the highest geosmin concentration was 17 ng/L in July 2005. There was a trend of increasing MIB concentrations between 2003 and 2007 but levels declined in the last three years.

- MIB from the Delta is transported down the California Aqueduct to O’Neill Forebay Outlet but the concentrations decrease with distance down the aqueduct. Peak levels measured at O’Neill Forebay Outlet are 21 ng/L of MIB and 10 ng/L of geosmin.

- San Luis Reservoir has low levels of MIB and geosmin (usually 4 ng/L or lower) at Pacheco and at the Inlet/Outlet tower on the east side of the reservoir.

- MIB and geosmin are generated in the aqueduct downstream from San Luis Reservoir. Peak levels of 27 ng/L of MIB and 50 ng/L of geosmin have been found at Check 41. In the East Branch at Check 66, peak levels have reached 130 ng/L for MIB and 260 ng/L for geosmin. MIB and geosmin concentrations have exceeded 10 ng/L every summer since monitoring was initiated at Check 66 in 1999.

- Castaic Lake has high levels of geosmin every summer (up to 830 ng/L) and occasional MIB peaks greater than 10 ng/L. Geosmin concentrations routinely exceed 10 ng/L and occasionally exceed 100 ng/L in the surface waters. High levels of geosmin can extend throughout the water column during an algal bloom. In Castaic the great depth of the outlet generally ameliorates the T&O produced in the surface waters.

- Silverwood Lake has peaks of both compounds that exceed 10 ng/L but do not reach the high levels found in Castaic Lake. However, since Silverwood Lake is fully mixed, the downstream SWP Contractors receive whatever levels of MIB and geosmin are present in Silverwood Lake water. It is critical to control T&O producing algae in the East Branch before Silverwood is loaded with the T&O compounds.

Algal Toxins

- *Microcystis aeruginosa* blooms have occurred routinely in the summer months in the Delta since 1999. While blooms are found throughout the Delta, the highest cell densities are routinely found in the south Delta in Old River and Middle River.

- DWR conducted cyanotoxin monitoring at various locations in the SWP for four years. In 2007 microcystin-LR was detected at all locations that were monitored, except Barker Slough. It was below the reportable limit of 1 µg/L.

TURBIDITY

- Turbidity levels in the Sacramento River are related to flows, with higher turbidities associated with higher flows. The San Joaquin River shows the same pattern of rapidly increasing turbidity when flows first increase in the winter months; however during prolonged periods of high flows, turbidity drops back down. Median turbidity levels at Vernalis (19 NTU) are higher than at Hood (11 NTU).

- The turbidity levels at Barker Slough are substantially higher (median of 32 NTU) and more variable than at Hood or any other SWP monitoring location. Peak turbidity levels occur in the winter months and in July. The high turbidity levels create treatment challenges for the NBA Contractors.

- The median turbidity at Banks (9 NTU) is statistically significantly lower than in the Sacramento and San Joaquin rivers, reflecting settling in Delta channels and Clifton Court Forebay. Although the median turbidity is low, there is tremendous variability in turbidity at Banks. The turbidity levels at DV Check 7 on the SBA are similar to those at Banks and there is a small but statistically significant decrease with a median turbidity of 6 NTU at the Terminal Tank. This could reflect the influence of settling in Lake Del Valle. Turbidity levels are low in the SWP reservoirs with a median of 2 NTU in Pacheco and Devil Canyon and 1 NTU at Castaic Outlet. Turbidity decreases from a median of 9 NTU at Banks to a median of 6 NTU at O’Neill Forebay Outlet below San Luis Reservoir and then does not decrease significantly between O’Neill Forebay Outlet and Check 41.

- There are a number of real-time instruments measuring turbidity in the SWP. While some of the real-time data (Pacheco and Check 41) show good correspondence with the grab sample data, the others generally show poor correspondence. In most cases the real-time instruments produce results that are consistently higher than the grab samples and in some cases the real-time results are lower than the grab samples.

- Time series graphs at each key location were visually inspected to determine if there are any discernible trends. Turbidity levels appear to be lower and less variable at a few locations and there are no apparent long-term trends at most locations. Turbidity is influenced by hydrologic conditions and by system operation.

- Turbidity levels are statistically significantly lower during dry years than wet years at most locations that were included in this analysis, as shown in **Table 3-8**. At several locations, including San Luis Reservoir and Castaic Outlet, there was no statistically significant difference between dry and wet years.

- The seasonal patterns vary greatly. The Sacramento River has high turbidity during the winter months and low turbidity during the summer. The San Joaquin River shows an opposite pattern with high turbidity during the summer. The seasonal pattern at Banks is similar to the San Joaquin River. Along the aqueduct, there are peaks in the winter months and again in June or July.

Table 3-8. Comparison of Dry Year and Wet Year Turbidity Levels

Location	Median Turbidity (NTU)		Turbidity Difference (NTU)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	10	12	-2	-20	D<W
Vernalis	19	18	1	5	No
Banks	8	10	-2	-25	D<W
Barker Slough	28	39	-11	-39	D<W
DV Check 7	8	9	-1	-13	No
McCabe	13	14	-1	-8	No
Pacheco	2	2	0	0	No
O'Neill Forebay Outlet	5	7	-2	-40	D<W
Check 21	5	7	-2	-40	D<W
Check 41	6	9	-3	-50	D<W
Castaic Outlet	1	1	0	0	No
Devil Canyon	2	3	-1	-50	D<W

PATHOGENS

- The NBA Contractors and DWR completed the Long-term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) monitoring during the study period, resulting in a Bin 1 classification. Peak total coliform monthly medians were higher than historical values, often exceeding 1,000 MPN/100 ml and were the highest in the SWP sources evaluated. However, fecal coliform monthly medians remained stable and below the 200 MPN/100 ml advanced treatment threshold in all but one month. The current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements are adequate for the water treatment plants (WTPs) that treat NBA water.

- The SBA Contractors completed additional protozoan monitoring and the results were consistent with the previous Bin 1 classification. The highest coliform densities were seen at ACWD's WTP2, but the *E. coli* monthly medians were still less than the 200 MPN/100 ml advanced treatment threshold. Peak total coliform densities occurred in the summer months while peak *E. coli* densities occurred in the winter months. The current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements continue to be appropriate for the WTPs that treat SBA water.

- SCVWD completed additional protozoan monitoring for the Santa Teresa WTP, which receives water from San Luis Reservoir, and the results were consistent with the previous Bin 1 classification. Peak total coliform monthly medians were higher than historical values, while *E. coli* monthly medians remained stable and well below the 200 MPN/100 ml advanced treatment threshold. Peak *E. coli* densities occurred during wet weather months. The current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements continue to be appropriate for the Santa Teresa and DWR San Luis O&M WTPs.

- The City of Avenal (CVP Contractor) conducted coliform and protozoan monitoring for its diversion on the San Luis Canal. The densities of total and fecal coliforms were generally low. There were four months when the fecal coliform monthly median was greater than 200 MPN/100 ml. Protozoan analysis of the source water resulted in no detections. The pathogen and coliform data indicate 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements may be appropriate for the WTPs that utilize the San Luis Canal portion of the California Aqueduct.

- CCWA completed LT2ESWTR monitoring during the study period, resulting in a Bin 1 classification. The coliform data continued to show generally low overall densities. Peak total coliform monthly medians were higher than in the 2006 Update, while fecal coliform and *E. coli* remained stable and well below the 200 MPN/100 ml advanced treatment threshold. The data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the Polonio Pass WTP.

- KCWA conducted coliform and protozoa monitoring near its turnout on the California Aqueduct. *Giardia* and *Cryptosporidium* were not detected. The source was classified as Bin 1 under the LT2ESWTR and no additional action is required at this time. Total coliform can exceed 1,000 MPN/100 ml with peak monthly medians greater than those presented in the 2006 Update. *E. coli* densities remained stable and well below the 200 MPN/100 ml advanced treatment threshold. The protozoan and *E. coli* data indicate that the California Aqueduct in this reach requires 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses.

- MWDSC and CLWA completed LT2ESWTR for their WTPs taking water from Castaic Lake during the study period, resulting in a Bin 1 classification. Total coliform monthly medians at MWDSC's Jensen WTP intake exceed 1,000 MPN/100 ml during the summer months and peak densities were higher than those presented in the 2006 Update. Fecal coliform and *E. coli* remained stable and well below the 200 MPN/100 ml advanced treatment threshold, with peak values occurring in 2006 and early 2007. Coliform densities in Castaic Lake are lower and stable throughout the year. The fecal coliform, *E. coli* and protozoan data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the West Branch.

- AVEK completed its LT2ESWTR monitoring in 2006 and Palmdale completed its monitoring in 2007. All four of AVEK's WTPs and Palmdale's WTP were classified as Bin 1. AVEK and Palmdale did not provide any new protozoa data for the study period. The AVEK total coliform monthly medians were less than 1,000 MPN/100 ml and the fecal coliform and *E. coli* monthly medians were well below the 200 MPN/100 ml advanced treatment threshold. The Palmdale total coliform monthly medians increased in 2009 and 2010 and were often above 1,000 MPN/100 ml. The fecal coliform monthly medians were well below the 200 MPN/100 ml threshold. The fecal coliform, *E. coli* and protozoan data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the East Branch.

- MWDSC completed LT2ESWR monitoring at the Mills WTP and CLAWA completed monitoring at its Silverwood Lake intake, resulting in Bin 1 classifications for both agencies. MWDSC's data show that total coliform monthly medians exceed 1,000 MPN/100 ml during the second half of most years and peak densities are higher than those presented in the 2006 Update. Fecal coliform and *E. coli* remained stable and well below the 200 MPN/100 ml advanced treatment threshold. The fecal coliform, *E. coli* and protozoan data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the East Branch lakes.

ORGANIC CHEMICALS AND TRACE ELEMENTS

- DWR collects samples three times each year for organic chemicals. Chemical scans include carbamate pesticides, chlorinated organic pesticides, chlorinated phenoxy herbicides, sulfur pesticides, glyphosate, phosphorus/nitrogen pesticides, and purgeable (volatile organics). Simazine, diuron, 2,4-D, and metolachlor are the chemicals most frequently detected in the SWP. None of the detected chemicals was present in concentrations exceeding a Maximum Contaminant Level (MCL); however, simazine was detected at 3.35 µg/L at Check 41 in March 2007, which is close to the MCL of 4 µg/L.

- Lake Del Valle was listed by the State Water Resources Control Board on the 2006 and 2010 303(d) lists of impaired waterbodies for mercury and polychlorinated biphenyls (PCBs). The listing is based on a finding of elevated levels of these pollutants in the tissues of fish taken from the lake in April 2001. DWR analyzed 44 water samples collected at the Lake Del Valle Conservation Outlet (Conservation Outlet) for dissolved mercury between 1998 and 2010. Mercury was not detected in any of the samples with a detection limit of 0.0002 mg/L. There are no PCB data for the Conservation Outlet in DWR's Water Data Library.

- Of the inorganic chemicals for which MCLs exist, only arsenic is believed to have the potential to be a problem in SWP supplies. The source of the arsenic is groundwater that is allowed into the aqueduct between Check 21 and Check 41. When substantial inflows are allowed into the California Aqueduct, the arsenic concentration at Check 41 is substantially higher than the concentration at Check 21. This topic is discussed in greater detail in Chapter 14.

CONSTITUENTS OF EMERGING CONCERN

- Studies on the occurrence, fate, and transport; health effects; analytical methods; and removal of constituents of emerging concern (CECs) in drinking water and wastewater have been completed in the last five years. The five most frequently detected chemicals in surface water in a recent nationwide study were cholesterol, metolachlor, cotinine, β-sitosterol, and 1,7-dimethylxanthine (Focazio et al., 2008). Another study showed the five most frequently detected chemicals in surface waters were sulfamethoxazole, carbamazepine, atrazine, phenytoin, and meprobamate (American Water Works Research Foundation, 2008).

- In 2010, the National Water Resources Institute (NWRI), MWDSC, and Orange County Water District completed a source, fate, and transport study of endocrine disruptors (EDCs) and pharmaceuticals and personal care products (PPCPs) that included eleven sampling sites associated with the SWP (Guo et al., 2010). Of the 49 PPCPs and organic wastewater contaminants analyzed, 21 analytes were detected at or above the minimum reporting level, whereas the other 28 were not detected at all locations with the existing minimum reporting levels. The most frequently detected CECs were carbamazepine, diuron, sulfamethoxazole, caffeine, primidone, and TCEP. Many of the maximum concentrations for the most frequently detected compounds were located in the San

Joaquin River at Holt Road, just downstream of the Stockton Regional Wastewater Control Facility. Certain PPCPs (carbamazepine, primidone, gemfibrozil, and sulfamethoxazole) are highly attenuated as water moves downstream along the California Aqueduct. However, detectable levels of some PPCPs were found at terminal reservoirs in southern California. The NWRI study concluded there is no evidence of human health risk from low levels of the commonly detected EDCs and PPCPs in drinking water or drinking water supplies; however, more toxicological studies are needed.

- MWDSC and DWR completed a two-year study in April 2010 of the sources and occurrence of N-nitrosodimethylamine (NDMA), other nitrosamines, and their precursors in the Delta (DiGiorgio et al., 2010). The only instantaneous nitrosamine detected was NDMA, once at the Mossdale sampling location at 4.2 ng/L, and once at the Vernalis sampling location at 2.5 ng/L. NDMA formation potential concentrations were generally two to four times higher downstream of the wastewater treatment plants. The second phase of this study began in early 2011.

- The State Water Resources Control Board convened a CEC Science Advisory Panel to develop guidance for the establishment of monitoring programs to assess potential CEC threats from water recycling activities. The final report identified four indicator compounds based on their toxicological relevance for groundwater recharge projects: NDMA, 17 beta-estradiol, caffeine, and triclosan. Four additional CECs were identified as viable performance indicators (N,N-Diethyl-meta-toluamide (DEET), gemfibrozil, iopromide, and sucralose).

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following actions related to the water quality monitoring program:

SWPCA will Support Development and Implementation of DWR's Comprehensive Plan

This action item was classified as an immediate action because it was important to address current critical water quality concerns. The comprehensive plan refers to the efforts to develop the Real-Time Data and Forecasting Program (RTDF) and includes the following elements:

- Review existing DWR water quality monitoring programs on an ongoing basis.

- Identify the need for new monitoring activities, particularly real-time data collection, to enhance the ability to rapidly detect and react to water quality events, and to forecast water quality conditions in the SWP.

- Coordinate monitoring, assessment, and forecasting activities between DWR and SWC agencies, and within various DWR units.

- Provide resources to implement necessary improvements.

- Provide continuing oversight and coordination.
- Develop the Aqueduct Blending Model.

DWR determined that seven new staff positions were needed to support the RTDF Program. The SWP Contractors agreed to provide the additional funding needed to support this effort and have been doing so since 2008.

Request that DWR Discontinue SWP Monitoring for Methyl Tertiary Butyl Ether (MTBE)

This action item was classified as an immediate action because it is easy to implement and does not require significant staff time. The rationale for this recommendation was that MTBE has been banned in gasoline in California and MTBE had not been detected in the SWP since 2003. The SWP Contractors verbally requested that MTBE monitoring be discontinued in October 2001. O&M has continued to monitor MTBE three times per year in the SWP.

POTENTIAL ACTIONS

MONITORING PROGRAM

MWQI, O&M, and other DWR Divisions should Continue to Enter Data Analyzed at Other Laboratories in the Water Data Library, When Feasible.

When data are analyzed by outside laboratories, the data are not automatically entered into the Water Data Library. For example, the MIB and geosmin data analyzed by MWDSC are transmitted to the SWP Contractors in Excel files to provide quick access to the data. This should be continued; however, the data should subsequently be entered into the Water Data Library to provide a permanent record. Bacteria and pathogen data are another example of data that should be entered into the Water Data Library. Analytical methods, detection limits, and all other information normally included for samples analyzed at DWR’s laboratory should also be included when data from other laboratories are entered into the Water Data Library.

O&M should Enter All Historical Data Collected on the SWP in the Water Data Library.

MWQI conducted an analysis of all of their data in 2011 to determine if it had been entered into the Water Data Library. The O&M Division has conducted a similar analysis and has plans to enter all remaining data; however, it is currently not a high priority due to limited staff resources. Examples of missing data include TOC data at Banks between 1989 and 1998 and data collected at the check structures along the California Aqueduct prior to December 1997. The SWP Contractors should consider providing financial assistance to ensure that the data are entered into the Water Data Library.

REAL-TIME MONITORING

O&M should Evaluate the Real-time and Grab Sample Data to Determine if the Apparent Anomalies are Real, and if They Are, Determine What Corrective Action is Needed.

O&M should conduct a more rigorous analysis of the real-time and grab sample data listed in **Table 3-9** to determine if there are problems with the real-time instruments that can be corrected with more frequent maintenance.

Table 3-9. Real-time Equipment Anomalies

Location	Constituent	Issue
Vernalis	EC	The real-time sampler does not often measure the peak levels above 1,000 µS/cm that are measured in the grab samples.
Banks	EC	The real-time sampler peak levels are often higher than grab samples collected on the same day.
Cordelia	EC	The real-time measurements are generally lower than the grab samples.
Devil Canyon	EC	The real-time measurements are often higher than the grab samples.
Banks	Turbidity	The real-time measurements are systematically higher than the grab samples.
Barker	Turbidity	The real-time measurements are routinely higher than the grab samples.
Cordelia	Turbidity	The real-time measurements are routinely higher than the grab samples.
DV Check 7	Turbidity	The real-time measurements are often substantially higher than the grab samples.
O'Neill Forebay Outlet	Turbidity	The real-time measurements are often substantially higher than the grab samples.
Devil Canyon	Turbidity	The real-time measurements are often lower than the grab samples.

O&M and the SWP Contractors should Review the Real-time Data Frequently to Allow Instrument Malfunctions to be Detected and Quickly Corrected.

In some cases, there are long periods of time when an instrument was clearly providing erroneous readings. These problems could be caught and corrected by reviewing the real-time data on a regular basis.

INFLUENCE OF THE SAN JOAQUIN RIVER

MWQI should Conduct a Review of Literature and Data Collected on the San Joaquin Watershed.

This review should identify the sources of key drinking water contaminants in the watershed and identify any data and information gaps. This information will be valuable in evaluating the results from the WARMF model for the San Joaquin watershed which is under development. This effort should be coordinated with CV-SALTS to determine if the necessary information on salt and nitrate has been developed through that effort.

WATER QUALITY TRENDS

O&M should Conduct an Analysis of the Changes in Water Quality between O'Neill Forebay Outlet and Check 21.

The analysis should include a review of TOC and other constituents to examine the seasonal patterns. The changes between O'Neill Forebay Outlet and Check 21 should be related to flows in the aqueduct, inflows to the aqueduct, and any other factors that could affect water quality between the two locations.

TASTE AND ODOR INCIDENTS AND ALGAL TOXINS

The SBA Contractors should Consider Analyzing T&O Samples from Banks and the SBA in their Laboratories.

Due to the proximity of the SBA to Banks Pumping Plant, water moves quickly into the SBA and T&O issues occasionally arise in the SBA before the weekly email reports reach the SBA Contractors. While the SBA Contractors can monitor general trends in MIB and geosmin over the course of several weeks, there can be times when the concentrations increase rapidly. O&M currently ships the samples to MWDSC for analysis in its laboratory. If the SBA Contractors analyzed the Banks and SBA samples, the information could be available to them within 24 hours of sample collection rather than several days after the samples are collected.

PATHOGENS

SWP Contractors should Consider Using *E. coli* as the Fecal Indicator Organism.

Most SWP Contractors are using *E. coli* as the fecal indicator organism. Two agencies (City of Fairfield and Palmdale) are using fecal coliforms. These agencies should consider converting to or adding *E. coli* as their source water fecal indicator. *E. coli* has been determined by USEPA to be a better indicator of the potential presence of protozoa and is used under the LT2ESWTR.

Coliform Samples should be Adequately Diluted to Allow Enumeration of Peak Values.

The SWP Contractors should review their coliform data results to determine if and when peak values exceeded enumeration limits (results reported as greater than an upper limit) and if so, develop a plan to require dilution by the lab during periods that are projected to have elevated coliform levels to provide enumerated values for coliform.

CONSTITUENTS OF EMERGING CONCERN

SWPCA should Track On-going Research on PPCPs and EDCs.

The Water Research Foundation has a number of CEC-related studies in progress regarding analytical methods, planning monitoring programs, statistical tools, and consumer perceptions towards EDCs and PPCPs. Some of the SWP Contractors are participating in these studies. The SWP Contractors should stay apprised of recent research. Some of the on-going studies to track are:

- Evaluation of Analytical Methods for EDCs and PPCPs via Inter-Laboratory Comparison #4167
- Water Utility Framework for Responding to Emerging Contaminant Issues - #4169
- Building a National Utility Network to Address EDC/PPCP Issues - #4261
- EDC/PPCP Benchmarking and Monitoring for Drinking Water Utilities - #4260
- Consumer Perceptions and Attitudes Toward EDCs and PPCPs in Drinking Water #4323

In addition, the USEPA Endocrine Disruptor Screening Program is underway and will determine which chemicals are of greatest risk for endocrine disruption to the environment and to human health.

SWPCA should Work with both the City of Sacramento and the County of Sacramento on Proper Disposal Instructions.

Controlling these contaminants at the source will likely be most cost-effective and will result in benefits to drinking water and aquatic organisms. The websites for the City and the County do not clearly address disposal of medications. The SWP Contractors should work with the City and the County to ensure information on proper disposal of unused PPCPs and locations where residents can safely dispose of medications is available on their respective websites. Many consumers are advised by their pharmacists to dispose of unneeded drugs by flushing them down the toilet or pouring them down the drain.

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CHAPTER 4 ORGANIC CARBON

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CHAPTER 4 ORGANIC CARBON

WATER QUALITY CONCERN

Organic matter in a waterbody consists of dissolved and particulate materials of plant, animal, and bacterial origins, in various stages of growth and decay. Total organic carbon (TOC) exists as particulate organic carbon and dissolved organic carbon (DOC) and can be divided into humic and non-humic substances. Humic substances are high molecular weight compounds largely formed as a result of bacterial and fungal action on plant material and include soluble humic and fulvic acids and insoluble humin. Non-humic substances include proteins, carbohydrates, and other lower molecular weight substances that are more available to bacterial degradation than humic substances. Strong oxidants, such as chlorine and ozone, are used to destroy pathogenic organisms in drinking water treatment plants, but these oxidants also react with organic carbon compounds (primarily humic substances) present in the water to produce disinfection byproducts (DBPs).

TOC is a precursor to many DBPs. Increased levels of TOC in source waters affect DBP concentrations by increasing the amount of precursor material available to react with the disinfectant and by increasing the amount of disinfectant required to achieve adequate disinfection. According to the U.S. Environmental Protection Agency (USEPA), DBPs have been associated with an increased risk of cancer; liver, kidney and central nervous system problems; and adverse reproductive effects (USEPA, 2001). While many DBPs have been identified, only a few are currently regulated. Concern over potential health effects of total trihalomethanes (TTHMs) and haloacetic acids (HAA5) has resulted in federal and state drinking water regulations controlling their presence in treated drinking water. As discussed in Chapter 2, the Stage 1 Disinfectants and Disinfection Byproducts (D/DBP) Rule reduced the TTHM Maximum Contaminant Level (MCL) from 0.10 mg/L to 0.080 mg/L and established an MCL for HAA5 of 0.060 mg/L. In addition, this rule established treatment requirements based on the concentrations of organic carbon and the levels of alkalinity in source waters, as shown in **Table 4-1**. Organic carbon is a concern for drinking water agencies treating State Water Project (SWP) water in conventional water treatment plants because TOC concentrations fall in the range that require action under this Rule. TOC removal compliance is based on the running annual average (RAA), calculated quarterly, of monthly removal ratios. The removal ratio is the ratio of the removal achieved divided by the removal required. The RAA of the removal ratios needs to equal or exceed 1.00.

Table 4-1. Percent TOC Removal Requirements

TOC (mg/L)	**Alkalinity (mg/L as $CaCO_3$)**		
	0 – 60	> 60 – 120	> 120
> 2.0 – 4.0	35.0	25.0	15.0
> 4.0 – 8.0	45.0	35.0	25.0
> 8.0	50.0	40.0	30.0

Furthermore, on January 4, 2006, the USEPA adopted the Stage 2 Disinfectants and Disinfection Byproducts (Stage 2 DBP) Rule. Under the Stage 2 DBP Rule, public water systems that deliver disinfected water are required to meet TTHM and HAA5 MCLs as an average at each compliance monitoring location (instead of as a system-wide average as in previous rules). The Stage 2 DBP Rule will reduce DBP exposure and related potential health risks, and provide more equitable public health protection. Stage 2 DBP Rule compliance monitoring under the federal rule began in April 2012 for the largest water systems. CDPH will adopt its own version of the Stage 2 DBP Rule regulations in the near future.

WATER QUALITY EVALUATION

Organic carbon can be present in source waters in dissolved and particulate forms. Although the Stage 1 D/DBP rule refers only to TOC which includes both dissolved and particulate matter, DOC is also of interest to the SWP Contractors. DOC is measured in a sample that has been filtered through a 0.45 µM filter to remove particulate matter. Therefore, measured DOC concentrations should consist of dissolved organic carbon plus any particulate matter smaller than 0.45 µM in diameter. DOC is of interest because coagulation and filtration processes employed in drinking water treatment plants treating SWP water remove most particulate matter. Therefore, DOC may be a better indicator of organic carbon that remains available to form DBPs. Therefore, this analysis includes both TOC and DOC.

The organic carbon data used in this evaluation include real-time and grab sample data from the Department of Water Resources (DWR) Municipal Water Quality Investigations (MWQI) Program and grab sample data from the Division of Operations and Maintenance (O&M) SWP Water Quality Monitoring Program. Organic carbon concentrations have been measured by DWR using two laboratory methods. The combustion method oxidizes organic carbon at high temperature whereas the wet oxidation method oxidizes organic carbon with chemical oxidants. The combustion method is thought to result in a more complete oxidation of organic carbon and often produces higher concentrations, particularly when the turbidity of the water is high. Ngatia and Pimental (2007) evaluated organic carbon data from five locations in the SWP and found that the two methods are comparable. Ngatia et al. (2010) conducted an analysis of data collected from the Sacramento River at Hood (Hood). The samples were analyzed in the field and in the laboratory by both methods. The data were analyzed with a classical statistical test (Kruskal-Wallis analysis of variance) and with an equivalence test that was based on 20 percent differences in samples. The equivalence level of 20 percent was selected because laboratory duplicate analyses of organic carbon are considered to be within acceptable limits if their differences are less than or equal to 20 percent. Ngatia et al. (2010) found that the two methods were equivalent and that the field instruments were equivalent to the laboratory instruments at the 20 percent equivalence level.

Organic carbon samples measured with the oxidation method are discussed in this chapter since there is a longer period of record. The grab samples that are analyzed by the oxidation method are compared to real-time results that are analyzed by the combustion method since most of the real-time analyzers use the combustion method.

ORGANIC CARBON FINGERPRINTS

DWR uses the fingerprinting method to identify the sources of DOC at Clifton Court Forebay (Clifton Court) and at the C.W. "Bill" Jones Pumping Plant (Jones) in the Sacramento-San Joaquin Delta (Delta) (see Chapter 3 for a description of the fingerprinting methodology). The DOC fingerprints for the 1991 to 2010 period are shown in **Figures 4-1 and 4-2**. These figures show that the three primary sources of DOC at the south Delta pumping plants are the Sacramento and San Joaquin rivers and Delta agricultural drainage. During the 1991 to 2010 period, the Sacramento River contributed a median DOC concentration of 1.2 mg/L at Clifton Court, the San Joaquin River contributed 0.5 mg/L, and agricultural drains contributed 1.0 mg/L. The eastside streams contributed a median of 0.2 mg/L and the median contribution from seawater was 0 mg/L. During wet years when flows on the San Joaquin River are high, most of the DOC at the pumping plants comes from that river. During dry years, the Sacramento River has more influence on DOC concentrations at the pumping plants. **Figure 4-2** also shows the greater influence of the San Joaquin River on water quality at Jones. During the 1991 to 2010 period, the San Joaquin River contributed a median DOC concentration of 1.2 mg/L at Jones, the Sacramento River contributed 0.9 mg/L, and agricultural drains contributed 0.8 mg/L. The eastside streams contributed a median of 0.1 mg/L and the median contribution from seawater was 0 mg/L. In the summer of 2004 water pumped off of Jones Tract, after the levee break was repaired, added to the DOC concentrations at both pumping plants for several months.

ORGANIC CARBON CONCENTRATIONS IN THE SWP

Organic carbon data are analyzed in this chapter to examine changes in concentrations as the water travels through the SWP system and to determine if there are seasonal or temporal trends. All available organic carbon data from DWR's MWQI Program and the O&M monitoring program through December 2010 were obtained for a number of locations along the SWP. **Table 4-2** shows the period of record for each location included in this analysis.

Figure 4-1. DOC Fingerprint at Clifton Court

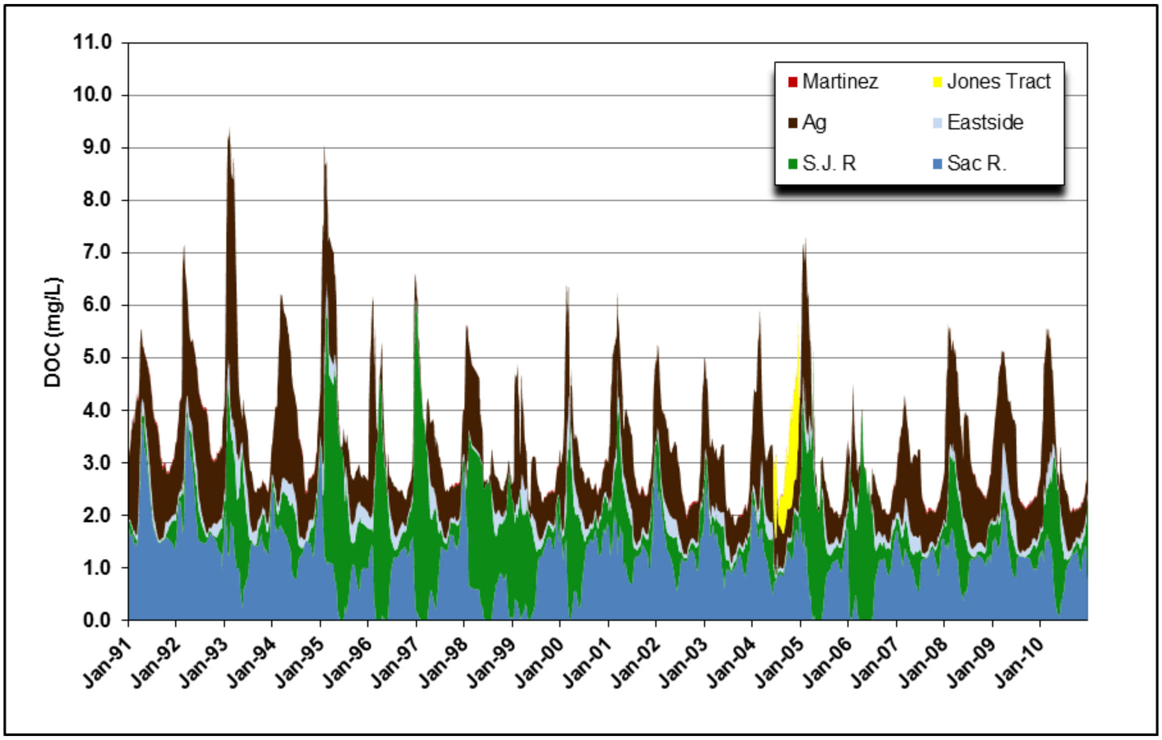


Figure 4-2. DOC Fingerprint at Jones

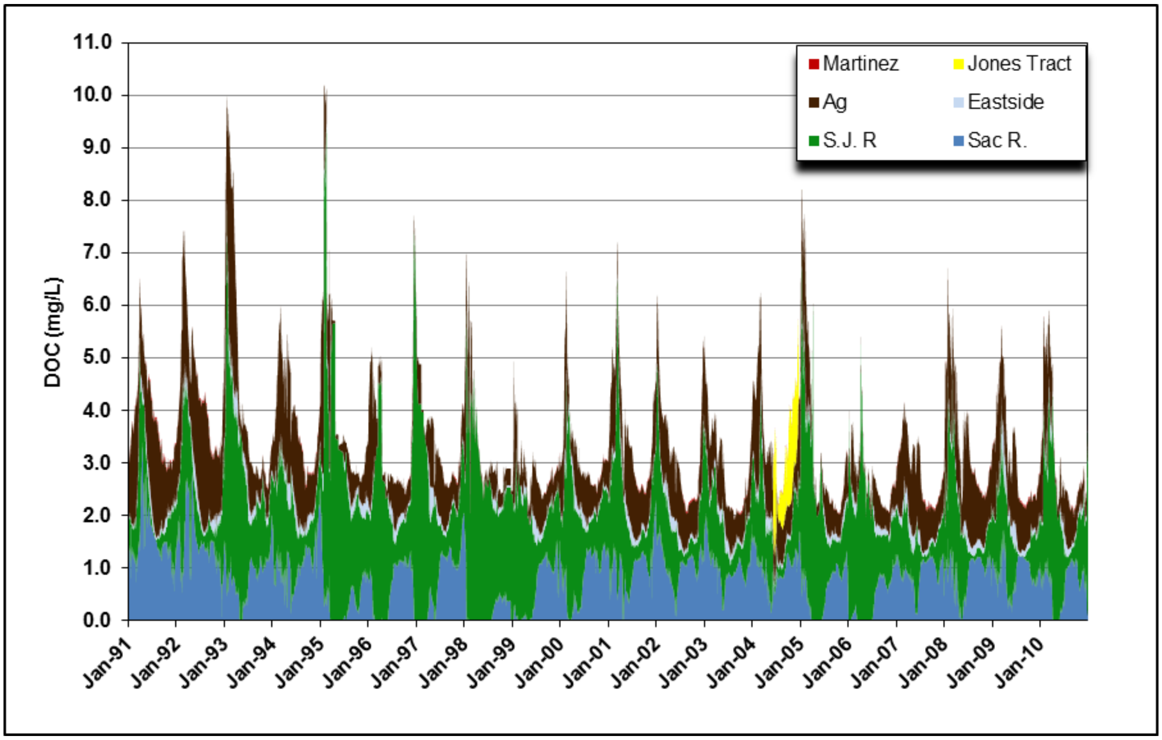


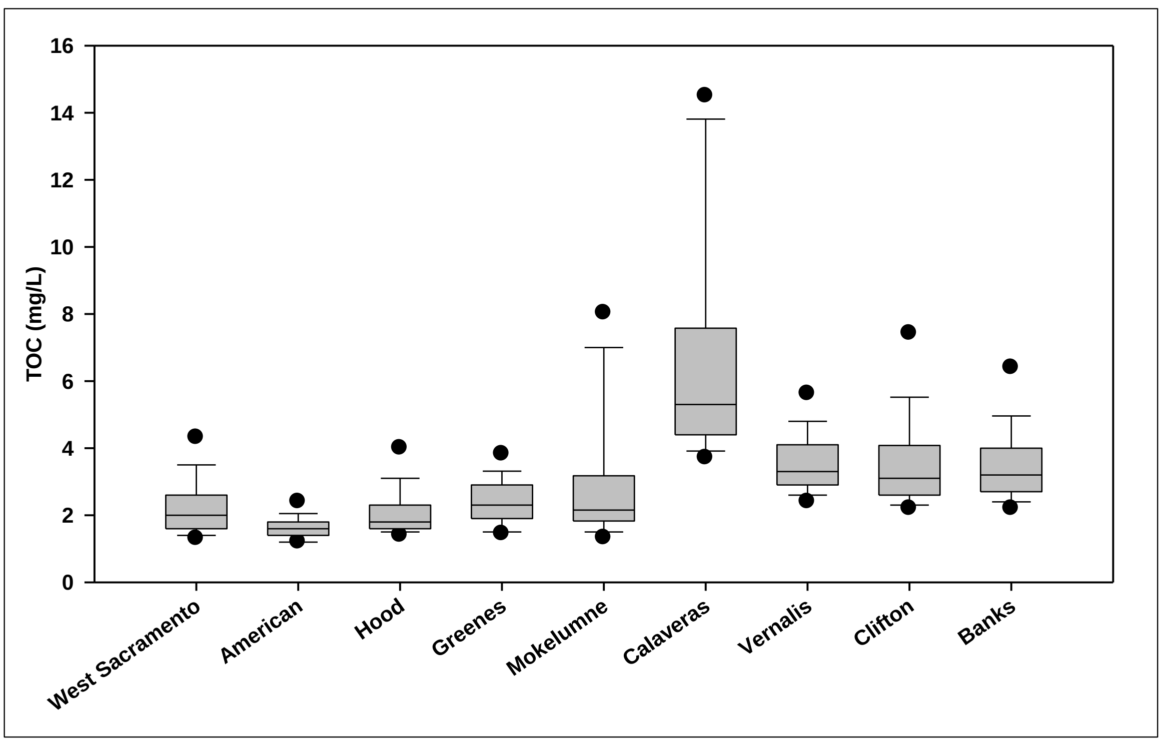
Table 4-2. Organic Carbon Data

Location	TOC			DOC		
	No. of Samples	Start Date	End Date	No. of Samples	Start Date	End Date
West Sacramento	217	Feb 1995	Dec 2010	271	Apr 1994	Dec 2010
American	244	Nov 1986	Dec 2010	308	Jun 1989	Dec 2010
Hood	605	Sep 1997	Dec 2010	698	Aug 1997	Dec 2010
Greenes Landing	69	Feb 1995	May 1998	249	Jul 1989	May 1998
Mokelumne	44	Dec 2008	Dec 2010	44	Dec 2008	Dec 2010
Calaveras	40	Dec 2008	Dec 2010	40	Dec 2008	Dec 2010
Vernalis	536	Nov 1986	Dec 2010	734	Dec 1986	Dec 2010
Clifton Court	208	Nov 1986	Dec 2010	246	Nov 1989	Dec 2010
Banks	283	Nov 1986	Dec 2010	424	Jul 1989	Dec 2010
Barker Slough	339	Sep 1988	Dec 2010	406	Jul 1989	Dec 2010
DV Check 7	140	Dec 1997	Dec 2010	117	Feb 2000	Dec 2010
Jones	19	Jan 2009	Dec 2010	19	Jan 2009	Dec 2010
McCabe	152	Dec 1997	Dec 2010	130	Mar 2000	Dec 2010
Pacheco	89	Apr 2000	Dec 2010	88	Apr 2000	Dec 2010
O’Neill Forebay Outlet	198	Jul 1988	Dec 2010	183	Aug 1990	Dec 2010
Check 21	152	Feb 1998	Dec 2010	138	Mar 2000	Dec 2010
Check 29	139	Apr 2000	Dec 2010	164	Apr 2000	Dec 2010
Check 41	164	Dec 1997	Dec 2010	138	Mar 2000	Dec 2010
Castaic Outlet	138	Feb 1998	Dec 2010	130	Mar 2000	Dec 2010
Devil Canyon Headworks	117	Jun 2001	Dec 2010	117	Jun 2001	Dec 2010
Devil Canyon Afterbay	40	Dec 1997	May 2001	15	Mar 2000	May 2001
Perris Outlet	131	Mar 2000	Dec 2010	132	Mar 2000	Dec 2010

The SWP Watershed

Figure 4-3 presents the TOC data for the tributaries to the Delta and for Clifton Court and H.O. Banks Pumping Plant (Banks). Data from the Sacramento River at West Sacramento (West Sacramento) represent the quality of water upstream of the Sacramento metropolitan area and upstream of the American River. Hood and Greenes Landing represent the quality of water flowing into the Delta from the Sacramento River. The Mokelumne River at Wimpy's Marina (Mokelumne) and Calaveras River at Brookside Road (Calaveras) provide information on the quality of these two eastside streams as they flow into the Delta. Data collected from the San Joaquin River at Vernalis (Vernalis) are used to represent the San Joaquin River inflow to the Delta. **Figure 4-3** indicates that TOC concentrations are lower in the Sacramento River than the San Joaquin River. TOC data have been collected twice a month from the Mokelumne and Calaveras rivers since December 2008. The limited data show that the Mokelumne River TOC concentrations are similar to the Sacramento River concentrations, whereas the Calaveras River concentrations are higher than Vernalis.

Figure 4-3. TOC Concentrations in the SWP Watershed



Hood – **Figure 4-4** shows all available TOC data at Hood. The concentrations range from 1.0 to 6.6 mg/L during the period of record with a median of 1.8 mg/L.

- Comparison of Real-time and Grab Sample Data – **Figure 4-5** compares the real-time data with the grab sample data at Hood. The real-time instrument measures TOC every 15 minutes. MWQI staff provided daily average concentrations for this analysis. There is a good correspondence between the two data sets when samples collected on the same day are compared. The real-time data show that peak concentrations of TOC are considerably higher than those measured with the grab samples, as would be expected with more frequent data collection.

- Spatial Trends – **Figure 4-3** presents all available data for West Sacramento, the American River (American), and Hood. These three locations were selected to examine the impact of the Sacramento urban area on water quality at Hood. The period of record varies between the three stations so the data collected during the 1998 to 2010 period at all three locations were examined to determine if there are spatial trends. The median concentrations during the 1998 to 2010 period are the same as shown on **Figure 4-3**, which presents all available data at each location. The American median TOC concentration of 1.6 mg/L is statistically significantly lower than the median of 2.0 mg/L at West Sacramento and the median of 1.8 mg/L at Hood (Mann-Whitney, p=0.0000). There is no statistically significant difference between West Sacramento and Hood (Mann-Whitney, p=0.3395), despite the fact that the high quality American River enters the Sacramento River between these two locations. This is likely due to the fact that urban runoff and treated wastewater from the Sacramento urban area are discharged to the river between West Sacramento and Hood.

- Long-Term Trends – MWQI staff conducted an analysis of long-term trends in TOC and DOC at Hood (Personal Communication, Carol DiGiorgio, DWR). MWQI staff combined DOC data from Greenes Landing and Hood for this analysis since data were not collected at Hood prior to 1997. During the 1990 to 2008 period there was a decreasing trend in DOC concentrations (p=0.04) but no trend in DOC loads or flow. During the 1999 to 2008 period there was an increasing trend in DOC and TOC concentrations (p<0.01). **Figure 4-6** presents the DOC data for Greenes Landing (July 1989 to July 1997) and Hood (August 1997 to December 2010). As shown in this figure, the starting point of the 20-year trend analysis was the 1990 to 1992 period when DOC concentrations were high. These were the last three years of a six year drought. The 20-year trend analysis ended in 2008, which was the second year of a four year drought. DOC concentrations in 2008 were lower than in 1990, thus leading to a decreasing trend. The ten-year trend analysis, which showed an increasing trend in both DOC and TOC concentrations, started in 1999 which was the fifth year in a six year wet cycle, when DOC concentrations were low. The ending point (2008) had higher DOC concentrations than in 1999. The DOC concentrations at Hood are driven by the hydrology of the system so long-term trends are very much a function of the hydrology during the starting and ending points of the analysis.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. Wet years are defined as those that are classified as wet and above normal. Dry years are defined as those that are classified as below normal, dry, and critical. The median concentration during dry years of 1.9 mg/L is statistically significantly higher than the median during wet years of 1.7 mg/L (Mann-Whitney, p=0.0000). This difference could be due to greater volumes of high quality water with low TOC concentrations being released from reservoirs during the spring and summer months of wet years. It could also be partially due to the greater influence of treated wastewater, urban runoff, and agricultural discharges during low flow periods of dry years.

- Seasonal Trends – All available data (1997 to 2010) were sorted by month and plotted on **Figure 4-7.** This figure indicates that the TOC concentrations are generally low from March to October. During the late spring and early summer months, snow melt results in high flows with low concentrations of TOC. During the late summer and fall months, high quality water is released from upstream reservoirs to maintain flows in the river. The concentrations increase during the November to February period when storm events flush the carbon from the watershed.

- DOC/TOC Relationship – **Figure 4-8** shows the relationship between DOC and TOC at Hood. There is good correspondence at low concentrations and considerable variability at higher concentrations.

Figure 4-4. TOC Concentrations at Hood

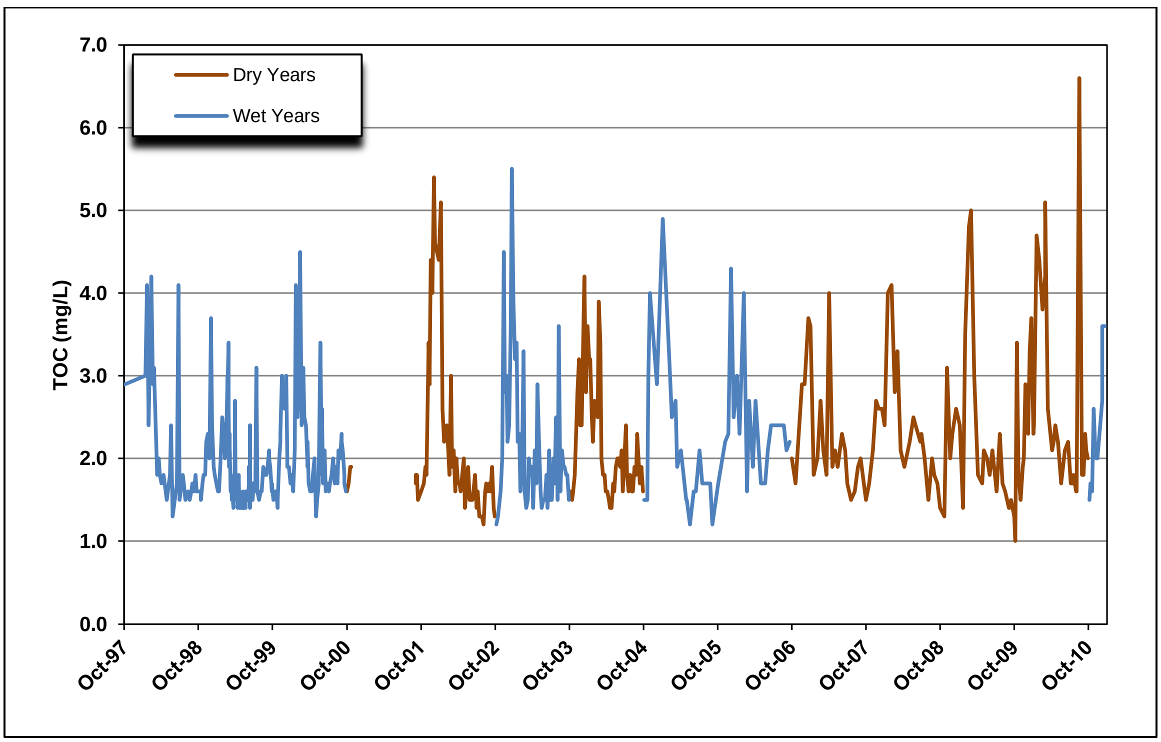


Figure 4-5. Comparison of Hood Real-time and Grab Sample TOC Data

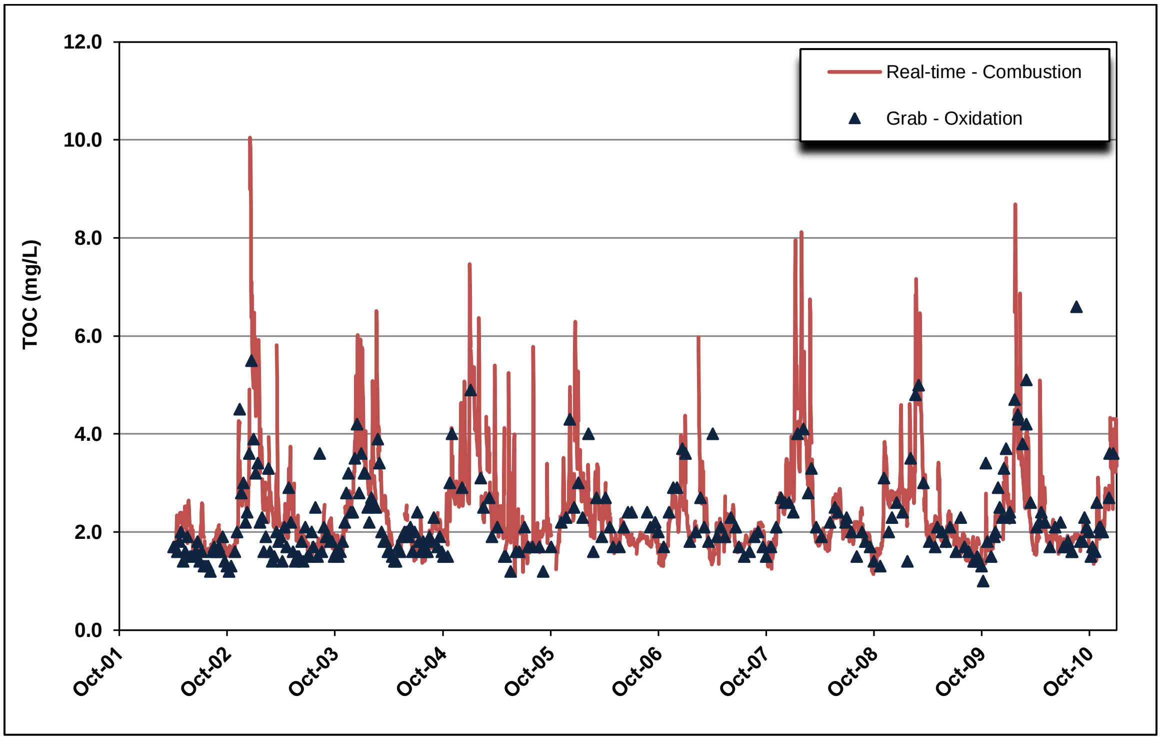


Figure 4-6. DOC Concentrations at Greenes Landing and Hood

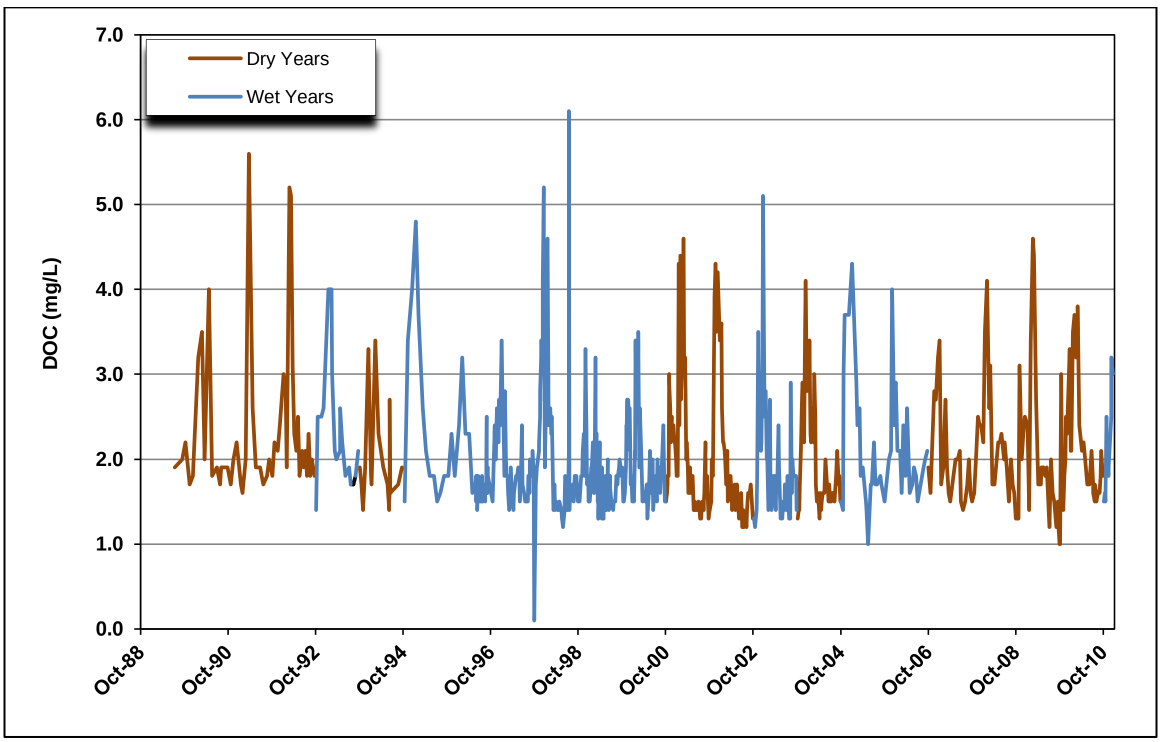


Figure 4-7. Monthly Variability in TOC at Hood

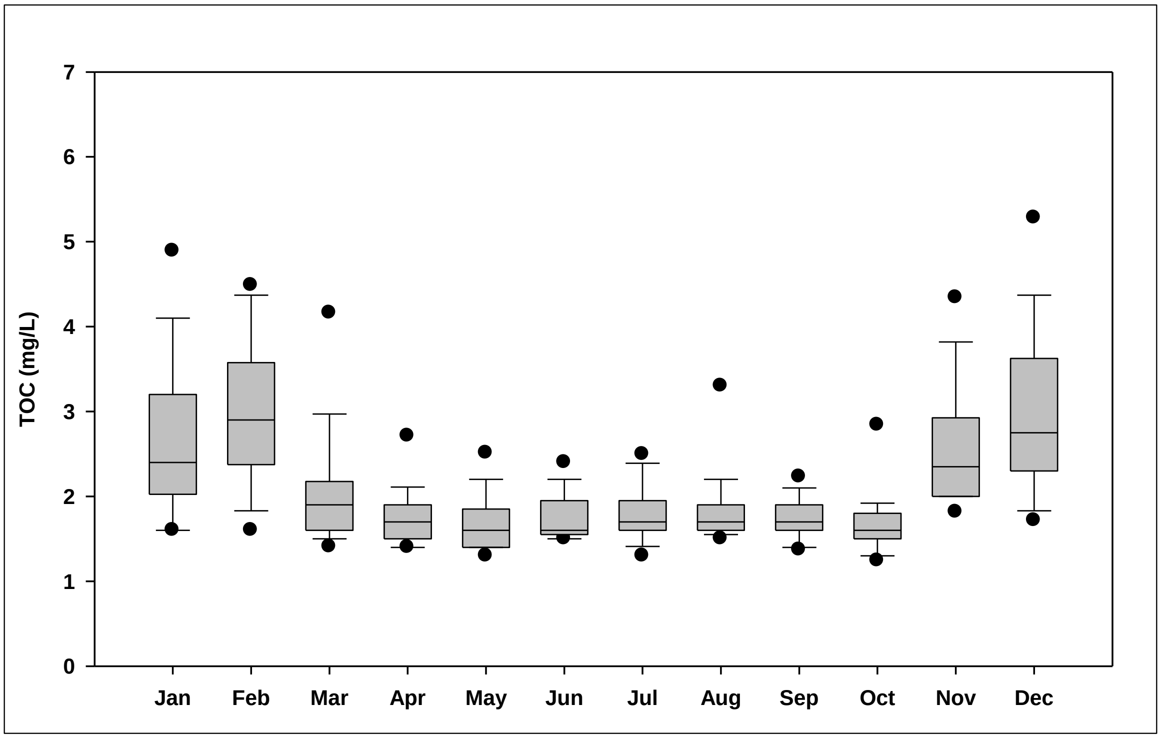
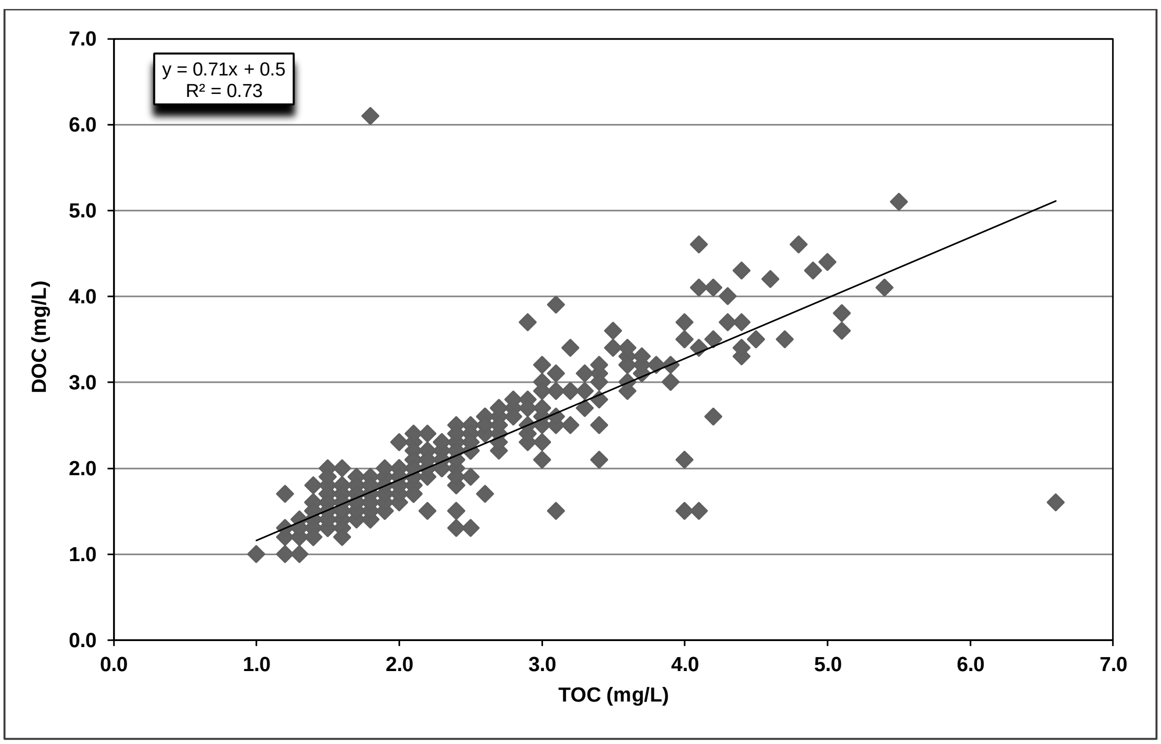


Figure 4-8. Relationship between DOC and TOC at Hood



Vernalis – **Figure 4-9** shows all available TOC data at Vernalis. The concentrations range from 2.0 to 10.5 mg/L during the period of record with a median of 3.3 mg/L.

- Comparison of Real-time and Grab Sample Data – **Figure 4-10** compares the real-time data with the grab sample data at Vernalis. The real-time instrument measures TOC every 15 minutes. MWQI staff provided daily average concentrations for this analysis. There is a good correspondence between the two data sets when samples collected on the same day are compared. As at Hood, the real-time data show that peak concentrations of TOC are considerably higher than those measured with the grab samples.

- Spatial Trends – DWR does not collect data upstream of Vernalis on the San Joaquin River so spatial trends were not examined.

- Long-term Trends – MWQI staff conducted an analysis of long-term trends in TOC and DOC at Vernalis (Personal Communication, Carol DiGiorgio, DWR). During the 1987 to 2008 period there was a decreasing trend in DOC concentrations (p=0.02) but no trend in DOC loads or flow. During the 1999 to 2008 period there was an increasing trend in DOC and TOC concentrations. (p<0.01). These trends are the same as the trends for Hood. **Figure 4-11** presents the DOC data for Vernalis. MWQI staff concluded that hydrology drives the system on the San Joaquin River, as it does on the Sacramento River.

- Wet Year/Dry Year Comparison – The median concentration during dry years of 3.6 mg/L is statistically significantly higher than the median during wet years of 3.2 mg/L (Mann-Whitney, p=0.0000). This could be due to the greater influence of agricultural drainage during dry years and to the release of high quality water from the reservoirs during the spring and summer of wet years.

- Seasonal Trends – The seasonal pattern on the San Joaquin River is different from the Sacramento River. **Figure 4-12** shows that TOC concentrations are highest during the winter months with peaks generally around 7 to 8 mg/L. Concentrations decline during the early spring months when flows are high on the San Joaquin River, increase in the summer (median of 3.7 mg/L in July), and then drop back down in the fall. Surface runoff from the watershed is responsible for the wet season peaks, while the probable cause of the dry season peaks is the discharge of agricultural drainage to the river. During the summer months, flows in the San Joaquin River are low, generally below 2,000 cubic feet per second (cfs), so there is minimal dilution of agricultural drainage.

- DOC/TOC Relationship – **Figure 4-13** shows the relationship between DOC and TOC at Vernalis. There is more variability at low concentrations and a tighter fit at higher concentrations.

Figure 4-9. TOC Concentrations at Vernalis

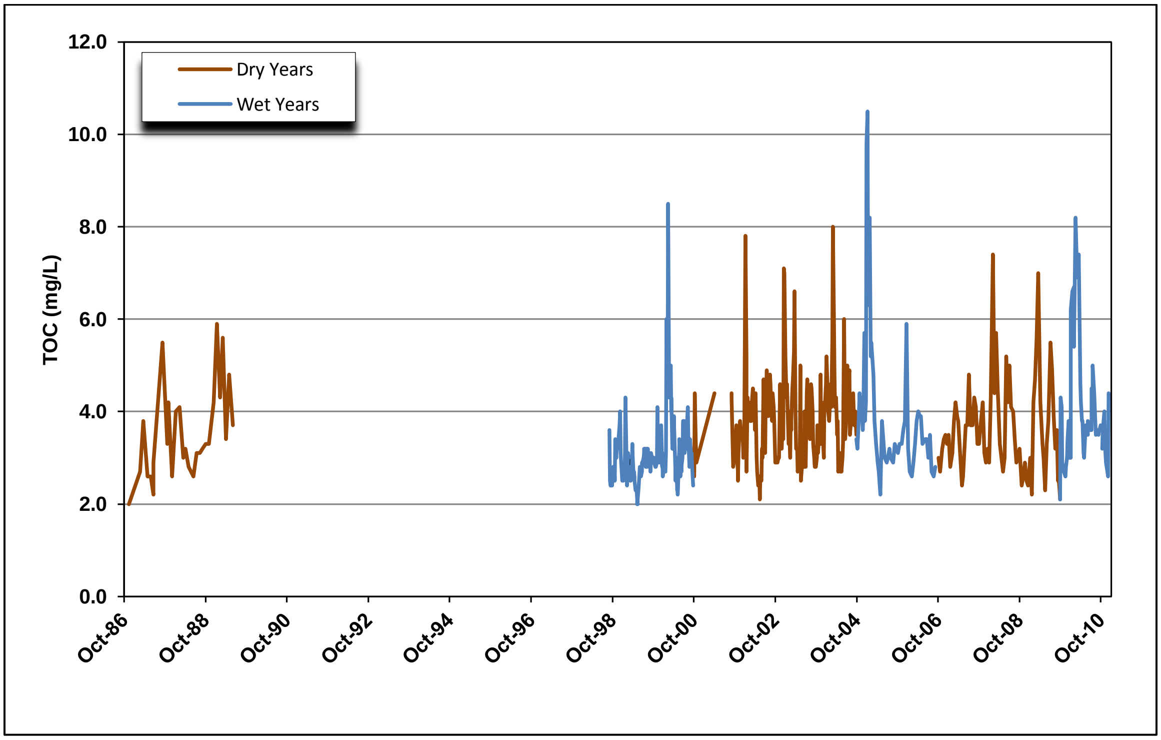


Figure 4-10. Comparison of Vernalis Real-time and Grab Sample TOC Data

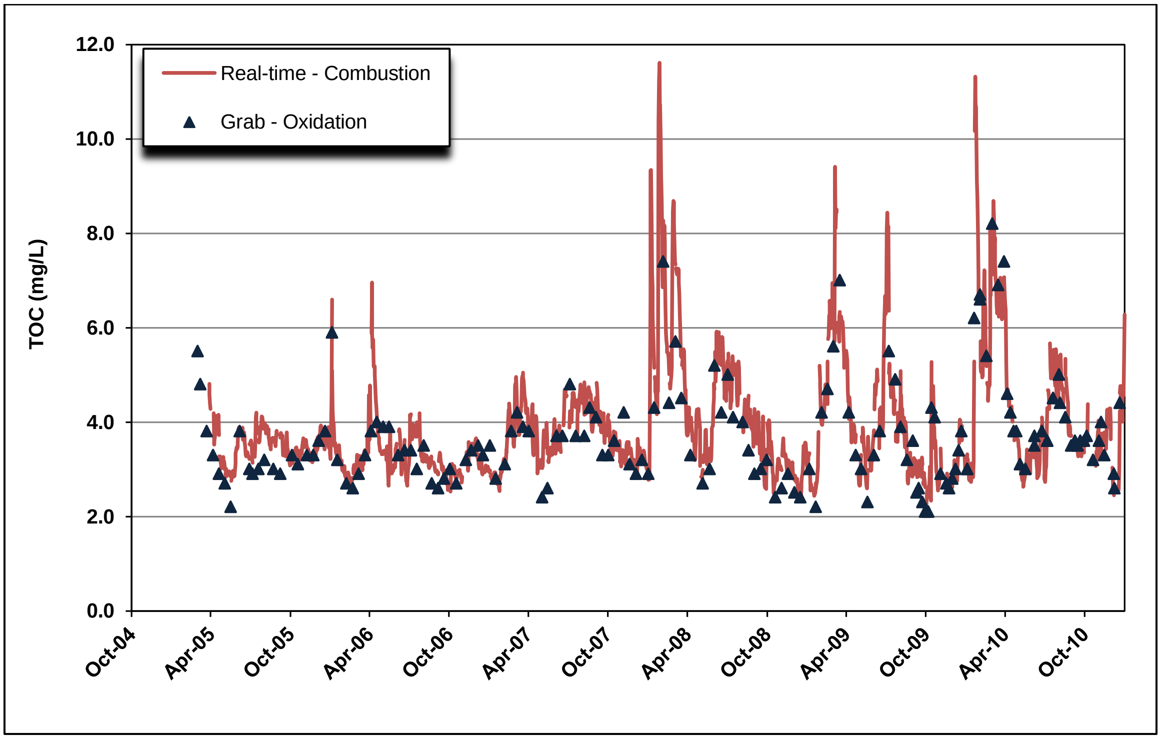


Figure 4-11. DOC Concentrations at Vernalis

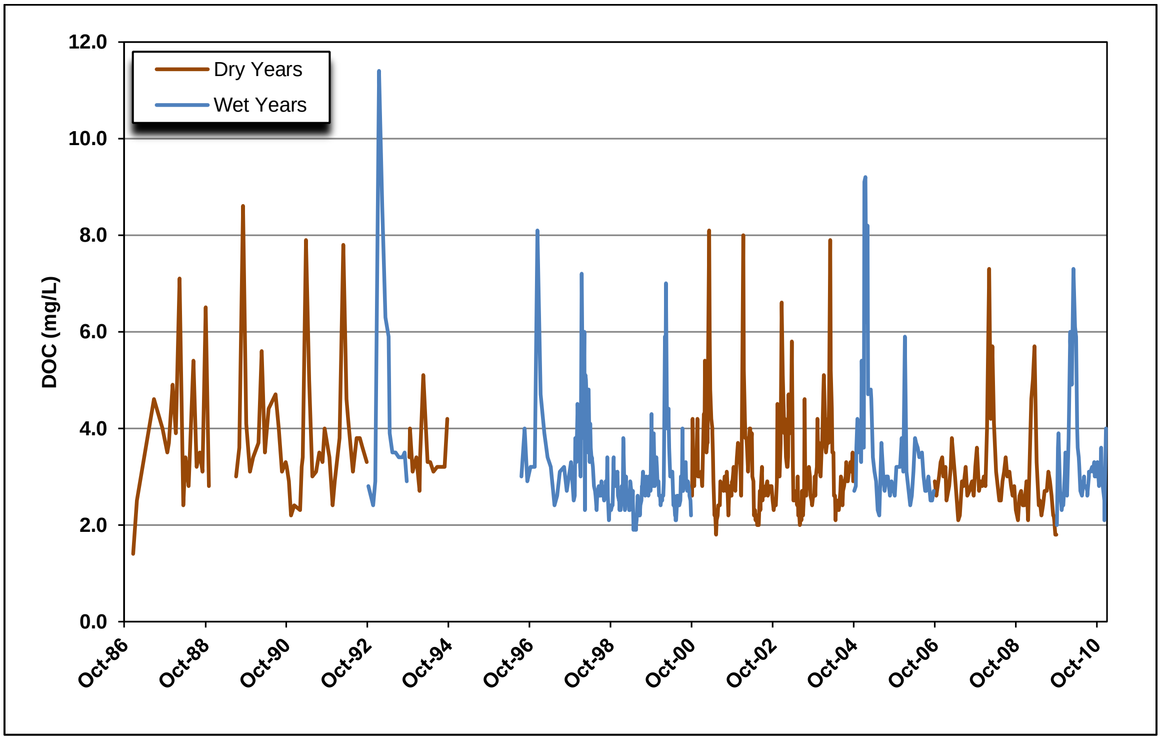


Figure 4-12. Monthly Variability in TOC at Vernalis

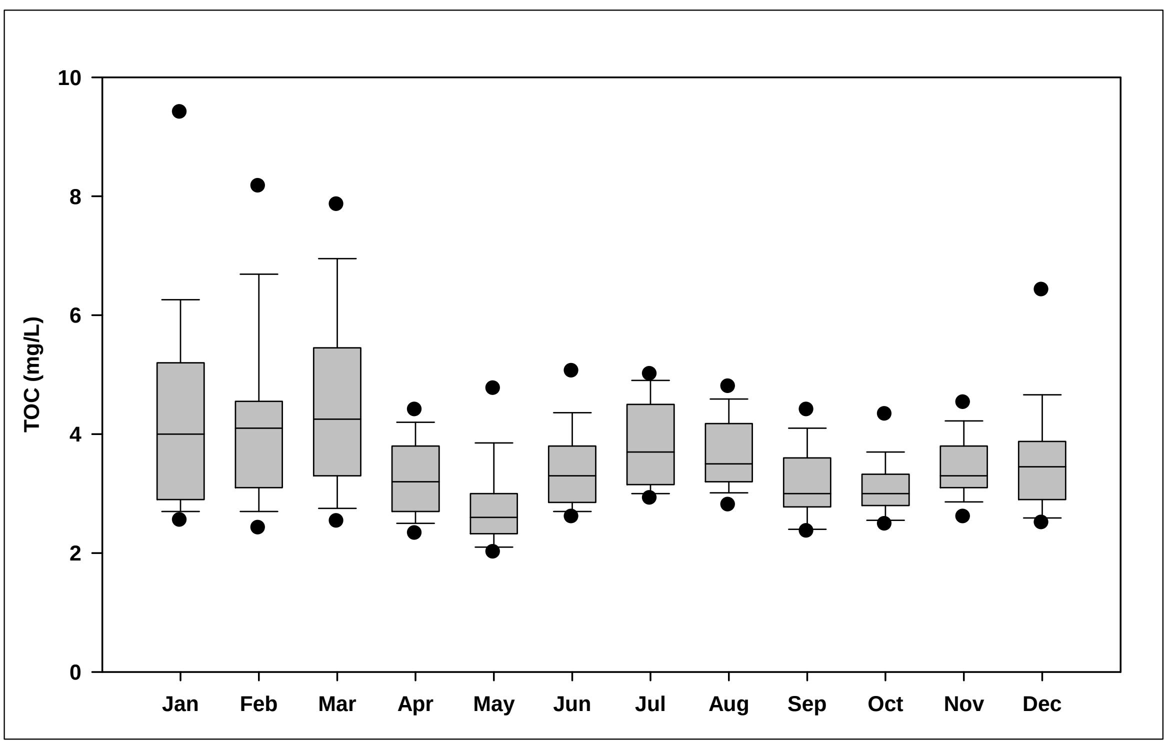
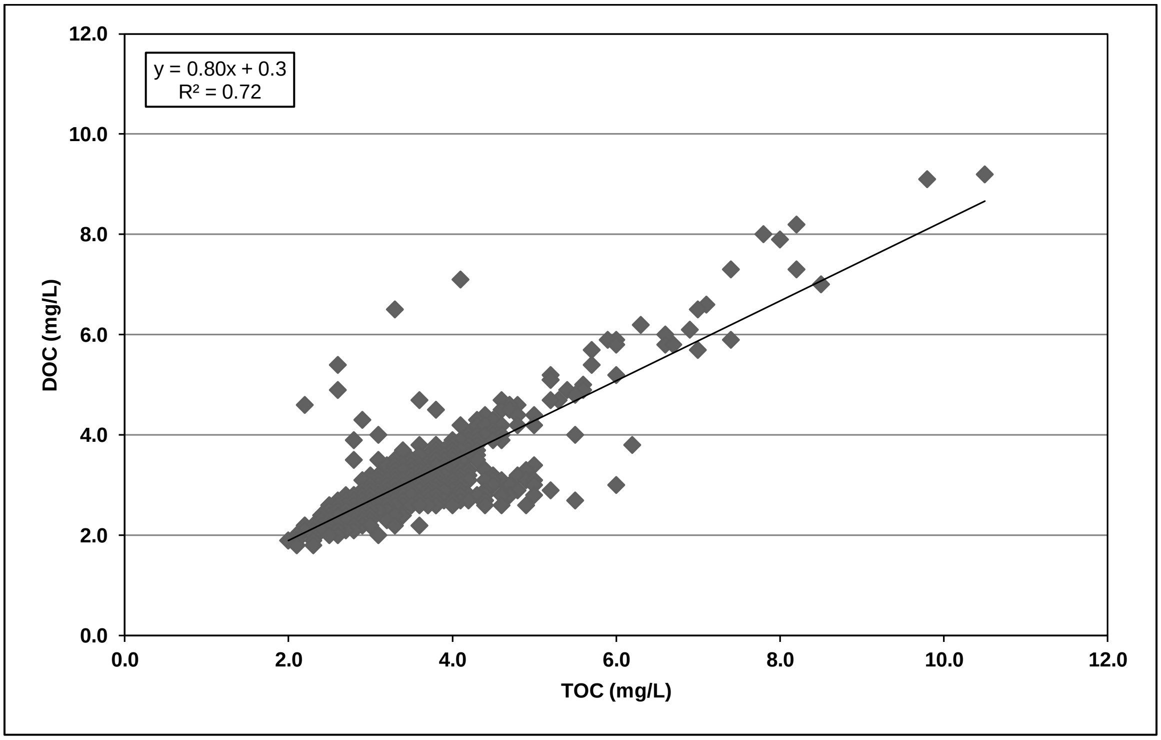


Figure 4-13. Relationship Between DOC and TOC at Vernalis



Banks – As shown in **Figure 4-1**, the primary sources of organic carbon at Clifton Court and Banks are the Sacramento and San Joaquin rivers and Delta agricultural drainage. **Figure 4-14** shows all available TOC data at Banks. The concentrations range from <0.1 to 8.4 mg/L during the period of record with a median of 3.2 mg/L.

- Comparison of Real-time and Grab Sample Data – **Figure 4-15** compares the real-time data with the grab sample data at Banks. The real-time instrument measures TOC every 15 minutes. MWQI staff provided daily average concentrations for this analysis. There is good correspondence between the data sets after September 2003. As with the two river stations, the real-time data show that peak TOC concentrations are higher than those captured by the grab sample data. During the winters of 2005, 2006, and 2008, the peak concentrations measured with the real-time instrument were about 2 mg/L higher than the peaks measured in the grab samples.

- Spatial Trends – Sacramento River water is degraded as it flows through the Delta by discharges from Delta islands and mixing with the San Joaquin River. All available data from Hood, Vernalis, and Banks were presented previously in **Figure 4-3**. Since the period of record varies between the three stations, a subset of the data that includes only data collected at the three stations during the same time period (1998 to 2010) are shown in **Figure 4-16**. The median TOC concentration of 3.1 mg/L at Banks is statistically significantly higher than the median of 1.8 mg/L at Hood (Mann-Whitney, p=0.0000) and statistically significantly lower than the median of 3.3 mg/L at Vernalis (p=0.0011).

- Long-term Trends – MWQI staff examined DOC trends at Banks from 1989 to 2008 and from 1999 to 2008 (Personal Communication, Carol DiGiorgio, DWR). DOC concentrations decreased between 1989 and 2008 and showed no trend between 1999 and 2008. MWQI staff also analyzed TOC during the 1989 to 2009 period and found no trend. In another DWR study, a decreasing trend in TOC was found between 1990 and 2003 (DWR, 2005). The decreasing trends were attributed to increased pumping at Banks during the summer months, which drew more Sacramento River water into the Delta. The DOC data at Banks are shown in **Figure 4-17.**

- Wet Year/Dry Year Comparison – Although the range of concentrations during dry years is larger than during wet years, the median concentrations are the same at 3.2 mg/L.

- Seasonal Trends – **Figure 4-18** indicates that the lowest TOC concentrations occur in the summer and fall months. Concentrations increase in the winter when storm events wash TOC from the watershed and when Delta island agricultural drainage increases.

- DOC/TOC Relationship – **Figure 4-19** shows the good relationship between DOC and TOC at Banks. DOC is generally about 92 percent of TOC at Banks.

Figure 4-14. TOC Concentrations at Banks

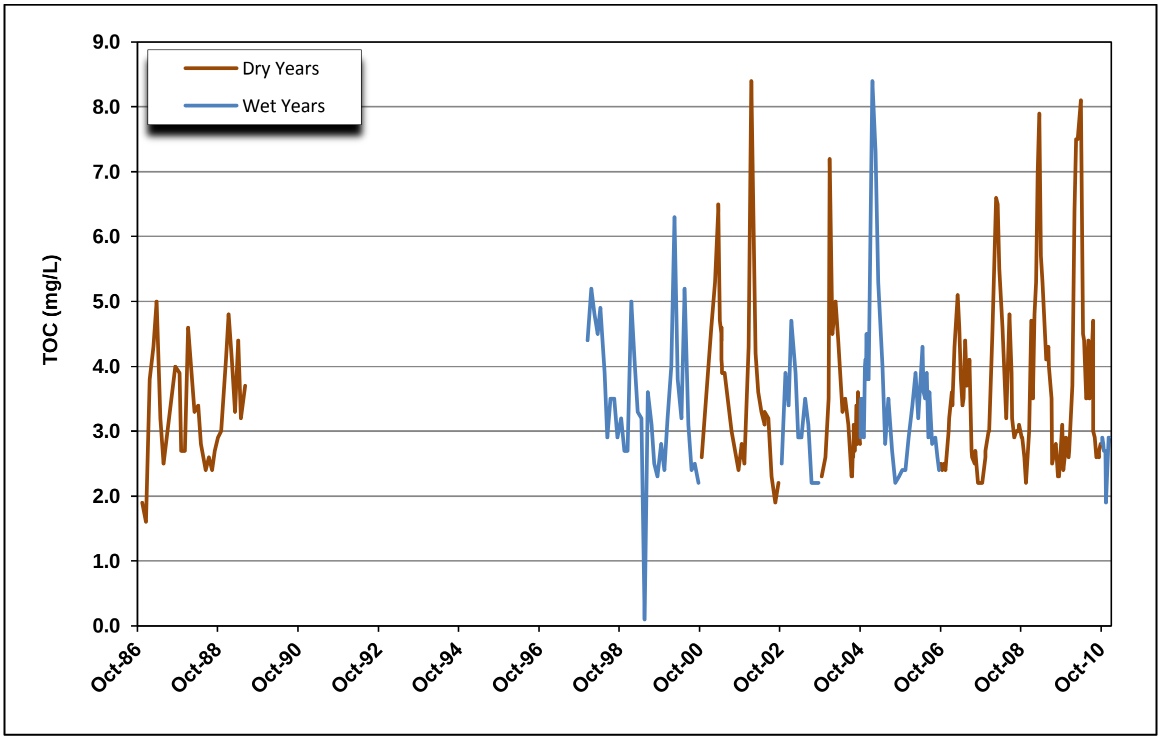


Figure 4-15. Comparison of Banks Real-time and Grab Sample TOC Data

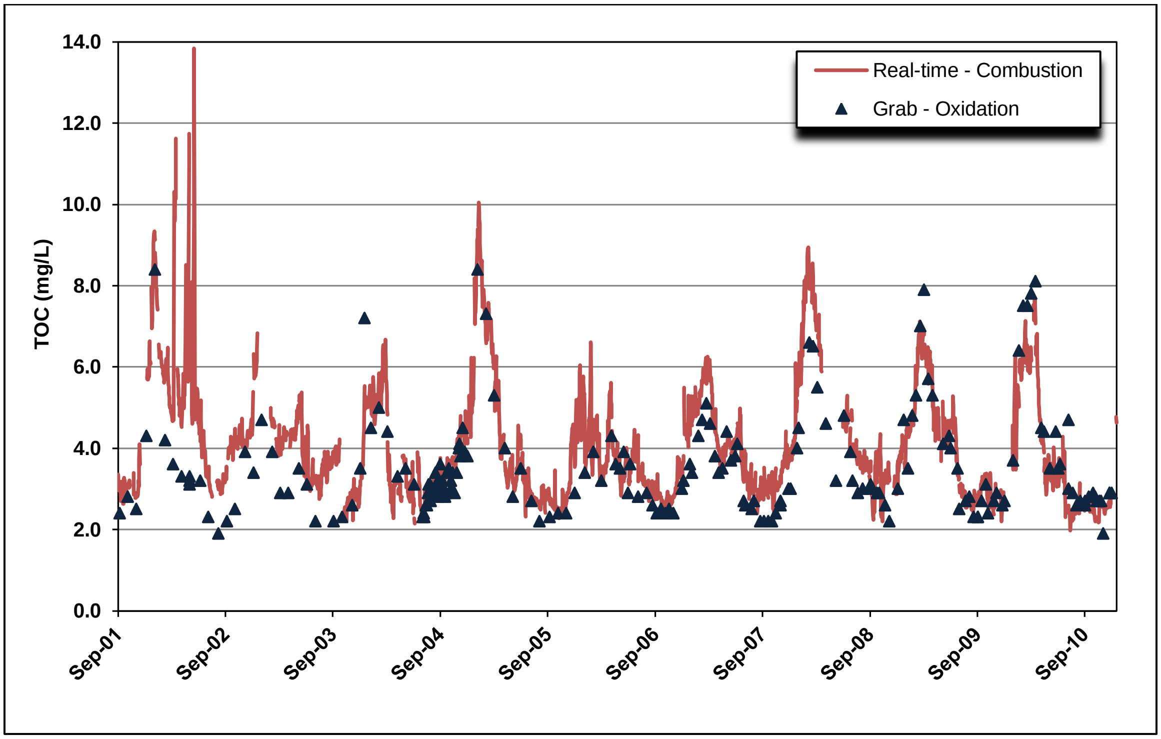


Figure 4-16. Comparison of Locations During Same Period of Record (1998-2010)

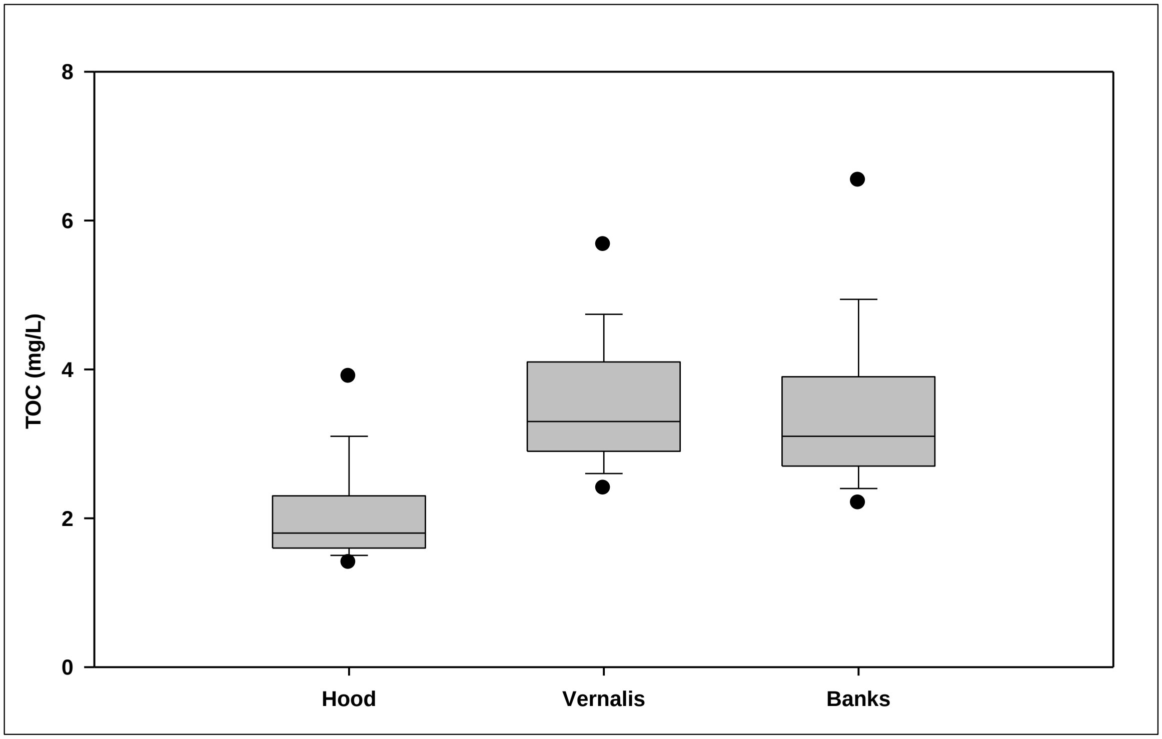


Figure 4-17. DOC Concentrations at Banks

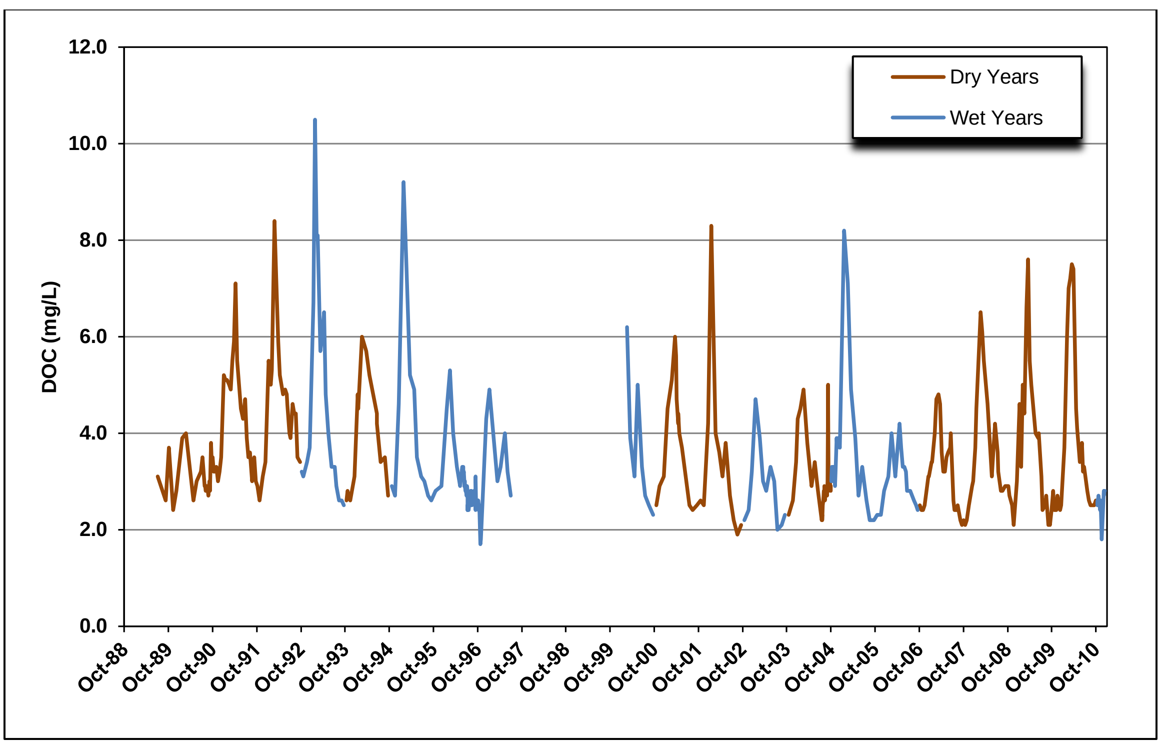


Figure 4-18. Monthly Variability in TOC at Banks

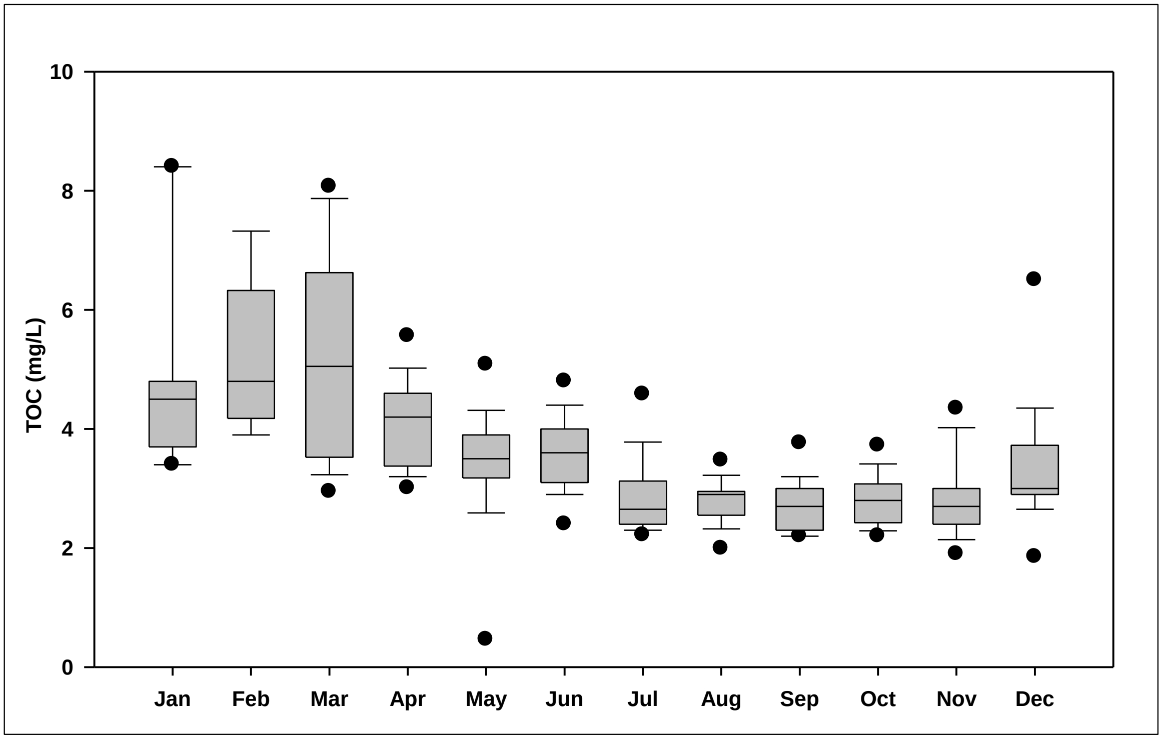
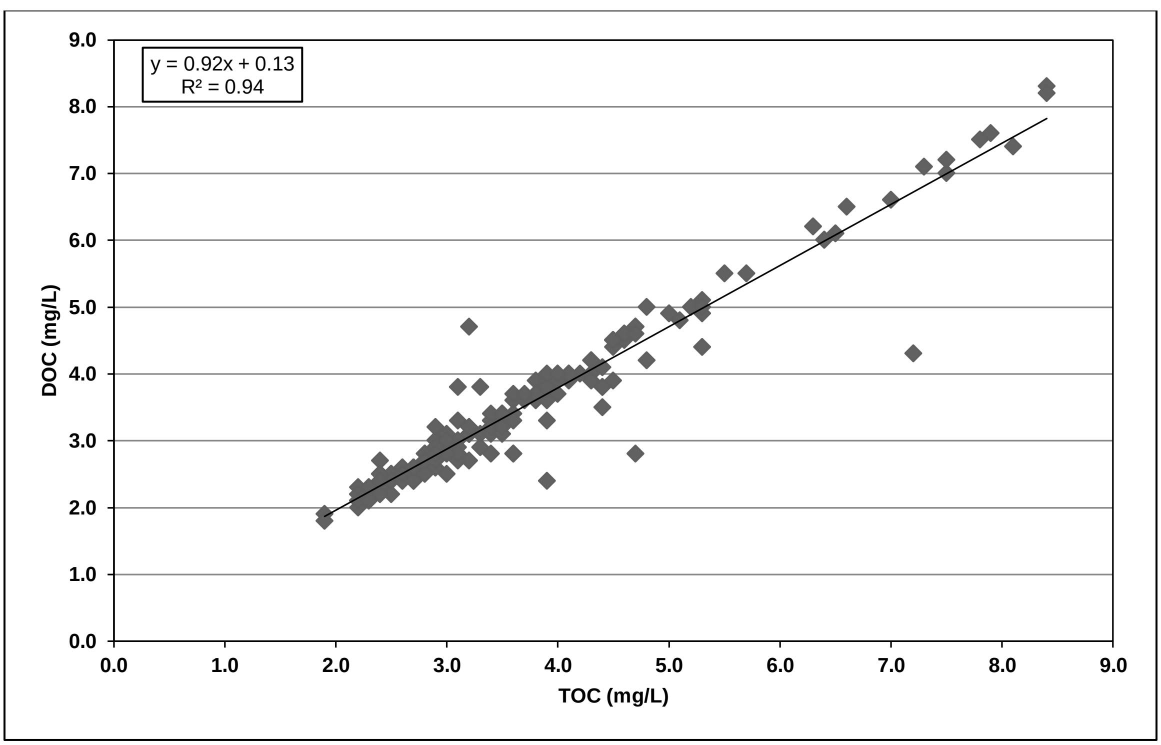


Figure 4-19. Relationship Between DOC and TOC at Banks



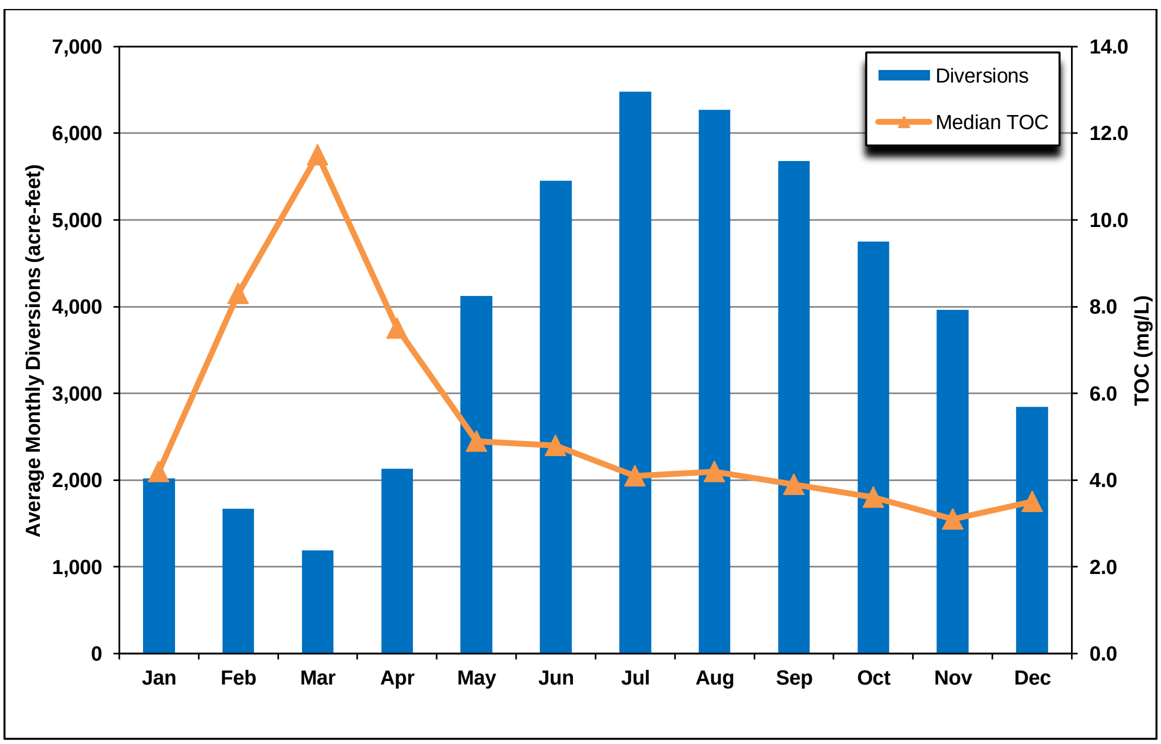
North Bay Aqueduct

Water from the north Delta is pumped into the North Bay Aqueduct (NBA) at the Barker Slough Pumping Plant. The sources of water to the NBA are the Sacramento River, the local Barker Slough watershed, and other neighboring drainage inputs. The NBA is an enclosed pipeline between Barker Slough and the Cordelia Forebay. Water is delivered to the cities of Vacaville, Fairfield, and Travis Air Force Base between these two points. From Cordelia Forebay, enclosed pipelines deliver water to the cities of Vallejo, Benicia, and to the Napa Terminal Tanks which serve the cities of Napa and American Canyon in Napa County.

Project Operations

Since the NBA is an enclosed pipeline, the quality of water delivered to NBA users is governed by the timing of diversions from Barker Slough. **Figure 4-20** shows average monthly diversions at Barker Slough for the 1998 to 2010 period and median monthly TOC concentrations. As discussed in Chapter 3, the Wanger Decision and the biological opinions have not greatly affected the pumping patterns at Barker Slough. This figure shows that pumping is highest between May and November when TOC concentrations are lowest in Barker Slough. The pumping pattern is dictated by both the demand for water and the quality of the NBA water. Many of the NBA users have alternative sources of water that are used during the winter and spring months when TOC concentrations are highest at Barker Slough. Other NBA users have limited alternative supplies and continue to take Barker Slough water during the months that TOC concentrations are high.

Figure 4-20. Average Monthly Barker Slough Diversions and Median TOC Concentrations



TOC Concentrations in the NBA

Organic carbon data are collected at Barker Slough but not at Cordelia Forebay. Figure **4-21** presents all available TOC data for Barker Slough. The concentrations range from 0.1 to 43 mg/L with a median concentration of 5.5 mg/L. As discussed previously, TOC removal requirements by water treatment plants are based on source water TOC and alkalinity concentrations (see **Table 4-1**). The average TOC concentration at Barker Slough is 6.8 mg/L and the average alkalinity concentration is 99 mg/L as $CaCO_3$. Based on these average concentrations, the water agencies treating NBA water must remove 35 percent of the TOC. There are many months when TOC concentrations exceed 8 mg/L as shown in **Figure 4-21**. Alkalinity concentrations are often low when TOC concentrations are high, leading to the requirement to remove up to 50 percent of the TOC in the source water.

- Spatial Trends – Data have been collected for a longer period of record at Barker Slough than at Hood. **Figure 4-22** presents the data for Hood and Barker Slough collected during the same time period (1998 to 2010). This figure shows that TOC concentrations in Barker Slough are substantially higher and more variable than the concentrations at Hood. The Sacramento River is the primary source of water to the NBA but the local Barker Slough watershed contributes a substantial amount of TOC.

- Long-term Trends – Visual inspection of **Figure 4-21** does not reveal any discernible long-term trend in the data.

- Wet Year/Dry Year Comparison – **Figure 4-21** shows sharp TOC concentration increases at Barker Slough during the wet season; typically between 15 and 20 mg/L. Although this pattern appears to be relatively insensitive to hydrology, the dry year median concentration of 4.2 mg/L is statistically significantly lower than the wet year median concentration of 5.8 mg/L (Mann-Whitney, p=0.0228).

- Seasonal Trends – **Figure 4-23** shows that TOC concentrations are highest during the winter and early spring months when the local watershed is contributing runoff to Barker Slough. The concentrations decline throughout the summer and fall.

- DOC/TOC Relationship – **Figure 4-24** shows the good relationship between DOC and TOC at Barker Slough. DOC is generally about 86 percent of TOC.

Figure 4-21. TOC Concentrations at Barker Slough

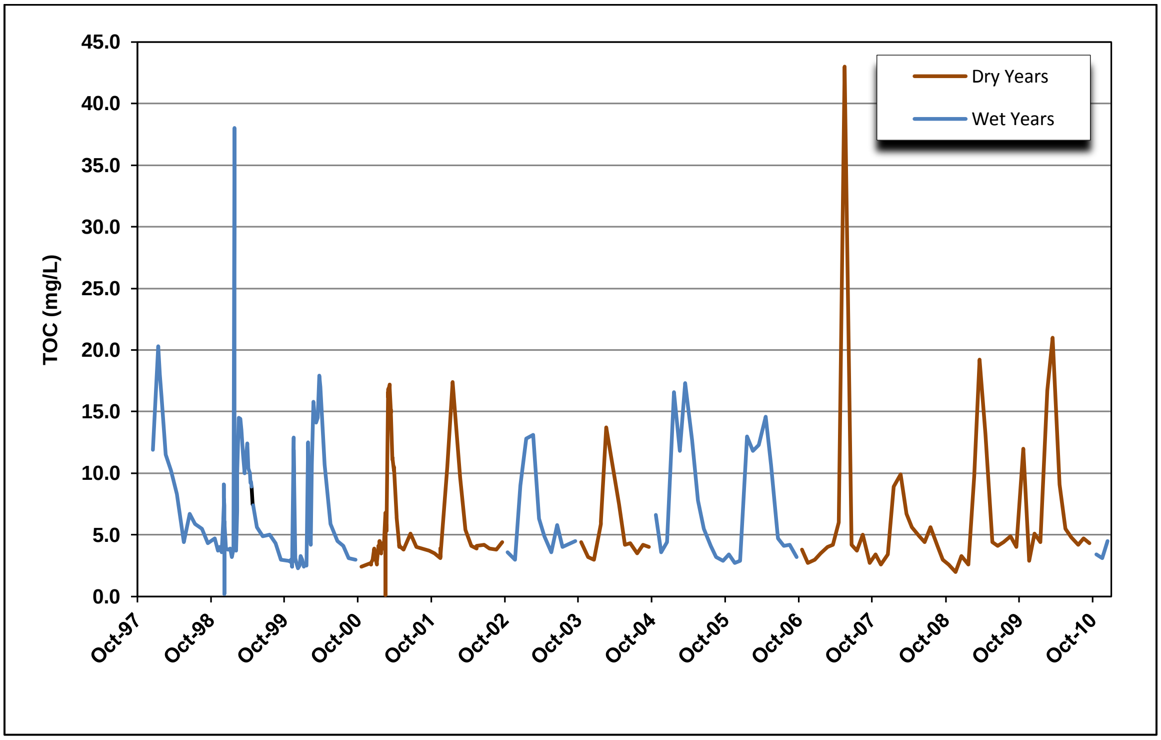


Figure 4-22. TOC Concentrations at Hood and Barker Slough (1998-2010)

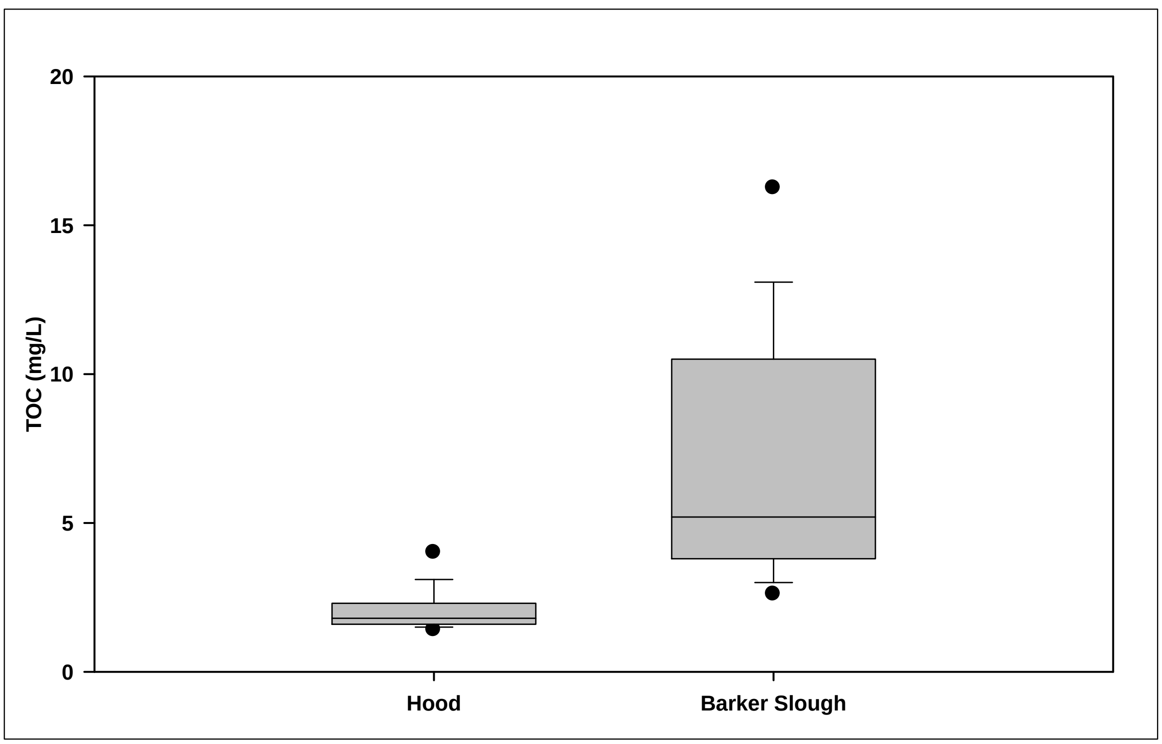
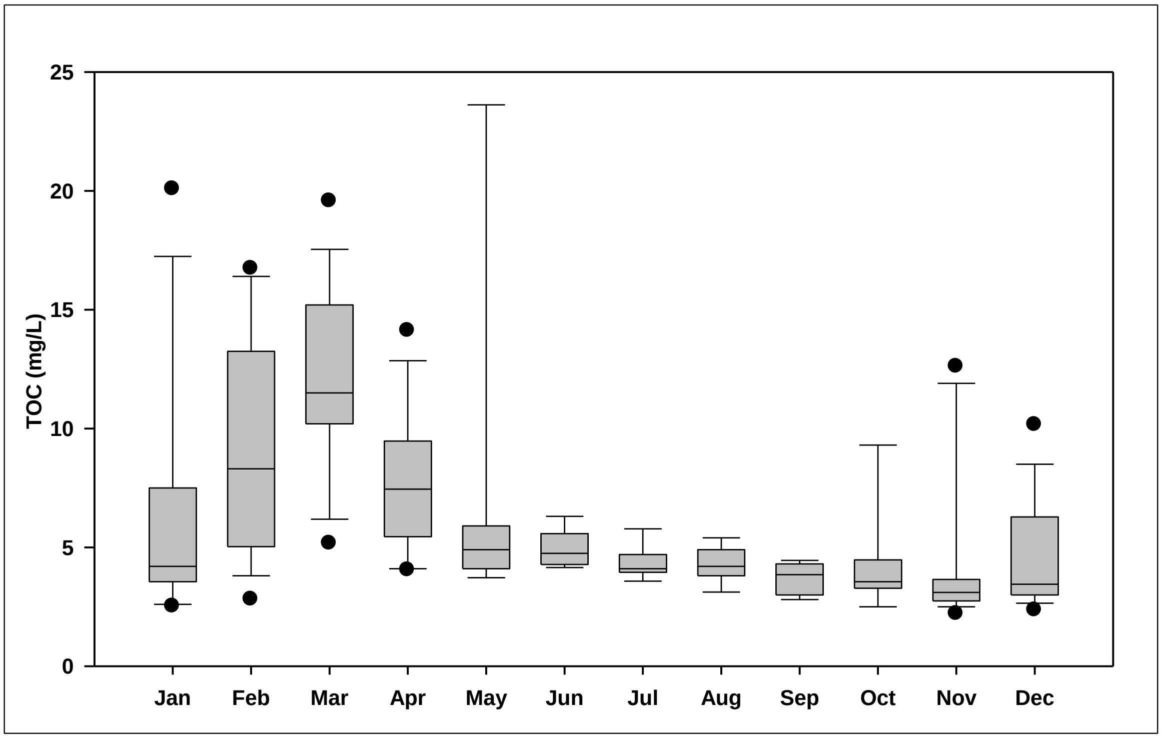
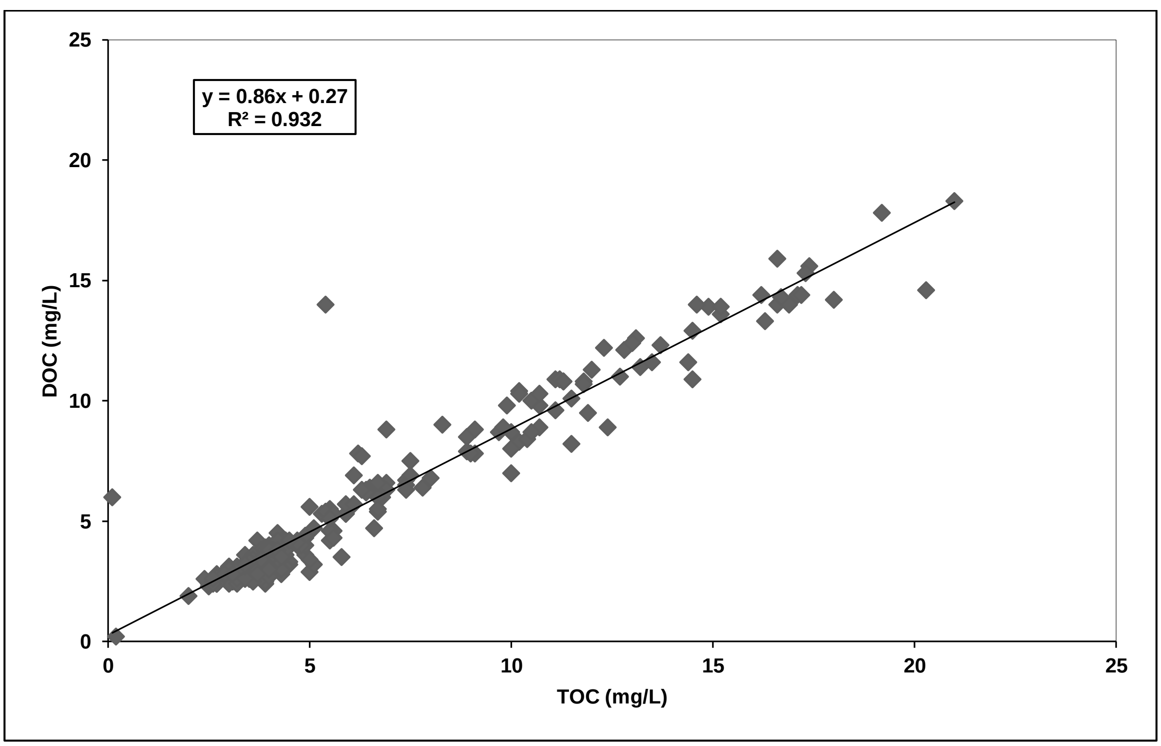


Figure 4-23. Monthly Variability in TOC at Barker Slough



Note: Insufficient data to plot all percentiles.

Figure 4-24. Relationship Between DOC and TOC at Barker Slough



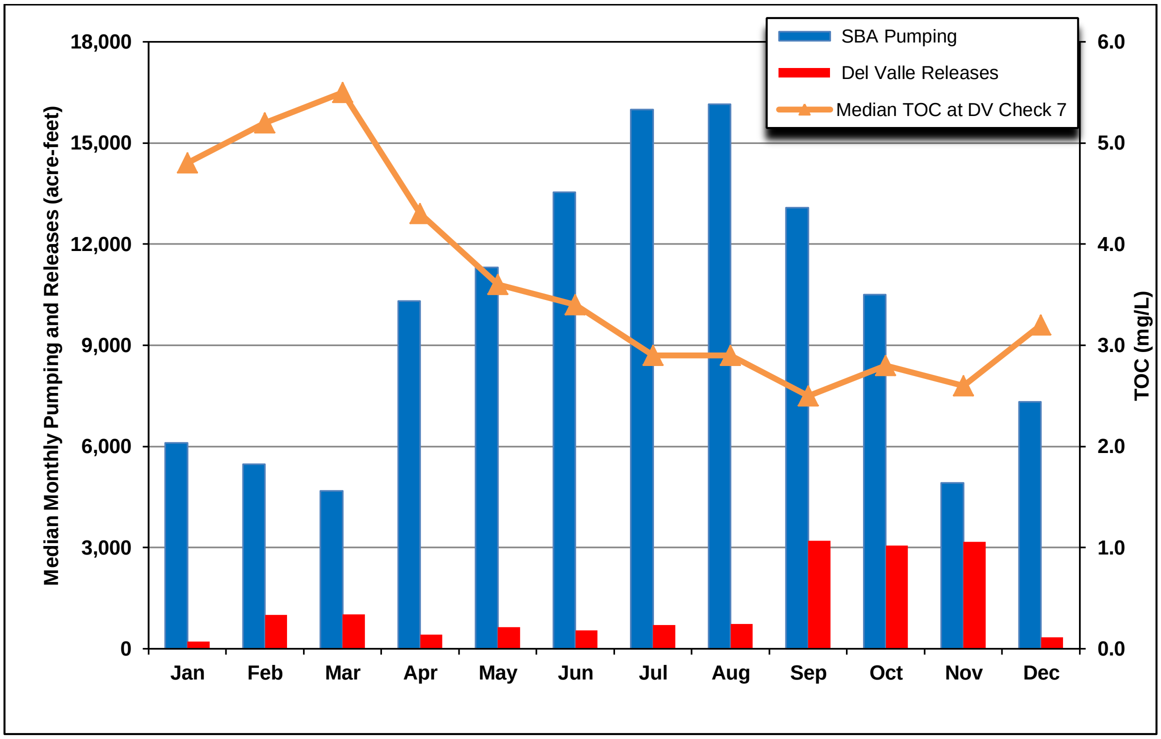
South Bay Aqueduct

The Delta is the primary source of water for the South Bay Aqueduct (SBA). Water is diverted into the SBA at the South Bay Pumping Plant on Bethany Reservoir, 1.2 miles downstream from Banks. The SBA consists of about 11 miles of open aqueduct followed by about 34 miles of pipeline and tunnel. There is some runoff from the Bethany watershed and historically a limited amount of drainage from hillsides upslope of the open canal section of the SBA flowed into the aqueduct. Water from the SBA can be pumped into or released from Lake Del Valle at the Del Valle Pumping Plant. Runoff from the Lake Del Valle watershed mingles with Delta water in the lake. Water is delivered to the Patterson Pass WTP owned by Zone 7 Water Agency of the Alameda County Flood Control and Water Conservation District (Zone 7 Water Agency) before the Del Valle Conservation Outlet (Conservation Outlet), where Lake Del Valle water is released into the SBA. Zone 7 Water Agency's Del Valle WTP and the treatment plants for Alameda County Water District (ACWD) and Santa Clara Valley Water District (SCVWD) take water downstream of Lake Del Valle. The SBA is an enclosed pipeline from Lake Del Valle to the Santa Clara Terminal Reservoir (Terminal Tank).

Project Operations

The quality of water delivered to the SBA Contractors is governed by the timing of diversions from Bethany Reservoir and releases from Lake Del Valle. **Figure 4-25** shows average monthly diversions at the South Bay Pumping Plant, releases from Lake Del Valle, and median monthly TOC concentrations at Del Valle Check 7 (DV Check 7). Diversion data were not available for 2010. This figure shows that TOC concentrations are in the range of 2.5 to 3.5 mg/L when most of the water is diverted into the SBA. TOC data are generally only collected at Lake Del Valle during the times that water is released into the SBA. The overall TOC median concentration during the 1999 to 2010 period that data have been collected is 4.2 mg/L, indicating that Del Valle releases may increase the concentration of TOC delivered to SBA Contractors.

Figure 4-25. Average Monthly Diversions at the South Bay Pumping Plant, Releases from Lake Del Valle, and Median TOC Concentrations



TOC Concentrations in the SBA

TOC is measured at DV Check 7 on the SBA, located just upstream of the Del Valle Branch Pipeline. There are limited TOC data for Lake Del Valle at the Conservation Outlet and TOC is not measured at the Terminal Tank. **Figure 4-26** shows all available TOC data at DV Check 7. The concentrations range from 2.1 to 9.2 mg/L during the period of record with a median of 3.4 mg/L. The average TOC concentration at DV Check 7 is 3.8 mg/L and the average alkalinity concentration is 68 mg/L as $CaCO_3$. Based on these average concentrations, the water agencies treating SBA water must remove 25 percent of the TOC. There are many months when TOC concentrations exceed 4 mg/L as shown in **Figure 4-26**. Alkalinity concentrations are generally in the range of 60 to 120 mg/L as $CaCO_3$ when TOC concentrations are high, leading to the requirement to remove 35 percent of the TOC in the source water.

- Spatial Trends – **Figure 4-27** compares data collected from the same time period (1997 to 2010) at Banks and DV Check 7. The median concentration of 3.4 mg/L at DV Check 7 is not statistically significantly higher than the median concentration of 3.2 mg/L at Banks (Mann-Whitney, p=0.1881). **Figure 4-28** compares TOC concentrations at the Conservation Outlet and DV Check 7. The limited data from the Conservation Outlet show that TOC is less variable in Lake Del Valle, with most values falling between 3.0 and 5.0 mg/L. At times, such as the fall of 2005 and 2006, the TOC concentrations at the Conservation Outlet were higher than at DV Check 7. This indicates that during the fall months when water is being released from Lake Del Valle to the SBA, the TOC concentrations downstream of Lake Del Valle are potentially higher than the concentrations in water coming from the Delta.

- Long-term Trends – The peak TOC concentrations during water years 2009 and 2010 are higher than concentrations during the previous years. This is likely due to the fact that these are the third and fourth years of a four year drought, rather than any long-term trend.

- Wet Year/Dry Year Comparison – The dry year median concentration of 3.6 mg/L is not statistically different from the wet year median concentration of 3.2 mg/L (Mann-Whitney, p=0.0609).

- Seasonal Trends – **Figure 4-29** shows the monthly data for DV Check 7. TOC concentrations are highest during the winter and early spring months and then decline during the summer months. This is the same pattern exhibited at Banks. The monthly medians were not compared statistically between the two locations but they are similar.

- DOC/TOC Relationship – **Figure 4-30** shows the relationship between DOC and TOC at DV Check 7. DOC is generally about 86 percent of TOC, slightly lower than the 92 percent at Banks. In general DOC represents a smaller fraction of TOC during the summer months. The increased particulate organic carbon in the summer months could potentially be due to algal growth in the SBA.

Figure 4-26. TOC Concentrations at DV Check 7

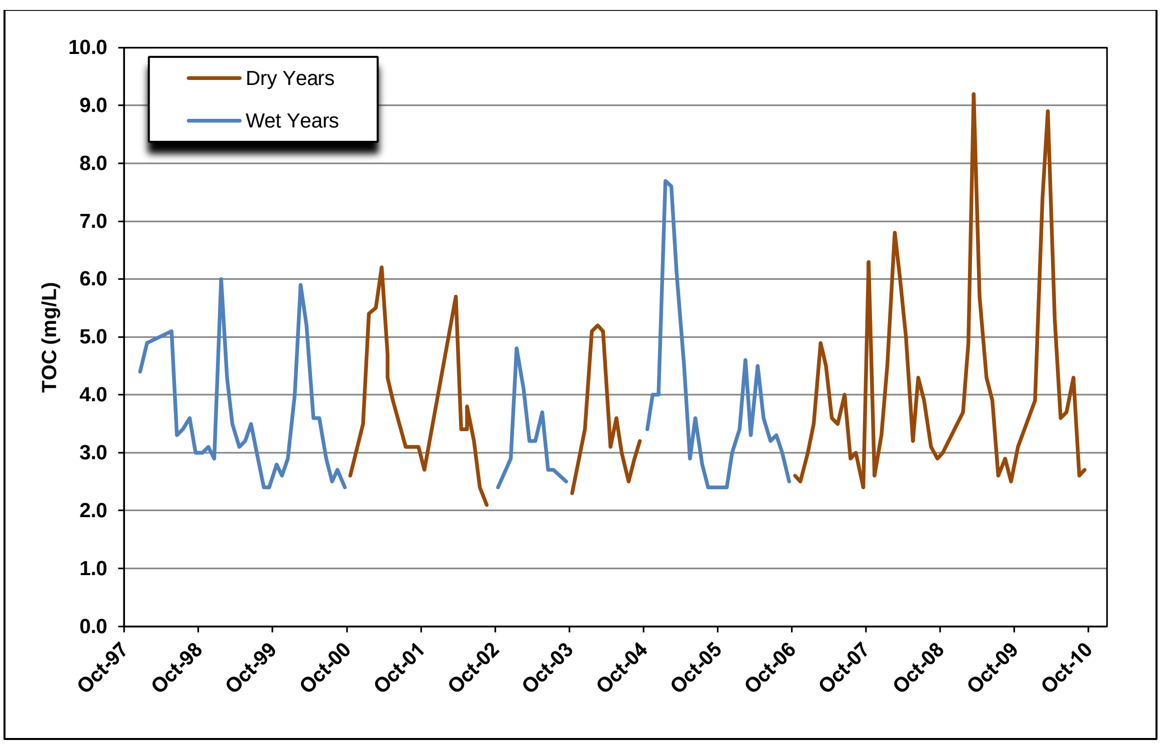


Figure 4-27. TOC Concentrations at Banks and DV Check 7 (1997-2010)

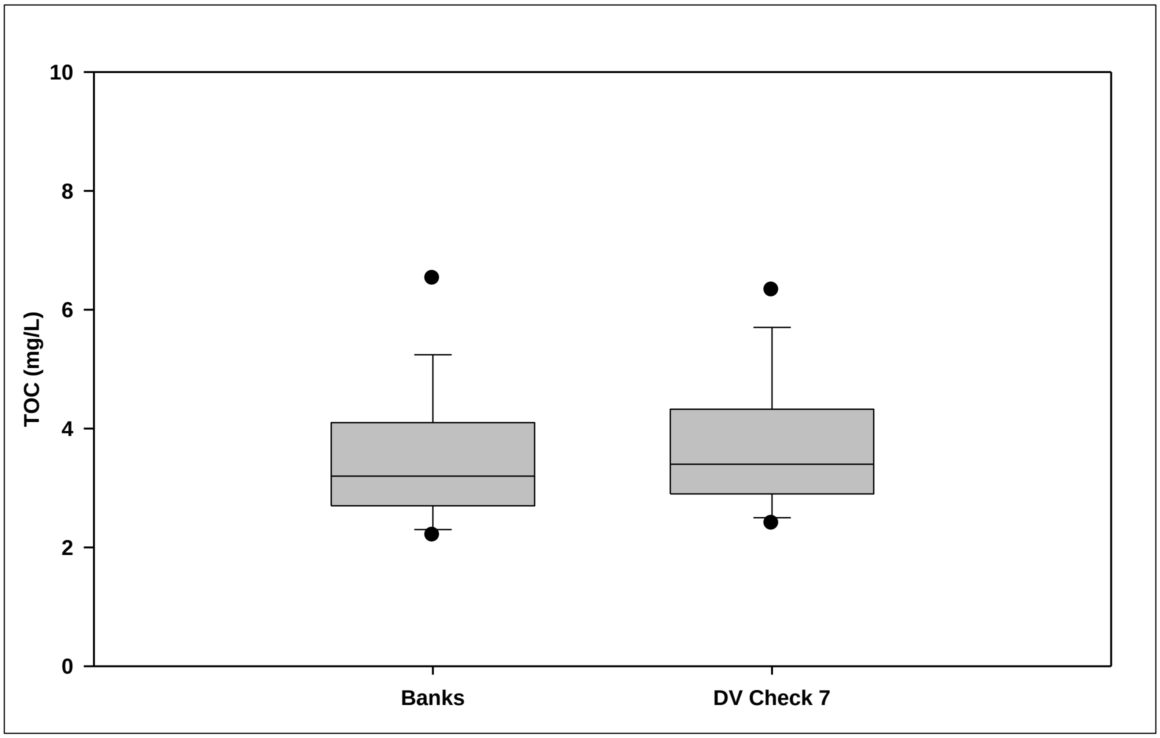


Figure 4-28. TOC Concentrations at DV Check 7 and the Conservation Outlet

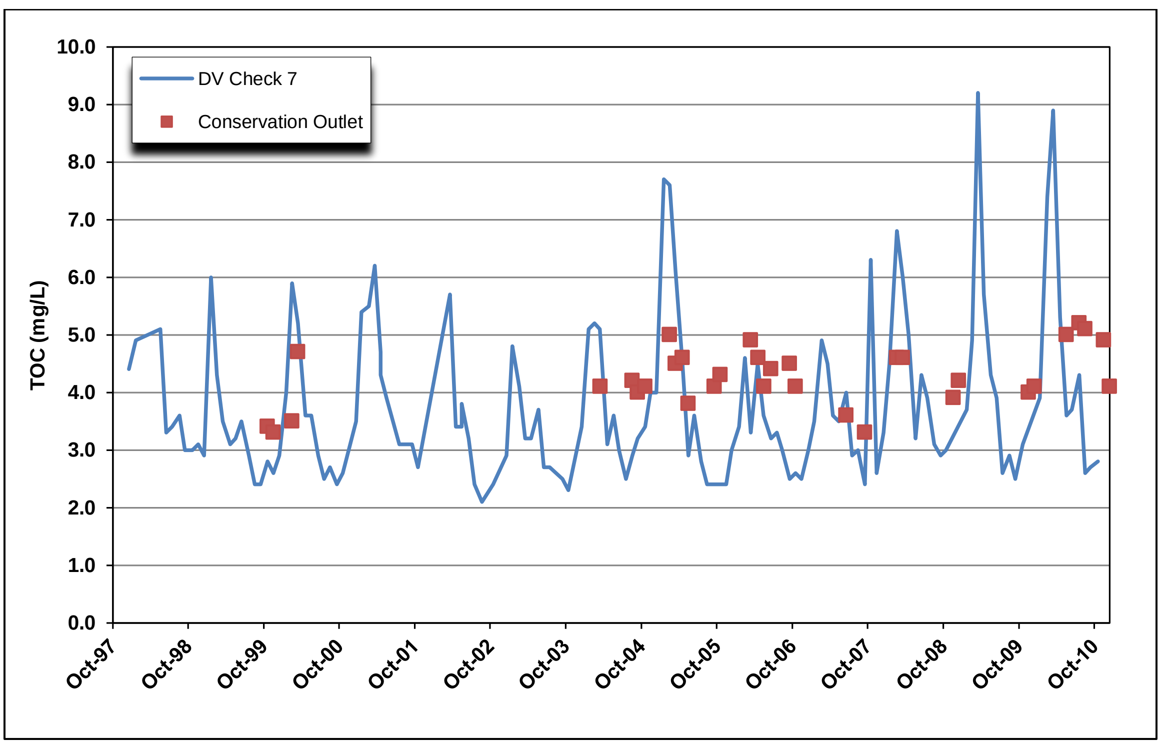
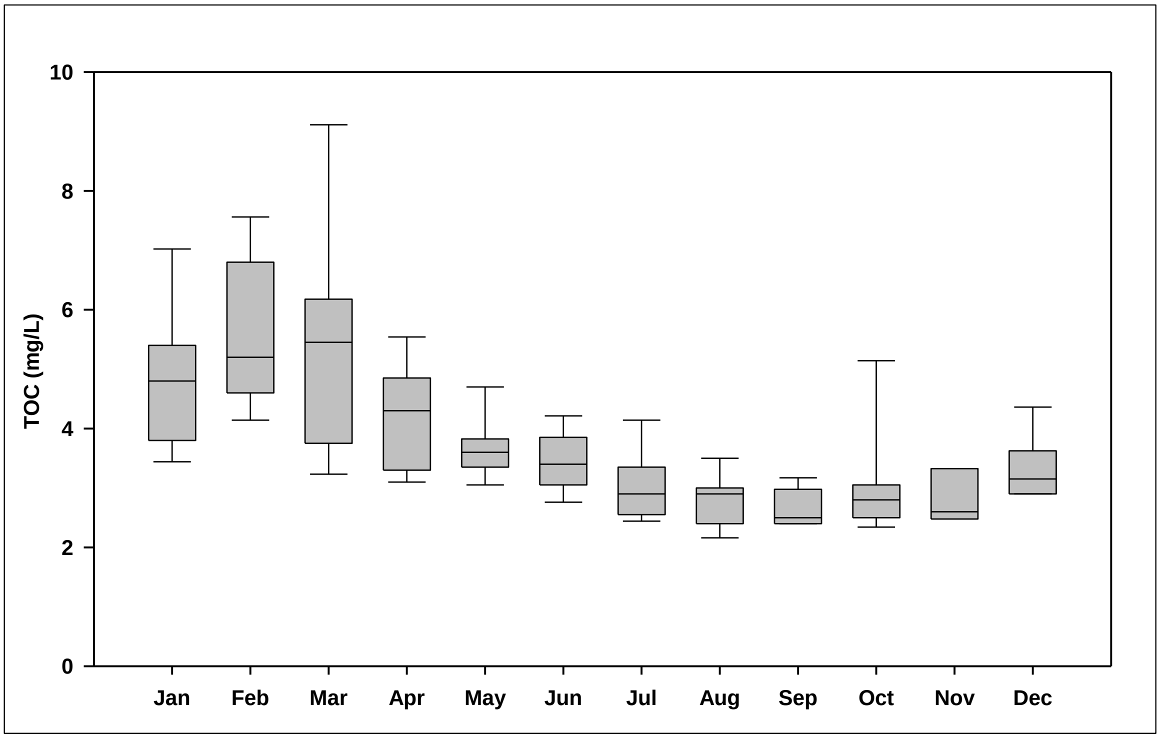
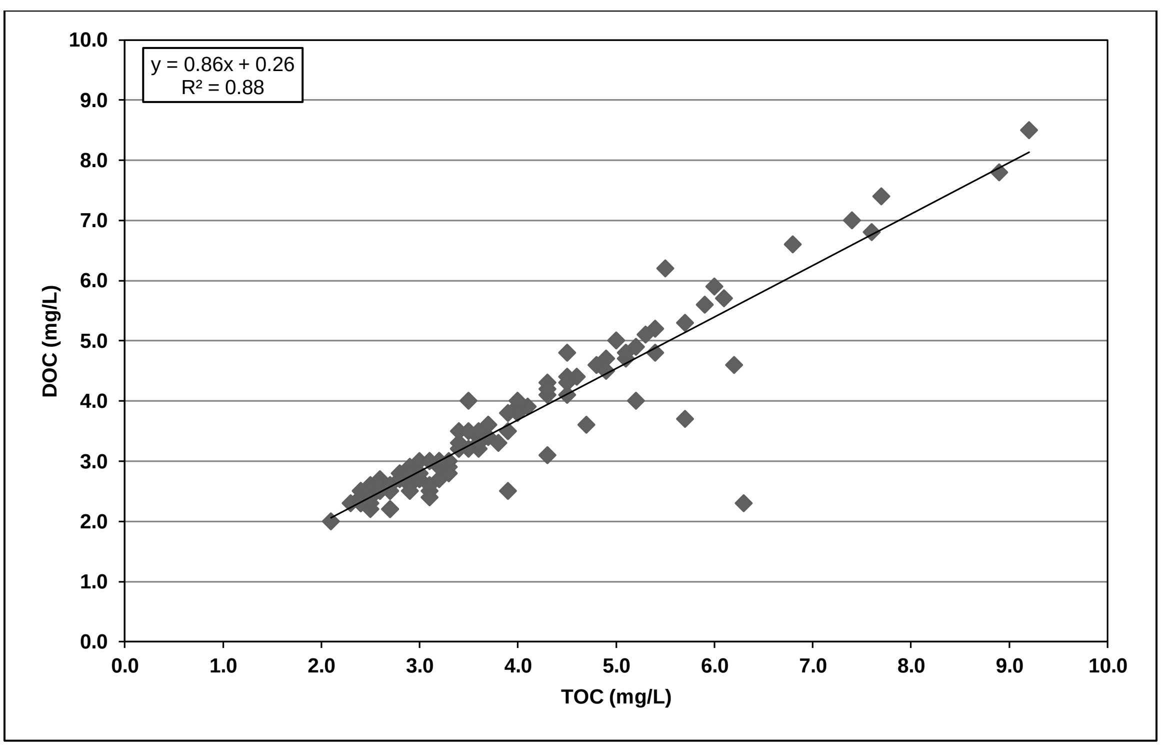


Figure 4-29. Monthly Variability in TOC at DV Check 7



Note: Insufficient data to plot all percentiles.

Figure 4-30. Relationship Between DOC and TOC at DV Check 7



California Aqueduct and Delta-Mendota Canal

A number of SWP Contractors take water from the SWP between San Luis Reservoir and the terminal reservoirs. This section is organized by various reaches of the SWP and individual SWP contractors taking water from each reach are described in the following sections.

Project Operations

The quality of water delivered to SWP Contractors south of San Luis Reservoir is governed by the timing of diversions from the Delta at Banks, pumping into O'Neill Forebay from the Delta-Mendota Canal (DMC), releases from San Luis Reservoir, non-Project inflows to the Governor Edmund G. Brown California Aqueduct (California Aqueduct), and storage in terminal reservoirs. The impact of non-Project inflows on water quality is discussed in Chapter 14 and the influence of terminal reservoirs in modulating TOC concentrations is discussed later in this chapter.

Figure 4-31 shows average monthly diversions at the Banks Pumping Plant and median monthly TOC concentrations. The diversions are shown for 1998 to 2006 when Delta operations were governed by the 1995 Bay-Delta Plan (D-1641) and for the 2007 to 2010 period when operations were governed by the Wanger Decision and the biological opinions. The diversion pattern during the 2007 to 2010 period was the same as the prior years; however, less water was diverted at Banks in every month of the year. The impact of the biological opinions on water quality is discussed in Chapter 15. Diversion patterns may shift depending upon the actions required by the final biological opinions. Since 1998, diversions have been highest in the July to September period when median TOC concentrations are less than 3.0 mg/L. A considerable amount of water is diverted during the January to March period when median TOC concentrations exceed 4.0 mg/L.

Figure 4-32 shows the average monthly amount of water pumped from the DMC at O'Neill Pump-Generation Plant into O'Neill Forebay and the median TOC concentrations in the DMC at McCabe Road (McCabe). During the 1998 to 2009 period that data were available, the DMC contributed between 26 and 44 percent of the water entering O'Neill Forebay with a median of 30 percent. The pumping pattern is different from Banks. A limited amount of water is pumped into O'Neill Forebay during the summer months when agricultural demands on the DMC are high. Pumping increases through the fall months, peaks in January, and then declines to the low point in the summer. Median TOC concentrations range from 2.6 to 3.2 mg/L during the fall months and from 4.0 to 4.7 mg/L during the spring months. These concentrations are similar to those found at Banks.

Figure 4-31. Average Monthly Banks Diversions and Median TOC Concentrations

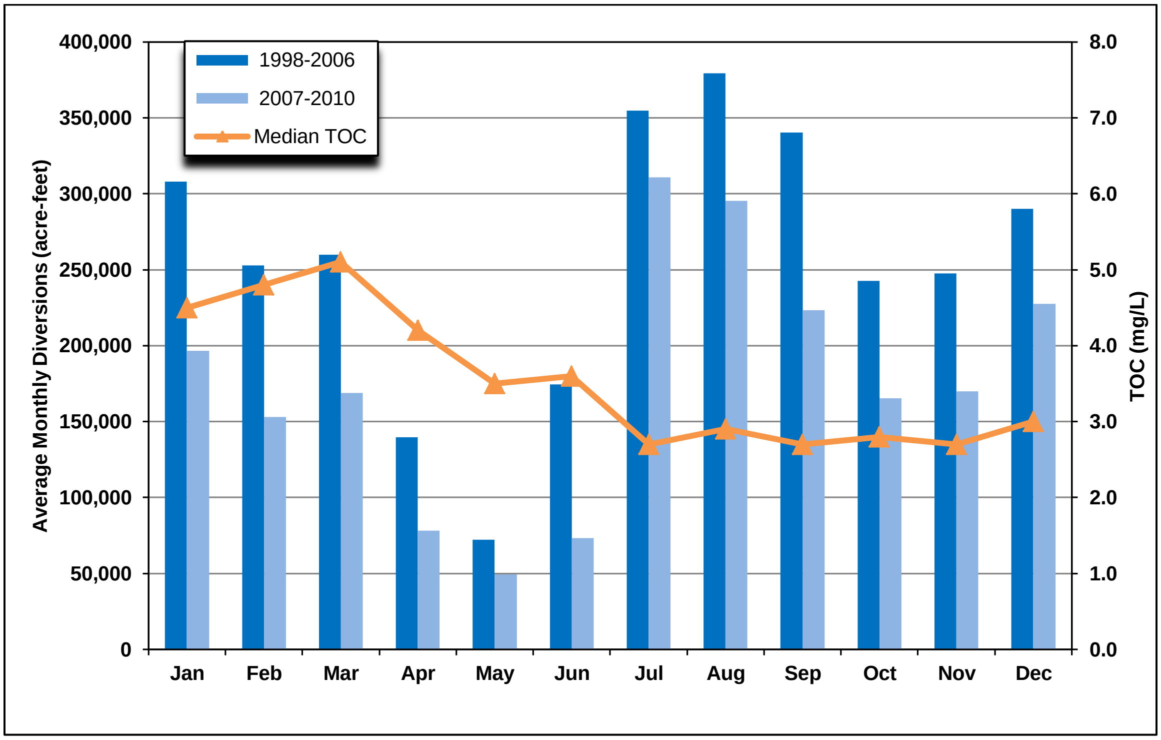
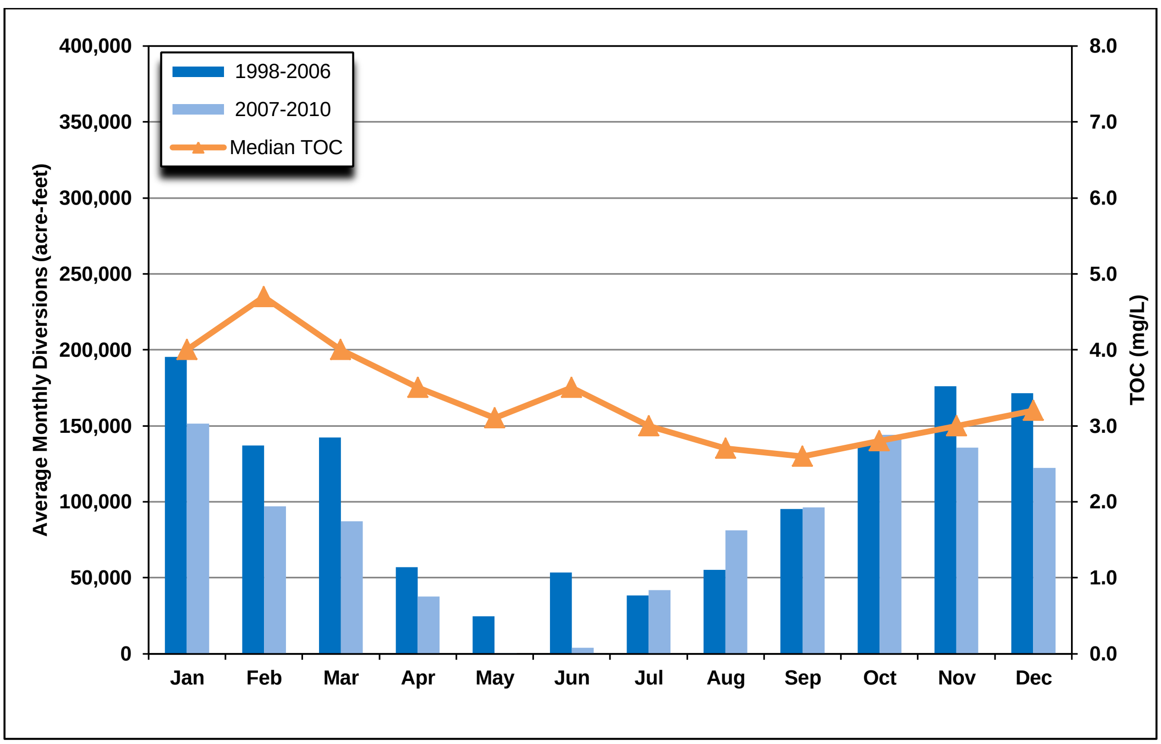


Figure 4-32. Average Monthly Pumping at O'Neill and Median TOC Concentrations



The operation of San Luis Reservoir impacts water quality in the California Aqueduct south of the reservoir. Water from O'Neill Forebay is pumped into San Luis Reservoir at the William R. Gianelli Pumping-Generating Plant (Gianelli) and water released from San Luis Reservoir flows into O'Neill Forebay before entering the California Aqueduct. Water is also pumped out of San Luis Reservoir on the western side at the Pacheco Pumping Plant (Pacheco) for SCVWD. **Figure 4-33** shows the pattern of pumping into the reservoir and releases from the reservoir to O'Neill Forebay. Water is generally pumped into the reservoir from September to March and released from the reservoir from April to August. The median TOC concentration at Banks is shown in the figure to represent the quality of water pumped into San Luis Reservoir from the California Aqueduct. The McCabe TOC data represent the quality of water pumped into the reservoir from the DMC. TOC data are not currently collected on releases from San Luis Reservoir to O'Neill Forebay so the data from Pacheco are shown to represent the quality of water entering O'Neill Forebay from the reservoir. DWR is currently installing a water quality monitoring station in the channel between San Luis Reservoir and O'Neill Forebay. This will provide valuable information on the quality of water released to O'Neill Forebay.

Figure 4-33. San Luis Reservoir Operations and Median TOC Concentrations

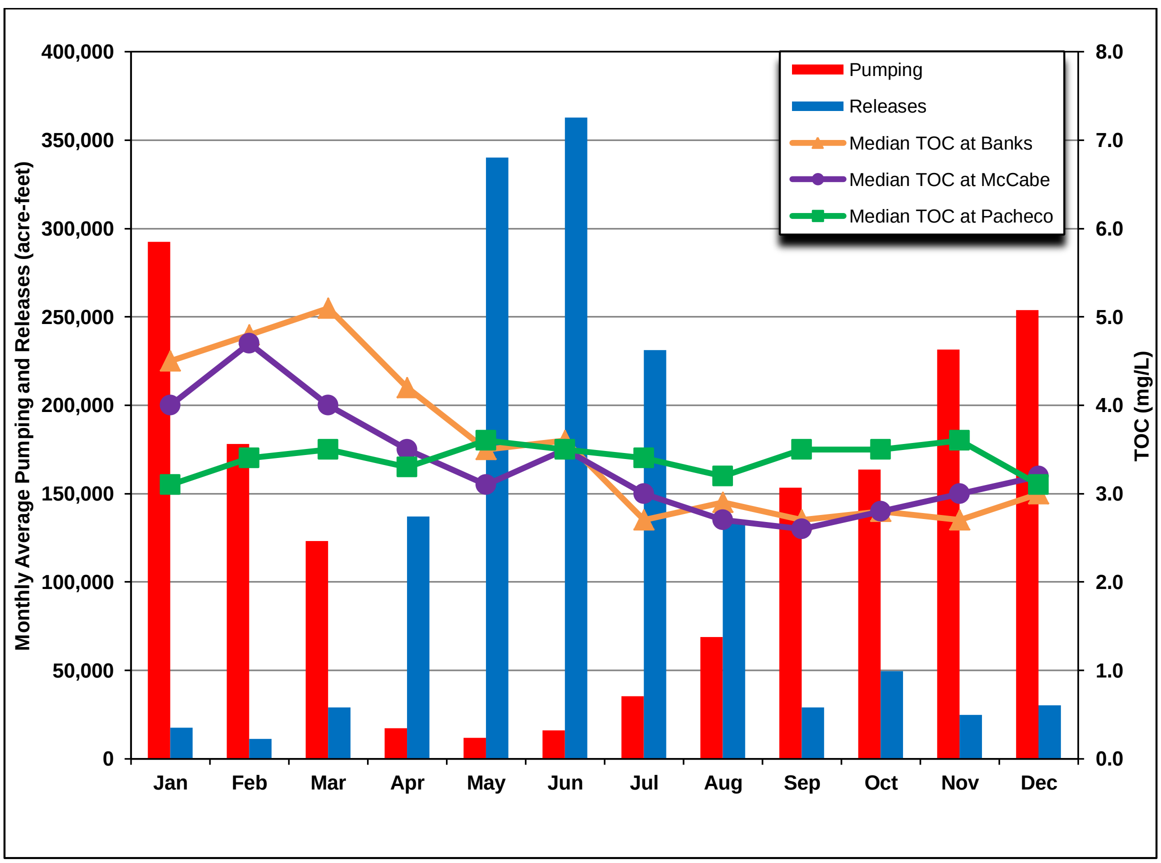


Figure 4-33 shows there are three distinctly different periods for San Luis Reservoir with respect to TOC concentrations:

- Fall Filling – The reservoir is filled from September to December when median TOC concentrations in water entering the reservoir are relatively low (2.7 to 3.0 mg/L at Banks and 2.6 to 3.2 mg/L at McCabe).

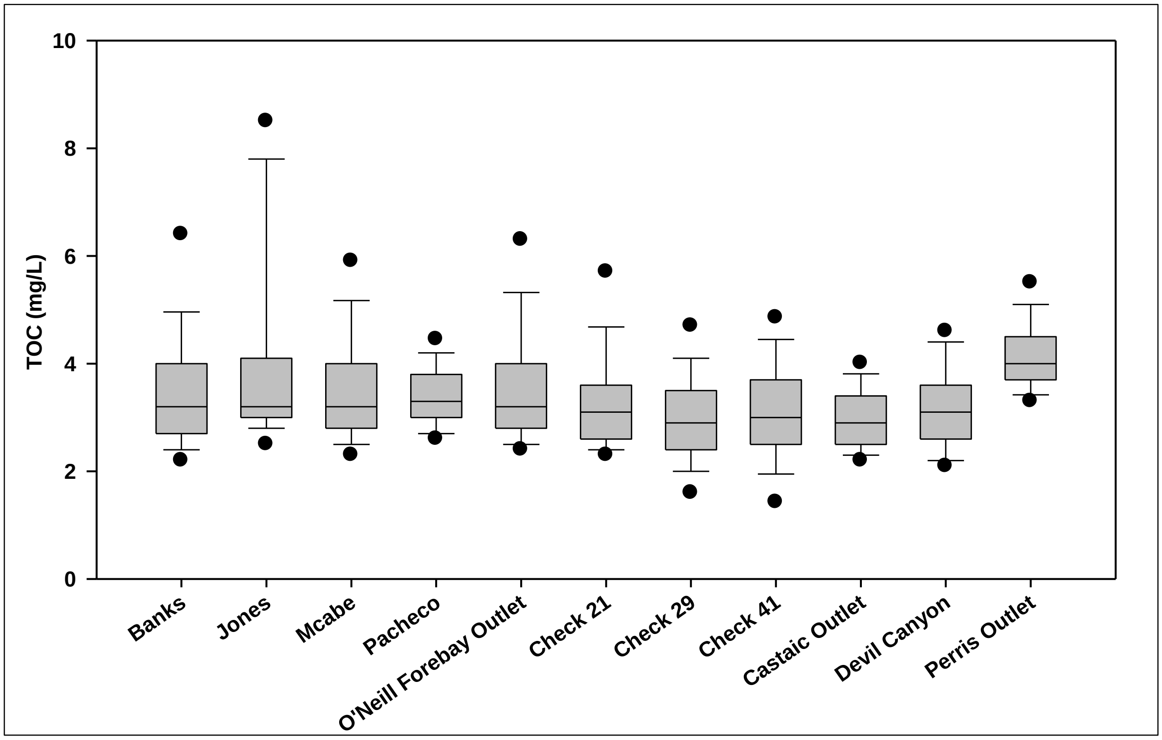
- Winter Filling – Filling continues between January and March when median TOC concentrations at Banks (4.5 to 5.1 mg/L) and McCabe (4.0 to 4.7 mg/L) are high

- Spring and Summer Releases – Water is released during the April to August period when median TOC concentrations at Pacheco range from 3.3 to 3.6 mg/L. During April, the TOC concentration in water released from San Luis Reservoir (median of 3.3 mg/L) is initially lower than the water entering O'Neill Forebay from the California Aqueduct (median of 4.0 mg/L) and the DMC (median of 3.5 mg/L). During May the concentrations in the DMC (median of 3.1 mg/L) are lower than in the California Aqueduct (median of 3.5 mg/L) and the releases from San Luis Reservoir (median of 3.6 mg/L). In June, the median concentration is 3.5 mg/L at all three locations. In July and August, the concentrations are higher in water released from the reservoir than in water entering O'Neill Forebay from the California Aqueduct and the DMC.

<u>TOC Concentrations in the DMC and SWP</u>

Figure 4-34 presents a summary of all TOC data collected at each of the locations along the DMC, California Aqueduct, and SWP reservoirs. Once the water enters the California Aqueduct, TOC concentrations generally do not change appreciably. There is some reduction in variability in concentrations leaving San Luis and Castaic reservoirs due to the blending of water with varying concentrations over time in the reservoirs. Median TOC concentrations along the California Aqueduct range from 2.9 to 3.3 mg/L, with the exception of the terminal reservoir, Lake Perris. The median concentration in Lake Perris is 4.0 mg/L, likely due to algal growth in the reservoir during the summer months. There isn't a clear pattern of change as water flows south in the SWP system.

Figure 4-34. TOC Concentrations in the DMC and SWP



Delta-Mendota Canal – Water from the DMC is pumped into O'Neill Forebay and comingles with water from the California Aqueduct. Unlike the California Aqueduct between Banks and O'Neill Forebay, there are a number of locations along the DMC where drainage is allowed to enter the canal. A field survey of the DMC was conducted for the 1990 Sanitary Survey (Brown and Caldwell, 1990). There are 191 drain inlets that convey agricultural drainage into the DMC above the intake channel to O'Neill Forebay. There are also numerous "weep holes" through which shallow groundwater can rise up into the canal.

Data have historically been collected at McCabe, just upstream of O'Neill Forebay. Data have also been collected at Jones since March 2009. **Figure 4-34** shows all available TOC data for both locations. The TOC median concentration at Jones and McCabe is 3.2 mg/L. **Figure 4-35** presents the TOC data for McCabe. The concentrations range from 2.3 to 9.7 mg/L.

- Spatial Trends – There are currently limited data at Jones so it is not possible to compare the Jones and McCabe data to evaluate the impacts of inflows to the DMC that occur upstream of the McCabe station. At this time, the McCabe data are compared to Banks data to determine if there are differences in the quality of water entering O'Neill Forebay from the two systems. All available data from Banks, Jones, and McCabe are presented in **Figure 4-34**. Since the period of record is longer for Banks, a subset of the data that includes only data collected at Banks and McCabe during the same time period (1997 to 2010) was analyzed. The median concentration is 3.2 mg/L at both locations for the 1997 to 2010 period and the data spread is similar, despite the fact that the DMC receives more water from the San Joaquin River and there are inputs to the DMC upstream of McCabe.

- Long-Term Trends – Visual inspection of **Figure 4-35** does not display any discernible trend in the TOC concentrations.

- Wet Year/Dry Year Comparison – The McCabe median concentration is 3.2 mg/L during wet years and dry years.

- Seasonal Trends – **Figure 4-36** shows there is a seasonal pattern of low concentrations from May to October and then concentrations increase during the late fall and winter months. This is similar to the seasonal pattern at Banks but quite different from the pattern at Vernalis. Vernalis has a secondary peak in TOC concentrations during the summer that does not appear at McCabe.

- DOC/TOC Relationship – There is a good relationship between DOC and TOC (R^2=0.93), as shown in **Figure 4-37**. DOC is approximately 93 percent of TOC, which is similar to Banks.

Figure 4-35. TOC Concentrations at McCabe

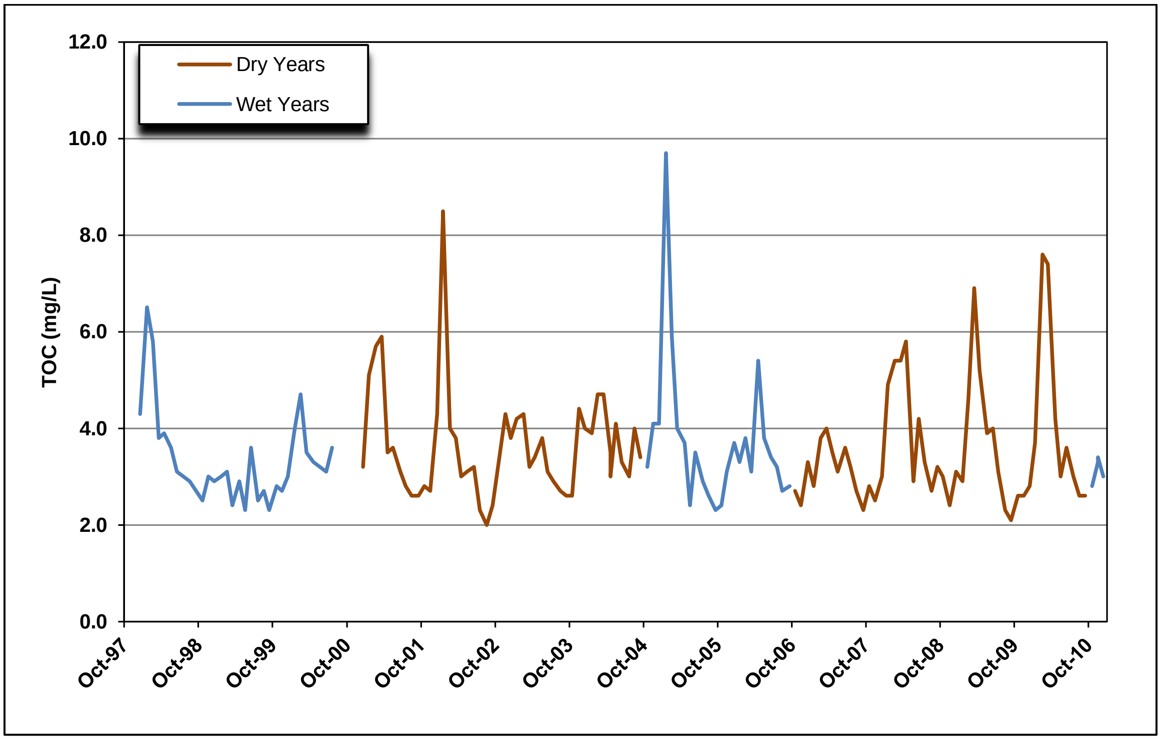
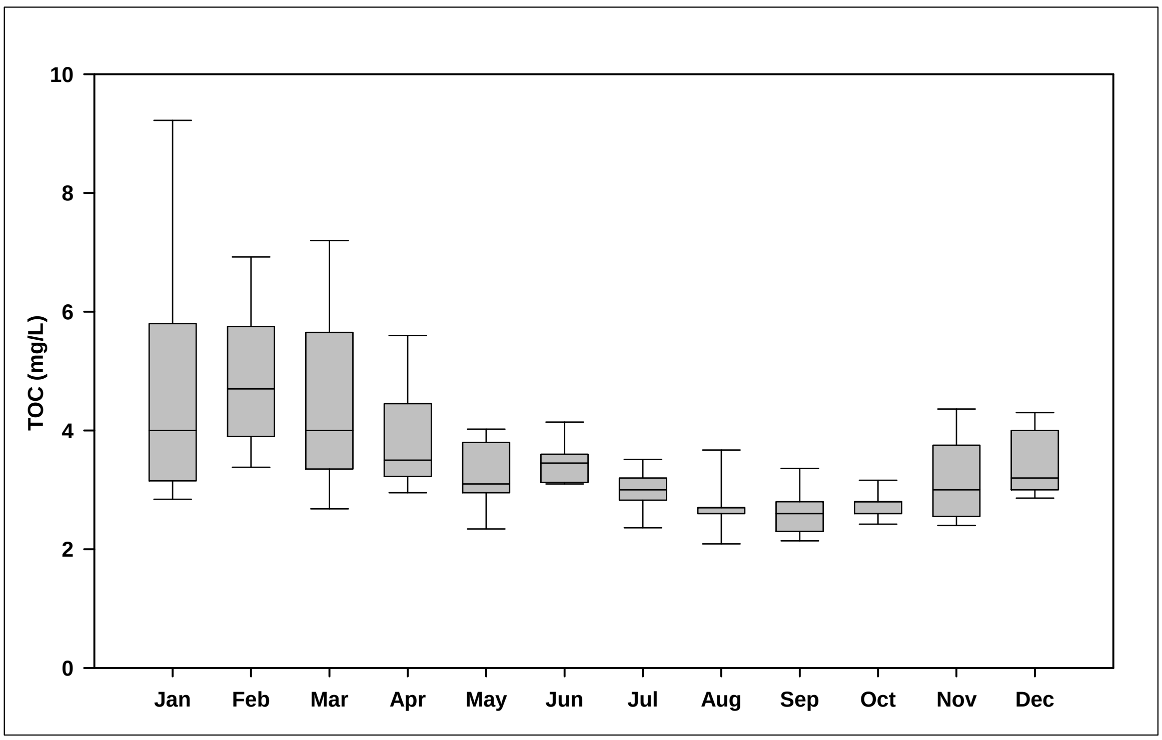
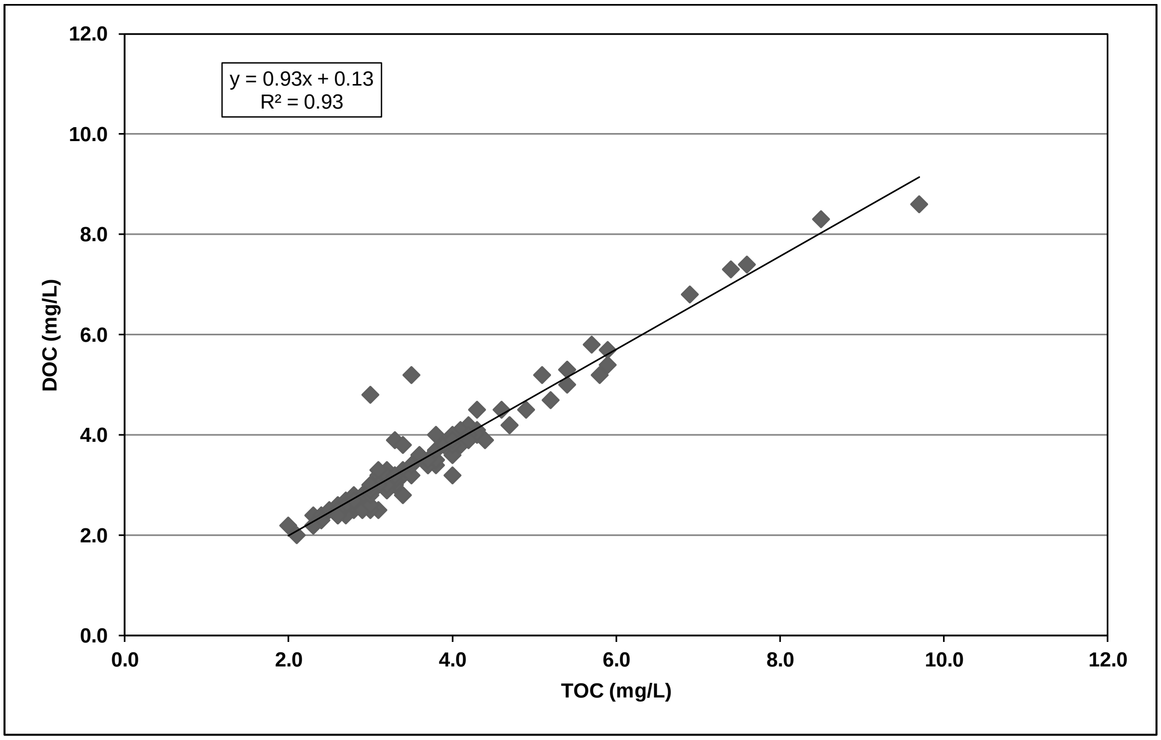


Figure 4-36. Monthly Variability in TOC at McCabe



Note: Insufficient data to plot all percentiles.

Figure 4-37. Relationship Between DOC and TOC at McCabe



San Luis Reservoir – Water is pumped out of San Luis Reservoir on the western side at Pacheco for SCVWD and on the eastern side at Gianelli for a number of SWP Contractors south of the reservoir. Data are available at Pacheco but data have not historically been collected at Gianelli. **Figure 4-38** presents all of the available TOC data for Pacheco. There is much less variability in TOC concentrations in the reservoir than in the aqueduct. The TOC concentrations at Pacheco range from 2.3 to 4.6 mg/L with a median of 3.3 mg/L.

- Spatial Trends – All available data from Banks, McCabe, and Pacheco are presented in **Figure 4-34**. Since the period of record is longer for Banks, a subset of the data that includes only data collected at Banks, McCabe, and Pacheco during the same period (2000 to 2010) is shown in **Figure 4-39**. The median concentration of 3.4 mg/L at Pacheco is not statistically significantly different from the median of 3.2 mg/L at Banks (Mann-Whitney, $p=0.3432$) or the median of 3.3 mg/L at McCabe (Mann-Whitney, $p=0.4420$), although the data spread is much tighter for Pacheco. Although, there are no apparent differences in TOC concentrations, the organic matter composition of water in San Luis Reservoir is different from water entering the reservoir due to algal production and degradation processes in the reservoir. Water in San Luis Reservoir has a greater propensity to form DBPs during the spring and summer months (Krause et al., 2011). This is the period when most water is released from the reservoir and flows south in the California Aqueduct.

- Long-Term Trends – Visual inspection of **Figure 4-38** does not display any discernible trend in the TOC concentrations in the 10 year period of record.

- Wet Year/Dry Year Comparison – The Pacheco dry year median concentration of 3.2 mg/L is statistically significantly lower than the wet year median concentration of 3.5 mg/L (Mann-Whitney, $p=0.0130$).

- Seasonal Trends – **Figure 4-40** shows there is little variability in the data from month to month; however the highest concentrations occur in the summer and the lowest concentrations occur in the winter. This is opposite of the pattern seen at Banks and most other locations. It is difficult to interpret the Pacheco data because samples are collected at different depths, depending on the depth at which water is being withdrawn from the Pacheco outlet tower and the amount of water in the reservoir. Samples are collected in the hypolimnion (bottom layer) when the reservoir is full during the winter months and in the epilimnion (surface layer) when the reservoir level is low during the late summer and fall months. The TOC concentrations in the hypolimnion are dependent on the TOC concentrations of water pumped into San Luis Reservoir from the Delta and, to some extent, on degradation of algae settling out of the epilimnion. Samples from the epilimnion have more algae and therefore may have higher TOC concentrations than samples from the hypolimnion.

- DOC/TOC Relationship – There is a good relationship between DOC and TOC ($R^2=0.90$), as shown in **Figure 4-41**. DOC is approximately 96 percent of TOC.

Figure 4-38. TOC Concentrations at Pacheco

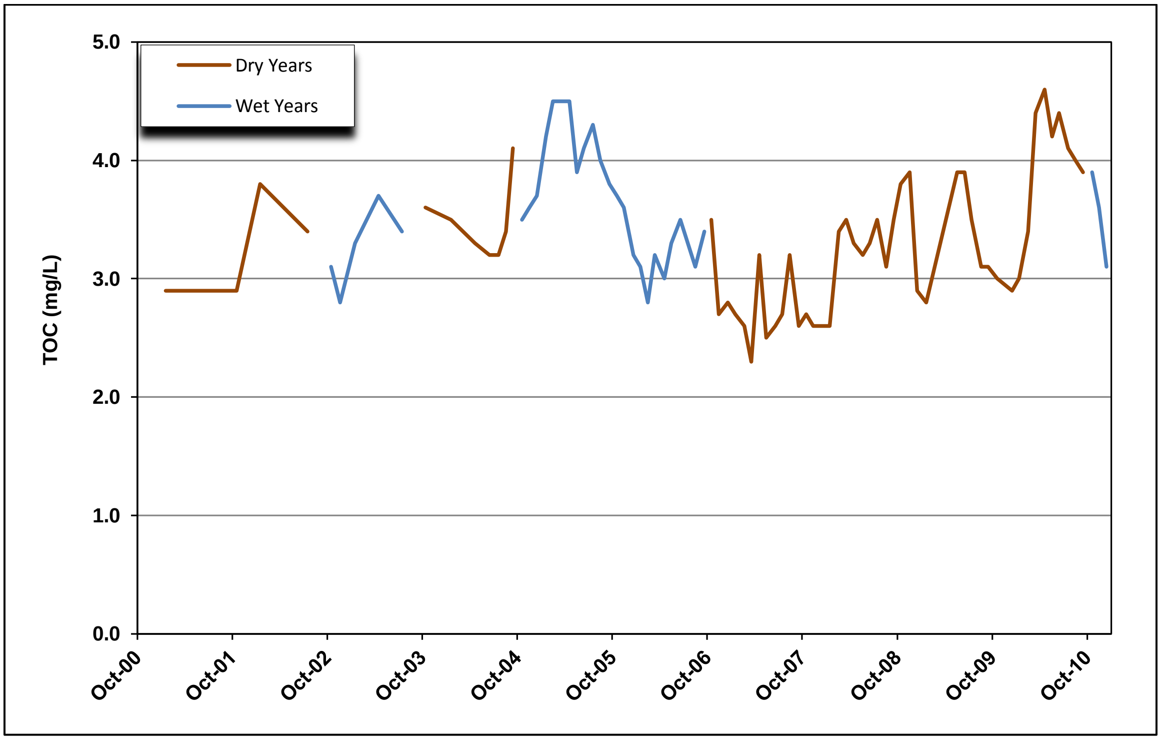


Figure 4-39. TOC Concentrations at Banks, McCabe, and Pacheco (2000-2010)

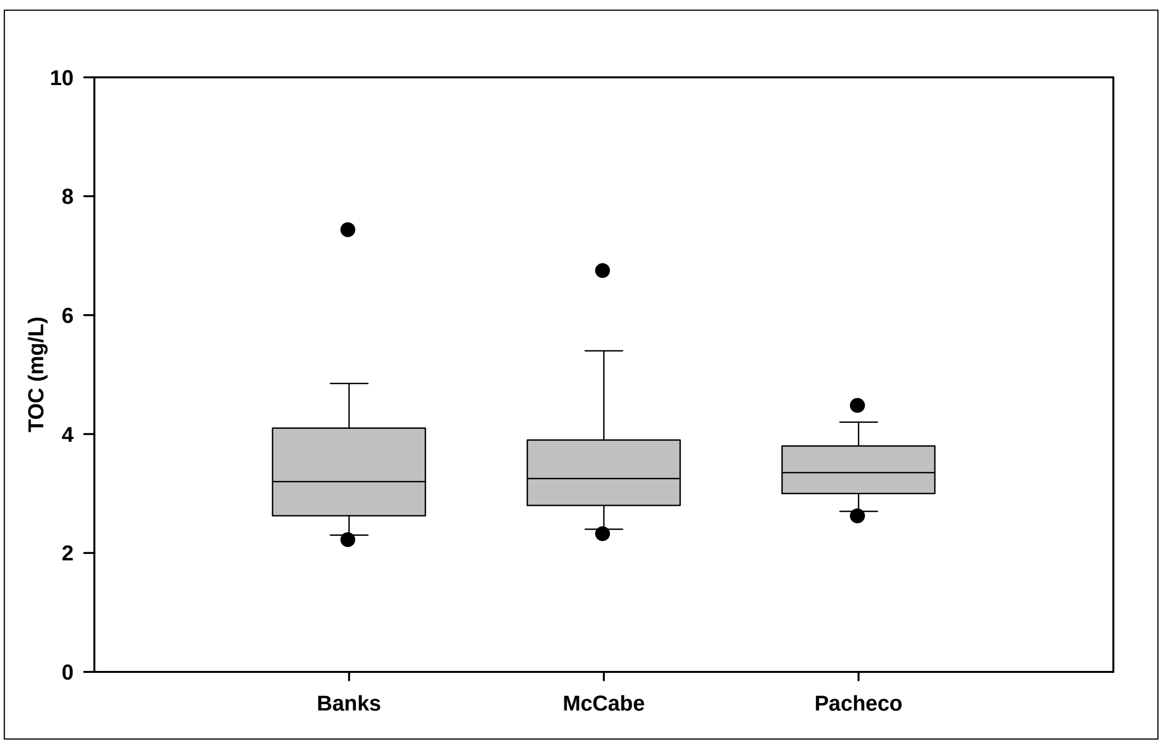
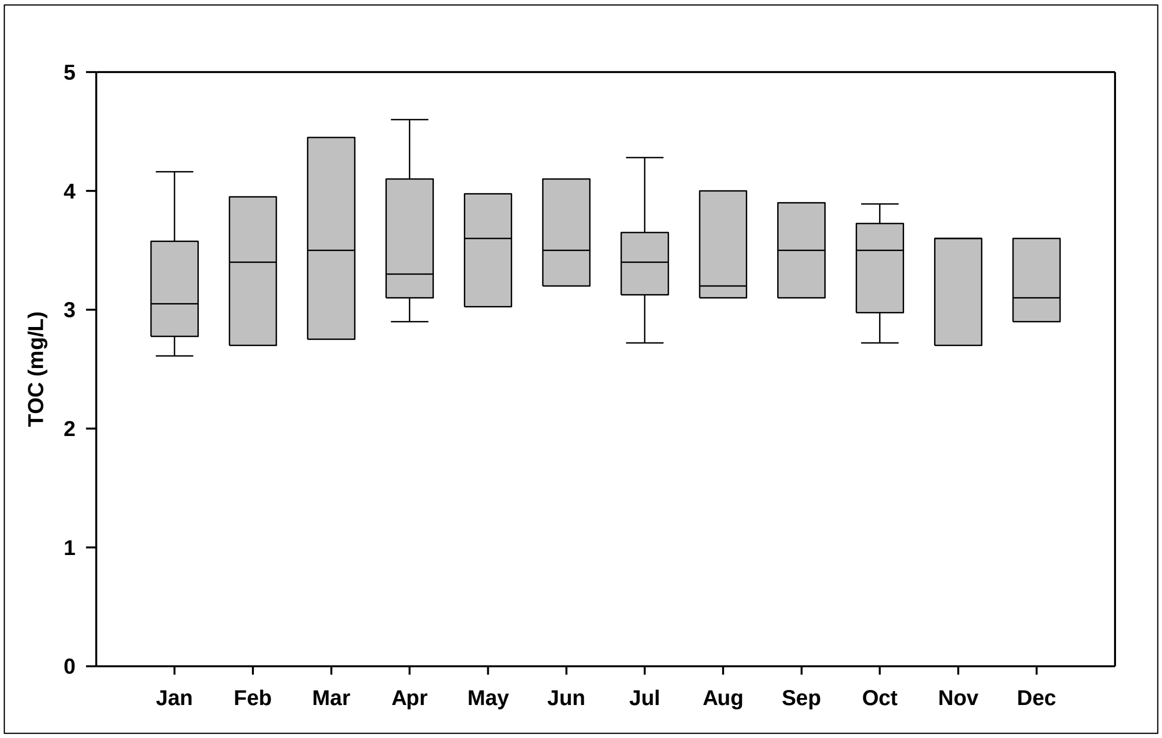
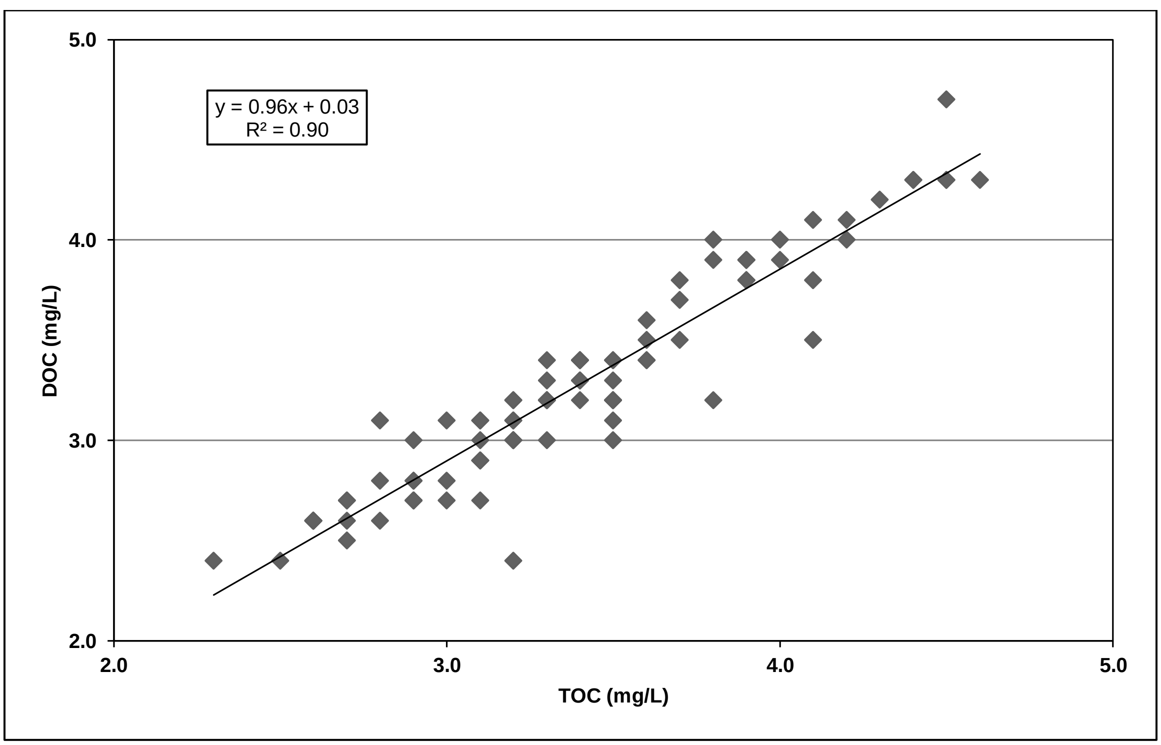


Figure 4-40. Monthly Variability in TOC at Pacheco



Note: Insufficient data to plot all percentiles.

Figure 4-41. Relationship Between DOC and TOC at Pacheco



O'Neill Forebay Outlet – Water released from San Luis Reservoir flows into O'Neill Forebay before entering the San Luis Canal section of the California Aqueduct at O'Neill Forebay Outlet. Water also flows through O'Neill Forebay without being pumped into San Luis Reservoir so O'Neill Forebay Outlet is a mixture of water from San Luis Reservoir, the California Aqueduct, and the DMC. **Figure 4-42** presents all of the available TOC data for O'Neill Forebay Outlet. The TOC concentrations at O'Neill Forebay Outlet range from 2.1 to 8.1 mg/L with a median concentration of 3.2 mg/L.

The average TOC concentration at O'Neill Forebay Outlet is 3.6 mg/L and the average alkalinity concentration is 74 mg/L as $CaCO_3$. Based on these average concentrations, the water agencies treating SWP water in conventional water treatment plants must remove 25 percent of the TOC. There are many months when TOC concentrations exceed 4 mg/L as shown in a number of the following figures for various locations along the SWP. Alkalinity concentrations are generally in the range of 60 to 120 mg/L as $CaCO_3$ when TOC concentrations are high, leading to the requirement to remove 35 percent of the TOC in the source water in conventional water treatment plants and to implement TOC removal in addition to ozone disinfection. On occasion, alkalinity concentrations drop below 60 mg/L when TOC concentrations exceed 4 mg/L leading to the requirement to remove 45 percent of the TOC in the source water.

- Spatial Trends – All available data from Banks, McCabe, and O'Neill Forebay Outlet are presented in **Figure 4-34**. Since the period of record is longer for Banks, a subset of the data that includes only data collected at Banks, McCabe, and O'Neill Forebay Outlet during the same time period (1997 to 2010) was analyzed. The median concentration at all three locations is 3.2 mg/L during this period. While TOC concentrations entering the California Aqueduct at O'Neill Forebay Outlet are not statistically significantly different from the water at Banks, the organic matter composition is sometimes different (Krause et al., 2011).

- Long-Term Trends – Visual inspection of **Figure 4-42** does not display any discernible trend in the TOC concentrations in the 13 year period of record.

- Wet Year/Dry Year Comparison – The O'Neill Forebay Outlet dry year median concentration of 3.2 mg/L is not statistically significantly different than the wet year median concentration of 3.3 mg/L (Mann-Whitney, p=0.6212).

- Seasonal Trends – **Figure 4-43** shows there is a distinct seasonal pattern with the lowest concentrations in the summer months and the highest concentrations in March. This is the same seasonal pattern exhibited at Banks.

- DOC/TOC Relationship – There is a good relationship between DOC and TOC (R^2=0.96), as shown in **Figure 4-44**. DOC is approximately 94 percent of TOC.

Figure 4-42. TOC Concentrations at O'Neill Forebay Outlet

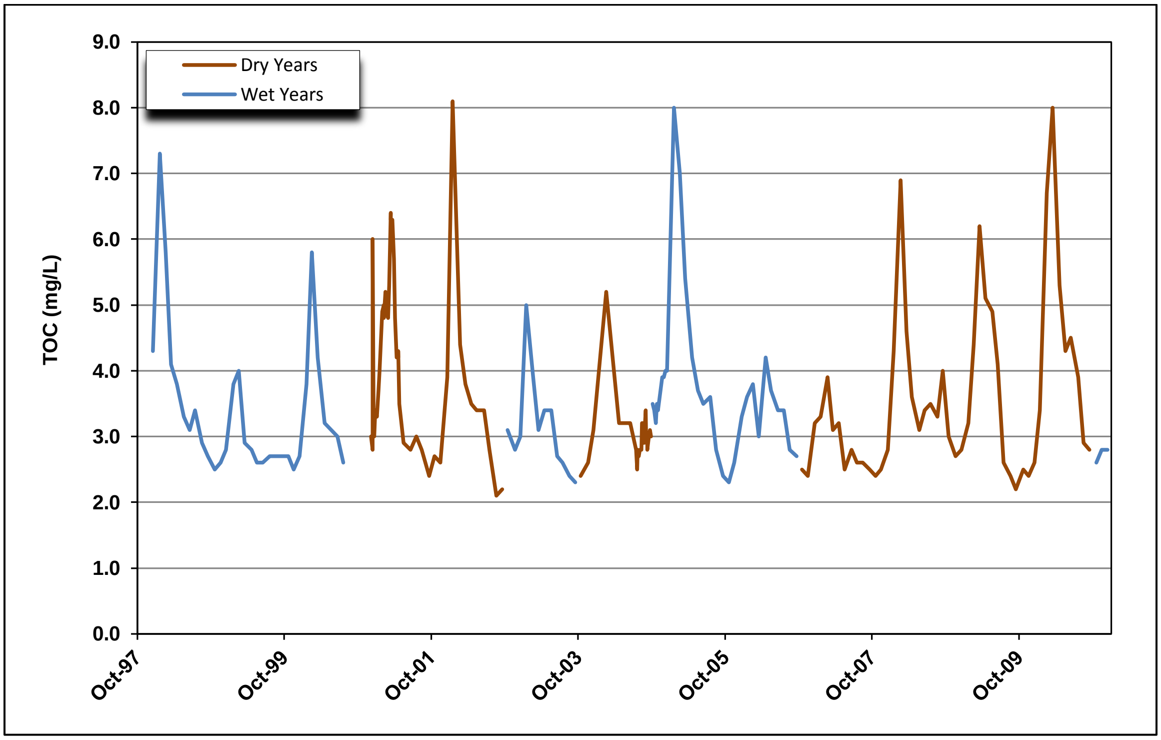
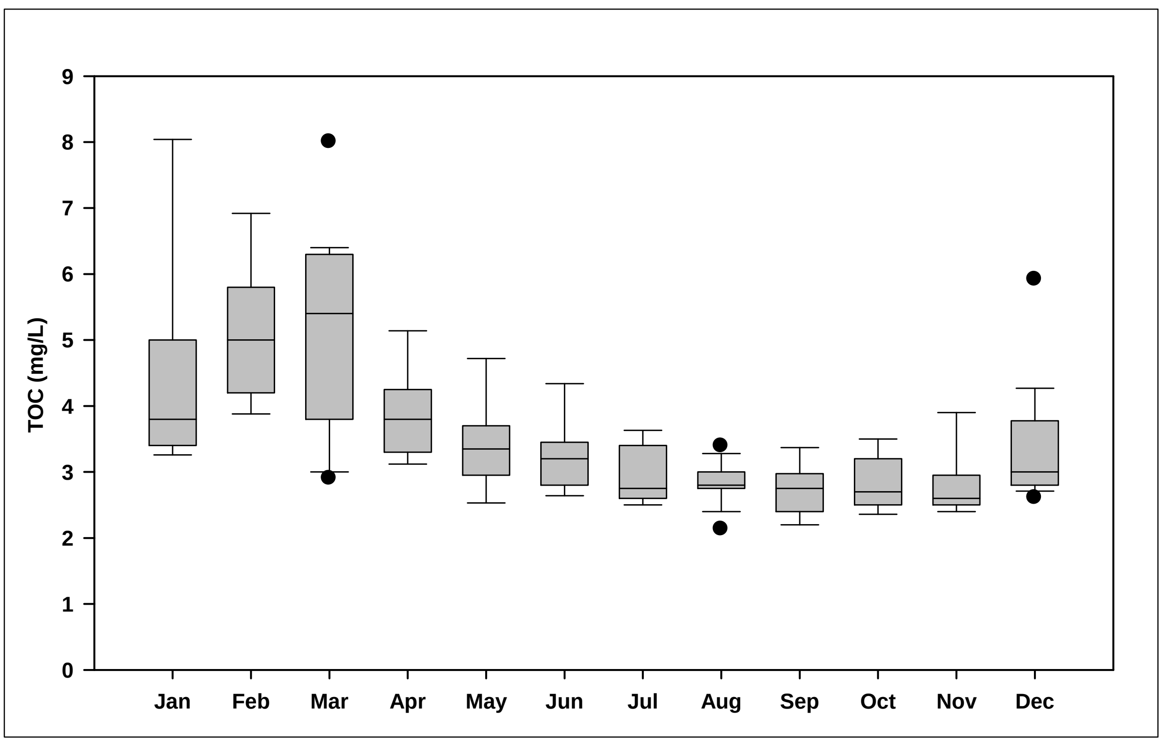
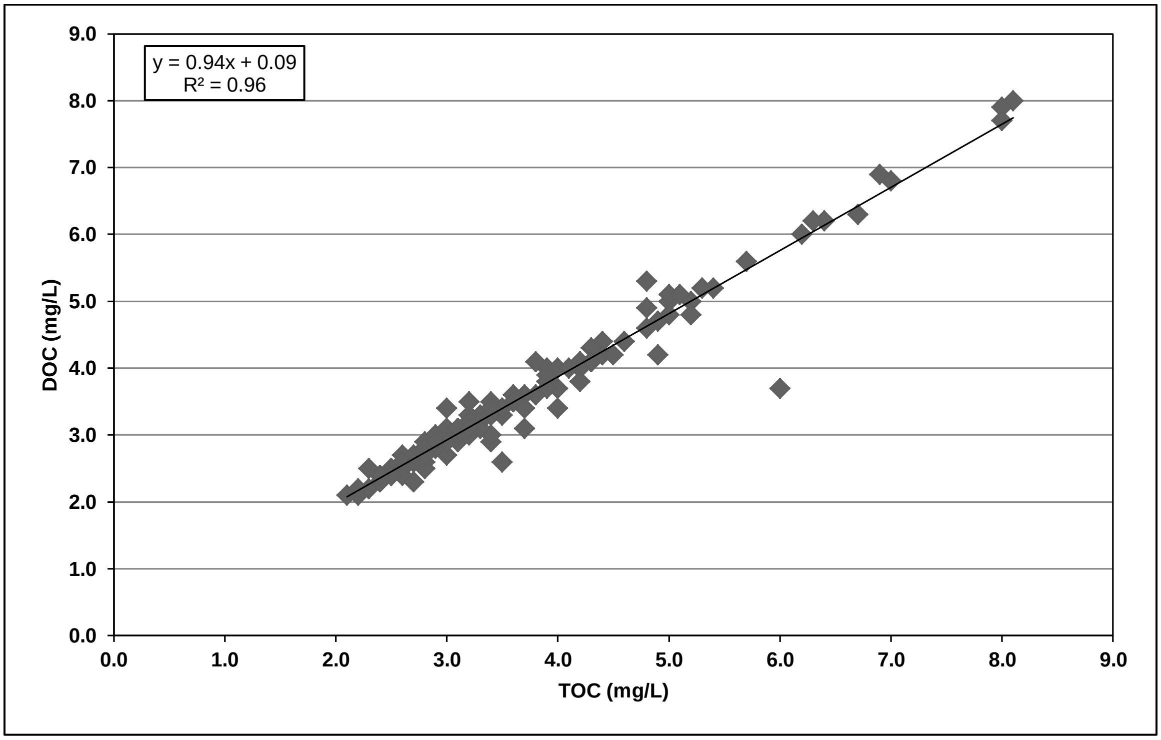


Figure 4-43. Monthly Variability in TOC at O'Neill Forebay Outlet



Note: Insufficient data to plot all percentiles.

Figure 4-44. Relationship Between DOC and TOC at O'Neill Forebay Outlet



Check 21 – Check 21, located on the California Aqueduct 12 miles upstream of the Coastal Branch junction is the site where the quality of water entering the Coastal Branch is measured. The Coastal Branch provides water to CCWA and San Luis Obispo County Flood Control and Water Conservation District. **Figure 4-45** presents all available data for Check 21. During the 1997 to 2010 time period, TOC concentrations ranged from 2.0 to 7.1 mg/L with a median of 3.1 mg/L.

- Spatial Trends – The median concentration of 3.1 mg/L at Check 21 is not statistically different from the median concentration of 3.2 mg/L at O'Neill Forebay Outlet during the 1997 to 2010 period that data have been collected at the two locations (Mann-Whitney, p=0.3183). Between O'Neill Forebay Outlet and Check 21 floodwater periodically enters the aqueduct from creeks draining the Diablo Range to the west and water ponding against the western side of the aqueduct. Groundwater has been pumped into this reach of the aqueduct (see Chapter 14 for more details). The 2001 Update contains a detailed discussion of the inflows to this reach of the aqueduct (DWR, 2001). DWR collected TOC data on a variety of floodwater inflows between 1996 and 1998 and found concentrations ranging from 4 to 49 mg/L. The monthly monitoring data collected at Checks 13 and 21 do not reflect an increase in TOC that might be expected with floodwater inflows.

  Figure 4-46 presents a comparison of data at O'Neill Forebay Outlet and Check 21 for the last five years. This figure shows that the peak concentrations of TOC at Check 21 occurred approximately one month later than at O'Neill Forebay Outlet in 2008, 2009, and 2010 and the peak concentrations were about 1 mg/L lower at Check 21. The shift in the timing of the peak is likely due to low flows on the aqueduct during this period. In February 2006, flow through the Dos Amigos Pumping Plant, upstream of Check 21, was over 355,000 acre-feet, whereas in February 2009 less than 30,000 acre-feet flowed through the plant. The lower TOC concentrations at Check 21 compared to O'Neill Forebay Outlet during the 2007 to 2010 period are inexplicable. A small amount of groundwater (12,581 acre-feet) was pumped into this reach of the aqueduct by Westlands Water District in the summer of 2008, which may have led to the decrease in September 2008 but that does not explain the differences during the spring of every year except 2007.

- Long-Term Trends – Visual inspection of **Figure 4-45** does not display any discernible trend in the TOC concentrations in the 13 year period of record.

- Wet Year/Dry Year Comparison – The Check 21 dry year median concentration of 3.0 mg/L is not statistically significantly different than the wet year median concentration of 3.2 mg/L (Mann-Whitney, p=0.7176).

- Seasonal Trends – **Figure 4-47** shows there is a distinct seasonal pattern with the lowest concentrations in the summer months and the highest concentrations in the wet months of January to April.

- DOC/TOC Relationship – DOC is approximately 92 percent of TOC, as shown in **Figure 4-48**.

Figure 4-45. TOC Concentrations at Check 21

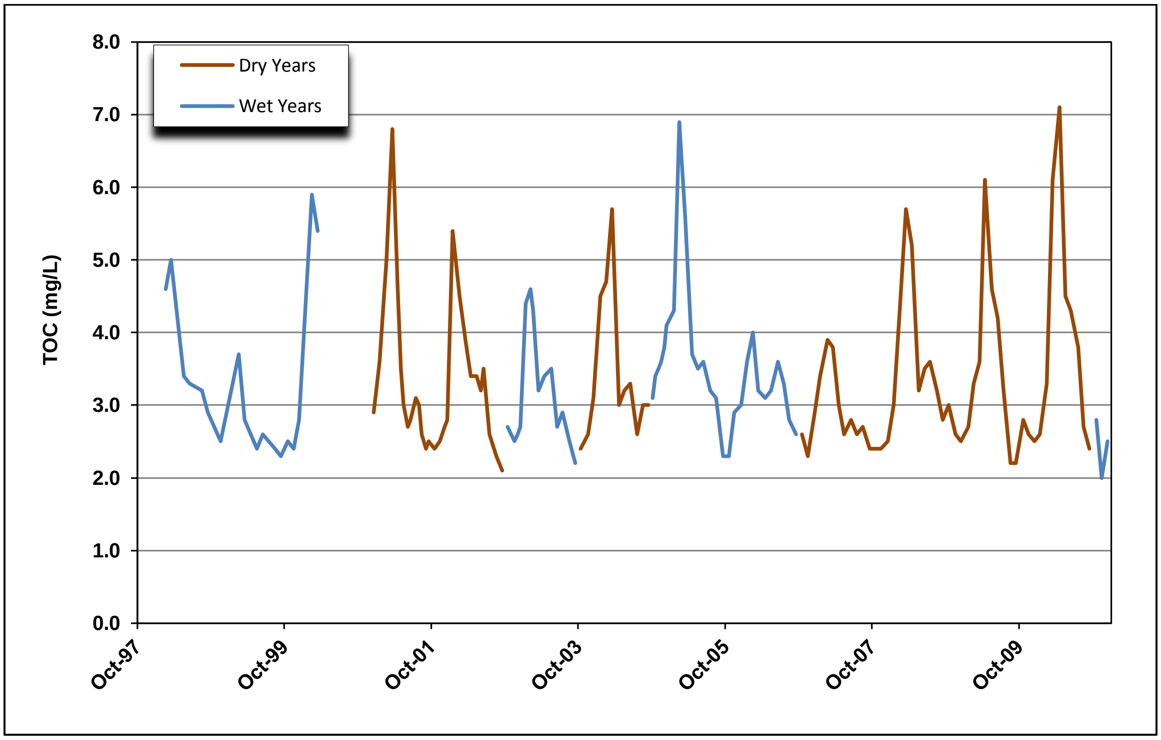


Figure 4-46. Comparison of O'Neill Forebay Outlet and Check 21 TOC Concentrations

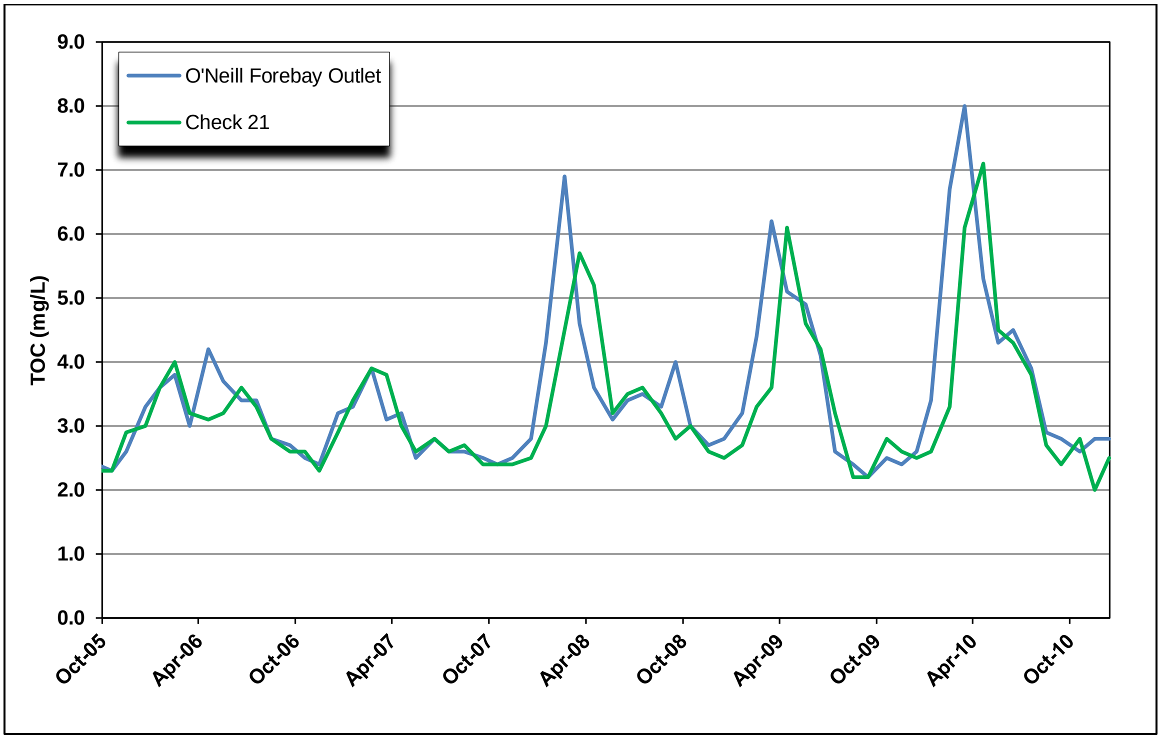
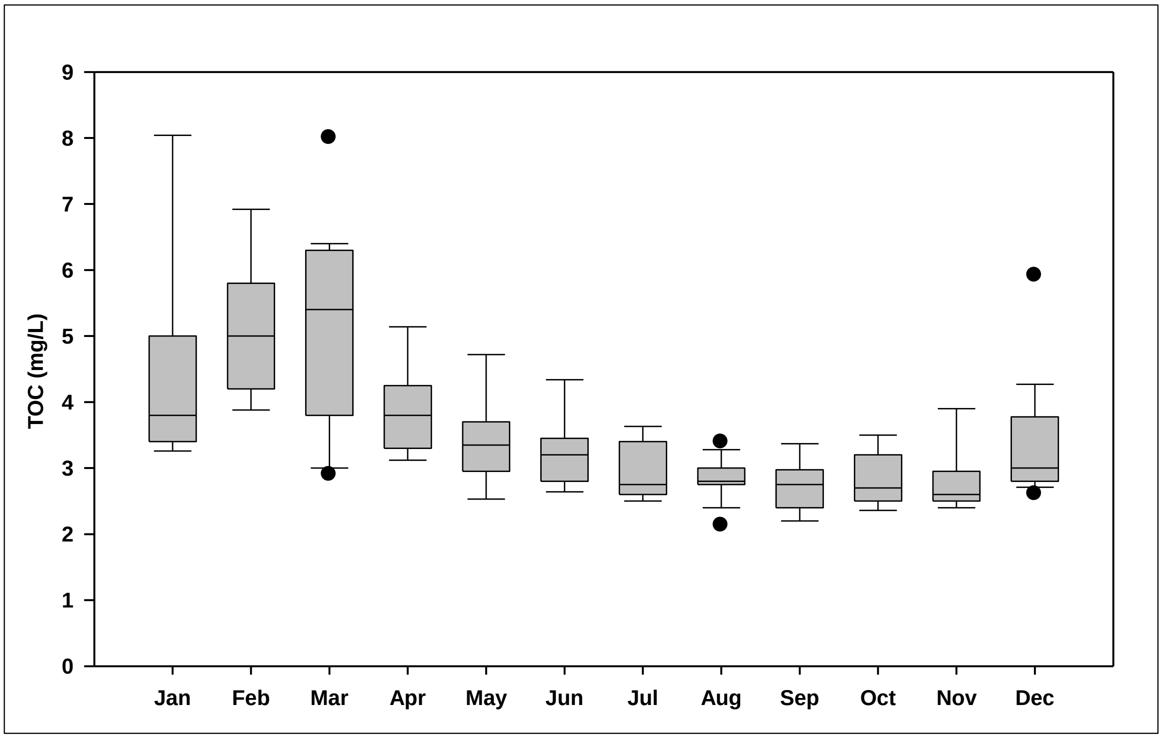
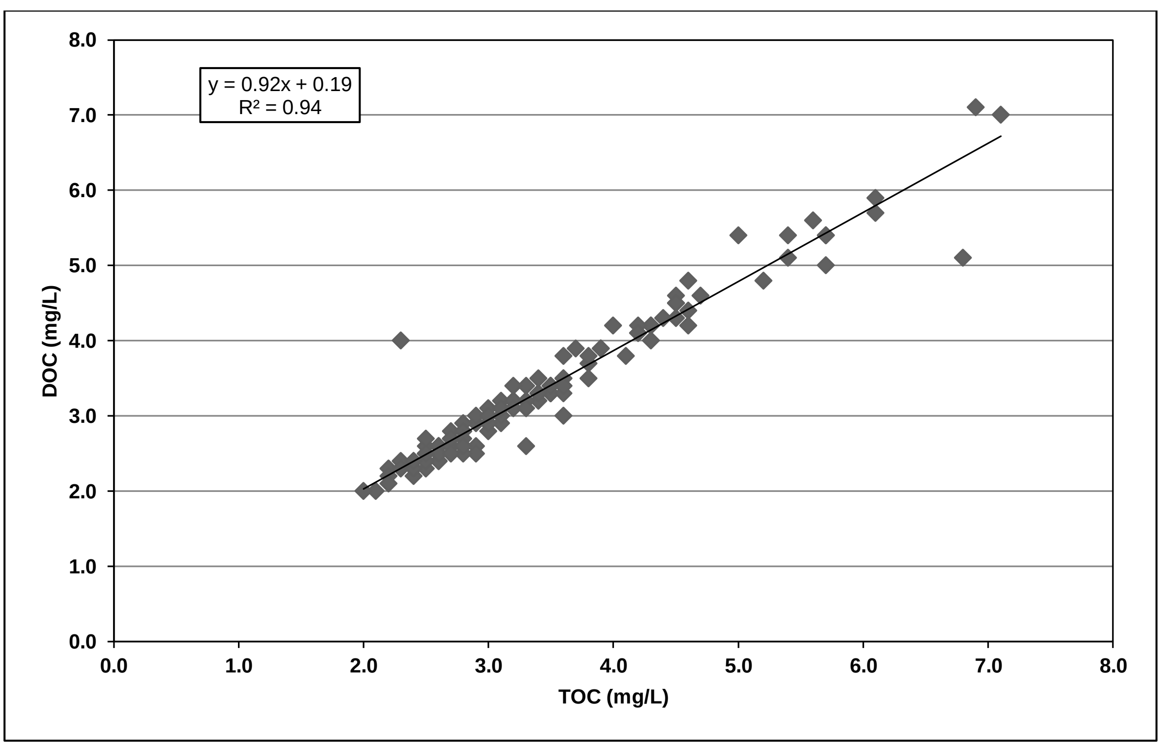


Figure 4-47. Monthly Variability in TOC at Check 21



Note: Insufficient data to plot all percentiles.

Figure 4-48. Relationship Between DOC and TOC at Check 21



Check 41 – Check 41 is located on the California Aqueduct just upstream of Tehachapi Afterbay where the aqueduct bifurcates into the east and west branches. **Figure 4-49** presents all available data for Check 41. TOC concentrations range from 0.7 mg/L to 9.3 mg/L with a median of 3.0 mg/L.

- Spatial Trends – The median concentration of 3.0 mg/L at Check 41 is not statistically different from the median concentration of 3.1 mg/L at Check 21 (Mann-Whitney, p=0.3517) or from the median concentration of 3.2 mg/L at O'Neill Forebay Outlet (Mann-Whitney, p=0.0663) during the 1998 to 2010 period that data have been collected at the three locations. As discussed in Chapter 14, large volumes of groundwater and some surface water enter the aqueduct between Checks 21 and 41. The TOC concentrations of the non-Project inflows in this reach are lower than the concentrations in the aqueduct. **Figure 4-50** presents the data for Check 21 and Check 41 for the last five years. From September 2007 to June 2010, the TOC concentrations at Check 41 were, at times, up to 2 mg/L lower than the concentrations at Check 21. This is discussed in more detail in Chapter 4.

- Long-Term Trends – Visual inspection of **Figure 4-49** shows that TOC concentrations have been lower in the last several years due to the substantial non-Project inflows of low TOC water.

- Wet Year/Dry Year Comparison – The Check 41 dry year median concentration of 2.9 mg/L is statistically significantly lower than the wet year median concentration of 3.2 mg/L (Mann-Whitney, p=0.0270). This is due to the lower TOC concentrations during the last several dry years caused by the inflow of low TOC water.

- Seasonal Trends – **Figure 4-51** shows there is a distinct seasonal pattern with the lowest concentrations in the fall months and the highest concentrations in the wet months of January to March.

- DOC/TOC Relationship – DOC is approximately 93 percent of TOC, as shown in **Figure 4-52**.

Figure 4-49. TOC Concentrations at Check 41

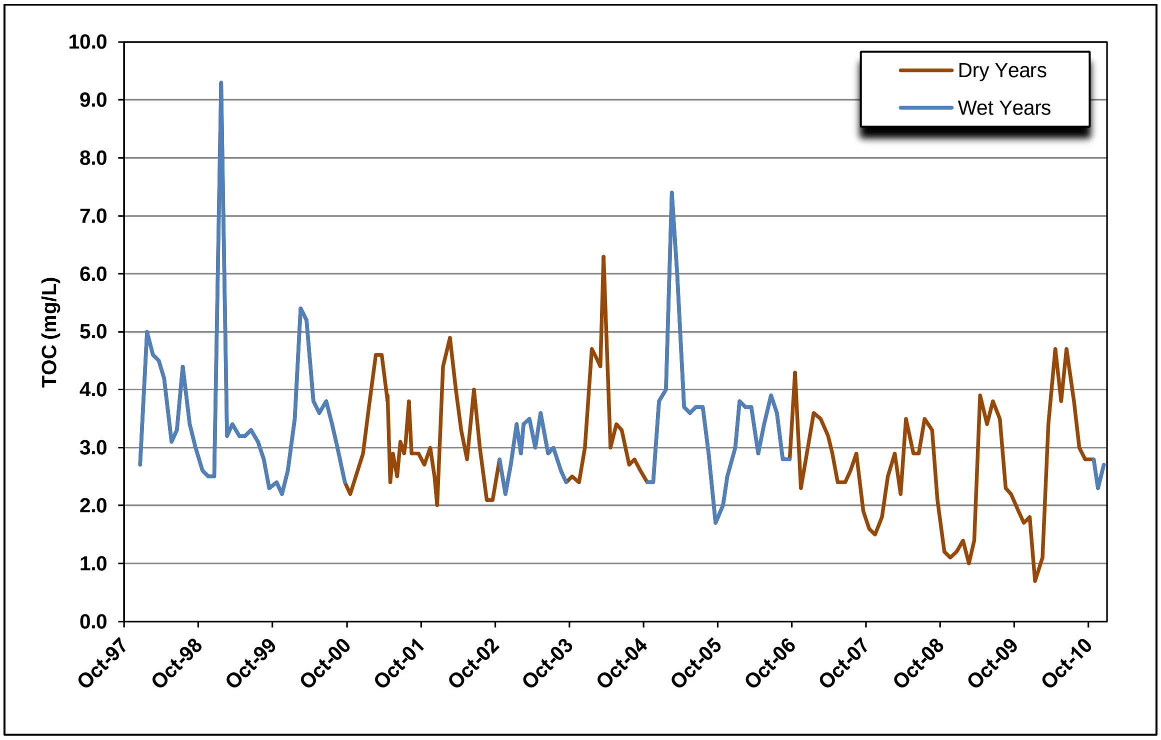


Figure 4-50. Comparison of Check 21 and Check 41 TOC Concentrations

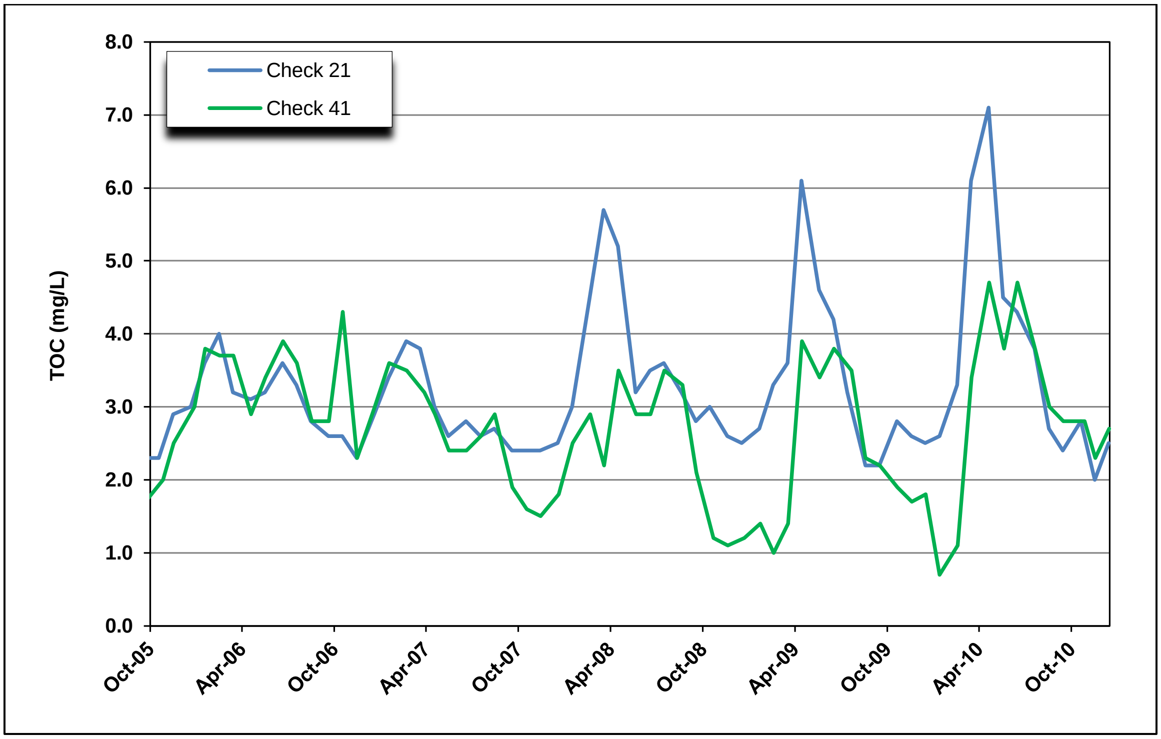
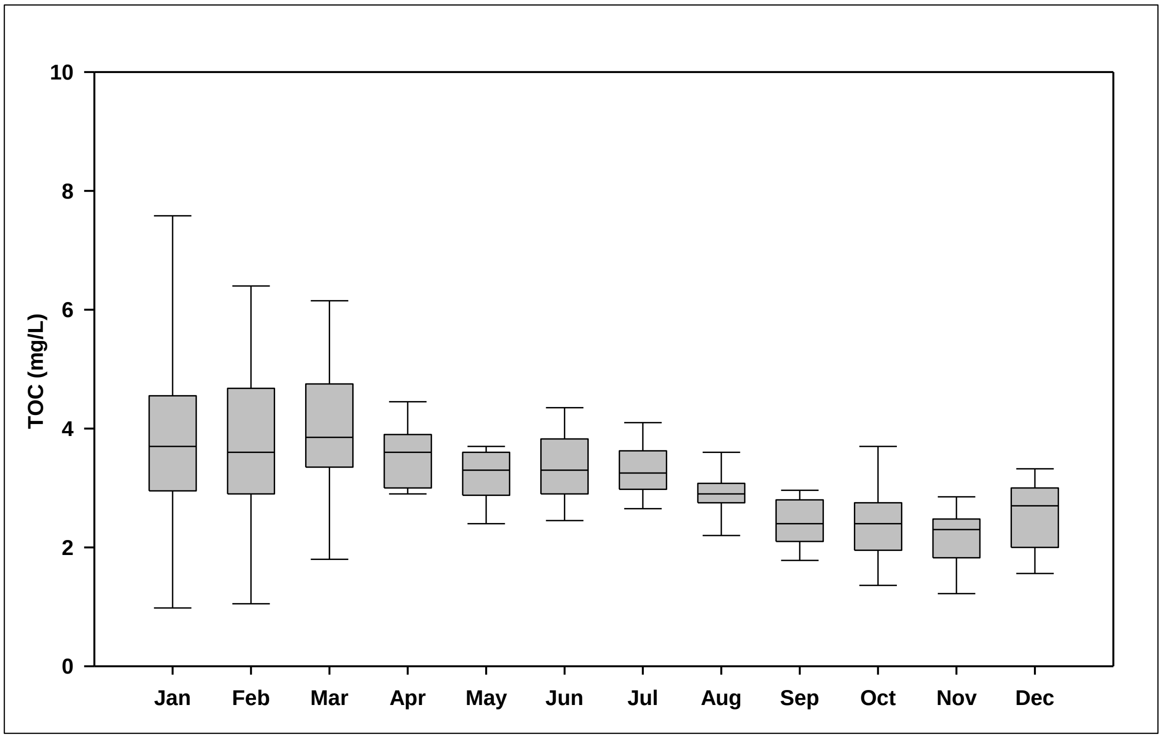
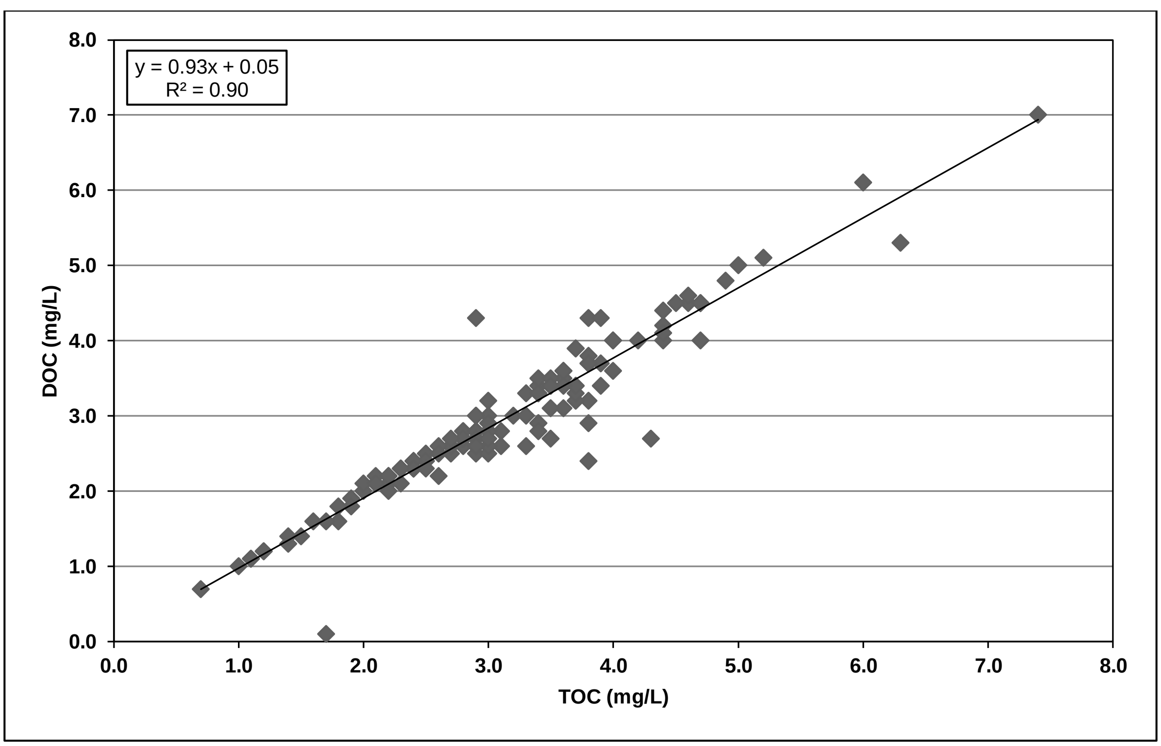


Figure 4-51. Monthly Variability in TOC at Check 41



Note: Insufficient data to plot all percentiles.

Figure 4-52. Relationship Between DOC and TOC at Check 41



Castaic Outlet – Castaic Lake is the terminus of the West Branch of the California Aqueduct. Metropolitan Water District of Southern California (MWDSC) and Castaic Lake Water Agency treat water from the lake. Castaic Lake is immediately downstream of Pyramid Lake. The two lakes provide a combined 0.5 million acre-feet of storage. **Figure 4-53** presents all available DWR data for Castaic Outlet. The samples are collected at a depth of 1 meter in the epilimnion (surface layer) of the lake. TOC concentrations range from 1.8 mg/L to 7.7 mg/L with a median of 2.9 mg/L. MWDSC withdraws water from the hypolimnion (bottom layer) of Castaic Lake and treats it at the Jensen WTP. MWDSC data, collected in the influent of the Jensen WTP, are compared to DWR data collected at Castaic Outlet in **Figure 4-54**. TOC concentrations in the Jensen WTP influent range from 1.6 to 4.0 mg/L with a median of 2.7 mg/L. While the minimum and median concentrations are similar to the DWR data, the peak concentrations in the influent of the Jensen WTP are considerably lower than at Castaic Outlet. The largest differences occur during the summer months, indicating that the higher concentrations in the epilimnion at Castaic Outlet are likely due to algal biomass.

- Spatial Trends – The median concentration of 2.9 mg/L at Castaic Outlet is statistically significantly different from the median concentration of 3.0 mg/L at Check 41 during the 1998 to 2010 period that data have been collected at both locations (Mann-Whitney, p=0.0484). This may be due to the dampening effects of storage in the lake or to inflows from the local watershed.

- Long-Term Trends – A trend analysis was not conducted for this location; however, there appears to be a downward trend in the TOC concentrations shown in **Figure 4-53**. This is likely a function of hydrology since the initial year that data were collected at this location was a wet year with high TOC concentrations and the last several years were dry years with low TOC concentrations. The lower concentrations in the last few years may be related to the non-Project inflows of low TOC water to the aqueduct.

- Wet Year/Dry Year Comparison – The Castaic Outlet dry year median concentration of 2.7 mg/L is statistically significantly lower than the wet year median concentration of 3.0 mg/L (Mann-Whitney, p=0.0000). This is likely due to the lower TOC concentrations during the last several dry years due to the non-Project inflows of the low TOC water.

- Seasonal Trends – **Figure 4-55** shows a different seasonal trend at Castaic Outlet than at the aqueduct locations. The highest concentrations of TOC occur in the summer months and the lowest concentrations occur in the winter months. Since the DWR samples are collected in the epilimnion, the higher concentrations in the summer months are likely due to algal biomass.

- DOC/TOC Relationship – DOC is approximately 87 percent of TOC at Castaic Outlet, as shown in **Figure 4-56**. This is slightly lower than in the aqueduct, indicating that algal growth in Castaic Outlet may be responsible for the higher particulate organic carbon in the lake. The MWDSC data from the Jensen WTP influent show that DOC is 97 percent of TOC. As algal biomass settles to the hypolimnion of the lake, it is degraded so there is less particulate organic carbon in the water withdrawn from the hypolimnion.

Figure 4-53. TOC Concentrations in the Epilimnion at Castaic Outlet

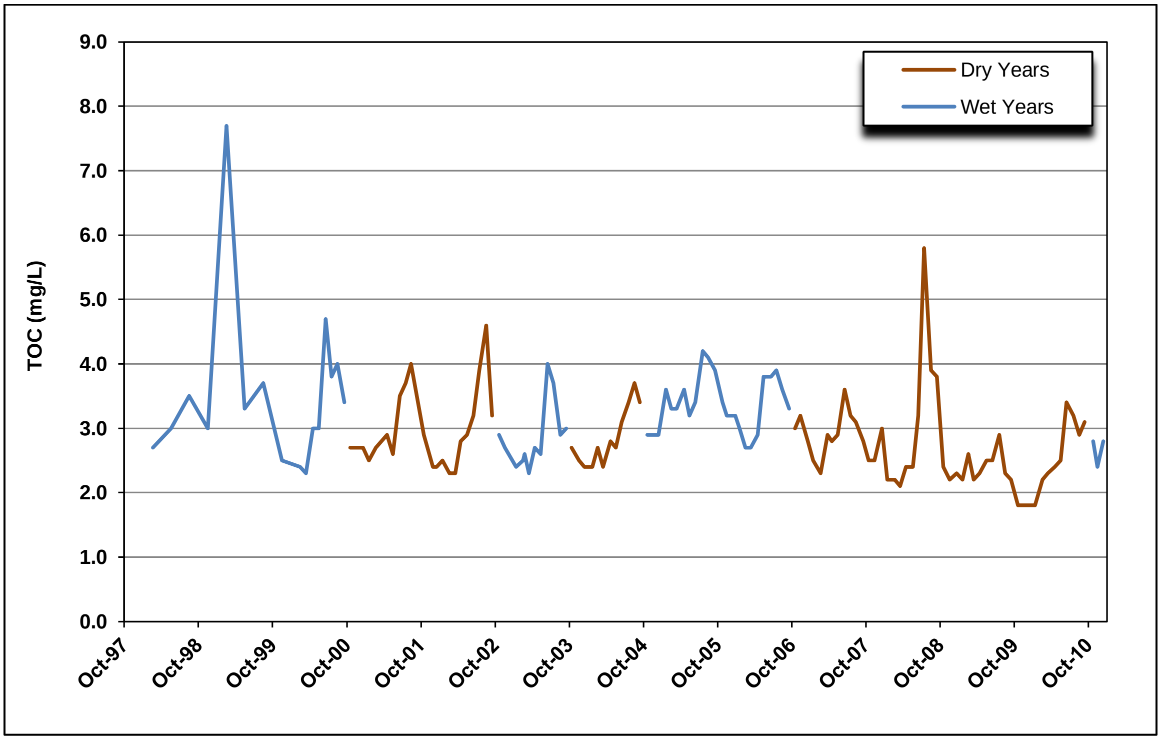


Figure 4-54. TOC Concentrations in Jensen WTP Influent and Castaic Outlet

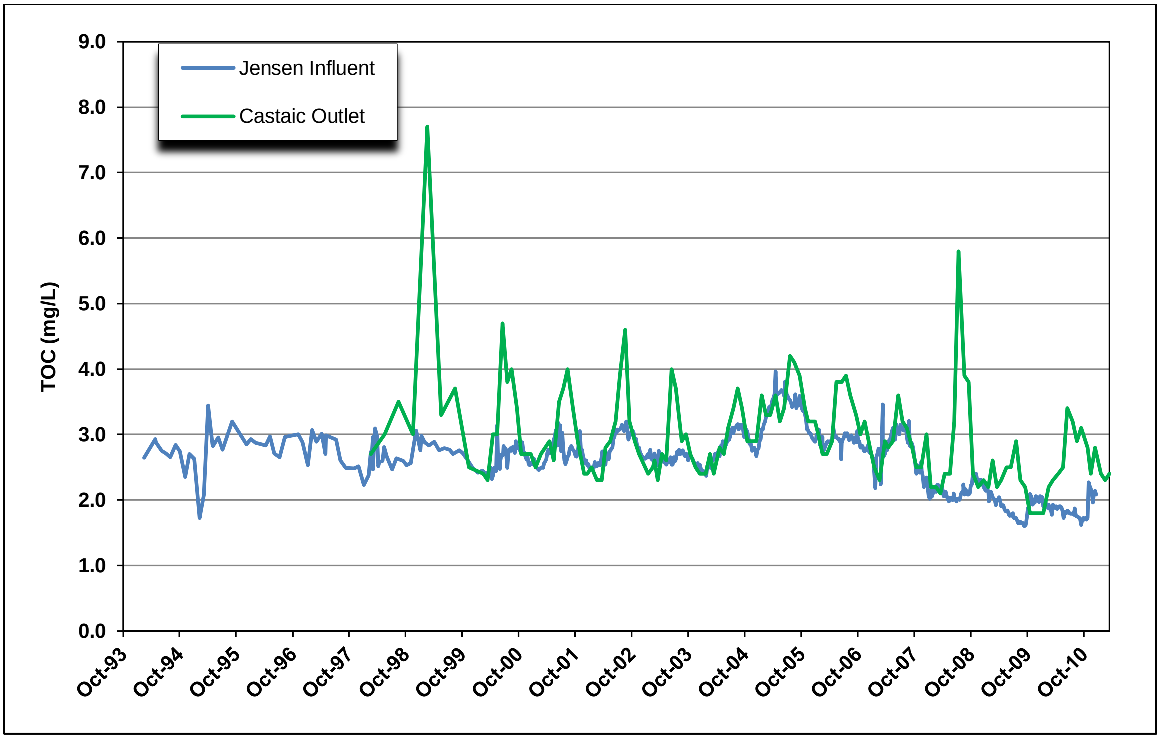
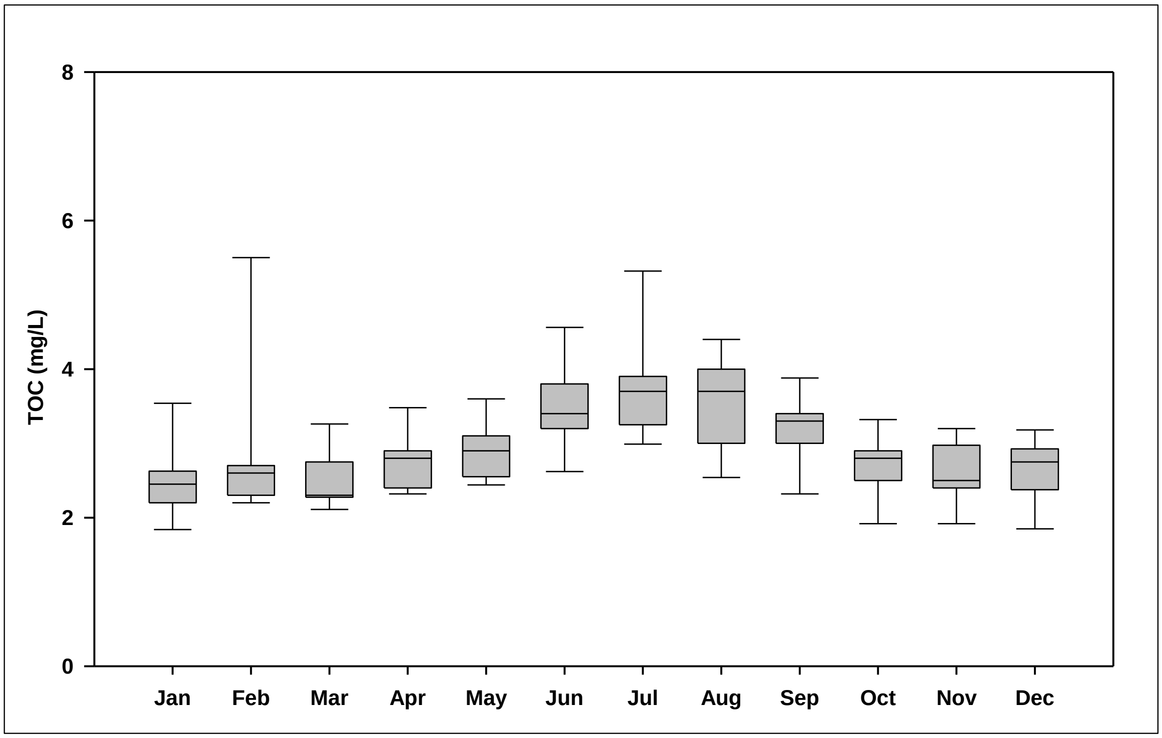
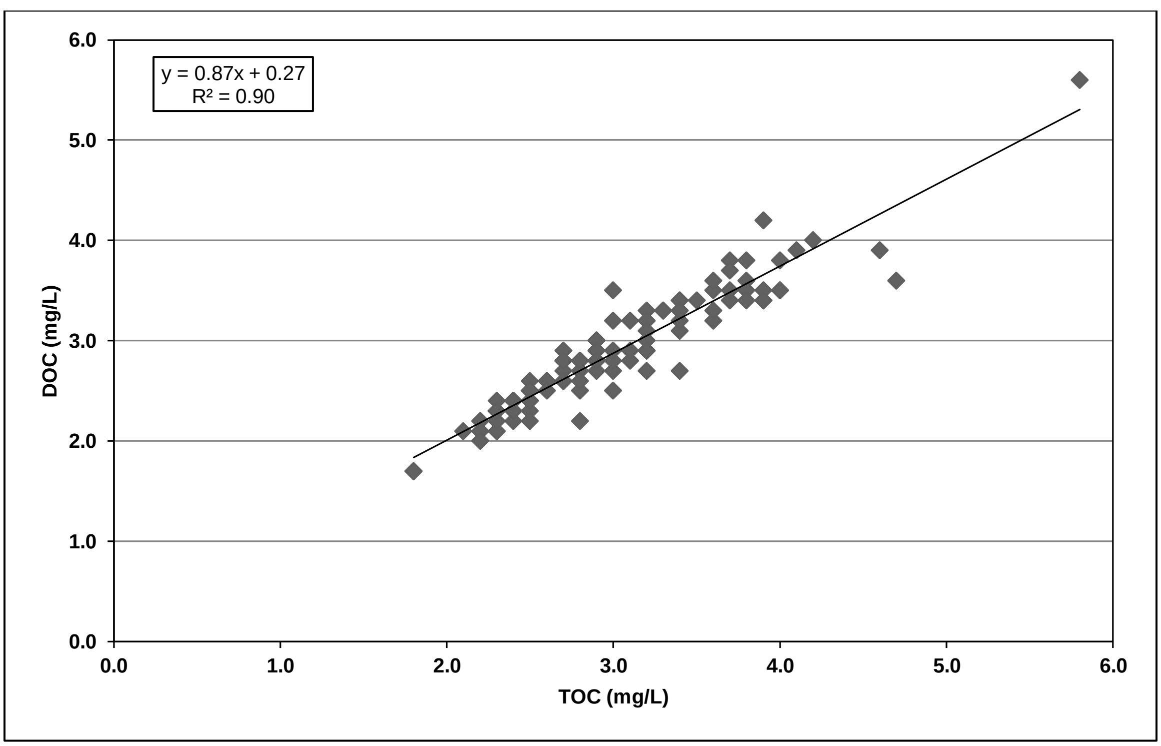


Figure 4-55. Monthly Variability in TOC at Castaic Outlet



Note: Insufficient data to plot all percentiles.

Figure 4-56. Relationship Between DOC and TOC at Castaic Outlet



Devil Canyon – Silverwood Lake provides water to MWDSC, CLAWA, and San Benardino Valley Municipal Water District. CLAWA takes water directly from Silverwood Lake and MWDSC and San Bernardino Valley Municipal Water District take water from Devil Canyon Afterbay. Water samples are collected from Devil Canyon Afterbay, which is immediately downstream of Silverwood Lake on the East Branch of the California Aqueduct. Silverwood Lake, with a capacity of 74,970 acre-feet, is small in comparison to the West Branch reservoirs. **Figure 4-57** presents all available data for Devil Canyon. Data were collected at Devil Canyon Afterbay from 1997 to 2001 and from Devil Canyon Headworks from 2001 to 2010. The data from both locations were combined in **Figure 4-57**. TOC concentrations range from 1.8 mg/L to 8.6 mg/L with a median of 3.1 mg/L.

- Spatial Trends – The median concentration of 3.1 mg/L at Devil Canyon is not statistically significantly different from the median concentration of 3.0 mg/L at Check 41 during the 1998 to 2010 period that data have been collected at both locations. Since the capacity of Silverwood Lake is small in comparison to the West Branch reservoirs, the dampening effect seen in the West Branch is not seen in the East Branch.

- Long-Term Trends – Visual inspection of **Figure 4-57** does not show a discernible trend in TOC concentrations. This is surprising due to the large volume of non-Project inflows that have entered the aqueduct in the last five years. **Figure 4-58** compares the TOC concentrations at Check 41 to Devil Canyon. This figure clearly shows that the low TOC concentrations found at Check 41 during the period of high non-Project inflows are not seen at Devil Canyon. Silverwood Lake lies between the two locations but it normally does not have the dampening effect on concentration fluctuations that is seen in San Luis Reservoir and Castaic Lake.

- Wet Year/Dry Year Comparison – The Devil Canyon wet year median concentration of 3.2 mg/L is not statistically significantly higher than the dry year median concentration of 3.0 mg/L.

- Seasonal Trends – **Figure 4-59** shows the same seasonal trend at Devil Canyon that is seen at Check 41. The highest concentrations of TOC occur in March and the lowest concentrations occur in November.

- DOC/TOC Relationship – **Figure 4-60** shows the relationship between DOC and TOC at Devil Canyon. There is one outlier in this figure where the TOC concentration is much higher (8.6 mg/L) than would be expected based on the other data and the DOC concentration is in the range of other values (4.3 mg/L). As shown in **Figure 4-61**, if that point is removed the relationship between DOC and TOC improves and is similar to the relationship at other sites along the aqueduct.

Figure 4-57. TOC Concentrations at Devil Canyon

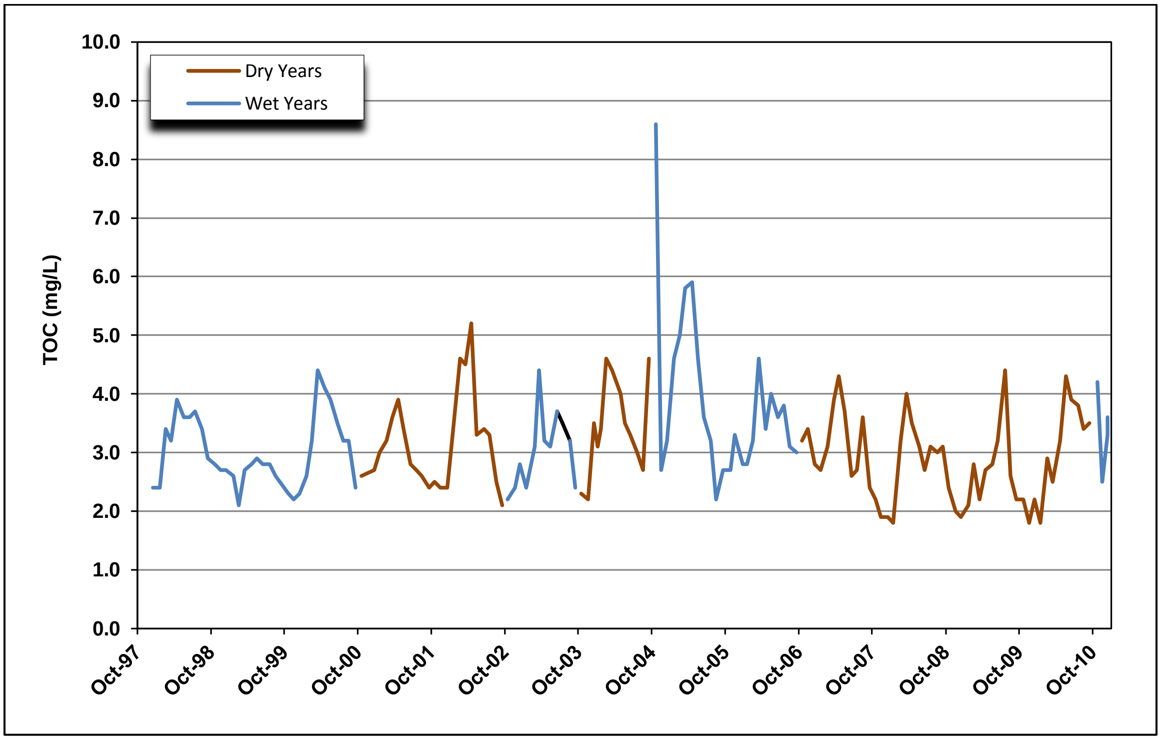


Figure 4-58. Comparison of Check 41 and Devil Canyon TOC Concentrations

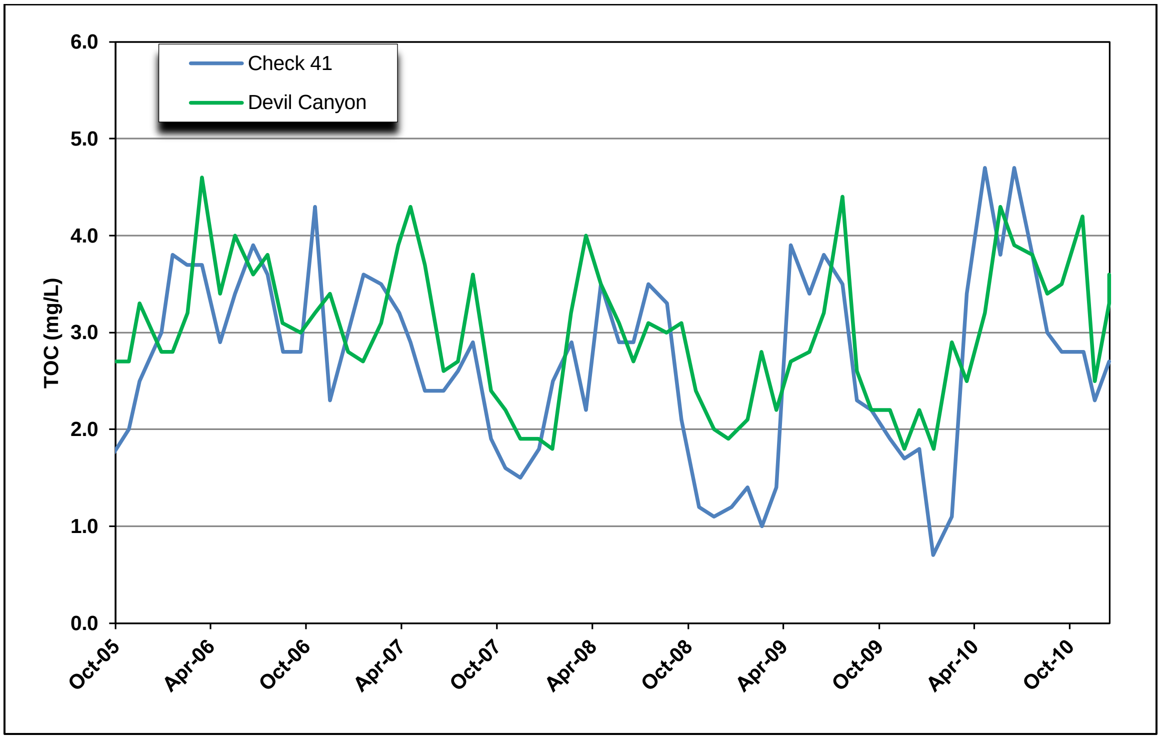
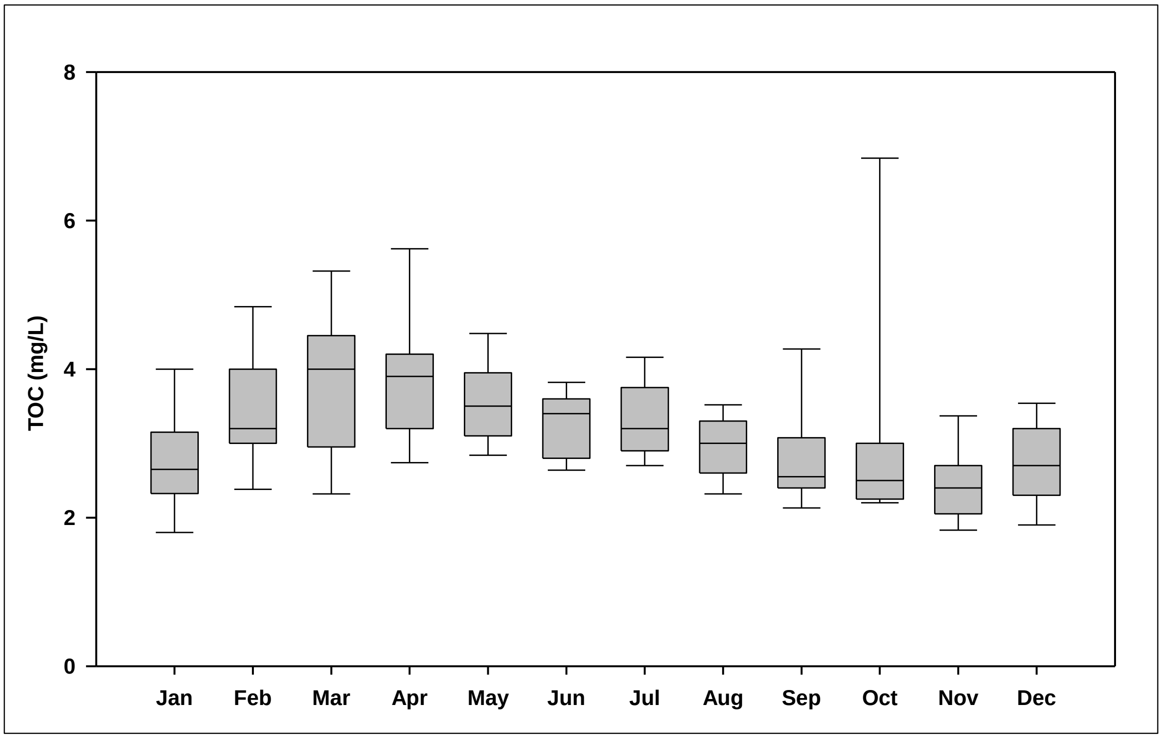


Figure 4-59. Monthly Variability in TOC at Devil Canyon



Note: Insufficient data to plot all percentiles.

Figure 4-60. Relationship Between DOC and TOC at Devil Canyon (All Data)

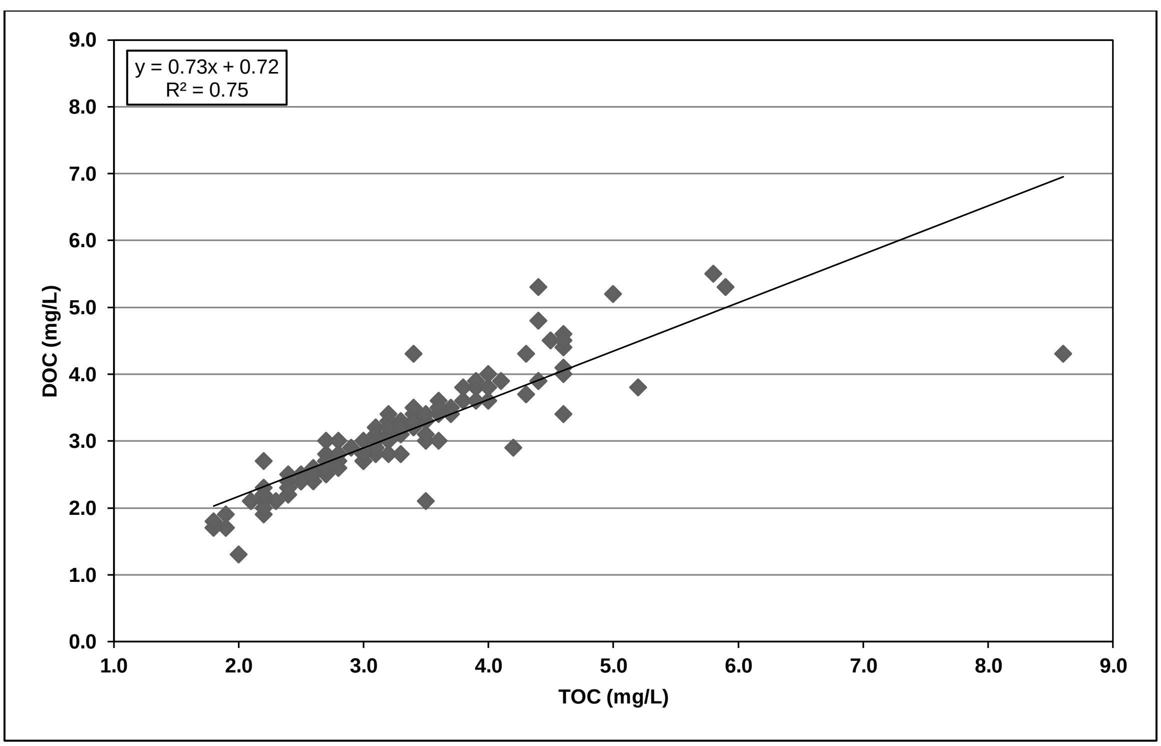
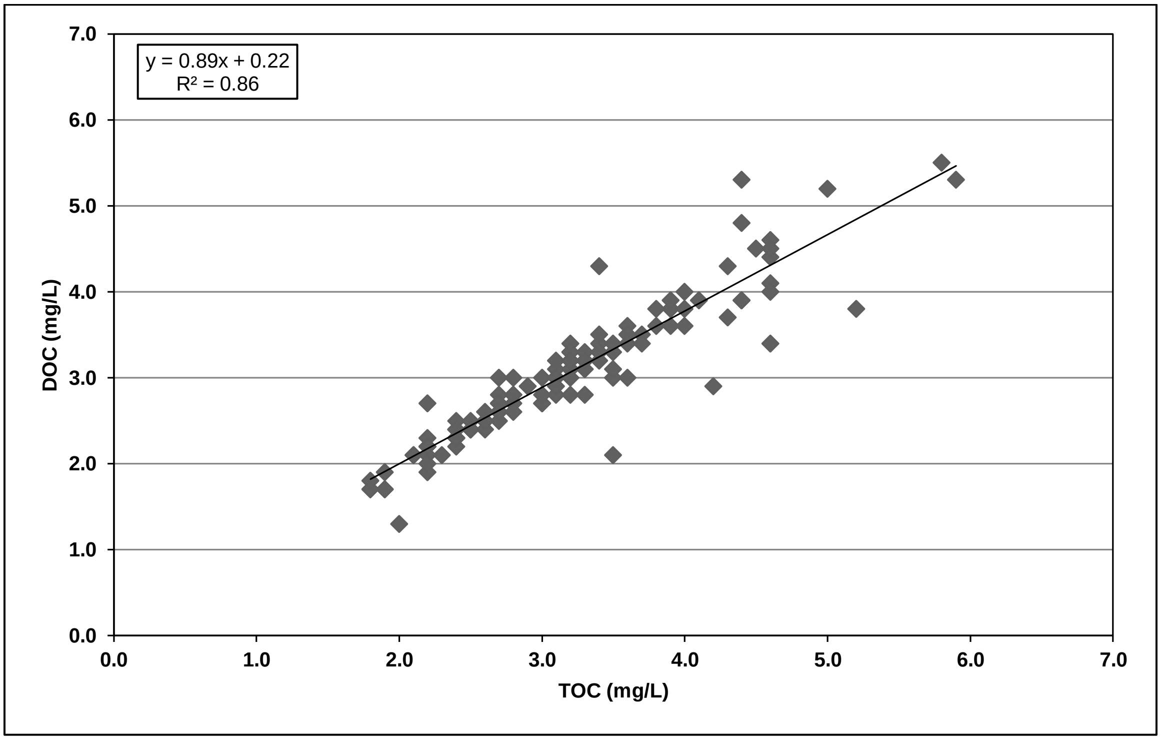


Figure 4-61. Relationship Between DOC and TOC at Devil Canyon (Outlier Removed)



SUMMARY

- The DOC fingerprints indicate that the San Joaquin River is the primary source of DOC at the south Delta pumping plants when flows on that river are high. During dry years, the Sacramento River has more influence on DOC concentrations at the pumping plants. Delta agricultural drainage is also a source of DOC at the pumping plants.

- TOC concentrations are measured with both the combustion and oxidation methods at various locations in the SWP. Ngatia et al. (2010) found that the two methods were equivalent and that the field instruments were equivalent to the laboratory instruments at the 20 percent equivalence level. Organic carbon samples measured with the oxidation method were evaluated in this chapter since there is a longer period of record. The grab samples that are analyzed by the oxidation method were compared to real-time results that are analyzed by the combustion method since most of the real-time samplers use the combustion method.

- The median TOC concentration of 1.8 m/L at Hood is not statistically significantly different from the median TOC concentration of 2.0 mg/L at West Sacramento), which is upstream of the Sacramento urban area Mann-Whitney, p=0.3395). This is despite the fact that the high quality American River (median of 1.6 mg/L) enters the Sacramento River between these two locations. This is likely due to the fact that urban runoff and treated wastewater from the Sacramento urban area are discharged to the river between West Sacramento and Hood. The median TOC concentration of 3.3 mg/L at Vernalis is statistically significantly higher than the median concentration of 1.8 mg/L at Hood (p=0.0000).

- TOC concentrations are much higher in the NBA than any other location in the SWP. Wet season peak concentrations are generally in the range of 14 to 20 mg/L and the median concentration is 5.5 mg/L. The local Barker Slough watershed is the source of this TOC.

- TOC concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct when data collected during comparable periods of time are aggregated and analyzed. The median TOC concentrations along the aqueduct range from 3.0 to 3.2 mg/L. San Luis Reservoir and Castaic Lake have less variability in TOC concentrations than the aqueduct due to the dampening effect of reservoir mixing. The dampening effect is not seen in Silverwood Lake on the East Branch due to its limited hydraulic residence time. Changes in TOC concentrations are apparent in the aqueduct during periods when non-Project inflows are introduced between Checks 21 and 41.

- Water agencies treating SWP water in conventional water treatment plants must remove TOC from their influent water based on the TOC and alkalinity concentrations of the water. Agencies treating NBA water typically remove 35 percent of the TOC and at times, are required to remove up to 50 percent of the TOC. The SWP Contractors treating water from the California Aqueduct in conventional water treatment plants typically have to remove 25 percent of the TOC. Alkalinity levels are often low when TOC concentrations are high, leading to the requirement to remove 35 percent of the TOC in the source water in conventional water treatment plants and to implement TOC removal in addition to ozone disinfection. On occasion, alkalinity concentrations drop below 60 mg/L when TOC concentrations exceed 4 mg/L leading to the requirement to remove 45 percent of the TOC in the source water.

- The real-time samplers at Hood, Vernalis, and Banks provide valuable information on the variability of TOC concentrations at these locations. The real-time monitoring data compare well with the grab sample data collected on the same day. The real-time data show that TOC peaks are higher than previously measured in grab samples. Peak concentrations at Hood and Vernalis are more than 3 mg/L higher than those measured in grab samples. There is a smaller difference at Banks with real-time peaks being about 1.5 mg/L higher than those measured in grab samples.

- MWQI staff conducted a long-term trend analysis at Hood, Vernalis, and Banks. Trends were analyzed for the entire period of record through 2008 at each location and for the 1999 to 2008 period. Different results were obtained for the different periods of time. For example, the analysis showed a declining trend in DOC at all three locations during the longer period and an increasing trend at Hood and Vernalis and no trend at Banks during the more recent period. This analysis showed that trends are very much a function of the hydrology of the system during the starting and ending points of the analysis. Another trend analysis conducted at Banks between 1990 and 2003 by DWR O&M staff reached the same conclusion.

- Time series graphs at all of the other key locations were visually inspected to determine if there are any discernible trends. There are no apparent long term trends at most of the locations included in this analysis. TOC concentrations have been lower at Check 41 and Castaic Outlet in recent years as a result of the substantial amount of non-Project inflows that are low in TOC. Inexplicably, the lower TOC concentrations have not been seen at Devil Canyon.

- There are no statistically significant differences between median TOC concentrations in dry years and wet years at many of the locations along the aqueduct, as shown in **Table 4-3**. Dry year concentrations are statistically significantly lower than wet year concentrations at Barker Slough, Pacheco, Check 41, and Castaic Outlet. Conversely, dry year concentrations are statistically significantly higher in the Sacramento and San Joaquin rivers. With the exception of Barker Slough, there is generally only about a 10 percent difference between dry year and wet year median concentrations of TOC at the locations where there is a statistically significant difference.

- There is a distinct seasonal pattern in TOC concentrations in the Sacramento River, the Delta, and the aqueducts. High concentrations (5 to 9 mg/L) occur during the wet season and low concentrations (2 to 3 mg/L) occur in the late summer months. Vernalis has a slightly different pattern with both winter and summer peaks. The summer peak is attributed to agricultural drainage entering the river during low flow periods. San Luis Reservoir and Castaic Lake display a different seasonal pattern. Concentrations are highest in the summer months and lowest in the winter months.

- There is a good correlation between DOC and TOC at most locations in the SWP system. DOC is generally about 85 to 95 percent of TOC and the coefficient of determination (R^2) is generally 0.9 or better. The two rivers have more particulate organic carbon and poorer R^2 values.

Table 4-3. Comparison of Dry Year and Wet Year TOC Concentrations

Location	Median TOC (mg/L)		TOC Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	1.9	1.7	0.2	11	D>W
Vernalis	3.6	3.2	0.4	11	D>W
Banks	3.2	3.2	0	0	No
Barker Slough	4.2	5.8	-1.6	-38	D<W
DV Check 7	3.6	3.2	0.4	11	No
McCabe	3.2	3.2	0	0	No
Pacheco	3.2	3.5	-0.3	-9	D<W
O'Neill Forebay Outlet	3.2	3.5	-0.3	-9	No
Check 21	3.0	3.2	-0.2	-7	No
Check 41	2.9	3.2	-0.3	-10	D<W
Castaic Outlet	2.7	3	-0.3	-11	D<W
Devil Canyon	3	3.2	-0.2	-7	No

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Personal Communication

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CHAPTER 5 SALINITY

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CHAPTER 5 SALINITY

WATER QUALITY CONCERN

Salinity of water is caused by dissolved anions (sulfate, chloride, bicarbonate) and cations (calcium, magnesium, sodium, and potassium). Salinity is measured as total dissolved solids (TDS) and electrical conductivity (EC). High levels of TDS in drinking water can cause a salty taste, and become aesthetically objectionable to consumers. The U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH) have established secondary Maximum Contaminant Levels (MCLs) for TDS and a number of other constituents that affect the aesthetic acceptability of drinking water. The federal standards are unenforceable guidelines, but the California standards are enforceable, and are based on the concern that aesthetically unpleasant water may lead consumers to unsafe sources. The secondary MCLs related to salinity are listed in **Table 5-1**. Conventional water treatment adds chemicals and increases salinity. Therefore, the concentration of dissolved minerals in the source water is a significant factor determining the palatability of the treated drinking water.

Table 5-1. Secondary Maximum Contaminant Levels

Constituent	Maximum Contaminant Level Ranges		
	Recommended	Upper	Short Term
TDS (mg/L)	500	1,000	1,500
EC (µS/cm)	900	1,600	2,200
Chloride (mg/L)	250	500	600
Sulfate (mg/L)	250	500	600

High TDS in drinking water supplied to consumers can have economic impacts, in that mineralized water can shorten the life of plumbing fixtures and appliances, and create unsightly mineral deposits on fixtures and outdoor structures. An important economic effect can be the reduced ability to recycle water or recharge groundwater high in dissolved solids. For example, the Santa Ana Regional Water Quality Control Board is implementing a Watershed Management Initiative that has salt management as a main component. In that area, it is not permissible to discharge recycled water or recharge groundwater if TDS concentrations exceed established limits. The trend has been toward increasingly stringent limits.

The Sacramento and San Joaquin rivers contain salts from natural sources, urban discharges, and agricultural discharges. As the water from the rivers flows through the Sacramento-San Joaquin Delta (Delta), salinity intrusion from the Pacific Ocean and agricultural and urban discharges in the Delta contribute additional salt. The Delta is connected to the Pacific Ocean through San Pablo Bay and San Francisco Bay. Freshwater outflow from the watersheds of the Delta repels seawater and maintains the Delta as a freshwater source. Because the flows of freshwater vary with hydrologic conditions and releases from upstream reservoirs, there is variation in how much seawater intrudes into the Delta. Therefore, the salinity levels in Delta waters are also impacted by hydrologic conditions and releases from upstream reservoirs, and are generally inversely related to the amount of freshwater outflow from the Delta.

WATER QUALITY EVALUATION

EC FINGERPRINTS

The Department of Water Resources (DWR) uses the fingerprinting method to identify the sources of EC at Clifton Court Forebay (Clifton Court) and the C.W. "Bill" Jones Pumping Plant (Jones). The EC fingerprints for the 1991 to 2010 period are shown in **Figures 5-1 and 5-2. Figure 5-1** shows that the primary sources of EC at Clifton Court are seawater intrusion, Delta agricultural drainage, and the San Joaquin and Sacramento rivers. During the late summer and fall months, seawater intrusion contributes 300 to 600 µS/cm at Clifton Court. During wet years when seawater intrusion is reduced, the San Joaquin River and Delta agricultural drainage are the primary sources. **Figure 5-2** shows the San Joaquin River and seawater intrusion are the primary sources of EC at Jones. The San Joaquin River has a greater influence on EC at Jones than at Clifton Court.

EC LEVELS IN THE SWP

EC data are analyzed in this chapter to examine changes in salinity as the water travels through the SWP system and to determine if there are seasonal or temporal trends. All available EC data from DWR's Municipal Water Quality Investigations (MWQI) Program and the Division of Operations and Maintenance (O&M) State Water Project (SWP) monitoring program through December 2010 were obtained for a number of locations along the SWP. Both grab samples and continuous recorder data are included in this analysis. Data are presented in summary form for all locations and analyzed in more detail for a number of key locations. **Table 5-2** presents a summary of the period of record for data included in this analysis.

Figure 5-1. EC Fingerprint at Clifton Court

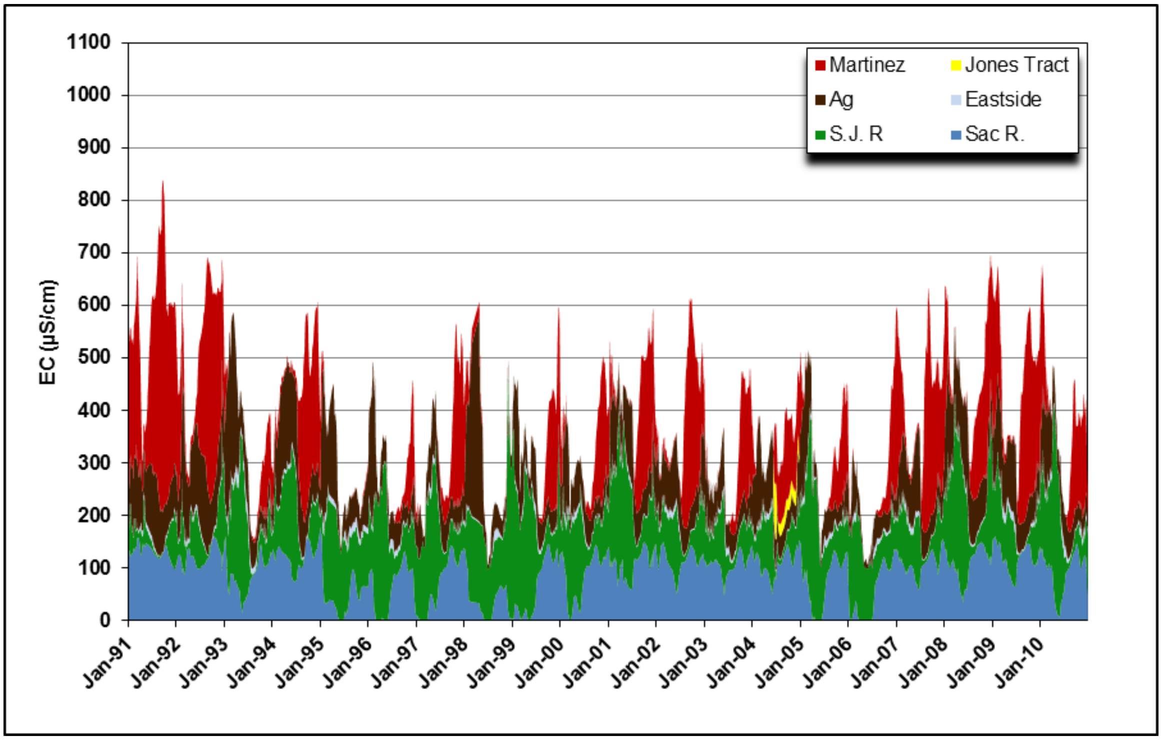


Figure 5-2. EC Fingerprint at Jones

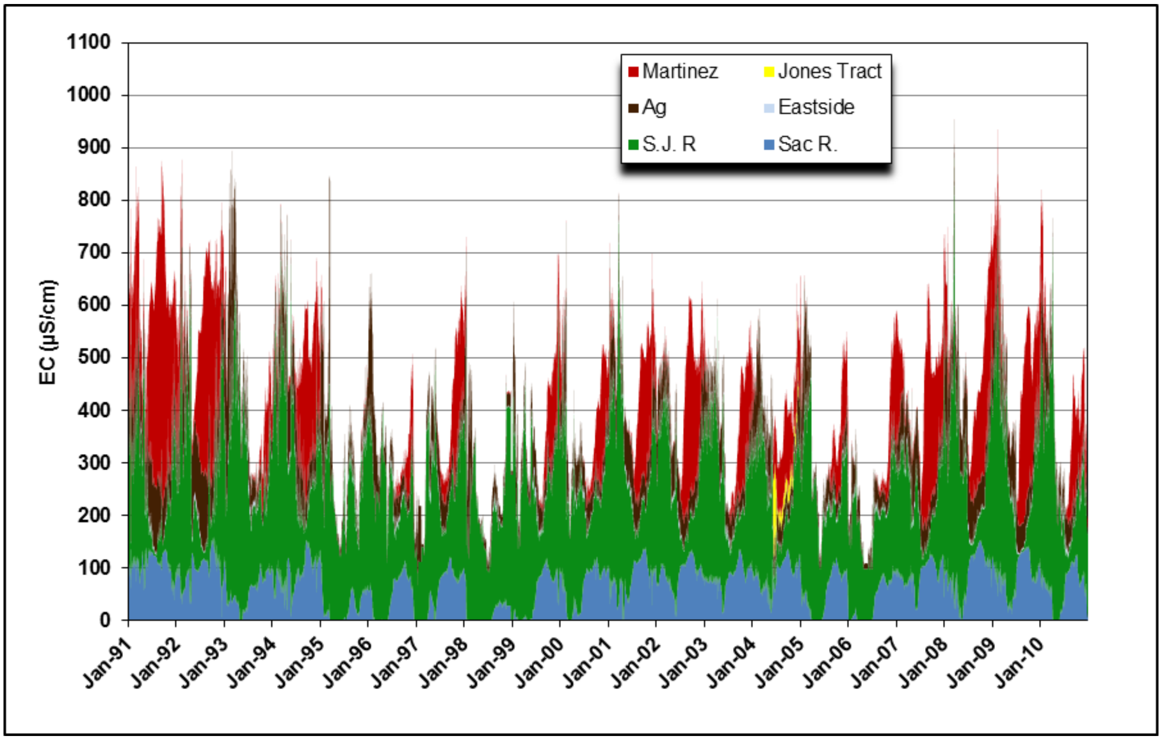


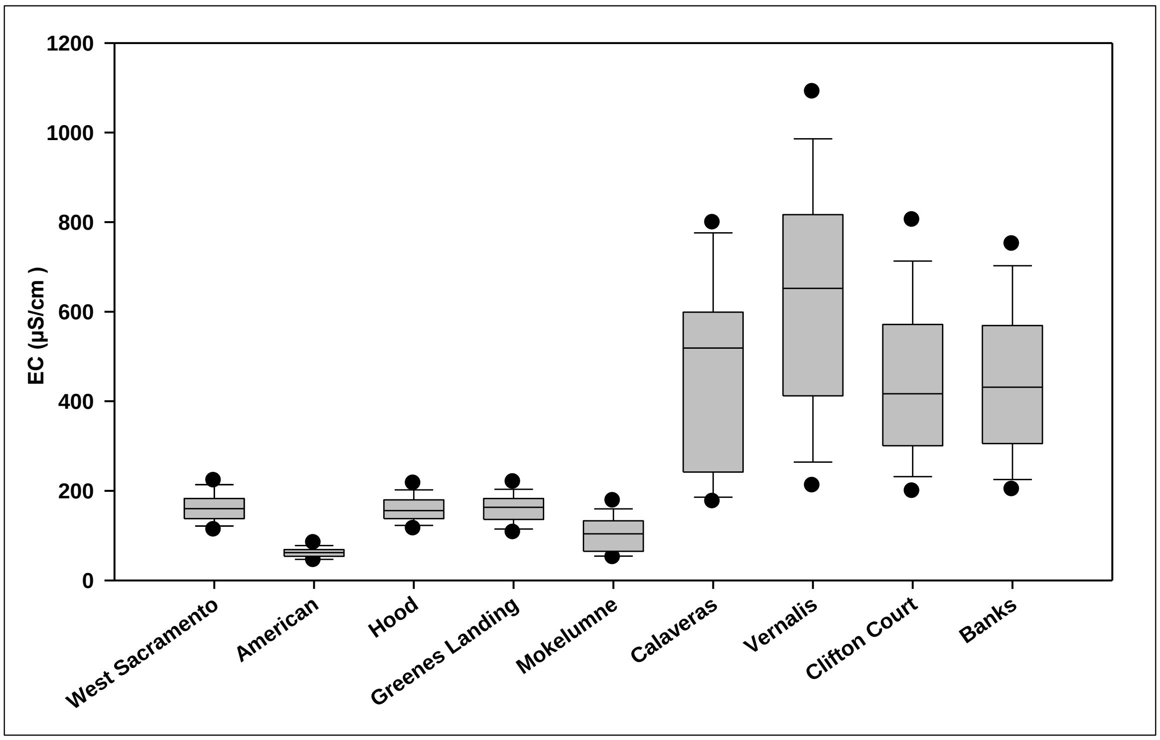
Table 5-2. EC Data

Location	Grab Samples			Real-time	
	No. of Samples	Start Date	End Date	Start Date	End Date
West Sacramento	263	Apr 1994	Dec 2010		
American	317	Jul 1983	Dec 2010		
Hood	513	Mar 1982	Dec 2010	Jan 2004	Dec 2010
Greenes Landing	225	Jul 1983	May 1998		
Mokelumne	43	Dec 2008	Dec 2010		
Calaveras	39	Dec 2008	Nov 2010		
Vernalis	722	Mar 1982	Dec 2010	Aug 1999	Dec 2010
Clifton Court	266	Jul 1983	Dec 2010	Jan 1987	Dec 2010
Banks	412	Mar 1982	Dec 2010	Jan 1986	Dec 2010
Barker Slough	272	Sep 1988	Dec 2010	Feb 1989	Dec 2010
Cordelia	34	Nov 2000	Nov 2010	Jan 1990	Dec 2010
DV Check 7	143	Dec 1997	Oct 2010	Jun 1994	Dec 2010
Conservation Outlet	47	Feb 1998	Dec 2010	Nov 2008	Dec 2010
Vallecitos				Mar 2002	Dec 2010
Terminal Tank	65	Feb 1998	Nov 2010	Jan 1986	Aug 2002
Jones				Aug 1999	Dec 2010
McCabe	90	Dec 1997	Dec 2010		
Pacheco	123	Mar 2000	Dec 2010	Jul 1989	Dec 2010
O’Neill Forebay Outlet	170	Jul 1988	Dec 2010	Jan 1990	Dec 2010
Check 21	173	Dec 1997	Dec 2010	Jun 1990	Dec 2010
Check 29	189	May 1998	Dec 2010	Jan 1990	Dec 2010
Check 41	340	Dec 1997	Dec 2010	Jun 1993	Dec 2010
Castaic Outlet	59	Feb 1998	Nov 2010	Jan 2000	Dec 2010
Silverwood	53	Feb 1998	Nov 2010		
Devil Canyon Headworks	116	Jun 2001	Dec 2010	Jun 1993	Mar 2010
Devil Canyon Afterbay	46	Dec 1997	May 2001	Feb 2006	Dec 2010
Perris Outlet	263	Apr 1994	Dec 2010		

The SWP Watershed

Figure 5-3 presents the EC data for the tributaries to the Delta and for Clifton Court and the Harvey O. Banks Delta Pumping Plant (Banks). EC levels are considerably lower in the Sacramento River than the San Joaquin River at Vernalis (Vernalis). EC data have been collected twice a month from the Mokelumne River at Wimpy's Marina (Mokelumne) and the Calaveras River at Brookside Road (Calaveras) since December 2008. The limited data show that the Mokelumne EC levels are lower than the Sacramento River at Hood (Hood) levels, whereas the Calaveras levels are closer to the levels at Vernalis.

Figure 5-3. EC Levels in the SWP Watershed



Hood – **Figure 5-4** shows all available grab sample EC data at Hood. The levels range from 73 to 352 µS/cm during the period of record with a median of 156 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-5** compares the real-time data with the grab sample data at Hood. Average daily EC, calculated from hourly measurements, was downloaded from the California Data Exchange Center (CDEC) for this analysis. There is a good correspondence between the two data sets when samples collected on the same day are compared. The real-time data show that peak levels are only slightly higher than those measured in grab samples.

- Spatial Trends – **Figure 5-3** presents all available data for the Sacramento River at West Sacramento (West Sacramento), the American River (American), and Hood. The period of record varies between the three stations so the data collected during the 1998 to 2010 period at all three locations were examined to determine if there are spatial trends. The median concentrations during the 1998 to 2010 period are slightly higher at West Sacramento (163 µS/cm) and Hood (158 µS/cm) than those shown in **Figure 5-3**. The American median EC level of 62 µS/cm is statistically significantly lower than the medians at West Sacramento and Hood (Mann-Whitney, p=0.0000) and the median level at Hood is statistically significantly lower than the median at West Sacramento (Mann-Whitney, p=0.0263). This demonstrates the impact that the American River inflow has on the Sacramento River.

- Long-Term Trends – Visual inspection of **Figure 5-4** does not show any discernible long-term trends.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median concentration during wet years of 146 µS/cm is statistically significantly lower than the median during dry years of 168 µS/cm(Mann-Whitney, p=0.0000). **Figure 5-6** shows the influence of flows on EC levels during different year types. Water year 2006 was a wet year with flows reaching 90,000 cubic feet per second (cfs) on the Sacramento River at Freeport (a few miles upstream of Hood). EC levels dropped as flows increased. Water year 2007 was a dry year and 2008 was a critical year. Peak flows during those two years reached 40,000 cfs and dry season flows dropped to less than 10,000 cfs. During these two years, EC levels gradually increased. During low flow periods, the treated wastewater, urban runoff, and agricultural discharges to the river have a greater influence than during the high flow periods.

- Seasonal Trends – **Figure 5-7** presents the grab sample monthly data for the entire period of record. This figure indicates that the EC levels decline during the spring months and levels are lowest in July. During the late spring and early summer months, snow melt results in higher flows with low EC levels. The EC levels rise during the late summer and fall months when flows on the river are low.

Figure 5-4. EC Levels at Hood

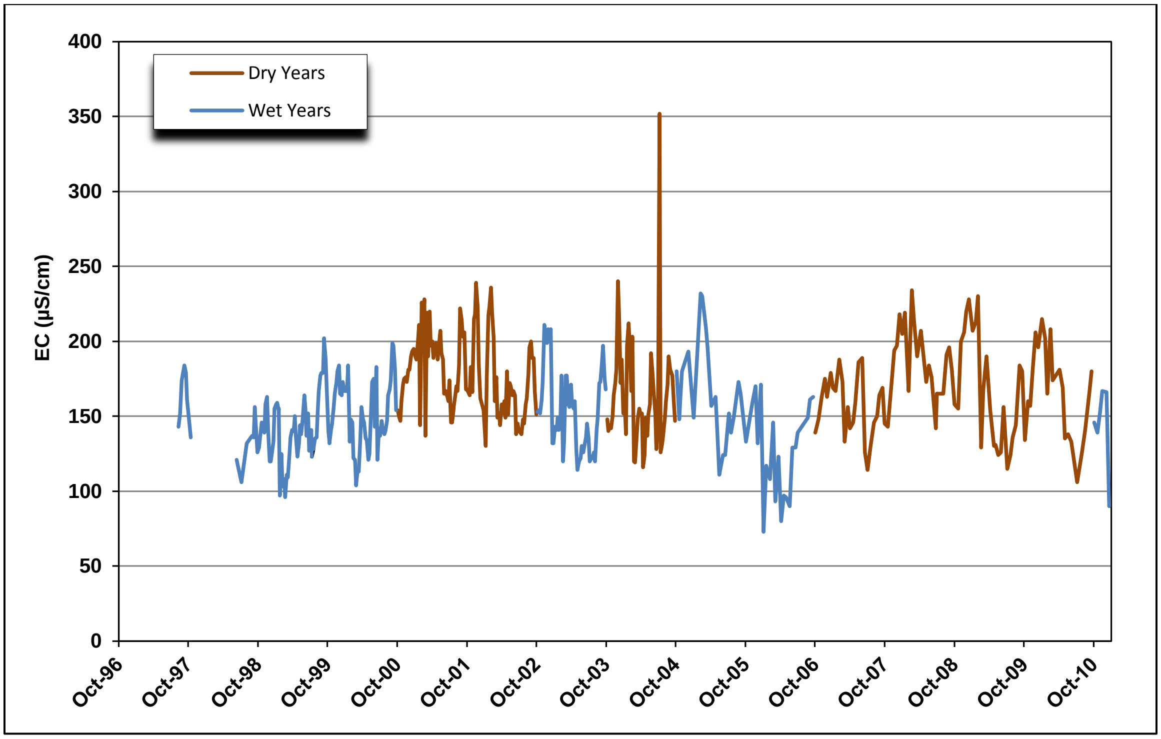


Figure 5-5. Comparison of Hood Real-time and Grab Sample EC Data

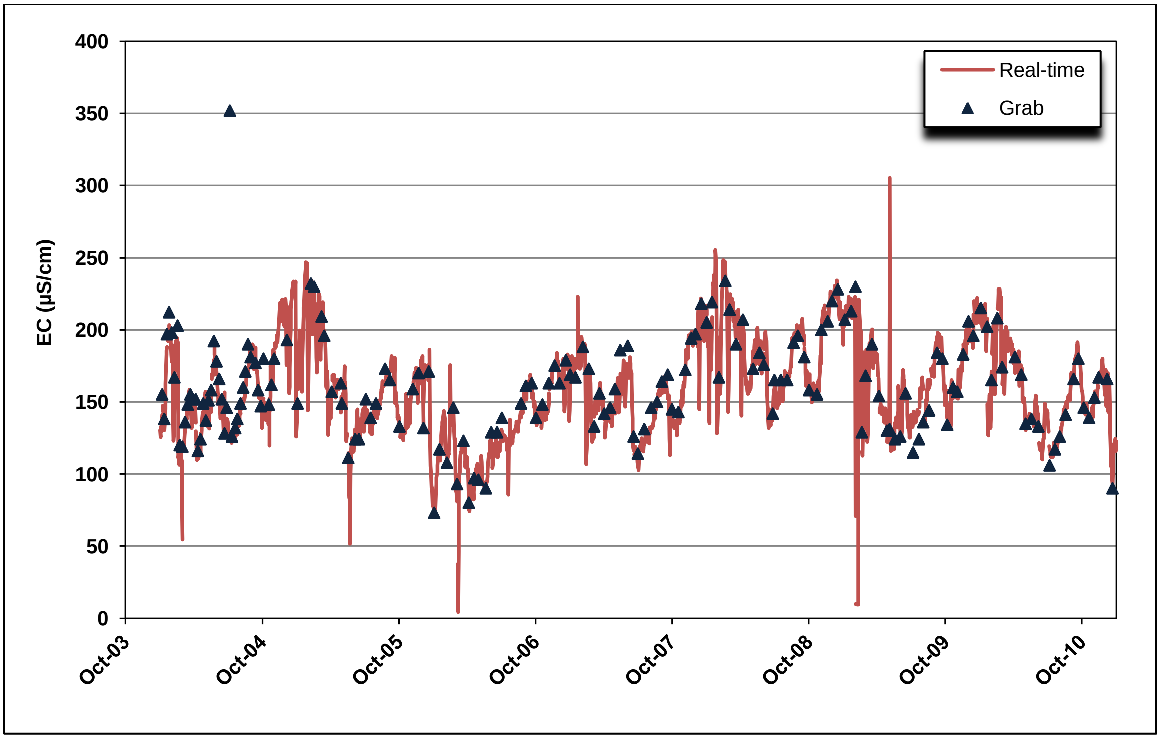


Figure 5-6. Relationship Between EC and Flow at Hood

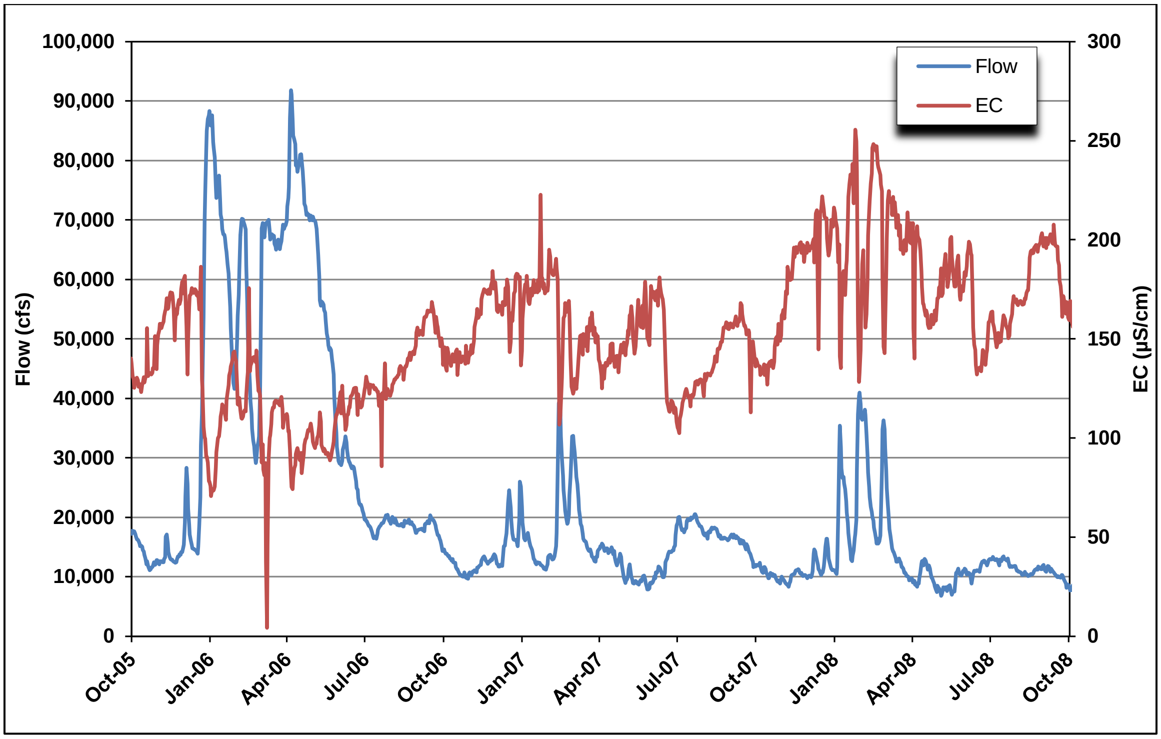
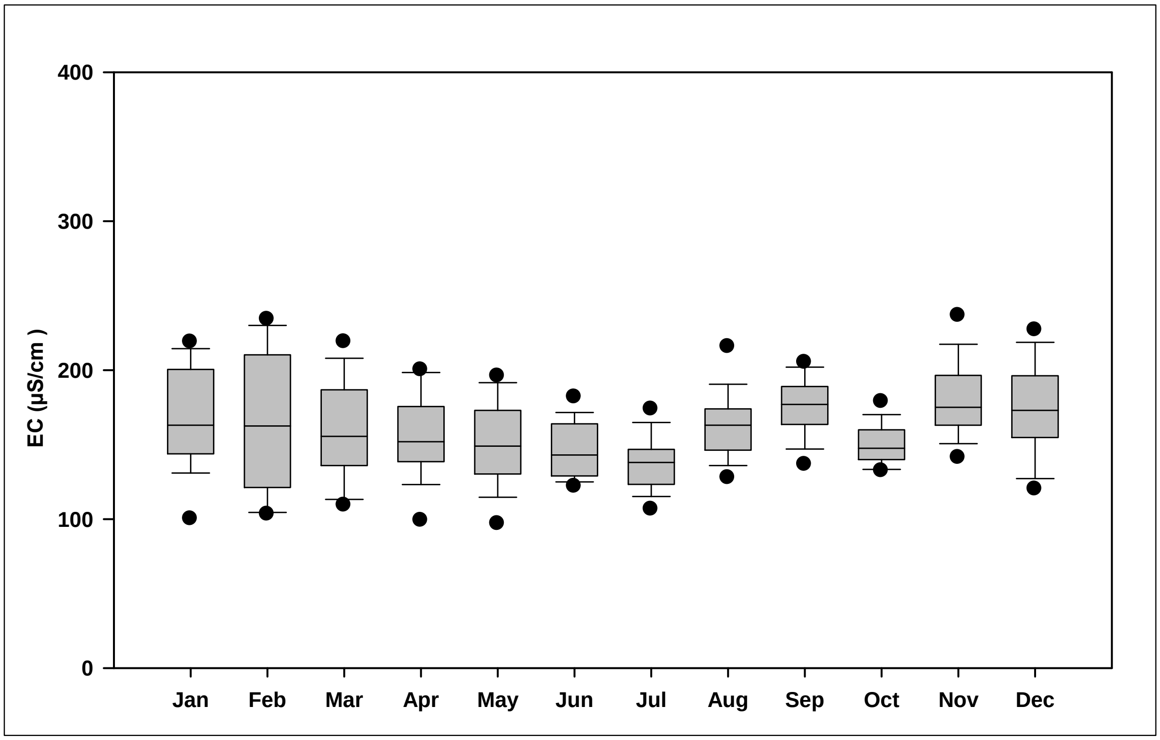


Figure 5-7. Monthly Variability in EC at Hood



Vernalis – **Figure 5-8** shows all available grab sample EC data at Vernalis. The levels range over an order of magnitude from 118 to 1,550 µS/cm during the period of record with a median of 652 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-9** compares the real-time data with the grab sample data at Vernalis. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. There is generally a good correspondence between the two data sets when samples collected on the same day are compared. However, the real-time sampler does not often measure the peak levels above 1,000 µS/cm that are measured in the grab samples.

- Spatial Trends – DWR does not collect data upstream of Vernalis on the San Joaquin River.

- Long-Term Trends – Visual inspection of **Figure 5-8** does not show any discernible long-term trend but does indicate that the hydrology of the system affects EC at Vernalis. EC levels clearly increase during dry periods and decrease during wet periods.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median concentration during wet years of 456 µS/cm is statistically significantly lower than the median during dry years of 745 µS/cm (Mann-Whitney, p=0.0000). **Figure 5-10** shows the influence of flows on EC levels during different year types. Water year 2006 was a wet year with flows reaching almost 35,000 cfs on the San Joaquin River at Vernalis. EC levels dropped to 118 µS/cm as flows increased. Water years 2007 and 2008 were critical years and 2009 was a below normal year. Peak flows during those three years were less than 5,000 cfs and dry season flows dropped to less than 1,000 cfs. During these years EC levels increased during the fall and winter months. Relatively small increases in flow produce large drops in EC as shown in the spring of 2008, 2009, and 2010. This is due to the influence of the high quality eastern tributaries of the San Joaquin River.

- Seasonal Trends – **Figure 5-11** presents the grab sample monthly data for the entire period of record. This figure indicates that the EC levels decline during the spring months and levels are lowest in May. The low EC levels during the spring months are largely due to the high flows on the river mandated by the Vernalis Adaptive Management Plan (VAMP). VAMP is mandated by the State Water Board in Decision 1641. From April 15 to May 15 high quality water is released from reservoirs to increase flows on the San Joaquin River to increase the survival of chinook salmon smolts migrating to the ocean. The EC levels rise during the summer and fall months when flows on the river are low and agricultural drainage is discharged to the river. The high EC levels generally persist until late winter when there is sufficient rain to increase flows in the river.

Figure 5-8. EC Levels at Vernalis

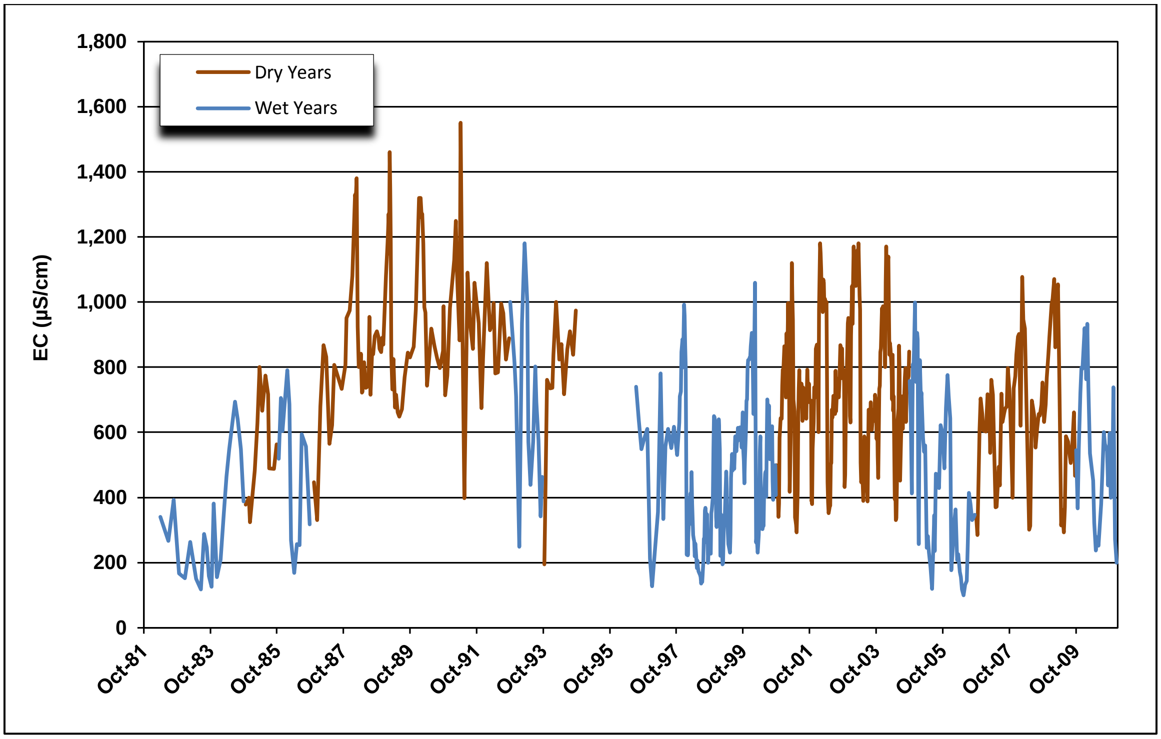


Figure 5-9. Comparison of Vernalis Real-time and Grab Sample EC Data

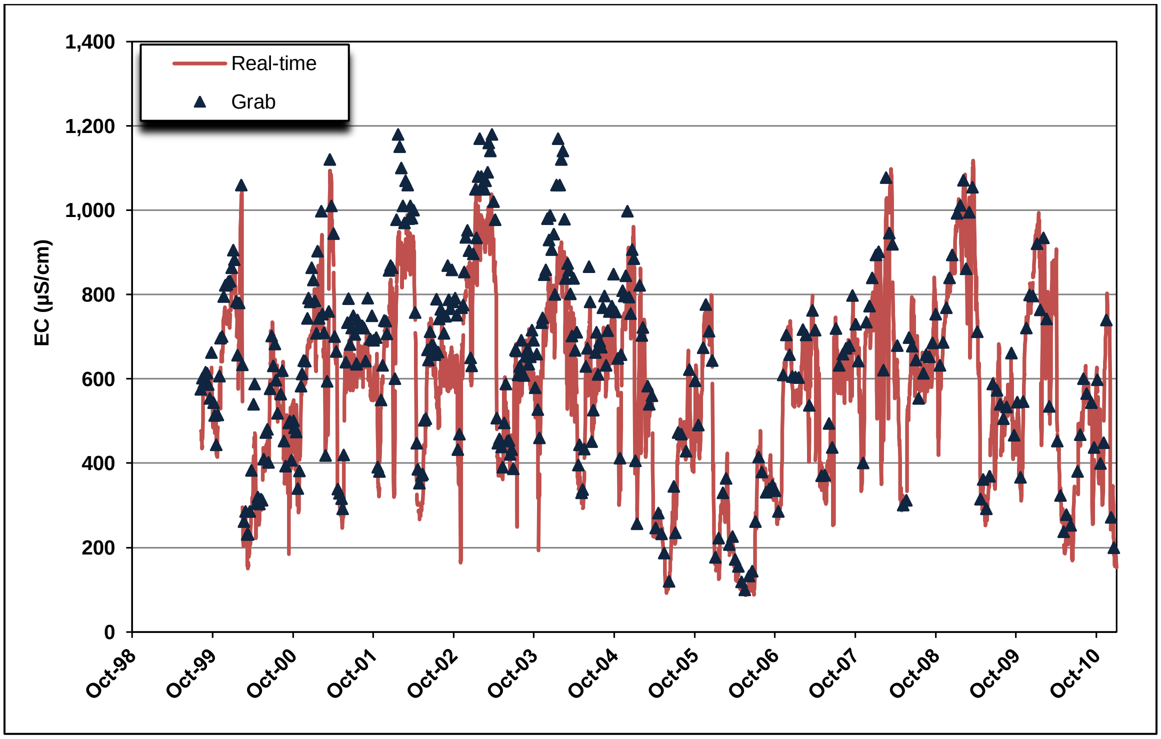


Figure 5-10. Relationship Between EC and Flow at Vernalis

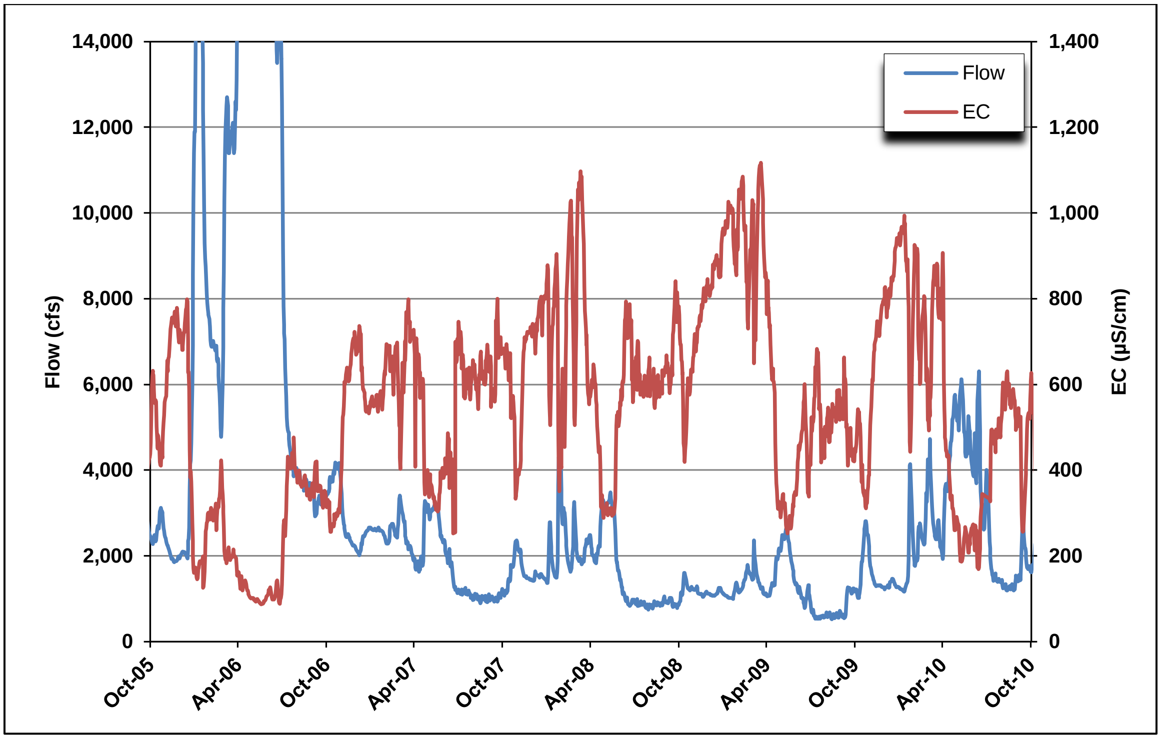
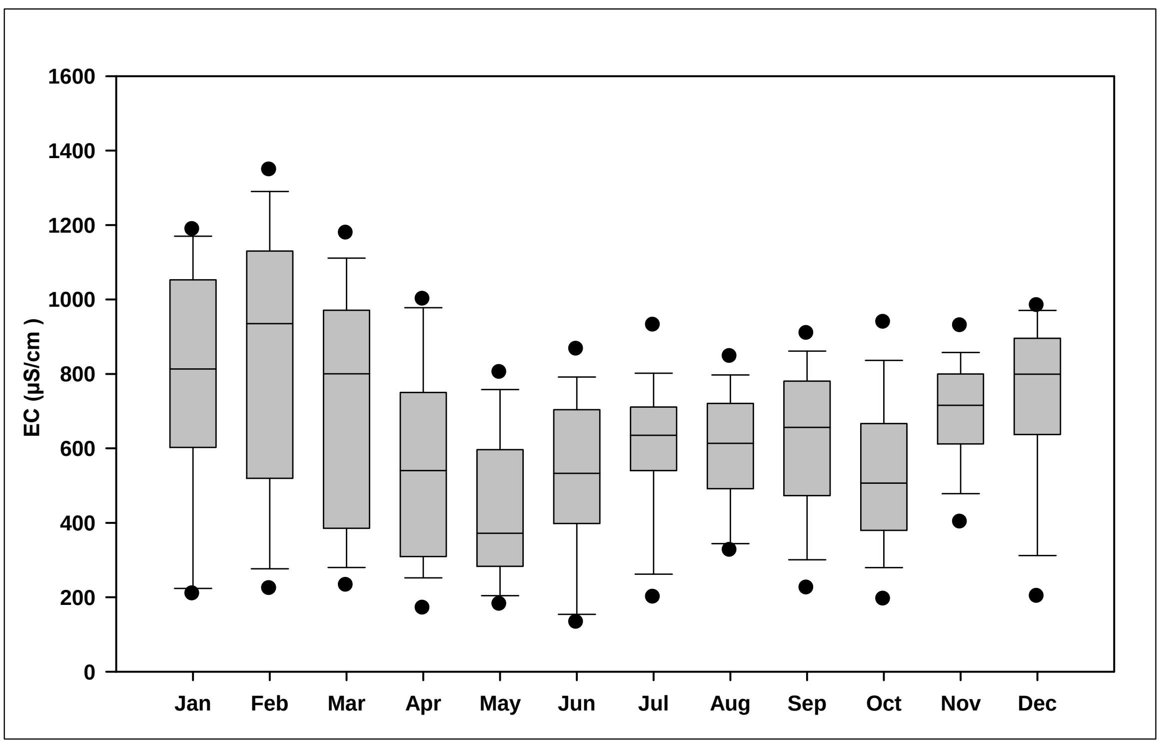


Figure 5-11. Monthly Variability in EC at Vernalis



Banks – As shown in **Figure 5-1**, the sources of EC at Clifton Court and Banks are the Sacramento and San Joaquin rivers, seawater intrusion, and Delta agricultural drainage. **Figure 5-12** shows all available grab sample EC data at Banks. The levels range from 139 to 877 µS/cm during the period of record with a median of 432 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-13** compares the real-time data with the grab sample data at Banks. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. There is generally a good correspondence between the two data sets when samples collected on the same day are compared. However, the grab sample data does not often measure the peak levels above 800 µS/cm that are measured by the real-time equipment.

- Spatial Trends – Sacramento River water is degraded as it flows through the Delta by discharges from Delta islands and mixing with the San Joaquin River. All available data from Hood, Vernalis, and Banks are presented in **Figure 5-3**. Since the period of record varies between the three stations, a subset of the data that includes only data collected at the three stations during the same time period (1998 to 2010) was analyzed. The median EC at Banks (392 µS/cm) is statistically significantly higher than the median of 158 µS/cm at Hood and statistically significantly lower than the median of 629 µS/cm at Vernalis (Mann-Whitney, p=0.0000).

- Long-Term Trends – DWR conducted an assessment of long-term salinity trends at Banks using data from 1970 to 2002 and concluded that the salinity in SWP exports has neither increased nor decreased over that period (DWR, 2004). Visual inspection of **Figure 5-12** indicates that EC trends are a function of hydrology.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median concentration during wet years of 312 µS/cm is statistically significantly lower than the median during dry years of 497 µS/cm (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 5-14** presents the grab sample monthly data for the entire period of record. This figure indicates that the EC levels decline during the spring and early summer months when flows on the rivers are high. The lowest EC levels at Banks are in July. EC generally increases from August to December due to low river flows, agricultural drainage from the San Joaquin Valley and the Delta, and seawater intrusion. The seasonal pattern at Banks is similar to the pattern at Hood.

Figure 5-12. EC Levels at Banks

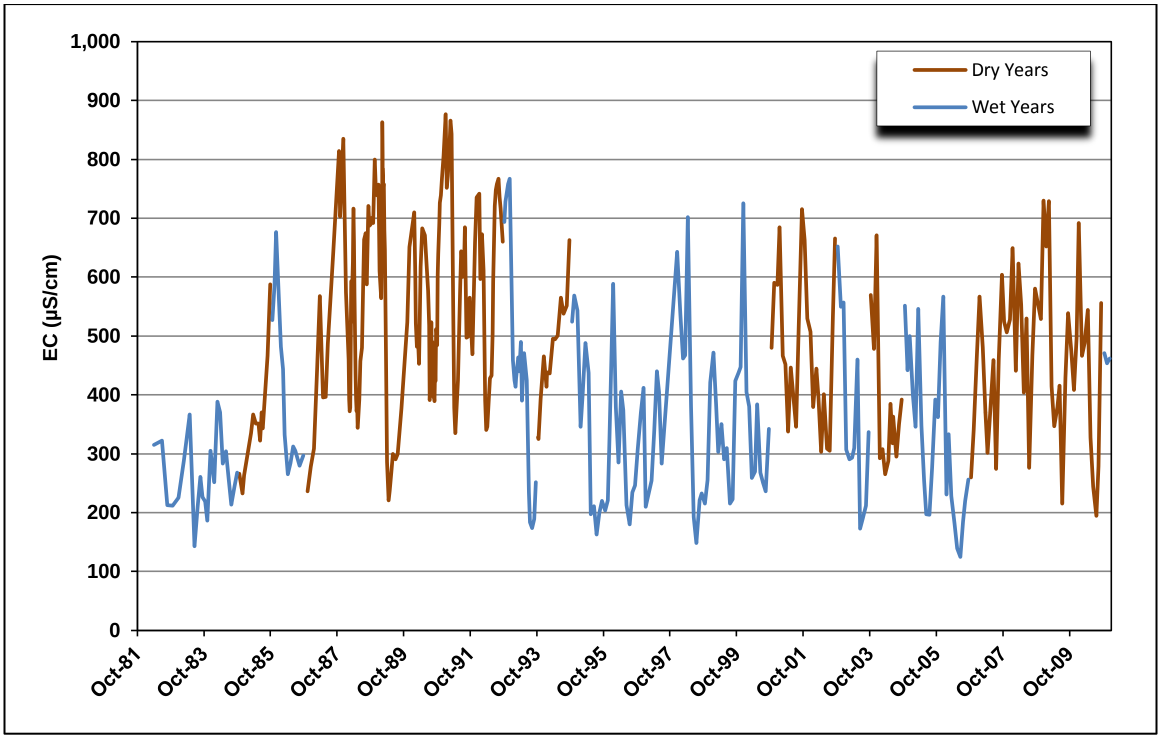


Figure 5-13. Comparison of Banks Real-time and Grab Sample EC Data

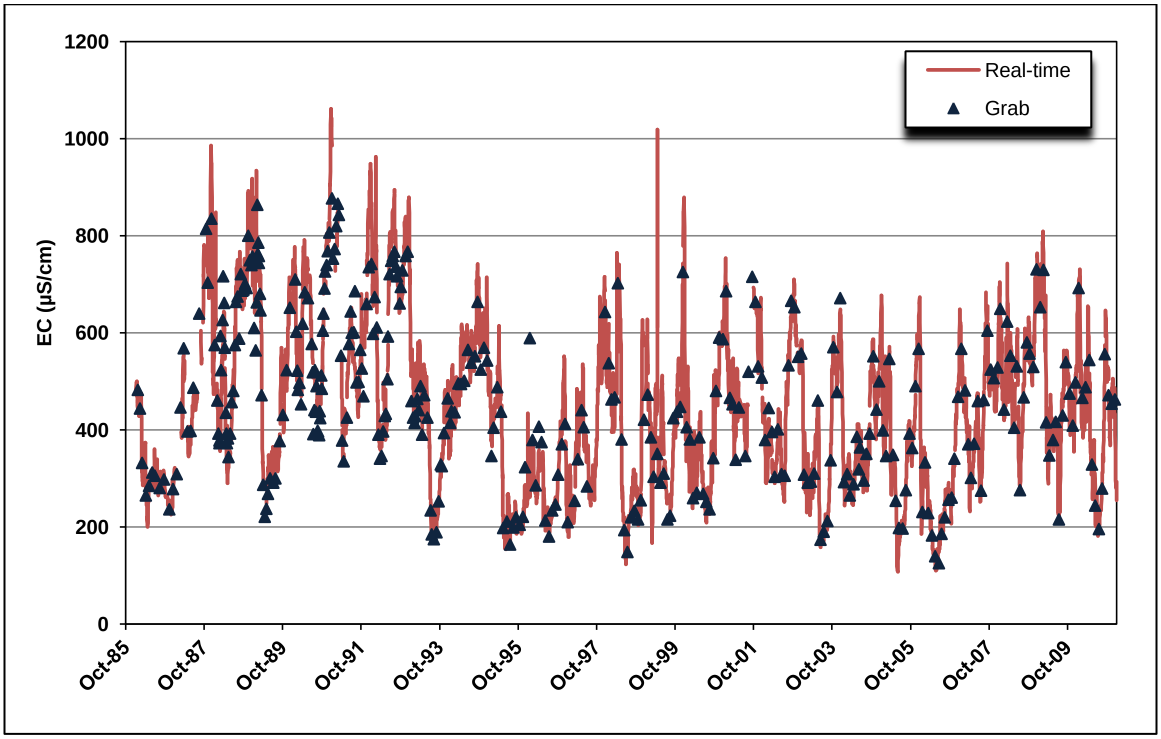
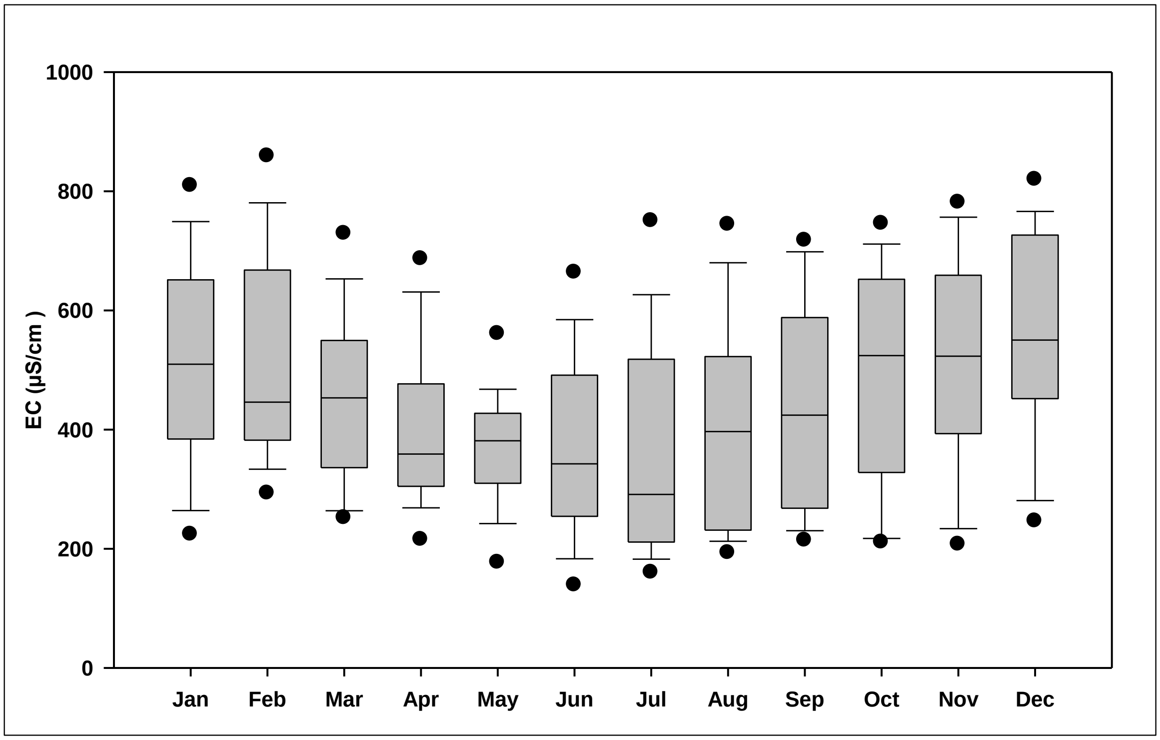


Figure 5-14. Monthly Variability in EC at Banks



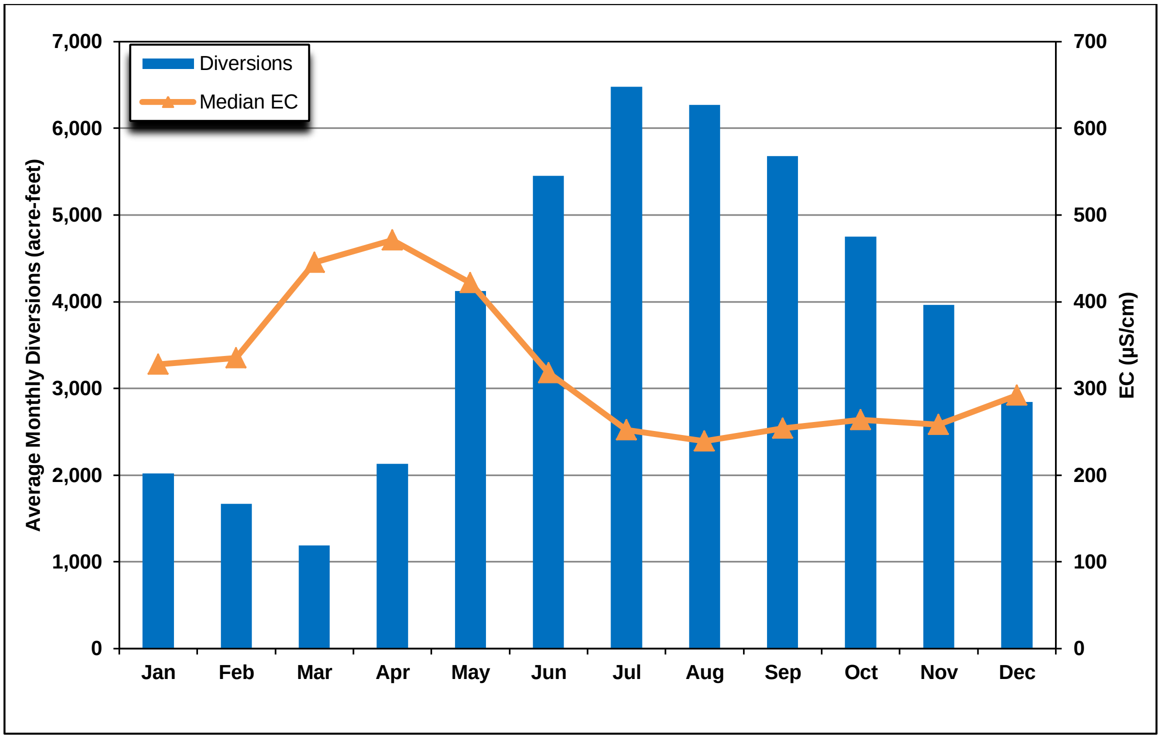
North Bay Aqueduct

Chapters 3 and 4 contain a description of the North Bay Aqueduct (NBA). The sources of water are the local Barker Slough watershed and the Sacramento River.

Project Operations

Since the NBA is an enclosed pipeline, the quality of water delivered to NBA users is governed by the timing of diversions from Barker Slough and it shouldn't be affected by any other factors. **Figure 5-15** shows average monthly diversions at Barker Slough for the 1998 to 2010 period and median monthly EC levels. This figure shows that pumping is highest between May and November. The median EC is 422 µS/cm during May but it declines to less than 300 µS/cm during the summer and fall months. As discussed in Chapter 4, many of the NBA users switch to alternative supplies during the winter and spring months when EC levels are highest.

Figure 5-15. Average Monthly Barker Slough Diversions and Median EC Levels



EC Levels in the NBA

Real-time and grab sample EC data are collected for the NBA at Barker Slough and Cordelia Forebay (Cordelia). **Figure 5-16** shows all available grab sample EC data at Barker Slough. The levels range from 104 to 609 µS/cm during the period of record with a median of 292 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-17** compares the real-time data with the grab sample data at Barker Slough. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. There is generally a good correspondence between the two data sets when samples collected on the same day are compared. The real-time data show that there are greater fluctuations in EC than are captured by the grab samples. **Figure 5-18** compares the real-time and grab sample data for Cordelia. There is a poor correspondence between the two data sets. The grab samples are generally higher than the real-time results.

- Spatial Trends – **Figure 5-19** compares the real-time and grab sample data at Barker Slough and Cordelia for the 1998 to 2010 period when samples were collected at both locations. The Barker Slough real-time median of 277 µS/cm is not statistically significantly different from the grab sample median of 268 µS/cm. The Cordelia grab sample median of 468 µS/cm is statistically significantly higher than the real-time median of 266 µS/cm (Mann-Whitney, p=0.0000). Although the Cordelia real-time median is only 11 µS/cm less than the Barker Slough median, it is statistically different due to the large sample size (Mann-Whitney, p=0.0000). There is apparently some anomaly with the Cordelia grab samples because there is no reason they should be substantially higher than the Cordelia real-time results or the results for Barker Slough. There is a 200 µS/cm increase in the grab sample medians between Barker Slough and Cordelia. Since the NBA is an enclosed pipeline, the increase in inexplicable.

- Long-Term Trends – There is not a discernible long-term trend at Barker Slough or Cordelia based on visual inspection of **Figures 5-16 to 5-18**.

- Wet Year/Dry Year Comparison – The Barker Slough grab sample data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median concentration during wet years of 283 µS/cm is not statistically significantly lower than the median during dry years of 298 µS/cm (Mann-Whitney, p=0.0626).

- Seasonal Trends – **Figure 5-20** shows the relationship between pumping and EC in Barker Slough. In general, there is an inverse relationship with the lowest EC levels occurring when pumping is high. The higher pumping rates pull fresher water in from the Sacramento River through Lindsey Slough. **Figure 5-21** presents the grab sample monthly data for the entire period of record. This figure indicates that the EC levels are lowest in the late summer and early fall months and then increase from late fall to early spring.

Figure 5-16. EC Levels at Barker Slough

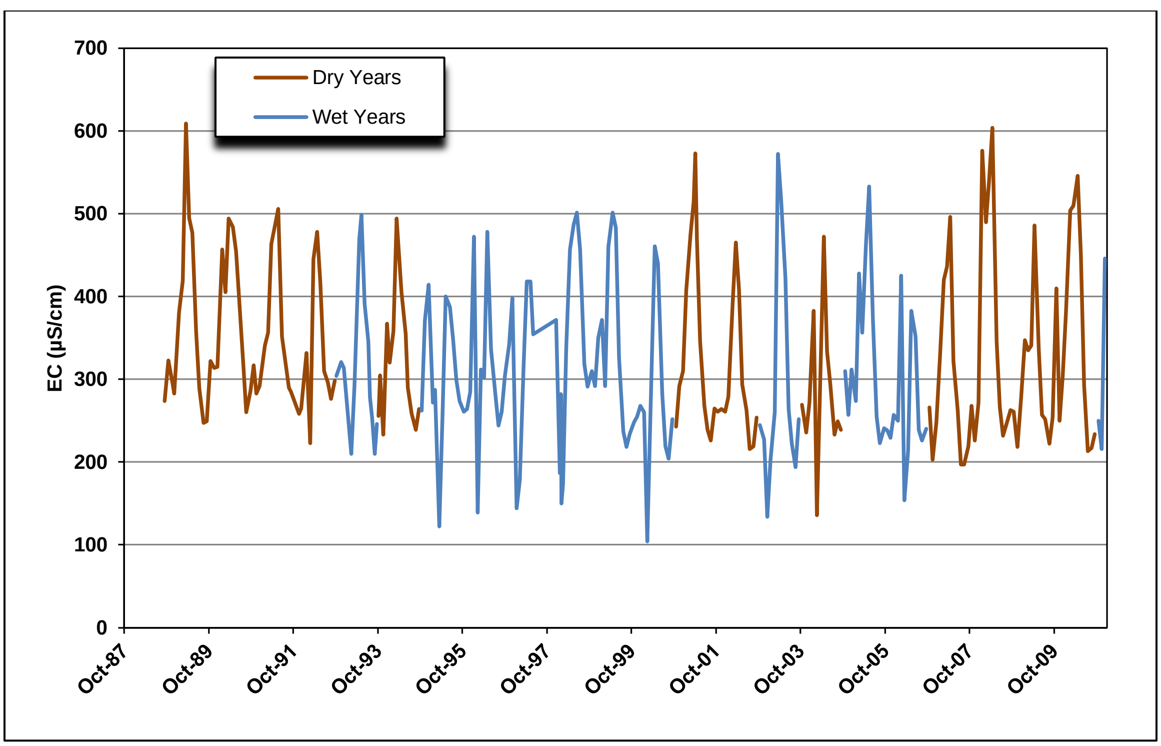


Figure 5-17. Comparison of Barker Slough Real-time and Grab Sample EC Data

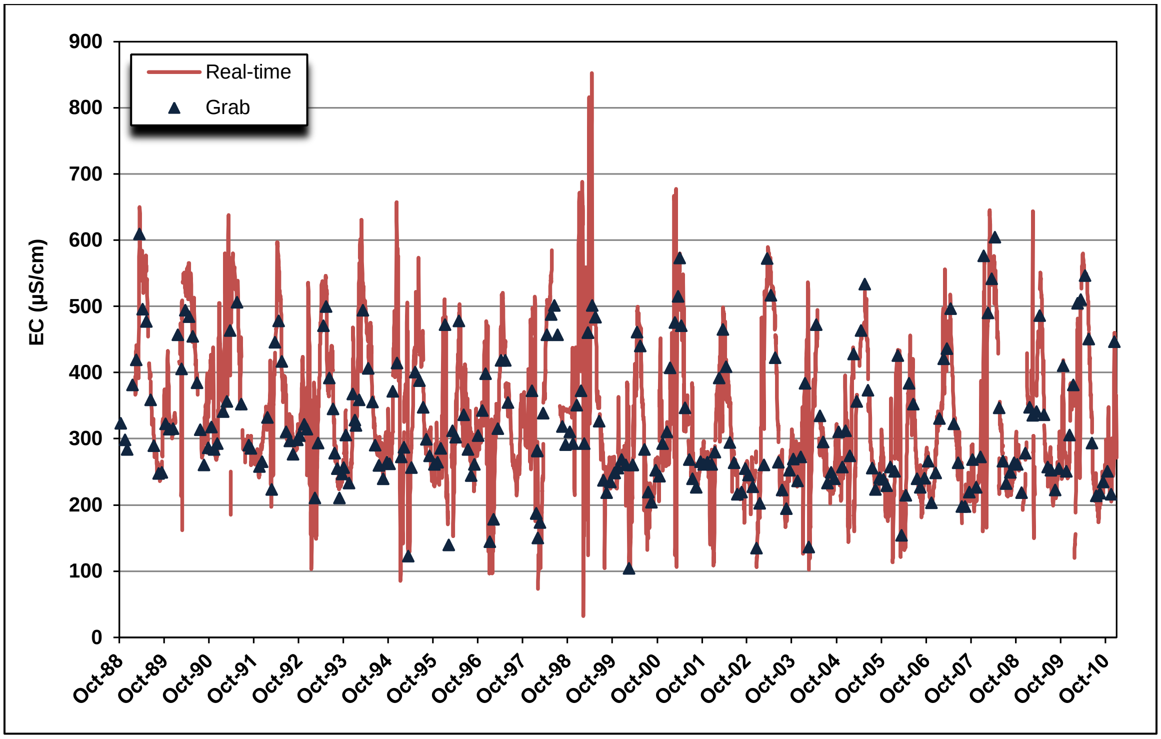


Figure 5-18. Comparison of Cordelia Real-time and Grab Sample EC Data

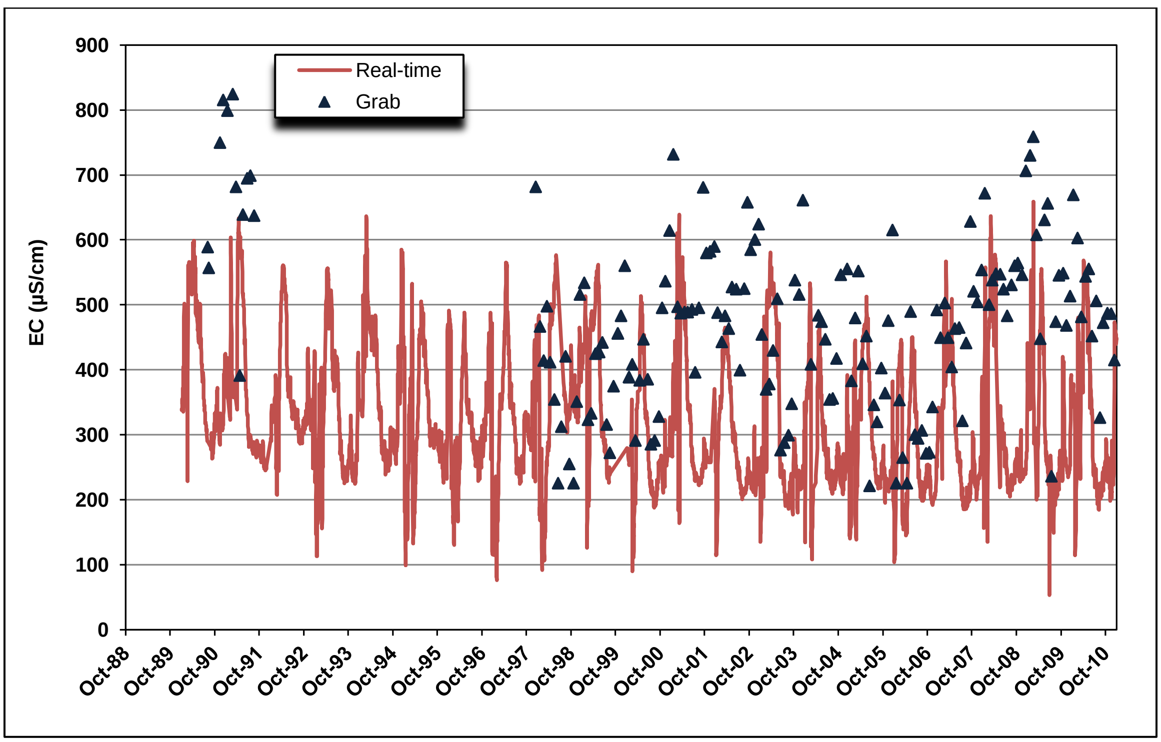


Figure 5-19. Comparison of EC at Barker Slough and Cordelia

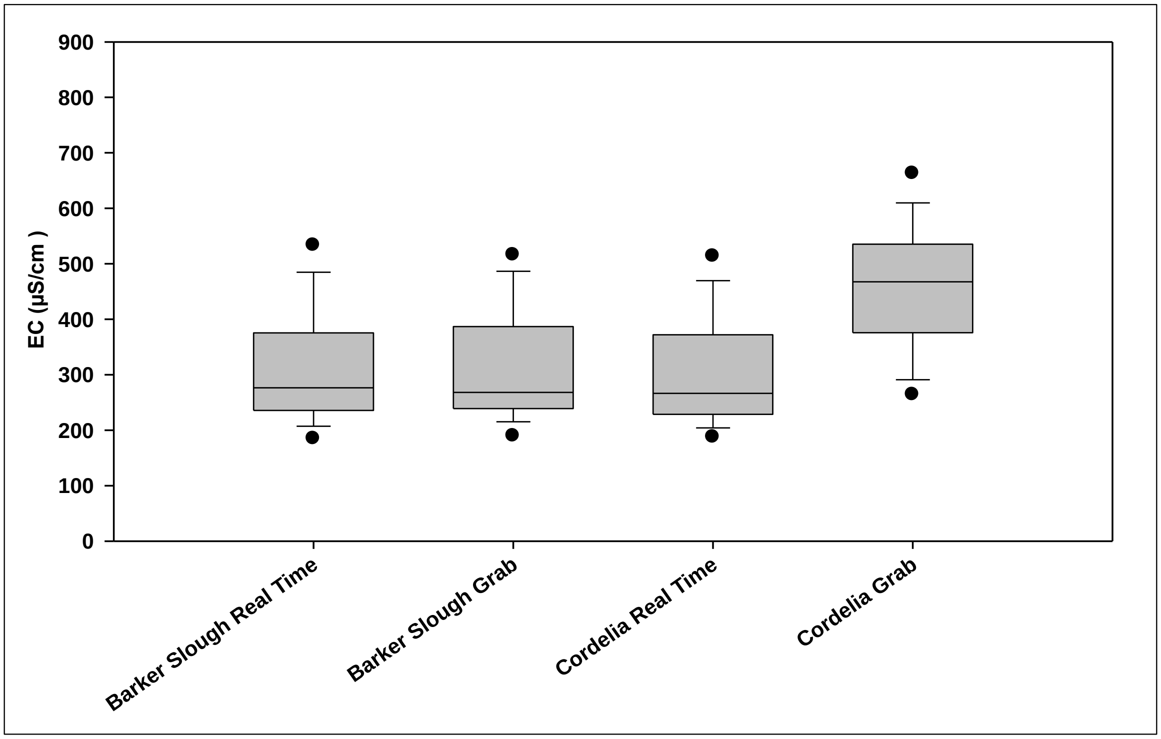


Figure 5-20. Relationship Between Barker Slough Pumping and EC

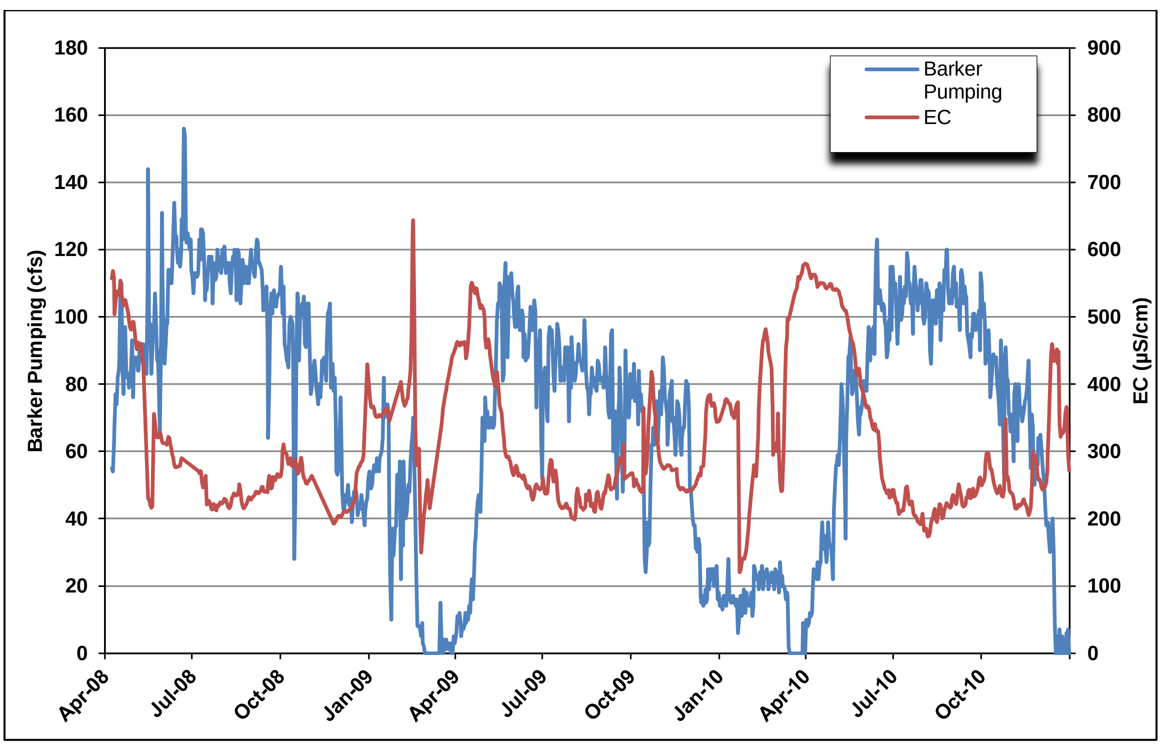
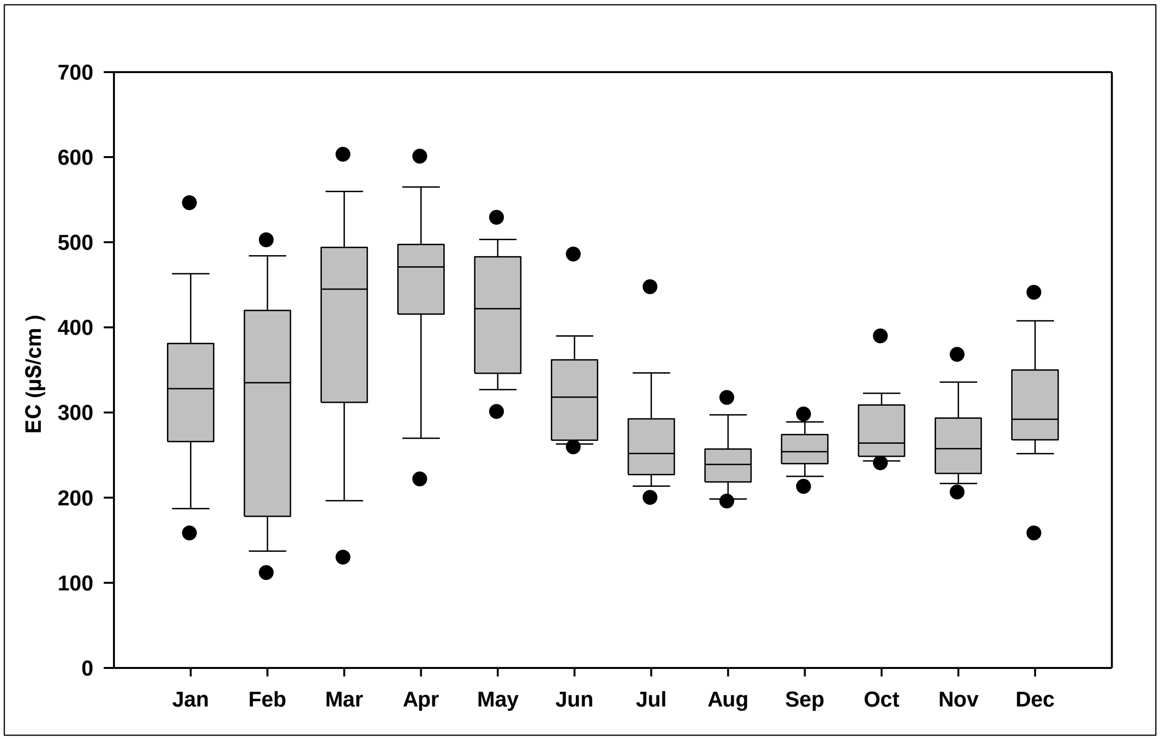


Figure 5-21. Monthly Variability in EC at Barker Slough



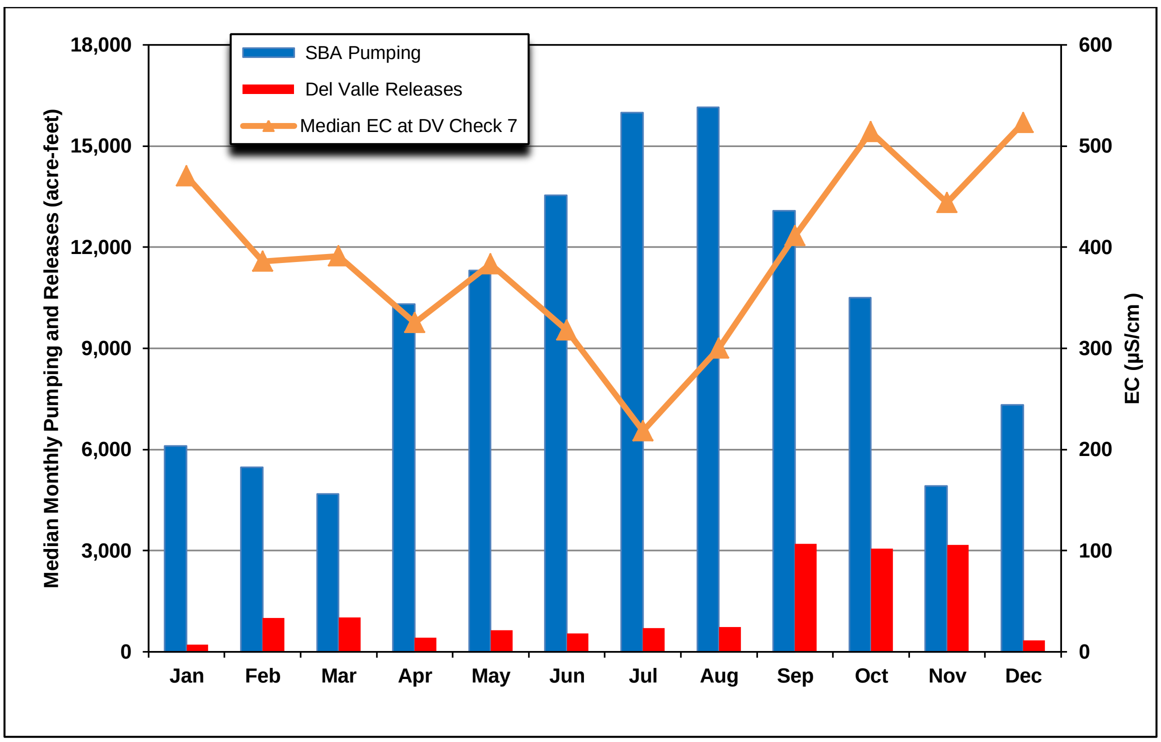
South Bay Aqueduct

Chapters 3 and 4 contain a description of the South Bay Aqueduct (SBA). The Delta is the primary source of water and Lake Del Valle is the secondary source.

Project Operations

The quality of water delivered to the SBA Contractors is governed by the timing of diversions from Bethany Reservoir and releases from Lake Del Valle. **Figure 5-22** shows average monthly diversions at the South Bay Pumping Plant and releases from Lake Del Valle for the 1998 to 2009 period. Diversion data were not available for 2010. Median monthly EC levels at Del Valle Check 7 (DV Check 7) are also shown. This figure shows that EC levels are less than 400 µS/cm when most of the water is pumped into the SBA and are near 300 µS/cm during the peak pumping of the summer months. EC increases sharply during the fall months at DV Check 7. Water is released from Lake Del Valle primarily between September and November. The median EC level at the Lake Del Valle Conservation Outlet (Conservation Outlet) is 394 µS/cm, indicating the Del Valle releases may decrease the EC level of water delivered to SBA Contractors during the fall months.

Figure 5-22. Average Monthly Diversions at the South Bay Pumping Plant, Releases from Lake Del Valle, and Median EC Levels



EC Levels in the SBA

EC data have been collected at four locations along the SBA for varying periods of record. **Figure 5-23** shows all of the data collected at each location along the SBA and at Banks. The DV Check 7 location has the longest period of record for both grab and real-time data. **Figure 5-24** presents all available grab sample EC data at DV Check 7. The EC levels range from 116 to 756 µS/cm with a median of 389 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-25** compares the real-time data with the grab sample data at DV Check 7. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. There is generally a good correspondence between the two data sets when samples collected on the same day are compared. The real-time data show some peaks that were not captured by the grab samples.

- Spatial Trends – It is not possible to compare all locations along the SBA that have been monitored due to varying periods of record. The grab sample data from 1998 to 2010 for Banks, DV Check 7, and the Santa Clara Terminal Reservoir (Terminal Tank) are shown in **Figure 5-26**. The median concentration at DV Check 7 (388 µS/cm) is not statistically significantly different than the median concentration at Banks (397 µS/cm) or the median concentration at the Terminal Tank (389 µS/cm). Water from Lake Del Valle enters the SBA between DV Check 7 and the Terminal Tank but does not appear to statistically significantly affect EC levels when the data are aggregated in this manner. **Figure 5-27** presents a comparison of data collected at DV Check 7, the Conservation Outlet, and the Terminal Tank. This figure shows that EC levels in Lake Del Valle are relatively constant compared to DV Check 7. The levels at the Terminal Tank are similar to the levels at the Conservation Outlet during the fall months when water is released from Lake Del Valle. During the remainder of the year, the EC levels at the Terminal Tank are similar to those found at DV Check 7.

- Long-Term Trends – Visual inspection of **Figure 5-24** does not reveal a discernible trend in the data from DV Check 7.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median concentration during wet years of 311 µS/cm is statistically significantly lower than the median during dry years of 452 µS/cm (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 5-28** presents the grab sample monthly data for the entire period of record at DV Check 7. The EC levels at DV Check 7 show the same monthly pattern as at Banks with the lowest levels in July and increasing EC during the fall months.

Figure 5-23. EC in the SBA

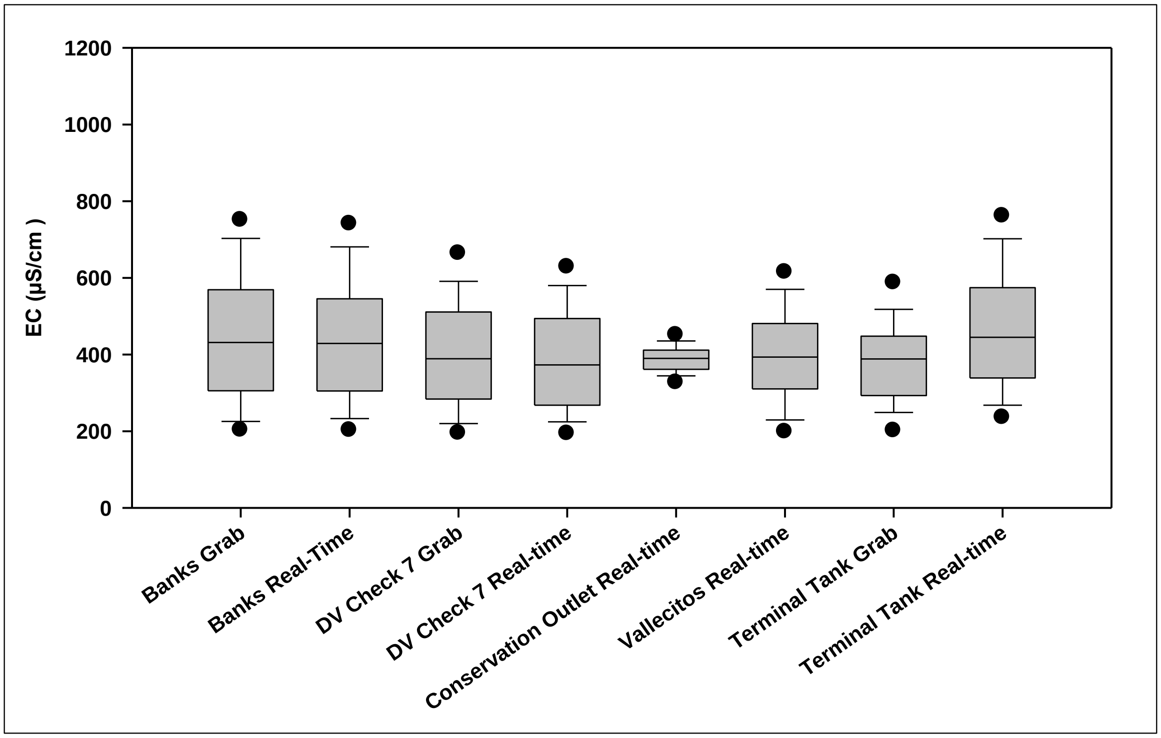


Figure 5-24. EC at DV Check 7

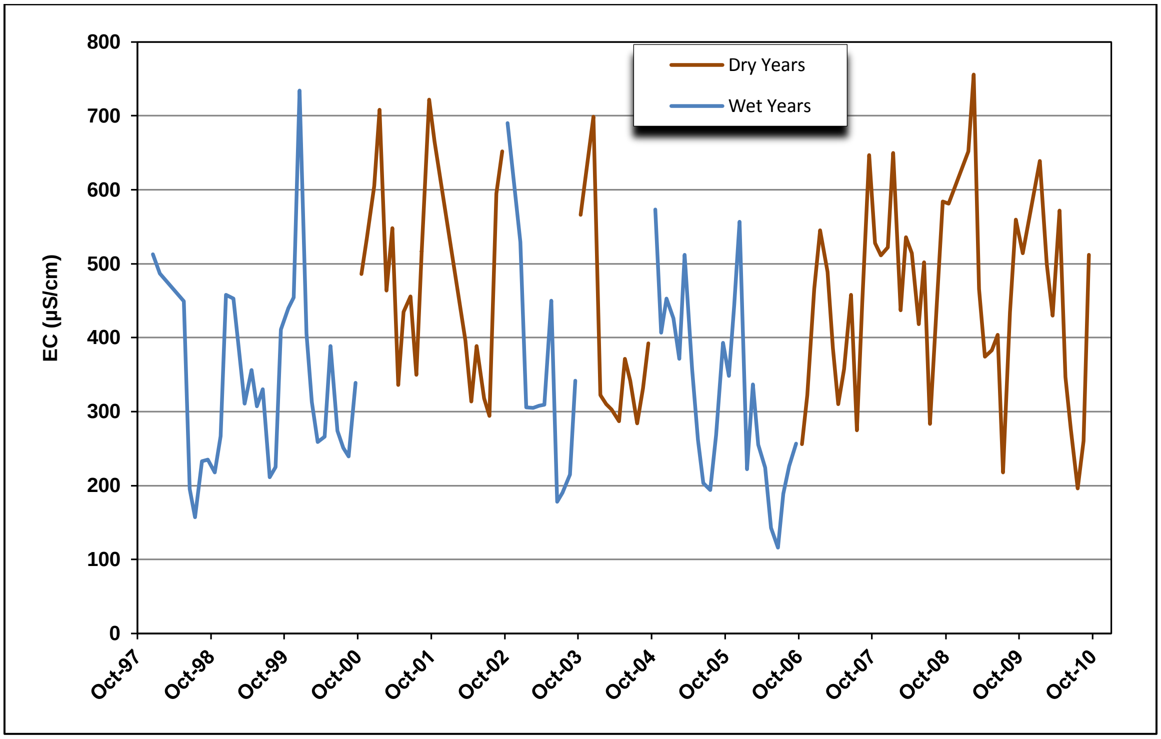


Figure 5-25. Comparison of DV Check 7 Real-time and Grab Sample EC Data

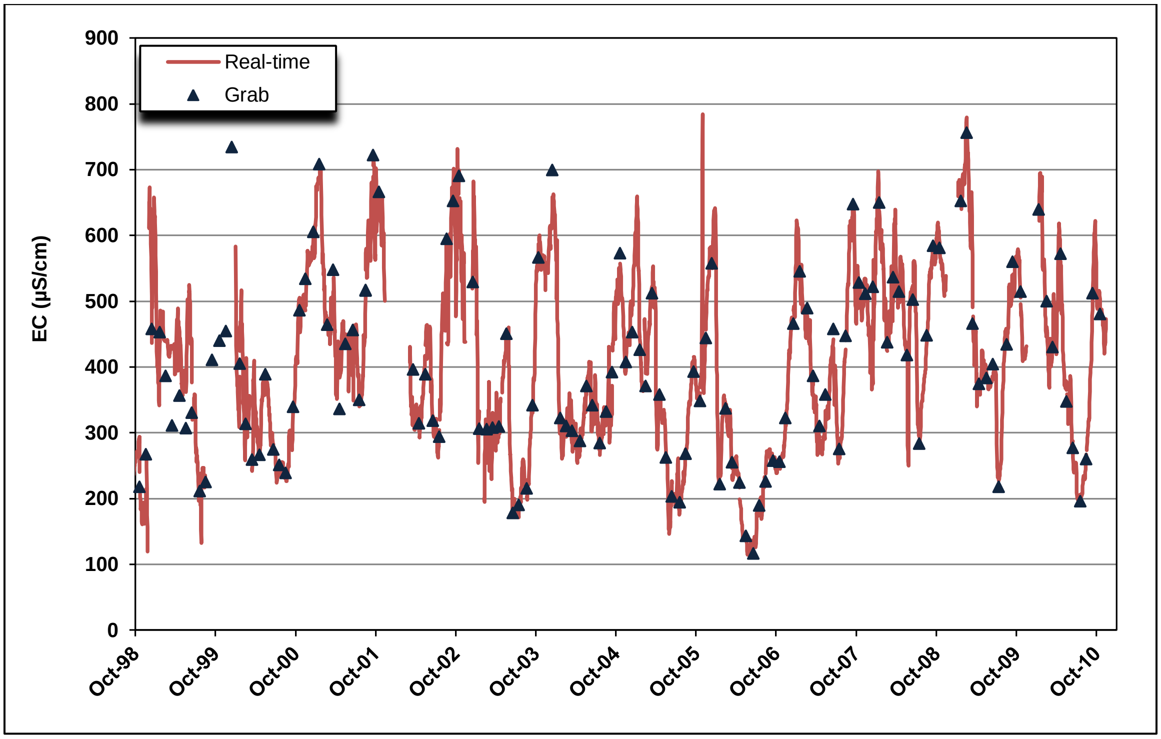


Figure 5-26. Comparison of EC at Banks, DV Check 7 and the Terminal Tank (1998-2010)

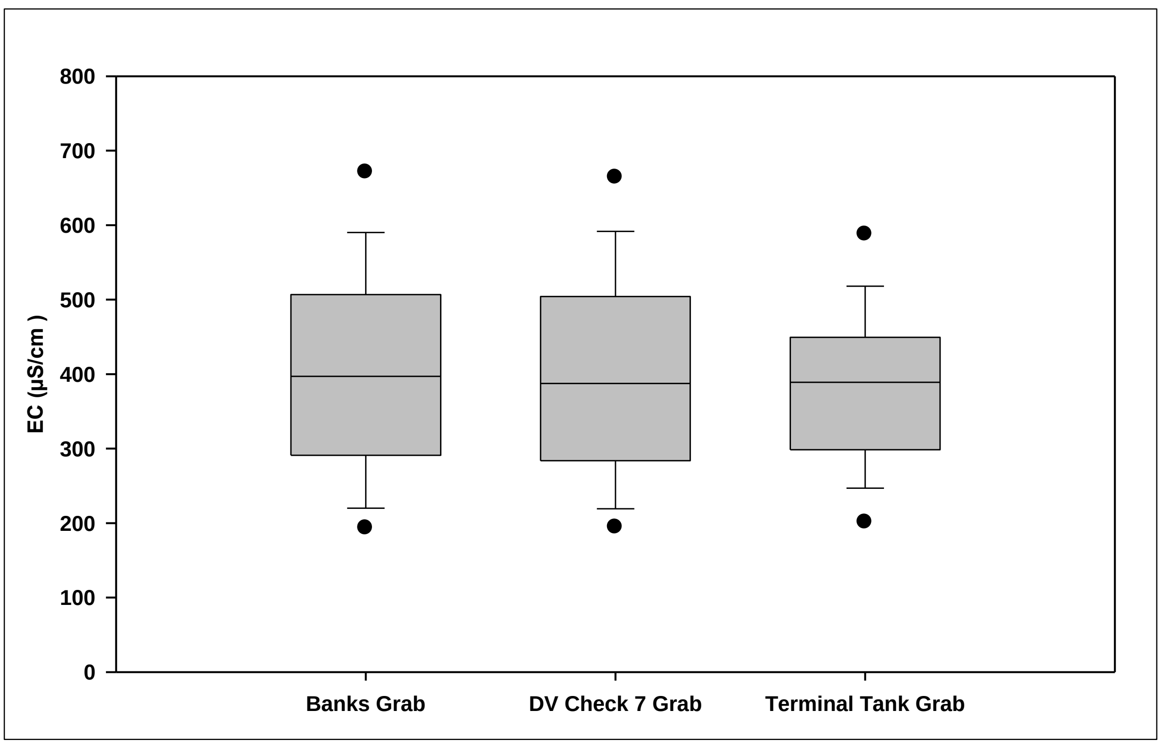


Figure 5-27. EC in the SBA and Conservation Outlet

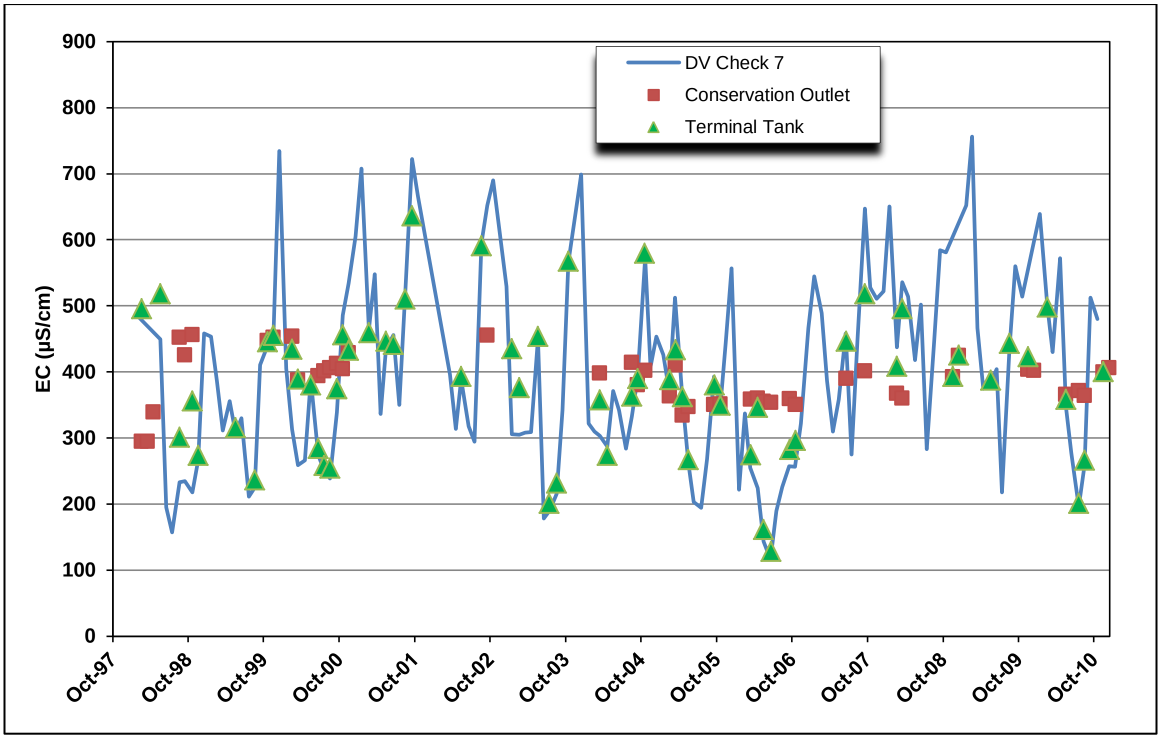
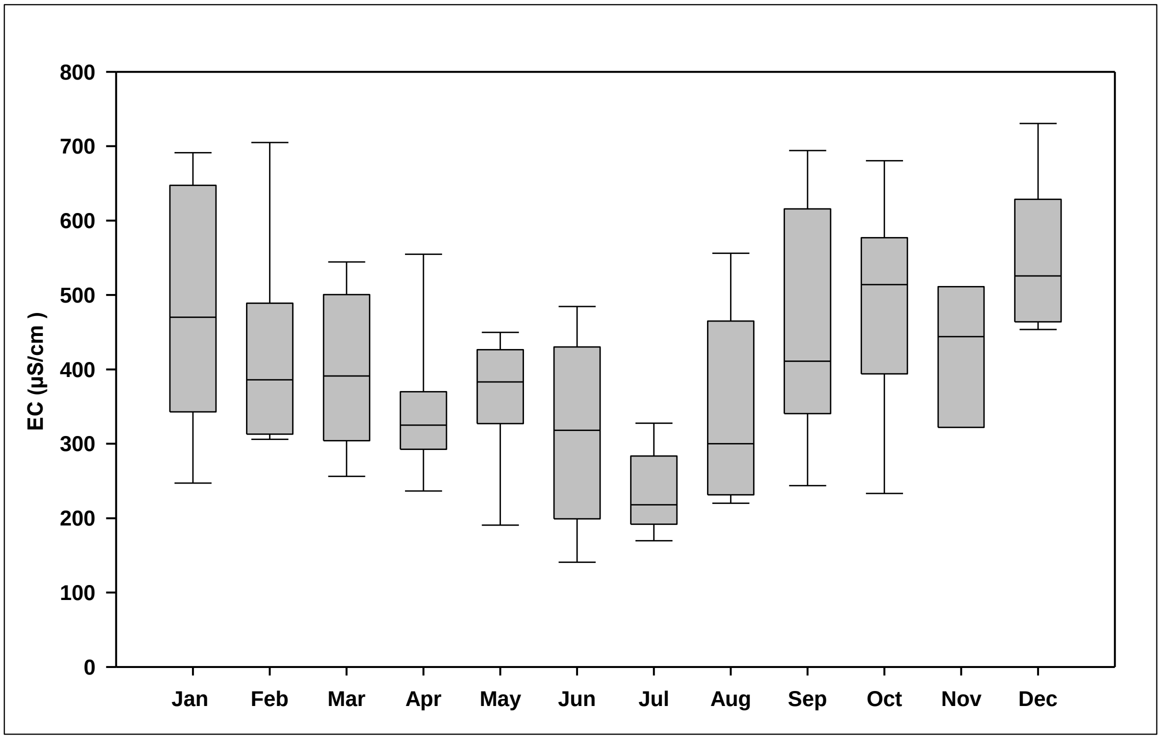


Figure 5-28. Monthly Variability in EC at DV Check 7



Note: Insufficient data to plot all percentiles.

California Aqueduct and Delta-Mendota Canal

A number of SWP Contractors take water from the SWP between San Luis Reservoir and the terminal reservoirs. This section is organized by various reaches of the SWP and individual SWP Contractors taking water from each reach are described in the following sections.

Project Operations

The quality of water delivered to SWP Contractors south of San Luis Reservoir is governed by the timing of diversions from the Delta at Banks, pumping into O'Neill Forebay from the Delta-Mendota Canal (DMC), releases from San Luis Reservoir, non-Project inflows to the Governor Edmund G. Brown California Aqueduct (California Aqueduct), and storage in terminal reservoirs. The impact of non-Project inflows on water quality is discussed in Chapter 14 and the influence of terminal reservoirs in modulating EC levels is discussed later in this chapter.

Figure 5-29 shows average monthly diversions at the Banks Pumping Plant and median monthly EC levels for the 1998 to 2010 period. As described in Chapter 3, operations were governed by the 1995 Bay-Delta Plan (D-1641) from 1998 to 2006 and by the Wanger Decision and the biological opinions from 2007 to 2010 so both periods are shown. Median EC levels range from 291 to 424 µS/cm during the peak diversion months of July to September; however the median EC levels range from 446 to 550 µS/cm during the October to March period when a substantial amount of water is diverted from the Delta at Banks. Due to constraints on pumping, very little water is diverted during the April to June period when median EC levels are less than 400 µS/cm.

Figure 5-30 shows the average monthly amount of water pumped from the DMC at O'Neill Pump-Generating Plant into O'Neill Forebay and the median EC level in the DMC at McCabe Road (McCabe). The median EC levels show the same seasonal pattern as at Banks but the EC levels at McCabe are higher. The pumping pattern at O'Neill is different from the pattern at Banks. There is little pumping into O'Neill Forebay during the April to August period when EC levels are lowest. Most of the pumping occurs between September and March when median EC levels range from 500 to 700 µS/cm. During the 1998 to 2009 period that data were available, the DMC contributed between 26 and 44 percent of the water entering O'Neill Forebay with a median of 30 percent.

Figure 5-29. Average Monthly Banks Diversions and Median EC Levels

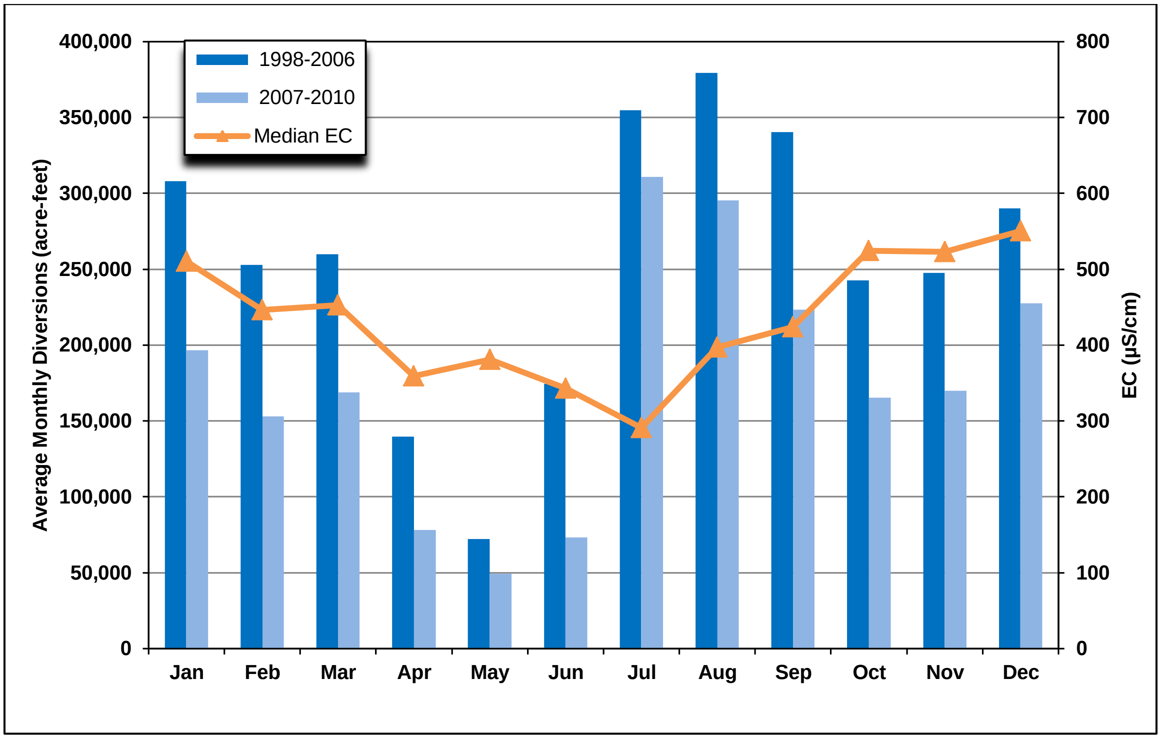
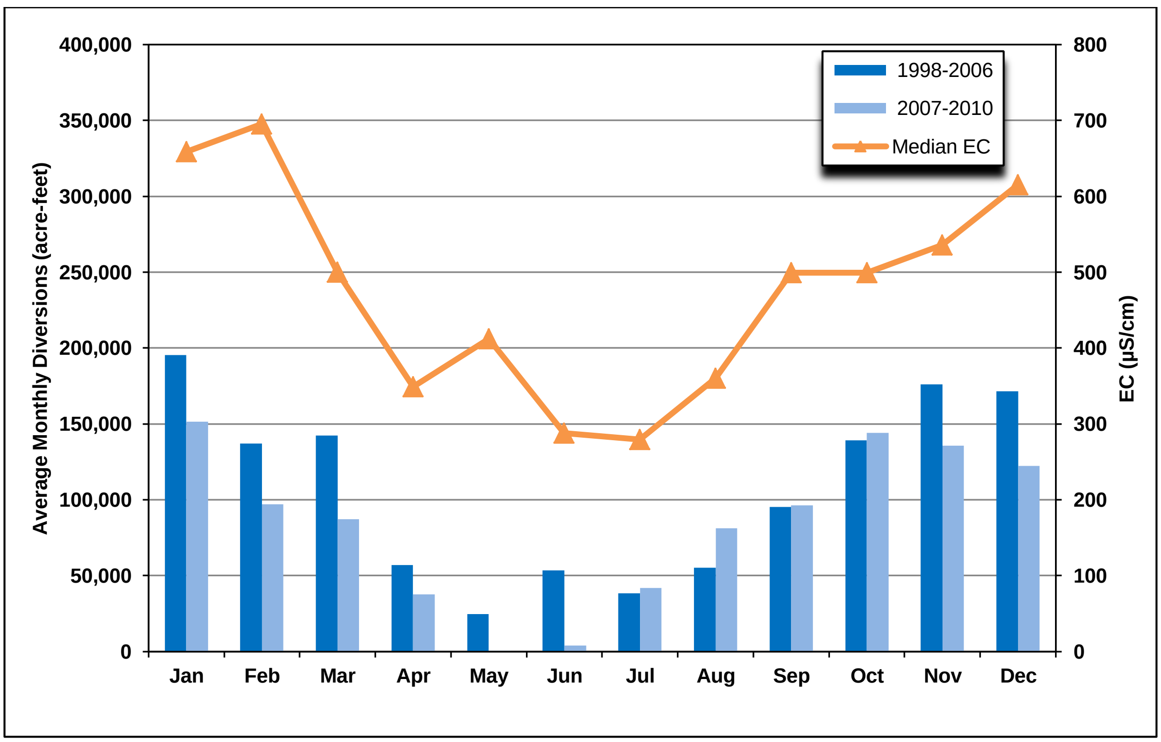


Figure 5-30. Average Monthly Pumping at O'Neill and Median EC Levels

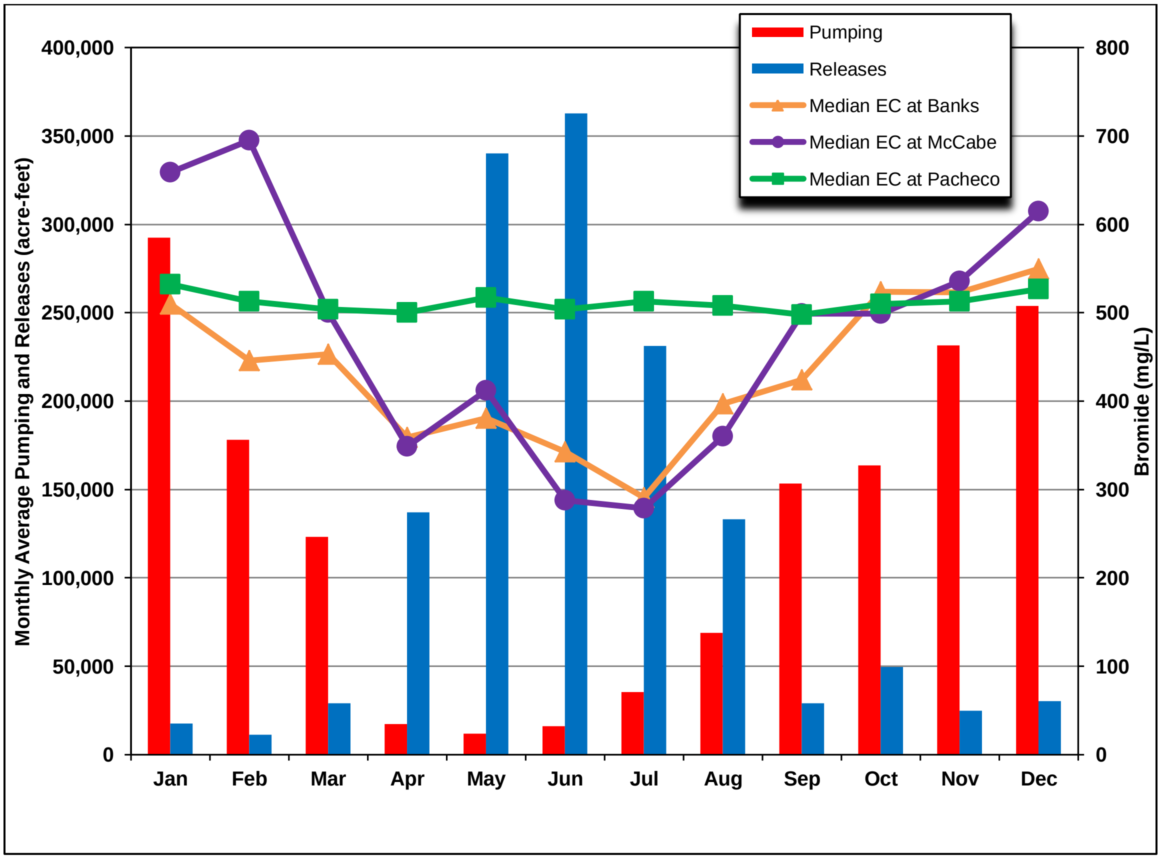


The operation of San Luis Reservoir impacts water quality in the California Aqueduct south of the reservoir. **Figure 5-31** shows the pattern of pumping into the reservoir and releases from the reservoir to O'Neill Forebay. The median EC level at Banks represents the quality of water pumped into the reservoir from the California Aqueduct and the median EC level at McCabe represents the quality of water pumped in from the DMC. Since data are not currently available on the quality of water released to O'Neill Forebay from San Luis Reservoir, data from the Pacheco Pumping Plant (Pacheco) are used. **Figure 5-31** shows there are two distinct periods for San Luis Reservoir with respect to EC levels:

- Fall and Winter Filling – The reservoir is filled from September to March when the median EC levels in water entering the reservoir are high (424 to 550 µS/cm at Banks and 499 to 695 µS/cm at McCabe).

- Spring and Summer Releases – Water is released during the April to August period when median EC levels at Pacheco range from 504 to 517 µS/cm. During the release period, the EC levels in water released from San Luis Reservoir are higher than the EC levels in the water entering O'Neill Forebay from the California Aqueduct and the DMC, indicating that releases from the reservoir increase EC levels in the aqueduct.

Figure 5-31. San Luis Reservoir Operations and Median EC Levels



EC Levels in the DMC and SWP

Figure 5-32 presents a summary of all grab sample EC data collected at each of the locations along the DMC, the California Aqueduct, and SWP reservoirs. There are varying periods of record for each location so differences between locations may be due to the hydrologic conditions under which the samples were collected. Changes in EC along the aqueduct are described in the following sections. There is some reduction in variability in EC levels in the reservoirs due to the blending of water with varying EC levels over time in the reservoirs. Lake Perris has the highest median EC (573 µS/cm) in the SWP system. Real-time data are available for varying periods of record at a number of locations along the California Aqueduct. **Figure 5-33** presents the real-time data from June 1993 to December 2010. The same general pattern is shown between the real-time data and the grab sample data. The median EC levels are lower in the real-time data because the drought years of 1987 to 1992 are not included since data were not available at all locations during those years. Spatial differences are examined in more detail in the following sections.

Figure 5-32. EC Levels in the DMC and SWP

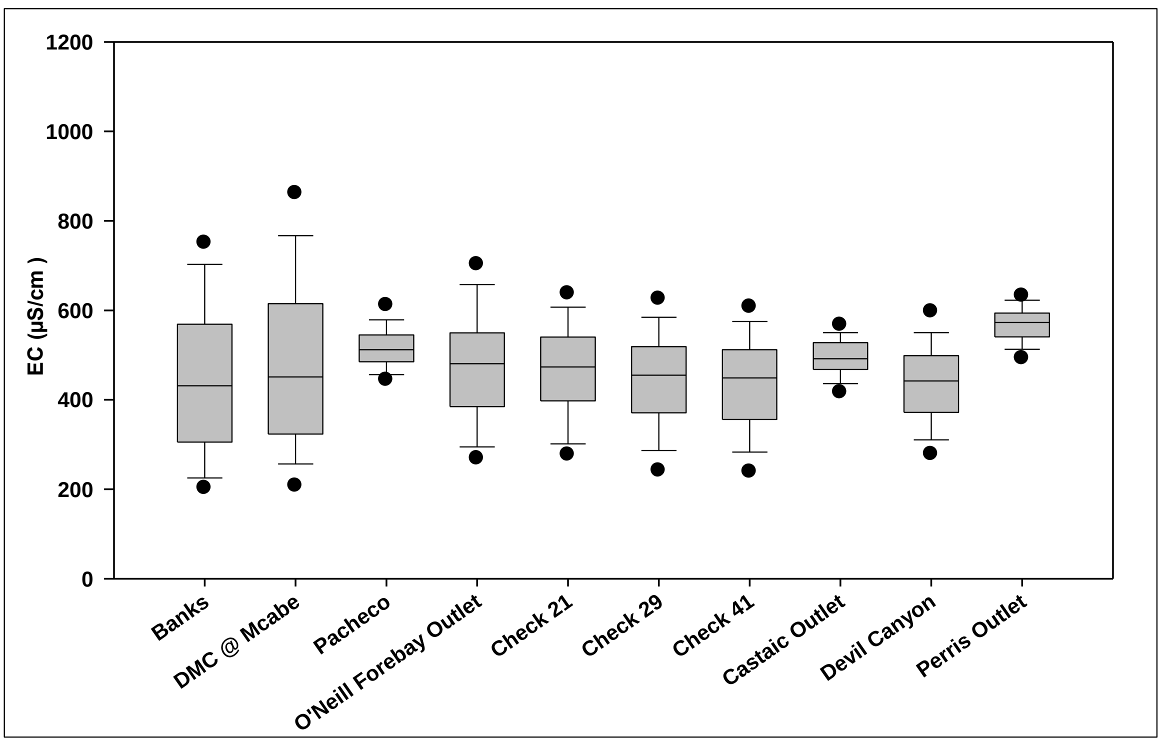
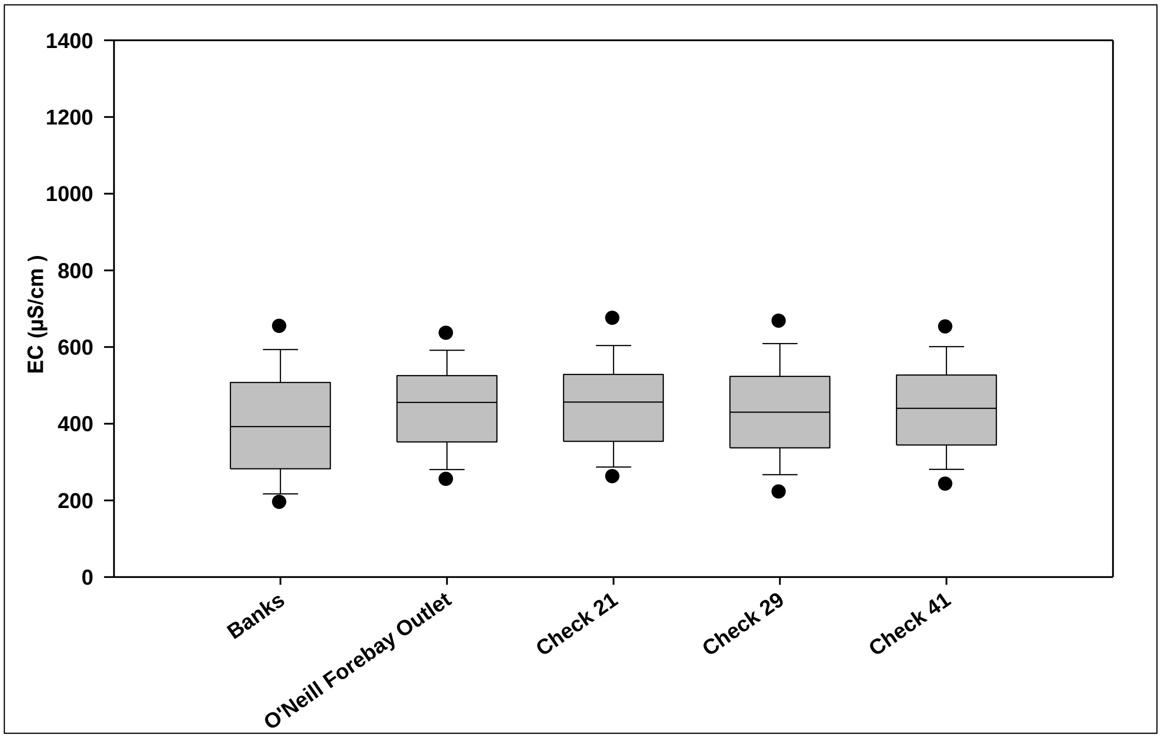


Figure 5-33. Real-time EC Levels in the California Aqueduct (1993-2010)



Delta-Mendota Canal – Grab sample EC data have been collected from McCabe and real-time data have been collected at Jones and at the O'Neill Pump-Generating Plant (O'Neill Intake), which is the point at which the DMC enters O'Neill Forebay. **Figure 5-34** presents the EC data for McCabe. There is considerable variability in the data with EC levels ranging from 143 to 1150 µS/cm with a median of 451 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-35** compares the real-time data collected at O'Neill Intake to the grab sample data at McCabe. Average daily EC at O'Neill Intake, calculated from hourly measurements, was downloaded from CDEC for this analysis. These two locations are within a few miles of each other. There is a reasonable correspondence between the two data sets at low EC levels but the peak levels measured by the real-time sampler are often substantially lower than the grab sample measurements. The real time data at O'Neill Intake may be lower because water from the California Aqueduct enters the DMC when the O'Neill Pump-Generating Plant is generating power by releasing water from the higher elevation O'Neill Forebay into the DMC.

- Spatial Trends – **Figure 5-36** presents the EC data collected at Banks, Jones, McCabe, and O'Neill Intake between 1999 and 2010. This is the period when data were collected at all three locations. Banks data from this same time period are also shown. There is a statistically significant difference in EC levels at the two Delta pumping plants. The Jones median EC of 451 µS/cm is statistically significantly higher than the median EC at Banks of 408 µS/cm (Mann-Whitney, p=0.0082) due to the greater influence of the San Joaquin River at Jones. There is also a statistically significant increase in EC levels as water travels down the DMC. The median concentration at O'Neill Intake of 480 µS/cm is statistically significantly higher than the median concentration at Jones of 451 µS/cm (Mann-Whitney, p=0.0000). As discussed previously, there are a number of locations along the DMC where agricultural drainage is returned to the canal and groundwater seeps into the canal. This is the likely source of the increase in EC between Jones and O'Neill.

- Long-Term Trends – Visual inspection of **Figure 5-34** does not show any discernible long-term trend in EC levels at McCabe.

- Wet Year/Dry Year Comparison – The influence of hydrology on EC levels is clearly shown in **Figure 5-34** with dry years having higher levels of EC than wet years. The McCabe wet year median EC level of 359 µS/cm is statistically significantly lower than the dry year median of 516 µS/cm (Mann-Whitney, p=0.0.000).

- Seasonal Trends – **Figure 5-37** shows there is a seasonal pattern of declining EC levels during the spring months at McCabe with the lowest levels in July. During the late summer and fall months, EC levels rise with the highest levels occurring in January and February. The EC fingerprint (**Figure 5-2**) shows that the increase in EC levels at McCabe is due to a combination of seawater intrusion, high levels of EC at Vernalis, and Delta agricultural drainage. During August through September of most years, seawater intrudes into the Delta due to low flows on the Sacramento and San Joaquin rivers. During these months, temporary barriers are installed in the south Delta. This results in the San Joaquin River mixing with lower EC water in the central Delta before it is drawn to the Jones Pumping Plant. In many years, the barriers are removed in the late fall when flows on the San Joaquin River are increasing. This results in increasing EC levels at Jones as the San Joaquin River is once again drawn directly to the pumping plant. The increase in EC at McCabe during these months depends on the degree of mixing of the San Joaquin River with lower EC water in the south Delta. Delta agricultural drainage is also responsible for an increase in EC at Jones, primarily during January to February when water is pumped off of the islands.

Figure 5-34. EC Levels at McCabe

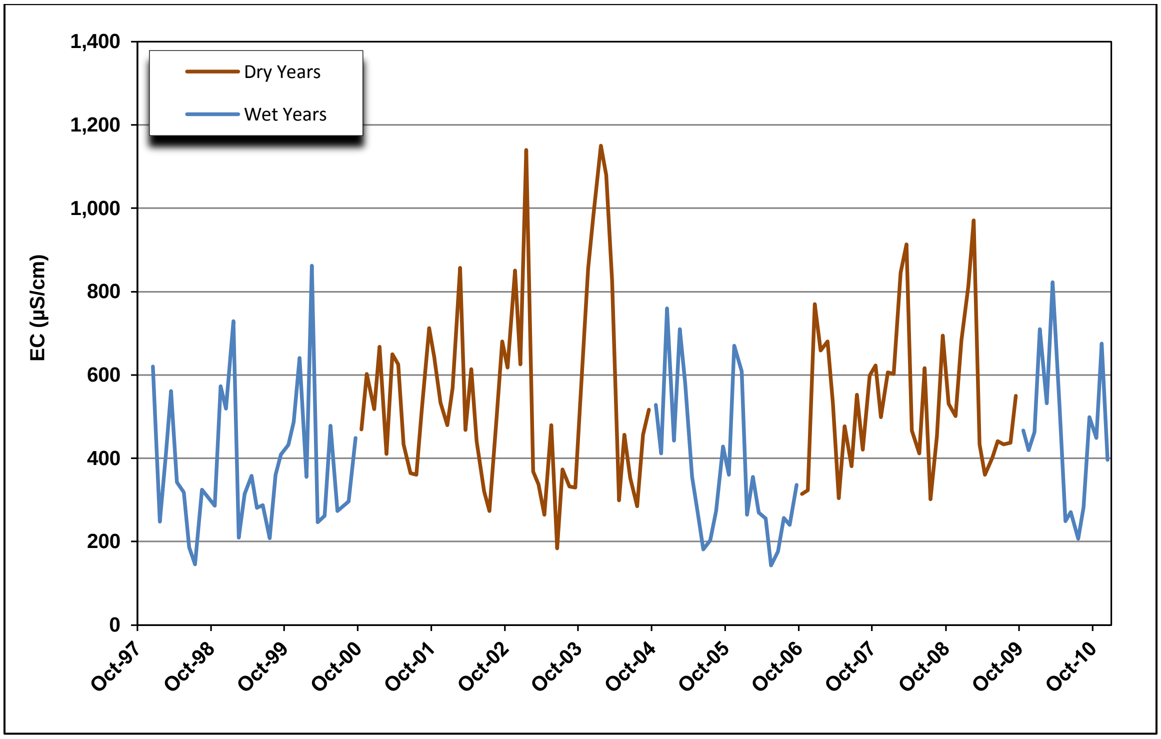


Figure 5-35. Comparison of O'Neill Intake Real-time and McCabe Grab Sample EC Data

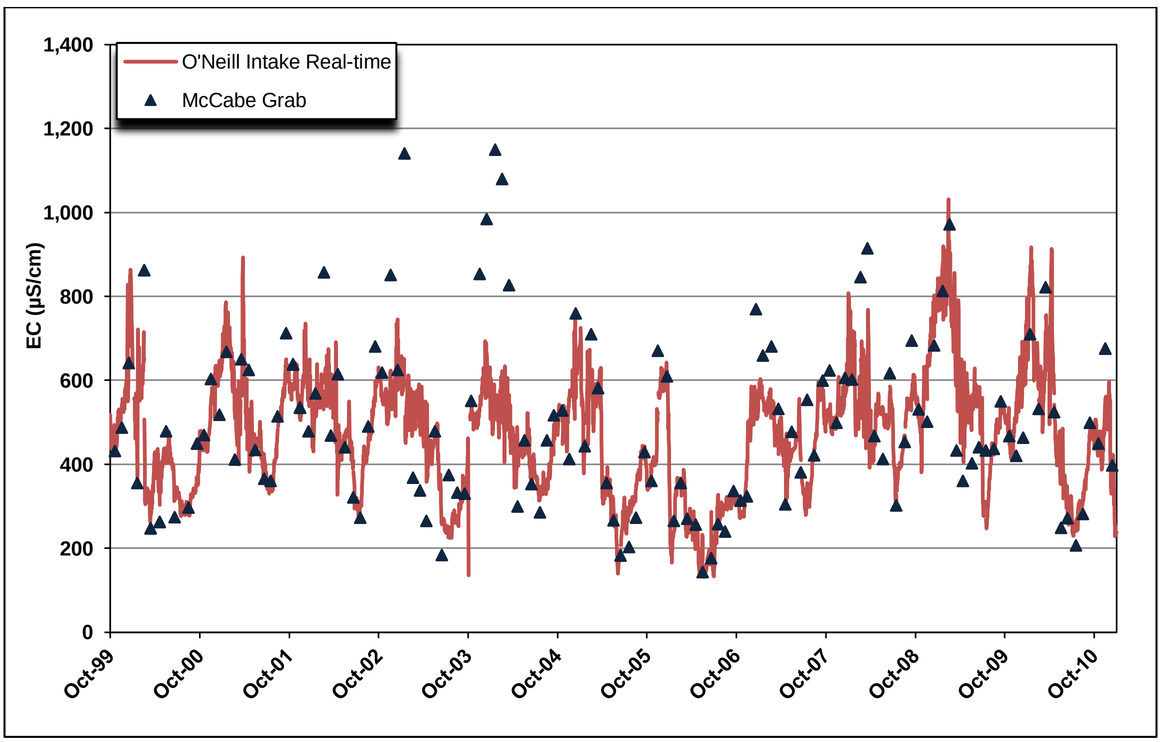


Figure 5-36. Comparison of DMC and Banks EC Levels (1999-2010)

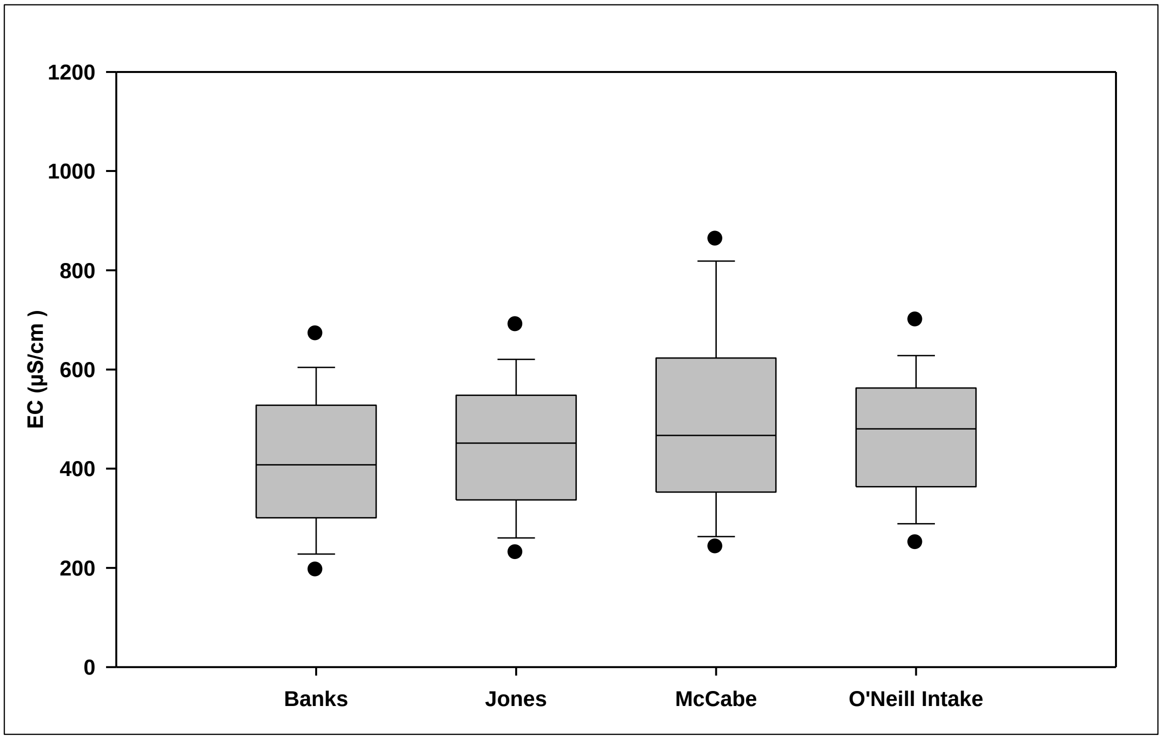
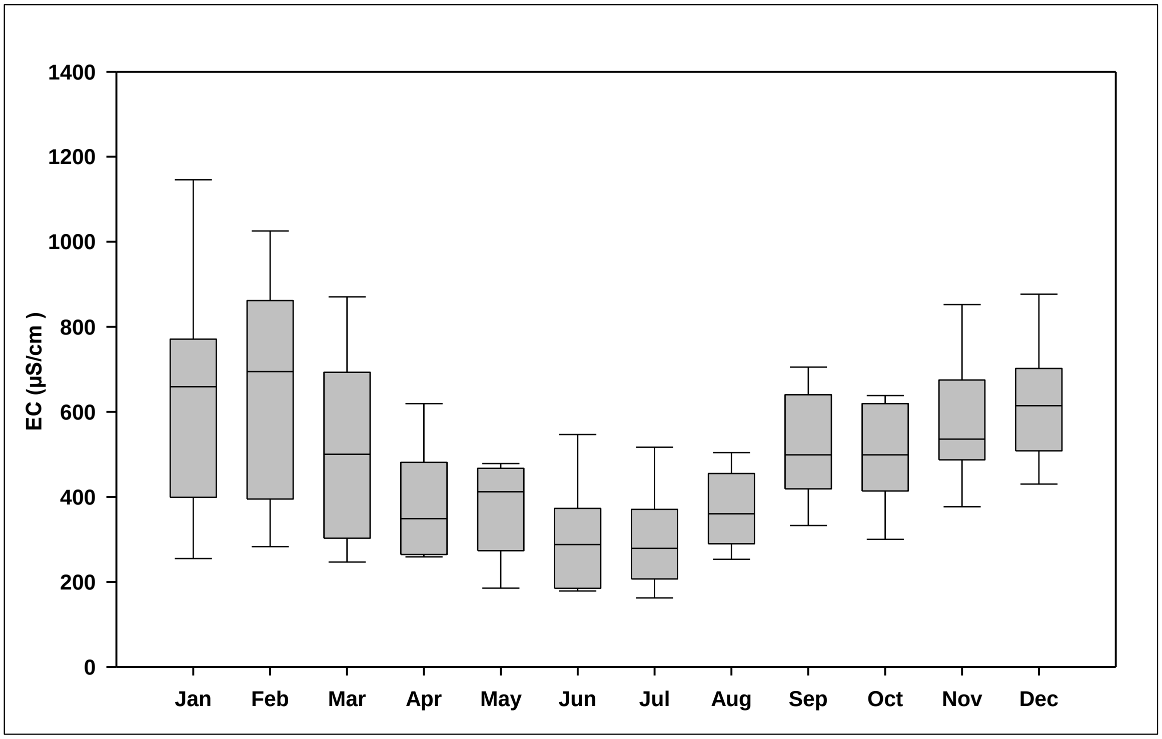


Figure 5-37. Monthly Variability in EC at McCabe



Note: Insufficient data to plot all percentiles.

San Luis Reservoir – Grab sample EC data have been collected at Pacheco since 2000 and real-time data have been collected since 1989. **Figure 5-38** presents all of the available grab sample EC data for Pacheco. There is much less variability in EC levels in the reservoir than in the aqueduct. The EC levels at Pacheco range from 419 to 667 µS/cm with a median of 512 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-39** shows there is good correspondence between the real-time and grab sample data collected between 2000 and 2010. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. The real-time data indicate that EC levels were considerably higher at Pacheco during the drought of the early 1990s. The peak level at that time was 873 µS/cm.

- Spatial Trends – The real-time data from Banks, the DMC at O'Neill Intake, and Pacheco for the 1999 to 2010 period are presented in **Figure 5-40** to show the variability between Pacheco and the two sources of water to San Luis Reservoir. The median EC level at Pacheco of 506 µS/cm is statistically significantly higher than the Banks median of 409 µS/cm and the O'Neill median of 480 µS/cm (Mann-Whitney, p=0.0000). The higher EC in San Luis Reservoir is likely due to a combination of evaporation in the reservoir and pumping of water into the reservoir during the fall and winter months when Delta salinity is high.

- Long-Term Trends – **Figure 5-39** shows that EC levels have declined considerably since 1991, which was the fifth year of a six year drought. This was followed by six wet years between 1995 and 2000 so the trend is a function of hydrology rather than any long-term change in EC in the reservoir.

- Wet Year/Dry Year Comparison – As shown with the real-time data and the grab sample data shown in **Figure 5-38**, EC levels are lower in wet years than in dry years. The Pacheco grab sample wet year median of 499 µS/cm is statistically significantly lower than the dry year grab sample median of 528 µS/cm (Mann-Whitney, p=0.0025.

- Seasonal Trends – **Figure 5-41** shows there is no distinct seasonal pattern, although EC levels are more variable during the fall months. The highest monthly median EC level of 532 µS/cm in January is not statistically significantly different from the lowest monthly median of 498 µS/cm in September (Mann-Whitney, p=0.4592).

Figure 5-38. EC Levels at Pacheco

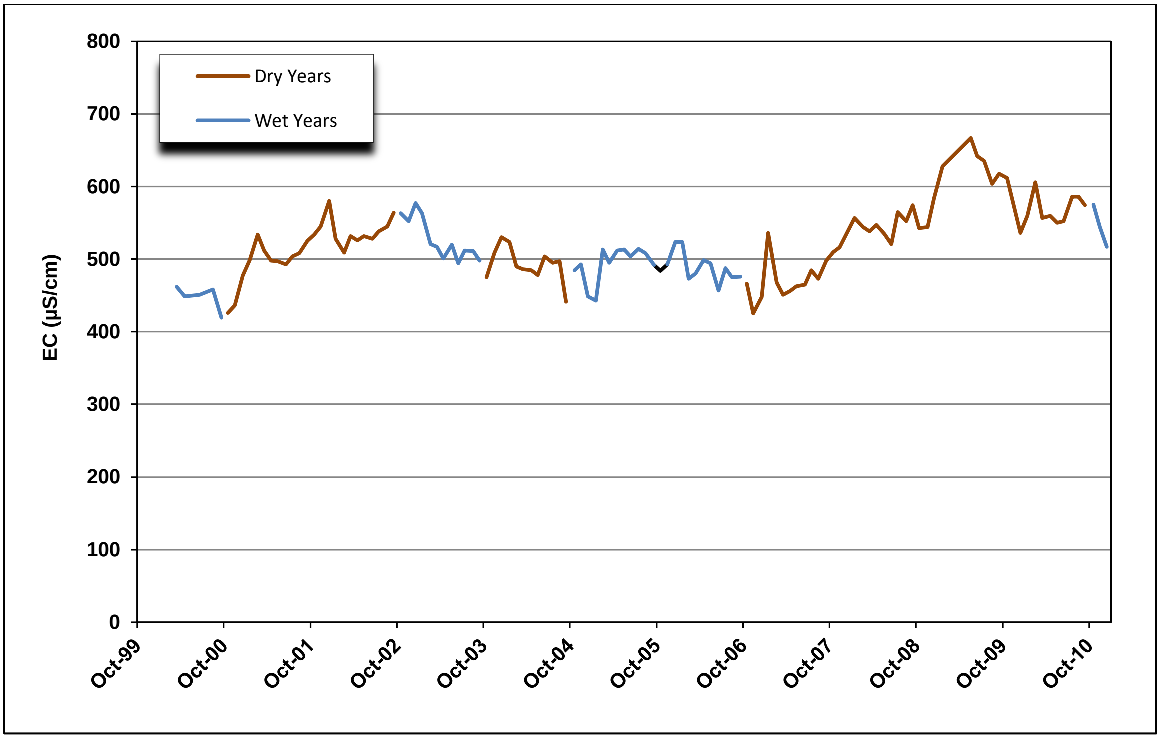


Figure 5-39. Comparison of Pacheco Real-time and Grab Sample EC Data

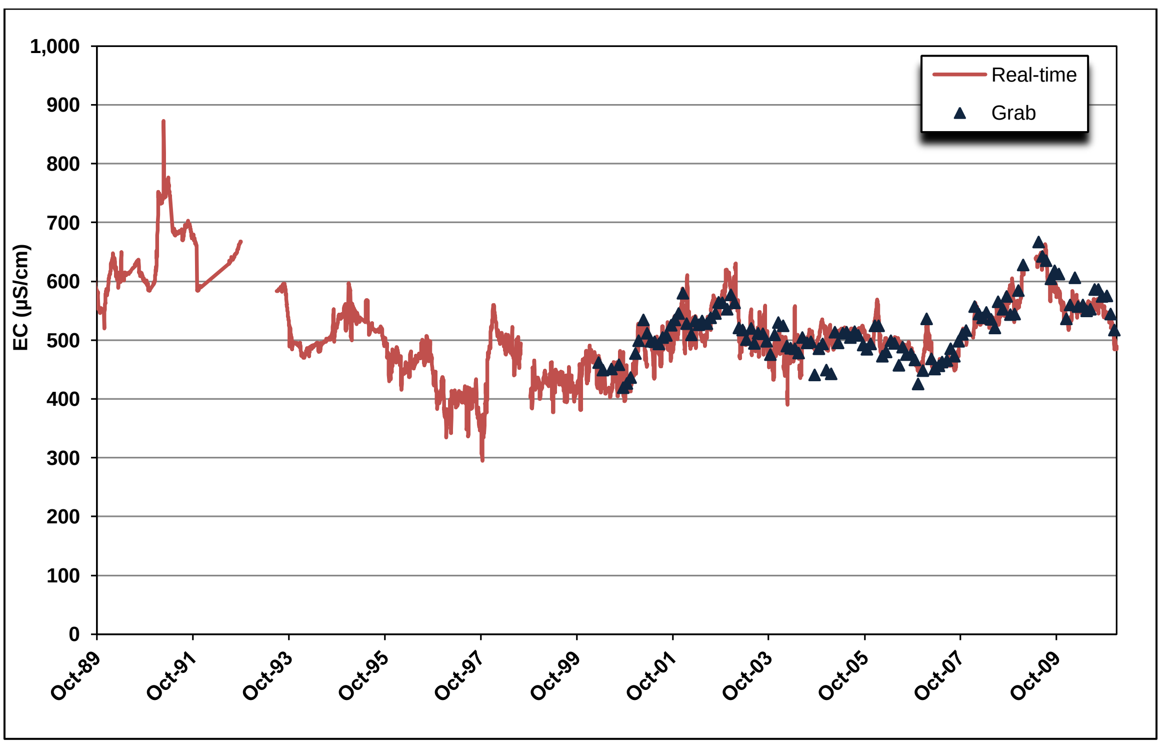


Figure 5-40. Comparison of Pacheco, Banks, and O'Neill EC Levels (1999-2010)

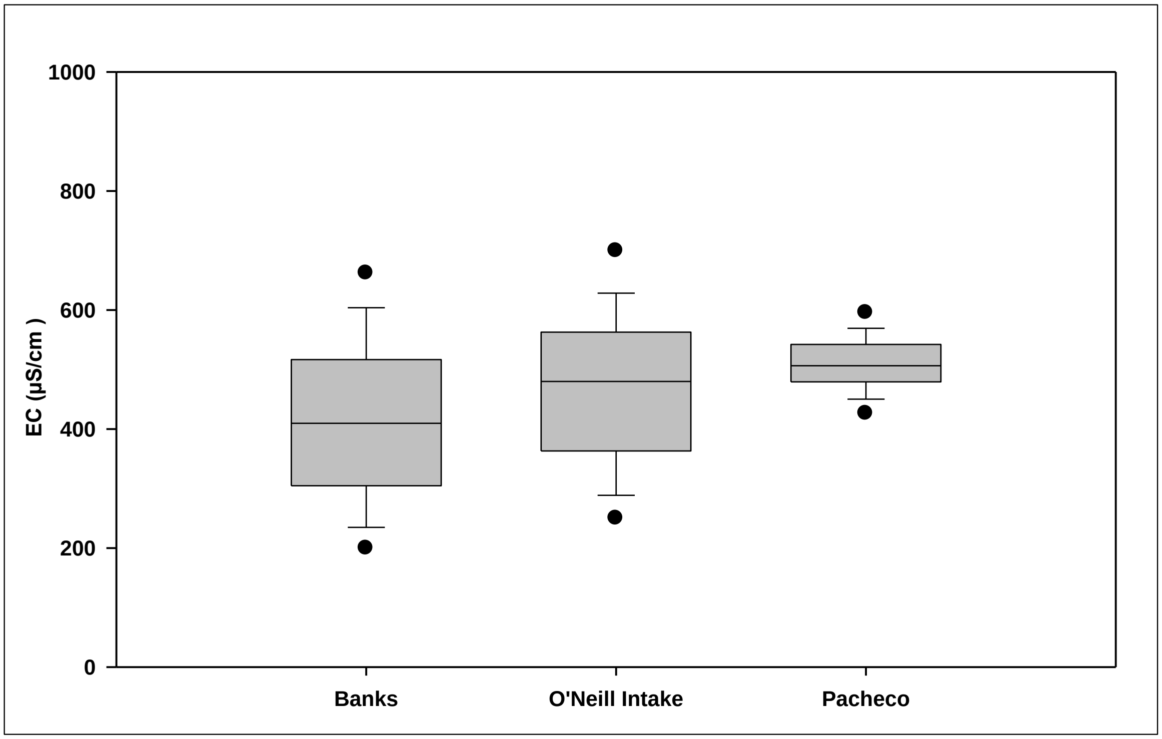
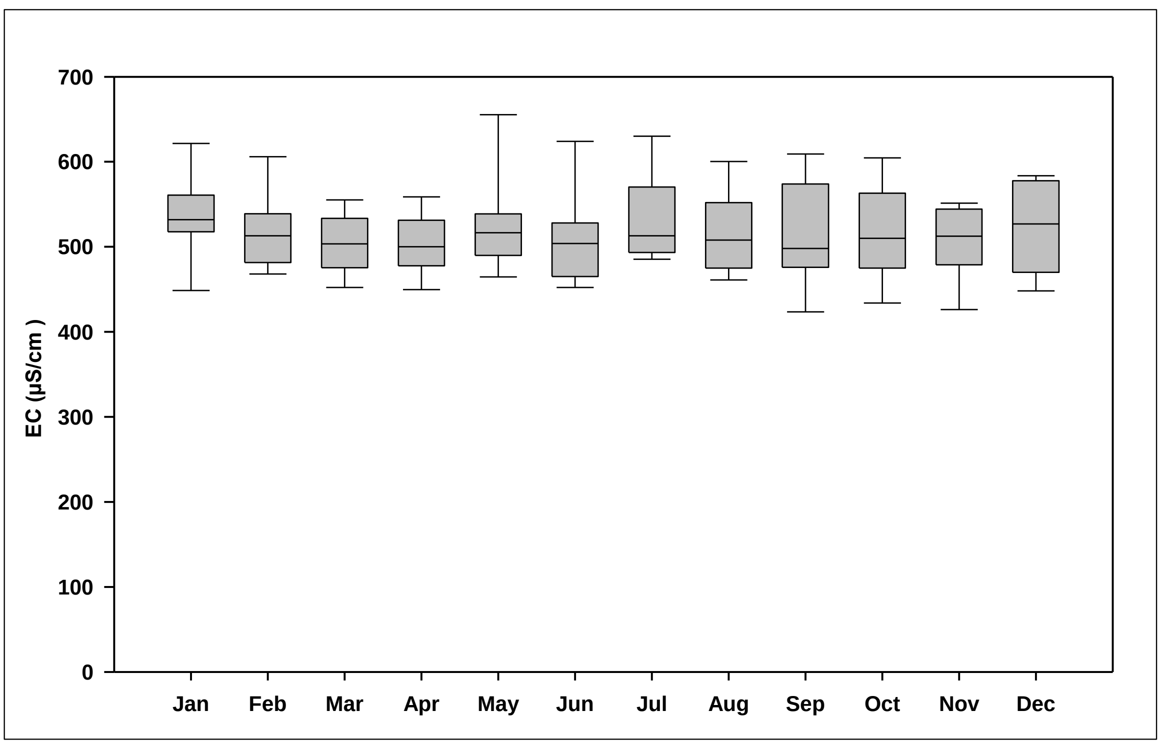


Figure 5-41. Monthly Variability in EC at Pacheco



Note: Insufficient data to plot all percentiles.

O'Neill Forebay Outlet – O'Neill Forebay Outlet on the California Aqueduct is a mixture of water from San Luis Reservoir, the California Aqueduct, and the DMC. **Figure 5-42** presents the EC grab sample data for O'Neill Forebay Outlet. The EC levels at O'Neill Forebay Outlet range from 225 to 824 µS/cm with a median of 481 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-43** shows there is good correspondence between the real-time and grab sample data. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. The real-time measurements captured peak levels above 900 µS/cm in 1990 that were not captured by the grab samples.

- Spatial Trends – **Figure 5-33** compares the real-time data collected between June 1993 and December 2010 at O'Neill Forebay Outlet to a number of other locations along the aqueduct. EC increases between Banks and O'Neill Forebay Outlet due to storage in San Luis Reservoir and to mixing with water from the more saline DMC in O'Neill Forebay. The O'Neill Forebay Outlet median concentration of 455 µS/cm is statistically higher than the Banks median of 392 µS/cm (Mann-Whitney, p=0.0000).

- Long-Term Trends – **Figure 5-43** shows a sharp decline in EC concentrations from 1990 to 1997. As discussed previously, there was a six year drought between 1987 and 1992 with high EC levels at many locations in the SWP. This was followed by a wet period between 1995 and 2006, with low EC levels. The downward trend is a function of hydrology rather than a long-term pattern.

- Wet Year/Dry Year Comparison – The O'Neill Forebay Outlet wet year median EC level of 389 µS/cm is statistically significantly lower than the dry year median of 524 µS/cm (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 5-44** shows there is a distinct seasonal pattern with the lowest concentrations in the summer months and the highest concentrations in the fall. This is similar to the seasonal pattern exhibited at Banks; however, EC levels at O'Neill Forebay Outlet are higher than EC levels at Banks from April to August. Water with EC levels around 500 µS/cm is generally released from San Luis Reservoir during these months.

Figure 5-42. EC Levels at O'Neill Forebay Outlet

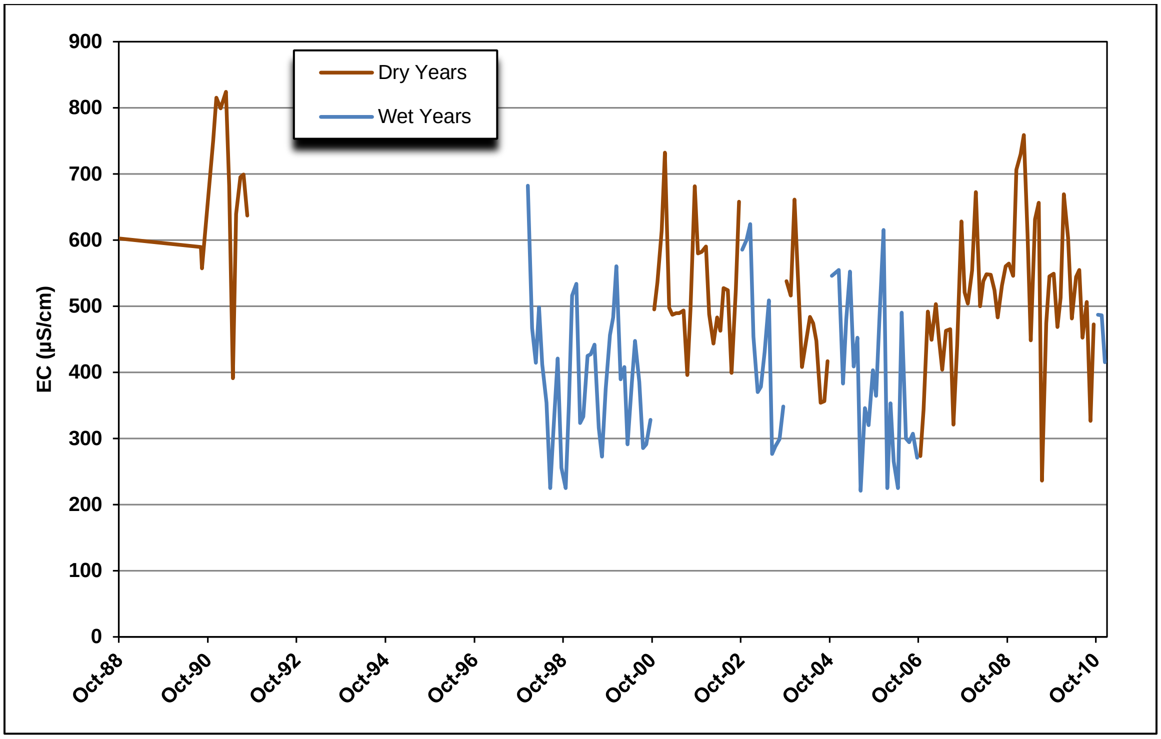


Figure 5-43. Comparison of O'Neill Forebay Outlet Real-time and Grab Sample EC Levels

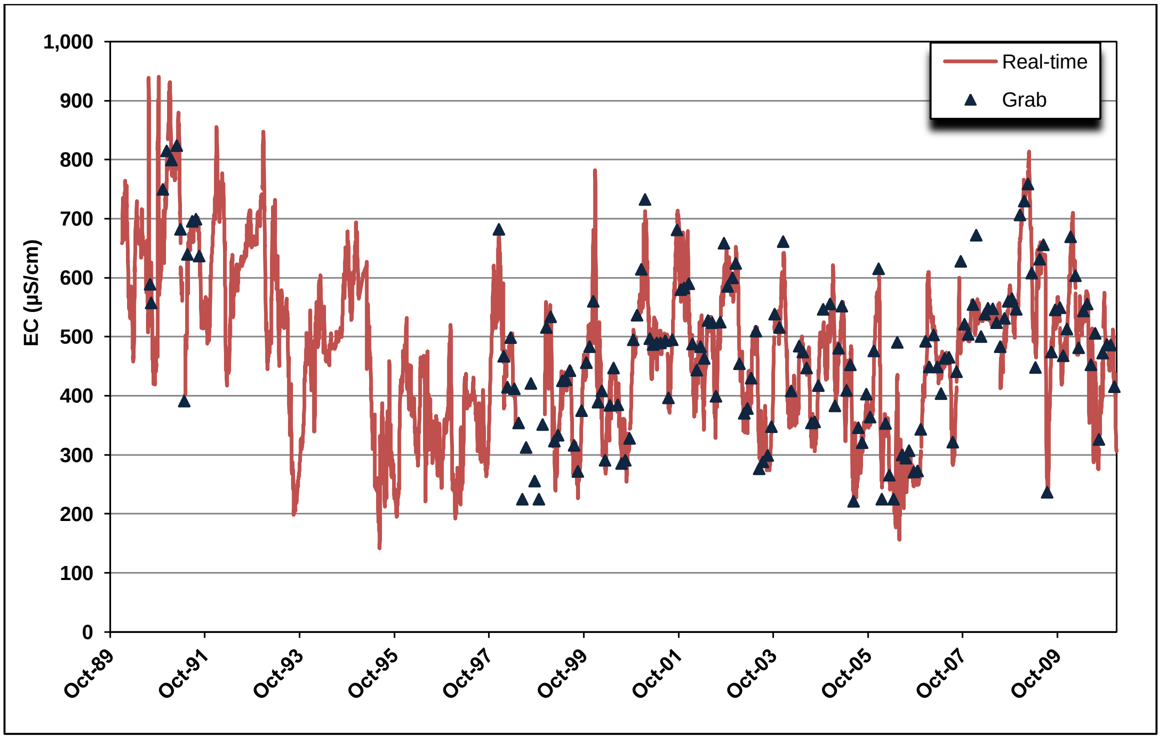
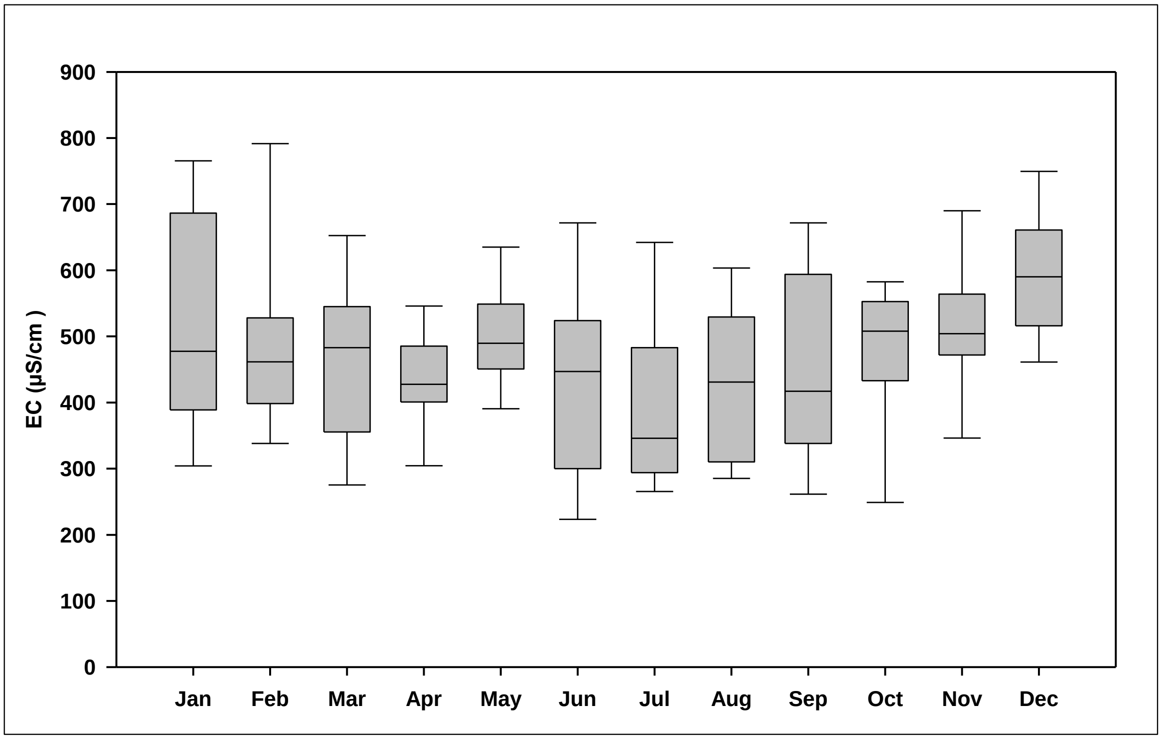


Figure 5-44. Monthly Variability in EC at O'Neill Forebay Outlet



Note: Insufficient data to plot all percentiles.

Check 21 – Check 21 represents the quality of water entering the Coastal Branch. **Figure 5-45** presents the EC grab sample data for Check 21. The EC levels at Check 21 range from 218 to 883 µS/cm with a median of 474 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-46** shows there is good correspondence between the real-time and grab sample data. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. The real-time measurements captured peak levels above 600 µS/cm in several years that were not captured by the grab samples.

- Spatial Trends – **Figure 5-33** compares the real-time data collected between June 1993 and December 2010 at Check 21 to a number of other locations along the aqueduct. Although there are flood and groundwater non-Project inflows into the aqueduct between O'Neill Forebay Outlet and Check 21, the median EC at Check 21 is only 1 µS/cm higher than at O'Neill Forebay Outlet and the variability of the data is similar. The non-Project inflows are discussed more fully in Chapter 14.

- Long-Term Trends – Visual inspection of **Figure 5-45** does not reveal any discernible long-term trend.

- Wet Year/Dry Year Comparison – The Check 21 wet year median EC of 418 µS/cm is statistically significantly lower than the dry year median EC level of 504 µS/cm (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 5-47** shows the same seasonal pattern as O'Neill Forebay Outlet. EC levels are highest in the fall and there is a secondary peak in May and June due to releases from San Luis Reservoir.

Figure 5-45. EC Levels at Check 21

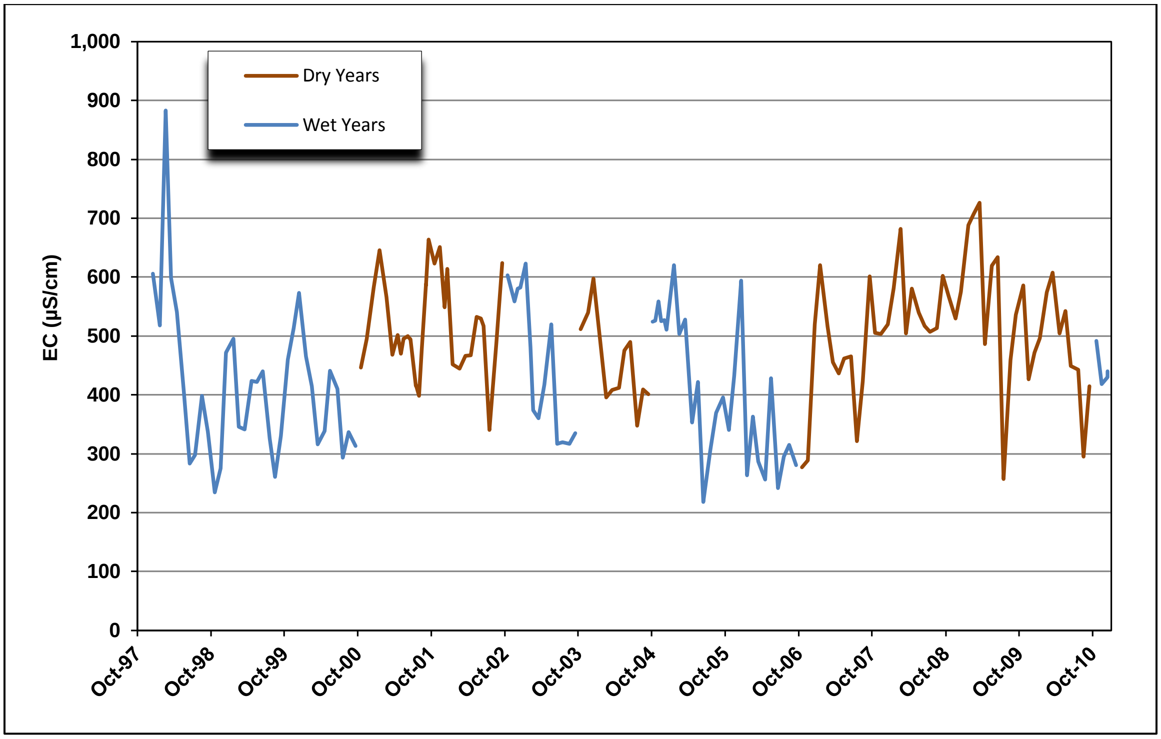


Figure 5-46. Comparison of Check 21 Real-time and Grab Sample EC Levels

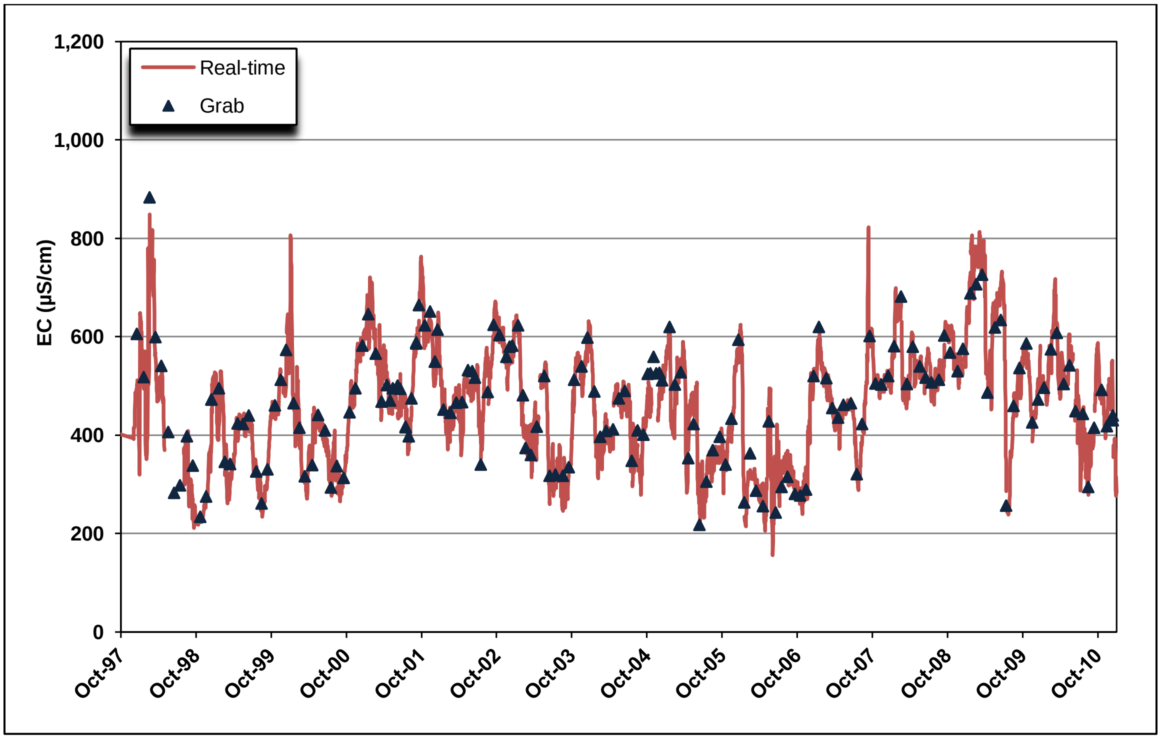
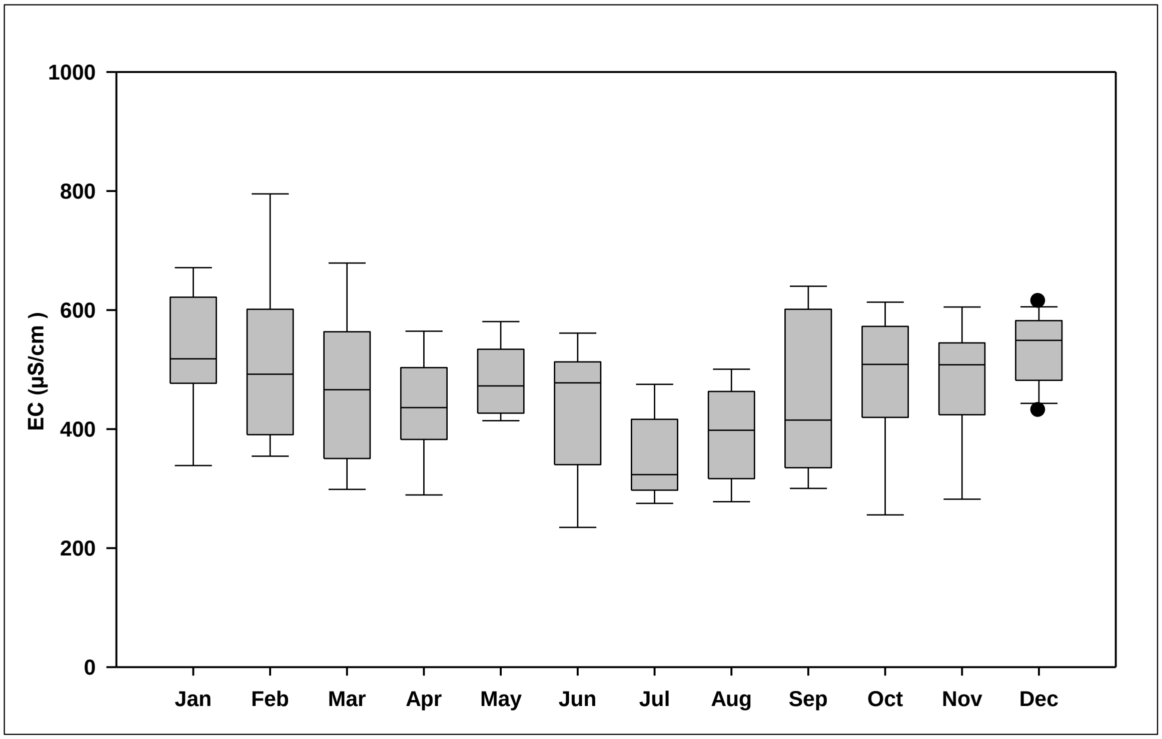


Figure 5-47. Monthly Variability in EC at Check 21



Note: Insufficient data to plot all percentiles.

Check 41 – Check 41 is just upstream of the bifurcation of the aqueduct. **Figure 5-48** presents the EC grab sample data for Check 41. The EC levels at Check 41 range from 106 to 693 µS/cm with a median of 449 µS/cm.

- Comparison of Real-time and Grab Sample Data – **Figure 5-49** shows there is good correspondence between the real-time and grab sample data. Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. The real-time captured peak levels above 600 µS/cm in several years that were not captured by the grab samples. The auto-sample results also show that EC levels were much higher in the early 1990s than in recent years.

- Spatial Trends – **Figure 5-33** compares the real-time data collected between June 1993 and December 2010 at Check 41 to a number of other locations along the aqueduct. This figure shows that EC levels drop between Check 21 and Check 29 and then rise between Check 29 and Check 41. Even with the rise between Check 29 and Check 41, there is still a reduction in EC between Check 21 and Check 41. The median EC of 440 µS/cm at Check 41 is statistically significantly different from the median of 456 µS/cm at Check 21 (Mann-Whitney, p=0.0001). As discussed in Chapter 4, large volumes of groundwater and some surface water enter the aqueduct between Checks 21 and 41. The EC levels of some non-Project inflows are lower than the levels in the aqueduct and the levels of some non-Project inflows are higher than the aqueduct. **Figure 5-50** presents the data for Check 21 and Check 41 for the last five years. From January 2007 to July 2010, the EC levels at Check 41 were substantially lower than the levels at Check 21. This is discussed in more detail in Chapter 14.

- Long-Term Trends – **Figures 5-48 and 5-49** show the same hydrology-based trend as seen at other locations. EC increases during dry years and then decreases during wet year. The wet year decreases are due to a combination of better quality water pumped from the Delta and non-Project inflows with low EC.

- Wet Year/Dry Year Comparison – The Check 41 wet year median EC level of 381 µS/cm is statistically significantly lower than the dry year median EC level of 482 µS/cm (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 5-51** shows the same seasonal pattern as O'Neill Forebay Outlet. EC levels are highest in the fall and there is a secondary peak in May and June due to releases from San Luis Reservoir.

Figure 5-48. EC Levels at Check 41

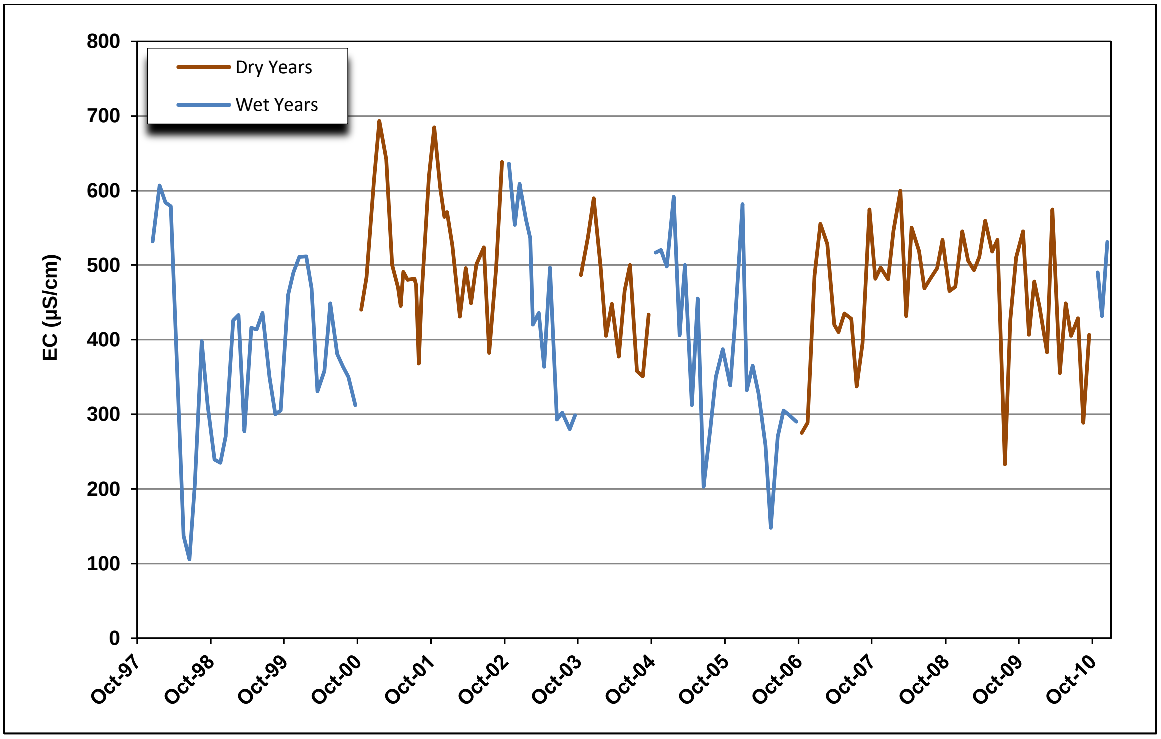


Figure 5-49. Comparison of Check 41 Real-time and Grab Sample EC Levels

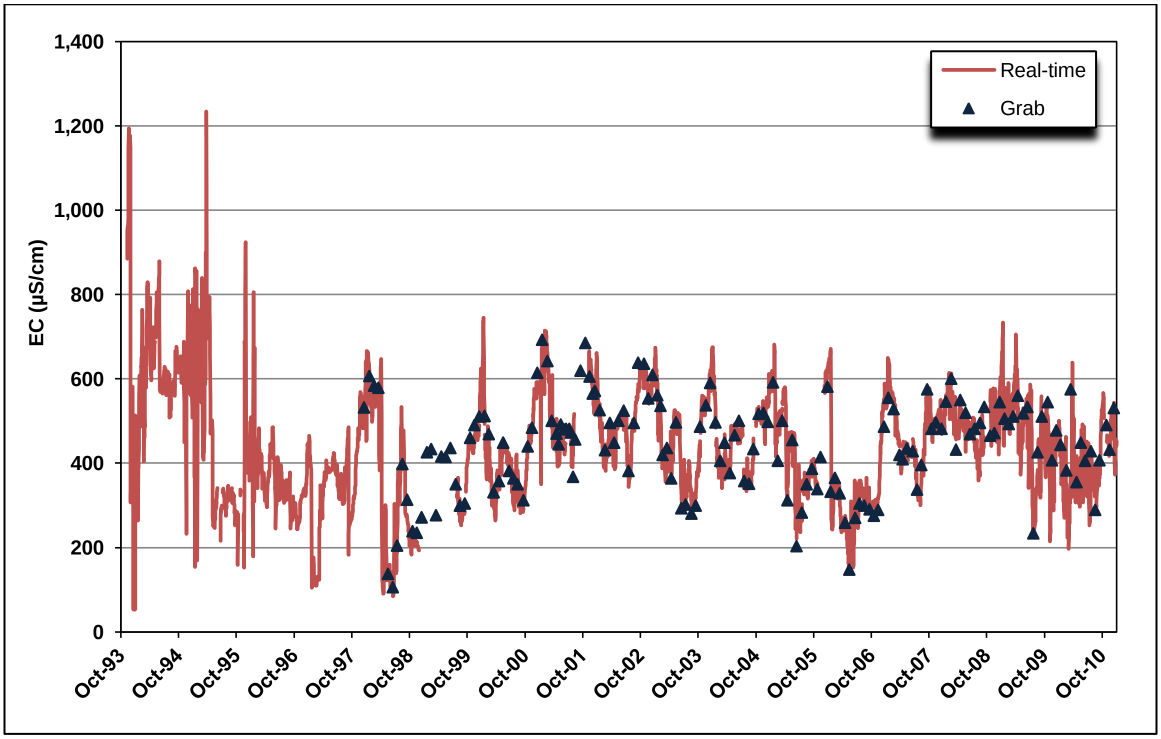


Figure 5-50. Comparison of Check 21 and Check 41 EC Levels

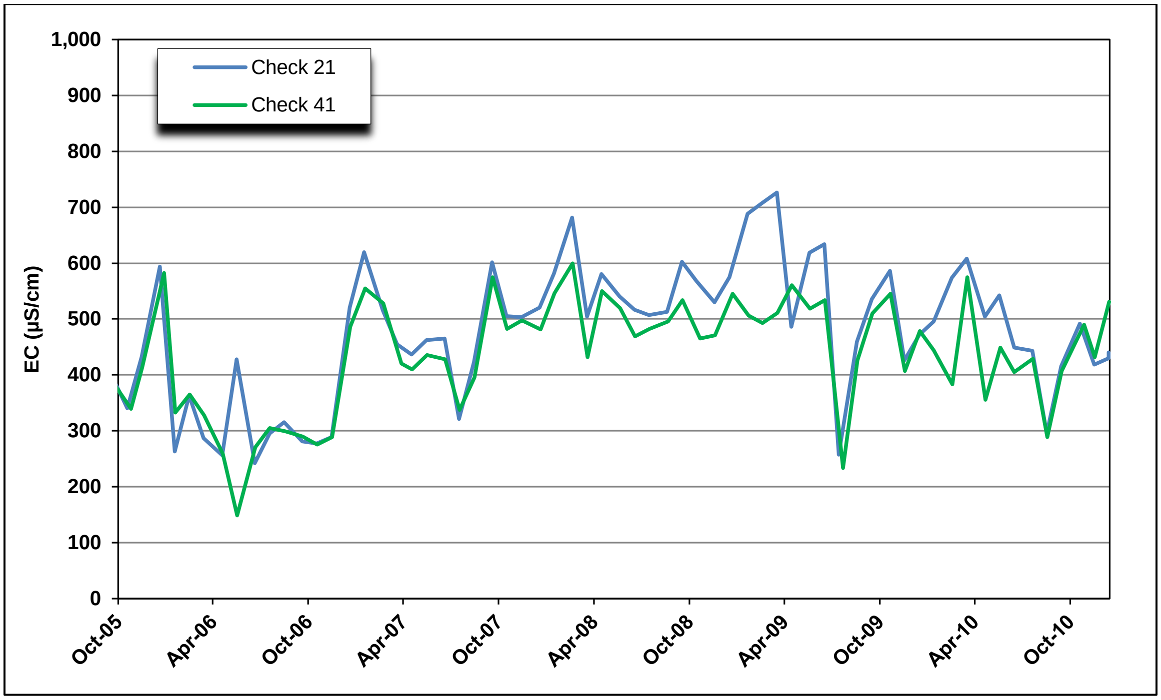
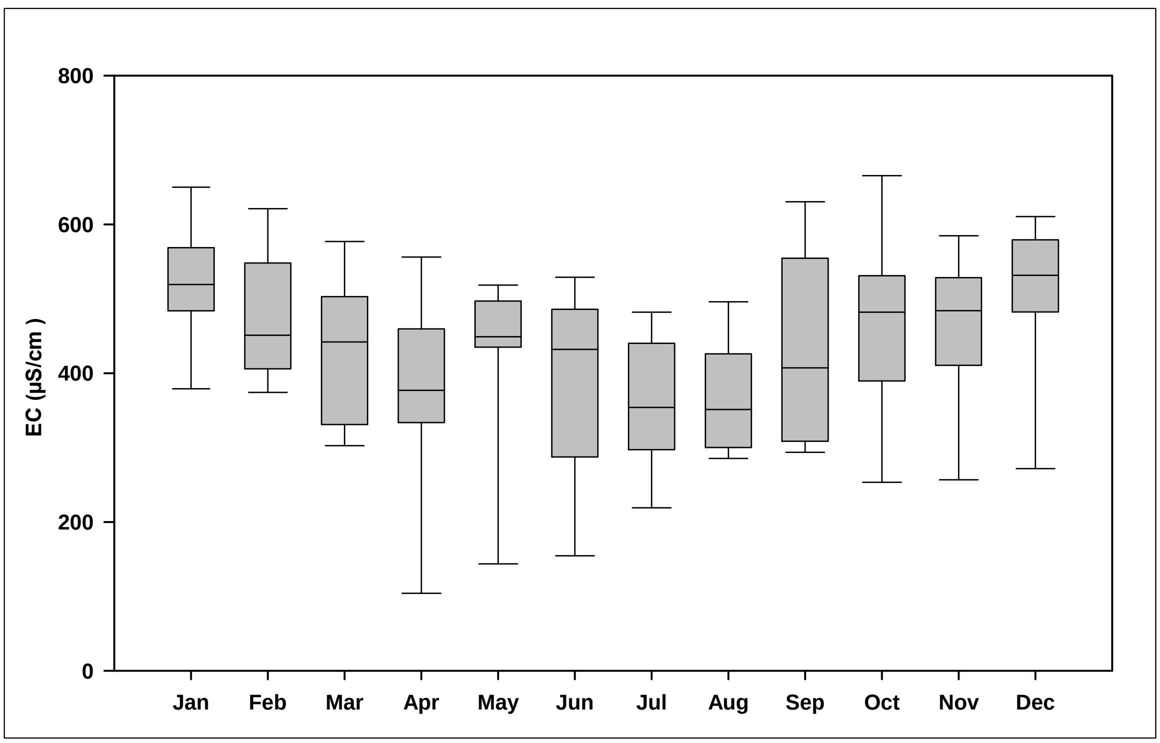


Figure 5-51. Monthly Variability in EC at Check 41



Note: Insufficient data to plot all percentiles.

Castaic Outlet – Castaic Lake is the terminus of the West Branch of the California Aqueduct. **Figure 5-52** presents the EC grab sample data for Castaic Outlet. The EC levels at Castaic Outlet range from 395 to 578 µS/cm with a median of 492 µS/cm. There is much less variability in the EC data in the lake compared to the Aqueduct.

- Comparison of Real-time and Grab Sample Data – Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. **Figure 5-53** shows there is good correspondence between the real-time and grab sample data except for the 2008-2009 period when the real-time appears to have malfunctioned.

- Spatial Trends – **Figure 5-54** compares Check 41 data to Castaic Outlet data. Because samples are collected quarterly at Castaic Outlet and monthly at Check 41, only the quarterly data are included in this analysis. The median EC level of 492 µS/cm at Castaic Outlet is statistically significantly higher than the median EC of 435 µS/cm at Check 41 (Mann-Whitney, p=0.000).

- Long-Term Trends – **Figure 5-52** shows the same hydrology-based trend as seen at other locations. EC increases during dry years and then decreases during wet years.

- Wet Year/Dry Year Comparison – The Castaic Outlet wet year median EC level of 491 µS/cm is not statistically significantly lower than the dry year median of 497 µS/cm (Mann-Whitney, p=0.5631).

- Seasonal Trends – Due to the quarterly sampling, **Figure 5-55** does not show any clear seasonal trend. Examination of the time series data in **Figure 5-53** shows that the highest EC levels occur in May and June and the lowest EC levels occur in November.

Figure 5-52. EC Levels at Castaic Outlet

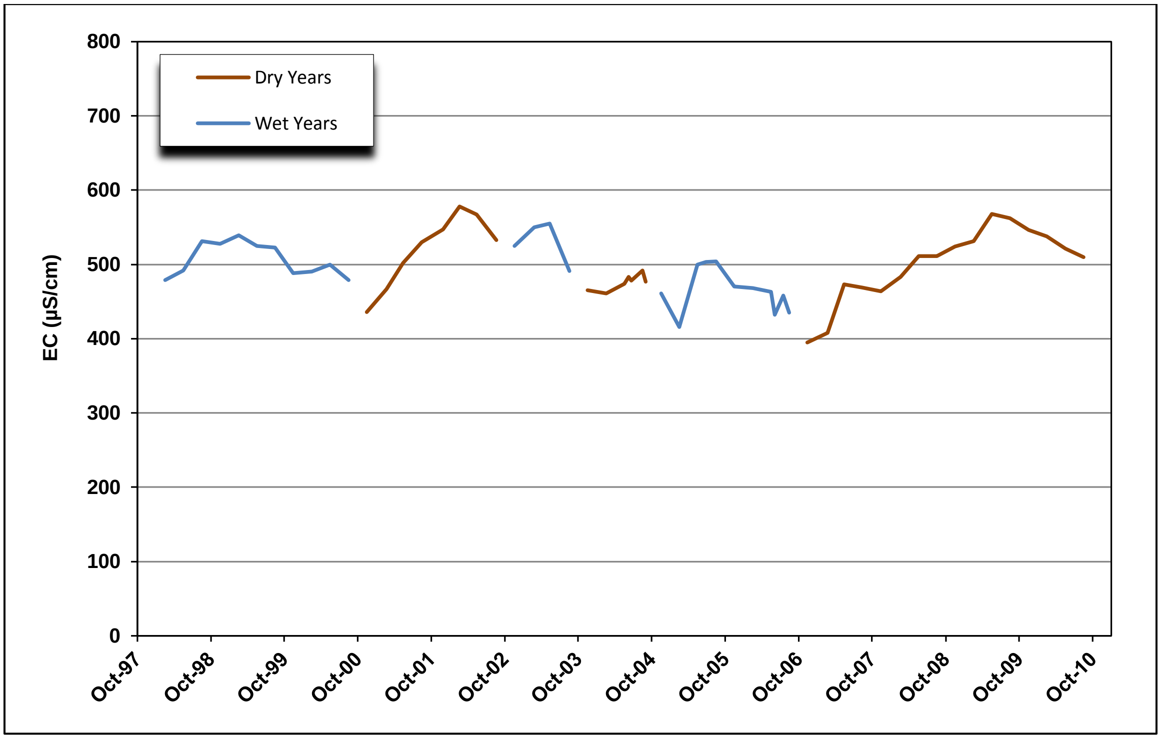


Figure 5-53. Comparison of Castaic Outlet Real-time and Grab Sample EC Levels

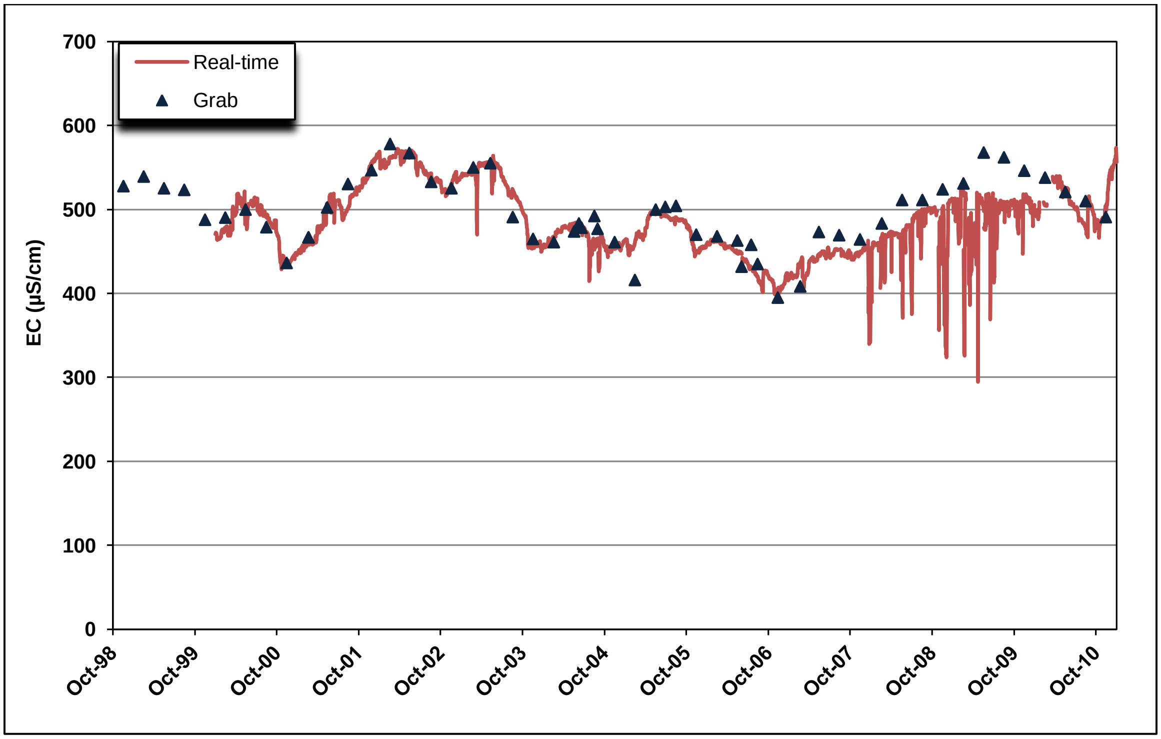


Figure 5-54. Comparison of EC Levels at Check 41 and Castaic Outlet (1998-2010)

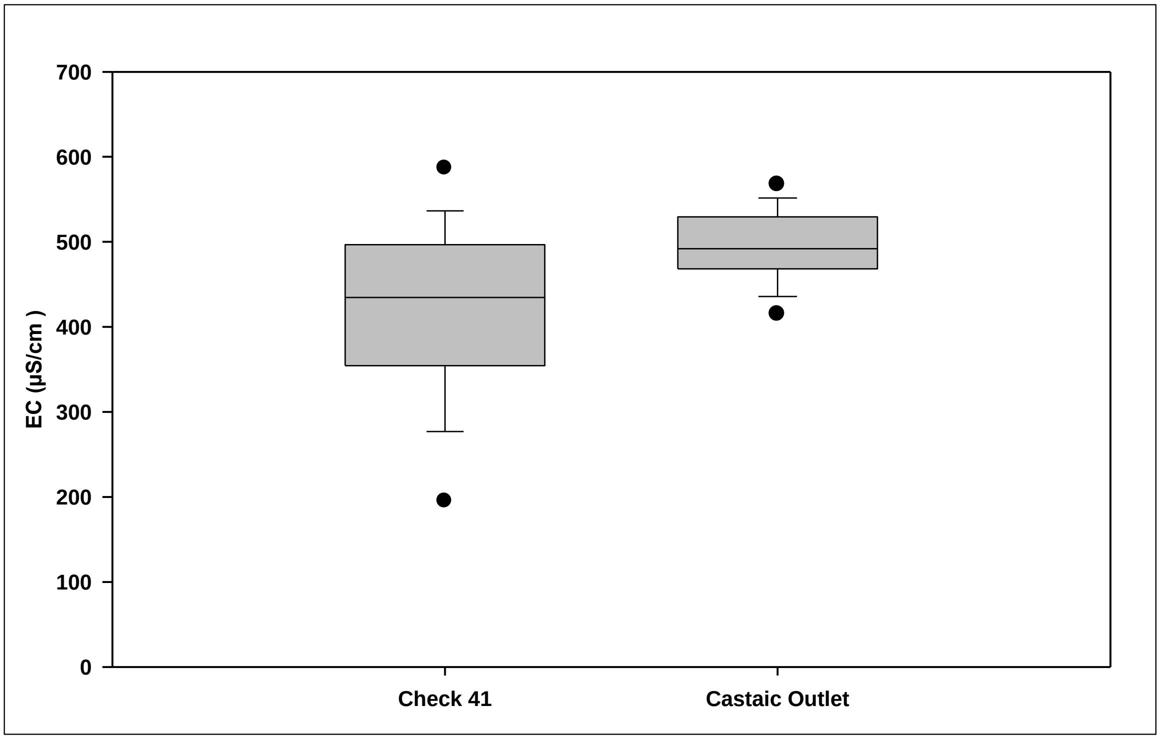
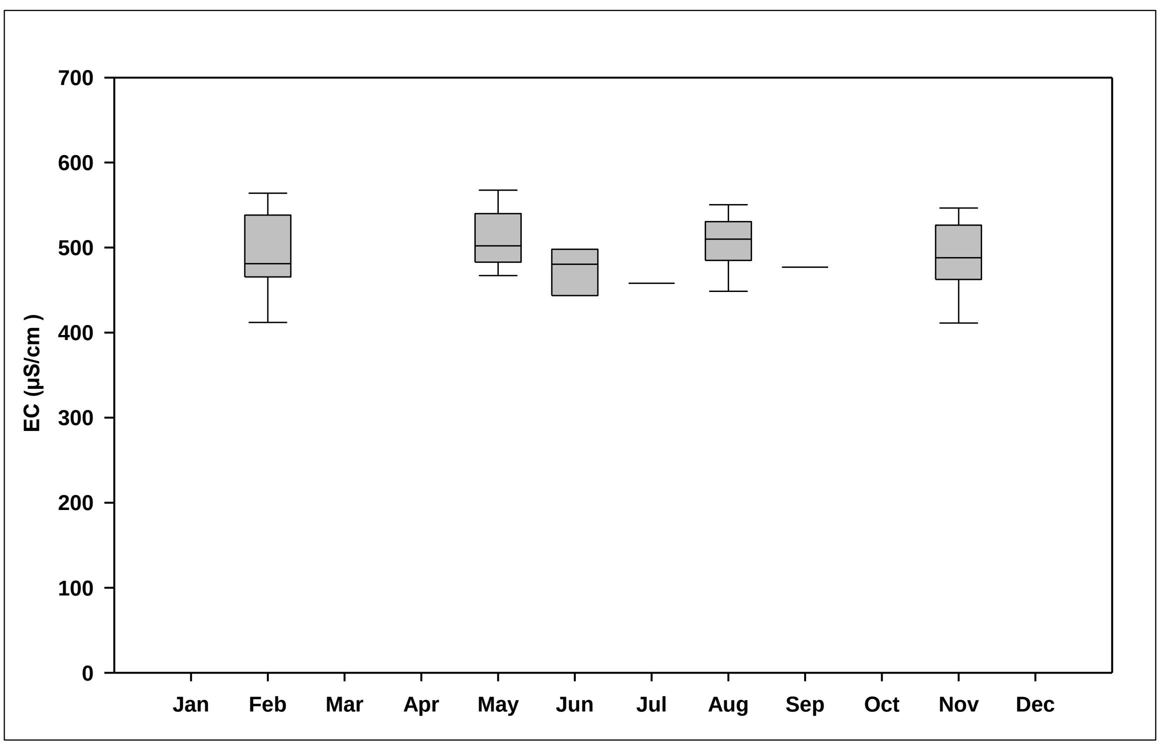


Figure 5-55. Monthly Variability in EC at Castaic Outlet



Note: Note: Insufficient data to plot all percentiles. Data are not collected in all months at Castaic Outlet. A flat line indicates one sample.

Devil Canyon – Devil Canyon Afterbay is downstream of Silverwood Lake on the East Branch of the California Aqueduct. **Figure 5-51** presents the EC grab sample data for Devil Canyon. The EC levels at Devil Canyon range from 206 to 615 µS/cm with a median of 442 µS/cm.

- Comparison of Real-time and Grab Sample Data – Average daily EC, calculated from hourly measurements, was downloaded from CDEC for this analysis. **Figure 5-52** shows there is good correspondence between the real-time and grab sample data; however the real-time data show that peak EC levels are often higher than those captured by the grab sample data.

- Spatial Trends – **Figure 5-32** compares Check 41 data to Devil Canyon data for the 1997 to 2010 period when data are available at both locations. The median EC level of 442 µS/cm at Devil Canyon is not statistically significantly different than the median EC of 449 µS/cm at Check 41(Mann-Whitney, p=0.7540).

- Long-Term Trends – **Figure 5-51** shows the same hydrology-based trend as seen at other locations. EC increases during dry years and then decreases during wet years.

- Wet Year/Dry Year Comparison – The Devil Canyon wet year median EC level of 387 µS/cm is statistically significantly lower than the dry year median of 482 µS/cm (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 5-52** shows the same bimodal seasonal pattern that exists in the aqueduct, with concentrations increasing through the fall months to a peak in January, followed by declining concentrations in the late winter and early spring, followed by a secondary peak in May and June. EC levels are lowest in August, about one month later than at O'Neill Forebay Outlet.

Figure 5-56. EC Levels at Devil Canyon

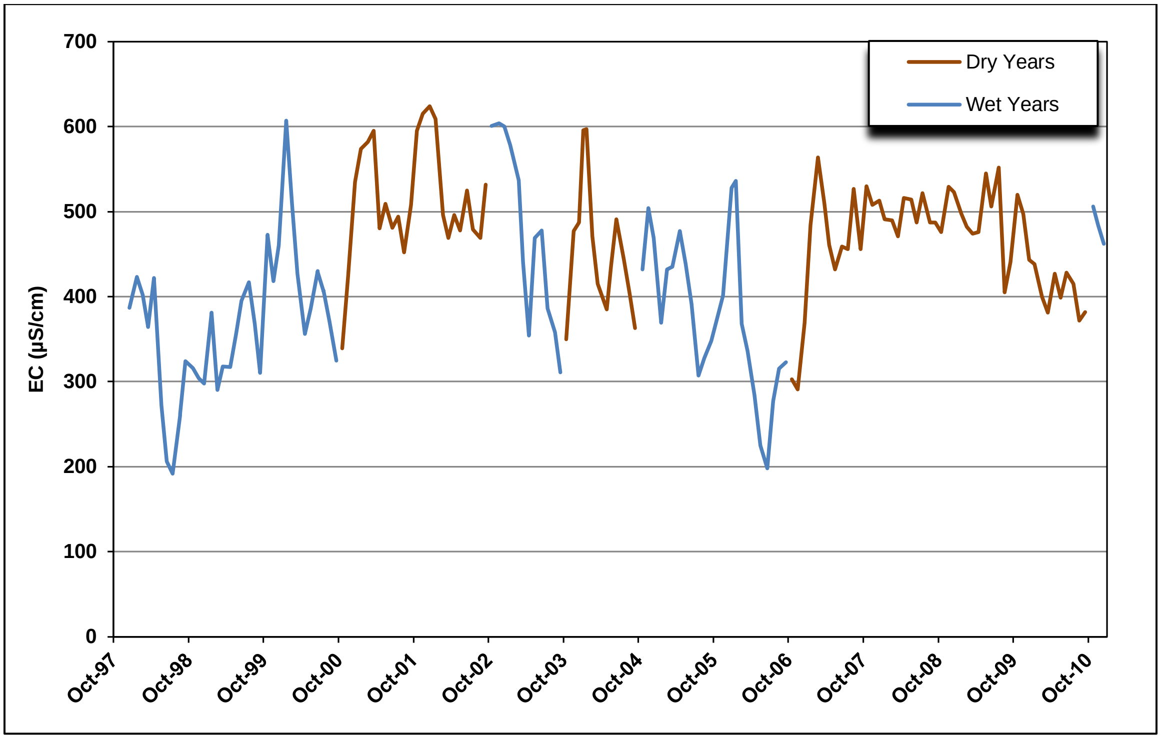


Figure 5-57. Comparison of Devil Canyon Real-time and Grab Sample EC Levels

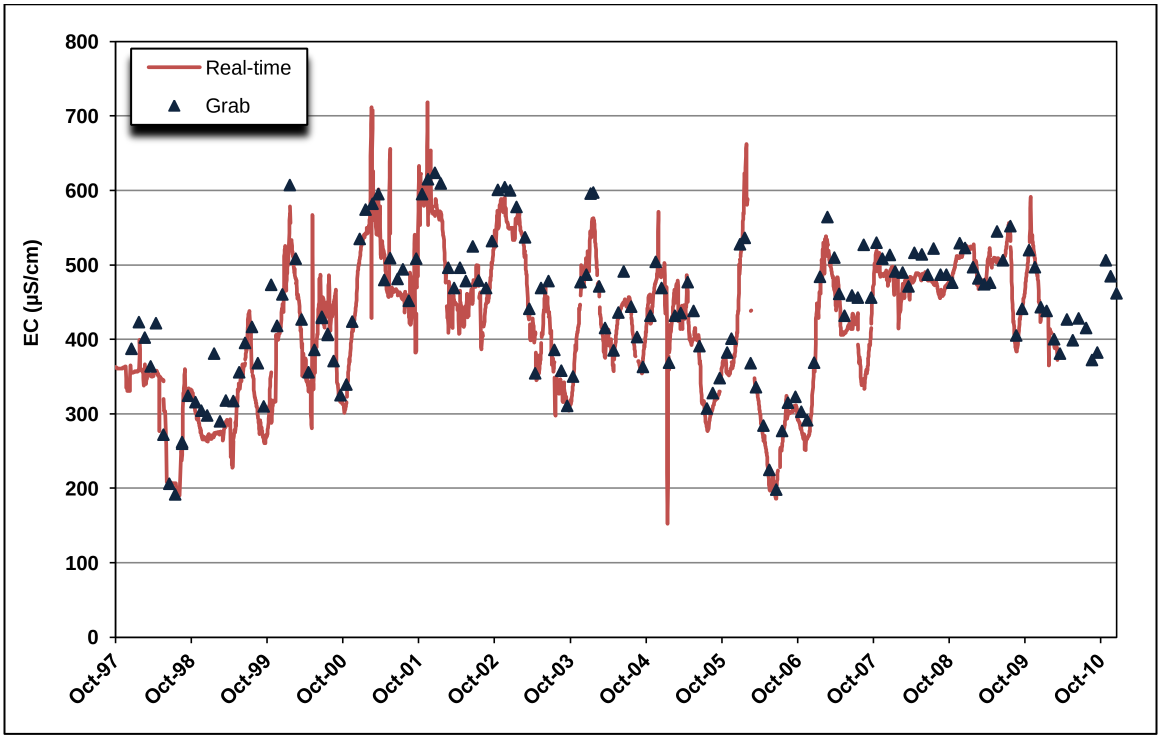
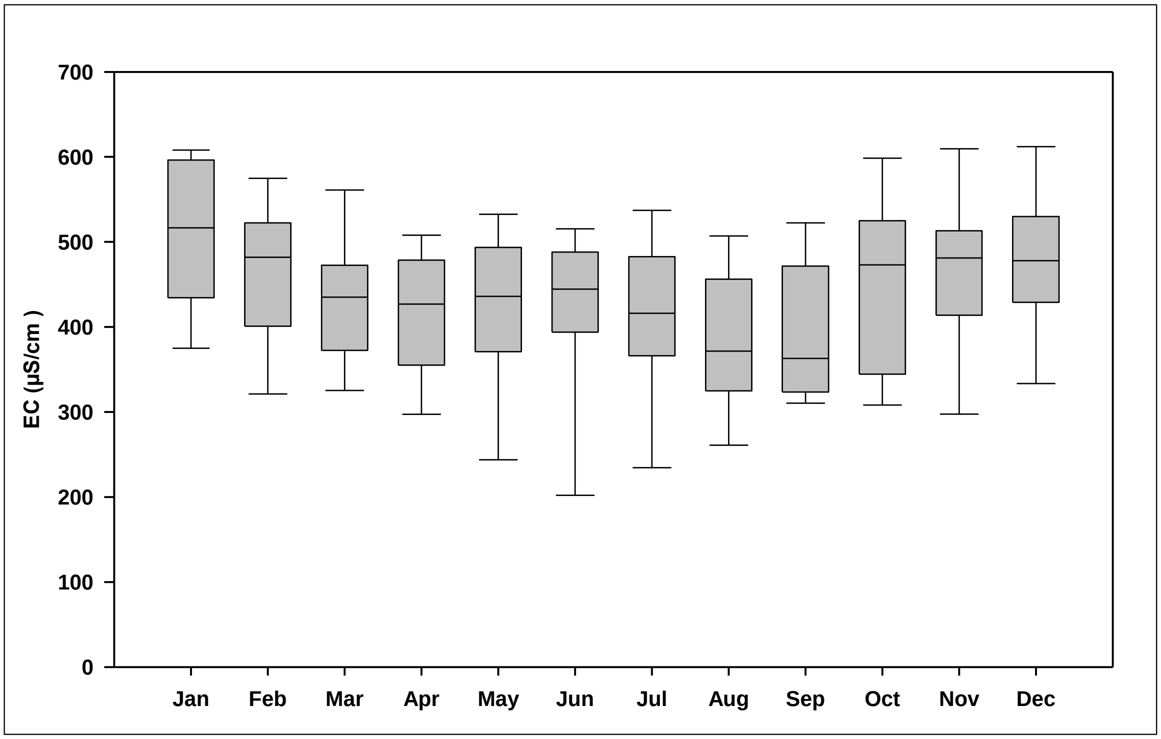


Figure 5-58. Monthly Variability in EC at Devil Canyon



Note: Insufficient data to plot all percentiles.

SUMMARY

- The EC fingerprints indicate that the San Joaquin River, seawater intrusion, and Delta agricultural drainage are the primary sources of EC at the south Delta pumping plants. The San Joaquin River has a greater influence on EC at Jones than at Banks.

- The median EC at Hood (158 µS/cm) is statistically significantly lower than the median of 163 µS/cm at West Sacramento when data from the same period of record are compared. This small decrease in the median level is due to the inflow of the American River (median EC of 62 µS/cm). The decrease is lower than expected and probably due to the discharge of Sacramento area urban runoff and treated wastewater to the river. EC levels at Vernalis (median of 629 µS/cm) are statistically significantly higher than the levels in the Sacramento River.

- EC levels in the NBA are higher and more variable than at Hood but lower than the levels at Banks. Peak EC levels are found in April with a clear indication that the local Barker Slough watershed is a contributor of salinity. The real-time results reveal a small but statistically significant decrease in EC between Barker Slough (277 µS/cm) and Cordelia (266 µS/cm).

- The median EC at Banks (408 µS/cm) is statistically significantly lower than the median EC at Jones (457 µS/cm) due to the greater influence of the San Joaquin River at Jones. EC does not change significantly between Banks, DV Check 7, and the Terminal Tank on the SBA. EC changes in the California Aqueduct and SWP reservoirs are complex. Because different periods of record are available at sampling locations, varying time periods are used to compare locations and each time period has a different median at any given location. Consequently, the changes in the aqueduct and reservoirs are described in terms of the increase or decrease in EC levels rather than by comparing medians in this summary. There is an increase of 97 µS/cm in EC between Banks and Pacheco; however the variability of EC in the reservoir is greatly reduced. The increase between Banks and Pacheco is due to evaporation in the reservoir, the timing of filling the reservoir, and the mixing of DMC water with aqueduct water in O’Neill Forebay. EC increases along the DMC by 29 µS/cm between Jones and O’Neill Intake. There is an increase of 63 µS/cm between Banks and O’Neill Forebay Outlet and no statistically significant change in EC between O’Neill Forebay Outlet and Check 21. There is a statistically significant decrease in EC between Check 21 and Check 41 of 16 µS/cm. This is likely due to the non-Project inflows of lower EC water in recent years. The median EC at Castaic Outlet is 57 µS/cm higher than at Check 41 but there is no statistically significant change between Check 41 and Devil Canyon. EC levels at Castaic Outlet are less variable than the aqueduct locations, due to the dampening effect of about 500,000 acre-feet of storage on the West Branch. The dampening effect is not seen in Silverwood Lake on the East Branch due to its limited hydraulic residence time.

- There are a number of real-time monitoring locations in the watersheds, along the California Aqueduct, and in the reservoirs. There is good correspondence between the grab sample and real-time EC data at most locations. There are differences at Vernalis, Banks, Cordelia, and Devil Canyon. The EC levels in grab samples at Cordelia are substantially higher than those measured by the real-time equipment. This warrants some investigation because there is good correspondence between the real-time data at Barker Slough and at Cordelia. Cordelia is a small forebay so it's difficult to explain why there would be such a difference between the real-time and grab sample data. The real-time data at most other locations show that peak EC levels are slightly higher than those measured in the grab samples. This is likely due to the sampling frequency, with the real-time instruments capturing peaks that occur between the days that grab samples are collected.

- DWR (2004) conducted an assessment of long-term salinity trends at Banks using data from 1970 to 2002 and concluded that the salinity in SWP exports has neither increased nor decreased over that period. Time series graphs at each key location were visually inspected to determine if there are any discernible trends. The only trends observed in the data are related to hydrology, with EC increasing during dry years and decreasing during wet years.

- EC levels during wet years are statistically significantly lower than EC levels during dry years at all locations except Barker Slough and Castaic Outlet, as shown in Table 5-3. The higher levels during dry years are due to less dilution of agricultural drainage, urban runoff, and treated wastewater discharged to the rivers and Delta during low flow periods and to seawater intrusion in the Delta during periods of low Delta outflow. Barker Slough is influenced more by the local watershed than by differences in Delta conditions in different year types. There is little variability in Castaic due to the dampening effects of storage.

- There are distinct seasonal patterns in EC levels but they vary between locations. On the Sacramento River, EC levels are lowest in the early summer, increase in the fall and then decrease during the spring months. On the San Joaquin River, EC levels are lowest in the spring during the VAMP flows, increase during the summer months due to agricultural drainage discharges, continue to climb during the fall due to seawater intrusion, and remain high until late winter or early spring when flow increases on the river. The seasonal pattern at Banks is similar to the Sacramento River with the lowest levels in July and the highest levels in the fall months. The pattern seen at Banks is seen at most of the other locations except below San Luis Reservoir there is a bimodal seasonal pattern with a secondary peak in EC during May and June. Large amounts of water are released from the reservoir during these months, resulting in higher EC levels in the California Aqueduct.

Table 5-3. Comparison of Dry Year and Wet Year EC Levels

Location	Median EC (μS/cm)		EC Difference (μS/cm)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	168	146	22	13	D>W
Vernalis	745	456	289	39	D>W
Banks	497	312	185	37	D>W
Barker	298	283	15	5	No
DV Check 7	452	311	141	31	D>W
McCabe	516	359	157	30	D>W
Pacheco	528	499	29	5	D>W
O'Neill Forebay Outlet	524	389	135	26	D>W
Check 21	504	418	86	17	D>W
Check 41	482	381	101	21	D>W
Castaic Outlet	497	491	6	1	No
Devil Canyon	482	387	95	20	D>W

REFERENCES

Literature Cited

California Department of Water Resources. 2004. Factors Affecting the Composition & Salinity of Exports from the South Sacramento-San Joaquin Delta.

CHAPTER 6 BROMIDE

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FIGURES

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CHAPTER 6 BROMIDE

WATER QUALITY CONCERN

Bromide is of concern to State Water Project (SWP) Contractors because it reacts with oxidants used for disinfection in water treatment to form disinfection byproducts (DBPs). When chlorine is used as a disinfectant, bromide reacts with chlorine and TOC to form brominated trihalomethanes (THMs) and haloacetic acids (HAA5s). The Stage 1 Disinfectants and Disinfection Byproduct (D/DBP) Rule limits the concentration of total trihalomethanes (TTHMs) to 0.080 mg/L and HAA5 to 0.060 mg/L as a running annual average in drinking water distribution systems. Three of the four regulated trihalomethanes, bromodichloromethane, dibromochloromethane, and bromoform contain bromide and two of the regulated HAA5s, monobromoacetic acid and dibromoacetic acid contain bromide. Another DBP, bromate, is formed when ozone is used for disinfection. The Stage 1 Maximum Contaminant Level (MCL) for bromate is 0.010 mg/L, measured at the entrance to the distribution system. Compliance with the Stage 1 and Stage 2 D/DBP Rules presents challenges for the SWP Contractors whose source water contains both bromide and organic carbon.

WATER QUALITY EVALUATION

BROMIDE CONCENTRATIONS IN THE SWP

Bromide data are analyzed in this section to examine changes in bromide as the water travels through the SWP system and to determine if there are seasonal or temporal trends. All available bromide data from the Department of Water Resources (DWR's) Municipal Water Quality Investigations (MWQI) Program and the Division of Operations and Maintenance (O&M) SWP monitoring program through December 2010 were obtained for a number of locations along the SWP. Both grab samples and real-time data are included in this analysis. Data are presented in summary form for all locations and analyzed in more detail for a number of key locations. **Table 6-1** shows the period of record for data at each location that was evaluated.

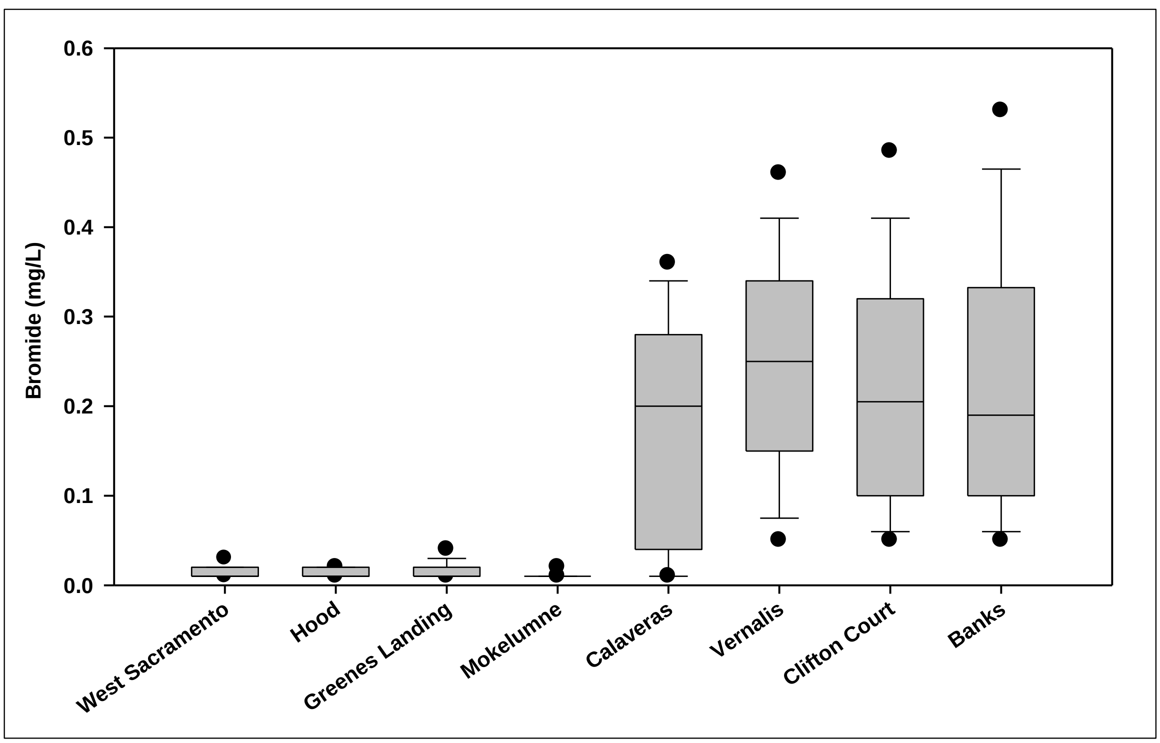
Table 6-1. Bromide Data

Location	Grab Samples			Real-time	
	No. of Samples	Start Date	End Date	Start Date	End Date
West Sacramento	254	Apr 1994	Dec 2010		
American	277	May 1990	Dec 2010		
Hood	463	Aug 1997	Dec 2010		
Greenes Landing	148	Jan 1990	May 1998		
Mokelumne	44	Dec 2008	Dec 2010		
Calaveras	39	Dec 2008	Nov 2010		
Vernalis	613	Jan 1990	Dec 2010	Jun 2006	Dec 2010
Clifton Court	170	Feb 1990	Dec 2010		
Banks	314	Feb 1991	Dec 2010	May 2006	Dec 2010
Barker Slough	261	Feb 1990	Dec 2010		
Cordelia	35	Aug 2000	Nov 2010		
DV Check 7	142	Dec 1997	Oct 2010		
Conservation Outlet	47	Feb 1998	Dec 2010		
Terminal Tank	60	Feb 1998	Oct 2010		
Jones	14	Mar 2009	Dec 2010		
McCabe	160	Dec 1997	Jan 2007		
Pacheco	108	Mar 2000	Dec 2010		
O'Neill Forebay Outlet	166	Aug 1990	Dec 2010		
Check 21	162	Feb 1998	Dec 2010		
Check 29	179	Jan 1999	Dec 2010		
Check 41	164	Dec 1997	Dec 2010		
Castaic Outlet	135	Nov 1998	Dec 2010		
Silverwood	121	Feb 1999	Dec 2010		
Devil Canyon Headworks	116	Jun 2001	Dec 2010		
Devil Canyon Afterbay	43	Dec 1997	May 2001		
Perris Outlet	136	Feb 1999	Dec 2010		

The SWP Watershed

Figure 6-1 presents the bromide data for the tributaries to the Sacramento-San Joaquin Delta (Delta), Clifton Court Forebay (Clifton Court) and the Harvey O. Banks Delta Pumping Plant (Banks). The American River is not shown on this figure because with the exception of one sample, all measurements were below the detection limit of 0.01 mg/L. **Figure 6-1** clearly demonstrates that bromide concentrations in the Sacramento River are quite low, with a median concentration of 0.01 mg/L at West Sacramento, Hood, and Greenes Landing. There is little variability in the bromide concentrations in the Sacramento River because it is not substantially impacted by seawater intrusion at the three sites that are shown in the figure. The maximum concentration ever measured was 0.09 mg/L in November 1997 at Greenes Landing. Due to the low levels of bromide in the Sacramento River, the data were not analyzed to evaluate seasonal and spatial trends. Bromide data have been collected twice a month from the Mokelumne and Calaveras rivers since December 2008. The limited data show that the Mokelumne median bromide is low at 0.01 mg/L whereas the Calaveras bromide median is 0.2 mg/L. The San Joaquin River at Vernalis (Vernalis) has the highest median concentration in the watershed (0.25 mg/L).

Figure 6-1. Bromide Concentrations in the SWP Watershed



Vernalis – **Figure 6-2** shows all available grab sample bromide data at Vernalis. The levels range over an order of magnitude from 0.02 to 0.65 mg/L during the period of record with a median of 0.25 mg/L.

- Comparison of Real-time and Grab Sample Data – **Figure 6-3** compares the real-time data with the grab sample data at Vernalis. Bromide is measured hourly with the Dionex analyzer. MWQI staff provided average daily concentrations calculated from the hourly measurements for this analysis. There is generally a good correspondence between the two data sets with the exception of the first year that the real-time equipment was operating. DWR conducted a thorough analysis of the anion analyzers at Banks and Vernalis and concluded that they performed well (DWR, 2008).

- Spatial Trends – DWR does not collect data upstream of Vernalis on the San Joaquin River.

- Long-Term Trends – Visual inspection of **Figure 6-2** shows a downward trend in the data. This is a function of the hydrology of the system. Bromide data were first collected at Vernalis during the drought years of the early 1990s when bromide levels were high.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median concentration during dry years of 0.30 mg/L is statistically significantly higher than the median during wet years of 0.17 mg/L (Mann-Whitney, p=0.0000). **Figure 6-4** shows the relationship between flow and bromide concentrations at Vernalis. This figure indicates that bromide concentrations vary over a wide range at low flows but once flow on the San Joaquin River exceeds 5,000 cubic feet per second (cfs), bromide concentrations drop below 0.20 mg/L.

- Seasonal Trends – **Figure 6-5** indicates that the lowest bromide concentrations occur during April and May when flows on the San Joaquin River are high due to the Vernalis Adaptive Management Plan (VAMP). Flows are increased on the San Joaquin River between April 15 and May 15 of each year by releasing water from reservoirs on the Merced, Stanislaus, and Tuolumne rivers. Combined exports at the Banks and Jones pumping plants are reduced to 1,500 cfs. These actions that are taken to improve salmon smolt survival also improve water quality. Concentrations increase during the summer and fall months with the highest median concentrations of 0.33 mg/L in December and 0.32 mg/L in January. The primary source of bromide at Vernalis is agricultural irrigation waters diverted from the Delta at Jones and returned to the river as drainage. During the summer and fall months, there is minimal flow in the river to dilute the agricultural drainage.

Figure 6-2. Bromide Concentrations at Vernalis

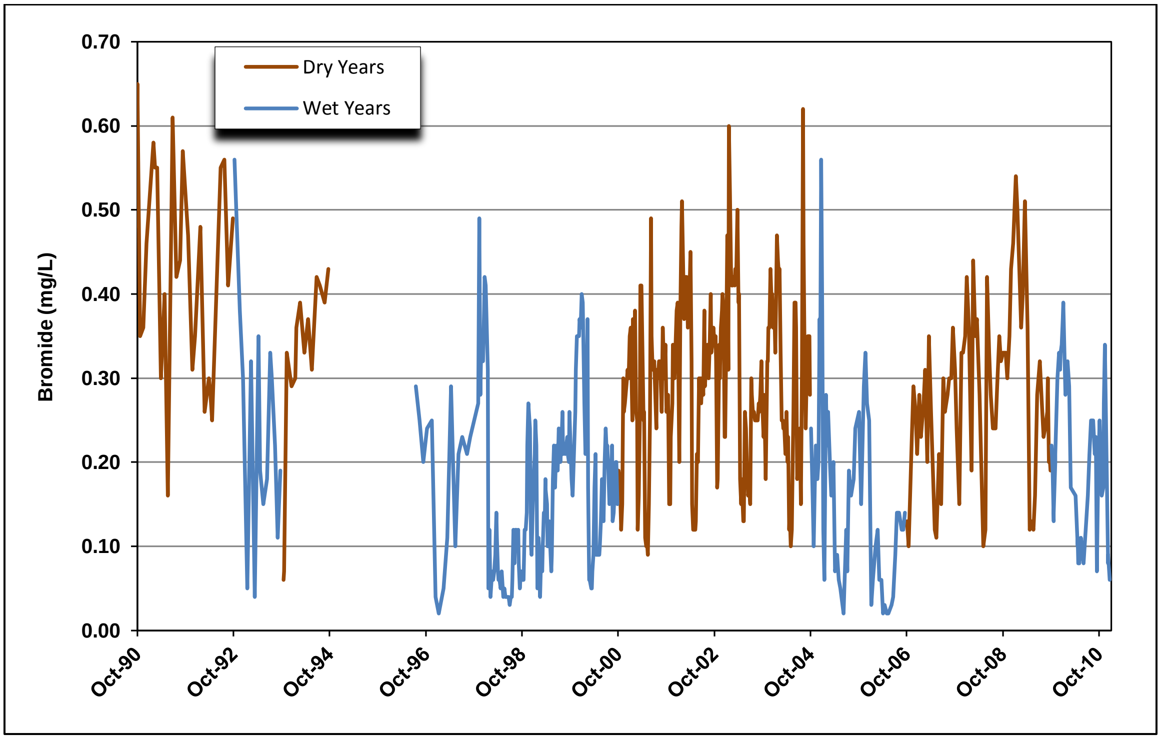


Figure 6-3. Comparison of Vernalis Real-time and Grab Sample Bromide Data

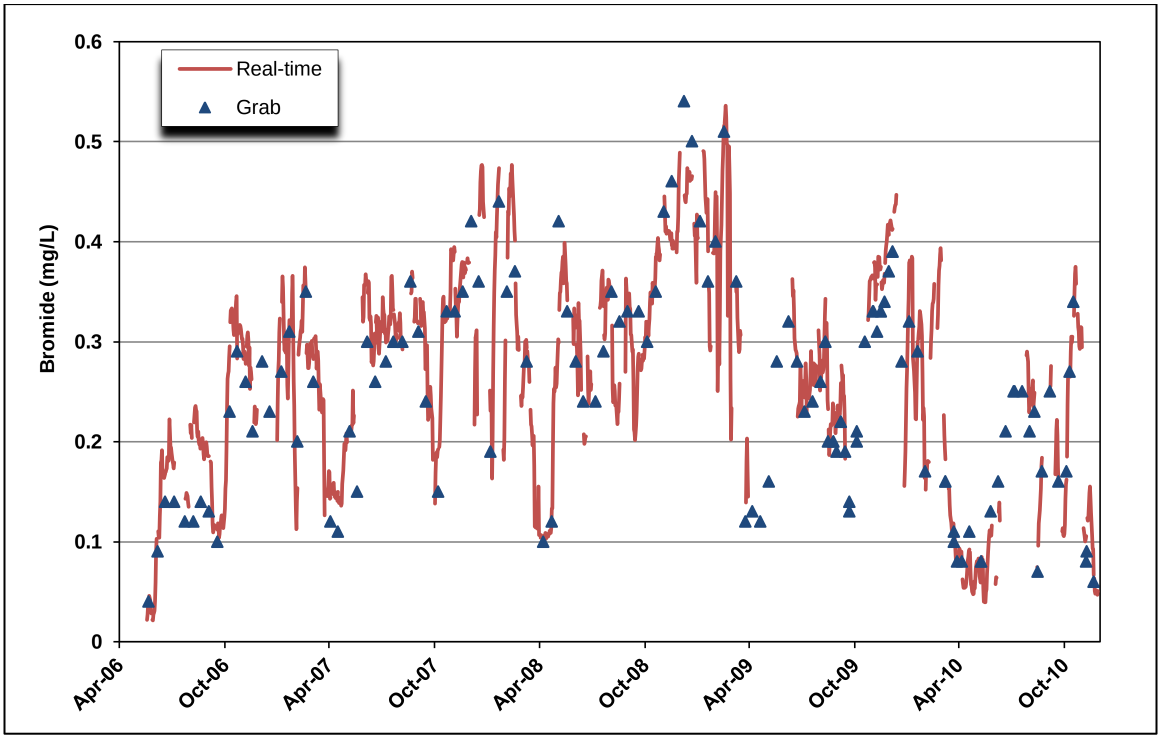


Figure 6-4. Relationship Between Bromide and Flow at Vernalis

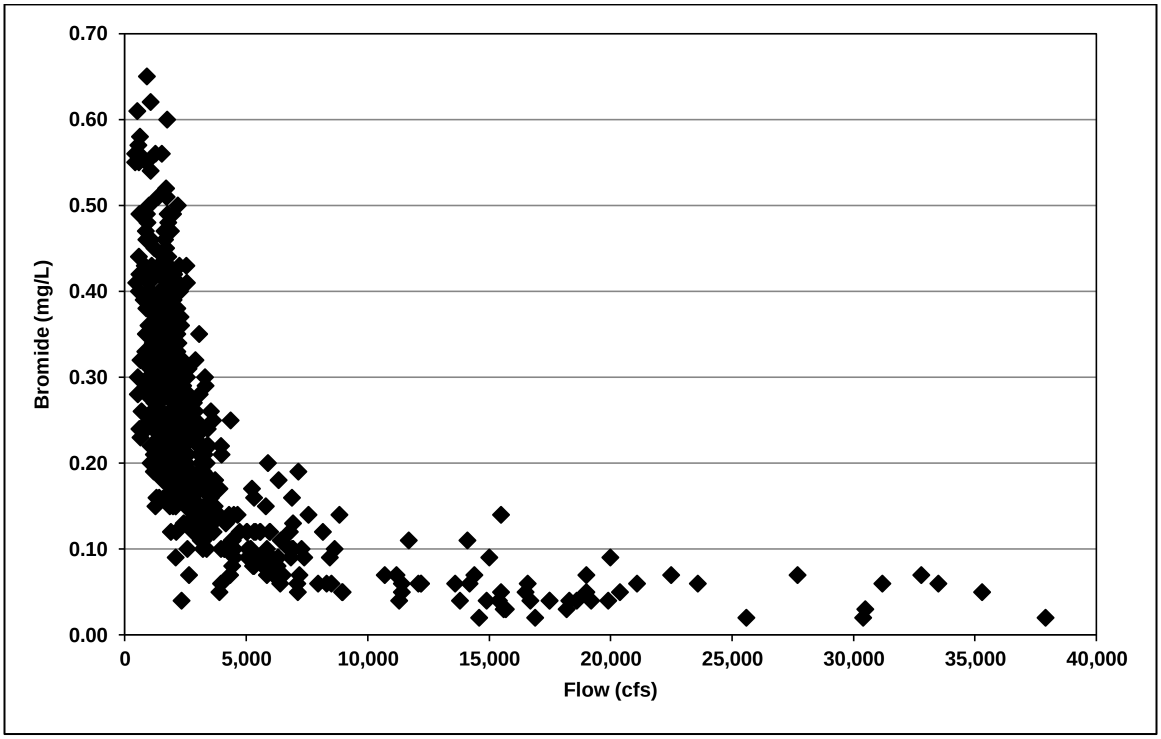
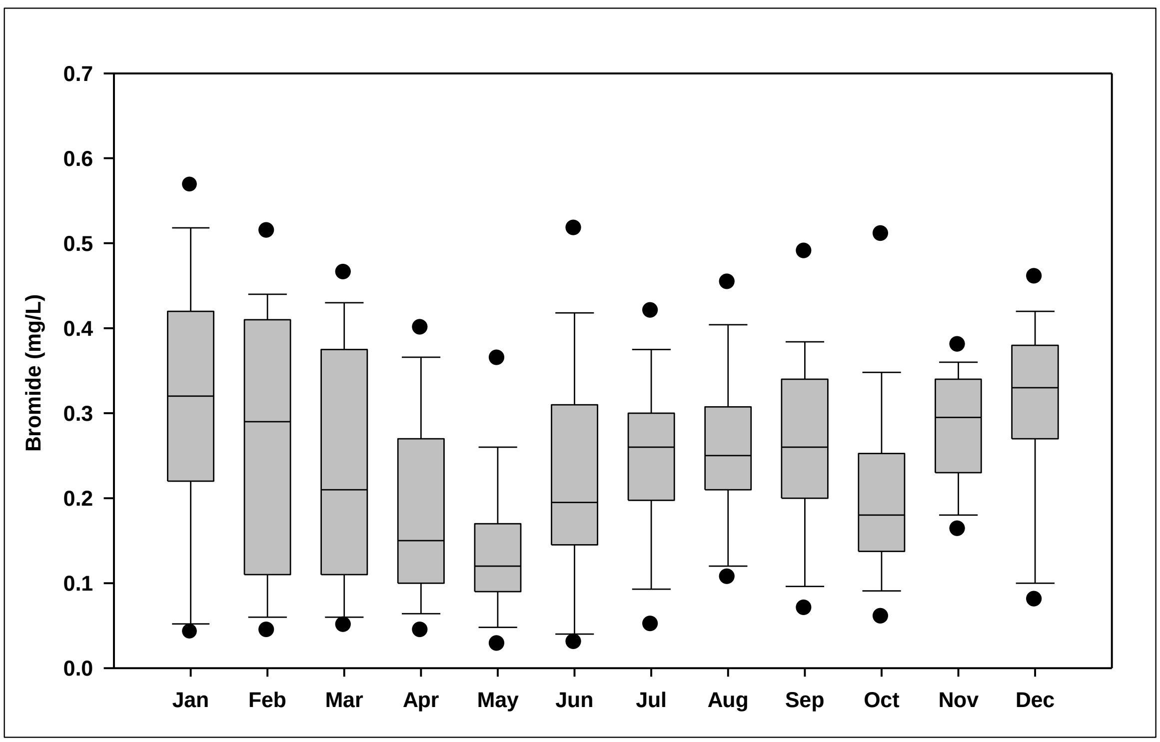


Figure 6-5. Monthly Variability in Bromide at Vernalis



Banks – The sources of bromide at Clifton Court and Banks are primarily the San Joaquin River and seawater intrusion. Seawater contains about 68 mg/L of bromide; therefore, during periods of significant seawater intrusion, substantial amounts of bromide are mixed into the Delta. The median concentrations of bromide at Clifton Court and Banks are 0.21 mg/L and 0.19 mg/L, respectively. **Figure 6-6** shows all available bromide data at Banks. The concentrations range from 0.03 to 0.64 mg/L during the period of record.

- Comparison of Real-time and Grab Sample Data – **Figure 6-7** compares the real-time data with the grab sample data at Banks. Bromide is measured hourly with the Dionex analyzer. MWQI staff provided average daily concentrations calculated from the hourly measurements for this analysis. There is good correspondence between the data sets and the real-time data show that peak bromide concentrations are higher than those captured by the grab sample data.

- Spatial Trends – All available data from Hood, Vernalis, and Banks are presented in **Figure 6-1**. It is obvious that the bromide concentrations at Hood are statistically significantly lower than the bromide concentrations at Vernalis and Banks. The period of record for Vernalis and Banks is the same (1990 to 2010). The median bromide concentration at Banks (0.19 mg/L) is statistically significantly lower than the median of 0.25 mg/L at Vernalis (Mann-Whitney, p=0.0099). This is due to the mixing of the higher quality Sacramento River with San Joaquin River water and in-Delta sources at Banks.

- Long-Term Trends – Visual inspection of **Figure 6-6** shows a downward trend in the data. This is a function of the hydrology of the system. Bromide data were first collected at Banks during the drought years of the early 90s when bromide levels were high.

- Wet Year/Dry Year Comparison – The median concentration during wet years is 0.12 mg/L and the median concentration during dry years is 0.27 mg/L. Bromide concentrations were statistically significantly higher during dry years than during wet years (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-8** indicates that the lowest bromide concentrations occur in the spring. Concentrations increase throughout the summer and fall when flows are lower on the Sacramento and San Joaquin rivers and seawater intrudes into the Delta.

Figure 6-6. Bromide Concentrations at Banks

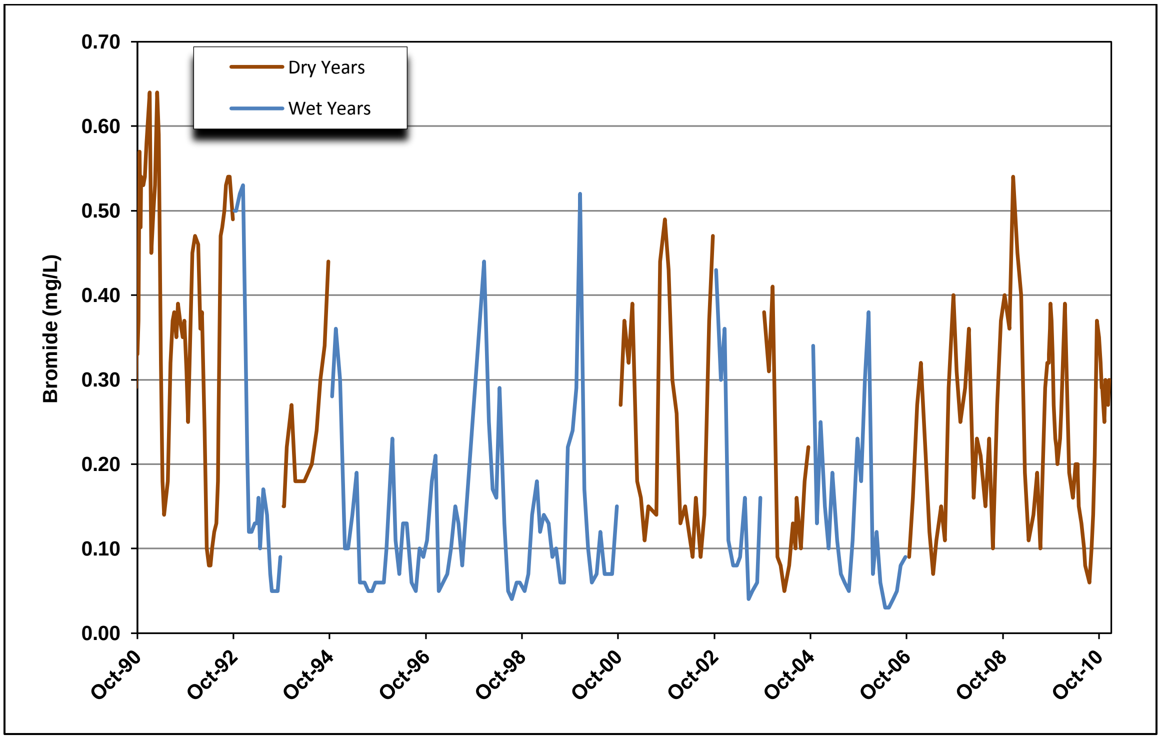


Figure 6-7. Comparison of Banks Real-time and Grab Sample Bromide Data

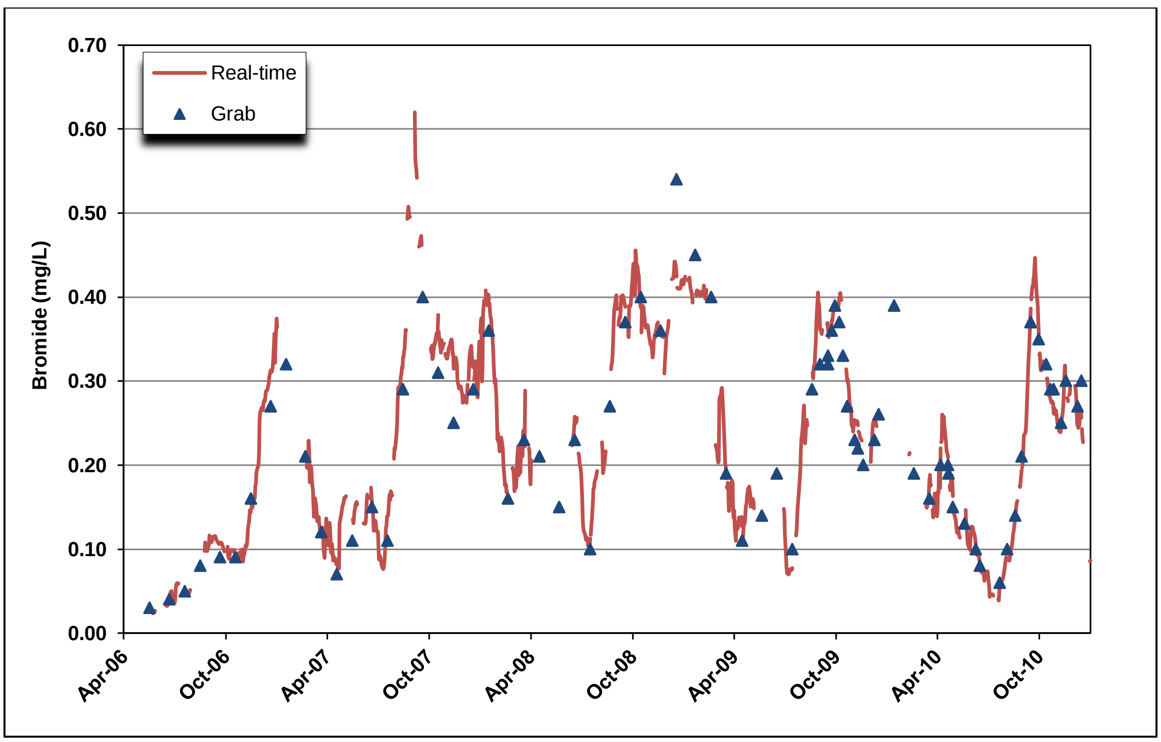
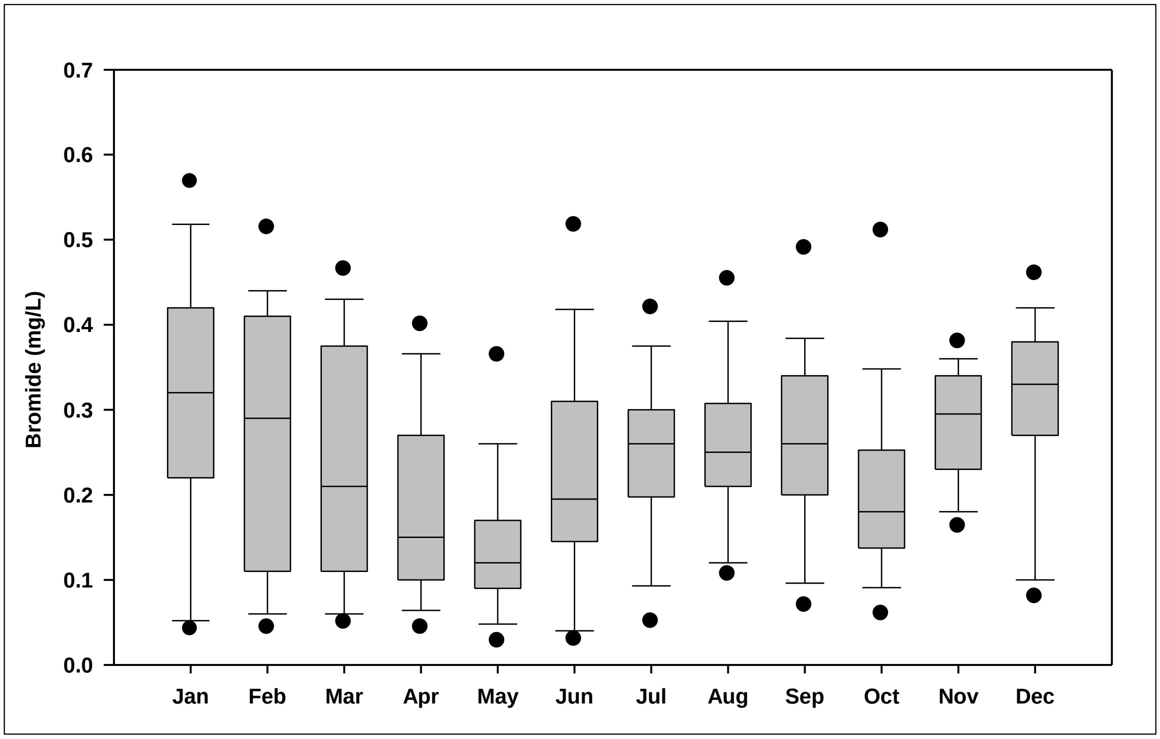


Figure 6-8. Monthly Variability in Bromide at Banks



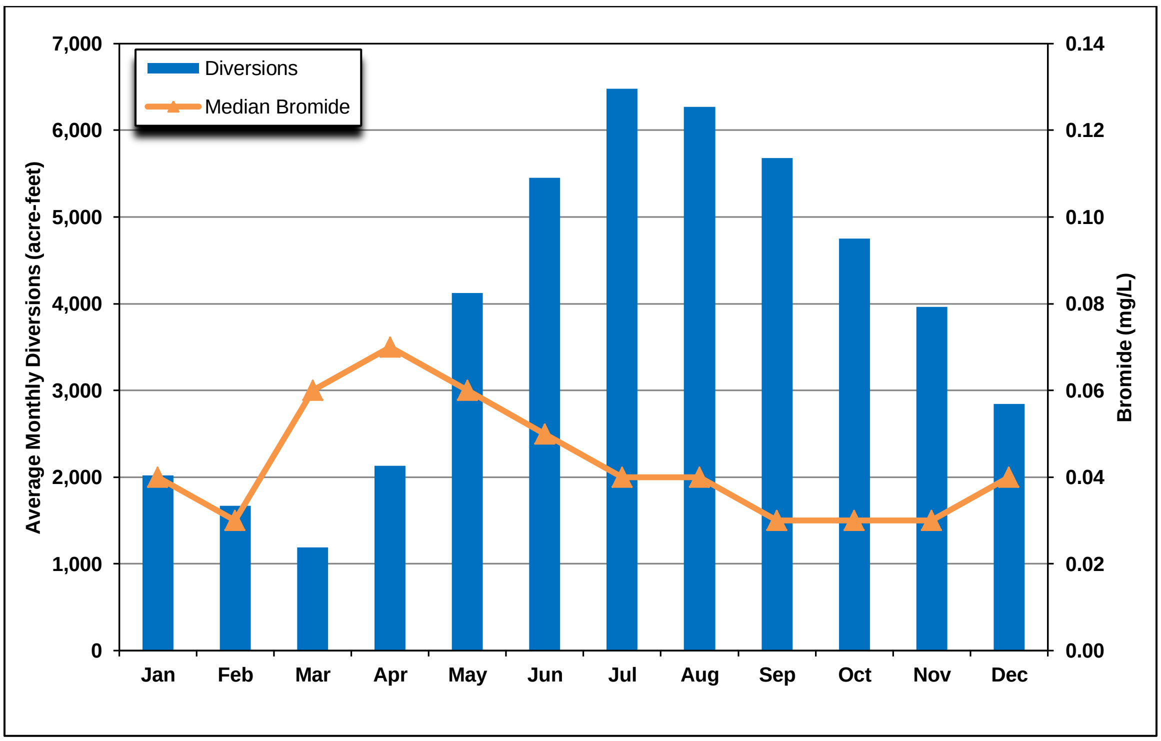
North Bay Aqueduct

Chapters 3 and 4 contain a description of the North Bay Aqueduct (NBA). The sources of water are the local Barker Slough watershed and the Sacramento River.

Project Operations

Since the NBA is an enclosed pipeline, the quality of water delivered to NBA users is governed by the timing of diversions from Barker Slough and it shouldn't be affected by any other factors. **Figure 6-9** shows average monthly diversions at Barker Slough for the 1998 to 2010 period and median monthly bromide concentrations. This figure shows that pumping is highest between May and November. The median bromide is 0.06 mg/L during May but it declines to 0.03 to 0.04 mg/L during most of the summer and fall months.

Figure 6-9. Average Monthly Barker Slough Diversions and Median Bromide Concentrations



Bromide Concentrations in the NBA

Figure 6-10 shows all available bromide data at Barker Slough. The concentrations generally range from 0.01 to 0.10 mg/L during the period of record with a median of 0.04 mg/L.

- Spatial Trends – **Figure 6-11** shows that the NBA monitoring locations of Barker Slough and Cordelia Forebay (Cordelia) have higher bromide concentrations than Hood, indicating there is a source of bromide in the Barker Slough watershed. The median concentration is 0.04 mg/L at both Barker Slough and Cordelia, whereas the median concentration at Hood is 0.01 mg/L.

- Long-Term Trends – Visual inspection of **Figure 6-10** shows there is no discernible trend in the data.
- Wet Year/Dry Year Comparison – The median concentration during both dry and wet years is 0.04 mg/L indicating no difference between water year types.
- Seasonal Trends – There is a seasonal pattern of low concentrations during the fall and winter months and peak concentrations in the spring, as shown in **Figure 6-12**. The source of bromide during the spring months is likely due to groundwater or subsurface flows from the Barker Slough watershed (Personal Communication, Alex Rabidoux).

Figure 6-10. Bromide Concentrations at Barker Slough

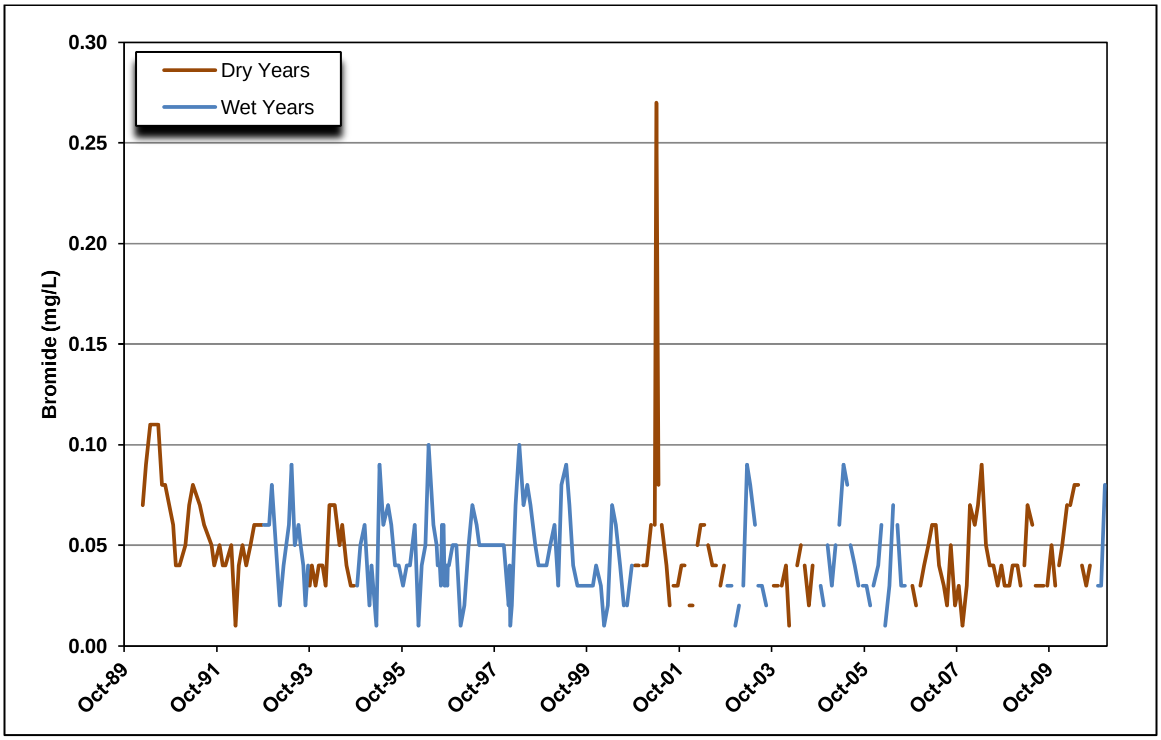
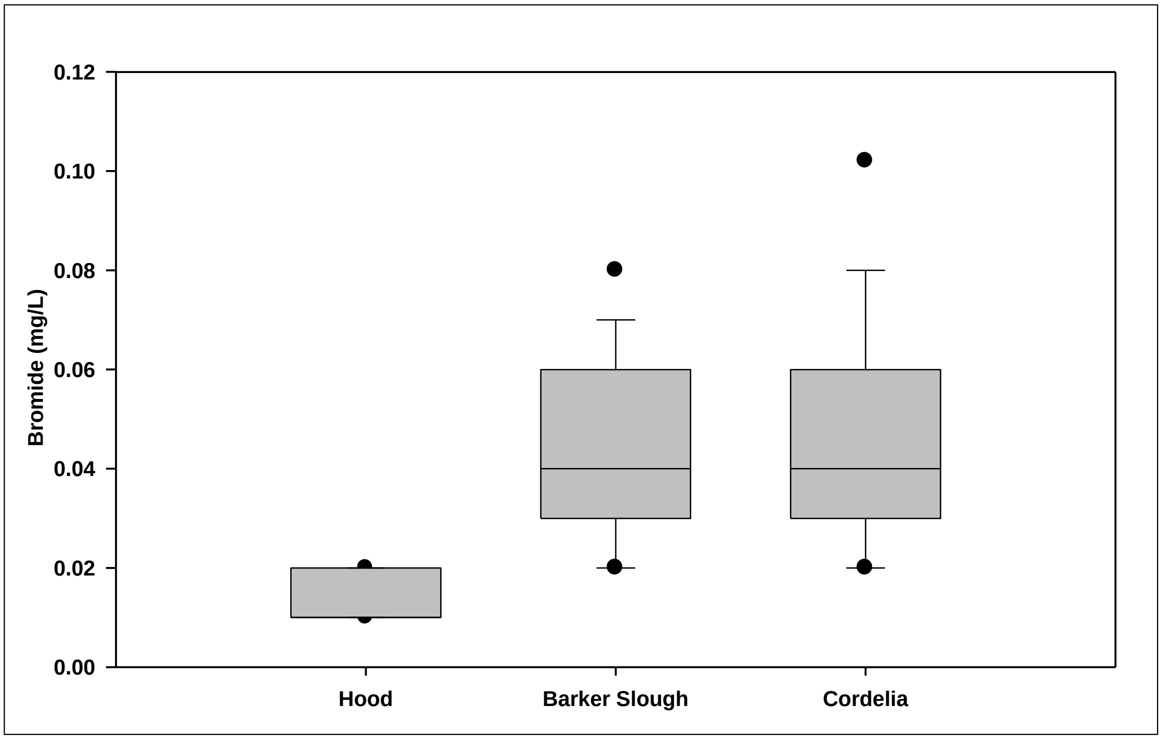
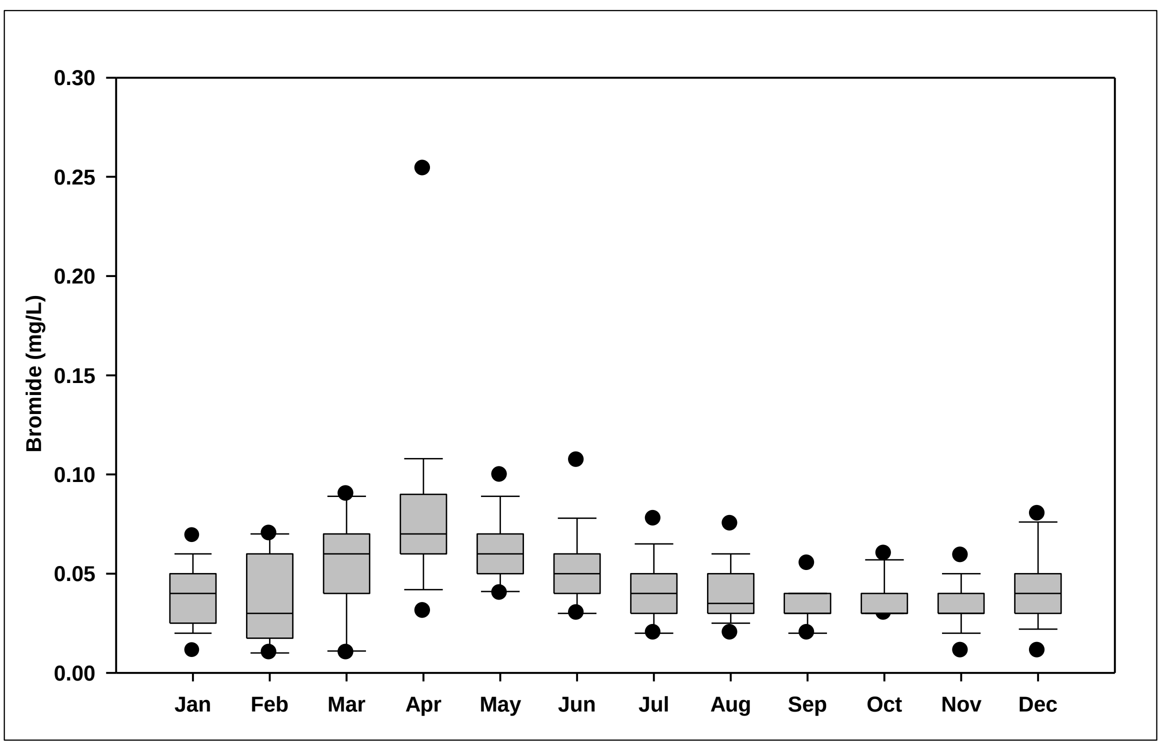


Figure 6-11. Comparison of Bromide at Hood, Barker Slough, and Cordelia



Note: The Hood median of 0.01 mg/L is the same as the 25th percentile.

Figure 6-12. Monthly Variability in Bromide at Barker Slough



Note: Insufficient data to plot all percentiles.

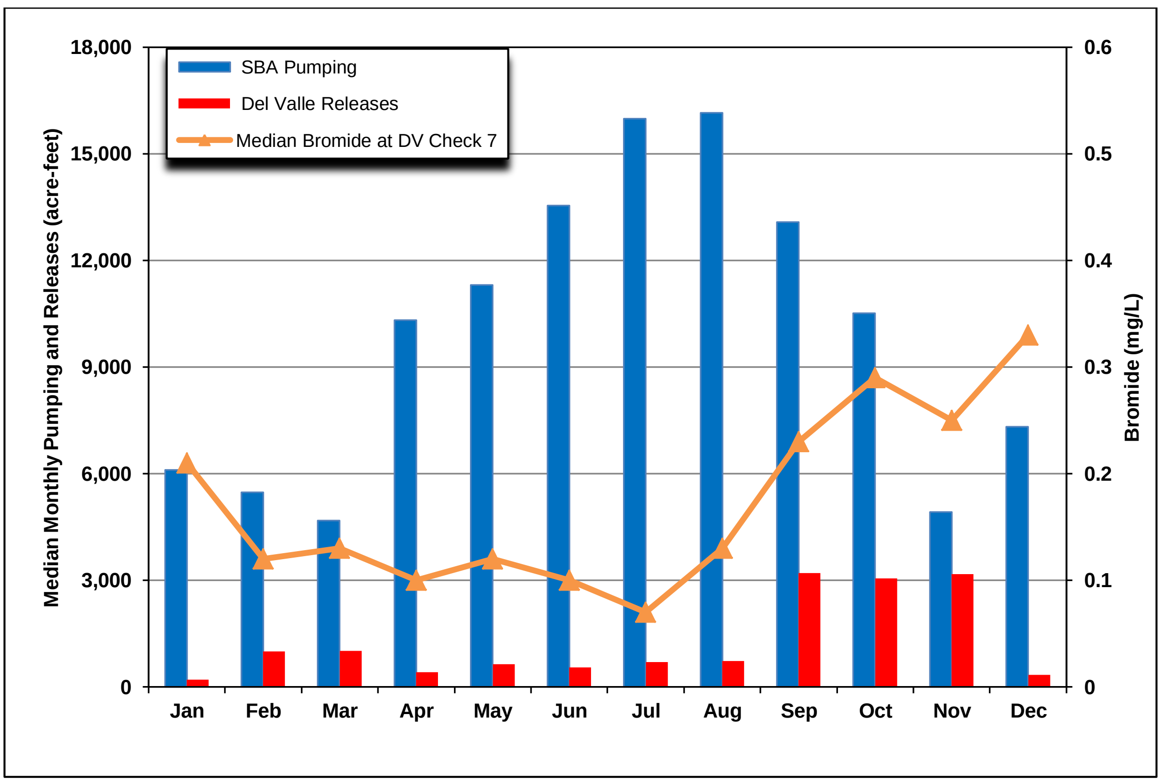
South Bay Aqueduct

Chapters 3 and 4 contain a description of the South Bay Aqueduct (SBA). The Delta is the primary source of water and Lake Del Valle is the secondary source.

Project Operations

The quality of water delivered to the SBA Contractors is governed by the timing of diversions from Bethany Reservoir and releases from Lake Del Valle. **Figure 6-13** shows average monthly diversions at the South Bay Pumping Plant, releases from Lake Del Valle, and median monthly bromide concentrations at Del Valle Check 7 (DV Check 7). Diversion data were not available for 2010. This figure shows that median bromide concentrations are around 0.1 mg/L during the April to July period of peak pumping into the SBA. The median concentrations increase rapidly during the August to October period when pumping is high. Water is released from Lake Del Valle primarily between September and November. The median bromide concentration at the Lake Del Valle Conservation Outlet (Conservation Outlet) is 0.04 mg/L, indicating the Del Valle releases decrease the bromide concentrations of water delivered to SBA Contractors during the fall months.

Figure 6-13. Average Monthly Diversions at the South Bay Pumping Plant, Releases from Lake Del Valle, and Median Bromide Concentrations



Bromide Concentrations in the SBA

Grab sample bromide data are collected at DV Check 7 and the Santa Clara Terminal Reservoir (Terminal Tank) on the SBA. A limited amount of bromide data is available from Lake Del Valle at the Conservation Outlet (Conservation Outlet). **Figure 6-14** shows all available bromide data at DV Check 7. The concentrations range from 0.04 to 0.52 mg/L during the period of record with a median of 0.14 mg/L.

- Spatial Trends – **Figure 6-15** compares bromide concentrations at Banks, DV Check 7, and the Terminal Tank on the SBA. The period of record is longer at Banks than at the SBA locations and samples are only collected quarterly at the Terminal Tank. A subset of data collected quarterly between 1998 and 2010 was analyzed to determine if there are changes in bromide concentrations between Banks and the SBA locations. There are no statistically significant differences between the median concentration of 0.12 mg/L at DV Check 7 and the median of 0.13 mg/L at Banks (Mann-Whitney, p=0.9899). Similarly, there are no statistically significant differences between the median of 0.13 mg/L at Banks and the median of 0.11 mg/L at the Terminal Tank (Mann-Whitney, p=0.1901). There are no sources of bromide or other factors that could affect bromide concentrations between Banks and DV Check 7. Water from Lake Del Valle enters the SBA between DV Check 7 and the Terminal Tank but does not appear to statistically significantly affect bromide concentrations when the data are aggregated in this manner. **Figure 6-16** presents a comparison of data collected at DV Check 7, the Conservation Outlet of Lake Del Valle, and the Terminal Tank. This figure shows that bromide concentrations in Lake Del Valle are substantially lower than the concentrations at DV Check 7. Bromide concentrations at the Terminal Tank are often lower than the concentrations at DV Check 7 during the fall months when water is released from Lake Del Valle.

- Long-Term Trends – **Figure 6-14** shows there is no discernible trend in the data.

- Wet Year/Dry Year Comparison – The DV Check 7 median concentration of 0.18 mg/L during dry years is significantly higher than the 0.12 mg/L median during wet years (Mann-Whitney, p=0.0012).

- Seasonal Trends – **Figure 6-17** shows there is a seasonal pattern of low concentrations from February to August and then concentrations increase during the late summer and fall months due to seawater intrusion in the Delta. This is similar to the pattern at Banks.

Figure 6-14. Bromide Concentrations at DV Check 7

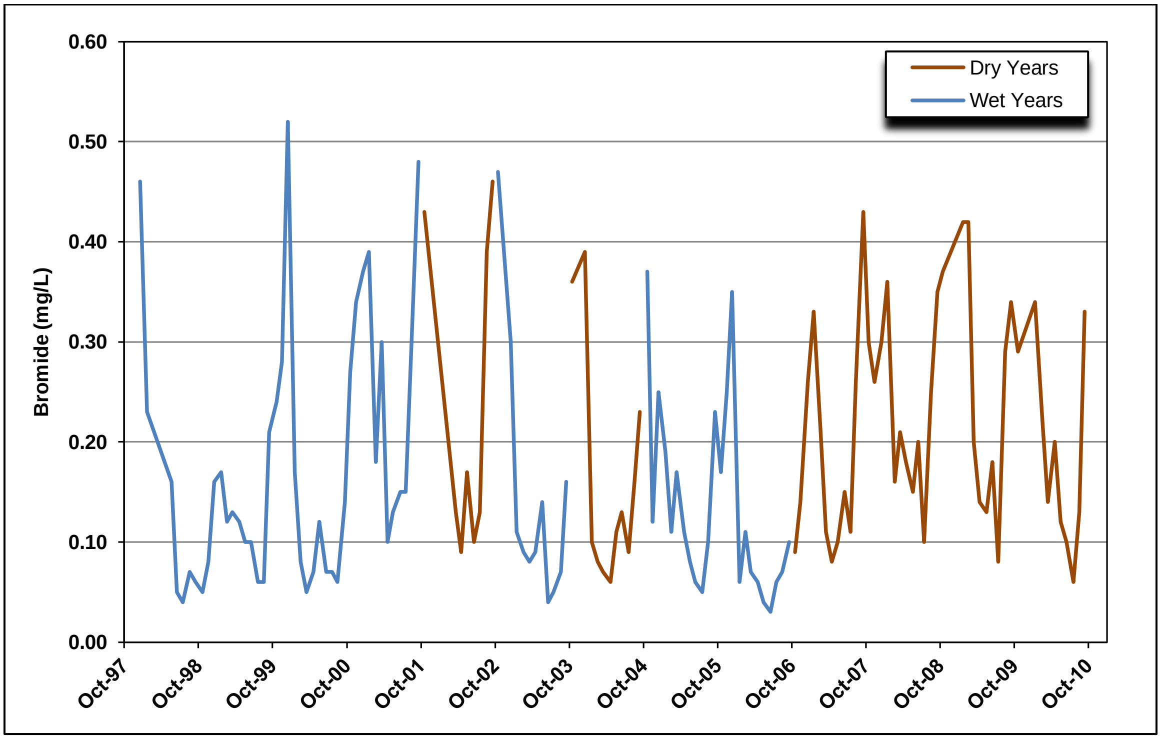


Figure 6-15. Comparison of Bromide at Banks, DV Check 7, and the Terminal Tank (Quarterly Data, 1998-2010)

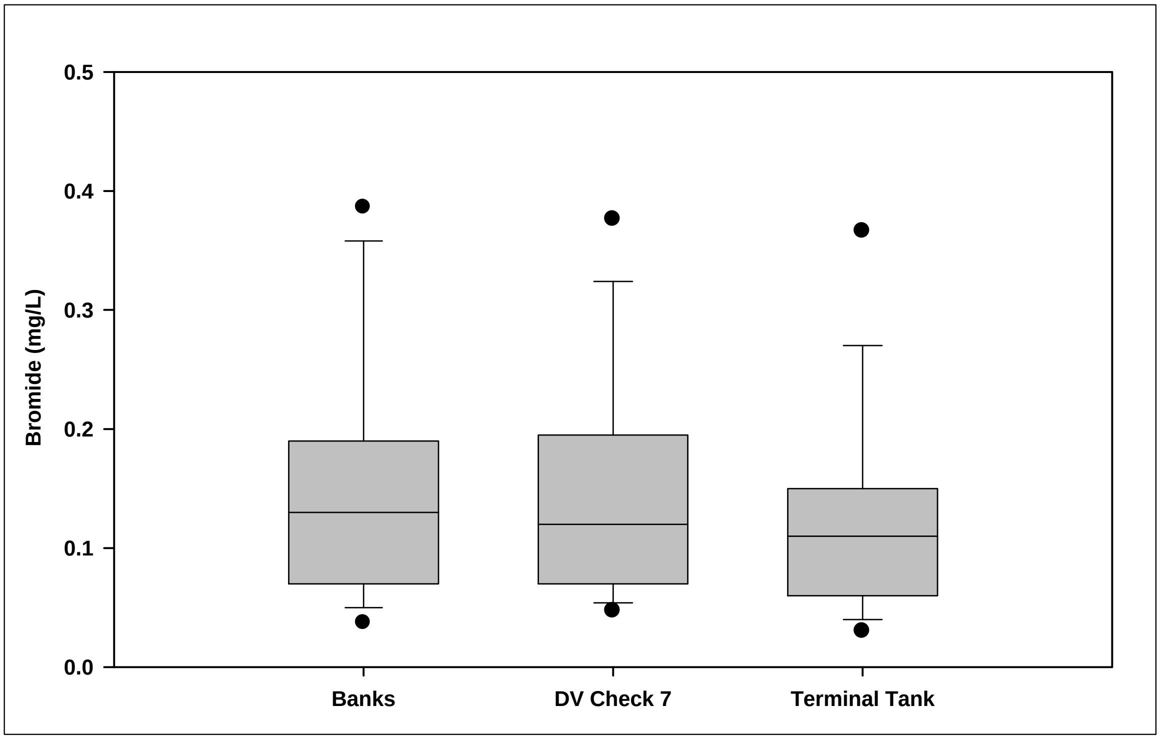


Figure 6-16. Bromide Concentrations in the SBA and Conservation Outlet

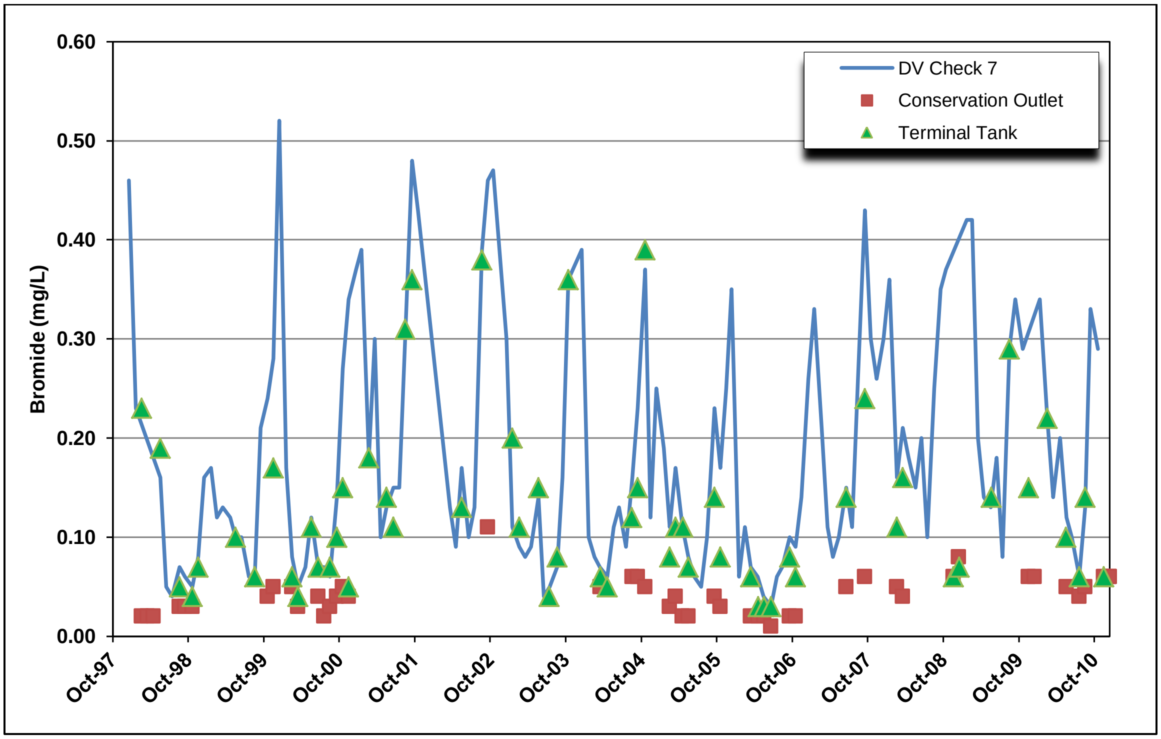
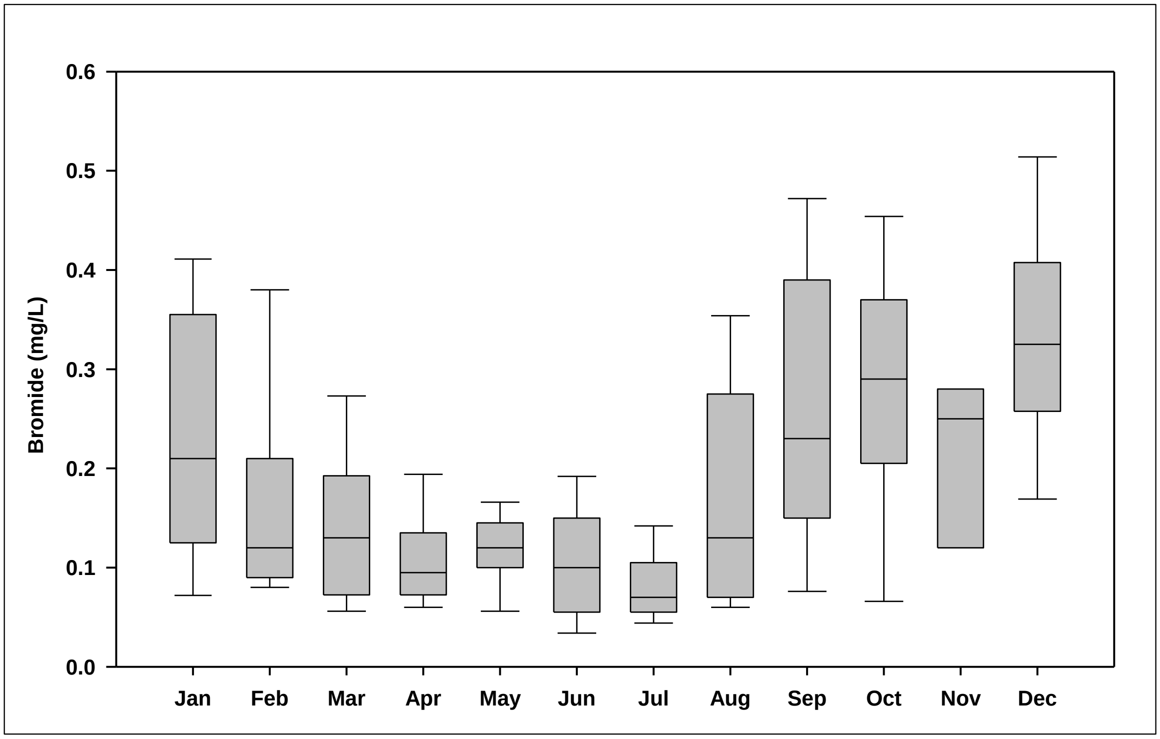


Figure 6-17. Monthly Variability in Bromide at DV Check 7



Note: Insufficient data to plot all percentiles.

California Aqueduct and Delta-Mendota Canal

A number of SWP Contractors take water from the SWP between San Luis Reservoir and the terminal reservoirs. This section is organized by various reaches of the SWP and individual SWP Contractors taking water from each reach are described in the following sections.

Project Operations

The quality of water delivered to SWP Contractors south of San Luis Reservoir is governed by the timing of diversions from the Delta at Banks, pumping into O'Neill Forebay from the Delta-Mendota Canal (DMC), releases from San Luis Reservoir, inflows to the Governor Edmund G. Brown California Aqueduct (California Aqueduct), and storage in terminal reservoirs. The impact of non-Project inflows on water quality is discussed in Chapter 14 and the influence of terminal reservoirs in modulating bromide concentrations is discussed later in this chapter.

Figure 6-18 shows average monthly diversions at the Banks Pumping Plant and median monthly bromide concentrations. As described in Chapter 3, operations were governed by the 1995 Bay-Delta Plan (D-1641) from 1998 to 2006 and by the Wanger Decision and the biological opinions from 2007 to 2010 so both periods are shown. As shown in **Figure 6-18**, the median bromide concentrations are relatively low during the first half of the year, ranging from 0.13 to 0.22 mg/L but then increase sharply from 0.1 mg/L in July to 0.33 mg/L in September when diversion rates are higher. They remain high during the fall months when a substantial amount of water is diverted at Banks.

Figure 6-19 shows the average monthly amount of water pumped from the DMC at O'Neill Pump-Generation Plant into O'Neill Forebay and the median bromide concentrations in the DMC at McCabe Road (McCabe). The median bromide concentrations show the same seasonal pattern as at Banks. The pumping pattern at O'Neill is different from the pattern at Banks. There is little pumping into O'Neill Forebay during the April to August period when bromide concentrations are lowest. Most of the pumping occurs between September and March when median bromide concentrations range from 0.18 to 0.34 mg/L. During the 1998 to 2009 period that data were available, the DMC contributed between 26 and 44 percent of the water entering O'Neill Forebay with a median of 30 percent.

Figure 6-18. Average Monthly Banks Diversions and Median Bromide Concentrations

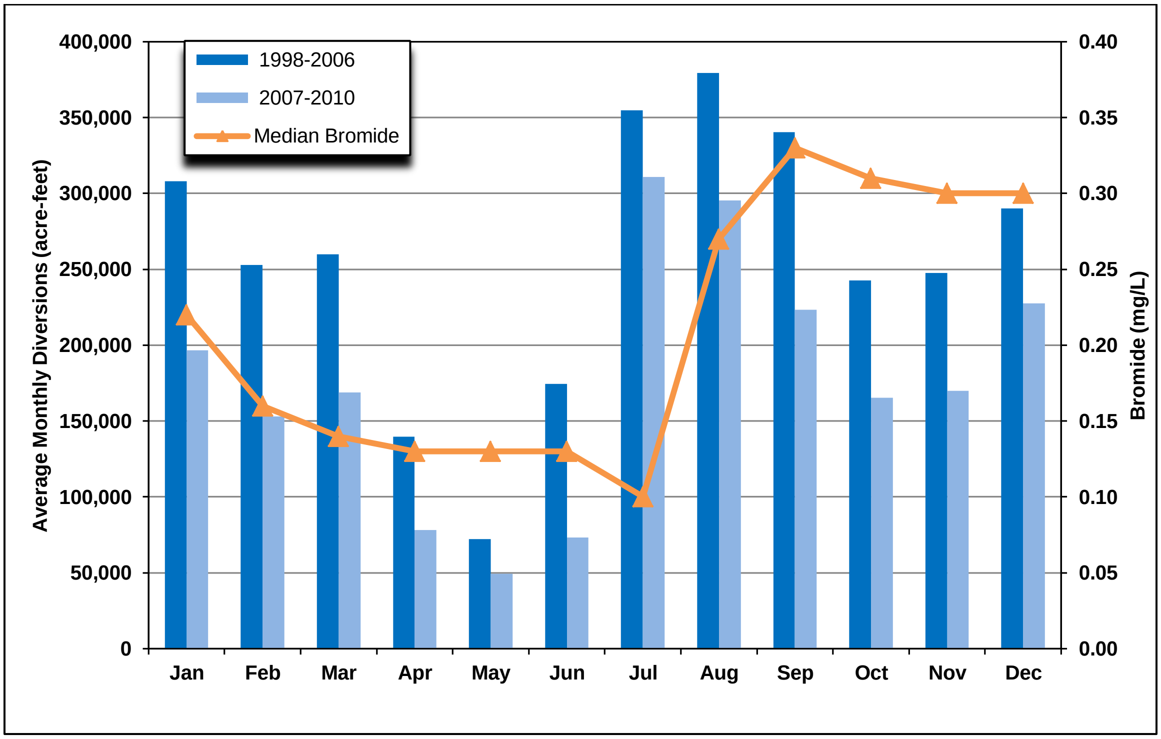
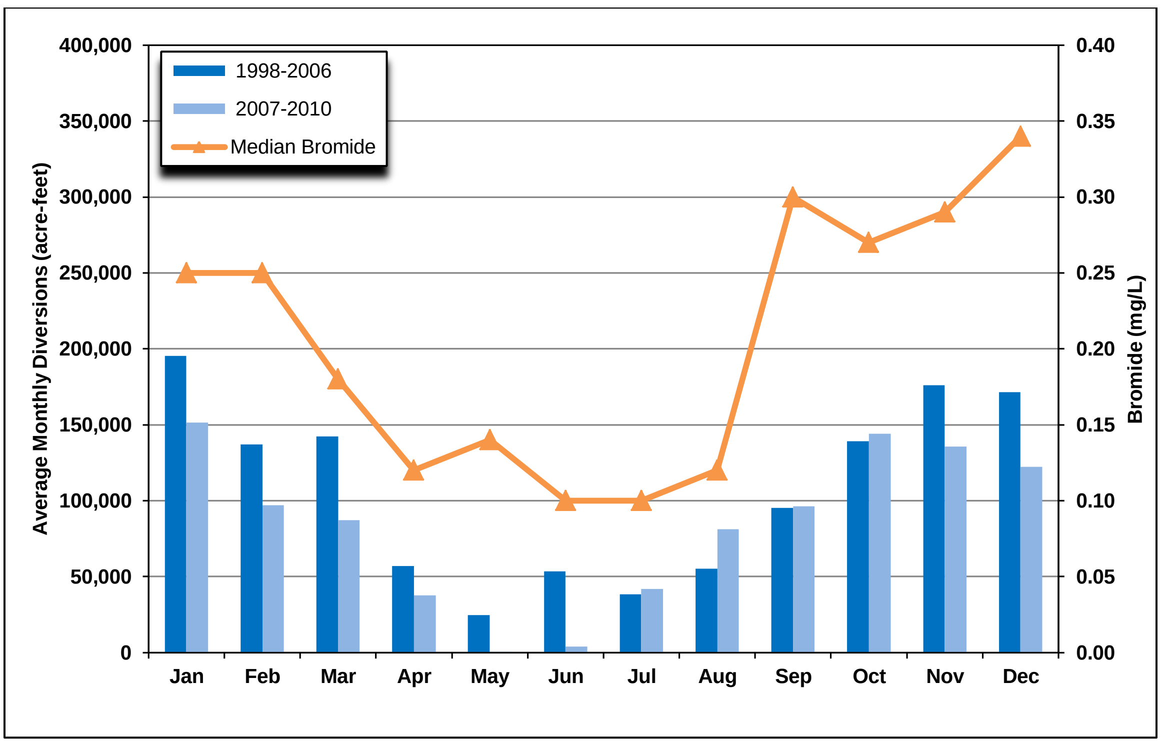


Figure 6-19. Average Monthly Pumping at O'Neill and Median Bromide Concentrations

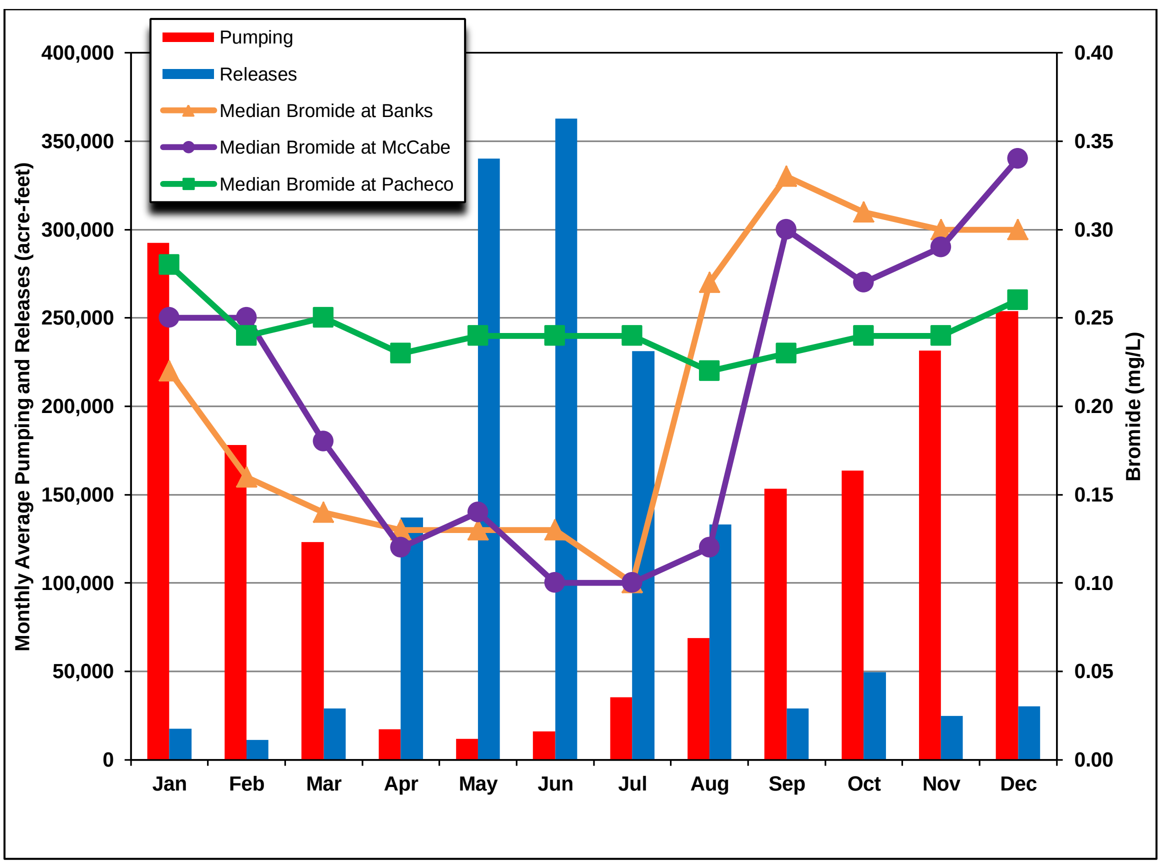


The operation of San Luis Reservoir impacts water quality in the California Aqueduct south of the reservoir. **Figure 6-20** shows the pattern of pumping into the reservoir and releases from the reservoir to O'Neill Forebay. The median bromide concentration at Banks represents the quality of water pumped into the reservoir from the California Aqueduct and the median bromide concentration at McCabe represents the quality of water pumped in from the DMC. Since data are not currently available on the quality of water released to O'Neill Forebay from San Luis Reservoir, data from the Pacheco Pumping Plant (Pacheco) are used. **Figure 6-20** shows there are the same two distinct periods for San Luis Reservoir with respect to bromide concentrations as there were for EC levels:

- Fall and Winter Filling – The reservoir is filled from September to March when the bromide concentrations in water entering the reservoir are high (0.14 to 0.33 mg/L at Banks and 0.18 to 0.34 mg/L at McCabe).

- Spring and Summer Releases – Water is released during the April to August period when median bromide concentrations at Pacheco range from 0.22 to 0.24 mg/L. During the release period, bromide concentrations are about twice as high as the concentrations entering O'Neill Forebay from the California Aqueduct and the DMC. This indicates that releases from the reservoir increase bromide concentrations in the aqueduct south of O'Neill Forebay.

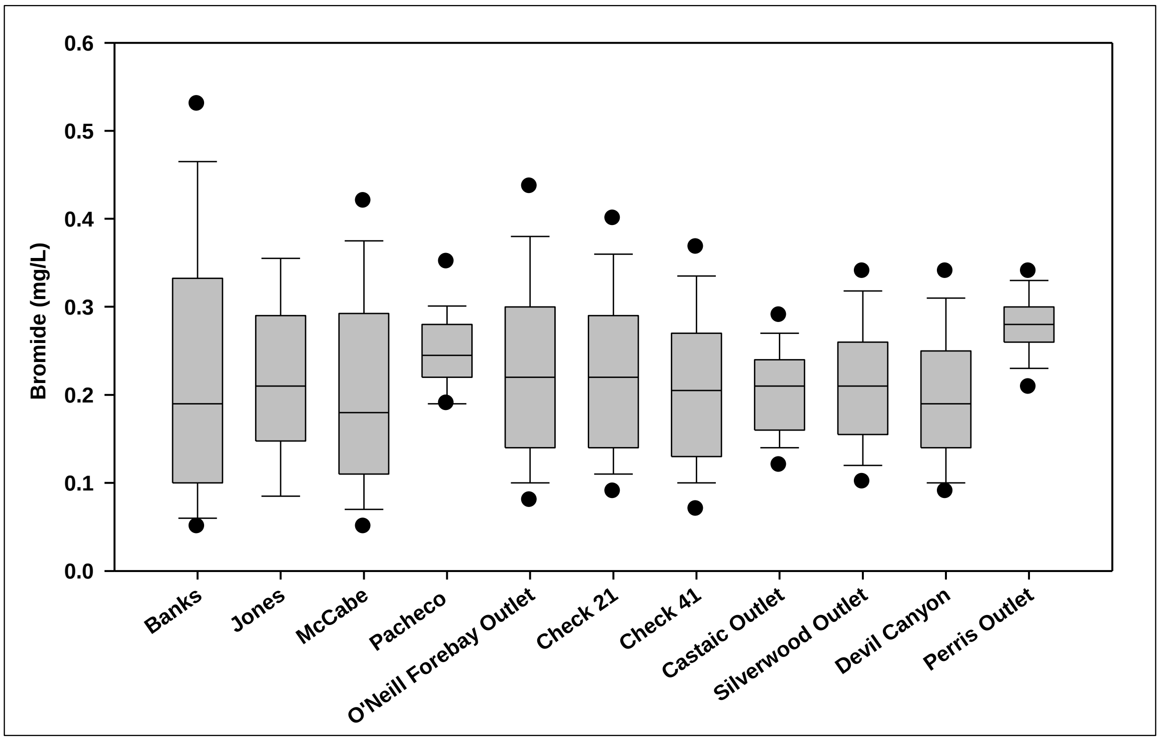
Figure 6-20. San Luis Reservoir Operations and Median Bromide Concentrations



Bromide Concentrations in the DMC and SWP

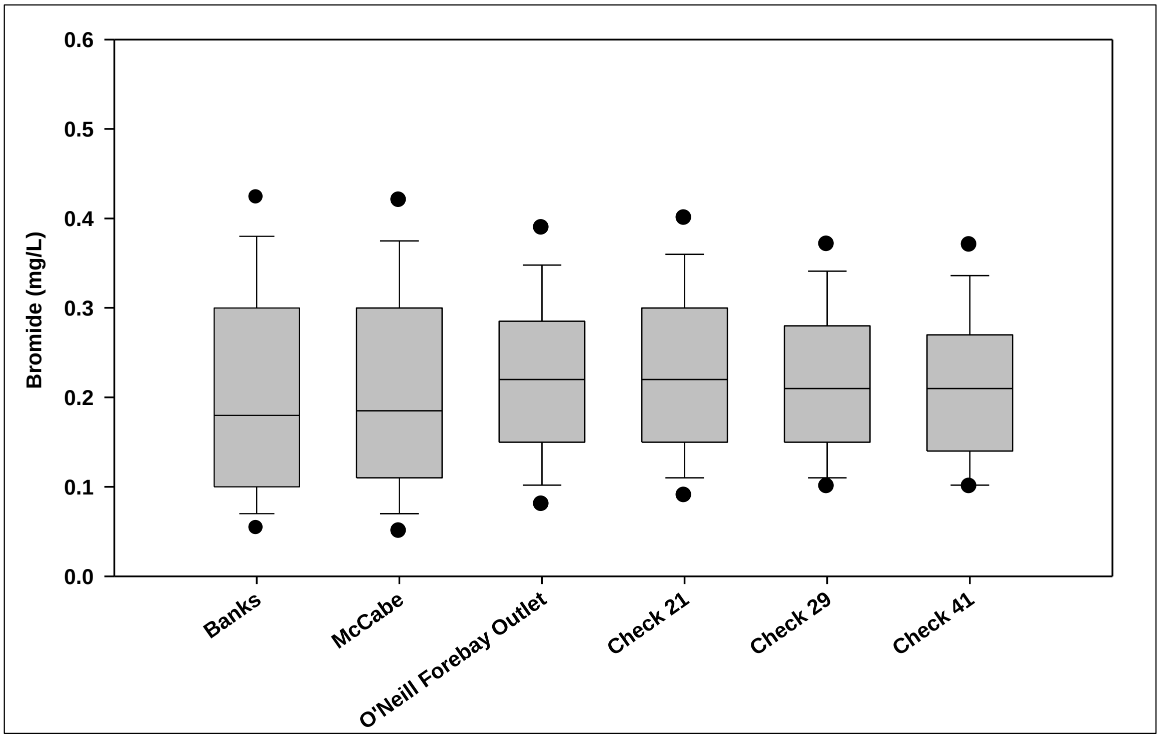
Figure 6-21 presents a summary of all grab sample bromide data collected at each of the locations along the DMC, California Aqueduct, and SWP reservoirs. There are varying periods of record for each location so differences between locations may be due to the hydrologic conditions under which the samples were collected. **Figure 6-21** shows that Lake Perris has the highest median bromide (0.28 mg/L) in the SWP system. A subset of data collected during the same time period (1999 to 2010) was analyzed for several locations along the aqueduct and for McCabe on the DMC. **Figure 6-22** presents these data. Spatial differences are examined in more detail in the following sections.

Figure 6-21. Bromide Concentrations in the DMC and SWP



Note: Insufficient data to plot all percentiles.

Figure 6-22. Bromide Concentrations in the DMC and California Aqueduct (1999-2010)



Delta-Mendota Canal – Grab sample bromide data have been collected at McCabe since December 1997. Data have also been collected at Jones since March 2009. There are no real-time data. **Figure 6-23** indicates that there is considerable variability in the data with bromide concentrations ranging from 0.01 to 0.54 mg/L with a median of 0.18 mg/L.

- Spatial Trends – **Figure 6-22** compares the bromide data from McCabe to the bromide data collected at Banks between 1999 and 2010. The median concentration of 0.19 mg/L at McCabe is not statistically significantly higher than the median concentration of 0.18 mg/L at Banks (Mann-Whitney, p=0.6903). Although the San Joaquin River has a greater influence on the DMC than it does on the aqueduct, both systems are subject to seawater intrusion in the fall months. The EC fingerprints indicate that Banks is subject to more seawater intrusion than is Jones.

- Long-Term Trends – **Figure 6-23** does not display any discernible long-term trend in bromide concentrations at McCabe.

- Wet Year/Dry Year Comparison – The McCabe median concentration of 0.24 mg/L during dry years is statistically significantly higher than the median concentration of 0.13 mg/L during wet years (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-24** shows there is a seasonal pattern of low concentrations from March to August and then concentrations increase during the late summer and fall months. This is similar to the pattern at Banks. Seawater intrusion in the fall months is the primary factor contributing to the rising bromide concentrations.

Figure 6-23. Bromide Concentrations at McCabe

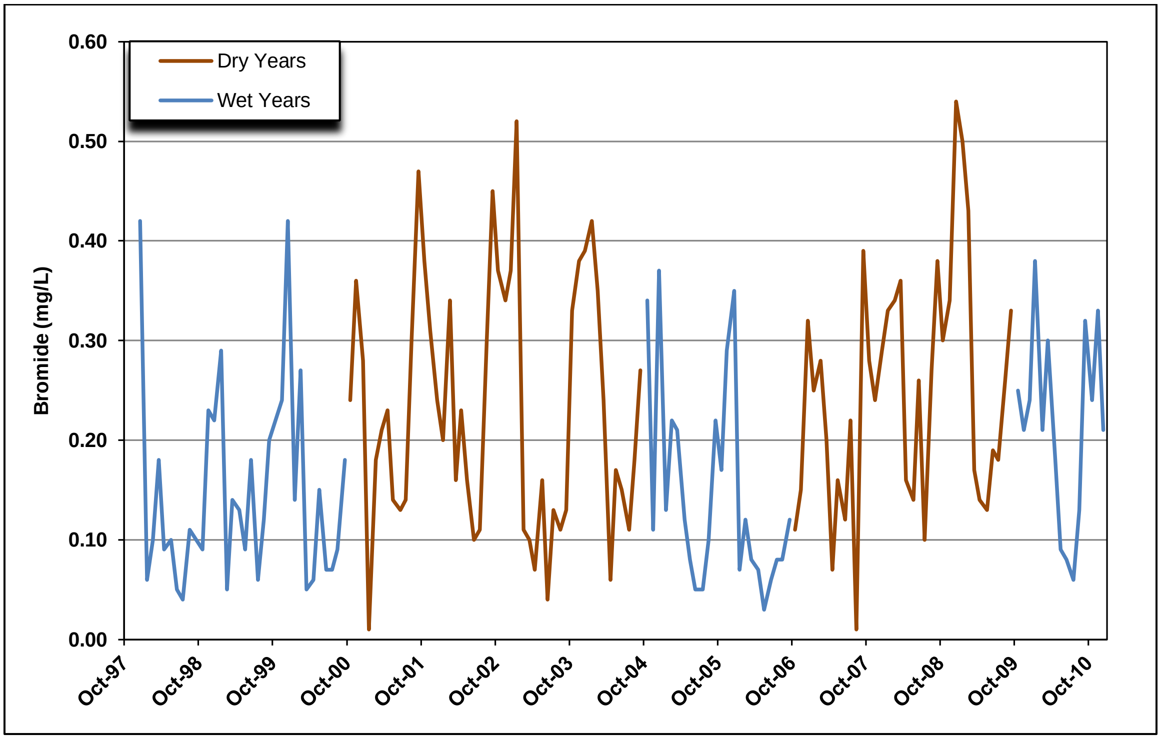
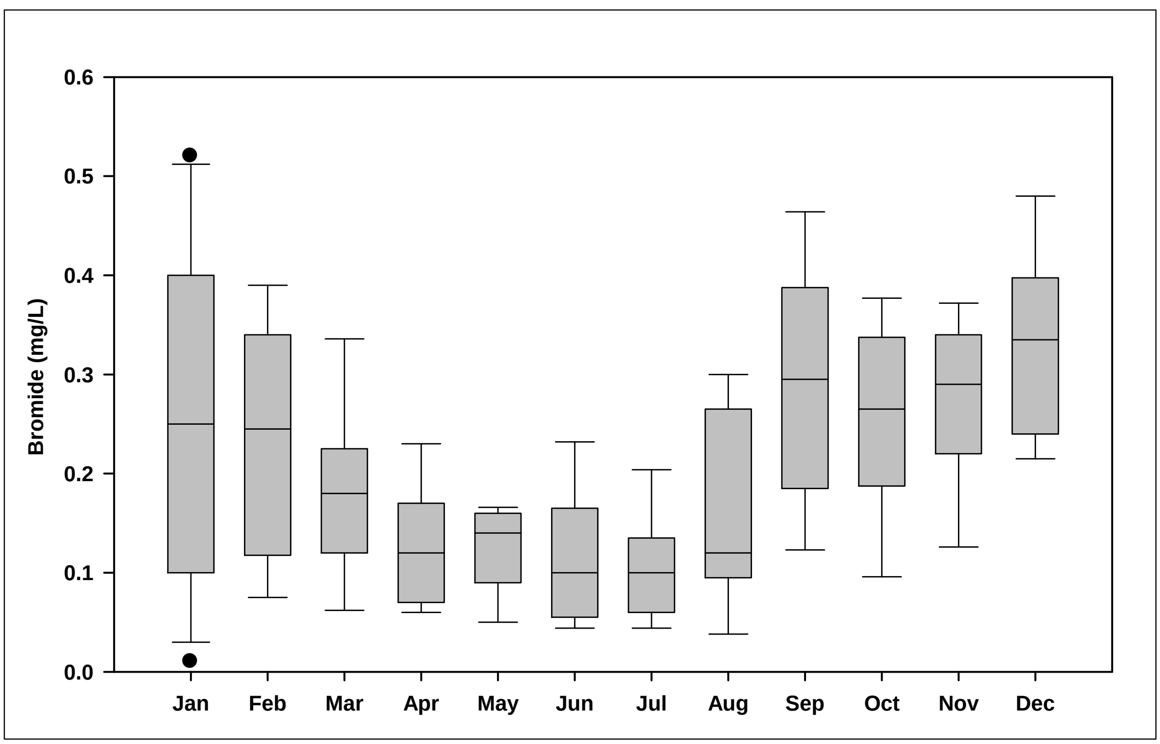


Figure 6-24. Monthly Variability in Bromide Concentrations at McCabe



Note: Insufficient data to plot all percentiles.

San Luis Reservoir – Grab sample bromide data have been collected at Pacheco since March 2000. A limited amount of daily bromide data is available at Pacheco. **Figure 6-25** presents all of the available grab sample bromide data for Pacheco. There is much less variability in bromide concentrations in the reservoir than in the Aqueduct. The bromide concentrations at Pacheco range from 0.14 to 0.39 mg/L with a median of 0.25 mg/L.

- Spatial Trends – **Figure 6-22** shows the concentrations of bromide at Banks, Pacheco, and O'Neill Forebay Outlet. A subset of the data that includes only data collected at the three locations during the same time period (2000 to 2010) is shown in **Figure 6-26**. The Pacheco bromide concentrations are less variable than the other two locations and are statistically higher than Banks (Mann-Whitney, p=0.0002) and O'Neill Forebay Outlet (Mann Whitney, p=0.0036). The higher bromide concentrations in San Luis Reservoir are likely due to a combination of evaporation in the reservoir and pumping of water into the reservoir during periods when Delta bromide concentrations are high.

- Long-Term Trends – **Figure 6-25** shows that bromide concentrations are increasing in the reservoir. This is due to the fact that bromide data were first collected at Pacheco in 2000, which was the end of six wet years and bromide concentrations were low (about 0.20 mg/L). Seven of the last ten years have been dry years and recent concentrations have been between 0.30 and 0.40 mg/L.

- Wet Year/Dry Year Comparison – The median concentration of 0.26 mg/L during dry years is statistically significantly higher than the median concentration of 0.23 mg/L during wet years (Mann-Whitney, p=0.0278).

- Seasonal Trends – **Figure 6-27** presents the monthly data for Pacheco, which illustrates that there is a mild seasonal trend with increasing concentrations in the fall and early winter months. The same trend of increasing bromide concentrations is found at Banks and McCabe. Since water is pumped into San Luis Reservoir during the fall and winter months the trend in the reservoir mimics the trend in the source waters, although the changes in concentrations in the reservoir are smaller due to mixing with lower bromide water in the reservoir.

Figure 6-25. Bromide Concentrations at Pacheco

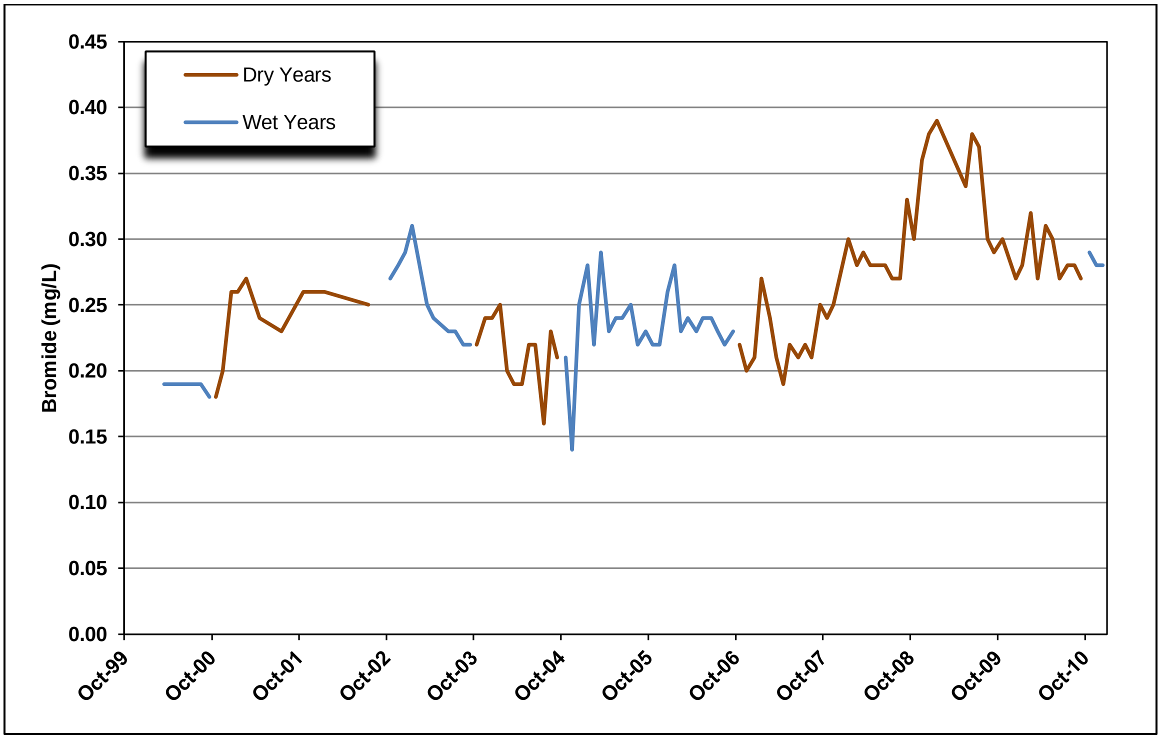


Figure 6-26. Comparison of Bromide Concentrations at Pacheco to Banks and O'Neill Forebay Outlet (2000-2010)

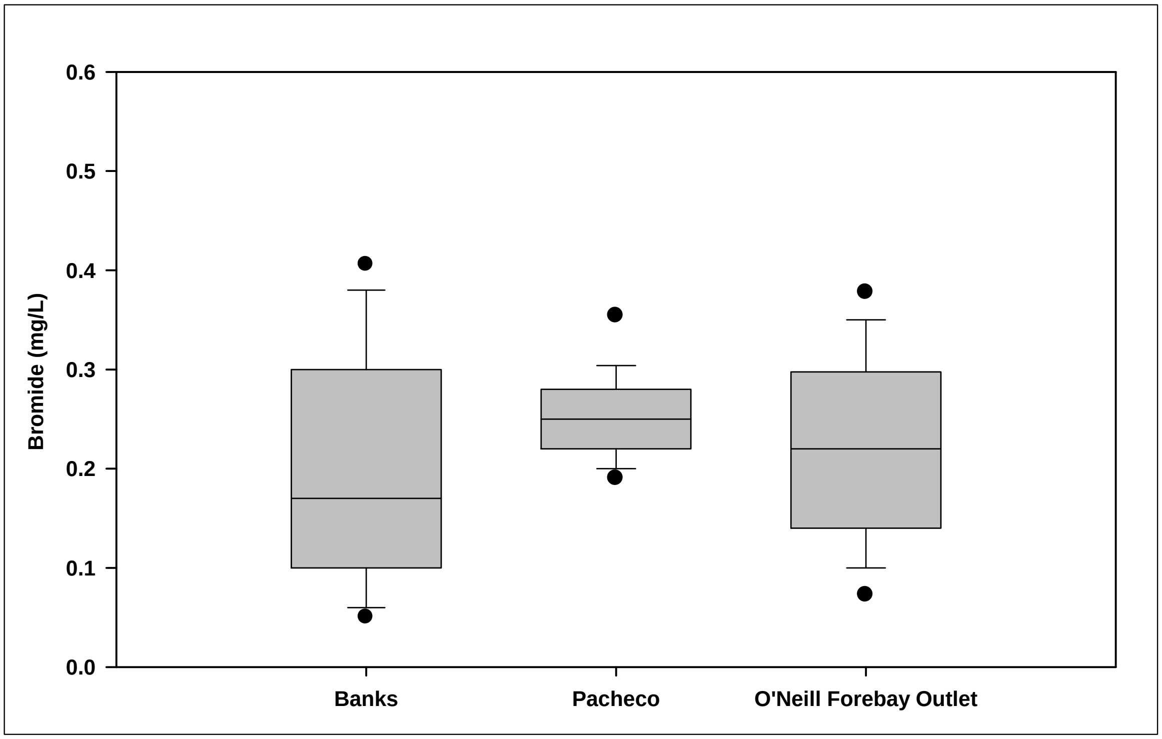
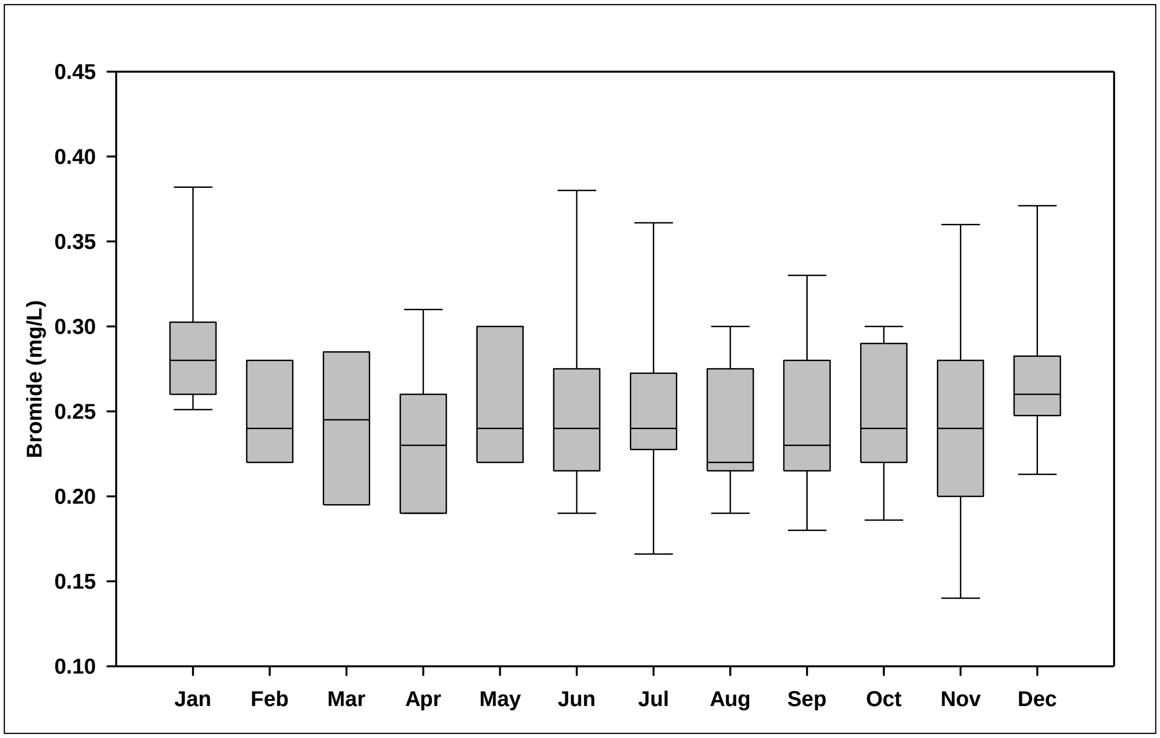


Figure 6-27. Monthly Variability in Bromide Concentrations at Pacheco



Note: Insufficient data to plot all percentiles.

O'Neill Forebay Outlet – O'Neill Forebay Outlet on the California Aqueduct is a mixture of water from San Luis Reservoir, the California Aqueduct, and the DMC. Grab sample data have been collected at O'Neill Forebay Outlet on a regular basis since 1998. **Figure 6-28** presents the bromide grab sample data for O'Neill Forebay Outlet. The bromide concentrations at O'Neill Forebay Outlet range from 0.06 to 0.56 mg/L with a median of 0.22 mg/L.

- Spatial Trends – **Figure 6-22** compares the data collected between 1999 and 2010 at O'Neill Forebay Outlet to a number of other locations along the aqueduct. Bromide increases between Banks and O'Neill Forebay Outlet due to storage in San Luis Reservoir and to mixing with water from the DMC in O'Neill Forebay. The O'Neill Forebay Outlet median concentration of 0.22 mg/L is statistically significantly higher than the Banks median of 0.18 mg/L (Mann-Whitney, p=0.0465).

- Long-Term Trends – **Figure 6-28** shows that bromide concentrations are driven by the hydrology of the system and no apparent long-term trends are evident.

- Wet Year/Dry Year Comparison – The O'Neill Forebay Outlet dry year median bromide concentration of 0.27 mg/L is statistically significantly higher than the wet year median of 0.16 mg/L (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-29** shows there is a distinct seasonal pattern with the lowest concentrations in the summer months and the highest concentrations in the fall. The median bromide concentrations from January to March are similar to the concentrations found at Banks. From April to July the concentrations at O'Neill Forebay Outlet range from 0.17 to 0.22 mg/L and are higher than the concentrations at Banks (0.10 to 0.13 mg/L) because water is released from San Luis Reservoir that contains higher bromide concentrations (0.23 to 0.25 mg/L). From August to November the concentrations at O'Neill Forebay Outlet are lower than the concentrations at Banks. During these months the water released from San Luis Reservoir has lower bromide concentrations than the Delta.

Figure 6-28. Bromide Concentrations at O'Neill Forebay Outlet

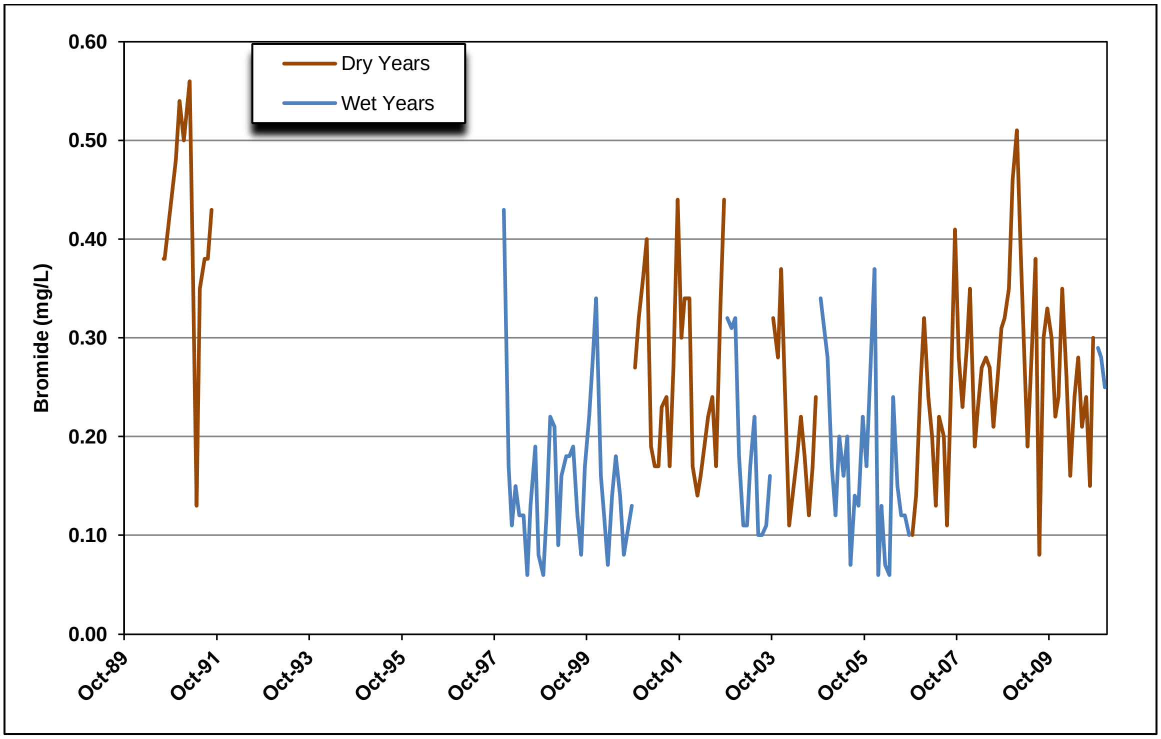
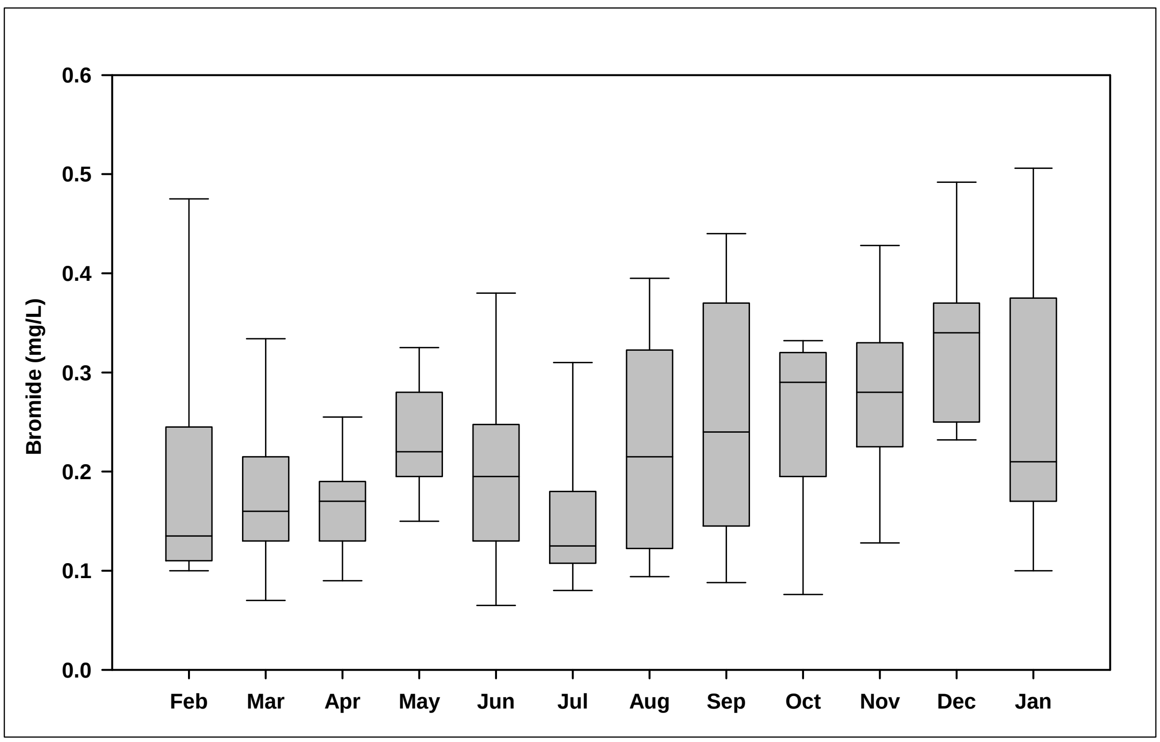


Figure 6-29. Monthly Variability in Bromide at O'Neill Forebay Outlet



Note: Insufficient data to plot all percentiles.

Check 21 – Check 21 represents the quality of water entering the Coastal Aqueduct. Grab sample data have been collected at Check 21 since 1998. **Figure 6-30** presents the bromide grab sample data for Check 21. The bromide concentrations at Check 21 range from 0.07 to 0.43 mg/L with a median of 0.22 mg/L.

- Spatial Trends – **Figure 6-22** compares the data collected between 1999 and 2010 at Check 21 to a number of other locations along the aqueduct. Although there are flood and groundwater inflows into the aqueduct between O'Neill Forebay Outlet and Check 21, the median bromide concentration at Check 21 is the same as the median at O'Neill Forebay Outlet and the variability in the data is similar.

- Long-Term Trends – **Figure 6-30** shows that bromide concentrations were lower during the wet years of the late 1990s and there is no apparent trend in recent years.

- Wet Year/Dry Year Comparison – The Check 21 dry year median bromide concentration of 0.24 mg/L is statistically significantly higher than the wet year median of 0.15 mg/L (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-31** shows there is a distinct seasonal pattern with the lowest concentrations in the summer months and the highest concentrations in the fall. There is a secondary peak in bromide concentrations during May and June due to releases from San Luis Reservoir. The seasonal pattern at Check 21 is similar to the pattern at O'Neill Forebay Outlet.

Figure 6-30. Bromide Concentrations at Check 21

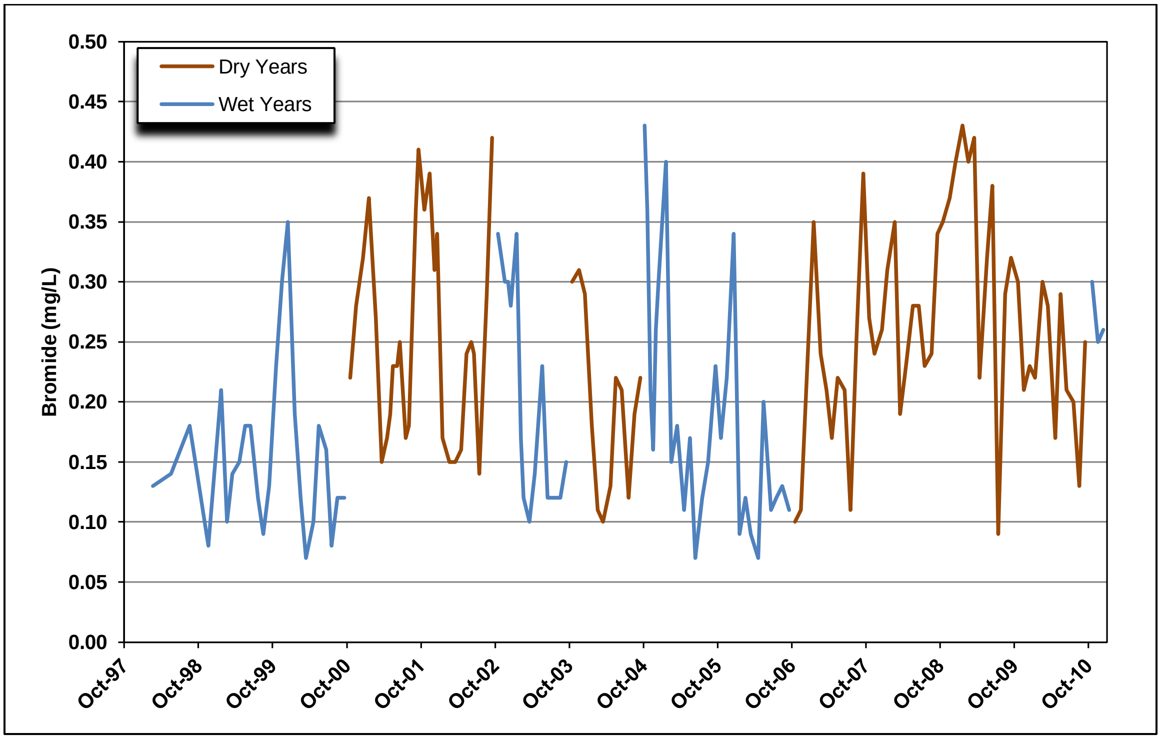
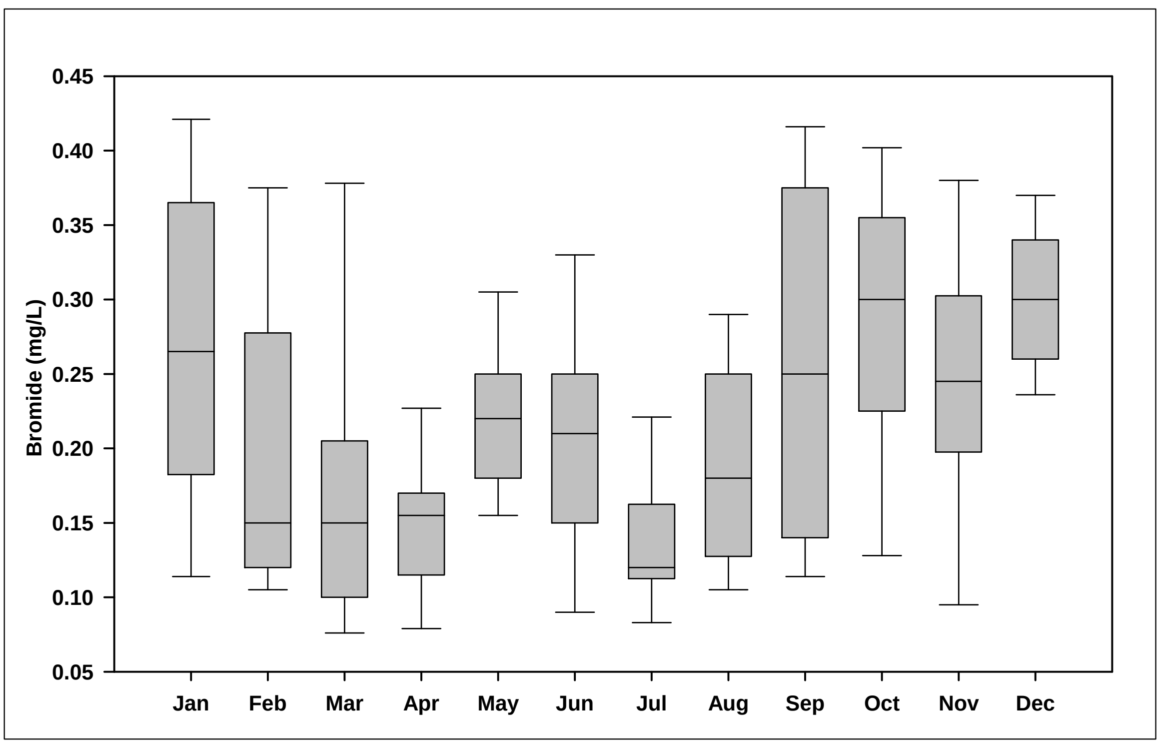


Figure 6-31. Monthly Variability in Bromide at Check 21



Note: Insufficient data to plot all percentiles.

Check 41 – Check 41 is immediately upstream of the bifurcation of the aqueduct. Grab sample data have been collected at Check 41 since December 1997. **Figure 6-32** presents the bromide grab sample data for Check 41. The bromide concentrations at Check 41 range from 0.01 to 0.47 mg/L with a median of 0.21 mg/L.

- Spatial Trends – **Figure 6-22** compares the data collected between 1999 and 2010 at Check 41 to a number of other locations along the aqueduct. The Check 41 median concentration of 0.21 mg/L is not statistically significantly lower than the Check 21 median of 0.22 mg/L. As discussed in Chapter 14, large volumes of groundwater and some surface water enter the aqueduct between Checks 21 and 41. The bromide levels of some inflows are lower than the levels in the aqueduct and the levels of some inflows are higher than the aqueduct. **Figure 6-33** presents the data for Check 21 and Check 41 for the last five years. During this period, there are times when the bromide levels at Check 41 were substantially lower than the levels at Check 21. This is discussed in more detail in Chapter 14.

- Long-Term Trends – **Figure 6-32** shows that there is no apparent long-term trend. Bromide concentrations at Check 41 fluctuate due to hydrology and to upstream inflows.

- Wet Year/Dry Year Comparison – The Check 41 dry year median bromide concentration of 0.22 mg/L is statistically significantly higher than the wet year median of 0.14 mg/L (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-34** shows there is a distinct seasonal pattern with the lowest concentrations in the summer months and the highest concentrations in the fall. There is a secondary peak in bromide concentrations during May and June due to releases from San Luis Reservoir. This is the same pattern seen at Check 21; however, the monthly medians are often 0.02 to 0.05 mg/L lower at Check 41.

Figure 6-32. Bromide Concentrations at Check 41

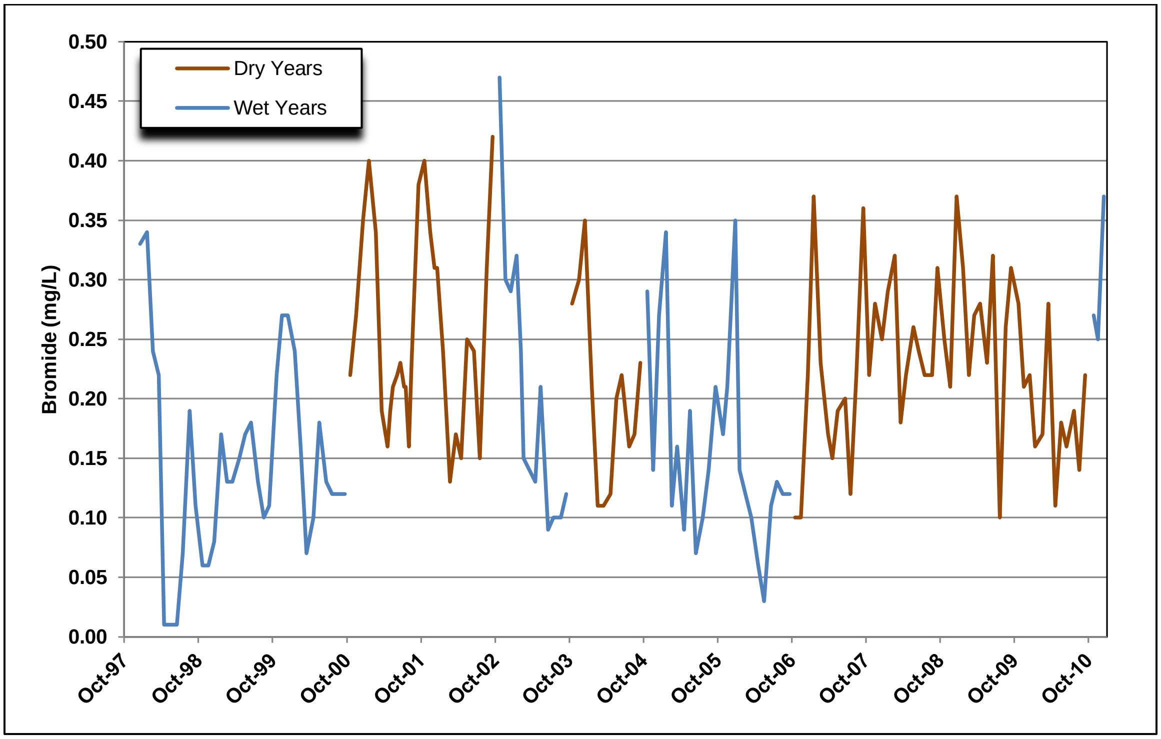


Figure 6-33. Comparison of Check 21 and Check 41 Bromide Concentrations

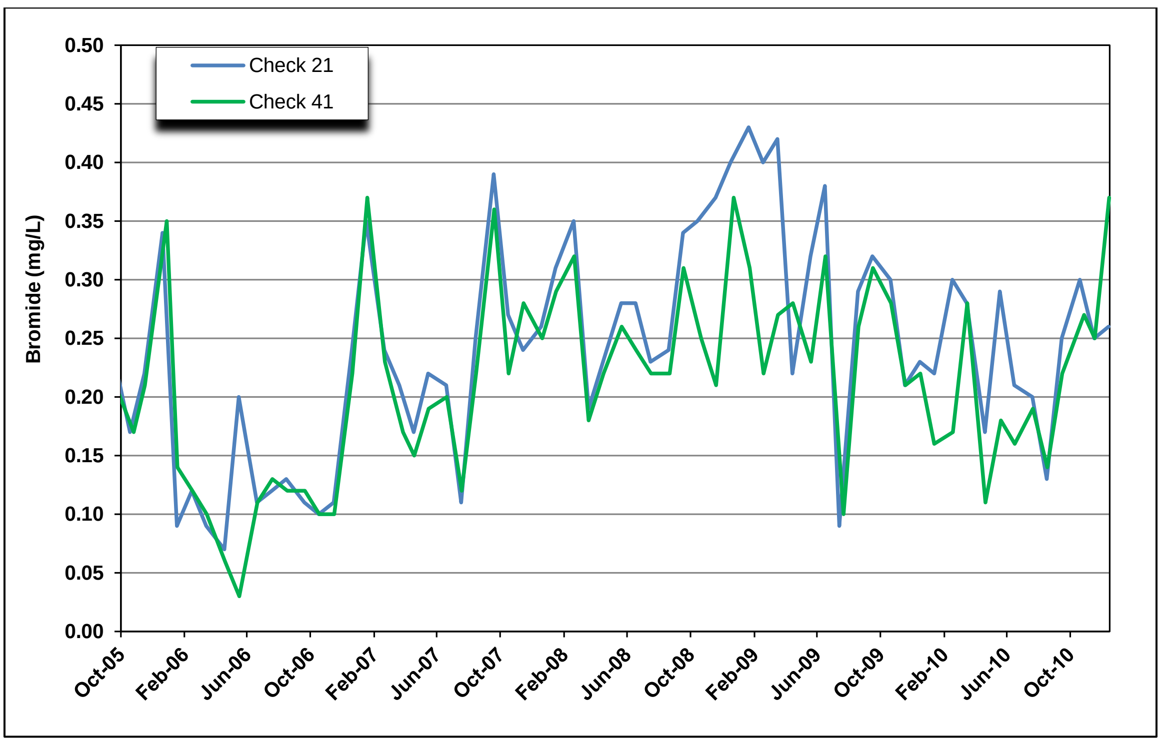
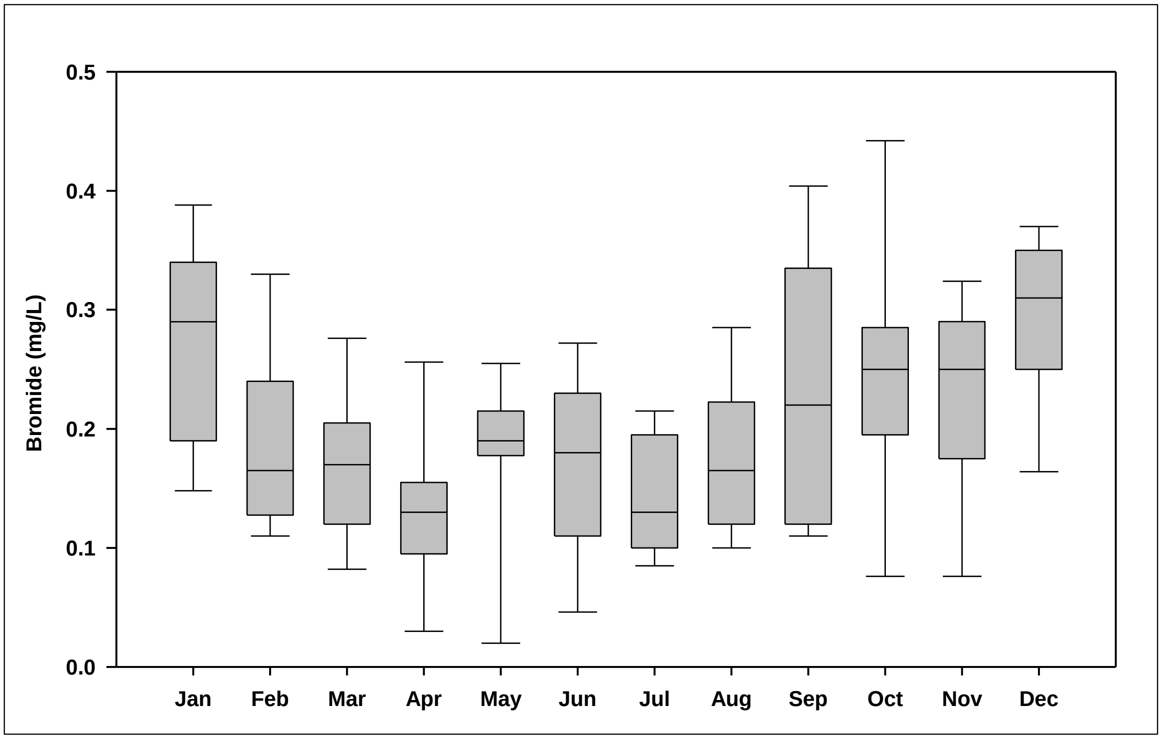


Figure 6-34. Monthly Variability in Bromide at Check 41



Note: Insufficient data to plot all percentiles.

Castaic Outlet – Castaic Lake is the terminus of the West Branch of the California Aqueduct. Grab sample data have been collected at Castaic Outlet since 1998. **Figure 6-35** presents the bromide grab sample data for Castaic Outlet. The bromide concentrations range from 0.11 to 0.33 mg/L with a median of 0.21 mg/L. There is much less variability in the bromide data in the lake compared to the aqueduct.

- Spatial Trends – **Figure 6-22** compares Check 41 data to Castaic Outlet data. Because samples were collected less frequently at Castaic Outlet during 1998 and 1999, a subset of the data collected during the same months was examined. The median bromide concentration in the data subset was the same at both locations (0.21 mg/L).

- Long-Term Trends – **Figure 6-35** shows that bromide concentrations increase during dry years and decrease during wet years.

- Wet Year/Dry Year Comparison – The Castaic Outlet dry year median bromide concentration of 0.23 mg/L is statistically significantly higher than the wet year median of 0.16 mg/L (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-36** shows that there is little variability in bromide concentrations throughout the year at Castaic Outlet.

Figure 6-35. Bromide Concentrations at Castaic Outlet

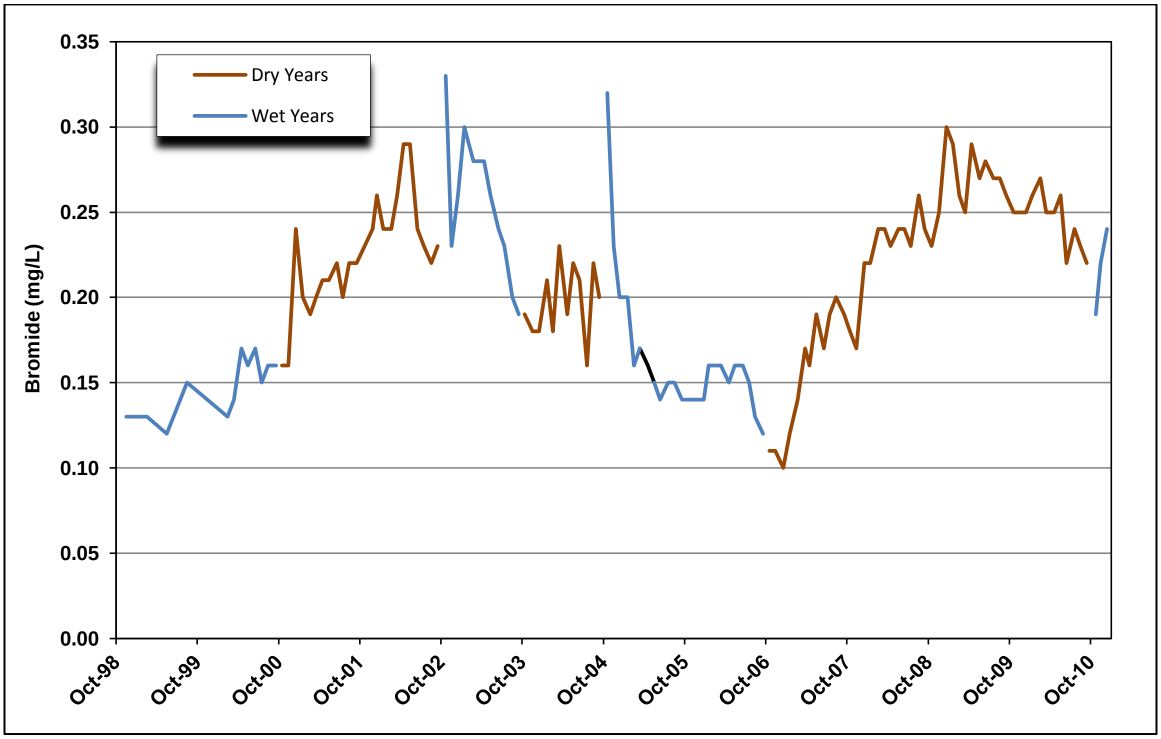
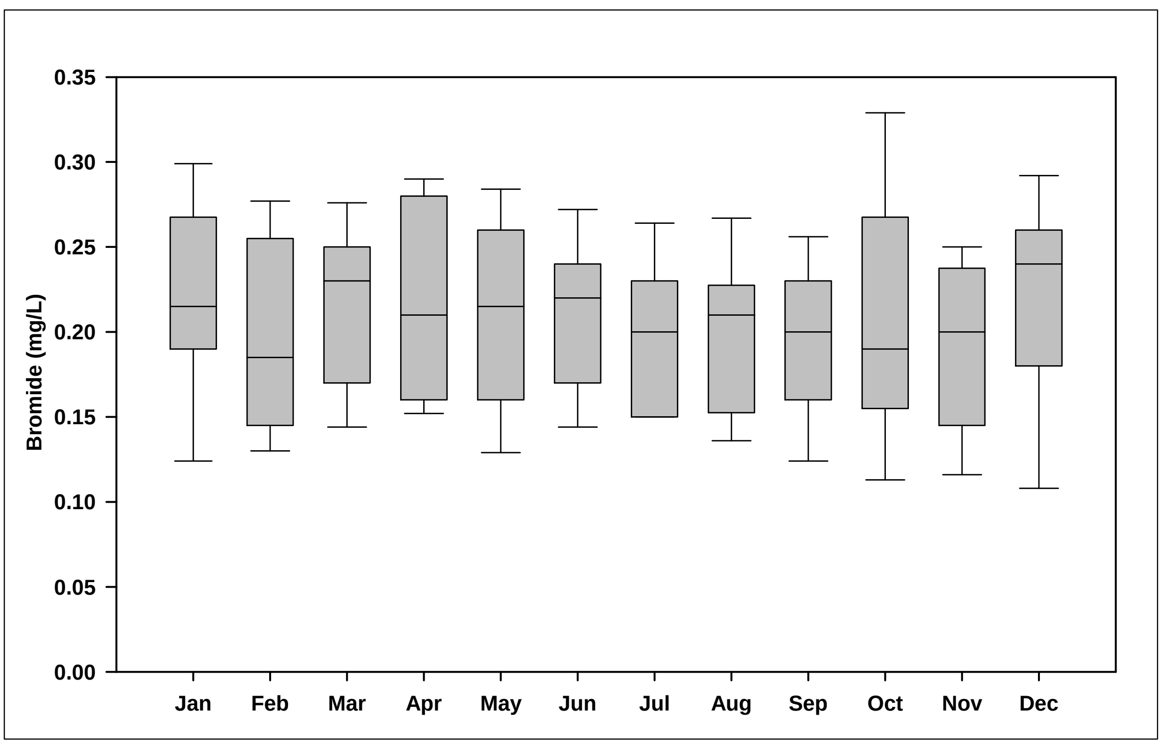


Figure 6-36. Monthly Variability in Bromide at Castaic Outlet



Note: Insufficient data to plot all percentiles.

Devil Canyon – Devil Canyon Afterbay is downstream of Silverwood Lake on the East Branch of the California Aqueduct. Grab sample data have been collected at Devil Canyon since December 1997. **Figure 6-37** presents the bromide grab sample data for Devil Canyon. The bromide concentrations range from 0.04 to 0.40 mg/L with a median of 0.19 mg/L.

- Spatial Trends – **Figure 6-22** compares Check 41 data to Devil Canyon data collected between December 1997 and December 2010 at both locations. The median bromide concentration of 0.19 mg/L at Devil Canyon is not statistically significantly different from the median of 0.21 mg/L at Check 41.

- Long-Term Trends – **Figure 6-37** shows that there is no discernible long-term trend in the data. Bromide concentrations increase during dry years and decrease during wet years.

- Wet Year/Dry Year Comparison – The Devil Canyon dry year median bromide concentration of 0.23 mg/L is statistically significantly higher than the wet year median of 0.15 mg/L (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 6-38** shows the same seasonal pattern as the upstream check structures on the aqueduct. The limited storage on the East Branch does not have the same effect of reducing the fluctuations in bromide concentrations that is seen on the West Branch.

Figure 6-37. Bromide Concentrations at Devil Canyon

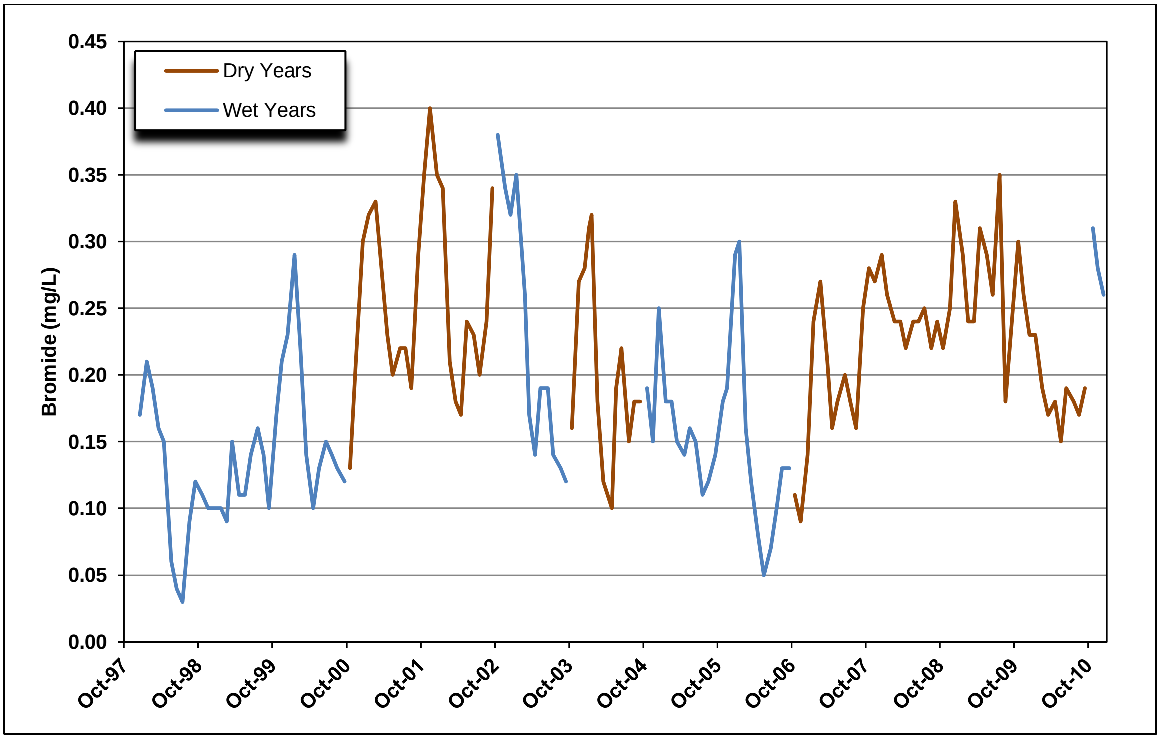
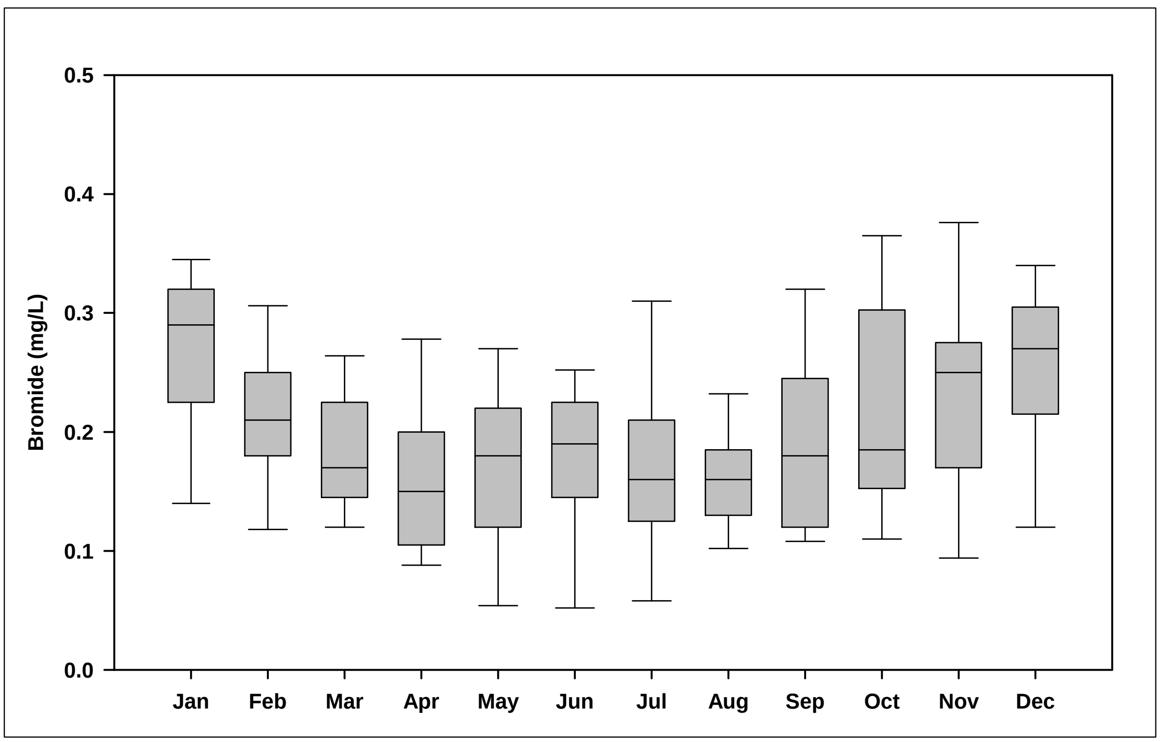


Figure 6-38. Monthly Variability in Bromide at Devil Canyon



Note: Insufficient data to plot all percentiles.

SUMMARY

- Bromide concentrations in the Sacramento River are low, often at or near the detection limit of 0.01 mg/L. Conversely, bromide concentrations are high in the San Joaquin River (median of 0.25 mg/L).

- Bromide concentrations in the NBA are higher and more variable than at Hood but substantially lower than the levels at Banks. The Barker Slough watershed is the source. The median bromide concentration (0.04 mg/L) is the same at Barker Slough and Cordelia.

- The median concentration of bromide does not change significantly between Banks, DV Check 7, and the Terminal Tank on the SBA. There is a statistically significant increase in bromide between Banks (median of 0.18 mg/L) and San Luis Reservoir (median of 0.25 mg/L) (Mann-Whitney, p=0.0002); however, the variability of bromide in the reservoir is greatly reduced. Bromide concentrations in the DMC at McCabe (median of 0.20 mg/L) are not statistically significantly different from Banks so the increase between Banks and Pacheco is attributed to evaporation in the reservoir and filling of the reservoir when bromide concentrations are high in the Delta. There is a statistically significant increase in bromide concentrations between Banks and O'Neill Forebay Outlet (median of 0.22 mg/L) but bromide does not change statistically significantly between O'Neill Forebay Outlet and Castaic Outlet and Devil Canyon. Bromide concentrations in Castaic Lake are slightly less variable than the aqueduct locations; however, the dampening effect is not seen in Silverwood Lake.

- Anion analyzers have measured bromide concentrations continuously at Banks and Vernalis for over four years. There is good correspondence between the grab sample and real-time data at these two locations. The real-time data at Banks show that bromide concentrations are occasionally higher than the levels measured in grab samples.

- Bromide concentrations are a function of the hydrology of the system. There are apparent downward trends in bromide concentrations at Vernalis and Banks that are simply due to the fact that data collection began at these two sites during the drought of the early 1990s. There is an apparent upward trend in bromide concentrations at Pacheco that is due to the fact that bromide data were first collected in 2000, which was the end of six wet years and bromide concentrations were low. There are no apparent long term trends at any of the other locations included in this analysis.

- Bromide concentrations during dry years are statistically significantly higher than bromide concentrations during wet years at all locations except Barker Slough, as shown in **Table 6-2**. There are no statistically significant differences between year types at this location. The median bromide concentrations during dry years are 50 to 100 percent higher than the median concentrations during wet years. This is due to seawater intrusion in the Delta during periods of low Delta outflow.

- There are distinct seasonal patterns in bromide concentrations but they vary between locations. At Barker Slough, bromide concentrations increase during the spring months due to groundwater and subsurface flows from the Barker Slough watershed and then decrease throughout the summer and fall months. On the San Joaquin River, concentrations decrease throughout the winter and spring months to minimum levels in May during the VAMP flows. The concentrations then increase throughout the summer, fall, and early winter months. Concentrations are low at Banks from February through May and then increase steadily throughout the summer, fall, and early winter months due to the discharge of agricultural drainage and seawater intrusion. Downstream of San Luis reservoir, bromide concentrations show the same pattern as Banks except there is a secondary peak in May and June due to the release of large amounts of water from San Luis Reservoir.

Table 6-2. Comparison of Dry Year and Wet Year Bromide Concentrations

Location	Median Bromide (mg/L)		Bromide Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	<0.01	<0.01	0	0	No
Vernalis	0.30	0.17	0.13	43	D>W
Banks	0.27	0.12	0.15	56	D>W
Barker	0.04	0.04	0	0	No
DV Check 7	0.18	0.12	0.06	33	D>W
McCabe	0.24	0.13	0.11	46	D>W
Pacheco	0.26	0.23	0.03	12	D>W
O'Neill Forebay Outlet	0.27	0.16	0.11	41	D>W
Check 21	0.24	0.15	0.09	38	D>W
Check 41	0.22	0.14	0.08	36	D>W
Castaic Outlet	0.23	0.16	0.07	30	D>W
Devil Canyon	0.23	0.15	0.08	35	D>W

REFERENCES

Literature Cited

California Department of Water Resources. 2008. Quality Assurance Project Plan for Real-Time, Continuous Monitoring of Bromide and Nutrients at H.O. Banks Pumping Plant and San Joaquin River near Vernalis.

Personal Communication

Rabidoux, Alex, Solano County Water Agency.

CHAPTER 7 NUTRIENTS

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CHAPTER 7 NUTRIENTS

WATER QUALITY CONCERN

Nutrients are required for the proper functioning of aquatic ecosystems but when they are present in drinking water supplies at concentrations that exceed natural background levels, a number of adverse impacts occur. When nutrients are readily available and other environmental conditions favorable, algal growth can reach levels that cause taste and odor in drinking water, produce algal toxins, add organic carbon, obstruct water conveyance facilities, clog filters and increase the quantity and expense of handling solid waste from the treatment process. Excess algal growth can result in anaerobic conditions in the hypolimnion of reservoirs when the algae decompose and settle out of the water column. While ammonia concentrations are typically low in surface waters, anaerobic conditions can lead to high levels. This can result in higher levels of disinfection byproducts (DBPs) and can impact the chlorine demand, potentially reducing the production rate of the water treatment plant.

The U.S. Environmental Protection Agency (USEPA) has established nitrogen and phosphorus reference conditions for Ecoregion I, which includes California's Central Valley. The reference concentration for total nitrogen (total N) is 0.31 mg/L, and for total phosphorus (total P) it is 0.047 mg/L (USEPA, 2001). Temperate streams were classified by Dodds et al. (1998), as shown in **Table 7-1**.

Table 7-1. Trophic Level Classification of Streams

Constituent (mg/L)	Oligotrophic - Mesotrophic Boundary	Mesotrophic - Eutrophic Boundary
Mean total N	0.700	1.500
Mean total P	0.025	0.075

The nutrient concentrations in the State Water Project (SWP) are discussed in this chapter and compared to the reference conditions and the stream trophic level boundary conditions. The impacts on algal blooms and taste and odor compounds are discussed in Chapter 8.

WATER QUALITY EVALUATION

Measurement of nutrient concentrations provides an indication of the potential for algal and vascular plant growth in systems that are not limited by other factors, such as light availability or adverse temperatures. Of the required nutrients, nitrogen and phosphorus are most important, but potassium and silicon, in addition to small quantities of various other elements are also required. Potassium is believed to be in sufficient supply in the aquatic environment of California that it does not limit algal production. Silicon is required by diatoms for growth of their "frustules," or silicon outer bodies, but it is generally present in sufficient quantities to support diatom growth. Nitrogen and phosphorus are, therefore, the subjects of this analysis.

Nitrogen in the aquatic environment can be present in several forms; organic nitrogen, ammonia, nitrite, nitrate, and gaseous nitrogen; that are biochemically inter-convertible. Although gaseous (atmospheric) nitrogen is actually part of the biochemical cycle, its relationship to the other nitrogen forms is complex. Nitrogen is discussed here as the summation of the forms for which SWP waters are analyzed. Total nitrogen as used in this report does not include nitrogen gas, but does include its other forms, nitrate, nitrite, ammonia, and organic nitrogen.

Phosphorus is present in both dissolved and particulate forms. Particulate phosphorus consists of organic phosphorus incorporated in planktonic organisms, inorganic mineral phosphorus in suspended sediments, and phosphate adsorbed to inorganic particles and colloids. The dissolved forms include dissolved organic phosphorus, orthophosphate, and polyphosphates. Dissolved orthophosphate is the only form that is readily available for algal and plant uptake; however total P is a better indicator of the productivity of a system.

NUTRIENT CONCENTRATIONS IN THE SWP

Nutrient data used in this analysis were drawn from the Department of Water Resources (DWR) Municipal Water Quality Investigation (MWQI) Program and from the Division of Operations and Maintenance (O&M) water quality monitoring program. Unlike water quality constituents such as salinity, nitrogen and phosphorus are not conservative in the environment, but change forms as they are incorporated into living organisms and released back into the water at the end of the organisms' life cycles. As a consequence, examining trends can be somewhat more complex than for conservative constituents. The nutrient data were analyzed to determine if there are any changes in concentrations as water travels through the SWP system, and to identify seasonal patterns and changes over time. Data are presented in summary form for all locations and analyzed in more detail for a number of key locations. **Table 7-2** shows the period of record for each location that was evaluated.

The SWP Watershed

Figure 7-1 presents the total N data and **Figure 7-2** presents the total P data for the tributaries to the Sacramento-San Joaquin Delta (Delta), Clifton Court Forebay (Clifton Court), and the Harvey O. Banks Delta Pumping Plant (Banks). Total N and total P concentrations are low at the American River and the Sacramento River at West Sacramento (West Sacramento) sites. There is a considerable increase in both nutrients at the Sacramento River at Hood (Hood); however the Hood concentrations are much lower than those found in the San Joaquin River at Vernalis (Vernalis). Nutrient data have been collected twice a month for the Mokelumne and Calaveras rivers since December 2008. The limited data show that the Mokelumne nutrient concentrations are lower than the Hood concentrations. The Calaveras total N concentrations are nearly as high as the concentrations at Vernalis but the total P concentrations are similar to those at Hood. Both the total N and total P concentrations at Banks are slightly higher than the Hood concentrations.

Table 7-2. Total N and Total P Data

Location	Total N			Total P		
	No. of Samples	Start Date	End Date	No. of Samples	Start Date	End Date
West Sacramento	97	Nov 2002	Dec 2010	98	Nov 2002	Dec 2010
American	97	Nov 2002	Dec 2010	96	Nov 2002	Dec 2010
Hood	162	Nov 2002	Dec 2010	164	Nov 2002	Dec 2010
Greenes Landing						
Mokelumne	43	Dec 2008	Dec 2010	43	Dec 2008	Dec 2010
Calaveras	39	Dec 2008	Nov 2010	39	Dec 2008	Nov 2010
Vernalis	163	Nov 2002	Dec 2010	164	Nov 2002	Dec 2010
Clifton Court	46	Mar 2007	Dec 2010	48	Mar 2007	Dec 2010
Banks	162	Jan 1998	Dec 2010	163	Dec 1997	Dec 2010
Barker Slough	156	Jan 1998	Dec 2010	158	Dec 1997	Dec 2010
DV Check 7	141	Jan 1998	Oct 2010	142	Dec 1997	Oct 2010
Conservation Outlet	46	Feb 1998	Dec 2010	46	Feb 1998	Dec 2010
Jones						
McCabe	18	Jul 2009	Dec 2010	18	Jul 2009	Dec 2010
Pacheco	132	Mar 2000	Dec 2010	132	Mar 2000	Dec 2010
O’Neill Forebay Outlet	78	Jun 2004	Dec 2010	78	Jun 2004	Dec 2010
Check 21	128	Apr 2000	Dec 2010	128	Apr 2000	Dec 2010
Check 29	82	Jun 2000	Dec 2010	82	Jun 2000	Dec 2010
Check 41	157	Jan 1998	Dec 2010	158	Dec 1997	Dec 2010
Castaic Outlet	155	Jan 1998	Dec 2010	157	Dec 1997	Dec 2010
Check 66	155	Jan 1998	Dec 2010	156	Dec 1997	Dec 2010
Silverwood Outlet	156	Jan 1998	Dec 2010	157	Dec 1997	Dec 2010
Devil Canyon Headworks	121	Jun 2001	Dec 2010	121	Jun 2001	Dec 2010
Devil Canyon Afterbay	41	Jan 1998	May 2001	42	Dec 1997	May 2001
Perris Outlet	157	Jan 1998	Dec 2010	158	Dec 1997	Dec 2010

Figure 7-1. Total N Concentrations in the SWP Watershed

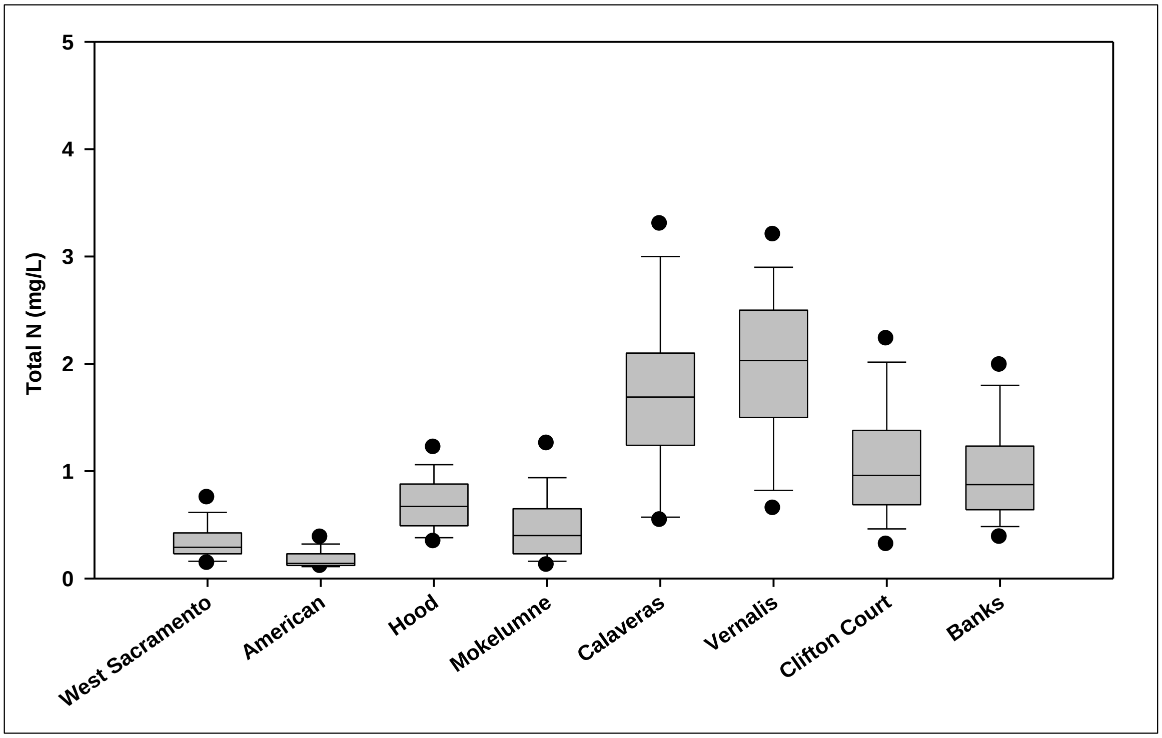


Figure 7-2. Total P Concentrations in the SWP Watershed

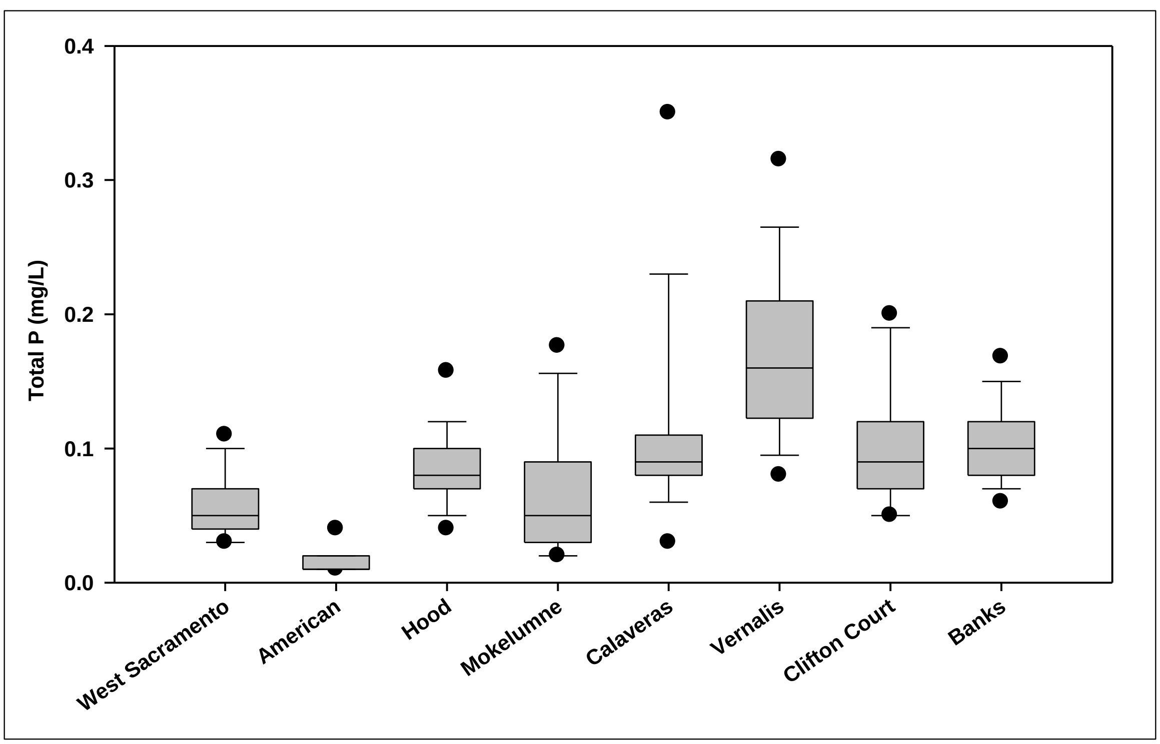


Table 7-3 presents the mean concentrations of total N and total P and the resultant trophic level classification based on the values shown in **Table 7-1** from Dodds et al. (1998). Based on this classification system, the American River is oligotrophic and the Sacramento River is oligotrophic/mesotrophic at West Sacramento, upstream of the Sacramento urban area. Downstream of the urban area, the Sacramento River is classified as mesotrophic/eutrophic at Hood. The San Joaquin River is eutrophic, with mean total N and total P concentrations substantially higher than the boundary condition. Although Banks is not a stream, it is shown in the table to indicate that the water pumped into the California Aqueduct is classified as mesotrophic/eutrophic.

Table 7-3. Mean Nutrient Concentrations and Stream Classifications

Location	Total N (mg/L)	Total P (mg/L)	Classification
West Sacramento	0.34	0.06	Total N – Oligotrophic Total P – Mesotrophic
American	0.19	0.02	Total N – Oligotrophic Total P – Oligotrophic
Hood	0.71	0.09	Total N – Mesotrophic Total P – Eutrophic
Mokelumne	0.49	0.07	Total N – Oligotrophic Total P – Mesotrophic
Calaveras	1.73	0.12	Total N – Eutrophic Total P – Eutrophic
Vernalis	1.98	0.17	Total N – Eutrophic Total P – Eutrophic
Banks	1.00	0.11	Total N – Mesotrophic Total P – Eutrophic

Hood – **Figure 7-3** shows all available total N data and **Figure 7-4** shows total P data at Hood. The total N concentrations range from 0.12 to 1.44 mg/L with a median of 0.67 mg/L and the total P concentrations range from 0.03 to 0.22 mg/L with a median of 0.08 mg/L.

- Spatial Trends – **Figures 7-1 and 7-2** present all available data for West Sacramento, American, and Hood. The period of record is the same for all three stations (November 2002 to December 2010). Total N and total P are both very low at American, with median concentrations of 0.14 mg/L for total N and 0.01 mg/L for total P. The median concentrations at West Sacramento are 0.29 mg/L for total N and 0.05 mg/L for total P. Concentrations increase considerably between West Sacramento and Hood, despite the inflow of the high quality American River, due mainly to the discharge from the Sacramento Regional Wastewater Treatment Plant. The median concentrations of total N (0.67 mg/L) and total P (0.08 mg/L) at Hood are statistically significantly higher than the median concentrations at West Sacramento (Mann-Whitney, p=0.0000)

- Long-Term Trends – **Figures 7-3** and **7-4** do not reveal any discernible trends in the data collected in the last eight years.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median total N concentration during dry years of 0.74 mg/L is statistically significantly higher than the median of 0.60 mg/L during wet years (Mann-Whitney, p=0.0049). The dry year median total P concentration of 0.09 mg/L is not statistically significantly higher than the wet year median of 0.08 mg/L (Mann-Whitney, p=0.1138). The higher total N concentrations during dry years could be due to the greater influence of the Sacramento Regional Wastewater Treatment Plant. The plant discharges a relatively larger load of nitrogen than phosphorus to the river. Chapter 13 contains a discussion of this plant and its effluent quality.

- Seasonal Trends – **Figures 7-5 and 7-6** show a clear seasonal pattern of higher concentrations during the wet months of November to February and lower concentrations from March to October. There is a secondary peak in total N during June. The higher concentrations in the wet months are likely due to nutrients being flushed from the watershed during storm events. The spring months may have lower nutrient concentrations due to high quality water being released from reservoirs and the summer months have lower concentrations due to biological uptake. The secondary peak in total N in June may be due to the greater influence of the Sacramento Regional Wastewater Treatment Plant during periods of low flows on the river.

Figure 7-3. Total N Concentrations at Hood

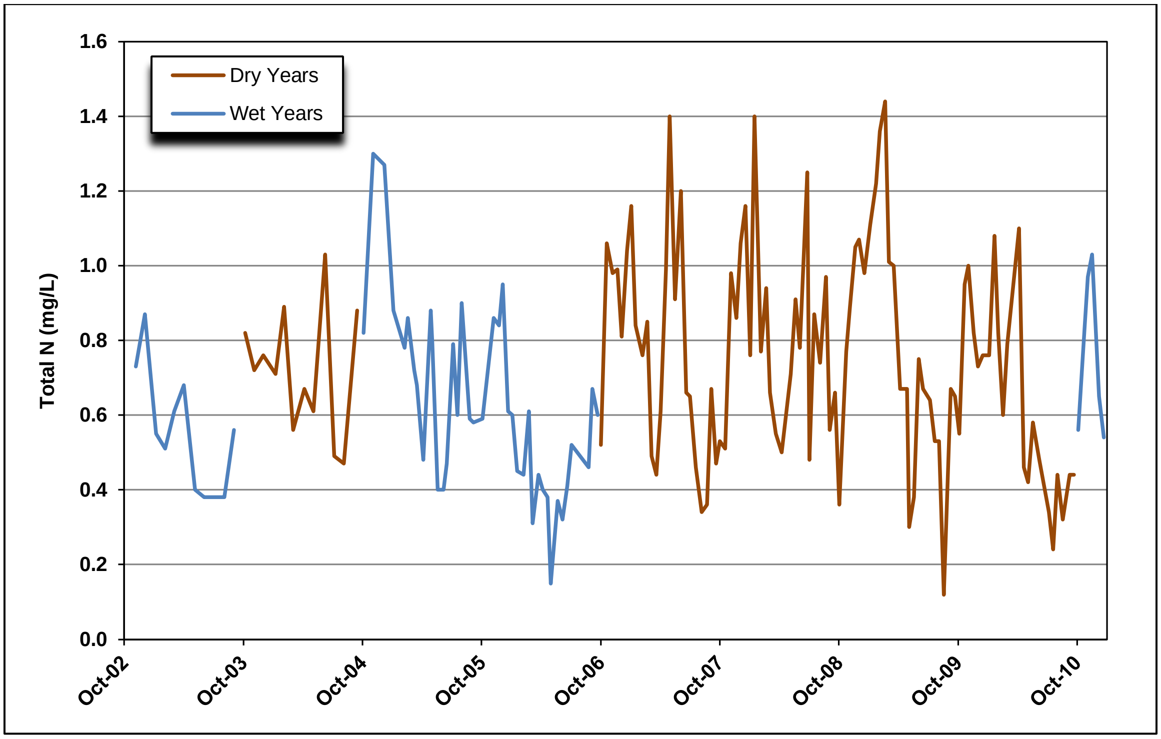


Figure 7-4. Total P Concentrations at Hood

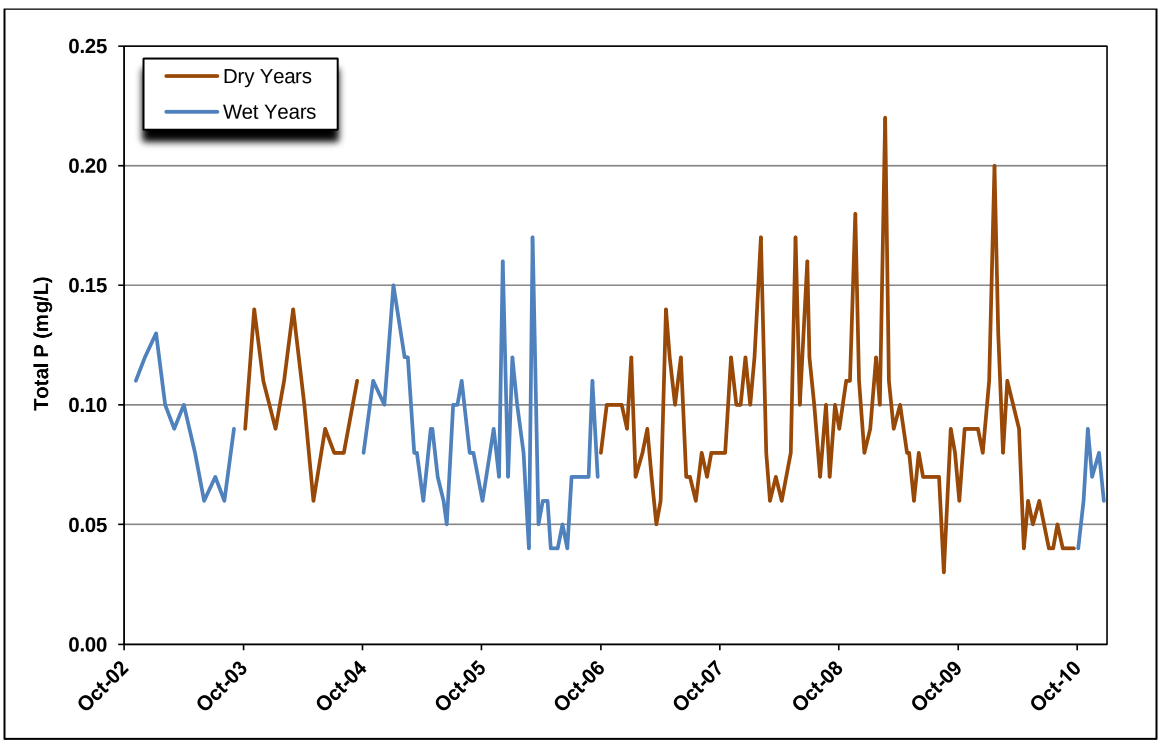
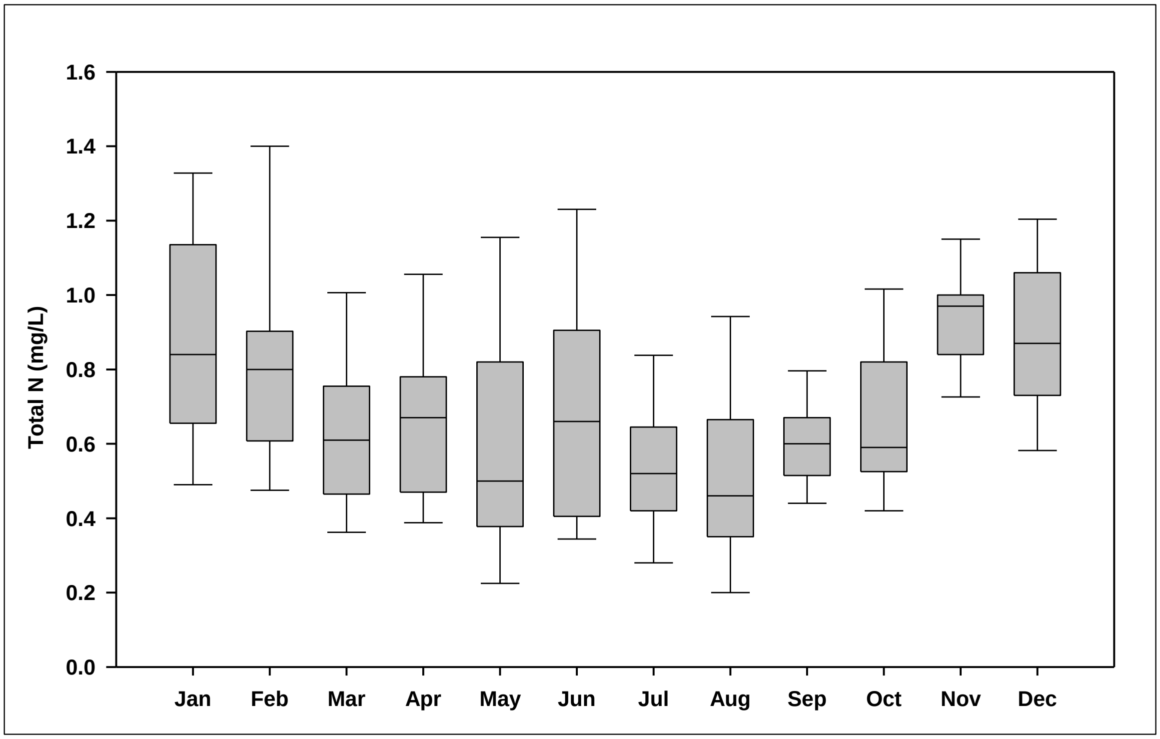
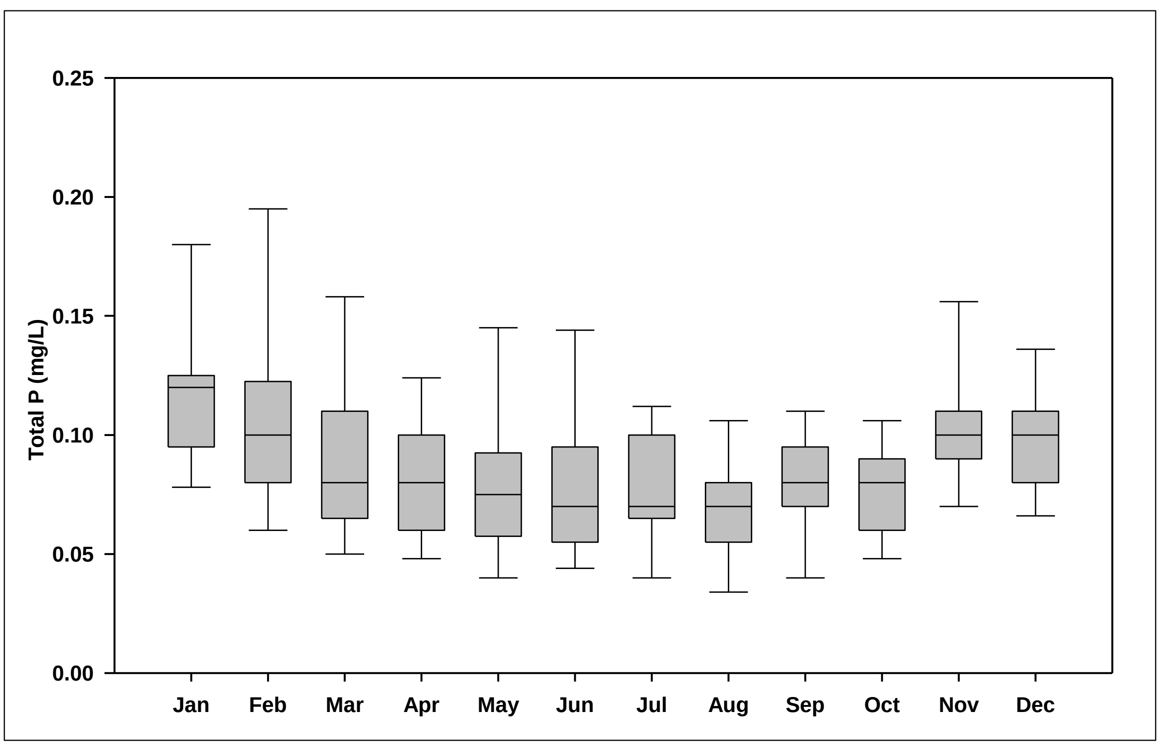


Figure 7-5. Monthly Variability in Total N at Hood



Note: Insufficient data to plot all percentiles.

Figure 7-6. Monthly Variability in Total P at Hood



Note: Insufficient data to plot all percentiles.

Vernalis **- Figures 7-7 and 7-8** present the total N and total P data at Vernalis. The total N concentrations range from 0.28 to 3.9 mg/L with a median of 2.0 mg/L and the total P concentrations range from 0.05 to 0.45 mg/L with a median of 0.16 mg/L. The median total N concentration at Vernalis is triple the median concentration at Hood, whereas the total P concentration is only twice the concentration at Hood. These higher concentrations are a reflection of the agricultural nature of the San Joaquin watershed.

- Spatial Trends – DWR does not collect data upstream of Vernalis.

- Long-Term Trends – **Figure 7-7** does not show any discernible trend in total N concentrations during the last eight years. Total P concentrations were higher during 2004 and the first few months of 2005 than in recent years but the cause of this is unknown. It may be due to the fact that 2004 was the fourth consecutive dry year in the San Joaquin Basin and flows in the river were low.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median total N concentration during dry years of 2.2 mg/L is statistically significantly higher than the median of 1.8 mg/L during wet years (Mann-Whitney, p=0.0000). The median total P concentration was 0.16 mg/L in both dry and wet years.

- Seasonal Trends – **Figures 7-9 and 7-10** show a clear seasonal pattern of low concentrations in April and May, followed by progressively increasing nutrient concentrations during the summer months. The concentrations decrease slightly during the fall and then increase again in the winter months. The low concentrations in the spring are due to the release of high quality water from reservoirs to meet the Vernalis Adaptive Management Plan (VAMP) flow requirements. Agricultural drainage is discharged to the river during the summer months when flows on the San Joaquin River are low. The slight decrease in concentrations during the fall months may be due to less agricultural drainage entering the river during this time and the increase in the winter months is likely due to storm events flushing nutrients from the watershed.

Figure 7-7. Total N Concentrations at Vernalis

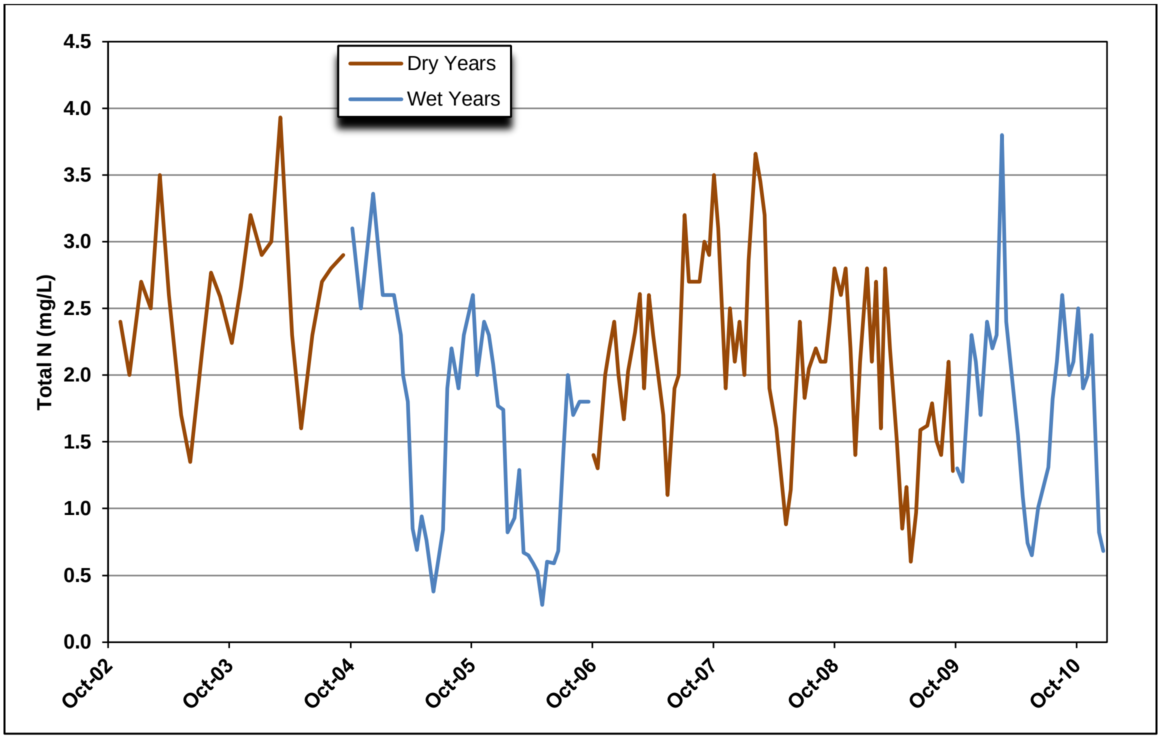


Figure 7-8. Total P Concentrations at Vernalis

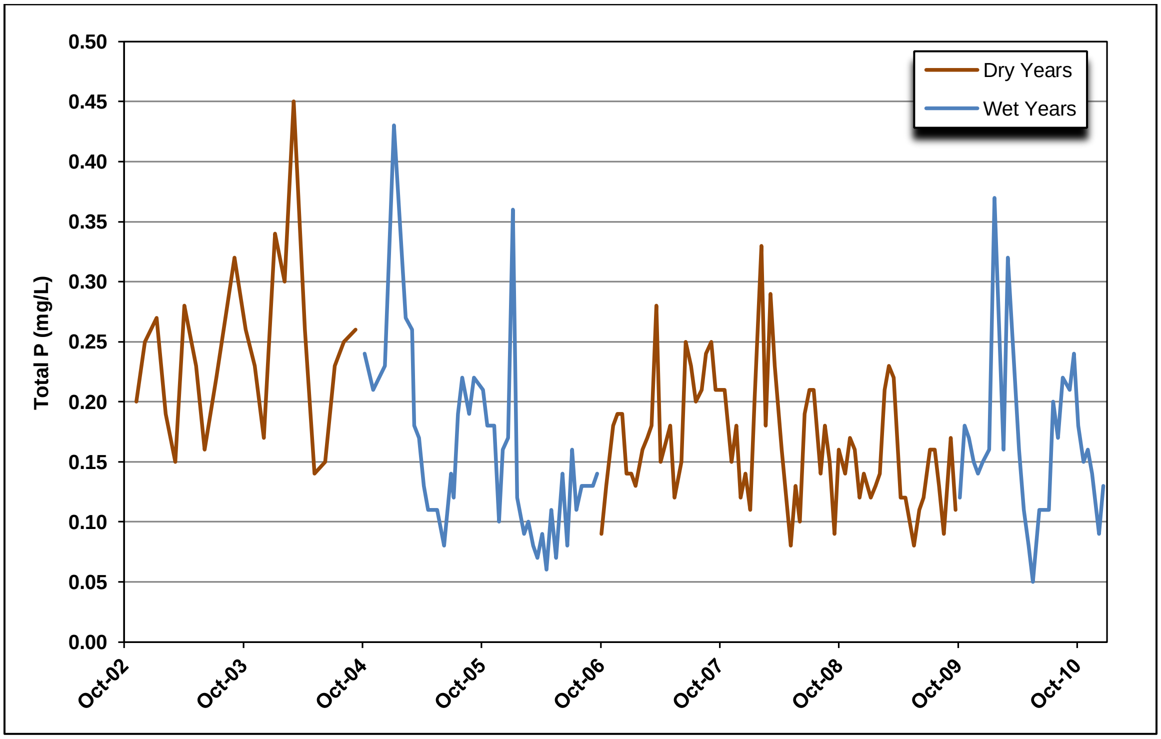
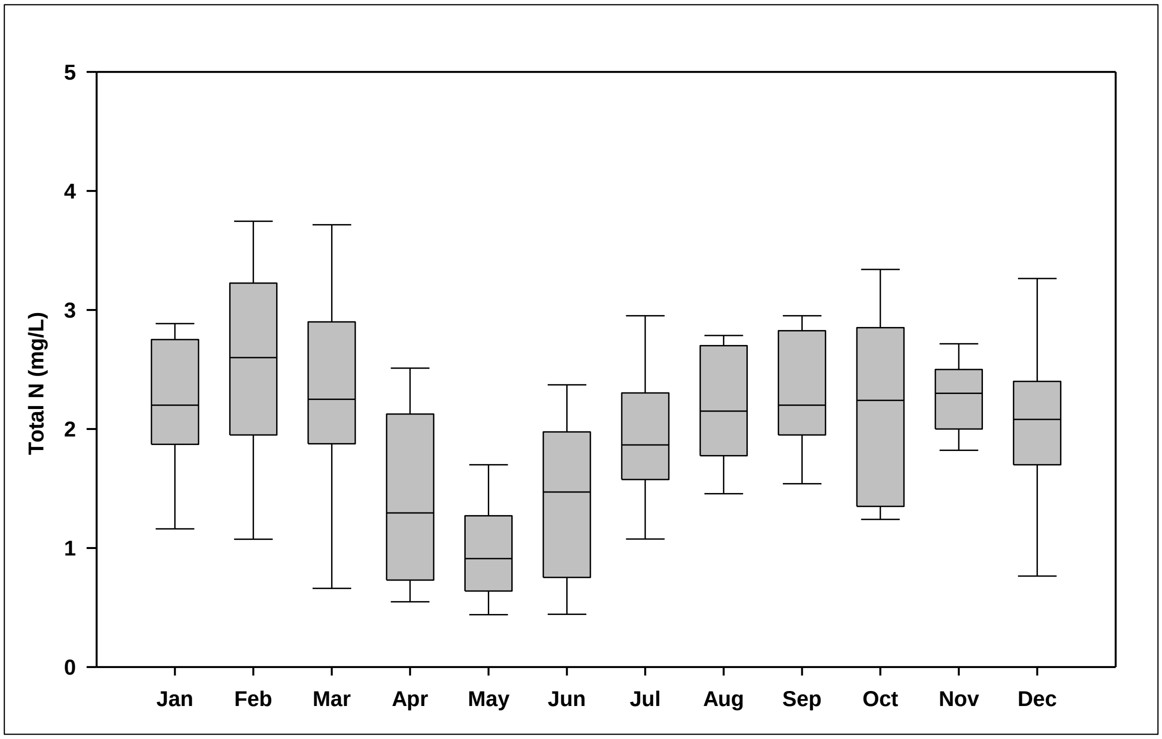
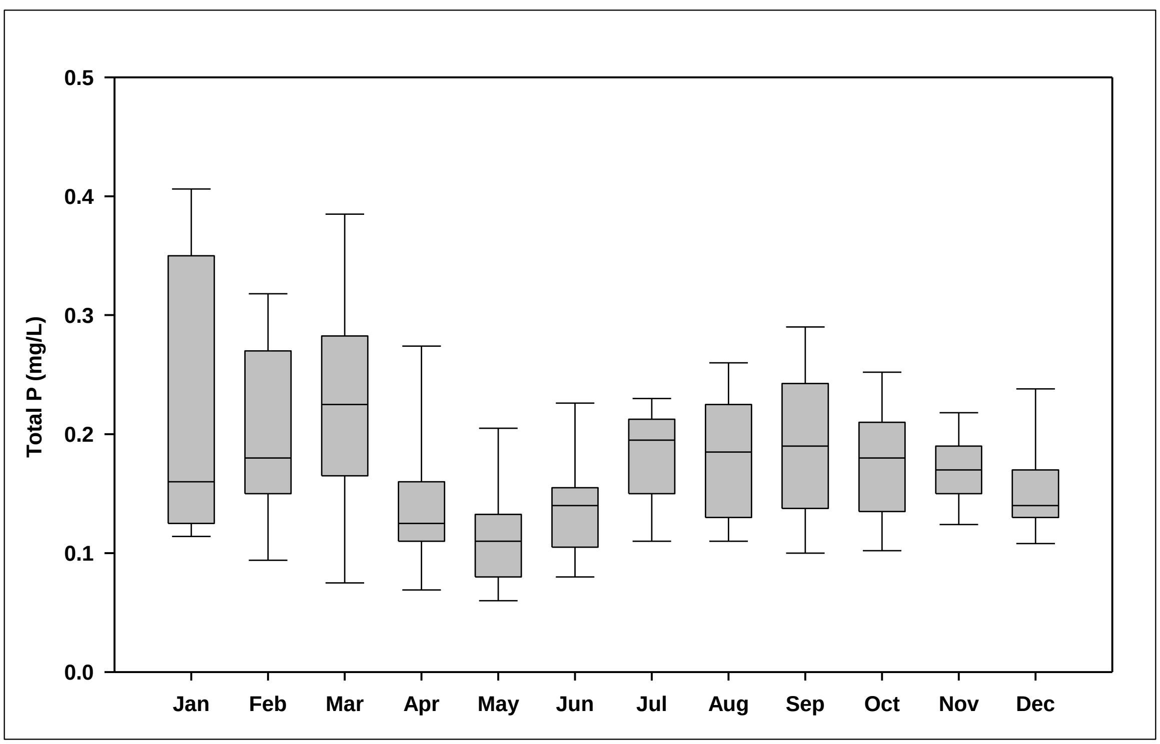


Figure 7-9. Monthly Variability in Total N at Vernalis



Note: Insufficient data to plot all percentiles.

Figure 7-10. Monthly Variability in Total P at Vernalis



Note: Insufficient data to plot all percentiles.

Banks – **Figure 7-11** shows all available total N data and **Figure 7-12** shows total P data at Banks. The period of record is longer at Banks than at Vernalis and Hood. The total N concentrations range from 0.15 to 2.5 mg/L with a median of 0.88 mg/L and the total P concentrations range from 0.04 to 0.28 mg/L with a median of 0.10 mg/L.

- Spatial Trends – Although the Sacramento River is the primary source of water diverted through Banks into the SWP system, the total N concentration at Banks (median of 0.88 mg/L) is about 30 percent higher than the median concentration of 0.67 mg/L at Hood (Mann-Whitney, p=0.0002) and the data are more variable. The median total P concentration of 0.10 mg/L is slightly, but statistically significantly higher than the median concentration of 0.08 mg/l at Hood (Mann-Whitney, p=0.0046) and the Banks data exhibit the same variability as the Hood data. As discussed previously, the median total N concentration at Vernalis is more than triple the median concentration at Hood whereas the median total P is about double. This may partially explain why the total N concentrations at Banks increase more than the total P concentrations; however there are also in-Delta sources of nutrients. Another complicating factor is that nutrients are not conservative constituents.

- Long-Term Trends – **Figure 7-11** does not reveal any discernible trend in the total N data collected in the last 13 years. **Figure 7-12** indicates that total P concentrations appear lower in the last several years.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median total N concentration during dry years of 0.99 mg/L is not statistically significantly higher than the median of 0.82 mg/L during wet years (Mann-Whitney, p=0.5340). The median total P concentration is 0.10 mg/L in both dry and wet years.

- Seasonal Trends – **Figures 7-13 and 7-14** show different seasonal patterns for total N and total P at Banks. The total N pattern is similar to the pattern at Hood with high concentrations during the winter months, declining concentrations in the spring and summer and increasing concentrations during the fall months. The total P concentrations are high in the winter months, decrease during April, but then increase again in May and June before declining throughout the rest of the summer and fall. As shown in **Figure 3-11**, the San Joaquin River contributes a substantial amount of water at Clifton Court during May and June, approaching 100 percent in some years. Although nutrient concentrations are lowest at Vernalis in May (total P monthly median of 0.11 mg/ and total N monthly median of 0.91), these levels are about the same as those observed at Banks in May and June.

Figure 7-11. Total N Concentrations at Banks

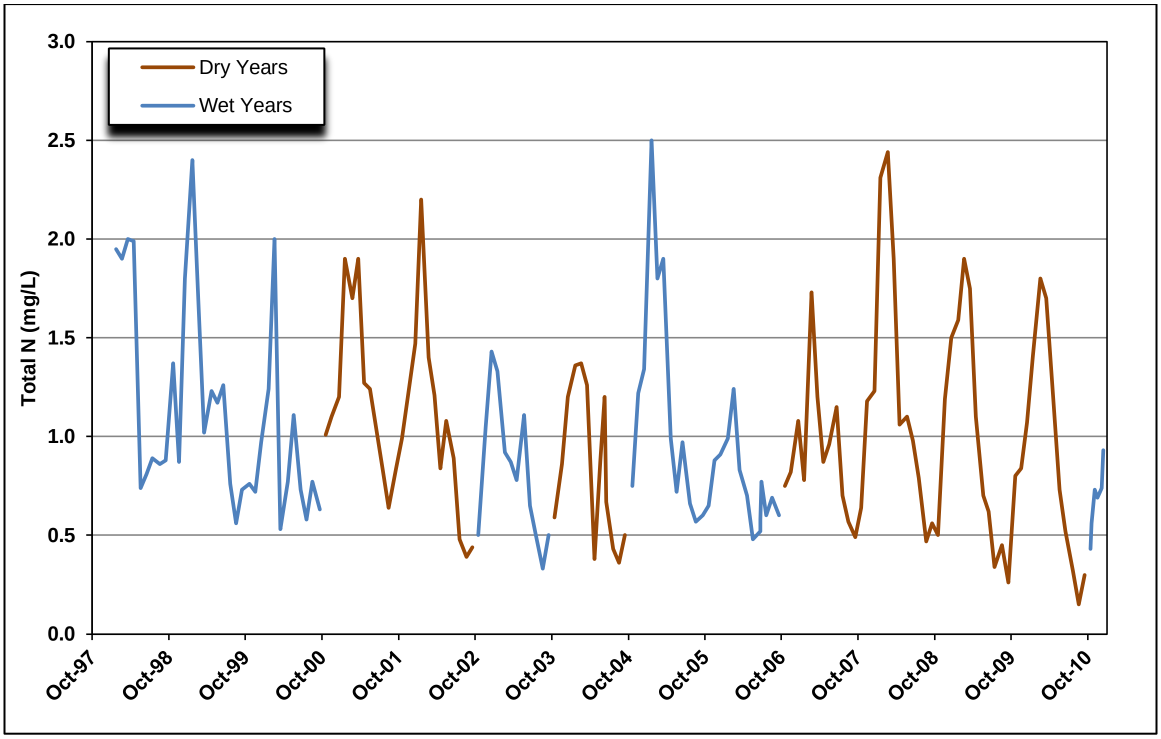


Figure 7-12. Total P Concentrations at Banks

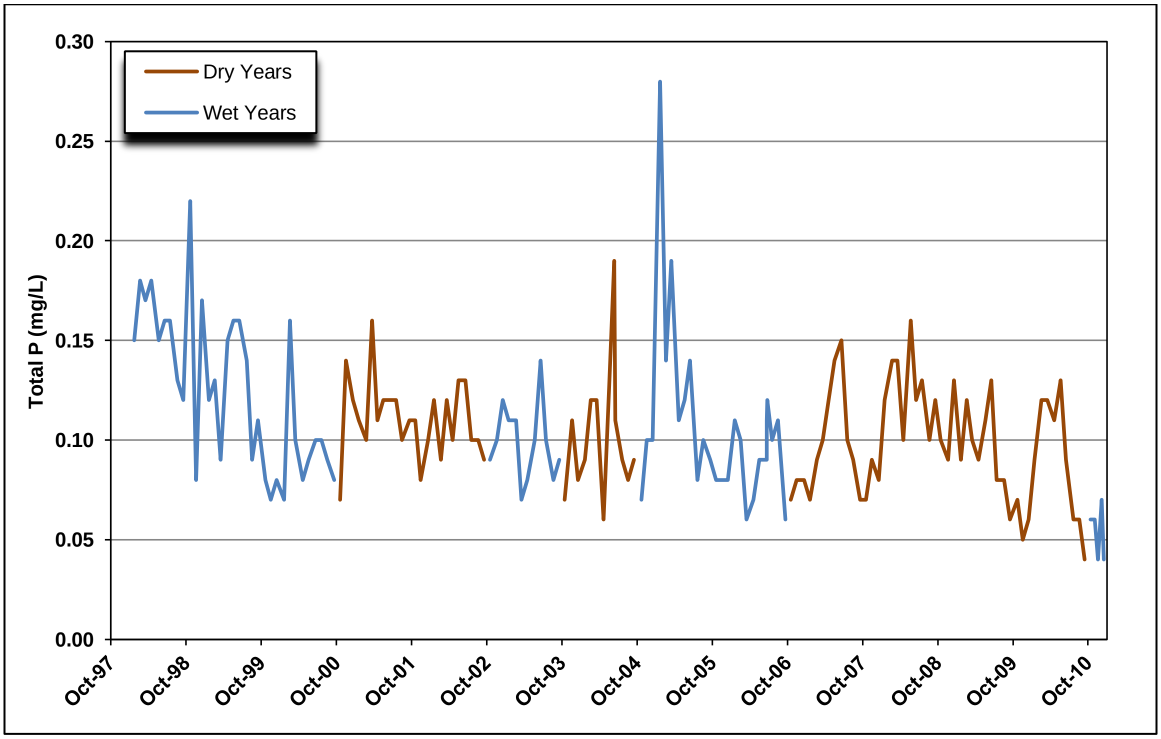
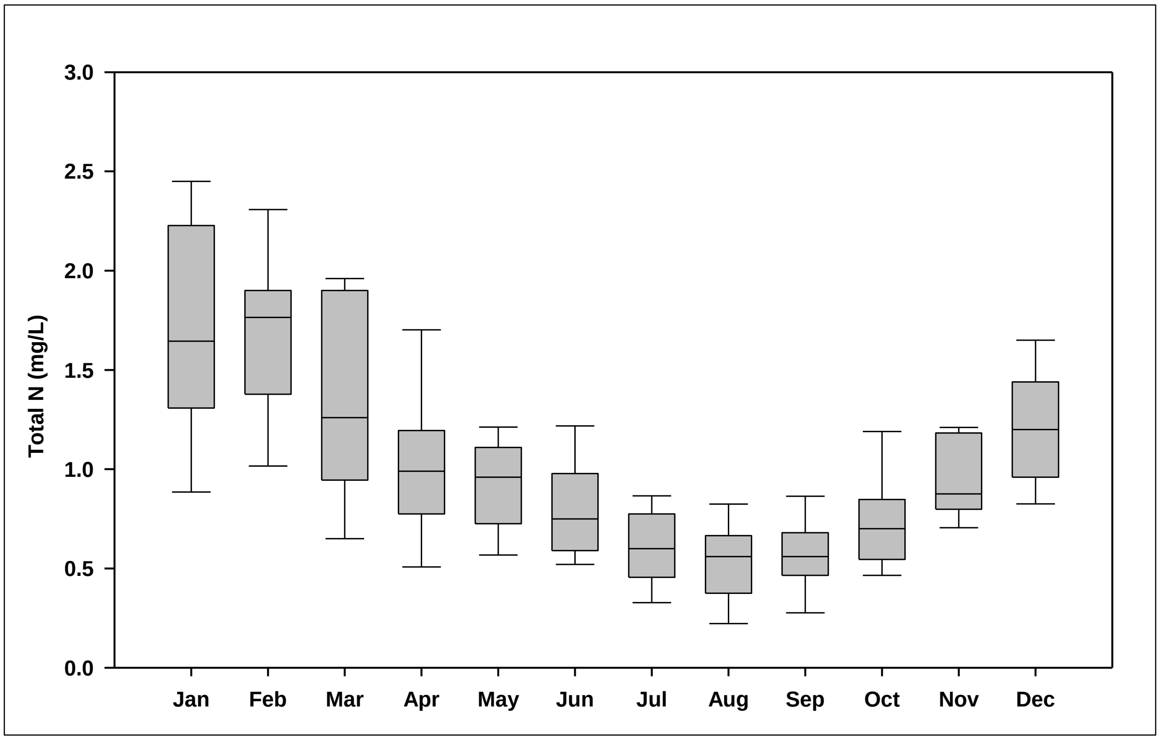
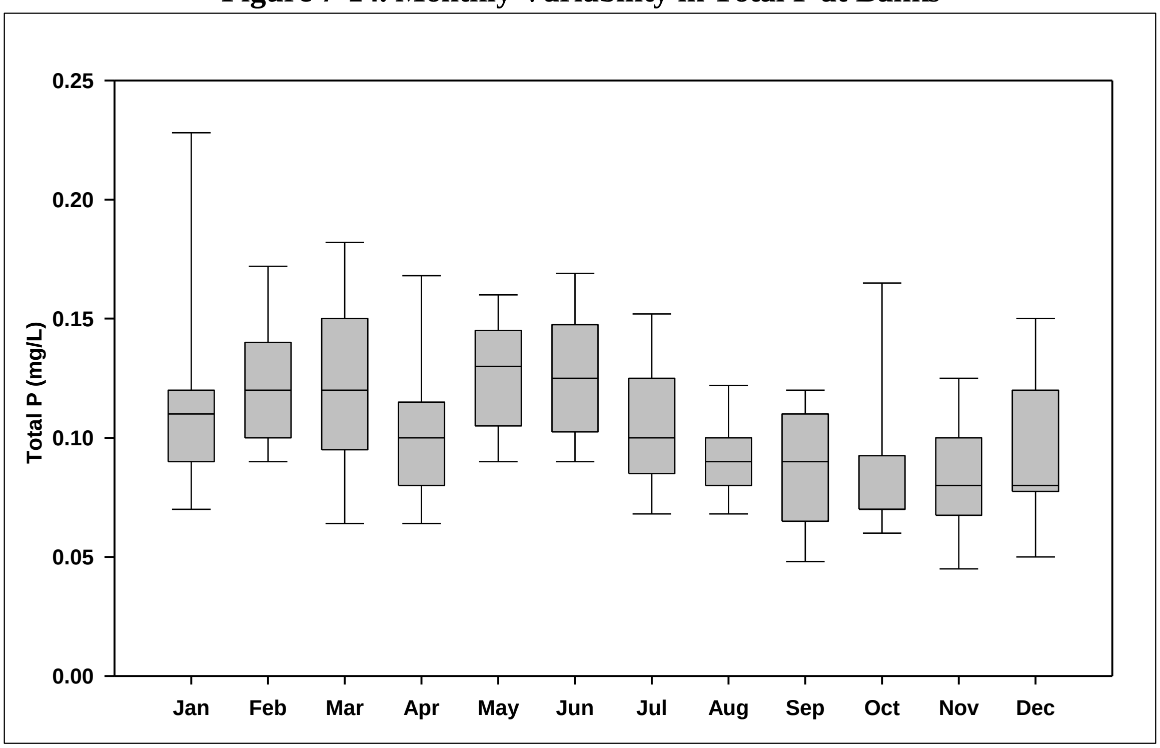


Figure 7-13. Monthly Variability in Total N at Banks



Note: Insufficient data to plot all percentiles.

Figure 7-14. Monthly Variability in Total P at Banks



Note: Insufficient data to plot all percentiles. The October median of 0.07 mg/L is the same as the 25th percentile.

North Bay Aqueduct

Chapters 3 and 4 contain a description of the North Bay Aqueduct (NBA). The sources of water are the local Barker Slough watershed and the Sacramento River.

Project Operations

Since the NBA is an enclosed pipeline, the quality of water delivered to NBA users is governed by the timing of diversions from Barker Slough and it shouldn't be affected by any other factors. **Figure 7-15** shows average monthly diversions at Barker Slough for the 1998 to 2010 period and median total N concentrations and **Figure 7-16** shows diversions and median total P concentrations. These figures show that the period of highest diversions coincides with the lowest total N concentrations, and total P concentrations decline steadily during the period of highest diversions.

Figure 7-15. Average Monthly Barker Slough Diversions and Median Total N Concentrations

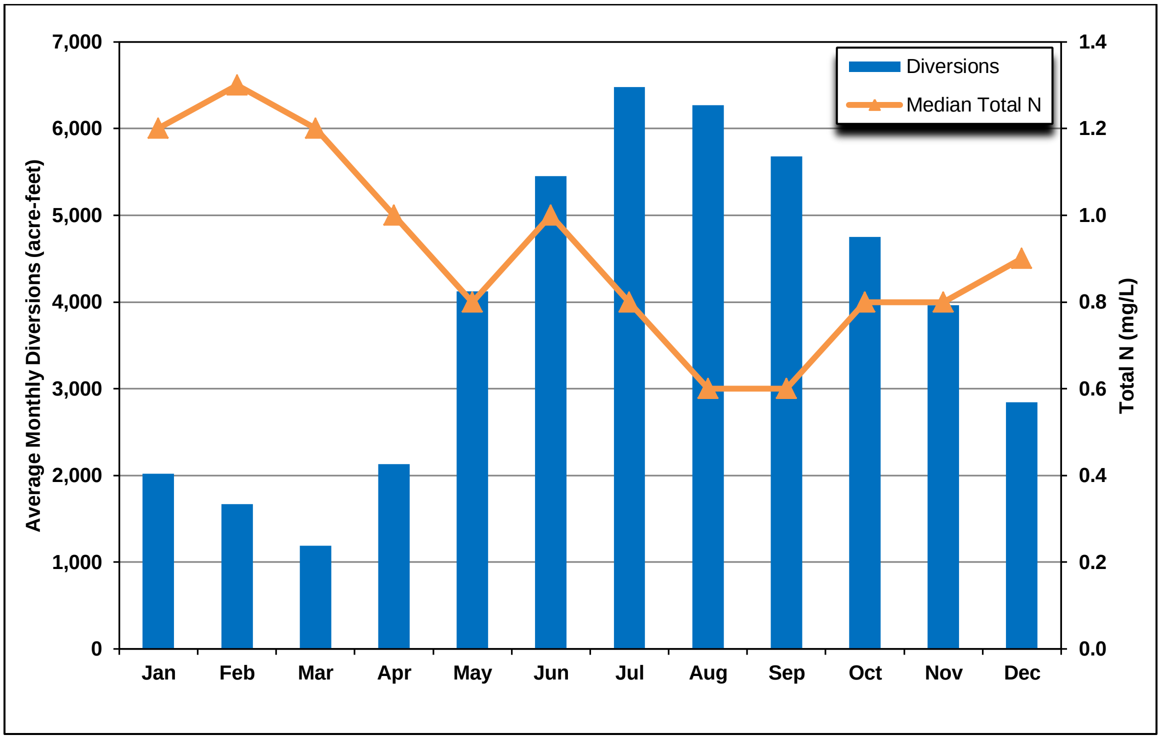
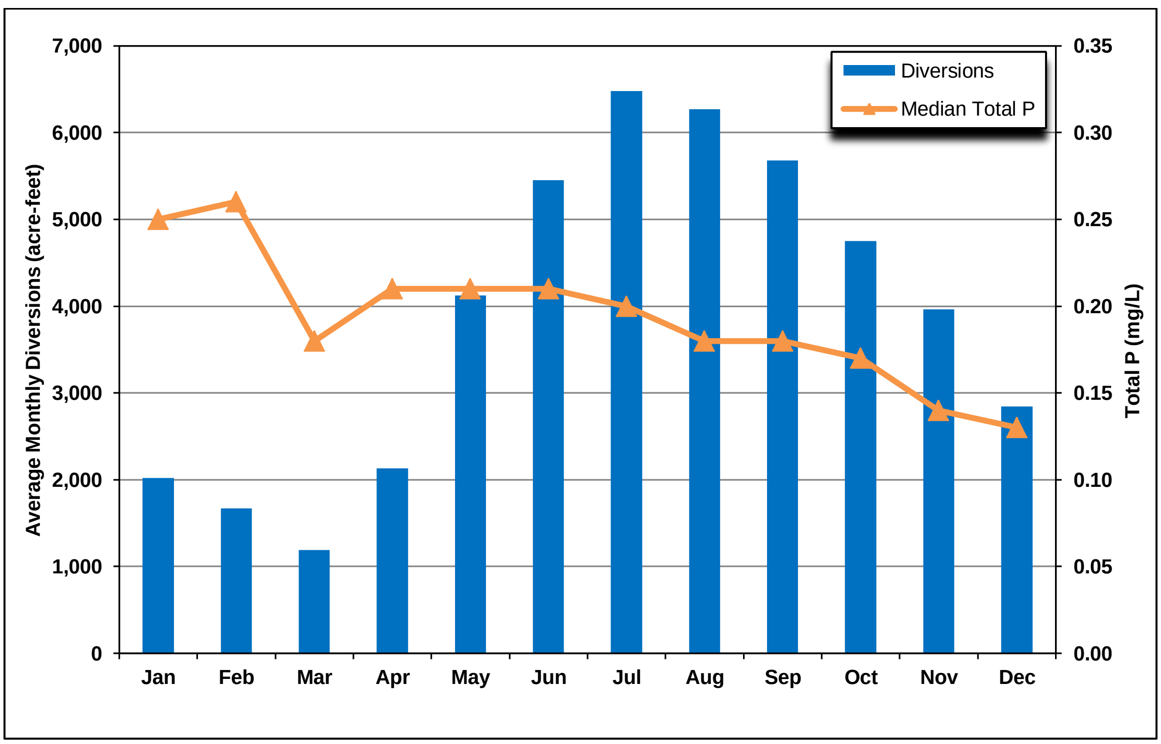


Figure 7-16. Average Monthly Barker Slough Diversions and Median Total P Concentrations



<u>Nutrient Concentrations in the NBA</u>

Nutrient levels have been monitored at Barker Slough since 1997; however, total P is not monitored at Cordelia and nitrate is the only nitrogen species monitored. **Figure 7-17** shows all available total N data and **Figure 7-18** shows total P data at Barker Slough. The total N concentrations range from 0.4 to 2.2 mg/L with a median of 0.8 mg/L and the total P concentrations range from 0.05 to 0.64 mg/L with a median of 0.18 mg/L. The average nutrient concentrations were calculated to compare to the trophic levels in **Table 7-1**. The average total N concentration is 0.9 mg/L, placing Barker Slough in the mesotrophic level. The average total P concentration is 0.21 mg/L, placing Barker Slough in the eutrophic level.

- Spatial Trends – Since nutrient data have been collected for a longer period at Barker Slough than at Hood, a subset of the data were analyzed to compare medians from the same time period (2002 to 2010). During this time period, the Barker Slough total N median concentration of 0.82 mg/L is statistically significantly higher than the median of 0.67 mg/L at Hood (Mann-Whitney, p=0.0000). This represents about a 20 percent increase over Hood. The Barker Slough total P median concentration of 0.2 mg/L is statistically significantly higher than the Hood median of 0.08 mg/L (Mann-Whitney, p=0.0000). This is about a 150 percent increase over Hood. The Sacramento River is the primary source of water to Barker Slough, so it is evident that the local watershed supplies some nitrogen and a substantial amount of phosphorus to the NBA. There is extensive cattle grazing and farming throughout the watershed, and there is a golf course in the upper part of the watershed; all potential sources of nutrients.

- Long-Term Trends – **Figures 7-17 and 7-18** do not reveal any discernible trends in the data collected in the last 13 years.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median total N concentration during dry years of 0.82 mg/L is not statistically significantly lower than the median of 0.84 mg/L during wet years (Mann-Whitney, p=0.4221). The dry year median total P concentration of 0.18 mg/L is also not statistically significantly different from the wet year median of 0.20 mg/L (Mann-Whitney, p=0.3474).

- Seasonal Trends – **Figures 7-19 and 7-20** show a clear seasonal pattern of higher concentrations during the winter months and lowest concentrations in the summer and fall. This pattern also indicates that the nutrients are from the local watershed, and are transported to Barker Slough during winter storm events.

Figure 7-17. Total N Concentrations at Barker Slough

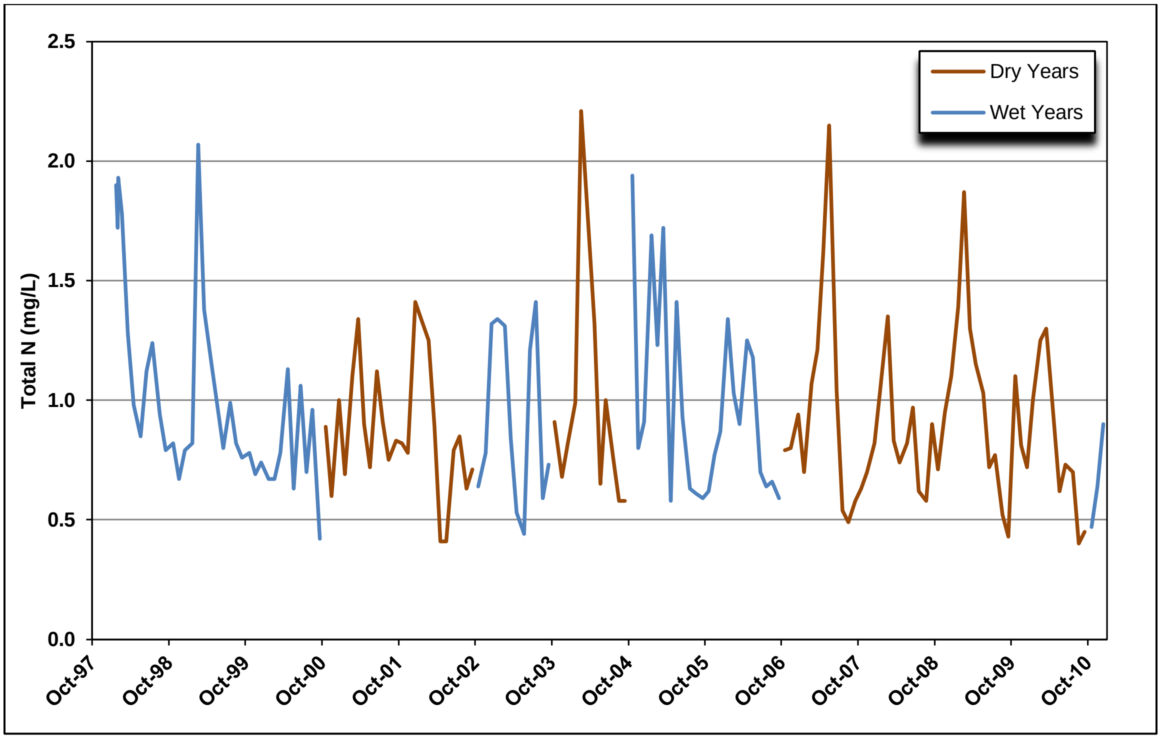


Figure 7-18. Total P Concentrations at Barker Slough

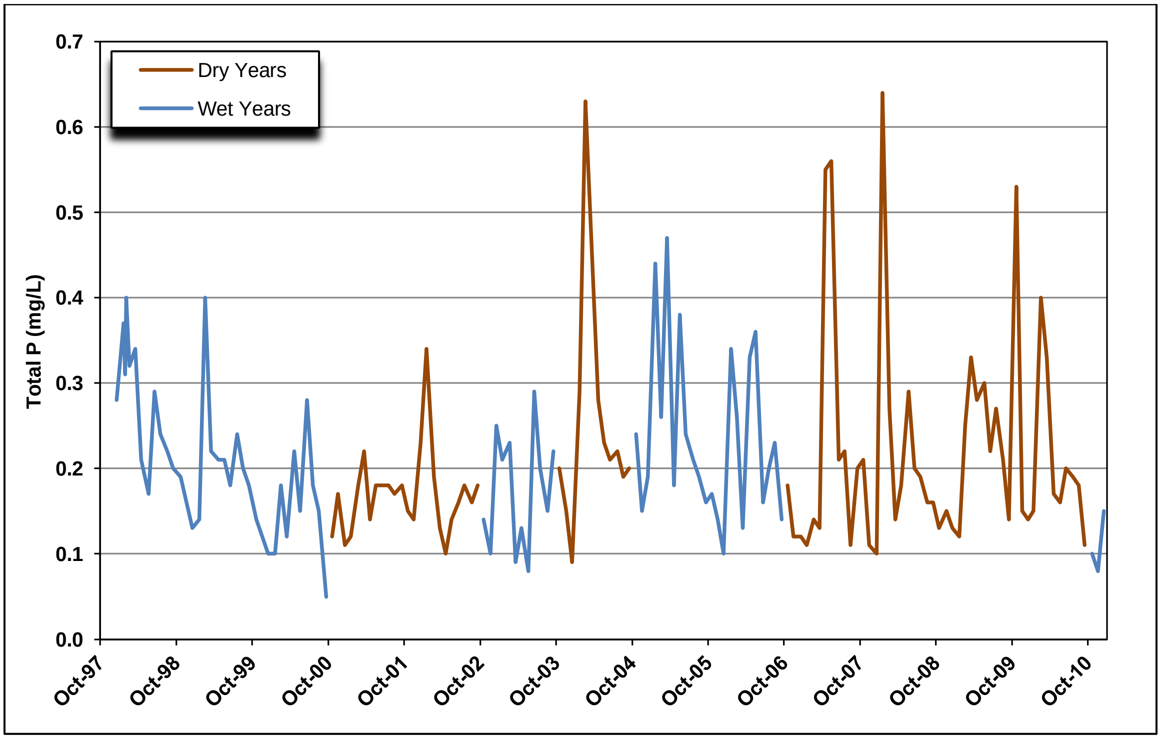
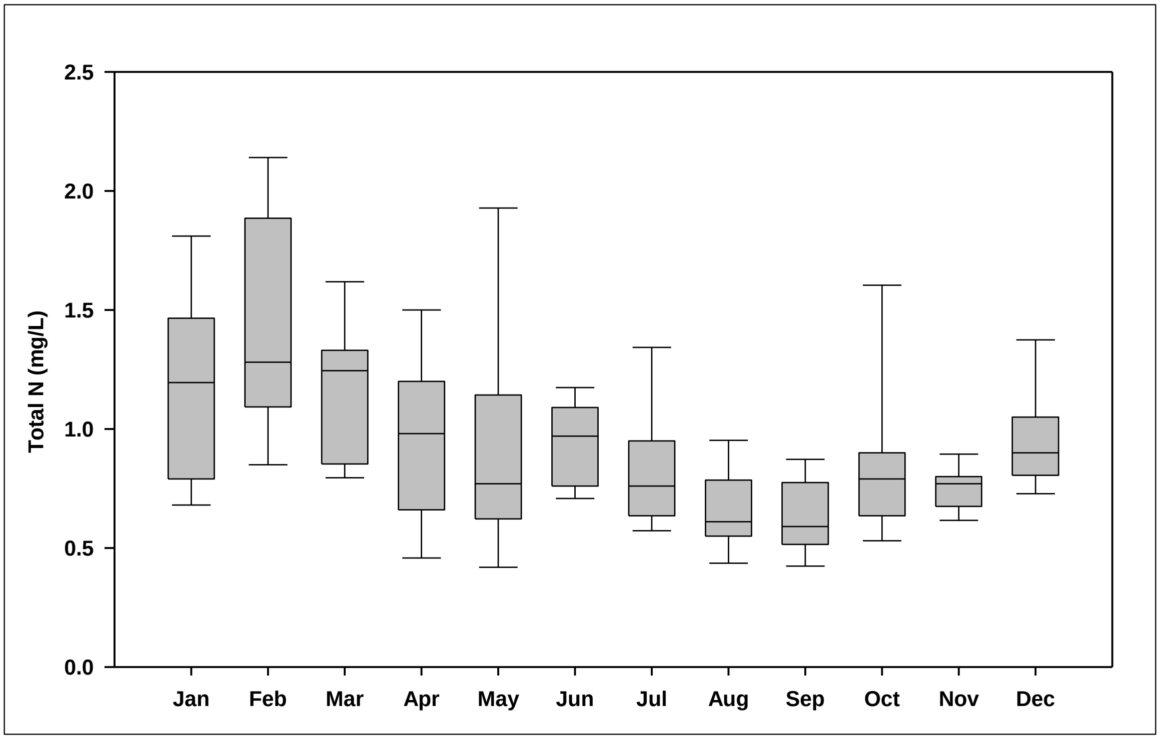
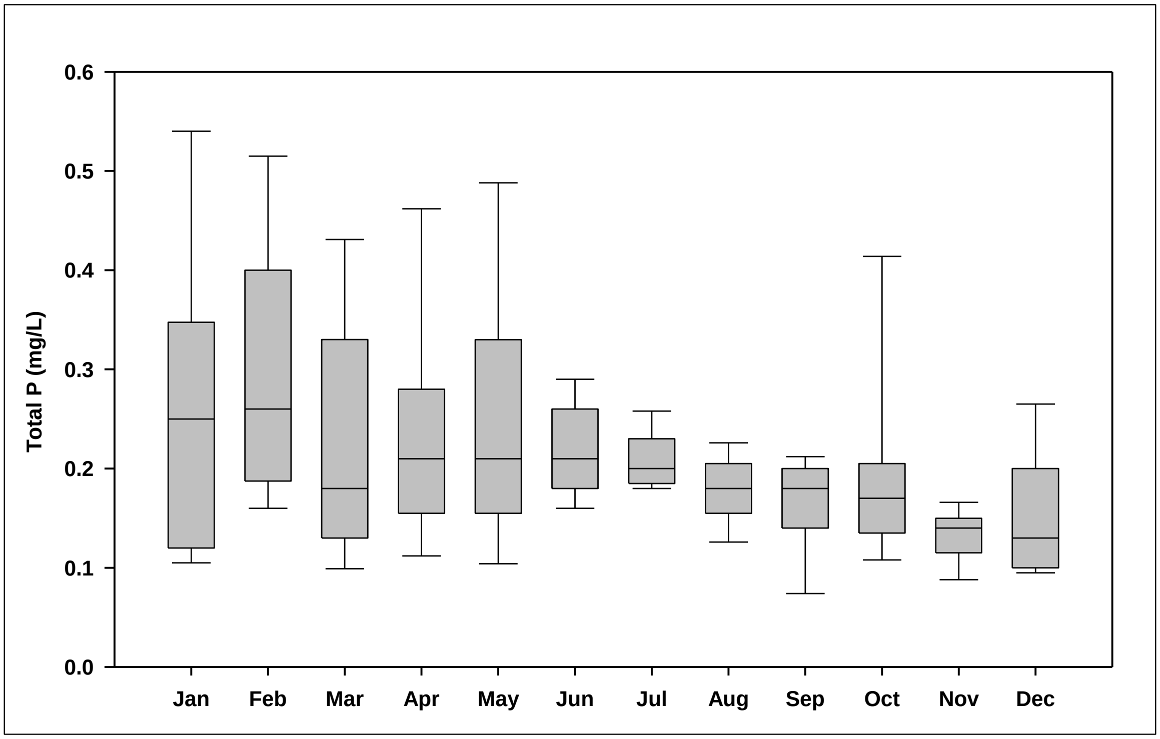


Figure 7-19. Monthly Variability in Total N at Barker Slough



Note: Insufficient data to plot all percentiles.

Figure 7-20. Monthly Variability in Total P at Barker Slough



Note: Insufficient data to plot all percentiles.

South Bay Aqueduct

Chapters 3 and 4 contain a description of the South Bay Aqueduct (SBA). The Delta is the primary source of water and Lake Del Valle is the secondary source.

Project Operations

The quality of water delivered to the SBA Contractors is governed by the timing of diversions from Bethany Reservoir and releases from Lake Del Valle. **Figures 7-21 and 7-22** show average monthly diversions at the South Bay Pumping Plant and releases from Lake Del Valle for the 1998 to 2009 period. Diversion data were not available for 2010. The median total N concentrations are shown in **Figure 7-21** and the median total P concentrations are shown in **Figure 7-22**. These graphs show that nitrogen and phosphorus behave differently in the system. The median total N concentrations are relatively low, ranging from 0.5 to 0.9 mg/L during the period of maximum diversions to the SBA. The median total P concentrations are highest in the May through July period (0.11 to 0.12 mg/L) and then decline for the next several months. The nutrient concentrations at the Lake Del Valle Conservation Outlet (Conservation Outlet) are substantially lower than the concentrations in the SBA. The median total N concentration at the Conservation Outlet is 0.4 mg/L and the median total P concentration is 0.02 mg/L, indicating that releases from Lake Del Valle in the fall months reduce the nutrient concentrations in the SBA downstream of the Del Valle Branch Pipeline.

Figure 7-21. Average Monthly Diversions at the South Bay Pumping Plant, Releases from Lake Del Valle, and Median Total N Concentrations

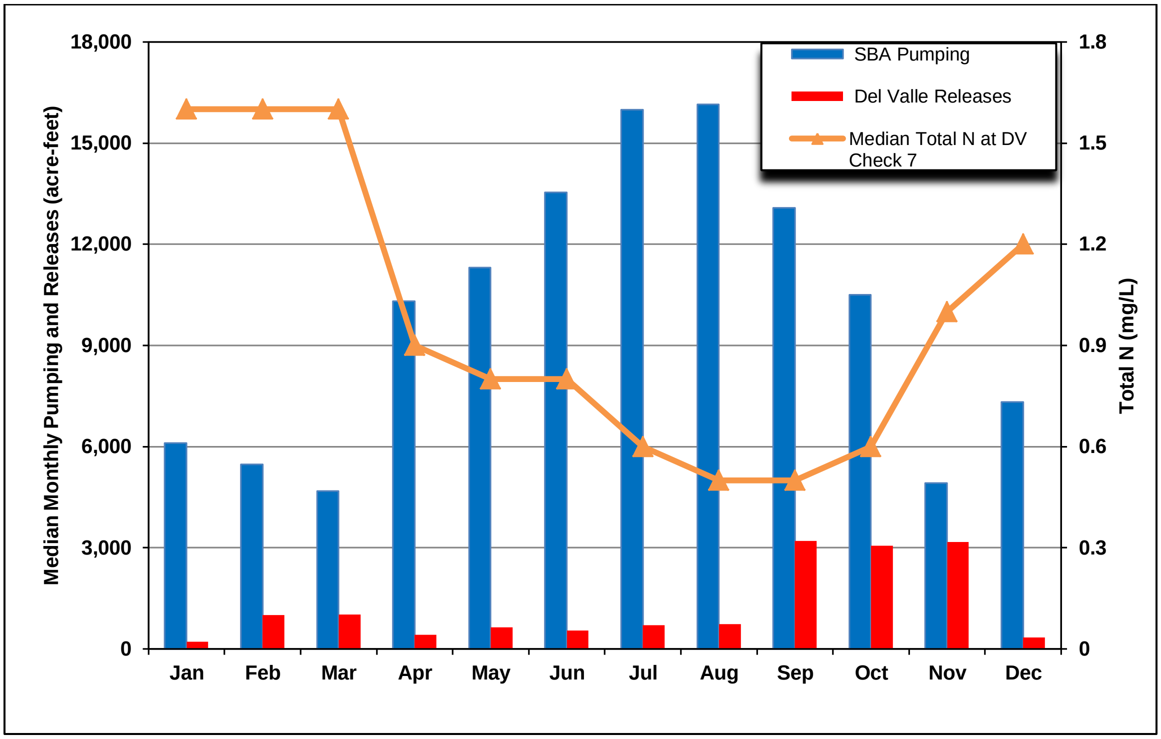
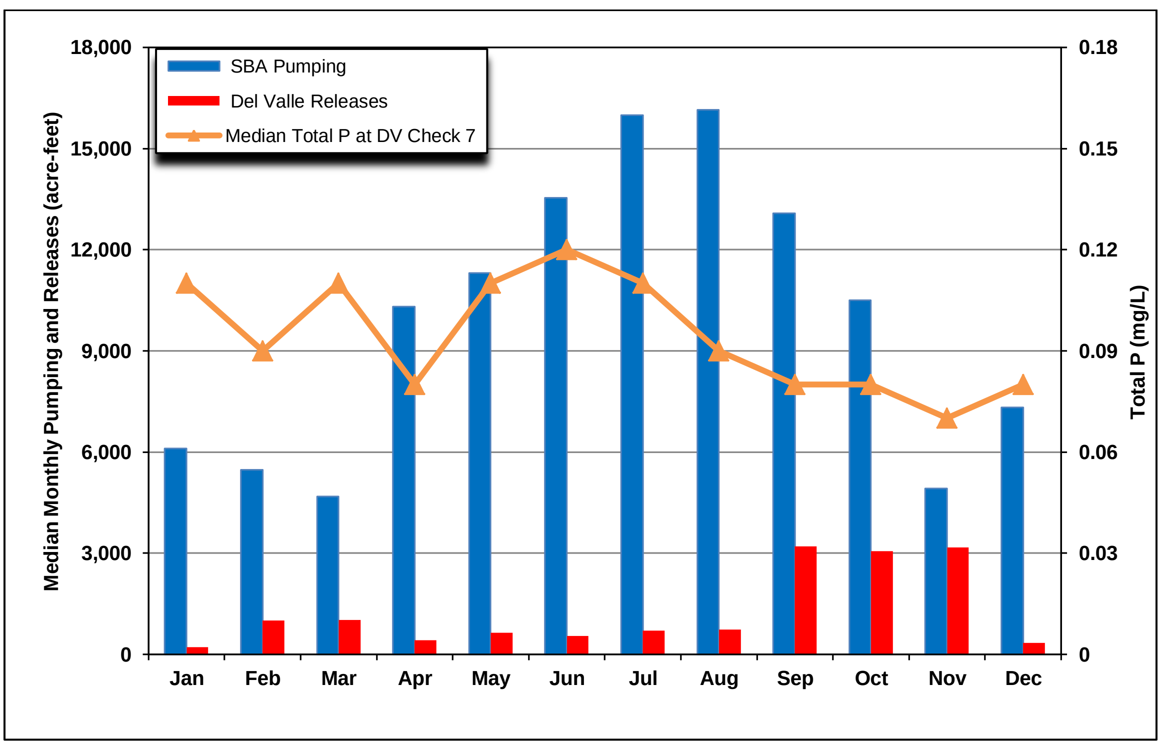


Figure 7-22. Average Monthly Diversions at the South Bay Pumping Plant, Releases from Lake Del Valle, and Median Total P Concentrations



Nutrient Concentrations in the SBA

Total P is monitored and total N can be calculated from total Kjeldahl nitrogen (TKN) and nitrate plus nitrite at DV Check 7 and at the Conservation Outlet. There were only three nutrient samples collected at the Terminal Tank between 2004 and 2010. **Figures 7-23 and 7-24** present the total N and total P data for DV Check 7. Total N concentrations range from 0.2 to 2.9 mg/L with a median of 0.86 mg/L. Total P concentrations are an order of magnitude lower and range from 0.01 to 0.30 mg/L with a median of 0.09 mg/L. The average nutrient concentrations were calculated to compare to the trophic levels in **Table 7-1**. The average total N concentration is 1.0 mg/L, placing the SBA in the mesotrophic level. The average total P concentration is 0.10 mg/L, placing the SBA in the eutrophic level.

- Spatial Trends – DV Check 7 data were compared to Banks data collected between 1998 and 2010 to determine if there are any statistically significant differences between the two locations. The total N median of 0.86 mg/L at DV Check 7 is not statistically significantly different from the median of 0.88 mg/L at Banks (Mann-Whitney, p=0.4079 and the total P median of 0.09 mg/L at DV Check 7 is not statistically significantly different from the Banks median of 0.1 mg/L (Mann-Whitney, p=0.1537). This is expected due to the short travel time in the SBA and because DV Check 7 is upstream of the releases from Lake Del Valle. **Figures 7-25 and 7-26** compare nutrient concentrations at the Conservation Outlet and DV Check 7. Both total N and total P concentrations are substantially lower at the Conservation Outlet than at DV Check 7. This indicates that the concentrations at the Terminal Tank are likely lower than the concentrations at DV Check 7 during the fall months when water is released from Lake Del Valle.

- Long-Term Trends – **Figures 7-23 and 7-24** show a slight downward trend in both total N and total P. The downward trends don't appear to be due to hydrology because the nutrient concentrations during dry years are similar to the concentrations during wet years. Visual inspection of the nutrient plots at Banks (**Figures 7-11** and **7-12**) don't appear to show the same trend. A statistical analysis of the data is needed to determine if there are long-term trends.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median total N concentration of 0.84 mg/L in dry years is not statistically significantly different from the median concentration of 0.89 mg/L in wet years (Mann-Whitney, p=0.7859). Similarly, the median total P concentration of 0.09 mg/L in dry years is not statistically significantly different from the wet year median of 0.095 mg/L.

- Seasonal Trends – **Figures 7-27 and 7-28** show that the trend in total N and total P at DV Check 7 is the same as at Banks. The concentrations are high in the winter months, decline in the spring and summer, and increase during the fall months. The total P concentrations are high in the winter months, decrease during April, but then increase again in May and June, likely due to the greater amount of San Joaquin River water pumped from the Delta in these months. The total P concentrations then decline through the rest of the summer and fall.

Figure 7-23. Total N Concentrations at DV Check 7

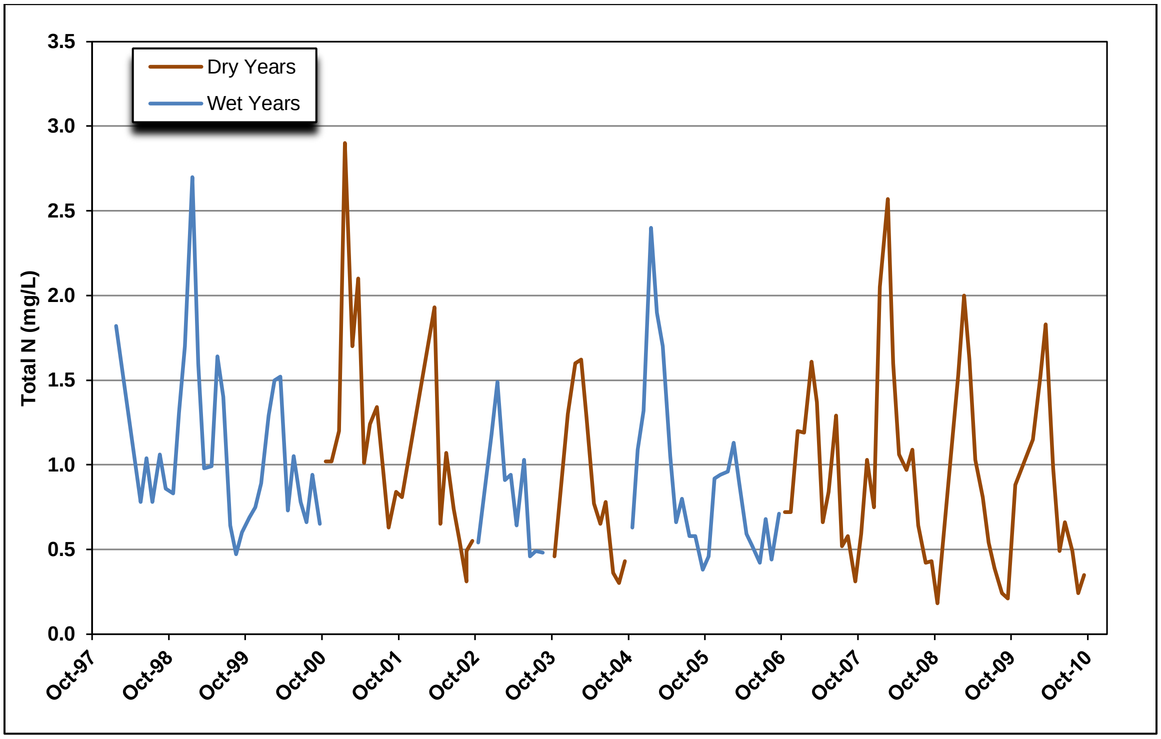


Figure 7-24. Total P Concentrations at DV Check 7

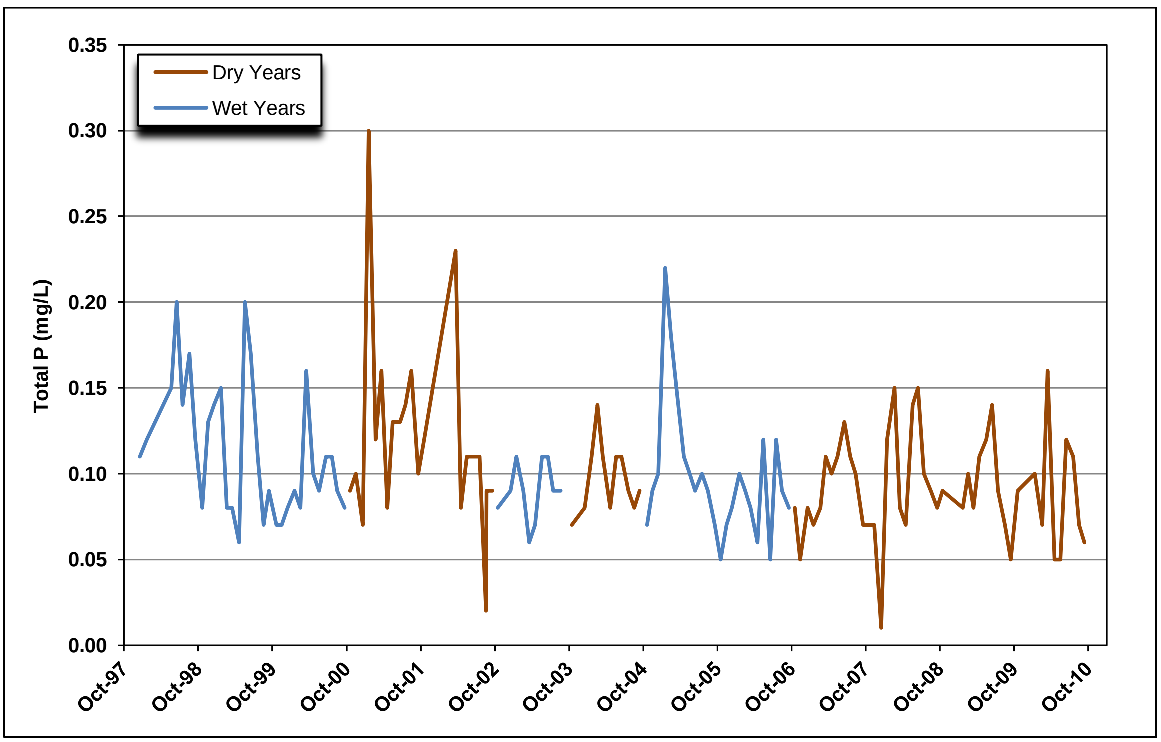


Figure 7-25. Total N Concentrations at DV Check 7 and the Conservation Outlet

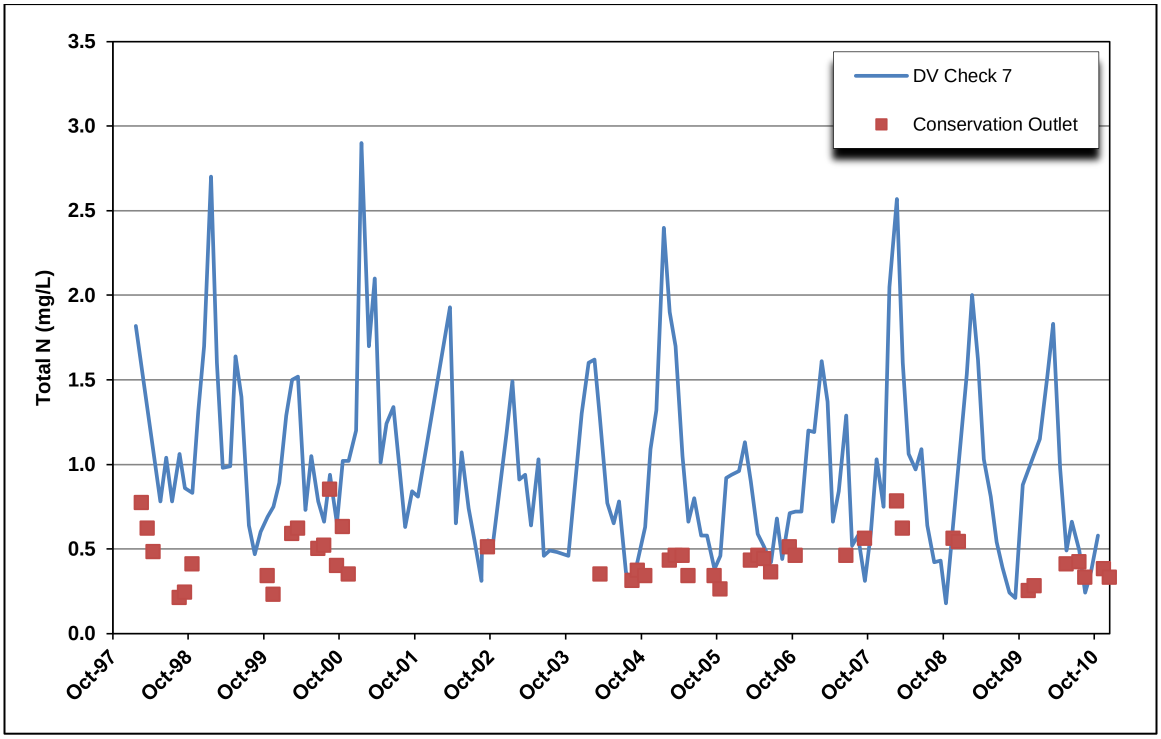


Figure 7-26. Total P Concentrations at DV Check 7 and the Conservation Outlet

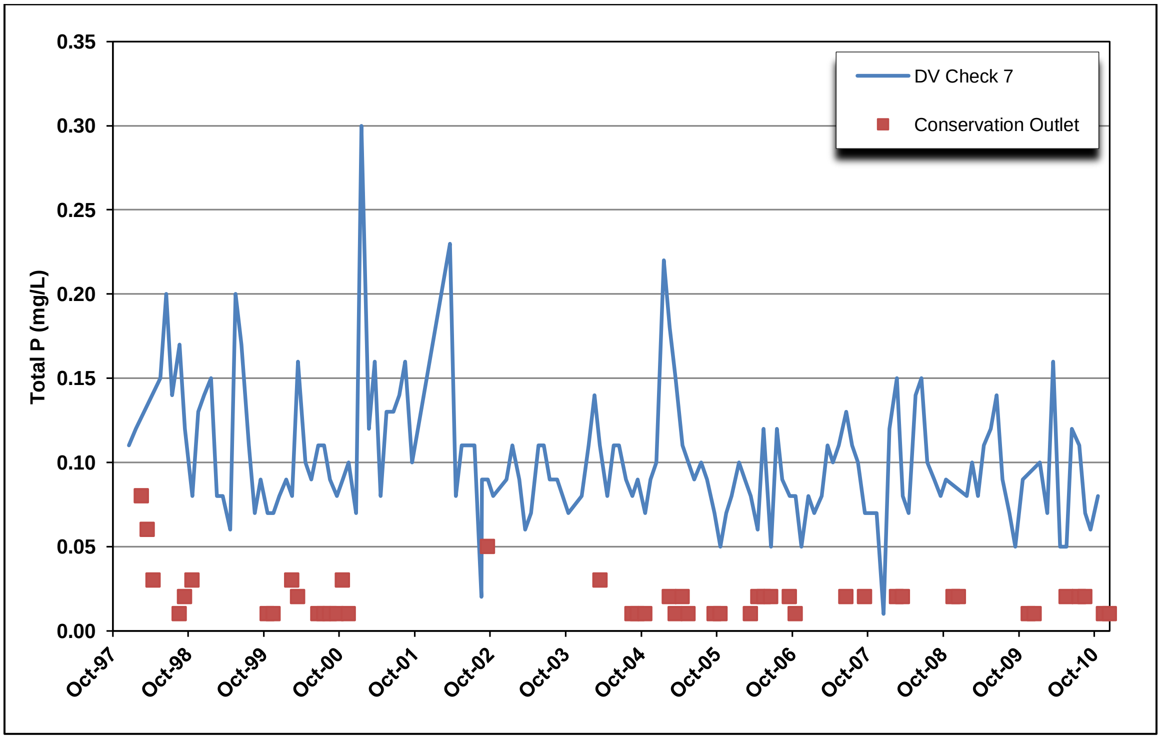


Figure 7-27. Monthly Variability in Total N at DV Check 7

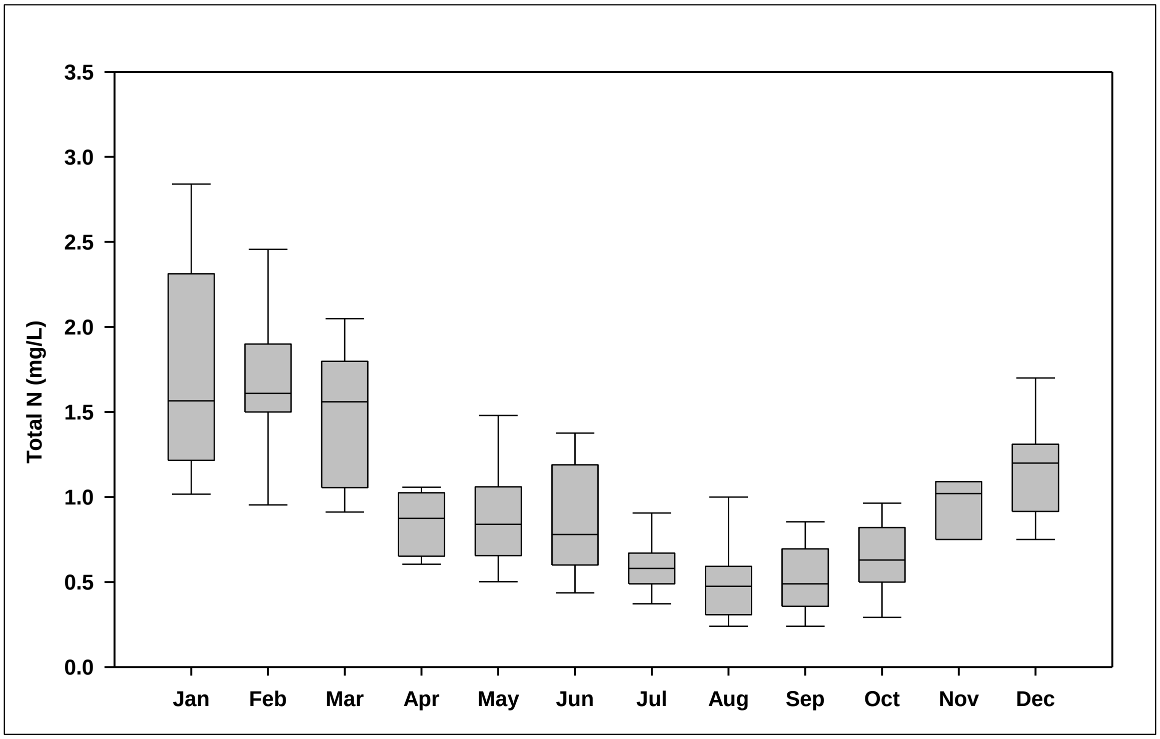
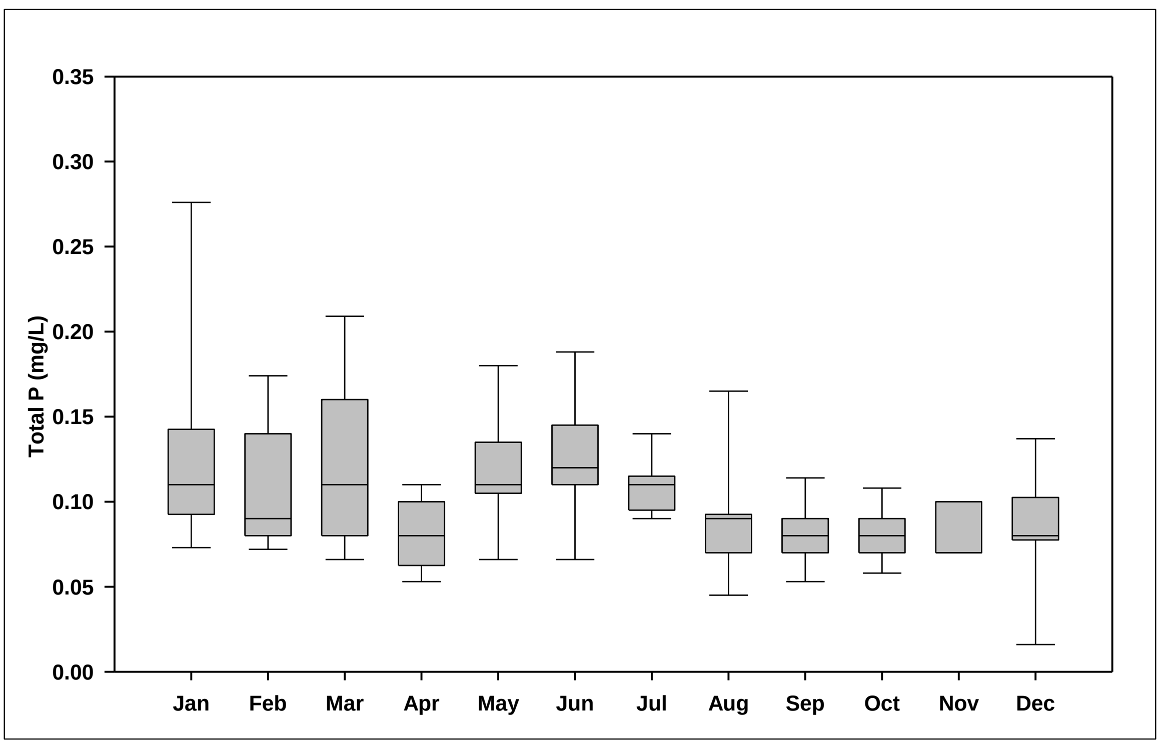


Figure 7-28. Monthly Variability in Total P at DV Check 7



California Aqueduct and Delta-Mendota Canal

A number of SWP Contractors take water from the SWP between San Luis Reservoir and the terminal reservoirs. This section is organized by various reaches of the SWP and individual SWP contractors taking water from each reach are described in the following sections.

Project Operations

The quality of water delivered to SWP Contractors south of San Luis Reservoir is governed by the timing of diversions from the Delta at Banks, pumping into O'Neill Forebay from the Delta-Mendota Canal (DMC), releases from San Luis Reservoir, inflows to the Governor Edmund G. Brown California Aqueduct (California Aqueduct), and storage in terminal reservoirs. The impact of non-Project inflows on water quality is discussed in Chapter 14 and the influence of terminal reservoirs in modulating nutrient concentrations is discussed later in this chapter.

Figures 7-29 and 7-30 show average monthly diversions at the Banks Pumping Plant and median monthly total N and total P concentrations, respectively. As described in Chapter 3, operations were governed by the 1995 Bay-Delta Plan (D-1641) from 1998 to 2006 and by the Wanger Decision and the biological opinions from 2007 to 2010 so both periods are shown. These graphs show that nitrogen and phosphorus behave differently in the system. The median total N concentrations are relatively low (0.6 mg/L) during the peaks summer diversion months but then concentrations increase sharply during the fall months to reach a peak monthly median of 1.8 mg/L in February when diversions are still high. The peak median total P concentration of 1.3 mg/L occurs in the spring when diversions are low. During the summer months when diversions are highest the median total P concentrations range from 0.09 to 1.0 mg/L.

During the 1998 to 2009 period that diversion data are available, the DMC contributed between 26 and 44 percent of the water entering O'Neill Forebay with a median of 30 percent. Total N and total P data are only available since July 2009 for the DMC and appear to be similar to the concentrations found at Banks but the data are too limited to understand the impacts of pumping water from the DMC into O'Neill Forebay.

Figure 7-29. Average Monthly Banks Diversions and Median Total N Concentrations

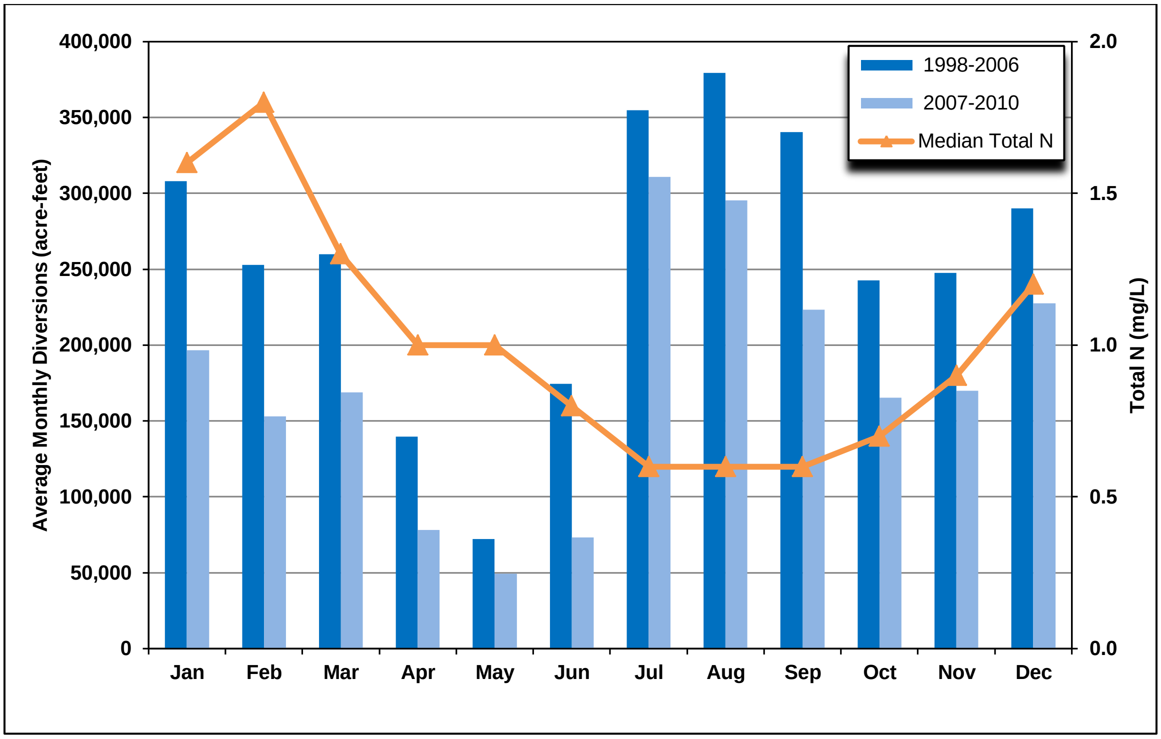
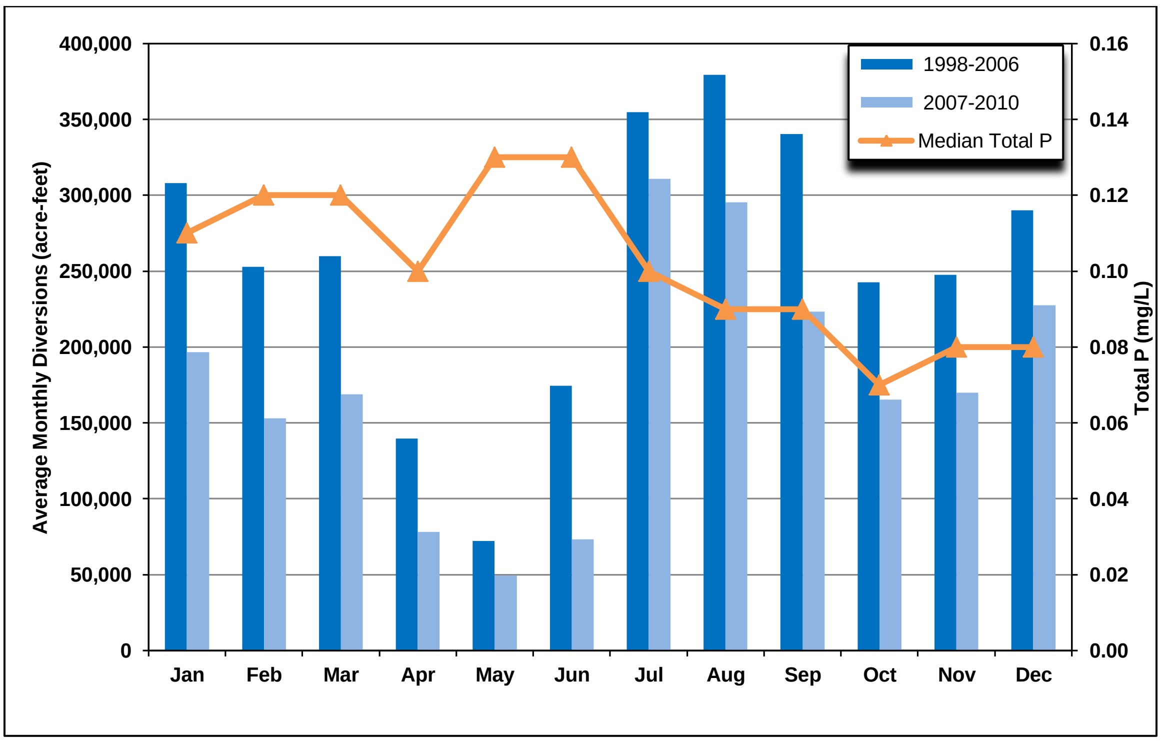


Figure 7-30. Average Monthly Banks Diversions and Median Total P Concentrations



The operation of San Luis Reservoir impacts water quality in the California Aqueduct south of the reservoir. **Figures 7-31 and 7-32** show the pattern of pumping into the reservoir, releases from the reservoir to O’Neill Forebay, and median nutrient concentrations. The median nutrient concentrations at Banks represent the quality of water pumped into the reservoir from the California Aqueduct. Since data are not currently available on the quality of water released to O’Neill Forebay from the William R. Gianelli Pumping-Generating Plant (Gianelli), data from the Pacheco Pumping Plant (Pacheco) are used. There are two distinct periods:

- Fall and Winter Filling – The reservoir is filled from September to March when the median total N concentrations at Banks range from a low of 0.6 mg/L in September to 1.8 mg/L in March. The median total P ranges from 0.07 mg/L in October to 0.12 mg/L in March. **Figures 7-31 and 7-32** show that the highest nutrient concentrations occur during the January to March period.

- Spring and Summer Releases – Water is released during the April to August period when median total N concentrations at Pacheco are higher than the concentrations at Banks, indicating that the releases are increasing the total N concentrations in the California aqueduct downstream of San Luis Reservoir. Total P concentrations in the releases are generally lower than the concentrations at Banks.

Nutrient Concentrations in the DMC and SWP

Figures 7-33 and 7-34 present a summary of all total N and total P data collected at each of the locations along the DMC, California Aqueduct, and SWP reservoirs. There are varying periods of record for each location so differences between locations may be due to the hydrologic conditions under which the samples were collected. Data have been collected at a number of locations from 2004 to 2010. **Figures 7-35 and 7-36** display the subset of data that allows comparison between locations. Spatial differences are examined in more detail in the following sections.

Delta-Mendota Canal – Total N and total P data are only available since July 2009 for the DMC so this does not allow much analysis of the data. **Figure 7-37** presents the total N data and **Figure 7-38** presents the total P data. Based on this limited amount of data, the total N and total P concentrations are similar to the concentrations at Banks.

Figure 7-31. San Luis Reservoir Operations and Median Total N Concentrations

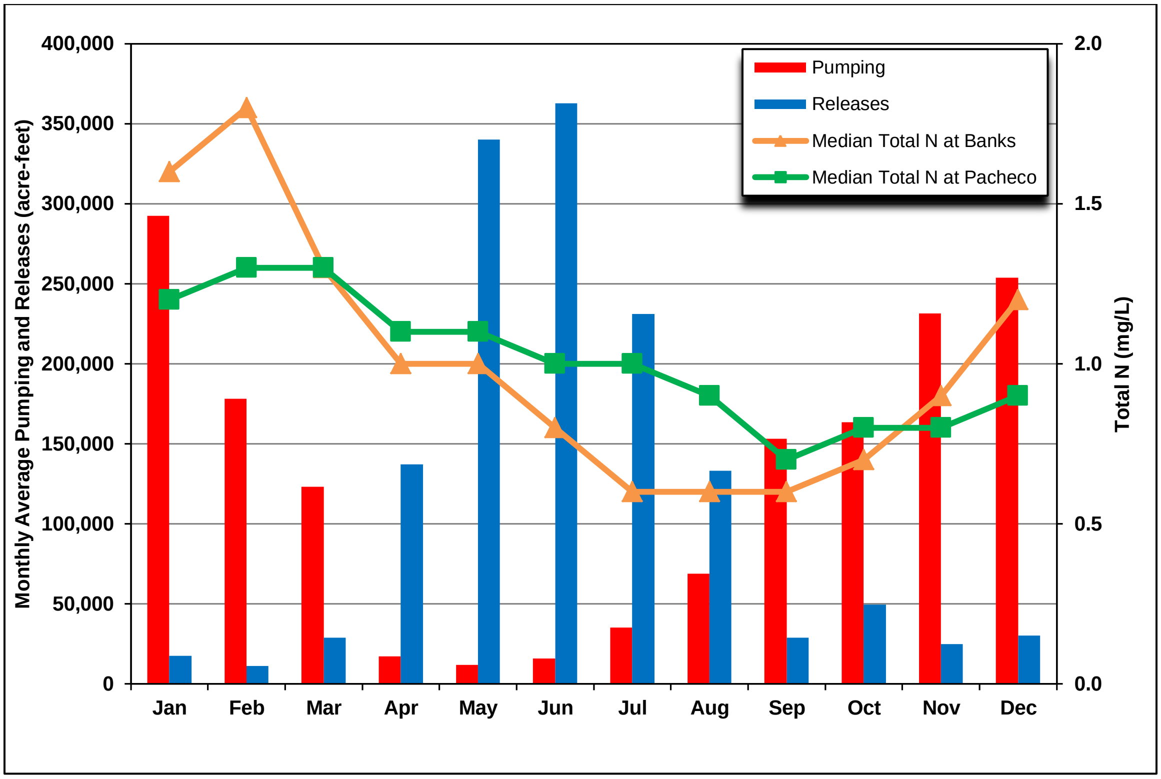


Figure 7-32. San Luis Reservoir Operations and Median Total P Concentrations

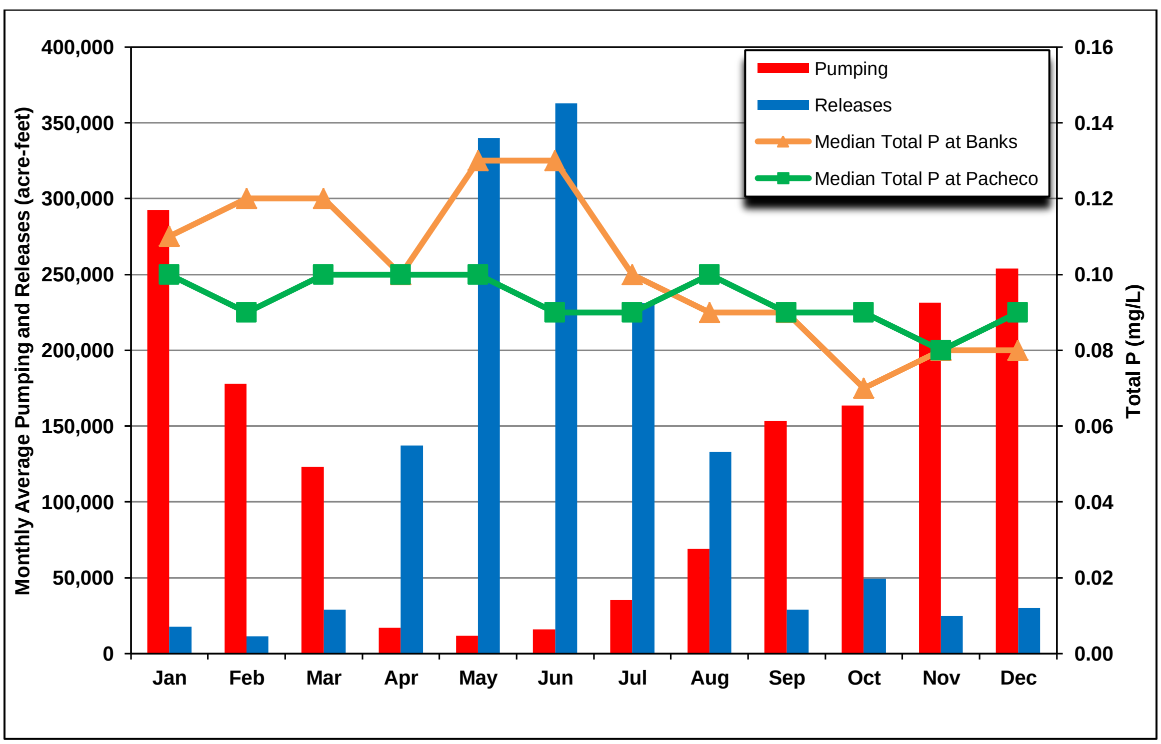
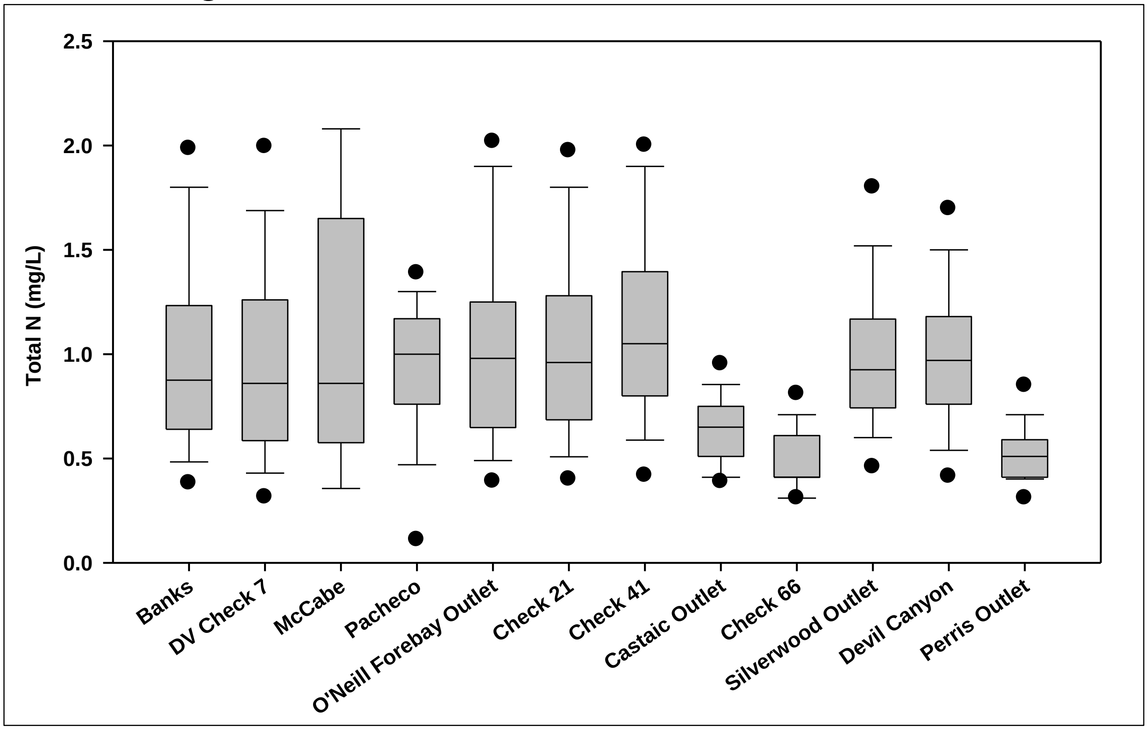
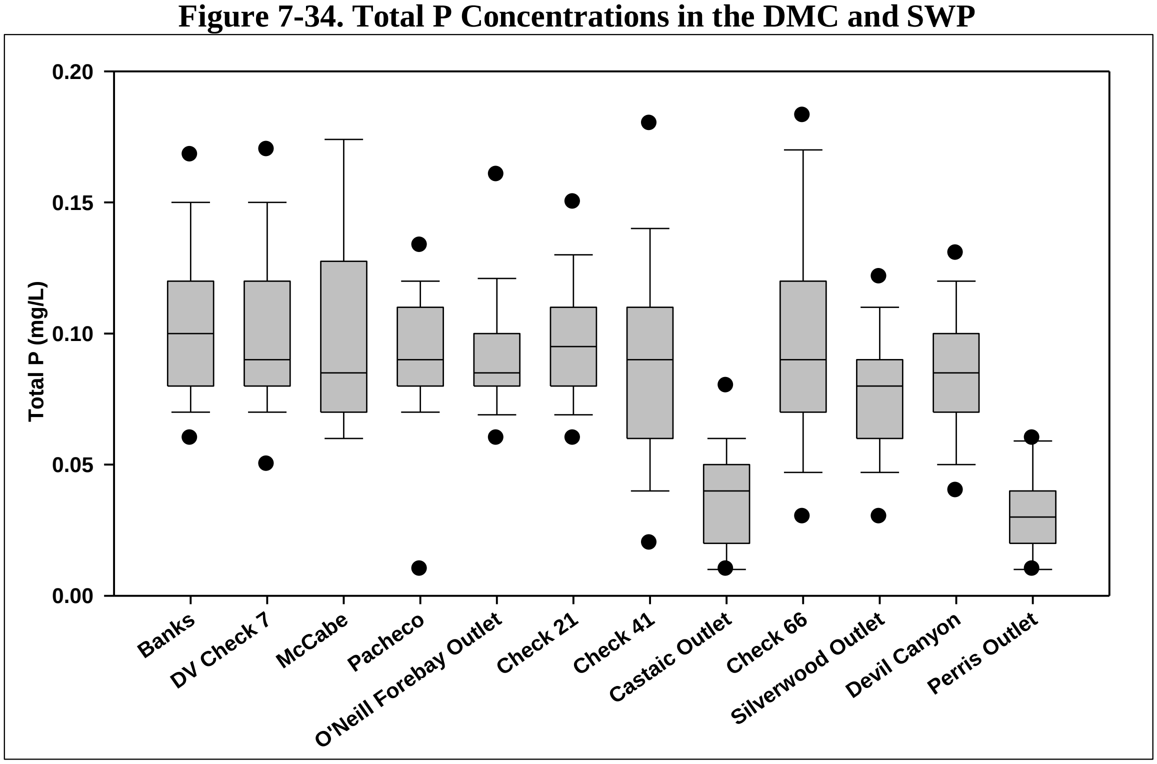


Figure 7-33. Total N Concentrations in the DMC and SWP



Note: Note: Insufficient data to plot all percentiles. The Check 66 median of 0.41 mg/L is the same as the 25th percentile.

Figure 7-34. Total P Concentrations in the DMC and SWP



Note: Insufficient data to plot all percentiles.

Figure 7-35. Total N Concentrations in the SWP (2004-2010)

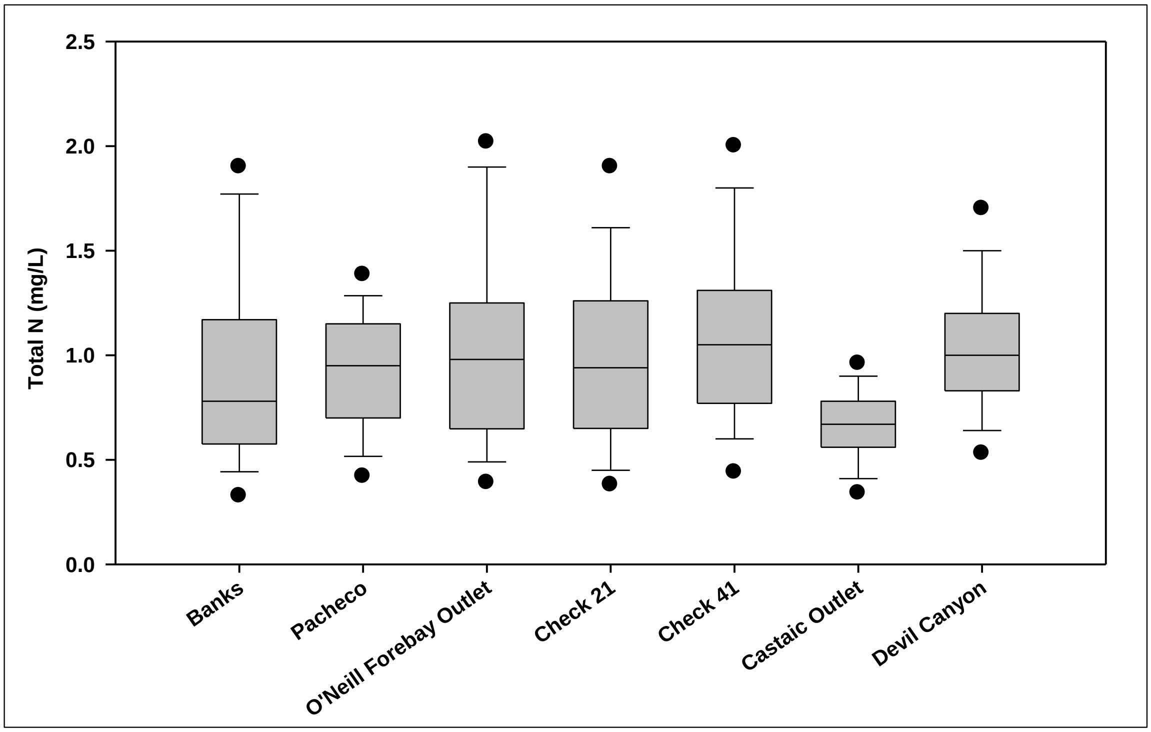


Figure 7-36. Total P Concentrations in the SWP (2004-2010)

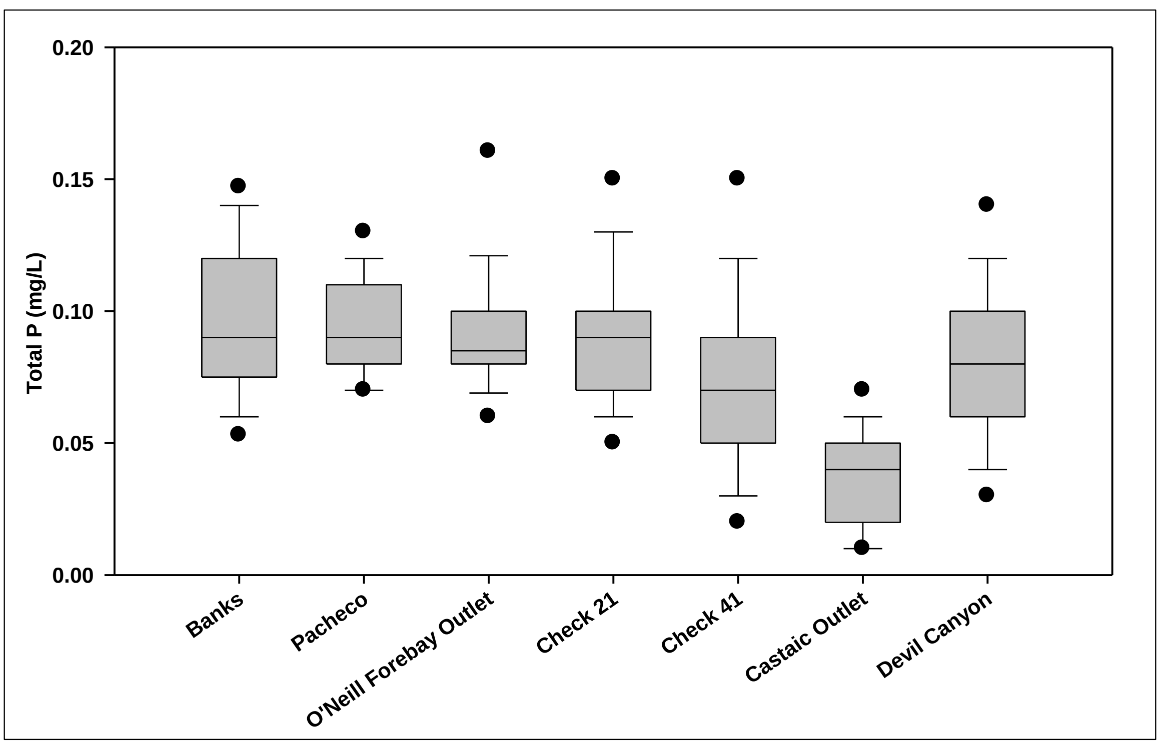


Figure 7-37. Total N Concentrations at McCabe

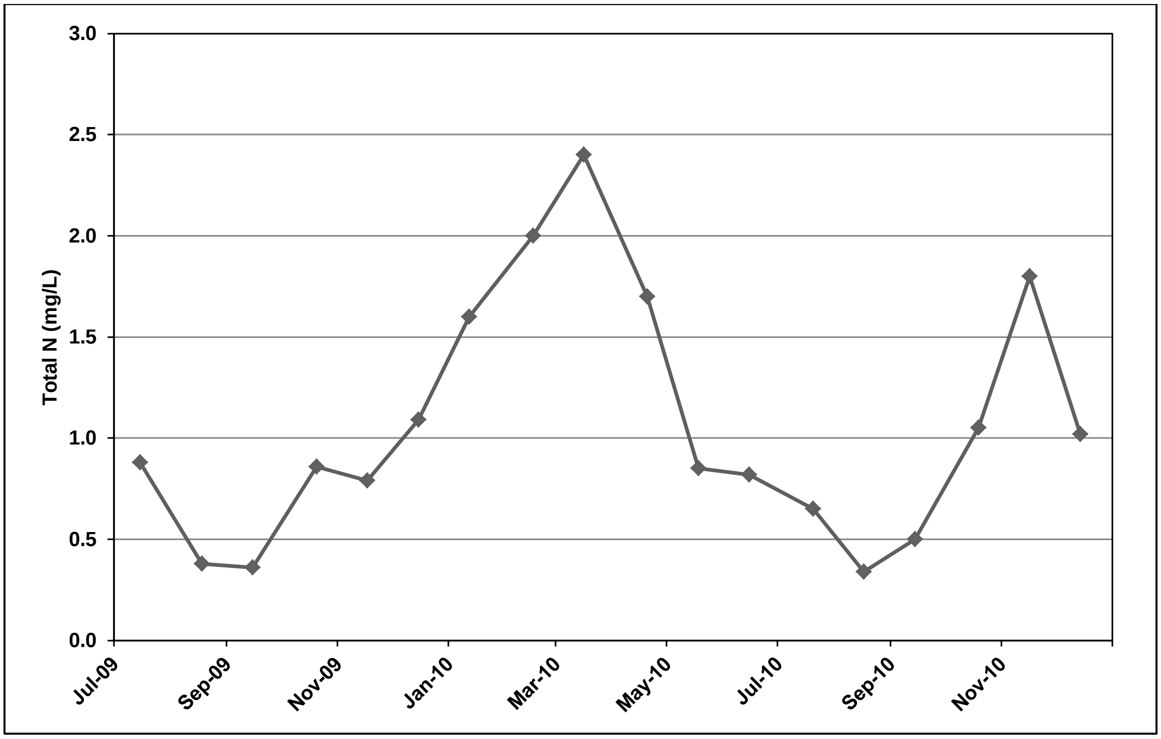
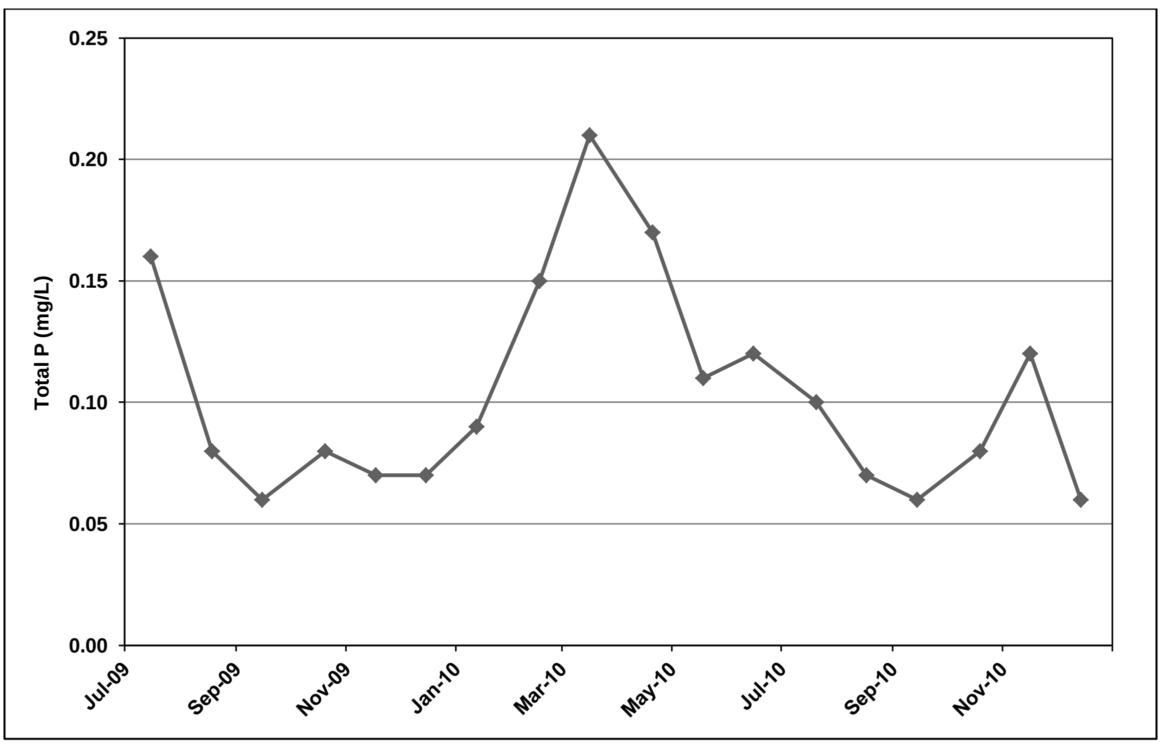


Figure 7-38. Total P Concentrations at McCabe



San Luis Reservoir – **Figure 7-39** presents the total N data for Pacheco and **Figure 7-40** presents the total P data. The total N concentrations at Pacheco range from <0.1 to 1.96 mg/L with a median of 1.0 mg/L and the total P concentrations range from <0.01 to 0.38 mg/L with a median of 0.09 mg/L. There is slightly less variability in the data than there is at Banks.

- Spatial Trends – All available data from Banks, McCabe, and Pacheco are presented in **Figures 7-33 and 7-34**. Since the period of record is longer for Banks, a subset of the data that includes only data collected at Banks, and Pacheco during the same period (2004 to 2010) are shown in **Figures 7-35 and 7-36**. As discussed previously, there are not sufficient data at McCabe to allow a comparison to other locations. The median total N concentrations are not statistically significantly different at Banks (0.78 mg/L) and Pacheco (0.95 mg/L) during the 2004 to 2010 period (Mann-Whitney, p=0.4793). The total P median at both locations is 0.09 mg/L.

- Long-Term Trends – **Figures 7-39 and 7-40** do not display any discernible trends in the nutrient concentrations in the slightly over ten years that data have been collected. There does seem to be less variability in the concentrations, particularly for total P in recent years.

- Wet Year/Dry Year Comparison – There is a small but statistically significant difference in the nutrient concentrations when dry and wet years are compared. The dry year total N median concentration of 0.96 mg/L is statistically significantly lower than the wet year median of 1.0 mg/L (Mann-Whitney, p=0.0107) and the dry year total P median concentration of 0.09 mg/L is statistically significantly lower than the wet year median of 0.1 mg/L (Mann-Whitney, p=0.0082).

- Seasonal Trends – **Figure 7-41** shows that total N concentrations increase slightly during the fall months and decline to their lowest levels during the late summer and fall months. There is very little variability in total P concentrations from month to month, as shown in **Figure 7-42**. It is difficult to interpret the Pacheco data because samples are collected at different depths, depending on the depth at which water is being withdrawn from the Pacheco outlet tower and the amount of water in the reservoir. Samples are collected in the hypolimnion (bottom layer) when the reservoir is full during the winter months and in the epilimnion (surface layer) when the reservoir level is low during the late summer and fall months. The nutrient concentrations in the hypolimnion are dependent on the nutrient concentrations of water pumped into San Luis Reservoir from the Delta and, to some extent, on degradation of algae settling out of the epilimnion. Samples from the epilimnion have more algae and therefore may have higher total nutrient concentrations than samples from the hypolimnion.

Figure 7-39. Total N Concentrations at Pacheco

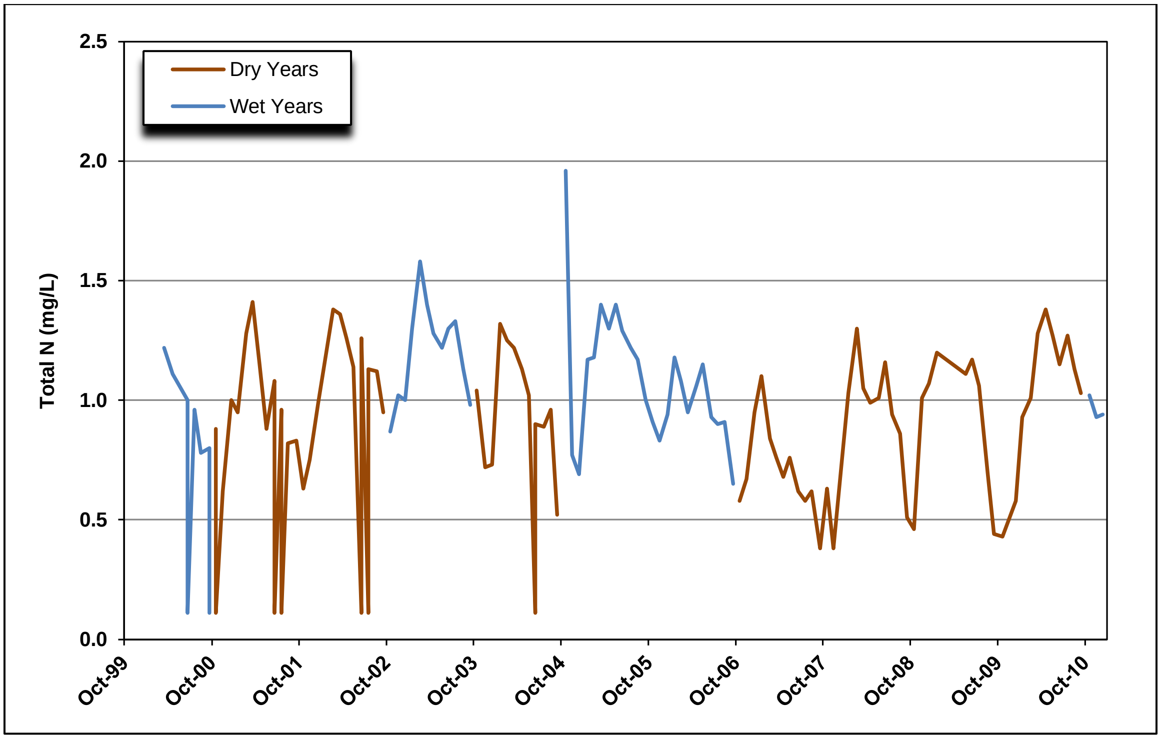


Figure 7-40. Total P Concentrations at Pacheco

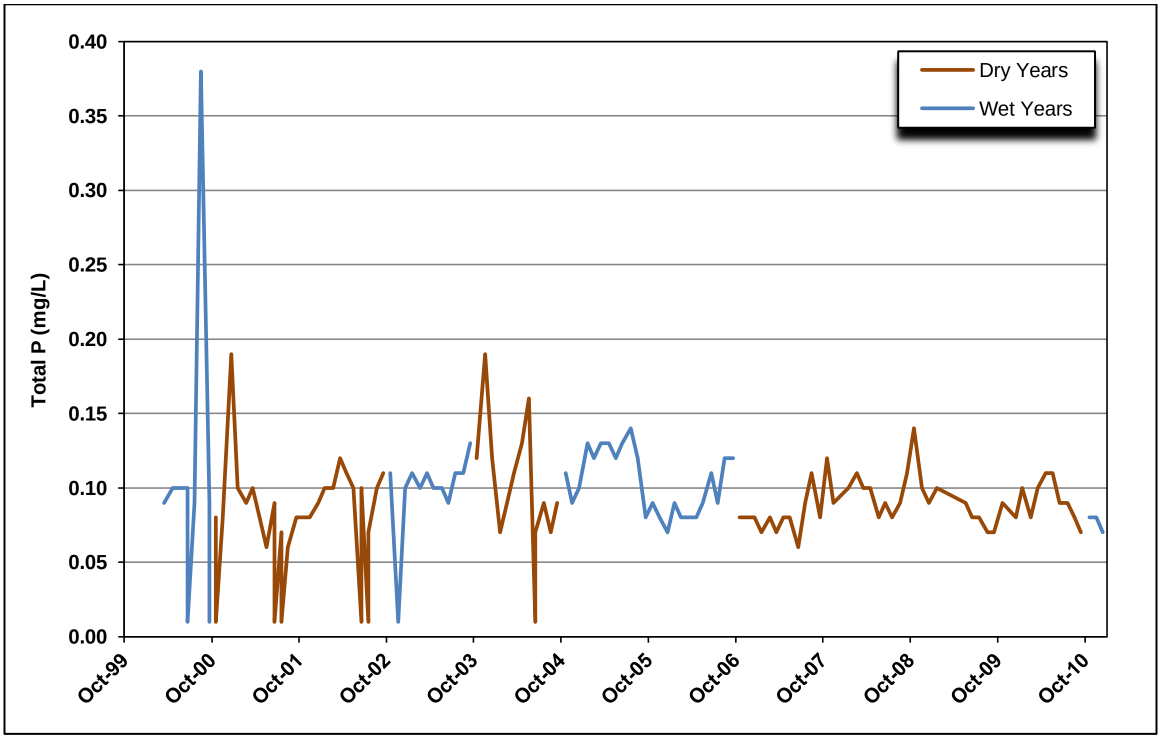
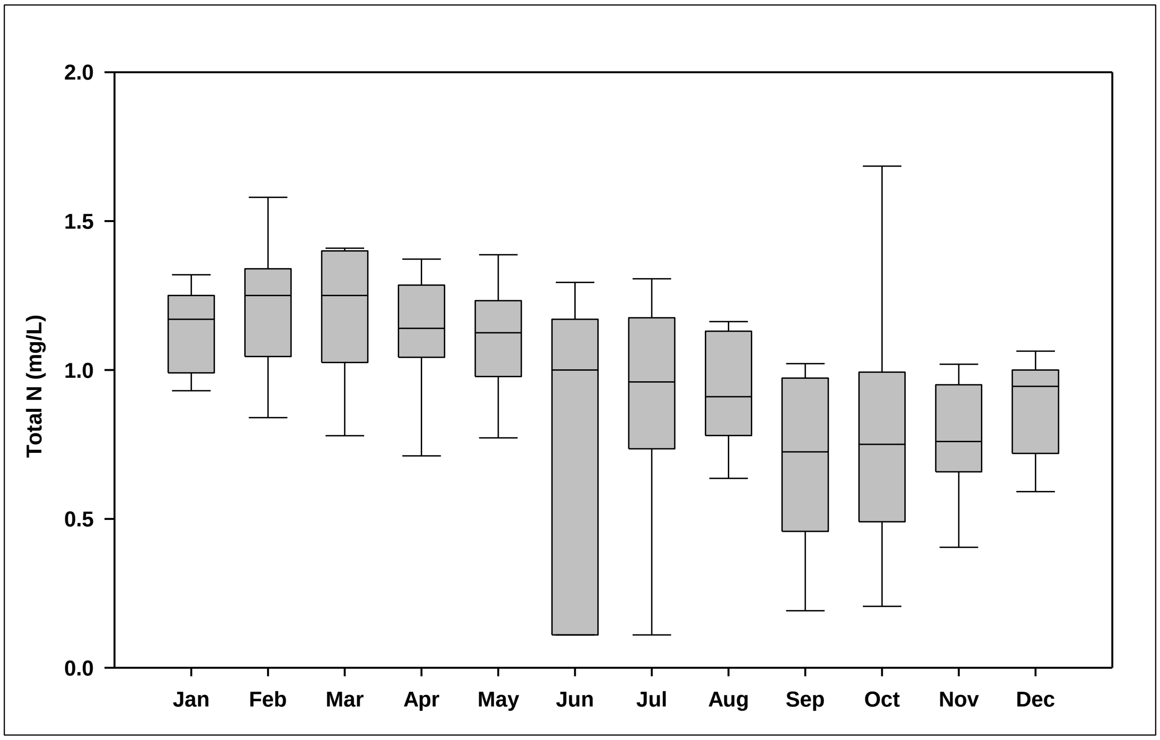
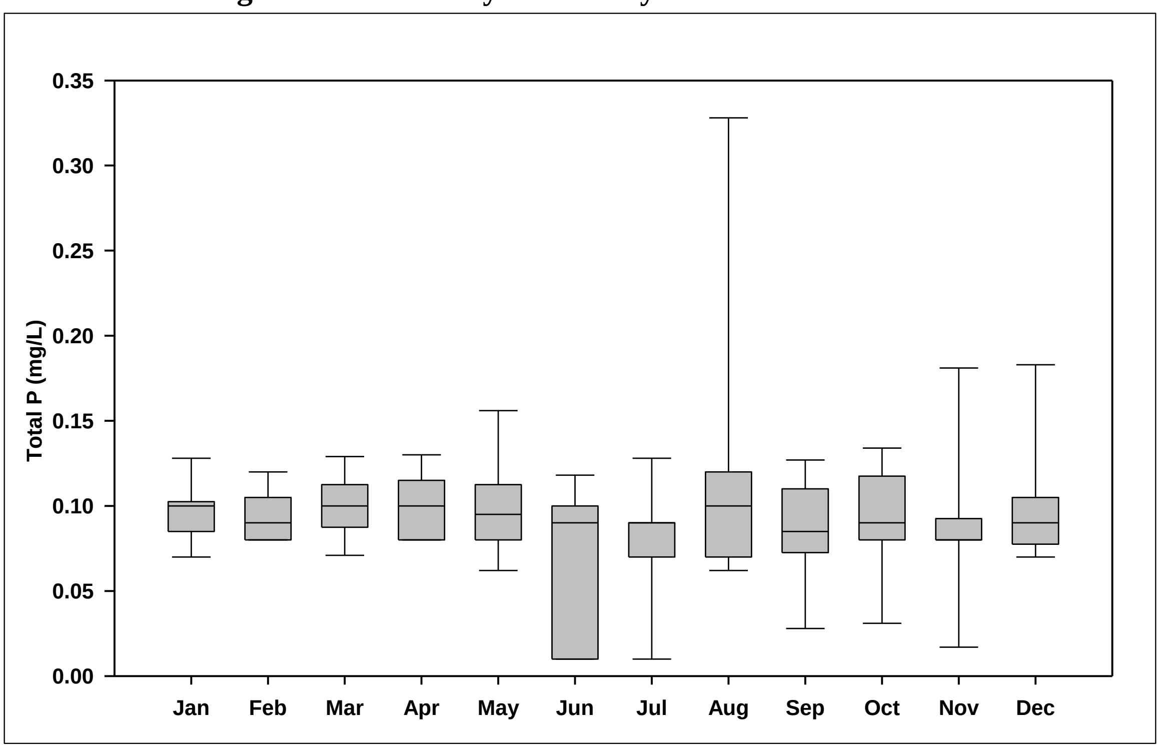


Figure 7-41. Monthly Variability in Total N at Pacheco



Note: Insufficient data to plot all percentiles.

Figure 7-42. Monthly Variability in Total P at Pacheco



Note: Note: Insufficient data to plot all percentiles. The July median of 0.09 mg/L is the same as the 75th percentile.

O'Neill Forebay Outlet – O'Neill Forebay Outlet on the California Aqueduct is a mixture of water from San Luis Reservoir, the California Aqueduct, and the DMC. **Figure 7-43** presents the total N data and **Figure 7-44** presents the total P data for O'Neill Forebay Outlet. Total N concentrations range from 0.27 to 2.5 mg/L with a median of 0.98 mg/L. Total P concentrations range from 0.06 to 0.21 mg/L with a median of 0.09 mg/L. The average nutrient concentrations were calculated to determine the trophic level classification of water entering the California Aqueduct downstream of San Luis Reservoir. The trophic level classifications were previously shown in **Table 7-1**. The average total N concentration is 1.0 mg/L, placing it in the mesotrophic level. The average total P concentration is 0.09 mg/L, placing it in the eutrophic level.

- Spatial Trends – **Figures 7-35 and 7-36** compare the nutrient data collected between 2004 and 2010 at O'Neill Forebay Outlet to a number of other locations along the aqueduct. Median total N concentrations increase from 0.78 mg/L at Banks to 0.98 mg/L at O'Neill Forebay Outlet during this period but the increase is not statistically significant (Mann-Whitney, p=0.0733). Total P concentrations remain the same, with a median of 0.09 mg/L at both locations.

- Long-Term Trends – **Figures 7-43 and 7-44** show that both total N and total P concentrations are less variable and lower in the last few years. There is a relatively short period of record so it's not clear if this is a trend or if it's due to the fact that the last several years have been dry years and nutrient data were first collected at O'Neill Forebay Outlet during a wet period.

- Wet Year/Dry Year Comparison – The median nutrient concentrations are not statistically different between dry and wet years (Mann-Whitney, p=0.8862 for total N and p=0.4178 for total P). The total N median is 0.99 mg/L for dry years and 0.98 mg/L for wet years. The total P median is 0.08 mg/L for dry years and 0.10 mg/L for wet years.

- Seasonal Trends – **Figures 7-45 and 7-46** present the monthly nutrient data for O'Neill Forebay Outlet. The total N seasonal pattern is the same as at Banks. The concentrations are high in the winter months, decline in the spring and summer, and increase during the fall months. The total P concentrations are slightly higher in the winter months and remain low from May through November. As discussed previously, water released from San Luis Reservoir (Pacheco) has lower total P concentrations and higher total N concentrations during the spring and summer months compared to Banks. During May and June the total P concentrations at O'Neill Forebay Outlet are lower than those found at Banks but the total N concentrations do not show the influence of releases from San Luis Reservoir. It may be that the nutrient data collected at Pacheco do not reflect the nutrient concentrations in water released at Gianelli.

Figure 7-43. Total N Concentrations at O'Neill Forebay Outlet

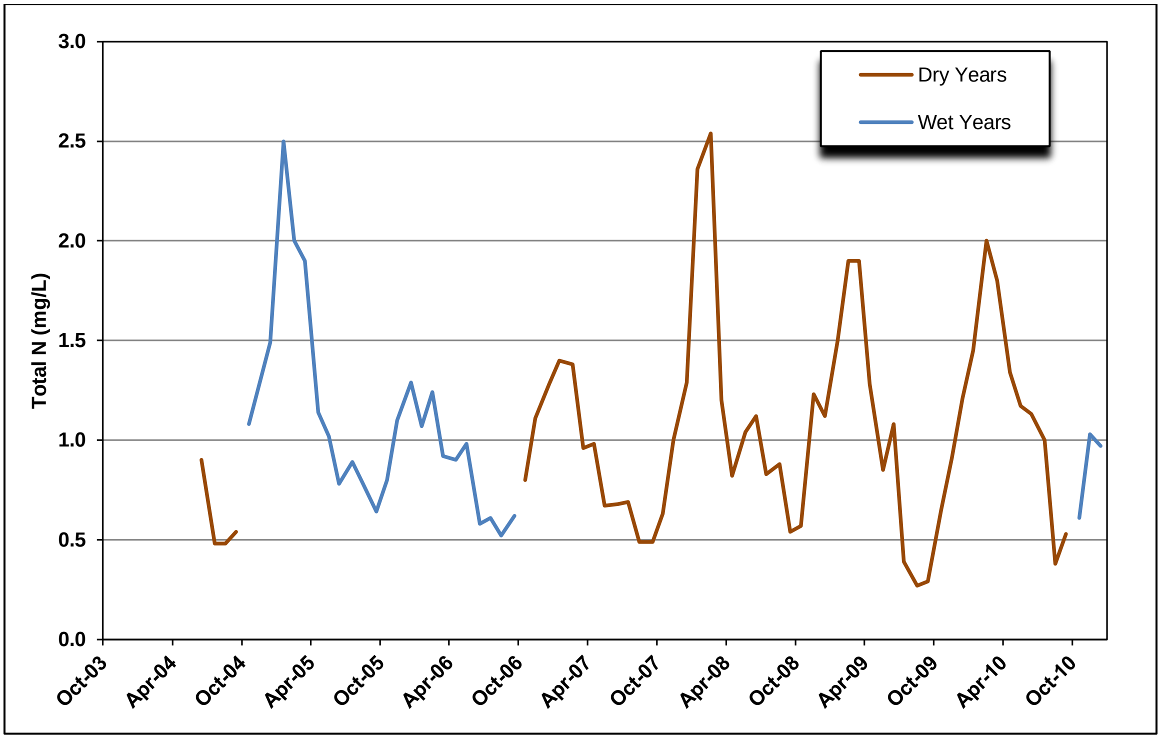


Figure 7-44. Total P Concentrations at O'Neill Forebay Outlet

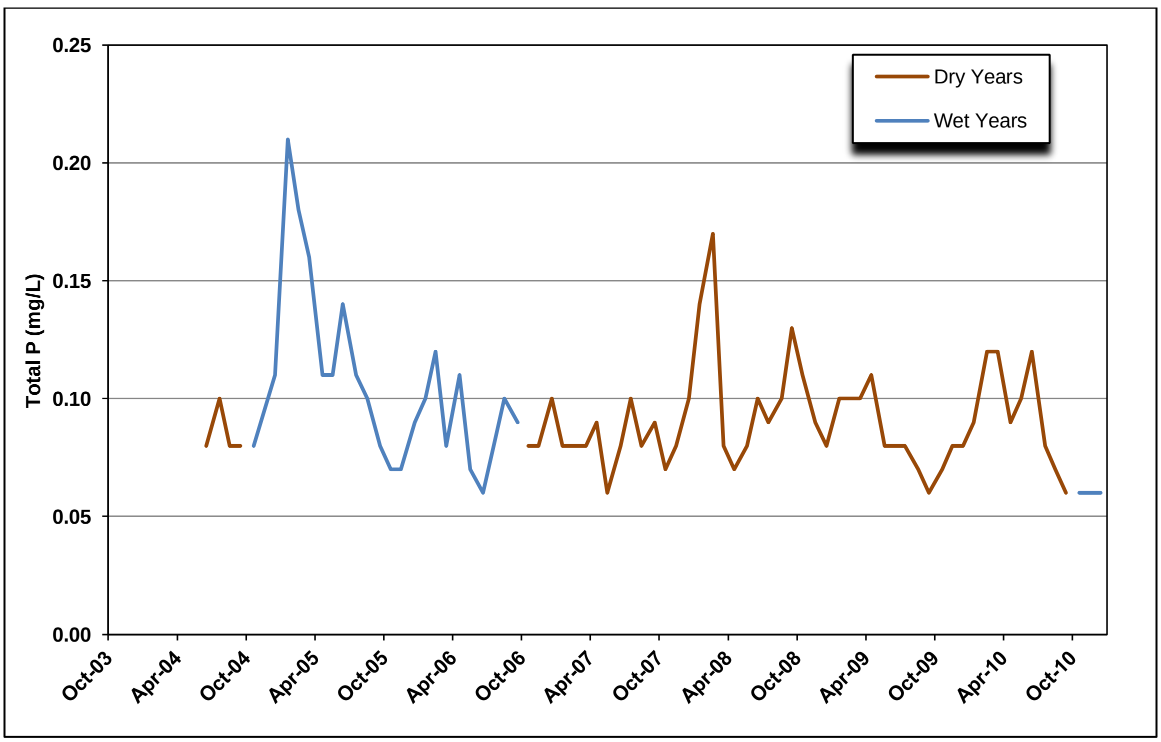
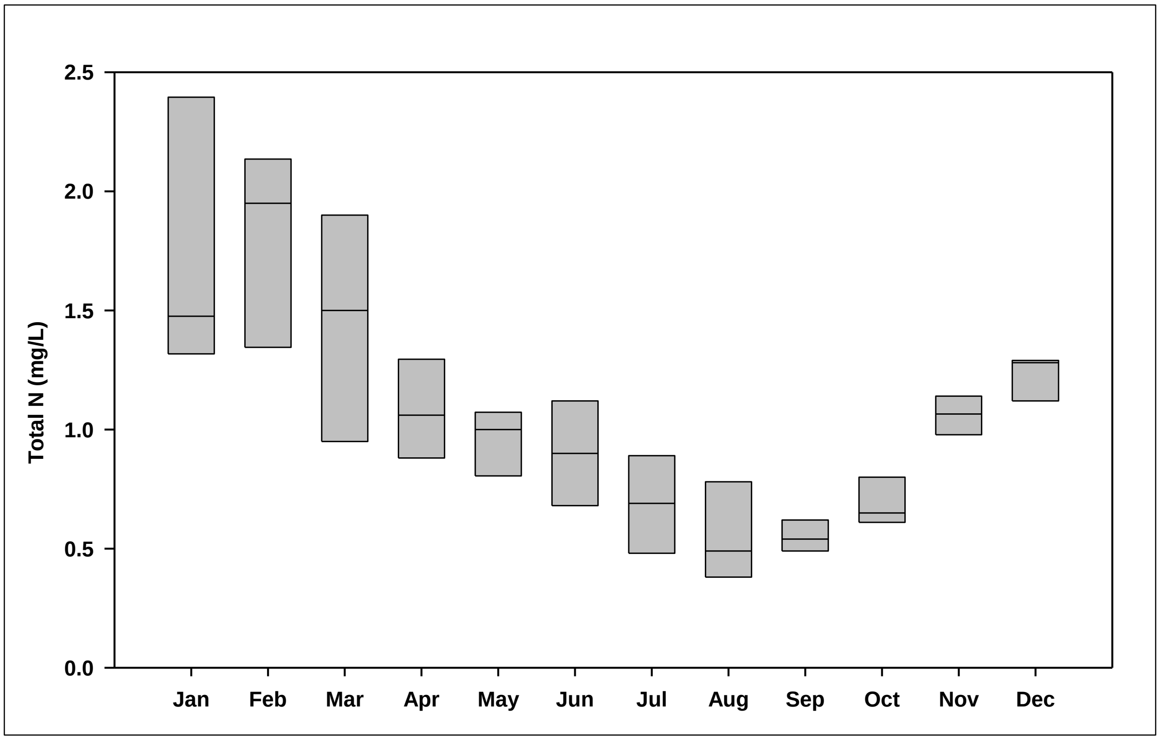
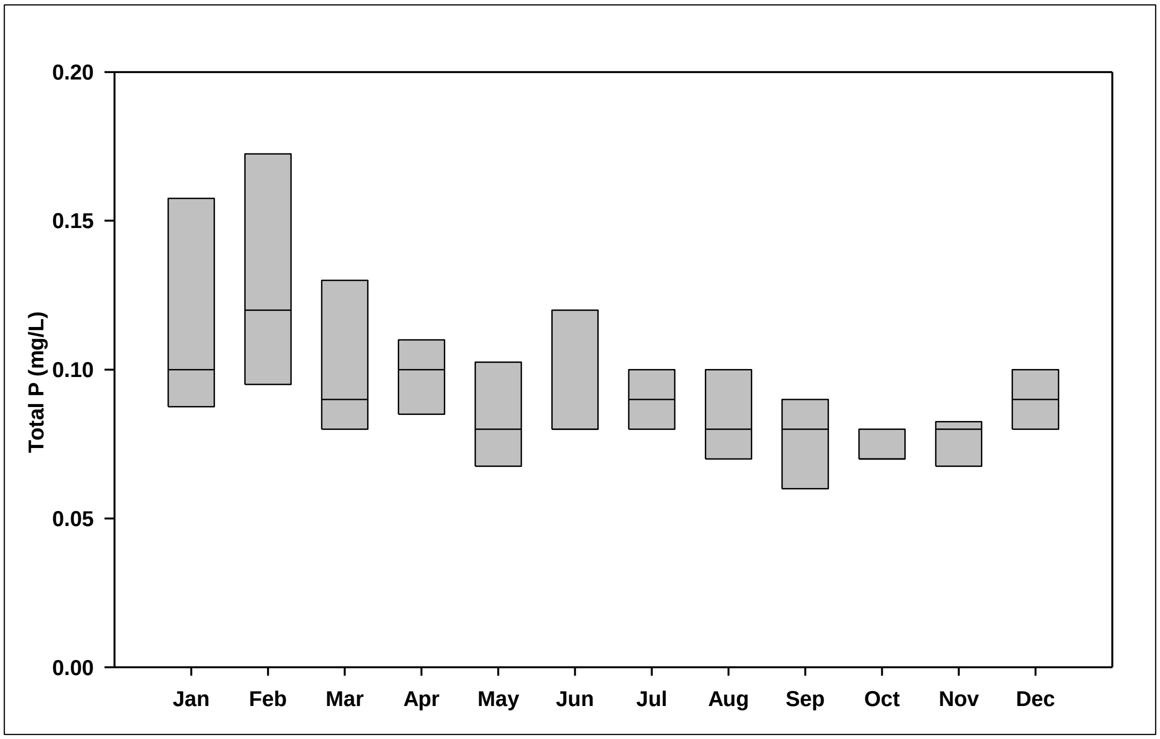


Figure 7-45. Monthly Variability in Total N at O'Neill Forebay Outlet



Note: Note: Insufficient data to plot all percentiles. The December median of 1.28 mg/L is the same as the 75th percentile.

Figure 7-46. Monthly Variability in Total P at O'Neill Forebay Outlet



Note: Insufficient data to plot all percentiles. The June median of 0.08 mg/L and the October median of 0.07 mg/L are the same as the 25th percentiles in each month.

Check 21 – Check 21 on the California Aqueduct is representative of the water entering the Coastal Branch. **Figure 7-47** presents the total N data and **Figure 7-48** presents the total P data for Check 21. Total N concentrations range from 0.11 to 2.4 mg/L with a median of 0.96 mg/L. Total P concentrations range from 0.01 to 0.20 mg/L with a median of 0.10 mg/L. The average nutrient concentrations were calculated to determine the trophic level classification of water entering the Coastal Branch. The trophic level classifications were previously shown in **Table 7-1**. The average total N concentration is 1.0 mg/L, placing it in the mesotrophic level. The average total P concentration is 0.10 mg/L, placing it in the eutrophic level.

- Spatial Trends – **Figures 7-35 and 7-36** compare the nutrient data collected between 2004 and 2010 at Check 21 to a number of other locations along the aqueduct. Median total N concentrations decrease from 0.98 mg/L at O'Neill Forebay Outlet to 0.94 mg/L at Check 21 during this period but the decrease is not statistically significant (Mann-Whitney, p=0.5588). Total P concentrations remain the same, with a median of 0.09 mg/L at both locations. These data indicate that there are no substantial changes in nutrient concentrations as water moves from the Delta to Check 21, despite the inflow from the DMC, storage in San Luis Reservoir, and inflows between San Luis Reservoir and Check 21.

- Long-Term Trends – The total N concentrations, shown in **Figure 7-47** do not show any discernible trend. **Figure 7-48** shows that total P concentrations have been lower in recent years but it's not clear if this is a long-term trend.

- Wet Year/Dry Year Comparison – The total N median concentration of 0.9 mg/L in dry years is not statistically significantly lower than the median of 1.1 mg/L in wet years (Mann-Whitney, p=0.1779) and the total P median of 0.10 mg/L in dry years is not statistically significantly different from the wet year median of 0.09 mg/L (Mann-Whitney, p=0.8672).

- Seasonal Trends – **Figures 7-49 and 7-50** present the monthly nutrient data for Check 21. The total N seasonal pattern is the same as at Banks. The concentrations are high in the winter months, decline in the spring and summer, and increase during the fall months. The total P concentrations are slightly higher in the winter months, decline in the spring and then have a secondary peak in July. This is similar to Banks except the summer peak occurs one month later at Check 21 than it does at Banks.

Figure 7-47. Total N Concentrations at Check 21

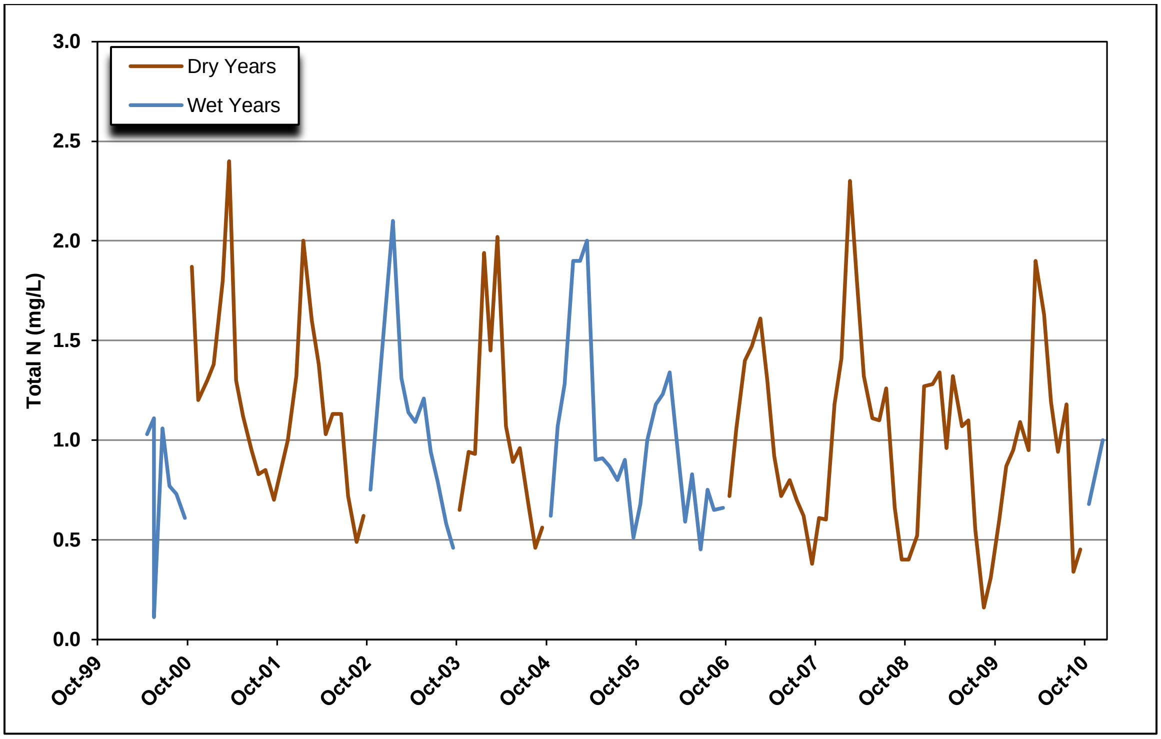


Figure 7-48. Total P Concentrations at Check 21

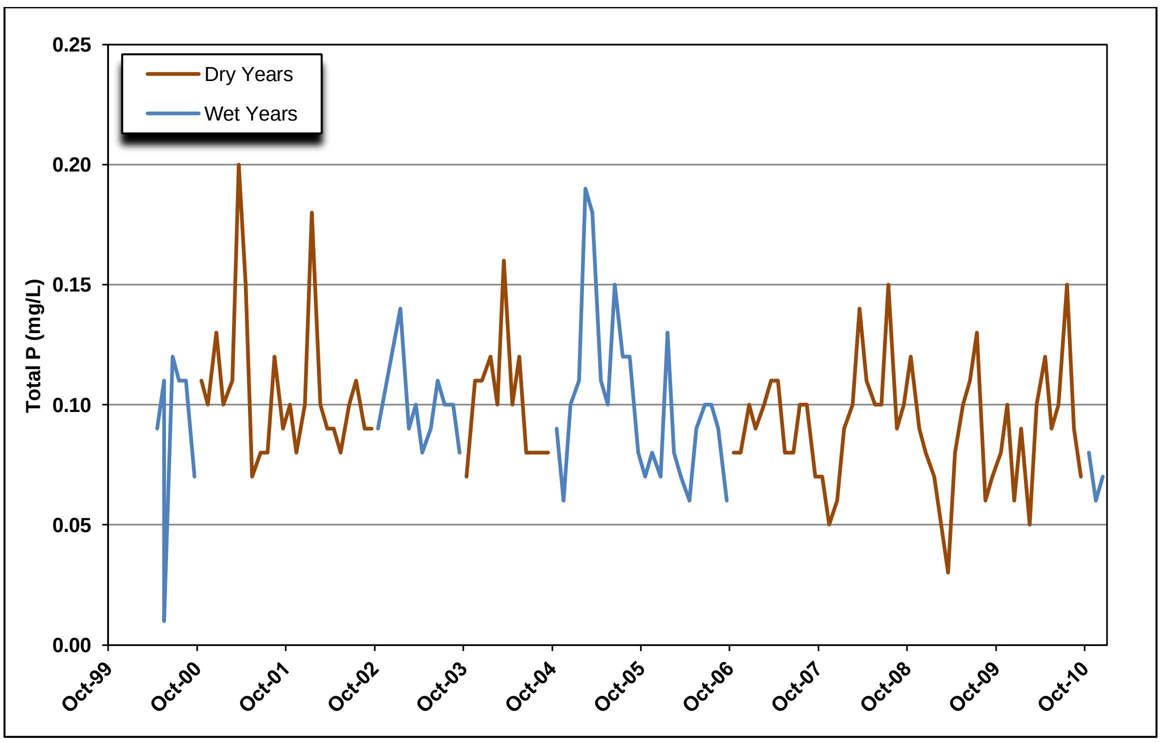
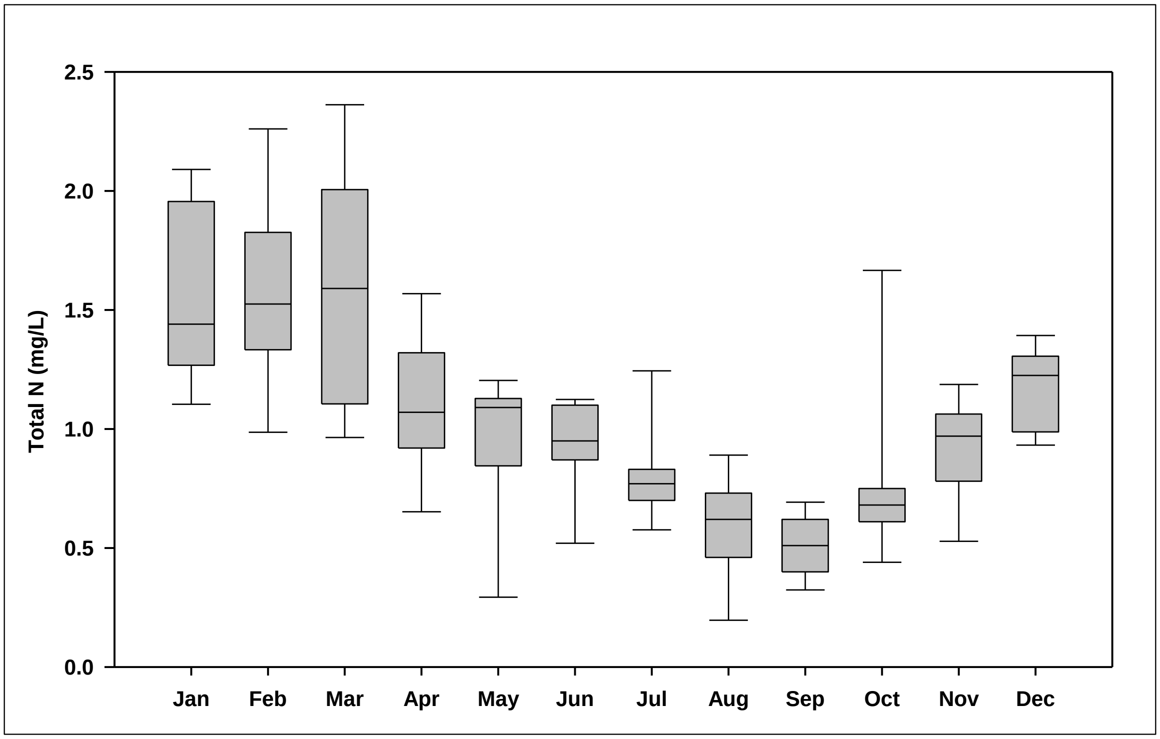
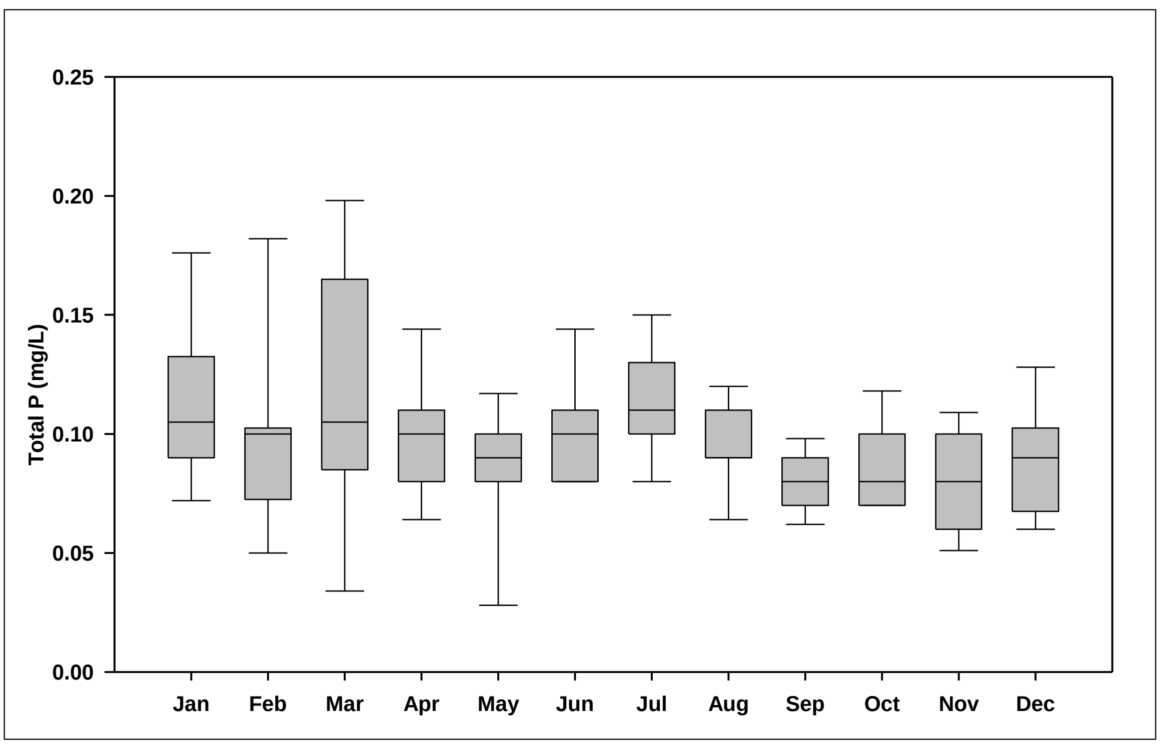


Figure 7-49. Monthly Variability in Total N at Check 21



Note: Insufficient data to plot all percentiles.

Figure 7-50. Monthly Variability in Total P at Check 21



Note: Insufficient data to plot all percentiles.

Check 41 – Check 41 is immediately upstream of the bifurcation of the California Aqueduct into the east and west branches. **Figure 7-51** presents the total N data and **Figure 7-52** presents the total P data for Check 41. Total N concentrations range from 0.11 to 3.1 mg/L with a median of 1.05 mg/L. Total P concentrations range from 0.01 to 0.23 mg/L with a median of 0.09 mg/L. The average nutrient concentrations were calculated to determine the trophic level classification of water entering the east and west branches of the California Aqueduct and subsequently flowing into the terminal reservoirs. The trophic level classifications were previously shown in **Table 7-1**. The average total N concentration is 1.1 mg/L, placing it in the mesotrophic level. The average total P concentration is 0.08 mg/L, placing it in the eutrophic level.

- Spatial Trends – **Figures 7-35 and 7-36** compare the nutrient data collected between 2004 and 2010 at Check 41 to a number of other locations along the aqueduct. Median total N concentrations increase from 0.94 mg/L at Check 21 to 1.05 mg/L at Check 41 during this period but the increase is not statistically significant (Mann-Whitney, p=0.0784). There is a statistically significant increase between the total N median concentration of 0.78 mg/L at Banks and 1.05 mg/L at Check 41 (Mann-Whitney, p=0.0034). There is a statistically significant decrease in total P concentrations from a median of 0.09 mg/L at Check 21 to a median of 0.07 mg/L at Check 41 (Mann-Whitney, p=0.0001).

  The data for the last five years were examined to determine if there is any evidence that the substantial amount of inflows into the aqueduct that occurred between 2007 and 2010 had an impact on nutrient concentrations. **Figures 7-53** and **7-54** present the nutrient data for Checks 21 and 41. These figures show that total N concentrations increase and total P concentrations decrease substantially between the two check structures. For example, in October 2008, the total N concentration increased from 0.4 mg/L to 1.5 mg/L and the total P concentration decreased from 0.12 mg/L to 0.03 mg/L. During this month over 53,000 acre-feet of inflows entered the Aqueduct, representing 61 percent of the flow at Check 41. The inflow program is discussed in more detail in Chapter 14.

- Long-Term Trends – The total N concentrations, shown in **Figure 7-51** do not show any discernible trend. **Figure 7-52** shows that total P concentrations have been lower in recent years as a result of the inflow program.

- Wet Year/Dry Year Comparison – The total N median concentration of 1.1 mg/L in dry years is statistically significantly higher than the median of 0.97 mg/L in wet years (Mann-Whitney, p=0.0295). Conversely, the total P median of 0.08 mg/L in dry years is statistically significantly lower than the wet year median of 0.10 mg/L (Mann-Whitney, p=0.0001).

- Seasonal Trends – **Figures 7-55 and 7-56** present the monthly nutrient data for Check 41. The total N seasonal pattern is the same as at Banks. The concentrations are high in the winter months, decline in the spring and summer, and increase during the fall months. The total P concentrations are slightly higher in the winter months, decline in the spring, and then have a secondary peak in July. This is similar to Banks except the summer peak occurs one month later at Check 41 than it does at Banks.

Figure 7-51. Total N Concentrations at Check 41

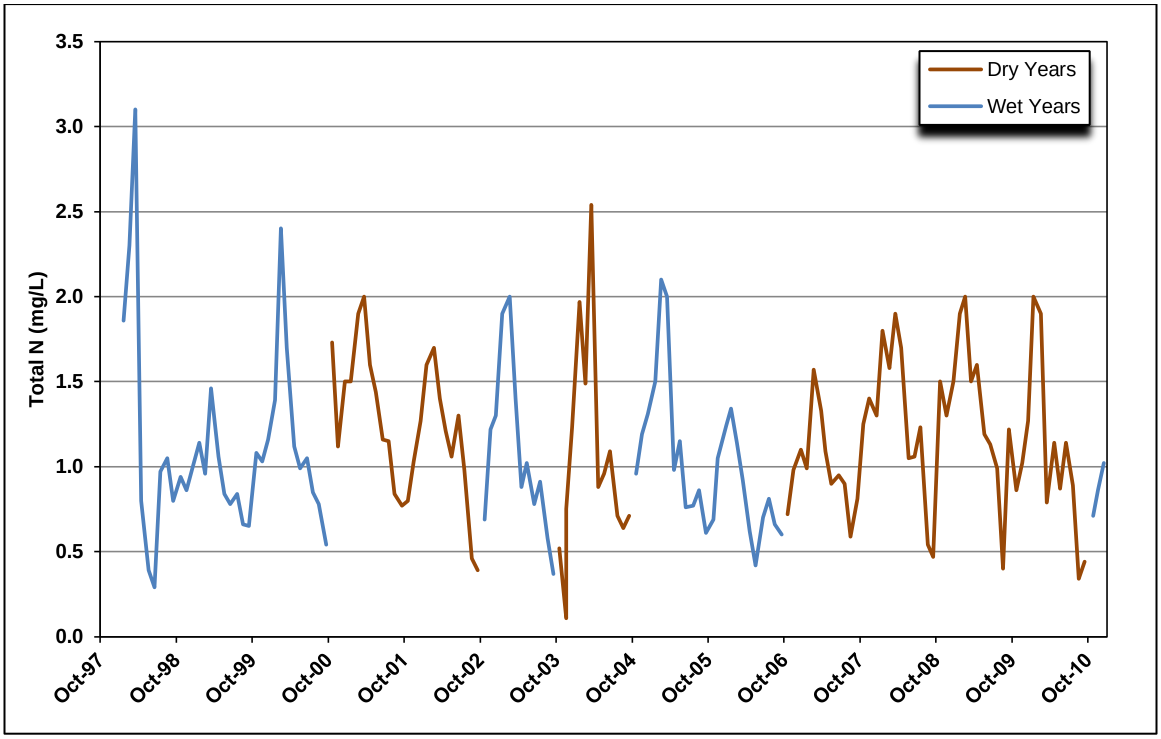


Figure 7-52. Total P Concentrations at Check 41

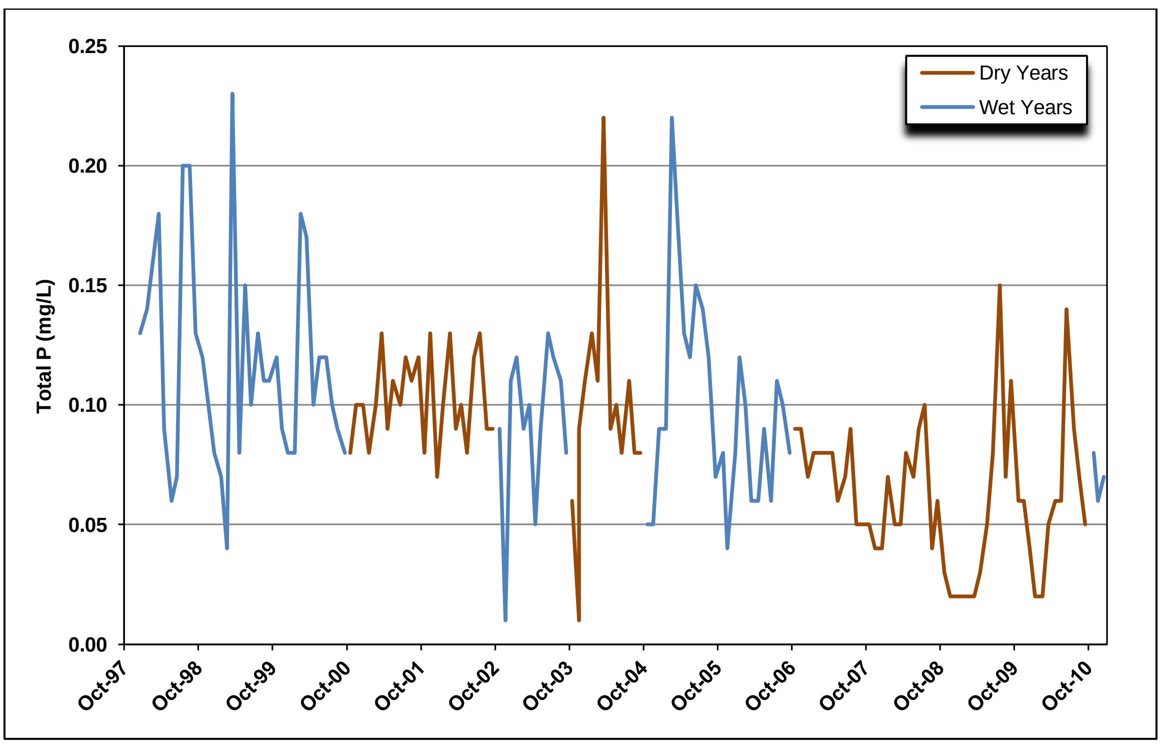


Figure 7-53. Comparison of Check 21 and Check 41 Total N Concentrations

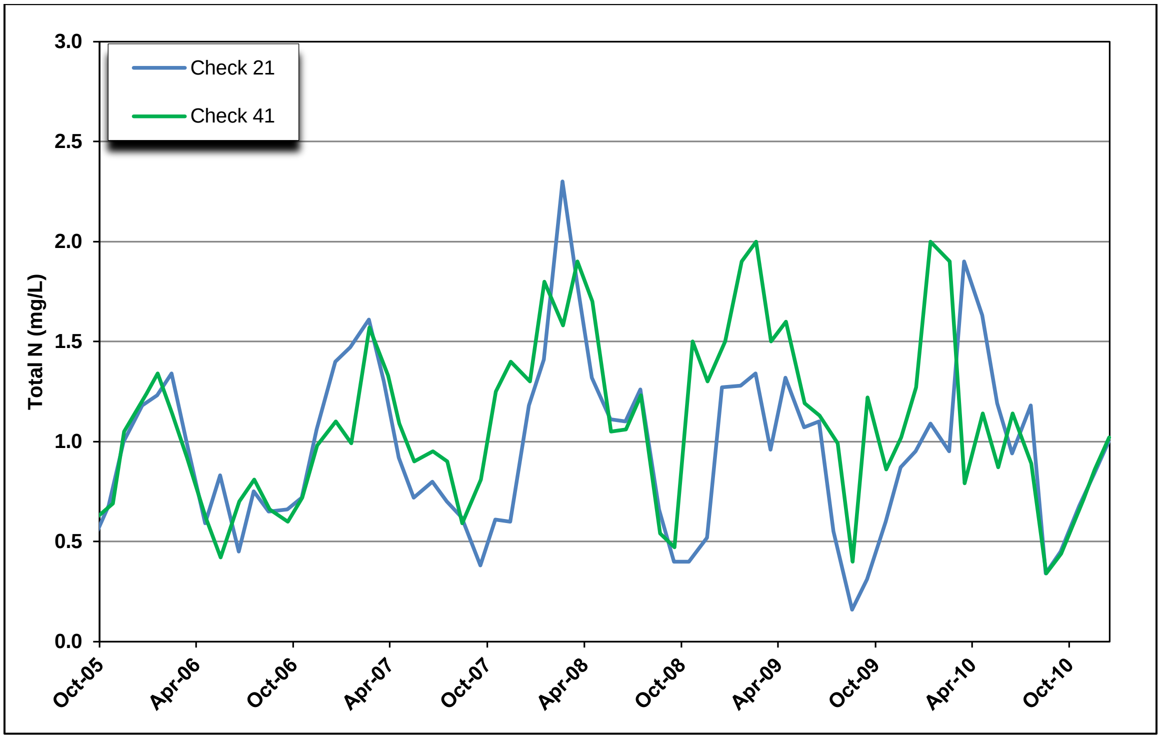


Figure 7-54. Comparison of Check 21 and Check 41 Total P Concentrations

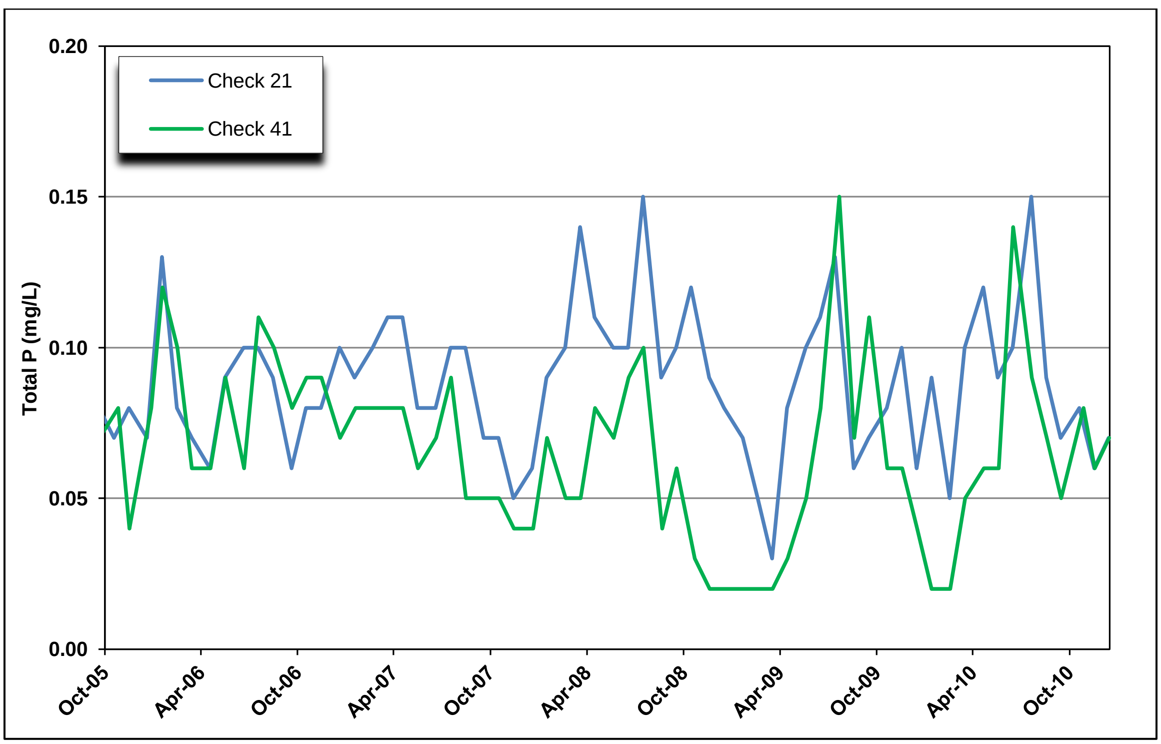
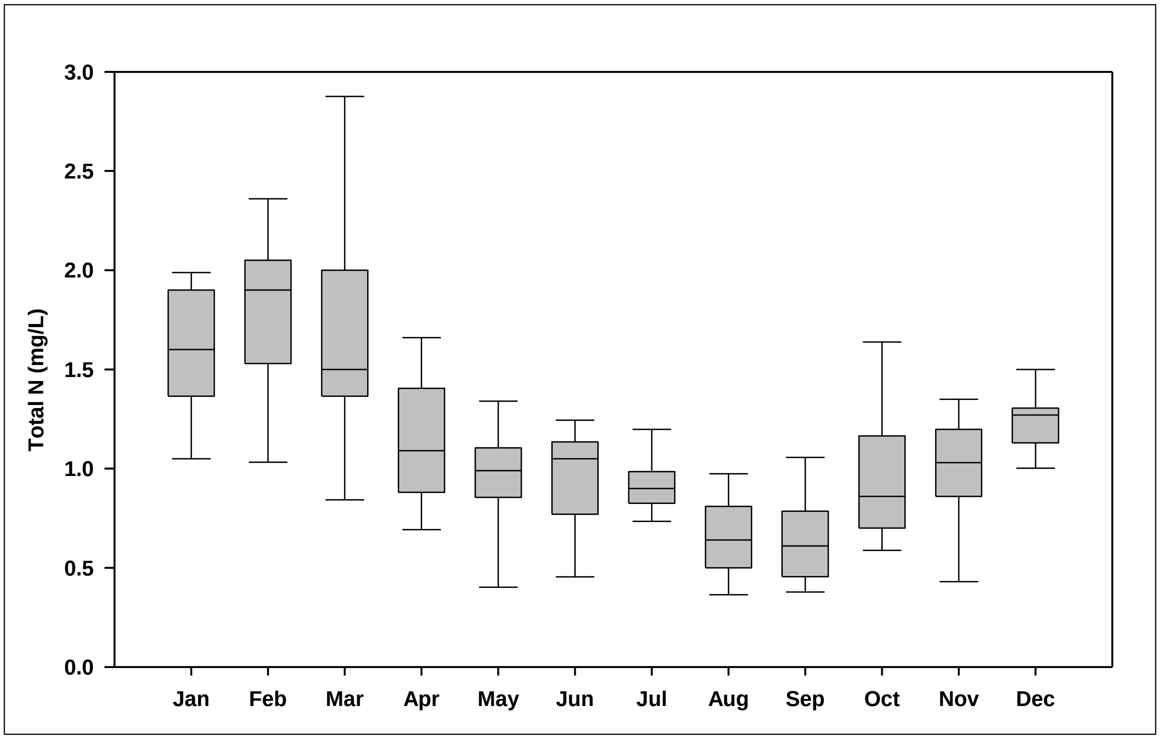
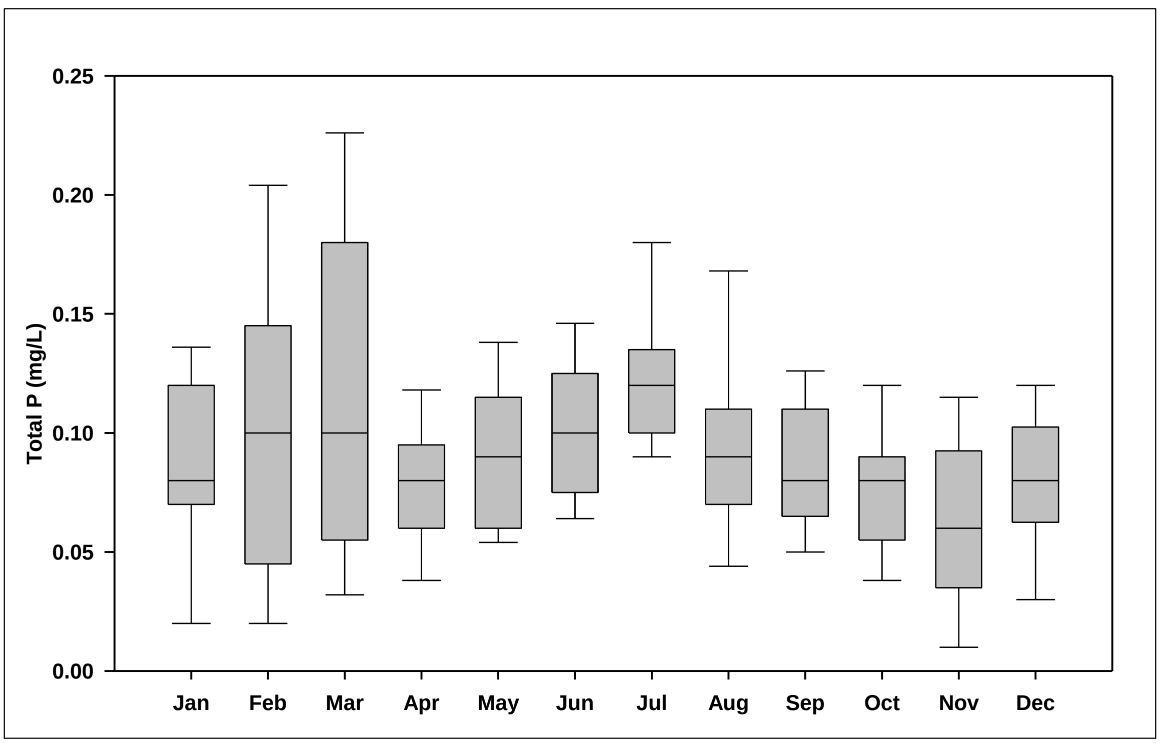


Figure 7-55. Monthly Variability in Total N at Check 41



Note: Insufficient data to plot all percentiles.

Figure 7-56. Monthly Variability in Total P at Check 41



Note: Insufficient data to plot all percentiles.

Castaic Outlet – **Figure 7-57** presents the total N data and **Figure 7-58** presents the total P data for Castaic Outlet. Total N concentrations range from 0.31 to 2.8 mg/L with a median of 0.65 mg/L. Total P concentrations range from 0.01 to 0.10 mg/L with a median of 0.04 mg/L.

- Spatial Trends – **Figures 7-35 and 7-36** compare the nutrient data collected between 2004 and 2010 at Castaic Outlet to a number of other locations along the aqueduct. There is a statistically significant decrease in median total N concentrations from 1.05 mg/L at Check 41 to 0.67 mg/L at Castaic Outlet (Mann-Whitney, p=0.0000) and median total P concentrations from 0.07 mg/L at Check 41 to 0.04 mg/L at Castaic Outlet (Mann-Whitney, p=0.0000). These data show the effect of reservoir storage in moderating the range of nutrient concentrations and, perhaps, indicate a loss of nutrients due to algal uptake and settling of organic detritus in the West Branch reservoirs. Water flows from the hypolimnion of Pyramid Lake, at an outlet portal located at about 160 feet deep, through Elderberry Forebay, through a valve that entrains air, and then into Castaic Lake. The entrained air tends to cause water entering Castaic Lake to rise to the surface where biologically available nutrients drawn from the hypolimnion of Pyramid Lake are available for algal uptake. Algal uptake and subsequent settling of organic matter in Castaic Lake, due at least in part to the unique configuration and operational pattern of this part of the SWP system, may be responsible for the lower nutrient concentrations in Castaic Outlet water. An additional factor to consider in understanding the relatively low concentrations of nutrients in Castaic compared to Check 41 is that the nutrient samples are collected at a depth of 1 meter in the epilimnion of Castaic Lake. During much of the year, virtually all of the nutrients are tied up in algal biomass which settles into the hypolimnion. Water is generally released from the hypolimnion of Castaic Lake so nutrient concentrations in water treated by MWDSC and Castaic Lake Water Agency are likely higher than the levels measured in the epilimnion.

- Long-Term Trends – The total N concentrations, shown in **Figure 7-57** and the total P concentrations, shown in **Figure 7-58** do not show any discernible long-term trends. From the beginning of data collection in 1998 until early 2003, it appeared as though nutrient concentrations were increasing, although the upstream aqueduct locations did not show any apparent increase. This period was followed by lower concentrations in the two subsequent years, again without any apparent change in the aqueduct concentrations. In recent years, total N and total P concentrations have been more stable with no upward or downward trend.

- Wet Year/Dry Year Comparison – The total N median concentration of 0.7 mg/L in dry years is statistically significantly higher than the median of 0.55 mg/L in wet years (Mann-Whitney, p=0.0000). The total P median of 0.04 mg/L in dry years is statistically significantly higher than the wet year median of 0.03 mg/L (Mann-Whitney, p=0.0001).

- Seasonal Trends – **Figures 7-59 and 7-60** present the monthly nutrient data for Castaic Outlet. The total N seasonal pattern is the same as at Banks except that there are smaller differences between the peak winter months and the low levels in the summer months. The total P concentrations show a strong seasonal pattern with very low levels in the summer months. This is likely due to algal uptake and subsequent settling of algae.

Figure 7-57. Total N Concentrations at Castaic Outlet

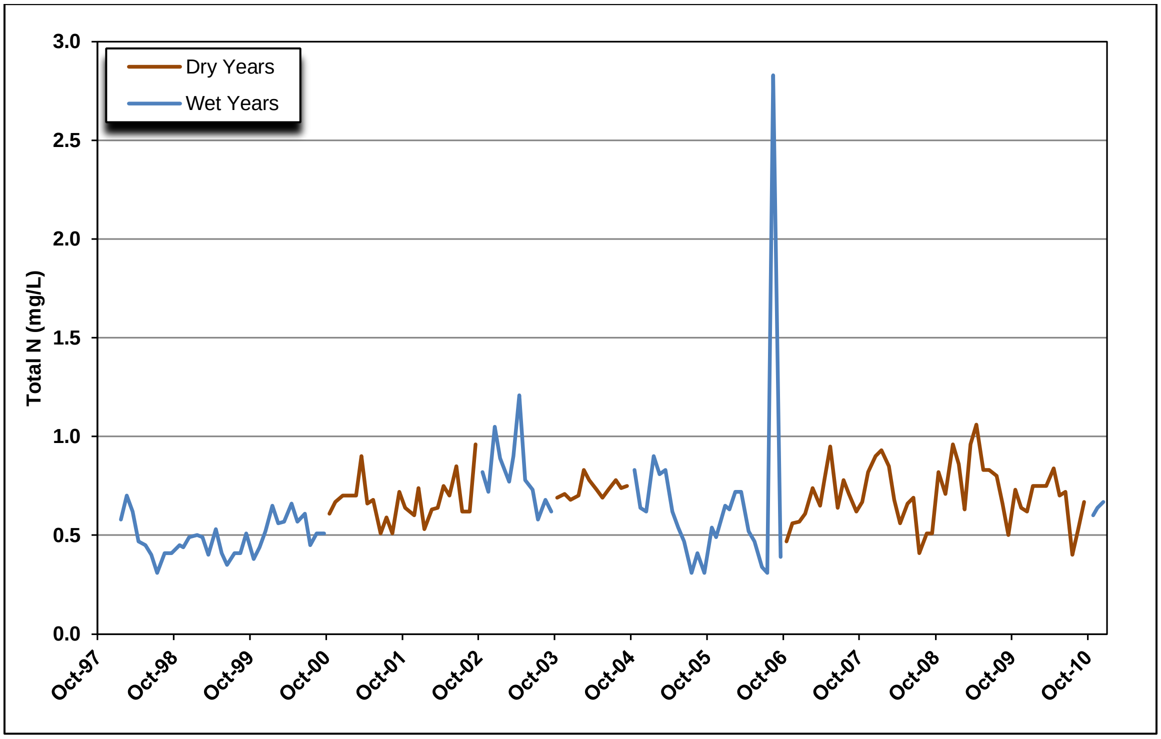


Figure 7-58. Total P Concentrations at Castaic Outlet

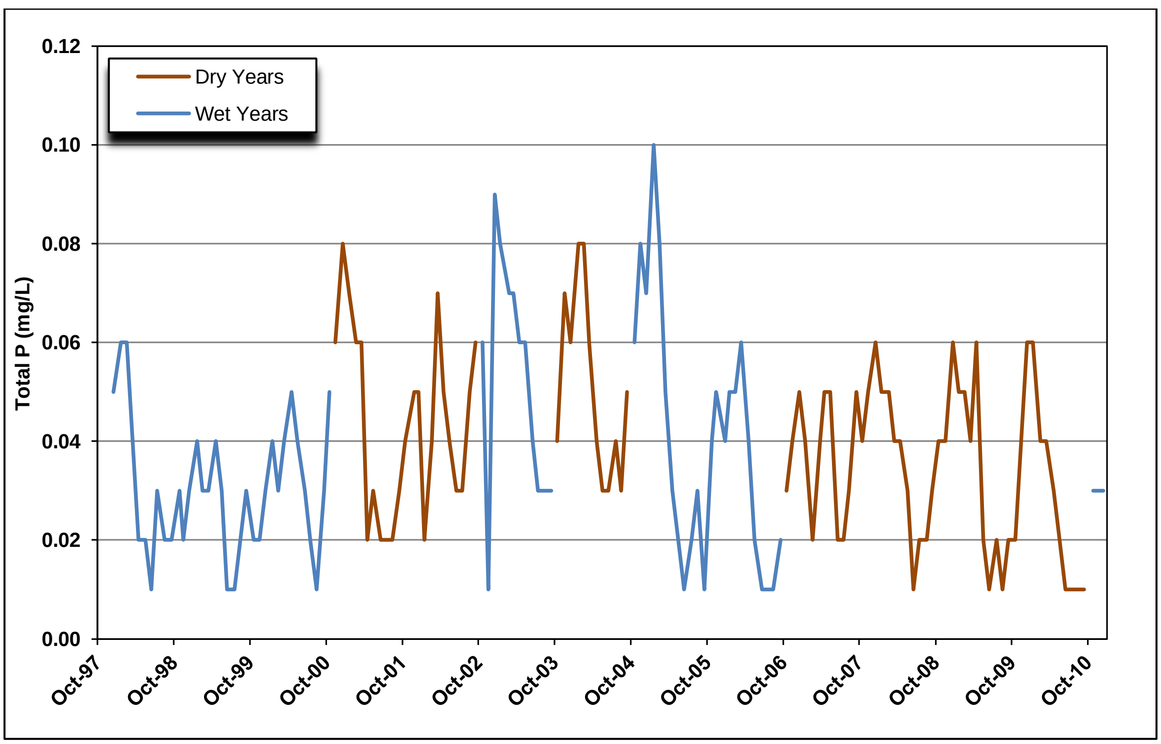
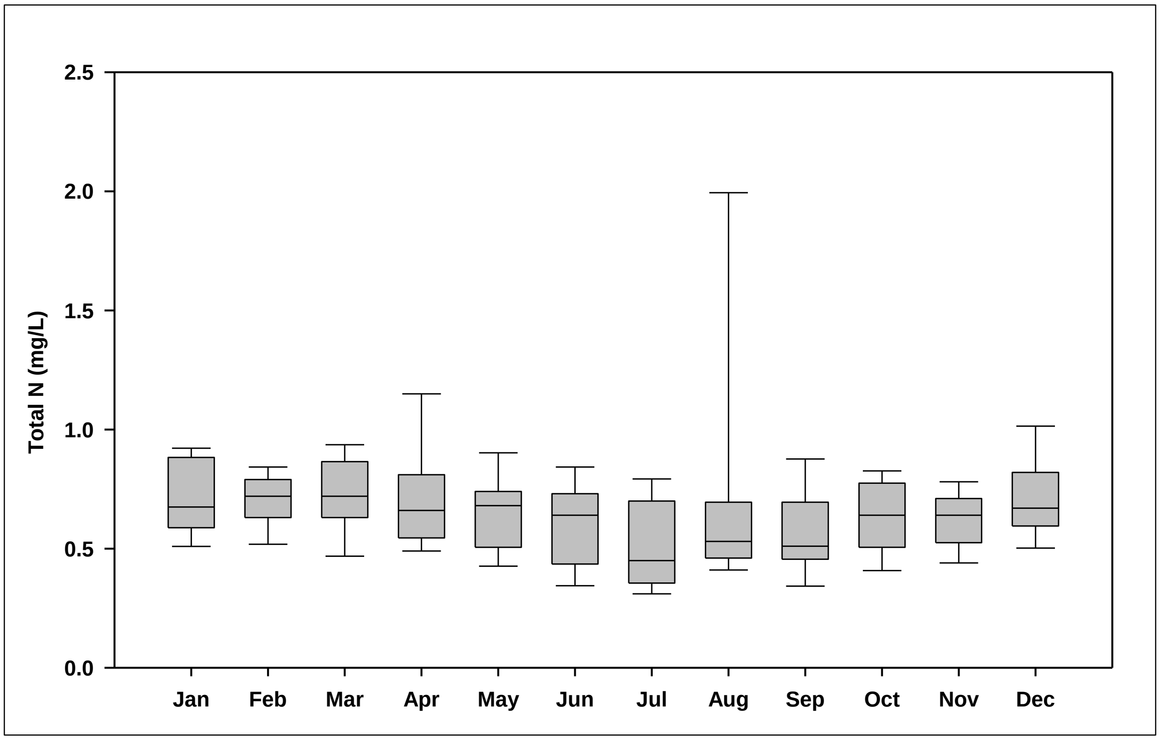
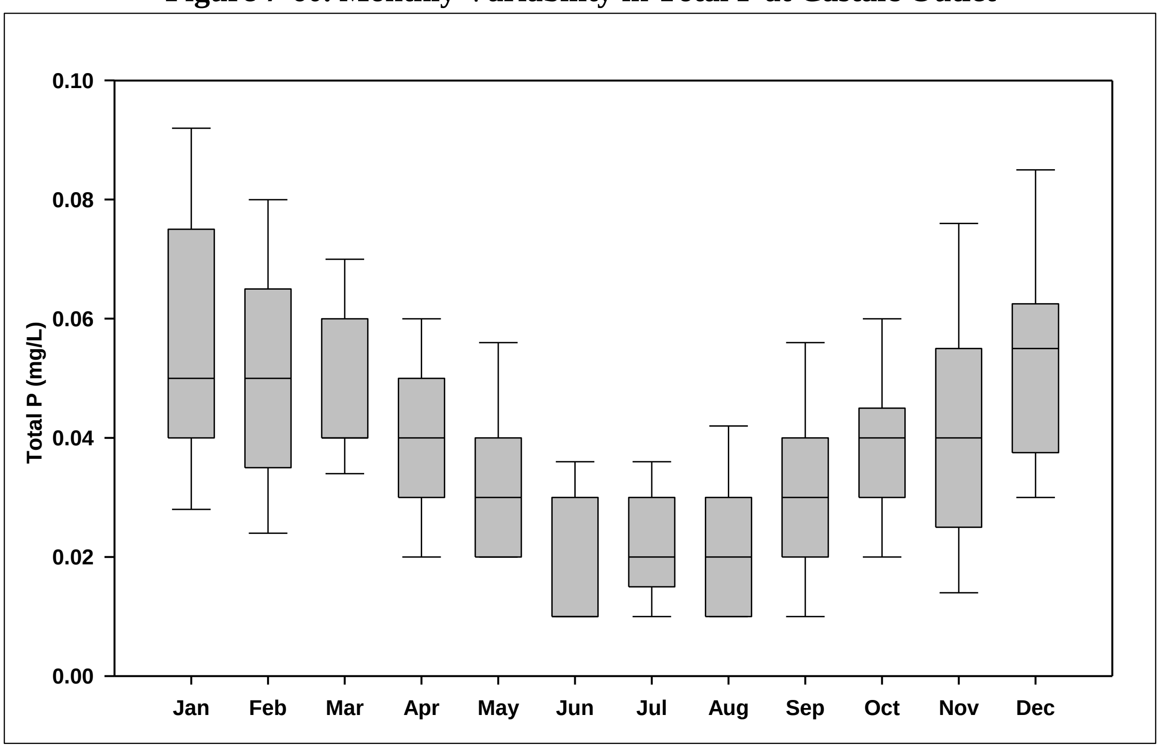


Figure 7-59. Monthly Variability in Total N at Castaic Outlet



Note: Insufficient data to plot all percentiles.

Figure 7-60. Monthly Variability in Total P at Castaic Outlet



Note: Note: Insufficient data to plot all percentiles. The March median of 0.04 mg/L and the June median of 0.01 mg/L are the same as the 25th percentiles for each month.

Devil Canyon – **Figure 7-61** presents the total N data and **Figure 7-62** presents the total P data for Devil Canyon. Total N concentrations range from <0.1 to 2.1 mg/L with a median of 0.97 mg/L. Total P concentrations range from <0.01 to 0.46 mg/L with a median of 0.09 mg/L.

- Spatial Trends – **Figures 7-35 and 7-36** compare the nutrient data collected between 2004 and 2010 at Devil Canyon to a number of other locations along the aqueduct. Unlike on the West Branch, where there are statistically significant declines in nutrient concentrations, there are no statistically significant changes in nutrient concentrations between Check 41 and Devil Canyon (Mann-Whitney, p=0.6487 for total N and p=0.0692 for total P.

- Long-Term Trends – The total N concentrations, shown in **Figure 7-61** do not show any discernible trend. **Figure 7-62** shows that total P concentrations have been lower in recent years but there was also a period in 2002 and 2003 when concentrations were low.

- Wet Year/Dry Year Comparison – The total N median concentration of 1.0 mg/L in dry years is statistically significantly higher than the median of 0.88 mg/L in wet years (Mann-Whitney, p=0.0428). The total P median of 0.08 mg/L in dry years is statistically significantly lower than the wet year median of 0.09 mg/L (Mann-Whitney, p=0.0146).

- Seasonal Trends – **Figures 7-63 and 7-64** present the monthly nutrient data for Devil Canyon. The total N seasonal pattern is the same as at Banks except the winter peak occurs one month later. The concentrations are high in the winter months, decline in the spring and summer, and increase during the fall months. The total P concentrations are slightly higher in the winter months, decline in the spring, and then have a secondary peak in July. This is similar to Banks except the summer peak occurs one month later at Devil Canyon than it does at Banks.

Figure 7-61. Total N Concentrations at Devil Canyon

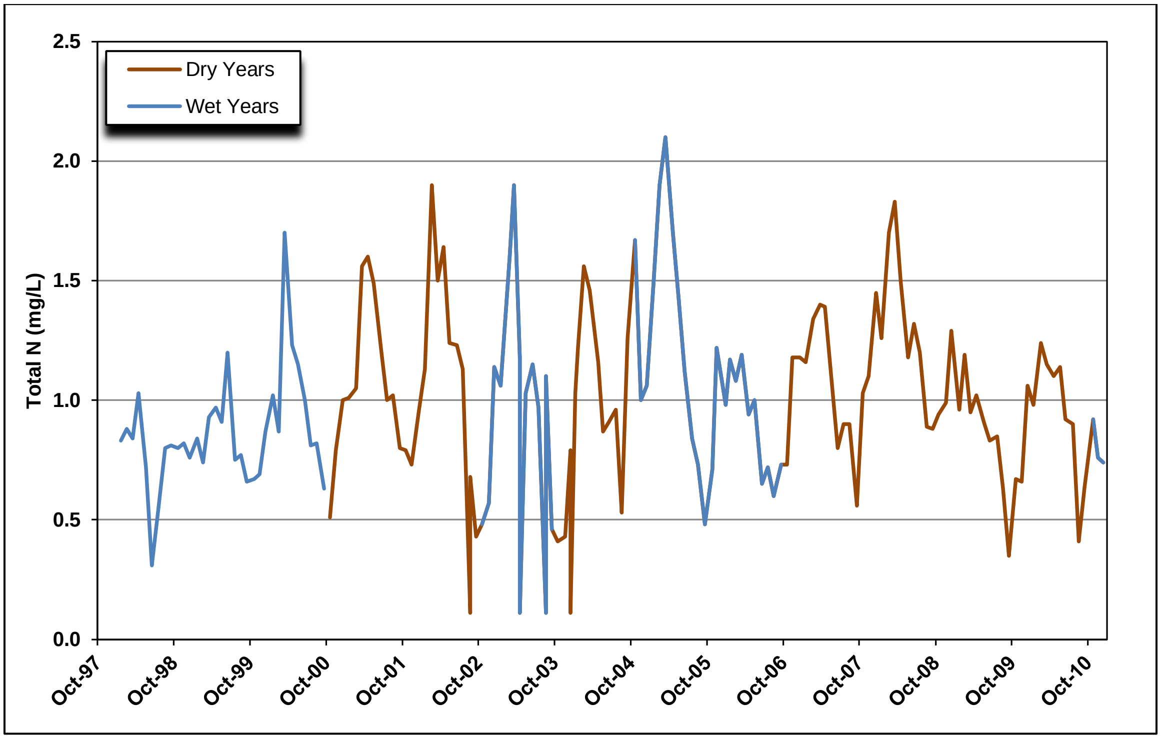


Figure 7-62. Total P Concentrations at Devil Canyon

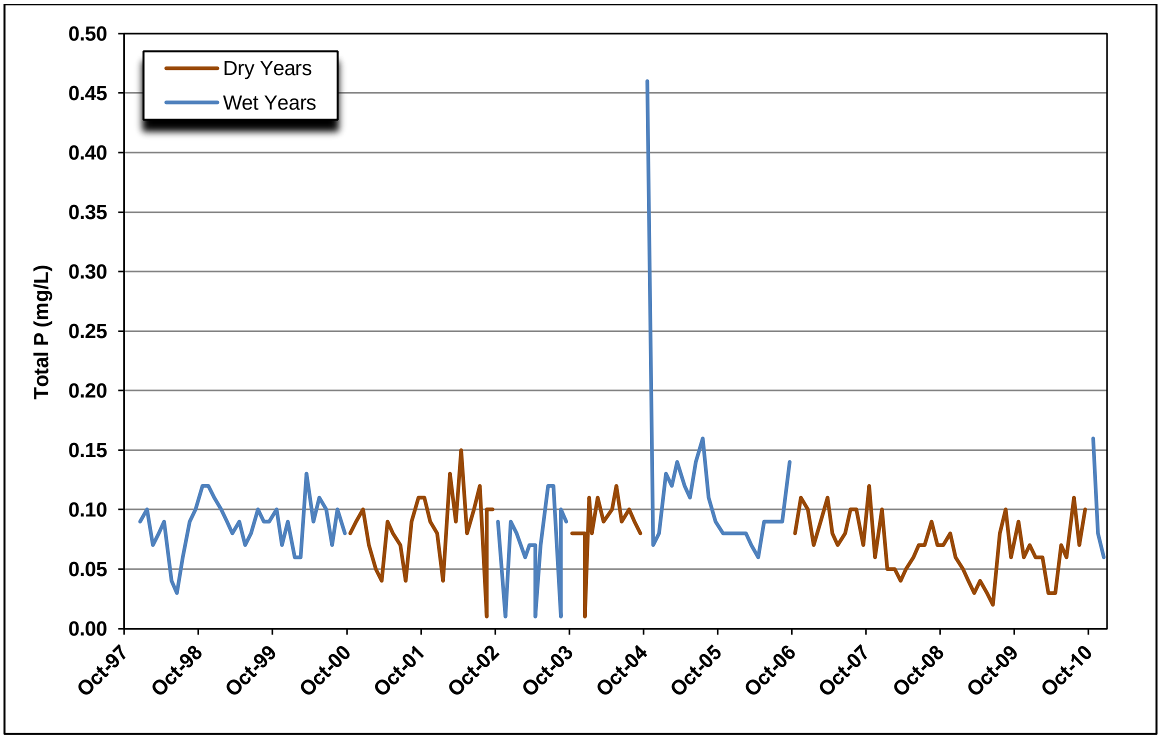
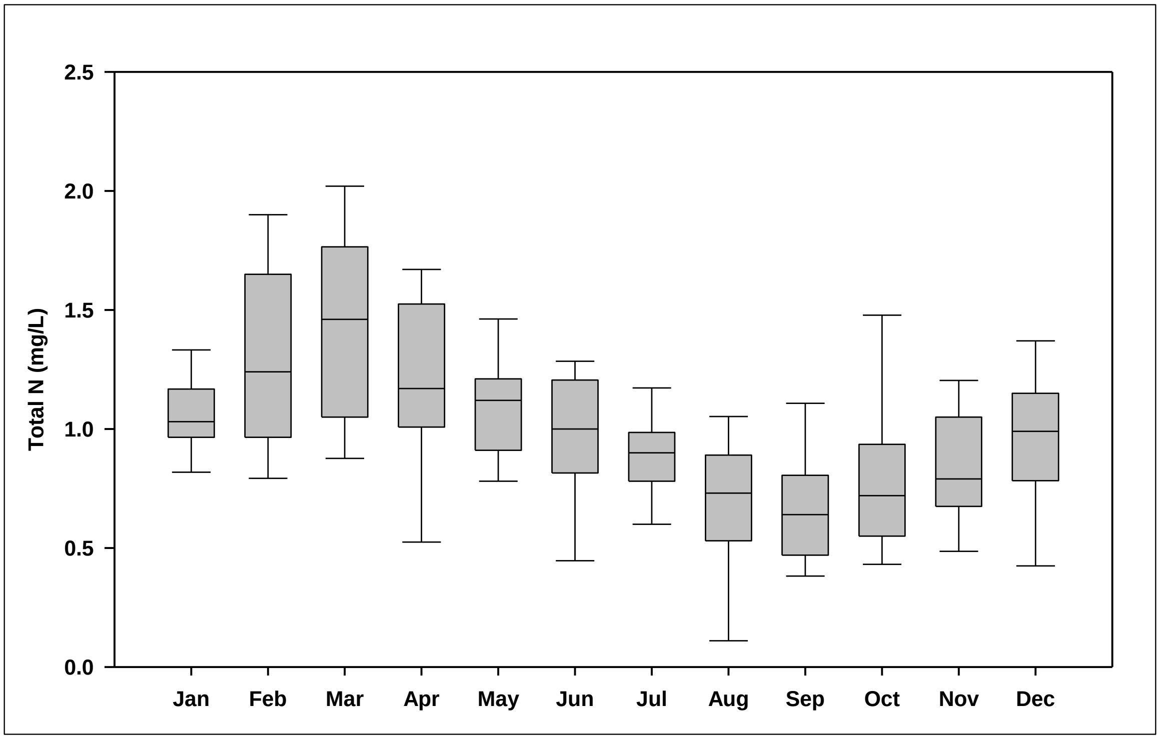
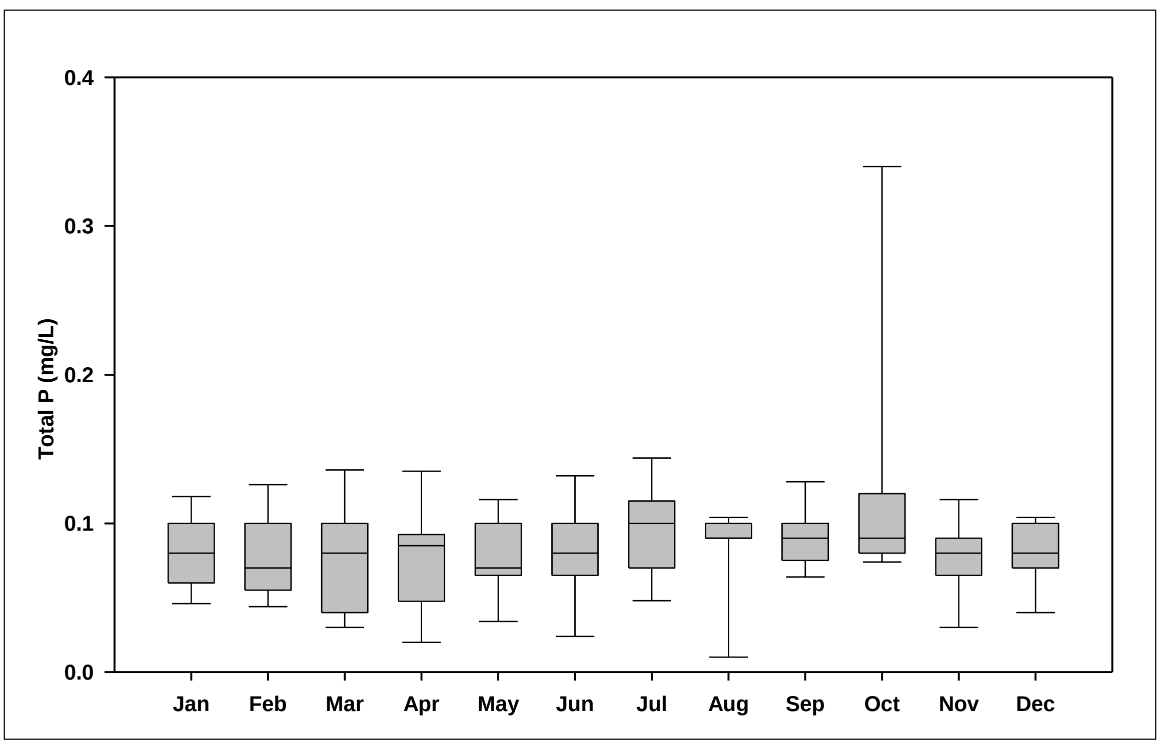


Figure 7-63. Monthly Variability in Total N at Devil Canyon



Note: Insufficient data to plot all percentiles.

Figure 7-64. Monthly Variability in Total P at Devil Canyon



Note: Insufficient data to plot all percentiles.

SUMMARY

- Nutrient concentrations increase considerably in the Sacramento River between West Sacramento and Hood, despite the inflow of the high quality American River, due mainly to the discharge from the Sacramento Regional Wastewater Treatment Plant. The median concentrations of total N (0.67 mg/L) and total P (0.08 mg/L) at Hood are statistically significantly higher than the median concentrations of total N (0.29 mg/L) and total P (0.05 mg/L) at West Sacramento. Total N and total P concentrations in the San Joaquin River are considerably higher and more variable than concentrations in the Sacramento River. The median total N concentration at Vernalis of 2 mg/L is the highest in the SWP system. The total P median is 0.16 mg/L, twice the level found at Hood.

- Nutrient concentrations in the NBA are higher than in the Sacramento River. The median total N concentration is 0.8 mg/L and the median total P concentration is 0.18 mg/L. The highest concentrations occur in the winter months due to the influence of runoff from the local Barker Slough watershed.

- Total N and total P concentrations in water exported from the Delta at Banks are sufficiently high to cause algal blooms in the aqueducts and downstream reservoirs.

- Nutrient concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct. Median total N concentrations are about 1.0 mg/L and median total P concentrations are about 0.1 mg/L throughout the system, with the exception of Castaic Outlet and Perris Outlet. The median concentrations are substantially lower at Castaic Outlet (total N is 0.67 mg/L and total P is 0.04 mg/L) and at Perris Outlet (total N is 0. 51 mg/L and total P is 0.03 mg/L). Algal uptake and subsequent settling of particulate matter may be responsible for the lower nutrient concentrations in the terminal reservoirs.

- There is a shorter period of record for nutrient data than for other water quality constituents such as organic carbon and EC, at many of the key locations. Time series graphs at each key location were visually inspected to determine if there are any discernible trends. Total P concentrations at DV Check 7 and along the California Aqueduct below San Luis Reservoir have been lower and less variable in the last five years. It's not clear if this is a trend or if it is related to hydrology since four of the last five years have been dry years.

- Comparison of nutrient concentrations in dry years and wet years does not produce a consistent pattern throughout the system, as shown in **Tables 7-4 and 7-5**. At many locations there are no differences between dry and wet years. At Hood and Vernalis, total P concentrations are not statistically different between dry years and wet years but total N concentrations are statistically significantly higher during dry years. This may be due to the greater influence of the Sacramento Regional Wastewater Treatment Plant at Hood and to agricultural drainage at Vernalis. At Pacheco, both total N and total P are statistically significantly lower in dry years. This is likely due to algal uptake and settling in the reservoir since samples are collected in the epilimnion of the reservoir more frequently during dry years when water levels are lower. The pattern at Castaic Lake is different with both total N and total P being statistically significantly higher in dry years. Check 41 and Devil Canyon show the same pattern of higher total N concentrations in dry years and lower total P concentrations in dry years. This may be related to non-Project inflows that occur more frequently in dry years.

Table 7-4. Comparison of Dry Year and Wet Year Total N Concentrations

Location	Median Total N (mg/L)		Total N Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	0.74	0.60	0.14	19	D>W
Vernalis	2.2	1.8	0.40	18	D>W
Banks	0.99	0.82	0.17	17	No
Barker Slough	0.82	0.84	-0.02	-2	No
DV Check 7	0.84	0.89	-0.05	-6	No
McCabe	NA	NA			
Pacheco	0.96	1.0	-0.04	-4	D<W
O'Neill Forebay Outlet	0.99	0.98	0.01	1	No
Check 21	1.0	1.1	-0.10	-10	No
Check 41	1.1	0.97	0.13	12	D>W
Castaic Outlet	0.7	0.55	0.15	21	D>W
Devil Canyon	1.0	0.88	0.12	12	D>W

Table 7-5. Comparison of Dry Year and Wet Year Total P Concentrations

Location	Median Total P (mg/L)		Total P Difference (mg/L)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	0.09	0.08	0.01	11	No
Vernalis	0.16	0.16	0	0	No
Banks	0.10	0.10	0	0	No
Barker Slough	0.18	0.20	0.02	11	No
DV Check 7	0.09	0.10	-0.01	-11	No
McCabe	NA	NA			
Pacheco	0.09	0.10	-0.01	-11	D<W
O'Neill Forebay Outlet	0.08	0.10	-0.02	-25	No
Check 21	0.10	0.09	-0.01	-10	No
Check 41	0.08	0.10	-0.02	-25	D<W
Castaic Outlet	0.04	0.03	0.01	25	D>W
Devil Canyon	0.08	0.09	-0.01	-13	D<W

- Seasonal trends also vary throughout the system. On the Sacramento River, total N and total P concentrations are highest during the wet season of November to February. There is a secondary peak in total N concentrations in June that is likely due to the greater influence of the Sacramento Regional Wastewater Treatment Plant during periods of low flow on the river. On the San Joaquin River nutrient levels are highest from January to March and lowest in May due to VAMP flows. The concentrations of both nutrients gradually increase during the summer months due to agricultural drainage being discharged to the river. Total N concentrations are highest at Banks from January through March, decline during the summer months and gradually increase during the fall months. The total P concentrations are high in the winter months, decrease during April, but then increase again in May and June before declining throughout the rest of the summer and fall. The seasonal pattern at a number of the check structures on the aqueduct is similar to the pattern at Banks except that peak levels of total P occur about one month later.

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Dodds, W.K., J.R. Jones, and E.B Welch. 1998. *Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types By Chlorophyll, Total Nitrogen, And Phosphorus.* Water Resources 32 (5) pp 1455-1462.

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CHAPTER 8 TASTE AND ODOR INCIDENTS AND ALGAL TOXINS

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CHAPTER 8 TASTE AND ODOR INCIDENTS AND ALGAL TOXINS

This chapter contains a discussion of two issues associated with algal growth in the Sacramento-San Joaquin Delta (Delta) and the State Water Project (SWP) aqueducts and reservoirs.

- Taste and odor (T&O) Incidents – T&O incidents are common in the Delta and SWP. Monitoring by the Department of Water Resources (DWR) has shown that the incidents are commonly associated with geosmin and 2-methylisoborneol (MIB). This section contains a discussion of the monitoring data.

- Algal Toxins – Blooms of *Microcystis aeruginosa* (*M. aeruginosa*) have occurred in the Delta in recent years. This section contains a discussion of the blooms and the monitoring for algal toxins.

TASTE AND ODOR INCIDENTS

WATER QUALITY CONCERN

Certain cyanobacteria and actinomycete bacteria produce chemical compounds that are not removed in conventional water treatment processes and are capable of causing unpleasant tastes and odors in drinking water. T&O incidents in the SWP are commonly associated with geosmin and MIB that are produced by certain algae and bacteria. The ability of individuals to detect these chemicals varies, but the general population can detect either compound at a concentration of about 10 ng/L (parts per trillion) and sensitive individuals can detect even lower concentrations.

This section contains an update on the monitoring for MIB and geosmin throughout the SWP. Two incidents that occurred in the last several years are worth noting: (1) the introduction of *Planktothrix perornata* (*P. perornata*) into the SWP system and its colonization of southern California reservoirs and (2) the first T&O issue in the North Bay Aqueduct (NBA).

Planktothrix perornata

P. perornata was introduced to the SWP system and colonized southern California reservoirs after the Jones Tract levee break in June 2004. A 300-foot section of levee on the west side of Upper Jones Tract, adjacent to Middle River, failed on June 3. After the levee was repaired, Delta water was impounded on Upper and Lower Jones tracts, creating a 12,000 acre lake that was 12 to 16 feet deep (DWR, 2009). DWR began pumping water off of the island in mid-July and it took until mid-December to dewater the island. During the summer and fall of 2004 the shallow, nutrient-rich lake on the island provided ideal conditions for algal growth.

DWR collected and analyzed samples for T&O compounds and for algal identification while water was being pumped off the island. MIB was measured at greater than 1,000 ng/L in samples collected from the island, and there was a corresponding peak of 70 ng/L at the Harvey O. Banks

Delta Pumping Plant (Banks). At the time, Jones Tract was contributing about 5 to 10 percent of the water at Banks. The organism responsible for the MIB production on Jones Tract was identified as a planktonic cyanobacterium, *P. perornata*. This cyanobacterium had previously been found in aquaculture ponds in Mississippi but had never been reported in California.

As a result of the levee break, this organism has been introduced into southern California reservoirs. In 2005, and most years subsequently, *P. perornata* has been a problem in Metropolitan Water District of Southern California's (MWDSC's) Lake Skinner (presumably receiving an inoculation of the algae in 2004). *P. perornata* was first detected in Lake Skinner in August 2005 at less than 1 organism/ml. MIB was detected at 20 ng/L at low cell densities of *P. perornata* (10 organisms/ml). *P. perornata* eventually reached 2,300 organisms/ml and MIB concentrations peaked at about 1,300 ng/L. MWDSC applied copper sulfate three times that summer to control the growth of *P. perornata*. This species has been present in Lake Skinner every summer since it was introduced. MWDSC applies copper sulfate to control *P. perornata* and other T&O producing cyanobacteria.

The introduction of a problematic alga into the SWP, and its colonization of downstream reservoirs, is a warning of the potential problems that can emanate from the Delta; in this case a T&O producing algae propagated from a flooded island. This incident has demonstrated a mechanism by which an action in the Delta can have far reaching impacts throughout the SWP and the water storage and conveyance facilities it touches.

North Bay Aqueduct

MIB and geosmin were not routinely monitored in the NBA until there was a severe T&O event in February 2009. The Barker Slough watershed drains to Campbell Lake, a privately-owned 37-acre lake, located approximately 1.5 miles upstream of the Barker Slough Pumping Plant. Runoff from the watershed is impounded in this lake until it is released by the property owner removing boards in the dam to lower the lake level or by overtopping of the dam. In mid-February 2009, a moderate 1-inch rainfall event occurred, causing Campbell Lake to fill up and spill on February 16. All of the NBA users began to receive customer complaints by February 18. During the next week over 800 customer complaints were received.

The Solano County Water Agency (SCWA) initiated monitoring for MIB and geosmin and phytoplankton enumeration as soon as it was notified of the problem. The phytoplankton enumeration, conducted by DWR's Division of Operations and Maintenance (O&M), showed that the likely T&O producer was *Aphanizomenon gracile (A. gracile)*. *A. gracile* was confirmed as the geosmin producer through cell isolation and culturing. This incident has led to routine monitoring of MIB and geosmin and the periodic treatment of Campbell Lake to control algal growth.

WATER QUALITY EVALUATION

Geosmin and MIB data for the SWP were provided by O&M staff and by MWDSC. Samples have been collected from SWP facilities and analyzed for the T&O producing compounds, MIB and geosmin, since 2000. Since that time, sampling has expanded from a few southern California locations to a more general monitoring program. This monitoring provides a direct measurement of T&O potential in drinking water supplies. O&M staff sends out weekly email reports to the SWP Contractors with the results from the monitoring conducted earlier that week. This provides the South Bay Aqueduct (SBA) Contractors with useful information on trends and it provides the remaining SWP Contractors with advanced notice of potential T&O problems.

Because human ability to detect tastes and odors varies, T&O thresholds are a somewhat subjective measurement. Also, agencies differ in their approaches to managing T&O, so there is no single number that reflects an acceptable level of MIB, nor of geosmin. While 10 ng/L is generally accepted as the concentration that begins to result in customer complaints, the SBA Contractors have developed the thresholds shown in **Table 8-1.**

Table 8-1. SBA Contractor Thresholds

SBA Contractor	MIB (ng/L)	Geosmin (ng/L)
Zone 7 Water Agency	9	4
ACWD	5	5
SCVWD	8	10

In southern California, the DWR Southern Field Division works in partnership with MWDSC to manage T&O problems and uses the magnitude and the rate of change in T&O compound concentrations in assessing the need for treatment to control algal producer growth. When early warning surveillance indicates problematic production of T&O compounds, a synoptic survey is performed to pinpoint the location of the producer for spot treatment in the case of attached algae in the east branch of the Governor Edmund G. Brown California Aqueduct (California Aqueduct) or the reservoirs or a general water column treatment for planktonic algae in the reservoirs. It is important to note that MIB and geosmin producing algae are a small minority of the cyanobacteria and further that problematic levels of these compounds can be produced by a species that is not a dominant algae in the system.

MIB and Geosmin Concentrations in the SWP

All available data are discussed in this chapter; however, the period of record varies from location to location.

The SWP Watershed

Although most of the nutrients responsible for algal blooms come from the Sacramento and San Joaquin rivers, the algal blooms responsible for T&O incidents occur in the Delta and the aqueducts and reservoirs of the SWP system. The rivers are not monitored for MIB and geosmin.

MIB and geosmin are monitored at Clifton Court Forebay (Clifton Court) and at Banks. Monitoring started at Clifton Court in 2003 and at Banks in 2001.

Figures 8-1 and **8-2** show that peak concentrations of MIB and geosmin occur each summer and levels exceeding 10 ng/L have been present for a number of weeks each summer in most years. Although still reaching problematic levels, the concentrations were lower during the summers of 2009 and 2010 at Clifton Court and from 2008 to 2010 at Banks.

MIB has been more problematic than geosmin. In August 2005 and 2008 MIB peaked at 78 ng/L in Clifton Court. The highest level measured at Banks was 74 ng/L in August 2004. Peak geosmin concentrations occurred in Clifton Court (29 ng/L) in July 2007 and at Banks (32 ng/L) in September 2006.

These data indicate that T&O issues can arise both in the Delta and within Clifton Court Forebay. Benthic cyanobacteria are the primary sources of T&O compounds in the Delta (Personal Communication, Jeff Janik, DWR). At times the concentration of MIB is higher at Banks than at Clifton Court. For example, in July 2003, MIB reached 31 ng/L at Banks but was present at only 7 ng/L at Clifton Court. DWR attributed the peaks to benthic cyanobacteria growing in Clifton Court Forebay. The increase in T&O concentration as water traverses Clifton Court Forebay indicates the forebay can also be a source of production, most often a result of benthic algal production. There is insufficient residence time for planktonic algae to greatly contribute to the increase in T&O concentration and treatments to control benthic cyanobacteria T&O production in Clifton Court have been successful.

The Jones Tract incident showed that when water is impounded on Delta islands planktonic algae can become problematic. An MIB peak of 55 ng/L occurred at Clifton Court in late July 2004 and a peak of 74 ng/L was found at Banks less than a week later. These peaks were attributed to pumping water off of Jones Tract after the levee break.

North Bay Aqueduct

As stated previously, MIB and geosmin were not routinely monitored in the NBA until there was a severe T&O event in February 2009. **Table 8-2** presents the results of the monitoring that was conducted in response to the T&O event. High levels of *A. gracile* were found at the Barker Slough Pumping Plant (Barker Slough) on February 18 and in Cordelia Forebay (Cordelia), the Napa Terminal Tank, and at the American Canyon Water Treatment Plant (WTP) the following week. Geosmin peaked at 330 ng/L at Cordelia and 393 ng/L at the Napa Terminal Tank.

Figure 8-1. MIB and Geosmin at Clifton Court

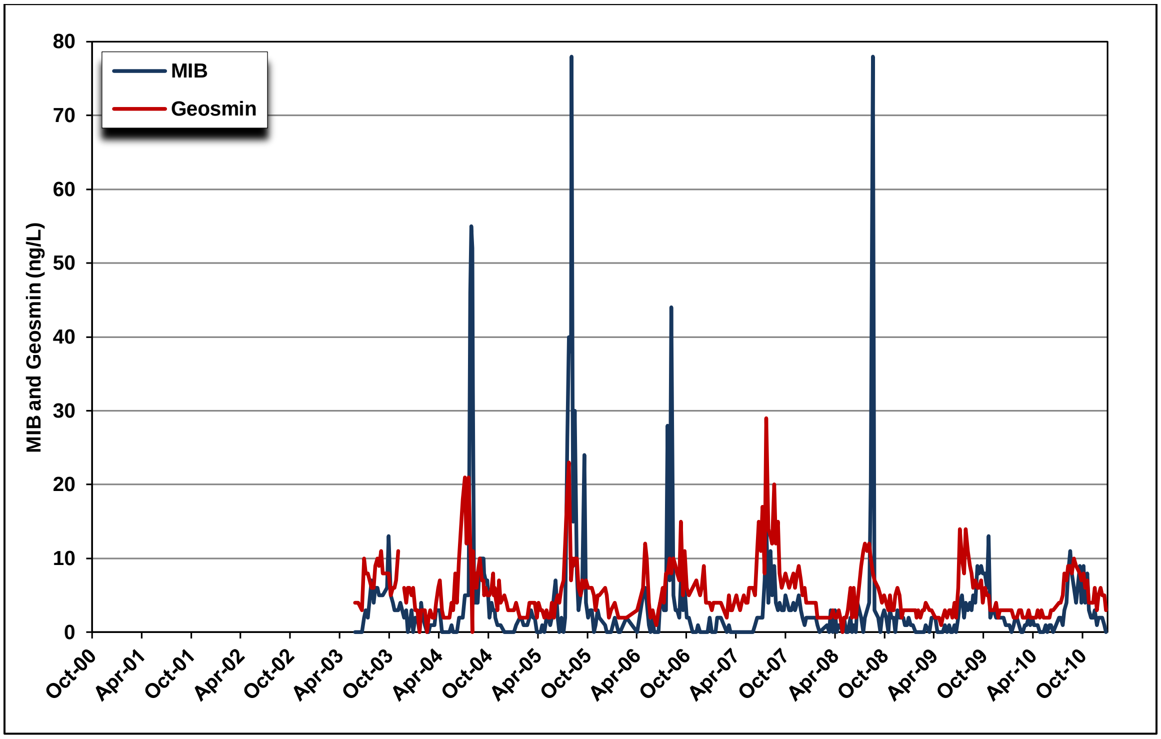


Figure 8-2. MIB and Geosmin at Banks

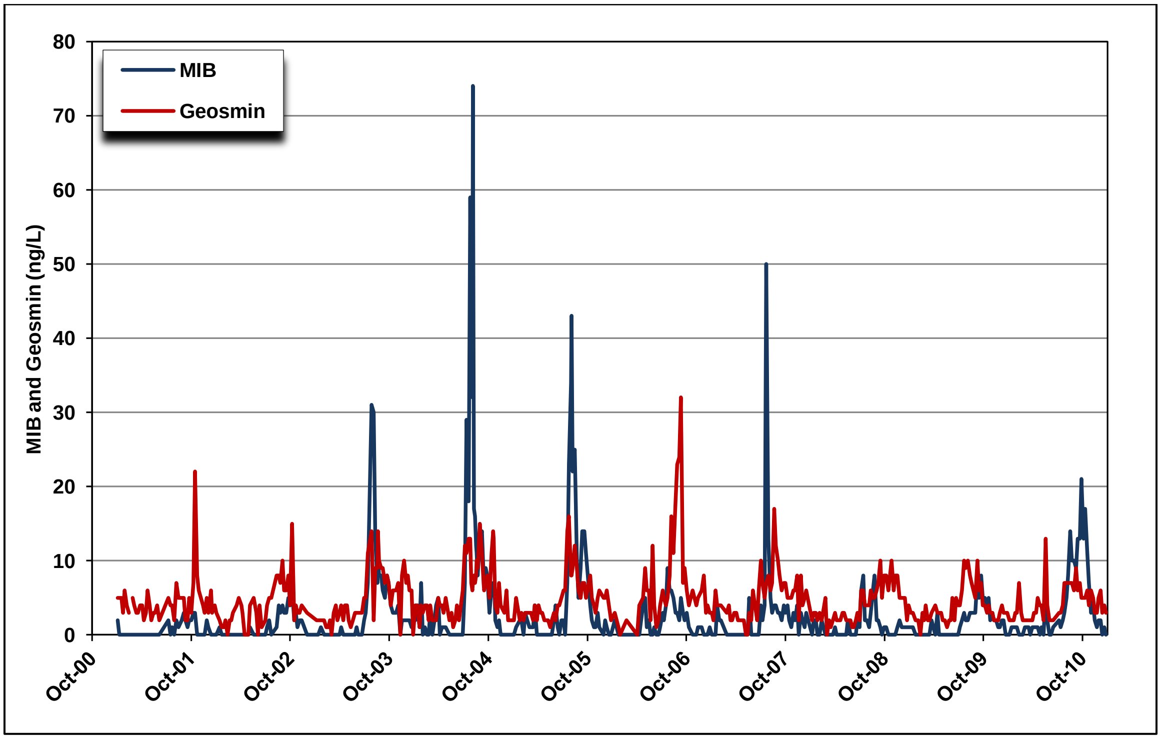


Table 8-2. T&O and Phytoplankton Monitoring Results for NBA T&O Event

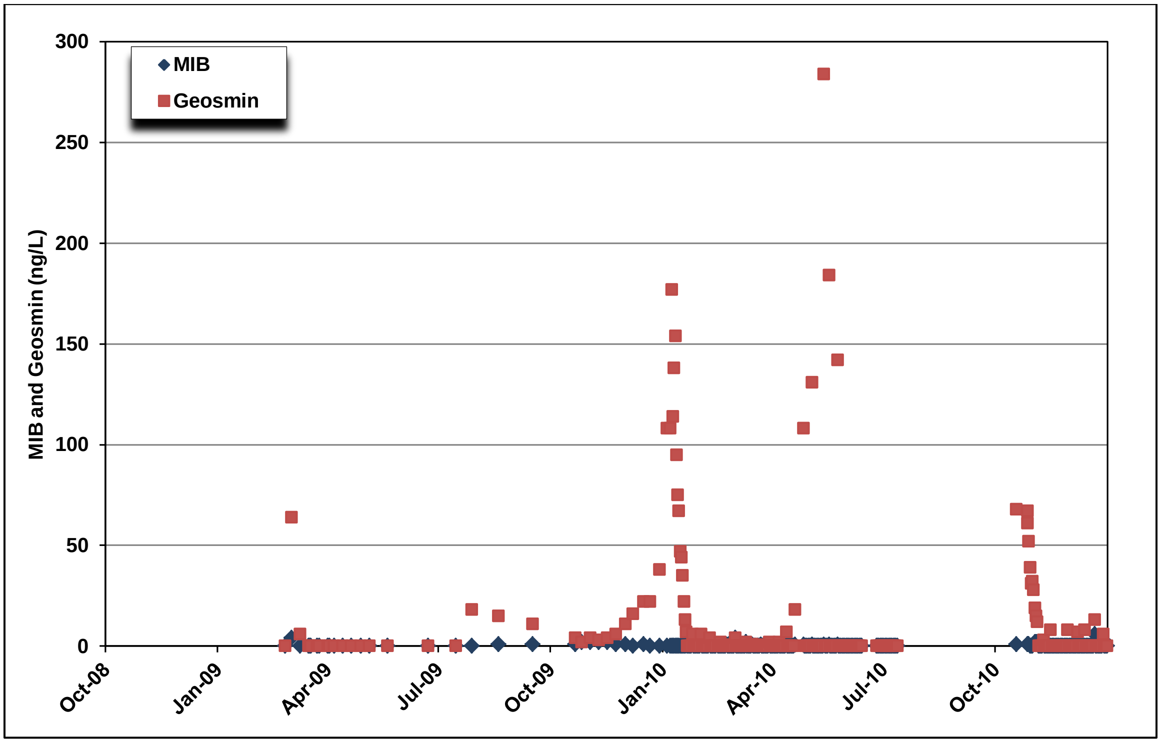
Date	Location	*A. gracile* (filaments/ml)	MIB (ng/L)	Geosmin (ng/L)
2/24/09	Campbell Lake	10	---	---
1/21/09	Barker Slough	0	---	---
2/18/09	Barker Slough	6,521	---	---
2/24/09	Barker Slough	42	---	---
2/25/09	Barker Slough	---	3	11
3/02/09	Barker Slough	4	5	12
3/09/09	Barker Slough	---	<1	1
3/02/09	Travis Surge Tank	4	6	74
3/17/09	Travis Surge Tank	---	2	15
3/23/09	Travis Surge Tank	---	2	1
2/25/09	Cordelia	1,521	<1	330
3/02/09	Cordelia	442	4	198
3/09/09	Cordelia	---	<1	90
4/06/09	Cordelia	---	1	2
2/25/09	Napa Terminal Tank	6,010	<1	393
3/02/09	Napa Terminal Tank	1,625	5	57
4/06/09	Napa Terminal Tank	---	2	2
2/26/09	American Canyon WTP	17,292	---	---

This event had severe operational and cost implications for the NBA users. None of the NBA users had the ability to effectively treat the high levels of geosmin so all users except Benicia stopped taking NBA water. Benicia was able to blend water with a local supply for about one week. The entire NBA system had to be drained to remove the geosmin-laden water. This took six weeks and resulted in the NBA Contractors losing a considerable amount of water that could have been pumped from the Delta during this time.

SCWA and DWR initiated a routine monitoring program in response to this event. Weekly samples are collected at Campbell Lake for T&O compounds and phytoplankton enumeration. Samples are also collected at Barker Slough when levels are high in Campbell Lake. **Figure 8-3** presents the Campbell Lake results for 2009 and 2010. Geosmin levels were exceedingly high in January 2010 (peak of 177 ng/L), May 2010 (peak of 284 ng/L) and October 2010 (peak of 68 ng/L). *A. gracile* was responsible for the high levels.

SCWA contracts with Clean Lakes, Inc. to apply PAK™27, a peroxide-based algaecide that is fast acting and effective with cyanobacteria. When MIB and geosmin concentrations exceed background levels in Campbell Lake and T&O producing phytoplankton begin to show exponential growth, a PAK™27 treatment is done. The combination of monitoring to detect problems and PAK™27 treatments has been effective since the NBA users have had no further customer complaints.

Figure 8-3. MIB and Geosmin in the NBA



South Bay Aqueduct

The high concentrations of nutrients, combined with shallow canal depth, abundant sunlight, and warm water temperatures during the spring, summer, and fall months leads to excessive algal growth in the SBA. This creates a number of treatment challenges for the SBA Contractors. A benthic diatom, *Melosira sp*., forms chains of cells that are sloughed off of the bottom when the chains become long and this leads to filter clogging problems at SBA water treatment plants. The population of *Melosira* generally increases from March to July and then again in the fall months (Personal Communication, Jeff Janik, DWR). The primary mechanism for controlling algal growth in the SBA is by application of copper sulfate. Copper sulfate is applied from March or April until September, depending upon water temperatures and algal conditions. To effectively deal with the filter clogging algae, while minimizing the use of copper sulfate, O&M uses a three-pronged approach of monitoring algal fluorescence, monitoring algal counts, and visual observations. Copper sulfate effectively reduces algal populations but the dead algae release T&O producing compounds. O&M provides notice to the SBA Contractors 48 hours in advance of a copper sulfate treatment is planned.

Figure 8-4 shows that the peak levels of MIB at Banks rapidly show up at Del Valle Check 7 (DV Check 7). The highest MIB concentration measured at DV Check 7 was 50 ng/L in July 2007 and the highest geosmin concentration was 17 ng/L in July 2005. There was a trend of increasing MIB concentrations between 2003 and 2007 but levels declined in the last three years. **Figure 8-5** shows that MIB and geosmin levels are generally below threshold levels in water released from Lake Del Valle at the Conservation Outlet (Conservation Outlet).

Figure 8-4. MIB and Geosmin at DV Check 7

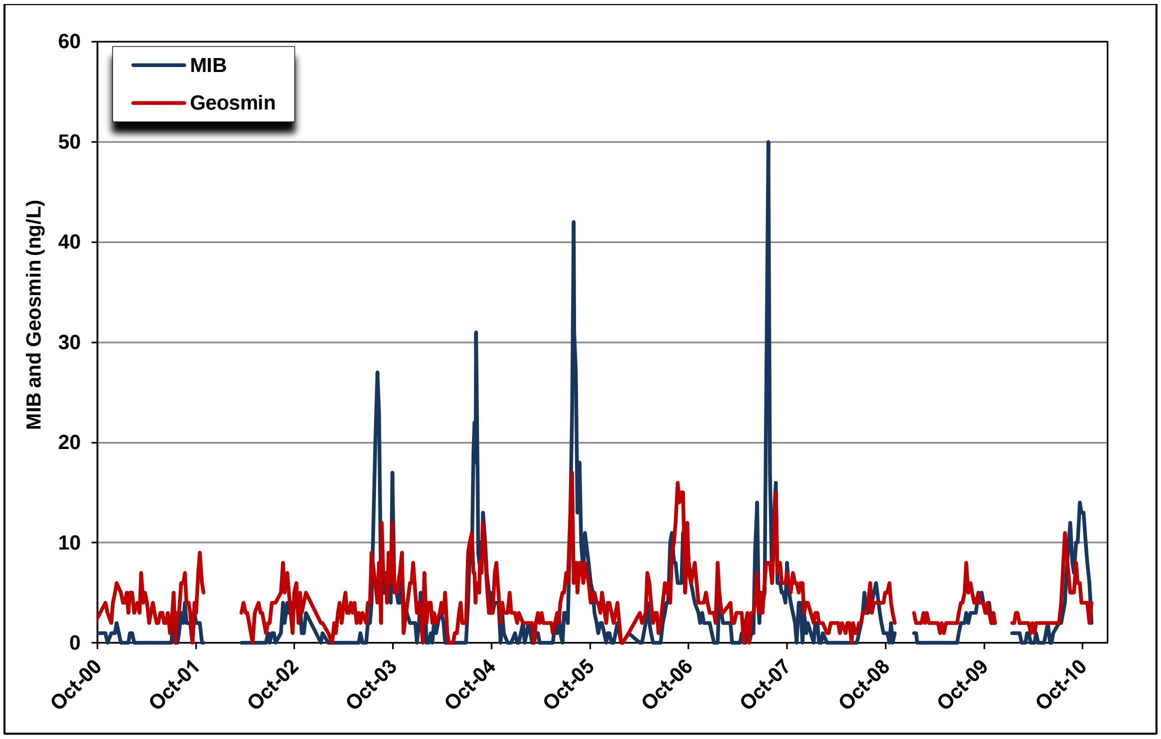
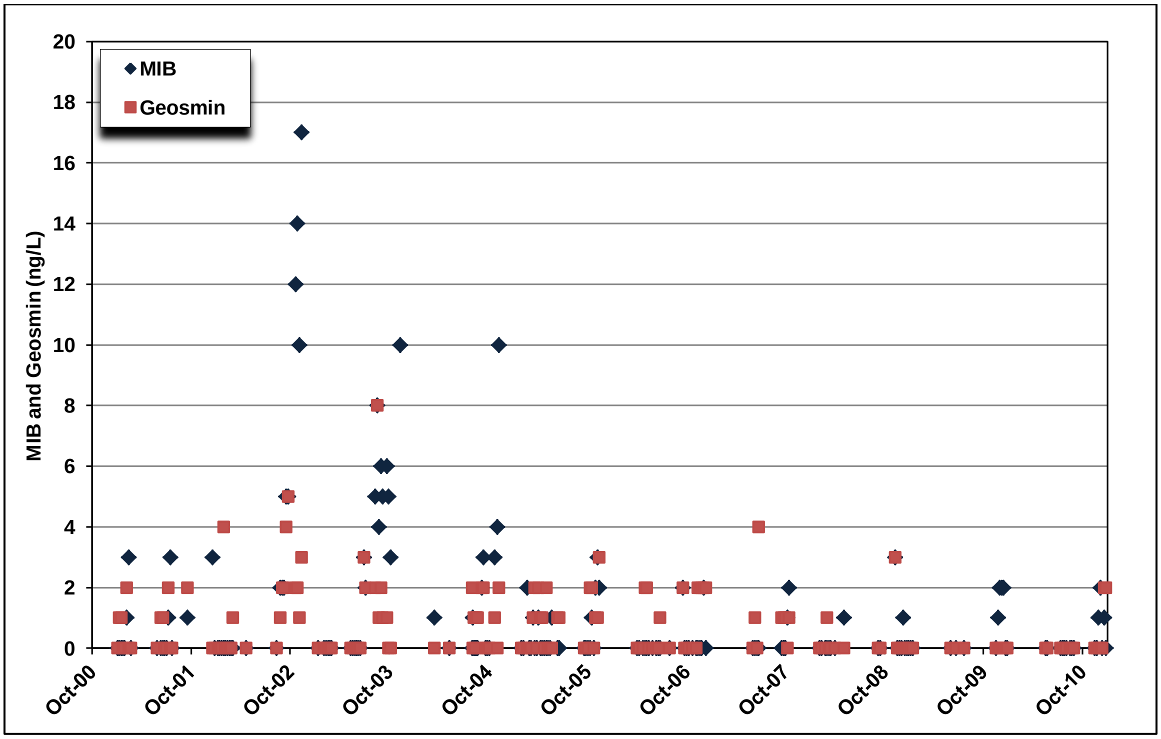


Figure 8-5. MIB and Geosmin at Conservation Outlet



California Aqueduct and Delta-Mendota Canal

Delta-Mendota Canal – MIB and geosmin data are not collected in the Delta Mendota Canal (DMC).

San Luis Reservoir – MIB and geosmin have been monitored since 2003 at the Pacheco Pumping Plant (Pacheco) on the west side of San Luis Reservoir. Monitoring began at the William R. Gianelli Pumping-Generating Plant (Gianelli) inlet/outlet tower on the east side of the reservoir in 2004. The Pacheco samples are collected at varying depths, depending upon the depth that water is being withdrawn from the reservoir. The Gianelli samples are collected at a depth of 3 meters. **Figure 8-6** presents the results for Pacheco and **Figure 8-7** presents the results for Gianelli. Geosmin was measured between 6 and 11 ng/L at Pacheco in August 2003. Other than the geosmin peak in 2003, all other measurements of MIB and geosmin have been less than 4 ng/L and many of the samples did not have detectable levels of either compound. The levels at Gianelli appear to be higher than the levels at Pacheco, although with the exception of one MIB sample, all of the measurements were 4 ng/L or lower.

Figure 8-6. MIB and Geosmin at Pacheco

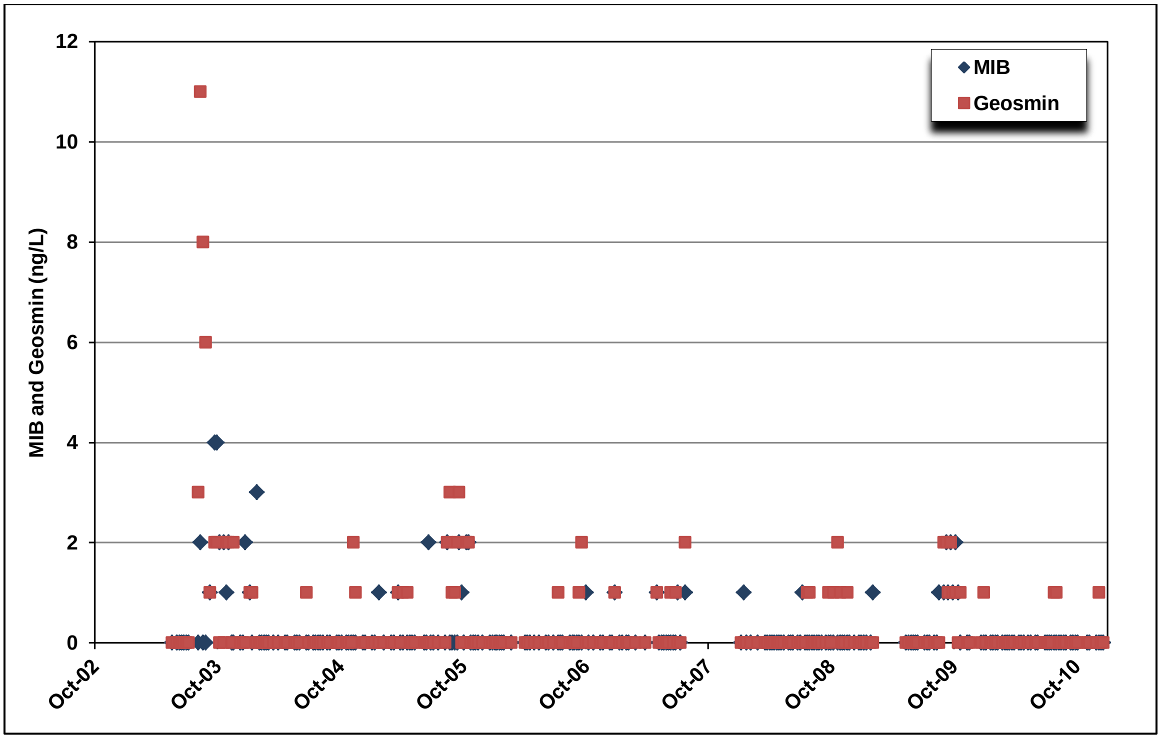
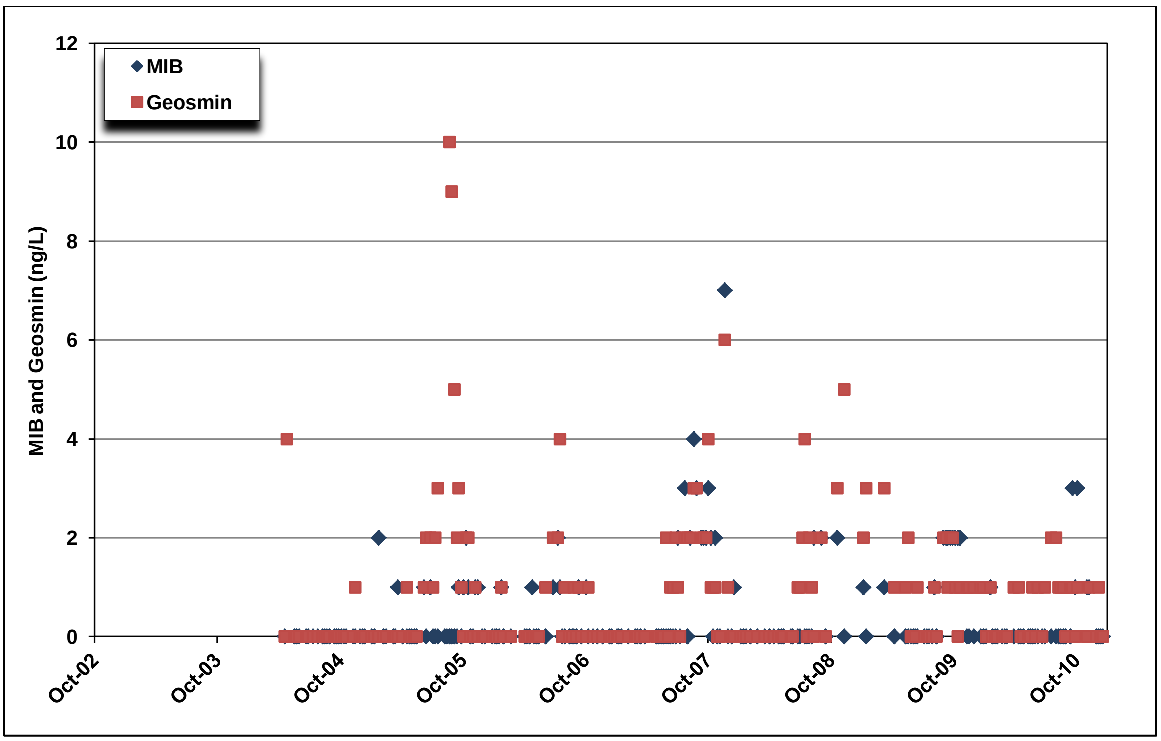


Figure 8-7. MIB and Geosmin at Gianelli



California Aqueduct Check Structures – Monitoring was initiated at O'Neill Forebay Outlet at the end of 2002. **Figure 8-8** shows that peak levels of MIB occur in August and generally occur five days to two weeks after the peaks occur at Banks, 68 miles upstream. The peak concentrations found at O'Neill Forebay Outlet (13 to 24 ng/L) are lower than those found at Banks, likely due to releases from San Luis Reservoir and to volatilization and breakdown of the compounds entering the aqueduct from the Delta. The levels of both MIB and geosmin were lower in recent years, showing the same trend that is seen at Banks.

Figure 8-9 shows that MIB peaks also occur in the summer at Check 41, although the highest concentration measured was 27 ng/L in December 2010. The summer peak levels are comparable to those detected at O'Neill Forebay Outlet. Geosmin concentrations are higher at Check 41 than at O'Neill Forebay Outlet. In late May 2003, a significant geosmin peak (50 ng/L) was detected at Check 41 that evidently did not originate in the Delta or Clifton Court Forebay. DWR attributed this peak to high levels of benthic algae growing in the aqueduct downstream of Check 28 (DWR SWP Water Quality Summary, June 19, 2003). These data indicate that MIB and geosmin generated in the Delta or in Clifton Court Forebay can persist at levels of concern to the bifurcation of the aqueduct and that benthic algae growing in the aqueduct are an additional source of T&O compounds.

Figure 8-10 shows that MIB and geosmin are both frequently present at high concentrations at Check 66 in the East Branch of the aqueduct. The maximum concentrations recorded were 130 ng/L of MIB in September 2001 and 240 ng/L of geosmin in May 2003. The MIB peak did not originate upstream as the levels found at Check 41 (**Figure 8-9**) were less than 5 ng/L at this time. The Check 66 geosmin peak was also likely generated in the East Branch. Although levels of geosmin up to 50 ng/L were found at Check 41 in May 2003, it is unlikely that a peak of over 200 ng/L was missed because Check 41 samples were being analyzed every two to three days at that time. DWR attributed the high levels of geosmin and moderate levels of MIB to benthic algae growing in the East Branch. Peaks of MIB in July 2004 and 2005 also appear to have been generated in the East Branch. The MIB peaks have been lower in the last several years but geosmin has frequently been high. In December 2010 geosmin was found at 106 ng/L; an unusually high concentration for the winter.

Figure 8-8. MIB and Geosmin at O'Neill Forebay Outlet

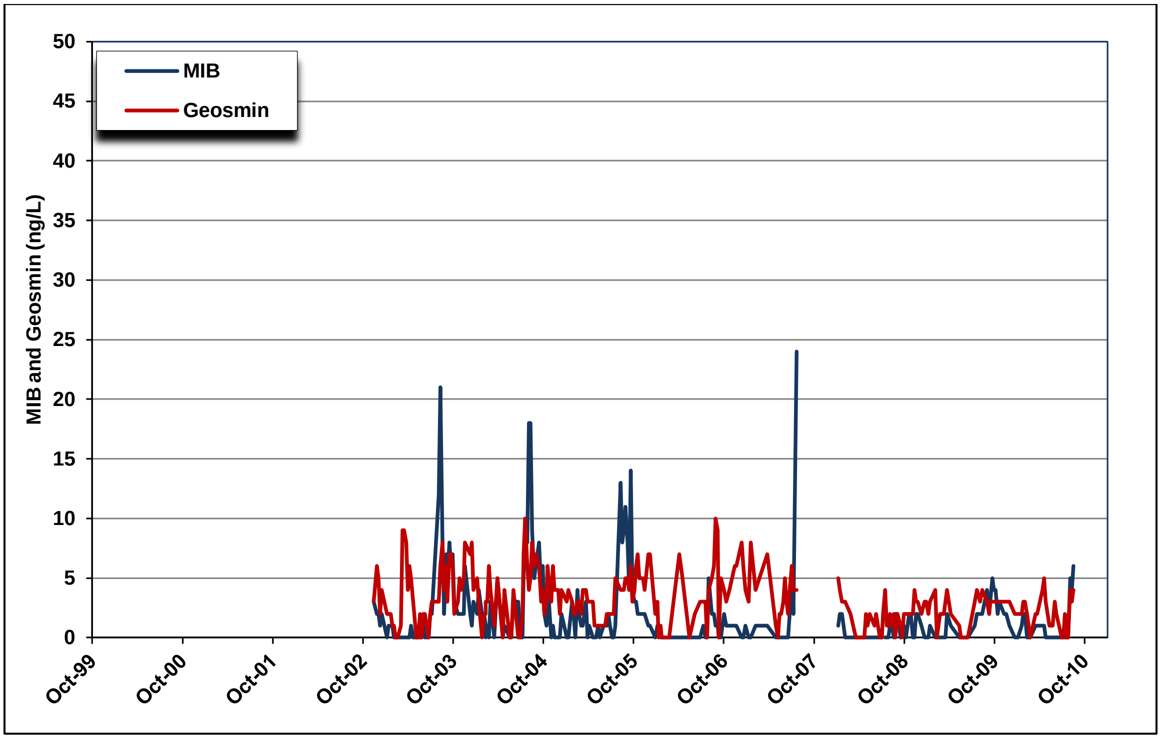


Figure 8-9. MIB and Geosmin at Check 41

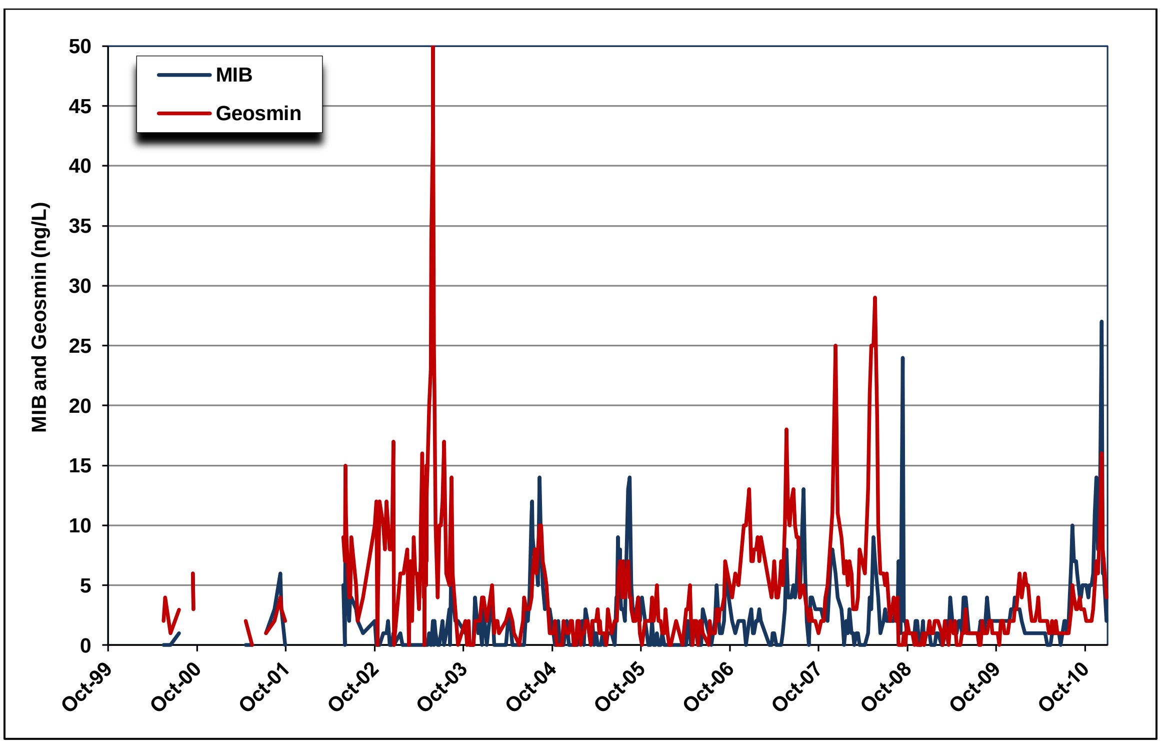
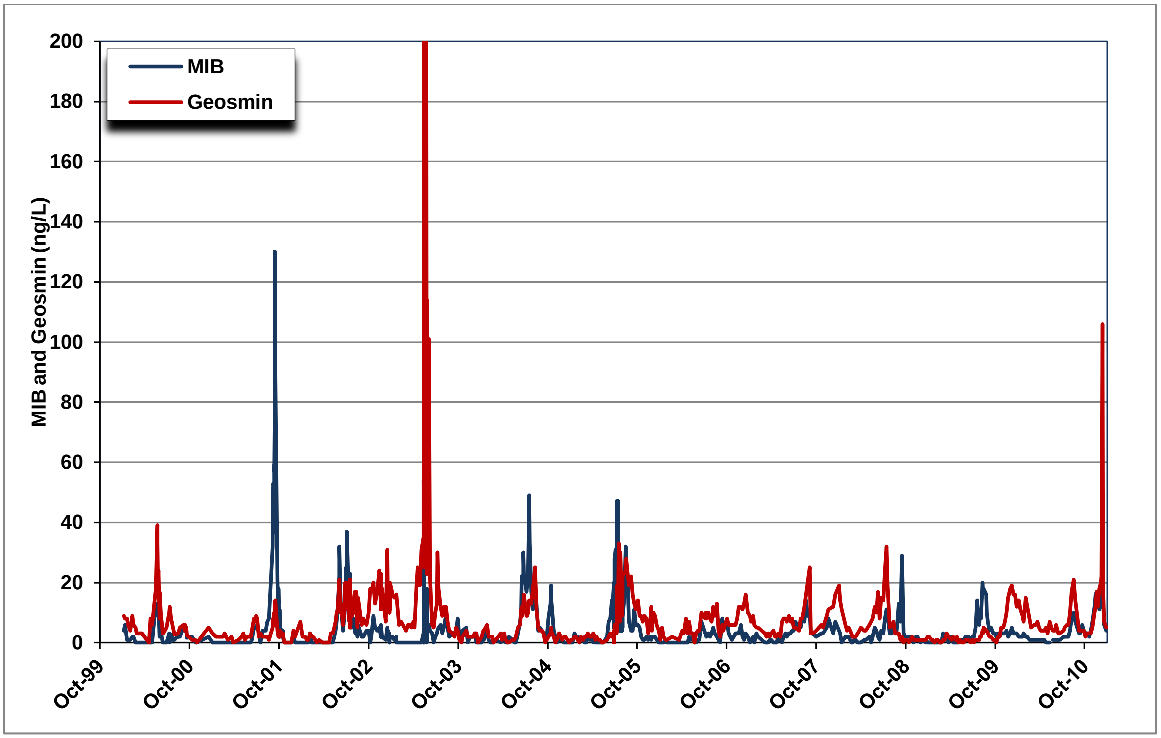


Figure 8-10. MIB and Geosmin at Check 66



Castaic Lake – MIB and geosmin are measured at a number of locations and at a number of depths in Castaic Lake. The data used in this analysis are collected near the outlet tower. The MIB and geosmin data are displayed differently than at the other locations due to the large difference between MIB and geosmin concentrations. **Figure 8-11** shows that MIB levels at and near the surface typically range from not detected to 2 ng/L with a few peaks. Data were collected from the surface from 1998 to the spring of 2005 and from a depth of one meter after that. The two data sets are combined. The main T&O problem in Castaic Lake is geosmin. Castaic Lake has annual geosmin spikes that occur in June or July and often last for several weeks, as shown in **Figure 8-12**. In June 2004, geosmin was measured as high as 830 ng/L. Since then, the summer peak levels have declined gradually. In 2010 there were no samples that contained MIB in excess of the 10 ng/L threshold that commonly results in customer complaints. The June 2004 peak is examined in more detail in **Figure 8-13**. MIB levels were found throughout the depth of the reservoir with a concentration of 41 ng/L at a depth of 36 meters.

Figure 8-11. MIB in Castaic Lake at the Surface

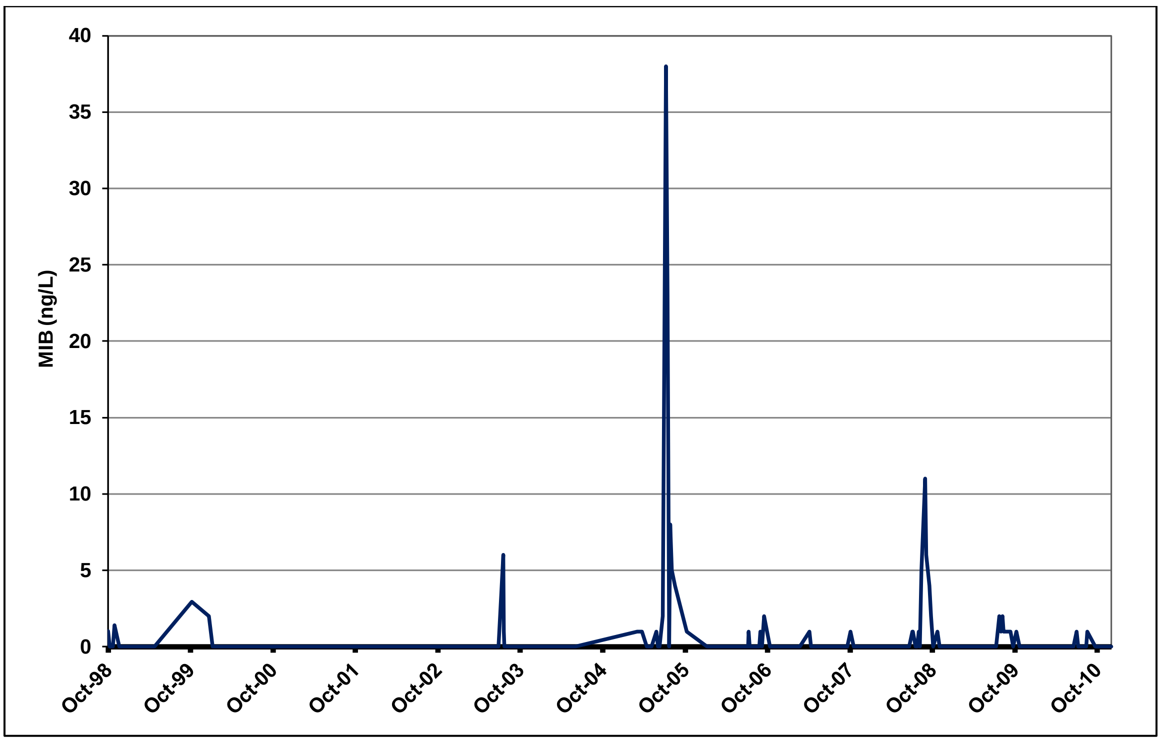


Figure 8-12. Geosmin in Castaic Lake at the Surface

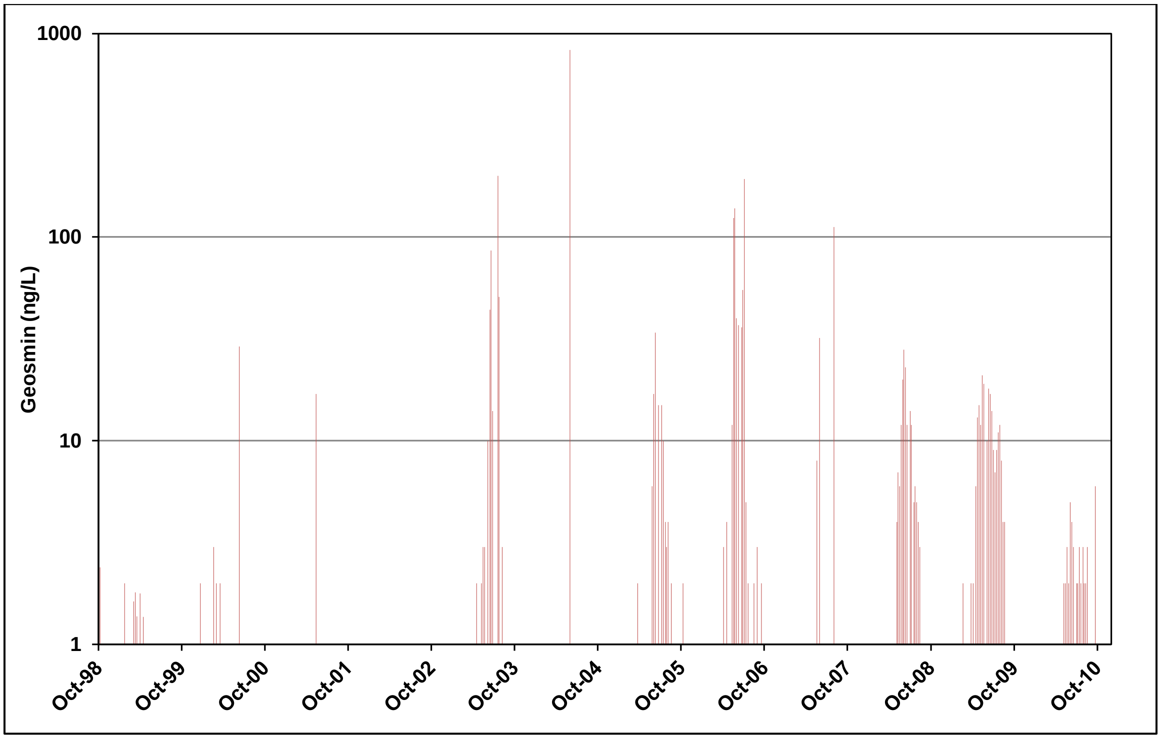
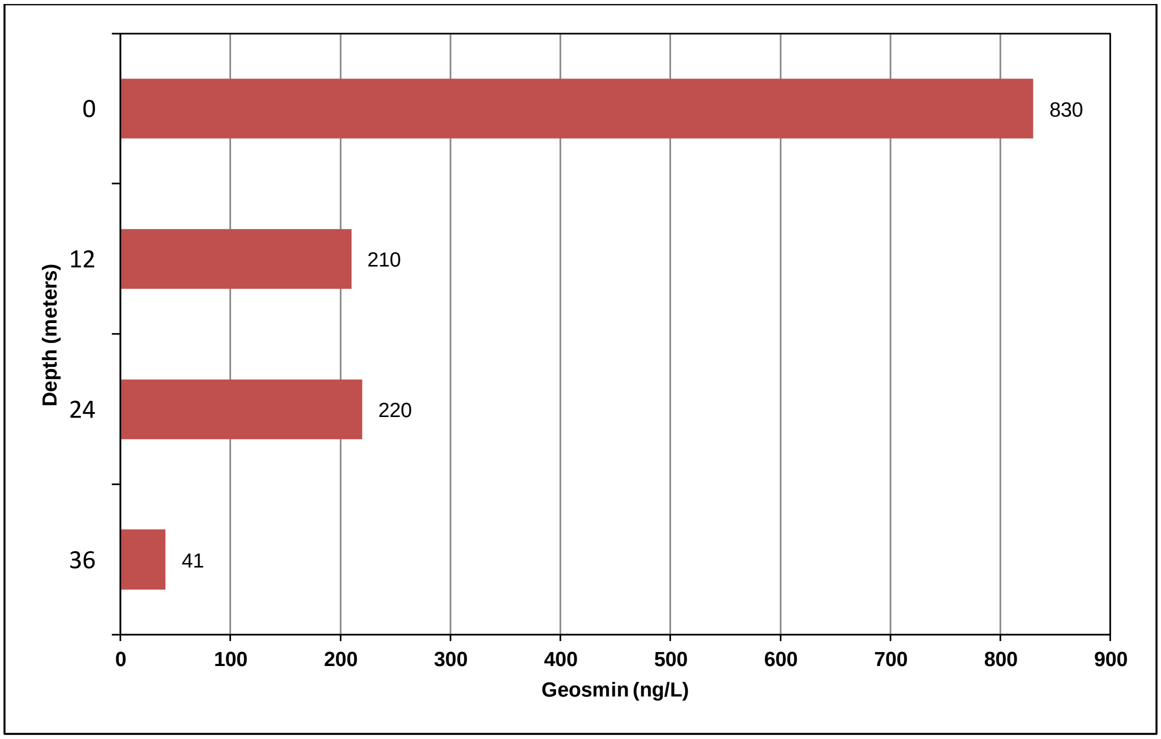
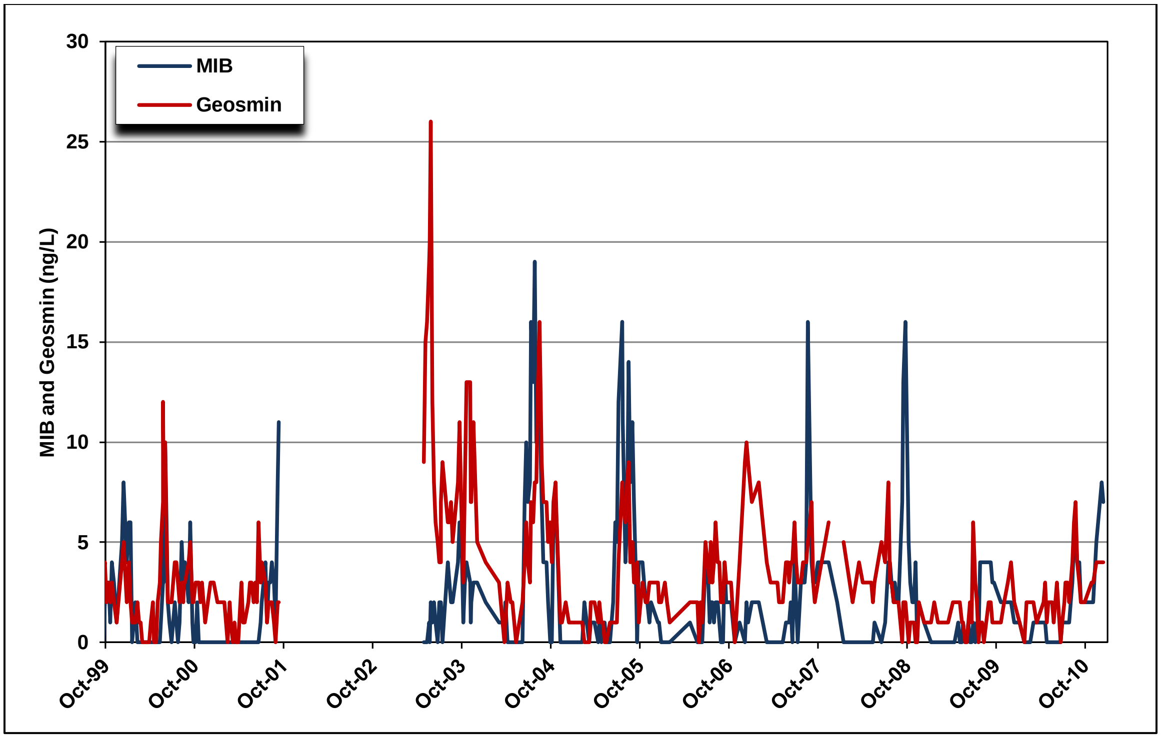


Figure 8-13. Geosmin Distribution During Algal Bloom



Silverwood Lake – **Figure 8-14** depicts the results of monitoring at Silverwood Outlet. MIB and geosmin concentrations show the same general pattern as at Check 66; however the summer peak concentrations at Check 66 at Silverwood Outlet a few days later at much lower concentrations. The peak MIB concentration of 19 ng/L occurred in July 2004 and the peak geosmin concentration of 26 ng/L occurred in May 2003. The geosmin concentrations have declined in recent years and haven't exceeded 10 ng/L since August 2004. These data indicate that the source of MIB and geosmin is the California Aqueduct rather than algal growth in the lake.

Figure 8-14. MIB and Geosmin at Silverwood Outlet



SUMMARY

- Monitoring of MIB and geosmin was initiated at a number of locations in the SWP between 2001 and 2005. Monitoring was initiated on the NBA in 2009. The samples are quickly analyzed and email reports are sent to the SWP Contractors alerting them to potential T&O problems.

- The NBA Contractors experienced a severe T&O episode in February 2009 that resulted in numerous customer complaints when geosmin concentrations quickly increased to over 300 ng/L. The likely T&O producer was *A. gracile*. The NBA had to be shut down for over six weeks, resulting in a significant loss of Delta water for the NBA users. SCWA works with DWR to monitor T&O compounds and to periodically treat Campbell Lake. The combination of monitoring to detect problems and treatments has been effective since the NBA users have had no further customer complaints.

- MIB and geosmin peaks in excess of 10 ng/L have occurred at Clifton Court every summer since monitoring was initiated in 2003. MIB concentrations have exceeded 10 ng/L every year and geosmin concentrations have exceeded 10 ng/L in five of the ten years that monitoring has been conducted at Banks. Concentrations exceeding 10 ng/L can be detected by most people and result in customer complaints to drinking water providers. The highest MIB concentration measured at Banks was 74 ng/L in August 2004 and the highest geosmin concentration was 32 ng/L in September 2006. Benthic cyanobacteria are responsible for most of the T&O production in the Delta and Clifton Court.

- The peak levels of MIB and geosmin at Banks are quickly transported to the SBA. MIB and geosmin concentrations at DV Check 7 exceeded 10 ng/L every summer between 2003 and 2007 and again in 2010. The highest MIB concentration measured at DV Check 7 was 50 ng/L in July 2007 and the highest geosmin concentration was 17 ng/L in July 2005. There was a trend of increasing MIB concentrations between 2003 and 2007 but levels declined in the last three years.

- MIB from the Delta is transported down the California Aqueduct to O'Neill Forebay Outlet but the concentrations decrease with distance down the aqueduct. Peak levels measured at O'Neill Forebay Outlet are 21 ng/L of MIB and 10 ng/L of geosmin.

- San Luis Reservoir has low levels of MIB and geosmin (usually 4 ng/L or lower) at Pacheco and at the Inlet/Outlet tower on the east side of the reservoir.

- MIB and geosmin are generated in the aqueduct downstream from San Luis Reservoir. Peak levels of 27 ng/L of MIB and 50 ng/L of geosmin have been found at Check 41. In the East Branch at Check 66, peak levels have reached 130 ng/L for MIB and 260 ng/L for geosmin. MIB and geosmin concentrations have exceeded 10 ng/L every summer since monitoring was initiated at Check 66 in 1999.

- Castaic Lake has high levels of geosmin every summer (up to 830 ng/L) and occasional MIB peaks greater than 10 ng/L. Geosmin concentrations routinely exceed 10 ng/L and occasionally exceed 100 ng/L in the surface waters. High levels of geosmin can extend throughout the water column during an algal bloom. In Castaic the great depth of the outlet generally ameliorates the T&O produced in the surface waters.

- Silverwood Lake has peaks of both compounds that exceed 10 ng/L but do not reach the high levels found in Castaic Lake. However, since Silverwood Lake is fully mixed, the downstream SWP Contractors receive whatever levels of MIB and geosmin are present in Silverwood Lake water. It is critical to control T&O producing algae in the East Branch before Silverwood is loaded with the T&O compounds.

ALGAL TOXINS

WATER QUALITY CONCERN

Some blue-green algae (more correctly known as cyanobacteria), one of which is *M. aeruginosa*, are capable of emitting potent toxins when cells die and release their contents. Blooms of *M. aeruginosa* have occurred in the Delta in recent years. Some blooms of *M. aeruginosa* produce microcystins, which are liver toxins. If digested, it can adversely affect humans, wildlife, livestock, copepods, and various fish species. There are currently no regulatory limits for algal toxins in drinking water supplies. Cyanobacteria and their toxins are on the federal Drinking Water Contaminant Candidate List, indicating they may be regulated in the future. The World Health Organization (WHO) has an advisory level of 1 µg/L for microcsytin-LR, the most commonly found of the microcystins.

DELTA BLOOMS

M. aeruginosa was first detected in the Delta in the eastern Stockton Ship Channel on September 27, 1999. This cyanobacteria has bloomed every year following its initial detection during the late summer and early fall throughout the central and southern Delta. In the Delta, the bloom is characterized by green, irregularly shaped colonies, approximately one-eighth to two inches in diameter that float on or near the water surface (Waller et al., 2005). The Interagency Ecological Program has conducted monitoring to evaluate the ecological impacts of the blooms on the Delta. The information related to the presence of *M. aeruginosa* and microcystins in summarized in the following bullet points.

- 2000 – *M. aeruginosa* was detected in mid July 2000, during routine compliance monitoring. A special study, conducted on July 27, included 15 stations throughout the central and southern Delta. Phytoplankton analysis confirmed *M. aeruginosa* presence in all samples collected. The highest concentrations were observed in Old River between Sand Mound Slough and Rock Slough, however *M. aeruginosa* was also found in the Stockton Ship Channel, the juncture of the San Joaquin and Mokelumne rivers, the Sacramento River at Collinsville, and in Benicia Harbor (Waller, 2000). Water samples were not analyzed for microcystins but concentrated samples of algae were analyzed. Concentrations of combined microcystins type LR and RR totaled 1.8 µg/L exceeding the 1 µg/L WHO guideline at Mound Slough near Franks Tract (Lehman, 2003).

- 2002 – *M. aeruginosa* blooms occurred in the southern regions of the Delta in Middle and Old rivers, and the lower San Joaquin River westward to Antioch (Lehman, 2003).

- 2003 – *M. aeruginosa* was observed in the Delta on September 12, 2003, which led to a special study conducted on October 15, 2003 at 14 stations selected to represent different habitat types (Lehman et al., 2005). *M. aeruginosa* and microcystins were present at all stations. High phytoplankton biomass and microcystin concentrations in the San Joaquin and Old rivers were accompanied by a combination of higher water temperature, lower salinity, and higher water transparency than the Sacramento River and Suisun Bay (Lehman et al., 2005).

- 2004 – *M. aeruginosa* was sampled between July 13 and November 3, 2004, in the Delta at 9 stations, ranging from freshwater to brackish water regions that represent different habitat types. *M. aeruginosa* was found throughout the central Delta and lower Sacramento River, with the highest cell densities in the San Joaquin River and Old River. *M. aeruginosa* cell density, chlorophyll a concentrations, and total microcystin concentrations peaked during the summer and fall between August and September.

- 2005 – *M. aeruginosa* was sampled between August 1 and September 30, 2005 at 10 stations throughout the freshwater to brackish water reaches of the Delta. *M. aeruginosa* was found throughout the Delta and the highest cell densities were once again in the San Joaquin and Old rivers. Microcystins were present in algal tissue at all locations and the highest levels were also found in the San Joaquin and Old rivers (Lehman et al., 2010).

- 2008 – The *M. aeruginosa* bloom arrived late during August 2008 instead of June or July as in previous years. However, the bloom reach relatively higher levels in August and September compared with previous years (Lehman, 2009).

SWP MONITORING

O&M initiated cyanotoxin monitoring in 2006 at Barker Slough, the inlet to Clifton Court, Pacheco, and O'Neill Forebay Outlet. The program was expanded to include other locations, as shown in **Table 8-3**. Samples were initially analyzed by the California Animal Health and Food Safety Laboratory at UC Davis for the four most commonly found microcystins (LR, LA, YR, and RR). The program was expanded in 2008 to include anatoxin-a. Anatoxin-a has not been detected in any of the samples from the Delta or SWP. Microcystin-LR was detected at all of the locations that were monitored in 2007, except Barker Slough. It was initially detected in mid-June in Clifton Court and then detected at Banks, Pacheco, and O'Neill Forebay Outlet in July. It persisted throughout the summer. Although it was detected, it was below the reportable limit of 1 µg/L so the concentrations could not be quantified. Microcystin was not detected in 2008 or 2010.

Table 8-3. Summary of SWP Cyanotoxin Monitoring Results

Location	No. of Samples	No. of Detections	Years Monitoring Conducted
Barker Slough	17	0	2006, 2007, 2008, 2010
Clifton Court Inlet	48	5	2006, 2007, 2008, 2010
Clifton Court Outlet	5	1	2007
Banks	26	5	2007, 2008, 2010
Lake Del Valle	5	0	2008, 2010
Pacheco	39	3	2006, 2007, 2008, 2010
Gianelli	2	0	2010
O'Neill Forebay Outlet	39	0	2006, 2007, 2008, 2010

SUMMARY

- *M. aeruginosa* blooms have occurred routinely in the summer months in the Delta since 1999. While blooms are found throughout the Delta, the highest cell densities are routinely found in the south Delta in the Old River and the Middle River.

- DWR conducted cyanotoxin monitoring at various locations in the SWP for four years. In 2007 microcystin-LR was detected at all locations that were monitored, except Barker Slough. It was below the reportable limit of 1 µg/L.

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Personal Communication

Janik, Jeff, California Department of Water Resources, Division of Operations and Maintenance. Meeting held on Sep 29, 2011.

CHAPTER 9 TURBIDITY

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FIGURES

TABLES

CHAPTER 9 TURBIDITY

WATER QUALITY CONCERN

Turbidity in drinking water supplies has both beneficial and undesirable aspects. The water supplies of the State Water Project (SWP) generally contain ample nutrient concentrations to permit growths of algae and cyanobacteria to levels that can obstruct water treatment facilities and cause taste and odor (T&O) problems in treated drinking water. Turbidity can limit these growths by reducing light penetration in the water column. In water treatment, the presence of some turbidity can be helpful in attaining efficient flocculation and sedimentation. The California Department of Public Health (CDPH) has established a treated water turbidity standard of 0.3 NTU that must be achieved 95 percent of the time and turbidity can never exceed 1.0 NTU. Rapid increases in source water turbidity can create challenges with adequately clarifying and disinfecting the water, and can increase expenses for treatment chemicals and sludge handling. Turbidity can also harbor and be an indicator of increased microbial contamination. In parts of the SWP where water velocity tends to be slower, such as in reservoirs and forebays to pumping plants, turbidity can settle, forming sediment beds. These sediment beds can reduce the capacity of the system, and encourage growths of cyanobacteria responsible for T&O in drinking water. Sediment can also increase the growth of pondweed, leading to the need to apply herbicides.

WATER QUALITY EVALUATION

TURBIDITY LEVELS IN THE SWP

Turbidity data are analyzed in this section to examine changes in turbidity as the water travels through the SWP system and to determine if there are seasonal or temporal trends. the Department of Water Resources (DWR's) Municipal Water Quality Investigations (MWQI) Program and the Division of Operations and Maintenance (O&M) SWP monitoring program through December 2010 were obtained for a number of locations along the SWP. Both discrete samples and real-time data are included in this analysis. Data are presented in summary form for all locations and analyzed in more detail for a number of key locations. **Table 9-1** presents the period of record for the data included in this analysis.

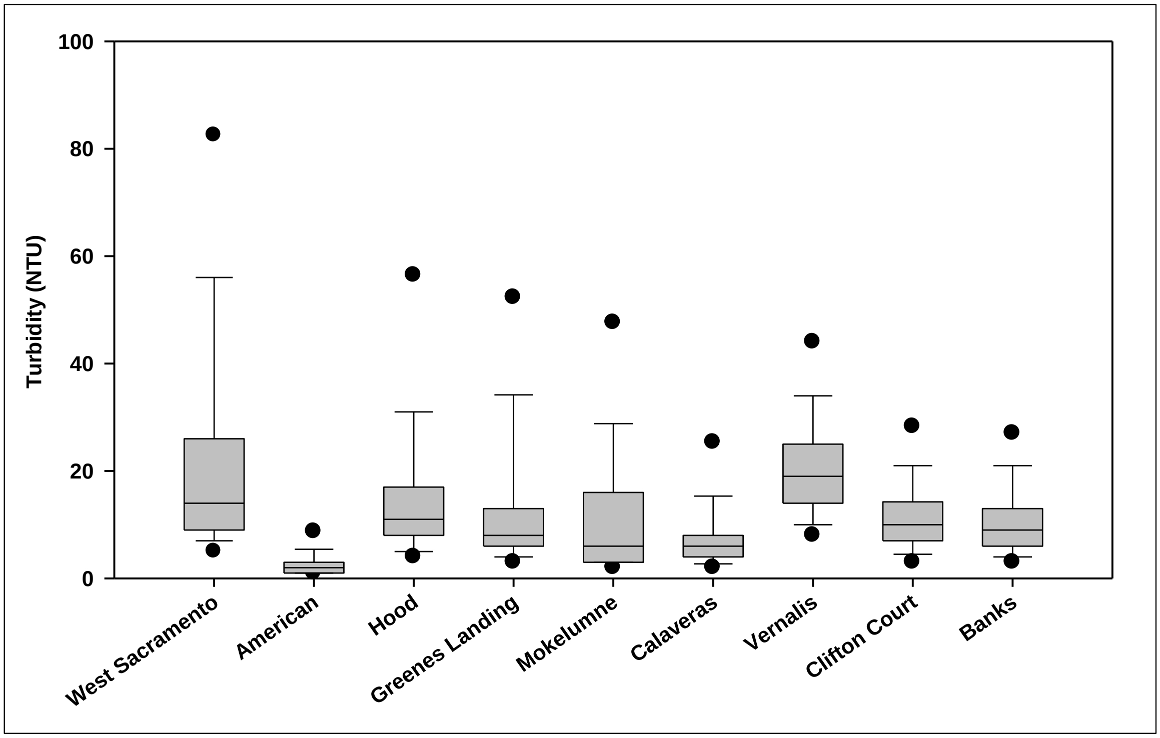
Table 9-1. Turbidity Data

Location	Grab Samples			Real-time	
	No. of Samples	Start Date	End Date	Start Date	End Date
West Sacramento	269	Apr 1994	Dec 2010		
American	317	Jul 1983	Dec 2010		
Hood	543	Mar 1982	Dec 2010		
Greenes Landing	207	Jul 1983	Dec 1997		
Mokelumne	43	Dec 2008	Dec 2010		
Calaveras	36	Dec 2008	Nov 2010		
Vernalis	826	Mar 1982	Dec 2010		
Clifton Court	314	Jul 1983	Dec 2010	Mar 1988	Dec 2010
Banks	425	Mar 1982	Dec 2010	Jun 1988	Dec 2010
Barker Slough	403	Sep 1988	Dec 2010	Jun 1989	Dec 2010
Cordelia	34	Aug 2000	Nov 2010	Mar 1993	Dec 2010
DV Check 7	145	Dec 1997	Oct 2010	Jun 1994	Dec 2010
Terminal Tank	65	Feb 1998	Nov 2010	Nov 1992	Aug 2002
McCabe	181	Dec 1997	Dec 2010		
Pacheco	120	Apr 2000	Dec 2010	Jul 1989	Dec 2010
O’Neill Forebay Outlet	186	Aug 1990	Dec 2010	Jul 1991	Dec 2010
Check 21	196	Dec 1997	Dec 2010	Jun 1990	Dec 2010
Check 29	197	May 1998	Dec 2010	Jan 1990	Dec 2010
Check 41	218	Dec 1997	Dec 2010	Jun 1993	Dec 2010
Castaic Outlet	66	Feb 1998	Nov 2010	Jan 2000	Dec 2010
Silverwood	62	Feb 1998	Nov 2010		
Devil Canyon Headworks	170	Jun 2001	Dec 2010	Oct 1995	Mar 2010
Devil Canyon Afterbay	44	Dec 1997	May 2001	Feb 2006	Dec 2010
Perris Outlet	93	Feb 1998	Nov 2010		

The SWP Watershed

Figure 9-1 presents the turbidity data for the tributaries to the Sacramento-San Joaquin Delta (Delta) and for Clifton Court Forebay (Clifton Court) and the Harvey O. Banks Delta Pumping Plant (Banks). Turbidity levels are considerably lower in the Sacramento River at Hood (Hood) than in the San Joaquin River at Vernalis (Vernalis). Turbidity data have been collected twice a month from the Mokelumne and Calaveras rivers since December 2008. The limited data show that the turbidity levels are lower than the Hood levels in both rivers.

Figure 9-1. Turbidity Levels in the SWP Watershed



Hood – **Figure 9-2** shows all available grab sample turbidity data at Hood. The levels range from 2 to 174 NTU during the period of record with a median of 11 NTU.

- Spatial Trends – **Figure 9-1** presents all available data for the Sacramento River at West Sacramento (West Sacramento), the American River, and Hood. The period of record varies between the three stations so the data collected during the 1998 to 2010 period at all three locations were examined to determine if there are spatial trends. The median concentrations during the 1998 to 2010 period are identical to those shown in **Figure 9-1**. The American median turbidity level of 2 NTU is statistically significantly lower than the 14 NTU median at West Sacramento (Mann-Whitney, p=0.0000) and the 11 NTU median at Hood (Mann-Whitney, p=0.0000). The median level at Hood is statistically significantly lower than the median at West Sacramento (Mann-Whitney, p=0.0000). This demonstrates the impact that the American River inflow has on the Sacramento River.

- Long-Term Trends – **Figure 9-2** does not show any discernible long-term trends.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median turbidity level of 10 NTU during dry years is statistically significantly lower than the 12 NTU median during wet years (Mann-Whitney, p=0.0001).

- Seasonal Trends – On the Sacramento River, turbidity is directly related to flow in the river, as shown in **Figure 9-3**. When flows increase, turbidity increases (maximum measured value of 174 NTU). When flows drop below about 20,000 cubic feet per second (cfs), turbidity is generally less than 10 NTU. **Figure 9-4** presents the grab sample monthly data for the entire period of record. This figure indicates that the turbidity levels decline during the spring and summer months and reach the lowest levels in the fall when flows on the river are lowest. Turbidity levels rise when storm events result in increasing flows during the winter months.

Figure 9-2. Turbidity Levels at Hood

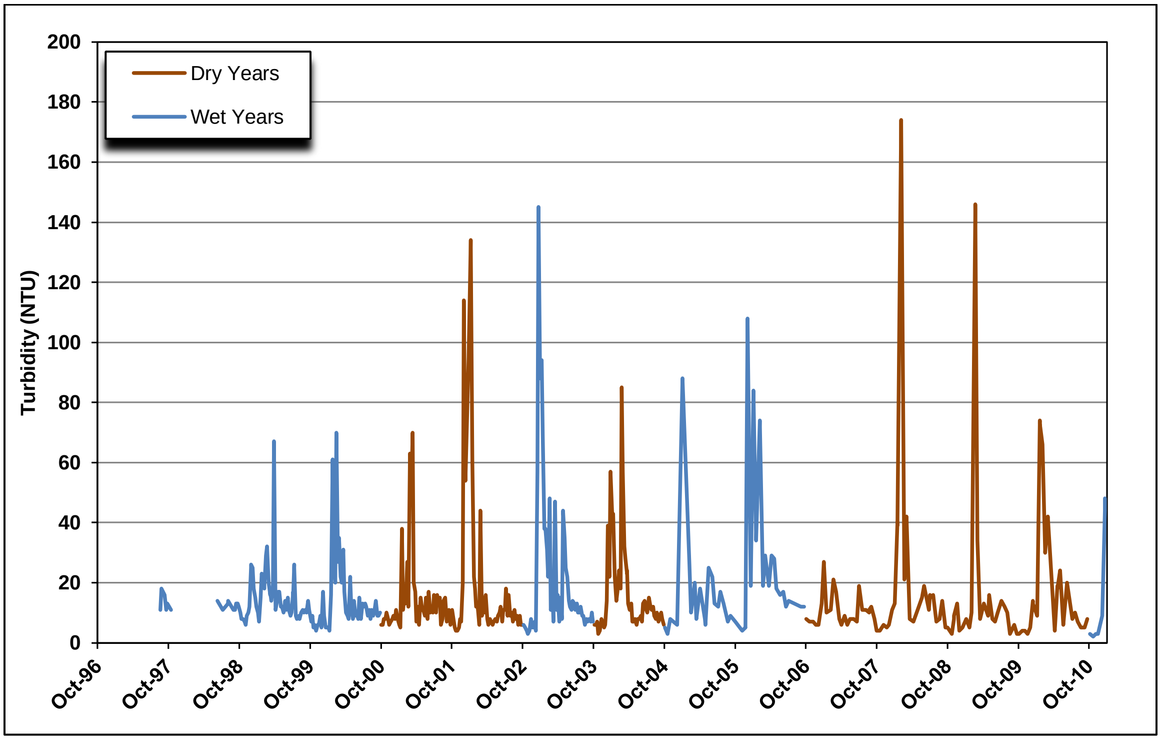


Figure 9-3. Relationship Between Flow and Turbidity at Hood

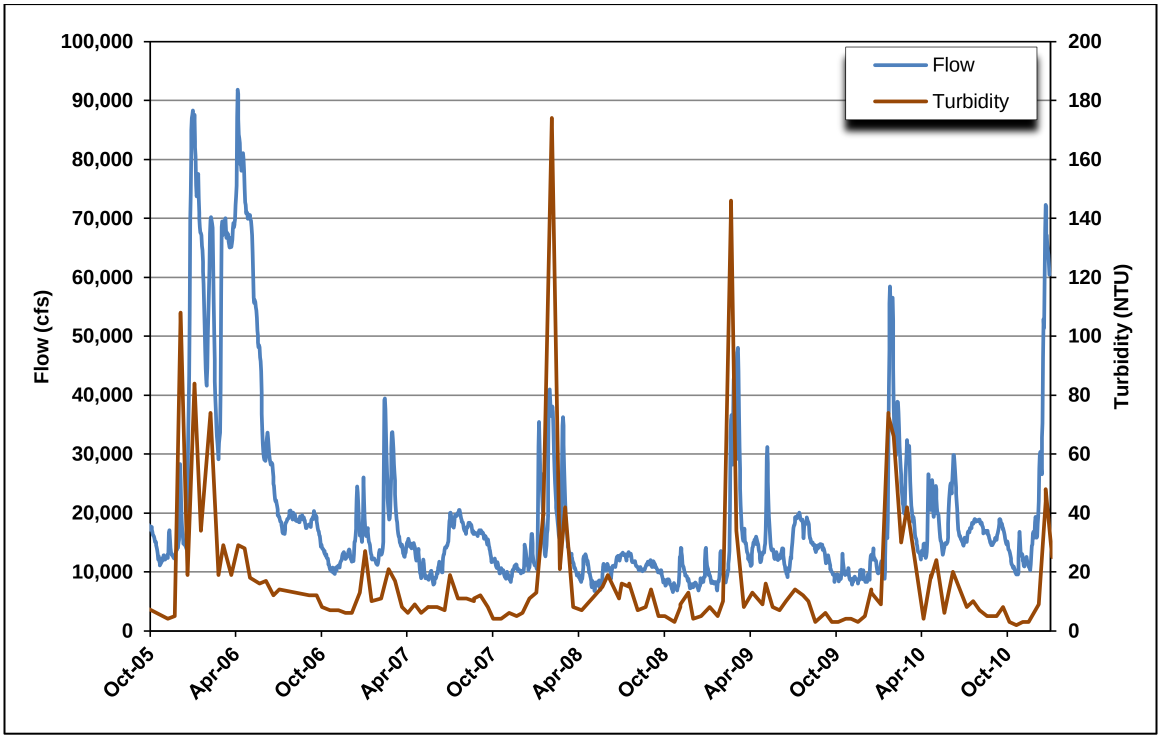
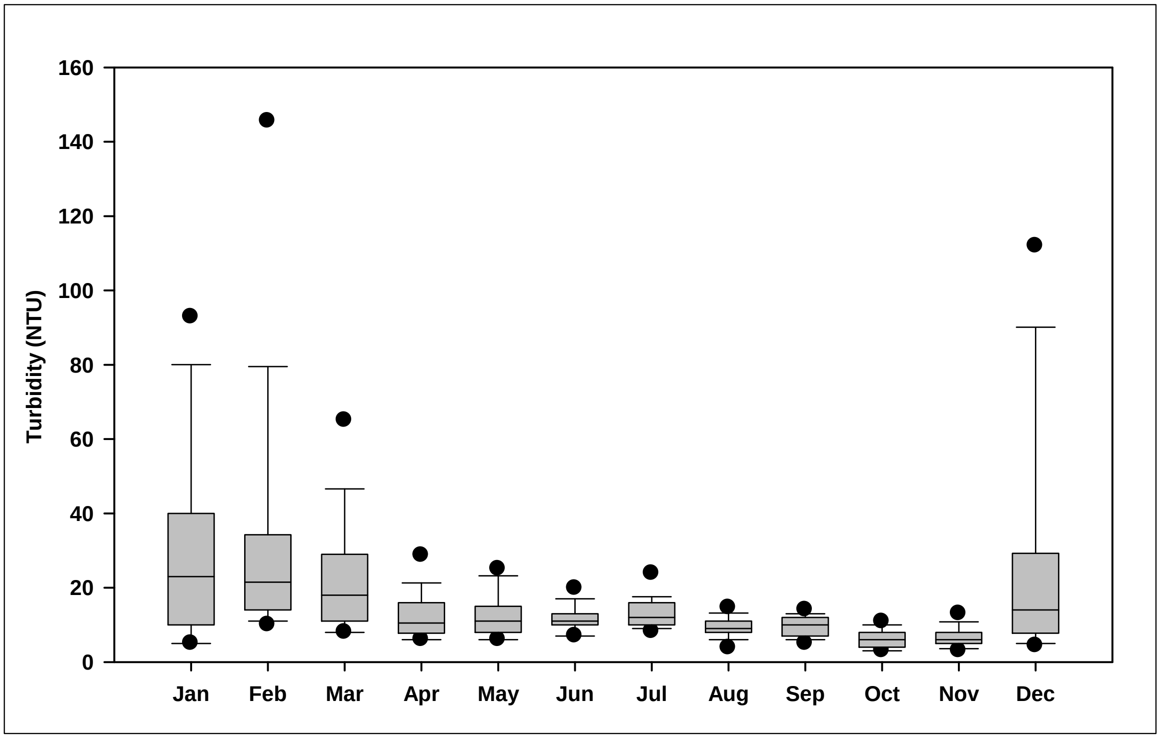


Figure 9-4. Monthly Variability in Turbidity at Hood



Vernalis – **Figure 9-5** presents all available grab sample turbidity data at Vernalis. Turbidity is highly variable, ranging from 2 to 178 NTU during the period of record with a median of 19 NTU. The range is similar to Hood but the median is almost twice the median level at Hood.

- Spatial Trends – DWR does not collect data on the San Joaquin River upstream of Vernalis.
- Long-Term Trends – **Figure 9-5** does not show any discernible long-term trends.
- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are differences between wet years and dry years. The median turbidity level of 19 NTU during dry years is not statistically significantly higher than the 18 NTU median during wet years (Mann-Whitney, p=0.4227).
- Seasonal Trends – **Figure 9-6** indicates that the San Joaquin River has a pattern of rapidly increasing turbidity when flows first increase in the winter months due to storm events (maximum measured value of 178 NTU); however during prolonged periods of high flows, such as in 2005, turbidity drops down to less than 20 NTU. This could be due to high quality water being released from upstream reservoirs rather than to storm-generated flows. During the summer months, turbidity appears to be inversely proportional to flow. As the river flow decreases in the summer, a larger percent of the water in the river is agricultural drainage, which could be one source of the summer high turbidity levels. Another possible source is increased algal production during the summer months. **Figure 9-7** presents the grab sample monthly data for the entire period of record. This figure shows that the median turbidity level is highest in July but the variability in turbidity is greatest during the winter months due to storm events.

Figure 9-5. Turbidity Levels at Vernalis

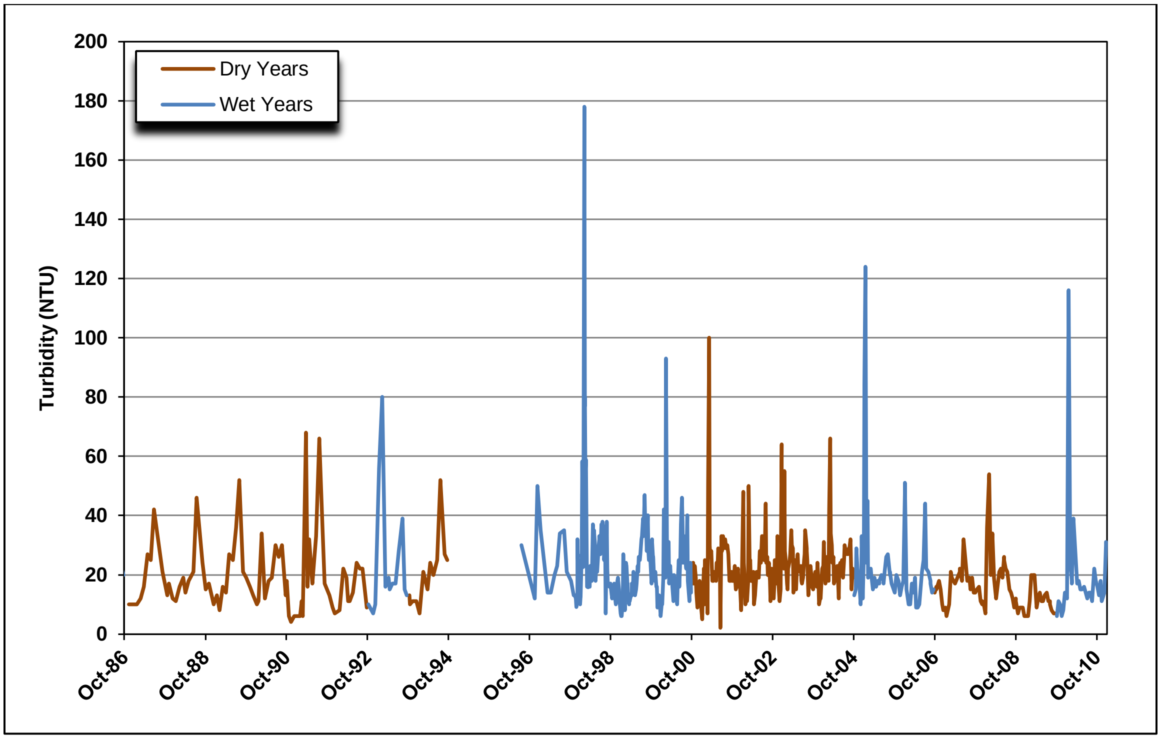


Figure 9-6. Relationship Between Turbidity and Flow at Vernalis

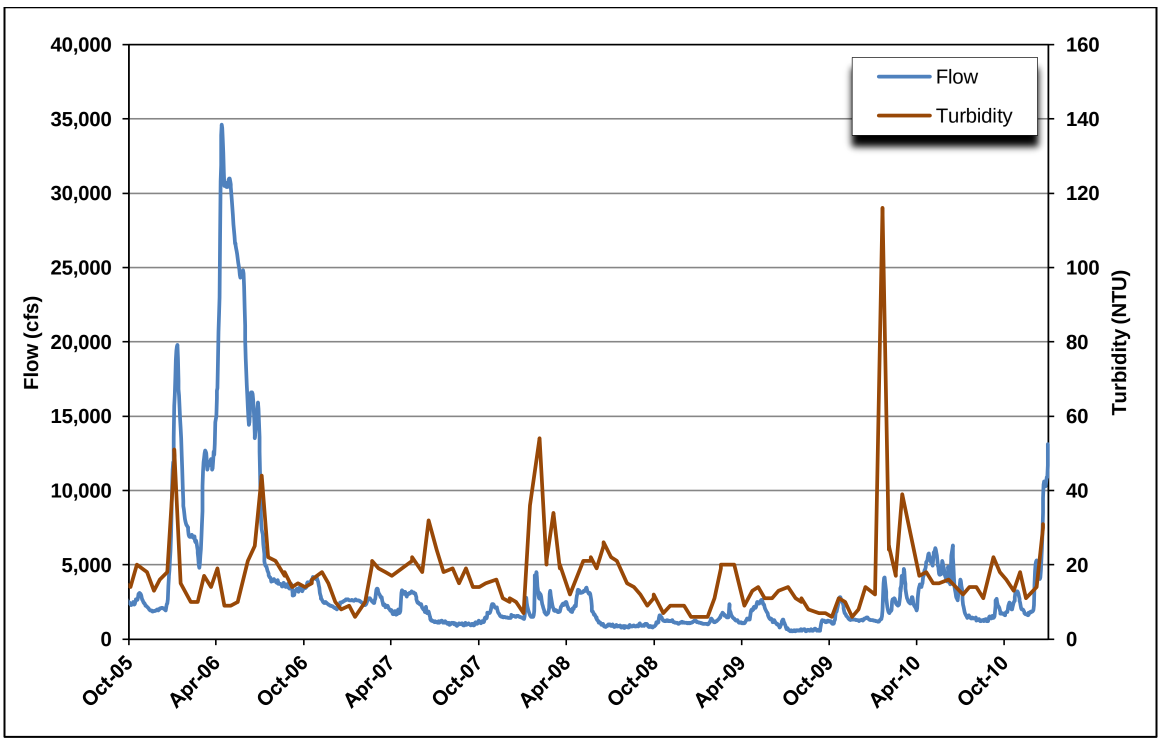
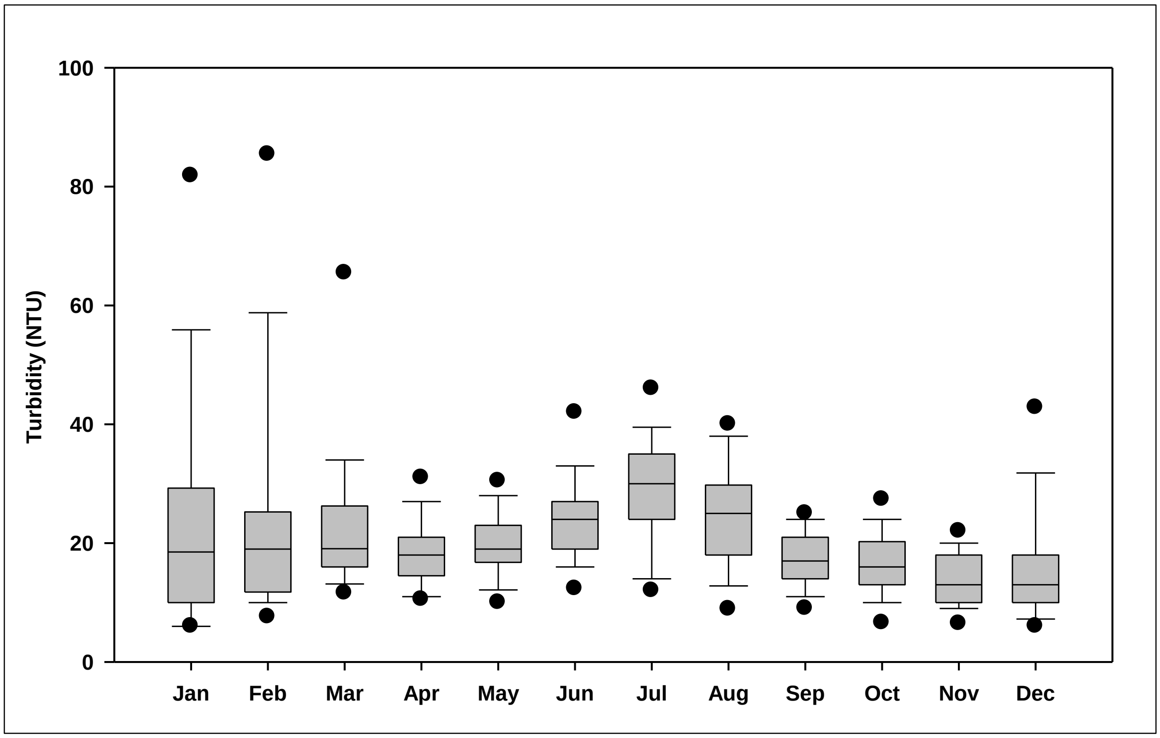


Figure 9-7. Monthly Variability in Turbidity at Vernalis



Banks – **Figure 9-8** shows all available grab sample turbidity data at Banks. There is considerable variability in turbidity at Banks with levels ranging from 3 to 70 NTU with a median of 9 NTU.

- Comparison of Real-time and Grab Sample Data – **Figure 9-9** compares the real-time data with the grab sample data at Banks. The real-time data shows substantially higher turbidity levels than those measured in the grab samples. This may be due to the fact that grab samples are only collected monthly and peak turbidity levels are missed or it may be due to problems with the turbidity sensor. DWR O&M staff conducted an analysis of turbidity at Banks for the South Bay Aqueduct (SBA) Contractors in 2002 that indicated that the summer peaks in turbidity are potentially due to the re-suspension of sediment in Clifton Court due to high winds in the Delta during the summer months. Wind-generated peaks in turbidity would be difficult to measure with monthly grab samples but they are measured with the real-time samplers. The October 2008 to December 2010 period was examined more closely to evaluate this issue. **Figure 9-10** presents the auto sampler continuous data for that period, the grab sample data, and the real-time data for the same days that grab samples were collected. It is clear from this figure that peak turbidity levels are missed with the monthly grab sample data; however, this figure also shows that the real-time measurements are systematically higher than the grab sample measurements. During this period the median difference between real-time and grab sample measurements was 63 percent.

- Spatial Trends – **Figure 9-1** indicates that turbidity levels at Banks are lower and less variable than the Sacramento and San Joaquin rivers. This is likely due to some settling of sediment in Delta channels and Clifton Court. Reservoirs and forebays, such as Clifton Court, act as settling basins due to the low velocity of water in the reservoir compared to the channels that feed the reservoir. All available data from Hood, Vernalis, and Banks are presented in **Figure 9-1**. Since the period of record varies between the three stations, a subset of the data that includes only data collected at the three stations during the same time period (1998 to 2010) was analyzed. The median levels in the subset of data are the same as those shown in **Figure 9-1**. The median turbidity at Banks (9 NTU) is statistically significantly lower than the median of 11 NTU at Hood (Mann-Whitney, p=0.0002) and statistically significantly lower than the median of 19 NTU at Vernalis (Mann-Whitney, p=0.0000).

- Long-Term Trends – No discernible long-term trend is evident in turbidity levels in **Figure 9-8**.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median turbidity of 8 NTU during dry years is statistically significantly lower than the median of 10 NTU during wet years (Mann-Whitney, p=0.0053).

- Seasonal Trends – **Figure 9-11** presents the grab sample monthly data for the entire period of record. This figure indicates that the peak turbidity levels at Banks occur between May and July with June having the highest levels. The summer peaks in turbidity are potentially due to the re-suspension of sediment in Clifton Court Forebay. High pumping rates in the summer create high velocities in the forebay which may re-suspend sediment and lead to higher turbidity. Re-suspension of sediment due to high winds in the Delta during the summer months is another possible cause.

Figure 9-8. Turbidity Levels at Banks

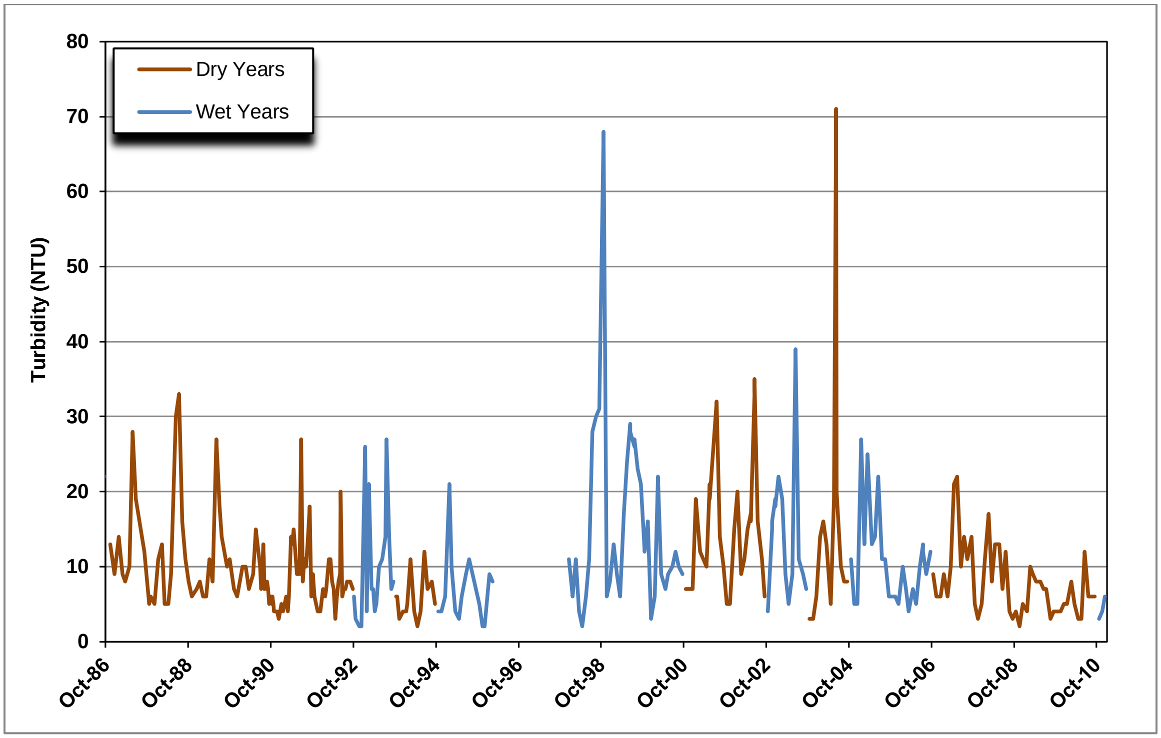


Figure 9-9. Comparison of Banks Real-time and Grab Sample Turbidity Data

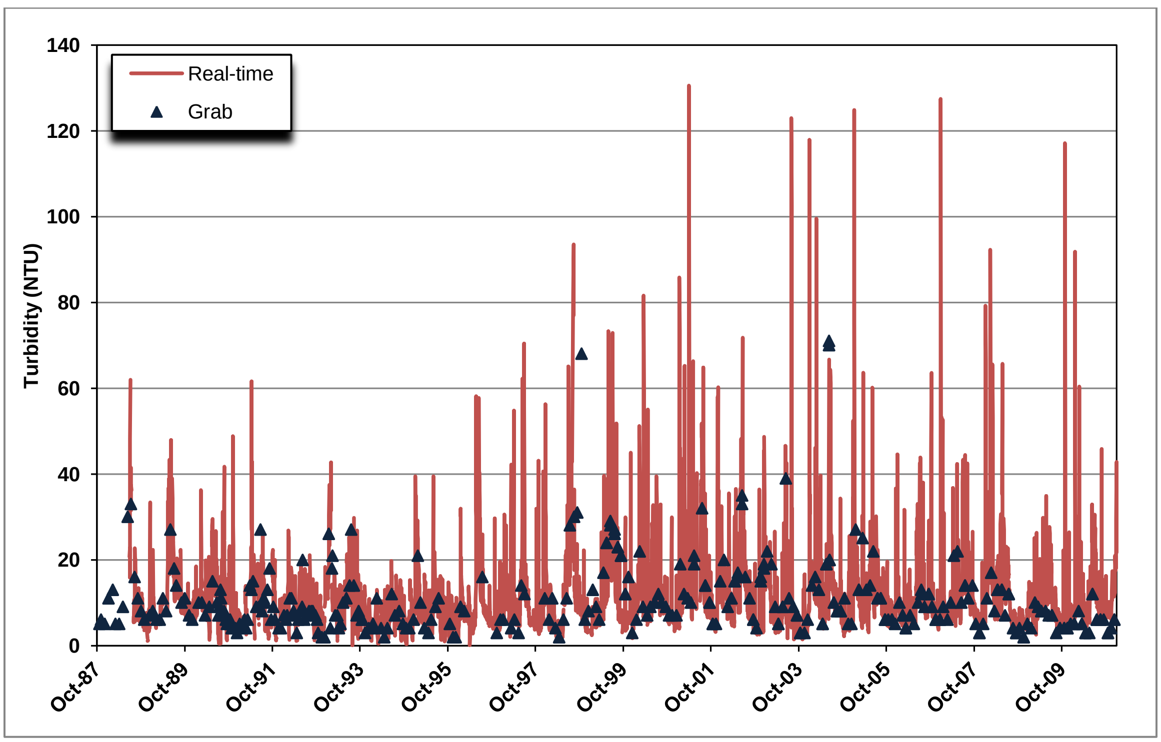


Figure 9-10. Differences Between Real-time and Grab Sample Data

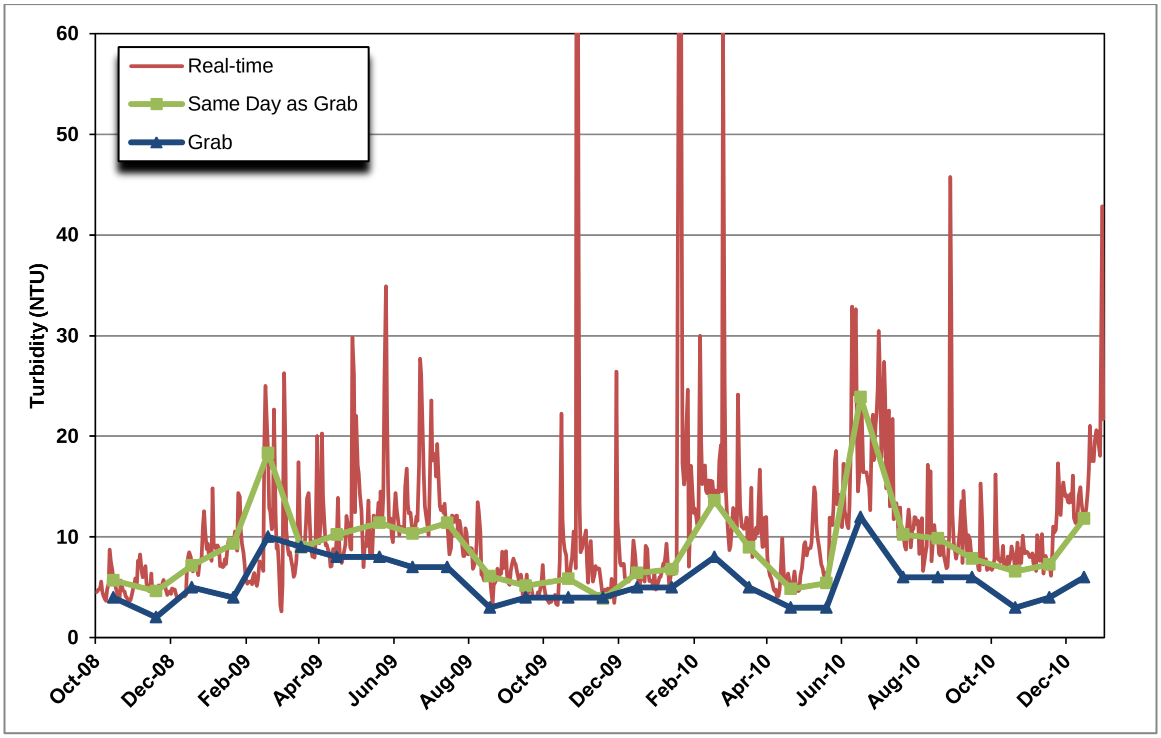
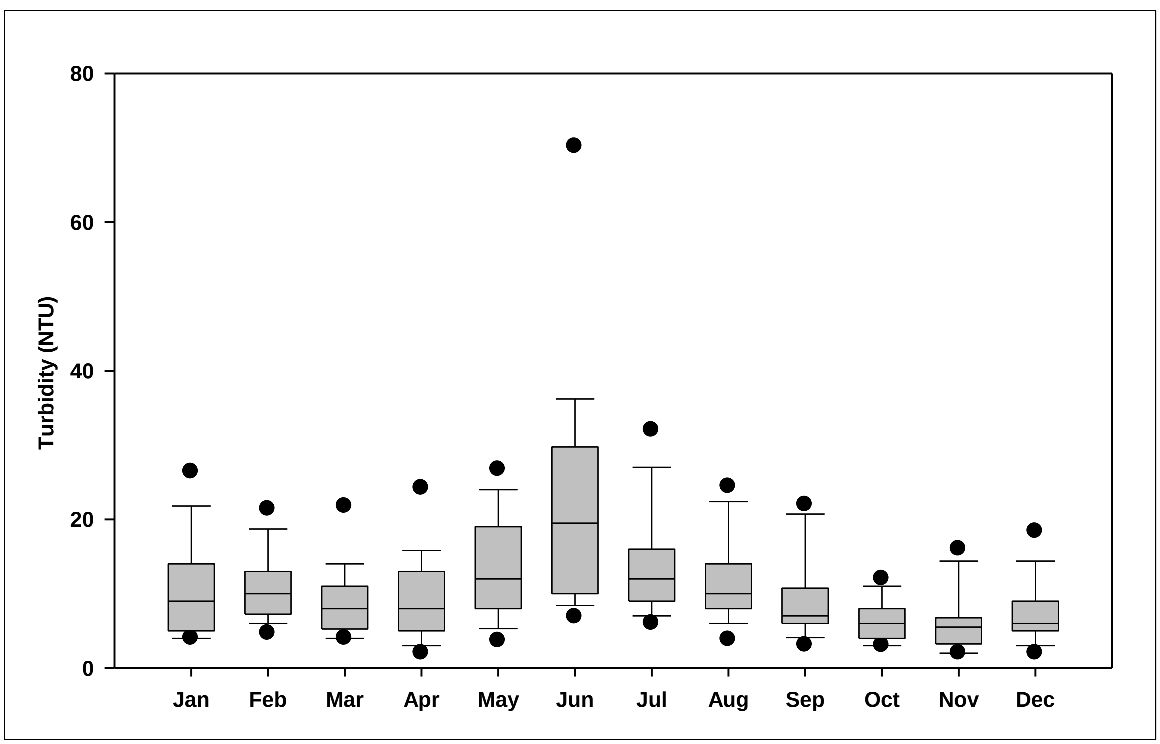


Figure 9-11. Monthly Variability in Turbidity at Banks



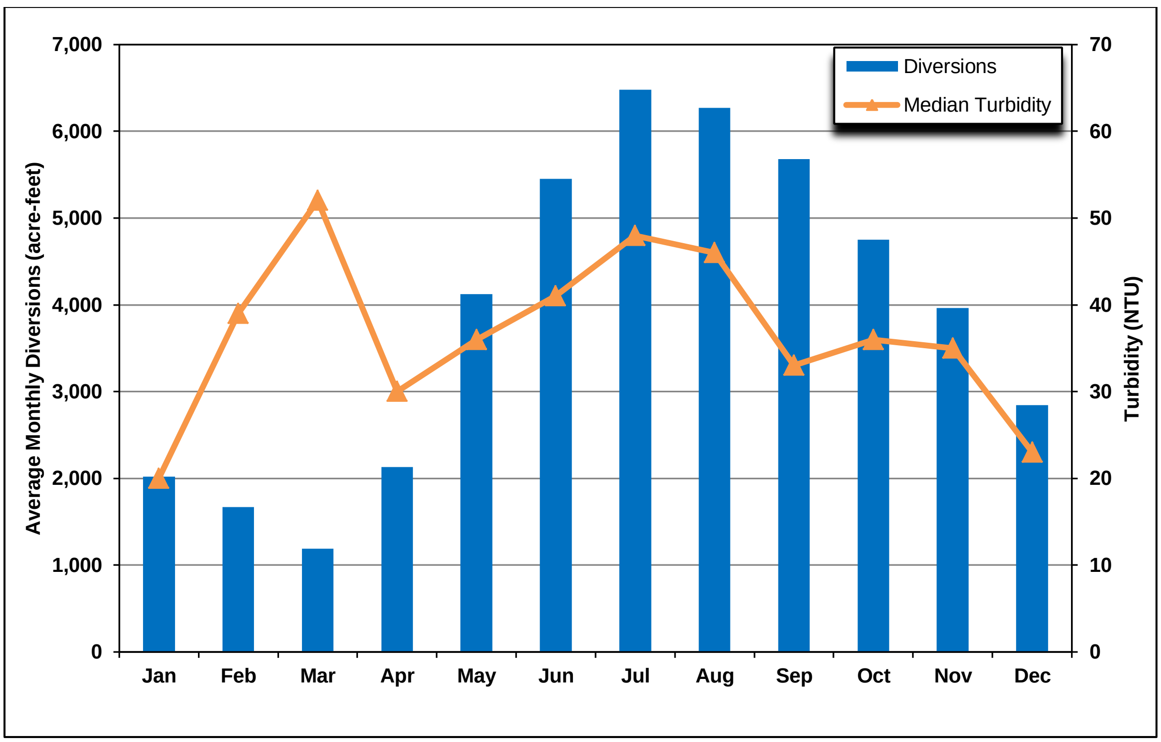
North Bay Aqueduct

Chapters 3 and 4 contain a description of the North Bay Aqueduct (NBA). The sources of water are the local Barker Slough watershed and the Sacramento River.

Project Operations

Since the NBA is an enclosed pipeline, the quality of water delivered to NBA users is governed by the timing of diversions from Barker Slough and it shouldn't be affected by any other factors. **Figure 9-12** shows average monthly diversions at Barker Slough for the 1998 to 2010 period and median monthly turbidity levels. This figure shows that pumping is highest between May and November and turbidity levels are correspondingly high, indicating that the pumps stir up sediment in Barker Slough. Median monthly turbidity levels are above 30 NTU from May to November.

Figure 9-12. Average Monthly Barker Slough Diversions and Median Turbidity Levels



Turbidity Levels in the NBA

Real-time and grab sample turbidity data are collected at Barker Slough and Cordelia Forebay (Cordelia). **Figure 9-13** shows all available grab sample turbidity data at Barker Slough. The levels range from 4 to 975 NTU with a median of 32 NTU. The turbidity levels at Barker Slough are substantially higher and more variable than at Hood or any other SWP monitoring location.

- Comparison of Real-time and Grab Sample Data – **Figure 9-14** compares the real-time data with the grab sample data at Barker Slough and **Figure 9-15** compares the real-time and grab sample data for Cordelia. There isn't a good correspondence between the real-time and grab sample data at either location. The data were not examined as closely as the data at Banks but it appears that the real-time measurements are routinely higher than the grab samples.

- Spatial Trends – **Figure 9-16** compares the real-time and grab sample data at Barker Slough and Cordelia for the 1998 to 2010 period when samples were collected at both locations. This figure shows that the real-time medians are much higher than the grab sample medians at both locations. The Cordelia grab sample median of 36.5 NTU is not statistically significantly different than the Barker Slough grab sample median of 37 NTU (Mann-Whitney, p=0.836).

- Long-Term Trends – **Figure 9-13** shows that there is not a discernible long-term trend at Barker Slough.

- Wet Year/Dry Year Comparison – The Barker Slough grab sample data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median turbidity of 28 NTU in dry years is statistically significantly lower than the median of 39 NTU in wet years (Mann-Whitney, p=0.0000).

- Seasonal Trends – **Figure 9-17** presents the Barker Slough grab sample monthly data for the entire period of record. This figure indicates that turbidity levels are relatively high and variable in most months of the year with the highest and most variable turbidities found in February.

Figure 9-13. Turbidity Levels at Barker Slough

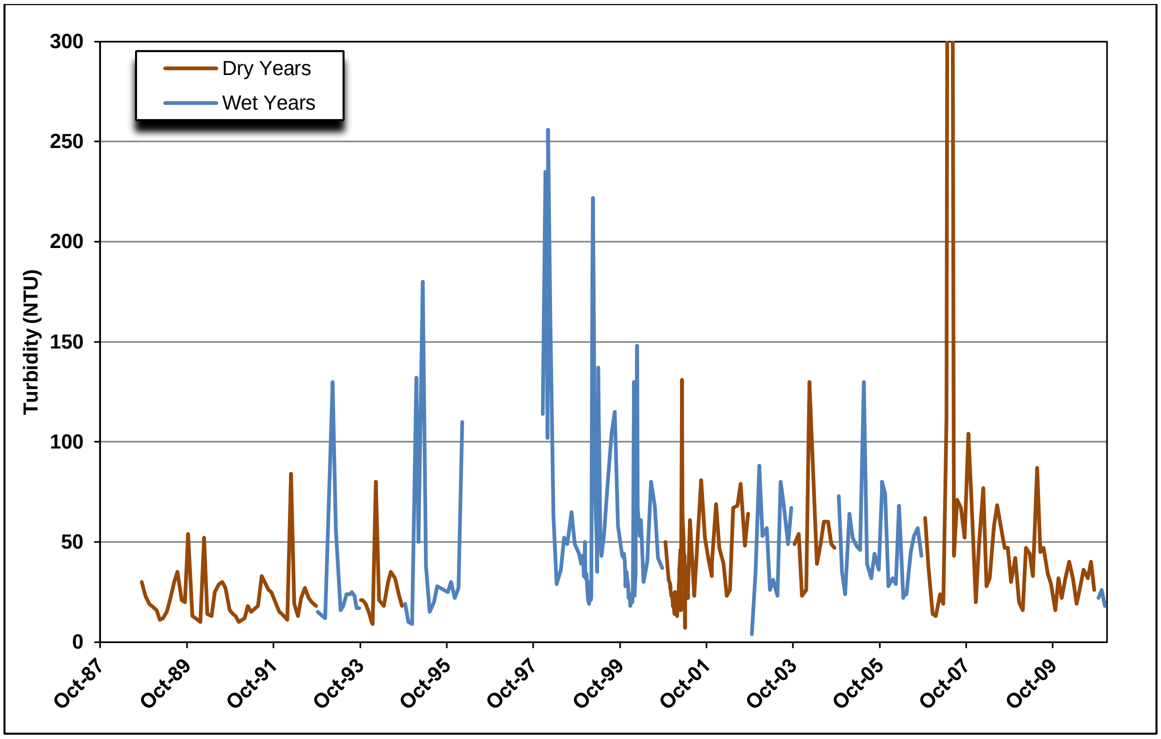


Figure 9-14. Comparison of Barker Slough Real-time and Grab Sample Turbidity Data

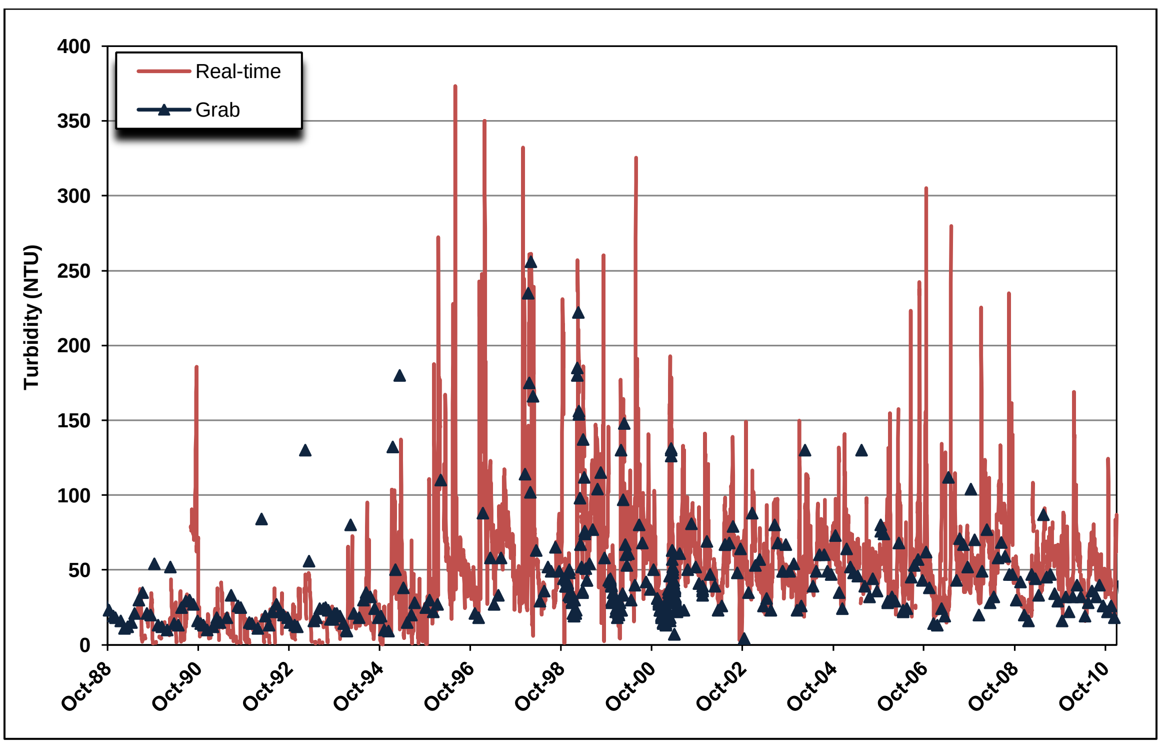


Figure 9-15. Comparison of Cordelia Real-time and Grab Sample Turbidity Data

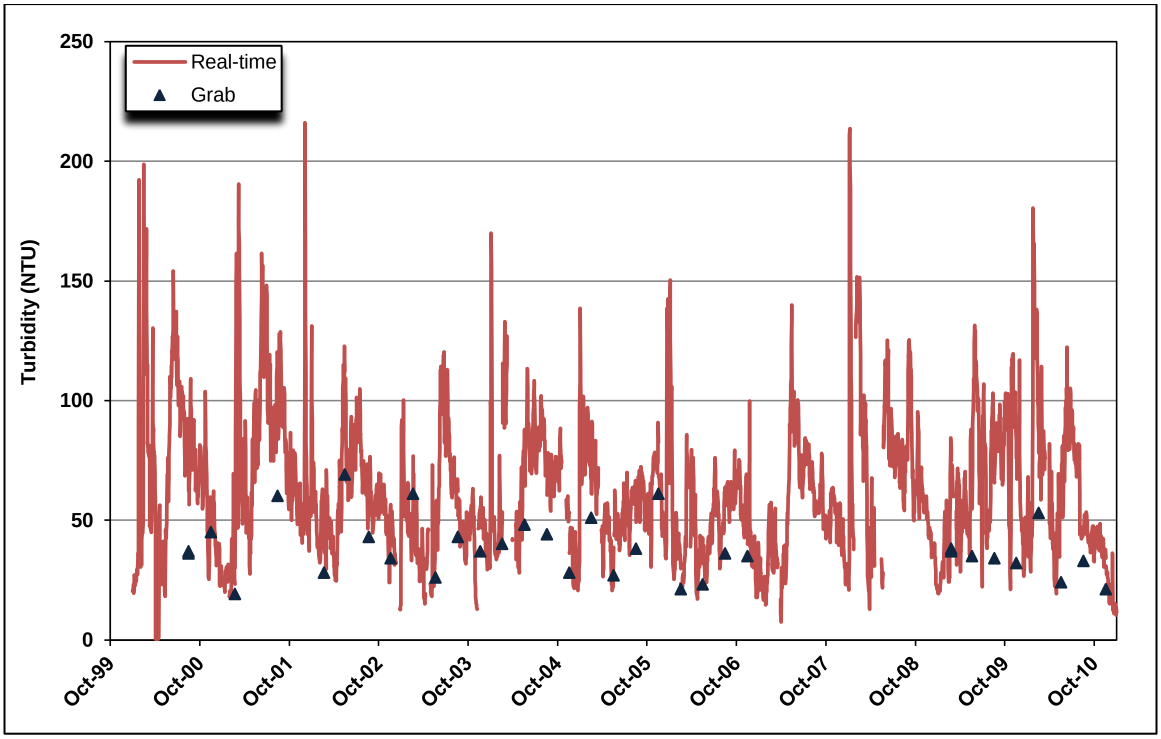


Figure 9-16. Comparison of Turbidity at Barker Slough and Cordelia

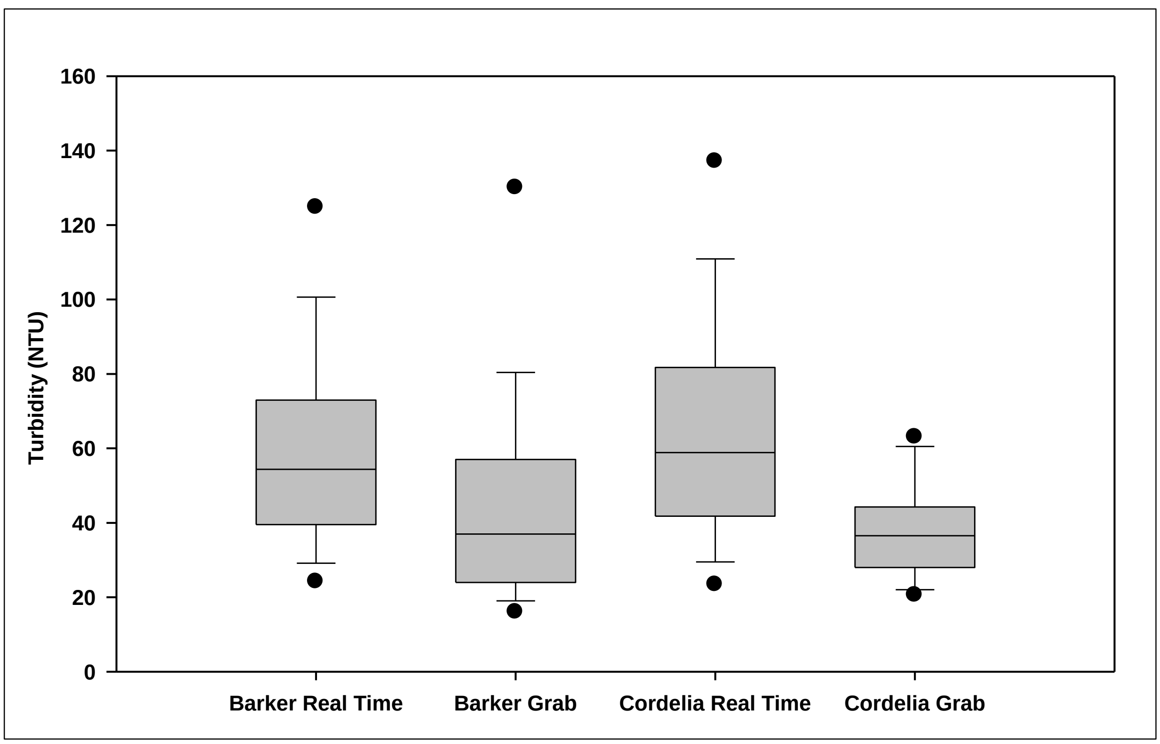
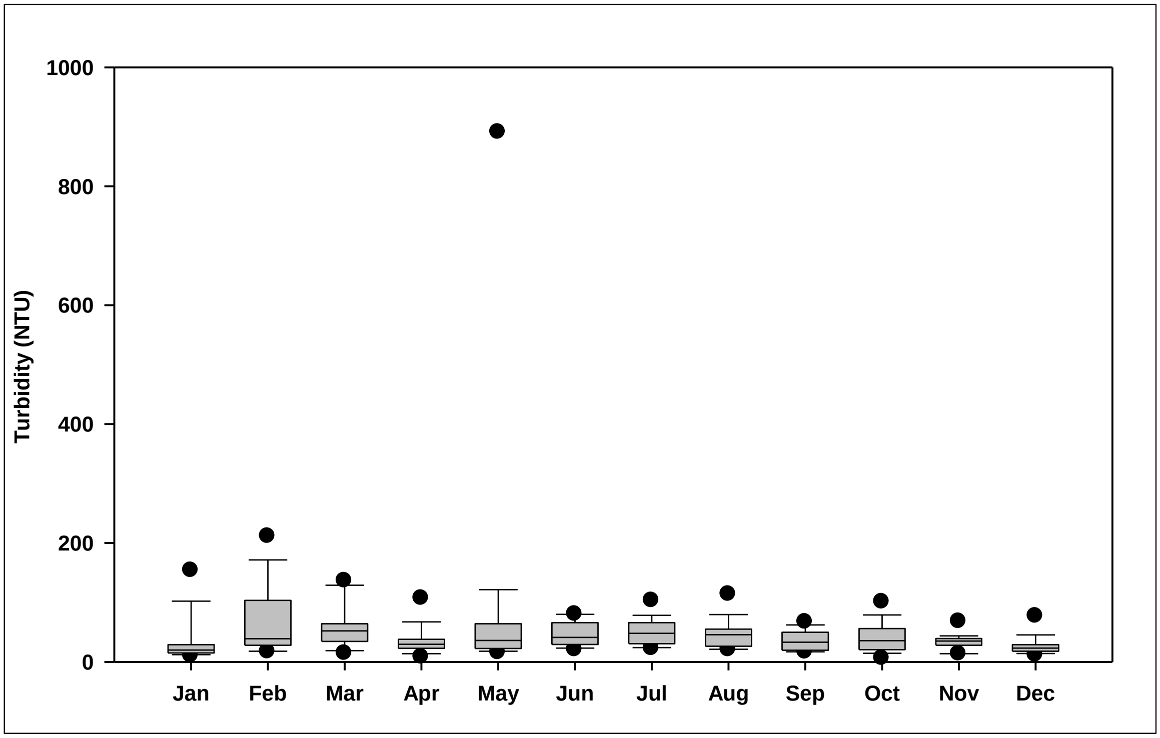


Figure 9-17. Monthly Variability in Turbidity at Barker Slough



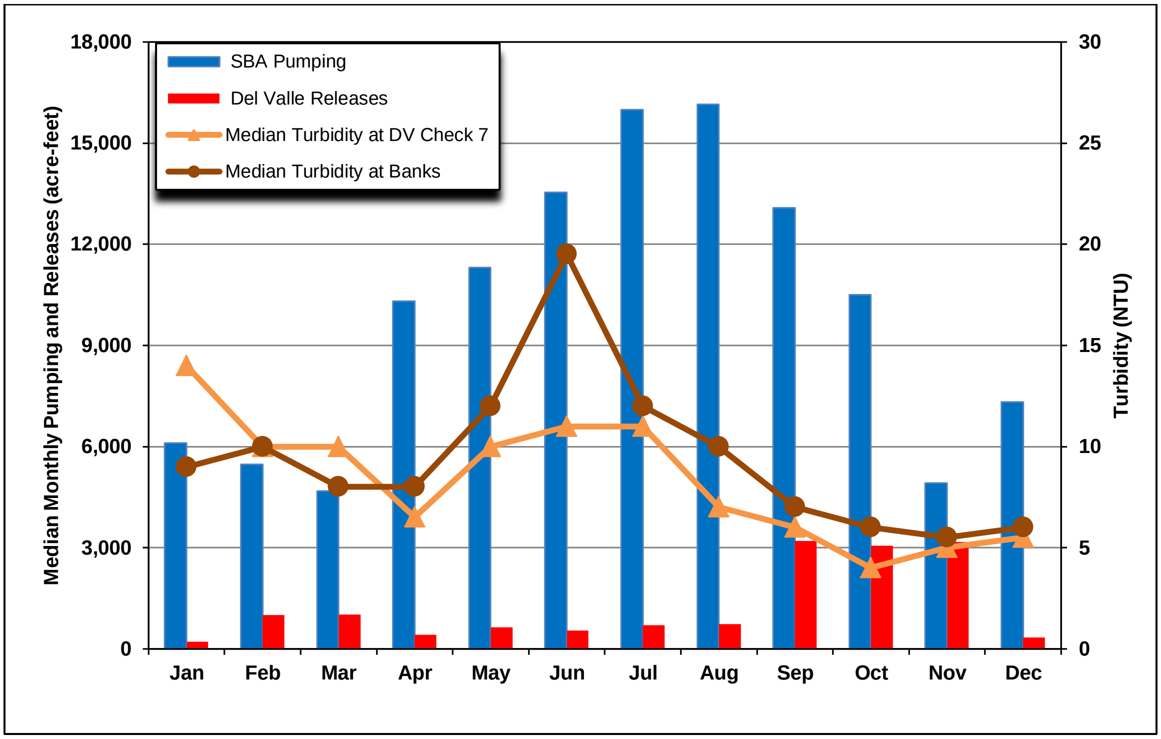
South Bay Aqueduct

Chapters 3 and 4 contain a description of the SBA. The Delta is the primary source of water and Lake Del Valle is the secondary source.

<u>Project Operations</u>

The quality of water delivered to the SBA Contractors is governed by the timing of diversions from Bethany Reservoir and releases from Lake Del Valle. **Figure 9-18** shows average monthly diversions at the South Bay Pumping Plant, releases from Lake Del Valle, and median monthly levels at Banks and Del Valle Check 7 (DV Check 7). There are few factors that affect water quality between Banks and DV Check 7 for most water quality constituents but turbidity is different since particles can settle and be re-suspended in the aqueducts and Bethany Reservoir. Median turbidity is only a rough indicator of the impacts of timing of diversions since turbidity is quite variable, as shown previously in **Figure 9-10** for Banks. **Figure 9-18** shows that median turbidity levels are highest at Banks during the summer months when diversions at the South Bay Pumping Plant are high. There is some reduction in turbidity between Banks and DV Check 7 possibly due to settling in Bethany and the SBA. Water is released from Lake Del Valle primarily between September and November. The median turbidity level at the Lake Del Valle Conservation Outlet (Conservation Outlet) is 3 NTU, which is about 50 percent lower than the median concentrations at DV Check 7 during the fall months.

Figure 9-18. Average Monthly Diversions at the South Bay Pumping Plant, Releases from Lake Del Valle, and Median Turbidity Levels



Turbidity Levels in the SBA

Turbidity data have been collected at four locations along the SBA for varying periods of record. **Figure 9-19** shows all of the data collected at each location along the SBA and at Banks. The DV Check 7 location has the longest period of record for both grab and real-time data. **Figure 9-20** presents all available grab sample turbidity data at DV Check 7. The turbidity levels range from 2 to 42 NTU with a median of 8 NTU.

- Comparison of Real-time and Grab Sample Data – **Figure 9-21** compares the real-time data with the grab sample data at DV Check 7. The two data sets show the same general pattern, although the real-time data tend to be 1 to 2 NTU higher at low turbidity levels than the grab sample data when data collected on the same day are visually compared. When turbidity is higher, the real-time measurements are often substantially higher than the grab sample measurements. The real-time shows peak turbidity levels that are not captured in the grab samples.

- Spatial Trends – It is not possible to compare all locations along the SBA that have been monitored due to varying periods of record. The grab sample data from 1998 to 2010 for Banks, DV Check 7, and the Santa Clara Terminal Reservoir (Terminal Tank) are shown in **Figure 9-22**. There is not a statistically significant difference between the median level of 8 NTU at DV Check 7 and the median of 9 NTU at Banks (p=0.1674). The median turbidity of 6 NTU at the Terminal Tank is statistically significantly lower than the 8

NTU median at DV Check 7 (p=0.0352). This may be due to settling of sediment in the aqueduct or blending of Lake Del Valle water into the SBA.

- Long-Term Trends – **Figure 9-20** shows that turbidity levels are lower in recent years that in the 1997 to 2001 period. In recent years, there have not been the spikes in turbidity in the summer months that occurred in the earlier period and the winter peak turbidity levels have been lower. The lower winter levels may be due to the dry conditions in the last four years but it's not clear why the summer peaks have decreased in magnitude.

- Wet Year/Dry Year Comparison – The data were analyzed to determine if there are statistically significant differences between wet years and dry years. The median turbidity of 8 NTU in dry years is not statistically significantly lower than the median of 9 NTU in wet years (Mann-Whitney, p=0.1761).

- Seasonal Trends – **Figure 9-23** presents the grab sample monthly data for the entire period of record at DV Check 7. Peak turbidity levels occur in the winter and in the summer. The winter peak is due to winter storms when turbidity in the rivers and Delta is high. The summer peak is generated in the Delta and may be due to wind-driven suspension of sediment in Clifton Court or to higher pumping. Another potential cause is increased algal production during the summer months.

Figure 9-19. Turbidity in the SBA

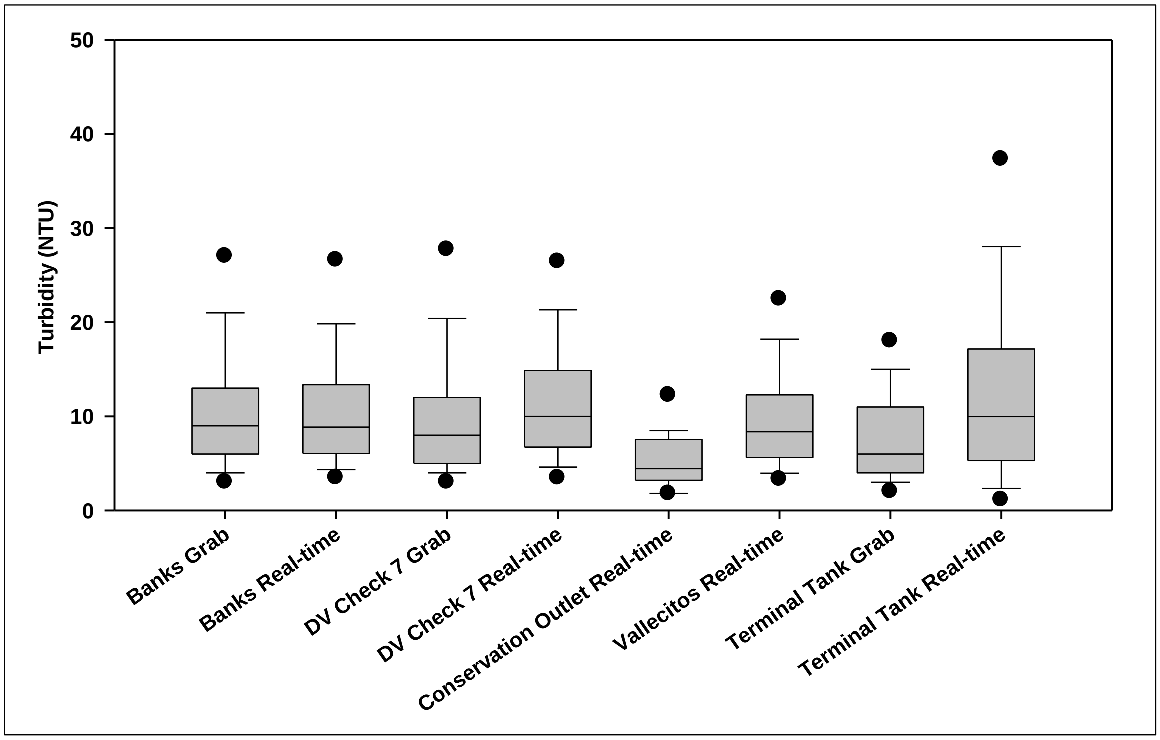


Figure 9-20. Turbidity at DV Check 7

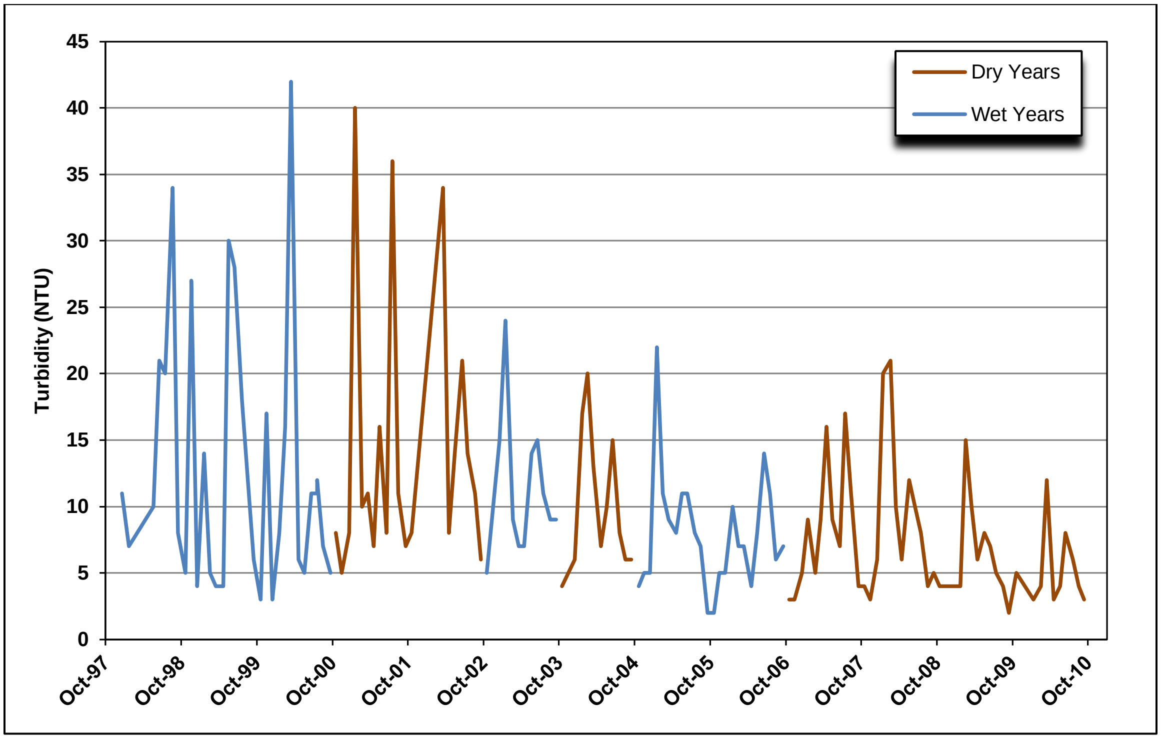


Figure 9-21. Comparison of DV Check 7 Real-time and Grab Sample Turbidity Data

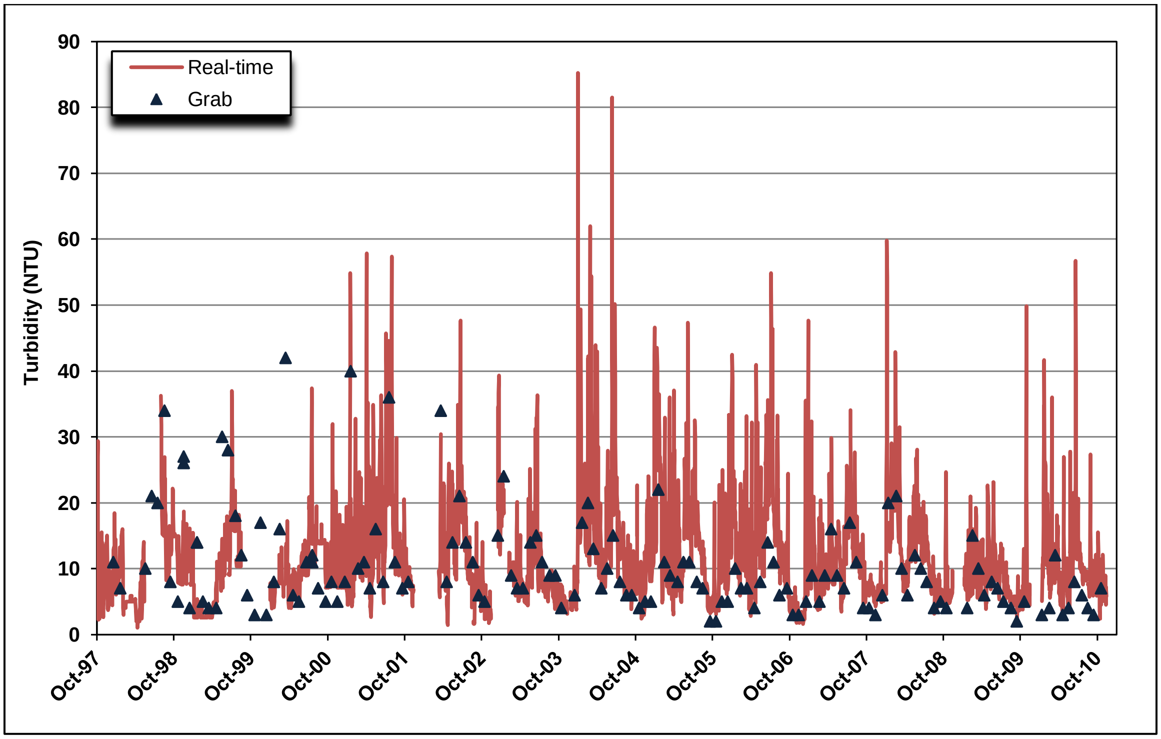


Figure 9-22. Comparison of Turbidity at Banks, DV Check 7, and the Terminal Tank (1998-2010)

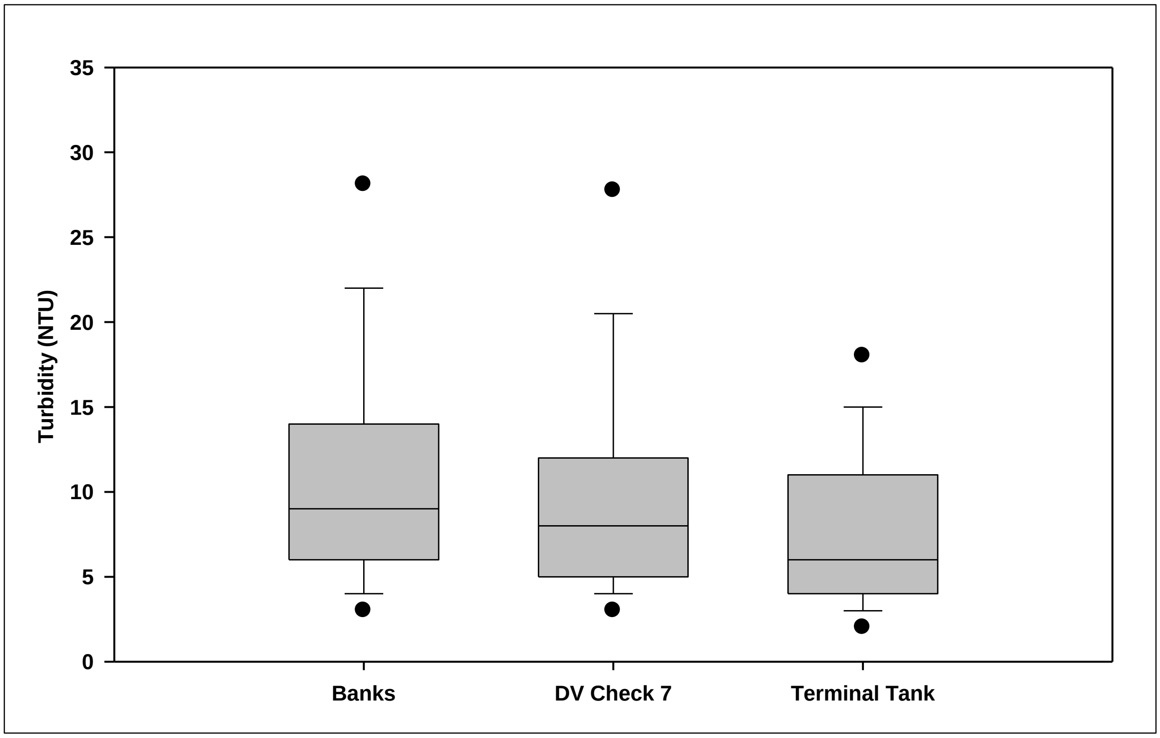
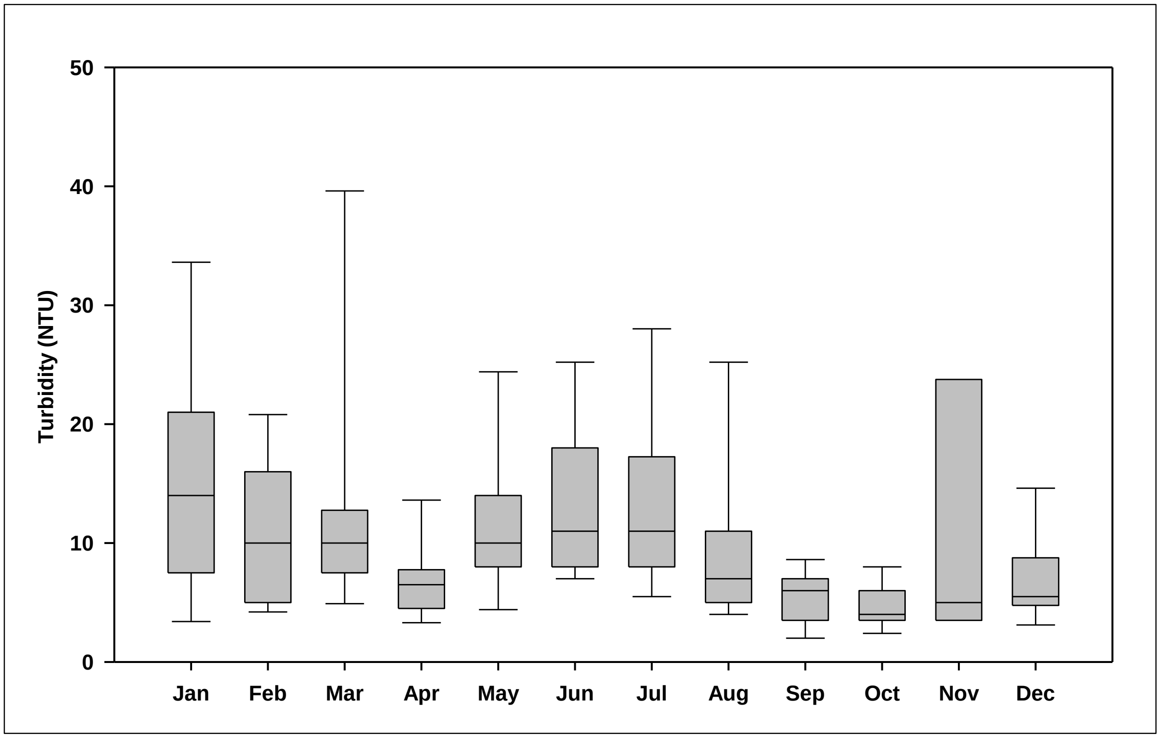


Figure 9-23. Monthly Variability in Turbidity at DV Check 7



Note: Insufficient data to plot all percentiles.

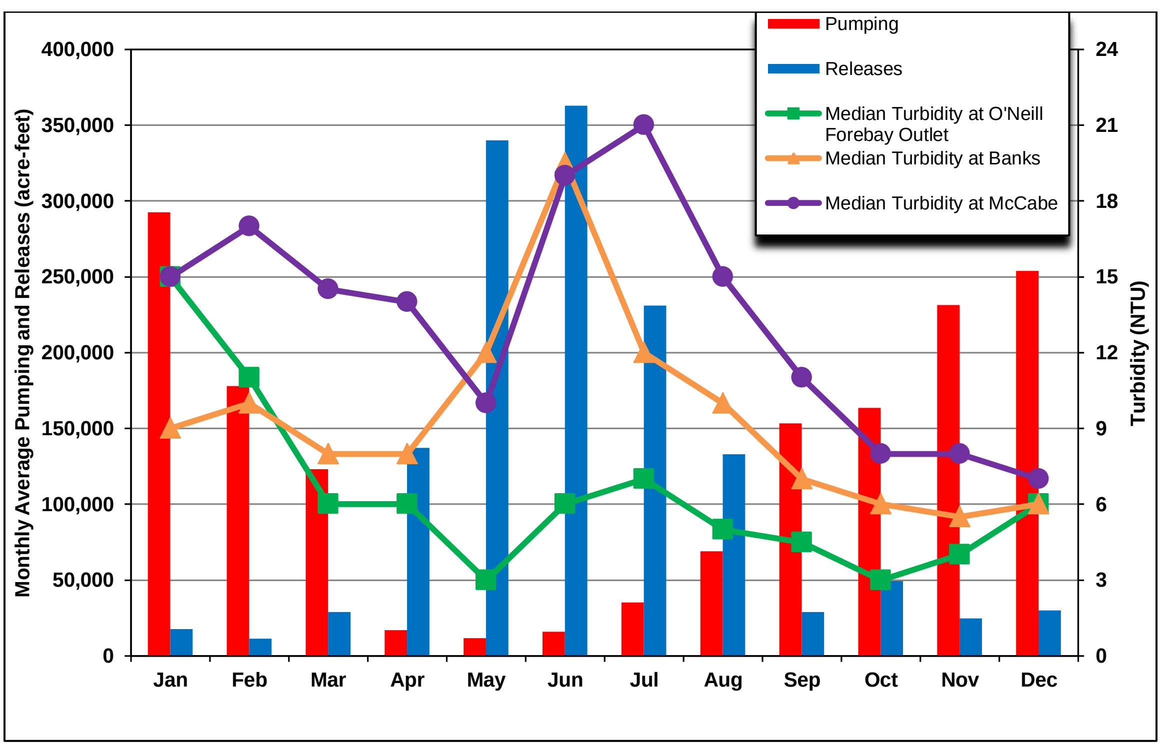
California Aqueduct and Delta-Mendota Canal

A number of SWP Contractors take water from the SWP between San Luis Reservoir and the terminal reservoirs. This section is organized by various reaches of the SWP and individual SWP Contractors taking water from each reach are described in the following sections.

Project Operations

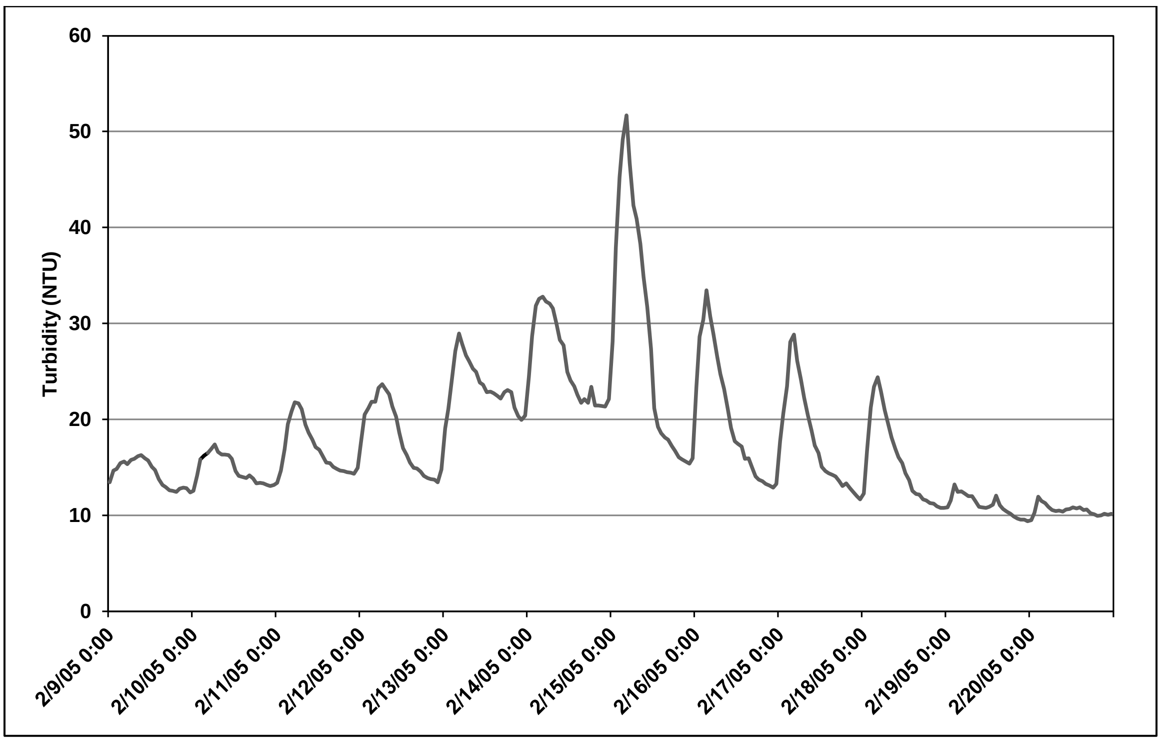
San Luis Reservoir acts as a large settling pond for the sediment that is pumped in with water from the Governor Edmund G. Brown California Aqueduct (California Aqueduct) and the Delta-Mendota Canal (DMC). The timing of diversions at Banks and pumping into O'Neill Forebay at the O'Neill Pump-Generation Plant do not ultimately affect the turbidity of water released from San Luis Reservoir. As discussed in a following section, the monthly median turbidity of water leaving San Luis at the Pacheco Pumping Plant (Pacheco) varies from 1 to 3 NTU. The turbidity of water delivered to SWP Contractors south of San Luis Reservoir is governed by the turbidity of water leaving O'Neill Forebay, the operations of the pumping plants along the California Aqueduct and inflows to the aqueduct. **Figure 9-24** shows the pattern of pumping into and releases from San Luis Reservoir. The monthly median turbidity levels at O'Neill Forebay Outlet are shown to illustrate the turbidity level of water entering the California Aqueduct south of the reservoir. The median turbidity at Banks and McCabe are shown to illustrate that the seasonal pattern of turbidity at O'Neill Forebay Outlet is similar to the patterns in the source waters but the levels are much lower during the period that water is released from San Luis Reservoir.

Figure 9-24. San Luis Reservoir Operations and Median Turbidity Levels



The California State Water Project Watershed Sanitary Survey 2006 Update (2006 Update) contains an analysis of how pumping plant operations affect turbidity in the California Aqueduct. That analysis is repeated in this section to illustrate how quickly turbidity levels can change due to operations. The velocity of water in the aqueduct is controlled by pumping plants along the system. These plants are generally operated off-peak, meaning that pumps are turned on during night time hours when energy costs are lower and turned off during times of peak energy costs. This operating pattern has significant effects on suspended sediments, causing settling during the day and re-suspension at night. Hourly turbidity data from the continuous recorder at Check 29 are plotted in **Figure 9-25**. This location was chosen because it is in the area of the San Joaquin Valley where wind-blown sediments are problematic and, it is downstream of the San Luis Reach and some of the major non-Project inflows. The plot depicts the daily variability in turbidity over a particular 12-day period when fluctuations were pronounced. Daily fluctuations over 30 NTU were observed at this location, but the amount of daily fluctuation was variable.

Figure 9-25. Daily Turbidity Variability at Check 29



Turbidity Levels in the DMC and SWP

Figure 9-26 presents a summary of all grab sample turbidity data collected at each of the locations along the DMC, California Aqueduct, and SWP reservoirs. There are varying periods of record for each location so differences between locations may be due to the hydrologic conditions under which the samples were collected. A subset of data collected during the same time period (1998 to 2010) was analyzed for several locations along the aqueduct and for McCabe on the DMC. **Figure 9-27** presents these data. Spatial differences are examined in more detail in the following sections.

Figure 9-26. Turbidity Levels in the DMC and SWP

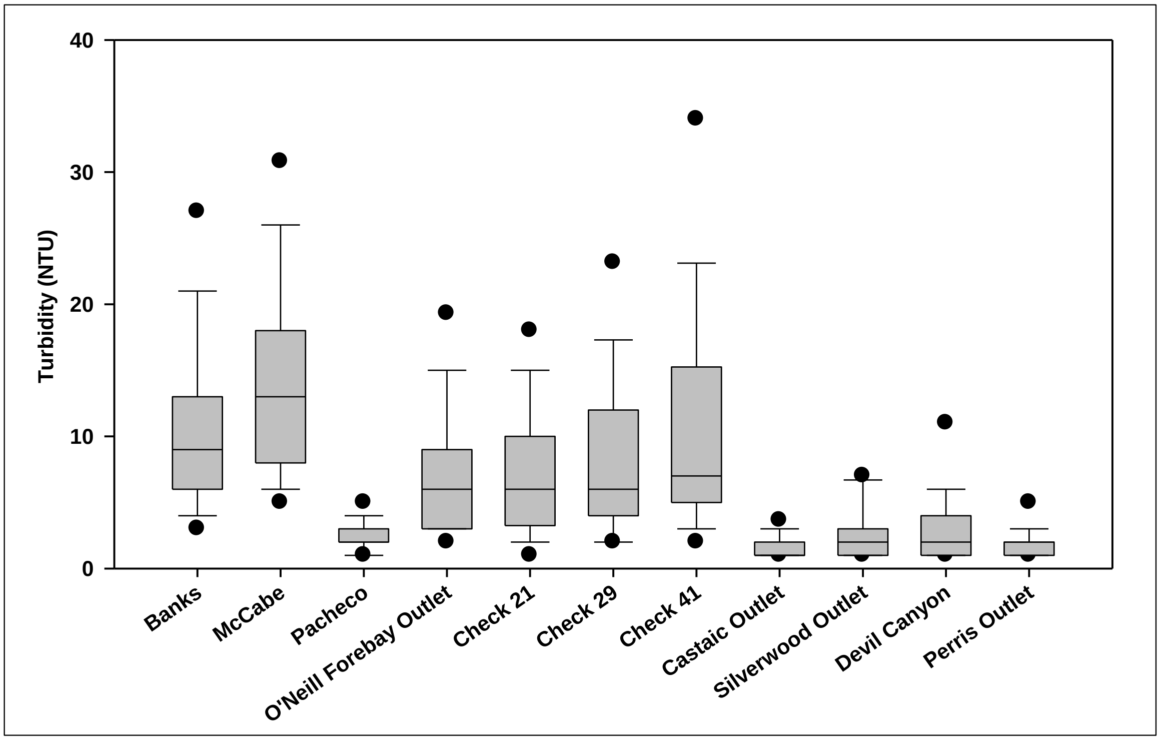
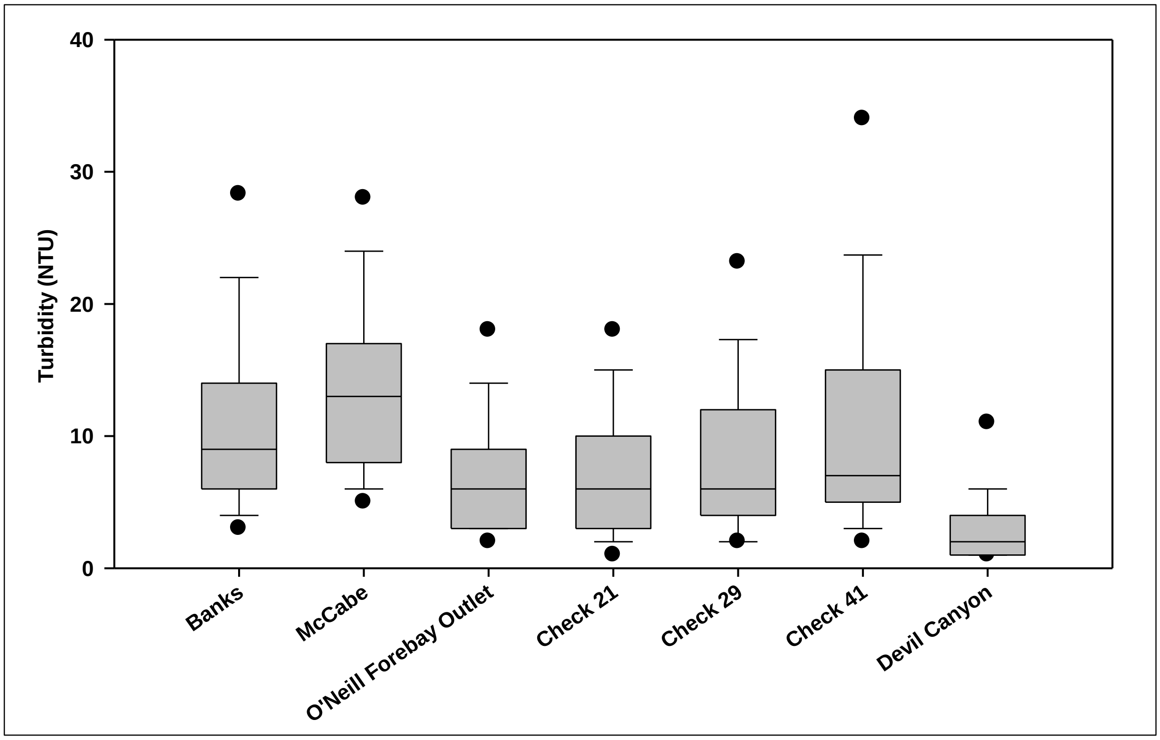


Figure 9-27. Turbidity Levels in the California Aqueduct (1998-2010)



Delta-Mendota Canal – Grab sample turbidity data have been collected at McCabe since 1997. **Figure 9-28** presents the turbidity data for McCabe. There is considerable variability in the data with turbidity levels ranging from 3 to 55 NTU with a median of 13 NTU.

- Spatial Trends – **Figure 9-27** compares the turbidity data collected at McCabe to Banks. The median turbidity of 13 NTU at McCabe is statistically significantly higher than the median turbidity of 9 NTU at Banks (Mann-Whitney, p=0.0000). **Figure 9-27** also shows that turbidity is more variable at McCabe. The small increase in turbidity at McCabe may be due to agricultural drainage which is discharged to the canal between Jones and McCabe or it may be due to the greater influence of the San Joaquin River at Jones.

- Long-Term Trends – **Figure 9-28** shows that turbidity levels have been lower in recent years. This is likely a function of hydrology since data were first collected during the wet period of the late 1990s.

- Wet Year/Dry Year Comparison – As shown in **Figure 9-28**, there is no apparent relationship between year type and turbidity levels at McCabe. The dry year median turbidity of 13 NTU is not statistically significantly different from the wet year median of 14 NTU (Mann-Whitney, p=0.2513)

- Seasonal Trends – **Figure 9-29** shows that the peak turbidity levels at McCabe occur in June and July and there is another peak in January and February. This is similar to the seasonal pattern at Banks.

Figure 9-28. Turbidity Levels at McCabe

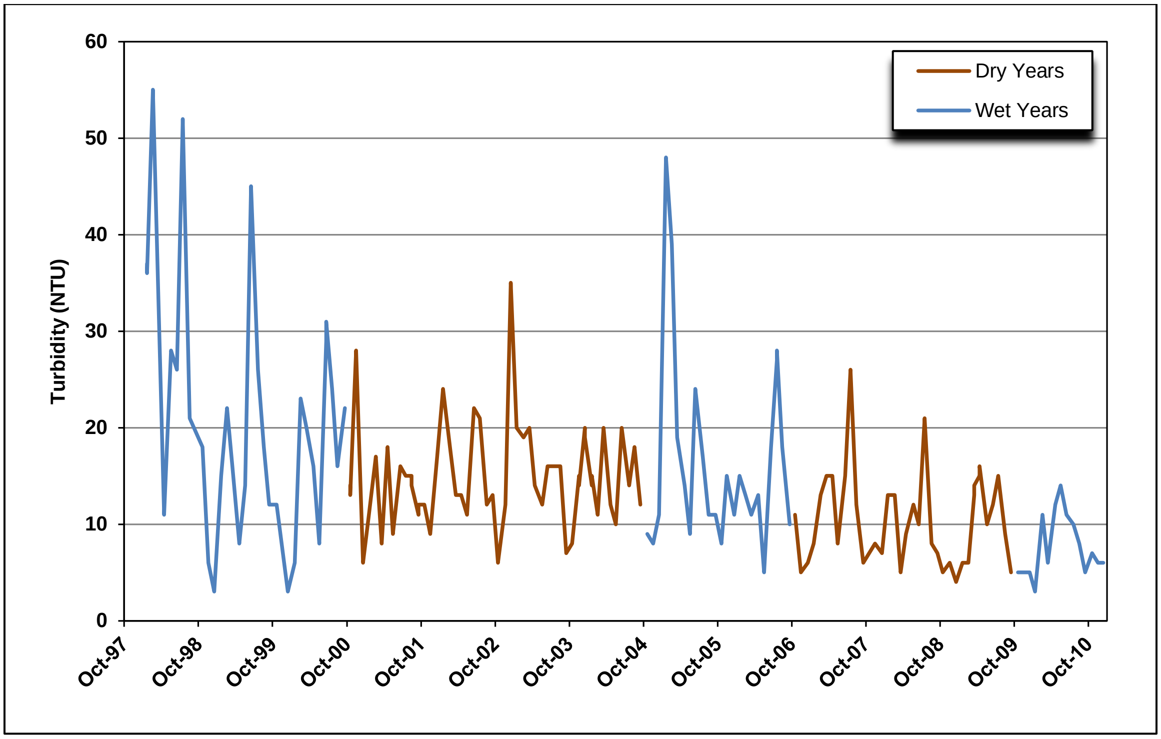
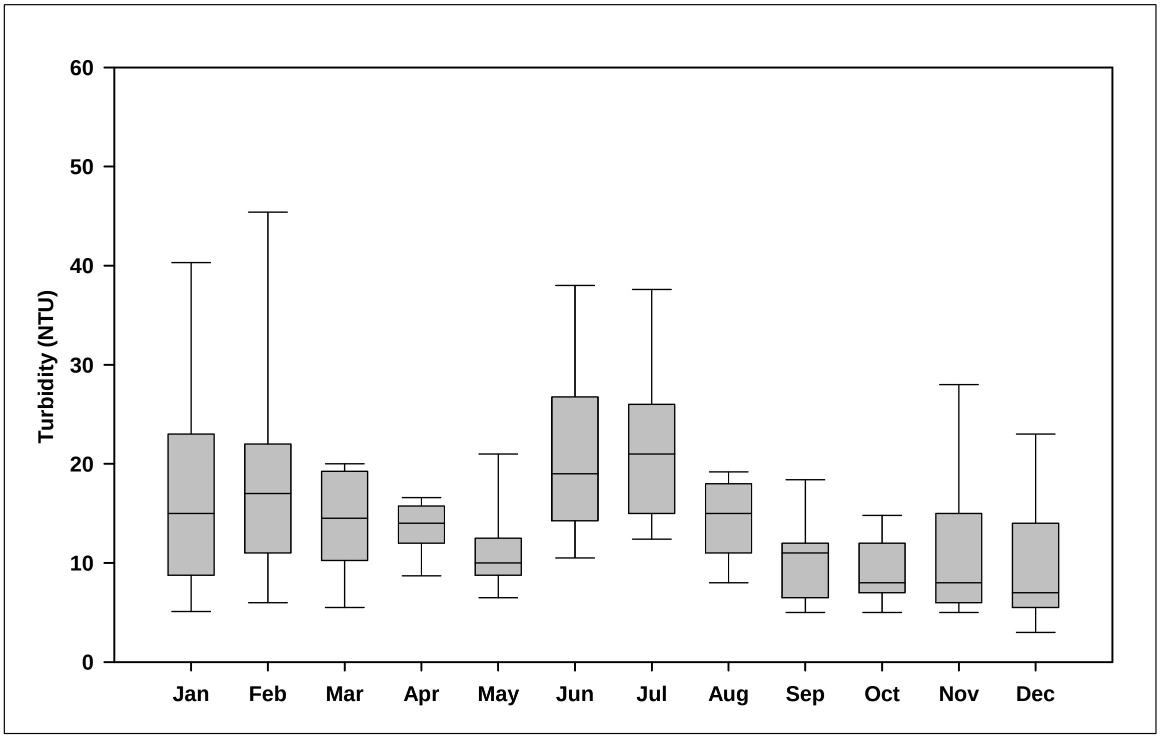


Figure 9-29. Monthly Variability in Turbidity at McCabe



Note: Insufficient data to plot all percentiles.

San Luis Reservoir – Grab sample turbidity data have been collected at Pacheco since 2000 and real-time data have been collected since 1989. **Figure 9-30** presents all of the available grab sample turbidity data for Pacheco. There is much less variability in turbidity levels in the reservoir than in the aqueduct. The turbidity levels at Pacheco range from the reporting limit (<1) to 8 NTU with a median of 2 NTU.

- Comparison of Real-time and Grab Sample Data – **Figure 9-31** shows there is good correspondence between the real-time and grab sample data collected between 2000 and 2010. It's not clear if the real-time and grab sample data would be comparable at higher levels of turbidity. The real-time data indicate that turbidity peaks in the past have exceeded the levels seen in recent years. This was due, in part, to an error in setting the turbidity meter to read a maximum of 7.999 NTU. DWR O&M adjusted the setting in September 2008.

- Spatial Trends – **Figure 9-26** shows all of the data at Pacheco, Banks, and McCabe. A subset of data collected between 2000 and 2010 at all three locations was analyzed. The median turbidity level at Pacheco (2 NTU) is statistically significantly lower than the median turbidity of 9 NTU at Banks (Mann-Whitney, p=0.0000) and the median turbidity of 12 NTU at McCabe during the 2000 to 2010 period (Mann-Whitney, p=0.0000).

- Long-Term Trends – **Figure 9-30** shows that turbidity levels appear to be slightly higher in recent years. Since there is a relatively short period of record at Pacheco, it's not clear if this is a trend or if it's related to hydrology.

- Wet Year/Dry Year Comparison – The median turbidity is 2 NTU during both dry and wet years.

- Seasonal Trends – **Figure 9-32** shows that turbidity levels are highest and more variable during the summer months, although there is little change from one month to the next since the median turbidity levels range from 1 to 3 NTU.

Figure 9-30. Turbidity Levels at Pacheco

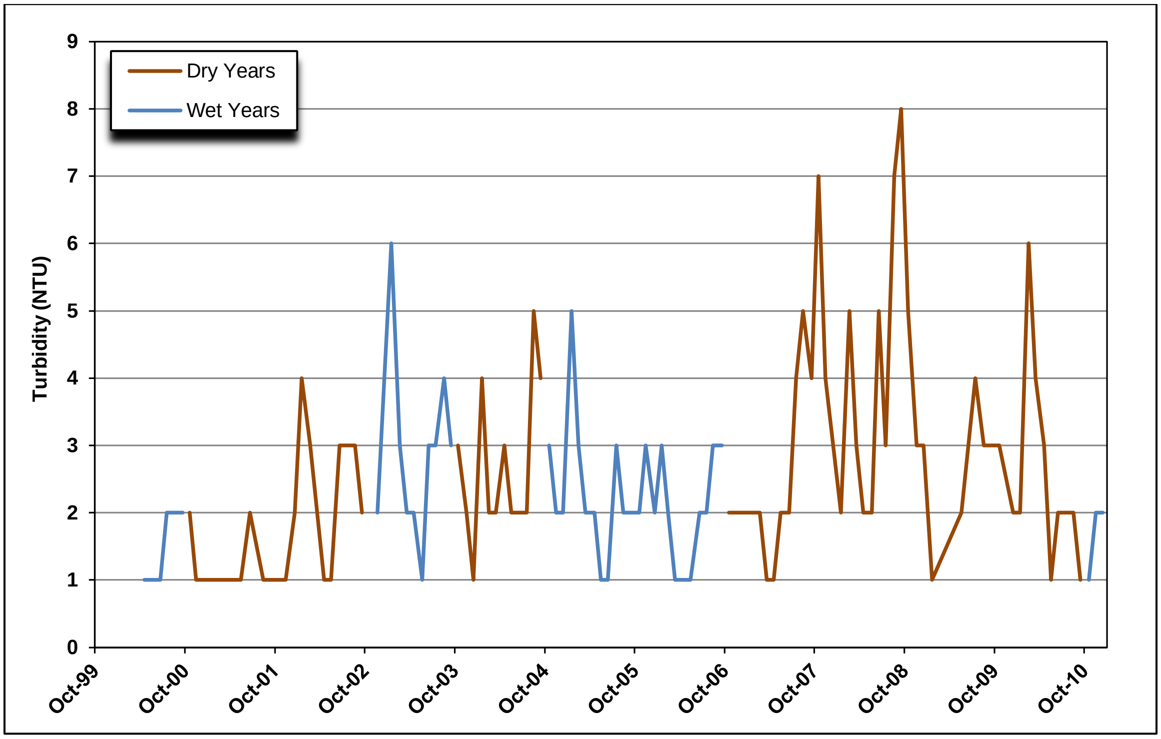


Figure 9-31. Comparison of Pacheco Real-time and Grab Sample Turbidity Data

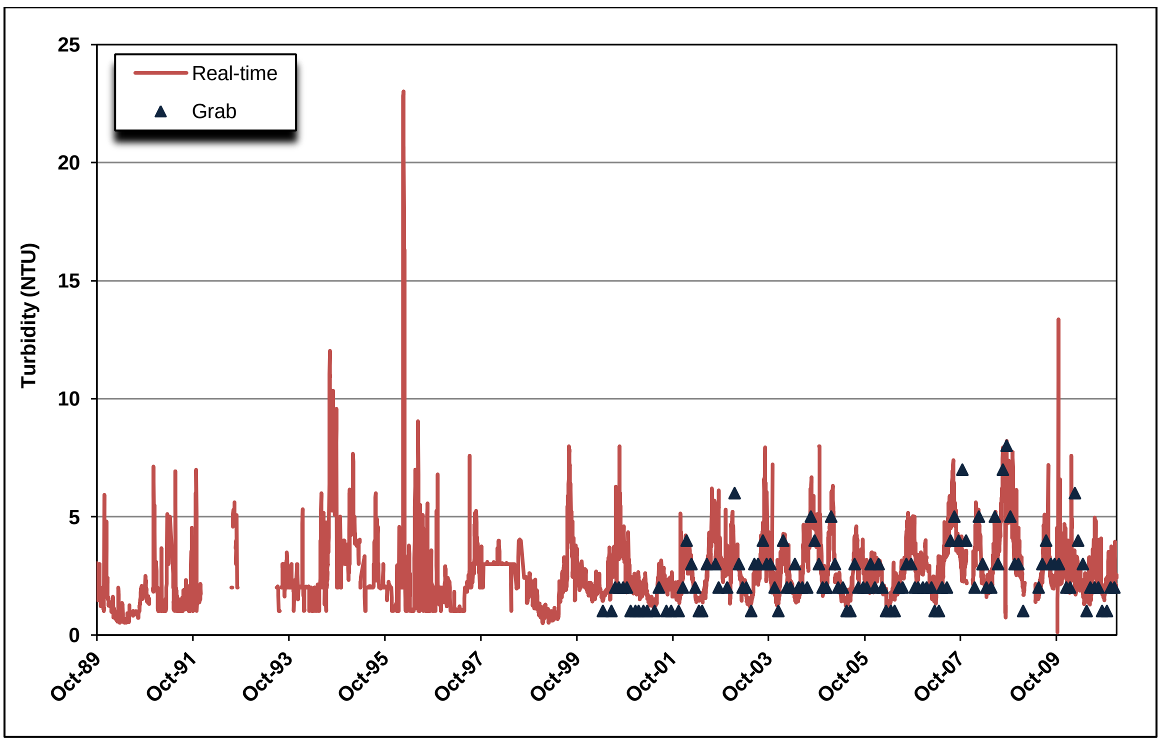
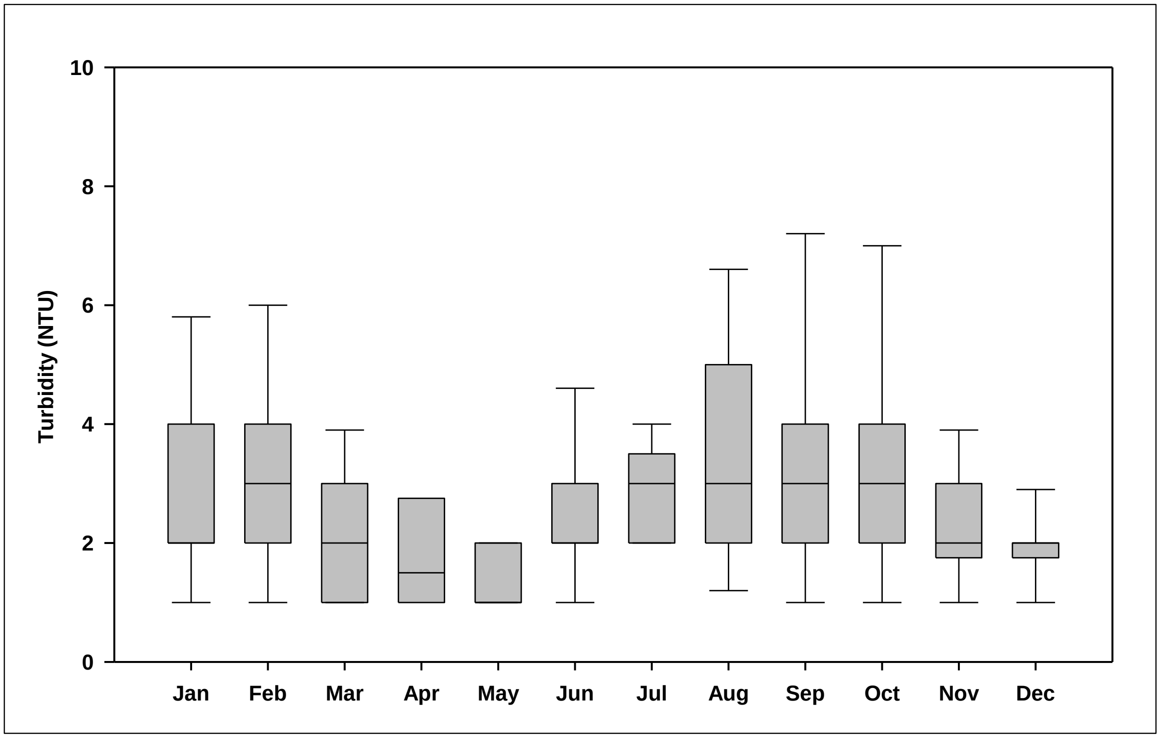


Figure 9-32. Monthly Variability in Turbidity at Pacheco



Note: Insufficient data to plot all percentiles.

O'Neill Forebay Outlet – O'Neill Forebay Outlet on the California Aqueduct is a mixture of water from San Luis Reservoir, the California Aqueduct, and the DMC. **Figure 9-33** presents the turbidity grab sample data for O'Neill Forebay Outlet. The turbidity levels at O'Neill Forebay Outlet range from <1 to 32 NTU with a median of 6 NTU.

- Comparison of Real-time and Grab Sample Data – **Figure 9-34** shows that the real-time and grab sample data generally follow the same trend; however, visual inspection of the data indicates that at low turbidity levels, the real-time measurements are generally 1 to 3 NTU higher than the grab sample measurements. At times, such as in the winter of 2008, the auto-sample results are as much as 15 NTU lower than the grab sample results.

- Spatial Trends – **Figure 9-27** compares the grab sample data collected between 1998 and 2010 at O'Neill Forebay Outlet to a number of other locations along the aqueduct. Turbidity decreases between Banks and O'Neill Forebay Outlet due to settling in the forebay and releases of low turbidity water from San Luis Reservoir. The O'Neill Forebay Outlet median turbidity of 6 NTU is statistically lower than the Banks median of 9 NTU (Mann-Whitney, p=0.0000).

- Long-Term Trends – **Figure 9-33** shows a decline in turbidity levels from 1997 to 2010. This may be due to hydrology since there were six wet years between 1995 and 2000 and there were four dry years between 2007 and 2010.

- Wet Year/Dry Year Comparison – The O'Neill Forebay Outlet dry year median turbidity of 5 NTU is statistically significantly lower than the wet year median of 7 NTU (Mann-Whitney, p=0.0001).

- Seasonal Trends – **Figure 9-35** shows there is a distinct seasonal pattern with the highest turbidity levels during the winter months and lower levels in the spring. Turbidity increases again during June and July. The summer peaks at O'Neill Forebay Outlet are similar to the peaks at Banks and McCabe, although the levels at O'Neill Forebay Outlet are lower. This is likely due to low turbidity water being released from San Luis Reservoir in the summer months.

Figure 9-33. Turbidity Levels at O'Neill Forebay Outlet

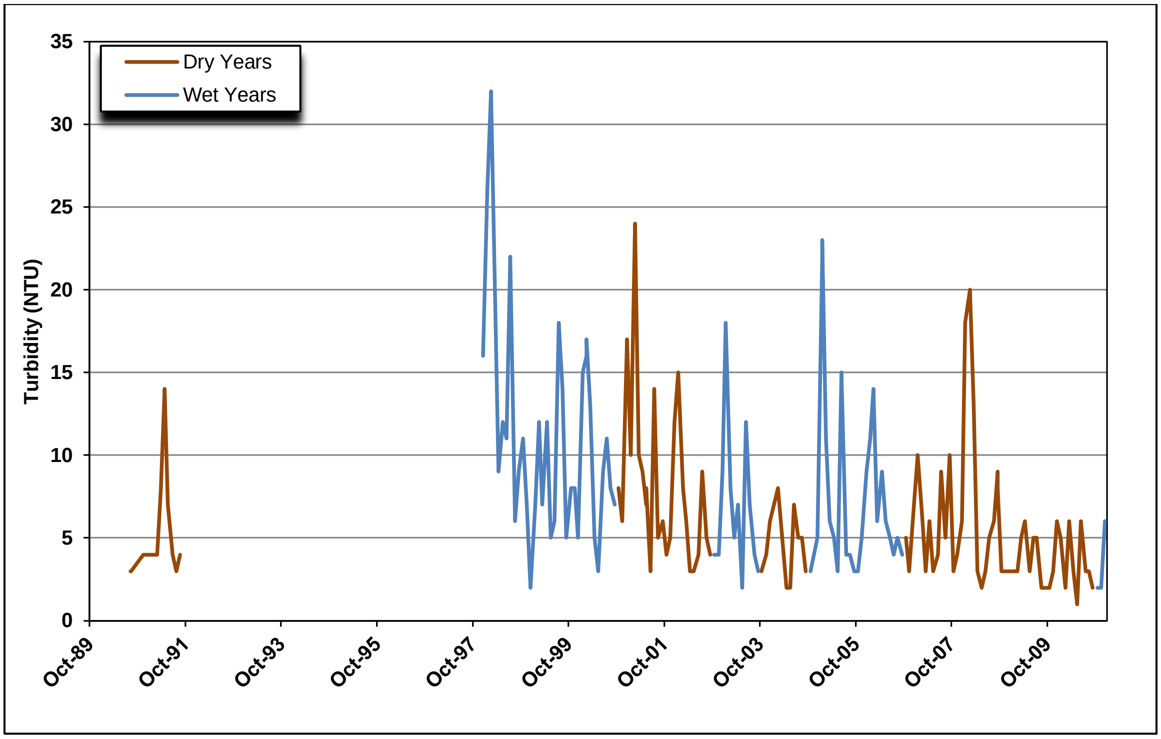


Figure 9-34. Comparison of O'Neill Forebay Outlet Real-time and Grab Sample Turbidity Levels

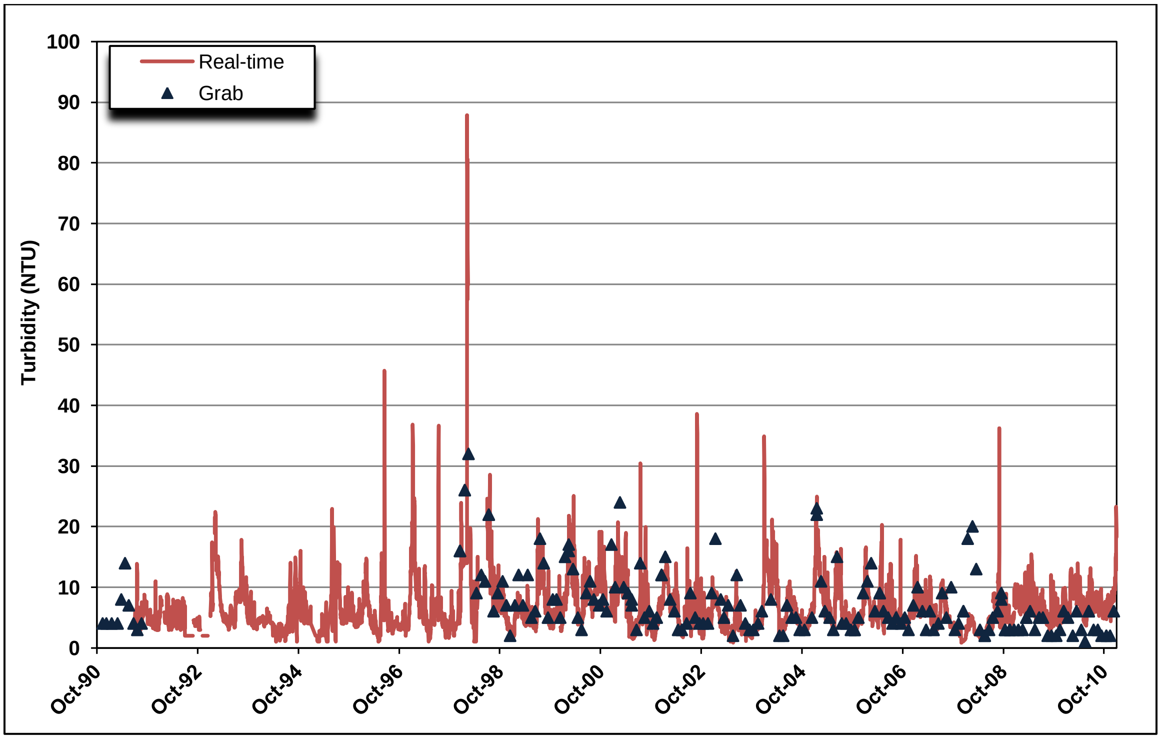
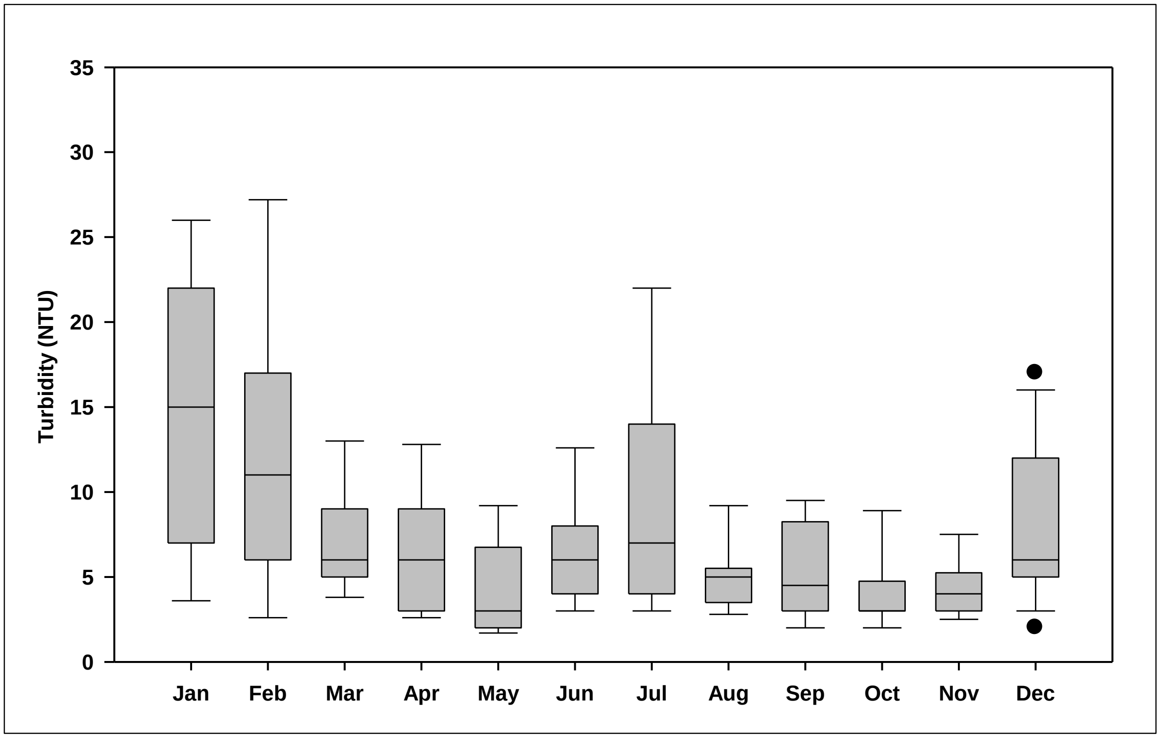


Figure 9-35. Monthly Variability in Turbidity at O'Neill Forebay Outlet



Note: Insufficient data to plot all percentiles.

Check 21 – Check 21 represents the quality of water entering the Coastal Branch. **Figure 9-36** presents the turbidity grab sample data for Check 21. The turbidity levels at Check 21 range from 1 to 71 NTU with a median of 6 NTU.

- Comparison of Real-time and Grab Sample Data – **Figure 9-37** shows that the real-time and grab sample data generally follow the same trend. Visual inspection of the data indicates that at low turbidity levels, the real-time measurements and grab sample measurements are close. There are times, such as the summer of 2008 when the real-time measurements were 4 to 6 NTU lower than the grab sample results.

- Spatial Trends – **Figure 9-27** compares the grab sample data collected between 1998 and 2010 at Check 21 to a number of other locations along the aqueduct. Although there are flood and groundwater inflows into the aqueduct between O'Neill Forebay Outlet and Check 21, the median turbidity is 6 NTU at both locations. **Figure 9-38** shows that the turbidity levels at Check 21 are higher than the levels at O'Neill Forebay Outlet during the summer months and lower during the winter months.

- Long-Term Trends – **Figure 9-36** shows higher turbidity levels between 1998 and 2001 than in recent years. This may be a function of hydrology since the earlier years were wet and the last four years were dry years.

- Wet Year/Dry Year Comparison – The Check 21 dry year median turbidity of 5 NTU is statistically significantly lower than the wet year median of 7 NTU (Mann-Whitney, p=0.0021).

- Seasonal Trends – **Figure 9-39** shows that turbidity levels increase during the winter months, decline in the spring, and then increase again in the summer. The monthly pattern is similar to the pattern at O'Neill Forebay Outlet but the peak turbidity occurs about one month later.

Figure 9-36. Turbidity Levels at Check 21

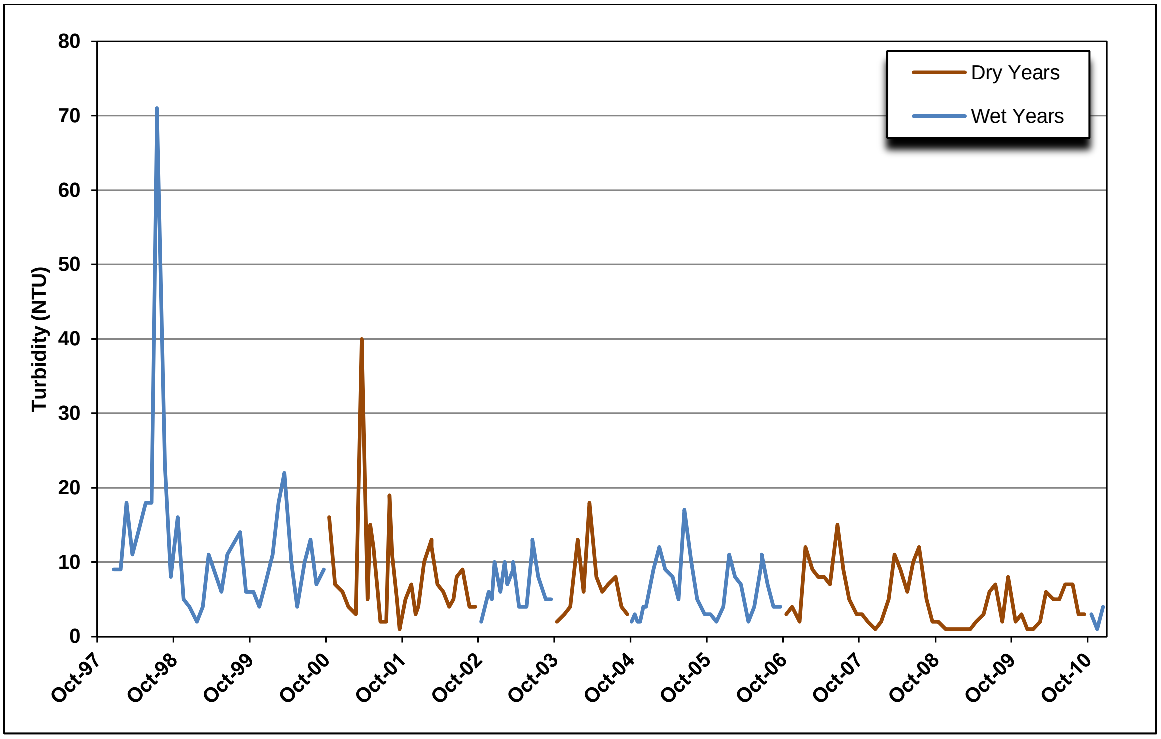


Figure 9-37. Comparison of Check 21 Real-time and Grab Sample EC Levels

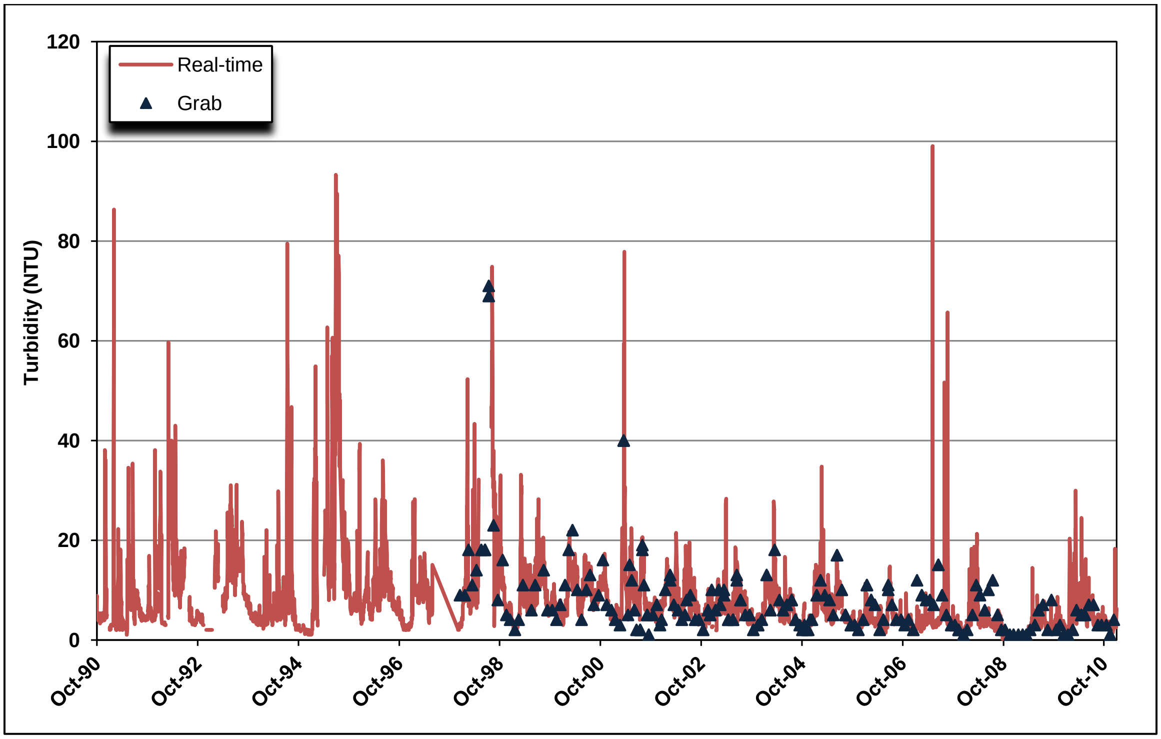


Figure 9-38. Comparison of O'Neill Forebay Outlet and Check 21 Turbidity Levels

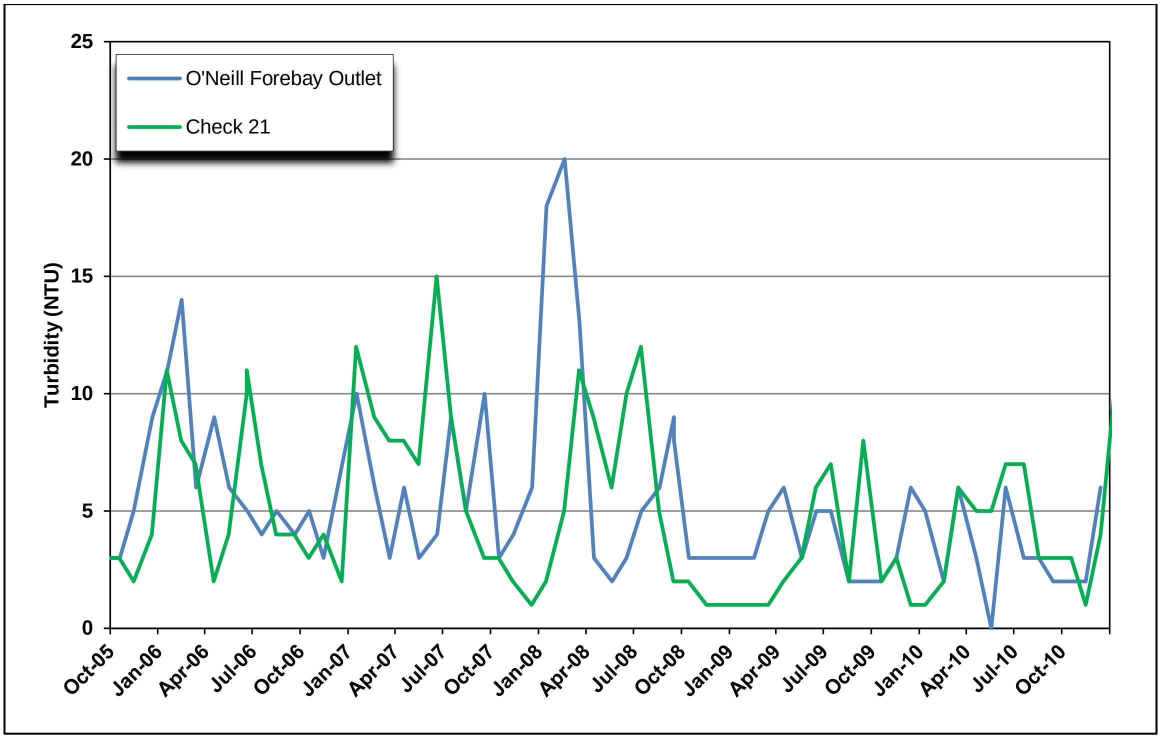
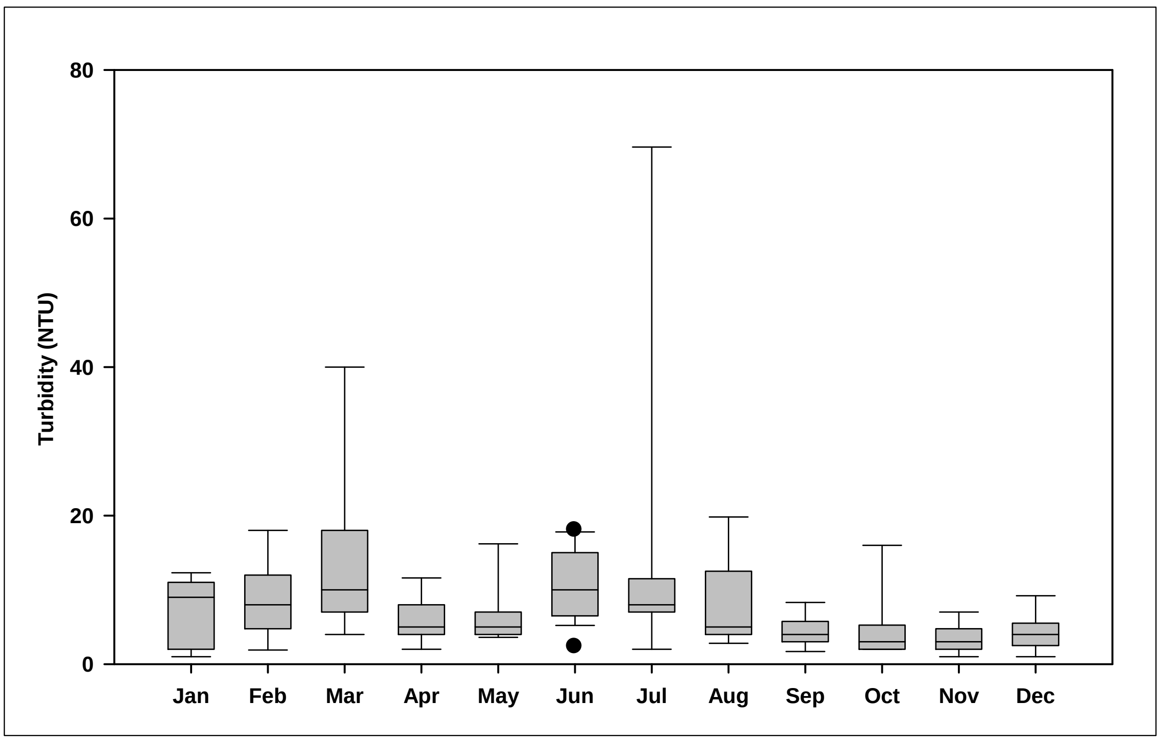


Figure 9-39. Monthly Variability in Turbidity at Check 21



Note: Insufficient data to plot all percentiles.

Check 41 – Check 41 is immediately upstream of the bifurcation of the aqueduct into the east and west branches. Data from this location can be used to evaluate changes along both branches of the aqueduct. **Figure 9-40** presents the turbidity grab sample data for Check 41. The turbidity levels at Check 41 generally range from <1 to 40 NTU with a median of 7 NTU. There was one large spike in turbidity up to 140 NTU in July 1998.

- Comparison of Real-time and Grab Sample Data – **Figure 9-41** shows that the real-time and grab sample data generally follow the same trend. Unlike many of the other locations, visual inspection of the data indicates that there is good correspondence between the real-time and grab sample data.

- Spatial Trends – **Figure 9-27** compares the grab sample data collected between 1998 and 2010 at Check 41 to a number of other locations along the aqueduct. As discussed in Chapter 14, large volumes of groundwater and some surface water enter the aqueduct between Checks 21 and 41. The median concentration at Check 41 is 1 NTU higher than at Check 21 and there is more variability in the data. **Figure 9-42** shows that during the summers of 2006, 2009 and 2010, the turbidity levels at Check 41 were substantially higher than at Check 21. The converse was true in the summers of 2007 and 2008. During May and Jun of 2006, 101,740 acre-feet of Kern River water entered the aqueduct at the Kern River Intertie. This could have been the source of the higher turbidity at Check 41. Kern River water did not enter the aqueduct in 2009 and information is not available for 2010. The source of the lower turbidity at Check 41 during the summers of 2007 and 2008 is likely inflows of water from the Kern Water Bank. Almost 30,000 acre-feet of inflows occurred in July of both years when turbidity was lowest. A substantial portion of the inflows came from the Kern Water Bank.

- Long-Term Trends – **Figure 9-40** shows turbidity levels declined between 1998 and 2008. The levels increased slightly in 2009 and 2010. The decline between 1998 and 2008 is likely a function of hydrology since the earlier years were wet and the later years were dry.

- Wet Year/Dry Year Comparison – The Check 41 dry year median turbidity of 6 NTU is statistically significantly lower than the wet year median of 9 NTU (Mann-Whitney, p=0.0013).

- Seasonal Trends – **Figure 9-43** shows that turbidity levels increase throughout the winter and spring months with the peak turbidity in July. The levels then decline during the fall months.

Figure 9-40. Turbidity Levels at Check 41

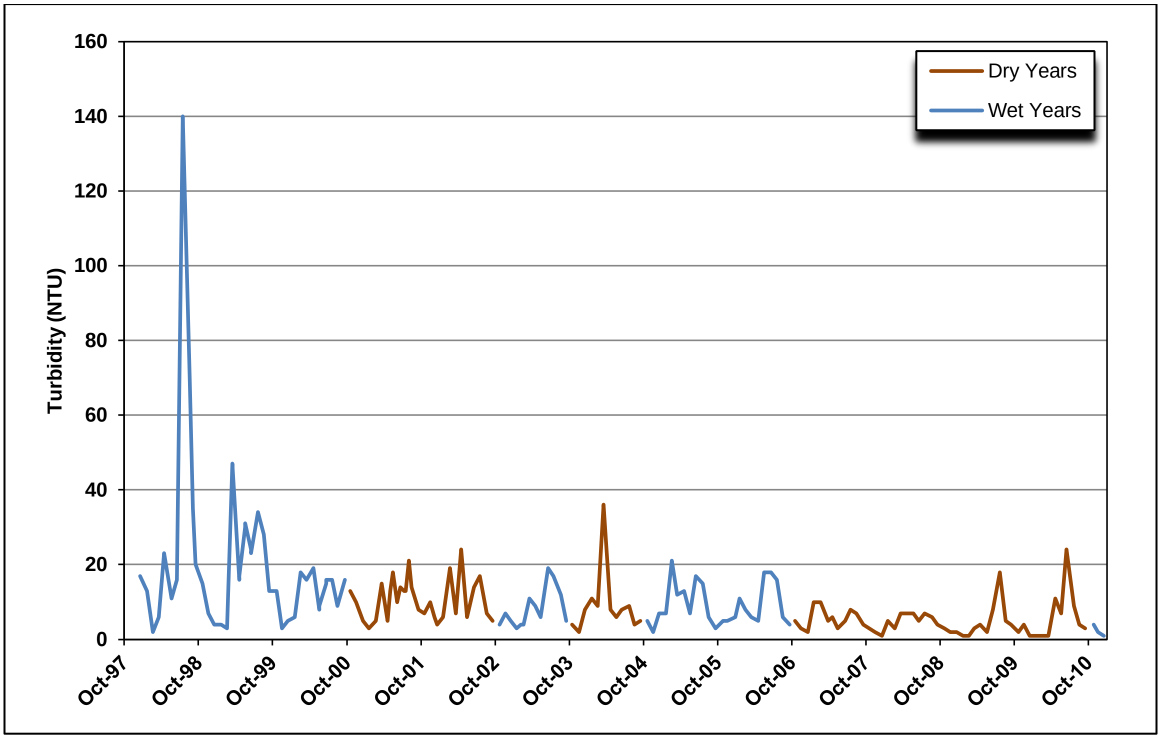


Figure 9-41. Comparison of Check 41 Real-time and Grab Sample Turbidity Levels

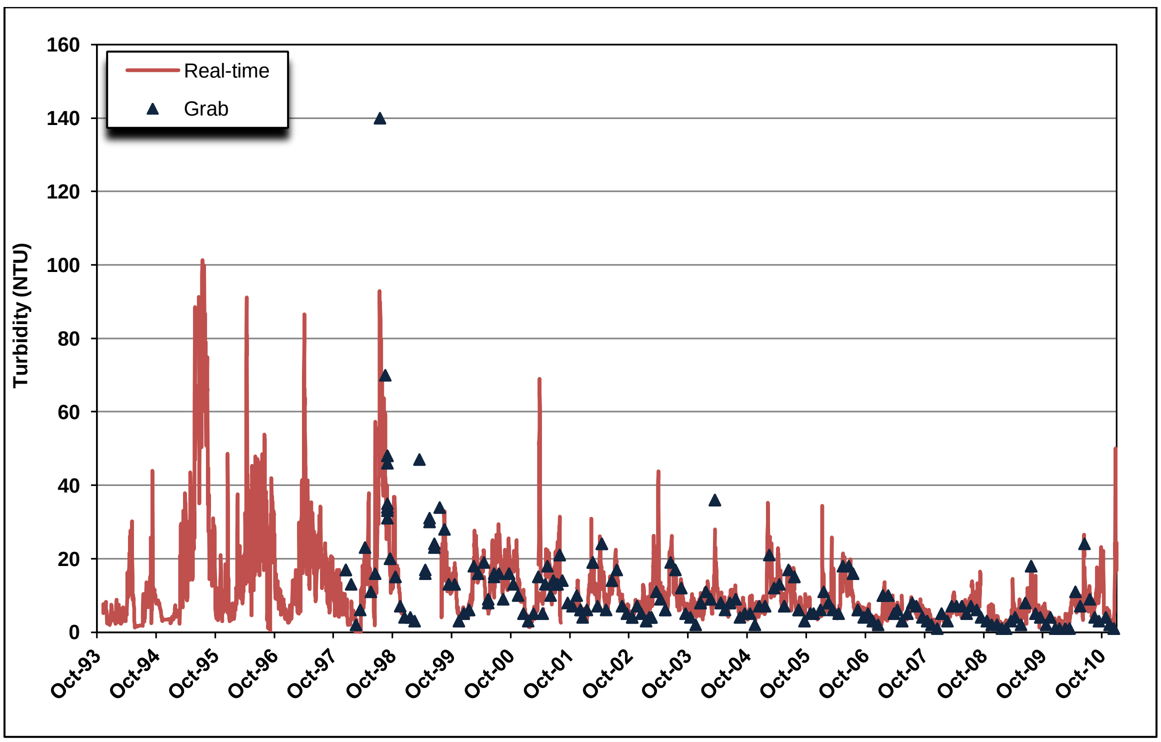


Figure 9-42. Comparison of Check 21 and Check 41 Turbidity Levels

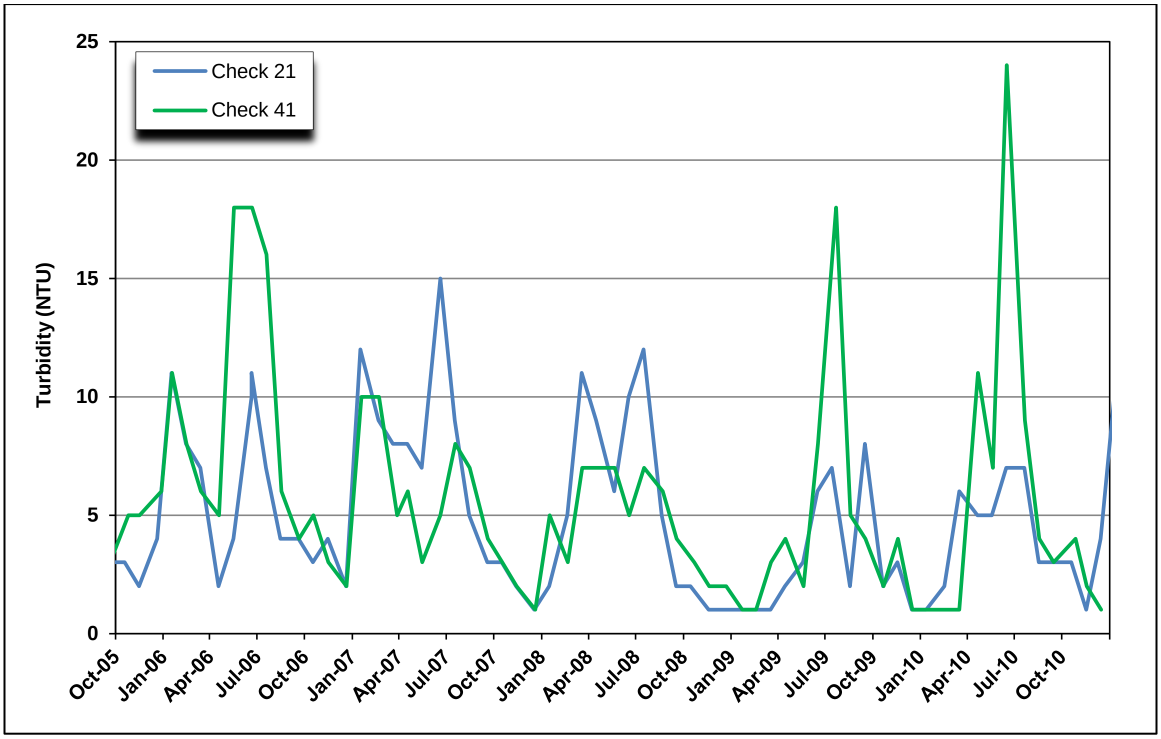
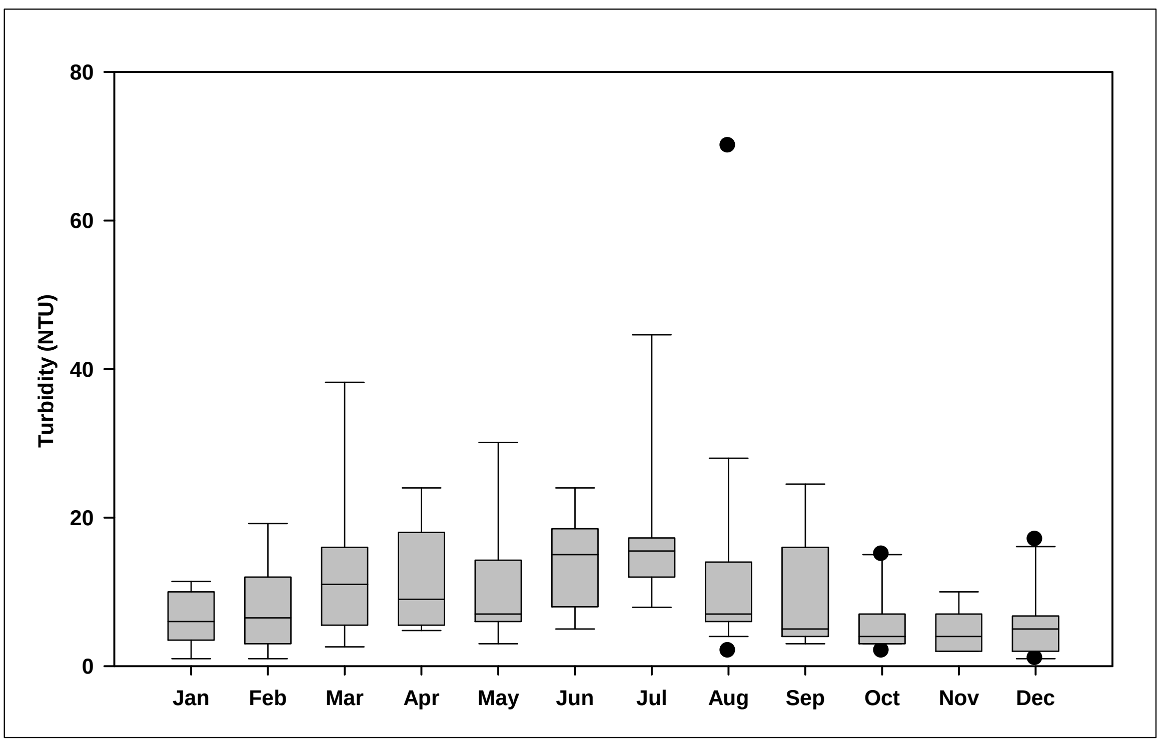


Figure 9-43. Monthly Variability in Turbidity at Check 41



Note: Insufficient data to plot all percentiles.

Castaic Outlet – Castaic Lake is the terminus of the West Branch of the California Aqueduct. **Figure 9-44** presents the turbidity grab sample data for Castaic Outlet. The turbidity levels at Castaic Outlet range from <1 to 16 NTU with most values being in the range of 1 to 4 NTU. The median turbidity is 1 NTU. There is much less variability in the turbidity data in the lake compared to the aqueduct.

- Comparison of Real-time and Grab Sample Data – **Figure 9-45** shows that the grab samples are frequently 1 to 2 NTU higher than the real-time measurements.

- Spatial Trends – Although the periods of record are different and the sampling frequency differs between Check 41 and Castaic Outlet, **Figure 9-27** clearly shows that turbidity levels in Castaic Outlet are lower than in the Aqueduct due to settling of sediment in both Pyramid and Castaic lakes.

- Long-Term Trends – A trend analysis was not conducted for this location. **Figure 9-45** shows that turbidity levels are low throughout the period of record with the exception of a spike in February 2005. This was a period of high rainfall with a large amount of runoff from the watershed.

- Wet Year/Dry Year Comparison – The median turbidity level is 1 NTU in both dry and wet years.

- Seasonal Trends – **Figures 9-44 and 9-46** indicate that turbidity generally increases above 1 NTU in August. The median monthly turbidity is 2 NTU in August. The slightly higher levels may be due to algal blooms in the lake.

Figure 9-44. Turbidity Levels at Castaic Outlet

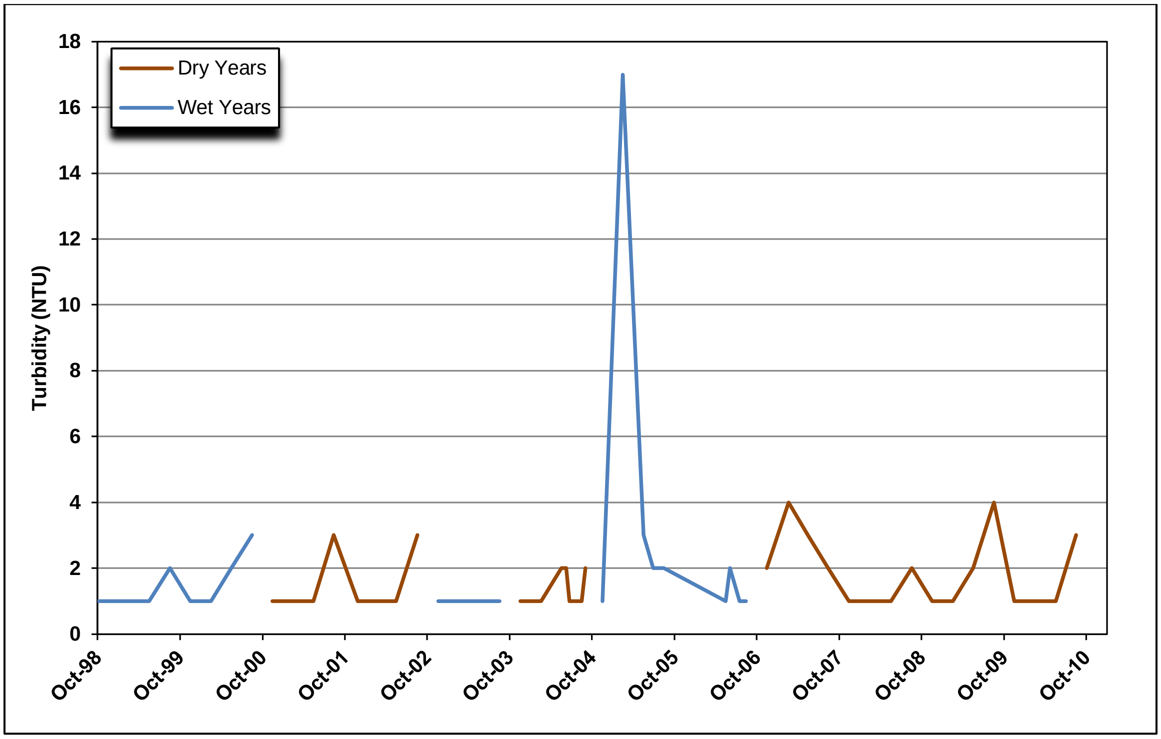


Figure 9-45. Comparison of Castaic Outlet Real-time and Grab Sample Turbidity Levels

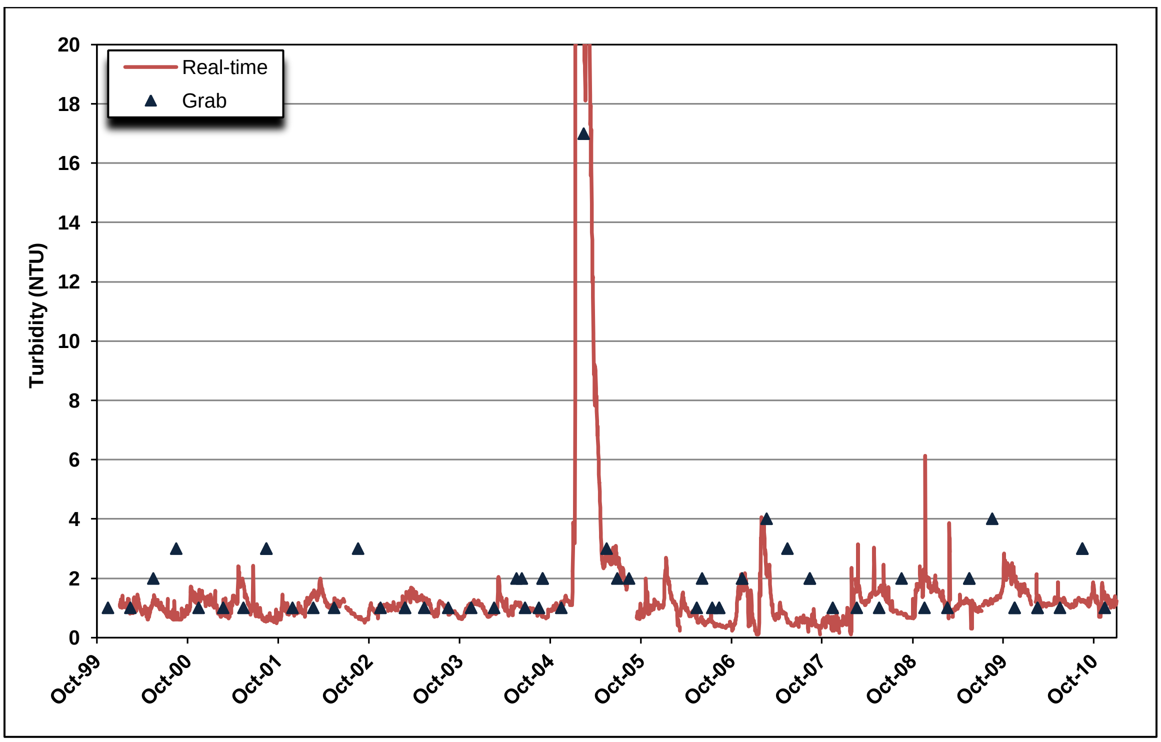
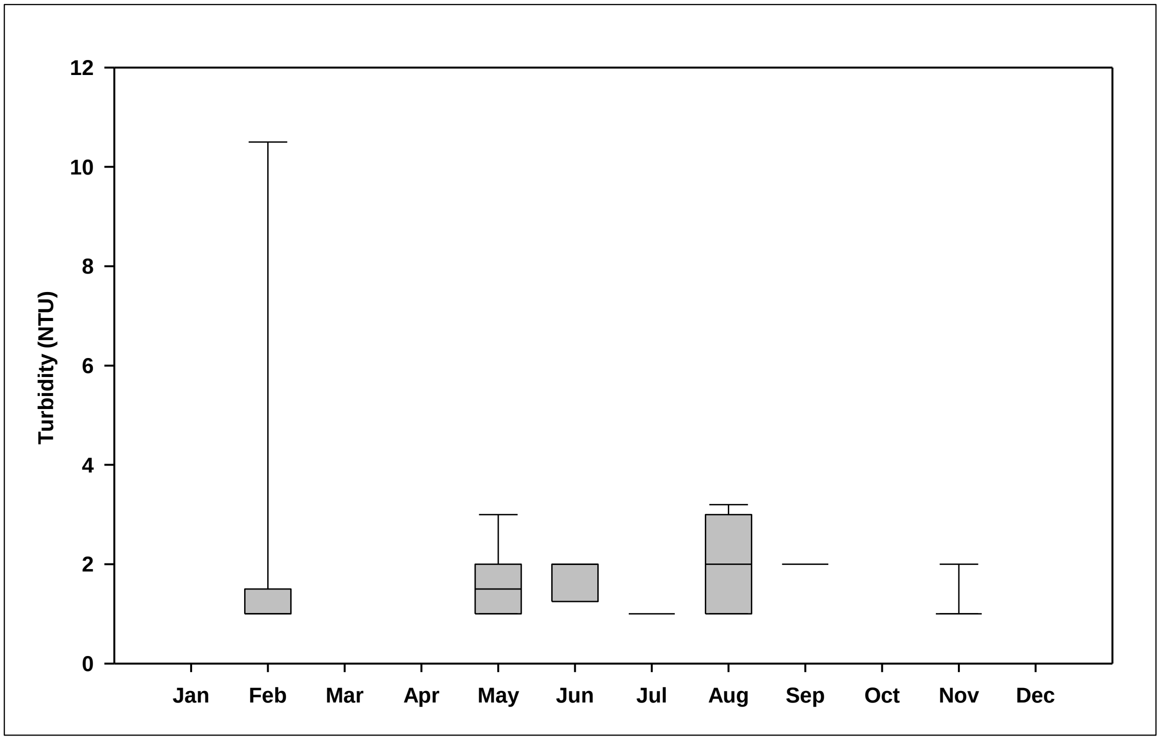


Figure 9-46. Monthly Variability in Turbidity at Castaic Outlet



Note: Insufficient data to plot all percentiles.

Devil Canyon – Devil Canyon Afterbay is downstream of Silverwood Lake on the East Branch of the California Aqueduct. **Figure 9-47** presents the turbidity grab sample data for Devil Canyon. The turbidity levels in the grab samples at Devil Canyon range from <1 to 18 NTU with the exception of one value of 167 NTU in October 2004. The median turbidity is 2 NTU. There was substantial rain and runoff from the Silverwood Lake watershed in the fall of 2004 and winter of 2005 that resulted in high turbidity at Devil Canyon. **Figure 9-48** presents the real-time data, which better illustrate the impact of the local runoff on turbidity.

- Comparison of Real-time and Grab Sample Data – **Figure 9-48** shows that there is little correspondence between the real-time and grab sample data above about 4 NTU. The grab sample measurements are often higher than the real-time measurements.

- Spatial Trends – **Figure 9-27** compares Check 41 data to Devil Canyon data for the 1998 to 2010 period when data are available at both locations. The median turbidity level of 2 NTU at Devil Canyon is statistically significantly lower than the median of 7 NTU at Check 41 (Mann-Whitney, p=0.0000). The lower levels at Devil Canyon are due to settling of sediment in Silverwood Lake.

- Long-Term Trends – **Figure 9-47** does not show any discernible trend.

- Wet Year/Dry Year Comparison – There is very little difference between turbidity levels in dry and wet years at Devil Canyon, although the dry year median turbidity level of 2 NTU is statistically significantly lower than the wet year median of 3 NTU (Mann-Whitney, p=0.0008). The statistically significant difference is due to the large number of data points but it is not meaningful since turbidity levels are very low in both wet and dry years.

- Seasonal Trends – **Figure 9-49** shows that there is little variation in turbidity throughout the year at Devil Canyon, although the data are more variable in the fall months.

Figure 9-47. Turbidity Levels at Devil Canyon

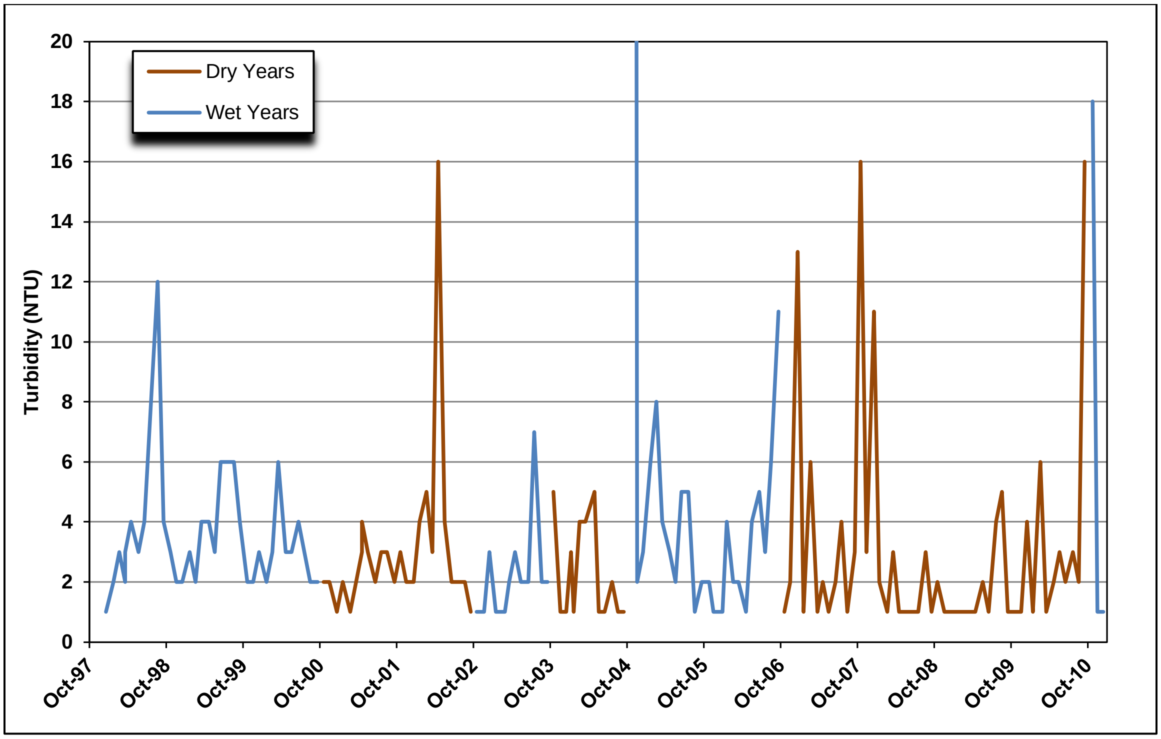


Figure 9-48. Comparison of Devil Canyon Real-time and Grab Sample Turbidity Levels

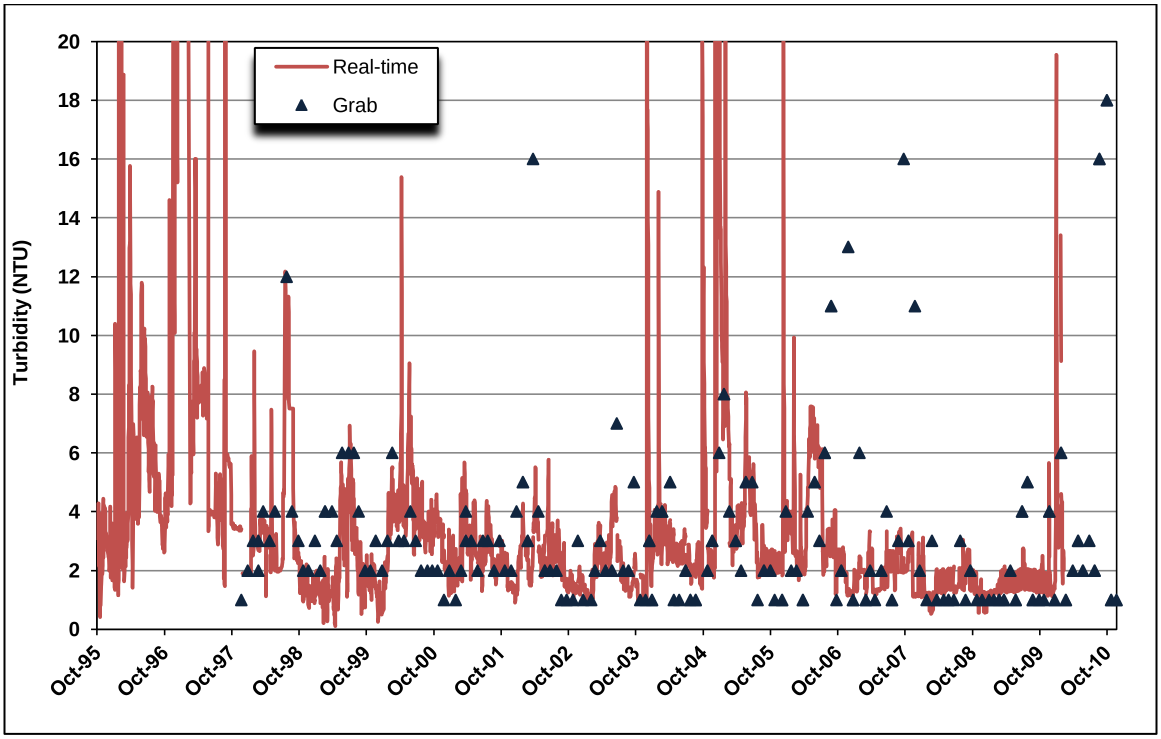
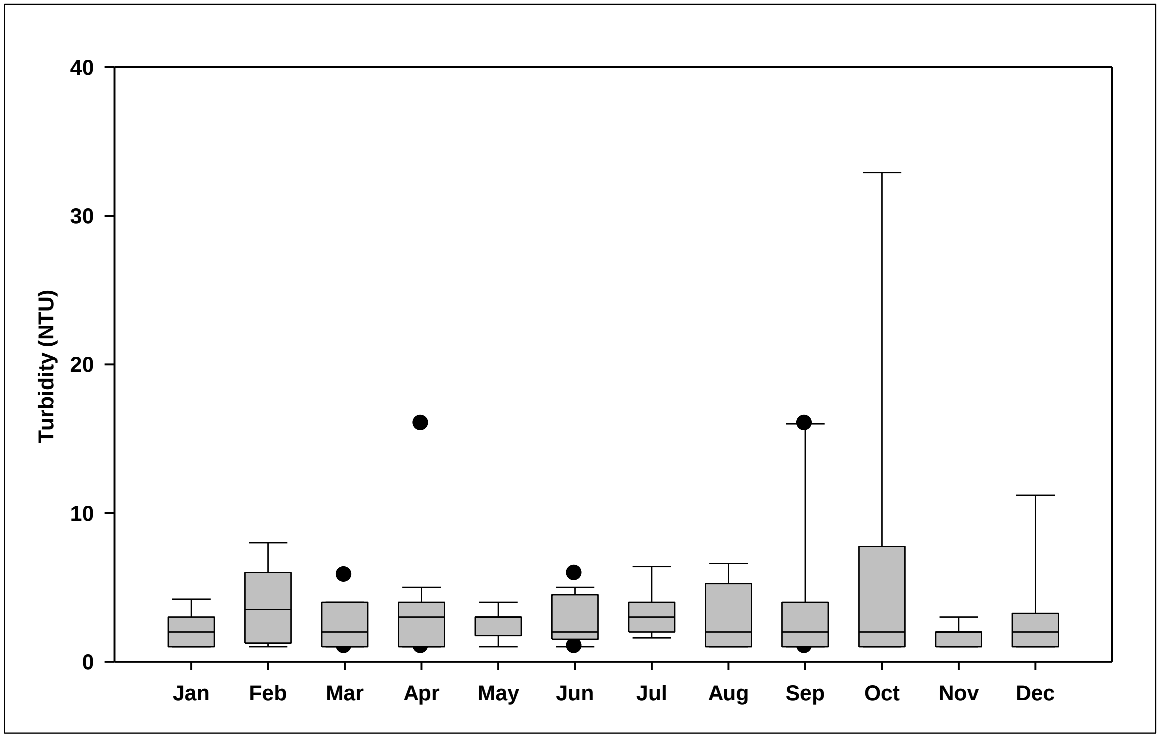


Figure 9-49. Monthly Variability in Turbidity at Devil Canyon



Note: Insufficient data to plot all percentiles.

SUMMARY

- Turbidity levels in the Sacramento River are related to flows, with higher turbidities associated with higher flows. The San Joaquin River shows the same pattern of rapidly increasing turbidity when flows first increase in the winter months; however during prolonged periods of high flows, turbidity drops back down. Median turbidity levels at Vernalis (19 NTU) are higher than at Hood (11 NTU).

- The turbidity levels at Barker Slough are substantially higher (median of 32 NTU) and more variable than at Hood or any other SWP monitoring location. Peak turbidity levels occur in the winter months and in July. The high turbidity levels create treatment challenges for the NBA Contractors.

- The median turbidity at Banks (9 NTU) is statistically significantly lower than in the Sacramento and San Joaquin rivers, reflecting settling in Delta channels and Clifton Court Forebay. Although the median turbidity is low, there is tremendous variability in turbidity at Banks. The turbidity levels at DV Check 7 on the SBA are similar to those at Banks and there is a small but statistically significant decrease with a median turbidity of 6 NTU at the Terminal Tank. This could reflect the influence of settling in Lake Del Valle. Turbidity levels are low in the SWP reservoirs with a median of 2 NTU in Pacheco and Devil Canyon and 1 NTU at Castaic Outlet. Turbidity decreases from a median of 9

NTU at Banks to a median of 6 NTU at O'Neill Forebay Outlet below San Luis Reservoir and then does not decrease significantly between O'Neill Forebay Outlet and Check 41.

- There are a number of real-time instruments measuring turbidity in the SWP. While some of the real-time data (Pacheco and Check 41) show good correspondence with the grab sample data, the others generally show poor correspondence. In most cases the real-time instruments produce results that are consistently higher than the grab samples and in some cases the real-time results are lower than the grab samples.

- Time series graphs at each key location were visually inspected to determine if there are any discernible trends. Turbidity levels appear to be lower and less variable at a few locations and there are no apparent long-term trends at most locations. Turbidity is influenced by hydrologic conditions and by system operation.

- Turbidity levels are statistically significantly lower during dry years than wet years at most locations that were included in this analysis, as shown in **Table 9-2**. At several locations, including San Luis Reservoir and Castaic Outlet, there was no statistically significant difference between dry and wet years.

- The seasonal patterns vary greatly. The Sacramento River has high turbidity during the winter months and low turbidity during the summer. The San Joaquin River shows an opposite pattern with high turbidity during the summer. The seasonal pattern at Banks is similar to the San Joaquin River. Along the aqueduct, there are peaks in the winter months and again in June or July.

Table 9-2. Comparison of Dry Year and Wet Year Turbidity Levels

Location	Median Turbidity (NTU)		Turbidity Difference (NTU)	Percent Difference	Statistical Significance
	Dry Years	Wet Years			
Hood	10	12	-2	-20	D<W
Vernalis	19	18	1	5	No
Banks	8	10	-2	-25	D<W
Barker	28	39	-11	-39	D<W
DV Check 7	8	9	-1	-13	No
McCabe	13	14	-1	-8	No
Pacheco	2	2	0	0	No
O'Neill Forebay Outlet	5	7	-2	-40	D<W
Check 21	5	7	-2	-40	D<W
Check 41	6	9	-3	-50	D<W
Castaic Outlet	1	1	0	0	No
Devil Canyon	2	3	-1	-50	D<W

CHAPTER 10 PATHOGENS AND INDICATOR ORGANISMS

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CHAPTER 10 PATHOGENS AND INDICATOR ORGANISMS

Source waters may be contaminated with a number of pathogenic bacteria, viruses, and protozoa, along with non-pathogenic naturally occurring microorganisms. Routine monitoring for all possible pathogens is impractical so the focus of most source water monitoring is on indicator bacteria and the regulated pathogenic protozoa, *Giardia* and *Cryptosporidium.*

Under the Surface Water Treatment Rule (SWTR), the general requirements are to provide treatment to ensure at least 3-log reduction of *Giardia* cysts and at least 4-log reduction of viruses. The California SWTR Staff Guidance Manual provides a description of source waters that require additional treatment above the minimum 3-log *Giardia* and 4-log virus reduction (California Department of Health Services, 1991). The Guidance Manual states:

> *"...in a few situations, source waters are subjected to significant sewage and recreational hazards, where it may be necessary to require higher levels of virus and cyst removals..."*

Due to the expense and uncertainties associated with pathogen monitoring, California Department of Public Health (CDPH) staff historically relied on monthly median total coliform levels as a guide for increased treatment. When monthly medians exceeded 1,000 most probable number per 100 milliliters (MPN/100 ml), CDPH staff considered requiring additional log reduction. Coliform bacteria have been used for decades to assess the microbiological quality of drinking water. These bacteria are present in the intestines of humans and other warm-blooded animals and are found in large numbers in fecal wastes. Most species occur naturally in the aquatic environment so their presence does not always indicate fecal contamination. More recently, CDPH staff has started to rely upon fecal coliform and *Escherichia coli* (*E. coli)* as more specific indicators of mammalian fecal contamination. When the monthly median *E. coli* or fecal coliform density exceeds 200 MPN/100 ml, CDPH staff considers requiring additional log reduction. Evaluation of pathogen reduction levels based on coliform bacterial density is not as scientifically valid as basing them on actual pathogen concentrations. The relationship between coliforms and pathogenic cysts is tenuous, but in the absence of other information, CDPH uses coliform density to determine required pathogen reduction levels for individual water treatment plants (WTPs).

The Interim Enhanced Surface Water Treatment Rule (IESWTR) requires 2-log reduction of *Cryptosporidium*. Additional removal/inactivation of *Cryptosporidium* may be required based on source water monitoring for *Cryptosporidium* conducted in accordance with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Filtered water systems are classified in one of four bins based on their monitoring results, as shown in **Table 10-1**.

Table 10-1. LT2ESWTR Bin Classification and Action Requirements

Bin Classification	Maximum Running Annual Average (oocysts/L)	Action Required (log reduction)
1	< 0.075	none
2	0.075 to < 1.0	1
3	1.0 to < 3.0	2
4	≥ 3.0	2.5

To the extent data are available, both protozoan and coliform densities are presented and discussed in this chapter for the State Water Project (SWP) Contractors treating water from the various reaches of the SWP. Data were provided by a number of SWP Contractors and by the Department of Water Resources (DWR) Division of Operations and Maintenance (O&M) SWP Water Quality Monitoring Program. There is considerable variability in the data that were provided including varying sampling frequencies (daily to monthly), different methods for determining indicator bacteria densities, and different periods of record. All useful, available data are included in this chapter. To calculate median densities, data results that were reported as non-detectable were set to zero and those results that were reported as greater than an upper limit were set at the specific upper limit.

NORTH BAY AQUEDUCT

The Solano County Water Agency (SCWA) and Napa County Flood Control and Water Conservation District (Napa County) have contracts with DWR for North Bay Aqueduct (NBA) water. SCWA provides untreated water to Travis Air Force Base (AFB) and the cities of Benicia, Fairfield, Vacaville, and Vallejo. Fairfield and Vacaville receive treated water from the 40-million gallons per day (mgd) North Bay Regional (NBR) WTP, Benicia treats water at the 12-mgd Benicia WTP, and Vallejo treats NBA water at the 42-mgd Fleming Hill WTP, as well as the 7.5 mgd Travis AFB WTP. Napa County provides untreated water to the cities of American Canyon, Calistoga, Napa, and Yountville. The City of American Canyon operates a 5.5 mgd WTP. The City of Napa treats water at the 12-mgd Jameson Canyon WTP and provides treated water for the cities of Napa, Calistoga, and Yountville. The NBA is an enclosed pipeline, with the exception of the Cordelia Forebay (surface area of 2 acres). Collectively, the NBA provides municipal water for approximately 500,000 people in Napa and Solano counties.

While there is variability in some water quality constituents between Barker Slough and the WTP intakes, microbiological data collected at Barker Slough and at the NBR WTP intake are considered to be representative of the quality of water received by all of the cities and Travis AFB.

PROTOZOA

DWR's O&M Division collected monthly *Giardia* and *Cryptosporidium* samples at Barker Slough from January 2006 through September 2008 to comply with the LT2ESWTR. The samples were analyzed using USEPA Method 1623. There were no detects of *Cryptosporidium*, therefore the maximum running annual average (RAA) for *Cryptosporidium* during that period was 0 oocysts/L. Since this is below the trigger of 0.075 oocysts/L, the source is placed in Bin 1 under the LT2ESWTR and requires no additional action at this time. Most of the *Giardia* samples (29 out of 33) were reported as non-detects also, with the detection limit of 0.1 cysts/L in most samples. **Table 10-2** presents the data collected on days that *Giardia* was detected. These data indicate that when protozoa are detected, *E. coli* densities are generally at or above 30 MPN/100 ml. However, there were many samples with *E. coli* at or above this level with no detected protozoa. These data are similar to the data presented in the California State Water Project Watershed Sanitary Survey 2006 Update (2006 Update).

Table 10-2. Protozoan Detections at Barker Slough Pumping Plant, DWR Monitoring Program

Date	*Giardia* (cysts/L)	*Crypto-sporidium* (oocysts/L)	Turbidity (NTU)	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	*E. coli* (MPN/100 ml)
1/18/06	0.1	<0.1	40	170	130	80
2/15/06	0.1	<0.1	36	170	30	30
4/18/07	0.3	<0.1	32	>2419	-	93.3
12/19/07	0.1	<0.1	23.8	285.1	-	45.5

In addition to these protozoa data, the City of Fairfield also conducted protozoa monitoring during the study period at the Barker Slough Pumping Plant. Fourteen samples were collected approximately quarterly in 2006, 2007, 2008, and 2010. Only three samples had detectable *Giardia* (two in 2006 and one in 2007) and four samples had detectable *Cryptosporidium* (two in 2006, one in 2008, and one in 2010). **Table 10-3** provides a summary of the annual average data for both protozoa. The annual average levels of both protozoa were highest in 2006, with significantly lower levels in the other years. There are no companion coliform data to assess the overall water quality.

Table 10-3. Annual Average Protozoan Levels at Barker Slough Pumping Plant, City of Fairfield Monitoring Program

Year	Annual Average Giardia (cysts/L)	Annual Average Cryptosporidium (oocysts/L)
2006	0.17	0.27
2007	0.025	0
2008	0	0.07
2010	0	0.025

INDICATOR ORGANISMS

The available total and fecal coliform data were also analyzed to provide more information on the microbial quality of the NBA. The most comprehensive data are collected at the NBR WTP intake. NBA water is treated at the NBR WTP primarily from May or June through November or December and Solano Project water from Lake Berryessa is treated during the wet season. During the periods when NBA water is treated, samples are collected almost every day from the NBR WTP intake.

Total coliform densities ranged from 30.3 to 30,760 MPN/100 ml, with a median density of 1,553 MPN/100 ml. The peak total coliform density measured at the NBR WTP intake was 30,760 MPN/100 ml on September 17, 2010. A number of samples collected were not diluted sufficiently during analysis so results were reported as greater than 2,419 MPN/100 ml, so the actual peak levels cannot be confirmed. **Figure 10-1** presents the monthly median total coliform data for the NBR WTP intake and **Figure 10-2** presents the fecal coliform data. The monthly median total coliform densities ranged from 190 to 8,215 MPN/100 ml. The median densities in most months exceed 1,000 MPN/100 ml. The monthly median peak values are greater than those presented in the 2006 Update.

Fecal coliform densities ranged from 2 to greater than 1,600 MPN/100 ml, with a median density of 80 MPN/100 ml. The peak fecal coliform density measured at the NBR WTP intake was 1,600 MPN/100 ml. This occurred on numerous occasions throughout the year. Several samples collected were reported as greater than 1,600 MPN/100 ml, so the actual peak levels cannot be determined. The monthly median fecal coliform densities ranged from 8 to 220 MPN/100 ml. The monthly median fecal coliform densities were below 200 MPN/100 ml, with the exception of November 2008. The monthly median peak values were similar to those presented in the 2006 Update.

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

Although the monthly median total coliform densities exceed 1,000 MPN/100 ml during several months of the year at the intake to the NBR WTP, median fecal coliform densities are almost always less than 200 MPN/100 ml during the months that the NBR treats NBA water. Sufficient data were not available during the wet season to fully evaluate median coliform levels.

The monthly protozoan monitoring that has been conducted at the Barker Slough Pumping Plant by DWR indicates that *Cryptosporidium* was not detected and *Giardia* was only occasionally detected (4 out of 33 samples positive). Although the Barker Slough watershed does not contain significant sources of human wastes, a large amount of the watershed is devoted to cattle and sheep grazing. The *Cryptosporidium* and *E. coli* monitoring required by the LT2ESWTR confirm that the current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements are adequate for the WTPs that treat NBA water.

Figure 10-1. Monthly Median Total Coliforms at the NBR WTP Intake

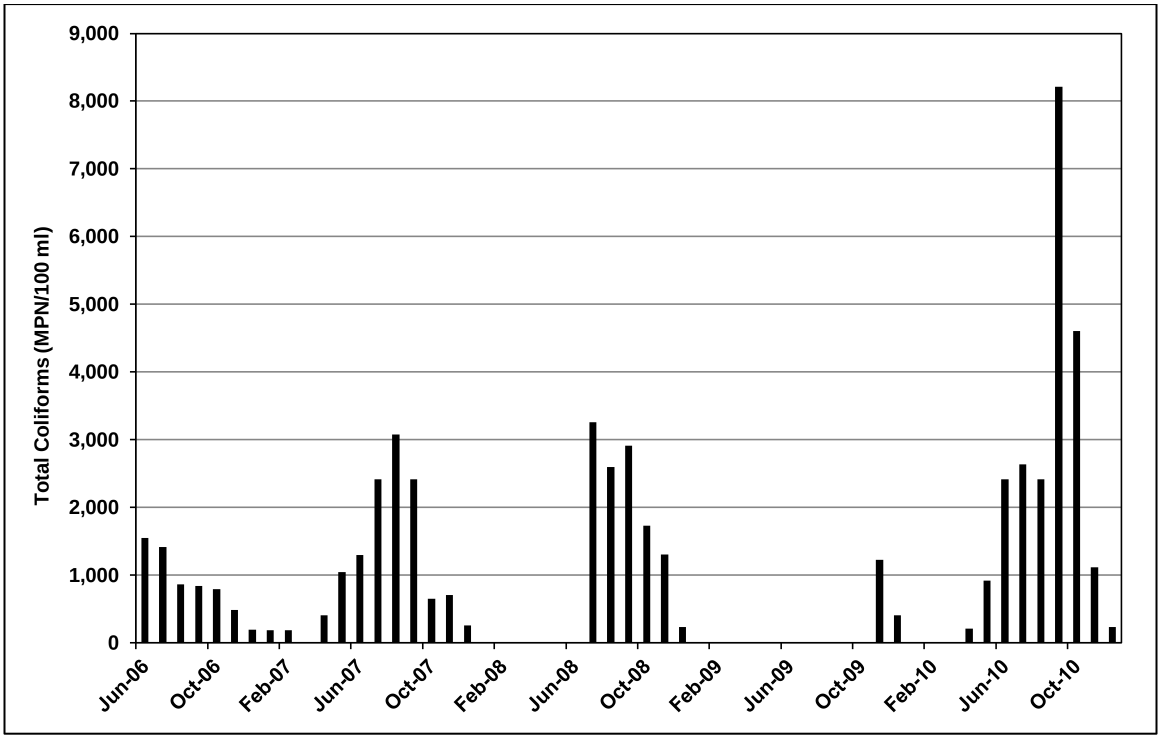
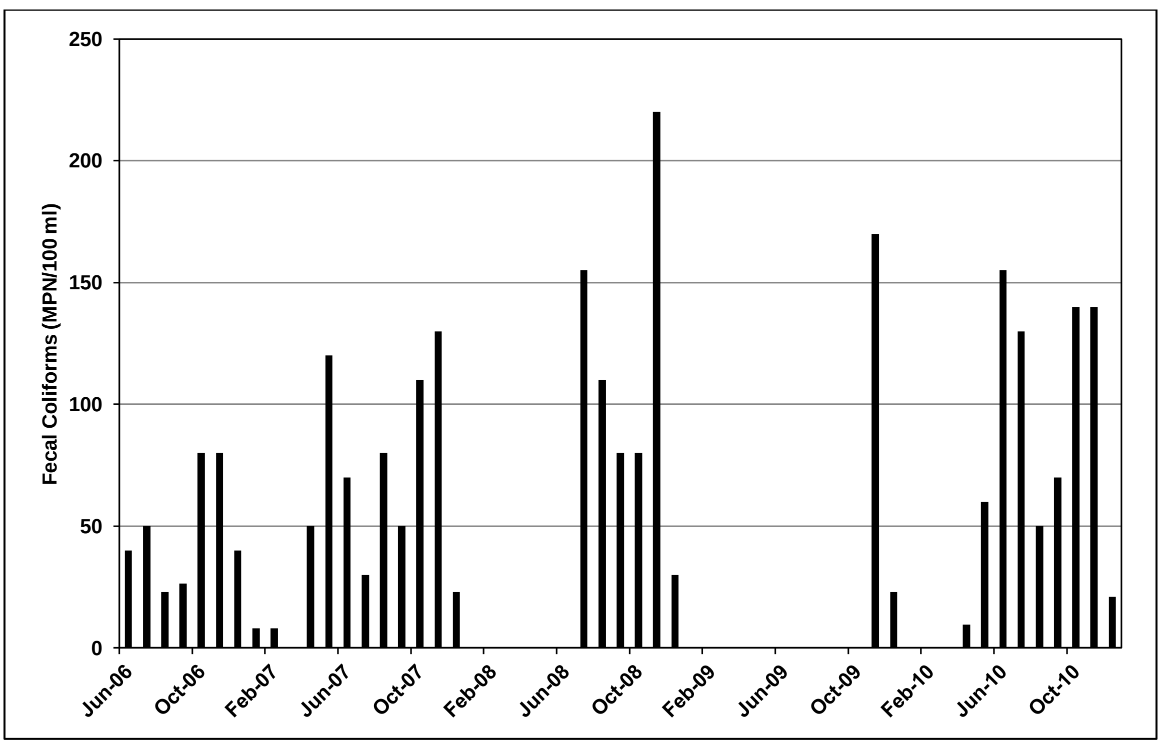


Figure 10-2. Monthly Median Fecal Coliforms at the NBR WTP Intake



SOUTH BAY AQUEDUCT

Three water agencies have contracts with DWR to receive water from the South Bay Aqueduct (SBA): Zone 7 Water Agency of the Alameda County Flood Control and Water Conservation District (Zone 7 Water Agency), Alameda County Water District (ACWD), and Santa Clara Valley Water District (SCVWD). Together, the SBA Contractors provide treated drinking water to nearly two million people in the San Francisco Bay Area. Zone 7 Water Agency provides drinking water from two water treatment plants (19-mgd Patterson Pass and 40-mgd Del Valle) to four retail water systems in the Livermore Valley (cities of Pleasanton and Livermore, Dublin San Ramon Services District, and Cal Water Service Company – Livermore). Zone 7 Water Agency also provides drinking water to 12 direct users, including a local vineyard, hospital, and park. The Patterson Pass WTP intake is upstream of the point where Lake Del Valle enters the SBA so it treats 100 percent SBA water, whereas the Del Valle WTP treats varying blends of SBA and Del Valle water. ACWD provides drinking water to customers in Fremont, Newark, and Union City. ACWD operates two surface water treatment plants, the 8.5-mgd Mission San Jose WTP (MSJWTP) and 28-mgd WTP2. The intakes to these two WTPs are next to each other and downstream of the point where Lake Del Valle enters the SBA so they treat varying blends of SBA and Del Valle water. SCVWD provides treated water from the 40-mgd Penitencia, 80-mgd Rinconada, and 100-mgd Santa Teresa WTPs (primarily uses San Luis Reservoir water) to seven retailers in Santa Clara County. The Penitencia WTP primarily treats varying blends of SBA and Lake Del Valle water but at times water from San Luis Reservoir and Anderson Reservoir (a local SCVWD reservoir) is treated at the Penitencia WTP. Although the Penitencia plant occasionally treats water that comes from San Luis Reservoir and the local reservoirs that are not part of the SWP, the analysis of the protozoan and bacteria data was conducted on all of the data that was provided by SCVWD. This is appropriate because the analysis is specific to a water treatment plant and the data are not being used to compare different locations along the SWP. Since the SBA is an enclosed pipeline after water from Lake Del Valle enters it, the microbial quality of Del Valle, MSJWTP, WTP2, Penitencia, and Rinconada WTPs should be similar.

PROTOZOA

The SBA Contractors conducted their LT2ESWTR monitoring between 2003 and 2005 and were assigned a Bin 1 classification by CDPH. SCVWD continued to monitor *Giardia* and *Cryptosporidium* at the Penitencia and Rinconada WTPs between 2006 and 2010. As shown in **Table 10-4**, *Cryptosporidium* was not detected at the Penintencia WTP, but was detected twice at the Rinconada WTP. *Giardia* was detected once at each WTP, at 0.1 cyst/L. The maximum running annual average (RAA) of *Cryptosporidium* at both WTPs is very low, below the Bin 1 threshold limit of 0.075 oocysts/L. These data are consistent with the data collected for LT2ESWTR compliance.

INDICATOR ORGANISMS

Coliform data were available for varying periods of time for each of the treatment plants that treat water from the SBA. The total coliform and *E. coli* data for each WTP was compiled and evaluated. **Table 10-5** provides a summary of the statistics for the individual samples at each WTP. The data show a wide range in both total coliform and *E. coli* densities at each of the

WTPs. The overall median density of total coliforms is less than 600 MPN/100 ml and *E. coli* is less than 50 MPN/100 at all of the WTPs. Peak values were seen at WTP2, in July 2006. The peak monthly median values for total coliforms occurred during the summer months while the peak monthly median values for *E. coli* occurred during the winter months.

Table 10-4. Protozoan Detections at Penitencia and Rinconada WTPs, SCVWD Monitoring Program

WTP	Monitoring Period	No. of Samples	***Cryptosporidium*** **(oocysts/L)**		***Giardia*** **(cysts/L)**	
			No. of Detects	**Maximum RAA**	**No. of Detects**	**Maximum RAA**
Penitencia	1/17/06 – 12/14/10	55	0	0	1	0.008
Rinconada	1/17/06 – 12/14/10	59	2	0.009	1	0.008

Table 10-5. SBA Coliform Data Summary

WTP	**Total Coliform (MPN/100 ml)**		***E. coli*** **(MPN/100 ml)**	
	Range	**Median**	**Range**	**Median**
Patterson Pass	<2 – >2,000	50	<2 – 109	3.1
Del Valle	<2 – >2,000	80	<2 – 200.5	6.4
MSJWTP	<2 – 1,153	240	<2 – 168	31
WTP2	<2 – 198,628	591	<2 – 10,462	10
Penitencia	<2 – >24,200	276	<2 – 500	17
Rinconada	<2 – >24,200	135	<2 – 300	4

The monthly median total coliform and *E. coli* densities are presented in **Figures 10-3 to 10-12**. ACWD provided data for the MSJWTP for six months during the study period (February, March and June 2006, March 2007, and March and April 2010). For this limited data set, all the total coliform monthly median densities were less than 300 MPN/100 ml and the *E. coli* monthly median densities were less than 70 MPN/100 ml. The other WTPs have monthly median total coliform densities greater than 1,000 MPN/100 ml, typically during the summer months. None of the WTPs have monthly median *E. coli* densities greater than 200 MPN/100 ml. The total coliform peak monthly median densities at the Patterson Pass, Del Valle, and Penitencia WTPs were higher during the last five years compared with the data presented in the 2006 Update. *E. coli* peak monthly median densities were only higher at the Del Valle WTP, compared with the historical data.

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

The monthly median *E. coli* data and the protozoan monitoring indicate that 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction continues to be appropriate for the Patterson Pass, Del Valle, MSJWTP, WTP2, Penitencia, and Rinconada WTPs. This is consistent with the LT2ESWTR Bin 1 classification by CDPH.

Figure 10-3. Monthly Median Total Coliforms at the Patterson Pass WTP Intake

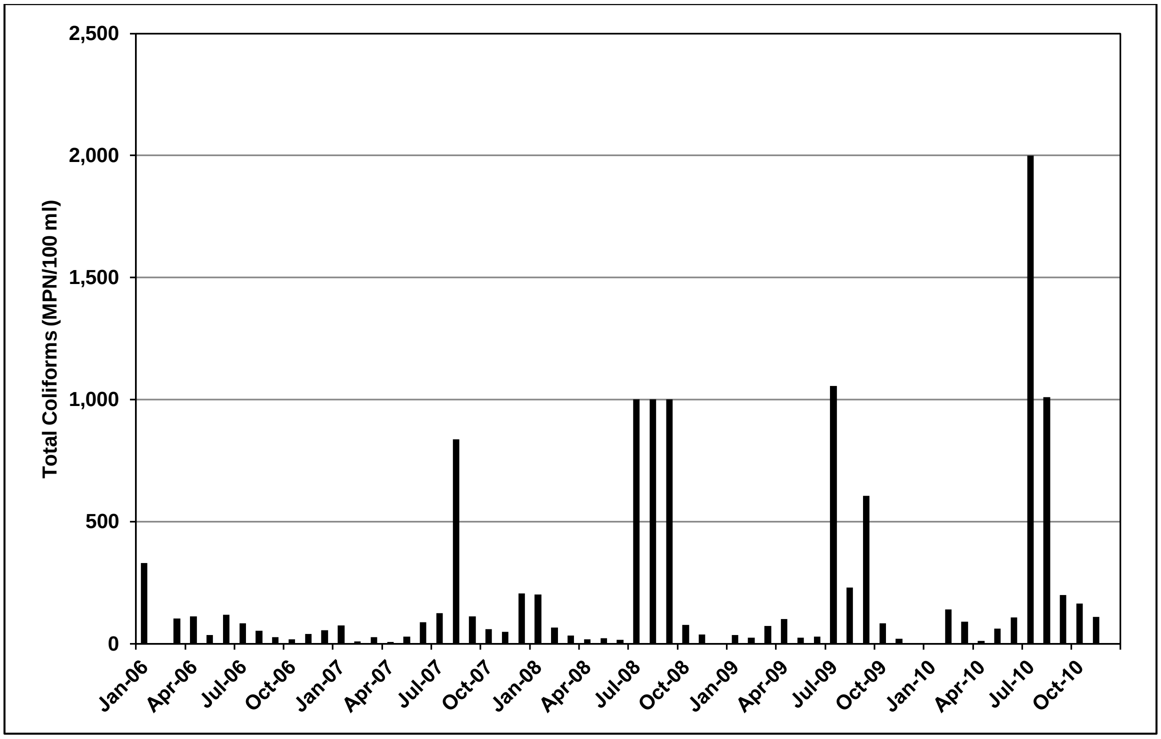


Figure 10-4. Monthly Median *E. coli* at the Patterson Pass WTP Intake

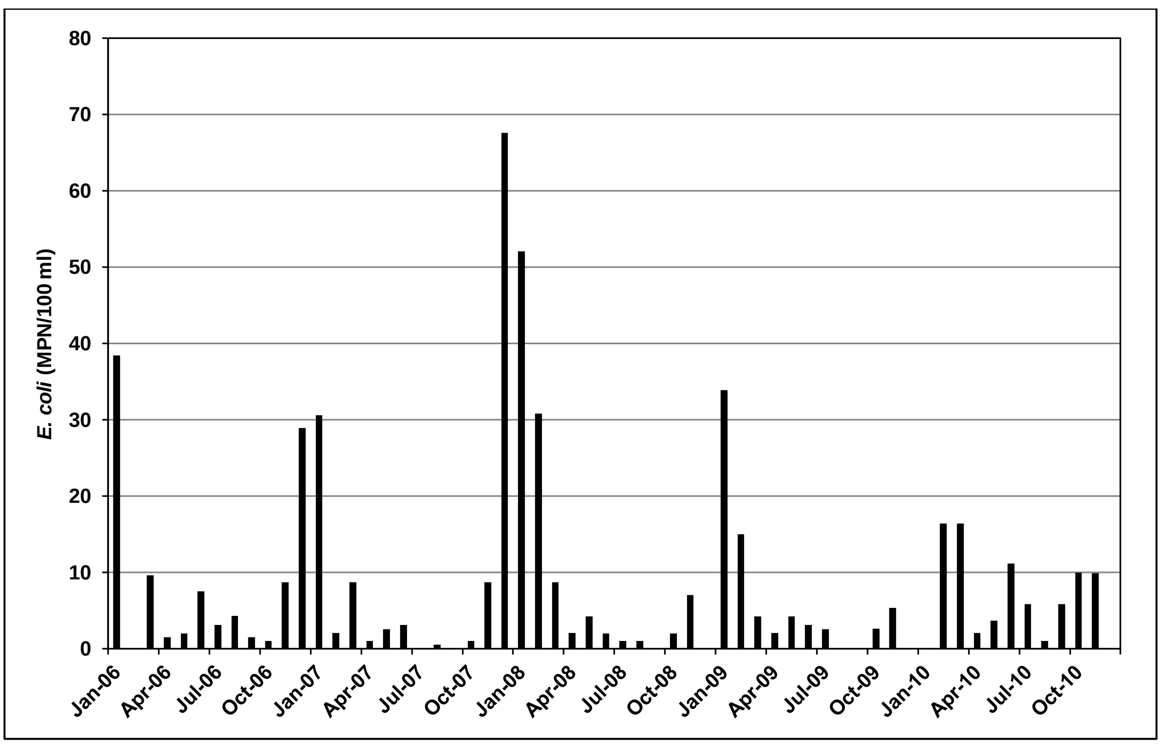


Figure 10-5. Monthly Median Total Coliforms at the Del Valle WTP Intake

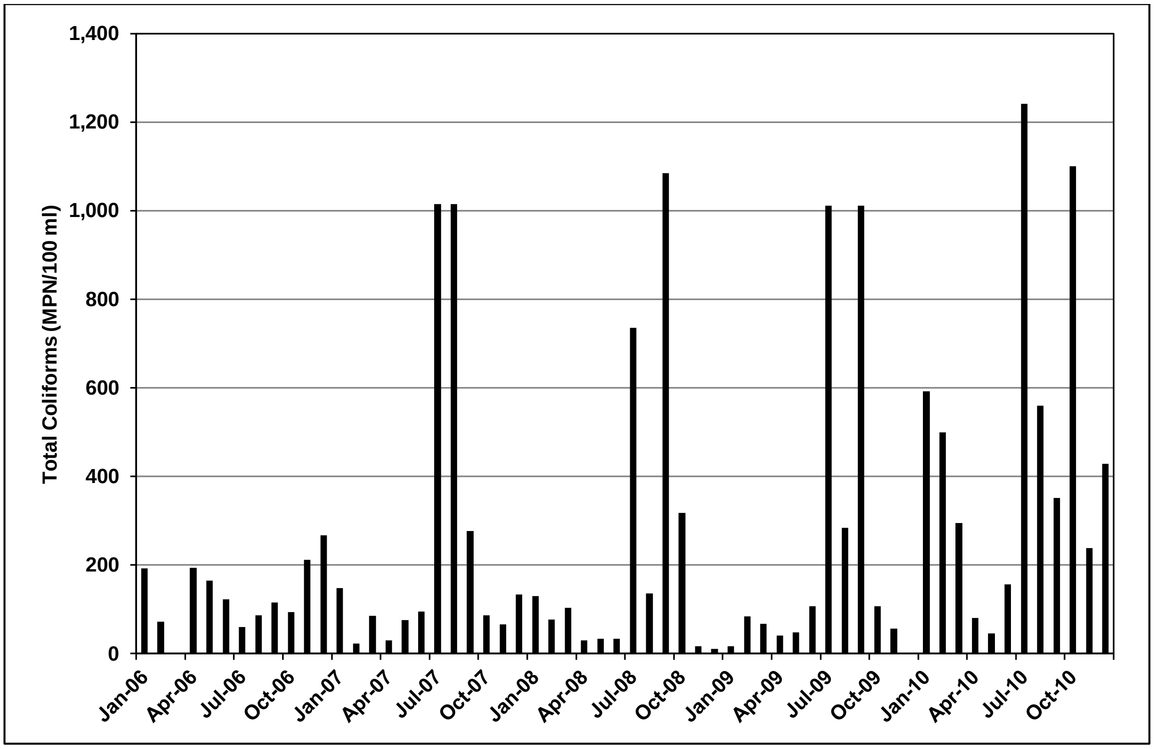


Figure 10-6. Monthly Median *E. coli* at the Del Valle WTP Intake

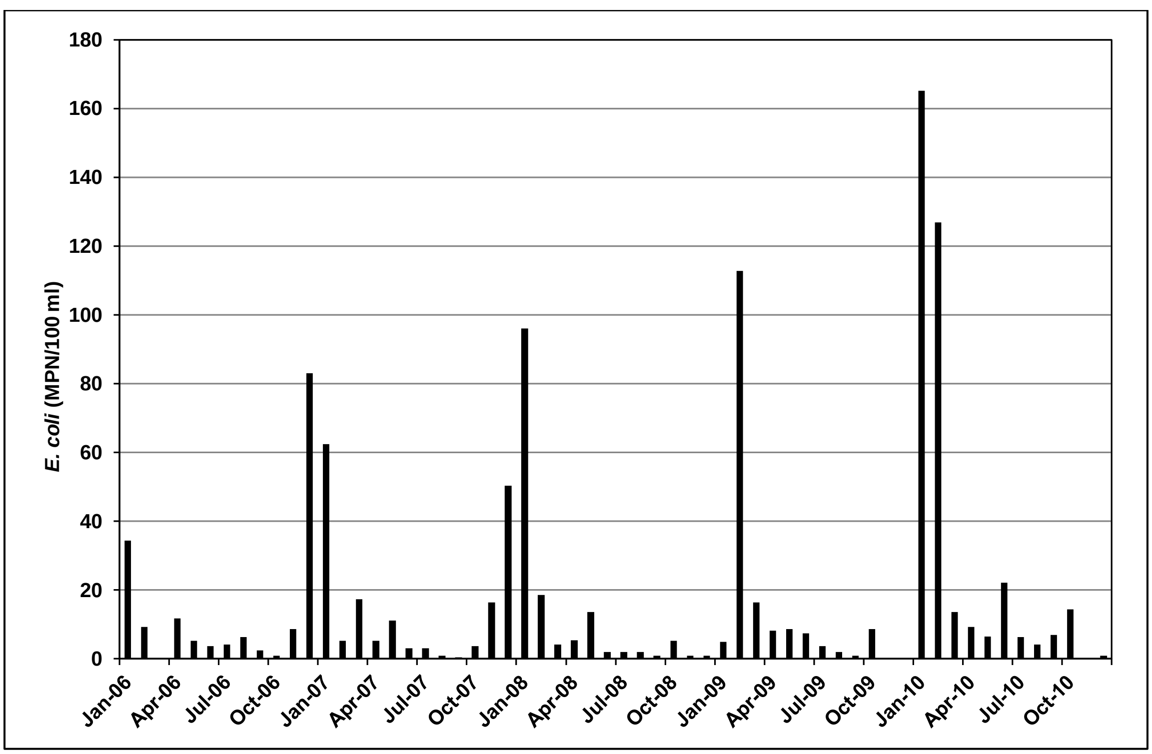


Figure 10-7. Monthly Median Total Coliforms at the WTP2 Intake

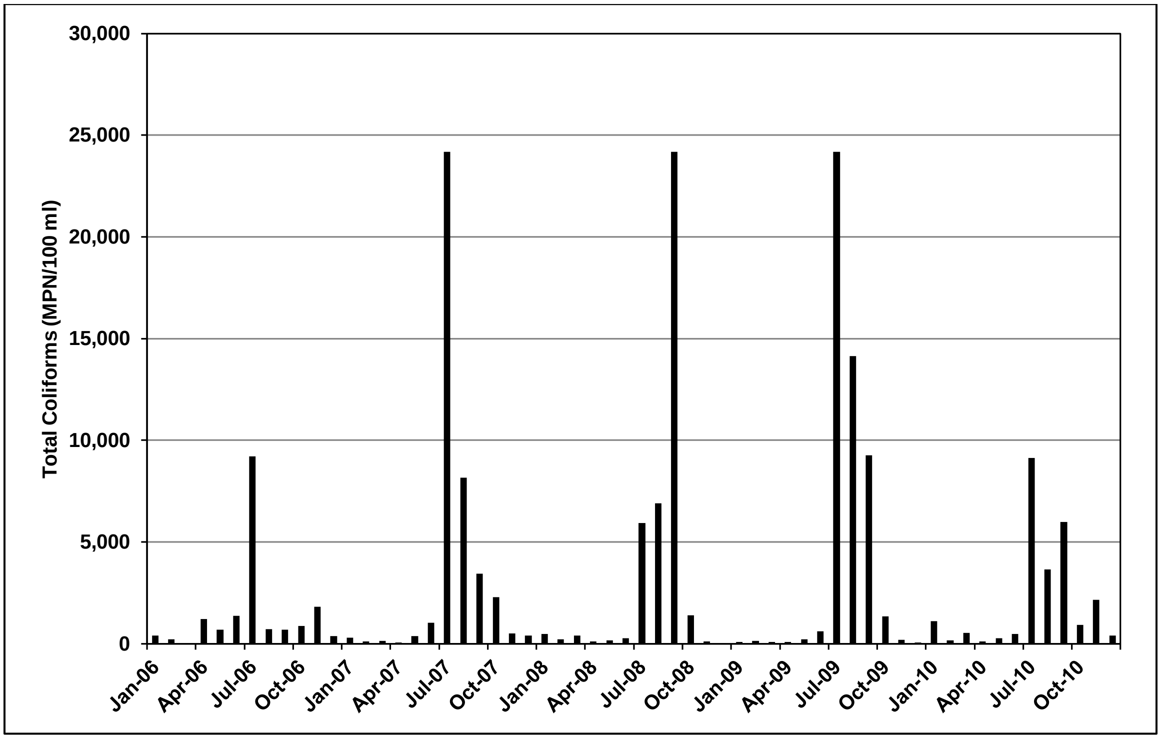


Figure 10-8. Monthly Median *E. coli* at the WTP2 Intake

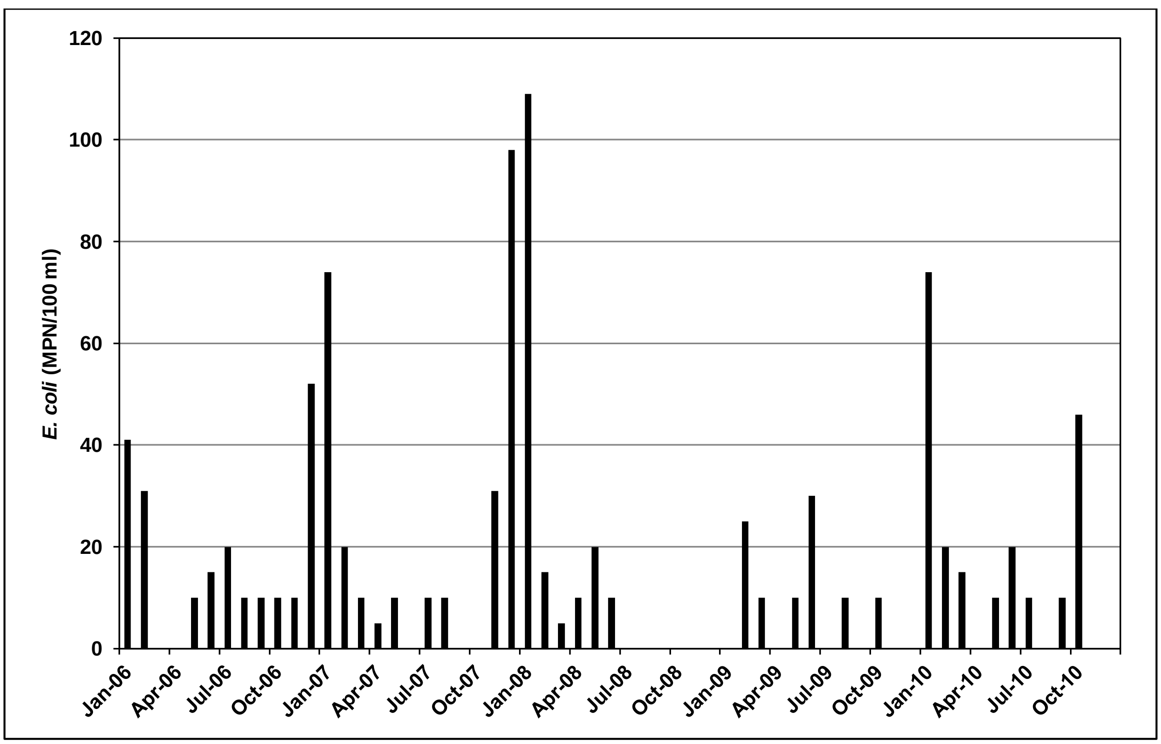


Figure 10-9. Monthly Median Total Coliforms at the Penitencia WTP Intake

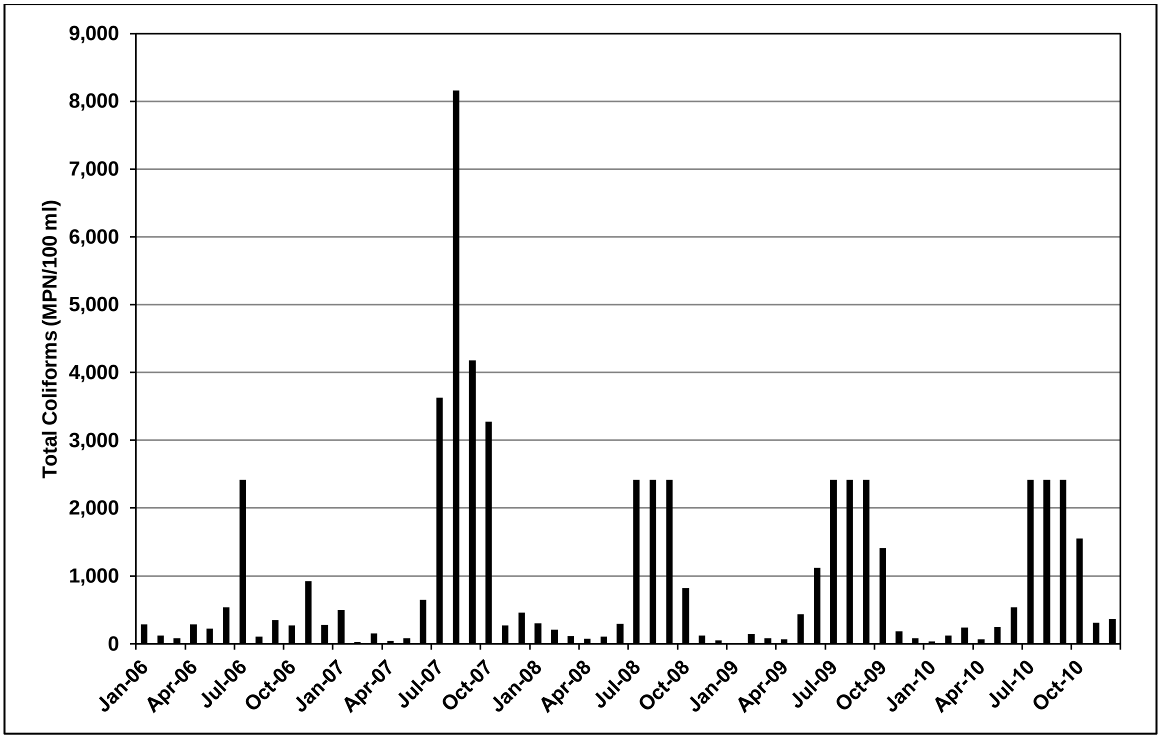


Figure 10-10. Monthly Median *E. coli* at the Penitencia WTP Intake

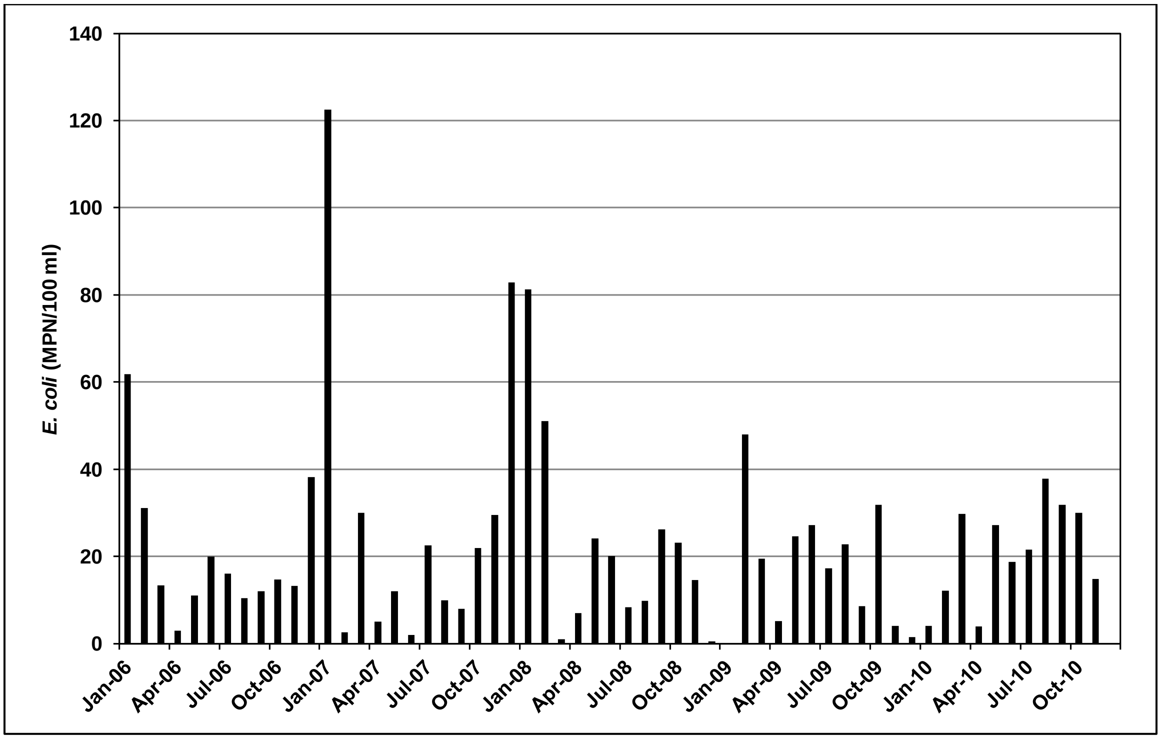


Figure 10-11. Monthly Median Total Coliforms at the Rinconada WTP Intake

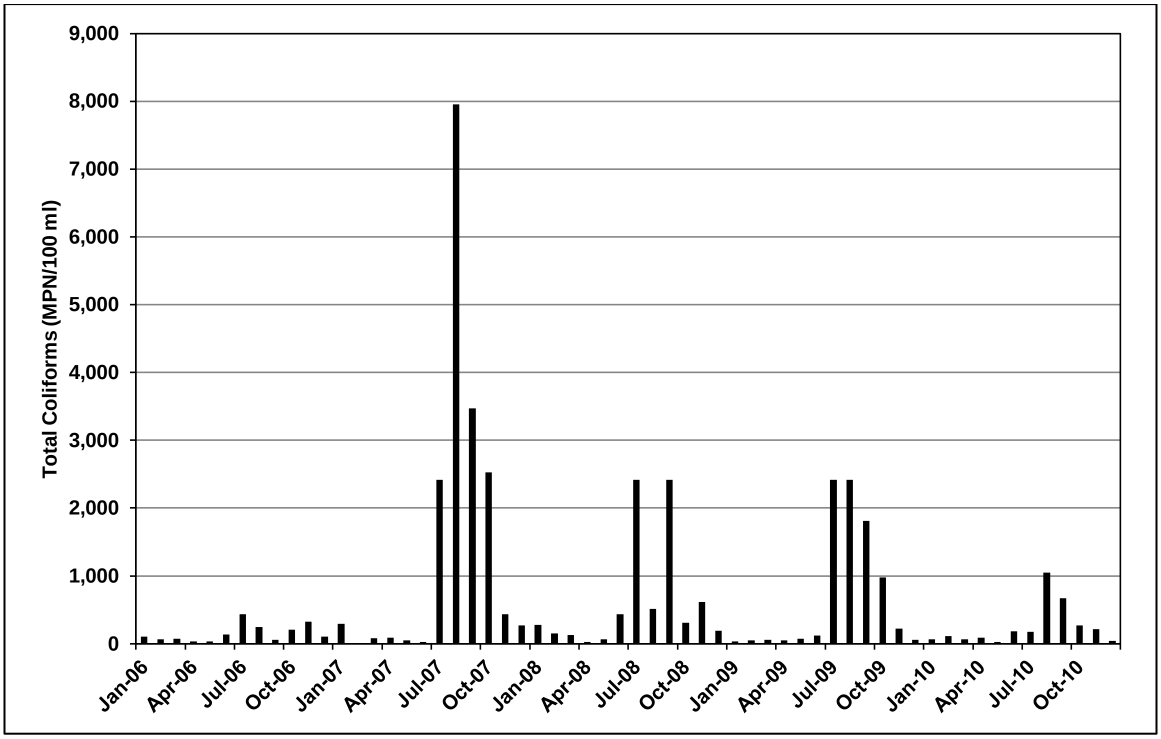
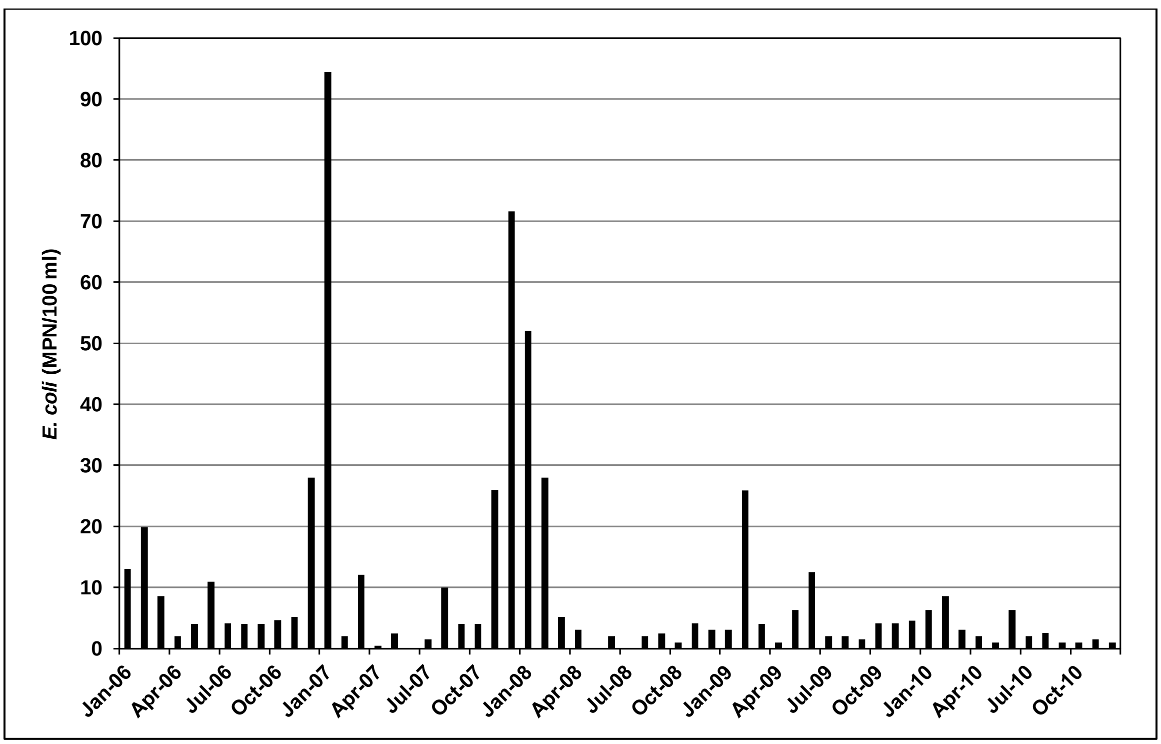


Figure 10-12. Monthly Median *E. coli* at the Rinconada WTP Intake



SAN LUIS RESERVOIR

SCVWD is the only Contractor who diverts municipal and industrial (M&I) water from San Luis Reservoir. Water is diverted from the western side of the reservoir at the Pacheco Pumping Plant (Pacheco) and flows through the Santa Clara Tunnel to SCVWD's service area. Although San Luis Reservoir water can be treated at all of SCVWD's WTPs, the Santa Teresa WTP treats primarily San Luis Reservoir water. The Santa Teresa WTP occasionally treats water from the SCVWD's local reservoirs. All data provided for the Santa Teresa WTP were included in the evaluation so local source water is also represented.

DWR operates a small WTP at the San Luis O&M Center. This WTP treats 6.7 million gallons per year and provides water for DWR employees. The WTP draws water from penstocks 1 and 4 of the William R. Gianelli Pumping-Generating Plant (Gianelli). When water is being pumped from O'Neill Forebay into San Luis Reservoir, the source of water to the WTP is O'Neill Forebay. When power is being generated, the source of water is San Luis Reservoir.

PROTOZOA

SCVWD conducted its LT2ESWTR monitoring in 2003 and 2004 and was assigned a Bin 1 classification by CDPH. SCVWD continued to monitored *Giardia* and *Cryptosporidium* monthly at the intake of the Santa Teresa WTP. Samples were collected monthly between January 2006 and November 2010, for a total of 58 samples analyzed. *Cryptosporidium* and *Giardia* were not detected in any of the samples. DWR has not collected pathogen data at the intake of their WTP.

INDICATOR ORGANISMS

Figures 10-13 and 10-14 present the coliform data for the Santa Teresa WTP intake. Total coliform densities ranged from non-detect to greater than 9,680 MPN/100 ml, with a median density of 61 MPN/100 ml. Total coliform monthly medians were generally less than 1,000 MPN/100 ml, with the exception of five months in 2007, two months in 2008, and two months in 2009. Peak monthly median values generally occur in the summer months. The total coliform densities between 2006 and 2010 were higher than those presented in the 2006 Update for the 2000 to 2005 period.

E. coli densities ranged from non-detect to 51 MPN/100 ml, with a median density of non-detect. The *E. coli* monthly medians were always less than 10 MPN/100 ml. The peak values typically occur during the winter months. These data are consistent with the data for 2000 to 2005.

Figures 10-15 and 10-16 presents the coliform data for the DWR WTP. During most months, only one sample was collected, therefore the monthly medians generally represent a single sample. Four months had total coliform densities greater than 1,000 MPN/100 ml (June and July 2008, July and September 2009). All *E. coli* densities were less than 50 MPN/100ml. Due to the complex operations of O'Neill Forebay and San Luis Reservoir, it is difficult to determine the source of the higher total coliforms; however, water is normally being released from San Luis Reservoir during the summer months when the highest coliform levels were reported.

Figure 10-13. Monthly Median Total Coliforms at the Santa Teresa WTP Intake

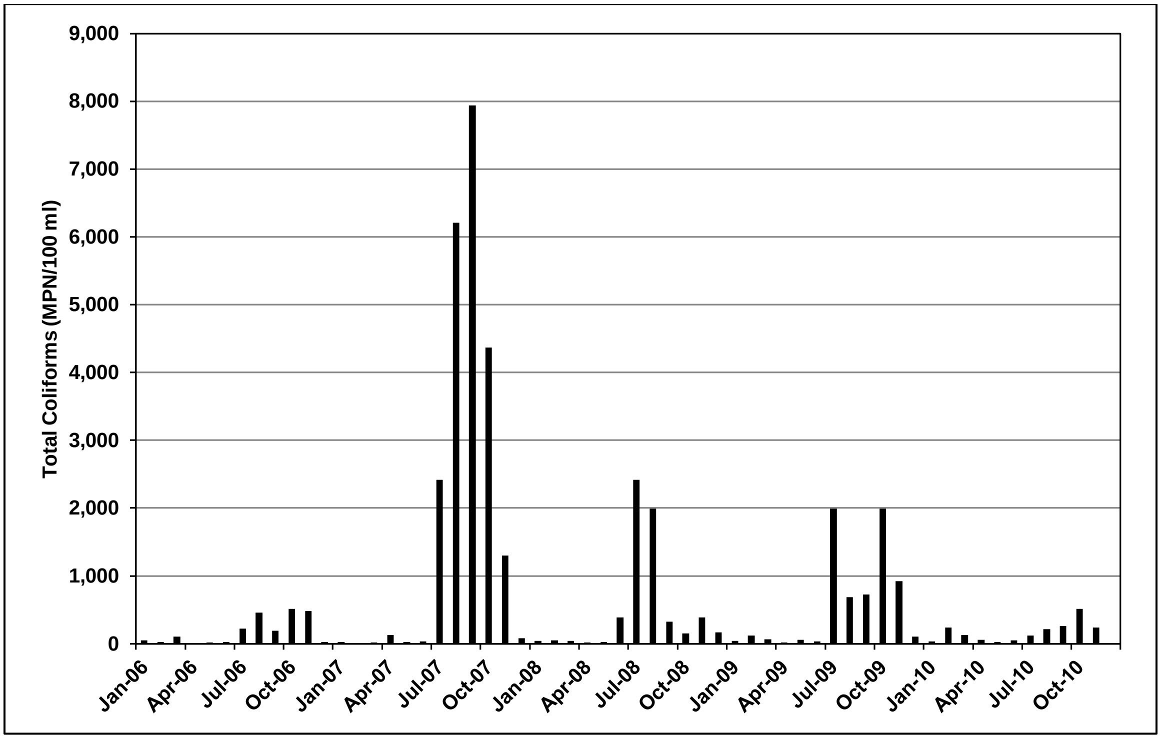


Figure 10-14. Monthly Median *E. coli* at the Santa Teresa WTP Intake

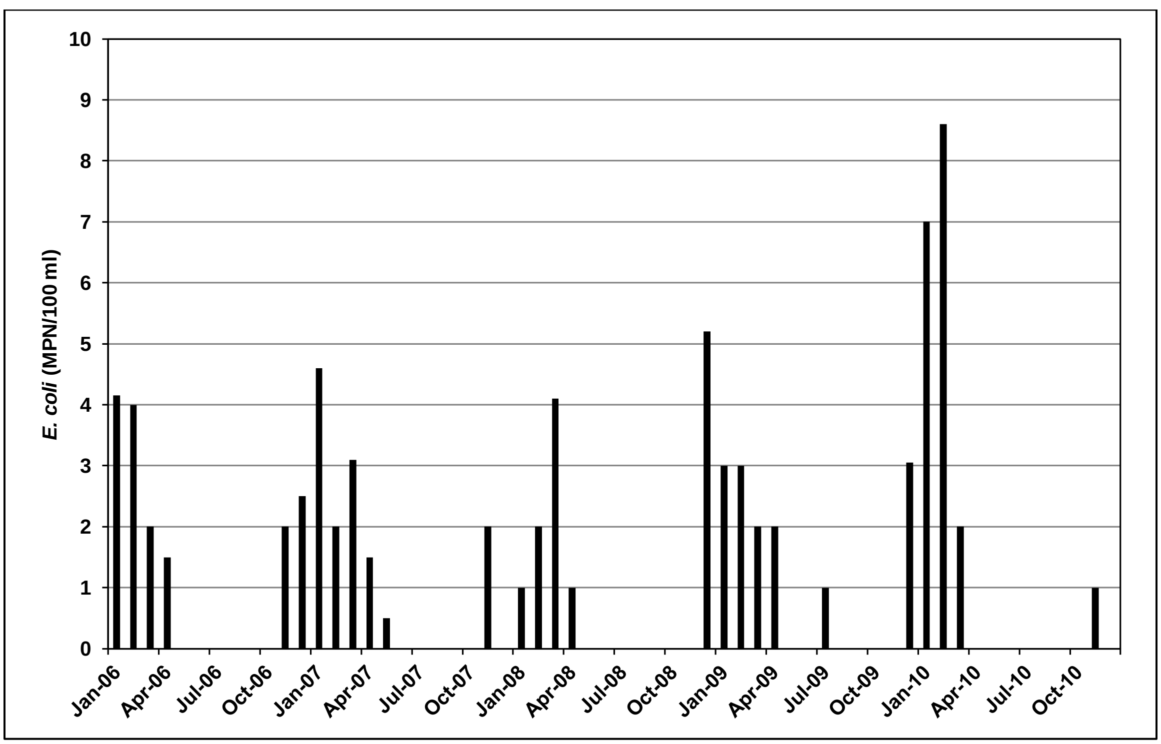


Figure 10-15. Monthly Median Total Coliforms at the San Luis O&M Center WTP Intake

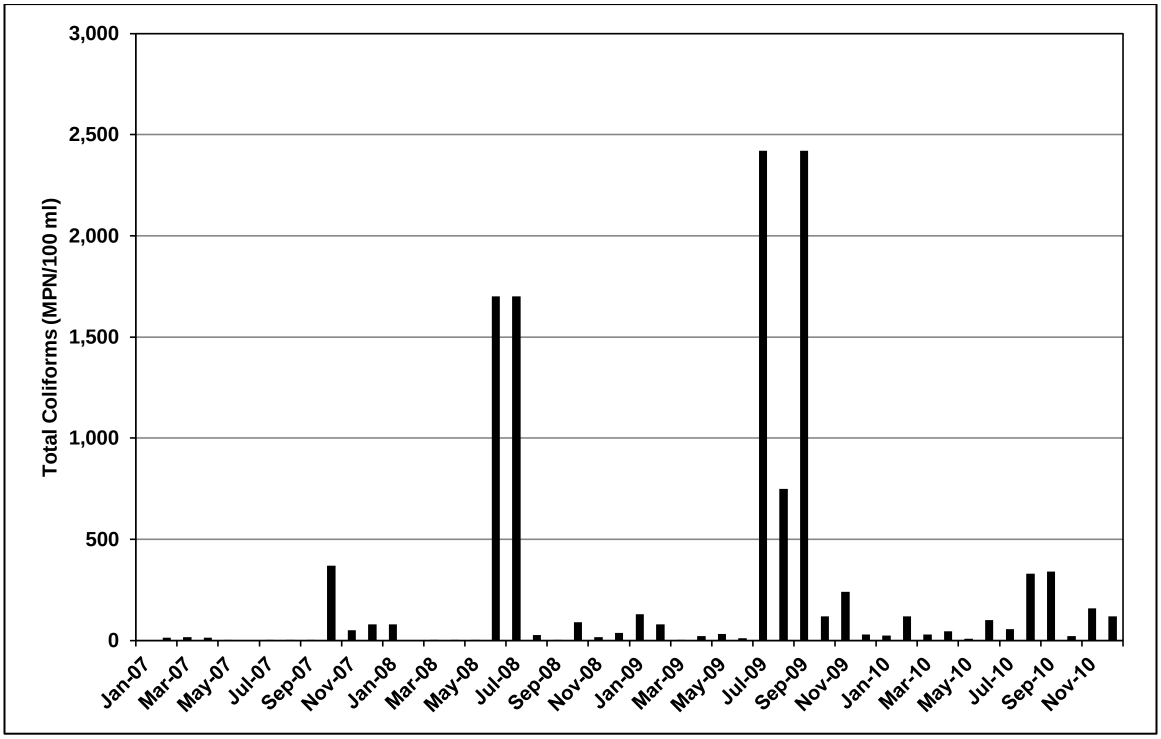
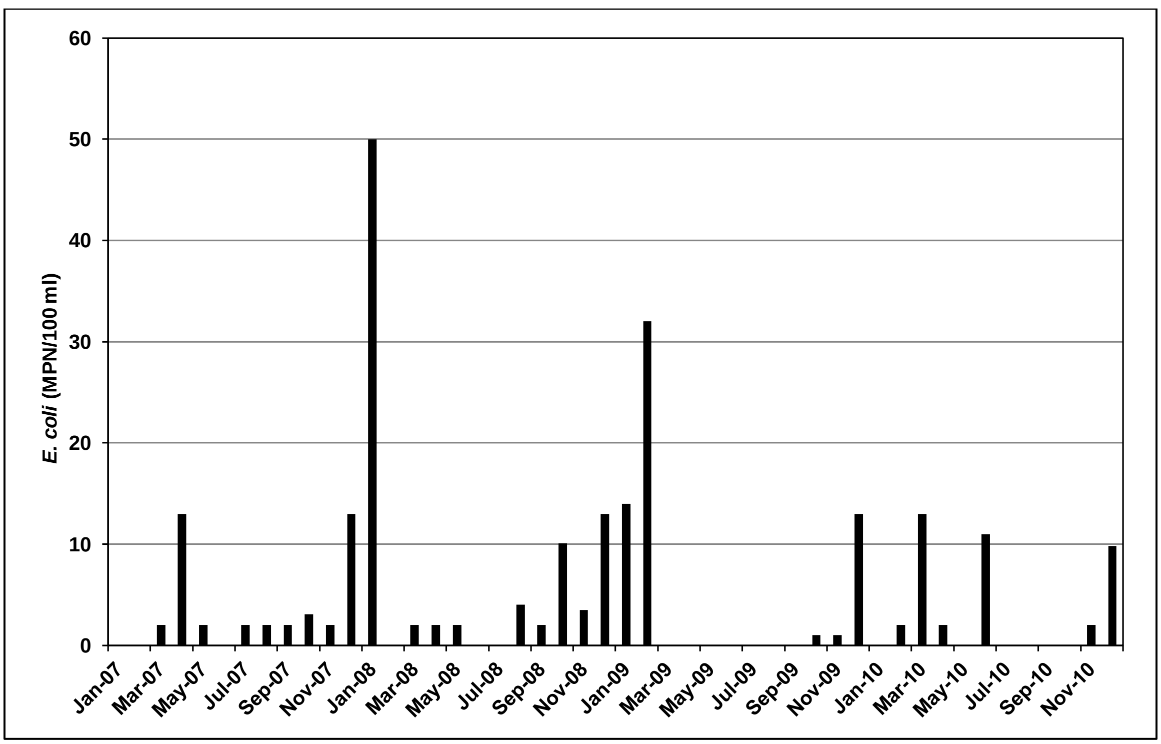


Figure 10-16. Monthly Median *E. coli* at the San Luis O&M Center WTP Intake



EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

The pathogen and indicator organism data demonstrate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia* and 4-log reduction of viruses continue to be appropriate for the Santa Teresa WTP and the DWR San Luis O&M WTP.

CALIFORNIA AQUEDUCT, SAN LUIS CANAL

The small cities of Coalinga, Huron, Dos Palos, and Avenal divert water from the San Luis Canal portion of the California Aqueduct. Data were obtained from the City of Avenal for its diversion off the California Aqueduct. Avenal is a CVP Contractor.

PROTOZOA

Avenal diverts water from the San Luis Canal to use at its surface water treatment plant. Sixteen protozoa samples were collected between May 2008 and March 2010. All of these were analyzed for *Cryptosporidum* and none was detected. Fifteen of the samples were also analyzed for *Giardia* and none was detected.

INDICATOR ORGANISMS

Avenal provided weekly total and fecal coliform data from the San Luis Canal. The total coliform densities ranged from non-detect to greater than 1,600 MPN/100 ml, with a median density of 50 MPN/100 ml. As shown in **Figure 10-17**, only two monthly median total coliform densities were greater than 1,000 MPN/100 ml (August 2007 and July 2010).

The fecal coliform densities ranged from non-detect to greater than 1,600 MPN/100 ml, with a median density of 4 MPN/100 ml. **Figure 10-18** presents the fecal coliform data. There were only four monthly median fecal coliform densities greater than 200 MPN/100 ml (May, August and December 2007 and July 2010).

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

The pathogen and indicator organism data demonstrate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia* and 4-log reduction of viruses are likely appropriate for the San Luis Canal portion of the California Aqueduct.

Figure 10-17. Monthly Median Total Coliforms at City of Avenal Diversion

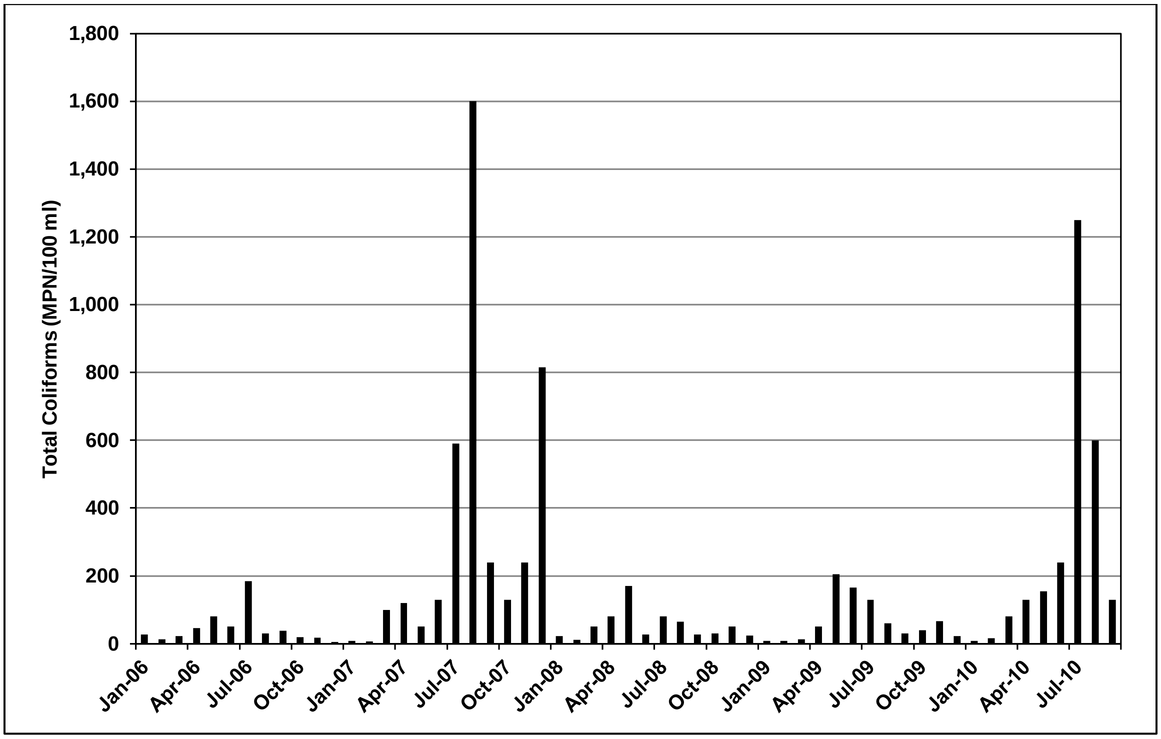
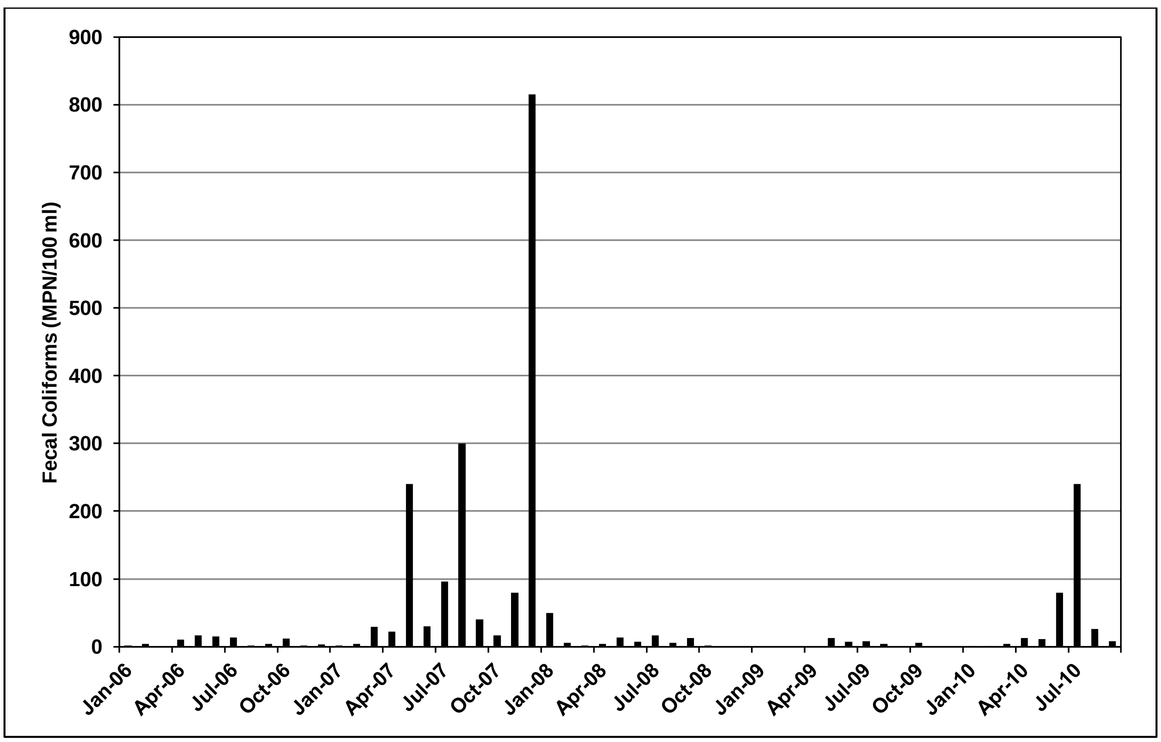


Figure 10-18. Monthly Median Fecal Coliforms at City of Avenal Diversion



COASTAL BRANCH OF THE CALIFORNIA AQUEDUCT

Central Coast Water Authority (CCWA) treats water at the 43-mgd Polonio Pass WTP. Treated water is delivered via pipeline from Polonio Pass WTP to a number of communities in San Luis Obispo and Santa Barbara counties. The source water quality data evaluated in this chapter is applicable to all of the communities that receive the treated water.

PROTOZOA

CCWA conducted the LT2ESWTR monitoring between April 2007 and March 2009 and was assigned a Bin 1 classification by CDPH. Between March 2006 and December 2010, CCWA collected a total of 35 samples for *Giardia* and *Cryptosporidium. Cryptosporidium* and *Giardia* were not detected in any of the samples.

INDICATOR ORGANISMS

CCWA provided weekly coliform data (total coliform, fecal coliform, and *E. coli*) from January 2006 through December 2010 from the intake to the Polonio Pass WTP. The total coliform densities ranged from non-detect to 2,419 MPN/100 ml, with a median density of 39 MPN/100 ml. As shown in **Figure 10-19**, the monthly median total coliform densities were less than 1,000 MPN/100 ml in all but one month (September 2009) and were below 250 MPN/100 ml in 90 percent of samples. The peak monthly medians were greater than those presented in the 2006 Update.

Figure 10-20 presents the fecal coliform data. The fecal coliform densities ranged from non-detect to 120 MPN/100 ml, with a median density of 4 MPN/100 ml. The monthly median fecal coliform densities were less than 50 MPN/100 ml in all months.

The *E. coli* densities ranged from non-detect to 90 MPN/100 ml, with a median density of 4 MPN/100 ml. As shown in **Figure 10-21**, the monthly median *E. coli* densities were less than 27 MPN/100 ml in all but one month (November 2006) and were below 17 MPN/100 ml in 90 percent of samples.

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

CCWA initiated LT2ESWTR monitoring in April 2007. The protozoa data collected placed the Polonio Pass WTP in Bin 1 and no additional action beyond 2-log reduction is required. The pathogen and indicator organism data indicate that 2-log reduction of Cryptosporidium, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the Polonio Pass WTP.

Figure 10-19. Monthly Median Total Coliforms at the Polonio Pass WTP Intake

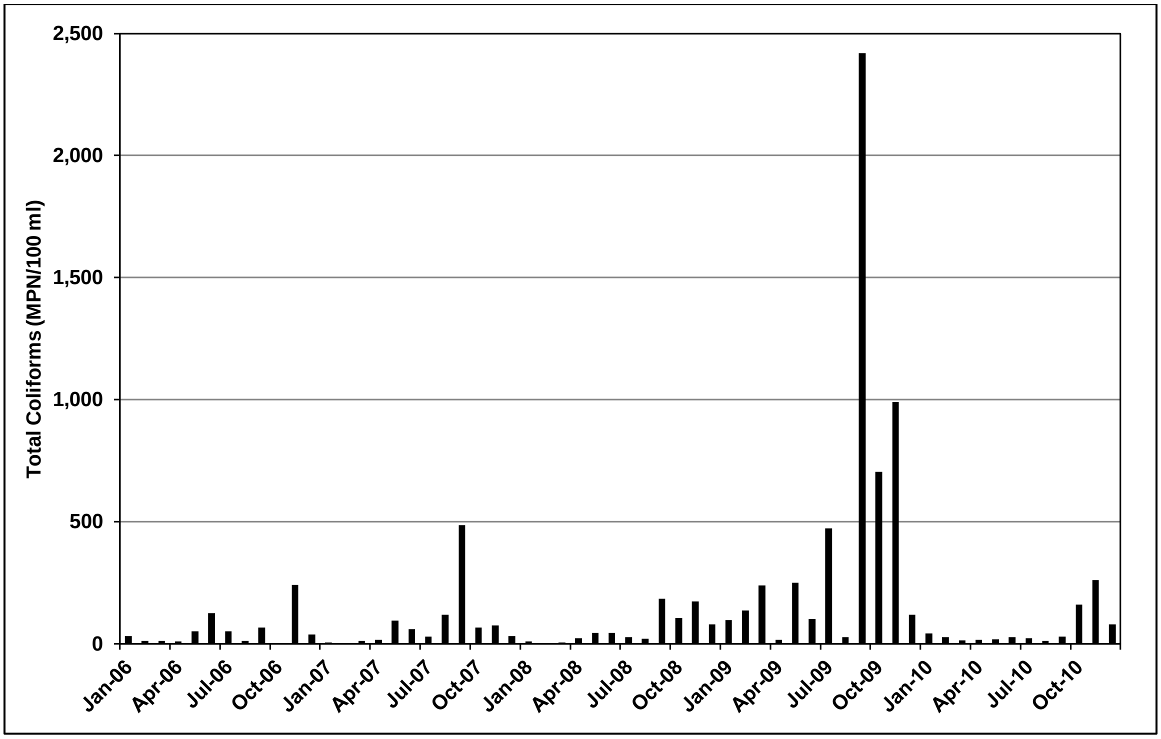


Figure 10-20. Monthly Median Fecal Coliforms at the Polonio Pass WTP Intake

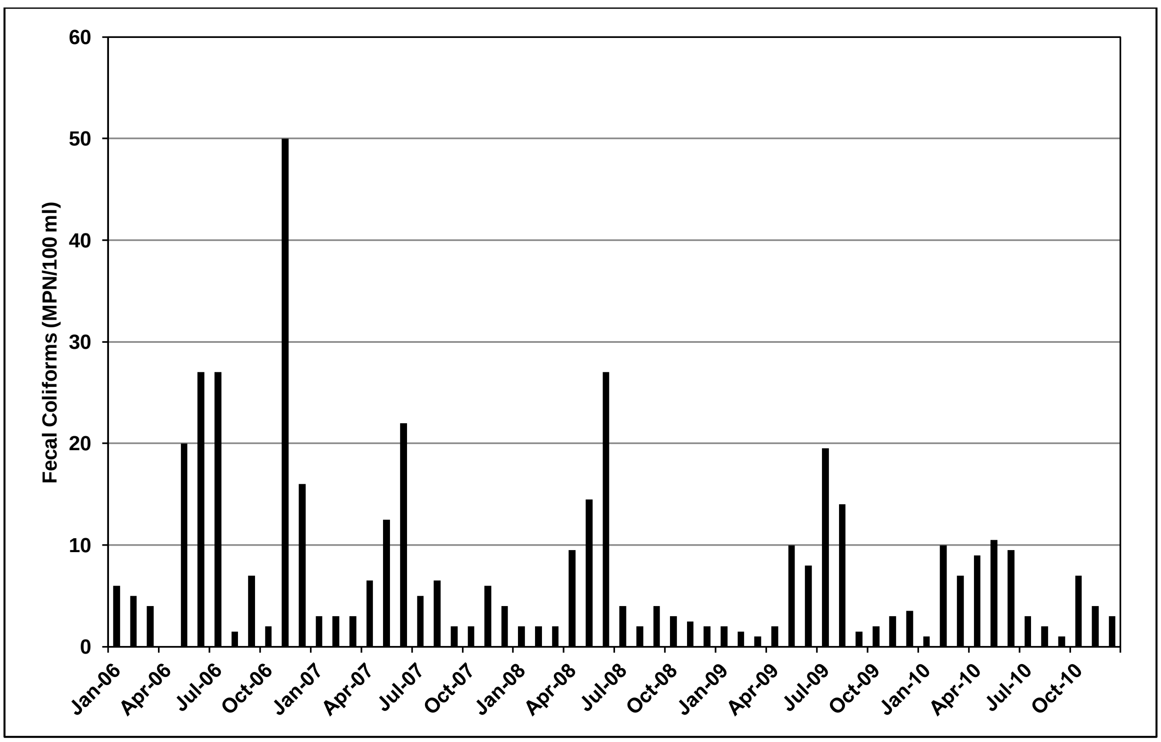
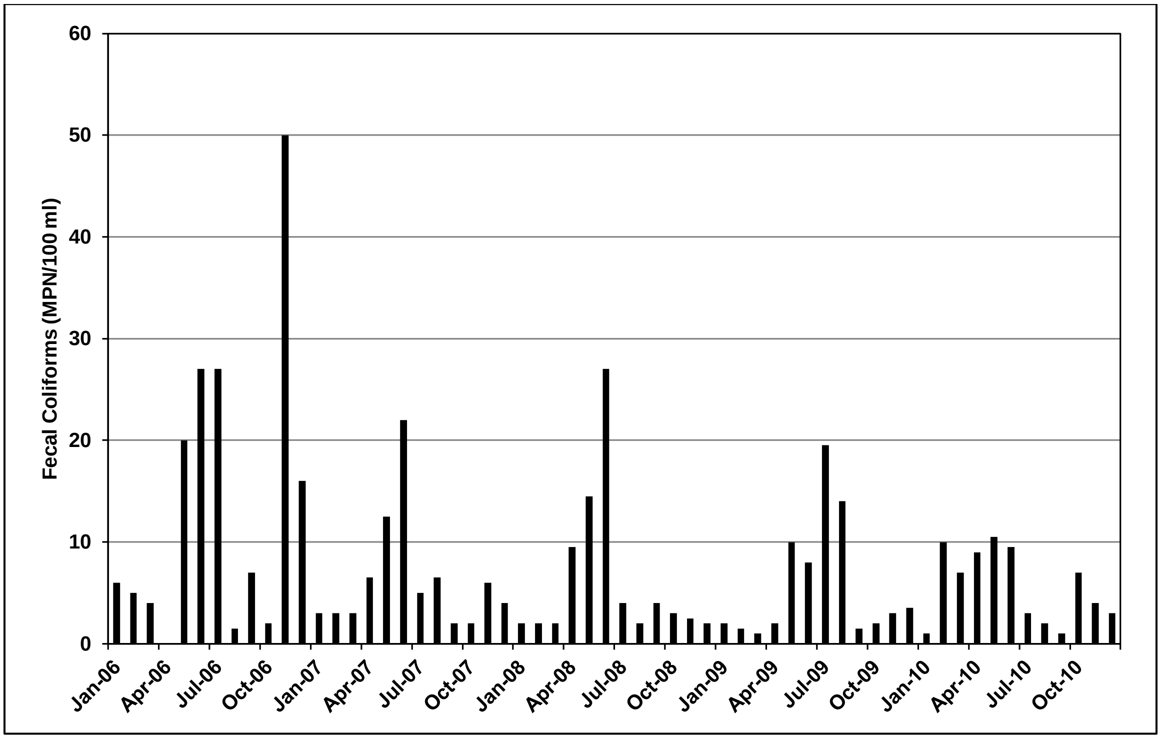


Figure 10-21. Monthly Median *E. coli* at the Polonio Pass WTP Intake



CALIFORNIA AQUEDUCT, SAN JOAQUIN FIELD DIVISION

Kern County Water Agency (KCWA) is the only SWP Contractor who diverts M&I water from this reach of the California Aqueduct. Water is diverted from the California Aqueduct and conveyed in the 22-mile-long Cross Valley Canal to the 72-mgd Henry C. Garnett Water Purification Plant. Treated water is sold to several retail agencies that provide drinking water for the metropolitan Bakersfield area. SWP water is exchanged whenever possible for Kern River water due to the higher quality of the Kern River. Therefore, Kern River water is used more frequently than SWP water as the source water for the Henry C. Garnett Water Purification Plant.

PROTOZOA

Twenty-four samples were collected and analyzed for *Giardia* and *Cryptosporidium* between October 2006 and September 2008, in compliance with the LT2ESWTR. These samples were collected from the California Aqueduct near the Cross Valley Canal turnout. Neither of these pathogens was detected in any of the samples, therefore the California Aqueduct at this location is classified as Bin 1 and no additional action is required at this time.

INDICATOR ORGANISMS

Total coliforms and *E. coli* were analyzed on the same dates that pathogen data were collected. After the LT2ESWTR monitoring was completed, KCWA continued to collect quarterly samples through December 2010. These data are shown in **Figures 10-22 and 10-23**. The data show that the total coliform densities can exceed 1,000 MPN/100 ml, but *E. coli* densities never exceeded 50 MPN/100 ml. Total coliform peak densities were greater than those presented in the 2006 Update.

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

Since the Kern River is the primary source of water for the Henry C. Garnett Water Purification Plant, log reductions are based primarily on Kern River water quality rather than the microbial quality of the California Aqueduct. When using the California Aqueduct source, protozoa results place the source in Bin 1 under the LT2ESWTR and no additional action beyond 2-log reduction is required. The indicator organism data indicate that 3-log reduction of *Giardia* and 4-log reduction of viruses are appropriate as well.

Figure 10-22. Total Coliforms in the California Aqueduct near the KCWA Turnout

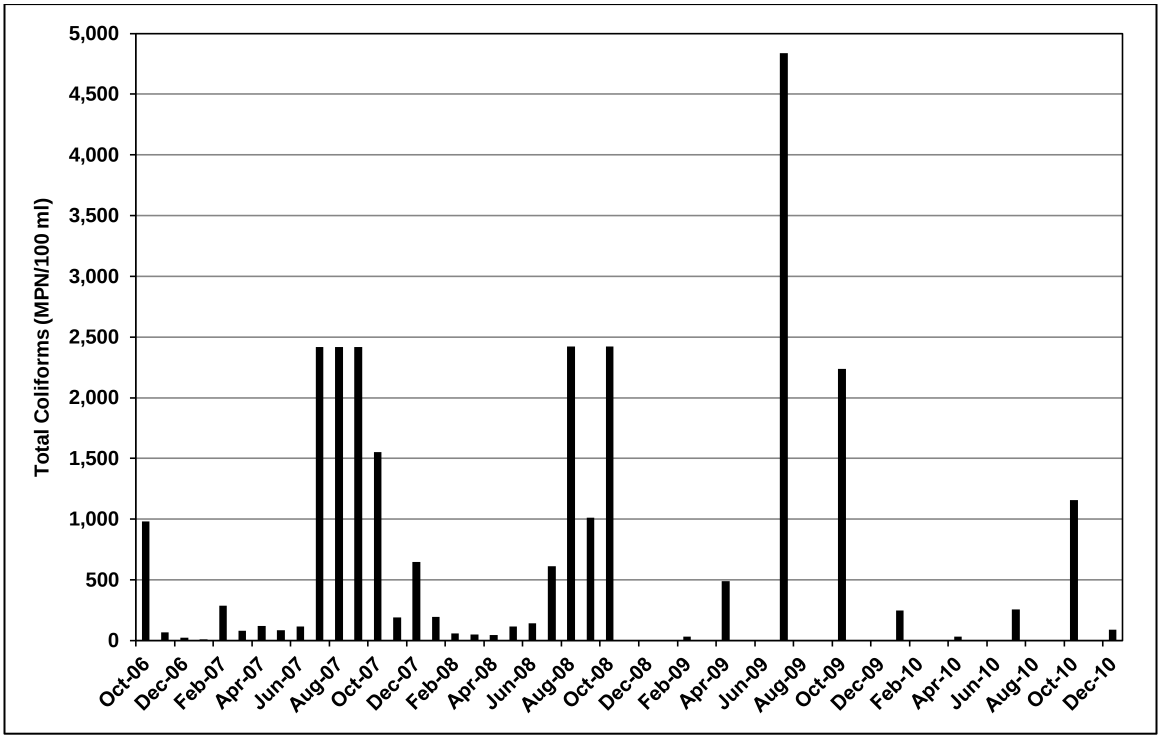
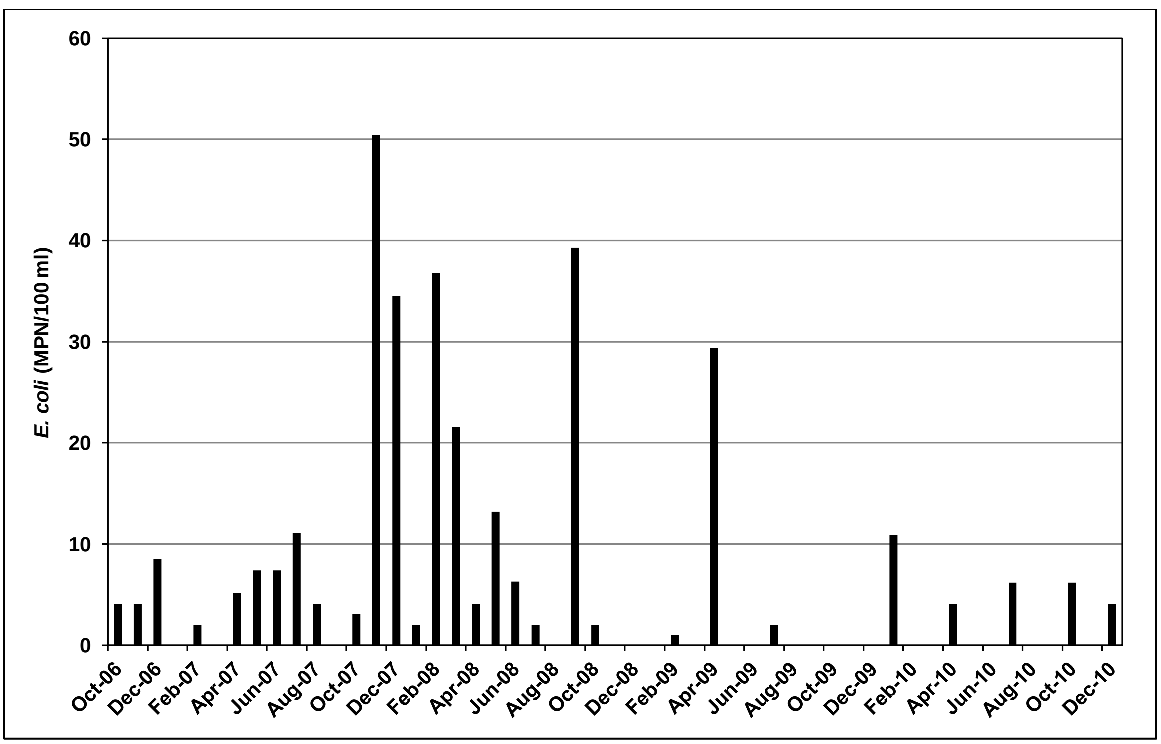


Figure 10-23. *E.coli* in the California Aqueduct near the KCWA Turnout



WEST BRANCH OF THE CALIFORNIA AQUEDUCT

The Metropolitan Water District of Southern California (MWDSC) and Castaic Lake Water Agency (CLWA) take water from Castaic Lake on the West Branch. Water is diverted from Castaic Lake and travels through the Foothill Feeder to the 750-mgd Joseph Jensen (Jensen) WTP, which serves the San Fernando Valley, Ventura County, west Los Angeles, Santa Monica, and the Palos Verdes Peninsula. CLWA treats water from Castaic Lake at the 56-mgd Earl Schmidt Filtration Plant and the 66-mgd Rio Vista Treatment Plant. CLWA provides treated water to four retailers in the Santa Clarita Valley (Los Angeles County Water Works District #36, Newhall County Water District, Santa Clarita Water Division, and Valencia Water Company). Data from the Jensen WTP intake, Castaic Lake, and the Rio Vista WTP are evaluated in this chapter.

PROTOZOA

MWDSC collected monthly samples for *Giardia* and *Cryptosporidium* at the Jensen WTP intake from January 2006 through December 2010. *Giardia* was not detected in any of the samples and *Cryptosporidium* was detected in one sample collected in March 2007 at 0.2 oocysts/L. The LT2ESWTR data were collected between October 2006 and September 2008. The maximum RAA was 0.017 oocysts/L, well below the Bin 1 threshold level of 0.075 oocysts/L.

CLWA initiated its LT2ESWTR monitoring at the Rio Vista WTP in April 2007. Twenty-three monthly samples were collected and analyzed for *Giardia* and *Cryptosporidium*. There were no detections of either protozoan, therefore the source is classified as Bin 1 and no additional action is required.

INDICATOR ORGANISMS

MWDSC provided monthly median indicator organism data for the period of January 2006 through December 2010. The monthly medians for total coliforms, fecal coliforms, and *E. coli* are shown in **Figures 10-24 through 10-26.** These data indicate that monthly median total coliform densities exceed 1,000 MPN/100 ml, with peaks generally occurring during the summer months. The highest monthly total coliform medians occurred in August and September 2007 and again in July 2009. The peak total coliform monthly medians are higher than those presented in the 2006 Update. The monthly median fecal coliform densities were below 14 MPN/100 ml for all months, which are lower than those presented in the 2006 Update. The monthly median *E. coli* densities were below 12 MPN/100 ml for all months. Fecal coliform and *E. coli* monthly medians were highest in 2006 and early 2007.

Figure 10-24. Monthly Median Total Coliforms at the Jensen WTP Intake

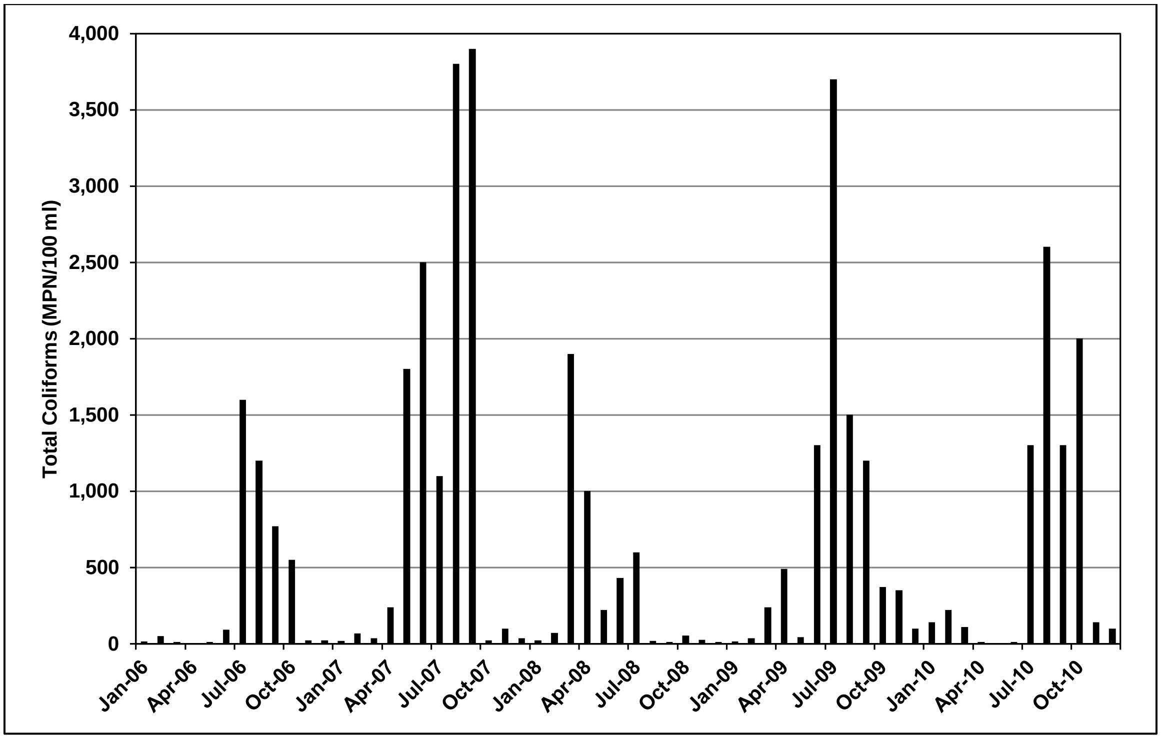


Figure 10-25. Monthly Median Fecal Coliforms at the Jensen WTP Intake

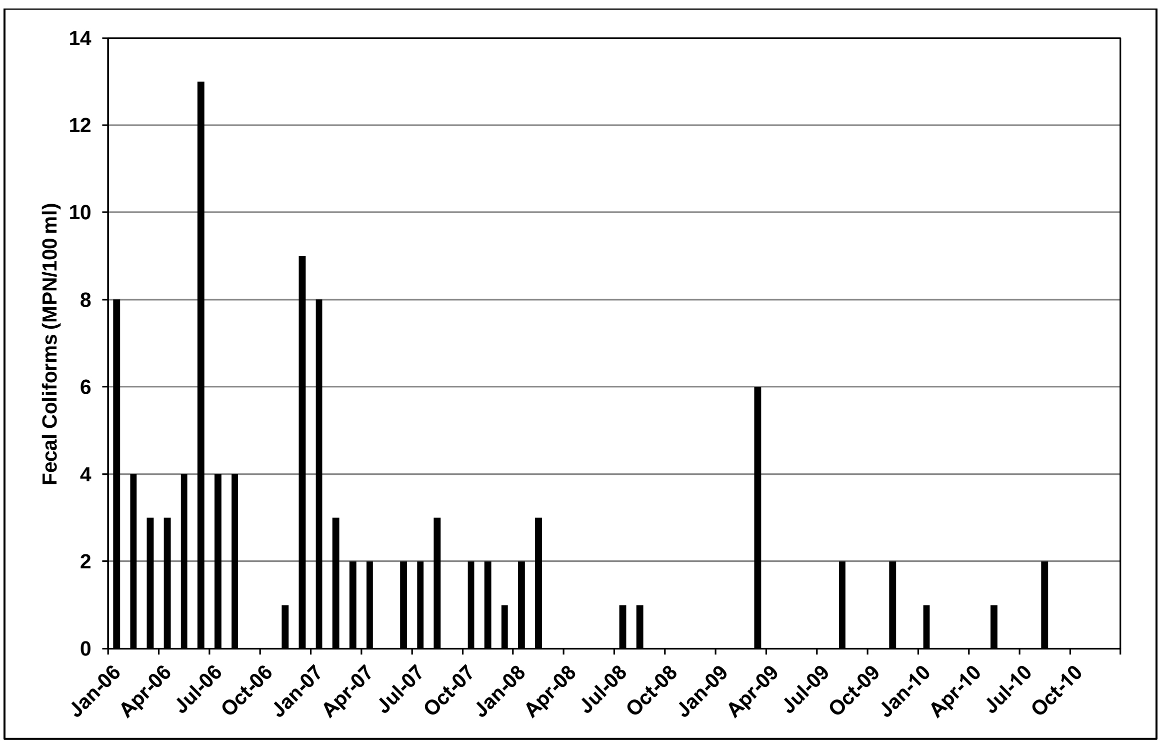
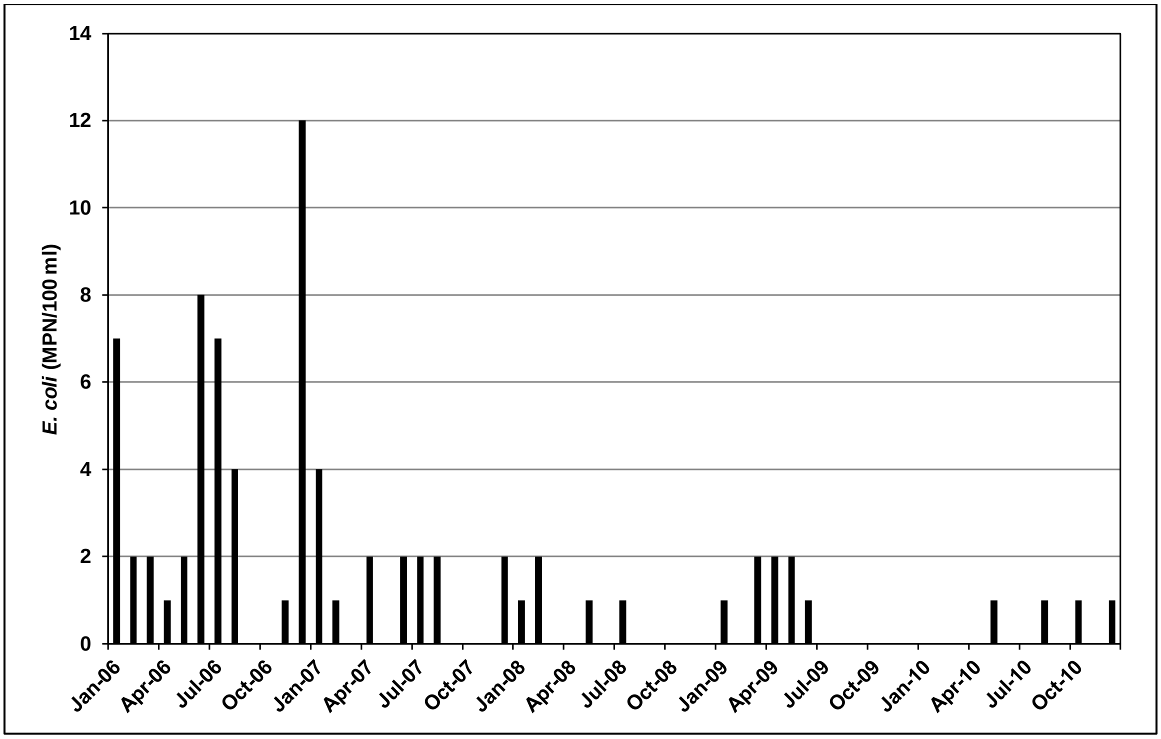


Figure 10-26. Monthly Median *E. coli* at the Jensen WTP Intake



CLWA collects weekly total and fecal coliform samples from Castaic Lake. Data from January 2006 through December 2010 were evaluated for this study. Total coliform densities ranged from non-detect to 900 MPN/100 ml, with a median density of 23 MPN/100 ml. **Figure 10-27** shows that the monthly median total coliform densities do not exceed 35 MPN/100 ml. The fecal coliform densities range from non-detect to 23 MPN/100 ml, with a non-detectable median density. **Figure 10-28** shows the monthly median fecal coliform densities, with none exceeding 4 MPN/100 ml. Coliform densities are consistent throughout the year in Castaic Lake.

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

Both the indicator organism data and the five years of *Giardia* and *Cryptosporidium* data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia*, and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the West Branch.

Figure 10-27. Monthly Median Total Coliforms in Castaic Lake

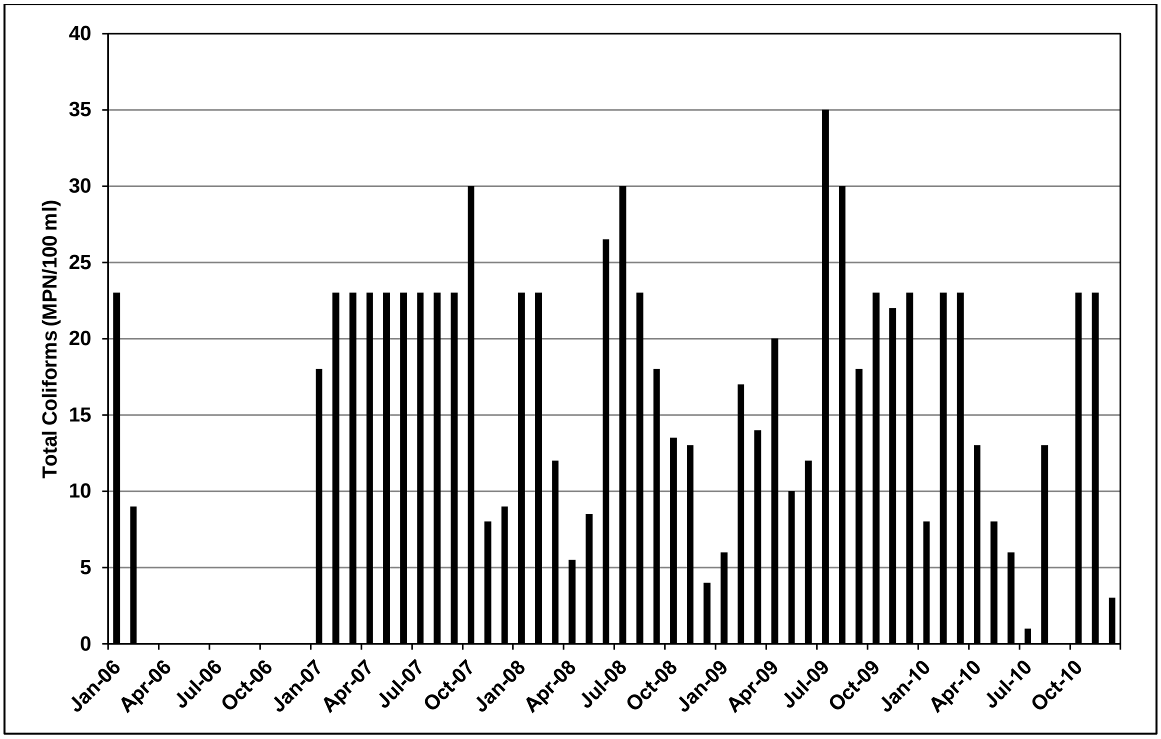
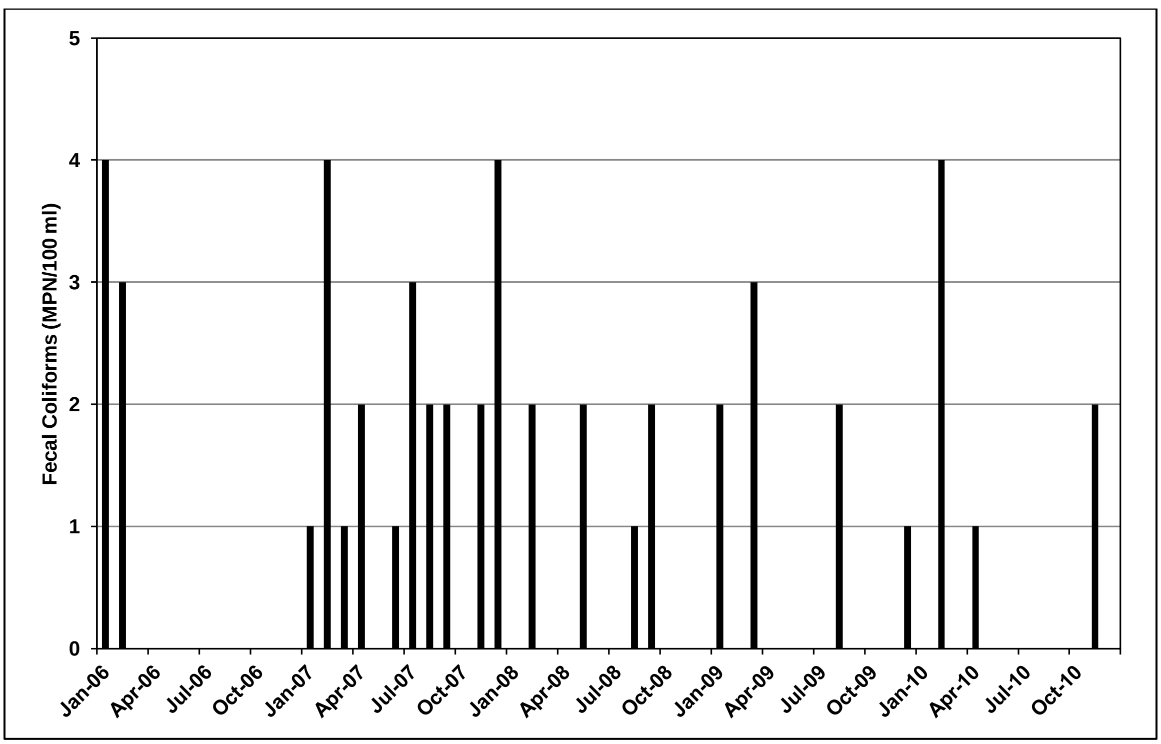


Figure 10-28. Monthly Median Fecal Coliforms in Castaic Lake



EAST BRANCH OF THE CALIFORNIA AQUEDUCT (CHECK 42 TO CHECK 66)

The Antelope Valley-East Kern Water Agency (AVEK) and Palmdale Water District (Palmdale) divert water from this reach of the East Branch and provide drinking water to customers in the Mojave Desert. AVEK diverts M&I water at four locations and treats it at the 4-mgd Acton WTP, 10-mgd Eastside WTP, 65-mgd Quartz Hill WTP, and the 14-mgd Rosamond WTP. Palmdale treats water at the 30-mgd Palmdale Water District WTP.

PROTOZOA

AVEK completed its LT2ESWTR monitoring in February 2006 and Palmdale completed its monitoring in March 2007. All four of AVEK's WTPs and the Palmdale WTP were placed in the Bin 1 classification. There were no new protozoan data collected during the study for this reach of the California Aqueduct.

INDICATOR ORGANISMS

AVEK provided coliform data from January 2006 to December 2010 at all four of their WTPs. The data are summarized in **Table 10-6**. These data indicate that the monthly median total coliform densities are below 1,000 MPN/100 ml and the fecal coliform and *E. coli* medians are below 30 MPN/100 ml. The peak total coliform monthly medians were greater than those presented in the 2006 Update, but *E. coli* monthly medians were lower. Since the coliform densities are low at all of the WTPs, only the monthly medians for total coliforms and *E. coli* for the Acton WTP are shown in **Figures 10-29 and 10-30.**

Table 10-6. Summary of AVEK Coliform Data

WTP	Total Coliforms (MPN/100ml)		Fecal Coliforms (MPN/100ml)		*E. coli* (MPN/100ml)	
	Maximum Detected	Monthly Median Range	Maximum Detected	Monthly Median Range	Maximum Detected	Monthly Median Range
Acton	>1,600	ND - 900	80	ND - 30	220	ND - 30
Eastside	>1,600	3 - 825	170	ND - 26.5	170	ND - 23.5
Quartz Hill	>1,600	ND - 110	80	ND - 17	80	ND - 17
Rosamond	300	ND - 53.5	70	ND - 8	140	ND - 8

Palmdale collects weekly coliform data at their WTP as well. The monthly median densities for total and fecal coliform were calculated and are shown in **Figures 10-31 and 10-32**. There was an increase in total coliform densities in 2009 and 2010, with a majority of the monthly medians greater than 1,000 MPN/100 ml. The peak densities occur during the summer months. All of the fecal coliform monthly median densities were less than 50 MPN/100 ml and did not vary during the study period.

Figure 10-29. Monthly Median Total Coliforms at the Acton WTP

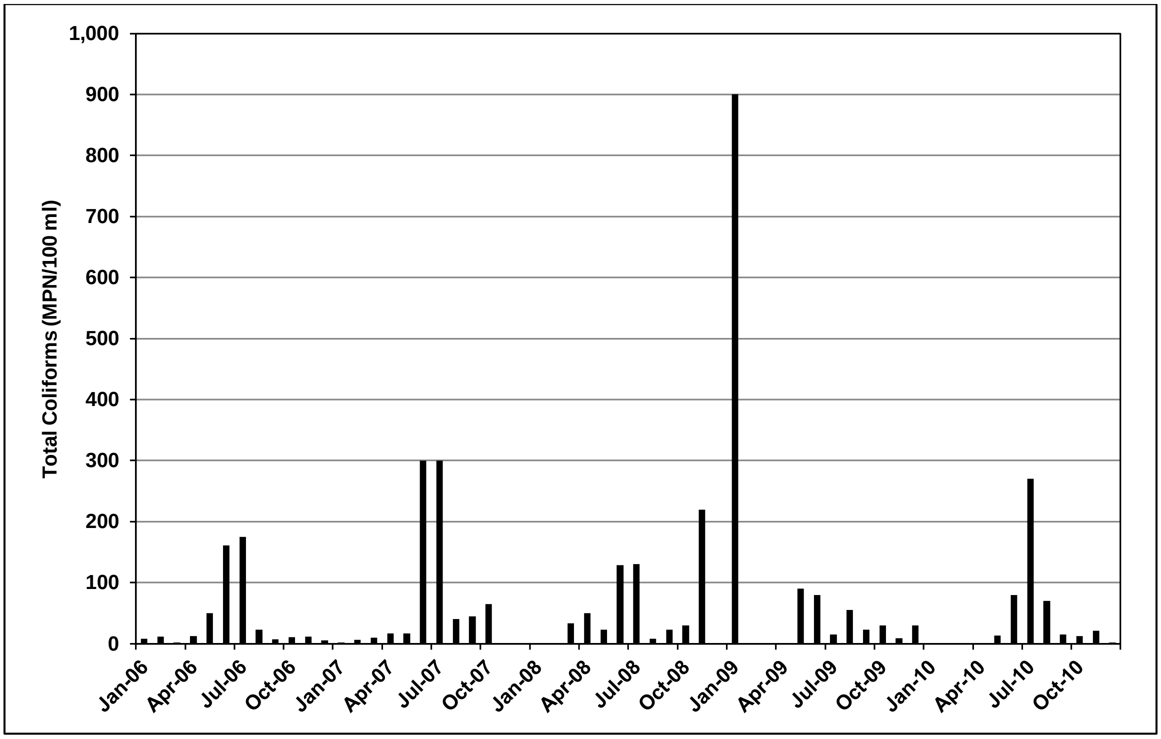


Figure 10-30. Monthly Median *E. coli* at the Acton WTP

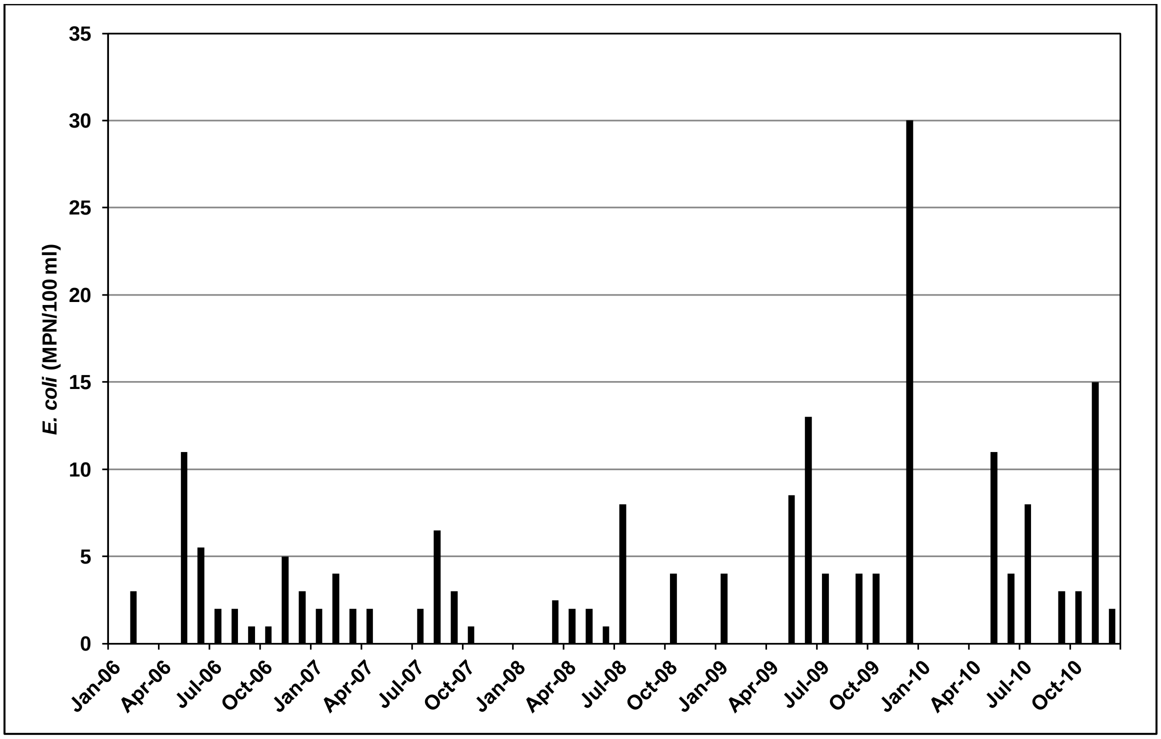


Figure 10-31. Monthly Median Total Coliforms at the Palmdale WTP

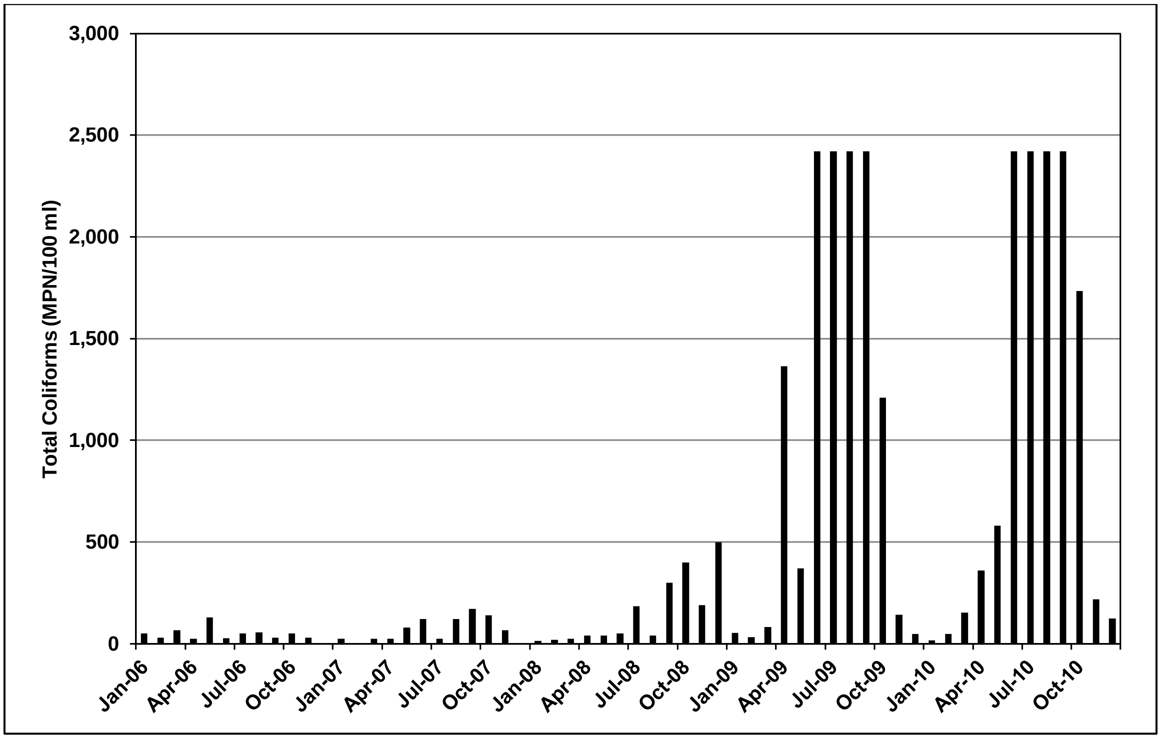
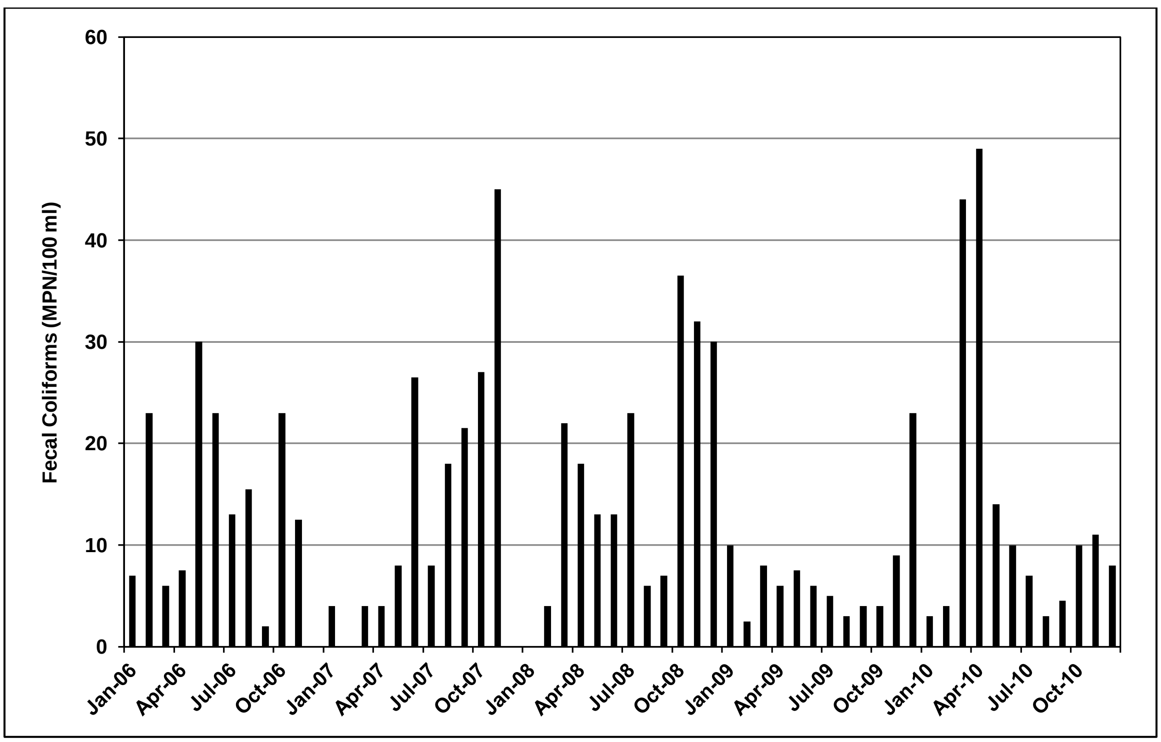


Figure 10-32. Monthly Median Fecal Coliforms at the Palmdale WTP



EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

The indicator organism data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia*, and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from this reach of the East Branch.

EAST BRANCH OF THE CALIFORNIA AQUEDUCT (SILVERWOOD LAKE TO LAKE PERRIS)

MWDSC and Crestline Lake Arrowhead Water Agency (CLAWA) are the only two agencies that divert water from this reach of the East Branch for direct use. San Bernardino Valley Municipal Water District is a wholesale agency that diverts water from the East Branch. Other agencies use East Branch water for groundwater recharge. MWDSC diverts water from Devil Canyon Afterbay, downstream of Silverwood Lake and treats it at the 326-mgd Henry J. Mills (Mills) WTP. MWDSC routinely takes water from Lake Perris. When water is taken from Lake Perris it is typically blended with Colorado River water and treated at the 520-mgd Robert A. Skinner WTP, but it can also be treated at the Mills WTP. CLAWA diverts water directly from the south side of Silverwood Lake and treats it at the 3-mgd CLAWA WTP. CLAWA delivers water to wholesale and residential customers in the San Bernardino Mountains. Data from the Mills WTP and the CLAWA Silverwood intake are evaluated in this section.

PROTOZOA

MWDSC collected monthly samples for *Giardia* and *Cryptosporidium* at the Mills WTP intake from January 2006 through December 2010. *Giardia* and *Cryptosporidium* were not detected in any samples. The LT2ESWTR data were collected between October 2006 and September 2008. The maximum RAA was 0 oocysts/L, well below the Bin 1 threshold level of 0.075 oocysts/L.

CLAWA collected 42 protozoa samples between February 2006 and November 2010. There were no detects of *Cryptosporidium* and only two detects of *Giardia* (May 2008 [0.1 cysts/L] and February 2010 [0.8 cysts/L]). These data place the Silverwood intake in Bin 1.

INDICATOR ORGANISMS

MWDSC provided monthly median indicator organism data for the period of January 2006 through December 2010 for the Mills WTP. The monthly medians for total coliforms, fecal coliforms, and *E. coli* are shown in **Figures 10-33 through 10-35.** These data indicate that monthly median total coliform densities exceed 1,000 MPN/100 ml, with peaks occurring during the second half of the year (July through December). The highest monthly total coliform medians occurred in January and July 2009. Peak total coliform monthly medians are higher than those reported in the 2006 Update.

The monthly median fecal coliform densities were below 65 MPN/100 ml in all months and less than 10 MPN/100 ml in 92 percent of the months. The monthly median *E. coli* densities were below 55 MPN/100 ml in all months and less than 10 MPN/100 ml in 94 percent of the months.

Figure 10-33. Monthly Median Total Coliforms at the Mills WTP

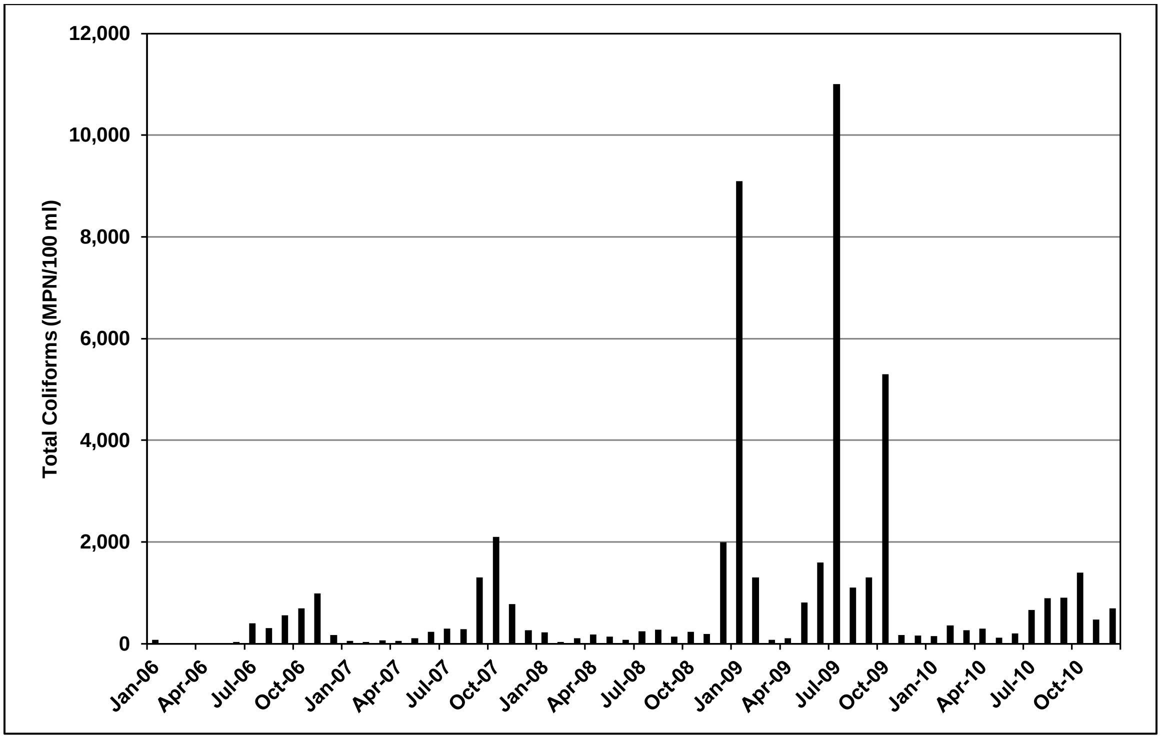


Figure 10-34. Monthly Median Fecal Coliforms at the Mills WTP

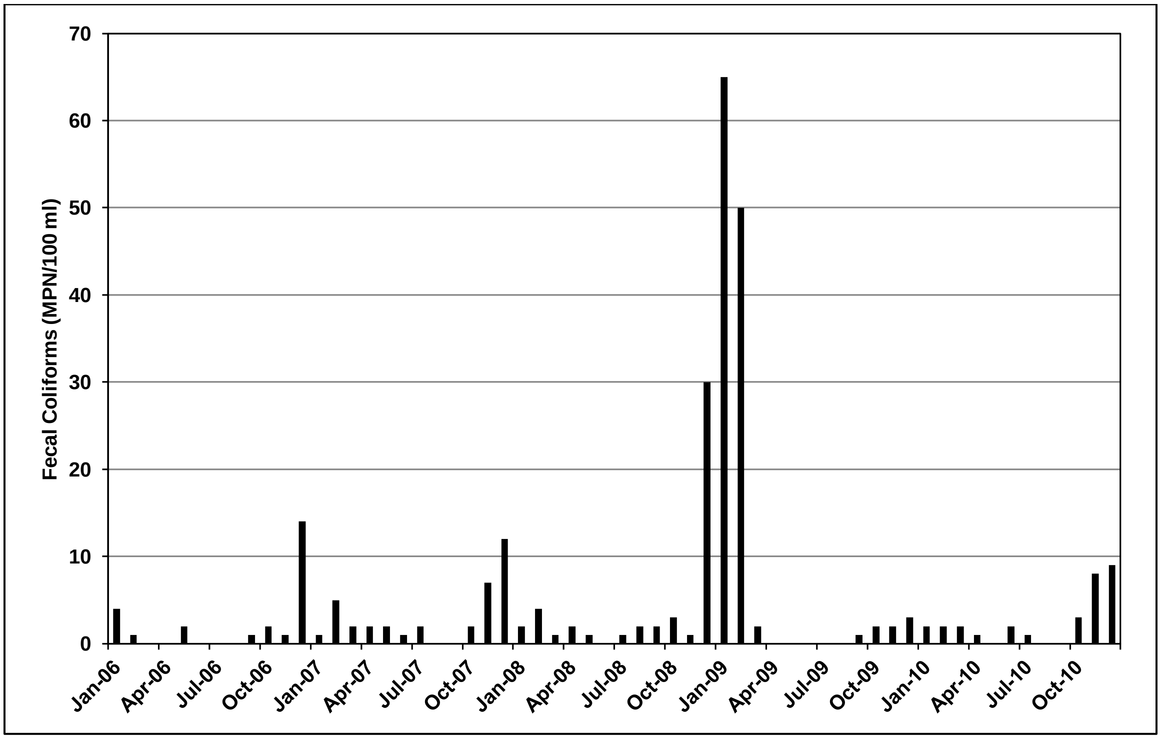
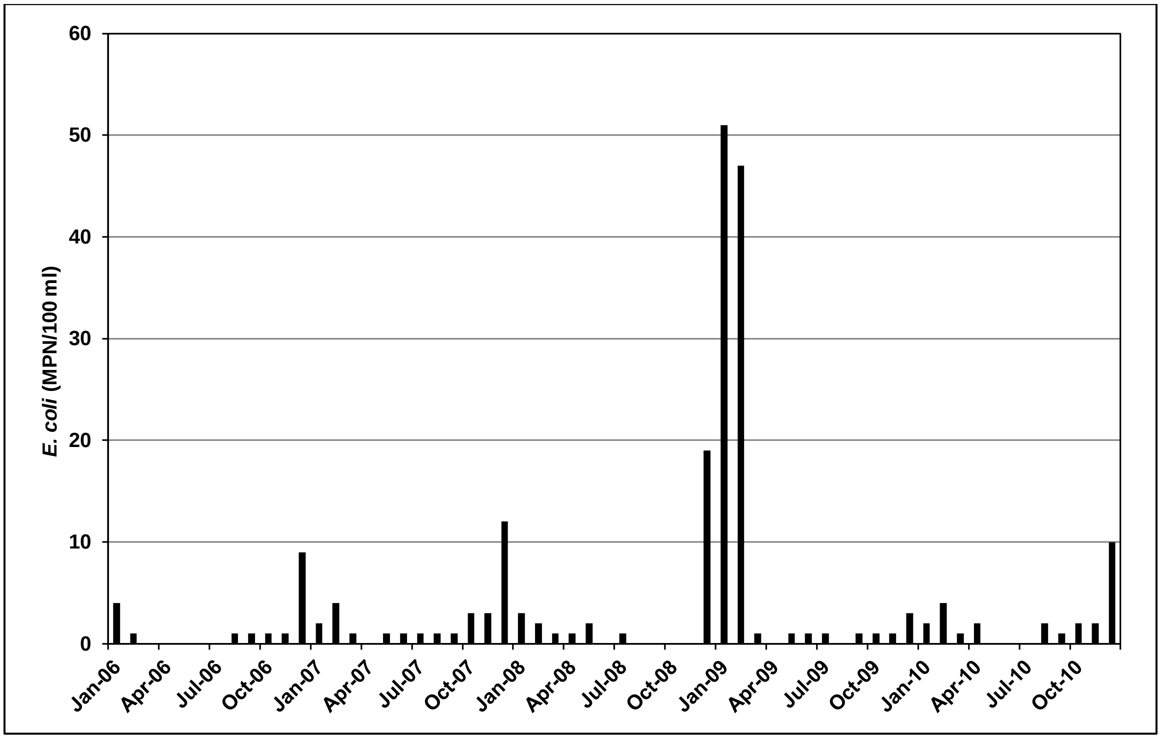


Figure 10-35. Monthly Median *E. coli* at the Mills WTP



CLAWA collected weekly total and fecal coliform samples from January 2006 through December 2010 and *E. coli* samples from July 2007 through December 2010. Total coliform densities ranged from non-detect to greater than 1,600 MPN/100 ml, with a median density of 14 MPN/100 ml. Monthly median densities were calculated and are shown in **Figure 10-36**; All of the monthly medians were below 300 MPN/100 ml.

Fecal coliform densities ranged from non-detect to 240 MPN/100 ml, with a median density of 2 MPN/100 ml. Monthly median densities were all less than 20 MPN/100 ml. *E. coli* densities ranged from non-detect to 16 MPN/100 ml, with a median density of 1 MPN/100 ml. Monthly median densities were all at or less than 12 MPN/100 ml.

EVALUATION OF PATHOGEN REDUCTION/INACTIVATION REQUIREMENTS

Both the indicator organism data and the five years of *Giardia* and *Cryptosporidium* data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia*, and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from this reach of the East Branch.

Figure 10-36. Monthly Median Total Coliforms at CLAWA Intake on Silverwood Lake

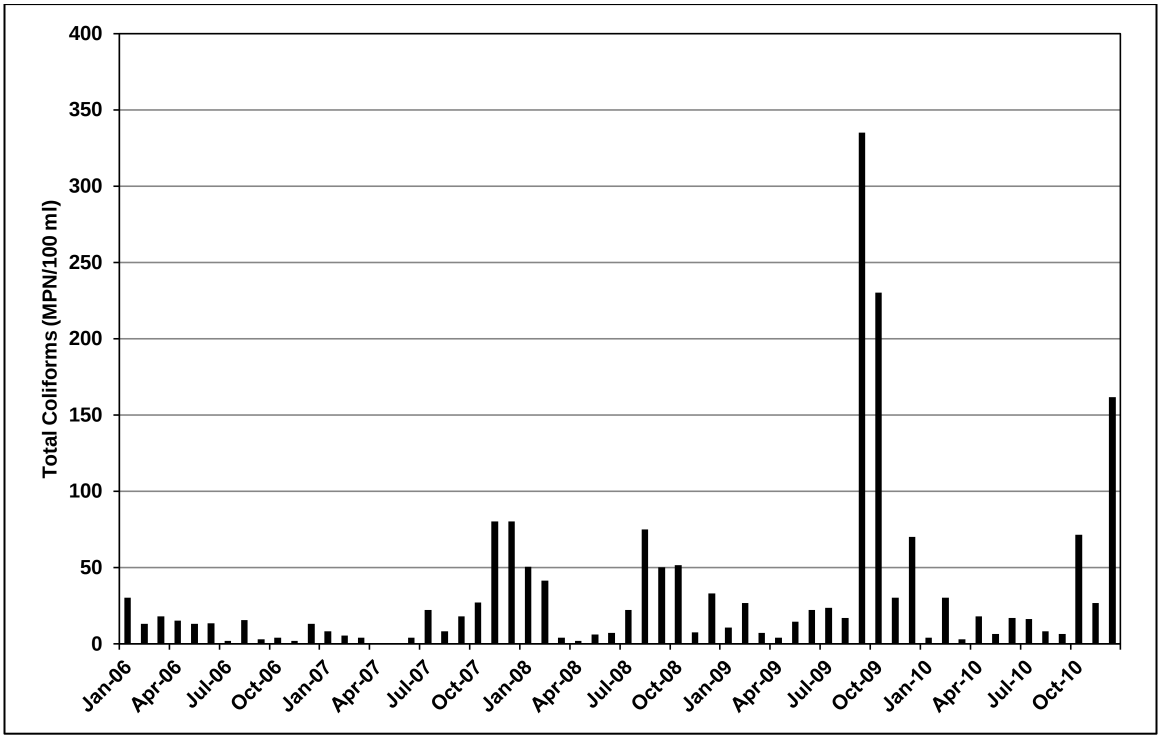


Figure 10-37. Monthly Median Fecal Coliforms at CLAWA Intake on Silverwood Lake

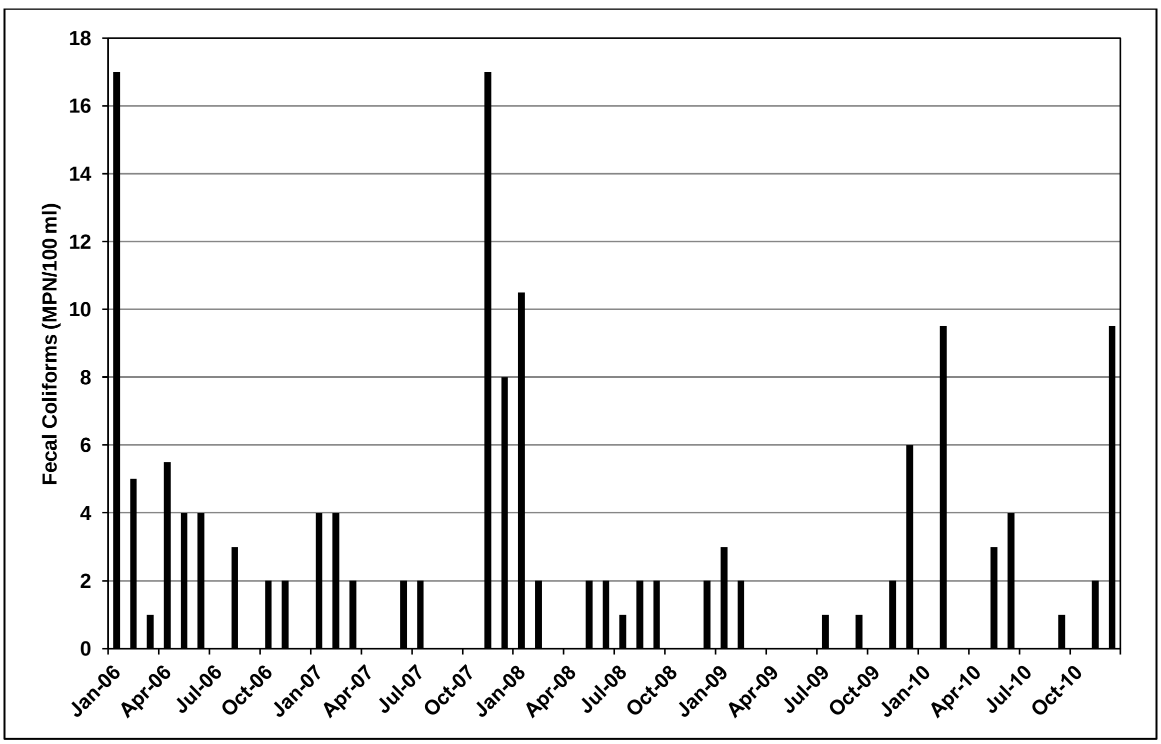
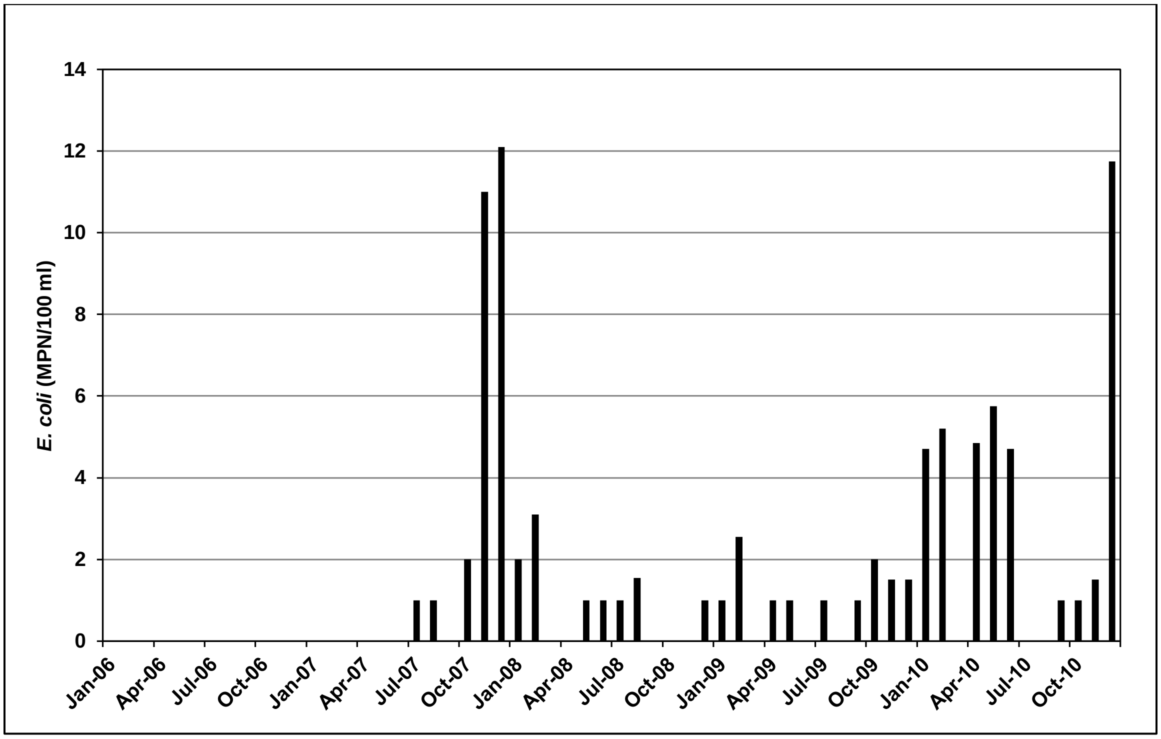


Figure 10-38. Monthly Median *E. coli* at CLAWA Intake on Silverwood Lake



SUMMARY

- The NBA Contractors and DWR completed LT2ESWTR monitoring during the study period, resulting in a Bin 1 classification. Peak total coliform monthly medians were higher than historical values, often exceeding 1,000 MPN/100 ml and were the highest in the SWP sources evaluated. However, fecal coliform monthly medians remained stable and below the 200 MPN/100 ml advanced treatment threshold in all but one month. The current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements are adequate for the WTPs that treat NBA water.

- The SBA Contractors completed additional protozoan monitoring and the results were consistent with the previous Bin 1 classification. The highest coliform densities were seen at ACWD's WTP2, but the *E. coli* monthly medians were still less than the 200 MPN/100 ml advanced treatment threshold. Peak total coliform densities occurred in the summer months while peak *E. coli* densities occurred in the winter months. The current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements continue to be appropriate for the WTPs that treat SBA water.

- SCVWD completed additional protozoan monitoring for the Santa Teresa WTP, which receives water from San Luis Reservoir, and the results were consistent with the previous Bin 1 classification. Peak total coliform monthly medians were higher than historical values, while *E. coli* monthly medians remained stable and well below the 200 MPN/100 ml advanced treatment threshold. Peak *E. coli* densities occurred during wet weather months. The current 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements continue to be appropriate for the Santa Teresa and DWR San Luis O&M WTPs.

- The City of Avenal (CVP Contractor) conducted coliform and protozoan monitoring for its diversion on the San Luis Canal. The densities of total and fecal coliforms were generally low. There were four months when the fecal coliform monthly median was greater than 200 MPN/100 ml. Protozoan analysis of the source water resulted in no detections. The pathogen and coliform data indicate 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus reduction requirements may be appropriate for the WTPs that utilize the San Luis Canal portion of the California Aqueduct.

- CCWA completed LT2ESWTR monitoring during the study period, resulting in a Bin 1 classification. The coliform data continued to show generally low overall densities. Peak total coliform monthly medians were higher than in the 2006 Update, while fecal coliform and *E. coli* remained stable and well below the 200 MPN/100 ml advanced treatment threshold. The data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia*, and 4-log reduction of viruses continue to be appropriate for the Polonio Pass WTP.

- KCWA conducted coliform and protozoa monitoring near its turnout on the California Aqueduct. *Giardia* and *Cryptosporidium* were not detected. The source was classified as Bin 1 under the LT2ESWTR and no additional action is required at this time. Total coliform can exceed 1,000 MPN/100 ml with peak monthly medians greater than those presented in the 2006 Update. *E. coli* densities remained stable and well below the 200 MPN/100 ml advanced treatment threshold. The protozoan and *E. coli* data indicate that the California Aqueduct in this reach requires 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses.

- MWDSC and CLWA completed LT2ESWTR for their WTPs taking water from Castaic Lake during the study period, resulting in a Bin 1 classification. Total coliform monthly medians at MWDSC's Jensen WTP intake exceed 1,000 MPN/100 ml during the summer months and peak densities were higher than those presented in the 2006 Update. Fecal coliform and *E. coli* remained stable and well below the 200 MPN/100 ml advanced treatment threshold, with peak values occurring in 2006 and early 2007. Coliform densities in Castaic Lake are lower and stable throughout the year. The fecal coliform, *E. coli* and protozoan data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the West Branch.

- AVEK completed its LT2ESWTR monitoring in 2006 and Palmdale completed its monitoring in 2007. All four of AVEK's WTPs and Palmdale's WTP were classified as Bin 1. AVEK and Palmdale did not provide any new protozoa data for the study period. The AVEK total coliform monthly medians were less than 1,000 MPN/100 ml and the fecal coliform and *E. coli* monthly medians were well below the 200 MPN/100 ml advanced treatment threshold. The Palmdale total coliform monthly medians increased in 2009 and 2010 and were often above 1,000 MPN/100 ml. The fecal coliform monthly medians were well below the 200 MPN/100 ml threshold. The fecal coliform, *E. coli*, and protozoan data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the East Branch.

- MWDSC completed LT2ESWR monitoring at the Mills WTP and CLAWA completed monitoring at its Silverwood Lake intake, resulting in Bin 1 classifications for both agencies. MWDSC's data show that total coliform monthly medians exceed 1,000 MPN/100 ml during the second half of most years and peak densities are higher than those presented in the 2006 Update. Fecal coliform and *E. coli* remained stable and well below the 200 MPN/100 ml advanced treatment threshold. The fecal coliform, *E. coli* and protozoan data indicate that 2-log reduction of *Cryptosporidium*, 3-log reduction of *Giardia,* and 4-log reduction of viruses continue to be appropriate for the treatment plants treating water from the East Branch lakes.

CHAPTER 11 ORGANIC CHEMICALS AND TRACE ELEMENTS

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CHAPTER 11 ORGANIC CHEMICALS AND TRACE ELEMENTS

ORGANIC CHEMICALS

Maximum Contaminant Levels (MCLs) have been established by the California Department of Public Health (CDPH) for a number of organic chemicals that pose a risk in drinking water supplies. Most of these chemicals have never been detected in the State Water Project (SWP) and those that have been detected are found at concentrations well below the MCLs. However, the watershed for the SWP receives agricultural drainage, treated wastewater from urban areas, and urban runoff, all potential sources of organic chemicals. As a result, the Department of Water Resources (DWR) conducts monitoring three times each year for chlorinated organic chemicals, organo-phosphorus pesticides, herbicides, carbamate pesticides, and a variety of other synthetic organics throughout the SWP.

DWR collects samples in March, June, and September of each year for organic chemicals. Chemical scans include carbamate pesticides, chlorinated organic pesticides, chlorinated phenoxy herbicides, sulfur pesticides, glyphosate, phosphorus/nitrogen pesticides, and purgeable (volatile organics). Chemicals detected during the 2001 to 2005 period and the 2006 to 2010 period are compared in **Table 11-1**. **Table 11-2** shows the chemicals that were detected, the number of times they were detected (out of 15 samples) and the maximum concentration detected at each location that is monitored. The left column of the table lists the relevant MCL, if one exists. Inspection of the table demonstrates that none of the detected chemicals was present in concentrations exceeding an MCL; however, simazine was detected at 3.35 µg/L at Check 41 in March 2007, which is close to the MCL of 4 µg/L.

Simazine, diuron, 2,4-D, and metolachlor are the chemicals most frequently detected in the SWP. Simazine is an herbicide used to control broad-leaf weeds and annual grasses in crop fields and along public rights-of-way. Introduced in 1956, Simazine use in California has gradually declined over the past 20 years from 1,186,069 pounds applied in 1990 to 415,314 pounds applied in 2009. Simazine is applied mostly in orange groves (33.5% of the total applied in California), followed by wine grapes (21.6%), almonds (11.6%), table and raisin grapes (11.2%), walnuts (8.1%), and public rights-of-way (3%). Diuron is an herbicide that inhibits a target plant's photosynthesis process. Introduced in 1954, Diuron use in California has declined from a peak of 1,504,268 pounds in 1998 to 615,314 pounds in 2009. Diuron is applied mostly to public rights-of-way and orange groves, 30.6% and 22.1%, respectively, followed by alfalfa (15%), tangerines (10.3%), landscape maintenance (7.9%), and walnuts (2.8%). 2,4-D is an herbicide used to control broadleaf weeds. It has been used widely in California since World War II and is applied in California mostly in almond orchards and wheat fields. Metolachlor is a pre-emergent herbicide used to control broad-leaf weeds and annual and other grasses. Metolachlor was registered for use in 1977 and is applied primarily around beans, corn, sorghum, potatoes, and cotton.

Table 11-1. Pesticides and Organic Chemicals Detected in the SWP

Chemical	2001-2005 Detections	2006-2010 Detections
Simazine	34	55
Diuron	28	43
2,4-D	17	18
Metolachlor	7	14
Atrazine	1	2
Diazinon	12	1
Dacthal	0	1
Dimethoate	0	1
Triclopyr	0	1
Methoxychlor	0	1
Chlorpyrifos	4	0
MTBE	3	0
Trifluralin	3	0
Styrene	2	0
Toluene	2	0
Pentachlorophenol	1	0

MERCURY AND POLYCHLORINATED BIPHENYLS

Lake Del Valle was listed by the State Water Resources Control Board on the 2006 and 2010 303(d) lists of impaired waterbodies for mercury and polychlorinated biphenyls (PCBs). The listing is based on a finding of elevated levels of these pollutants in the tissues of fish taken from the lake in April 2001. Four species of fish were sampled for mercury and one species was sampled for PCBs. Mercury was found at levels exceeding the Office of Environmental Health Hazard Assessment (OEHHA) screening value of 0.3 µg/g in one channel catfish and three largemouth bass. Mercury was not detected in the other eight fish that were sampled (three bluegills, three redear sunfish, and two other channel catfish). PCBs exceeded the OEHHA screening value of 20.0 ng/g in all three channel catfish that were sampled. No other fish species were tested for PCBs. The source of the mercury and PCBs is unknown. DWR analyzed 44 water samples collected at the Lake Del Valle Conservation Outlet (Conservation Outlet) for dissolved mercury between 1998 and 2010. Mercury was not detected in any of the samples with a detection limit of 0.0002 mg/L. There are no PCB data for the Conservation Outlet in DWR’s Water Data Library. Mercury and PCBs are often found in sediments and fish tissue and not in the water column. It is possible therefore, that if these contaminants are present in the Lake Del Valle system, they are confined to the lake’s sediments and may bioaccumulate in fish tissue but do not pose a threat to drinking water quality. The San Francisco Bay Regional Water Quality Control Board will develop a total maximum daily load (TMDL) for each of these contaminants. The TMDL will identify the sources of mercury and PCBs in the watershed and will include a plan for controlling the sources and reducing the levels in fish tissues. The mercury TMDL is scheduled for completion in 2013 and the PCB TMDL is scheduled for completion in 2019.

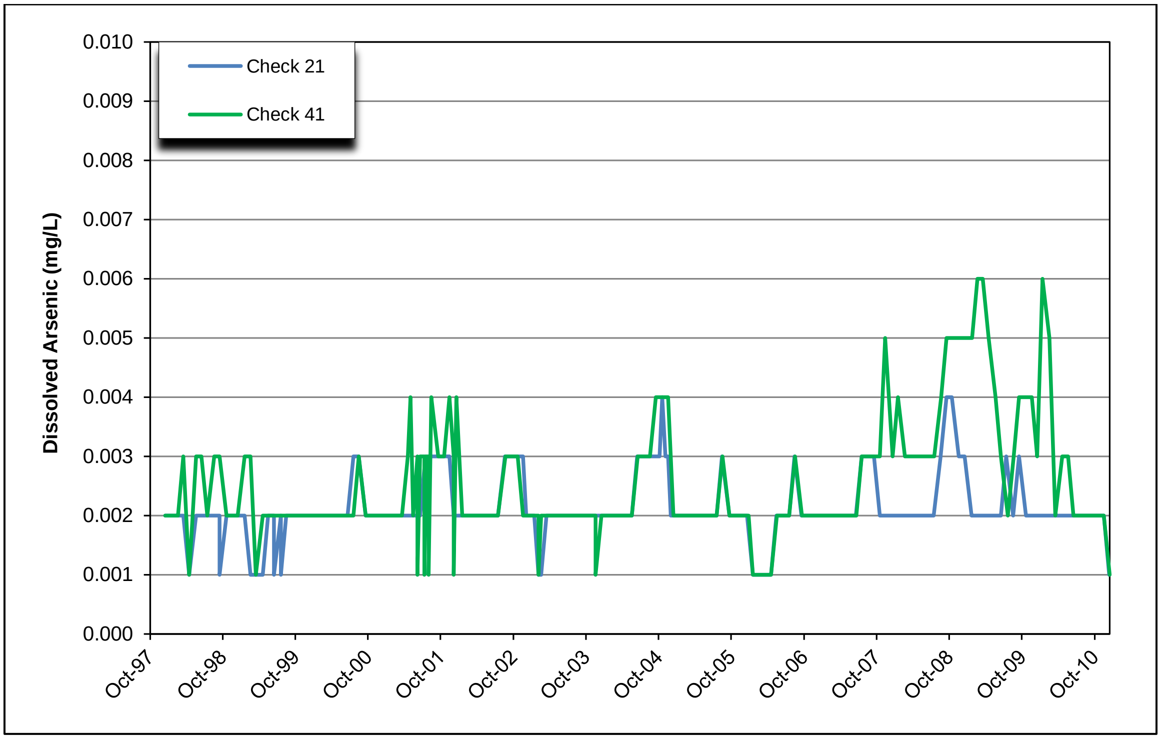
Table 11-2. Summary of Detected Pesticides and Other Synthetic Organic Chemicals (µg/L)

Compound	MCL	Barker Slough		Banks		O'Neill Forebay Outlet		Delta Mendota Canal		Check 21		Check 29		Check 41		Devil Canyon	
		No.	**Max**	**No.**	**Max**	**No.**	**Max**	**No.**	**Max**	**No.**	**Max**	**No.**	**Max**	**No.**	**Max**	**No.**	**Max**
2001 to 2005																	
2,4-D	70	1	0.32	3	0.30	3	0.20	4	0.43	3	0.20	2	0.11			1	0.10
Atrazine	1							1	0.02								
Chlorpyrifos	none			1	0.03	1	0.02					1	0.01	1	0.06		
Diazinon	none	1	0.01	1	0.01	1	0.01	2	0.01	2	0.01	3	0.03	1	0.01	1	0.01
Diuron	none	3	0.89	4	1.10	4	3.20	4	1.00	3	1.50	3	0.94	4	2.10	3	1.70
Metolachlor	none	1	0.10	1	0.10	1	0.10			1	0.10	2	0.10	1	0.10		
MTBE	13							3	2.20								
Pentachlorophenol	1							1	0.10								
Simazine	4	3	0.24	3	0.12	4	0.14	4	0.09	5	0.12	5	0.15	5	0.20	5	0.20
Styrene	100	1	0.70	1	0.80												
Toluene	150	1	1.10	1	0.73												
Trifluralin	none	1	0.01	1	0.01							1	0.08				
2006 to 2010																	
2,4-D	70	3	0.1	4	0.4	2	0.4	3	0.6	2	0.3	2	0.4	2	0.3		
Atrazine	1	1	0.11					1	0.02								
Dacthal (DCPA)	none											1	0.12				
Diazinon	none											1	0.03				
Dimethoate	none	1	0.02														
Diuron	none	6	0.81	5	0.81	4	0.69	5	2.35	6	1.25	6	1.40	6	7.72	5	1.72
Methoxychlor	30							1	0.06								
Metolachlor	none	4	0.4	4	0.2			4	0.2	1	0.1			1	0.1		
Simazine	4	3	0.46	7	0.12	9	0.10	6	0.13	8	0.12	7	0.12	7	3.35	8	0.69
Triclopyr	none	1	0.02														

ARSENIC

Of the inorganic chemicals for which MCLs exist, only arsenic is believed to have the potential to be a problem in SWP supplies. The source of the arsenic is groundwater that is allowed into the aqueduct between Check 21 and Check 41. **Figure 11-1** shows the arsenic concentrations at Check 21, which is upstream of most of the groundwater inflows, and Check 41, which is downstream of most of the inflows. When substantial inflows are allowed into the California Aqueduct, such as the fall of 2001 and 2007 to 2009, the arsenic concentration at Check 41 is substantially higher than the concentration at Check 21. The dissolved arsenic concentrations have never exceeded the MCL of 0.010 mg/L for total arsenic. Groundwater inflows to the SWP system and their impact on arsenic levels in the California Aqueduct are discussed in Chapter 14.

Figure 11-1. Arsenic Concentrations in the California Aqueduct



CHAPTER 12 CONSTITUENTS OF EMERGING CONCERN

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CHAPTER 12 CONSTITUENTS OF EMERGING CONCERN

Constituents of Emerging Concern (CECs) can be broadly defined as any chemicals not commonly monitored that have the potential to cause adverse ecological or human health impacts. Due to rapid advances in analytical technology, the ability to detect infinitesimally small chemical concentrations has caused an "emergence" of chemicals previously undetectable such as caffeine, antibiotics, detergents, perfumes, disinfectants, insecticides, pain killers, steroids, other personal care products, drugs, and natural and synthetic hormones. Chemicals known as endocrine disruptors are thought to be adversely affecting the reproductive systems of fish that inhabit waters that also serve as drinking water sources. This chapter provides a brief overview of the issues associated with these emerging constituents and what is currently known about occurrence, fate and transport; health effects; removal by wastewater and drinking water treatment processes; and regulations.

CLASSES OF EMERGING CONSTITUENTS

Pharmaceuticals or pharmaceutically active chemicals (PhACs) and personal care products (PCPs) are often grouped together and called pharmaceuticals and personal care products (PPCPs). PPCPs include a diverse group of thousands of chemicals that are ingested by humans and animals or applied to the bodies of humans and animals. This wide-ranging class includes prescription and non-prescription drugs (for both humans and animals), soaps, fragrances, insect repellant, and sunscreen, among others. These chemicals enter sewer systems when they are excreted or washed off the body. Unused medications are also disposed of by flushing them down the toilet or pouring them down the drain. Incomplete removal in wastewater treatment plants results in numerous PPCPs being discharged to surface waters at very low (µg/L to ng/L) concentrations. They can also enter surface waters from land application of organic materials and by runoff contaminated by animal excrement.

In addition to PPCPs, other classes of emerging constituents include polybrominated diphenyl ethers (PBDEs), pyrethroids, and perfluorocarbons (PFCs). Recently, several other types of high volume use chemicals have gained the attention of researchers and regulators including current-use flame retardants, antimicrobials, nanomaterials, cyclosiloxanes, and quaternary ammonium compounds. PFCs are chemicals used in non-stick cookware, stain-resistant fabrics, and food packaging. The use of PFCs has been restricted over the past decade because of concerns with their potential toxicity to humans and wildlife, but they are frequently detected in the environment worldwide. Triclosan and triclocarban are antimicrobials found in many consumer products such as soaps, toothpaste, and other personal care products. Concerns over these compounds include their potential for endocrine disruption in wildlife, antibiotic resistance, and potential toxicity to algal and microbial communities. Nanomaterials such as nanosilver, titanium dioxide, and carbon nanotubes are used in commercial applications and are currently being studied to investigate their environmental fate and potential toxicity. Cyclosiloxanes are persistent contaminants used in a wide variety of personal care products, silicones, and in commercial applications as carriers, lubricants, and solvents. Information on cyclosiloxanes such as Decamethylcyclopentasiloxane is limited due to the difficulty in measuring in environmental matrices. Quaternary ammonium compounds are cationic surfactants widely used in industrial applications and consumer products such as fabric softeners and detergents.

Endocrine disrupting chemicals (EDCs) are chemicals that interfere with the normal functioning of hormones in the bodies of humans and animals. It is debatable which compounds should be considered as EDCs, as compounds not currently considered EDCs may be determined to have endocrine disruptive effects after further screening. Modes of action of EDCs include mimicking natural hormones, interfering with hormone function, and degrading hormones. Some PPCPs such as phthalates, used in hair spray, fingernail polish, and cosmetics, and hormones contained in oral contraceptives are EDCs but not all EDCs are PPCPs. For example, industrial waste products such as dioxins (TCDD) and furans, industrial chemicals such as perchlorate, polychlorinated biphenyls (PCBs) and organometals (e.g. tributyltin, an anti-fouling agent in boat paint), organochlorine pesticides and their degradation products, and flame retardants such as polybrominated diphenylether are all endocrine disruptors. In addition, potential EDCs are contained in natural products such as soybeans and alfalfa. EDCs enter surface waters from a variety of sources including industrial and municipal wastewater discharges and runoff from urban and agricultural areas.

Pyrethroids are primarily used as an insectide. The usage of pyrethroids dramatically increased in the early 2000s after the United States Environmental Protection Agency (USEPA) and manufacturers withdrew diazinon and chloropyrifos products for residential use because of health risks to users and their families (Aquatic Science Center, 2011). Pyrethroids have endocrine disrupting properties and notably, bifenthrin stands out among the group for its elevated concentration and frequency of detection in urban runoff, which originates from pesticide use around homes and commercial establishments.

Nitrosamines are a class of organic CECs that are of particular concern to drinking water agencies due to its carcinogenic nature. Nitrosamines can be formed as a byproduct of the disinfection of some natural waters with chloramines. It is anticipated that certain nitrosamines such as N-nitrosodimehtlyamine (NDMA), or a broader class of nitrosamines, may likely be the next disinfection byproduct(s) regulated by the USEPA.

OCCURRENCE IN THE ENVIRONMENT

EDCs and PPCPs were first recognized as potential contaminants when they were linked to adverse impacts on aquatic organisms. Aquatic organisms, particularly freshwater and anadromous fish, live in streams and lakes used as sources of drinking water so effects on fish can be a first sign of the presence of these compounds in drinking water sources.

EFFECTS ON AQUATIC ORGANISMS

Aquatic organisms are sensitive to low levels of exposure and are particularly vulnerable when exposure occurs during developmentally sensitive times such as before birth and during juvenile stages of growth. There are a number of studies that have shown developmental and reproductive effects on fish exposed to wastewater effluent, shellfish exposed to organotins, and alligators and frogs exposed to pesticides. Exposure to estrogenic hormones can result in more females than males in a given fish population, the presence of both male and female reproductive organs within an individual organism, and reduced reproductive success. The United States Geological Survey (USGS) has reported finding intersex or feminized male fish in many locations throughout the country. A nationwide USGS study that analyzed the concentrations of two hormones (17β-estradiol and 11-ketotestosterone) in the blood plasma of carp from 25 sites showed that fish from New Don Pedro Reservoir on the Tuolumne River had the highest concentrations (Goodbred et al., 1997). Fish collected from the San Joaquin River at two locations had lower concentrations of the two hormones.

A study of Chinook salmon collected from 13 locations in the Sacramento and San Joaquin watersheds indicated that up to 38 percent of the male fish exhibited complete sex reversal. The highest percent was found in the Mokelumne River, which is generally considered to be a high quality source of drinking water. The feminization of male salmon is potentially attributed to steroid hormones in wastewater effluent, agricultural wastes, and fish hatchery discharges; detergent metabolites used as carriers in pesticide formulations; and pyrethroid pesticides and their metabolites (Sedlak, 2006).

Under the Surface Water Ambient Monitoring Program, the Central Valley Regional Water Quality Control Board (Central Valley Regional Water Board) applied an estrogenic endocrine disrupting chemical (EEDC) screening procedure with juvenile rainbow trout to surface freshwaters collected in the Central Valley and northeastern California (Vlaming, 2006). The indicator used for this assessment was a juvenile rainbow trout liver vitellogenin (Vtg) gene expression assay. Vtg is the liver-synthesized egg yolk protein precursor and is usually silent or not expressed in male fish. The appearance of Vtg in the plasma of adult male or juvenile fish is widely accepted as evidence of exposure to estrogenic chemicals. Results showed that out of 113 samples, only six samples induced marginal, but statistically significant estrogenic activity in the screening procedure. EEDC concentrations in these six samples were low (at or near procedure threshold).

Since 2003, the U.S. Fish and Wildlife Service Environmental Contaminants Division has periodically deployed water sampling devices to assess potential contaminant effects on special status species in the Sacramento-San Joaquin Delta (Delta). In 2005, sampling frequency was increased to monthly, and extracts collected from the sampling devices were injected into juvenile striped bass. Analytical results showed numerous pesticides present at low levels in water. The laboratory tests demonstrated that low level mixtures of contaminants in Delta water can set off responses that signal endocrine disruption in fish (Aquatic Science Center, 2011). The results indicate a need for more comprehensive assessment of EDCs in the Delta. Another study conducted by Johnson et al. (2010) was to: 1) determine the presence of Vtg in the Sacramento splittail, a native fish of the Sacramento/San Joaquin River estuary and 2) to determine the presence of trace levels of organic contaminants by using passive sampling devices. Results showed that two male splittails out of 12 had extremely elevated Vtg. Legacy organochlorines (DDT, DDE, dieldrin) were found at all sites during all seasons; dieldrin, chlordane, and DDE were detected at 58.4 µg/L, 23.8 µg/L, and 61.2 µg/L, respectively. The organophosphate pesticides chlorpyrifos and dioxathion were detected; chlorpyrifos was detected at 154 µg/L in the False River site, a bend off the San Joaquin River. Pyrethroids were also detected; bifenthrin, cypermethrin and fenpropathrin were detected at much lower levels than the organochlorines and organophosphates. Triazine herbicides such as atrazine, atroton, prometon and simetryn were also observed. PCBs were detected at levels ranging from 32.3 µg/L to 73.4 µg/L.

Another study conducted by a university research team from UC Riverside and UC Berkeley found further evidence regarding low level mixtures of contaminants in Delta water and signs of endocrine disruption in fish (Lavado, 2009). This study evaluated the occurrence and sources of compounds capable of feminizing fish in agriculturally impacted waterways in the Central Valley. Out of 16 locations, estrogenic activity was repeatedly observed at six locations, with the Delta location showing the highest estradiol equivalents. However, the concentrations of compounds most frequently associated with feminization of fish (steroid hormones, alkylphenol polyethoxylates, and alkylphenols) were well below the threshold values for feminization of sensitive species, such as rainbow trout. The inconsistency between the water sample and bioassay results was attributed to the possibility that other compounds could be responsible for feminization of Delta fish species. Specifically, this study concluded that in waters impacted by agricultural activities, estrogenic activity may result from the presence of pesticide mixtures and/or their degradates as well as phytoestrogens, adjuvants, and other compounds with multiple endocrine targets and modes of action. Subsequent work has shown that there was a relationship between feminizing activity in fish and a mixture of alkylphenols and alkyphenols ethoxylates (widely used as surfactants) and the pyrethoid bifenthrin.

Another recent study investigated the contribution of cattle-grazing rangelands to steroids in surface waters (Kolodziej and Sedlak, 2007). Between April 2005 and March 2006, 30 sites were sampled in Stanislaus, Marin, and Sonoma counties in central California. All of the steroid analytes were detected in one or more of the 88 water samples. Estrone was detected more frequently than the other steroids, with detectable concentrations in 78 percent of the samples at concentrations as high as 38 ng/L. The estrogen 17α-estradiol was present in 31 percent of the samples at concentrations up to 25 ng/L, while 17β-estradiol was present in 18 percent of the samples at concentrations up to 1.7 ng/L. In approximately 10 to 20 percent of the samples, steroid concentrations exceeded predicted no-effect concentrations for the feminization of fish, indicating that allowing cattle direct access to surface waters may impact the health of aquatic organisms in receiving waters.

In summary, studies conducted to date in the Bay-Delta system have pointed to adverse effects to aquatic organisms from the presence of PPCPs; however, more study is needed.

OCCURRENCE IN SURFACE WATERS

PPCPs and EDCs have been detected in very small amounts in surface waters in the United States and Europe. One of the first comprehensive studies conducted in the United States was conducted by the USGS from 1999 to 2000. USGS sampled 139 streams in 30 states and found low levels of pharmaceuticals, antibiotics, and other organic wastes (Barnes et al., 2002). Samples were collected from sites downstream of urban and agricultural activities and analyzed for 95 chemicals. In 80 percent of the samples analyzed, one or more chemicals were detected, typically at ng/L concentrations. Steroids, non-prescription drugs (acetaminophen and ibuprofen), and insect repellants were the chemical groups most frequently detected.

Two subsequent USGS studies were conducted and results were published in 2008. The first study evaluated 100 target chemicals (pharmaceuticals and organic wastewater compounds) in 25 groundwater and 49 surface waters sources (Focazio et al., 2008). Sites were chosen in areas that were known or suspected to have at least some human and or animal wastewater sources in upstream or upgradient areas. Sixty-three of the 100 targeted chemicals were detected in at least one sample (Focazio et al., 2008). The five most frequently detected chemicals in surface water were cholesterol, metolachlor, cotinine, β-sitosterol, and 1,7-dimethylxanthine. The second USGS study reported on 63 different organic wastewater compounds in groundwater.

An American Water Works Research Foundation (AwwaRF) study also analyzed source waters, finished waters, and distribution system water supplies for 62 EDCs and PPCPs for 18 drinking water utilities across the United States (AwwaRF, 2008a). The suite of 62 chemicals included 20 pharmaceuticals, 26 potential EDCs, five steroid hormones, and 11 phytoestrogens. Forty-one of the 62 targeted chemicals were detected in at least one sample. Overall, pharmaceuticals were the most frequently detected in raw waters. The five most frequently detected chemicals in raw waters were sulfamethoxazole, carbamazepine, atrazine, phenytoin, and meprobamate. Both steroid hormones and phytoestrogens had low frequency of detection in raw water.

Although the nationwide studies provide a baseline of knowledge for the occurrence of PPCPs, it is important to note that occurrence patterns of PPCPs in wastewater effluent is region specific, and dependent on per-capita water consumption (AwwaRF, 2008b). In addition, the occurrence of PPCPs in surface waters highly depends on the degree of wastewater impact upon the source water. Therefore, it is important to derive occurrence information based on studies which have occurred in the watersheds draining to the State Water Project (SWP).

National Water Research Institute Study

In 2010, the National Water Research Institute (NWRI) completed a source, fate, and transport study of endocrine disruptors, pharmaceuticals, and personal care products which contained eleven sampling sites associated with the SWP (Guo et al., 2010). Sample collection was conducted quarterly from April 2008 to April 2009. **Table 12-1** shows the sampling locations and significance of the location. The treated effluents from the Sacramento Regional Wastewater Treatment Plant (SRWTP) and the Stockton Regional Wastewater Control Facility (Stockton WWCF) were not made available for sampling by the respective sanitation districts. However, samples were collected upstream and downstream of both wastewater treatment plants.

Table 12-1. Sampling Locations Associated with the SWP, NWRI 2010 Study

Sampling Location	Significance of the Location
Natomas East Main Drainage Canal (NEMDC)	Urban drainage
American River at E.A. Fairbairn WTP	Upstream of SRWTP
Sacramento River at W. Sacramento WTP	Upstream of SRWTP
Sacramento River at Hood	Downstream of SRWTP
San Joaquin River at Mossdale Landing	Upstream of Stockton WWCF
San Joaquin River at Holt Road	Downstream of Stockton WWCF
H.O. Banks Delta Pumping Plant	Entry into SWP
O'Neill Forebay (O'Neill Forebay Outlet)	Integration point of the Delta output
Check 41	Entry point into Southern California; impacted by agricultural runoff from the Central Valley
East Branch SWP at Devil Canyon	Representing a terminal reservoir
West Branch SWP at Foothill PCS	Representing a terminal reservoir

A total of 43 samples were collected during four sample events. Detectable amounts of PPCPs and organic wastewater compounds were found at all locations, except for the American River at the Fairbairn Water Treatment Plant (WTP) in April 2008, which had no detectable levels of any PPCPs or organic wastewater compounds. Of the 49 PPCPs and organic wastewater compounds analyzed, 21 analytes were detected at or above the minimum reporting level (MRL), whereas the other 28 were not detected at any locations with the existing MRLs. The occurrence of PPCPs is shown in **Table 12-2**, from the most to least frequently detected.

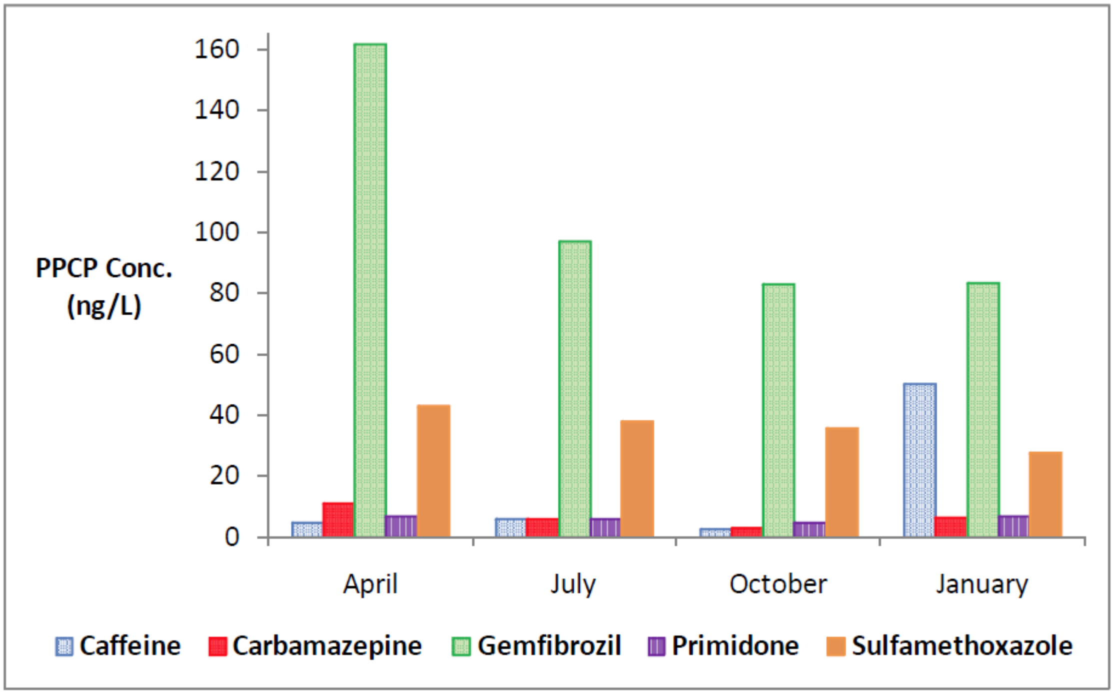
Overall, the median occurrence of targeted PPCPs was less than 30 ng/L, except for diuron (81 ng/L). Diuron is used extensively in California as a pre-emergent herbicide. **Table 12-2** also shows the locations where the maximum concentrations were detected. The highest concentrations of many of the most frequently detected compounds were found in samples from the San Joaquin River at Holt Road, just downstream of the Stockton WWCF.

Seasonal variations of PPCPs in wastewater effluent could not be determined because effluent samples could not be obtained from the SRWTP and Stockton WWCF. The seasonal variations of selected PPCPs downstream of the wastewater treatment plants were evaluated as shown in **Figures 12-1 and 12-2.** At both locations, caffeine was highest in winter (January 2009), possibly reflecting less biodegradation at the WWTPs or less biodegradation in the rivers during this season. In addition, there might also be less photolysis in the winter. Concentrations of PPCPs downstream of the Stockton WWCF were highest in January 2009. As stated in the NRWI study, since WWTP discharge rates do not vary that much from season to season, the flow in the San Joaquin River may have been lower than normal in January 2009. The flow data for the San Joaquin River were presented previously in Figure 3-14. During January 2009, flows ranged from 994 to 1380 cfs, which are typical low flows during dry years. The lowest flows during the period of the NWRI study actually occurred in July 2008.

Table 12-2. PPCPs and Organic Wastewater Compounds Detected in the SWP Watershed, NWRI 2010 Study

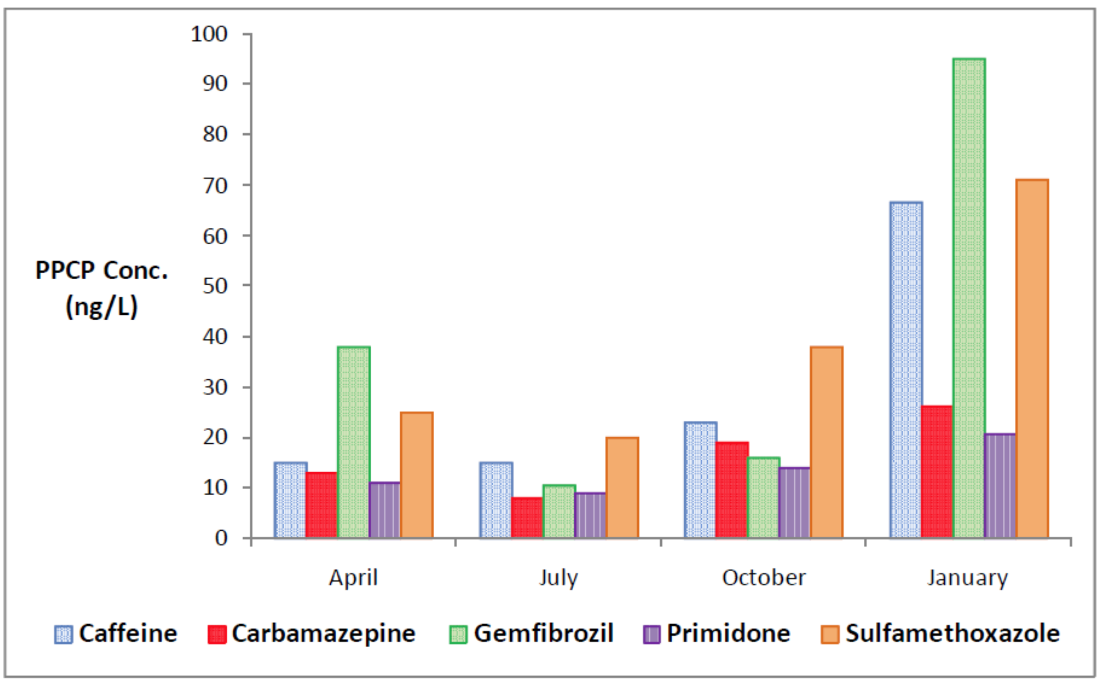
Analyte	Use	Detection Frequency (n=40)	Minimum (ng/L)	Median (ng/L)	Maximum (ng/L)	Location where Maximum was detected
Carbamazepine	Anti-Convulsant	88%	<1	3	26	Holt Road
Diuron	Herbicide	88%	<5	81	873	O'Neill Forebay
Sulfamethoxazole	Antibiotic	88%	<1	11	71	Holt Road
Caffeine		83%	<5	8	67	Holt Road
Primidone	Anti-Convulsant	70%	<2	4	21	Holt Road
TCEP		70%	<5	7	34	Holt Road
Gemfibrozil	Anti-Cholesterol	53%	<5	5	162	Hood
Dilantin	Anti-Convulsant	50%	<5	4	33	Holt
Simazine	Herbicide	38%	<20	<20	408	Devil Canyon
Atrazine	Herbicide	25%	<1	<1	2	Devil Canyon
o,p-DDD	Medicine	20%	<20	<20	82	Banks
Methoxychlor	Insecticide	18%	<20	<20	66	O'Neill
DEET	Insect Repellant	13%	<20	<20	35	Holt
Methylparaben	Anti-fungal agent	10%	<20	<20	744	Check 41
Acetaminophen	Medicine	5%	<1	<1	28	Banks
Linuron	Pesticide	5%	<5	<5	5	Banks
Bisphenol A	Plastics	3%	<30	<30	140	Check 41
Desisopropyl-atrazine	Herbicide	3%	<20	<20	25	
Ibuprofen	Analgesic	3%	<10	<10	47	Holt
Octylphenol	Rubber, Pesticide, Paints	3%	<20	<20	68	
Propylparaben	Cosmetic	3%	<20	<20	83	Check 41

Figure 12-1. Concentrations of Five Representative PCCPs in the Sacramento River at Hood (Downstream of SRWTP), April 2008-January 2009



Source: Adapted from Guo et al. (2010) NWRI Study

Figure 12-2. Concentrations of Five Representative PCCPs in the San Joaquin River at Holt Road (Downstream of Stockton WWCF), April 2008-January 2009

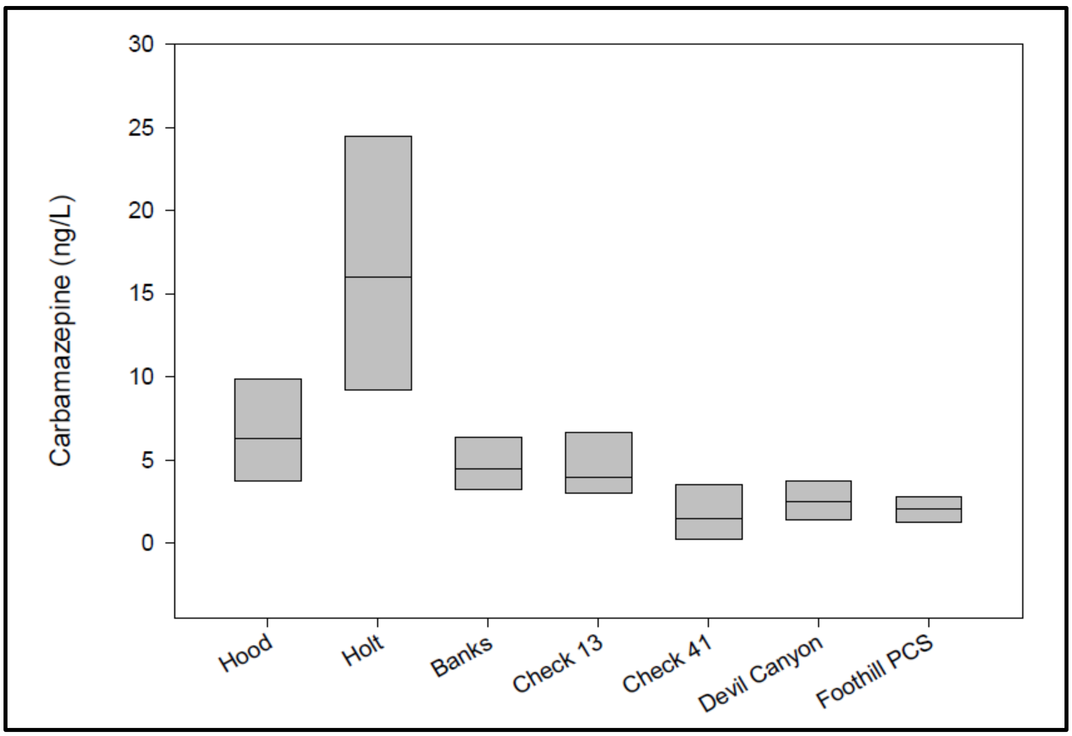


Source: Adapted from Guo et al. (2010) NWRI Study

The NWRI study also provides an upstream to downstream comparison for selected PPCPs along the SWP, beginning with sites just downstream of the SRWTP (Hood) and downstream of the Stockton WWTP (Holt). Certain PPCPs (carbamazepine, primidone, gemfibrozil, and sulfamethoxazole) are highly attenuated as shown in **Figures 12-3 through 12-5.** Since carbamazepine and primidone have been shown to be highly recalcitrant (Loffler et al., 2005; Krasner et al., 2006), the attenuation of carbamazepine and primidone can be attributed to dilution with non-wastewater-impacted water, such as groundwater inflows. Sulfamethoxazole has been shown to undergo biodegradation and sorption to sediments or soils (Boxall, 2008; Radke et al., 2009) and gemfibrozil has been shown to be attenuated by photolysis and biodegradation (Fono et al., 2006). Therefore, the attenuation of gemfibrozil and sulfamethoxazole were most likely due to a combination of dilution and natural degradation. However, detectable levels of some PPCPs were found at terminal reservoirs in southern California.

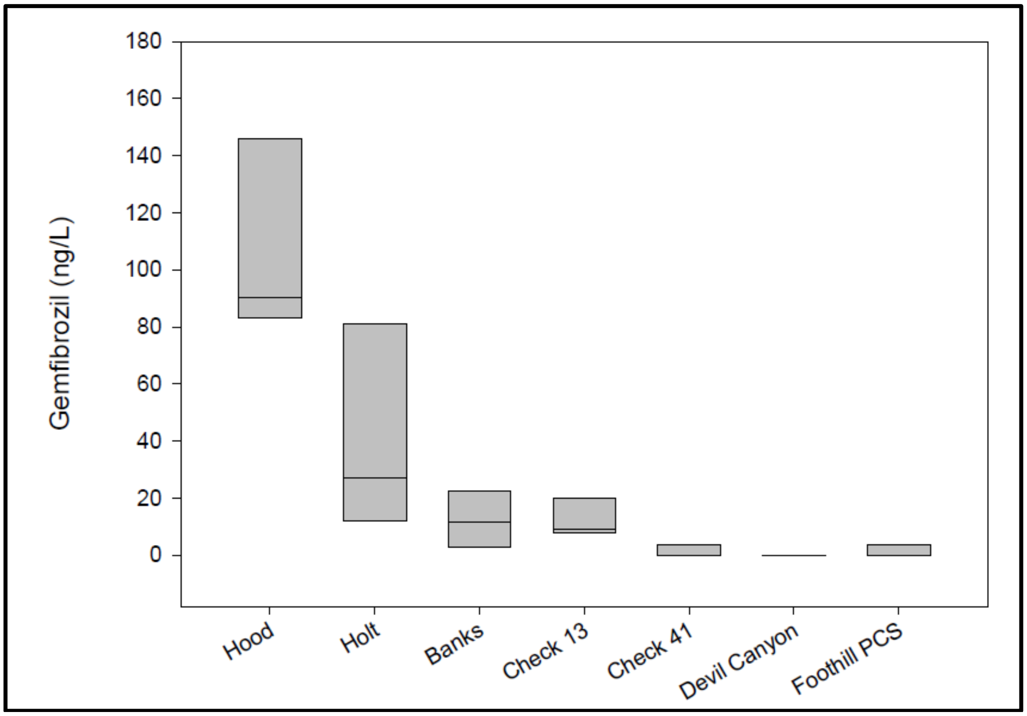
The general conclusion from the Guo et al. (2010) NWRI study is that there is no evidence of human health risk from low levels of the commonly detected EDCs and PPCPs in drinking water or drinking water supplies. However, more toxicological studies are needed.

Figure 12-3. Occurrence of Carbamazepine in the SWP



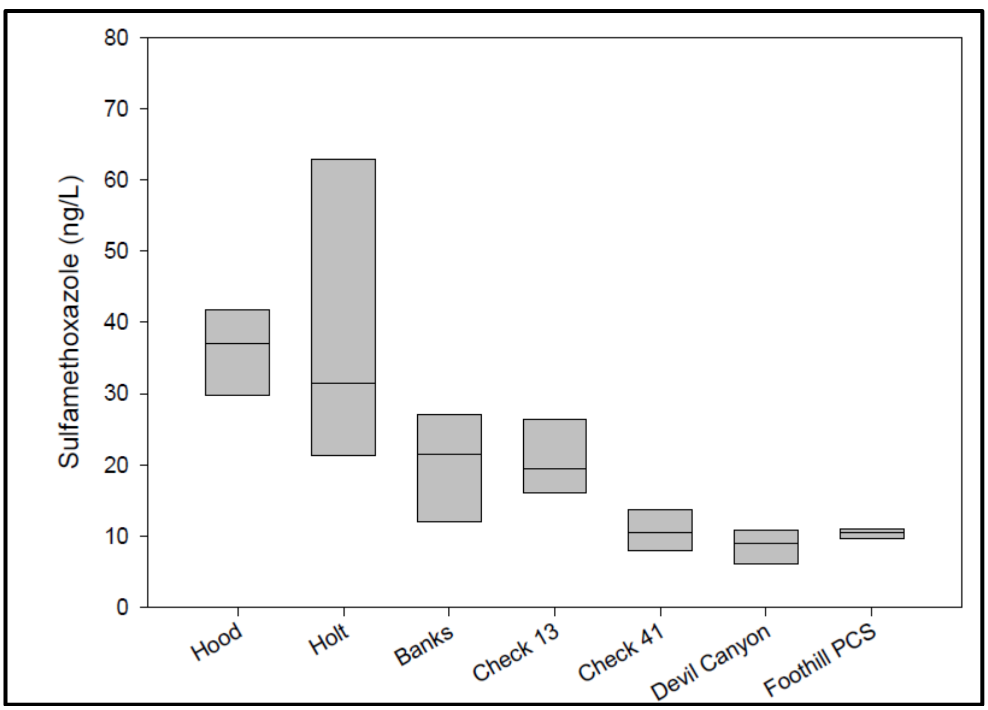
Source: Adapted from Guo et al. (2010) NWRI Study

Figure 12-4. Occurrence of Gemfibrozil in the SWP



Source: Adapted from Guo et al. (2010) NWRI Study

Figure 12-5. Occurrence of Sulfamethoxazole in the SWP



Source: Adapted from Guo et al. (2010) NWRI Study

University of California, Davis Aquatic Ecosystems Analysis Laboratory

A pilot study was conducted by the UC Davis Aquatic Ecosystems Analysis Laboratory to evaluate the presence of PPCPs in the Sacramento River (Schaefer et al., 2009). This work was conducted for the State Water Resources Control Board (State Water Board). Four locations along the Sacramento River were monitored using passive sampling devices: Freeport Marina (approximately 100 meters upstream of the SRWTP effluent discharge), West Bank (approximately 525 meters downstream of the effluent discharge), Cliff's Marina (approximately 1,180 meters downstream of the effluent discharge), and a private dock approximately 1,900 meters downstream of the effluent discharge). Sampling devices were deployed on May 28, 2009 and were retrieved for analysis on June 29, 2009. **Table 12-3** shows a summary of all detectable compounds during the study, as well as a comparison to concentrations found at Hood during the NWRI Study. It should be noted that none of the analytes was detected at the Freeport Marina site, which is upstream of the SRWTP effluent discharge.

Table 12-3. Detectable Results from 2009 PPCP Study of Sacramento River, Aquatic Ecosystems Analysis Laboratory, UC Davis

Analyte	Method Detection Limit (µg/L)	Freeport Marina (µg/L)	West Bank (µg/L)	Cliff's Marina (µg/L)	Private Dock (µg/L)	Hood (NWRI Study) (µg/L)
Caffeine	0.020	ND	7.5	ND	ND	ND – 51
Trimethoprim	0.002	ND	2.0	28.3	26.3	NS
Sulfamethoxazole	0.005	ND	5.92	13.0	13.0	28 – 43
Gemfibrozil	0.002	ND	19.3	ND	214	83 - 162
Ibuprofen	0.02	ND	ND	182	ND	ND
Carbamazepine	0.005	ND	ND	45.6	43.2	3 – 11
Fluoxetine	0.005	ND	17.6	20.8	20.8	NS
Xylene (polycyclic musk)	0.1	ND	1140	ND	100	NS
Nonylphenol	0.5	ND	ND	160	68.5	NS
Nonylphenol Ethoxylates	0.5	ND	ND	800	730	NS

NS – Not sampled

California Department of Water Resources/Metropolitan Water District of Southern California Joint Study

The Metropolitan Water District of Southern California (MWDSC) and the California Department of Water Resources (DWR) completed a two-year study in April 2010 of the sources and occurrence of NDMA, other nitrosamines, and their precursors in the Delta (DiGiorgio et al., 2010). Major conclusions from this study include:

- To date, the only instantaneous nitrosamine detected at sampling locations in the Delta was NDMA. It was detected once at the Mossdale sampling location at 4.2 ng/L, and once at the Vernalis sampling location at 2.5 ng/L. Photodegradation and/or dilution may be one explanation for nondetection.

- NDMA formation potential concentrations were generally two to four times higher downstream of the wastewater treatment plants.

- Primidone concentrations were generally three times higher downstream of the SRWTP and Stockton WWCF compared to upstream concentrations. These findings are generally similar to the NRWI study results, described previously.

- Diuron does not appear to be a major source of NDMA precursors.

- Dissolved organic carbon (DOC), trihalomethane formation potential (THMFP), and haloacetic acid formation potential are not good predictors of NDMA formation potential.

The second phase of this study began in early 2011 and will focus sampling efforts on the SRWTP and the Stockton WWCF. Unlike the previous study, this new study will collect samples by boat to better quantify nitrosamines, their precursors, and WWTP tracers (i.e., selected PPCPs) in discharge effluent as well as continue to quantify WWTP impacts in the Sacramento and San Joaquin rivers. The City of Stockton agreed to sample their treated effluent immediately prior to discharge, but no agreement has been made with the Sacramento Regional County Sanitation District. *Cryptosporidium* and *Giardia* will also be assessed in the treated effluent. The study will conclude at the end of 2012.

Central Valley Regional Water Quality Control Board

Under the Central Valley Regional Water Board's Surface Water Ambient Monitoring Program, a special study was conducted to assess the potential for aquatic life impairment in the Delta due to the occurrence and toxicity of pyrethroid pesticides in the water column. The current use of pyrethroids in California is 50 percent greater than what it was just five years ago (California Department of Pesticide Regulation, 2007). Samples were collected for the eight commonly used pyrethroid pesticides: bifenthrin, cyfluthrin, cypermethrin, esfenvalerate, lambda-cyhalothrin, deltamethrin, fenpropathrin, and permethrin. Water toxicity testing was done with a native crustacean, *Hyalella azteca*. Major conclusions from this study include:

- For several of the pyrethroids, threshold for water toxicity was as low as 2 parts per trillion.

- Virtually all urban runoff contained pyrethroids, typically at about four times the concentration that would paralyze *Hyalella*.

- Bifenthrin and cyfluthrin are the pyrethroids of greatest toxicological concern in urban runoff.

- Pyrethroids were present in 66 percent of the final effluent samples from wastewater treatment plants. They were found most often, and in highest concentration, at the SRWTP, followed by the Vacaville Easterly WWTP, and then the Stockton WWCF. The typical wastewater treatment plant effluent contains pyrethroids at about 1 to 1.5 times the concentrations that would paralyze *Hyalella.*

- Pyrethroids were present in 30 percent of agricultural discharges.

- Pyrethroids (most often bifenthrin) were found in the Sacramento River as it passed through the City of Sacramento. Concentrations peaked near the threshold for causing toxicity.

United States Geological Survey

After the national reconnaissance study was conducted by USGS from 1999 to 2000, there have been no USGS CEC follow-up studies for surface water within the Central Valley. The national reconnaissance study conducted by USGS from 1999 to 2000 included six sites within or tributary to the Delta: the Sacramento River at Freeport; the San Joaquin River near Vernalis; Mud Slough and Orestimba Creek, west-side tributaries to the San Joaquin River that are dominated by agricultural drainage; Turlock Irrigation District (TID) Lateral 5, a canal that receives agricultural drainage and municipal wastewater effluent and drains to the San Joaquin River; and French Camp Slough, a tributary to the San Joaquin River that is dominated by urban runoff. The key findings for this study were summarized in the previous watershed sanitary survey. The key findings for the Central Valley sites are:

- Steroid and Hormone Compounds – Samples were collected from the Sacramento River at Freeport and TID Lateral 5 and analyzed for seven steroid and hormone compounds. Cholesterol was detected at 0.383 µg/L in the Sacramento River and at 1.11 µg/L in TID Lateral 5. Coprostanol was found at 0.624 µg/L in TID Lateral 5.

- Pharmaceuticals – The samples were analyzed for ten pharmaceuticals. None of the pharmaceuticals was detected in the Sacramento River at Freeport, Mud Slough, and French Camp Slough. Acetaminophen was estimated to be 0.004 µg/L in Orestimba Creek and the San Joaquin River at Vernalis. Five pharmaceuticals were detected in TID Lateral 5; acetaminophen at 0.39 µg/L, caffeine at 0.68 µg/L, diltiazem at 0.017 µg/L, 1,7-Dimethylxanthine at 0.21 µg/L and codeine was estimated at 0.019 µg/L.

- Antibiotics – The USGS study reported that the antibiotic data were not yet analyzed for the sites in the Central Valley. The data are not available through the USGS National Water Information System (NWIS) database.

- Selected Organic Wastewater Contaminants – The samples were analyzed for eight organics that the USGS has identified as being present in wastewater. TID Lateral 5 was estimated to contain 0.01 µg/L of 1,4-dichlorobenzene and 0.04 µg/L of 2,6-di-tert-p-benzoquinone. None of the organics was detected at the other five sites.

These data indicate that TID Lateral 5, which receives municipal wastewater from the City of Turlock contained a number of compounds associated with human wastewater at low concentrations. Although the Freeport site on the Sacramento River is downstream of the Sacramento urban area, it is upstream of the discharge from the SRWTP. Due to tidal influence in the Sacramento River, the Freeport site can be influenced by the discharge from the treatment plant but these data do not adequately characterize the quality of water downstream from the discharge.

USGS also sampled for 63 organic wastewater compounds at the intake to West Sacramento's Bryte Bend WTP on the Sacramento River just upstream from the confluence with the American River. This location is upstream of the urban Sacramento area and downstream of a number of large agricultural drains. Eleven samples were collected between October 2004 and June 2005. Nine pesticides were detected and nine organics were verified but not quantified in the samples, including caffeine, cholesterol, and the insect repellant, N,N-Diethyl-meta-toluamide (DEET). The Bryte Bend site does not adequately characterize the quality of water entering the Delta because the largest wastewater discharger in the watershed (SRWTP) is downstream of this site.

OCCURRENCE IN DRINKING WATER

In general, the occurrence of PPCPs is more frequent and at higher median concentrations in source waters than in finished drinking water. The occurrence of these contaminants in finished drinking waters depends on their occurrence in source waters, the drinking water treatment processes, and the analytical detection limit. Some pharmaceuticals and their metabolites have been reported to occur at very low concentrations in some finished drinking water samples in the U.S. A recent, comprehensive study of source, raw, and finished waters for EDCs and pharmaceuticals was conducted for AwwaRF "Toxicological Relevance of EDCs and Pharmaceuticals in Drinking Water". In this study, finished drinking water samples were collected from 18 water utilities across the United States. The five most frequently detected PPCPs were atrazine, meprobamate, phenytoin, atenolol, and carbamazepine, with median concentrations less than 10 ng/L, with the exception of atrazine at a median concentration of 49 ng/L (Benotti et al., 2009 and Synder et al., 2008). Atrazine exhibited the highest frequency of occurrence (83%), followed by meprobamate (78%), phenytoin (56%), atenolol (44%), carbamazepine (44%), and gemfibrozil (39%).

FATE AND TRANSPORT

Concentrations of PPCPs in surface waters can be potentially reduced due to phase partitioning and abiotic and biotic transformation processes (AwwaRF, 2008b). Trace organic wastewater compounds, such as fragrances galaxolide and tonalide, have high octanol-water partition coefficients and can absorb onto river-bed sediments (Rimkus, 1999). However, most pharmaceuticals have low sorption potential and volatility, thus sorption and volatilization removal mechanisms are negligible. Abiotic transformation processes include hydrolysis and photolysis. Photolysis can occur either by direct absorption of light or indirectly by photosensitizers, such as nitrate and humic acids. Several pharmaceuticals such as diclofenac, triclosan, sulfamethoxazole and propranolol have been found to be amenable to photolytic decay in surface waters (AwwaRF, 2008b). Biotransformation mechanisms become more important for hydraulic travel times on the order of weeks. Ibuprofen, gemfibrozil, caffeine, and naproxen have been shown to be transformed via biotransformation processes.

As discussed earlier, the NWRI Study presents fate and transport information on three selected PPCPs through the SWP (Guo et al., 2010).

ANALYTICAL METHODS

One of the major challenges in evaluating CECs in water is that there are no national or international standardized methods. Currently the Water Research Foundation is sponsoring a project entitled "Evaluation of Analytical Methods for EDCs and PPCPs via Interlaboratory Comparison #4167". This project will evaluate current methodology commonly used for the analysis of EDCs and PPCPs by multiple laboratories in various water matrices.

The goal of the project is to provide guidelines to drinking water utilities on optimizing data quality for EDCs and PPCPs. The study will determine which factors are most important in determining the performance of a method at environmentally relevant (ng/L) concentrations. To accomplish this goal, a literature review and single-blind, multi-round interlaboratory studies will be carried out. Using statistical analysis and expert review of results from the interlaboratory studies, major factors that have the most important role in determining the performance of a method will be identified. After testing and evaluating various sample collection related parameters such as bottle type and preservation and quenching agents, the optimized method(s) will be implemented in several laboratories and further tested in a variety of matrices to ensure widespread applicability of the technique(s). This project will provide reliable data on the capabilities of both analytical methods and laboratories for measuring EDCs/PPCPs in typical drinking water related matrices. More importantly, the product of this research will provide the foundation for the establishment of standardized protocols for a representative target list of EDCs/PPCPs with supportable reporting levels. As of the writing of this report, the results of this study have not yet been published.

HEALTH EFFECTS

The initial concerns when EDCs and PPCPs were first reported in surface waters were focused on increased bacterial resistance to antibiotics and interference with growth and reproduction of aquatic organisms. More recently, concerns for human health due to exposure in drinking water have been expressed. Cause-effect relationships between low-level environmental exposures to specific EDCs and human health have not been established. Although no known health effects have been linked to exposure to drinking water with EDCs and PPCPs at trace levels, drinking water providers are concerned about potential effects and their consumers' perception of the safety of drinking water. Human and animal studies of the effects of continual, long-term exposure to environmentally relevant doses are lacking for most known or potential EDCs, but results of some animal studies indicate that certain EDCs can produce effects at low doses. There is sufficient evidence to conclude that adverse endocrine-mediated effects have occurred in some wildlife species. However, to date there is little evidence that levels of EDCs found in source waters have produced adverse endocrine effects in humans (Snyder et al., 2005). Studies examining EDC-induced effects in humans have yielded inconsistent and inconclusive results, highlighting the need for more rigorous studies.

An AwwaRF study titled "Toxicological Relevance of EDCs and Pharmaceuticals in Drinking Water" evaluated health effects by comparing levels of 16 pharmaceuticals, ten EDCs and three steroid hormones in drinking water to calculated health risk thresholds such as acceptable daily intakes (ADIs) and drinking water equivalent levels (DWELs) (AwwaRF, 2008a). Water samples were collected from 20 geographically diverse sites within the United States. ADIs are defined as the amount of a chemical to which a person can be exposed on a daily basis over an extended period of time (usually a lifetime) without suffering deleterious effect. ADIs were calculated using methods consistent with USEPA approaches for determining levels of exposure to environmental contaminants that are not likely to be associated with adverse health effects. A cautious, conservative approach was taken in developing the ADI values. ADIs can be converted to DWELs by multiplying the ADI by an assumed body weight and dividing by an average daily drinking water ingestion rate. Estradiol equivalents were also used as another approach to evaluate health effects.

The AwwaRF report showed that none of the EDCs and PPCPs detected in their drinking water samples exceeded the ADIs and DWELs, therefore none occurred at concentrations predicted to be of relevance to human health. Additionally, estradiol equivalents in the drinking water were either not detected or extremely low, much lower than some common food and beverage items like vegetable juice, coffee and soy milk. The evaluation indicates that although some pharmaceuticals and EDCs were detected in U.S. drinking waters, there is no evidence of human health risk from consumption of these waters. Furthermore, the exposure through water is expected to be small compared to medications, food and beverages, occupational exposures, and residential activities.

Similarly, the AwwaRF study titled "State of Knowledge of Endocrine Disruptors and Pharmaceuticals in Drinking Water" evaluated health effects by comparing maximum levels of pharmaceuticals in source and raw waters, to the lowest therapeutic dosage (i.e. the lowest recommended dosage level indicated on the package labeling, assumed to be the lowest exposure level at which the chemical produces the desired pharmacologic effect). The therapeutic dose was translated into a water concentration, assuming that a person drinks two liters of water at this concentration every day. To provide an additional margin of safety, the lowest therapeutic dose was divided by 1,000. For each pharmaceutical, the highest detected concentration in source or raw water was well below the concentration based on the lowest therapeutic dose divided by 1,000. Furthermore, the maximum detected concentrations in drinking water were a factor of 5 to 12,000 lower than the therapeutic dose divided by 1,000.

REMOVAL IN WASTEWATER TREATMENT PLANTS

Although PPCPs and EDCs can potentially originate from numerous sources and enter the environment by many routes, numerous studies have reported the occurrence of CECs in effluent from municipal wastewater treatment plants. EDCs and PCPPs are biologically active compounds. These compounds and their metabolites are not completely removed by current wastewater treatment technologies and are often found in treated effluents. As discussed in

Chapter 13, approximately 350 mgd of treated wastewater is discharged to surface waters in the Sacramento, San Joaquin, and Delta watersheds. There have been a number of studies to address removal of CECs using conventional wastewater treatment processes, with some of the larger studies as cited below. It is difficult to draw absolute conclusions regarding removal as there are numerous CECs, and removal studies tend to focus on a small group of constituents.

Conventional wastewater treatment facilities are not specifically designed to remove EDCs, and the degree with which they are removed varies from nearly complete to very little during primary and secondary treatment. Overall, biological treatment (namely activated sludge) is the most effective treatment process for CEC removal when conventional wastewater processes are employed. AwwaRF and the Water Environment Research Foundation (WERF) have conducted several studies on removal of CECs by wastewater treatment processes.

AWWARF STUDY # 2617 OCCURRENCE SURVEY OF PHARMACEUTICALLY ACTIVE COMPOUNDS

This study focused on PhACs likely to be present in wastewater at 18 wastewater treatment plants (AwwaRF, 2006). The key findings from that study are:

- PhACs are detectable in the effluent of conventional wastewater treatment plants. Diclofenac, gemfibrozil, metoprolol, naproxen, sulfamethoxazole, and trimethoprim were detected in almost all of the wastewater effluent samples. The median concentrations of the PhACs in effluent ranged from less than 10 to 1,400 ng/L.

- Reverse osmosis (RO) treatment plants remove most PhACs however metoproiol and propranolol were detected in the effluent from one RO plant.

Some preliminary work by researchers at UC Berkeley indicates that hormones such as estradiol are not transformed or removed by secondary treatment and that more advanced treatment is required before significant removals are observed. Others have reported similar results on a range of pharmaceutical compounds (Sakaji, 2004).

WERF STUDY 01-HHE-20T REMOVAL OF ENDOCRINE DISRUPTING COMPOUNDS IN WATER RECLAMATION PROCESSES

A WERF study conducted by Drewes et al. (2006) assessed conventional water reclamation trains and advanced treatment processes to determine their ability to reduce concentrations of endocrine disrupting compounds and activity. Studies were conducted at seven full-scale water reclamation facilities located in California, Arizona, Florida, Virginia, and Wisconsin. The target compounds included several steroid hormones (testosterone, 17β-estradiol, 17α-ethinylestradiol, estrone, estriol) and phenolic compounds (bisphenol A, 4-t-octylphenol, nonylphenol). In addition to chemical measurements, estrogenic activity was evaluated. Removal efficiencies after secondary treatment for total estrogenic activity, 17β-estradiol, estriol, and bisphenol A were at 90 percent or greater, while estrone, 4-nonylphenol, 4-t-octylphenol, and 17α-ethinylestradiol had lower removals of 48, 61, 80, and 71 percent respectively. This study also concluded that estrogenic activity in the influent correlated strongly with biochemical oxygen demand (BOD) loading, as well as BOD removal. Other findings included:

- High removal of EDCs and activity was achieved at solids retention times (SRT) exceeding two days.

- Additional removal of steroid hormones was achieved during chlorination, but only partial oxidation occurred for phenolic compounds.

- Ultra-violet (UV) light using low pressure, high intensity radiation had no effect on EDCs.

- Small amounts of activated carbon (10 mg/L) were required to remove steroid hormones to below detection limits and significantly reduce phenolic compounds.

- Microfiltration followed by RO was proven to remove EDCs and biological activity to no detection levels.

WERF STUDY 03-CTS-22UR FATE OF PHARMACEUTICALS AND PCP THROUGH MUNICIPAL WASTEWATER TREATMENT PROCESSES

A study conducted by Stephenson et al. (2007) evaluated the passage of PCPs through full-scale wastewater facilities located in the southwestern United States. The focus of the study was to evaluate the impact of SRT on PCP removal through secondary treatment, as well as media filtration. As shown in **Table 12-4**, the study concluded that for the target list of 20 PCP compounds, half of the compounds were well removed (greater than 80 percent) at SRTs equal to or less than 5 days. DEET required a longer SRT of greater than 13 days and TCEP, musk ketone, and galaxolide required greater than 25 days. Media filtration offered little additional removal of these compounds.

In 2003, the USGS and Metcalf and Eddy devised a multi-disciplinary collaborative research program to investigate concentrations of 63 trace contaminants at four wastewater treatment plants in New York. Samples were collected after the primary, secondary, tertiary and disinfection stages at each plant. A comparison of removal percentages among plants indicated that in general, the plants operating with activated sludge processes (plants A, B, C) were consistently capable of effecting greater emerging contaminant removal than the plant operating with the trickling filter process (plant D). **Table 12-5** shows results for seven of the 63 compounds, as these compounds are among the most frequently detected. The wastewater treatment plants examined were effective in removing significant amounts of emerging constituents using conventional wastewater treatment processes. Similar to the Stephenson study, biological treatment was the most important process for the reduction of the studied compounds, as compared to the filtration or disinfection processes. The median removals observed through the filtration and disinfection processes were less than ten percent at all plants, except for plant D.

Table 12-4. Percent Removals for Personal Care Products and Minimum Solids Retention Times Needed to Consistently Achieve Over 80 Percent Removal

Removal Bin	Median Percent Removal	Compound	SRT80a (days)
Excellent Removal	Greater than 80 Percent Removal	Methyl-3-phenylpropionate	0 – 5
		Caffeine	5
		Ibuprofen	5
		Oxybenzone	5
		Chloroxylenol	5
		Methylparaben	0 – 5
		Benzyl Salicylate	5
		3-Phenylpropionate	0 – 5
		Butylbenzyl Phthalate	5
		Octylmethoxycinnamate	5
		Benzophenone	13
Moderate Removal	Greater than 50 Percent Removal but less than 80 Percent Removal	Octylphenol	5 – 28
		Ethyl-3-phenylproprionate	>5
		Triclosan	10
Poor Removal	Less than 50 Percent Removal	TCEP	>25
		Triphenylphosphate	>5
		BHA	>8
		DEET	>13
		Musk Ketone	>25
		Galaxolide	>25

Source: WERF 2007
[a]Minimum solids retention time required to consistently achieve removal greater than 80%

Table 12-5. Median Influent and Effluent Concentration (µg/l) of Selected Emerging Contaminants and percent removals (from Influent to Effluent)

Analyte	Plant A			Plant B			Plant C			Plant D		
	Inf.	Eff.	% rem	Inf.	Eff.	% rem	Inf.	Eff.	% rem	Inf.	Eff.	% rem
AHTN	3.7	2.1	**44**	1.0	0.48	**53**	3.3	1.8	**41**	2.3	1.8	**21**
Caffeine	130	0.075	**>99**	51	0.056	**>99**	70	0.11	**>99**	41	20	**39**
Cholesterol	11	ND	**100**	17	ND	**100**	21	0.88	**96**	9.0	1.7	**66**
DEET	0.94	ND	**100**	0.56	ND	**100**	2.1	ND	**98**	1.6	1.3	**24**
Para-nonylphenol	13	ND	**100**	4.3	1.1	**75**	59	0.93	**98**	18	18	**8.1**
Triclosan	2.6	0.13	**94**	2.8	0.13	**94**	2.4	0.12	**94**	1.8	1.0	**36**
TBEP	14	0.15	**99**	3.1	ND	**100**	140	ND	**100**	12	11	**15**

% rem. = percent removal
Source: Esposito et al. (2006)

AWWARF STUDY #3012 COMPARING NANOFILTRATION AND REVERSE OSMOSIS FOR TREATING RECYCLED WATER

Today, the industry standard for subsurface injection of treated wastewater for groundwater recharge or for surface water augmentation projects is to have an integrated membrane system such as microfiltration pretreatment followed by RO. In this study, nanofiltration and ultra-low pressure RO (ULPRO) membranes were compared to conventional RO membranes with respect to removing total organic carbon (TOC), total nitrogen, and both regulated and unregulated trace organic compounds. The findings of this study reveal that ULPRO membranes can "consistently meet potable water quality requirements for treating source water of impaired quality with respect to TOC, total nitrogen, and both regulated and unregulated trace organic compounds." ULPRO membranes potentially offer lower operating expenses than conventional RO. Certain low fouling loose nanofiltration membranes were tested, and although they demonstrated effluent rejection of TOC and a high selectivity for a wide range of trace organics, they resulted in lowered permeate water quality for ammonia and nitrate.

REMOVAL IN WATER TREATMENT PLANTS

There has been a number of research projects conducted to evaluate specific water treatment processes in removing pharmaceuticals, and both regulated and unregulated trace organic compounds. Relevant information from four research projects is discussed below. The projects studied removal by potassium permanganate and potassium ferrate salts, ozonation, conventional water treatment processes (coagulation, sedimentation), chlorine, chloramines, UV, activated carbon, and membranes.

AWWARF STUDY #2758 REMOVAL OF EDCS AND PHARMACEUTICALS IN DRINKING IN DRINKING AND REUSE TREATMENT PROCESSES

This study evaluated various physical, chemical, and biological drinking water treatment plant processes on the removal/transformation efficiencies of EDCs and PPCPs in natural waters (AwwaRF, 2007). The key findings from this study are:

- Conventional Processes - Coagulation, flocculation, and sedimentation are ineffective for removing the majority of EDCs and PPCPs that were evaluated.

- Disinfectants - Free chlorine disinfection can remove many target compounds depending on the structure of the contaminant. Chloramines are less effective than free chlorine at removing EDCs and PPCPs. Ozone is more effective than chlorine, and is able to significantly remove the majority of target analytes. Ozone is likely the most cost effective measure for removing the majority of EDCs and PPCPs for water treatment. UV irradiation at typical disinfection doses is ineffective for removing most EDCs and PCPs; however, high energy UV at oxidative doses can be effective, and the combination of UV and hydrogen peroxide can achieve removal rates similar to ozone. As adapted from the NWRI study, **Table 12-6** summarizes the findings from the various disinfection processes.

- Activated Carbon – Activated carbon is highly effective, although exhausted activated carbon is ineffective.

- Magnetic Ion Exchange – Magnetic ion exchange processes are ineffective.

- Membranes – RO and nanofiltration are highly effective while ultrafiltration and microfiltration are largely ineffective.

Table 12-6. PPCP Removal/Transformation Efficiencies in Selected Drinking Water Treatment Processes

PPCP	Percent Removal			
	UV[a]	Chlorination[b]	Chloramination[c]	Ozonation
Caffeine	<20	<20	<20	>80[d]
Carbamazepine	<20	<20	<20	>95[e]
Diclofenac	50 – 80	>80	50 – 80	>95[e]
Gemfibrozil	<20	50 – 80	<20	>95[e]
Ibuprofen	<20	<20	<20	50 – 80[d]
Sulfamethoxazole	50 – 80	>80	<20	>95[e]
TCEP	<20	<20	<20	<20[d]
Triclosan	50 – 80	>80	>80	>95[e]

Source: Adapted from Snyder et al. (2007)
[a]UV dose = 40 mJ/cm^2
[b]Chorine dose = 3mg/L, contact time = 24 hours
[c]Chloramine dose = 3 mg/L, contact time = 24 hours
[d]Ozone dose = 2.5 mg/L, contact time = 24 minutes
[e]Ozone dose = 2.5 mg/L, contact time = 2 minutes

Little is known about the occurrence and potential toxicity of degradation products of EDCs and PCPPs that might result from treatment processes such as oxidation that alter chemical structures rather than removing chemicals from water. UV and ozone are possible treatment schemes but they create numerous oxidation products, thereby increasing the number of chemicals present (Daughton, 2006b).

AWWARF STUDY #3033 STATE OF KNOWLEDGE OF ENDOCRINE DISRUPTORS AND PHARMACEUTICALS IN DRINKING WATER

As this project was developed to provide the water industry with a current status of science available on EDCs and PPCPs, much of the information presented in AwwaRF project #2758 is repeated in this report. Therefore, only additional findings on water treatment will be presented.

- Chlorine dioxide is generally a stronger oxidant than free chlorine.

- Chlorine and chlorine dioxide react primarily with electron functional groups like amines and phenols. Ozone also attacks carbon-carbon double bonds and activate benzene rings.

- Advanced oxidation processes such as UV/hydrogen peroxide, ozone/hydrogen peroxide, and UV/ozone are very effective in oxidizing EDCs and PPCPs, however they provide only a small increase in removal efficiency compared to ozone.

- High-pressure membranes such as nanofiltration or RO can remove a wide range of EDCs and PPCPs. However, low-molecular weight organics, such as N-nitrosamines or certain pharmaceuticals (acetaminophen, phenacetine) can be problematic.

WATER RESEARCH FOUNDATION STUDY #4066 OXIDATION OF PHARMACEUTICALLY ACTIVE COMPOUNDS DURING WATER TREATMENT

One of the major objectives of this study was to identify pharmaceutically active compounds that are susceptible to rapid oxidation by permanganate and ferrate salts. Results from the initial bench-scale experiments indicated that permanganate and ferrate are selective oxidants that can be expected to oxidize only a fraction of pharmaceutically active compounds present in source waters. Of the eighteen compounds studied, only ten showed high or moderate activity with permanganate, and only eight showed high or moderate activity with ferrate. It is important to note that carbamazepine, one of the compounds with the highest (88 percent) detection frequency in the 2010 NWRI study, and resistant to oxidation by chlorine, is rapidly oxidized by permanganate and ferrate.

WATER RESEARCH FOUNDATION STUDY #3071 PPCPS AND EDCS – OCCURRENCE IN THE DETROIT RIVER AND THEIR REMOVAL BY OZONATION

The efficiency of ozonation in removing PPCPs and EDCs at the bench and pilot-scale was studied, and the effects of operating parameters including ozone dose, contact time, pH and temperature on process efficiency were investigated. In general, ozone dose, contact time and DOC loading were the governing factors in contaminant removal, while temperature and pH played secondary roles. The experiments which had the lowest removal rates had low ozone dose (0.8 mg/L) and high DOC loading (4.5 mg/L).

Results indicated that under optimized water quality and operating conditions, close to complete transformation of 12 (bisphenol A, carbamazepine, erythromycin, gemfibrozil, indomethacin, lincomycin, naproxen, sulfachloropyradizine, sulfamethazin, sulfamethoxazol, tetracycline, tylosin) of the 16 target substances is possible. Ibuprofen and clofibric acid were found to be most difficult to transform, as removal was limited to an average of 50 percent. Bezafibrate removal increased from 50 percent to 90 percent when ozone dose increased from 0.3 to 1.5 mg/L. Experiments with monensin were not conclusive.

REGULATIONS

The chemicals that are regulated in source waters and in treated drinking water by USEPA and the State of California represent a minor subset of chemicals that are potentially present due to natural occurrence and human actions. Regulatory programs are only just beginning to address these emerging constituents.

DRINKING WATER REGULATIONS

The concentrations of most PPCPs and EDCs are not regulated in drinking waters in the U.S. From USEPA's perspective, CECs remain something to be watched rather than actively pursued for regulation (Water Education Foundation, 2011). Some chemicals (e.g. several pesticides, PCBs) that are regulated in drinking water are not currently regulated based on their potential endocrine disrupting effects. One exception is perchlorate. Please refer to the System Environment Section for regulatory information regarding perchlorate.

Maximum Contaminant Levels (MCLs) are generally developed following detection of constituents in drinking water sources at levels that are thought to potentially have an impact on human health. The development of MCLs also requires identification of best available technologies for contaminant removal and the ability to monitor and detect the constituents at levels of concern. The analytical methods for many EDCs and PCPPs are still being developed and most commercial laboratories are not capable of measuring these constituents at the levels found in source waters and treated drinking water.

Based on the large number of potential EDCs, new regulations could shift towards regulating compounds as a class based on a common mechanism for toxicity (e.g. endocrine disruption) or similar chemical structure rather than by individual compound. Regulating compounds by class will be an effective technique for regulating due to the growing number of CECs being identified (Water Education Foundation, 2011). Another possible regulatory approach could require a specific treatment technology (e.g. granular activated carbon) for an array of chemicals, instead of setting standards for a class of chemicals or a proliferation of specific MCLs (AwwaRF, 2005).

WASTEWATER EFFLUENT LIMITATIONS

The concentrations of most PPCPs and EDCs are not regulated in wastewater discharge permits. As with drinking water standards, a few chemicals that have been found or suspected to be EDCs, are regulated based on other effects such as acute and chronic toxicity to aquatic organisms. Currently wastewater is primarily regulated on a chemical by chemical basis. It is not possible to test all chemicals and possible combinations of chemicals that may occur in wastewater effluent. As a result, National Pollutant Discharge Elimination System (NPDES) permits include a requirement for Whole Effluent Toxicity (WET) testing to determine the aggregate toxicity of an effluent in the aquatic environment. WET testing exposes laboratory populations of aquatic organisms (fish, invertebrates, and algae) to diluted and undiluted effluent samples to determine environmental toxicity of that sample. Acute and chronic tests focus on how well an organism survives, grows, and reproduces. However, current toxicity tests do not screen for endocrine disrupting effects. Daughton (2006a) advocates that a more accurate assessment of risks is needed; measuring and assigning toxicity based on the total amount of chemicals in wastewater that share the same mode of action or way of working.

GROUNDWATER RECHARGE REGULATIONS

Senate Bill 918, signed by the Governor and filed on Sept 30, 2010 states that the California Department of Public Health (CDPH) must adopt uniform water recycling criteria for groundwater recharge by December 31, 2013 and must adopt uniform water recycling criteria for surface water augmentation by December 31, 2016. CDPH released Draft Regulations for Groundwater Replenishment with Recycled Water in November 2011. After informal comments are received, the final proposed version will proceed through the formal adoption process and will be subject to public review and comment. There are three scenarios described in the draft regulations: 1) indirect potable reuse via groundwater replenishment surface application without full advanced treatment, 2) indirect potable reuse via groundwater replenishment surface application with full advanced treatment, and 3) indirect potable reuse via groundwater replenishment subsurface application. For scenario #3, an occurrence study must be completed on the project's municipal wastewater to identify indicator compounds for at least nine functional groups. The project's oxidation process must also demonstrate 0.3 to 0.5 log removal for the indicator compounds selected by pilot testing. In addition, CDPH must investigate the feasibility of developing uniform water recycling criteria for direct potable re-use and provide a report by December 31, 2016.

The State Water Board convened a CEC Science Advisory Panel to develop guidance for the establishment of monitoring programs to assess potential CEC threats from water recycling activities. The final report was completed in June 2010 which was followed by a Staff Report. The Staff Report provides recommendations for monitoring CECs in municipal recycled water used for groundwater recharge/reuse and landscape irrigation. The Staff Report also presents recommendations for additional research on CEC monitoring. A public hearing was held on December 15, 2010 to accept comments on the Staff Report. The State Water Board is currently considering comments received on the Staff Report.

According to State Water Board staff, an amendment will be written for the existing Recycled Water Policy developed in 2009. This amendment will address what constituents should be monitored for groundwater recharge/reuse projects. The amendment would then be peer-reviewed, and then open for public comment before final adoption, likely sometime in 2012.

The CEC Science Advisory Panel identified four indicator compounds based on their toxicological relevance for groundwater recharge projects: NDMA, 17 beta-estadiol, caffeine, and triclosan. Four additional CECs were identified as viable performance indicators (DEET, gemfibrozil, iopromide, and sucralose), along with certain surrogate parameters. Surrogates for groundwater recharge projects by surface spreading are ammonia, nitrate, DOC, and ultra-violet absorbance (UVA). Surrogates for groundwater recharge by injection are conductivity and DOC, and surrogates for landscape irrigation are turbidity, chlorine residual, and total coliform. CDPH recommended monitoring for certain additional CECs (bisphenyl A, boron, carbamazepine, chlorate, chromium VI, diazinon, 1,4-dioxane, naphthalene, N-nitrosodiethyamine (NDEA), N-nitrosodi-n-propylamine (NDPA), N-nitrosodiphenylamine, N-nitrosopyrrolidine (NPYR), 1,2,3-Trichloropropane, Tris(2-carboxyethyl)phosphate, and vanadium) which have been incorporated into the final Staff Report.

Numerous SWP contractors and their member agencies submitted comments on the Staff Report including Alameda County Water District, Zone 7 Water Agency of the Alameda County Flood Control and Water Conservation District, Coachella Valley Water District, Las Virgenes Municipal Water District, MWDSC, San Bernardino Valley Municipal Water District, and the San Diego County Water Authority. The main comments submitted to the State Water Board were: 1) to not add the 13 additional constituents for baseline CEC monitoring for groundwater recharge spreading projects, as specified in a comment letter from the CDPH, as the letter provided no scientific or technical basis, 2) the Regional Boards should not have the authority to select and add CECs to be monitored to individual permits, even if the CECs identified by the Panel are included as a minimum, and 3) the State Water Board should adopt the Panel's recommendation to conduct a one-year study of a particular class of CECs for which the Panel felt it had insufficient occurrence information (Table 8.4 in Panel Report). A few of the letters also recommended a clearer distinction for the monitoring requirements for irrigation projects from those applied to groundwater recharge. No additional monitoring of CECs is necessary for irrigation projects beyond the monitoring specified in Title 22. The Los Angeles Regional Water Quality Control Board commented that although the Panel chose to focus its recommendations on toxicological relevance of CECs to human health, they believe that this focus was too narrow, given that in the Los Angeles Region, most dischargers that recycle treated wastewater also discharge directly to surface waters where resident aquatic life is exposed to nearly 100 percent effluent. The Los Angeles Regional Water Quality Control Board believes it is imperative to consider toxicological impacts on ecological receptors in developing a monitoring strategy for CECs.

The Los Angeles Regional Water Quality Control Board is currently developing salt and nutrient management plans for groundwater basins within its region. Suggested elements of a salt/nutrient management plan include a placeholder for CECs. Requirements for monitoring CECs will be based on adoption of policy currently being developed by the State Water Board.

ENVIRONMENTAL RISK ASSESSMENTS

The U.S. Food and Drug Administration requires environmental risk assessments for new pharmaceuticals with predicted environmental concentrations greater than 1 µg/L (Snyder et al., 2005). Daughton (2006b) points out that the conventional toxicological procedures used in these risk assessments may not screen for the types of subtle effects that could occur from exposure to the low-levels found in surface waters.

ENDOCRINE DISRUPTOR SCREENING PROGRAM

This is a monitoring program through the USEPA Office of Science that was finalized in April 2009. This program only applies to pesticide manufacturers, importers, and potentially users. The USEPA developed criteria for screening endocrine disrupters to identify priority chemicals. USEPA will implement the workplan by using assays in a two-tiered screening and testing process (Endocrine Disrupters Screening Program):

- Through Tier 1 screening, USEPA hopes to identify chemicals that have the potential to interact with the endocrine system.

- Through Tier 2 testing, USEPA will determine the endocrine-related effects caused by each chemical and obtain information about effects at various doses.

USEPA will use this two-tiered approach to gather information needed to identify endocrine-active substances and take appropriate action. The initial list of 67 chemicals considered for Tier 1 screening is primarily pesticides – both active and inert ingredients. In December 2007, USEPA issued draft procedures for the initial screening. For active ingredients, test orders will be sent to technical registrants and for inert ingredients, test orders will be sent to manufacturers, importers, and potentially users of chemicals on the list. Some of these constituents are already regulated in drinking water and some are on the Contaminant Candidate List 3.

A second list of chemicals for Tier 1 screening was published in November 2010. The list of 134 chemicals includes a large number of pesticides, two PFCs, and three pharmaceuticals (erythromycin, nitroglycerin, and quinoline). This list also contains other chemicals, such as those used for industrial manufacturing processes, plasticizers, or in the production of PPCPs.

MANDATORY CONTROL PROGRAMS

There are three main types of programs that collect home-generated pharmaceuticals in California: continuous collection programs, events, or mail-back programs. The primary locations for continuous collection programs are pharmacies, law enforcement sites, and household hazardous waste collection sites. Mail-back collection programs are defined as programs that transport drug waste through the U.S. Postal Service to an appropriate disposal location. The three mail-back programs all began in 2009: the City of San Francisco, Teleosis (non-profit), and Santa Cruz County. CalRecycle has a directory that lists facilities in California that collect pharmaceuticals for disposal:
http://www.calrecycle.ca.gov/HomeHazWaste/HealthCare/Collection/Default.aspx

Based on information available to CalRecycle, collection programs in California currently collect approximately 200,000 pounds of home-generated pharmaceutical waste per year. However, several sources suggest that a very large amount is sold and that a significant percentage becomes waste. The Associated Press estimated that Americans generate at least 250 million pounds of pharmaceuticals and contaminated packaging in medical facilities each year. Relative to California population, that would be approximately 30 million pounds in California hospitals alone (CalRecycle, 2010).

The disposal of pharmaceutical waste is governed by provisions of SB 966 (Simitian, Chapter 542, Statutes of 2007). It requires the California Department of Resources Recycling and Recovery (CalRecycle) to develop, in consultation with appropriate government agencies, criteria and procedures for model programs for the collection and proper disposal of pharmaceutical waste. Provisions of SB 966 remain in effect until January 1, 2013. The goal is to provide local jurisdictions in California with the tools to implement collection programs as well as work with manufacturers, retailers, pharmacies, hospitals, and other health-related constituents for the proper disposition of medication and sharps in a single location.

As directed by SB 966, CalRecycle formed a working group that consisted of representatives from the Pharmacy Board, State Water Board, CDPH, and the Department of Toxic Substances

Control. CalRecycle staff convened the working group and conducted four workshops during 2008 to facilitate comments and suggestions from stakeholders representing local government, pharmaceutical companies, medical and hazardous waste haulers, for-profit and non-profit health care providers, and other interested parties. As a result of this collaboration, criteria and procedures are available for facilities willing to become model programs for the collection and proper disposal of pharmaceutical waste.

SB 1305 revised a section of the State of California Medical Waste Management Act to make it a violation of state law for home-generated sharps waste to be placed in solid waste collection containers, including recycling and green waste containers. SB 1305 also require sharps waste to be transported in an approved sharps containers and managed by a specified facility (i.e., household hazardous waste facility, medical waste generator facility, or a facility managed as part of a mail back program). SB 1305 was approved by Governor Schwarzenegger on July 12, 2006 and took effect on September 1, 2008.

VOLUNTARY CONTROL PROGRAMS

The United States Department of Justice Drug Enforcement Agency, in conjunction with state and local law enforcement throughout the United States, conducted the first ever National Prescription Take Back Day on September 25, 2010. Due to the overwhelming success of the first event, the Second National Prescription Take Back Day was held on April 30, 2011.

Some communities have taken a proactive approach and started to educate their customers on proper disposal practices for unused pharmaceuticals. One example is the "No Drugs Down the Drain" Program sponsored by the City of Los Angeles, Sanitation Districts of Los Angeles County, County of Los Angeles, Orange County Sanitation District, and the Cities of Riverside of San Diego. The No Drugs Down the Drain program is a public outreach program to provide California residents living in specific regions with available, safe and proper disposal choices. These agencies have a web page that discusses how to dispose of drugs depending on your geographical location Generally, the two recommended options are 1) take to a household hazardous waste collection center and 2) put in a sturdy and sealed container and then in the trash. In limited cases, unused or expired pharmaceuticals can be returned to pharmacies for "take-back" programs. Chemotherapy pharmaceuticals need to be returned to the clinic that dispensed them.

In addition, the Los Angeles County Sheriff's Department in conjunction with the Los Angeles County Department of Public Health and Public Works have developed a "Safe Drug Drop-Off Program". The program provides an opportunity for residents to safely and anonymously surrender any unused or expired prescriptions, over the counter medications, needles or other controlled substances. Controlled substances cannot be taken to a household hazardous waste collection center.

Websites for the cities of Sacramento and Stockton and the counties of Sacramento and San Joaquin were searched for information on disposal of PPCPs. The City of Sacramento and Sacramento County provide information on disposal of household hazardous waste (which includes sharps), electronic wastes, paints, and universal wastes (e.g. batteries, fluorescent light bulbs), but no information could be located on disposal of medications. The City of Stockton and

San Joaquin County lists prescription medicines as an example of household hazardous waste, and also lists one location where home generated sharps (needles) and medications can be disposed of.

The Sacramento Regional County Sanitation District has a "Don't Flush Your Meds" website where locations are given for disposal of both prescription and over the counter medications, as well as controlled substances.

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CHAPTER 13 KEY WATER QUALITY VULNERABILITIES OF THE SACRAMENTO-SAN JOAQUIN DELTA

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CHAPTER 13 KEY WATER QUALITY VULNERABILITIES OF THE SACRAMENTO-SAN JOAQUIN DELTA

The California State Water Project Watershed Sanitary Survey, 2011 Update (2011 Update) is the fifth watershed sanitary survey of the State Water Project (SWP). The key vulnerabilities and contaminant sources throughout the watershed have been documented in previous updates. The California Department of Public Health (CDPH), the SWP Contractors, and the Department of Water Resources (DWR) worked together to determine the Sacramento-San Joaquin Delta (Delta) and SWP vulnerabilities and contaminant sources to be addressed in the 2011 Update. This chapter contains a discussion of the following topics:

- Wastewater Treatment Plants – Information is presented on the current status of wastewater discharged to the watershed, with emphasis on Delta dischargers.

- Urban Runoff – This section contains a discussion of urban runoff discharged to the Delta and the impacts on water quality.

- Delta Land Conversions – The impacts of converting Delta lands to wetlands, efforts to reduce subsidence, and studies on sequestering carbon on Delta islands are discussed in this section.

- Recreational Use of the Delta – Information from the California State Water Project Watershed Sanitary Survey, 2006 Update (2006 Update) on recreational use of the Delta and efforts to protect Delta water quality are described in this section.

WASTEWATER TREATMENT PLANTS

BACKGROUND

The 2006 Update contains a detailed discussion of wastewater treatment plants in the Sacramento and San Joaquin basins and in the Delta. This section contains updated information on the major wastewater treatment plants and major spills in the Delta. New information is presented on the percent of wastewater at Delta intakes.

POPULATION GROWTH

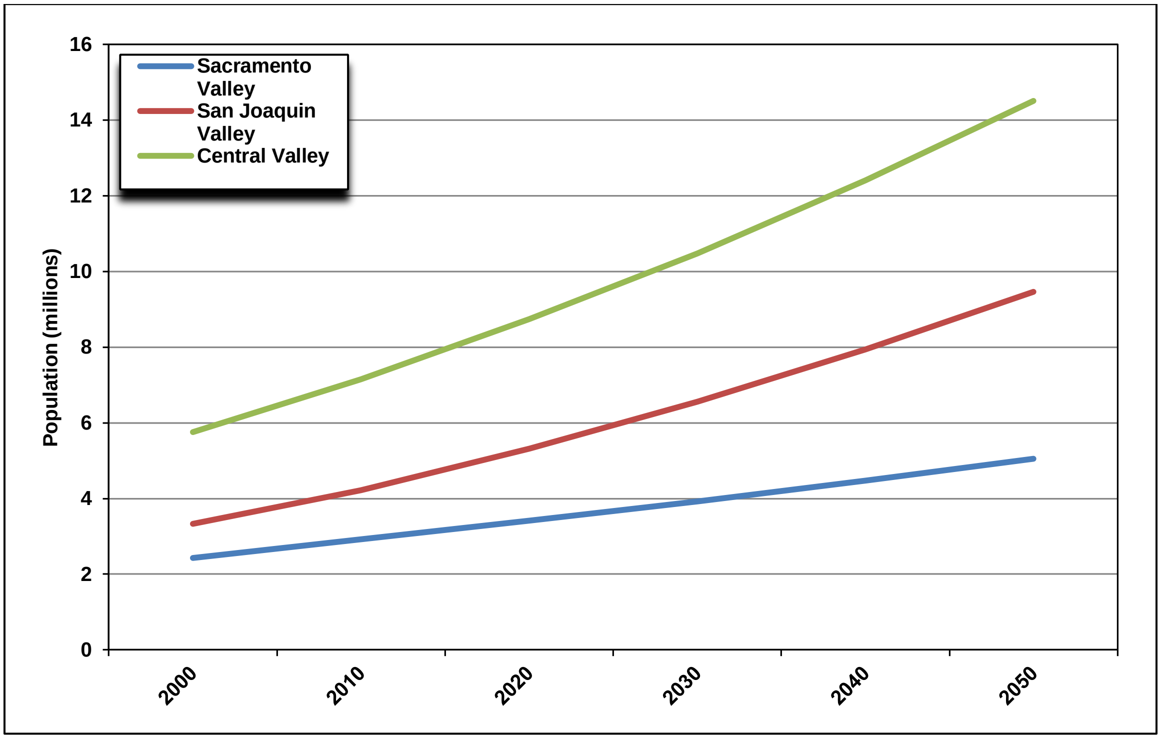
The Central Valley's population is growing faster than that of California as a whole. The rapid rate of population growth has been attributed to the lower cost of housing in the Central Valley compared to coastal communities. This growth raises serious questions about the impacts on ambient water quality as primarily agricultural land is converted to urbanized areas that generate wastewater and urban runoff.

California's population is projected to grow from 39.1 million in 2010 to 44.1 million in 2020 and 59.5 million in 2050. This represents a population increase of 13 percent by 2020 and 52 percent by 2050. As shown in **Figure 13-1**, the population of the Central Valley's 19 counties is projected to grow from 7.1 million in 2010 to 8.7 million in 2020 (22 percent increase) and to 14.5 million in 2050 (103 percent increase). This includes growth in the Sacramento Valley from 2.9 million in 2010 to 3.4 million in 2020 (17 percent increase) and to 5.1 million in 2050 (73 percent increase). There is projected to be greater growth in the San Joaquin Valley, with population projected to grow from 4.2 million in 2010 to 5.3 million in 2020 (26 percent increase) and to 9.4 million in 2050 (124 percent increase).

Many of the urbanized areas in the Delta are growing even more rapidly. **Table 13-1** presents the population estimates for all cities that are physically located in the Delta and for cities such as Sacramento and West Sacramento that are not located in the Delta but whose wastewater and some urban runoff are discharged to the Delta. The population estimates for the five counties in which the Delta is located are also shown.

There is no one agency with jurisdiction over land use decisions in the Delta so numerous housing developments are being constructed without an examination of the cumulative impacts on water quality of the increased population in the Delta. The increase in population in the watersheds of the SWP will result in greater quantities of wastewater and urban runoff discharged to the tributaries to the Delta and to Delta waterways.

Figure 13-1. Population Projections for the Central Valley



Data Source: Department of Finance Demographic Research Unit

Table 13-1. 2006 and 2011 Population Estimates for Cities and Counties that Discharge to the Delta

County or City	Total Population		Percent Change
	Jan 2006	Jan 2011	
Contra Costa County	1,029,377	1,056,064	2.6
Antioch	100,945	103,054	2.1
Brentwood	45,892	52,029	13.4
Pittsburg	62,979	63,730	1.2
Sacramento County	1,385,607	1,428,355	3.1
Sacramento	458,773	469,566	2.4
San Joaquin County	668,265	690,899	3.4
Lathrop	14,625	18,656	27.6
Manteca	63,703	68,410	7.4
Stockton	286,041	293,515	2.6
Tracy	80,461	83,420	3.7
Solano County	422,848	414,509	-2.0
Rio Vista	7,376	7,433	0.8
Vacaville	96,395	93,011	-3.5
Yolo County	190,344	201,759	6.0
West Sacramento	43,183	49,160	13.8

Data Source: Department of Finance Demographic Research Unit.

WASTEWATER FACILITIES IN THE WATERSHED

Wastewater discharged into Central Valley waterways contains numerous contaminants including human pathogens, organic carbon, nutrients that stimulate algal growth, and, in some cases, elevated levels of salinity. The increasing population of the Central Valley results in increasing amounts of wastewater discharged to source waters of the SWP. Of particular concern is the increased volume of wastewater discharged into Delta waterways in close proximity to drinking water diversion locations. Discharges of treated wastewater and large spills of untreated or partially treated wastewater are discussed in this chapter. **Table 13-2** presents a list of the major wastewater dischargers in the watershed. The California Regional Water Quality Control Board, Central Valley Region (Central Valley Regional Water Board) defines major dischargers as those that exceed 1 million gallons per day (mgd). The dischargers are grouped by the location in which the discharge occurs (Delta, eastern Delta tributaries, northern Delta tributaries, Sacramento River Basin, and San Joaquin River Basin). **Figure 13-2** shows the location of the wastewater treatment plants that discharge to the Delta.

The 1990 SWP Sanitary Survey indicated that average daily flow of major wastewater discharges was 268 mgd (Brown and Caldwell, 1990). DWR estimated that major wastewater flows were up to 329 mgd in the 2001 Update of the SWP Sanitary Survey (DWR, 2001) and discharges were estimated to be up to 352 mgd in the 2006 Update of the SWP Sanitary Survey (Archibald Consulting, 2006). Current estimates show that the major wastewater flows are nearly stable at 346 mgd. Wastewater flow volumes in the Central Valley are shown in **Figure 13-3**. Direct discharges to the Delta increased from 194 mgd in 1990, to 220 mgd in 2006, and are now at 204 mgd. Wastewater agencies are attributing the lower flows to water conservation efforts in the Central Valley.

Wastewater volumes discharged to the Delta and its watershed will increase with the increase in population in the Central Valley. A report prepared for the Central Valley Drinking Water Policy Work Group estimated that wastewater volume in the watershed would increase from 344 mgd in 2010 to 504 mgd by 2030 (West Yost Associates, 2011). This represents a 47 percent increase. As water meters are installed in Central Valley communities there is an expectation that per capita wastewater volumes will decrease. The West Yost study assumed a 10 percent reduction was likely the upper bound. There may also be reductions in the volume of wastewater discharged if wastewater agencies in the Central Valley invest in water recycling facilities.

Table 13-2. Wastewater Dischargers in the Central Valley and Delta

Discharger	Recent Average Dry Weather Flow[a] (mgd)	Permitted Average Dry Weather Flow (mgd)	Level of Treatment
Delta			
Sacramento Regional County Sanitation District – SRWTP	139	181	Secondary (Tertiary with Nitrification by 2020)
Stockton	28	55	Tertiary with Nitrification
Delta Diablo Sanitation District	9.5	16.5	Secondary
Tracy	7.09	9	Tertiary with NDN[b]
Lodi – White Slough	6.3	7.0	Tertiary with NDN
Manteca/Lathrop	5.7	9.87	Tertiary with NDN
Brentwood	3.2	5.0	Tertiary with NDN
Ironhouse Sanitary District	2.64	4.3	Tertiary with NDN
Discovery Bay	1.6	2.1	Secondary with Nitrification
Mountain House	0.6	3.0	Tertiary with NDN
Rio Vista – Beach	0.45	0.65	Secondary
Rio Vista – Northwest	0.2	1.0	Tertiary with NDN
Total Delta	***204.28***	***294.42***	
Eastern Delta Tributaries			
El Dorado Irrigation District – Deer Creek	3.23	3.6	Tertiary with NDN
Galt	2.3	4.5	Secondary with Nitrification
El Dorado Irrigation District – El Dorado Hills	2.0	4.0	Tertiary with NDN
Total Eastern Delta Tributaries	***7.53***	***12.1***	
Northern Delta Tributaries			
Vacaville – Easterly	8.2	15	Secondary with Nitrification (Seasonal Tertiary by 2015)
Davis	5.9	7.5	Secondary (Tertiary with NDN by 2017)
Woodland	5.6	10.4	Tertiary with NDN
University of California Davis	3.6	3.6	Tertiary with NDN
Total Northern Delta Tributaries	***23.3***	***36.5***	

Table 13-2 Wastewater Dischargers in the Central Valley and Delta (continued)

Discharger	Recent Average Dry Weather Flow[a] (mgd)	Permitted Average Dry Weather Flow (mgd)	Level of Treatment
Sacramento River Basin			
Roseville – Dry Creek	9.3	18	Tertiary with NDN
Redding – Clear Creek	8.2	8.8	Tertiary with Nitrification
Chico	7.6	12.0	Secondary with Nitrification
Roseville – Pleasant Grove	7.0	12	Tertiary with NDN
Yuba City	5.2	10.5	Secondary
Lincoln	3.5	4.2	Tertiary with NDN
Oroville Regional	3.4	6.5	Tertiary
Linda County Water District	3.0	5.0	Secondary
Redding – Stillwater	2.95	4.0	Tertiary with Nitrification
Olivehurst	1.9	5.1	Tertiary with NDN
Grass Valley	1.89	2.78	Tertiary with NDN
Placer County SMD No.1	1.7	2.18	Tertiary
Placerville – Hangtown Creek	1.5	2.3	Tertiary with NDN
Red Bluff	1.5	2.5	Tertiary with Nitrification
Auburn	1.3	1.67	Tertiary with Nitrification
Willows	1.2	1.2	Tertiary with Nitrification
Anderson	1.0	2.0	Tertiary with Nitrification
Shasta Lake	1.0	1.3	Tertiary with Nitrification
Corning	0.883	1.4	Secondary with Nitrification
Live Oak	0.72	1.4	Secondary (Tertiary with Nitrification Under Construction)
Nevada County SD Lake Wildwood	0.7	1.12	Tertiary with NDN
Total Sacramento Basin	***65.443***	***105.95***	
San Joaquin River Basin			
Modesto	20	70	Secondary
Turlock	11.4	20	Tertiary with Nitrification
Merced	8.5	12	Secondary with Nitrification
Atwater	3.0	6.0	Secondary with Nitrification (Tertiary with NDN by 2013)
Clovis	2.8	2.8	Tertiary with NDN
Total San Joaquin Basin	***45.7***	***110.8***	
TOTAL WATERSHED	**346**	**560**	

[a] Data on recent flows came from various permits, discharger reports and West Yost (2011).
[b] NDN – Nitrification and Denitrification

Figure 13-2. Wastewater Treatment Plants and Combined Sewer Systems Discharging to the Delta

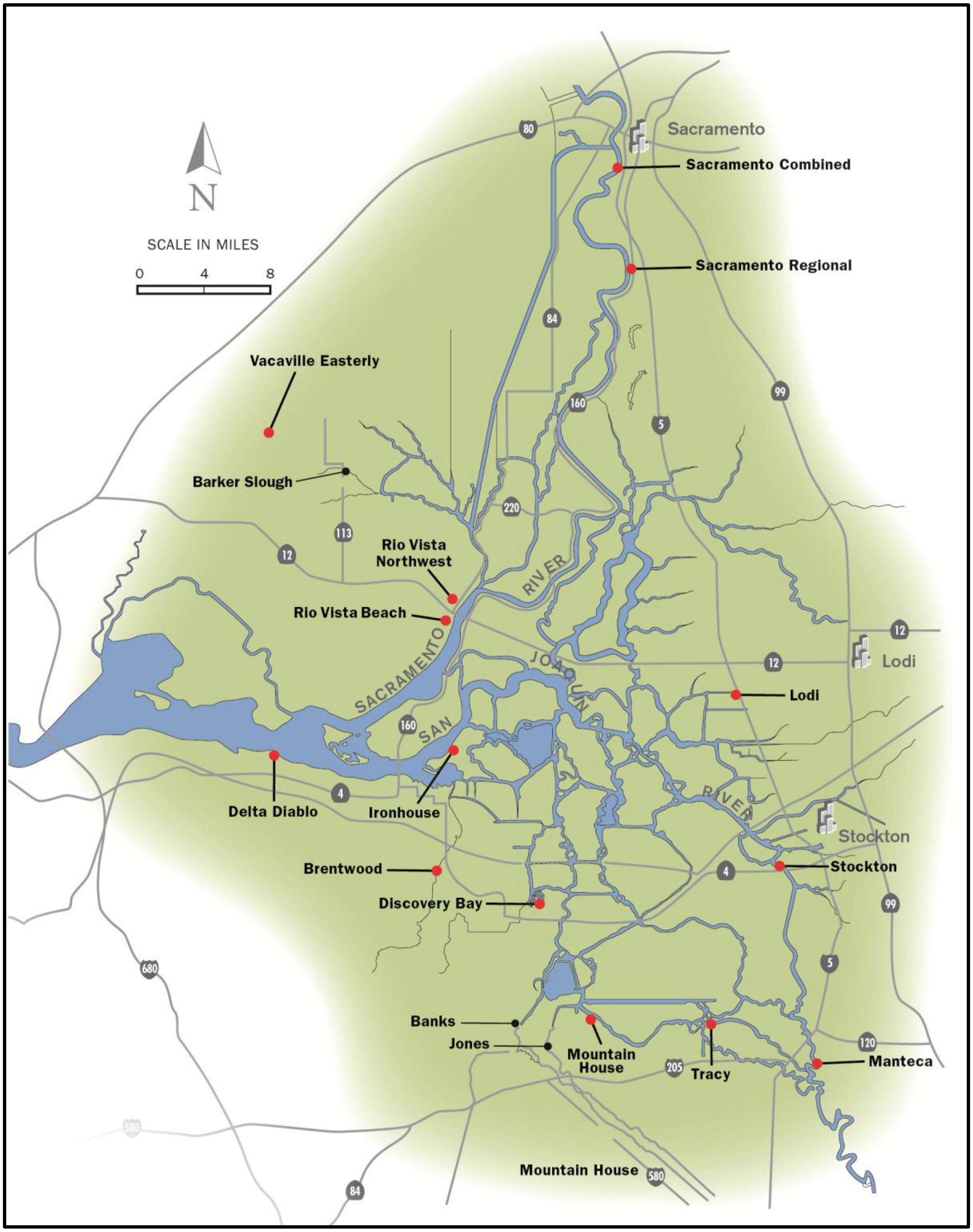
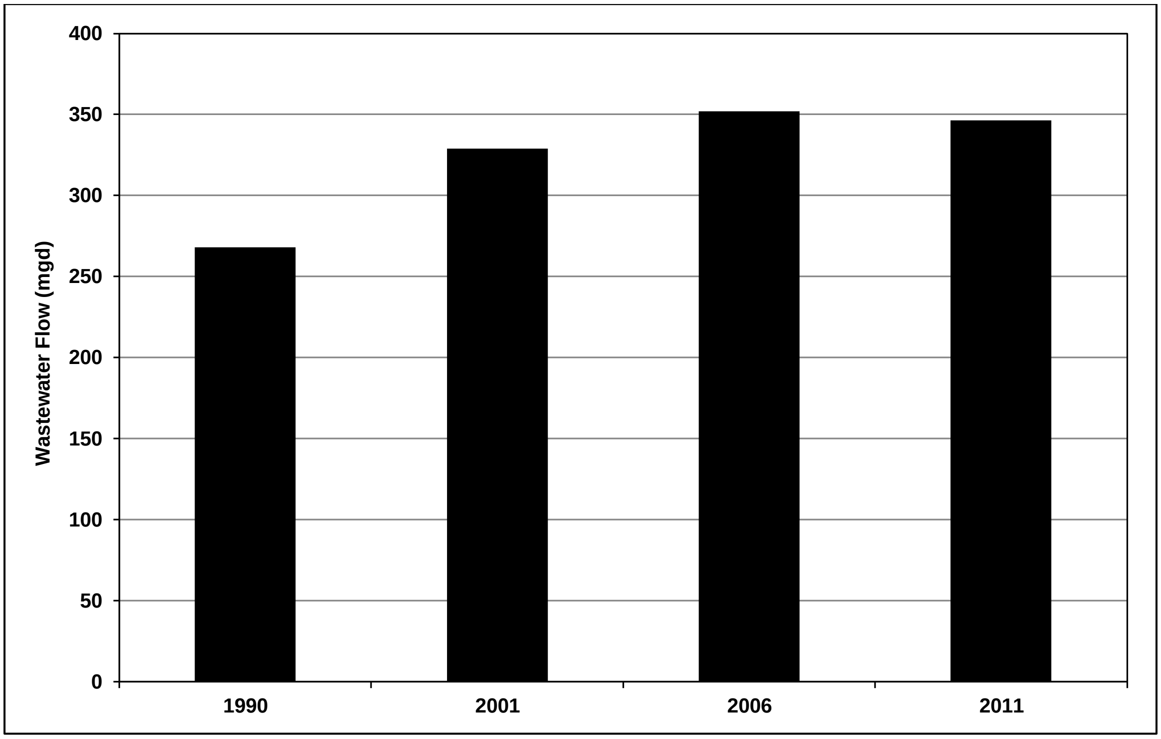


Figure 13-3. Wastewater Flows in the Central Valley



Volumetric Fingerprints

As described in more detail in **Chapter 3**, DWR uses the fingerprinting technique to identify the sources of water at Delta intakes. DWR has recently developed a fingerprint that includes wastewater volumes from the Sacramento Regional Wastewater Treatment Plant (SRWTP), the Stockton Regional Wastewater Control Facility, and the Manteca-Lathrop Wastewater Control Facility. DWR is currently gathering the data to add the Tracy Wastewater Treatment Plant to the fingerprint. **Figure 13-4** presents the percent of wastewater at Clifton Court Forebay (Clifton Court), the source of water for the Governor Edmund G. Brown California Aqueduct (California Aqueduct), and **Figure 13-5** presents the percent of wastewater at the C.W. "Bill" Jones Pumping Plant (Jones), the source of water for the Delta-Mendota Canal which goes into the SWP via the O'Neill Forebay. These three wastewater plants represent 82 percent of the wastewater volume discharged to the Delta so the fingerprints are a good estimation of the overall percent of wastewater at Delta pumping plants.

Figure 13-4. Percent of Wastewater at Clifton Court

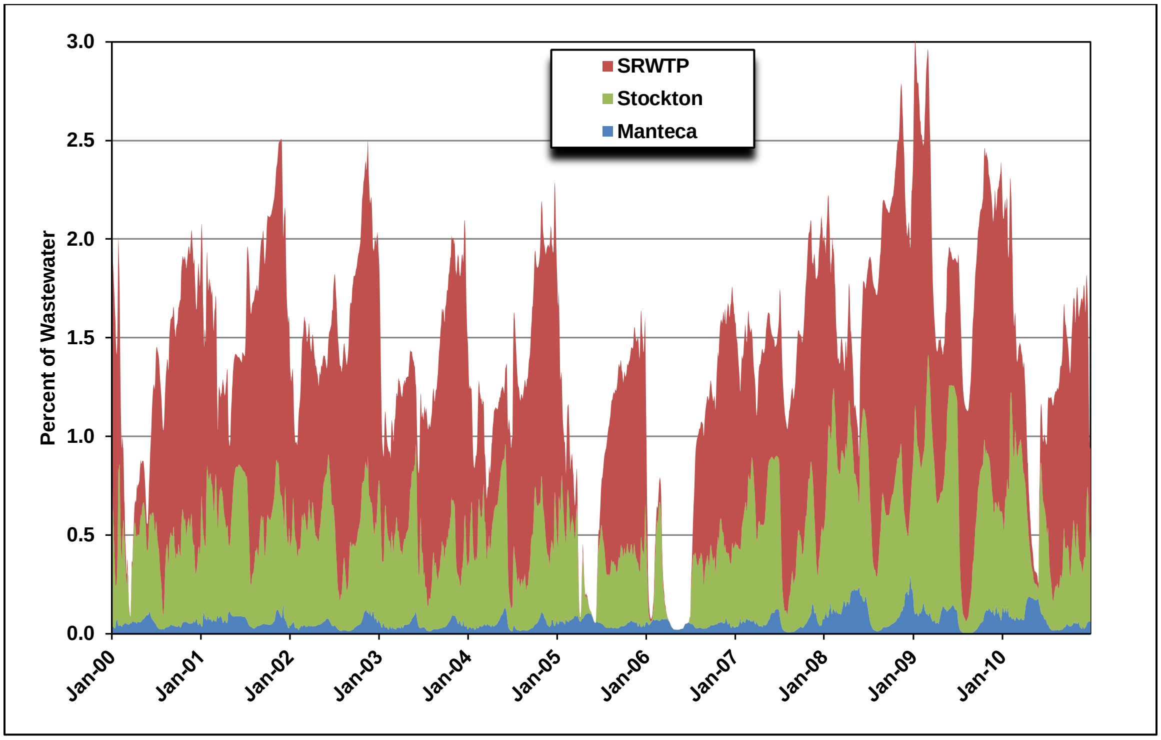
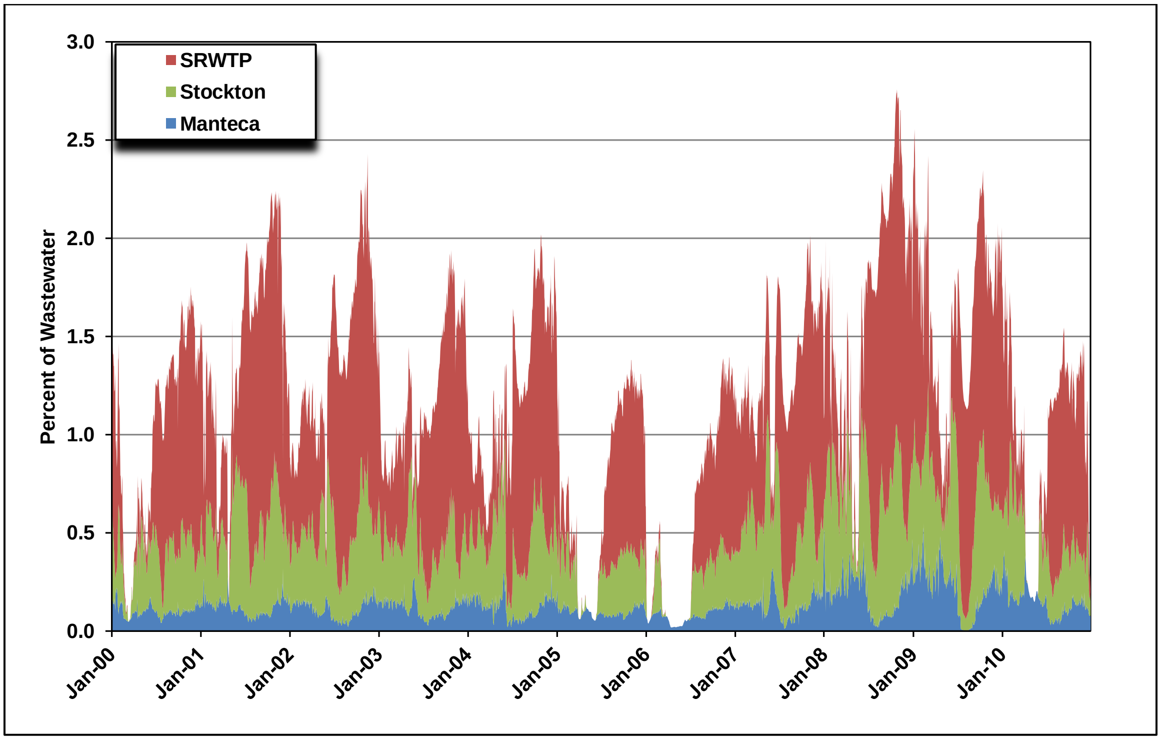


Figure 13-5. Percent of Wastewater at Jones



SRWTP contributes the majority of the wastewater at Clifton Court and Jones, followed by Stockton and Manteca. The wastewater contribution from these three plants ranges from zero to about three percent at both of the south Delta pumping plants. The contribution varies seasonally and by water year-type. The peak seasonal contribution occurs between early November and early January each year. **Figure 13-6** shows there is generally an inverse relationship between Sacramento River flow and the percent wastewater at Clifton Court. This indicates that there is less dilution of the wastewater during low flow periods so a greater percent of wastewater is transported to Clifton Court. During winter storm events there is a greater volume of wastewater discharged to the Sacramento River due to infiltration and inflow of stormwater into the sewer lines but a lower percent of wastewater is transported to Clifton Court due to the greater dilution capacity of the Sacramento River at high flows. **Figure 13-7** presents flow on the San Joaquin River and the percent of wastewater from Stockton and Manteca at Clifton Court. Unlike the Sacramento River, flow on the San Joaquin River does not influence the percent of wastewater from these two plants. This could be due to other Delta operations such as the greater influence of the Sacramento River at Clifton Court, the operation of south Delta barriers, and the location of Stockton relative to the south Delta pumping plants.

The percent of wastewater at the south Delta pumping plants will increase in the future due to population growth in the Central Valley. As discussed previously, the West Yost study projected a 47 percent increase in wastewater flows discharged to the watershed. Not all of this wastewater will reach the south Delta but this could be used as a conservative estimate of the increase in volumes at the pumping plants. Many wastewater treatment plants are upgrading their treatment so the increase in volume will not translate directly to an increase in load of all constituents. This is discussed later in this section.

Wastewater Facilities Discharging in the Delta

Wastewater discharged directly to the Delta is of particular concern due to the proximity of the discharges to drinking water intakes, especially those along the South Bay Aqueduct (SBA). In addition, the Vacaville Easterly plant discharges to Cache Slough, which flows into the Delta and the City of Sacramento's Combined Sewer System (CSS) occasionally discharges to the Delta. **Figure 13-2** shows the locations of the dischargers. Information is provided on the treatment processes and plans for expansion for each of the Delta dischargers in this section.

Figure 13-6. Sacramento River Flow and Wastewater Contribution at Clifton Court from SRWTP

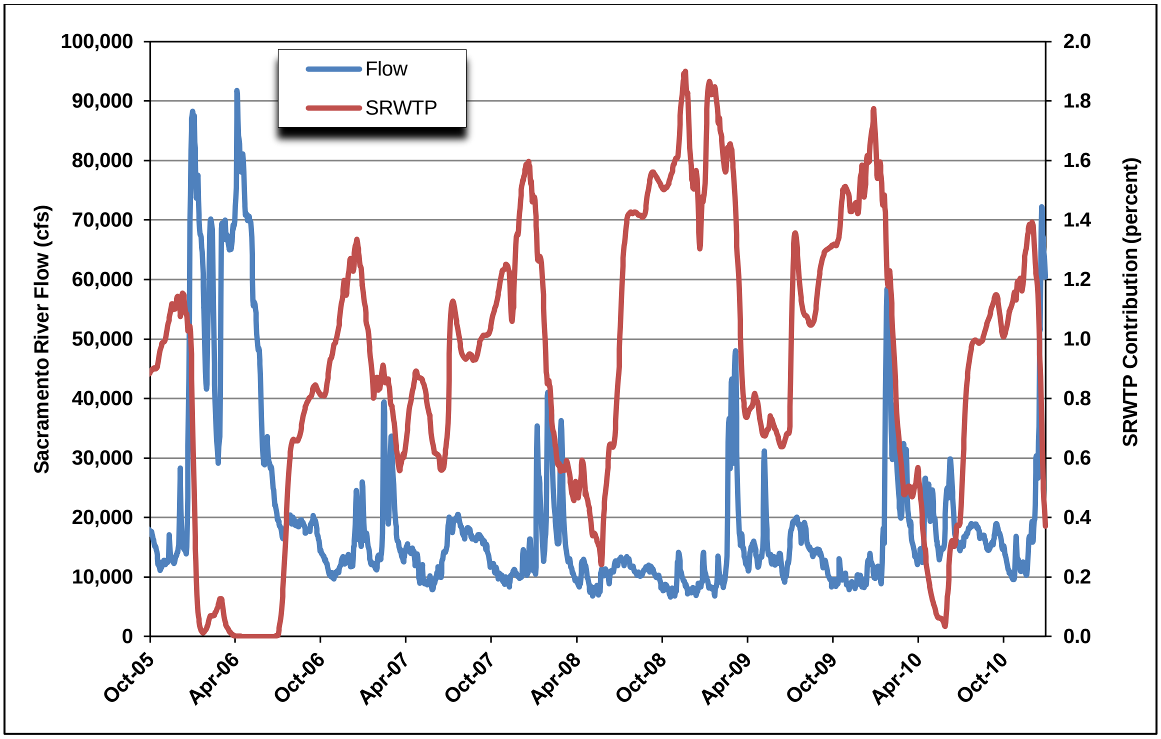
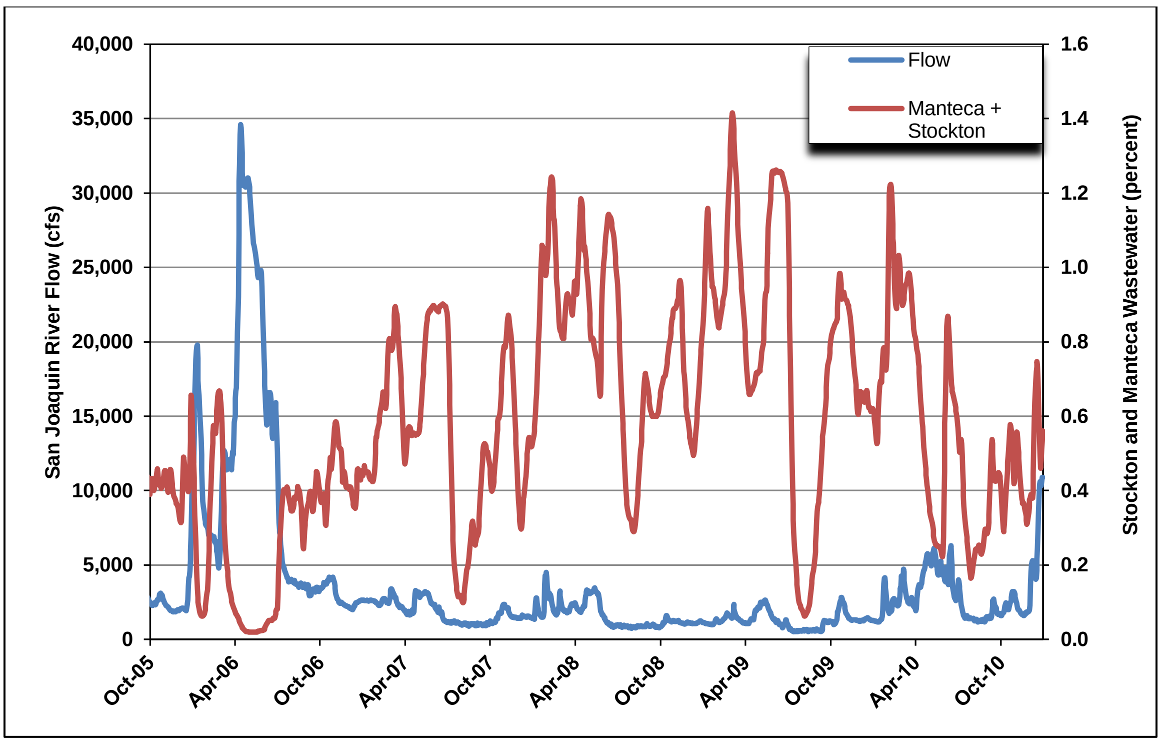


Figure 13-7. San Joaquin River Flow and Wastewater Contribution at Clifton Court from Stockton and Manteca



Sacramento Regional County Sanitation District

Sacramento Regional County Sanitation District (SRCSD) operates the SRWTP which is the largest inland discharge in the state. SRCSD provides wastewater treatment for approximately 1.3 million residents of the cities of Sacramento, Elk Grove, Folsom, Rancho Cordova, Citrus Heights, West Sacramento, the communities of Courtland and Walnut Grove, and most of the urbanized unincorporated areas in Sacramento County. The SRCSD service area encompasses over 250 square miles. According to the 2010 State of the District Report, the SRWTP has a permitted design capacity of 181 mgd, with an average dry weather flow of 139 mgd and peak wet weather flows up to 300 mgd (SRCSD, 2011). Effluent flows have decreased in recent years and the decrease is attributed to water conservation efforts in the service area (Personal Communication, Lysa Voight, SRCSD). Treated wastewater is discharged to the Sacramento River at Freeport, 20 miles upstream of the Delta Cross Channel.

The SRWTP's current treatment processes consist of influent barscreening, primary clarification, high purity oxygen activated sludge, and secondary clarification. The secondary effluent is disinfected with chlorine and then dechlorinated prior to discharge to the Sacramento River via a 120-inch diameter multi-port diffuser. Biosolids are thickened and digested in anaerobic digesters and then pumped to onsite solids storage basins. Solids are stored in the solids storage basins for four to five years and then injected into surface soils onsite. The SRWTP also has five emergency storage basins that serve multiple purposes, including storage during wet weather flow events and storage of chlorinated effluent. The National Pollutant Discharge Elimination System (NPDES) permit requires SRCSD to store chlorinated effluent and not discharge to the Sacramento River whenever the ratio of river to effluent flow drops below 14:1, or 1,300 cubic feet per second (cfs), as a result of tidal reversals and low river flows.

In December 2010, the Central Valley Regional Water Board adopted a new NPDES permit for the SRWTP. The new Permit contains many new requirements and mandates that require SRCSD to plan, design and build treatment facility upgrades for ammonia removal, nitrate removal, filtration and disinfection by December 1, 2020. Some of the key provisions of the new permit include:

- Pathogens
    - Lower effluent limitations for total coliform (2.2 MPN/100 ml [most probable number per 100 milliliters] as a 7-day median, 23 MPN/100 ml, not to be exceeded more than once in a 30-day period, and 240 MPN/100 ml as an instantaneous maximum). Filtration will be required to meet these limits.
    - A new turbidity operational requirement (2 nephelometric turbidity units [NTU] as a daily average) to assist with measuring the performance of filtration related to microbiological contamination.
    - Monthly sampling for *Giardia* and *Cryptosporidium* in the effluent.

- Nutrients
  - New effluent limitations for ammonia (1.8 mg/L average monthly and 2.2 mg/L maximum daily) to protect aquatic life in the Sacramento River and Delta and a new limitation for nitrate (10 mg/L average monthly) to protect drinking water supplies.
- Salinity
  - SRCSD prepared a Source Evaluation and Minimization Plan for Salinity and submitted to the Regional Board on August 31, 2011.
- Other Drinking Water Constituents of Concern
  - A new effluent limitation for N-nitrosodimethylamine (NDMA) of 0.00069 µg/L, as a monthly average, and 0.0014 µg/L maximum daily.
  - Continuance of the mercury Pollution Prevention Program and creation of an ammonia Pollution Prevention Program. Continued support of the pesticides and waste medications source control programs.
  - Special monitoring studies for perchlorate and 1,2-diphenyl-hydrazine in the effluent.

In January 2011, SRCSD and the California Sportfishing Protection Alliance appealed the permit to the State Water Resources Control Board (State Water Board). The State Water Board adopted Water Quality Order 2011-0013 at its September 2011 Board meeting. This order indicates that staff will review the permit to address some of the issues in the petitions, by April 2012. If staff is unable to complete the review in this time they must provide an update to the State Water Board at the May 2012 meeting.

SRCSD had one spill in 2006 and a number of permit violations.

- Spills – There was one spill event at the SRWTP in early 2006. This event was discussed in the 2006 Update. A blend of fully and partially treated effluent was discharged to the Sacramento River over a period of 36 hours over the New Year's holiday. The estimated volume of the spill was 590 million gallons.
- Permit Violations – The Central Valley Regional Water Board issued an Administrative Civil Liability (ACL) Complaint in November 2008 for effluent violations between January 2000 and April 2008. There were 26 effluent violations: coliform (11), chlorine residual (10), cyanide (2), settleable matter (2), and pH (1). The SRCSD was assessed a total mandatory minimum penalty of $54,000 for 18 of these violations. In the 2008 to 2010 period, there were 16 violations of the acute aquatic toxicity effluent limitation.

SRCSD constructed a 5 mgd water recycling plant adjacent to the SRWTP that became operational in 2003. Secondary effluent from the SRWTP is filtered and disinfected at the recycling plant. Recycled water from the plant is used to irrigate parks, school sites, and landscaped medians in the Elk Grove and Laguna areas south of the SRWTP. Currently, SRCSD produces about 3.5 mgd of recycled water at this facility. In 2004, the SRCSD Board of Directors approved a goal of expanding the recycling program up to 40 mgd by 2020. Since development has significantly slowed in south Sacramento County the recycling program has not been expanded. The program will be expanded when demand for recycled water increases (Personal Communication, Anna Johnson, SRCSD).

Stockton

Wastewater from the City of Stockton is treated at the Stockton Regional Wastewater Control Facility and discharged to the San Joaquin River about 1.5 miles upstream of the Stockton Deepwater Ship Channel. The plant treats domestic and industrial wastewaters, as well as a small amount of dry weather urban runoff flow, from a population of about 300,000 in Stockton and surrounding unincorporated areas. The plant consists of a secondary treatment plant and a tertiary treatment plant. The secondary treatment plant consists of headworks, primary sedimentation, followed by high rate trickling filters and secondary clarifiers. The wastewater from the secondary plant is piped under the San Joaquin River to a tertiary plant which consists of approximately 630 acres of unlined facultative oxidation ponds and engineered wetlands, followed by two nitrifying biotowers, dissolved air flotation, mixed-media filters, and chlorination and dechlorination. The plants currently have a design flow of 55 mgd, but generally treat an average of 28 mgd. Biosolids are treated by gravity thickeners, anaerobic digestion, and then dewatered by belt-press and removed by a private contractor for off-site use. Stockton is preparing mercury and salinity pollution prevention program plans to comply with their permit provisions.

Stockton had one spill in 2006 and a number of permit violations:

- Spills – There was a major spill event in June 2006, resulting in 8.7 million gallons of partially treated sewage being discharged to the San Joaquin River. This spill was discussed in the 2006 Update. Stockton paid a $2,425,000 penalty for this spill.

- Permit Violations – The Central Valley Regional Water Board issued ACL Complaints in June 2009 and in March 2011 for effluent violations between 2000 and November 2010. There were 37 effluent violations: coliform (13), dibromochloromethane (7), cyanide (7), oil and grease (4), ammonia (3), chlorine residual (2), and carbonaceous biochemical oxygen demand (1). Stockton was assessed mandatory minimum penalties of $72,000 for 24 of these violations.

Stockton determined that development of a recycled water project at its plant is not feasible. The City is currently investigating a joint Water Recycling Project with the City of Lodi for its White Slough Water Pollution Control Facility

Delta Diablo Sanitation District

Wastewater from the cities of Antioch and Pittsburg is treated at the Delta Diablo Sanitation District Wastewater Treatment Plant which discharges to New York Slough, a section of the San

Joaquin River near the confluence with the Sacramento River. The facility is currently permitted for 16.5 mgd average dry weather flow, with average flows of 9.5 mgd.

Wastewater treatment processes include screening and grit removal, primary clarification, biological treatment with trickling towers and/or aeration basins, secondary clarification, chlorination, and dechlorination. Peak wet weather flows are managed with flow equalization tanks and an emergency retention pond, in addition to storage in collection system pump stations. About half of the secondary-treated wastewater undergoes tertiary treatment at a Recycled Water Facility. Most of this water is used for cooling water makeup at the Delta and Los Medanos Energy Centers, with a minor amount used for irrigation at local parks. The cooling water is returned back to the plant (about 2 mgd) for chlorination/dechlorination and discharge with the effluent. Biosolids are concentrated using a gravity belt thickener, anaerobically digested, and dewatered by centrifuge. Biosolids are either sent to a landfill as alternative daily cover or are applied to land.

The district has received requests for additional recycled water (new irrigation sites and power plants). In response, it plans to recycle more of its secondary-treated effluent and possibly obtain recycled water from outside its service area. Some of this water would be returned to the plant for discharge with the effluent. The district is also considering use of its outfall for disposal of brine from a potential reverse osmosis desalination plant. If all of these projects are implemented, the total discharge could be up to 23.4 mgd. Plant improvements are required for this increase in discharge, which are expected to be completed in 2013.

A review of the California Regional Water Quality Control Board, San Francisco Bay Region (San Francisco Bay Regional Water Board) website as well as the California Integrated Water Quality System (CIWQS) website was conducted. During the study period there were no discharge violations or Mandatory Minimum Penalties issued. There was one ACL Complaint issued (R2-2006-0044) related to four minor discharges in 2003 and 2004 related to coliform and cyanide.

Tracy

Wastewater from the City of Tracy, located in the south Delta, is treated at the Tracy Wastewater Treatment Plant. The facility is currently permitted for 9.0 mgd, but can be expanded to 16 mgd. Currently, 7.09 mgd of treated wastewater is discharged to the Old River, approximately 7 miles upstream of Clifton Court and near the Jones Pumping Plant. The Tracy plant consists of a main treatment facility and an industrial pretreatment facility. The main treatment facility consists of raw influent bar screening, primary sedimentation, biofiltration, secondary aeration basins providing full nitrification/denitrification (NDN) using the Modified Ludzack-Ettinger process, tertiary filtration, chlorination, and dechlorination. Biosolids are thickened by dissolved air flotation, anaerobically digested and dewatered in drying beds. The dried biosolids are hauled off-site for land application or for disposal in a landfill. The industrial pretreatment facility consists of four unlined industrial ponds. In addition, Leprino Foods Company, a local cheese manufacturer, leases two aerated lagoons and one unlined oxidation pond from Tracy for pretreatment of its industrial food processing wastewater. Following pretreatment, the industrial waste enters the main treatment facility for further treatment.

Tracy is currently upgrading the facility to improve treatment and expand capacity. The treatment system will be expanded to 16 mgd through a four-phase expansion that will be completed in 2016. Capacity expansion to 10.8 mgd is expected to be completed by 2012.

The Central Valley Regional Water Board issued ACL Complaints to the City in August 2008 and in March 2009 covering the 2003 to 2008 period. There were 78 permit violations: dichlorobromomethane (27), chlorodibromomethane (26), biochemical oxygen demand (BOD) (21), aluminum (2), chlorine residual (1), and coliform (1). Tracy was assessed mandatory minimum penalties of $219,000 for 73 of these violations. Most violations were related to exceedances of the effluent limits for chlorodibromomethane and dichlorobromomethane. These disinfection problems began after conversion of the secondary treatment to the Modified Ludzack-Ettinger process and addition of tertiary filtration. Tracy has received a Time Schedule Order from the Central Valley Regional Water Board setting higher interim effluent limits for both constituents through March 2015 to allow time to investigate the causes and solutions. There were also several violations for total coliform, total chlorine residual, and aluminum permit limits.

Lodi

Wastewater from the City of Lodi, located in the eastern Delta, is treated at the White Slough Water Pollution Control Facility. The plant is currently permitted for 7.0 mgd (with an expansion up to 8.5 mgd), and treats an average of 6.3 mgd. Lodi owns and operates two separate wastewater collection systems, a municipal wastewater line and an industrial wastewater line that collects wastewater primarily from a cannery. The White Slough plant consists of headworks with comminutors, mechanical grit removal, primary sedimentation, conventional activated sludge, secondary sedimentation, tertiary treatment using cloth media filtration, and ultraviolet (UV) light disinfection. Lodi is upgrading the plant to improve treatment. The improvements will provide oxidized, nitrified, filtered, disinfected, and possibly wetland-polished (nitrate, metals, and organics removals) effluent for an average dry weather flow of 8.5 mgd.

In general, from September through June, the municipal wastewater is treated to tertiary standards and disinfected prior to discharge to Dredger Cut. During the summer months (mid-June through early-September), the municipal wastewater is treated to at least secondary level, and then pumped to unlined storage ponds, and is eventually used to irrigate 790 acres of agricultural fields adjacent to the facility. Throughout the year, Lodi also supplies treated recycled water to the Northern California Power Agency and San Joaquin County Vector Control District, for cooling water and fish rearing ponds.

Biosolids are treated by anaerobic digestion and stored in the facility’s lined sludge stabilization pond. During the summer months, this biosolid slurry is mixed with the storage ponds wastewater and the industrial untreated-wastewater stream, which is largely food processing waste (92 percent) with flows from metal finishers (7 percent) and winery waste (1 percent), and is applied by flood irrigation to the agricultural fields. During the remainder of the year, when the industrial wastewater flows are significantly less and primarily comprised of the metal finishers’ and wineries’ wastewater, the industrial wastewater is stored in the unlined ponds at the facility. Some of the water in the ponds seeps to groundwater and some is used to irrigate agricultural fields.

The Central Valley Regional Water Board issued ACL Complaints in August 2008 and July 2009 for a total of 35 effluent violations: coliform (26), pH (5), total suspended solids (TSS) (2), BOD (1), and manganese (1). Tracy was assessed a penalty of $21,000 for seven of these violations.

Manteca and Lathrop

The cities of Manteca and Lathrop continued to be rapidly growing urban areas located in San Joaquin County in the south Delta. They jointly own, and Manteca operates, the Manteca Wastewater Quality Control Facility which serves both cities, with a design flow of 9.87 mgd. The Facility is divided into two parallel treatment systems, the north and south treatment systems. Primary treatment, which is identical in both systems, consists of mechanical screening, aerated grit removal, and primary sedimentation. At the north plant, the primary effluent undergoes additional treatment through two biotowers with high-rate plastic media. The secondary treatment systems for both treatment systems are the same, which consists of conventional activated sludge, including NDN, followed by secondary sedimentation. Undisinfected secondary effluent is mixed with food processing waste and applied to approximately 260 acres of agricultural fields. Excess secondary effluent undergoes tertiary treatment through coagulation and flocculation, cloth media filtration, and UV disinfection. Disinfected tertiary level treated effluent is discharged to the San Joaquin River. Grit and screenings are hauled offsite to a landfill for disposal. Sludge removed from primary and secondary sedimentation is thickened by dissolved air flotation, and then pumped to anaerobic digesters. After digestion, the treated sludge is dewatered by centrifuge, and then removed offsite for disposal.

Lathrop currently owns and operates a wastewater recycling plant (WRP-1) with a capacity of 0.75 mgd. Lathrop filed a Report of Waste Discharge in 2004 and requested that the Central Valley Regional Water Board modify their waste discharge requirements to allow the city to expand WRP-1 to 3.12 mgd and to construct WRP-2 which will be identical to WRP-1. The wastewater recycling plants are needed to treat wastewater from several new developments in Lathrop. The Central Valley Regional Water Board issued a Master Reclamation Permit in 2006 permitting the expansion of the existing plant and construction of the new plant, subject to meeting a number of requirements for information. The wastewater is treated to tertiary standards and meets Title 22 requirements for reclaimed water using membrane bioreactor technology. The recycled water is used to irrigate agricultural crops, parks and median strips.

The Central Valley Regional Water Board issued ACL Complaints in June 2006, May 2008, November 2009, and March 2011 covering the period between February 2005 and November 2010. There were 94 permit violations: bromodichloromethane (23), coliform (16), dibromochloromethane (15), copper (13), settleable solids (12), pH (6), arsenic (4), ammonia (2), cyanide (2), and turbidity (1). Manteca was assessed mandatory minimum penalties of $267,000 for 89 of these violations.

Brentwood

The City of Brentwood is located in eastern Contra Costa County and is one of the most rapidly growing urban areas in the Delta. The Brentwood Wastewater Treatment Plant is a 5.0 mgd tertiary treatment plant that is designed to produce effluent suitable for unrestricted irrigation reuse. The tertiary plant consists of screens, grit removal, extended aeration activated sludge, denitrification by anoxic basins, secondary clarifiers, tertiary filtration, chlorination/ dechlorination, and a cascade aeration system. Biosolids are treated in an aerobic digester, dewatered in sludge drying beds, and disposed offsite. The facility is currently in construction for an expansion to 7.5 mgd.

The Brentwood plant currently treats average dry weather flows of 3.2 mgd and has three disposal options: offsite reclamation, land disposal to existing percolation ponds, and discharge to Marsh Creek. To minimize discharge to Marsh Creek, Brentwood has received a Master Reclamation Permit for the distribution and use of recycled water in its service area. The City uses recycled water for irrigation of parks and median strips, and sometimes other uses such as dust control at construction sites. The City plans to distribute recycled water for use on golf courses in the area. The Central Valley Regional Water Board has not issued any ACL Complaints to the City since 2004.

Ironhouse Sanitary District

The Ironhouse Sanitary District owns and operates a wastewater treatment plant and provides sewerage service for the communities of Oakley and Bethel Island, and unincorporated areas in between, serving a population of approximately 31,200. Historically, the District disposed of disinfected secondary treated wastewater through irrigation of agricultural lands for production of hay and pastureland for grazing cattle. The wastewater was settled and then dosed with sodium hypochlorite for disinfection prior to discharge to the irrigation fields. In 2007, the District submitted a Report of Waste Discharge to the Central Valley Regional Water Board applying for an NPDES permit to discharge up to 4.3 mgd to the San Joaquin River from a proposed plant. Subsequently, the District designed a new 4.3 mgd plant to produce tertiary treated effluent with UV light disinfection. Construction began in April 2009 and was completed in October 2011. The District will continue to maximize land disposal and water reclamation with tertiary, nitrified and denitrified effluent.

Discovery Bay

The Town of Discovery Bay is located in eastern Contra Costa County. The wastewater collection, treatment, and disposal system is owned by the town but operated by Southwest Water Company. The existing plant has a capacity of 2.1 mgd and serves a population of 16,000. Currently, 1.6 mgd of treated wastewater is discharged to the Old River. The treatment system includes two plants (Plant 1 and Plant 2) which each consist of a head works screen, an oxidation ditch (which provides NDN), two secondary clarifiers, and a shared UV disinfection system. Plant 1 also includes a flow equalization and storage basin. The influent flow is split between the two plants, and treated effluents rejoin at the shared UV disinfection system at Plant 2. Sludge handling is located at Plant 2 and consists of an aerated, clay lined lagoon (referred to as an aerobic digester), two clay lined sludge lagoons, a belt filter press, and two greenhouse solar drying beds. Sludge is stored on site in the solar drying bed building or adjacent to the building.

The Central Valley Regional Water Board issued ACL Complaints to Discovery Bay in March 2009, December 2009, and May 2011 covering the period between January 2008 and February 2011. During this time there were 39 violations: coliform (23), TSS (15), and electrical conductivity (EC) (1). Discovery Bay was assessed penalties of $93,000 for 31 of these violations.

Mountain House Community Services District

Mountain House is a newer residential, commercial, and industrial community developed in western San Joaquin County between Interstate 205 and Old River. This community is approximately three miles west of Tracy and is designed to have up to 44,000 residents.

Mountain House originally had a Phase I secondary plant with a design flow of 0.45 mgd. This facility was permitted for land disposal of its effluent. Once flows reached 0.3 mgd, Mountain House had to convert to a Phase II plant. The Phase II plant is designed for 3.0 mgd, and includes a headworks, an anoxic reactor for flow/load equalization and a carbon source for denitrification, sequencing batch reactors for biological treatment including NDN, tertiary filtration, UV disinfection, and aerobic sludge digestion. The Phase I lined aeration lagoons will be retained as emergency storage lagoons. Phase III will be an expansion of the Phase II plant to 5.4 mgd. The Mountain House plant currently treats 0.6 mgd of wastewater that is discharged to the Old River.

The Central Valley Regional Water Board issued ACL Complaints in September 2008 and March 2009 covering the period of March 2007 to December 2008. There were 14 permit violations: dibromochloromethane (10) and pH (4). Mountain House was assessed mandatory minimum penalties of $33,000 for 11 of these violations. They have since been issued a Time Schedule Order that established interim effluent limits for dibromochloromethane and requires a Pollution Prevention Plan. Chlorine is not used in the plant, so source control must be implemented.

Rio Vista Beach Wastewater Treatment Facility

The City of Rio Vista is located in the north-central portion of the Delta. The Beach Wastewater Treatment Facility services the central portion of Rio Vista with a population of approximately 4,500 people. The City owns the plant, but Veolia Water West Operating Services Inc. operates the plant. The Beach plant has a design capacity of 0.65 mgd, but typically operates at 0.45 mgd. The treatment system consists of bar screening and grit removal, two primary clarifiers, two activated sludge reactors, two secondary clarifiers, chlorination and dechlorination. Sludge is dewatered on drying beds (lined and unlined) and disposed offsite at a local landfill. Wastewater is discharged through an outfall into the Sacramento River. This facility was upgraded in response to numerous water quality objective violations related to settleable solids and coliform. This was effective, but the new permit adopted in 2008 included very low effluent limitations for disinfection by-products which resulted in more violations. Recently, the permit was amended to increase the effluent limitations for chlorodibromomethane and dichlorobromomethane.

Northwest Wastewater Treatment Facility

The Northwest Wastewater Treatment Facility services a small development serving approximately 3,400 people northeast of the City of Rio Vista. The City owns the Northwest plant, but Veolia Water West Operating Services Inc. operates the plant. The plant was constructed in 2006 to replace the privately owned Trilogy Wastewater Treatment Plant, which had numerous problems meeting water quality objectives. The Northwest plant has a design capacity of 1 mgd, but typically operates around 0.2 mgd. The treatment consists of fine screenings followed by activated sludge treatment via anoxic and aerobic basins, followed by membrane biological reactors which separate the liquid wastewater from the solids. The liquid wastewater from the membrane biological reactors is disinfected using UV light. The solids from the activated process are dewatered using belt filter press technology followed by drying in solar greenhouses. Once dried, the material is stockpiled in one of the solar greenhouses prior to disposal at a landfill. An emergency storage basin lined with high density polyethylene is used to accommodate flows in excess of the peak hydraulic capacity. Wastewater is discharged to the Sacramento River.

The Central Valley Regional Water Board issued an ACL Complaint in September 2010 for six permit violations: pH (2), coliform (2), and aluminum (2). Rio Vista was assessed a mandatory minimum penalty of $3,000 for one of these violations.

Vacaville

The City of Vacaville is located in Solano County. The Easterly Wastewater Treatment Plant treats wastewater from Vacaville and the unincorporated community of Elmira. Currently average dry weather flow of 8.2 mgd of treated municipal wastewater is discharged to Old Alamo Creek, which flows to Alamo Creek, then to Ulatis Creek to Cache Slough and finally the Sacramento River. The Easterly plant consists of two plants that operate in parallel with a design flow of 15 mgd. The treatment processes consist of headworks, primary sedimentation basins, aeration basins, secondary circular clarifiers, chlorination and dechlorination facilities, emergency ponds, dissolved aeration floatation thickener, anaerobic digesters, biosolids storage ponds, biosolids belt filter press, and biosolids drying beds. The NPDES permit requires that Vacaville provide seasonal tertiary treatment (May to October) by 2015. The NPDES permit requires preparation of Pollution Prevention Program plans for mercury, salinity, cyanide, chlorodibromomethane, and dichlorobromomethane.

Vacaville conducted a use attainability analysis to determine the appropriate beneficial uses for Old Alamo Creek and Ulatis Creek. The Central Valley Regional Water Board determined that the municipal beneficial use would not be removed, but rather site-specific water quality objectives would be established for chloroform (46 µg/L), chlorodibromomethane (4.9 µg/L), and dichlorobromomethane (16 µg/L). The Central Valley Regional Water Board adopted theses site specific objectives in 2010.

The Central Valley Regional Water Board issued ACL Complaints in June 2008 and September 2010 covering the period between April 2004 and June 2010. There were 32 permit violations: chlorine residual (14), pH (6), coliform (6), and settleable solids (6). Vacaville was assessed mandatory minimum penalties of $81,000 for 27 of these violations.

City of Sacramento Combined System

The City of Sacramento owns and operates a CSS that serves 24,000 parcels in the older neighborhoods of Sacramento. The CSS collects both wastewater and urban runoff. During the study period the City was discharging under Order No. R5-01-258, and the permit was renewed in 2010 under Order No. R5-2010-0004. The NPDES Permit specifies operating parameters, effluent limits for certain constituents, and monitoring requirements.

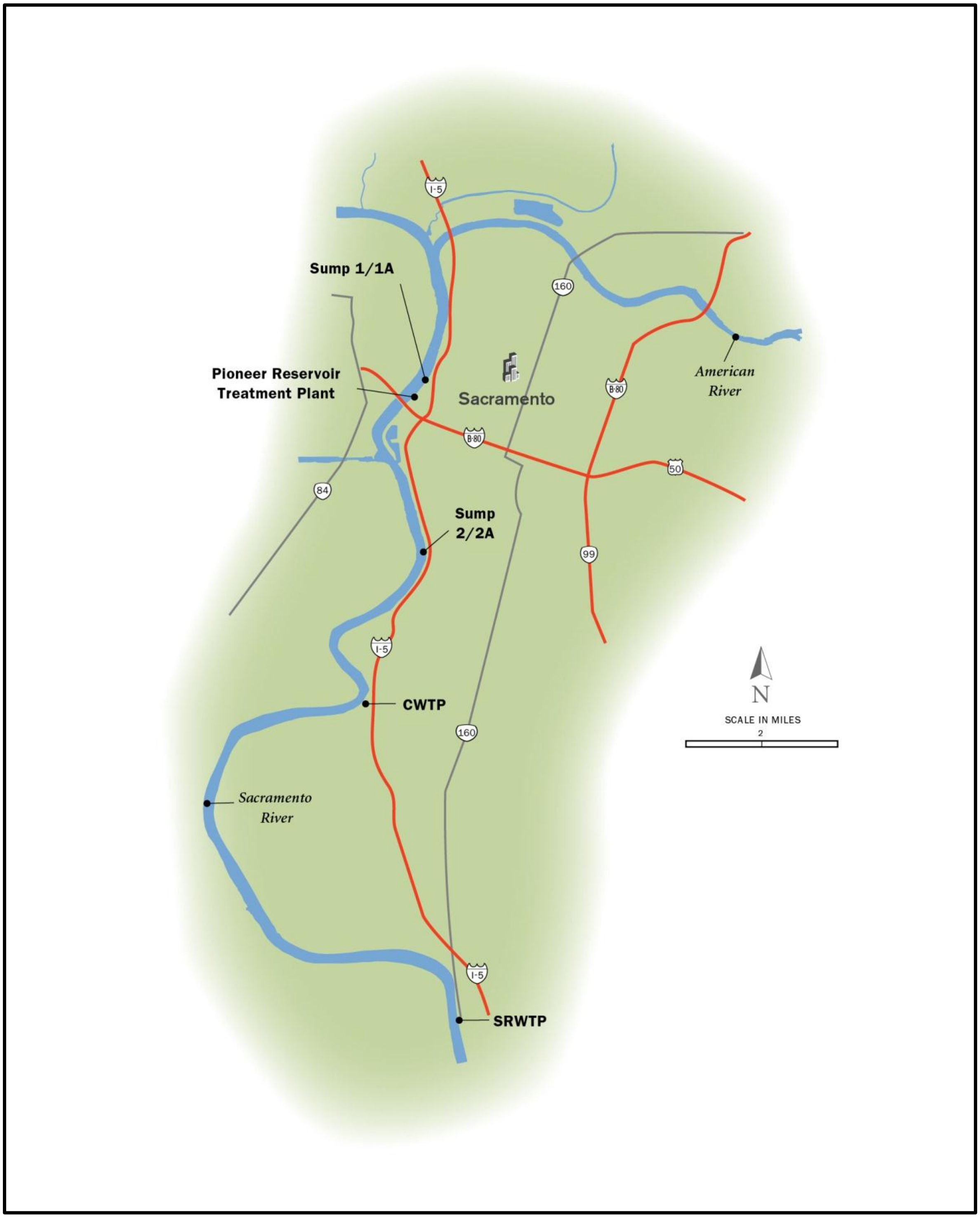
The CSS consists of four main facilities to manage the combined sewage: Sumps 1/1A, Sumps 2/2A, the Pioneer Reservoir Treatment Plant, and the Combined Wastewater Treatment Plant (CWTP). The locations of these facilities are shown in **Figure 13-8**. The system is operated to maximize treatment of the combined wastewater and minimize discharges of untreated combined wastewater to the Sacramento River.

The CSS conveys combined wastewater to Sumps 1/1A and 2/2A, where up to 60 mgd are pumped to the SRWTP for secondary treatment prior to discharge to the Sacramento River. When flows exceed 60 mgd, the additional flow is routed through the Pioneer Interceptor and stored at Pioneer Reservoir. The interceptor can store up to 5 million gallons and the reservoir can store up to 23 million gallons. After available storage in Pioneer Reservoir is exceeded, flows are routed via the CWTP Force Main to the CWTP which can store up to 9.2 million gallons between the plant and the interceptor. The objective is to store the combined wastewater and urban runoff for later treatment at the SRWTP.

When the system's storage capacity is exceeded, flows are sent to the Pioneer Reservoir treatment facility for treatment. The Pioneer Reservoir provides primary treatment and disinfection for up to 250 mgd. After the wastewater is dechlorinated, it is discharged to the Sacramento River. Flows can also be sent to the CWTP, where an additional 130 mgd of combined wastewater receives primary treatment and disinfection prior to discharge to the Sacramento River. As flows increase and treatment capacity limits for Pioneer Reservoir and the CWTP are reached, flows above 250 mgd are routed through Pioneer Reservoir for at least partial primary treatment and then discharged to the Sacramento River. During extreme high flow conditions, discharges of untreated combined wastewater may occur at Sumps 2/2A and at the Sump 1A bypass.

The permit applicable during the majority of the study period had limited water quality monitoring requirements. There were detectable levels of copper, lead, zinc, and diuron in the effluent. Of these constituents only zinc was consistently detected, sometimes at levels above the water quality objective. The new permit requires annual sampling of the effluent for priority pollutants, drinking water constituents with drinking water maximum contaminant levels (MCLs), pH and hardness. The permit also requires a Water Quality Assessment to be completed including sampling for *Giardia* and *Cryptosporidium* (expected in 2012). The new permit also requires notification to downstream water purveyors whenever there is a discharge to surface water.

Figure 13-8. Discharge Locations for Sacramento Combined System



There have been fewer combined sewer overflow (CSO) discharges, both treated and untreated, since the City increased system storage capacity and converted Pioneer Reservoir to a primary treatment facility with disinfection. Discharges during the 2006 to 2010 period include:

- 2005/2006
  - Treated CSOs – Eight from Pioneer Reservoir and five from CWTP with a combined volume of 749 million gallons.
  - Untreated CSOs – One from Sump 2 in Dec 2005 with a volume of 61.15 million gallons.

- 2006/2007 – No discharges.

- 2007/2008
  - Treated CSOs – Three from Pioneer Reservoir and two from CWTP with a combined volume of 228.8 million gallons.
  - Untreated CSOs – One from Sump 2 in Jan 2008 with a volume of 11.25 million gallons.

- 2008/2009
  - Treated CSOs – Four from Pioneer Reservoir and two from CWTP.

- 2009/2010
  - Treated CSOs – Five from Pioneer Reservoir and two from CWTP with a combined volume of 264.86 million gallons.

The recently adopted permit for the City's CSS included a Fact Sheet with a summary of the effluent water quality data from 2002 through 2009. The Central Valley Regional Water Board indicates that the system is generally in compliance with the existing water quality effluent limitations, with few violations. There was only a single detectable value of chlorine residual (January 2006 at 1.8 mg/L). The majority of fecal coliform samples were not detectable (< 2 MPN/100 ml), but there was a single event in January 2004 when fecal coliform was detected above the effluent limit (330 MPN/100 ml). **Table 13-3** provides a summary of the effluent water quality data.

Table 13-3. City of Sacramento CSS Effluent Data Summary

Constituent	Effluent Limitation			Monitoring Data (Nov 2002 – Jan 2009)		
	Storm Year Average[a]	Storm Maximum	Storm Year Median[a]	Highest Average Yearly Discharge	Highest Storm Maximum Discharge	Highest Storm Year Median Discharge
Total Suspended Solids (mg/L)	100[b,c]	--	--	103	--	--
Settleable Solids (mg/L)	--	1.0[c]	--	--	7.1	--
Chlorine Residual (mg/L)	--	0.02	--	--	1.8	--
Fecal Coliform (mg/L)	--	--	200[d,e]	--	--	330

[a] October 1 – September 30
[b] In addition, two consecutive samples shall not exceed 150 mg/L
[c] Pioneer Reservoir for flows less than 250 mgd and all flows at the CWTP
[d] In addition, no three consecutive samples shall exceed 1,000 MPN/100 mL
[e] Discharger shall continuously operate chlorination equipment when discharging to Sacramento River

In November 2008, the Central Valley Regional Water Board issued an ACL Complaint to the City for discharge violations between January 2000 and June 2008. Mandatory minimum penalties of $6,000 were assessed for violating the chlorine residual effluent limitation on two occasions. The complaint also noted two non-serious violations of the TSS effluent limitation and two non-serious violations of the pH effluent limitation.

WASTEWATER QUALITY AND EFFLUENT LIMITATIONS FOR DRINKING WATER CONSTITUENTS

As described in more detail in **Chapter 2**, the beneficial uses and receiving water objectives to protect those uses are established in the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins, known as the Basin Plan (Central Valley Regional Water Board, September 2009). The Central Valley Regional Water Board establishes effluent limitations for wastewater dischargers based on the beneficial uses and the water quality objectives of the water body that receives the discharge. Effluent limitations are specific to each discharge and vary throughout the Central Valley. If a discharge is to an ephemeral stream or a stream that the Central Valley Regional Water Board determines does not have any assimilative capacity for a contaminant, the discharger must meet the receiving water quality objectives in the effluent. If there is dilution capacity available in the receiving water, the Central Valley Regional Water Board establishes effluent limitations that allow for a mixing zone and dilution of the effluent in the receiving water. The Central Valley Regional Water Board establishes effluent limitations for a number of contaminants in waste discharge permits. The discussion in this section is limited to those constituents that have been identified by the Sanitary Survey Subcommittee as being of primary concern for SWP drinking water providers (see **Chapter 3**). As described in **Chapter 2**, the Basin Plan does not contain water quality objectives for some of the key drinking water constituents of concern (disinfection byproduct precursors, pathogens, nutrients) or the current objectives are not based on drinking water concerns (salinity, chloride). As a result, there are limited data on the quality of wastewater effluent for many of these constituents because the dischargers are not required to conduct monitoring. The data that are available are discussed in this section.

Pathogens and Indicator Organisms

Untreated wastewater contains human bacteria, parasites, and viruses. The Basin Plan contains a fecal coliform objective to protect contact recreation:

> *"In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200/100 ml, nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100ml."*

The Basin Plan does not contain a coliform objective for the protection of drinking water sources or objectives for actual pathogens such as *Giardia* and *Cryptosporidium*. The Central Valley Regional Water Board establishes effluent limitations for total coliform bacteria for all wastewater discharges but does not establish effluent limitations for actual pathogens. Wastewater treatment plants that provide secondary treatment are required to have a seven-day median total coliform count that does not exceed 23 MPN/100 ml and a maximum of 240 MPN/100 ml not more than once in 30 days. If the Central Valley Regional Water Board determines that the receiving water does not have sufficient dilution capacity and beneficial uses of the receiving water include municipal and domestic supply, water contact recreation, or agricultural supply for food crops, more stringent effluent limitations are included in waste discharge permits. The more stringent requirements are based on reclamation criteria for the reuse of wastewater established in Title 22 of the California Code of Regulations. Title 22 requires that for spray irrigation of food crops and public access areas such as parks, wastewater must be adequately treated so that effluent total coliform levels do not exceed 2.2 MPN/100 ml as a 7-day median, 23 MPN/100 ml more than once in 30 days, and a maximum of 240 MPN/100 ml. Title 22 also requires that recycled water used as a source of water supply for non-restricted recreational impoundments receive tertiary treatment and disinfection. The Central Valley Regional Water Board also establishes effluent limitations for turbidity to ensure that filters are operating properly to remove pathogens. These include a daily average of 2 NTU, not to exceed 5 NTU in five percent of daily samples, and never to exceed 10 NTU. The coliform effluent limits for the wastewater treatment plants that discharge to the Delta are shown in **Table 13-4**

SRCSD monitoring the SRWTP effluent for *Giardia* and *Cryptosporidium* from December 1999 through April 2006. The sampling frequency varied from every two weeks to every two months, for a total of 75 samples. **Table 13-5** presents a summary of the data. These data indicate that disinfected effluent that meets coliform effluent limitations still contains *Giardia* and

Cryptosporidium and possibly other pathogens. The significance of this pathogen loading to drinking water intakes in the Delta is unknown.

Table 13-4. Total Coliform Effluent Limitations

Discharger	**Total Coliform Effluent Limitations (MPN/100 ml)**		
	Weekly Median	**Monthly Maximum[a]**	**Instantaneous Maximum**
SRCSD	2.2	23	240
Stockton	2.2	23	240
Lodi	2.2	23	240
Tracy	2.2	23	240
Manteca/Lathrop	2.2	23	240
Brentwood	2.2	23	240
Discovery Bay	23	240	-
Mountain House	2.2	23	240
Ironhouse	2.2	23	240
Delta Diablo	-	33[b]	-
Rio Vista Northwest	23	240	-
Rio Vista Beach	23	240	-
Vacaville	2.2	23	240

[a] Cannot exceed more than once in any 30-day period.
[b] This is a 30-day mean for *Enterococcus* bacteria

Table 13-5. Pathogens in SRWTP Effluent

	***Giardia* (cysts/L)**		***Cryptosporidium* (oocysts/L)**	
	Total IFA[a]	**DAPI/DIC Positive[b]**	**Total IFA[a]**	**DAPI/DIC Positive[b]**
Percent Detected	100	95	96	89
Range	0.5 – 400	ND – 160	ND – 88	ND – 79
Mean	39	15	10	4.0
Median	30	11	5.4	1.1

[a] Total IFA indicates fluorescence antibody staining (presumptive)
[b] DAPI/DIC Positive indicates internal staining and structure identification (confirmed)

Nutrients

Untreated municipal wastewater contains high concentrations of nitrogen and phosphorus. The concentrations in the effluent depend upon the types of treatment processes that are employed to treat the wastewater. The Basin Plan does not have numeric water quality objectives for nutrients based on the potential to cause algal growth but does have the following narrative objective:

> *"Water shall not contain biostimulatory substances which promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses."*

The narrative objective is included in every waste discharge permit as a receiving water limitation. Effluent limitations for nitrate and ammonia are established in most waste discharge permits for Delta dischargers. The effluent limitations for ammonia are based on aquatic toxicity and are determined based on the dilution capacity of the receiving water. The effluent limitations for nitrate and nitrite are based on another narrative objective that is included in the Basin Plan:

> *"Water shall not contain chemical constituents in concentrations that adversely affect beneficial uses."*

This narrative objective is used to incorporate by reference all of the MCLs established by the U.S. Environmental Protection Agency (USEPA) and CDPH. Therefore, the Basin Plan establishes receiving water quality objectives of 10 mg/L as N for nitrate and 1 mg/L as N for nitrite for all waters designated with the municipal and domestic beneficial use, based on the MCLs. If the receiving water has sufficient assimilative capacity so that the discharge does not cause an exceedance of these objectives beyond the mixing zone in the water body, the Central Valley Regional Water Board does not establish an effluent limitation. If the receiving water does not contain assimilative capacity, the Central Valley Regional Water Board requires that the effluent limitations be set at 10 mg/L as N for nitrate and 1 mg/L as N for nitrite. The effluent limitations for the wastewater treatment plants that discharge to the Delta are shown in **Table 13-6** to show the variability in effluent limitations among plants.

Recently a Wastewater Control Measures Study was conducted for the Central Valley Drinking Water Policy Workgroup (West Yost Associates, 2011). The objective of this study was to evaluate current and projected future loads of key drinking water constituents discharged from wastewater treatment plants in the Central Valley. When direct monitoring data were unavailable, they identified assumed concentrations based on the level of treatment provided at the facility as shown in **Table 13-7**.

Table 13-6. Nutrient Effluent Limitations

Discharger	Ammonia (mg/L)		Average Monthly (mg/L)		
	Average Monthly	Daily Maximum	Nitrate	Nitrite	Nitrate + Nitrite
SRCSD	1.8	2.2	10	-	-
Stockton	2	5	-	-	40
Lodi	1.3	4.3	10	1.0	-
Tracy	1.3	2.1	10	1.0	-
Manteca/Lathrop	1.4	3.4	-	-	10
Brentwood	0.8	2.1	-	-	-
Discovery Bay	10	30	73[a]	-	-
Mountain House	1.0	2.1	10	1.0	-
Ironhouse	1.1	2.1	-	-	10
Delta Diablo	210	260	-	-	
Rio Vista Northwest	1.1	2.1	-	-	10
Rio Vista Beach	35	91	65[b]	3.1[b]	-
Vacaville	1.3	3.2	17	-	-

[a] There is also a maximum daily limit of 126 mg/L.
[b] These are maximum daily limits.

Table 13-7. Assumed Concentrations of Nutrients for Existing Major Wastewater Dischargers When Data are Unavailable

Treatment Level Category	Total Phosphorus (mg/L as P)	Total Nitrogen (mg/L as N)	Ammonia (mg/L as N)	Nitrate (mg/Las N)	Nitrite (mg/L as N)
Secondary	5[a]	26[a,b,c]	20[b,c]	3[a,c]	0.1[a,d]
Secondary with Nitrification	5[a,b]	18[a,b]	0.5[a,e]	15[a,e]	0.1[a,d]
Tertiary	3[b]	26[b]	18[b,c]	5[a,c]	0.1[a,d]
Tertiary with Nitrification	3[a]	18[a,b]	0.5[a,e]	15[a,e]	0.1[a,d]
Tertiary Treatment with NDN	1[a,f]	10[a,g]	0.5[a,e,g]	7[a,g]	0.1[a,d]

a Similar to average value of available data.
b Tchobanoglous and Burton (1991).
c Typical value for un-nitrified effluent. Assumes some nitrification will occur and nitrification capacity will be slightly greater in tertiary facilities.
d Typical value for treated wastewater
e Typical value for nitrified effluent. Assumes partial denitrification will occur.
f USEPA (2007).
g Typical value for wastewater treated with NDN.

Effluent quality data are presented for SRWTP, which is a secondary plant, and for Stockton, which is a tertiary plant. Many of the other dischargers have recently or are currently upgrading their treatment plants to include nitrification, so historical data do not reflect current conditions. **Figures 13-9 and 13-10** present the ammonia, nitrate, and nitrite data for SRWTP and Stockton, respectively. The sampling frequencies vary between the two plants. SRWTP ammonia, nitrate and nitrite are monitored twice a week. Stockton collects daily ammonia samples and weekly nitrate and nitrite samples. The effluent for the SRWTP contains primarily ammonia since it is a secondary treatment plant and does not have N/DN processes. Ammonia levels range from 10 to 45 mg/L, with a median of 24 mg/L. Nitrate levels range from 0.016 to 1.4 mg/L, with a median of 0.1 mg/L. Stockton is a tertiary plant with N/DN processes, so ammonia is converted to nitrate and some of the nitrate is converted to nitrogen gas. There was a significant shift in nitrogen species beginning around September 1, 2006. This is the time when the plant began implementation of nitrifying trickling filters as tertiary treatment (Personal Communication, Larry Parlin, City of Stockton). Ammonia levels ranged from 0.5 to 26.9 mg/L, with a median prior to September 1, 2006 of 22.4 mg/L and a median after of 1.5 mg/L. Nitrate levels ranged from 0.1 to 29 mg/L, with a median prior to September 1, 2006 of 0.6 mg/L and a median after of 17 mg/L.

Figures 13-11 and 13-12 present effluent total phosphorus (total P) data for SRWTP and Stockton, respectively. Stockton samples quarterly and SRSCD samples monthly. The SRWTP total P concentrations range from 1.4 to 3.3 mg/L, with a median of 2.4 mg/L. The Stockton total P concentrations range from 0.1 to 2.9 mg/L, with a median of 0.2 mg/L.

The Wastewater Control Measures Study, discussed previously, presents current and projected future (2030) nutrient loads from wastewater treatment plants that discharge in the Sacramento and San Joaquin basins and the Delta. Currently there are 29,320 pounds per day of ammonia discharged. The ammonia load will decrease to 6,650 pounds per day by 2030 if all of the treatment upgrades currently mandated in existing permits are constructed. A number of dischargers are required to add nitrification to their treatment plants, which will convert ammonia to nitrate. This is responsible for the large projected decrease in the ammonia load and the large projected increase in the nitrate load. Nitrate is currently estimated at 15,400 pounds per day and is projected to increase to 33,400 pounds per day under currently mandated treatment changes. Nitrite is currently estimated at 270 pounds per day and is projected to increase to 380 pounds per day under currently mandated treatment changes. Finally, total phosphorus is currently estimated at 7,200 pounds per day and is projected to decrease to 6,100 pounds per day under currently mandated treatment changes.

Figure 13-9. Ammonia, Nitrate and Nitrite Concentrations in SRWTP Effluent

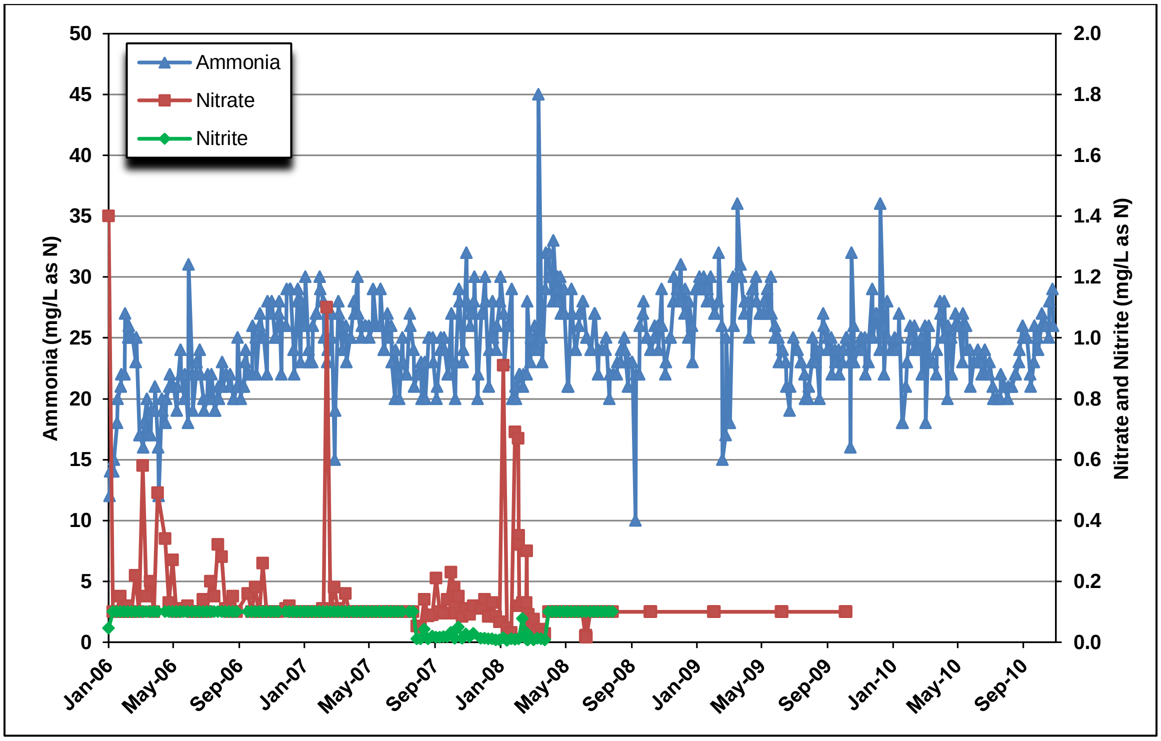


Figure 13-10. Ammonia, Nitrate and Nitrite Concentrations in Stockton Effluent

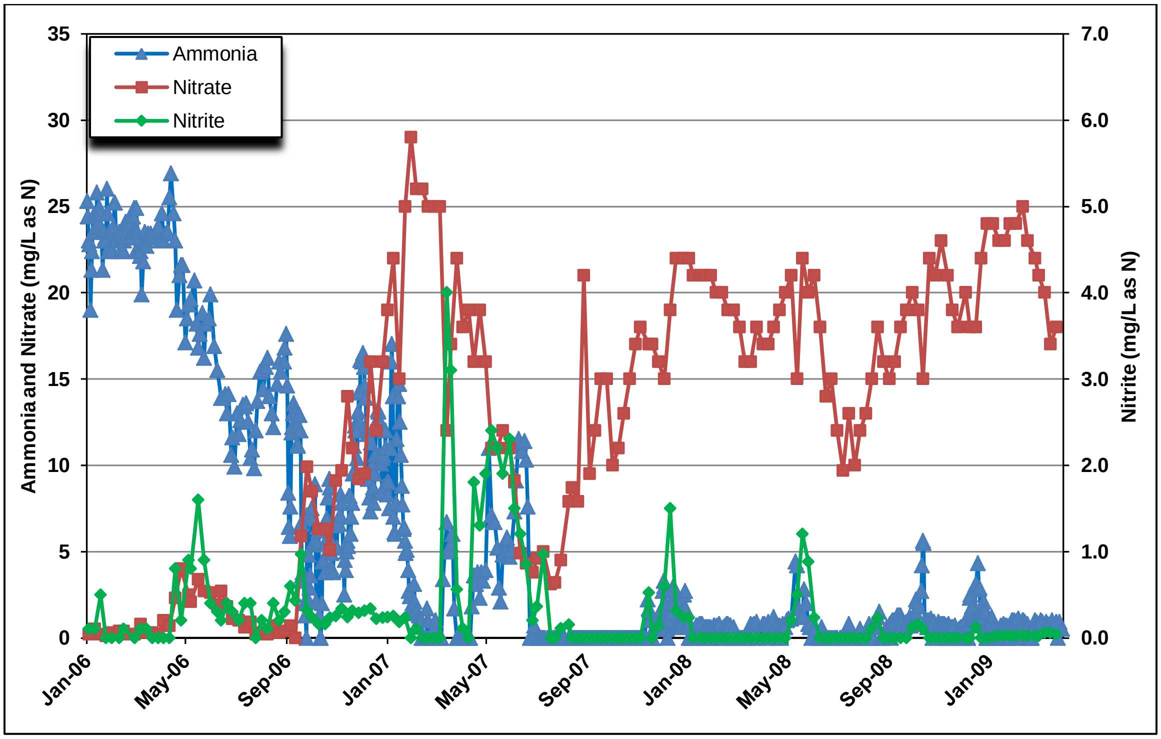


Figure 13-11. Total P Concentrations in SRWTP Effluent

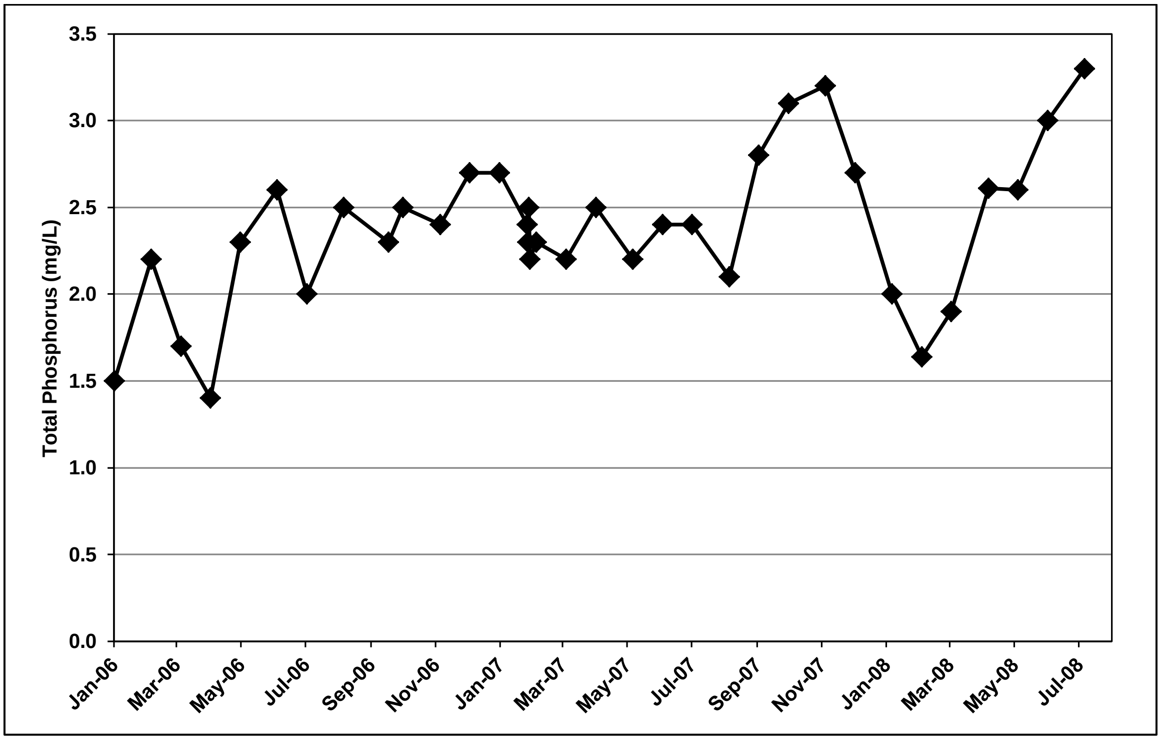
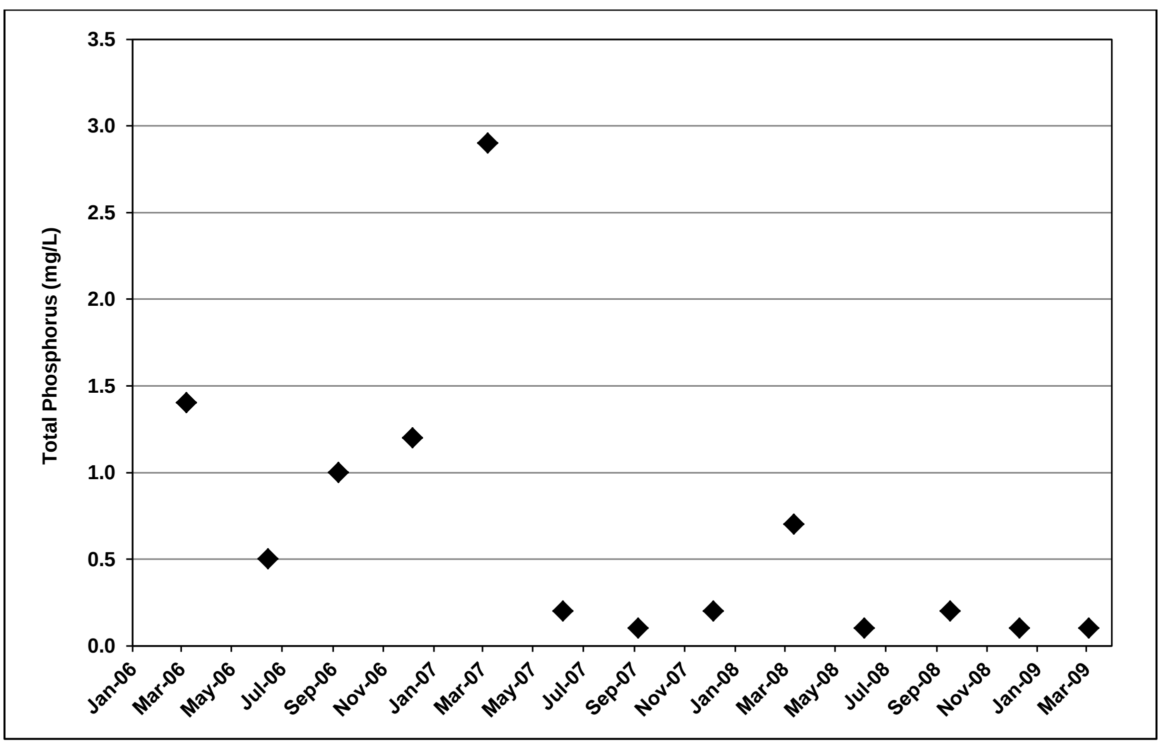


Figure 13-12. Total P Concentrations in Stockton Effluent

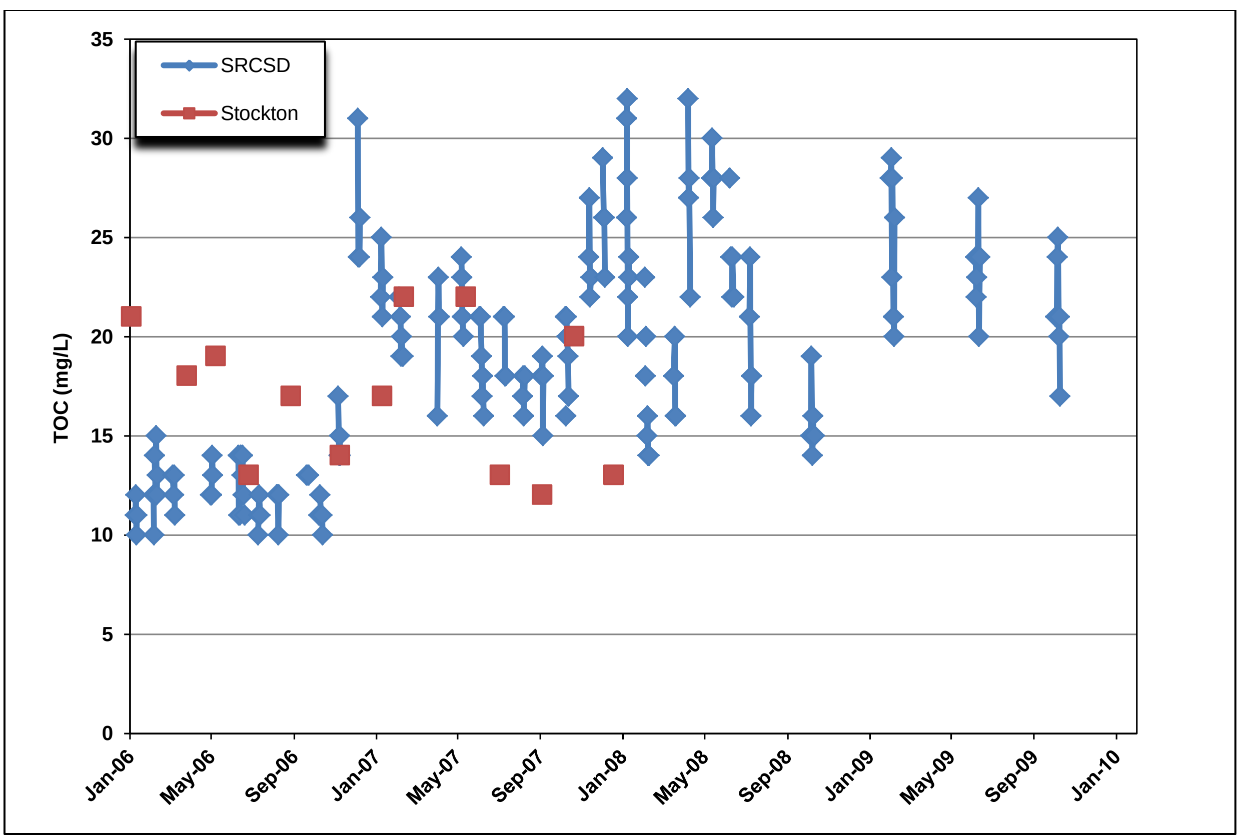


Organic Carbon

The Basin Plan does not contain a water quality objective for total organic carbon (TOC) so the Central Valley Regional Water Board does not establish effluent limitations and has historically not required wastewater dischargers to monitor their effluent for TOC. In the absence of site-specific data, the Wastewater Control Measures Study provided an assumed value in the effluent for the various types of treatment: secondary treatment - 20 mg/L, secondary treatment with nitrification and tertiary treatment - 10 mg/L, and tertiary treatment with nitrification or NDN - 8 mg/L.

Several of the dischargers in the watershed have monitored their effluent for TOC. Data are available for the two largest wastewater treatment plants that discharge to the Delta, SRWTP and Stockton. SRWTP has provided data going back to 1996, however only data from the study period 2006 through 2010 were used in the evaluation. SRWTP collected TOC data for four to five consecutive days each month and Stockton monitored weekly for TOC during 2006 and 2007. **Figure 13-13** indicates that TOC is quite variable between the two plants. The Stockton effluent ranged from 12 to 22 mg/L, with a median of 17 mg/L. The TOC concentrations in the SRWTP effluent are more variable ranging from 10 to 32 mg/L, with a median concentration of 19 mg/L.

Figure 13-13. TOC Concentrations in Stockton and SRWTP Wastewater Effluent



DWR has completed a fingerprint showing the amount of dissolved organic carbon (DOC) at the Delta pumping plants that is due to wastewater from SRWTP, Stockton, and Manteca. The fingerprints use average dry weather flow for the volume of effluent discharged from each plant and assume that DOC concentration is constant at 18 mg/L. DOC data are not available from the wastewater treatment plants so the average concentration of 18 mg/L was assumed based on the TOC data and an assumption that about 90 percent of the TOC was DOC. The fingerprint analysis also assumes that DOC is conservative and does not degrade as it moves through the Delta. The fingerprint modeling does not take into account the production of organic matter in the Delta as a result of the relative high levels of nutrients discharged from wastewater treatment plants.

Figure 13-14 presents the fingerprint for Clifton Court and **Figure 13-15** presents the fingerprint for Jones. These figures compare the total concentration of DOC from all sources to the concentration of DOC contributed by wastewater treatment plants. The wastewater DOC contribution at Clifton Court ranges from 0 to 0.54 mg/L with a median concentration of 0.26 mg/L. Wastewater contributes 0 to 18 percent of the DOC at Clifton Court. The wastewater DOC contribution at Jones ranges from 0 to 0.50 mg/L with a median concentration of 0.22 mg/L. Wastewater contributes 0 to 18 percent of the DOC at Jones.

The Wastewater Control Measures Study also presented current and future TOC loads from wastewater treatment plants in the Delta watershed. Currently, there are 47,800 pounds per day of TOC discharged. The TOC load will decrease to 37,300 pounds per day by 2030, if all of the currently mandated treatment upgrades are constructed (West Yost Associates, 2011).

Salinity

The salinity of a wastewater discharge is largely determined by the salinity of the drinking water supplied to the area served by the discharger. Additional salt is added through human usage and industrial dischargers. Salinity can be measured in terms of total dissolved solids (TDS) or EC. Primary and tertiary wastewater treatment does not significantly remove salinity.

The State Water Board established salinity standards at various locations in the Delta in the Bay-Delta Water Quality Control Plan that provide protection for drinking water, agricultural water and fish and wildlife beneficial uses (State Water Board, 1995). The SWP and Central Valley Project are required to meet salinity standards at various compliance points in the Delta. This generally requires that water be released from upstream reservoirs. The addition of salt from wastewater discharges has recently become a significant issue, particularly in the south Delta. Many of the wastewater treatment plants in the Delta have had their NPDES permits updated in the past five years to require the dischargers to submit Salinity Plans to the Central Valley Regional Water Board. These plans must evaluate methods for reducing the salinity of the effluent. The Salinity Plans must evaluate methods of obtaining lower salinity water sources and investigate salinity source control. In addition, the dischargers must contribute financial resources to the Central Valley Salinity Management Plan (discussed in **Chapter 2**).

Figure 13-14. DOC Fingerprint at Clifton Court

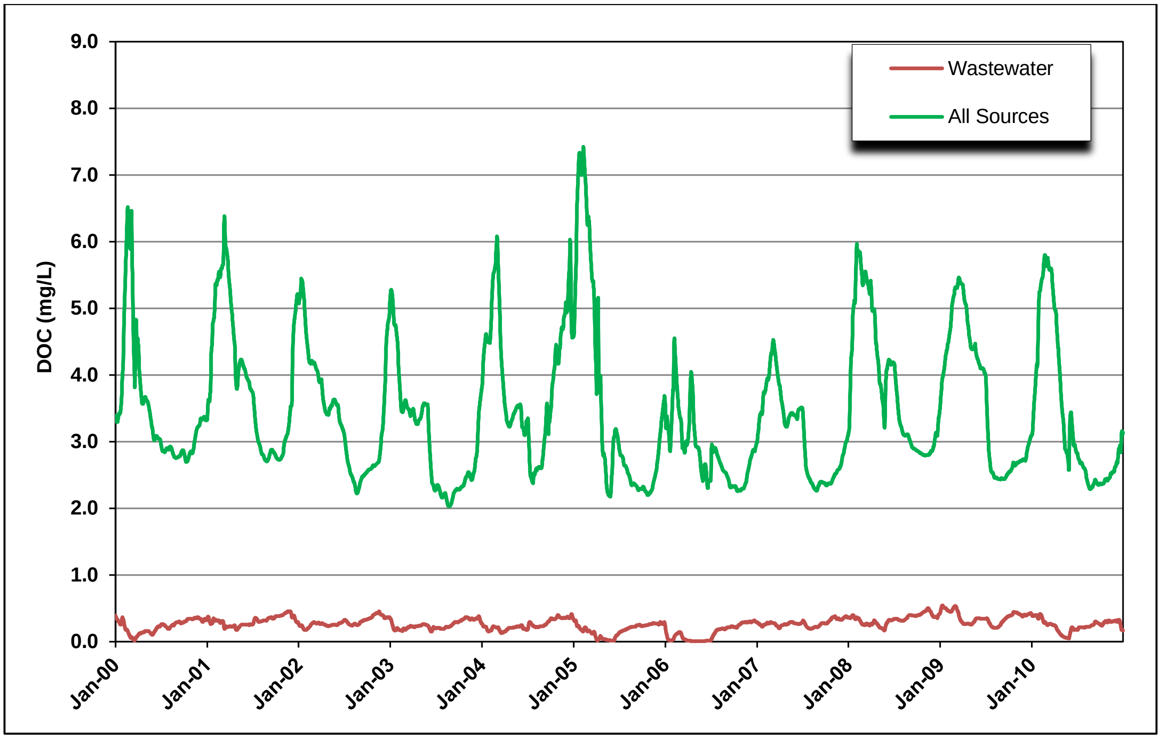
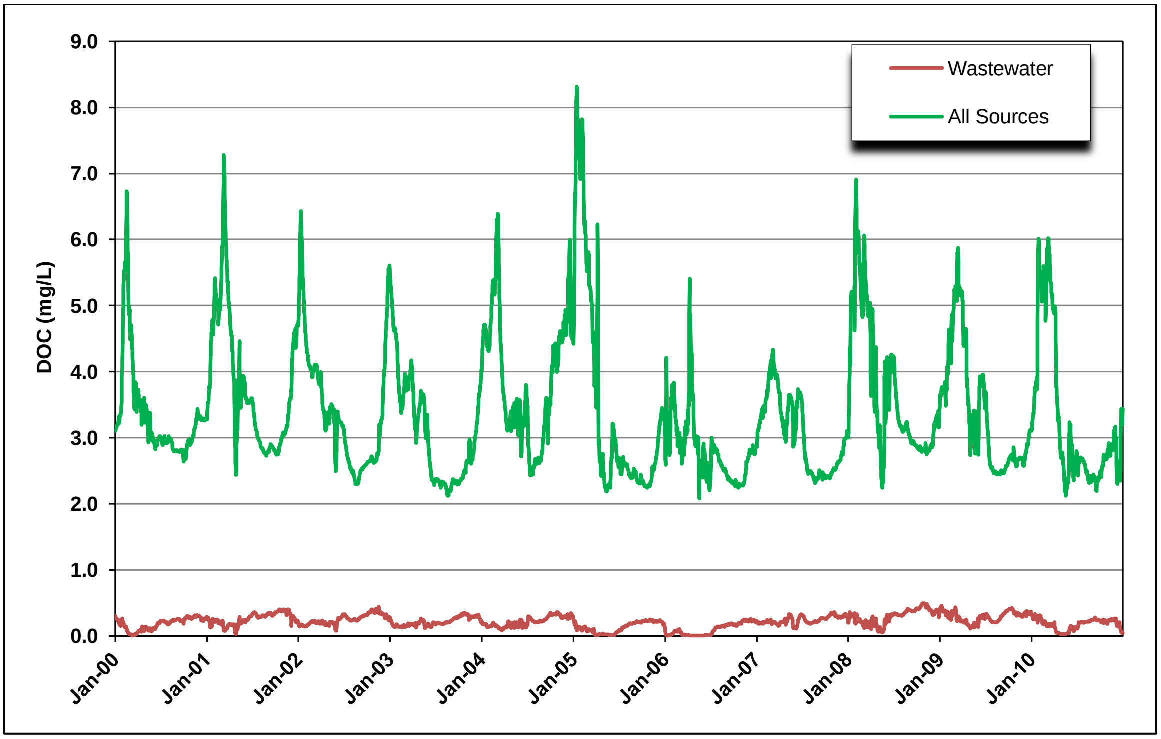


Figure 13-15. DOC Fingerprint at Jones



DWR has completed a fingerprint showing the amount of EC at the Delta pumping plants that is due to wastewater from SRWTP, Stockton, and Manteca. **Figure 13-16** presents the fingerprint for Clifton Court and **Figure 13-17** presents the fingerprint for Jones. These figures compare the EC due to all sources to the EC contributed by wastewater treatment plants. The wastewater contribution of EC at Clifton Court ranges from 0.2 to 30 µS/cm with a median of 15 µS/cm. Wastewater contributes 0 to 6 percent of the EC at Clifton Court. The wastewater EC contribution at Jones ranges from 0.2 to 30 µS/cm with a median of 12 µS/cm. Wastewater contributes 0 to 6 percent of the EC at Jones.

The Wastewater Control Measures Study also presented current and future TDS loads from wastewater treatment plants tributary to the Delta. Currently, there are 1,350,000 pounds per day of TDS discharged. The TDS load is projected to increase to 2,050,000 pounds per day by 2030 due to the projected increased volume of wastewater that will be discharged in 2030 (West Yost Associates, 2011). None of the currently mandated treatment upgrades will result in a reduction in TDS. The West Yost study projected a 52 percent increase in the TDS load discharged to the watershed. Not all of this load will reach the south Delta but this could be used as the maximum increase in the load at the pumping plants. Currently wastewater contributes 0 to 6 percent of the load at Clifton Court and Jones. In the future, this could increase to a maximum of about 10 percent of the load.

WASTEWATER SPILLS REPORTED IN THE DELTA

Spills of raw or partially treated wastewater occur from collection systems and from wastewater treatment plants. A sanitary sewer overflow (SSO) is any overflow, spill, release, discharge, or diversion of untreated or partially treated wastewater from a sanitary sewer system. Major causes of SSOs include grease, root, and debris blockages; sewer line flood damage; manhole structure failures; vandalism; pump station mechanical failures; power outages; excessive stormwater inflow or groundwater infiltration; improper construction; lack of proper operation and maintenance; insufficient capacity; and contractor-caused damage. Spills of raw or partially treated wastewater occur due to equipment malfunctions or operator errors at wastewater treatment plants. Spills also occur when there is stormwater inflow into a wastewater collection system and the capacity of the wastewater treatment plant is exceeded.

Reported Spills

The CIWQS database was queried for Delta counties (Sacramento, Yolo, San Joaquin, Contra Costa, and Solano) to identify the Category 1 SSOs reported that may impact Delta water quality. Wastewater spills greater than 1,000 gallons, all wastewater spills that enter waters of the state, and spills that occur where public contact is likely, regardless of the volume, are classified as Category 1 SSOs. Collection systems regulated by the Central Valley Regional Water Board were required to start reporting spills electronically in September 2007. **Table 13-8** presents a summary of all collections systems reporting Category 1 SSOs between September 2, 2007 and December 31, 2010 in the Delta. There were 81 Category 1 SSO events that contributed over 600,000 gallons of wastewater to the Delta waterways.

Figure 13-16. EC Fingerprint at Clifton Court

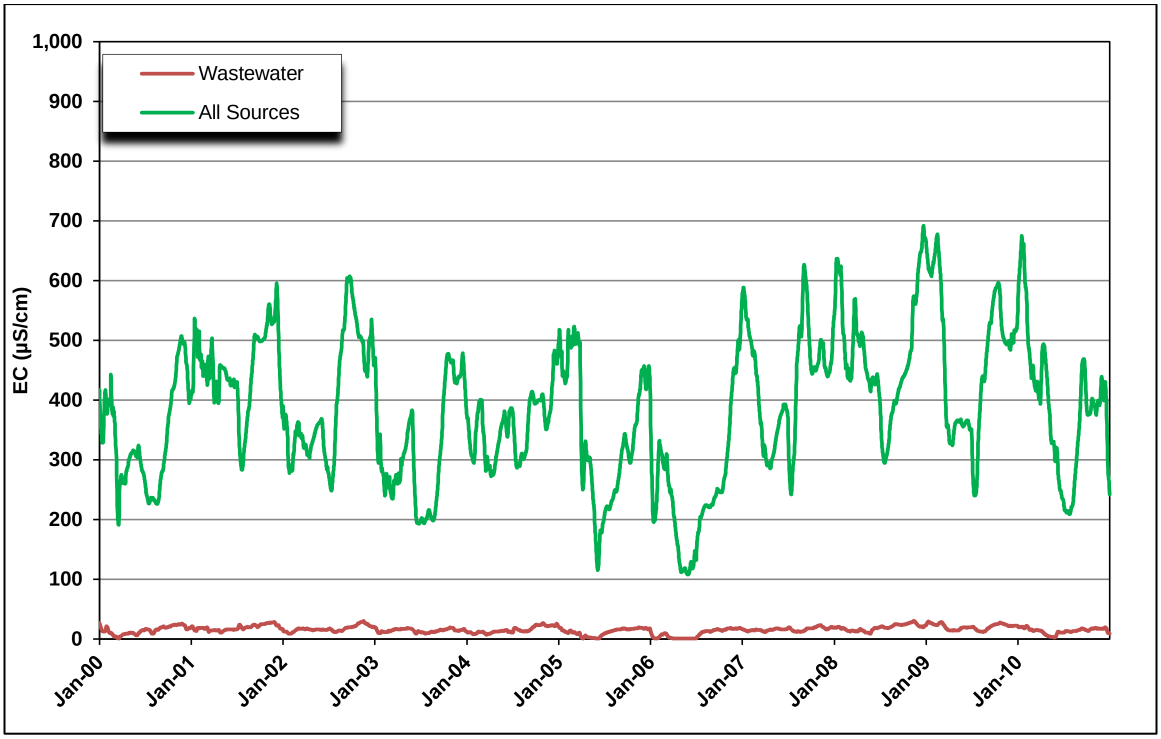


Figure 13-17. EC Fingerprint at Jones

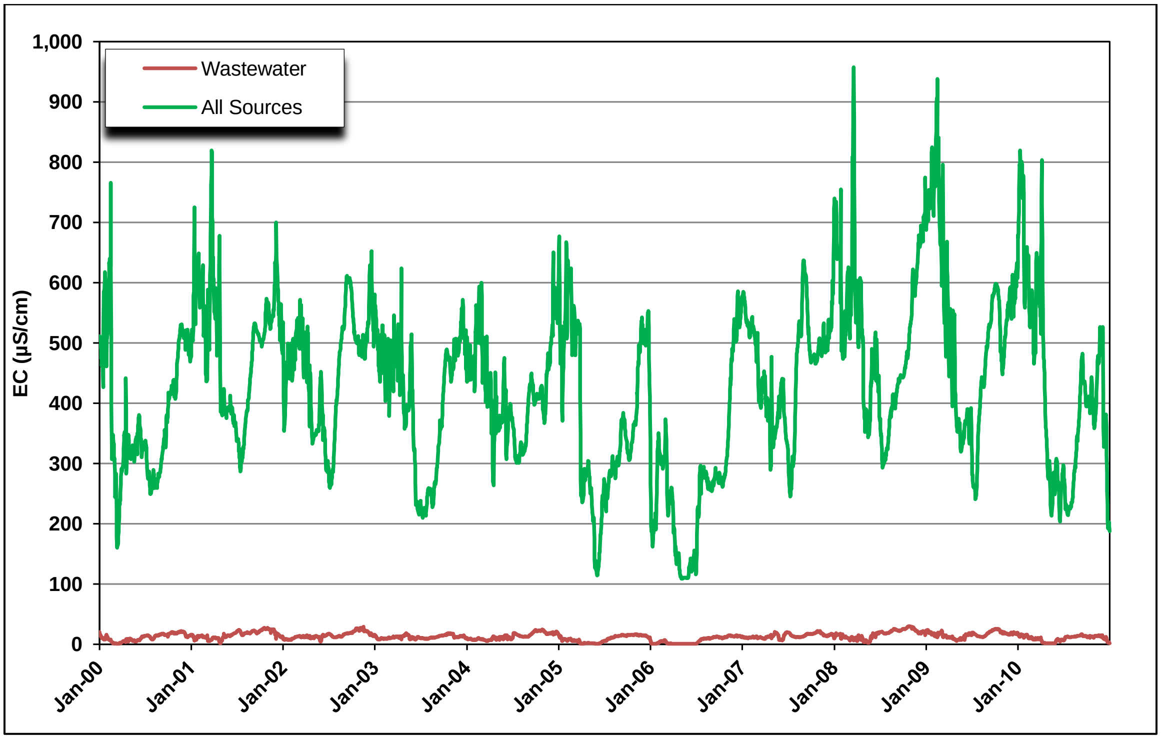


Table 13-8. Collection Systems with Category 1 SSOs in Delta Waterways, September 2007 – December 2010

Collection System	Number of Category 1 SSOs	Total Volume of SSOs (gallons)	Total Volume Reaching Surface Water (gallons)	Percent Reaching Surface Water
City of Manteca CS	1	71,431	1,197	1.7
City of Stockton MUD CS	33	149,850	28,980	19.3
Rio Vista Waste Trt Facility CS	3	34,240	32,340	94.5
City of Vacaville Easterly CS	11	63,760	50	0.1
City of Lodi White Slough CS	2	5,701	2,751	48.3
City of Lathrop WRP-1 CS	1	1,480	1,480	100.0
West Sacramento CS	5	19,600	16,330	83.3
SRCSD CS	2	54,144	54,125	100.0
Delta Diablo SD CS	2	2,700	450	16.7
City of Antioch CS	6	11,540	1,265	11.0
City of Brentwood CS	1	1,000	0	0.0
Delta Diablo SD CS	2	12,000	250	2.1
Ironhouse Sanitary District CS	4	10,775	5,000	46.4
Discovery Bay CS	8	165,050	138,050	83.6
TOTAL	81	603,271	282,268	46.8

Source: Data retrieved from the CIWQS Database

Of the 81 reported events, 40 did not result in discharge to a waterway, 18 had discharges less than 1,000 gallons, and the remaining 23 varied in size from 1,000 gallons to 100,000 gallons. The ten largest events accounted for 90 percent of the wastewater discharged. Those events are summarized below.

1. November 26, 2007: 12,600 gallons discharged to the Sacramento Deep Water Channel from the City of West Sacramento Collection System. A controls failure led to pressurization of a force main and failure of an isolation valve. This resulted in discharge to a storm drain and then to the Channel.

2. November 27, 2007: 8,600 gallons discharged to the Lakeshore Stormwater Lake from the Discovery Bay Collection System. A transducer failed at a pump station which led to a backup and failure at a manhole. The release went into a storm drain and then into the Lakeshore Stormwater Lake.

3. January 4, 2008: 54,124 gallons discharged to the Sacramento River from the SRCSD Collection System. There were high flows in the combined sewer system during an extreme weather event so a valve was fully opened by City of Sacramento staff. This caused an overflow at a manhole into the storm drain and then the receiving water.

4. March 15 – 17, 2008: 9,000 gallons discharged to the San Joaquin River from the City of Stockton Collection System. Debris caused blockage of the sewer line and a backup at a manhole.

5. July 17 – 18, 2008: 100,000 gallons discharged to a private lake from the Discovery Bay Collection System. A pump station failed due to a power outage. This caused a backup from a manhole into a stormdrain and then into a private stormwater lake.

6. December 22 – 23, 2008: 6,000 gallons discharged to Mosher Slough from the City of Stockton Collection System. Grease caused blockage of the sewer line and a backup at a manhole.

7. March 2, 2009: 9,000 gallons discharged to a private lake from the Discovery Bay Collection System. The cause is unknown, but a pipe failed resulting in a release to a stormdrain and eventually to the private stormwater drainage lake.

8. July 13, 2009: 5,000 gallons discharged to Dutch Slough from the Ironhouse Sanitary District Collection System. Pipe failure caused by unauthorized contractor activities resulted in a release to Dutch Slough.

9. June 22 – 23, 2010: 16,450 gallons discharged to Windward Bay from the Discovery Bay Collection System. A pipe failure caused a release from an air relief valve.

10. December 19, 2010: 32,000 gallons discharged to the Sacramento River from the Rio Vista Collection System. A pipe failed causing discharge to the storm drain then to the Sacramento River.

Water Quality Impacts

The impacts of a wastewater spill on water quality at the Delta pumping plants depend upon the location and volume of the spill, the type of spill (raw wastewater or partially treated wastewater), and the hydrologic conditions in the rivers and Delta at the time of the spill. **Table 13-9** presents information on the quality of untreated wastewater taken from a textbook (Tchobanoglous and Burton, 1991). Untreated wastewater contains high concentrations of organic carbon, nutrients, and pathogenic organisms and it may contain any number of pharmaceuticals and endocrine disrupting compounds.

Contra Costa Water District (CCWD) has set up a procedure to determine the impacts of spills occurring within the Delta at Delta water intakes, including CCWD's intakes, Clifton Court, and the North Bay Aqueduct (NBA). This information is also used by NBA and SBA Contractors. CCWD worked with DWR to routinely update the Delta Simulation Model 2 (DSM2) real-time simulation that represents recent historical conditions with a short-term forecast. When a spill occurs, CCWD staff inputs the location, volume, and duration of the spill into the real-time model. The model predicts the percent of wastewater mixed with Delta water showing up at the intakes over a number of days. CCWD also runs the model each week based on forecasted hydrologic conditions. The weekly model runs are used by CCWD staff to determine what size spill would warrant water quality monitoring or other actions at their treatment plants.

Table 13-9. Water Quality Characteristics of Untreated Wastewater

Constituent	Concentration Range
Total suspended solids (mg/L)	100 – 350
Biochemical oxygen demand (mg/L)	110 – 400
Total dissolved solids (mg/L)	250 – 850
Total organic carbon (mg/L)	80 – 290
Total nitrogen (mg/L)	20 – 85
Total phosphorus (mg/L)	4 – 15
Total coliform (MPN/100 ml)	$10^6 – 10^9$
Fecal coliform (MPN/100 ml)	$10^5 – 10^6$
Giardia cysts (cysts/L)	100 – 100,000
Cryptosporidium (oocysts/L)	100 – 10,000
Enteric viruses (No./L)	10,000 - 100,000

Source: Tchobanoglous and Burton (1991)

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following actions related to wastewater discharges in the Delta:

Support Development of the Central Valley Drinking Water Policy.

This action item was classified as immediate, meaning that it addresses current critical water quality issues. DWR's Municipal Water Quality Investigations (MWQI) Program staff has participated in the Drinking Water Policy Work Group as staffing permits. MWQI staff has participated in critical meetings when notified by California Urban Water Agencies that key decisions are being discussed.

Provide Comments on Waste Discharge Permits and EIRs.

This action item was also classified as immediate. The State Water Project Contractors Authority (SWPCA) has submitted comment letters on several waste discharge permits.

Participate in Delta Initiatives.

This action item was also classified as immediate. The specific action related to wastewater discharges in the Delta was to track progress on the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) Program through individual SWP Contractors who are directly participating in the effort. None of the SWP Contractors is actively participating in CV-SALTS at this time.

POTENTIAL ACTIONS

SWPCA, MWQI, and CDPH should Continue to Comment on Waste Discharge Permits, EIRs, and the Triennial Review of the Basin Plan.

While many wastewater treatment plants have upgraded to tertiary treatment or are required to upgrade, there are still several wastewater treatment plants in the Delta that are at secondary treatment and several dischargers, including SRCSD, have appealed their permits. The comments of the SWP Contractors, MWQI, and CDPH on past permits have been considered by the Central Valley Regional Water Board. In addition, data collected by MWQI have been used in evaluating permit conditions. It is important to continue these efforts and to continue commenting on EIRs on wastewater treatment plant expansion projects and on the Triennial Review of the Basin Plan. SWPCA, MWQI, and CDPH should continue to request that key drinking water constituents (pathogens, organic carbon, nutrients, and salinity) be included in the monitoring programs.

SWPCA should Track Development of Special Studies Required by the NPDES Permits for Delta Dischargers.

The Central Valley Regional Water Board often requires dischargers to conduct special studies as conditions of their permits. For example, in the recently issued permit for the SRWTP, the Central Valley Regional Water Board required a Salinity Evaluation and Minimization Plan and a special monitoring study for perchlorate. The recently issued permit for the City of Sacramento's CSS requires the City to prepare a Water Quality Assessment. SWPCA should track these studies and other studies required in future permits and prepare comments as needed.

The NBA and SBA Contractors should Continue to Work with CCWD to Model Wastewater Spills.

CCWD has set up a modeling procedure to determine the impacts of spills occurring within the Delta at Delta water intakes, including CCWD's intakes, Clifton Court, and the North Bay Aqueduct. The NBA and SBA Contractors should work with CCWD on a mechanism for disseminating the modeling results each week. This information could be posted on the MWQI website if a process for doing so is established.

URBAN RUNOFF

BACKGROUND

Stormwater and dry season runoff from the major urban areas of Sacramento, Stockton, Modesto, and some portions of Fresno, along with a number of smaller communities, is discharged to waterways of the Central Valley. Urban runoff contains numerous contaminants as a result of vehicle emissions, vehicle maintenance wastes, landscaping chemicals, household hazardous wastes, pet wastes, trash, and other waste from anthropogenic sources. As the Central Valley communities increase in population, natural and agricultural lands are converted to urban areas with an associated increased volume of urban runoff and increased load of contaminants. Natural vegetated areas absorb rainfall and remove contaminants through soil filtration. When these areas are converted to urban areas, the impervious surface area increases, which results in an increase of runoff and contaminants from urban activities. The variability of flow and types of contaminants between agricultural land and urban land is currently not well understood so the relative increase, or potential decrease, in contaminant load associated with converting agricultural land to urban land is unknown.

As described in **Chapter 2**, urban runoff in the Central Valley and Delta is regulated by the Central Valley Regional Water Board through municipal separate storm sewer system (MS4) NPDES permits. These permits require large (greater than 250,000 population) and medium (100,000 to 250,000 population) municipalities (designated as Phase I permittees) to develop stormwater management plans and conduct monitoring of stormwater discharges and receiving waters. The permits also require programs to control runoff from construction sites, industrial facilities, and municipal operations; eliminate or reduce the frequency of non-stormwater discharges to the stormwater system; educate the public on stormwater pollution prevention; and better control and treat urban runoff from new developments. Small communities (less than 100,000 population) are Phase II permittees, and are required to develop management plans but generally do not have to conduct monitoring. **Table 13-10** presents a list of the currently permitted MS4 systems in the Delta and North Tributary regions.

In 2005, the State Water Board adopted sustainability as a core value for all activities and programs and directed staff to consider sustainability in all future policies, guidelines, and regulatory actions. Low Impact Development (LID) is a sustainable practice applied to urban runoff that takes a different approach by using site design and stormwater management to maintain the site's pre-development runoff rates and volumes. The goal of LID is to mimic a site's pre-development hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall. LID is being incorporated into many of the Phase I stormwater NPDES permits and likely the renewed Phase II General Permit.

LID practices result in less disturbance of the development area, conservation of natural features, and are less expensive than traditional stormwater controls. LID includes specific techniques, tools, and materials to control the amount of impervious surface, increase infiltration, improve water quality by reducing runoff from developed sites, and reduce costly infrastructure. LID practices include; bioretention facilities or rain gardens, grass swales and channels, vegetated rooftops, rain barrels, cisterns, vegetated filter strips, and permeable pavements.

Table 13-10. Currently Permitted Municipal Separate Storm Sewer Systems in the Delta Region

MS4 System Name	MS4 Permit Type
Delta Dischargers	
Sacramento Stormwater Quality Partnership	Phase I
City of Stockton and County of San Joaquin	Phase I
Contra Costa Clean Water Program	Phase I
Stockton Port District	Phase I
City of West Sacramento	Phase II
City of Rio Vista	Phase II
City of Lodi	Phase II
City of Lathrop	Phase II
City of Manteca	Phase II
City of Tracy	Phase II
Tracy Unified School District	Phase II
Mountain House Community Services District	Phase II
North Delta Tributary Dischargers	
Fairfield Suisun Urban Runoff Management Program	Phase I
Yolo County	Phase II
Solano County	Phase II
City of Woodland	Phase II
City of Davis	Phase II
University of California at Davis	Phase II
City of Dixon	Phase II
City of Vacaville	Phase II

Source: State Water Board and Central Valley Regional Water Board Websites

KEY URBAN RUNOFF DISCHARGERS TO THE DELTA

Urban runoff from Sacramento, Stockton, and eastern Contra Costa County is discharged directly to the Delta. In addition, there are a couple of other selected urban runoff dischargers that will be briefly summarized; the cities of Fairfield and Vacaville for their close proximity to North Bay Aqueduct diverters and the City of Lathrop for its special water quality study by the MWQI Program. This section presents information on the stormwater programs for these major urban areas and the efforts that are aimed at reducing the contaminants of most concern to drinking water providers.

Sacramento Stormwater Quality Partnership

The greater Sacramento metropolitan area (including the cities of Sacramento, Citrus Heights, Elk Grove, Folsom, Galt, and Rancho Cordova, as well as the urban unincorporated area of Sacramento County) discharges urban runoff to the American and Sacramento river systems. There are approximately 55 direct discharge points to the American and Sacramento rivers. A few of the 55 drainage basins with direct discharge are relatively small, self-contained basins. Many, however, have multiple sub-basins and/or a network of urban creeks. The Natomas Main Drainage Canal (also called Steelhead Creek) and the Natomas East Main Drainage Canal carry urban runoff from large areas, as well as some agricultural runoff. Steelhead Creek also receive treated wastewater effluent from the City of Roseville. Morrison Creek drains a significant portion of the southeast area of the county. On the east side of the Sacramento River, stormdrain pumps, canals and creeks convey runoff to sumps that pump the runoff over the levee into the river on an episodic basis, based on sump capacity.

Management of Sacramento area urban runoff began in 1989 as a cooperative effort between Sacramento County, the City of Sacramento, and the smaller cities within the County to address stormwater pollution through a county-wide NPDES Phase I stormwater permit. The permit is renewed every five years, and the current permit is Order No. R5-2008-0142. As part of the permit, the permittees must develop a Stormwater Quality Improvement Plan that describes the stormwater pollution prevention activities to be undertaken over a five year period. This includes items such as construction activities, illegal discharges, industrial activities, municipal operations, and new development.

The permittees last revised their Stormwater Quality Improvement Plan in 2009 (Sacramento County et al., 2009). There are some joint activities, including: target pollutant reduction strategies, a water quality monitoring program, special studies, regional public outreach and education, a regional commercial/industrial program, and program effectiveness evaluation. There are three special studies required that may result in an impact to drinking water constituents of interest; detention basin effectiveness evaluation, pilot watershed monitoring for new development best management practices (BMPs), and proprietary treatment BMP effectiveness evaluation. The detention basin study is showing good reductions in TSS (75 percent) and *Escherichia coli* (*E. coli*) bacteria (87 percent).

The BMPs of particular interest to drinking water quality are:

- BMPs that seek to eliminate spills and dumping through storm drain marking, public outreach, enforcement, and an illicit discharge detection and elimination program.

- BMPs that provide education on the proper wastewater disposal practices for carpet cleaners, mobile auto cleaners, and landscapers through the Clean Water Business Partners Program.

- BMPs that address fecal waste including an illicit connection program, pet waste public education, and programs to maintain dog waste dispenser stations in parks developed in coordination with parks and recreation departments and districts, inspection of kennel facilities, street sweeping, and sump cleaning. This includes funding of the “Pups on the Parkway” and “Scoop the Poop” pet waste cleanup programs.

- BMPs that address TOC including detention basins and grassy swales, street sweeping, sump cleaning, erosion control at construction sites, public education and outreach for landscape management, and containerization of green waste in many parts of the greater Sacramento urban area. The City of Sacramento continued to expand its green waste containerization program with a voluntary containerized yard waste program with reduced rates beginning in August 2007. Currently, nearly 90,000 residents (76 percent) participate in the voluntary program.

- Other BMPs to reduce constituents in urban runoff through watershed-based public education and outreach that include participation in the Sacramento River Watershed Program, development of the Arcade Creek Watershed Group, sponsorship of three public service announcements related to pet waste, car washing, and pesticides, and funding school education programs, including the awarding-winning "Splash."

- New development treatment BMPs, including LID strategies. LID techniques are a way to decentralize stormwater collection to reduce runoff and contaminant loading to the receiving waters. Stormwater design standards are being updated in 2011 to account for LID strategies. The permit also requires completion of a Hydromodification Plan to control flows from the sites and maximize permeation. In addition, operation and maintenance agreements are required with developers to ensure that stormwater controls are operating effectively.

The target pollutant reduction program has led to creation of reduction strategies for several constituents including; sediment, pesticides, mercury, lead, copper, and pathogen indicators. Sediment is addressed through new development standards, construction BMPs, street sweeping, and basin/drain cleaning. In 2004, a Fecal Waste Reduction Strategy was completed which continues to be implemented, including prohibition of cross-connections from sewer system to the storm drain and discharges of pet waste into the storm drain, inspection of kennels for appropriate waste handling procedures, outreach promoting appropriate disposal of boating wastewater, outreach to increase appropriate disposal of pet waste, outreach promoting appropriate livestock manure management, sewer overflow management, and workgroup meetings to review current status of coliform/pathogen control efforts in the state. In 2006, a comprehensive Pesticides Plan was completed which is being implemented, including education and outreach related to integrated pest management and golf courses.

City of Stockton and County of San Joaquin

Urban runoff from the City of Stockton and urbanized areas of San Joaquin County is regulated under a MS4 permit issued jointly to the City and County in 2007 (Order No. R5-2007-0173). The Stockton Port District has a separate permit and is not discussed in this report. Runoff from the Stockton urban area is discharged to the Calaveras River and a number of sloughs and creeks that are tidally influenced and flow to the San Joaquin River. The Stockton Stormwater Management Program Plan was most recently submitted to the Central Valley Regional Water Board in 2009 (Larry Walker Associates, 2009). The plan identifies pesticides (including diazinon and chlorpyrifos), pathogens, and dissolved oxygen as the contaminants of concern. The plan identifies numerous programs and activities undertaken by the permittees to reduce contaminants in stormwater to the maximum extent practicable. The activities most related to reducing contaminants of concern to drinking water providers are briefly described.

- Pathogen Plan – Several water bodies that receive Stockton area runoff are impaired due to the presence of fecal indicator bacteria. The permittees updated the Pathogen Plan in

2009 to continue to identify, monitor, and mitigate pathogen sources. The Pathogen Plan outlines four phases:

- Characterization Monitoring – monitoring for fecal indicator bacteria in impaired water bodies and in runoff discharges.

- Source Identification Studies – microbial source tracking studies to evaluate whether the indicator bacteria are of human or non-human sources and upstream monitoring to identify the sources of fecal indicator bacteria. To date, it has been determined that the bacteria present include universal, human, cow/horse, and dog sources. The potential sources for human bacteria include houseboats, sanitary sewer overflows, and homeless encampments.

- BMP Development and Implementation – implementation of programs such as pet waste stations and kennel inspections, followed by additional control measures for high priority sites identified through the characterization monitoring and source identification studies. Pet waste stations were installed at 10 additional locations since 2008 in parks and near waterways, and kennel inspections have continued to be conducted.

- Effectiveness Monitoring and Plan Assessment – monitoring of the effectiveness of BMPs in reducing fecal indicator bacteria.

The Pathogen Plan is being implemented in phases with an overall completion date of June 2018. This work will be coordinated with the related pathogen total maximum daily load (TMDL) for Stockton urban waterways. Source identification studies and monitoring to locate the high risk sources within the storm drain system were initiated on Mormon Slough and Smith Canal in July 2004, with Mosher Slough and Five Mile Slough added in July 2007, and the Lower Calaveras River and Walker Slough added in July 2010.

- Requirements for New Developments – The Stormwater Quality Control Criteria Plan (City of Stockton, 2009) describes source control and treatment control measures that must be incorporated into site designs for new development and infill development for projects of a certain size or type. The Plan was updated to include LID development strategies for priority significant new development or redevelopment. This plan contains a table that lists the effectiveness (high, medium, and low) of various treatment measures (e.g. buffer strips, detention basins) in removing pollutants of concern, including bacteria. Developers must submit Project Stormwater Quality Control Plans and Maintenance Plans to the City. The City may also require a maintenance agreement.

- Study on Feasibility of Diverting Dry Weather Flows to the Sanitary Sewer System – The City and County were required to evaluate the feasibility of diverting dry weather discharges from the storm drainage system to the City's Regional Wastewater Control Facility or, alternatively, to provide treatment of dry weather discharges using BMP treatment controls. Using a prioritization process, each outfall in the storm drain system was analyzed to determine the feasibility for dry weather discharge diversion opportunities. The prioritization effort resulted in eight pump stations identified as potentially feasible for a 10 percent design assessment. Three pump stations (Swenson, 5-Mile Creek, Mariner Slough, Mosher Slough, and Stockton Airport Business Center), were determined to be feasible for diverting dry weather flows to the sanitary sewer. The City completed the design of this project in April 2010 and construction was completed in August 2011.

- Development of a SSO Response Plan – The City and County are required to minimize the impact of SSOs on receiving waters. They must manage the SSOs so as to prevent them from entering a storm drain or waterway. The City and County prepared a Response Plan during the study period.

- Detention Basin Study – Influent, effluent, and sediment chemistry sampling and analysis of a detention basin (La Morada) receiving runoff from industrial, commercial, and residential watersheds continued during the study period. Samples were analyzed for bacteria, turbidity, TSS, TDS, and organophosphate pesticides. Preliminary results are only available and it appears that the basins are consistently able to reduce levels of turbidity and bacteria, but TDS levels appear to increase in the basin.

- Media Filter Study – The City installed a media filter at one of its urban runoff pump stations in 2005 and is continuing to monitor to evaluate the effectiveness of the filter in removing metals, pesticides, bacteria, and nutrients. To date, there are no clear trends on the removal efficiency of the media filter stormwater treatment system.

- BMP Effectiveness Study – The City and County installed an LID BMP and they are attempting to assess the effectiveness of the technology. It is a Filterra device, which is a tree planted in a concrete box with engineered soil media. During the study, the catch basin overflowed so it has not been possible to collect samples that are representative of "effluent" and therefore they are unable to assess the BMP effectiveness.

- Green Waste Collection Program – The City continues to implement a green waste collection program in designated problem areas. This includes fall leaf pickup in 90 gallon wheeled carts instead of loose leaves on the curb.

Contra Costa Clean Water Program

Contra Costa County, its 19 incorporated cities, and the Contra Costa County Flood Control and Water Conservation District joined together to form the Contra Costa Clean Water Program to develop and implement a County-wide comprehensive storm water program. The county falls within the jurisdiction of both the Central Valley and San Francisco Bay Regional Water Boards. The cities of Antioch, Brentwood, and Oakley and eastern Contra Costa County discharge to the Delta and are under the purview of the Central Valley Regional Water Board. The Clean Water Program currently operates under two permits for the two regions, but these permits have been coordinated during the study period to allow for increased efficiency. The western portion of the county is included in the Municipal Regional Stormwater NPDES Permit (R2-2009-0074) from the San Francisco Bay Regional Water Board, issued in October 2009. The permit for Antioch, Brentwood, Oakley, and the eastern portion of Contra Costa County that drains to the Delta was issued by the Central Valley Regional Water Board in 2010, R5-2010-0102. The permit is unique in that it has been designed to merge the permit and the Stormwater Management Plan into a single document. The activities being conducted that are related to drinking water contaminants are briefly described.

- Requirements for New Developments – The program developed a New Development and Construction Controls Program that requires BMPs for new development. This includes the continuation of LID strategies which began implementation in 2003. The permit also required completion of a Hydromodification Plan to control flows from the sites and maximize permeation. This was originally done in 2006 and will be updated. In 2009 and 2010 the Stormwater Guidebook was updated to reflect new designs from the Hydromodification Plan. In addition, operation and maintenance agreements are required with developers to ensure that stormwater controls are operating effectively.

- BMP Effectiveness Studies – The Clean Water Program must conduct a study on the effectiveness of either a treatment or hydrograph modification control BMP.

- Green Street Pilot Projects – The permittees must conduct ten pilot green street pilot projects by December 2014 to assess the ability to use LID treatments on road or parking lot projects.

- Trash Load Reduction Plans – The permittees are required to implement both short-term and long-term trash load reduction plans to prevent trash from entering the storm drain system. The short-term plan must result in a 40 percent reduction in trash load by July 2015 and the long-term plan must result in a 100 percent reduction by 2023. The Clean Water Program initiated a “Litter Travels, But it Can Stop with You” media campaign in October 2009.

- Geomorphic Project – The permittees are required to implement a study to assess a selected waterbody or reach for potential retrofit of conventional BMPs to LID technologies to assess the ability to protect and possibly restore the watershed so that flows and pollutant discharge are reduced.

- Emerging Pollutant Study – The permittees are required to conduct a study to estimate the sources and loads of emerging pollutants, such as endocrine disrupting compounds, estrogen-like compounds, and perfluorooctane sulfonate / perfluoroalkyl sulfonate. The results of the study will be included in next permit update.

Other Selected Systems

The cities of Fairfield and Vacaville are in close proximity to the Delta so their stormwater programs are summarized briefly. The City of Lathrop is the location of a MWQI investigation so it is discussed briefly as well.

The City of Fairfield was regulated, with Suisun City, under the Phase I program and they developed a joint Urban Runoff Management Program. Historically, they were permitted individually by the San Francisco Regional Water Board but in 2009 they were included in the Municipal Regional Stormwater NPDES Permit. This permit has 76 co-permittees and includes western Contra Costa County. The requirements for the City of Fairfield are almost identical to the Contra Costa Clean Water Program, except that there are fewer water quality monitoring requirements and no BMP effectiveness investigation requirements for the City.

The City of Vacaville is smaller and was regulated under the Phase II program. The City prepared a Stormwater Management Plan jointly with the City of Dixon in 2003 and it was approved by the Central Valley Regional Water Board. The Plan meets the six minimum control measures identified in the Phase II General Permit: public education and outreach, public involvement and participation, illicit discharge detection and elimination, construction site stormwater runoff control, post construction stormwater management in redevelopment and new development, and pollution prevention for municipal operations. Water quality monitoring is not required.

The City of Lathrop was also regulated under the Phase II program. Similar to the City of Vacaville, the City prepared a Stormwater Management Plan in accordance with the General Permit which was approved by the Central Valley Regional Water Board in 2003. The City also prepared a Storm Drain Master Plan which guides the management of stormwater runoff. The system is based largely on conventional, centralized detention basins which then discharge directly to the San Joaquin River. There are 16 detention/retention basins and pump stations. Water quality monitoring is not required.

URBAN RUNOFF QUALITY FOR DRINKING WATER CONSTITUENTS

The MS4 permits do not contain effluent limitations for specific water quality constituents but do require municipalities to reduce urban runoff pollution to the maximum extent practicable through implementation of BMPs. Water quality data obtained by Sacramento and Stockton over a number of years and from a number of urban runoff discharge points are summarized in this section. The MWQI Program staff completed a study on Steelhead Creek in Sacramento and is currently implementing a similar study in Lathrop. The Steelhead Creek study is significant because it was a rapidly urbanizing watershed and it has been extensively investigated for many years. Information presented in the Water Quality Investigation is included in this section (DWR, 2008). Data were also obtained from MWQI for the on-going Lathrop Urban Runoff study. Additionally, the Central Valley Drinking Water Policy Work Group had an Urban Runoff Source Control Evaluation completed recently, which looked at available water quality data (Geosyntec Consultants, 2011).

Data presented in this section provide a general understanding of the quality of urban runoff in the Central Valley. It should be noted that urban runoff, particularly stormwater, is highly variable during storm events, from one location to another, and from storm to storm.

Pathogens and Indicator Organisms

Urban runoff contains high levels of coliform bacteria, relative to the levels found in receiving waters. Sources of fecal contamination in urban runoff include domestic and wild animals, in addition to human sources from illegal camping, illicit connections to the storm drain system or sewage spills to the storm drain system. Since fecal coliforms are used as indicators of fecal contamination, their presence indicates that urban runoff carries a significant amount of fecal material into the Delta and its tributaries. The primary impact of fecal contamination on water bodies is the potential presence of pathogens that may be associated with feces. The actual amount of pathogens discharged in urban runoff cannot be extrapolated from the indicator organism data.

Sacramento and Stockton Data

Table 13-11 presents the fecal coliform and *E. coli* data for Sacramento urban runoff from 2005 through 2010 (as applicable to the various sites). The drainage basins for these discharge locations are characterized as follows:

- Strong Ranch Slough – This is an open channel that drains 4,446 acres of mixed use.
- Sump 111 – This is a 439-acre watershed that is primarily industrial.
- Sump 104 – This is a 2,220-acre watershed that drains mixed residential and commercial.
- Natomas Basin 4 – This sump drains a 470-acre new housing development which was constructed using new development standards.

Table 13-12 presents the fecal coliform and *E. coli* data for Stockton urban runoff for the 2010/2011 monitoring season. The drainage basins for these discharge locations are characterized as follows:

- Mosher Slough – This is a 533-acre watershed that is primarily residential.
- Calaveras River – This is a 169-acre watershed that is primarily commercial.
- Duck Creek – This is a 343-acre watershed that is primarily industrial.
- Smith Canal – This is a 1,866-acre watershed that is mixed use.

All data results were reported as quantified values, thus medians reflect a true numerical data set. These data continue to indicate that high levels of fecal indicator bacteria are found in both dry weather and wet weather urban runoff. Generally, levels are higher during wet weather and they can vary significantly between drainage basins.

Table 13-11. Sacramento Urban Runoff Discharge Monitoring

Location	Fecal Coliform (MPN/100 ml)			*E. coli* (MPN/100 ml)		
	Range	Wet Median	Dry Median	Range	Wet Median	Dry Median
Strong Ranch Slough	230 – 170,000	22,000	3,000	140 – 170,000	13,000	1,550
Sump 104	3,000 – 1,700,000	70,000	6,000	190 – 1,100,000	22,000	3,000
Sump 111	20 – 70,000	13,000	4,000	80 – 80,000	3,000	750
Natomas Basin 4	40 – 242,000	23,000	4,000	40 – 3,000	23,000	1,580

Source: SSQP Annual Reports (2005/2006, 2006/2007, 2007/2008, 2008/2009, 2009/2010), Urban Runoff Source Control Evaluation (Geosyntec, 2011).

Table 13-12. Stockton Urban Runoff Discharge Monitoring

Location	Fecal Coliform (MPN/100 ml)		*E. coli* (MPN/100 ml)	
	Wet	Dry Median	Wet	Dry Median
Mosher Slough	23,000	2,750	3,255	3,959
Calaveras River	3,000	1,185	1,674	495
Duck Creek	11,000	80	3,873	20
Smith Canal	130,000	41,100	14,136	4,364

Source: Stockton Annual Report 2010/2011

Sacramento Studies

The Sacramento Stormwater Quality Partnership conducted a study on microbial source tracking and pathogen detection in receiving waters and urban runoff in 2005 and 2006. The data were summarized in a memorandum in August 2008. Four locations were sampled on four events. This included Arcade Creek, the American River at Discovery Park, the Sacramento River at Freeport Marina, and Strong Ranch Slough. The data covered two wet and two dry events. The study included evaluation of adenovirus, enterovirus, and *Bacteroidales*. *Bacteroidales* are anaerobic bacteria found in the gut of warm-blooded animals that are unable to grow or survive outside its host. There are quantitative markers for universal (many species) and human sources for this bacteria. Twenty-nine samples were analyzed. Viruses were not detected in any samples, but detection limits were higher than previous studies. Generally, there were very low or non-detectable levels of human *Bacteroidales* markers in the river water. There was no consistent trend related to weather conditions

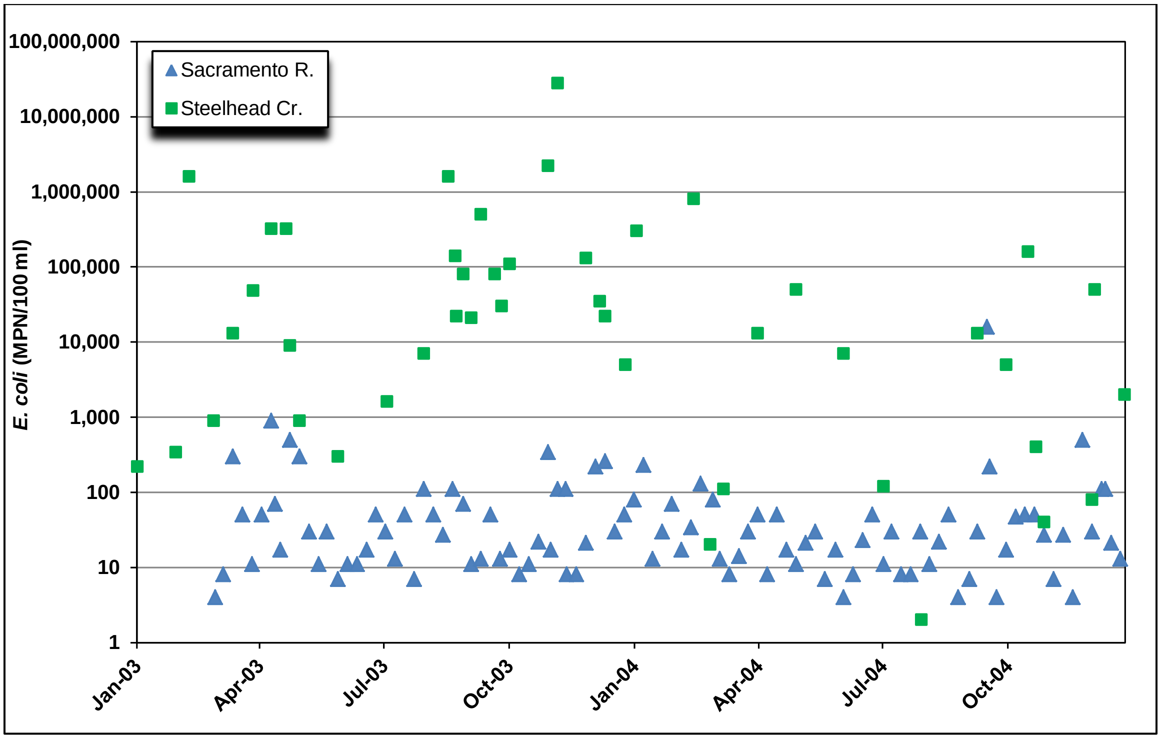
Stockton Studies

In 2005 and 2006, Stockton initiated microbial source tracking studies at several locations in its stormwater system. Source tracking studies are designed to determine if the bacteria present in urban runoff come from human or non-human sources. The targeted organism is *Bacteroidales*. The Stockton studies were conducted by University of California Davis researchers who have developed a polymerase chain reaction method that can identify bacteria from four source categories (universal – general warm-blooded animals; humans; cows and horses; and dogs). Characterization monitoring has been completed on both Smith Canal and Mosher Slough. Universal and human bacteria were detected in every sample, cow/horse bacteria and dog bacteria were detected in some samples. Agricultural sources may be largely upstream and outside of the City's and County's jurisdiction. The City has installed additional pet waste signs in existing parks in the Smith Canal and Mormon Slough drainage areas to address pet waste. Both the City and County have also installed pet waste stations along the Marina as part of the Keep the Delta Clean Program.

MWQI Steelhead Creek Water Quality Investigation

MWQI published a Final Technical Report of the Steelhead Creek Water Quality Investigation in February 2008. The study was initiated to investigate changes in water quality as the watershed transitioned from agricultural land to urban development and to obtain information on the loads of drinking water constituents entering the Sacramento River and the Delta. Coliform bacteria were monitored and assessed. Monthly median total coliform exceeded 1,000 MPN/100 ml in all months of the year. Monthly median fecal coliform and *E. coli* exceeded 200 MPN/100 ml in all months of the year as well. Analysis found that there was no clear seasonal variability, but peak loads were seen after major storm events. The levels found in Steelhead Creek were much higher than those at the Sacramento River Water Treatment Plant, just downstream of the confluence with the American River, as shown in **Figure 13-18**

Figure 13-18. *E. coli* Levels at Sacramento River WTP and Steelhead Creek



MWQI Lathrop Urban Runoff Water Quality Investigation

The study was initiated to investigate changes in water quality as the watershed transitioned from agricultural land to urban. The study has been conducted for two seasons (2009/2010 and 2010/2011) and focused on sample collection during wet events. Eight urban runoff pump stations were sampled for a variety of constituents. The sampling sites are shown in **Figure 13-19**. Nine events have been sampled for coliform between the two seasons and all data were considered usable for this evaluation. The median values of total coliform, fecal coliform, and *E. coli* at each pump station are shown in **Figure 13-20**. This figure also supports very high levels of bacteria in urban runoff during storm events. It should be noted that the San Joaquin River was also monitored during the same sample events, with river samples collected at upstream (Mossdale), in-town (SJL), and downstream (Brandt Bridge) locations. The data show that the levels of bacteria are in the same order of magnitude at all sites. For the three storms where all sites were monitored, the upstream site (Mossdale) and in-town site (SJL) both had median *E. coli* values of 31 MPN/100 ml, while the downstream site (Brandt Bridge) had a slightly lower median value of 10 MPN/100 ml.

Figure 13-19. Monitoring Site Locations for the MWQI Lathrop Urban Runoff Study

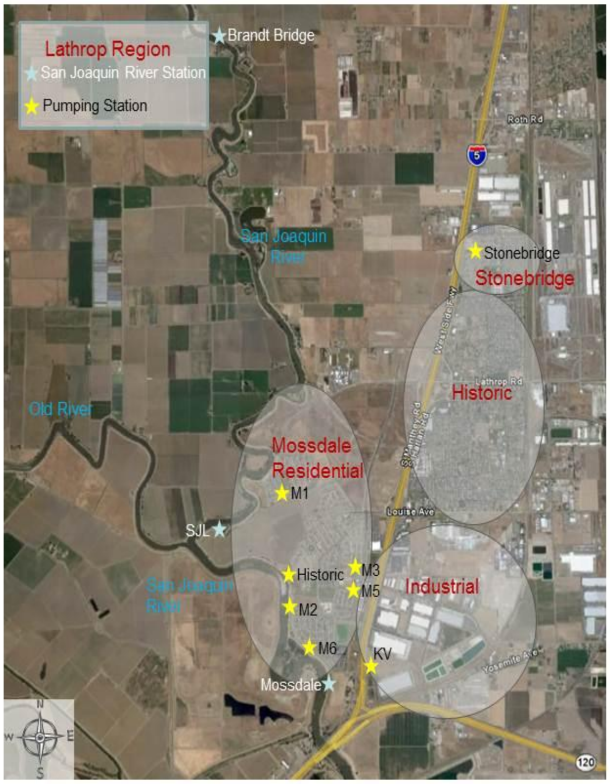
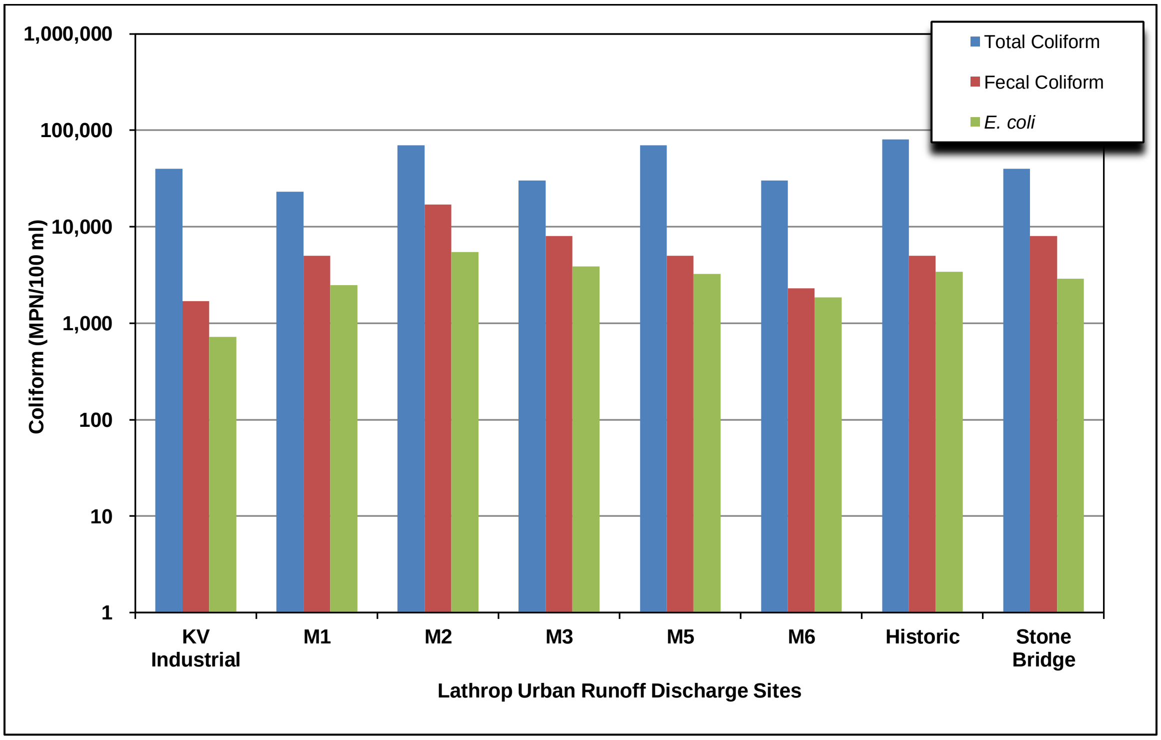


Figure 13-20. Median Coliform Levels in MWQI Lathrop Urban Runoff Study

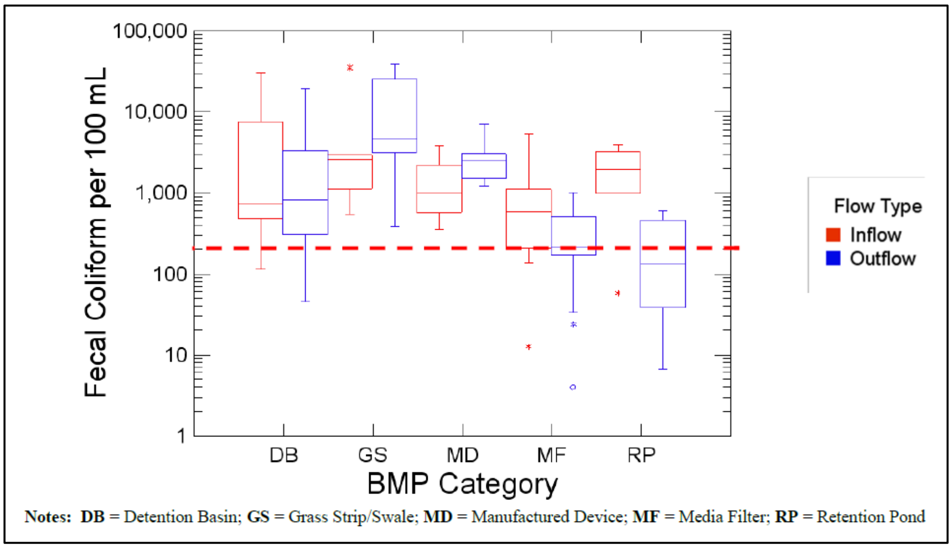


Source: MWQI Lathrop Urban Runoff Study Data, 2011.

BMP Effectiveness

The International BMP Database is an online searchable database on the effectiveness of urban runoff BMPs (www.bmpdatabase.org). A Pollutant Category Summary on Fecal Indicator Bacteria was published in December 2010 (Wright Water Engineers, Inc. et al.) on the effectiveness of urban runoff BMPs in removing bacteria or pathogens. They determined that source control was still the most effective means to reduce fecal matter, but a review of available data indicates that retention (wet) ponds are most efficient at reduction, followed by media filtration. **Figure 13-21** is from the Technical Summary and presents the influent and effluent levels of fecal coliform in the various types of BMPs.

Figure 13-21. Range of Geometric Means for Fecal Coliform Reduction at BMP Sites



Source: ISW BMP Database, Pollutant Category Summary Report: Fecal Indicator Bacteria, 2010.
Note: Dashed red line indicates the 200 MPN/100 ml recreational standard.

Nutrients

Fertilizer use in urban areas contributes nutrients to urban runoff. Urban runoff also delivers nutrients in leaves, woody debris, and insects that are carried to receiving waters, which degrade and release nutrients. Nutrient concentrations have been monitored in Sacramento and Stockton dry weather and stormwater runoff. The Sacramento data are presented in **Table 13-13** to give a general sense of the concentrations of nutrients present in Central Valley urban runoff. Total nitrogen is the sum of total Kjeldahl nitrogen (TKN), nitrate, and nitrite.

Table 13-13. Median Nutrient Concentrations in Sacramento Urban Runoff

Constituent	Strong Ranch Slough		Sump 104		Sump 111		Natomas Basin 4	
	Wet Median	Dry Median	Wet Median	Dry Median	Wet Median	Dry Median	Wet Median	Dry Median
Nitrate + Nitrite (mg/L as N)	0.54	0.1	0.72	1.8	0.65	0.35	0.78	0.51
TKN (mg/l as N)	1.8	1.05	1.7	1.0	1.6	1.0	1.4	1.2
Total P (mg/L)	0.26	0.2	0.4	0.4	0.25	0.4	0.35	0.3

Source: Urban Runoff Source Control Evaluation (Geosyntec, 2011).

MWQI Steelhead Creek Water Quality Investigation

Figures 13-22 and 13-23 show the nitrogen and phosphorus concentrations during the study period. Nitrogen concentrations consist primarily of nitrate and nitrite, indicating ammonia and organic nitrogen concentrations are low. Phosphorus is mainly comprised of dissolved orthophosphate. The levels in Steelhead Creek were highly variable over the study period. Peak concentrations occurred during dry periods when the Dry Creek Wastewater Treatment Plant effluent had a greater influence due to low flows in the creek. Total N and total P data from Steelhead Creek were compared to data from the Sacramento River at the West Sacramento Water Treatment Plant intake. The median total N concentration in the Sacramento River during the study was 0.20 mg/L, whereas the median in Steelhead Creek was an order of magnitude higher at 2.2 mg/L. The median total P concentration in the Sacramento River was 0.06 mg/L and the median in Steelhead Creek was 0.39 mg/L. There was little variation in the concentrations of both nutrients in the Sacramento River, but there was a wide range of both nutrients in Steelhead Creek. Urban runoff, agricultural drainage, and wastewater effluent contribute to the elevated concentrations in Steelhead Creek.

Figure 13-22. Nitrogen Concentrations in Steelhead Creek

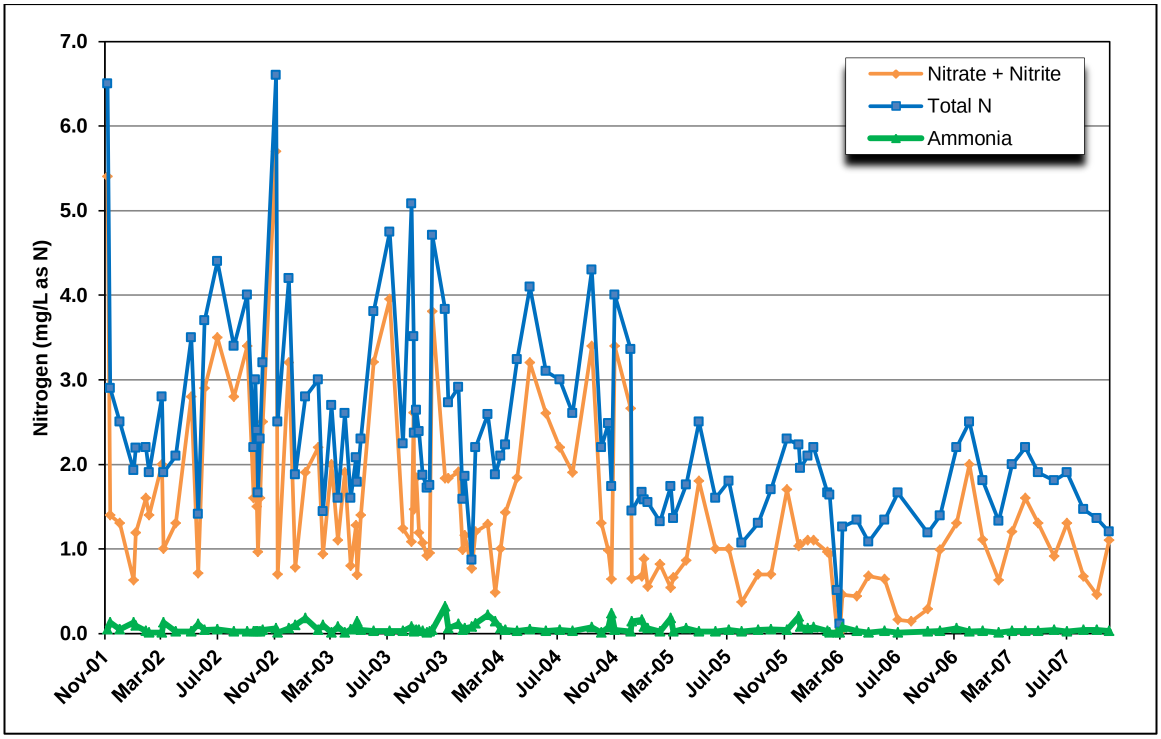
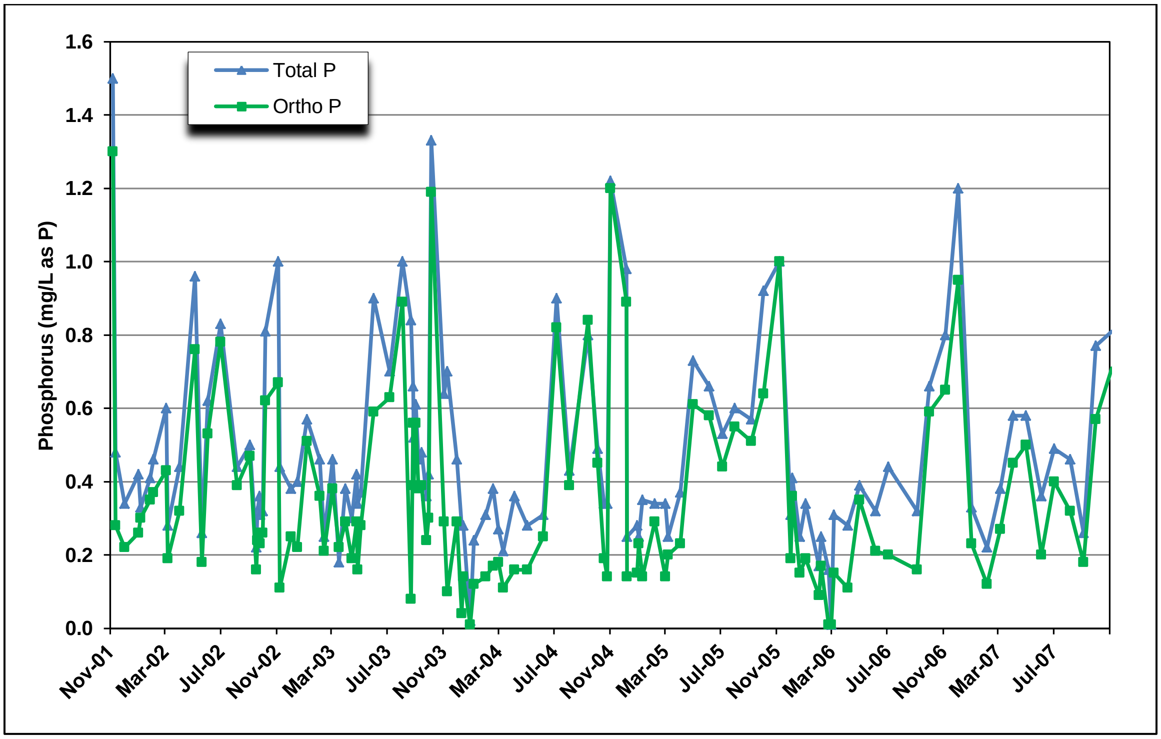


Figure 13-23. Phosphorus Concentrations in Steelhead Creek



MWQI Lathrop Urban Runoff Water Quality Investigation

Only data from the second season (November 2010 through June 2011) were considered in the nutrient evaluation due to concerns that some of the samples collected in the first season were not representative of stormwater. Three to six events per sample site were monitored during the second season. It should be noted that two pump stations were not monitored the second season, M5 and Stonebridge, as well as two river sites (in-town [SJL] and downstream [Brandt Bridge]) so no data are available at these sites. The two pump stations were not monitored because they either did not have enough water to pump, or the autosampler was not triggered due to signal error. The San Joaquin River stations were originally chosen to bracket Lathrop's stormwater discharge. Since discharge from the pumping stations is sporadic and unpredictable during storm events, it is not possible to see the effect of the discharges downstream on the San Joaquin River. Therefore, the San Joaquin River at Mossdale site was kept as a background water quality site but the two downstream river sites were dropped from the monitoring program.

Figure 13-24 shows the median nitrogen concentrations in the Lathrop urban runoff pump stations. The amount and type of nitrogen present can vary widely between the pump stations. The San Joaquin River was monitored at the upstream site (Mossdale) and had a median total N of 1.01 mg/L.

Total phosphorus and dissolved orthophosphate were both monitored as well in the Lathrop study. **Figure 13-25** shows the median phosphorus concentrations in the urban runoff pump stations. The amount and type of phosphorus present can also vary between the various pump stations. These values are similar to the Sacramento discharge data. The San Joaquin River was also monitored at the upstream site (Mossdale) and had a median total P concentration of 0.15 mg/L. The median dissolved orthophosphate concentration was near 0.08 mg/L.

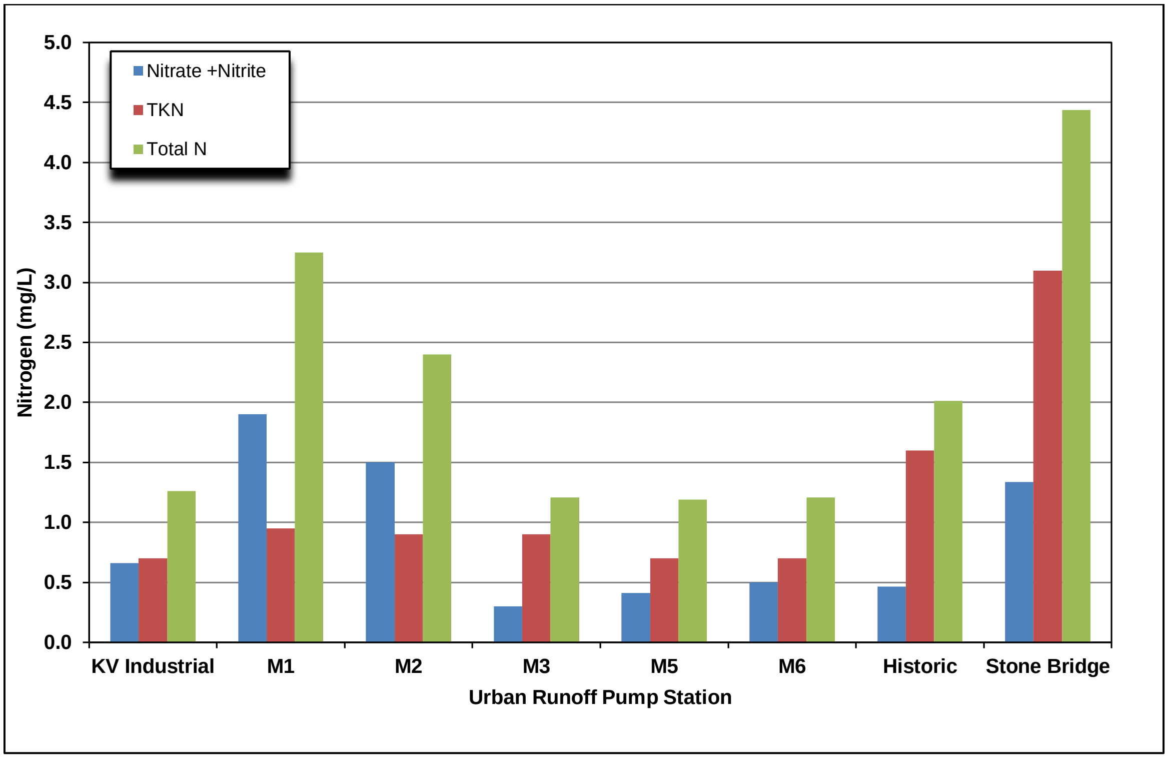
BMP Effectiveness

The International BMP Database also prepared a Pollutant Category Summary on Nutrients in December 2010 (Wright Water Engineers, Inc. et al.) on the effectiveness of urban runoff BMPs. A review of available data indicates that of the passive BMP treatments, those that provide particulate removal, such as detention basins, are most effective at phosphorus removal. Bioretention and retention ponds are most effective for nitrogen removal. **Figure 13-26** is from the Technical Summary and presents the influent and effluent levels of total P in the various types of BMPs. **Figure 13-27** presents the total N data.

Organic Carbon

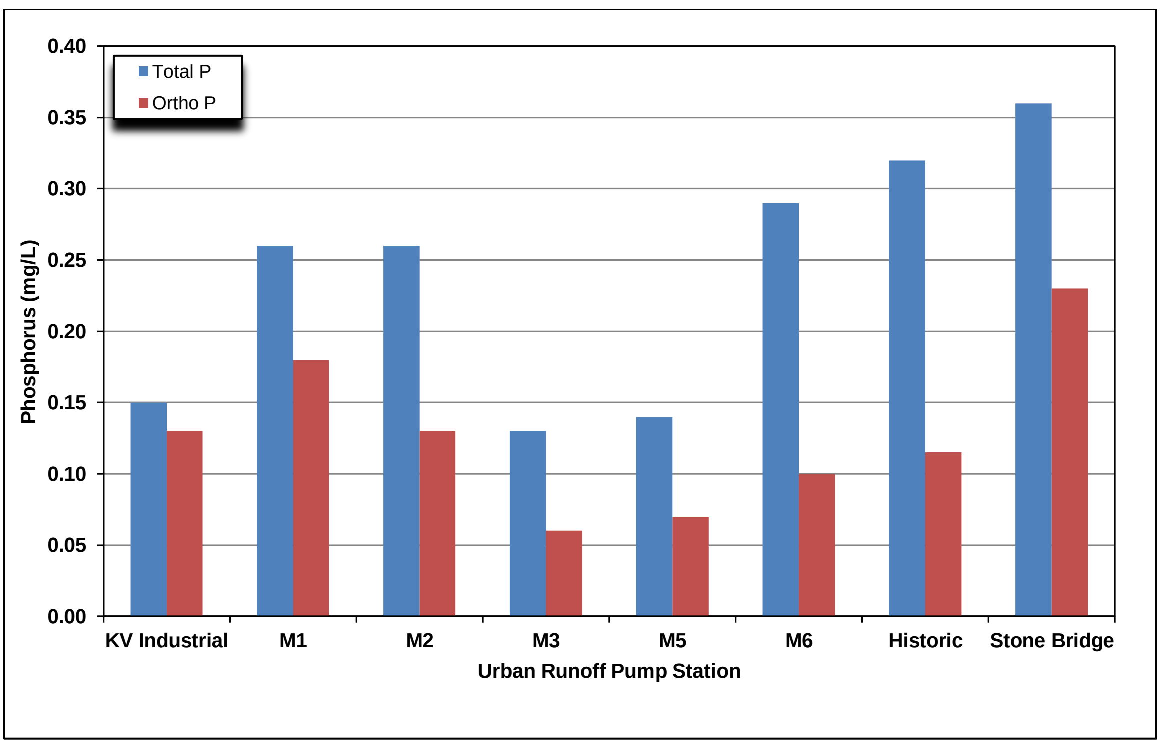
Urban runoff carries organic carbon to receiving waters in a variety of forms ranging from small soil particles to woody debris and small animals, such as rodents. Median TOC levels in Sacramento urban runoff from 2005 to 2010 are summarized in **Table 13-14.** Individual samples ranged from 3.8 to 73 mg/L. These concentrations are consistent with historical concentrations. The wet weather concentrations are higher than dry weather concentrations, with the exception of Sump 111. The concentrations at the new BMP site (Natomas Basin 4) are lower than the older urban runoff discharge locations, with a maximum TOC value of 12 mg/L and a maximum DOC value of 10 mg/L.

Figure 13-24. Median Nitrogen Concentrations in Lathrop Urban Runoff



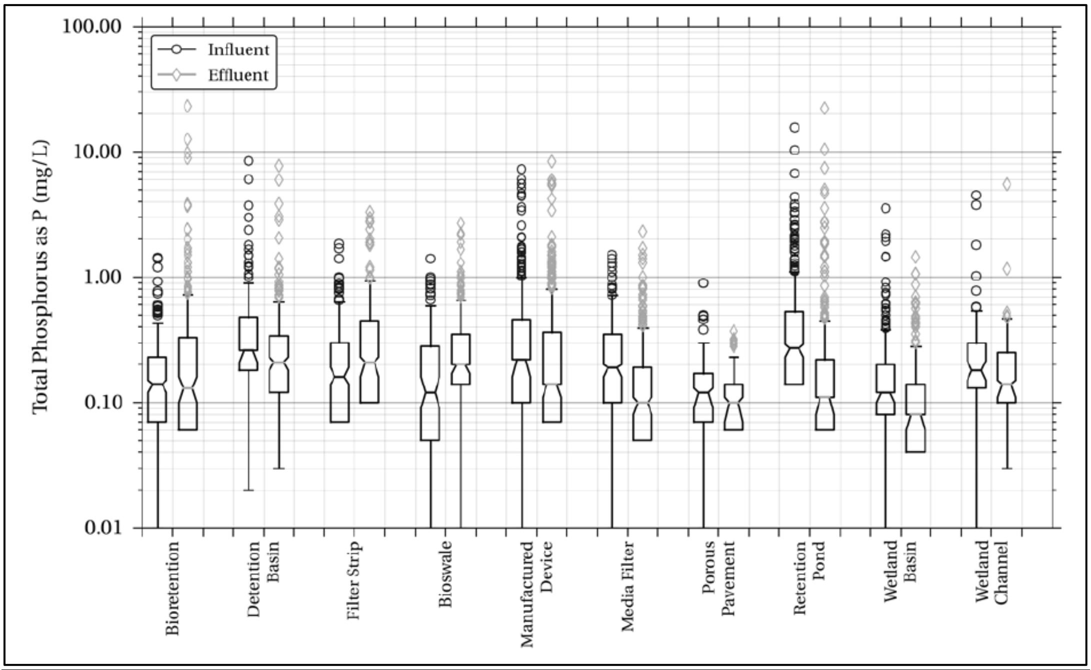
Source: MWQI Lathrop Urban Runoff Study Data, 2011.

Figure 13-25. Median Phosphorus Concentrations in Lathrop Urban Runoff



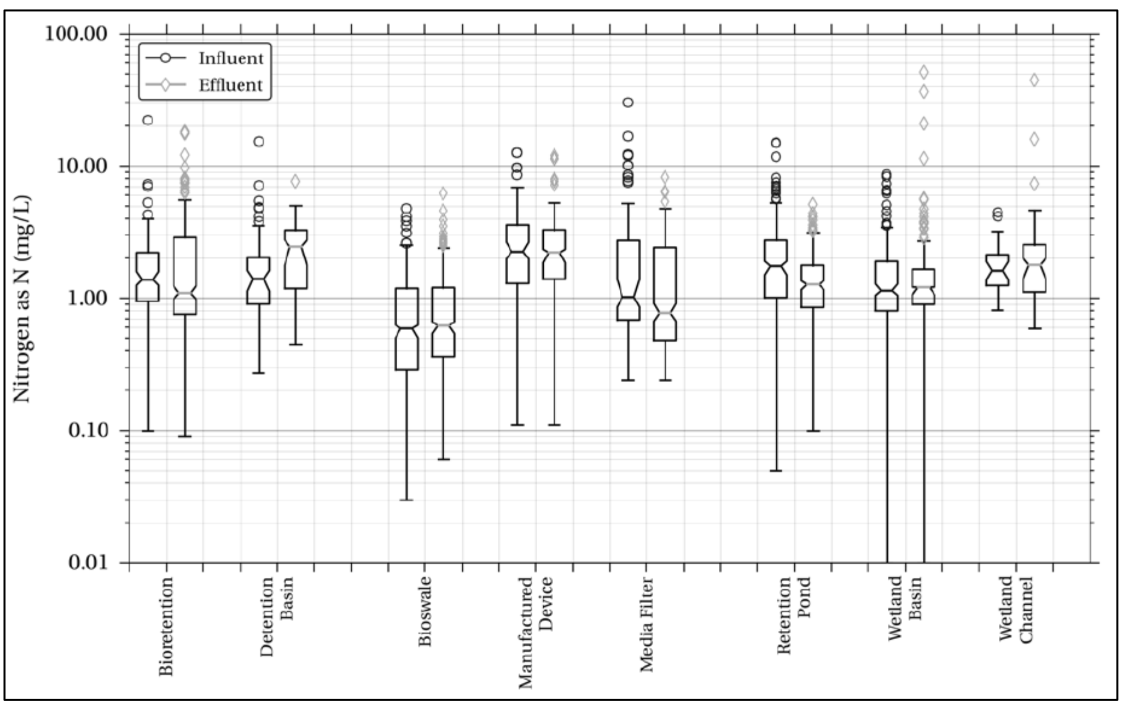
Source: MWQI Lathrop Urban Runoff Study Data, 2011.

Figure 13-26. Influent and Effluent Total P Concentrations at BMP Sites



Source: ISW BMP Database, Pollutant Category Summary Report: Nutrients, 2010.

Figure 13-27. Influent and Effluent Total N Concentrations at BMP Sites



Source: ISW BMP Database, Pollutant Category Summary Report: Nutrients, 2010.

Table 13-14. Median Organic Carbon Concentrations in Sacramento Urban Runoff

Constituent	Strong Ranch Slough		Sump 104		Sump 111		Natomas Basin 4	
	Wet Median	Dry Median	Wet Median	Dry Median	Wet Median	Dry Median	Wet Median	Dry Median
TOC (mg/L)	11	9.5	11	9.0	9.5	11	7.0	6.2
DOC (mg/L)	8.9	10.4	9.4	6.0	7.9	11	5.8	5.1

Source: Urban Runoff Source Control Evaluation (Geosyntec, 2011).

MWQI Steelhead Creek Water Quality Investigation

MWQI has monitored TOC and DOC in Steelhead Creek since 1997. The report presented the data analyzed using the wet oxidation method. **Figure 13-28** presents the TOC and DOC data from 1997 through the end of the study period in 2007. Concentrations of both TOC and DOC increase during wet periods. The median TOC and DOC concentrations during the wet season were 7.2 and 6.0 mg/L, respectively. The median concentrations were lower during the dry season (TOC = 5.0 mg/L and DOC = 4.9 mg/L). Generally, about 90 percent of the organic carbon was present in the dissolved form. The TOC data from Steelhead Creek were compared to data from the Sacramento River at the West Sacramento Water Treatment Plant intake. TOC concentrations in the Sacramento River are lower and less variable than in Steelhead Creek. The median concentration in the Sacramento River during the 2001 to 2006 study period was 2.1 mg/L, whereas the median in Steelhead Creek was 5.9 mg/L.

MWQI Lathrop Urban Runoff Water Quality Investigation

Only data from the second monitoring season was used for organic carbon analysis as well. **Figure 13-29** shows the median TOC and DOC levels at each of the urban runoff pump stations. The organic carbon concentrations were highly variable with TOC ranging from 2.2 to 20.3 mg/L, with an overall median of 5.8 mg/L, and DOC ranging from 2.1 to 15.2 mg/L, with an overall median of 5.0 mg/L. These are similar to the Steelhead Creek Study data. The San Joaquin River was also monitored at the upstream site (Mossdale) and had a median TOC concentration of 3.4 mg/L. The DOC median concentration at the upstream (Mossdale) site was 3.2 mg/L.

BMP Effectiveness

The International BMP Database also prepared a Pollutant Category Summary on Nutrients in December 2010 (Wright Water Engineers, Inc. et al.) on the effectiveness of urban runoff BMPs. A review of available data indicates that of the passive BMP treatments retention basins are most effective at TOC removal. **Figure 13-30** is from the Technical Summary and presents the influent and effluent levels of TOC in the various types of BMPs.

Figure 13-28. Organic Carbon Concentrations in Steelhead Creek

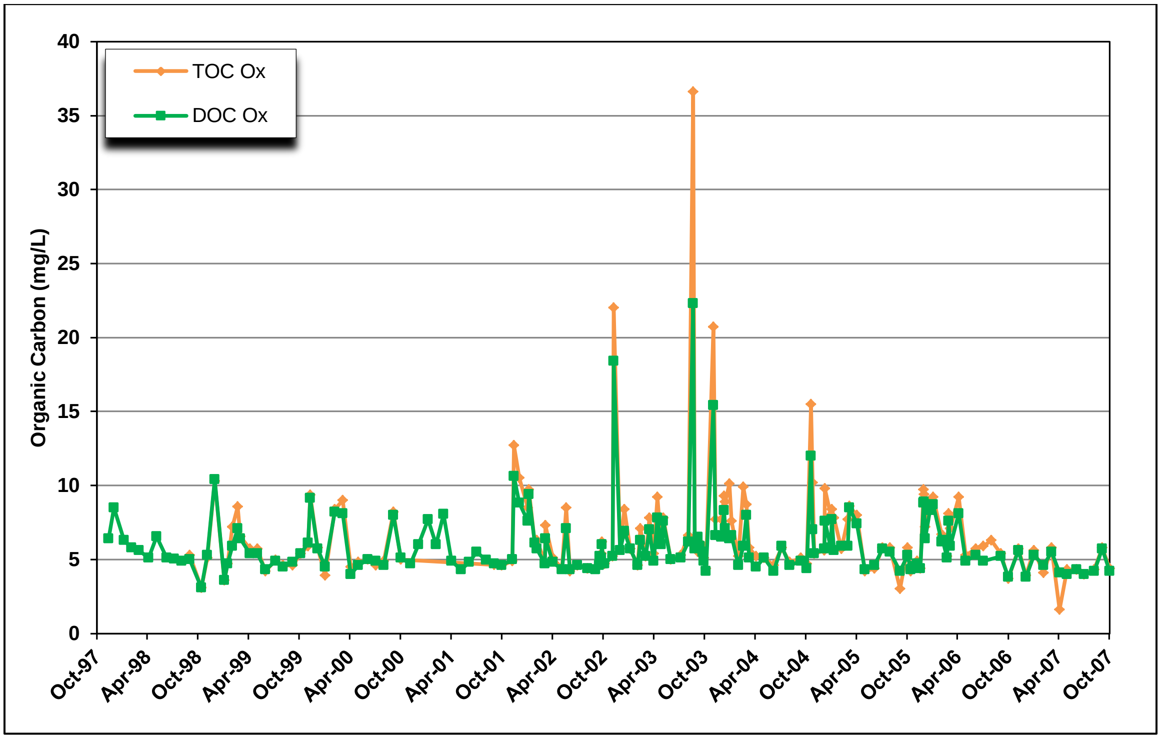
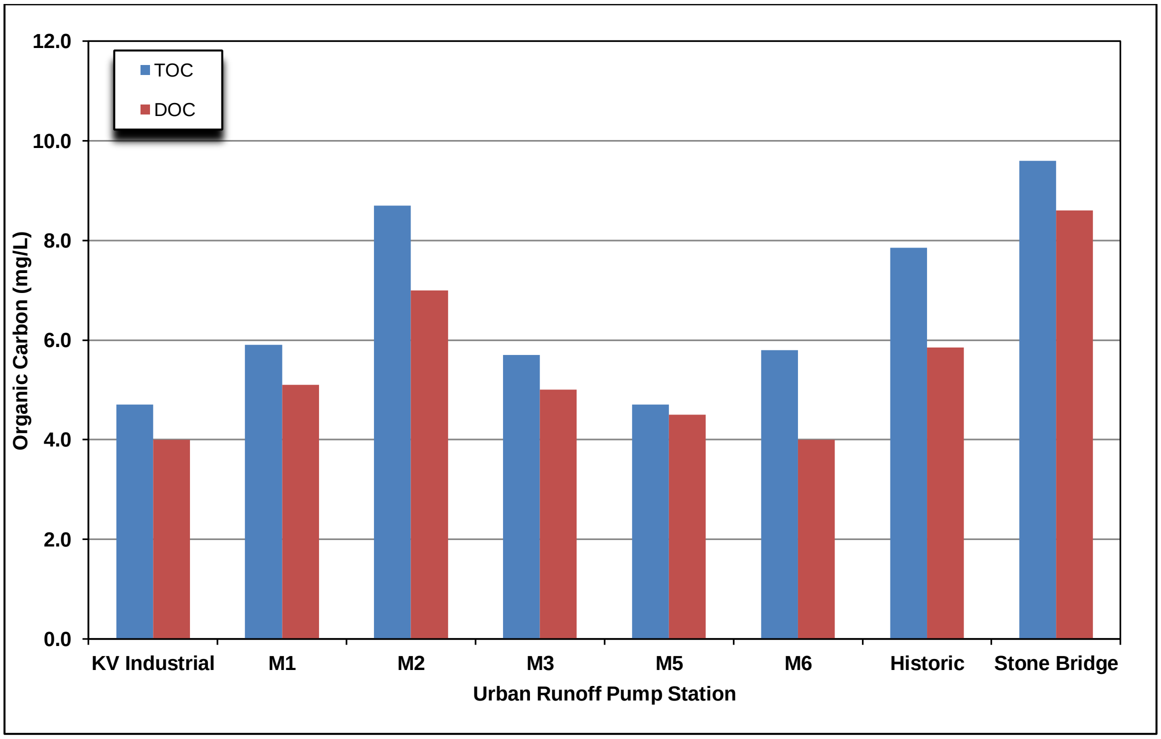
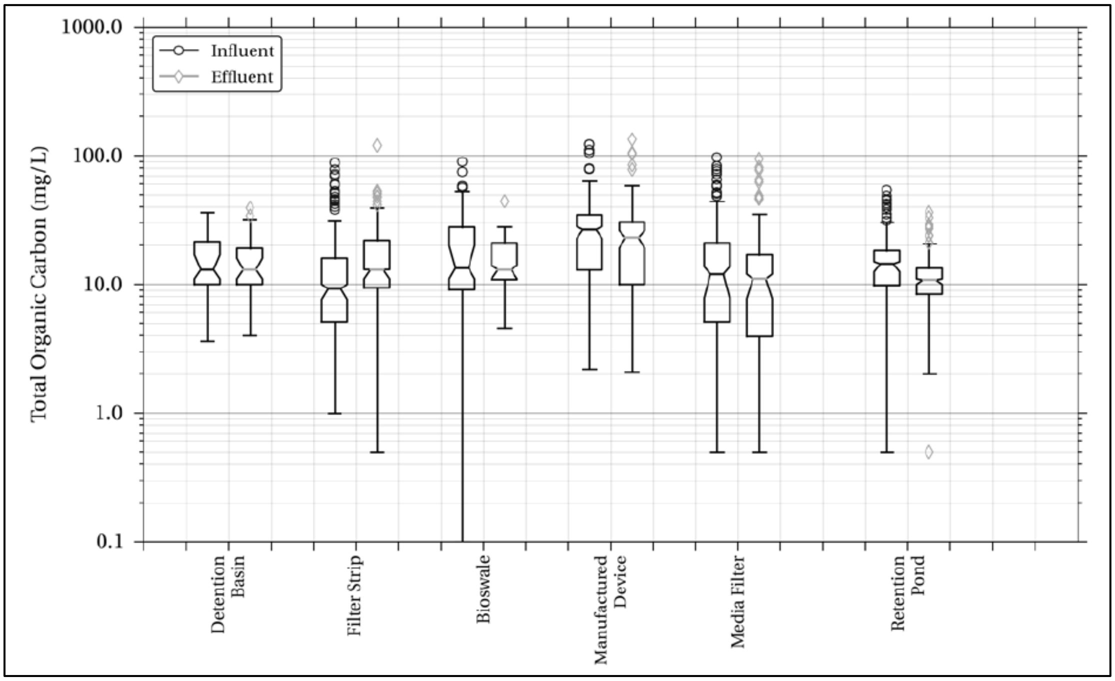


Figure 13-29. Median Organic Carbon Concentrations in Lathrop Urban Runoff



Source: MWQI Lathrop Urban Runoff Study Data, 2011.

Figure 13-30. Influent and Effluent TOC Concentrations at BMP Sites



Source: ISW BMP Database, Pollutant Category Summary Report: Nutrients, 2010.

Salinity

The TDS concentrations in urban runoff are quite variable, as shown with the Sacramento data in **Table 13-15**. Median concentrations are generally lower during wet events due to the dilution from precipitation. During the first part of a storm, runoff tends to have higher TDS concentrations as the impervious areas are washed of matter that has accumulated since the previous storm. As the storm progresses, TDS concentrations tend to decrease as there is less material to pick up and more dilution.

Table 13-15. Median TDS Concentrations in Sacramento Urban Runoff

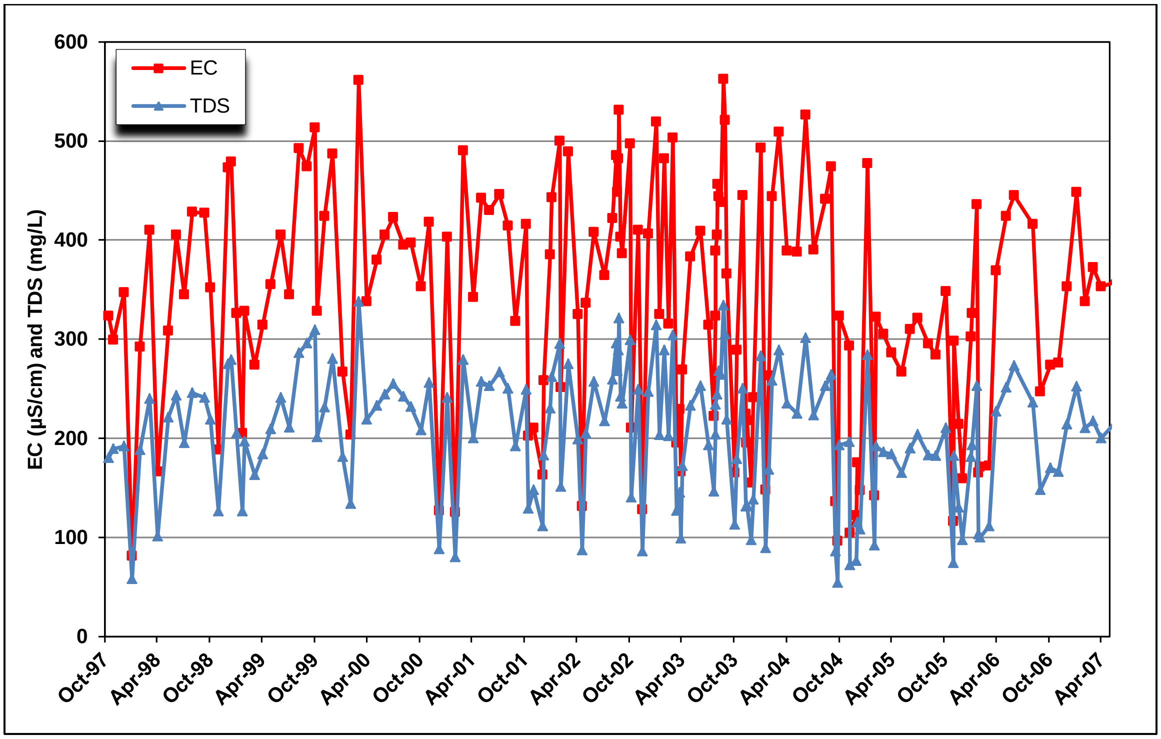
Constituent	**Strong Ranch Slough**		**Sump 104**		**Sump 111**		**Natomas Basin 4**	
	Wet Median	Dry Median	Wet Median	Dry Median	Wet Median	Dry Median	Wet Median	Dry Median
TDS (mg/L)	56.5	250	71.5	310	43.5	170	83	178

Source: Urban Runoff Source Control Evaluation (Geosyntec, 2011).

MWQI Steelhead Creek Water Quality Investigation

Figure 13-31 shows the TDS and EC measurements from 1997 to 2007. The TDS concentrations in Steelhead Creek were highly variable over the study period, ranging from 54 to 338 mg/L. The TDS concentrations in wet weather are lower than in dry weather but the highest loading occurs during the wet season.

Figure 13-31. TDS and EC Measurements in Steelhead Creek



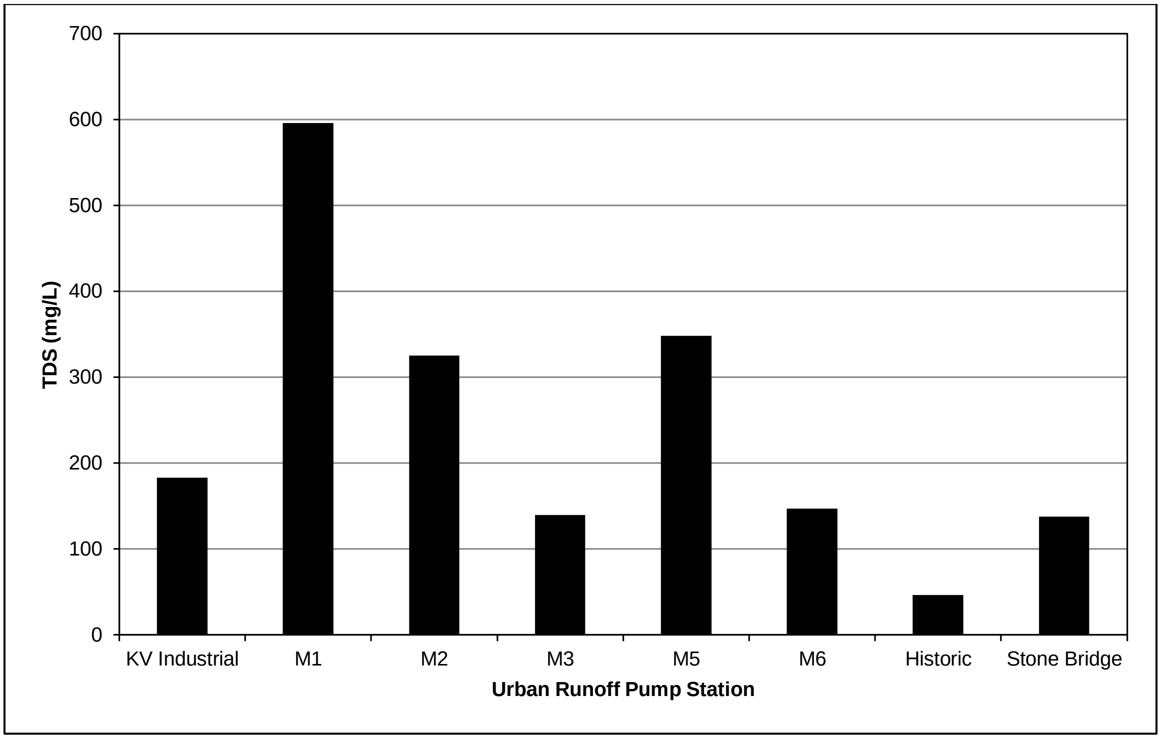
MWQI Lathrop Urban Runoff Water Quality Investigation

Only data from the second monitoring season was used for the salinity analysis as well. **Figure 13-32** shows the median TDS concentrations at each of the urban runoff pump stations. The TDS concentrations were also highly variable, ranging from 34 to 1,480 mg/L. The San Joaquin River was monitored at the upstream (Mossdale) site with a median TDS concentration of 157 mg/L.

BMP Effectiveness

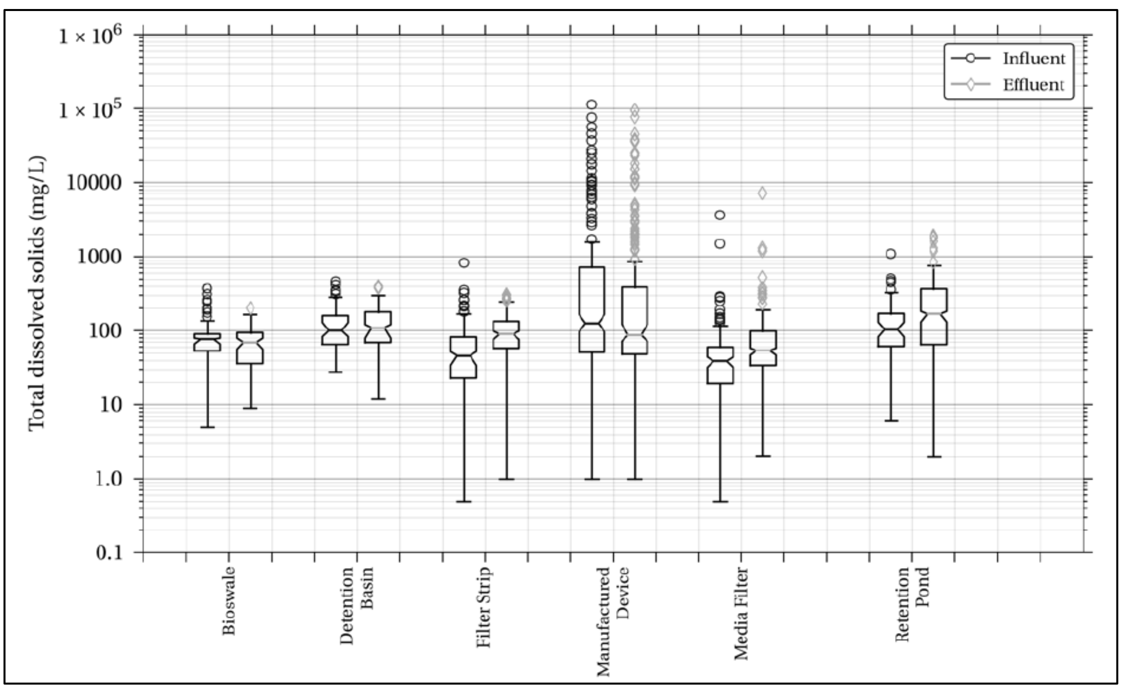
The International BMP Database also prepared a Pollutant Category Summary on Solids in May 2011 (Wright Water Engineers, Inc. et al.) on the effectiveness of urban runoff BMPs. A review of available data indicates that none of the passive BMP treatments is effective at TDS removal. **Figure 13-33** is from the Technical Summary and presents the influent and effluent TDS concentrations in the various types of BMPs.

Figure 13-32. Median TDS Concentrations in Lathrop Urban Runoff



Source: MWQI Lathrop Urban Runoff Study Data, 2011.

Figure 13-33. Influent and Effluent TDS Concentrations at BMP Sites



Source: ISW BMP Database, Pollutant Category Summary Report: Solids, 2011.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following actions related to urban runoff discharges in the Delta:

Support Development of the Central Valley Drinking Water Policy.

This action item was classified as immediate, meaning that it addresses current critical water quality issues. MWQI staff has participated in the Drinking Water Policy Work Group as staffing permits. MWQI staff has participated in critical meetings when notified by California Urban Water Agencies that key decisions are being discussed.

Work with Central Valley Regional Water Board to Include Drinking Water Constituents in Studies on Effectiveness of Urban Runoff Management Practices and to Require Maintenance of Management Practices.

This action item was also classified as immediate. MWQI has contacted both the Sacramento and Stockton Stormwater Programs to determine if they would be willing to include drinking water analytes of concern in their stormwater BMPs sampling. MWQI proposed to have the samples analyzed at DWR's Bryte Laboratory if the two stormwater programs would collect the samples. The City and County of Stockton declined to participate with MWQI, but the Sacramento Stormwater Program agreed to work with MWQI when a project is selected for a BMP effectiveness study (Personal Communication, Rachel Pisor, DWR).

POTENTIAL ACTIONS

The State Water Project Contractors Authority (SWPCA), MWQI, and CDPH Should Comment on Stormwater Permits.

Stormwater permits are renewed every five years. SWPCA, MWQI, and CDPH should provide comments on the permits for the large and medium systems that discharge to the Delta. Since there are limited data on the effectiveness of BMPs in controlling key drinking water constituents, such as organic carbon, nutrients, and pathogens, SWPCA, MWQI, and CDPH should request that the permits contain special studies to evaluate the effectiveness of BMPs in removing drinking water constituents. Drinking water constituents should also be included in the monitoring programs required by the permits.

SWPCA Should Track Development of Special Studies Required by the Stormwater Permits for Delta Dischargers.

The Central Valley Regional Water Board often requires dischargers to conduct special studies as conditions of their permits. For example, Contra Costa County is required to conduct a special monitoring program to evaluate the presence of CECs in urban runoff. This is being conducted over the next few years to be incorporated into the next permit. SWPCA should track this study and other studies required in future permits and prepare comments as needed.

DELTA LAND CONVERSIONS

BACKGROUND

There are a number of habitat restoration projects that are underway or being planned in the Delta. Conversion of agricultural lands to tidal marsh is called for by the Ecosystem Restoration Program's Conservation Strategy for Sacramento-San Joaquin Delta Ecological Management Zone (California Department of Fish and Game, 2010) and by the Bay Delta Conservation Plan (BDCP). Other ecosystem restoration projects may occur through the Sacramento-San Joaquin Delta Conservancy, and the Delta Wetlands project (discussed in Chapter 2). DWR currently has three habitat restoration projects underway which are described in this section.

Conversion of the Delta's traditional cultivated fields to managed wetlands or rice crops shows potential for stopping and reversing the effects of subsidence as well as potentially serving as a means of carbon sequestration. DWR and the United States Geological Survey (USGS) are jointly working on two major types of pilot projects on Delta islands to assess their effectiveness for subsidence reversal and carbon sequestration. These projects are part of the DWR Interim Delta Actions to continue incremental improvements in the Delta until a long-term solution is in place. These projects include managed wetlands and rice cultivation; both of which include flooding Delta islands.

A number of studies have been completed and others are on-going to evaluate the water quality impacts of these land conversion projects. This section contains an overview of current and planned projects and information on what has been learned to date about the effects of these land conversions on Delta water quality.

HABITAT RESTORATION PROJECTS

Long-Term Plans

There are two large-scale, long-term habitat restoration plans for the Delta.

<u>Ecosystem Restoration Program Conservation Strategy</u>

In 2000, the CALFED Bay-Delta Program began implementation of a program aimed at improving the Delta ecosystem and increasing the reliability of its water supply. The program was based, in part, on a preferred water conveyance alternative, which was continued conveyance of water through the Delta. CALFED program implementation was broken into two stages, Stage 1 (2000–2007) and Stage 2 (2008–2030), to allow reevaluation of its preferred alternative. A program performance evaluation conducted at the end of Stage 1 found that CALFED's through-Delta water supply conveyance alternative had not achieved sufficient progress in restoring the ecosystem or water supply reliability. In response the Ecosystem Restoration Program (ERP) implementing agencies developed the Conservation Strategy for Stage 2 (California Department of Fish and Game, 2010). The goal is to have the Conservation Strategy serve as the ecosystem component of the Delta Stewardship Council's Delta Plan. Specific actions related to habitat restoration and tidal marshes are listed below:

- Action 1 – Continue habitat restoration, property acquisition, planning, and monitoring on specified sites:
  - Hill Slough habitat restoration (Suisun Marsh)
  - Mein's Landing restoration (Suisun Marsh)
  - Blacklock Landing restoration (Suisun Marsh)
  - Cache Slough complex, including Prospect and Liberty islands, and Lindsey Slough
  - Yolo Bypass Wildlife Area (tidal and seasonal wetlands on 700 acres)

- Action 2 – Implement and monitor the Dutch Slough restoration project, which would restore up to 483 acres of emergent wetland (a portion of which would be tidal), and generate information on how to best restore tidal marsh habitat.

Bay Delta Conservation Plan

The BDCP is being prepared through a collaboration of state, federal, and local water agencies; state and federal fish agencies; environmental organizations; and other interested parties to identify a long-term solution for the Bay-Delta. The BDCP sets out a comprehensive conservation strategy designed to advance the co-equal planning goals of restoring ecological functions of the Delta and improving water supply reliability. It also prescribes actions that will produce fundamental, systemic and long-term physical changes to the Delta. These changes will involve substantial alterations to water conveyance infrastructure and water management regimes in combination with extensive restoration of habitat and action to reduce the impacts of various biological stressors. The timeframe to implement all elements of the BDCP is 50 years. The conservation strategy is divided into near-term and long-term implementation stages. The near-term implementation lasts until the north Delta diversion and tunnel/pipeline or canal conveyance facilities are constructed and operational, allowing for dual conveyance of water.

In a parallel effort, a joint Environmental Impact Report (EIR)/Environmental Impact Statement (EIS) for BDCP is currently being prepared by DWR, the Bureau of Reclamation, the U.S. Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, in cooperation with the California Department of Fish and Game, the USEPA, and the U.S. Army Corps of Engineers. The agencies developing the EIR/EIS will evaluate ecosystem restoration and water conveyance alternatives identified by the BDCP. The agencies will also evaluate additional alternatives identified through the environmental review process under the California Environmental Quality Act and National Environmental Policy Act. The Draft EIR/EIS is scheduled for completion in September 2012.

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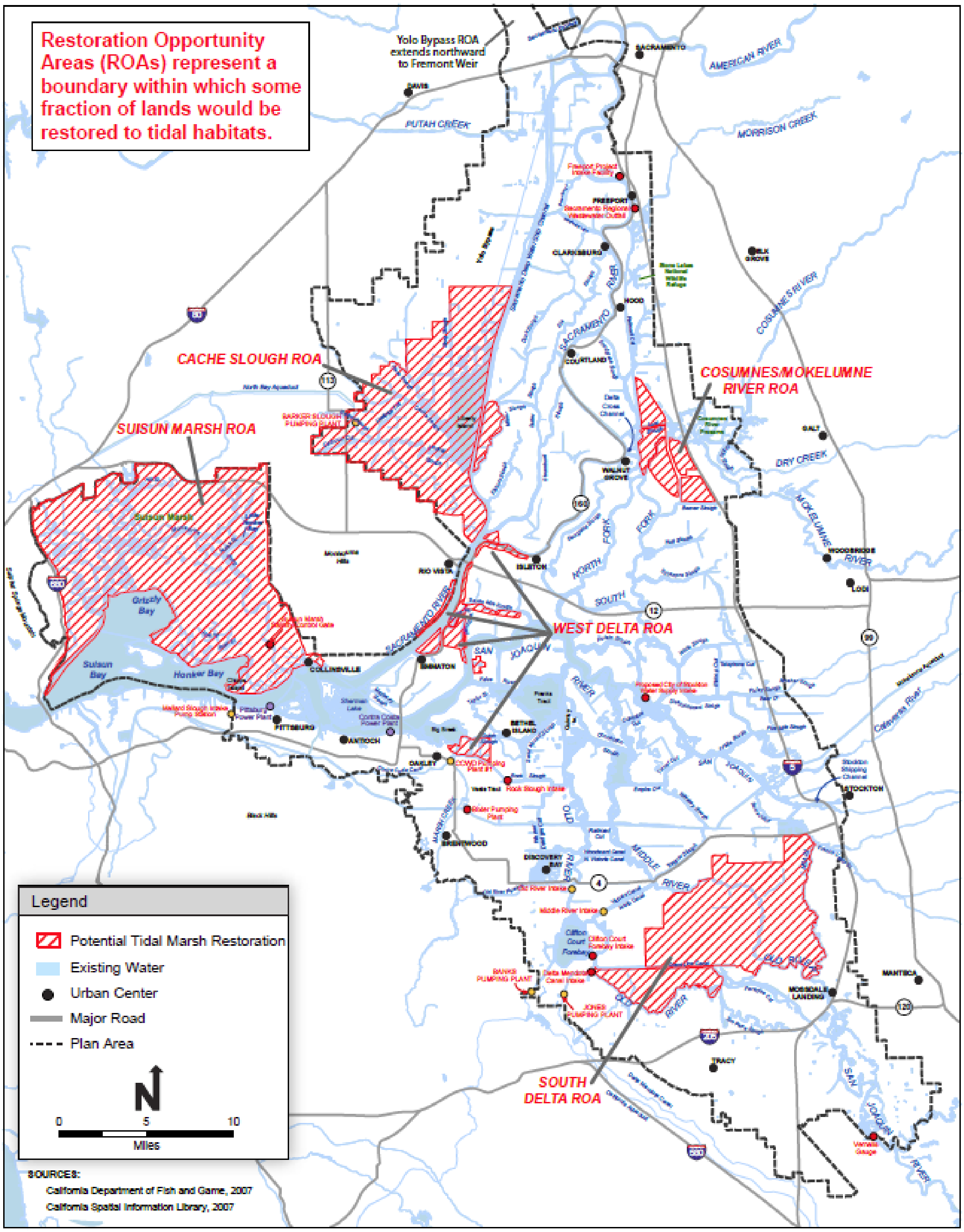
The BDCP Conservation Strategy identified Restoration Opportunity Areas (ROAs) which are locations that are considered to be the most appropriate for the restoration of tidal habitats within the Plan Area, as shown in **Figure 13-34**. In the near-term BDCP implementation period, actions to restore tidal habitat and riparian habitat will likely be directed at the Cache Slough, West Delta, Cosumnes/Mokelumne and Suisun March ROAs. Following commencement of dual water conveyance operations, restoration of tidal and riparian habitat will be expanded significantly into the South Delta ROA. The BDCP targets for freshwater and brackish tidal marsh restoration are 14,000 acres within 10 years, 25,000 acres within 15 years, and 65,000 acres within 40 years. The BDCP also proposes to increase the amount of agricultural land under BDCP conservation protection, from the current 11 percent to a range between 14 and 18 percent, which would total approximately 35,000 acres.

Figure 13-34. Restoration Opportunity Areas

DRAFT



Source: Draft BDCP, 2010

Current Habitat Restoration Projects

DWR currently has three habitat restoration projects underway which are intended to make incremental improvements until long-term solutions are in place for the Delta. DWR refers to these projects as "DWR Interim Delta Actions". The three projects are Dutch Slough Tidal Marsh Restoration Project, Liberty Island Studies, and Acquisition of Prospect Island. The locations of these projects are shown in **Figure 13-35**.

Dutch Slough Tidal Marsh Restoration Project

The Dutch Slough Tidal Marsh Restoration Project will restore 1,166 acres of tidal marsh and other native habitats in eastern Contra Costa County near Oakley. Because it will restore the natural hydrology and increase nutrients in the Delta's aquatic food chain, the project is expected to provide important benefits to the larger Delta ecosystem. DWR certified and approved the EIR in March 2010, and construction is planned to begin in 2012. The project will be designed and implemented to maximize opportunities to assess the development of habitat and measure ecosystem responses so that future Delta restoration projects can benefit from this information.

Liberty Island

Liberty Island is an inundated island encompassing 5,209 acres in the northern Delta. It has been flooded since 1998 when levees were breached during high flows. As part of the Biological Opinion issued for the delta smelt, DWR is required to coordinate with US Fish and Wildlife Service to enhance the existing marshes and wetlands that are already functioning. An enhancement plan is required to be completed by the end of 2012 (Personal Communication, Dennis McEwan, DWR). Restoration may include creating additional breaches in the levee to fill agricultural water delivery and drainage ditches, and excavating meandering sloughs to improve habitat quality and native fish access. In addition, Wildlands, Inc. is proposing to develop the Liberty Island Conservation Bank, located on the northern tip of Liberty Island. The project will preserve, restore, and enhance 165.7 acres of habitat for native fish species. The lead agency under the California Environmental Quality Act is Reclamation 2093.

Prospect Island

The northern part of Prospect Island was acquired by DWR in January 2010. The project entails breaching the Prospect Island levees to restore tidal marsh, open water habitat, and some upland/riparian habitat. The planning and design of this project is currently underway.

Figure 13-35. Habitat Restoration and Subsidence Reversal Projects

CARBON SEQUESTRATION AND SUBSIDENCE REVERSAL PROJECTS

Twitchell Island Wetland Research

Twitchell Island has a joint DWR and USGS Wetland Research Facility located on it. Two wetland sites, with a total of 14 acres, were constructed on DWR-owned land in 1997 as part of a pilot project to evaluate land surface elevation changes and carbon accretion due to the accumulation and decay of plant materials. The two ponds, East and West, are both flow-through, impounded wetlands created by constructing a berm of native soils around them. Water is supplied to the ponds from the nearby San Joaquin River. Water flows continuously into the ponds, with spillways along the northern edge of each pond to control the water depth. Flow rates are controlled to maintain a constant water depth of 60 cm in East Pond and 30 cm in West Pond. The studies at this facility have shown that land surface elevation increases 1.3 - 2.2 inches per year, while the surrounding areas used for conventional agricultural purposes have lost additional elevation due to subsidence. These projects include the potential for sequestering up to 25 tons of carbon annually per acre. In addition to studying the carbon accretion, water quality monitoring has been conducted and is discussed below.

Funding was received to expand this pilot project into the first-ever Carbon Capture Farming Demonstration Project. It expanded the project to full-scale over hundreds of acres. The purpose of the study is to ensure that wetland management approaches are developed that maximize subsidence reversal and carbon sequestration while minimizing adverse consequences, specifically impacts to water quality (methyl mercury production and DOC transport to receiving waters). Beginning in 2008 the project funding, and thus scope, was significantly reduced and is currently projected to end in June 2012 unless alternative funding is identified. Due to the reduced funding, there is less data available for evaluation.

Even though the pilot sites have shown that there is a great potential for carbon sequestration, there is concern that high methane effluxes may occur because the flooded landscape overlays carbon-rich and anaerobic soils (Baldocchi, 2011), which may offset the overall carbon capture. Recently a new contract with the University of California Berkeley was approved which will address the concerns related to greenhouse gas emissions by installing and operating a small network of eddy covariance towers to measure a suite of greenhouse gas fluxes across a variety of land-use classes in the Delta. These towers implement eddy covariance which is a technique to measure atmospheric flux by measuring and calculating vertical turbulent fluxes within atmospheric boundary layers. It implements a statistical method used in meteorology to analyze high-frequency wind and scalar atmospheric data series, and calculates the fluxes of these properties (including the exchange of methane and other gases). This will include baseline measurements over Twitchell Island, as well as over the demonstration sites (rice and wetlands on Twitchell Island and corn and wetlands on Sherman Island). This study will help to ascertain whether or not there is a net carbon capture gain through the Delta projects.

Water Quality Monitoring

The hydrologic and geochemical processes controlling the concentration and chemical characteristics of DOC, particulate organic carbon (POC), and trihalomethane (THM) precursors on the pilot project wetlands were researched and summarized in a memorandum by USGS (Fleck et al., 2006). This information is presented below.

The study found that the DOC concentration in the inlet waters varied seasonally and was approximately 1.5 mg/L in the summer months (mid-May through mid-November) and increased to over 4 mg/L in January. These concentrations are similar to the DOC concentrations in the Sacramento River at Freeport in both magnitude and seasonality. POC concentrations in the inlet waters ranged between 0.23 and 1.32 mg/L, with both winter and summer peaks. For the inlet waters the amount of TOC in the particulate fraction (POC/TOC) ranged from 8 to 41 percent, with maximum values in the summer months when DOC concentrations were low.

Outlet water samples had significantly higher DOC concentrations than inlet waters and were less seasonally variable. DOC concentrations in outlet waters ranged between 2.6 and 5.9 mg/L, with most of the high values occurring from January through June. It was hypothesized that the variability in DOC in the outlet water may be caused by the rate of microbial degradation of DOC (lower temperatures in the winter and spring months may suppress microbial degradation of DOC). If true, this would suggest that wetland surface water processes contribute DOC that is highly reactive in forming THMs. POC concentrations in the outlet waters ranged from 0.20 to 3.85 mg/L, with the highest concentrations between June and October. This corresponds to the time when algal growth in the pond was greatest. For the outlet waters, POC constituted between 7 and 34 percent of the TOC, again with the greatest contribution in the summer months.

The pore waters beneath the ponds were also sampled. Seepage constituted 10 to 25 percent of the water flow out of the ponds therefore, the quality of the seepage water strongly affects calculations of DOC loads from the pond. DOC concentrations ranged between 15 and 200 mg/L in the shallow soil layer pore waters and between 10 and 40 mg/L in the deep soil layer pore waters. In comparison, DOC concentrations in pore waters from other agricultural fields on Twitchell Island were between 40 and 120 mg/L at depths less than 2 meters and between 5 and 40 mg/L at depths greater than 2 meters. The authors believe that high DOC concentrations in ground water from historic agricultural activities and oxidation of the peat soil were still present in the shallow soil layer under the wetland during the first six years after establishment. They project that it would take over 15 years for the net load to stabilize. The authors found that the DOC with the highest propensity to form THMs came from new sediment accumulating in the constructed wetland, suggesting that wetlands restored on peat soils may release DOC with a higher THM formation potential per unit carbon than the DOC released from peat soils under agricultural management.

The results of this study indicate that the overall loads of DOC, POC, and THM precursors from a permanently flooded wetland can be similar in magnitude to the overall loads produced by agricultural management of similar areas with peat soils. The most efficient method of minimizing the loads from a constructed wetland is to limit water flow through the shallow soil layer beneath the wetland. This can be accomplished by reducing the hydraulic gradient between the constructed wetland and the surrounding areas, which may be difficult. Whole-island flooding would likely produce the least subsurface drainage, but large-scale flooding of peat islands would need to be carefully planned so that optimal water depths and surface water flows required for wetlands can be maintained. The carbon loads from the wetland have the opposite seasonal variation from the conventional agricultural systems. Wetland loads are lower in December through April when flows through the Delta may be diverted for filling reservoirs and recharging aquifers. Wetland loads are higher in May through November, but the exported POC and DOC may be more biodegradable and have greater food-web value.

Twitchell Island Farm-Scale Rice Pilot Project

Rice cultivation has been identified as a possibly effective and sustainable way to reduce subsidence and facilitate carbon sequestration, while maintaining a farm economy in the Delta. A 2006 CALFED study completed by Bachand and Associates hypothesized that flooding fields for rice production could eliminate subsidence of organic soils. Shortly after, a consortium of public and private organizations proposed to DWR to conduct research and plant rice on a farm-scale demonstration project on Twitchell Island to assess rice as a subsidence mitigation strategy. This pilot project began in mid-2008 and is being implemented to provide an opportunity to evaluate this technique while considering water quality, farming, and BMPs. The data analyzed during this project will allow DWR and others to develop recommendations on how this method can be applied to reduce subsidence and sequester carbon, while minimizing impacts to the environment. Data will also provide a road map for BMPs that can be used for rice growing in the Delta.

The project area consists of a 322 acre parcel on Twitchell Island, with 12 individual rice fields of varying acreage. Work was commenced in the fall of 2008 to prepare the fields. Crops have been grown annually since 2009. In April 2009, approximately 180 acres of rice and 167 acres of corn/oats were planted. As shown in **Figure 13-36**, fields 1-9 were planted with rice (Group 1), and fields 10-12 were planted with corn/oats (Group 2) in 2009. In April 2010, the fields that were previously planted with corn in 2009 were planted with rice, bringing the total acreage to 320 acres. The project is currently scoped for a final harvest in 2013 and to be completed in early 2014.

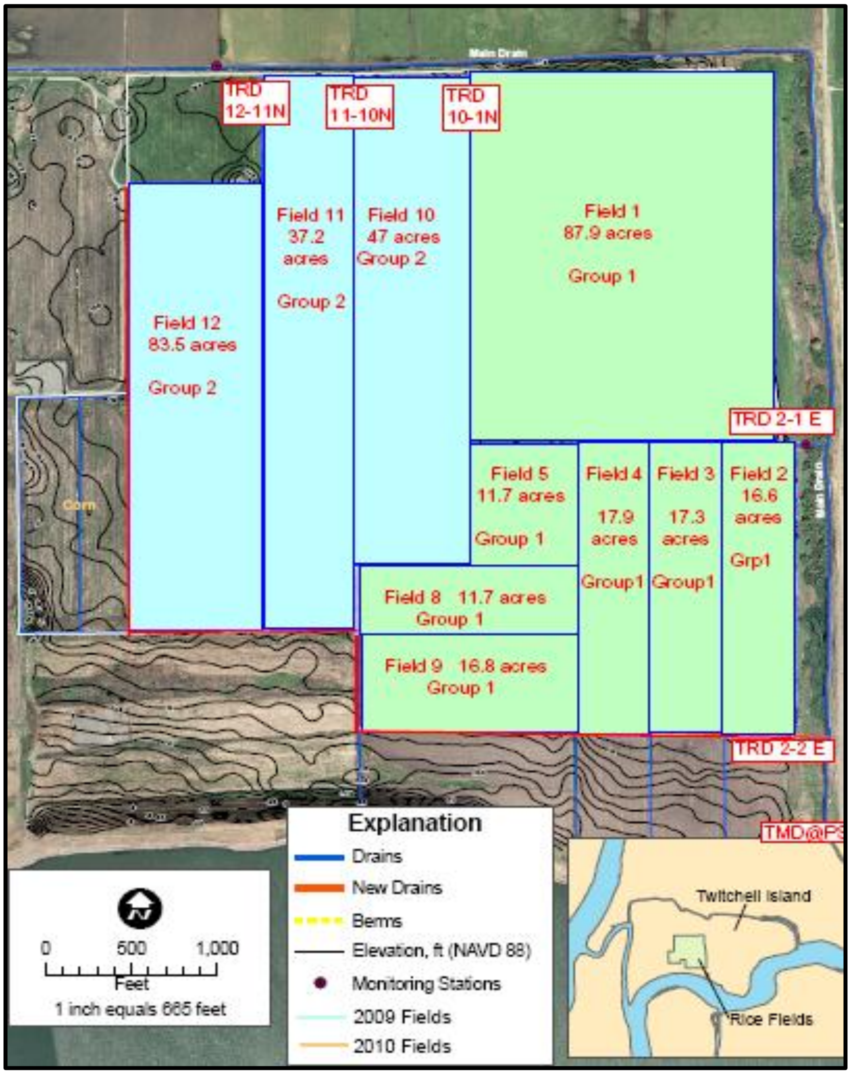
Studies have shown that the cultivation of rice on Twitchell Island is proving to be successful in reversing the loss of carbon dioxide from the island compared to standard agricultural cultivation of peat soils (Baldacchi et al., 2010), with a net gain of carbon over the rice fields. Also, methane losses have been lower than expected (compared with other California rice paddies and tule wetland sites) but the reasons are not well understood. Due to the flooding nature of the cultivation, a large amount of water is lost to evaporation over the growing season. Subsidence and water quality monitoring is being conducted and is discussed below.

Subsidence Monitoring

One extensometer was constructed in the rice fields, and one extensometer in the corn fields to monitor small-scale variations in land surface elevation. At both locations, land surface elevation was measured relative to the extensometer structure which was anchored below the peat so land-surface elevation variations reflected processes occurring in the peat. The extensometer data indicated that rice cultivation will stop subsidence. Specifically, the rice extensometer measured 19.9 mm of accretion during a 121-day period from early in the flooding (May 31, 2009) to shortly after draining (September 29, 2009). The corn extensometer measured 7.3 mm of inelastic subsidence during a 63 day period from mid-August to mid-October.

Similar to the 2009 results, the 2010 extensometer data indicated that rice cultivation will stop subsidence. The rice extensometer measured 42.6 mm of accretion during a 351-day period from mid-irrigation (June 27, 2009) to shortly after flooding (June 13, 2010). A second rice extensometer measured 38.5 mm of accretion during a 69-day period from early in the flooding (July 12, 2010) to soon after draining (September 19, 2010). The elevation increases measured by the rice extensometers are probably due to increased volume and hydraulic lifting of organic soils due to increased water content and buoyancy (Hydrofocus, 2010).

Figure 13-36. Schematic of Twitchell Island Rice Study Area



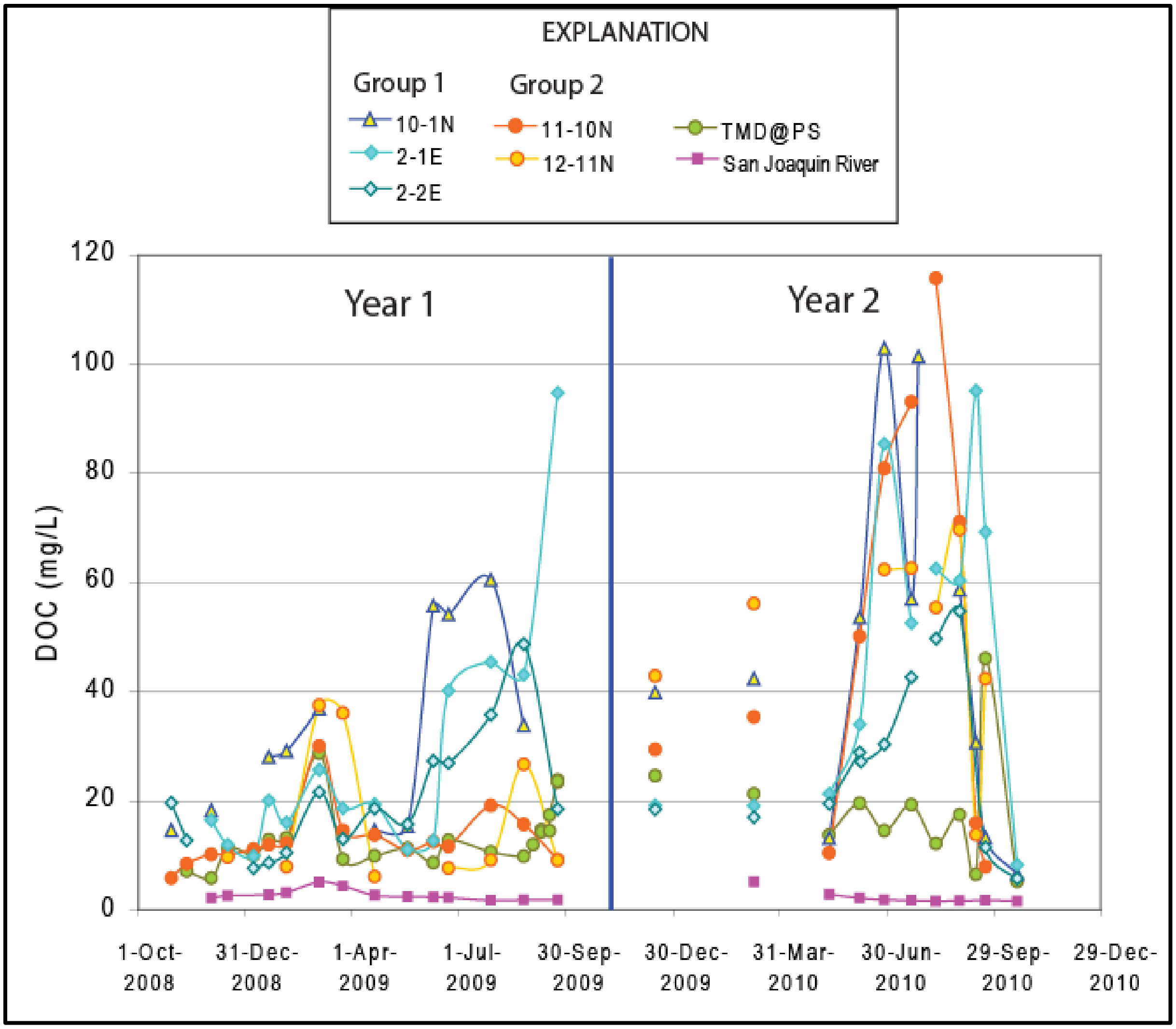
Source: USGS

Water Quality Monitoring

Water quality samples from the drain water of the rice paddies have been collected since October 2008 at six locations. **Figure 13-36** shows the agricultural operations at the rice study area and the sample locations. DOC, methyl mercury, and total dissolved nitrogen were analyzed in the samples.

There was a wide range in DOC concentrations during 2009 and 2010, the first two seasons of operation. The data were presented in a USGS 2010 Annual Report and are shown in **Figure 13-37.** Groups 1 and 2 were collected in the drains from the rice fields, with rice drains noted as 2-2E, 2-1E, 1-10N, and corn/oats drains noted as 13-11N and 11-10N. As stated above, since all fields were converted to rice in 2010, these drains represent rice drains in 2010. Site 2-1E represents the main ditch drain for the entire rice system. The TMD@PS site represents the recycled irrigation water applied to the rice fields from the Main Drain. The San Joaquin River site represents the raw water applied to the rice fields from the river.

Figure 13-37. DOC Concentrations in Twitchell Island Rice Study Area



Source: USGS

The lowest concentrations of DOC were found in the San Joaquin River and the recycled irrigation water applied to the rice fields. During 2009, when rice fields were flooded from May through August, DOC concentrations increased in the rice drains, but were lower in the corn/oats drains. High drain-water concentrations associated with rice are the result of flushing of DOC generated during oxidation in shallow soils. As only rice was planted in 2010, there were high DOC concentrations at all locations except for recycled irrigation water and the San Joaquin River. In 2010, median DOC concentrations during the irrigation season ranged from 35 to 80 mg/L.

Generally, there was a temporal trend showing peak concentrations during the June through September period of both harvest seasons for rice. This represents the flooding and draining periods of the harvest. DOC concentrations were also elevated during the winter season of 2009. The drain sites generally represented both surface and seepage flows, but Site 11-10N was blocked in the 2010 season so that it solely represented seepage flows from fields 10 and 11. This site accounted for the highest levels of DOC during the 2010 flood season.

During the 2009 and 2010 planting seasons, concentrations of methyl mercury in unfiltered drain water samples ranged from 0.1 to over 2.5 ng/L and were elevated in all drains relative to the nearby San Joaquin River water where previously reported concentrations ranged from 0.05 to 0.25 ng/L. Mean concentrations of methyl mercury were significantly higher in rice drains 10-1N and 2-2E relative to the corn/oats drain. In 2009, the highest methyl mercury concentrations occurred during the non-flooded conditions in the rice fields yet in 2010 the highest methyl mercury concentrations occurred during the irrigation season.

Sherman Island Mayberry Farms, Farm Scale Tule Project

The Mayberry Farms Subsidence Reversal Project was designed to permanently restore approximately 274 acres of wetlands on land owned by DWR on Sherman Island. The location is shown in **Figure 13-35**. The goals of the project include subsidence reversal, carbon sequestration, and use as a duck club for hunting. The property was historically managed as winter-flooded wetlands and for grazing. If successful, this project may be expanded to additional acreage on the island.

Project construction, completed in 2010, included improving the perimeter ditches, interior berms, interior water conveyance channels, intake siphons, and water control structures. In addition, a buttress berm and seasonally flooded loafing islands for waterfowl were constructed. The site is divided into seven wetland management units separated by four existing interior berms, and crossed with excavated conveyance channels to facilitate appropriate water and vegetation management capabilities. Water levels in each unit are manipulated independently to restore, create and maintain the desired conditions for tule growth throughout the site year-round, effectively creating a permanent wetland.

The project will be tracked for subsidence reversal by DWR, greenhouse gas carbon flux by the University of California Berkeley, and methyl mercury production through the wetlands by the California Department of Fish and Game. Since the goals of the project are focused on subsidence and carbon sequestration, at this time monitoring of water for organic carbon is not planned.

Other Studies Related to Wetlands and Organic Carbon

In addition to the work conducted by Fleck et al. (2006), there have been a number of studies investigating how wetlands may contribute DOC and POC to Delta waters as described below:

Kraus et al. (2008) evaluated a wider range of habitats in the Delta to determine which habitat types contribute DOC and DBP precursors, how they vary seasonally, and which habitats contribute to the composition of DOC being exported from the Delta at Clifton Court. The habitat types studied can be broadly divided into rivers, open waters, island drains, and wetlands. Three different wetland habitats were sampled: Mandeville Tip (WM), a natural freshwater tidal marsh located on peat soil in the central Delta; a reconstructed flow through a demonstration wetland (WD) located on Twitchell Island; and Shag Slough (WS), a dendritic wetland area located in the northern Delta on mineral soil, which drains the Yolo Bypass freshwater floodplain. Two open water sites created by the flooding of subsided islands were sampled: Little Frank's Tract (OF), dominated by submerged aquatic vegetation and Mildred Island (OM), dominated by algal production. In addition, two drains were sampled on Twitchell and Staten islands.

A scientific literature review related to DOC generation from tidal wetlands was completed in 2010 by the Solano County Water Agency. The purpose of the literature review was to provide background information for comments on the Liberty Island Conservation Bank Negative Declaration.

A study conducted from 2000 to 2003 (Deverel et al., 2007) on Twitchell Island quantified processes affecting organic carbon concentrations and loads in agriculture drainage water. This work is important in order to compare existing organic carbon loads produced from agriculture areas, to predicted organic carbon loads if these agricultural areas are converted to tidal wetlands, as proposed by the BCDP. The study attempted to measure the DOC and trihalomethane formation potential (THMFP) loads per area contributed by agricultural drainage, and identify the primary hydrologic and geochemical processes affecting DOC loads and concentrations.

The following key findings are based on reviewing these three sources of information:

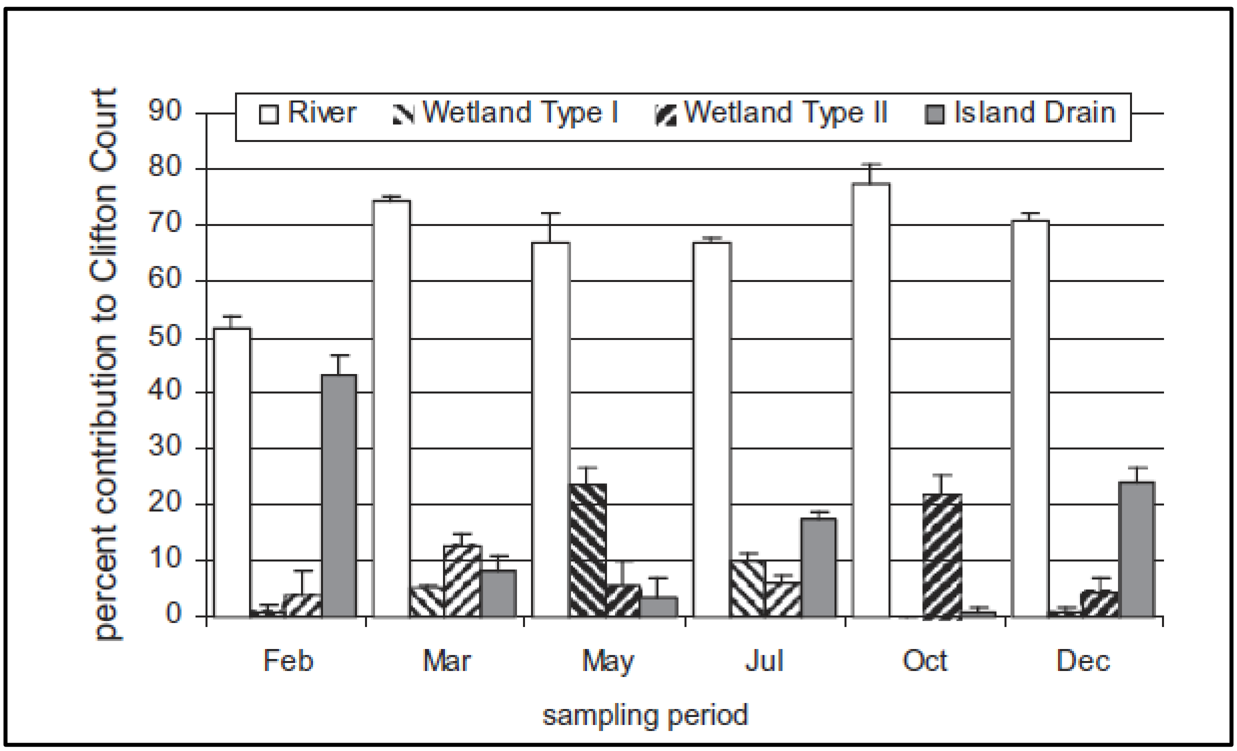
- The general consensus in the scientific literature is converting Delta islands currently managed for agriculture into tidal wetlands will increase DOC production in the Delta. Kraus et al. (2008) found that water leaving tidal wetlands (Shag Slough and Twitchell Island) typically has DOC concentrations 1.0 to 2.0 mg/L higher than ambient water in the adjacent Delta channels. This increase varied seasonally, with larger increases occurring in March through July. These results are similar to the findings of the Fleck study discussed earlier.

- Although there is consensus that DOC production will increase as a result of converting agricultural land into tidal wetlands, there is less consensus on the magnitude of the increase. This is because tidal wetlands exhibit differences in the amount and quality of DOC they produce. Soil type, soil history, hydrology, percentage of open water habitat, vegetation, and retention time have been shown in various studies to impact DOC loading. Therefore, accurate predictions of DOC loading and quality cannot be made in advance of restoration (ESA PWA, 2010).

- In addition to increasing DOC concentration, converting agricultural land to restored wetlands is likely to alter the chemical composition of DOC and the resulting DBPs. For example, DOC produced in tidal wetlands (per unit mass) typically has greater propensity to form TTHMs than DOC produced from rivers or agriculture (ESA PWA, 2010). Kraus et al. 2008 found that both THMFP and haloacetic acid formation potential (HAAFP) increased as water passed through the three shallow wetlands, ranging from a 1.0 to 3.3 fold increase in THMFP, to a 1.2 to 4.3 fold increase for HAAFP. Comparisons of HAA production rate vary, with some studies reporting greater rates for agriculture and others reporting greater rates for wetlands.

- The Kraus study determined the percent dissolved organic matter (DOM) contribution from different habitat types to DOM arriving at Clifton Court as shown in **Figure 13-38**. Overall, the Sacramento and San Joaquin rivers were the main sources of DOM at Clifton Court. Island drains are particularly important contributors to DOM at Clifton Court during February and December, contributing 43±9 percent and 24±7 percent respectively. In contrast to the winter months, wetlands appeared to be the primary source of DOM added by the Delta, with Type I (peat soil) wetlands contributing 24±7 percent and Type II (mineral soil) wetlands contributing 6±4 percent in May. In July, wetlands contributed 16 ± 2 percent of DOM to Clifton Court. Therefore, wetland DOC production peaks in the late spring and early summer, and agricultural DOC production peaks in winter when water is pumped from fields into Delta channels. This is consistent with work completed by Deverel et al. 2007 which showed that DOC loading from agricultural drains was highest from December to April, and lower from May to November.

Figure 13-38. Percent Contribution of DOM arriving at Clifton Court – Results from Linear Mixing Model



Source: Kraus et al. (2008).
Note: Error bars indicate standard error for different model runs (n=6)

OVERALL FINDINGS

There is consensus that DOC production will increase as a result of converting agricultural land into tidal wetlands. Recent studies have also shown that an expansion of wetlands has the potential for raising Delta DOM concentrations in spring and early summer. Therefore, restoration may shift the overall DOC peak towards spring and summer, later than the current winter peak. This temporal shift in DOC loading may affect the overall loading to drinking water since more water is typically pumped during the spring and summer than during the winter.

Studies conducted to date indicate that there is great opportunity for subsidence reversal and carbon capture through wetlands and rice cultivation in the Delta. It is still uncertain if widespread implementation of these projects will occur in the Delta. The studies have included evaluation of the potential impacts to receiving waters, in particular the contribution of DOC. Wetlands and rice cultivation have been shown to both contribute elevated amounts of DOC in the drainages, particularly in the seepage flows through shallow groundwater. The highest loading of DOC from both wetlands and rice occurred during the summer months. Additional studies on the managed wetlands and rice crops will further examine the amount, extent, and potential factors influencing the transport of DOC to receiving waters.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following action related to agricultural management practices in the Delta:

Track Research on Delta Agricultural Management Practices and Identify Appropriate Actions for SWPCA.

This action item was classified as a long-term action, meaning that it addresses longer-term water quality issues of a non-critical nature. Since USGS is continuing to conduct work on converting to rice crops on Delta islands, SWPCA and MWQI decided to await the results of the study before determining if any action is needed.

POTENTIAL ACTIONS

SWPCA and MWQI should Track Carbon Sequestration and Subsidence Reversal Projects being Conducted by USGS and DWR.

SWPCA and MWQI should track these projects to ensure that the impacts on drinking water quality are fully evaluated. The funding for monitoring for drinking water constituents has been substantially reduced. SWPCA should contact DWR and USGS to recommend that drinking water constituents be included in the monitoring programs. If needed, SWPCA should send a letter to DWR requesting that drinking water constituents be included in the monitoring program.

RECREATIONAL USE OF THE DELTA

BACKGROUND

The 2006 Update contains a detailed discussion of recreational use of the Delta, the impacts on water quality, and measures taken to protect water quality. This section contains an update on recreation management in the Delta.

The Delta Protection Commission (DPC) has estimated that there are over 12 million visitors to the Delta annually, including about 500,000 boaters (Sacramento-San Joaquin Delta Factsheet, DPC Website, 2011). This includes shoreline recreation (picnicking, hiking, camping, hunting), boating, fishing, water-skiing, and other recreational activities along the Delta's 57,000 acres of navigable waterways. All of these activities have the potential to impact water quality in the Delta. Recreational usage of the Delta occurs throughout the year but is most significant on weekends between Memorial Day and Labor Day, with peak usage over the Fourth of July weekend. Demand for recreational usage of the Delta is expected to increase as the population of communities in and near the Delta grows.

Recreational usage of the Delta can contribute trace metals from boat hull paints; petroleum hydrocarbons from fueling, spills, and fuel combustion from outboard motors; and pathogens from boat sewage discharges and personal sanitary habits. Petroleum hydrocarbons can be released into Delta waters but hydrocarbon contamination of Delta water supplies has not been identified by the Technical Review Committee as a significant concern. The primary impact of recreation on Delta water supplies is the release of human pathogens through body contact recreation and dumping of sewage from boats.

A Boater Survey was conducted by the California Coastal Commission (Coastal Commission) from 2007 through 2009 to better understand boaters and their habits (Boater Survey, 2011). This was a statewide survey which included boaters in the Delta (about 25 percent of the survey respondents). It found that over 40 percent of respondents believed that other boaters illegally discharge sewage into the water. Only about half of the boaters in the Delta reported having sanitation devices on their boats. The majority of boaters were unaware that there is a penalty (a fine up to $2,200) for illegal discharge, and less than one-third of the boaters recognized the National Sewage Pumpout logo. And while less than 19 percent of respondents knew that the Delta provides drinking water for over 50 percent of the State's population, a large majority said they were very concerned about the drinking water quality of the waters.

DELTA RECREATION MANAGEMENT

The DPC was created in 1992 as a means of implementing the Delta Protection Act and is charged with adaptively protecting, maintaining, and where possible, enhancing and restoring the overall quality of the Delta environment, including recreational activities. The DPC created a Land Use and Resource Management Plan to guide the activities. The plan is updated every five years, most recently in 2010. There are 13 policies related to recreation and access which guide the DPC activities, as shown below.

DPC Recreation and Access Policies

1. Ensure appropriate planning, development and funding for expansion, on-going maintenance and supervision of existing public recreation and access areas.
2. Encourage expansion of existing privately-owned, water-oriented recreation and access facilities that are consistent with local General Plans, zoning regulations and standards.
3. Assess the need for new regional public and private recreation and access facilities to meet increasing public need, and ensure that any new facilities are prioritized, developed, maintained and supervised consistent with local, state, and federal laws and regulations. Ensure that adequate public services are provided for all existing, new, and improved recreation and access facilities.
4. Encourage new regional recreational opportunities, such as Delta-wide trails, which take into consideration environmental, agricultural, infrastructure, and law enforcement needs, and private property boundaries. Also, encourage opportunities for water, hiking, and biking trails.
5. Encourage provision of publicly funded amenities such as picnic tables and boat-in destinations in or adjacent to and complimentary to private facilities, particularly if the private facility will agree to supervise and manage such amenities, thus lowering the long-term cost to the public.
6. Support multiple uses of Delta agricultural lands, such as seasonal use for hunting and provision of wildlife habitat.
7. Support improved access for bank fishing along State highways, county roads, and other appropriate areas where safe and adequate parking, law enforcement, waste management and sanitation facilities, and emergency response can be provided and where proper rights-of-access have been acquired.
8. Ensure, for the sake of the environment and water quality, the provision of appropriate restroom, pump-out and other sanitation and waste management facilities at new and existing recreation sites, including marinas; encourage the provision of amenities including but not limited to picnic tables and boat-in destinations.
9. Encourage the development of funding and implementation strategies by appropriate governing bodies for the surrender and/or removal of water-borne debris and dilapidated, unseaworthy and abandoned vessels from waterways, to minimize navigational and environmental hazards.
10. Promote and encourage Delta-wide communication, coordination, and collaboration on boating and waterway-related programs including but not limited to marine patrols, removal of debris and abandoned vessels, invasive species control and containment, clean and safe boating education and enforcement, maintenance of existing anchorage, mooring and berthing areas, and emergency response in the Delta.
11. Recognizing existing laws, encourage establishment of Delta-wide law enforcement protocols on local public nuisance and safety issues, such as trespassing, littering, and theft.
12. Support and encourage programs for waterways that provide opportunities for safe boating and recreation, including removal of floating and sunken debris and abandoned vessels from Delta waterways in collaboration with appropriate agencies.
13. Support the development of a strategic plan, in consultation with all law enforcement agencies having jurisdiction in the Delta, to improve law enforcement and the use of available resources to ensure an adequate level of public safety.

Department of Parks and Recreation Draft Recreation Proposal

In November 2009, the Delta Reform Act created the Delta Stewardship Council and charged it with developing a Delta Plan to balance the co-equal goals of drinking water supply and ecosystem health in the Delta. The Delta Plan will be adopted in the fall of 2012. This plan must include protection of recreational use of the Delta. As part of that planning, the California Department of Parks and Recreation (Parks and Recreation) prepared a Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh in May 2011.

The Recreation Proposal developed an inventory of state recreational facilities in the Delta and Suisun Marsh. Currently there are four parks (Brannan Island State Recreation Area [SRA], Franks Tract SRA, Delta Meadows and Locke Boarding House, and Stone Lake) located within the Delta and several others in close proximity. Parks and Recreation recommended modifying the facilities or uses at these parks and development of new parks in the Delta. The highlights of the recommendations include:

- Brannan Island SRA – Rehabilitate and expand facilities related to boating and fishing. This also includes partnerships to connect recreational opportunities on other Delta islands.

- Franks Tract SRA – Expand boating, fishing, and hunting activities.

- Delta Meadows and Locke Boarding House – Complete park planning and implementation, including on-shore activities, fishing, and possible water trails. This also includes partnerships to connect recreational opportunities with other state facilities.

- Stone Lake – Continue as a wildlife habitat, but consider connecting to a regional recreational trails system.

- Potential Future State Parks – Creation of wildlife habitat and passive recreational facilities at Barker Slough. Creation of an upland recreation area in the South Delta, possibly in the Old River area.

There are also recommendations related to the recreational use of other state and Federal lands. As part of all of these additional recommendations, Parks and Recreation is encouraging the development of floating campsites/day use areas and expanded waterfowl hunting programs (boat-in and longer-term). This includes potential development of a regional Water Trail Plan, creation of a National Heritage Area and the Great California Delta Trail through the DPC, and potentially increasing the recreational use of SWP facilities.

In addition, DPC is preparing an Economic Sustainability Plan that will inform the Delta Stewardship Council on the economic sustainability of recreational activities in the Delta. Boating and fishing are estimated to generate nearly 80 percent of the recreation and tourism spending in the Delta. Despite significant population growth in the area, data suggests that boating and fishing activity in the Delta has grown little in the past 20 years. Boat registrations, the number of marinas, and staffing at boating related businesses are about the same as a decade ago. DPC predicts that land-based activities such as agritourism, wine tasting, wildlife watching, historic and cultural tourism, bicycling, and driving for pleasure will constitute future growth in Delta recreation. Recreational visitation could increase by 3.4 million visitor days over the next 40 years.

Future Recreation Projects

In 2006, Senate Bill (SB) 1556 was passed which requires the DPC to establish a continuous recreation corridor, including bicycle and hiking trails, around the Delta. The vision is for the trail to link the San Francisco Bay Trail system and planned Sacramento River trails in Yolo and Sacramento counties to present and future trail ways around and in the Delta. This will include Delta shorelines in Contra Costa, San Joaquin, Solano, Sacramento, and Yolo counties. The DPC is facilitating the Delta Trail feasibility and planning process. A Blueprint Report for Contra Costa and Solano Counties was completed in September 2010. This was a pilot project to identify how the planning process would take place. Solano County has approved the report and Contra Costa County is currently reviewing it. A Blueprint Report for Sacramento, Yolo, and San Joaquin counties is now in the works and is expected in 2012. Once these reports are approved, a detailed Delta Trail Master Plan can be prepared which will have the specifics of the trail locations. Funding sources for trail planning and project design are being sought and it is expected that this will take five to ten years to complete (Personal Communication, Alex Westhoff, 2011).

WATER QUALITY IMPACTS

There are many sources of pathogens and indicator organisms in Delta waters, including recreation, discharges of treated wastewater, faulty septic systems, urban runoff, animal operations such as dairies, and wildlife. Although the contribution from recreation has not been quantified relative to other sources of contamination, those working in various aspects of recreation management consider recreation to be a source of human pathogens. Sources of human pathogens due to recreation can be attributed to three areas:

- Recreational Users – The Delta is used for boating and associated body-contact recreation such as water-skiing. There are few swimming beaches in the Delta. Pathogens are introduced to Delta waterways through shedding and personal sanitary habits during body-contact recreation and through dumping of untreated wastewater from boats. Even boats with marine sanitation devices (MSDs) may be sources of pathogens if the devices are not adequate or properly maintained. Sewage from boats is concentrated because MSDs use little water for flushing.

- Marinas and Liveaboards – A review of several sources indicates that there are 94 marina or landing facilities in the Delta. The sizes vary significantly. Less than half, 41, provide sewage pumpout facilities. Inadequate facilities or improper handling of sewage at marinas can be a source of pathogens. Liveaboards are people who live on their own boats or with the boat owner’s permission. Some marinas allow people to live on boats that are moored at the marina, often permanently. Some marinas have adequate restroom and pumpout facilities; however, some marinas have no restroom or pumpout facilities so liveaboards use the Delta to dispose of their waste. There are also people living on boats that are moored to private property or illegally.

- Abandoned Vessels and Squatters – Another problem is squatters living on abandoned derelict boats. Some boat owners illegally abandon their boats in Delta channels rather than paying to properly dispose of them when they are no longer wanted. The abandoned boats are often not seaworthy and do not have adequate restroom facilities, therefore sewage is routinely dumped overboard.

Several waterways in, or partly in, the Delta are listed as impaired for bacteria and/or pathogens. Six urban waterways (Lower Calaveras River, Five Mile Slough, Mormon Slough, Mosher Slough, Smith Canal, and Walker Slough) have had a TMDL developed and approved by the Central Valley Regional Water Board and USEPA in 2008, the Stockton Urban Water Bodies Pathogens TMDL. It was determined that urban runoff was the likely source, not recreation, and it is being further assessed through the City of Stockton Stormwater Program. There are four additional waterways in the eastern portion of the Delta waterways (Bear Creek, Lower Cosumnes River, French Camp Slough, and Pixley Slough) and three additional waterways in the western portion of the Delta waterways (Kellogg Creek, Marsh Creek and Sand Creek) that have been listed for *E. coli*, but the source is unknown at this time. A TMDL is expected for all of these waterways by January 1, 2021.

The Central Valley Regional Water Board has conducted five Safe-to-Swim studies: an initial screening study in 2007, a region-wide study in 2008, a follow-up study in 2009, another small follow-up study in June 2010, and a larger region-wide study in August and September 2010. In these studies, local swimming holes were sampled before, during, and after peak recreational use periods (generally holiday weekends) for a variety of pathogens and indicator organisms. The results vary significantly from site to site, but did include some sites that exceeded the USEPA body contact recreation guide for *E. coli* of 235 MPN/100 mL. The first four sampling studies did not include sampling sites located in the Delta and the results from the last study have not been posted yet.

Although high levels of indicator bacteria have been found in waterways tributary to the Delta, the indicator bacteria data that have been collected at the pumping plants that supply the SWP are much lower, and the levels of indicator bacteria at SWP Contractors' intakes are also much lower, as discussed in **Chapter 10**. In addition, the SWP Contractors who have conducted monitoring for *Cryptosporidium* have had few, if any, detections and have been placed in Bin 1 of the Long Term 2 Enhanced Surface Water Treatment Rule and will not be required to provide further removal or inactivation (see **Chapter 10**).

PROGRAMS TO PROTECT WATER QUALITY

The Clean Water Act prohibits untreated vessel discharge in U.S. waters and the Porter Cologne Act prohibits untreated sewage discharges throughout the state. Marinas and recreational boating are considered nonpoint sources of pollution and are regulated by the State Water Board's Nonpoint Source Program, primarily through voluntary programs. The Central Valley Regional Water Board has the authority and responsibility to enforce these acts but lacks staff resources to operate a program to inspect boats or take enforcement actions against illegal dumpers.

Enforcement of existing laws has been mainly by local agencies. Local agencies that patrol the Delta are the five county sheriff departments (Sacramento, Yolo, Solano, Contra Costa, and San Joaquin) and the police departments of the cities of Sacramento and West Sacramento.
Under current law, law enforcement officers can inspect a boat to determine if it has an operating MSD if there is reasonable cause to suspect illegal discharge of wastewater . If the boat has a working MSD, there is nothing else that can be done regardless of whether the officers believe the boat is not capable of traveling to a pumpout facility. Law enforcement officers must observe dumping of sewage or must have photos or video from a witness before any further action can be taken. Due to limited staffing associated with enforcing existing laws, there is virtually no chance that a law enforcement officer would actually observe a dumping incident.

Another opportunity to protect a drinking water intake is to have a No-Discharge Zone declared by the USEPA under Section 312 of the Clean Water Act. This would prevent vessels from discharging sewage in a designated zone near the intake. The state would need to apply to USEPA for this designation. Currently, there are no such designations in the Delta.

The 2008 Vessel General Permit regulates discharges incidental to the normal operation of vessels operating in a capacity as a means of transportation. Recreational vessels, as defined in Section 502(25) of the Clean Water Act, are not subject to this permit. The permit includes general effluent limits applicable to all discharges; general effluent limits applicable to 26 specific discharge streams; narrative water-quality based effluent limits; inspection, monitoring, recordkeeping, and reporting requirements; and additional requirements applicable to certain vessel types.

Recreational Boater Education

There are a number of boater education programs that provide information on boating safety, proper disposal of hazardous wastes, and proper sewage handling facilities.

- California Clean Boating Network – This program, established by the Coastal Commission in 1995, consists of a collaboration of government, environmental, business, boating, and academic organizations working to improve clean boating education efforts in California. They publish a quarterly newsletter, "The Changing Tide" which aims to educate boaters about clean boating in California.

- Boating Clean and Green Campaign – This program is a statewide boater education and technical assistance program conducted by the Coastal Commission in partnership with the California Department of Boating and Waterways (Boating and Waterways) that promotes environmentally sound boating practices information to marine businesses and boaters. Most of the funding is from the California Integrated Waste Management Board's Used Oil Program so the focus has been on oil and recycling issues. The program distributes boater kits, participates in boat shows, posts signs at boat launch ramps, provides displays at marinas, advertises in boating publications, and trains Dockwalkers. Dockwalkers are volunteers trained to talk to other boaters about clean and safe boating. To date, over 600 volunteer Dockwalkers have been trained, with about half of those in Northern California.

- Keep the Delta Clean Campaign – In 2004, Contra Costa County obtained grant funding from Proposition 13 for the Marina and Recreational Boating Program, entitled "Keep the Delta Clean, You Play In It, You Drink It Too!" The County teamed with the Coastal Commission and Boating and Waterways to implement the program. The program was piloted from 2004 to 2006 at five marinas to establish pollution prevention policies that include sewage pump-outs. In 2007, additional funding was received to expand the program to the other four Delta counties. That funding provided additional services through 2009 and now the managing agencies must maintain the program through 2029. The primary focus of the program is boater education and prevention of spills or purposeful disposal of hazardous materials such as motor oil. The Keep the Delta Clean Campaign has teamed with volunteer Dockwalkers to distribute free boater kits in the Delta. The kits include a Delta map showing the locations of marinas with sewage pumpout facilities and providing advice on proper handling of sewage. A website has been developed that provides links to other programs, the locations of environmental services throughout the Delta, and a very large, comprehensive map of the Delta.

- Dump at the Pump Website – The Estuary Project was originally funded by Clean Vessel Act funds administered by Boating and Waterways to create materials for distribution including fact sheets, maps showing locations of pumpouts and dump stations, a slide show, and a bill insert. This has been converted to a "Dump at the Pump" website, found on Boating and Waterways website, which provides pumpout locations throughout the state through mapping tools.

- Lakes and Reservoirs Appreciation Week – This is a statewide appreciation week designated by DWR, which occurs the first week of July each year. DWR provides a multi-media campaign in which environmentally mindful ways of enjoying lakes and reservoirs are promoted. The program also airs radio advertisements that focus on boater safety and sewage pollution prevention.

- Keep Our Waters Clean Campaign – This program is funded by local water providers, cities, and counties in the Sacramento region. The campaign focuses primarily on identifying and promoting the use of pumpouts and restrooms in Sacramento area waterways. A website was developed to provide the information as well. The program includes partner marinas flying flags that show the location of their pumpouts, and distribution of maps showing the location of pumpouts and restrooms at marinas, boater events, and through boat stores.

Marina Operations

Boating and Waterways administers the Pumpout Grant Program, under the 1992 Clean Vessel Act, that reimburses private marina owners and local governments for 75 percent of the cost for construction, renovation, operation, and maintenance of pumpout and dump stations that are open to the public. The goal of the program is to reduce discharge of vessel sewage into the state's waters. The Pumpout Grant Program typically grants $250,000 annually to inland waters (Personal Communication, Kevin Atkinson, Boating and Waterways). This includes one to five grant requests per year and can represent either new, replacement, or maintenance requests. For inland waters, there are more requests and funding for floating toilets from a combined program with the vessel grant program. Approximately $1million is granted annually throughout the state, with inland waters representing about eight to ten requests per year. None of these have been installed in the Delta to date and it is unlikely that they would receive funding since they are not considered “remote” from land access.

There is a considerable amount of information available to marina operators on how to operate an environmentally sound and clean marina.

- The Nonpoint Source Program Plan includes 16 voluntary management measures for new and expanding marinas (State Water Board et al., 2000). Two of the management measures deal with the design and maintenance of sewage facilities at marinas. The California Nonpoint Source Encyclopedia is an online tool which provides guidance on identification and implementation of management measures to protect water quality from nonpoint sources (State Water Board, 2008). This tool has a section devoted to marinas.

- In 2003, the San Diego Regional Water Board issued a draft NPDES permit for recreational boat marinas due to concerns that marinas were a significant source of unregulated contaminants. In response to the draft permit, marina operators worked with the San Diego Central Valley Regional Water Board to develop a Clean Marina Program that is administered by the Marina Recreation Association. This voluntary program relies on marinas to implement management measures and apply for certification as a clean marina. A certification checklist and guidance document was developed to assist marina owners in obtaining certification. Once obtained, the certification is good for five years. The program has expanded throughout California and into Nevada. One hundred thirteen marinas have been certified, mostly in Southern California. Three Delta marinas have been certified; the marinas for the cities of Pittsburg and Antioch as well as Tower Park Marina.

- The Coastal Commission developed a Clean Marina Toolkit to provide marina operators with information on management measures they could voluntarily implement to operate a marina with minimal impacts on water quality (Coastal Commission, 2004). The Toolkit also contains fact sheets and other public information materials, including a fact sheet on sewage management strategies.

Vessel Abatement Programs

There are three key state programs that address the issue of abandoned vessels. Boating and Waterways implements the Abandoned Watercraft Abatement Fund Program and the Vessel Turn-in-Program. The California Department of Resources, Recycling and Recovery (Cal-Recycle) operates the third program, providing grants administered from the Solid Waste Disposal Cleanup Program.

The Abandoned Watercraft Abatement Fund Program provides grants to public agencies to remove, store, and properly dispose of abandoned recreational vessels that pose a substantial hazard to navigation. A ten percent local agency matching fund is required. This program does not include commercial vessels. Between Fiscal Years 2005/2006 and 2010/2011, there were 16 contracts issued to agencies in Delta counties, totaling $920,000. This resulted in the removal of 209 hazards (Personal Communication, Denise Peterson, Boating and Waterways). Contra Costa and Sacramento counties have prepared grant proposals and have been awarded funds to remove abandoned boats in the Delta, but the other Delta counties have not been as active. As of April 2010, Contra Costa County had removed 350 recreational vessels through this program, with some of the matching funds provided by Contra Costa Water District. The Sacramento County Sheriff Marine Enforcement Detail also participates in the program and they typically receive funding to remove from one to four boats per year, mostly in the Delta. Obstacles to successful operation of this grant program are the difficulty raising local matching funds and the inability to use funds for abandoned commercial vessels. The DPC has organized an abandoned vessels workgroup to address these concerns, which includes representatives from law enforcement and resource management from the five Delta counties, the Coast Guard, and boating organizations. The workgroup is trying to develop a Delta specific fund for the local agency match and is pursuing regulatory change to allow commercial vessels to be included (Personal Communication, Marc Ceccarelli, DPC).

The second Boating and Waterways program is the Vessel Turn-in-Program, established by Assembly Bill (AB) 166. This program is different in that it targets boat owners who don’t want boats any longer and gives them an opportunity to surrender their boats to a local agency instead of abandoning them. This is a voluntary pilot program operating from 2010 through 2014. Similar to the Abandoned Watercraft Abatement Fund Program, it requires a ten percent matching fund. In the Delta, only the Contra Costa County Sheriff Marine Operations has participated. At this time there is no information available on the amount of funding (Personal Communication, Denise Peterson, Boating and Waterways).

Cal-Recycle implements the third program, which provides grants to public entities to abate illegal disposal sites, as part of the Solid Waste Cleanup Grants and Loans Program. AB 2136 required Cal-Recycle to initiate this program for cleanup of solid waste sites and solid waste at co-disposal sites where the responsible party either cannot be identified or is unwilling or unable to pay for timely remediation and where cleanup is needed to protect public health and safety and/or the environment. In 2009 and 2010, Cal-Recycle spent $850,000 to help clean up boats in the Delta through grants administered from this program. The funds go to local entities to help clean up abandoned vessels with hazardous materials onboard. The grant does not require matching funds and can be used for larger commercial and recreational vessels. In the Spring 2010, Contra Costa County Sheriff Marine Operations worked with Cal-Recycle to obtain a $350,000 grant for a major cleanup of Fisherman’s Cut (between Bradford Island and Webb Tract) and to remove 12 commercial vessels and remediate three water hazard sites in this long-used dumping area.

Other efforts to prevent abandonment of boats and to address untreated sewage dumping have also been pursued locally and statewide.

- AB 2362, which became law in 2003, expanded the right of law enforcement officers to board and inspect vessels when they reasonably suspect they are discharging illegally to determine if they have MSDs and to introduce dye tablets into holding tanks to determine if they are leaking.

- AB 1014 required Boating and Waterways to establish an Abandoned Vessel Advisory Committee in 2003 to develop strategies to address boat abandonment. This effort resulted in passage of AB 716 in 2005 which makes it easier for local agencies to remove and dispose of abandoned boats. The law increased penalties for abandoning a boat, reduced the waiting time before a local agency can sell a boat at auction, and made boats operating with registration expired for more than one year one of the criteria for removing a boat from a waterway.

- Currently, SB 595 is being proposed to streamline the process to adjudicate vessels as this has been difficult for some local law enforcement agencies. The bill proposes that the State Lands Commission remove and dispose of abandoned and trespassing vessels on state lands through an administrative process. An abandoned vessel will be identified and a posted notice will be placed on the vessel to inform the owners that they have 30 days to remove the vessel. If the owner refuses or does not respond, the removal can be approved by the State Lands Commission and the vessel disposed.

- Contra Costa County – A County ordinance prohibits mooring of all vessels in waterways, with the exception of houseboats and liveaboards that meet certain requirements. A properly-equipped houseboat or liveaboard can be moored in a waterway for up to 30 days if it does not impede navigation, is capable of self-propelled navigation, and has a Coast Guard certified MSD or a self-contained portable toilet. All other vessels can be moored at permitted docks or marinas, provided all permit conditions are met. Houseboats and liveaboards can also be moored at marinas or permitted docks if they are capable of self-propelled navigation, do not obstruct navigation, and have an operable MSD or are connected to a sewer system at a marina.

- Solano County – A County ordinance prohibits mooring of vessels, other than a houseboat or liveaboard, in a waterway in excess of 96 hours unless it is zoned, licensed, and bonded with an adjacent industrial or commercial business. A properly equipped houseboat or liveaboard can be moored in a waterway for up to 30 days if it does not impede navigation, is capable of self-propelled navigation, and has a Coast Guard certified MSD or a self-contained portable toilet. All other vessels can be moored at permitted docks or marinas, provided all permit conditions are met. Houseboats and liveaboards can also be moored at marinas or permitted docks if they are capable of self-propelled navigation, do not obstruct navigation, and have an operable MSD or are connected to a sewer system at a marina.

- San Joaquin County – A County ordinance prohibits mooring of vessels, other than a houseboat or liveaboard, in a waterway in excess of 15 days. A properly equipped houseboat or liveaboard can be moored in a waterway for up to 30 days if it does not impede navigation, is capable of self-propelled navigation, and has a Coast Guard certified MSD or a self-contained portable toilet. All other vessels can be moored at permitted docks or marinas, provided all permit conditions are met. Houseboats and liveaboards can also be moored at marinas or permitted docks if they are capable of self-propelled navigation, do not obstruct navigation, and have an operable MSD or are connected to a sewer system at a marina.

- Sacramento County – The County has the most detailed mooring restrictions. A County ordinance requires a permit to moor, anchor, ground, or otherwise locate any vessel in a waterway for more than 14 days. A vessel must have a Coast Guard certified MSD or a portable toilet to obtain a permit. With a valid permit, a vessel may be anchored in a waterway for up to 30 consecutive days in a 60 day period, provided: it is seaworthy and does not pose a threat of pollution or sanitation hazard, it does not impede navigation, is capable of self-propelled navigation, and has a Coast Guard certified MSD or a self-contained portable toilet. Vessels can also be moored at marinas or permitted docks if they are capable of self-propelled navigation, do not obstruct navigation, have an operable MSD or are connected to a sewer system at a marina, and meet all permit requirements. There are special allowances for Delta Meadows, Lost Slough, Steamboat Slough, and Snodgrass Slough. Vessels are allowed to anchor in these areas up to 180 days between May 1 and October 31, with a valid permit. This includes a proof of pumpout submitted to the Sheriff.

- City of Sacramento – A City ordinance prohibits the discharge of sewage into waterways, prohibits anchoring or mooring vessels that are not seaworthy, and requires an anchorage permit for anchoring longer than 30 days. Permitted boats must maintain a sanitation log and discharge sewage to a pumpout every four days. This ordinance only covers the part of the Delta that is within the jurisdiction of the City of Sacramento (Sacramento River between I Street Bridge and Freeport). This ordinance has resulted in the removal of derelict boats from the area.

STATUS OF ACTION ITEMS

The 2007 SWP Action Plan contains two actions related to recreation in the Delta.

Send Letters of Support to Coastal Commission and Boating and Waterways.

This action item was categorized as high priority because it was easy to implement and would alert these agencies to the fact that their programs to protect water quality are important to DWR and the SWP Contractors. Letters have not been sent because there has not been an event that would trigger a response from DWR and the SWP Contractors.

Contact Delta Protection Commission to Discuss Abandoned Vessels

This action item was categorized as long-term. After the preparation of the 2007 Action Plan, the DPC formed an abandoned vessels workgroup. A member of the MWQI Specific Projects Committee regularly attends the workgroup meetings. In addition, letters of support were sent to the Senate and Assembly Appropriations committees for bills that were introduced to more effectively manage abandoned vessels (AB 166 and SB 459).

POTENTIAL ACTIONS

SWPCA should Track Delta Recreational Management Plans and Proposals.

There are a number of activities in the Recreation Proposal, developed by Parks and Recreation, that could potentially impact Delta water quality. This plan will be incorporated into the Delta Plan that is scheduled to be adopted in the fall of 2012. SWPCA should track plans for various recreation projects and provide comments on EIRs and other documents on the need to protect drinking water quality when recreational projects are developed.

SWPCA should Support the DPC's Efforts to Develop a Matching Fund Program for Removal of Abandoned Vessels.

Establishing a fund that could be used by local agencies to provide the required ten percent matching funds would allow more of the state's funding to be used to remove abandoned vessels in the Delta. SWPCA should support the DPC in development of a matching fund program.

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CHAPTER 14 KEY WATER QUALITY VULNERABILITIES OF THE STATE WATER PROJECT

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CHAPTER 14 KEY WATER QUALITY VULNERABILITIES OF THE STATE WATER PROJECT

The California Department of Public Health (CDPH), the State Water Project (SWP) Contractors, and the Department of Water Resources (DWR) worked together to determine the SWP vulnerabilities and contaminant sources to be addressed in the California State Water Project Watershed Sanitary Survey, 2011 Update (2011 Update). This chapter contains a discussion of the following topics:

- North Bay Aqueduct (NBA) – This section contains a description of the activities undertaken by the NBA Contractors to address current and potential future water quality concerns in the Barker Slough watershed. Progress on developing an alternate intake is also discussed.

- Clifton Court Forebay (Clifton Court) – This section is a synopsis of work that was conducted for the 2006 Update and a status report on the action items.

- South Bay Aqueduct (SBA) – The watershed protection program and public education efforts of the SBA Contractors are described in this section. An update on the SBA Improvement and Enlargement Program and cattle grazing in the Bethany watershed are also included.

- Delta-Mendota Canal (DMC)/California Aqueduct Intertie – The intertie project and the potential impacts of the project on water quality are described.

- San Luis Reservoir – This section contains an update on the San Luis Low Point Improvement Project and cattle grazing in the watershed.

- Coastal Branch – Information from the California State Water Project Watershed Sanitary Survey, 2006 Update (2006 Update) on the efforts of the Central Coast Water Authority (CCWA) to address taste and odor (T&O) issues are updated with recent data.

- Non-Project Inflows – Although this topic was discussed in the 2006 Update, inflows were more substantial during the 2006 to 2010 period. The water quality impacts of the inflows are described in this section.

- Subsidence Along the Governor Edmund G. Brown California Aqueduct (California Aqueduct) – This section contains a brief description of an on-going study to understand subsidence along the aqueduct.

- Pyramid Lake – This section contains an update on the 2005 oil spill that was discussed in the 2006 Update and a discussion of a fire that occurred in 2006.

- Castaic Lake – This section contains an update on the high *Escherichia coli* (*E. coli*) levels discussed in the 2006 Update and a description of a wastewater spill that occurred in 2008.

- Hesperia Master Drainage Plan – Information on the efforts of San Bernardino County to address drainage entering the California Aqueduct are described in this section.

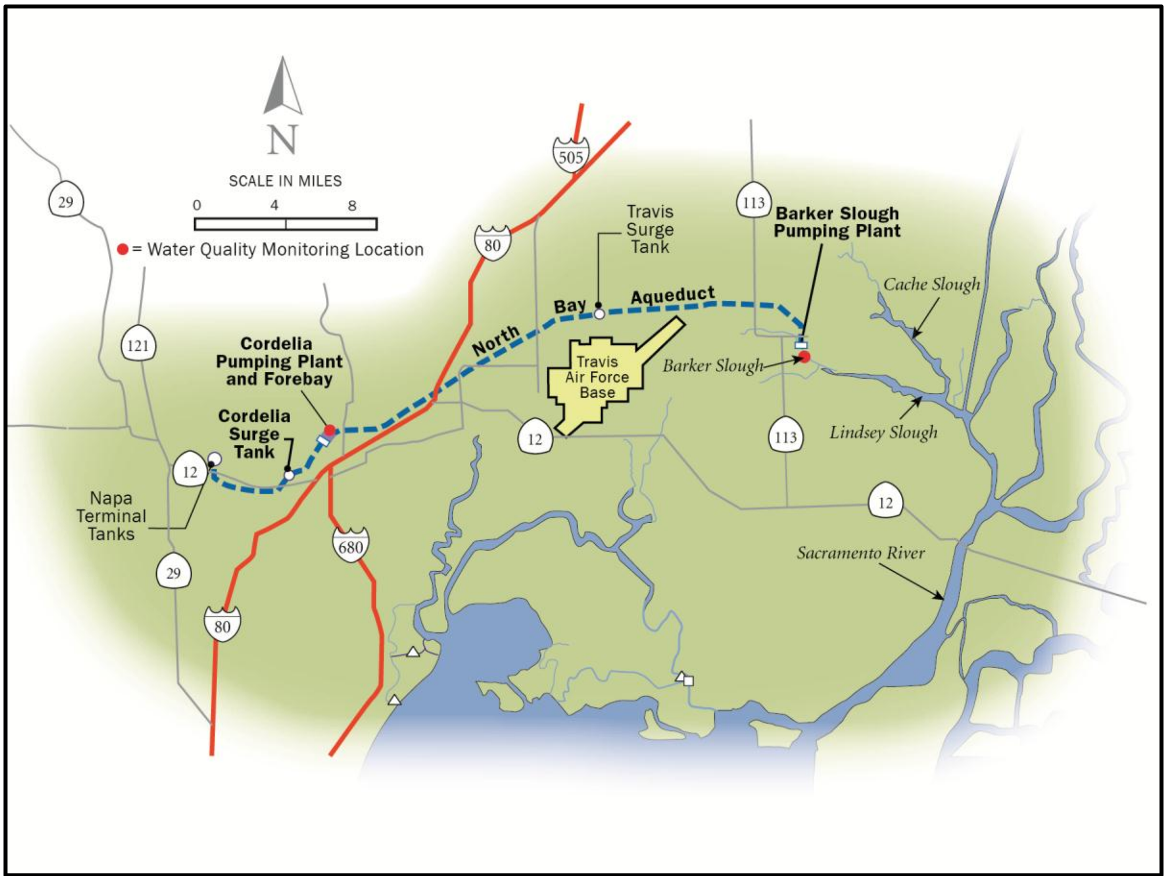
- Silverwood Lake – This section contains an update on the wastewater spills and the fire that were discussed in the 2006 Update.

- Lake Perris – This section contains an update on the seismic hazard, anoxic hypolimnion, and recreational usage of Lake Perris.

NORTH BAY AQUEDUCT

The NBA serves as a municipal water supply source for a number of municipalities in Solano and Napa counties. The Solano County Water Agency (SCWA) and the Napa County Flood Control and Water Conservation District (Napa County) are wholesale buyers of water from the SWP. SCWA delivers water to Travis Air Force Base and the cities of Benicia, Fairfield, Vacaville, and Vallejo. Napa County delivers water to the cities of Napa, and American Canyon. The NBA is a 27.6-mile long underground pipeline. Water is pumped from Barker Slough into the NBA at the Barker Slough Pumping Plant (BSPP). Barker Slough is a tidally influenced dead-end slough which is tributary to Lindsey Slough. Lindsey Slough is tributary to the Sacramento River. The pumping plant draws water from both the upstream Barker Slough watershed and from the Sacramento River, via Lindsey Slough. Other local sloughs may also contribute water to the NBA. The NBA facilities are shown in **Figure 14-1**.

Figure 14-1. NBA Facilities



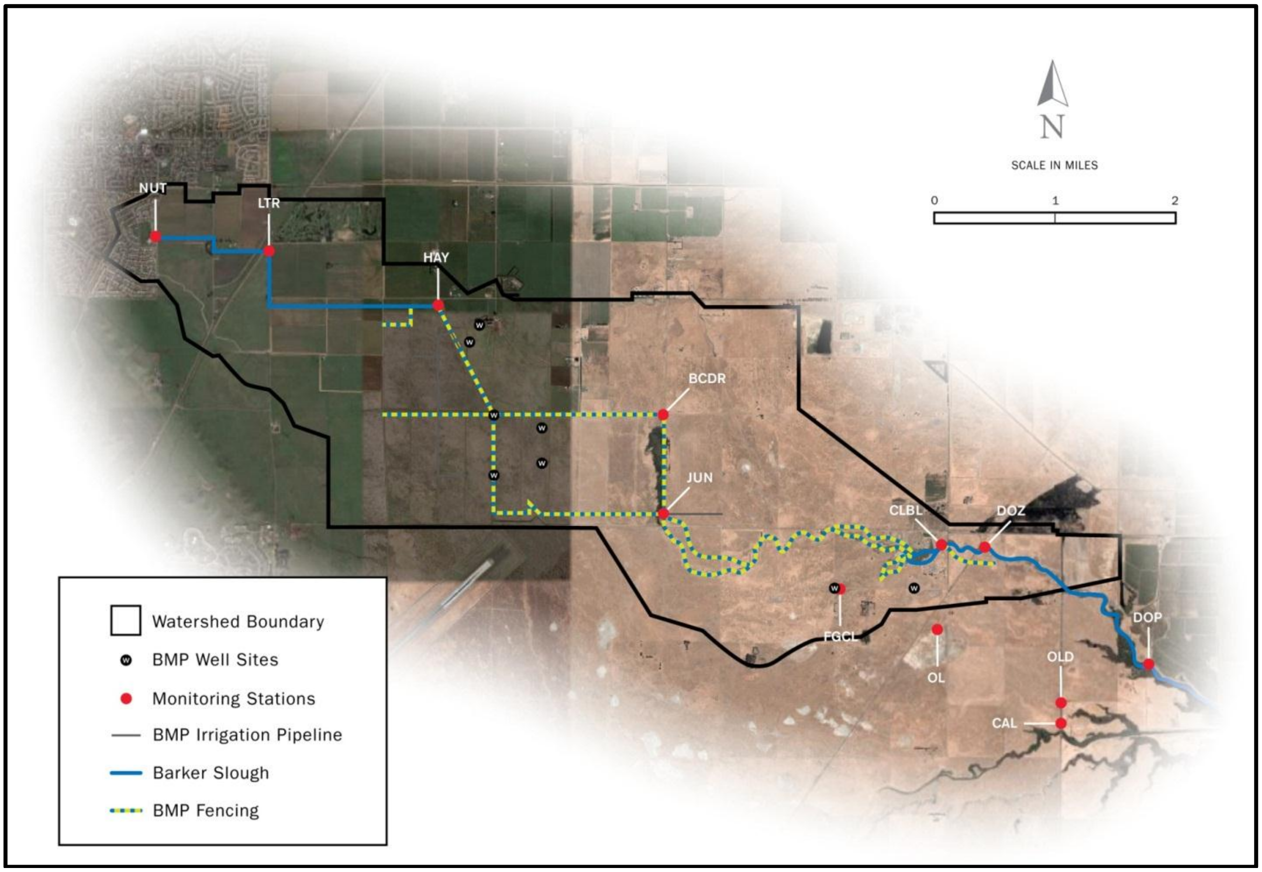
The 2006 Update contains a description of the Barker Slough watershed and the major water quality challenges of that watershed. The previous sanitary survey also contains a discussion of the multi-pronged approach that the NBA Contractors have taken to improve NBA water quality. This report provides an update on the Barker Slough Watershed Management Program, the hydrodynamic modeling, the monitoring program, and the Alternate Intake Project.

BARKER SLOUGH WATERSHED MANAGEMENT PROGRAM

Background

As a result of recommendations in the 1990 and 1996 watershed sanitary surveys, the NBA Contractors and the Municipal Water Quality Investigation (MWQI) Program conducted a series of special studies between 1996 and 1999 to understand the relative contributions of different surface waters to water quality in the NBA. In 1999, SCWA was awarded a grant from the State Water Resources Control Board (State Water Board) to evaluate and begin implementation of management practices in the watershed and to conduct monitoring to determine the effectiveness of the practices. Hydro Science prepared a Barker Slough Watershed Water Quality Improvement Plan (2001) and a Barker Slough Watershed Management Plan (2002). Figure **14-2** shows the Barker Slough watershed.

Figure 14-2. The Barker Slough Watershed



Base Map Source: Google

Hydro Science developed a water quality improvement plan which consisted of four tiers of management practices to be implemented in a progressive manner.

- Tier I includes fencing to exclude cattle from the Noonan Drain to the Junction and erosion control measures on Campbell Ranch (Argyll Park).
- Tier II includes additional fencing to exclude cattle from Barker Creek and some tributary drainages and potential alum treatment of Campbell Lake.
- Tier III includes improved management of Campbell Lake during wet and dry periods, improved irrigation practices, conversion of cropland to pasture, and soil treatments to reduce erosion.
- Tier IV includes channel restoration and potential modification of land use practices that would only be implemented if water quality does not improve significantly after implementation of the first three tiers of management practices.

Hydro Science and the NBA Contractors determined that the most effective practice to initially implement in the Barker Slough watershed was to restrict livestock access to Barker Slough and its tributaries by installing fencing, and providing alternate water supplies for livestock. Fencing, wells to provide livestock water, watering troughs, and irrigation pipe were installed at a cost of $670,000. Cattle are now excluded from Barker Slough upstream of Campbell Lake. **Figure 14-2** shows the location of the BMPs in the Barker Slough watershed.

Current Status

The SCWA has continued to monitor the Barker Slough watershed, as discussed on page 14-9; however, there has not been any additional work done to install BMPs in the Barker Slough watershed. As described in the following section, SCWA has turned to better understanding the full extent of the watershed that drains to the BSPP.

HYDRODYNAMIC MODELING

Background

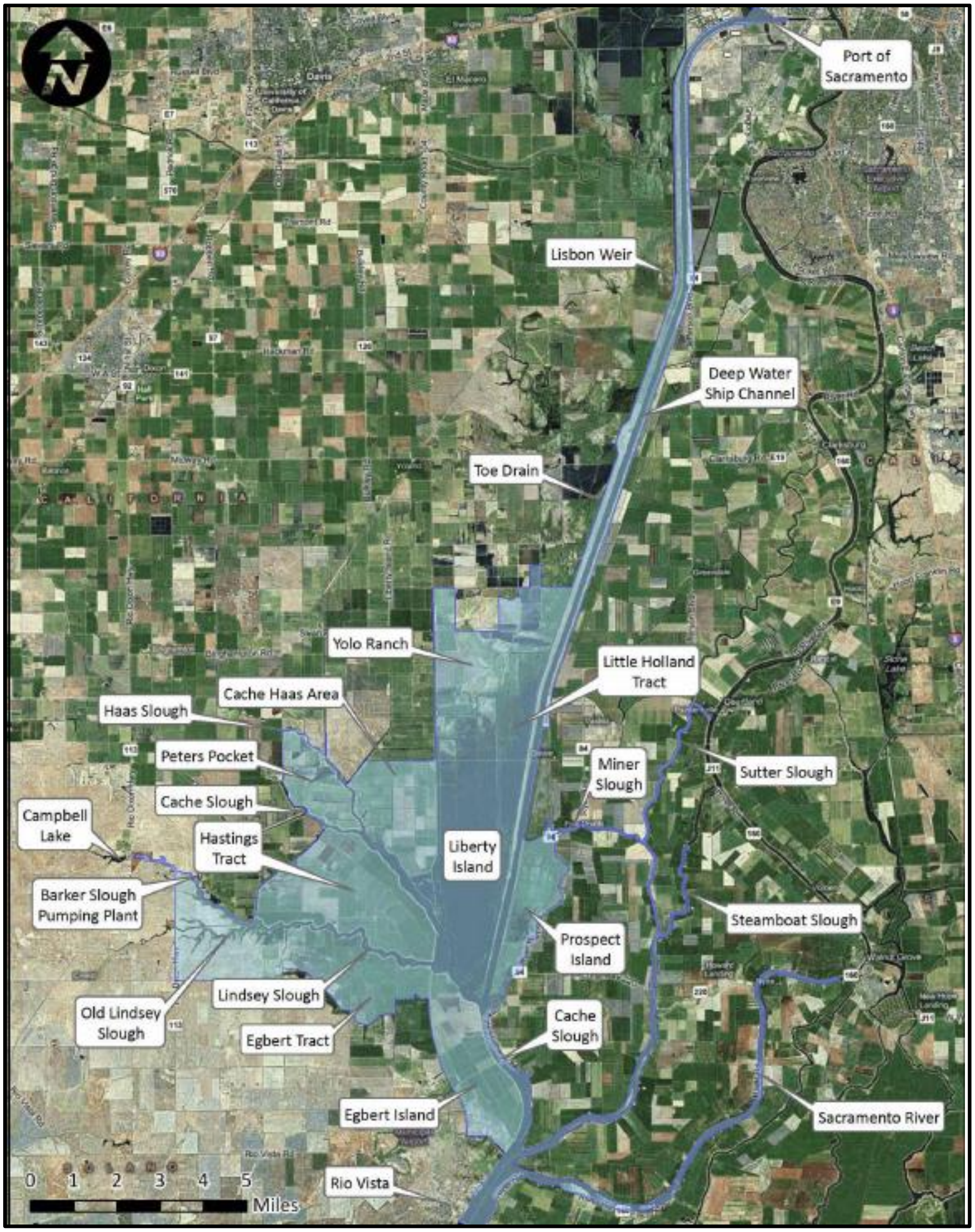
The BSPP is located at the tidal end of Barker Slough, which is a dead-end slough, as shown in **Figure 14-3**. Upstream of the pumping plant is a non-tidally influenced watershed comprised of 15 square miles of primarily agriculture, including pasture, row crops, grazing land, and some urban drainage (see **Figure 14-2**). When there is runoff from the watershed, it must pass by the pumping plant forebay on its way to Lindsey Slough. However, the water levels in the slough are tidally influenced and during the summer and fall when releases from Campbell Lake are at a minimum, the amount of water pumped into the NBA exceeds the runoff from the watershed. Therefore, the pumping plant creates reverse flow conditions and water is drawn up Lindsey Slough to Barker Slough. The flow hydraulics when there is runoff from the Barker Slough watershed are much more complicated and not well understood.

Current Status

The NBA Contractors contracted with PWA to develop a hydrodynamic model of Barker Slough, Lindsey Slough, and Calhoun Cut to better understand the sources of water at the BSPP.

PWA calibrated and validated the two-dimensional MIKE21 FM model (PWA, 2008). The model domain was extended in 2011 to include the entire Cache Slough Complex (CBEC, 2011). The current domain of the model is shown in **Figure 14-3**. The model has been used to understand the sources of water at the BSPP (PWA, 2009) and to evaluate the impacts of ecosystem restoration activities in the Cache Slough Complex (CBEC, 2011).

Figure 14-3. Hydrodynamic Model Domain



Source: CBEC (2011)

Sources of Water at Barker Slough Pumping Plant

To understand the sources of water at the BSPP under various hydrologic scenarios, SCWA and PWA developed the four scenarios shown in **Table 14-1** to be modeled (PWA, 2009).

Table 14-1. Modeled Scenarios

Scenario	Description	Barker Slough Pumping Rate	Tributary Inflow[a]	Lindsey Slough Water Surface Elevation
1	Localized storm event (1 in) No Yolo Bypass spill	Low	High + Pump 2 & 3	Jan 2006 data
2	Large regional event (1 in) Yolo Bypass spill	Low	High + Pump 2 & 3	Yolo Bypass Spill
3	Dry season: pure tidal	High	No inflow	Feb 2007 data
4	Small localized storm event Wet season (0.5 in)	Medium	Low (0.5 in rainfall) + gravity pipe at Pump 3	Feb 2007 data

Source: PWA (2009)
[a] Pumps 2 and 3 refer to drainage pumps on Hastings Tract and Upper Hastings Tract. The gravity pipe at Pump 3 allows water to drain by gravity from Upper Hastings Tract.

Key conclusions from this study are:

- Results of the tributary source modeling indicates that inflows from Campbell Lake dominate the Barker-Lindsey Slough system in the vicinity of the BSPP during local and regional storm events (Scenarios 1 and 2) and other tributaries become significant under smaller runoff/moderate pumping conditions (Scenario 4).

- When considering a two week scenario with the Yolo Bypass spilling, Campbell Lake is still the dominant source to the BSPP but other tributary sources from Calhoun Cut (previously called Old Lindsey Slough, as shown in **Figure 14-3**) begin to impact the pumping plant as well. It is also hypothesized that if the simulation run time were to be increased even longer, Lindsey Slough tributaries such as Big Ditch would also impact the BSPP for Scenarios 1 and 2, but at a later time than the Campbell Lake and Calhoun Cut tributaries.

- When considering a two week scenario, Campbell Lake's aggregate contribution to water pumped from BSPP was shown to be smaller when the Yolo Bypass spills (Scenario 2) than otherwise identical conditions. This can be explained by the large tidal excursion following the decline of elevated Yolo Bypass water levels at Lindsey Slough at Hastings Bridge.

- Flushing time analysis in the Barker-Lindsey Slough system has shown that after medium to large storm events in excess of 2- to 5-year events, the model domain initially flushes relatively quickly due to the high volume of tributary inflows. The system then transitions to a longer flushing rate influenced by the lower pumping rate at the BSPP. During the dry season, the flushing time estimate is shorter due to the high pumping rate at the BSPP.

- The time scale for the water quality in Barker-Lindsey Slough system to be restored to pre-storm conditions is dependent on the magnitude of the storm event, the presence or absence of Yolo Bypass flows, and the pumping rate at the BSPP.

Impacts of Ecosystem Restoration

The Yolo Bypass and Cache Slough area have been identified as important wetlands restoration opportunity areas. In September 2009, the BDCP released an Aquatic Habitat Restoration Map and Draft Conservation Strategy that shows tidal marsh restoration targets within the Yolo Bypass/Cache Slough area (BDCP, 2009a and 2009b). Creation of tidal marshes could result in higher levels of organic carbon at the BSPP. Studies undertaken by SCWA have shown that dissolved organic carbon (DOC) could increase by up to 3.5 mg/L at the BSPP, depending on the restoration scenario (PWA, 2008). A study on the financial impact to the NBA water treatment plants from increases in DOC showed that for every 1 mg/L increase in total organic carbon (TOC) at Barker Slough, the combined annual cost of treatment for the NBA would be approximately $300,000 in 2008 dollars. The study determined the capital cost for implementing new water treatment technologies to reduce disinfection byproduct formation for the entire NBA ranged between $40 and $90 million (2008 dollars), with an annual operating cost of $9 to $20 million (MWH, 2009).

SCWA contracted with CBEC to model the impacts of tidal marsh restoration in the Cache Slough Complex (CBEC, 2011). The key findings from that study are:

- In summary, DOC generated from tidal wetland restoration in the Cache Slough Complex and vicinity, and the resultant modifications to the system hydrodynamics, could have significant implications for water quality at the BSPP and would impact the pumping plant to varying degrees.

- Potential tidal wetland restoration both big and small on Lindsey Slough (e.g., Hastings Tract (breached via Lindsey Slough), Egbert Tract, and Old Lindsey Slough) presents a significant concern due to the direct connection to Lindsey Slough and subsequent net DOC flux up Barker Slough that would occur due to the pumping at the BSPP.

- Egbert Island and Hasting Tract (breached via Cache Slough) produce DOC impacts of the same magnitude, given their relatively large tidal prisms, proximity to the mouth of Lindsey Slough via the west bank of Cache Slough, and their ability to significantly modify system hydrodynamics due to their large tidal prisms.

- Restoration areas that pose a lesser, but perhaps still significant, concern to the BSPP include Prospect Island, given its Cache Slough connection roughly opposite Lindsey Slough.

- Restoration areas that pose an insignificant effect on the BSPP include Yolo Ranch, given its distance from Lindsey Slough and proximity to significant agricultural intakes (i.e., Shag Slough and the Toe Drain), followed by Peters Pocket and Moore Tract, given their distance from Lindsey Slough, their relatively small tidal prisms, and proximity to numerous agricultural intakes.

MONITORING PROGRAM

Background

SCWA has conducted water quality monitoring in the Barker Slough watershed since 1997. The initial focus of the monitoring was to understand the concentrations, loads, and sources of organic carbon and other key water quality constituents in the Barker Slough watershed, Calhoun Cut, and Lindsey Slough. These data were used and evaluated as part of the Barker Slough Watershed Management Program, discussed previously.

Current Status

In 2002 and subsequent years, the monitoring program was expanded to include data needed to support development of the hydrodynamic model. Currently SCWA is considering expanding its monitoring program to develop baseline organic carbon conditions. This information will be used to evaluate the impacts of ecosystem restoration projects in the Cache Slough Complex on organic carbon concentrations at the BSPP

EXCHANGE OF NBA WATER FOR SOLANO PROJECT WATER

Background

High quality water from Lake Berryessa is currently delivered via the Putah South Canal of the Solano Project to both agricultural and municipal customers in Solano County. SCWA is currently exploring options to exchange some of the lower quality NBA water that its municipal customers receive for the Solano Project water that agricultural customers receive. The Highline Canal Project is currently being evaluated. The proposed project involves pumping water from the NBA into Solano Irrigation District's (SID) Highline Canal, a conveyance for Solano Project water. The NBA water could then be delivered to agricultural customers in the SID service area. The cities of Fairfield, Vacaville, and Benicia would provide the NBA supply and would receive a portion of SID's Solano Project supply and the opportunity to take advantage of storage in Lake Berryessa. It is anticipated that 5,000 to 10,000 acre-feet per year of NBA water could be exchanged for an equivalent amount of Solano Project water. A pumping plant is needed to withdraw water from the NBA and a connection between the NBA and the Highline Canal would need to be constructed.

Current Status

The Highland Canal project is currently on-hold as it will not be needed if the NBA Contractors decide to pursue the Alternate Intake Project.

ALTERNATE INTAKE PROJECT

Background

The NBA Contractors are working with DWR to construct an alternate intake project to improve water quality and the reliability of their water supply. As discussed in Chapter 3, Barker Slough has high levels of TOC and turbidity, creating challenges for water treatment plant operations. In addition to water quality challenges, Barker Slough provides habitat for state and federally listed species, including delta smelt and longfin smelt, resulting in pumping restrictions. In addition, the capacity of the NBA is not large enough to supply future water needs.

Pumping Restrictions

SCWA and Napa County have an existing water supply entitlement through the NBA of 131,181 acre feet per year based on existing contracts and water right settlements. The U.S. Fish and Wildlife Service (USFWS) biological opinion for delta smelt reduced the annual diversions at the BSPP to 71,000 acre feet per year (USFWS, 2008). The California Department of Fish and Game issued an Incidental Take Permit for the preservation of longfin smelt in 2009 which imposed further pumping restrictions at the BSPP during dry and critical years between January 15 and March 31 (California Department of Fish and Game, 2009). A maximum of 50 cubic feet per second (cfs) (seven day average flow) can be pumped during this period.

As discussed previously, the Yolo Bypass and Cache Slough area have been identified as important wetlands restoration opportunity areas. Implementation of these strategies will likely result in greater numbers of listed species near the BSPP and that could potentially result in further pumping restrictions.

Water Supply Delivery Limitations

SCWA and Napa County project that by 2030 they will need the NBA to deliver their total water supply of 131,181 acre feet per year. This will require peak flows of 240 cfs through the NBA. The current capacity between the BSPP and the North Bay Regional Treatment Plant is 140 cfs.

The NBA Contractors conducted an engineering feasibility study that explored five possible locations for an alternate intake, nine pipeline alignments, and three alternatives for connecting the new supply to the NBA (Bookman-Edmonston et al., 2003). The intake locations originally considered were the Deep Water Ship Channel at two locations (near Clarksburg and near Courtland); Elk Slough, Sutter Slough, and the Sacramento River (all near Courtland), and Miner Slough near Courtland. The sites were evaluated and ranked and two sites were advanced for further analysis – the Sacramento River at Courtland and Sutter Slough near Courtland. In December 2009 the feasibility study was updated, with the focus on two pipeline alignments from the North Bay Regional Water Treatment Plant (WTP) to the Sacramento River, with an intake near Freeport and an intake near Courtland (CDM, 2009). Subsequently, the NBA Contractors decided that they would prefer to have the intake located near Freeport, upstream of the Sacramento Regional Wastewater Treatment Plant discharge. This plant currently discharges approximately 150 million gallons per day (mgd) of secondary treated wastewater to the Sacramento River at Freeport.

The feasibility study also recommended that the connection to the NBA not require that the water from the new intake be mixed with Barker Slough water. Two connection alternatives were advanced for further analysis. One alternative would allow mixing but also preserves the ability to convey only the new intake water to the water treatment plants. The other alternative is direct connection to the NBA. The construction cost for the intake, pipeline, and pumping stations is estimated at $436 million in 2008 dollars (CDM, 2009).

Current Status

The alternate intake project consists of the following facilities:

- An intake structure and pump station on the Sacramento River with state-of-the art, positive barrier fish screens

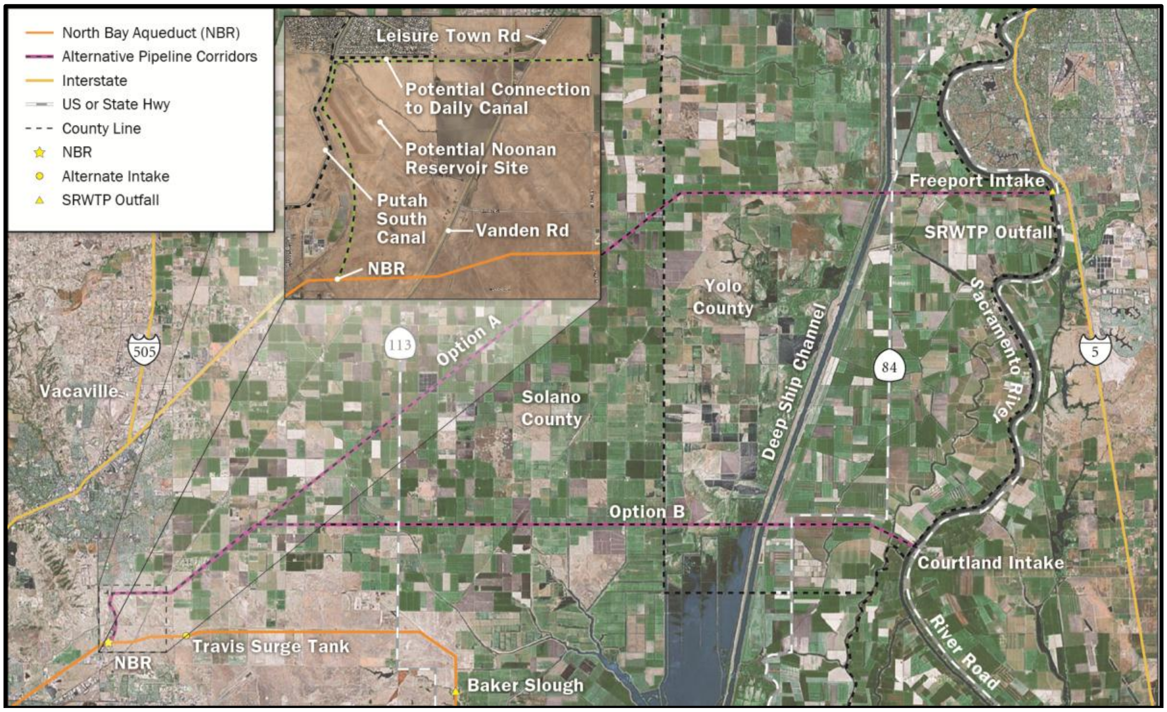
- A new pipeline segment to convey the water from the alternate intake to a point of connection with the existing NBA near the North Bay Regional WTP

- Other project-related support facilities including, but not limited to, surge tanks, etc.

Figure 14-4 shows the general location of the proposed facilities. The intake structure and pump station would be designed to accommodate projected future 2030 demands of up to 240 cfs. The estimated project cost is $0.5 billion. The alternate intake would be operated in conjunction with the existing intake at Barker Slough to provide operational flexibility and improve water quality. The BSPP would be used when water quality in Barker Slough is acceptable to the NBA Contractors and when listed species are not present. The alternate intake would be operated when Barker Slough water quality is unacceptable or when pumping is restricted due to the presence of listed species. A new segment of underground pipeline, estimated at 84 inches in diameter, will be installed that will connect the alternate intake with the existing NBA pipeline near the North Bay Regional WTP.

DWR is the lead agency for the Alternate Intake Project. DWR released a Notice of Preparation for an Environmental Impact Report (EIR) on the project in November 2009 and conducted public scoping meetings in December 2009. The Draft EIR is expected to be released in the summer of 2012.

Figure 14-4. Proposed Alternate Intake Locations



Source: Adapted from CDM (2009)

STATUS OF ACTION ITEMS

The 2007 SWP Action Plan did not contain any actions related to the NBA.

POTENTIAL ACTIONS

None.

The NBA Contractors are pursuing a comprehensive program to improve water quality. No other actions are recommended.

CLIFTON COURT FOREBAY

The 2006 Update contains a detailed discussion about the potential role that sedimentation in Clifton Court plays in stimulating T&O producing algae and vascular plants in the SBA. The issue is briefly recapped in this section, followed by a discussion of the status of the action items in the 2007 State Water Project Action Plan.

BACKGROUND

While developing the scope of work for the 2006 Update, the SBA Contractors expressed concerns that sedimentation of Clifton Court has resulted in a shallow water body that encourages algal and vascular plant growth that result in T&O problems. The 2006 Update contains an analysis of real-time water quality monitoring data that could potentially be used to detect algal blooms. Key findings from the 2006 Update are:

- Sedimentation – Sediment is accumulating in Clifton Court. Based on an analysis of suspended solids data, an estimated 80,000 cubic yards of sediment accumulated between 1993 and 2005.

- Fluorescence – Given the high variability of the data, and the inconsistent responsiveness of fluorometric measurements during known periods of algal blooms and presence of T&O compounds, fluorescence measurements do not reliably predict algal blooms and cannot reliably be used as an indication that T&O events are occurring in the Delta or Clifton Court.

- pH – pH measurements show daily fluctuations that should, at least in part, be attributable to photosynthetic and respiratory activity in the system; however, the instrumentation appears to be insensitive to conditions under which T&O compounds are formed.

- Turbidity – Turbidity readings would not likely reflect the presence of benthic algae, but might indicate the results of treatment if decomposing material entered the water column. No corroborative evidence was seen, however. Turbidity measurements made by unattended real-time equipment tend to be fairly reliable, but turbidity measurements do not distinguish between living and non-living suspended matter.

- Total and Volatile Suspended Solids – Discrete samples of total and volatile suspended solids can provide information that is generally better quality-controlled, but samples are currently collected monthly and are not useful for tracking algal blooms.

- Dissolved Oxygen (DO) – The limited available data are not conclusive in demonstrating whether DO measurements may be a useful tool for monitoring the presence of algae in Clifton Court, but this form of measurement has possible advantages. DO can be monitored continuously and relatively inexpensively by available automated instrumentation. Because DO fluctuates as a result of respiration and photosynthesis, it should be sensitive to algal population dynamics, whether the algae in question are planktonic or benthic. Also, oxygen fluctuations due to phytoplankton populations should be relatively insensitive to the distribution of organisms throughout the water column, so that floating algae, such as *Microcystis aeruginosa,* should be detectable.

CURRENT STATUS

The scope of work for the 2011 Update did not include any further analysis of the impact of sedimentation in Clifton Court on algal growth and T&O problems or of the ability of monitoring equipment to detect algal blooms.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following action items related to sedimentation of Clifton Court and algal blooms:

Conduct a Detailed Evaluation of in-situ Monitoring Equipment

This action item was classified as immediate because reliance on the real-time data will increase as DWR and the SWP Contractors transition to modeling and forecasting water quality conditions in advance. Standard Operating Procedures and Quality Assurance Project Plans have either been developed or are being finalized for all real-time instruments operated by MWQI. However, there are still cases where real-time instruments along the Aqueduct are not operating properly as discussed in Chapter 3.

Evaluate Current Equipment Capabilities to Detect Algal Blooms

This action item was classified as near-term pending completion of the evaluation of the in-situ monitoring equipment. The MWQI New Technologies Subcommittee is tracking work being conducted by the Interagency Ecological Program (IEP) and Metropolitan Water District of Southern California (MWDSC) on fluorometric quantification of planktonic algae.

Consider Continuous Measurement of Dissolved Oxygen to Detect Algal Blooms

This action item was classified as near-term pending completion of the evaluation of the in-situ monitoring equipment. It is currently on hold pending discussions between the SBA Contractors and the Delta Field Division.

POTENTIAL ACTIONS

Two action items from the 2007 SWP Action Plan were not completed and should be continued in the next several years.

MWQI should Evaluate Current Equipment Capabilities to Detect Algal Blooms.

This action item was classified as near-term in the 2007 SWP Action Plan pending completion of an evaluation of the in-situ monitoring equipment. The MWQI New Technologies Subcommittee is tracking work being conducted by IEP and MWDSC on fluorometric quantification of planktonic algae. The results of these studies should be reported to the MWQI Committee and a decision made on the usefulness of these methods in detecting algal blooms in Clifton Court.

The SBA Contractors should Consider Continuous Measurement of Dissolved Oxygen to Detect Algal Blooms.

This action item was classified as near-term in the 2007 SWP Action Plan pending completion of an evaluation of the in-situ monitoring equipment. It is currently on hold pending discussions between the SBA Contractors and the Delta Field Division. The SBA Contractors should determine if continuous measurement of dissolved oxygen would be helpful in detecting algal blooms in Clifton Court.

SOUTH BAY AQUEDUCT

The SBA conveys water from Bethany Reservoir to large portions of Alameda and Santa Clara counties. The Zone 7 Water Agency of the Alameda County Water Conservation and Flood Control District (Zone 7 Water Agency), the Alameda County Water District (ACWD), and Santa Clara Valley Water District (SCVWD) treat water from the SBA and provide drinking water to nearly two million customers. These three agencies are referred to as the SBA Contractors.

The SBA system is shown in **Figure 14-5**. Water is pumped from the Sacramento-San Joaquin Delta (Delta) at the Harvey O. Banks Delta Pumping Plant (Banks). Water flows a short distance down the California Aqueduct to Bethany Reservoir. Bethany Reservoir is essentially a wide spot on the California Aqueduct with a capacity of 5,070 acre-feet. Water is pumped into the SBA at the South Bay Pumping Plant on Bethany Reservoir. The first three miles of the SBA are an enclosed pipeline. This is followed by two miles of open canal, a tunnel under Interstate 580, and another two miles of open canal between the tunnel and Patterson Reservoir (a 100 acre-feet storage facility adjacent to the SBA). Water continues to flow seven miles in an open canal to Del Valle Check 7 (DV Check 7). From there the water flows in an enclosed pipeline to the Santa Clara Terminal Reservoir (Terminal Tank). About one mile beyond DV Check 7, SBA water can be pumped into Lake Del Valle and Lake Del Valle water can be released into the SBA via a 60-inch common inlet/outlet. Lake Del Valle is a multi-purpose reservoir that provides storage for the SBA, flood control for Alameda Creek, and recreation. The storage capacity is 77,110 acre-feet. The reservoir has an extensive 95,000-acre watershed that contributes local runoff to the reservoir.

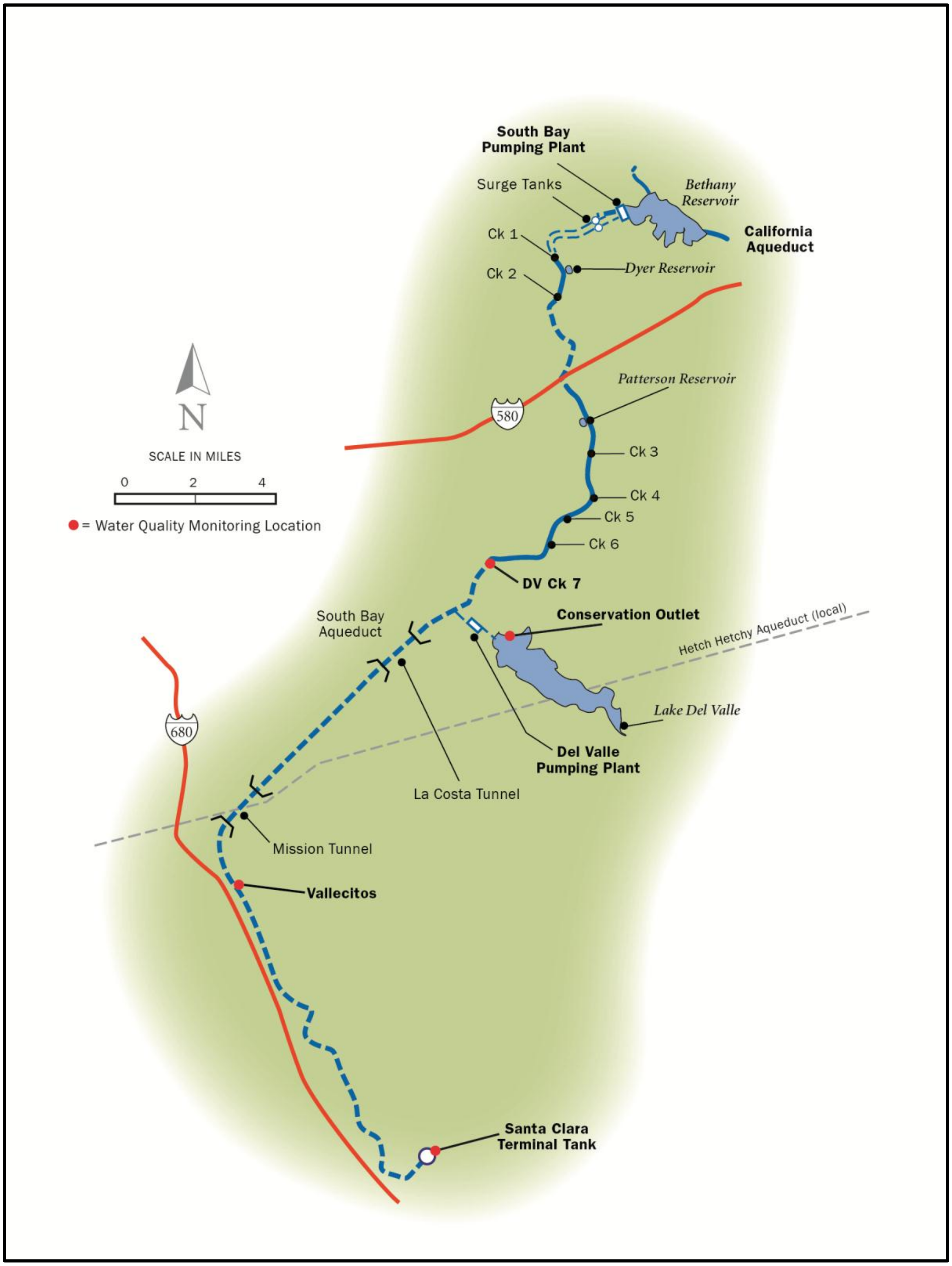
The 2006 Update contains a discussion of the SBA Improvement and Enlargement Program, the SBA Watershed Protection Program, the East Bay Regional Parks District (EBRPD) proposed trail along the SBA, algal growth and T&O issues, and the proposed listing of Lake Del Valle as an impaired waterway due to mercury and polychlorinated biphenyls (PCBs). This section provides an update on the SBA Improvement and Enlargement Program, the Watershed Protection Program, cattle grazing in the Bethany watershed, and the proposed trail along the SBA. Chapter 3 contains a discussion of algal growth and T&O issues and the mercury and PCB listing.

SBA IMPROVEMENT AND ENLARGEMENT PROGRAM

Background

The purpose of the SBA Improvement and Enlargement Program is to increase the capacity of the SBA, improve energy efficiency, and improve water supply reliability. Although the SBA was originally designed for 300 cfs conveyance capacity, the capacity has been reduced over time to 260 to 270 cfs. The project will make improvements to bring the existing capacity of the system up to its design capacity, and the expansion portion will add 130 cfs of conveyance capacity to meet future needs. Therefore, the project will result in a total conveyance capacity of 430 cfs for the SBA.

Figure 14-5. SBA Facilities



The project is comprised of the following principal features:

- Expansion of the South Bay Pumping Plant through addition of four 45 cfs pumps and expansion of the existing plant structure
- Construction of the 500 acre-foot Dyer Reservoir (425 AF of active storage)
- Construction of a 4.5 mile pipeline connecting the Dyer reservoir to the South Bay Pumping Plant
- Raising the height of the canal embankments, canal lining, and canal over-crossing structures and bridges along the Dyer, Livermore, and Alameda canals and at the Patterson Reservoir
- Modification of check structures and siphons along the Dyer, Livermore, and Alameda canals
- Construction of new drainage over crossing structures to eliminate drainage into the canals

Other features of the improvement project that address water quality concerns are replacing the wooden slat farm bridges that allow animal waste to enter the water with concrete bridges, as shown in **Figure 14-6**, and removing 2,000 to 3,000 cubic yards of sediment in the Bethany intake channel just upstream of the South Bay Pumping Plant.

Figure 14-6. New Concrete Farm Bridge with Old Wooden Farm Bridge in Background

Source: Zone 7 Water Agency

Current Status

Approximately 75 percent of the project is being funded by Zone 7 Water Agency, with ACWD and SCVWD funding the remainder. The total project cost is $190 million. All major features of the project have been completed, with the exception of canal modifications which are expected to be completed in June 2012. The expanded South Bay Pumping Plant began testing in late September 2011, and is expected to be on-line by July 2012. The Dyer Reservoir was completed in September 2011.

SBA WATERSHED PROTECTION PROGRAM

Background

ACWD obtained a Proposition 13 Non-point Source Pollution Control Grant from the State Water Board in 2003 to follow up on the recommendations from the Assessment of Watershed Contaminant Sources project, which was conducted in conjunction with completing the required Drinking Water Source Assessment for CDPH. A Watershed Protection Program Plan (WPPP) was developed under the guidance of a stakeholder-based Watershed Workgroup and the final report was issued in 2008 (ESA, 2008). The key elements of the WPPP were discussed in detail in the 2006 Update. The WPPP recommendations for Bethany Reservoir included limiting cattle access to riparian zones, improving infrastructure to manage sediment loads (particularly yields from large events), altering road drainage to reduce erosion and sediment delivery to the reservoir, and public education about the fact that Bethany Reservoir is a source of drinking water. The WPPP recommendations for Lake Del Valle included grazing management, road maintenance, erosion control, septic system design and maintenance and household hazardous waste management measures that could be recommended to private property owners. The WPPP also recommended measures for reducing the impact of recreation on water quality.

Current Status

The SBA Contractors conducted an extensive public information campaign in 2007 and 2008 that included development of brochures, hosting workshops, and development and posting of signs at Bethany Reservoir to educate the public on protecting drinking water quality.

<u>Brochures</u>

The SBA Contractors developed brochures on ranching and rural household information, recreational stewardship, and an overview of the SBA system. All three Contractors have copies of the brochures to hand out at public events.

Public Information Workshops

Four workshops were held between October 2006 and December 2007.

- EBRPD Lake Del Valle Workshop – This workshop was held on October 18, 2006 with East Bay Regional Park District rangers and addressed recreational usage of Lake Del Valle. One of the benefits of this workshop was that the rangers were educated on the fact that Lake Del Valle is a drinking water supply reservoir and there is a need to educate the public using the lake about protecting drinking water quality. This workshop also addressed the impacts of cattle grazing and methods of minimizing the water quality impacts.

- Community Stewardship for Clean Water Workshop (Fire Prevention and Water Pollution Prevention) – This workshop was held on November 3, 2007 and addressed the impacts of fires and urban runoff on water quality.

- Community Stewardship for Clean Water Workshop (Grazing and Erosion Management and Conservation Easements) – This workshop was held on November 14, 2007 and addressed the impacts of erosion and cattle grazing on water quality.

- Bethany Reservoir Water Quality Workshop – This workshop was held on December 11, 2007. The topics discussed included the results from the stormwater monitoring program conducted in 2005 and 2006 that showed that Bethany had the highest levels of pathogens, DWR's grazing leases, and methods of protecting water quality on grazing lands.

Public Information Signs

The SBA Contractors developed three signs that have been posted at Lake Del Valle and one sign that has been posted at Bethany Reservoir.

- The Water You Swim in Today…May be Your Drinking Water Next Week. This sign is shown in **Figure 14-7**.

- Your Tap Water Starts Here – This sign provides basic information about watershed and water quality protection.

- The South Bay Aqueduct…A Lifeline to the Bay Area – This sign provides basic information about the SBA.

Figure 14-7. SBA Public Education Sign

On-going Activities

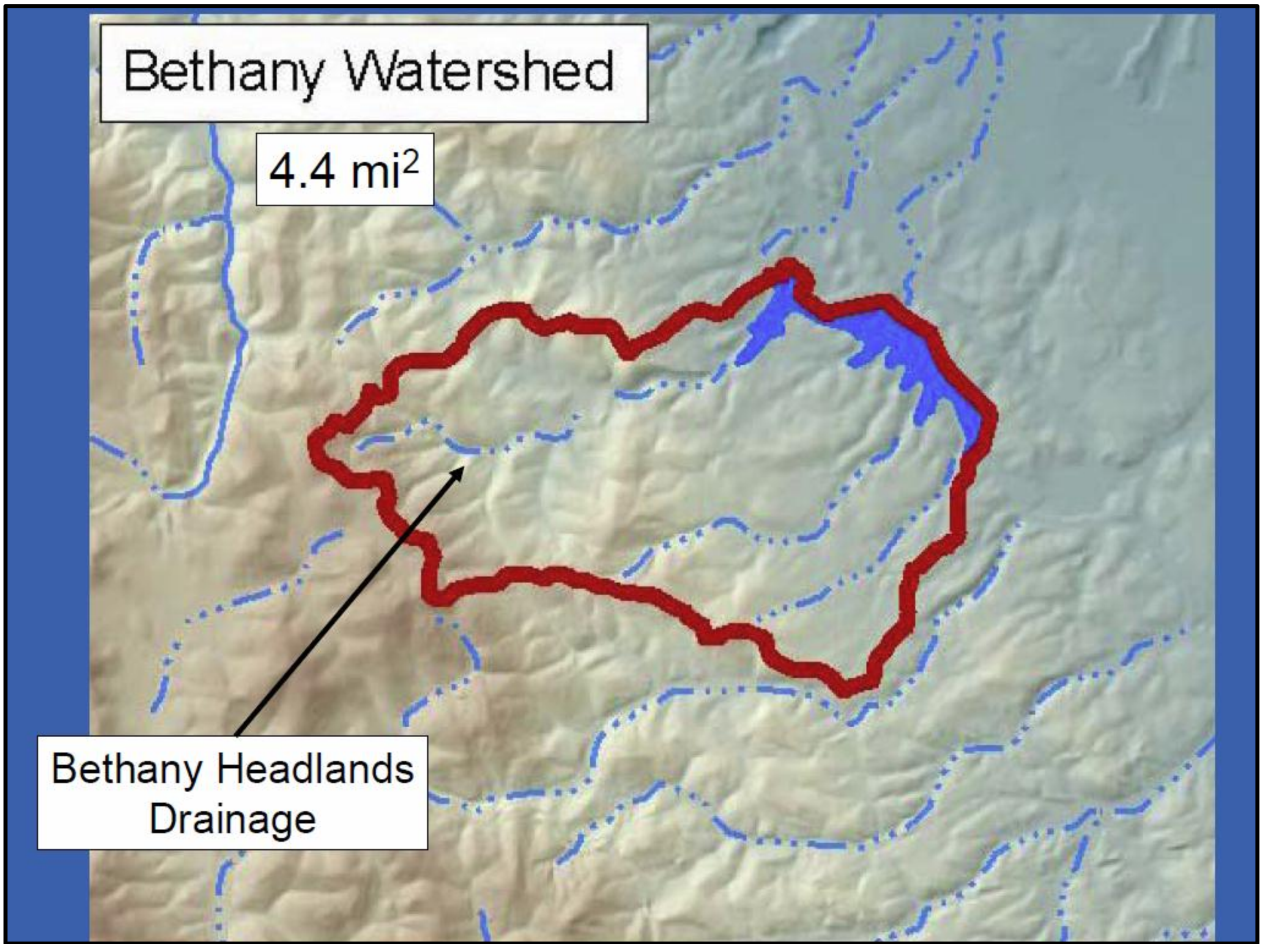
The SBA Contractors have not been able to conduct any additional workshops; however, there is close coordination between the SBA Contractors, DWR, and EBRPD. As a result of the outreach to EBRPD, staff from the district regularly attends the SBA Water Quality Task Force meetings.

CATTLE GRAZING IN THE BETHANY WATERSHED

Background

Figure 14-8 shows the watershed that drains to Bethany Reservoir is primarily on the southwest side of the reservoir. There is a small strip of land that is about 200 to 600 feet wide on the northeastern side that drains to the reservoir. Cattle grazing occurs on both private and state-owned land in the Bethany Reservoir watershed. Cattle have access to the southwestern shore of Bethany Reservoir and have been observed standing in the water. Grazing animals may contribute pathogens, nutrients, and organic carbon to Bethany Reservoir from their manure and may lead to increased loading of sediment and other contaminants due to overgrazing of the watershed, or trampling of drainage courses and the shoreline of the reservoir. Animals with access to the water pose a greater risk than those that graze in upland areas of the watershed, away from Bethany Reservoir or drainage courses.

Figure 14-8. Bethany Reservoir Watershed



Source: ACWD

Current Status

Cattle Grazing Leases

The Bethany Reservoir watershed is approximately 4.4 square miles. The majority of the watershed is privately owned, with three major property owners and a few smaller ones. The state owns the land within 300 to 500 feet of the southwestern shoreline and within 800 feet to a mile of the northwestern shoreline of Bethany Reservoir, as shown in **Figure 14-9**. This property is managed by DWR and much of it is leased for cattle grazing to two individuals in three separate lease agreements that total 353 acres. Most of the land that is leased on the northeastern shoreline is not in the Bethany watershed so drainage from that land does not enter Bethany Reservoir. DWR leases a 115-acre parcel on the southwestern shoreline as shown in **Figure 14-9**. The lessee grazes 22 head of cattle during the spring and summer and 11 head of cattle during the fall and winter on this parcel (Personal Communication, Linus Paulus, DWR).

DWR negotiates four- to five-year leases. The leases require that good grazing practices be used so the property is not over-grazed and allow DWR to inspect the property to determine if the land is being over-grazed. The leases also require that fences be constructed and maintained to prevent cattle from entering the property of adjacent property owners but there are no requirements for fencing to keep cattle out of Bethany Reservoir. There are fences that separate the DWR property from private property that is upslope from the DWR property but the condition of the fences is unknown. There are no fences along the southwestern shoreline of Bethany so cattle have access to the water (Personal Communication, Linus Paulus, DWR). Cattle grazing also occurs on private property in the watershed, but no information was readily available on the numbers of animals or grazing practices.

DWR is required to mitigate the impacts of the SBA Improvement and Enlargement Project on endangered species. A 168-acre conservation easement has been established on the northeastern side of Bethany Reservoir. Most of this land is outside of the Bethany watershed. DWR is in the process of establishing a 47-acre conservation easement on the southwest side of Bethany Reservoir. The locations of the conservation easements are shown in **Figure 14-9**. Cattle grazing is still allowed on the land that is in the conservation easements with the exception of 28 acres that is part of the larger northeastern easement that is being developed as wetlands mitigation.

Stormwater Monitoring

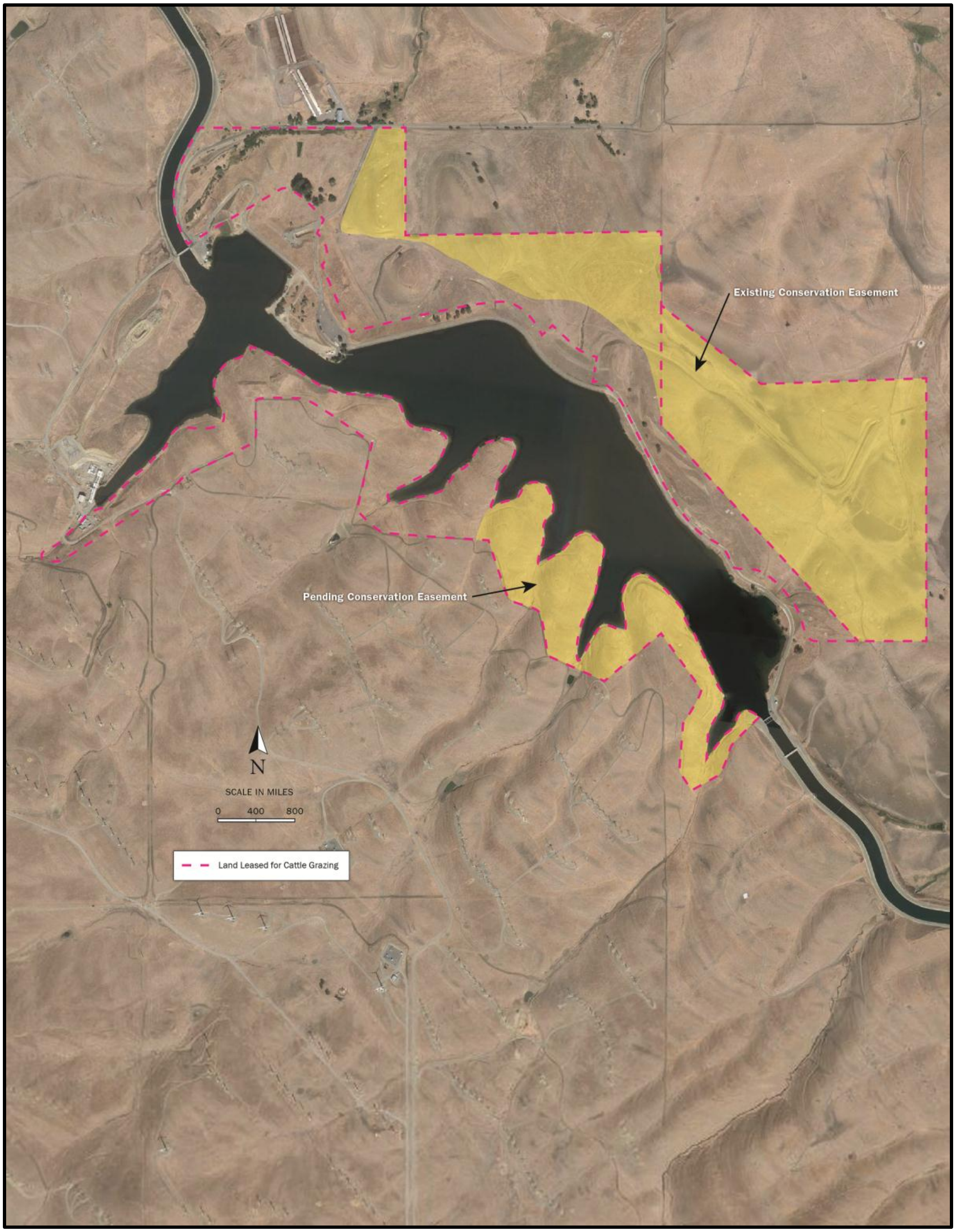
The WPPP project included monitoring stormwater inflows to Lake Del Valle and Bethany Reservoir during the winter of 2005-2006. Samples were collected from seven locations during five storm events and analyzed for a number of water quality constituents. The following locations, shown in **Figure 14-10 and 14-11**, were monitored at Bethany Reservoir.

- California Aqueduct (CA-1) – Samples were collected in the aqueduct just upstream of Bethany Reservoir to measure the quality of Delta water entering the reservoir.

- Bethany Headlands Drainage (BR-1 and BR-2) – The Bethany Headlands drainage course enters the inlet channel to the SBA right next to the SBA Pumping Plant. Samples were collected upstream and downstream of a small wetland that has developed in the drainage course near the inlet channel.

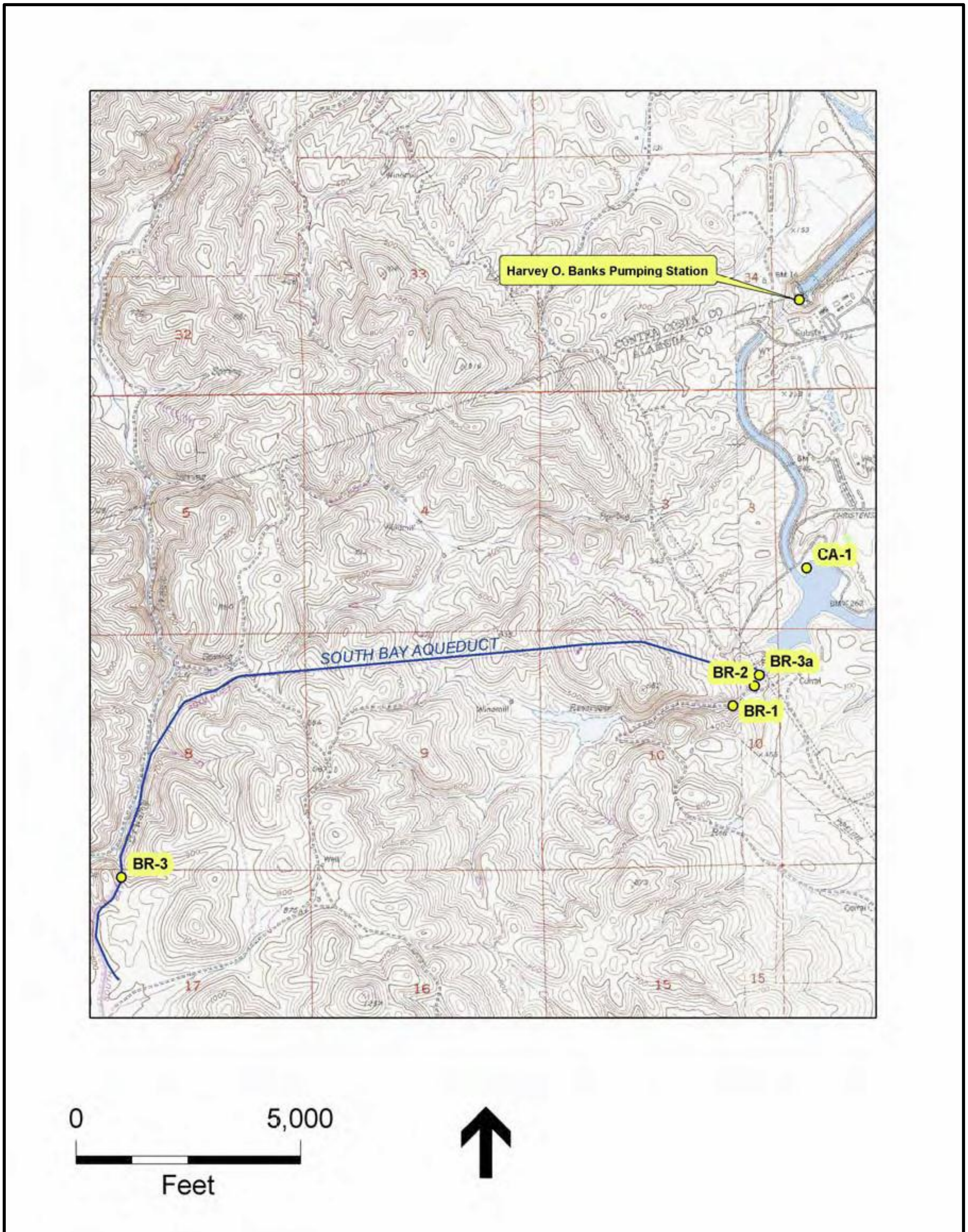
- South Bay Pumping Plant – Samples were collected in the Dyer surge pool (BR-3), the beginning of the open canal section of the SBA, to measure the quality of water entering the SBA when water was being pumped into the SBA. Samples were collected at the pumping plant (BR-3a) when the pumps were not operating at the time of sampling.

Figure 14-9. Cattle Leases in Vicinity of Bethany Reservoir



Note: Most of the land northeast of the reservoir is not in the Bethany watershed.

Figure 14-10. Bethany Reservoir Stormwater Monitoring Locations



Source: ESA (2005)

Figure 14-11. Aerial View of Bethany Reservoir Monitoring Locations

Source: ESA (2006)

The monitoring program and results are described in the SBA Watershed Protection Program Stormwater Monitoring Report (ESA, 2006). Only one sample was collected at each location during each storm event so the data provide a snapshot of water quality during storm events and do not adequately characterize the variability in concentrations that can be found during any given storm event. The data provide preliminary information on the relative quality of sources of water to the SBA. General conclusions from the monitoring program are:

- The Bethany Headlands drainage had the highest concentrations of most constituents that were monitored, although low flows were present during the events that were monitored.

- The quality of water in the Dyer Surge Pool was nearly identical to the quality of water entering Bethany Reservoir in the California Aqueduct, indicating that the Bethany Headlands drainage had no noticeable impact during the storms that were monitored.

The pathogen and indicator organism data from the stormwater monitoring program are described in more detail because cattle grazing in the Bethany Watershed was identified as an on-going concern. **Table 14-2** presents the range of total coliforms, *E. coli*, *Cryptosporidium*, and *Giardia* detected at each of the monitoring locations. Total coliform and *E. coli* levels were elevated at all locations. The *Giardia* and *Cryptosporidium* data indicate that these pathogens were detected in every sample collected from the Bethany Headlands drainage (BR-1 and BR-2). *Giardia* was detected once in the California Aqueduct and twice in the Dyer Surge Pool. *Cryptosporidum* was detected once in the Dyer Surge Pool.

Although the SBA Contractors have been placed in Bin 1 because *Cryptosporidium* was not detected during their Long Term 2 Enhanced Surface Water Treatment Rule monitoring, the detection of *Cryptosporidium* in every sample from the Bethany Headlands drainage is a cause for concern due to the fact that this drainage enters Bethany Reservoir approximately 50 feet from the South Bay Pumping Plant. During the storm events that were monitored there was minimal flow in the drainage (estimated at 0.1 cfs) and during the December 15, 2005 to March 15, 2006 period when the monitoring program was conducted, the California Aqueduct contributed 30,646 acre-feet of water to the SBA and the Bethany Headlands drainage contributed 36 acre-feet (ESA, 2006). However, it is conceivable that during a large storm event, the stock pond that dams the stream approximately 3,000 feet upstream of Bethany Reservoir could overtop and water containing relatively high levels of pathogens could be pumped into the SBA. Since cattle grazing is the primary use of this land and cattle are known carriers of these pathogens, cattle are the likely source. Local wildlife may also contribute to the pathogen load in the watershed.

Table 14-2. Storm Event Pathogen and Indicator Organism Data

Site	Total Coliform (MPN/100 ml)		*E. coli* (MPN/100 ml)		*Giardia* (cysts/L)		*Cryptosporidium* (oocysts/L)	
	Range	Median	Range	Median	Range	Median	Range	Median
BR-1	2000	2000	21 - 2000	700	0.1 - 2.9	0.9	<0.1 - <0.2	0.9
BR-2	1180 - 2000	1650	36 - 2000	380	0.1 - 2.0	0.5	0.2 - 5.0	0.5
BR-3	160 - 2,000	380	83 - 190	83	< 0.1 - 0.6	<0.1	< 0.1 - 0.1	<0.1
CA-1	270 - 2,000	780	100 - 2,000	250	< 0.1 - 0.6	<0.2	< 0.1 - <0.2	<0.1

PROPOSED TRAIL ALONG THE SBA

Background

The open canal sections of the SBA are fenced and are currently not accessible to the public. The East Bay Regional Park District (EBRPD) 1997 Master Plan and the 2007 Master Plan Map, the Livermore Area Regional Park District Master Plan (Personal Communication, Ken Craig, Livermore Area Regional Park District), and the City of Livermore Bikeways and Trails Master Plan (Wilbur Smith Associates et al, 2001) include a proposed trail along the SBA from Interstate 580 to Mines Road. The EBRPD 1997 Master Plan also includes a proposed trail along the upper section of the open canal portion of the SBA from the surge pool to Altamont Pass Road. This trail would then continue to Bethany Reservoir. The 2006 Update contained a discussion of potential water quality impacts associated with the trail along the SBA and potential measures to protect water quality.

Current Status

EBRPD is not actively pursuing development of the trail along the SBA or the trail to Bethany Reservoir. The current funding source (Measure WW), passed by the voters in 2008, cannot be used to fund trails in the Livermore area.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following actions related to the Watershed Protection Program and the proposed trail along the SBA:

Continue Open Communications with SBA Watershed Stakeholders

This action item was classified as an immediate action, meaning that it is important to address current critical water quality concerns or that it is easy to implement and does not require significant staff time. As described above, the SBA Contractors worked diligently for several years to conduct workshops and develop public information programs. Due to a lack of funding, this effort has not continued in the last several years. However, one of the benefits of the public information program is a continued relationship with the EBRPD.

Address Water Quality Concerns Associated with Proposed Trail along the SBA

This action item was classified as a long-term action, meaning it is an action that addresses longer-term water quality issues of a non-critical nature that will be reassessed periodically. The recommended action was for the SBA Contractors and DWR to meet with EBRPD staff to discuss their plans for a trail and identify security and water quality concerns associated with developing a trail along the SBA, if the proposed trail project was resurrected. As discussed previously, the trail is not currently a high priority for EBRPD.

POTENTIAL ACTIONS

SWPCA should Work with the DWR Division of Engineering Real Estate Branch to Evaluate Options for Restricting Cattle Access to Bethany Reservoir

A limited number of cattle on property managed by DWR currently have access to Bethany Reservoir. If DWR discontinued the lease on the southwestern side of the reservoir, cattle from the much larger privately-owned part of the watershed that is upstream of DWR property in the Bethany Reservoir watershed may still have access to the reservoir. The leases require that fences between state-owned property and private property be maintained by the lessees but the condition of those fences is unknown. The first step should be to inspect the fences to determine if discontinuing the lease would solve the problem of cattle having direct access to the reservoir.

The second consideration is that DWR has no control over activities on private property, which includes most of the Bethany Headlands drainage. SWPCA and the Real Estate Branch should explore options for communicating with the small number of large property owners in the watershed to determine if there are opportunities for better managing the grazing and the access of the cattle to the drainage courses.

DELTA-MENDOTA CANAL/CALIFORNIA AQUEDUCT INTERTIE

The Delta-Mendota Canal/California Aqueduct Intertie and Pipeline is a shared Federal/State water system improvement that is currently under construction in Alameda Country. The project will improve the reliability of the Central Valley Project (CVP) and provide operational flexibility during times of outages for both projects.

BACKGROUND

The C.W. "Bill" Jones Pumping Plant (Jones) pumps water into the CVP's DMC near Tracy. The water is primarily used for agricultural irrigation in the San Joaquin Valley, with excess water pumped into O'Neill Forebay via the O'Neill Pump-Generating Plant. The Jones maximum monthly average pumping rate for fall and winter is 4,600 cfs. The capacity of the DMC south of Jones and O'Neill's pumping capacity of about 4,200 cfs limit the amount of water that can be pumped at Jones. This can result in unmet water supply demands south of the Delta.

An intertie connecting the DMC to the California Aqueduct was identified as the best method to utilize the maximum pumping capacity at Jones. The California Bay-Delta Program (CALFED) Record of Decision included the Intertie in the Preferred Program Alternative which Congress confirmed as an operation and maintenance activity under the 2004 CALFED Bay Delta Authorization Act. The Final Environmental Impact Statement (Final EIS) for the project was prepared in 2009 and construction was initiated in the fall of 2010.

PROJECT DESCRIPTION

A Final EIS was prepared by the U.S. Bureau of Reclamation (Reclamation) in accordance with the requirements of the National Environmental Policy Act. Three action alternatives and the No Action Alternative were evaluated:

- Alternative 1 – No Action Alternative.
- Alternative 2 – Proposed Action – Construct and operate a pumping plant and pipeline connection between the DMC and the California Aqueduct north of the intersections of Highways 205 and 580.
- Alternative 3 – Construct and operate a pumping plant and pipeline connection between the DMC and the California Aqueduct a few miles south of Highway 580.
- Alternative 4 – Use Banks Pumping Plant capacity not used by the SWP for Table A deliveries (existing long-term SWP water supply contract amount) to pump the increment of CVP water that cannot be conveyed in the DMC without the Intertie and install a temporary intertie during emergencies and maintenance activities.

The Final EIS assessed the potential environmental, social, and economic effects resulting from the Intertie project. To ensure consistency with the National Environmental Policy Act and the Endangered Species Act, analysis and modeling assumptions in the Final EIS were based on the modeling assumptions used in the CVP/SWP Operations Biological Opinions (BOs). Although the BOs have operational constraints that affect the Intertie, the Final EIS analyses describe the maximum effects of operating the Intertie without restrictions from the BOs. After construction is complete, the operation of the Intertie would be subject to all applicable Delta export pumping restrictions for water quality and fishery protection.

Alternative 2 was determined to be the preferred alternative in the Final EIS and Record of Decision. The intertie is a shared project between Reclamation, DWR, and the San Luis & Delta-Mendota Water Authority. The intertie is located in Alameda County just north of Highway 205 where the California Aqueduct and DMC are only 500 feet apart. The location was shown previously in **Figure 3-5**. The project consists of two 108 inch diameter underground pipelines that will connect the DMC to the aqueduct. A pumping plant at the DMC will have the capacity to pump a maximum of 467 cfs from the DMC to the aqueduct. Although the pumping plant will have a capacity of 467 cfs, the maximum average monthly pumping is expected to be approximately 400 cfs. The intertie could be used to convey water in either direction. Up to 900 cfs of flow from the California Aqueduct to the DMC could be conveyed through the intertie using gravity flow. The total project cost is $28 million and construction was completed in April 2012.

The intertie will be used under three different scenarios:

- Up to 467 cfs will be pumped from the DMC to the California Aqueduct (a monthly average of 400 cfs) to help meet water supply demands of CVP contractors or be stored in the CVP portion of San Luis Reservoir for later release to meet CVP demands. This will allow Jones to pump to its monthly average design capacity of 4,600 cfs in the fall and winter months, subject to all applicable export pumping restrictions for water quality and fishery protections. The intertie will be operated primarily from September through March.

- Up to 467 cfs will be pumped from the DMC to the California Aqueduct to minimize impacts on water deliveries attributable to temporary restrictions in flow or water levels in the DMC south of the intertie, or the aqueduct north of the intertie, for system maintenance or because of an emergency outage.

- Up to 900 cfs will be conveyed from the California Aqueduct to the DMC using gravity flow to minimize impacts on water deliveries attributable to temporary restrictions in flow or water levels in the aqueduct south of the intertie, or the DMC north of the intertie, for system maintenance or for an emergency outage of the DMC, Jones, or Tracy Fish Facility.

During normal intertie use, water in the DMC will be conveyed to the California Aqueduct via the intertie. Water diverted through the intertie will be conveyed through the aqueduct to O’Neill Forebay. The CVP water reaching O’Neill Forebay may be pumped into San Luis Reservoir, released to the San Luis Canal and the Dos Amigos pumping plant, or released through the O’Neill Pump-Generating Plant to the lower DMC and Mendota Pool.

KEY WATER QUALITY CONCERNS

The Final EIS evaluated the impacts of increased pumping at Jones on EC (EC), DOC, temperature, and suspended sediment at a number of Delta locations. Changes in EC were simulated by the CALSIM model and the Delta Simulation Model 2 (DSM2). The CALSIM model estimated the future monthly Delta inflow and exports associated with the No Action Alternative and the Proposed Action. The DSM2 water quality model simulated EC data from 16 water years (1976 – 1991). This period is considered to be typical of the longer hydrologic period used in the CALSIM model and represents a range of hydrologic conditions including the 1976-77 drought and the wet years of 1983 and 1986. Comparisons of the No Action Alternative and the Proposed Action were used to evaluate probable water quality effects due to the installation of the intertie.

Changes in salinity were examined at Jersey Point, Rock Slough, Los Vaqueros Intake, Banks and Jones. **Table 14-3** presents a summary of the EC results. Changes in EC at all locations were generally minimal with no adverse effects.

Table 14-3. DSM2-Simulated Average EC (µS/cm) for Intertie and No Action Alternative

	Jersey Point	Rock Slough Intake	Los Vaqueros Intake	Banks	Jones
Intertie	1,116	570	487	473	495
Future No Action	1,111	571	485	471	494
Increase	5	-1	2	2	1
Maximum increase	274	49	126	136	100
Number of months with increase >100 µS/cm	10	0	1	1	1
Number of months with increase >10 µS/cm	47	21	29	19	17

Source: Final EIS, Table 3.3-1

The impacts of the project on other water quality constituents were handled qualitatively in the Final EIS. Due to the small changes in CVP and SWP exports, DOC concentrations are not expected to change between the No Action Alternative and the Proposed Action. No significant temperature impacts are expected from the Proposed Action since Delta temperatures are in equilibrium with the seasonal meteorology. Temperature changes are expected to be within normal seasonal variability. High suspended sediment concentrations or turbidity are generally attributed to surface runoff, re-suspension of bottom sediment materials following major storms, high winds or tidal currents. Therefore, no substantial changes are expected in turbidity concentrations due to the Proposed Action.

The Final EIS did not evaluate the impacts on the quality of water in the California Aqueduct, O'Neill Forebay, or San Luis Reservoir as a result of the intertie. The intertie will be operated mainly between September and March when EC levels and bromide concentrations are highest in the South Delta. The volume of water pumped from the DMC into the California Aqueduct (maximum of 467 cfs) is relatively small compared to the flows in the aqueduct so there may not be a change in EC levels.

POTENTIAL ACTIONS

SWPCA should Work with MWQI and the DWR Modeling Section to Use the Aqueduct Extension Model to Evaluate the Water Quality Impacts of the Intertie.

The Aqueduct Extension Model should be used to evaluate the water quality impacts of the intertie, whenever it is being used, to provide early warning to downstream SWP Contractors of increases in EC and bromide levels resulting from pumping water from the DMC into the California Aqueduct.

SAN LUIS RESERVOIR

San Luis Reservoir is a key component of both the SWP and the CVP, serving as the major storage facility south of the Delta. The San Luis Low Point Improvement Project and cattle grazing in the San Luis watershed were discussed in the 2006 Update. This section provides an update on these issues.

SAN LUIS LOW POINT IMPROVEMENT PROJECT

Background

Water is released from San Luis Reservoir on the west side through the Pacheco Pumping Plant (Pacheco), to meet the needs of federal CVP San Felipe Division Contractors in Santa Clara and San Benito counties. SWP and CVP Contractors in the San Joaquin Valley and southern California are served by releases from the east side of the reservoir through the William R. Gianelli Pumping-Generating Plant (Gianelli). **Figure 14-12** shows the facilities around San Luis Reservoir. San Luis Reservoir has a capacity of 2.03 million acre-feet. It is generally filled with Delta water during the fall and winter months and then drawn down during the spring and summer months.

Currently, state and federal water projects cannot fully utilize water stored in San Luis Reservoir without impacting the reliability of water deliveries to San Felipe Division Contractors. The location of the San Felipe Division intake, Delta operations, system-wide demands and diminished water quality together reduce project water supplies south of the Delta. These constraints are collectively known as the San Luis low-point problem. Water quality is one component of the low point problem. When the reservoir is substantially drawn down, the quality of water delivered via Pacheco can be adversely affected by algal growth in the reservoir. The San Luis Low-Point Improvement Project is attempting to address both water supply reliability and water quality issues.

Delta water stored in San Luis Reservoir contains sufficient nutrients to stimulate algal blooms in the reservoir, particularly when water levels are low in the late summer and early fall. Algae grow in the upper 30 feet of the reservoir. SCVWD has experienced severe T&O incidents and other treatment problems at its water treatment plants when algae are drawn into the Pacheco intake. The low-point begins to affect San Felipe Division operations when water level in the reservoir drops to an elevation of about 406 feet above mean sea level. At this elevation, 571,000 acre-feet of water are stored in the reservoir. When the water level approaches 406 feet, the upper intake of Pacheco (elevation 376 feet) is shut off to avoid drawing algae from the surface waters of the reservoir into the intake. If the water drops to an elevation of 369 feet (the low-point), algae can be drawn into the lower intake of Pacheco (elevation 334 feet). If the water level drops below the lower Pacheco intake, water deliveries to the San Felipe Division Contractors are interrupted. The top of the intake for Gianelli is 38 feet deeper than the lower Pacheco intake so it is not affected by algal growth as long as water levels are maintained at levels that allow withdrawal through the Pacheco intake. **Figure 14-13** is a schematic that illustrates the low- point problem.

Figure 14-12. San Luis Reservoir Facilities

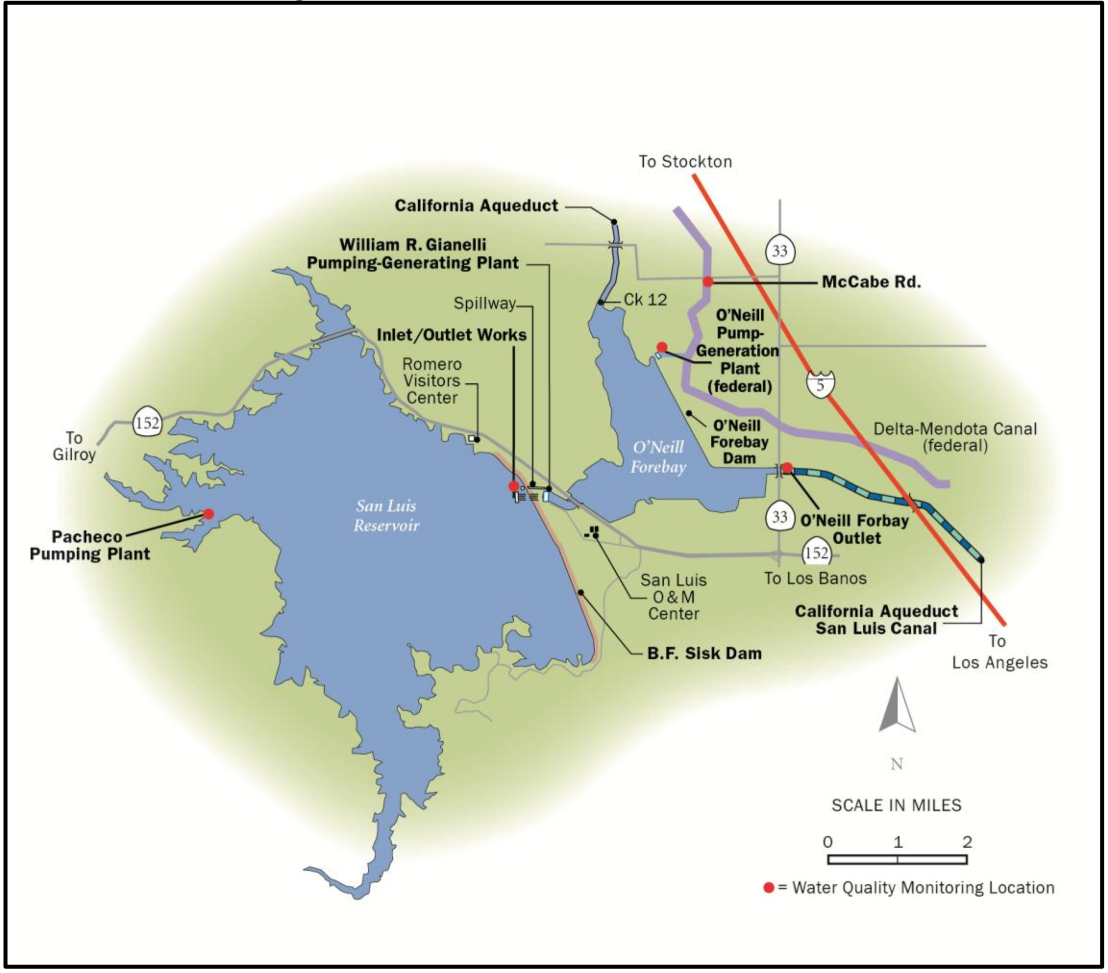
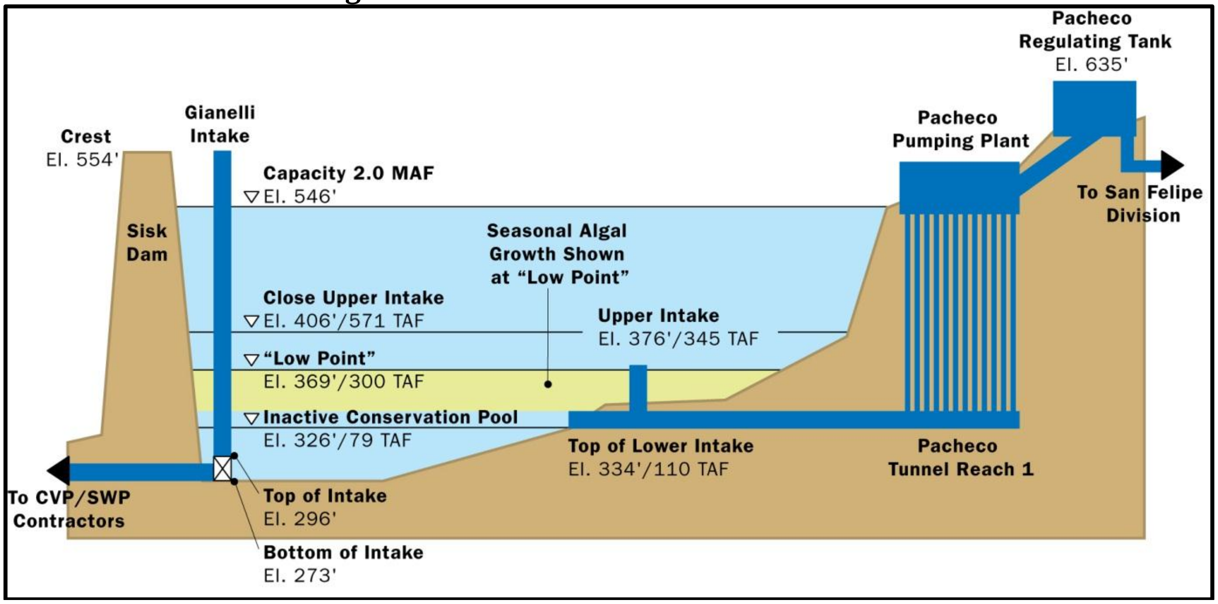


Figure 14-13. San Luis Low-Point Problem



Source: SCVWD

The low-point problem restricts the operational flexibility of San Luis Reservoir for all CVP and SWP Contractors south of the Delta. The need to maintain the water level in the reservoir at or above 300,000 acre-feet to meet San Felipe Division allocations reduces the available supply by about 200,000 acre-feet. As the state's population continues to expand, and demand for water continues to grow, there will be increased need to use the 200,000 acre-feet of water stored below the low-point.

Current Status

Water levels in San Luis Reservoir typically reach their annual minimum elevations in late summer or early fall. The elevation of the water surface at the low point in a given year depends on the amount of water that the CVP and SWP operators were allowed to export from the Delta, the amount of water remaining in the reservoir from the prior year, and the water demands of the CVP and SWP Contractors. In any given year the reservoir can be substantially drawn down to meet Contractor demands.

Given likely growth in future water demands, and additional regulatory requirements, it is anticipated that storage in San Luis Reservoir will be more fully exercised and result in more frequent and lower late-summer storage levels in the reservoir. A 2006 report prepared by Reclamation shows the simulated San Luis Reservoir end-of-month storage conditions under 2001 and 2020 levels of development over a 73-year hydrologic cycle from 1922 through 1994. Simulation results were extracted from the Operations Criteria and Plan CALSIM II studies. Under the 2001 level of development, it is expected that only in the rarest of circumstances would storage in San Luis Reservoir be drawn to the minimum conservation pool of 79,000 acre-feet. However, with a 2020 level of development, the reservoir storage level would reach the minimum conservation pool about 25 percent of the time.

As stated in the 2006 Update, Congress authorized the Secretary of the Interior, acting through Reclamation, to conduct a feasibility study of San Luis Reservoir. This 2004 authorization is under CALFED Bay-Delta Program, CALFED Bay-Delta Authorization Act (Public Law 108-361) Section 103(f)(1)(A).

The first report prepared by Reclamation after the federal legislation was signed, was the "San Luis Reservoir Low Point Improvement Project Final Appraisal Report", dated May 2006. The purpose of the study was to identify problems and potential solutions related to low water levels and other water resources issues associated with San Luis Reservoir and its operation. The report recommended that a Federal feasibility study be initiated. The four phases of a Federal feasibility study are:

- Initial Alternatives Phase
- Public Scoping
- Plan Formulation Phase
- Feasibility Report/EIS/EIR Phase

This section contains a discussion of each of the above components that have been completed, and the major findings.

Initial Alternatives Phase

The Initial Alternatives Information Report for the San Luis Low Point Improvement Project was completed in February 2008 by the study team, composed of representatives from Reclamation, SCVWD, San Luis and Delta-Mendota Water Authority, and consultants. The study team developed 25 initial alternatives which fell into seven general categories:

- Institutional or non-structural alternatives to reduce the likelihood of San Luis Reservoir reaching 300,000 acre-feet
- Source water quality control
- Water treatment
- Conveyance facilities that would allow San Felipe Division CVP supplies to bypass the San Luis Reservoir or lower the San Felipe intake
- Storage
- Alternative water supplies
- Combination alternative

The study team evaluated and screened the 25 alternatives under the Federal criteria (completeness, effectiveness, acceptability, and efficiency), and recommended that 17 alternatives be forwarded for further analysis.

Public Scoping

Reclamation and the SCVWD held public meetings in September 2008 to receive input on issues that needed to be addressed in the environmental documents on the project. The National Environmental Policy Act regulations require scoping to determine the scope of the issues to be addressed in the environmental review and to identify significant issues. The California Environmental Quality Act (CEQA) requires public notification of the initiation of an EIR through a Notice of Preparation. The SCVWD is the lead agency under CEQA. The NOP was filed with the State Clearing House on September 3, 2008.

Prior to the scoping meeting, but after the Initial Alternatives Information Report was completed, the study team determined that some alternatives did not fully meet the Federal criteria. The new information and analysis resulted in the study team screening out 14 of the 17 alternatives recommended for further analysis.

Plan Formulation Phase

The remaining three action alternatives, Lower San Felipe Intake Comprehensive Plan, Pacheco Reservoir Comprehensive Plan, and the Combination Comprehensive Plan were evaluated in detail in the Plan Formulation Report, completed in January 2011. The goal of this phase was to formulate, evaluate, and compare a set of alternatives in sufficient detail to determine if one should be tentatively selected for implementation in the Draft and Final Feasibility Report.

The Lower San Felipe Intake Comprehensive Plan includes construction of a new, lower San Felipe Intake to allow reservoir drawdown to its minimum operating level without algae reaching the San Felipe intake. Moving the San Felipe intake to an elevation equal to that of the Gianelli intake would allow operation of San Luis Reservoir below the 300,000 acre-feet level. The plan also includes exchanges, transfers, and groundwater banking to provide additional sources of water supply.

The Pacheco Reservoir Comprehensive Plan includes expansion of the existing Pacheco Reservoir to provide storage for San Felipe Division contractors. During low point months, San Felipe Division contractors would receive deliveries from Pacheco Reservoir, which would allow drawdown of San Luis Reservoir to its minimum operating level. Two alternative sizes are being considered in this phase of the study, an 80,000 acre-feet reservoir and a 130,000 acre-feet reservoir. The plan also includes exchanges, transfers, and groundwater banking to provide additional sources of water supply.

The Combination Comprehensive Plan includes multiple structural components and management measures to maximize operational flexibility and supply reliability in the San Felipe Division. The plan would include increased groundwater aquifer recharge and recovery capacity, desalination, institutional measures, and the re-operation of the SCVWD raw and treated water systems. Other elements which may be considered are drinking water treatment improvements, shallow groundwater pumping, and indirect potable reuse.

The report includes a detailed examination of how well each comprehensive plan meets the Federal criteria (completeness, effectiveness, acceptability, and efficiency). The report found that all three comprehensive plans generally performed well for all of the criteria. Therefore, all three action plans were recommended to be carried forward to the next phase of the Feasibility Study, which is the Feasibility Report/EIS/EIR Phase.

Feasibility Report/EIS/EIR

A Feasibility Report and companion EIS/EIR is currently being prepared. It is expected that the Feasibility Report will include an analysis of planning, engineering, environmental, social, economic, and financial issues. The EIR/EIS will address the potential effects of a recommended plan and alternatives. It is anticipated that the Feasibility Report and EIS/EIR will be completed by April 2013.

CATTLE GRAZING

Background

The issue of cattle grazing in the San Luis watershed was identified as a potential sanitary concern in the 2006 Update. Cattle have been observed primarily in the Cottonwood Bay area of San Luis Reservoir, and are able to access the water. The number of total cattle residing in the local watershed is unknown.

Current Status

In 2007, DWR and SWPCA discovered that there was no fencing to prevent cattle from accessing the water. Efforts are underway to coordinate among the cattle owner, the land owner (Reclamation) and the San Luis Field Division to prevent the cattle from accessing the water.

Figure 14-14 shows the approximate location of the cattle grazing area, and three potential fencing alignments. It would cost approximately $36,000 for the 6,029 meters of fencing (Personal Communication, John Coburn, SWPCA).

STATUS OF ACTION ITEMS

The 2007 SWP Action Plan contains the following action related to cattle grazing:

Improve Range Management and Restrict Cattle Access to SWP Facilities

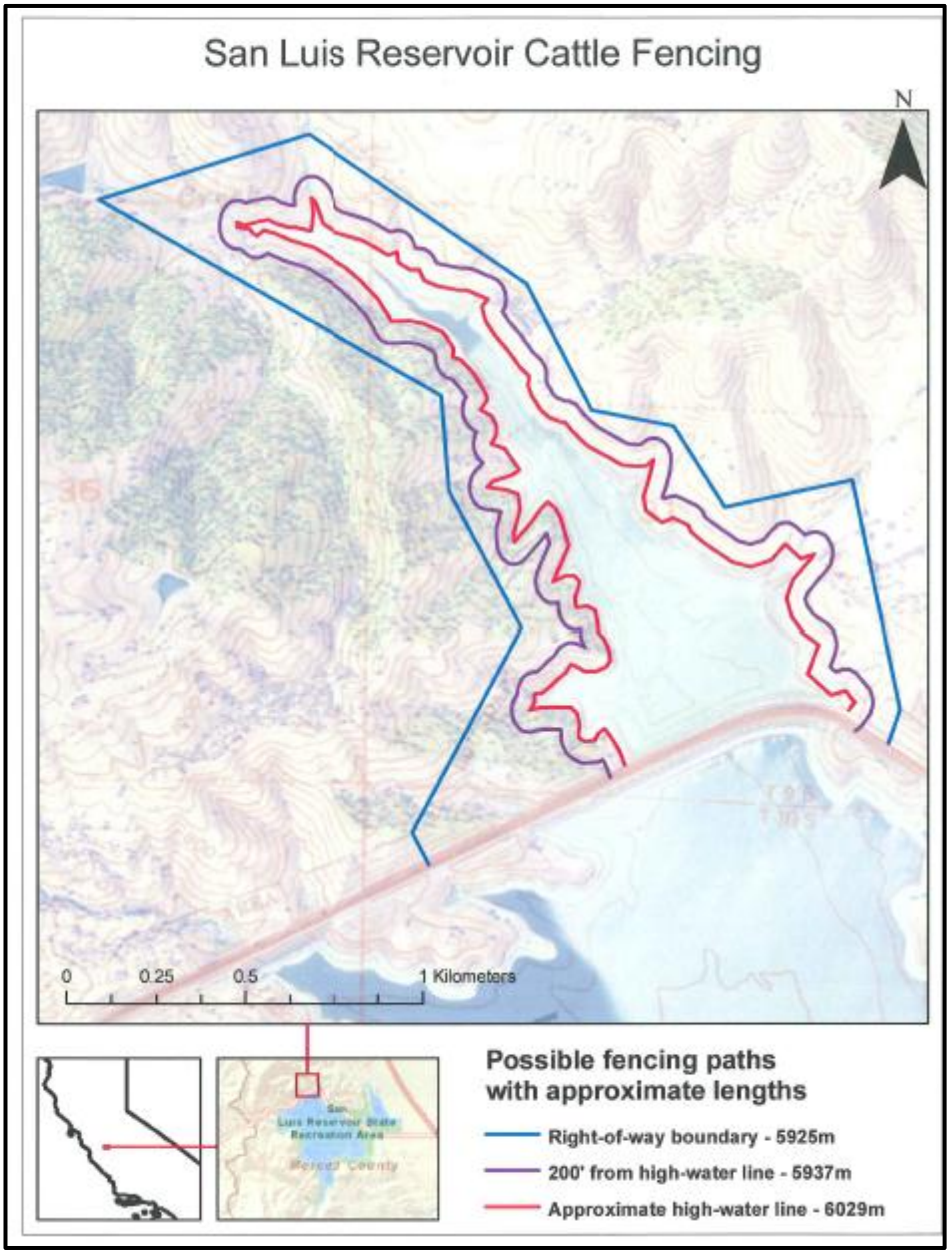
This action item was classified as immediate. As discussed previously, SWPCA has been working with DWR and Reclamation to restrict cattle access to San Luis Reservoir.

POTENTIAL ACTIONS

SWPCA and DWR should Continue their Efforts to Exclude Cattle from San Luis Reservoir.

CDPH has identified this as a high priority action.

Figure 14-14. Potential Fencing Alignments to Address Cattle Trespass Issue at San Luis Reservoir



Source: SWPCA

COASTAL BRANCH

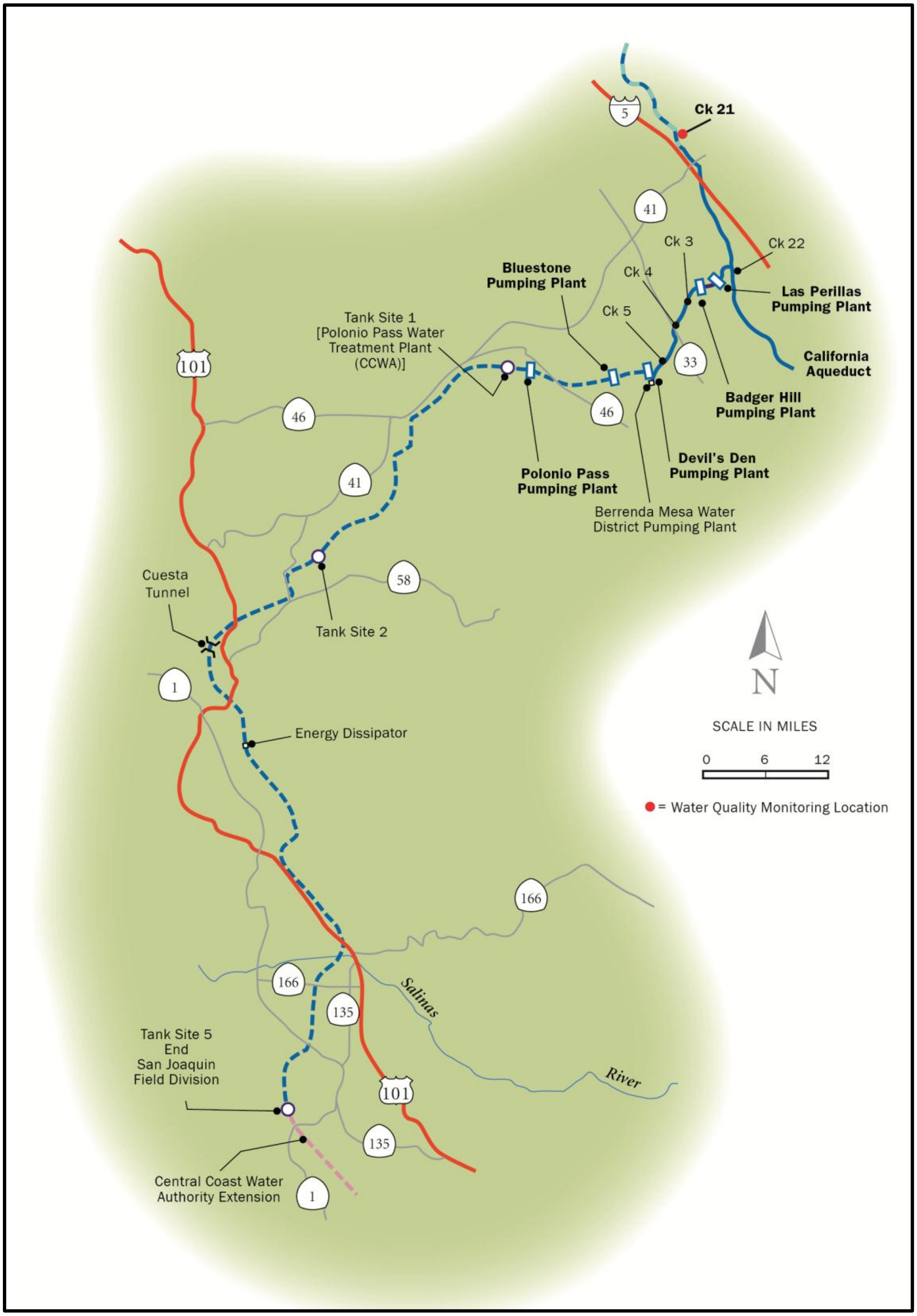
The Coastal Branch provides drinking water supplies to communities in California's central coast region through the CCWA. The Coastal Branch begins approximately 185 miles downstream of Banks and about 12 miles south of Check 21. The Coastal Branch extends about 115 miles from Kettleman City into northern Santa Barbara County and was constructed in two phases. The key features of the Coastal Branch are shown in **Figure 14-15.**

Phase I of the Coastal Branch was placed into operation in 1968 and consists of approximately 15 miles of open channel canal and two pumping plants, with a conveyance capacity of approximately 450 cfs. The first pumping plant off the aqueduct is the Las Perillas Pumping Plant, followed by the Badger Hill Pumping Plant. Both pumping plants receive water from an open channel canal and discharge into an open channel canal, with lifts of 55 and 151 feet respectively. The forebays for each pumping plant are relatively short and are designed so that the pump intakes are in-line with the canal flow direction. The terminal end of the Phase I Coastal Branch is the Berrenda Mesa Irrigation District Pumping Station, which has a similar forebay design as Las Perillas and Badger Hill Pumping Plants.

Phase II Coastal Branch was placed into service in 1997. Phase II consists of three pumping plants, a water treatment plant, approximately 600 feet of open channel canal, and approximately 100 miles of buried pipeline. The Phase II Coastal Branch starts at a point approximately one mile upstream of the Berrenda Mesa Irrigation District Pumping Plant, which is the terminal end of the Phase I Coastal Branch. The first 600 feet of the Phase II Coastal Branch is an open channel canal that connects to the Phase I canal in a perpendicular arrangement. The open channel canal portion of Phase II discharges into the forebay of the Devil's Den Pumping Plant. This pumping plant is followed by the Bluestone Pumping Plant and the Polonio Pass Pumping Plant. Each pumping plant draws water from its own forebay and discharges water into a pressurized pipeline, which ultimately discharges into the forebay of the next pumping plant. The Polonio Pass Pumping Plant discharges into the raw water tanks of the Polonio Pass Water Treatment Plant (PPWTP), which provide approximately 24.1 million gallons of storage

The portion of the Phase II Coastal Branch between its start and the PPWTP has a conveyance capacity of approximately 100 cfs, which is approximately 29 cfs higher than the conveyance capacity of the pipeline immediately downstream of the treatment plant. The reason for the higher conveyance capacity upstream of the PPWTP is to allow for the operation of the pumping plants during off-peak periods and to shut down the pumping operation during the on- peak periods. The three pumping plants collectively lift water approximately 1500 feet vertically. Due to the large energy requirements for pumping water with such a significant lift, it was determined to be more cost effective to design and build the pumping plants and connecting discharge piping for 100 cfs capacity, given the cost of power during the peak periods. This higher capacity would allow the pumping plants to operate only during off-peak periods. Consequently, the pumping plants are typically shutdown for periods of at least eight hours each day, during daylight hours.

Figure 14-15. Coastal Branch Facilities



This section will provide an update on the forebay, canal, and storage tank maintenance issues along the Coastal Branch as previously discussed in the 2006 Update. The following three key issues will be the focus of this section:

- Sediment accumulation in the three pumping plant forebays leading to the PPWTP
- Elevated 2-methylisoborneol (MIB) levels in the source water
- Elevated concentrations of ammonia at the PPWTP influent immediately before and after the DWR annual winter maintenance shutdown, depending on canal dewatering schedule

BACKGROUND

Due to the daily down time for the three pumping plants in the Phase II Coastal Branch, the potential for sedimentation and sediment accumulation exists within the open channel canal section, the pumping plant forebays and the raw water storage tanks. In addition, the forebay of each pumping plant is structured so that the pump intake is situated perpendicular to the flow path of water as it is discharged into the forebay. The observed sedimentation patterns within each forebay suggest that the "sidedraft" design may contribute towards sediment accumulation within certain sections of the forebays.

In response to T&O events from 2000 to 2005, CCWA staff conducted an investigation to evaluate the cause of each event. The investigation included staff field observations and a review of water quality data from the PPWTP influent, pumping plant forebays and the California Aqueduct. The investigation revealed that: (1) in some years, MIB concentrations increase from one pumping plant to the next, (2) when MIB was detected in the forebays, MIB concentrations from the California Aqueduct were low, (3) CCWA staff observed off-gassing from the accumulated sediment within the pumping plant forebays, and (4) elevated ammonia concentrations are typically observed in water samples collected from the forebays prior to and following the DWR Operations & Maintenance Division (O&M) annual winter maintenance shutdowns. Based on these observations, CCWA staff theorized that sediment accumulation in the forebays may provide an ideal environment for biological activity and may also produce blue-green algae, which could lead to the production of T&O compounds in the water.

CURRENT STATUS

Over the last five years, the CCWA has implemented a number of measures to address T&O issues that may arise from sediment accumulation in the forebays and canals. These measures include:

- Cooperating with and encouraging DWR to implement a routine sediment removal program from the open channel canal, forebays, and storage tanks
- Implementing a MIB Monitoring Program/Response Plan at the PPWTP, pumping plant forebays and selected canal locations

- Conducted an experiment using the SolarBee to evaluate its effectiveness in minimizing sediment accumulation and prevention of blue-green algae blooms in a pumping plant forebay

- Investigated alternative theories that may explain the monitoring data for MIB levels

Although the 2006 Update suggested that "sediment accumulation in the forebays and storage tanks of the Coastal Branch presents water quality concerns because sediments can support biological growths that can be a source of T&O compounds in treated drinking water", the CCWA has not been able to confirm this theory. Over the past five years, CCWA staff has not been able to confirm that greater amounts of accumulated sediment will lead to greater T&O incidents. However, there have been no major sustained T&O events from 2006 to 2010, at either Banks or the PPWTP.

Overall, sediment accumulation in the pumping plant forebays is still occurring and remains a concern, despite an active sediment removal program developed by DWR. Elevated ammonia levels are routinely observed in the PPWTP influent as the water levels in the canal are reduced just prior to the DWR annual winter shutdown. These elevated ammonia levels persist for up to two weeks after the DWR annual winter shutdown is over and water operations resume.

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Taste and Odor Issues

To address potentially elevated MIB concentrations in the PPWTP influent, CCWA has developed an MIB response plan. The basic components of the response plan are:

- CCWA reviews MIB data collected at Banks and O'Neill Forebay Outlet by DWR.

- When MIB levels at Banks or O'Neill Forebay Outlet are detectable, CCWA begins MIB monitoring at the PPWTP influent, which is typically late summer.

- When MIB levels at PPWTP influent reach a level of concern, CCWA conducts upstream MIB monitoring at the pumping plant forebays and selected canal locations.

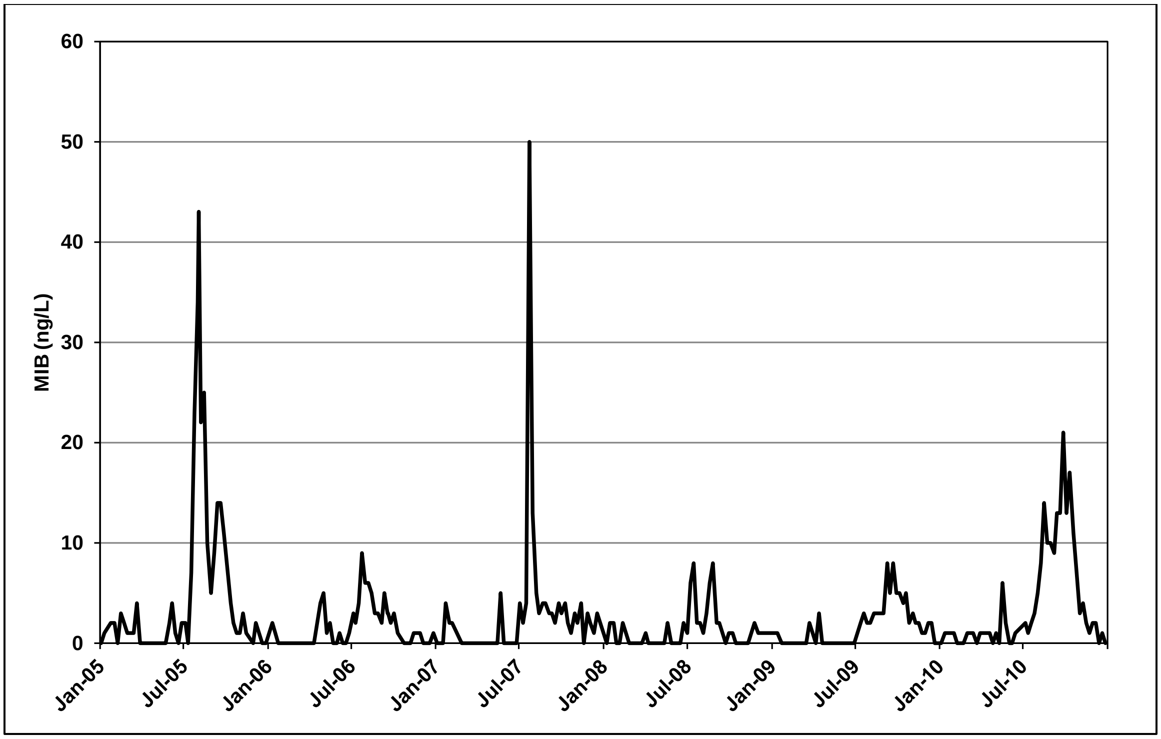
- If MIB levels are either above 10 ng/L at the PPWTP influent or elevated for longer than three weeks at the Banks sampling location, CCWA consults its project participants and, if directed, deploys a powdered activated carbon (PAC) dosing system at the PPWTP intake. Jar tests are conducted to determine the optimal PAC dose.

As part of developing an MIB response plan, the CCWA attempted to identify a MIB action level at O'Neill Forebay Outlet to provide early warning of a potential T&O event. However, O&M did not begin publishing and widely distributing MIB monitoring results from O'Neill Forebay Outlet until 2008. In addition, the MIB concentrations at O'Neill Forebay Outlet have been low from 2009 to 2010. Consequently, an action level could not be established.

MIB concentrations were correlated between Banks and the PPWTP influent, but the correlation appears to be highly influenced by differences in travel time in the California Aqueduct and releases from the San Luis Reservoir (Personal Communication, John Brady, CCWA). The CCWA tracks MIB levels at Banks to provide early warning for a potential T&O event.

In general, CCWA becomes increasingly concerned when MIB levels at Banks reach 20 ng/L for two or more weeks. As shown in **Figure 14-16**, there have been only two instances when MIB was above 20 ng/L at Banks since 2005. In 2005, MIB exceeded 20 ng/L for six weeks and in 2007 MIB exceeded 20 ng/L for one week.

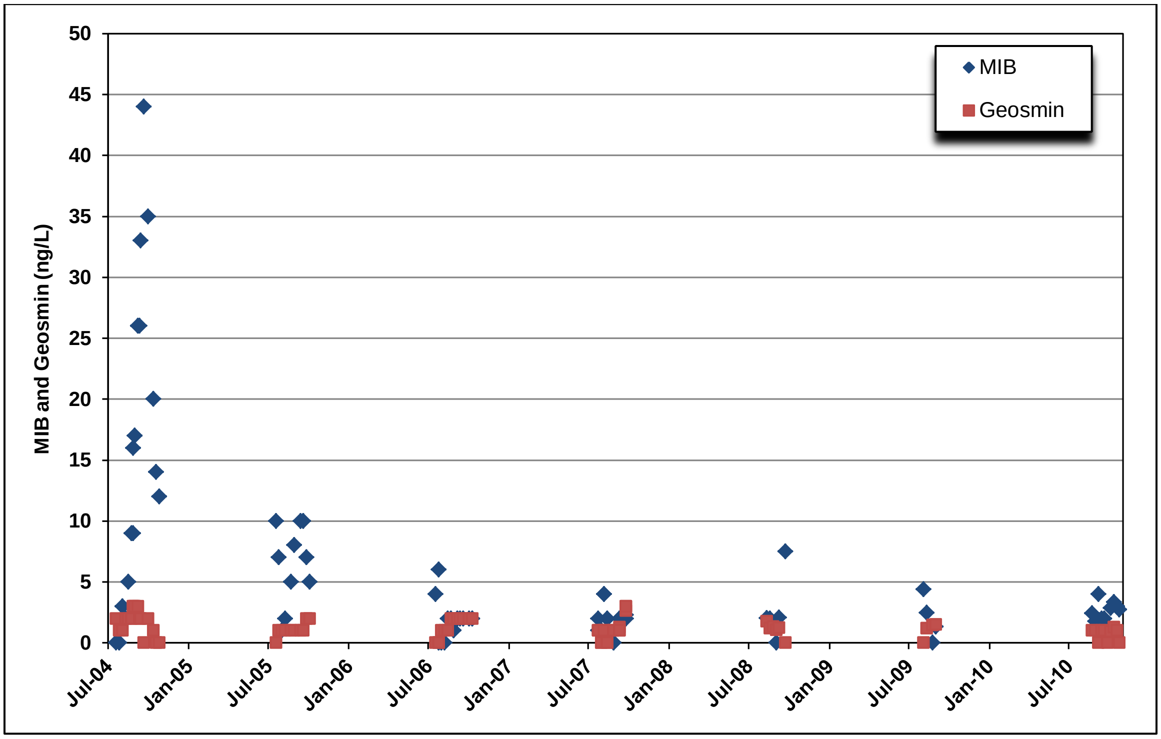
Figure 14-16. MIB Levels at Banks, 2005-2010



Note: Data collected by DWR

As shown in **Figure 14-17**, there have been no major MIB events impacting the PPWTP since the Jones Tract Levee failure. Jones Tract pumping began on July 14, 2004 and ended in January 2005. Consequently, it is unclear if the sediment removal activities within the pumping plant forebays are preventing MIB formation or not. Further, the on-going accumulation of sediment and the persistence of elevated ammonia concentrations in PPWTP influent prior to and following the annual DWR winter maintenance shutdown suggest that the sedimentation issue still creates an environment that supports biological activity.

Figure 14-17. MIB and Geosmin Levels in CCWA Raw Water Tanks



Note: Data collected by CCWA

Due to the continuing sediment accumulation and the detection of elevated ammonia levels in the Coastal Branch, CCWA staff conducted a literature review to determine if there may be alternative reasons why MIB appears to increase from one pumping plant to another in certain years. One paper identified by CCWA staff was prepared by Dickens, Graham, and Freese of the Umgeni Water Scientific Services Division. This paper suggests that T&O compounds are released into the water when algal cells are ruptured after being subjected to high pressure due to high head pumping. Experimental work conducted by Umgeni Water showed that pressure was the most significant factor accounting for algal rupture, with maximum rupture occurring in the range of 1320 kilopascals, or about 442 feet of head (Umgeni Water, 1996). According to CCWA, the Devils Den, Bluestone, and Polonio Pass pumping plants all provide 500 feet of lift each. In 2007, CCWA developed a study plan to test this hypothesis, but levels of MIB have not been high enough to initiate the study.

It is important for CCWA to understand why MIB formation occurs along the Coastal Branch, and to receive advanced warning of T&O events. The CCWA will not be able to rely on their granular activated carbon (GAC) filters to remove MIB as the CCWA has postponed GAC filter media replacement indefinitely as a cost savings measure. This decision was made after conducting both pilot and full-scale TOC removal studies to determine the appropriate replacement frequency of the GAC media. After the GAC media in eight filters was replaced in 2008, TOC removal rates through the filters were studied. After less than six months, the sorption capacity for TOC had been exhausted. A side by side study was then conducted, comparing TOC removal rates through an exhausted GAC column and an anthracite column. It was found that both columns performed equally in terms of TOC removal and the TOC removal efficiency was more than sufficient to meet regulatory standards for surface water treatment. Therefore, the decision was made to postpone GAC media replacement indefinitely. The trigger for replacing the GAC filter media will be based on declining hydraulic performance, which is currently routinely monitored.

Since the sorption capacity of the GAC filter media is exhausted, the ability to remove MIB by sorption is lost. Consequently, CCWA will rely on their MIB response plan (as described above) to address potential T&O incidents in the future.

Sediment Accumulation Issues and Elevated Ammonia Levels

Ongoing maintenance to address sediment accumulation is handled by both CCWA and DWR. Routine maintenance occurs annually during the two to four week winter maintenance shutdown. DWR drains selected open channel canals and forebays for inspection and sediment removal. According to CCWA, all five forebays have never been cleaned during the same shutdown. In 2010, 2,362 cubic yards of dredged sediment was removed from the Bluestone forebay and 6,488 cubic yards of dredged sediment were removed from the Polonio Pass Pumping Plant in 2011.

Sedimentation continues to occur, despite DWR's efforts to implement a routine sediment removal program. Sediment removal was initiated in 2003 and continues to be a major effort during each annual winter maintenance shutdown. **Table 14-4** is a summary of the sediment removal projects completed from 2003 to 2010.

According to CCWA, as soon as the shutdown is initiated and the canal dewatering is initiated, elevated concentrations of ammonia are observed at the PPWTP influent. This continues for up to two weeks even after the system is put back into full operation. Ammonia levels at the PPWTP immediately prior to and following the 2010 DWR annual winter maintenance shutdown are presented in **Figure 14-18.** .

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan included two action items related to the Coastal Branch.

Continue SolarBee Experiment and Collect Data to Assess Water Quality Impacts

This action item was prioritized as immediate in the 2006 Update, indicating that the issue was of critical nature. Accordingly, the CCWA initiated this study to evaluate the SolarBee for: (1) keeping sediment suspended within the pumping plant forebays and thus preventing sedimentation and (2) preventing conditions that may lead to the growth of blue-green algae or other similar biological activity leading to T&O issues (SolarBee Test Plan, 2005). It was noted during the study that the character of the sediment was unique and appeared to shift at the start of pumping operations, which suggested that the sediment was light. It was hoped that the SolarBee would be effective in suspending this sediment within the water column. The study focused on monitoring sediment accumulation and MIB concentrations to determine the effectiveness of the SolarBee.

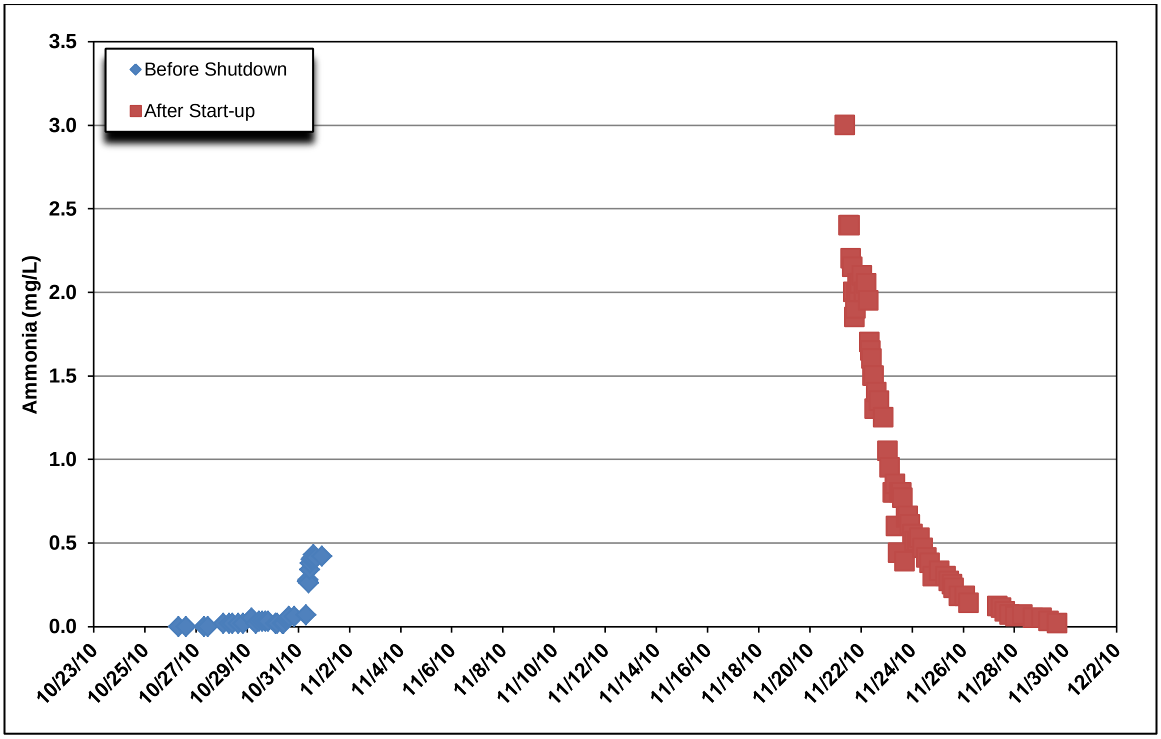
Table 14-4. Summary of Sediment Removal Projects along Coastal Branch

Date	Process
March 2003	Tank Site 1 and raw water tanks cleaned by CCWA staff. Sludge sent to lagoon "C".
Fall 2003	DWR partially cleaned Devils Den forebay.
November 2004	Devils Den forebay drained and cleaned.
June 2005	Polonio PP forebay was cleaned by CCWA staff with assistance from DWR. A temporary pipeline was placed between the pump plant and the PPWTP with two booster stations. The sludge was pumped to Lagoon "B". A floating dredge was fashioned by CCWA for sludge removal.
November 2005	Devils Den forebay cleaned.
November 2006	Devils Den drained/cleaned.
April 2007	Bluestone forebay was cleaned by DWR staff with assistance from CCWA. Sludge was pumped/dredged from the bottom and trucked to a DWR site for drying.
November 2007	Pools 3-6 drained/cleaned. Devils Den forebay cleaned.
November 2008	Pools 3-6 drained/cleaned. Modifications made to Devils Den forebay to provide a sump for sludge collection.
November 2009	Pools 2-6 drained/cleaned. Pool 2 has not been drained/cleaned since the 1980's. Devils Den forebay cleaned.
November 2010	Pools 1-6 drained. Pool 1 was cleaned and has not been drained/cleaned since the 1980's (info. from tenured DWR field staff). Devils Den forebay was cleaned. Bluestone forebay was cleaned, and sludge trucked to CCWA lagoon "A". Bluestone and Polonio forebays were at minimum water levels since operation began in 1997.

The use of the SolarBee was found to be limited, as the velocity of the SolarBee was not high enough to keep sediment suspended as hoped and did not appear to prevent subsequent sedimentation from occurring. Over a six month period of operation of the SolarBee, the average sediment depth in the Polonio Pass Pumping Plant forebay increased from 1.2 feet to 1.3 feet. However, to properly evaluate the effectiveness of the SolarBee operation and interpret this finding, a more thorough understanding of the sedimentation rate within the forebay would need to be developed.

Upon further evaluation, it was found that the SolarBee operation would turn-over one forebay volume of water approximately every 14 days of operation. This was very small when compared to the pumping plant operation. The pumping plant would turn-over one forebay volume of water in 1.1 hours when operating at full capacity. Also, the SolarBee's intake piping would routinely get trapped in sediment and clog, preventing the SolarBee from circulating in the forebay. Consequently, the use of the SolarBee was suspended in 2008.

Figure 14-18. Ammonia Levels at PPWTP Before and After 2010 Winter Shutdown



Prevent Sediment Accumulation in Forebays and Storage Tanks With Proper Maintenance

As mentioned earlier, CCWA and the DWR San Joaquin Field Division staff continue to work on sediment removal as part of routine maintenance during the annual winter shutdown. Due to water quality and operational impacts, along with on-going accumulation of sediment, CCWA is working with DWR to develop an alternative cleaning strategy that has less of an impact on water quality. In addition, the CCWA continues to study the impacts of sediment accumulation and MIB formation in the Coastal Branch.

POTENTIAL ACTIONS

O&M should Provide Adequate Monitoring and Data Reporting for T&O Compounds at O'Neill Forebay Outlet.

A review of the 2003 to 2010 O&M Water Quality Taste and Odor Report (distributed to SWP Contractors) revealed that O'Neill Forebay Outlet data were not widely available until 2008. In addition, O'Neill Forebay Outlet samples are not collected as frequently as the Banks sample location. The number of sampling events at Banks compared to O'Neill Forebay Outlet is shown in **Table 14-5**.

Table 14-5. Comparison of T&O Sampling Frequencies

Year	Number of Samples Collected at Banks	Number of Samples Collected at O'Neill Forebay Outlet	Percent Missed Sampling Opportunities at O'Neill Forebay Outlet
2008	51	38	25.5
2009	50	30	40.0
2010	51	35	31.4

CCWA and O&M staff should Endeavor to Develop Data Interpretation Techniques for MIB Production along the California Aqueduct.

MIB samples collected at the same time but at different locations along the California Aqueduct do not address whether or not MIB is being produced within the aqueduct itself. Data interpretation techniques should involve the concept of "same parcel" sampling, where the goal is to understand how the MIB concentration is changing within a given "parcel" of water as it makes its way from the source to the treatment plant.

O&M should Provide Additional Operational Data when MIB Samples are Collected at O'Neill Forebay Outlet.

When interpreting the O'Neill Forebay Outlet MIB data, it is important to know the blend ratio between releases from San Luis Reservoir and Banks. This information is helpful in understanding whether or not MIB production is occurring within O'Neill Forebay. O&M should: 1) provide information on the operating conditions during sample collection (i.e. stating if releases from San Luis Reservoir occurred prior to sample collection), or 2) develop a sampling protocol where samples are collected during times when the blending condition is known.

O&M should Sample more Frequently and Disseminate Data Promptly when MIB Concentrations are Increasing

Weekly sampling for MIB when levels are increasing in the California Aqueduct does not provide enough information to properly manage and/or prevent a T&O event. Sampling frequencies should be agreed upon by the impacted SWP Contractors and O&M.

O&M and CCWA should Continue to Study the Relationship between Operations and Maintenance Activities in the Coastal Branch with Water Quality Observations.

The occurrence of MIB has a range of causes. MIB may be produced at the source water, produced in the conveyance system, or there may be a delayed cell lysis issue. Likewise, the reduction in MIB may be due to blending or through some form of degradation.

O&M and CCWA should Continue to Work Together on Good Canal/Forebay/Tank Maintenance.

O&M and CCWA staff should continue to work together to develop an alternative cleaning strategy to lessen the impact on source water quality during the annual winter shutdown.

NON-PROJECT INFLOWS

BACKGROUND

DWR has accepted non-Project inflows to the California Aqueduct since the late 1970's. Originally, the concept of an "inflow", or conveyance of non-Project groundwater or surface water in the California Aqueduct came about during the historical drought of 1976 to 1977. Groundwater from local areas in the San Joaquin Valley was pumped into the California Aqueduct and conveyed to agricultural SWP Contractors.

Today, there are SWP Contractors who bank groundwater and need to utilize the California Aqueduct to move water from one point to another. These entities have long-term contracts with DWR. Occasionally other entities that are not SWP Contractors have been allowed to convey water in the California Aqueduct from locations where it is available to locations of critical shortage.

The ability to use aqueduct capacity to move water from a point of availability to a point of need is a valuable means of balancing increasing demands with limited supplies of California's water resources. Use of SWP facilities for conveying non-Project waters must, however, be made with the realization that efficient use of water supplies is inexorably linked to water quality. The water quality impacts of the inflows must be understood so that operational decisions can be based on water quality, along with other factors such as water supply needs.

Management of non-Project inflows by DWR, the volume of non-Project inflows, usage of the Kern Aqueduct Blending Model and the water quality impacts of the inflows are discussed in this section. The Semitropic Water Storage District's (Semitropic) Pilot Test Arsenic Removal System and the Westlands Water District's (Westlands) 2008 Emergency Pump-In are also discussed as special topics of interest.

Highlights regarding non-Project inflows from 2006 to 2010 include:

- Non-Project inflows introduced into the California Aqueduct totaled 1,490,164 acre-feet from 2006 to 2010, which was considerably higher than the 360,000 acre-feet introduced in the previous five years.

- Semitropic installed a pilot arsenic removal treatment system, which began operation in November 2007.

- Westlands Water District was approved to convey their groundwater on a one-time basis from June to September 2008 through a Governor's Executive Order addressing the drought.

- The Kern Aqueduct Blending Model was actively used by DWR and the non-Project inflow Facilitation Group to monitor the program during inflows.

MANAGEMENT OF NON-PROJECT INFLOWS

On March 1, 2001 DWR developed an "Interim Department of Water Resources Water Quality Criteria for Acceptance of Non-Project Water into the State Water Project", which sets the current policy for how all non-Project inflow proposals are evaluated. The purpose of the policy is to prevent any adverse impacts to SWP water deliveries, operations, or facilities. Inflows can be either groundwater or surface water.

The policy establishes two categories of inflows based on water quality. The water quality of Tier 1 inflows is equal to or better than the historical SWP water quality, measured at O'Neill Forebay Outlet, and therefore should not result in any degradation of water quality in the California Aqueduct. Inflows meeting this "no adverse impact" criterion are accepted, provided the project proponent follows established procedures for proposing, constructing, operating, and monitoring the project, and producing appropriate documentation.

A Tier 2 inflow is defined in the policy as containing constituents at concentrations that exceed the historical concentrations at O'Neill Forebay Outlet that could adversely affect SWP Contractors. Tier 2 proponents are referred to a Facilitation Group comprised of SWP Contractors. The Facilitation Group is an advisory body that reviews proposals, may consult with the project proponent, state or federal agencies, and others as appropriate, makes recommendations to DWR for acceptance or rejection of proposals, and recommends conditions for DWR acceptance. DWR has the ultimate responsibility for determining if an inflow will be accepted.

In addition to the March 1, 2001 Interim Policy, an additional document entitled "Implementation Procedures for the Review of Water Quality from Non-Project Water Introduced into the State Water Project" was developed in 2001 to further describe the procedures and responsibilities of the inflow entity, DWR and the Facilitation Group. The implementation procedures require that each inflow entity submit a project proposal to DWR prior to releasing any water to the California Aqueduct. The proposal must identify the water source(s); planned operation, timing, and volumes of inflow; impacts and benefits to downstream users; and water quality data for all sources of water.

The implementation procedures set forth water quality monitoring options that include monitoring of wells and monitoring at the point where the inflow is discharged to the aqueduct. Monitoring is required for all drinking water constituents for which there are Maximum Contaminant Levels (MCLs) listed in Chapter 15 of Title 22 of the California Code of Regulations (Title 22). In addition monitoring for constituents of concern such as total dissolved solids (TDS), bromide, TOC, nitrate, arsenic, chromium VI, uranium, and sulfate may be required. Specifically, there are three monitoring options:

- Option 1 – Title 22 testing is required for all participating wells. Constituents of concern are required for all participating wells at start-up and at the point of discharge to the California Aqueduct on a quarterly basis.

- Option 2 – Constituents of concern monitoring is required for all participating wells within two weeks of inflow start-up and Title 22 testing is required for representative wells. Representative wells need to be representative of the manifold area, and are subject to approval. Title 22 monitoring is required at the point of discharge to the California Aqueduct at start-up and constituents of concern must be monitored monthly at the point of discharge.

- Option 3 – The inflow entity may propose a monitoring program which is submitted to the Facilitation Group for review and approval.

The implementation procedures also clarify that under any of the three monitoring options, whenever Title 22 testing is required at individual wells, it must be repeated every three years or as otherwise acceptable to CDPH.

The policy and its accompanying implementation procedures set forth an orderly process whereby proposed projects are evaluated and a decision made by DWR for acceptance or rejection of proposals. A process for appealing DWR decisions is provided and there is a provision for majority and minority opinions from the Facilitation Group in case unanimity is not achieved in the deliberations of that group. Approved inflow projects are to be tracked and reviewed annually by DWR and evaluated to determine the need for additional information or modification of project operating requirements. Inflow entities are also required to annually submit additional information (summary of deliveries, water quality monitoring results, proposed changes). The policy states that DWR is required to prepare annual reports on the water quality impacts of the non-Project inflows.

Although the policy states that an annual review will be conducted, the non-Project inflows are actually evaluated on a weekly basis using the Kern Aqueduct Blending Model. Flow data are updated on a daily basis for the model. DWR staff uses the Kern Aqueduct Blending model to verify water quality impacts on an on-going basis. For example, the Facilitation Group has a goal of keeping arsenic concentrations in the aqueduct (downstream of non-Project water inflows) below 5 µg/L. It is important to note that the goal to keep arsenic concentration to below 5 µg/L is not an absolute fixed number, but rather a goal to be balanced with other factors such as providing reliable water supplies during a prolonged drought. If concentrations are at 5 µg/L, DWR will contact the inflow entity directly and ask that another well be put on-line to blend levels down, or to shut off the well with elevated arsenic concentrations. Additional conditions were placed specifically on Semitropic, in response to Semitropic’s 2007 project proposal. These conditions were:

- “Semitropic will attempt to achieve an arsenic concentration of 10 µg/L or less in its inflow water through full use of its resources.” Although the conditions placed on Semitropic are stated as above, it should be noted that the Semitropic inflow was actually evaluated as one component of the Kern program that also included Kern Water Bank, Kern County Water Agency, and the Wheeler Ridge-Maricopa Water Storage District (Wheeler Ridge). As such, the weighted average of all of the Kern program inflows was evaluated by the Facilitation Group and could not exceed any drinking water MCLs. Therefore, Semitropic was allowed to pump-in inflow water with arsenic concentrations greater than 10 µg/L as long as the weighted average of other Kern inflows and Semitropic inflows was less than 10 µg/L.

- "Semitropic will operate its inflow program to achieve an increase in downstream arsenic concentrations of no more than 2 µg/L over background levels in the California Aqueduct." Although background arsenic concentrations were measured upstream of the Semitropic inflow location and downstream arsenic concentrations were monitored at Check 39 (DWR) and Check 41 (MWDSC), the Facilitation Group was more likely to evaluate arsenic concentrations as estimated by the Kern Aqueduct Blending Model, rather than measured concentrations.

INFLOW VOLUMES

Seven entities participated in the inflow program between 2006 and 2010. Westlands and San Luis Water District (San Luis) released water into the San Luis Canal reach of the California Aqueduct, as shown in **Figure 14-19**. The other five entities release water between Check 21 and Check 39, as shown in **Figure 14-20**. Non-Project inflows introduced into the California Aqueduct totaled 1,490,164 acre-feet from 2006 to 2010. This is a substantial increase from the 360,000 acre-feet of non-Project inflows introduced from 2001 to 2005. As shown in **Table 14-6**, from 2006 to 2010, the Kern Water Bank Canal (KWB Canal) contributed the highest volume of non-Project inflows (757,545 acre-feet, or approximately 51 percent). The Cross Valley Canal (CVC) contributed 22 percent, Semitropic contributed 15 percent, Arvin-Edison Water Storage District (Arvin-Edison) contributed 10 percent, Wheeler Ridge contributed 1.2 percent, Westlands contributed 0.8 percent, and San Luis contributed 0.02 percent. The KWB Canal and the CVC deliver inflows from multiple sources including the Kern Water Bank, the Kern County Water Agency's Pioneer Project, the Berrenda Mesa Project, the City of Bakersfield's 2800 Acres Project, the Friant-Kern Canal and the Kern River.

Table 14-6. Non-Project Inflow Volumes, 2006 to 2010

Inflow Entity	Inflow Volume (acre-feet)	Percent of Total Inflows	Number of Wells	Water Type
KWB Canal	757,545	51	138 total for KWB Canal and CVC	Groundwater and Surface Water
CVC	328,278	22		Groundwater and Surface Water
Semitropic	222,640	15	394	Groundwater
Arvin-Edison	149,533	10	76	Groundwater
Wheeler Ridge	19,203	1.2	46	Groundwater
Westlands	12,581	0.8	58	Groundwater
San Luis	384	0.02	1	Groundwater
Total	1,490,164	100		

Figure 14-19. Location of Non-Project Inflows in the San Luis Canal Reach of the California Aqueduct

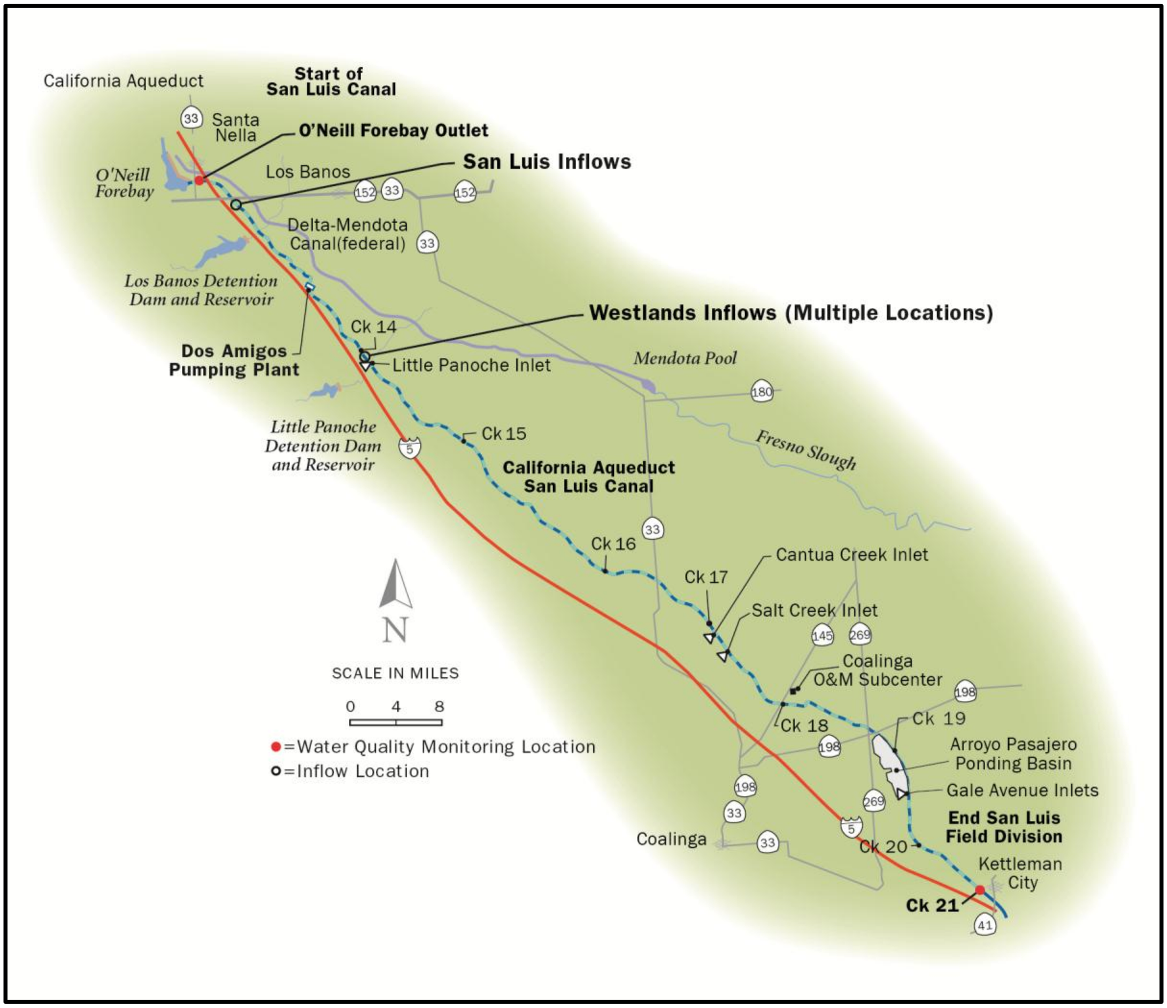


Figure 14-20. Location of Non-Project Inflows Between Check 21 and Check 41 of the California Aqueduct

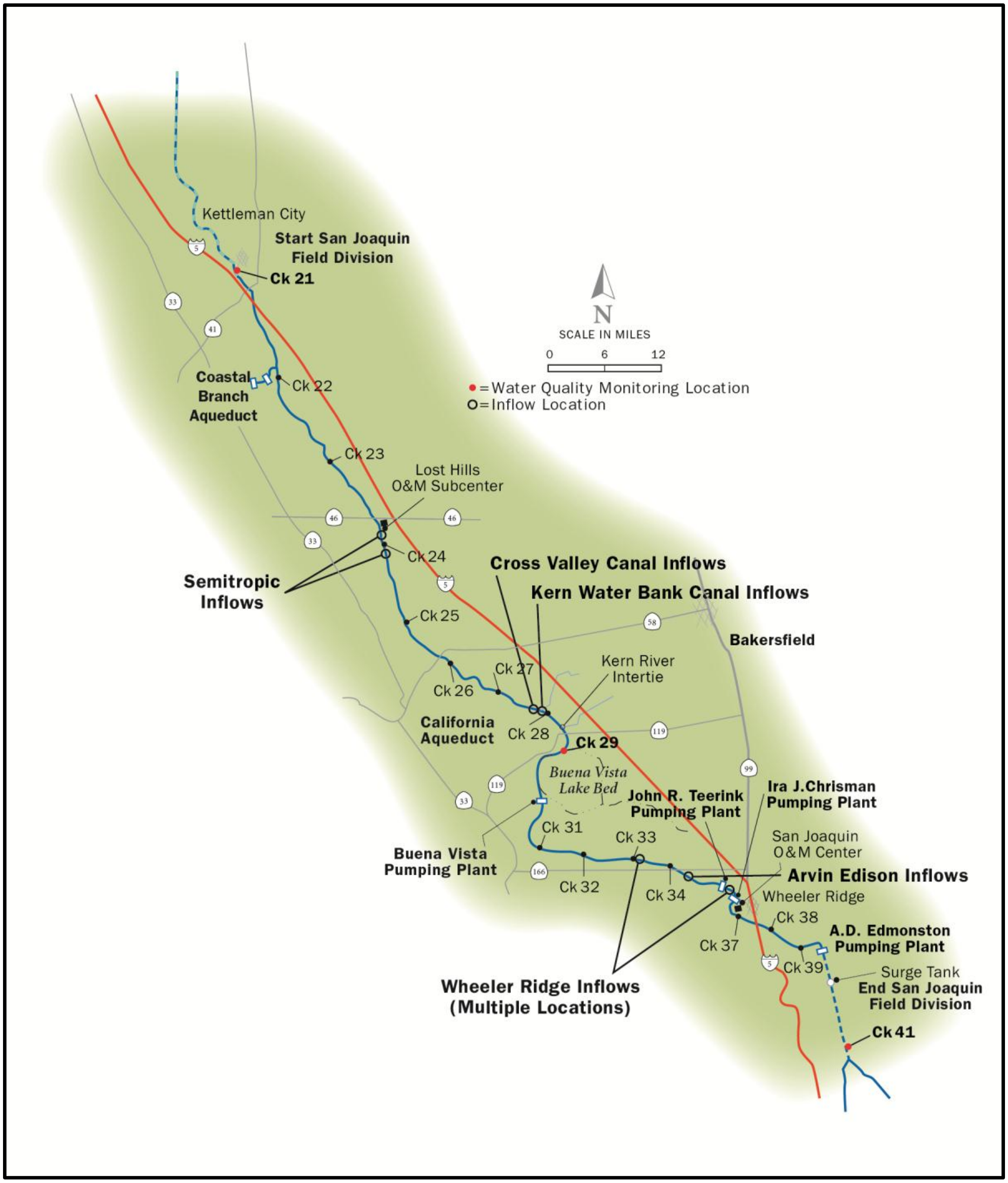
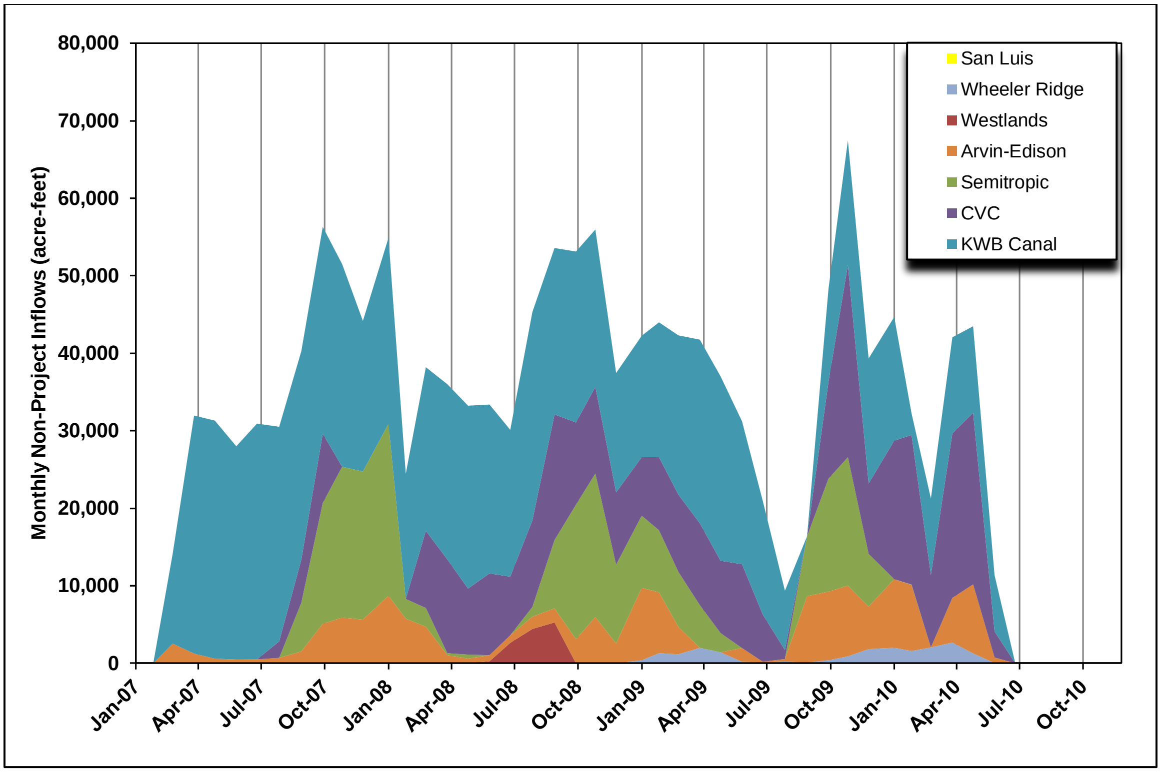


Figure 14-21 shows when the individual inflow entities were participating, and the contributing flows. There were no inflows in 2006. The active inflow period was March 2007 to June 2010. **Figure 14-21** shows a seasonal pattern for the Semitropic and the Arvin-Edison inflows, with inflows lower during the spring and summer and higher inflows in the fall and winter. This pattern is due to the fact that the wells are normally used exclusively for agriculture. Irrigation water demand decreases in late summer so the groundwater is then available from August to January.

Figure 14-21. Non-Project Inflow Monthly Volumes, 2007 to 2010



Monthly inflow volumes were also compared to monthly flow in the California Aqueduct at Checks 29 and 41, to estimate the percentage of California Aqueduct flow contributed by inflows. As flow is not directly measured at Checks 29 and 41, flows were estimated by using the nearest pumping plant volumes. Check 29 monthly flows were estimated from flows at Buena Vista Pumping Plant which is downstream of Check 29, as shown in **Figure 14-20**. Check 41 monthly flows were estimated from flows at Edmonston Pumping Plant which is upstream of Check 41, as shown in **Figure 14-20**. Although there is a turn-in/turn-out location between Check 29 and Buena Vista Pumping Plant, there was no activity on that flow meter from 2007 to 2010. There are no active turn-in/turn-out locations from Edmonston Pumping Plant to Check 41. As **Figures 14-22** and **14-23** show, inflows contributed a substantial percentage of the flow in the California Aqueduct during a number of months. For example, in February 2009, it is estimated that inflow volumes contributed 87 percent of the flow at Check 29 and 92 percent of the flow at Check 41. This is an increase over the 2001 to 2005 period, when the highest inflow volume represented 40 percent of the flow at Check 41.

Figure 14-22. Monthly Inflow Volumes Contributing to Aqueduct Flow at Check 29

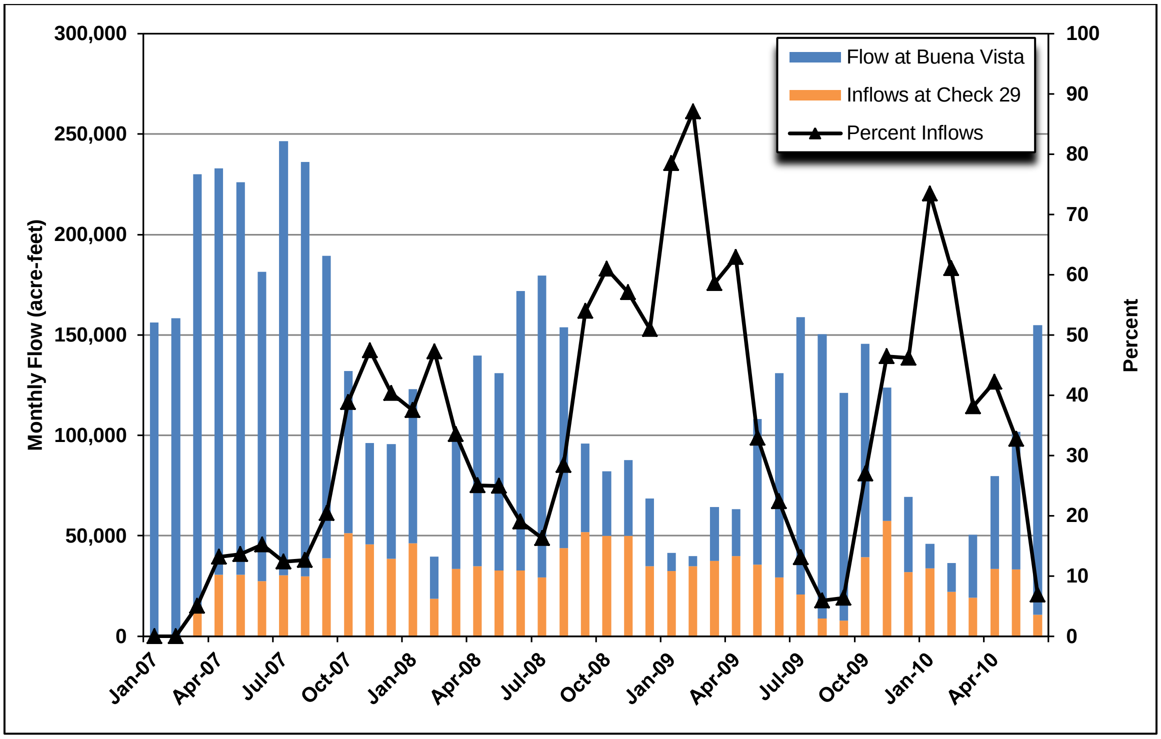
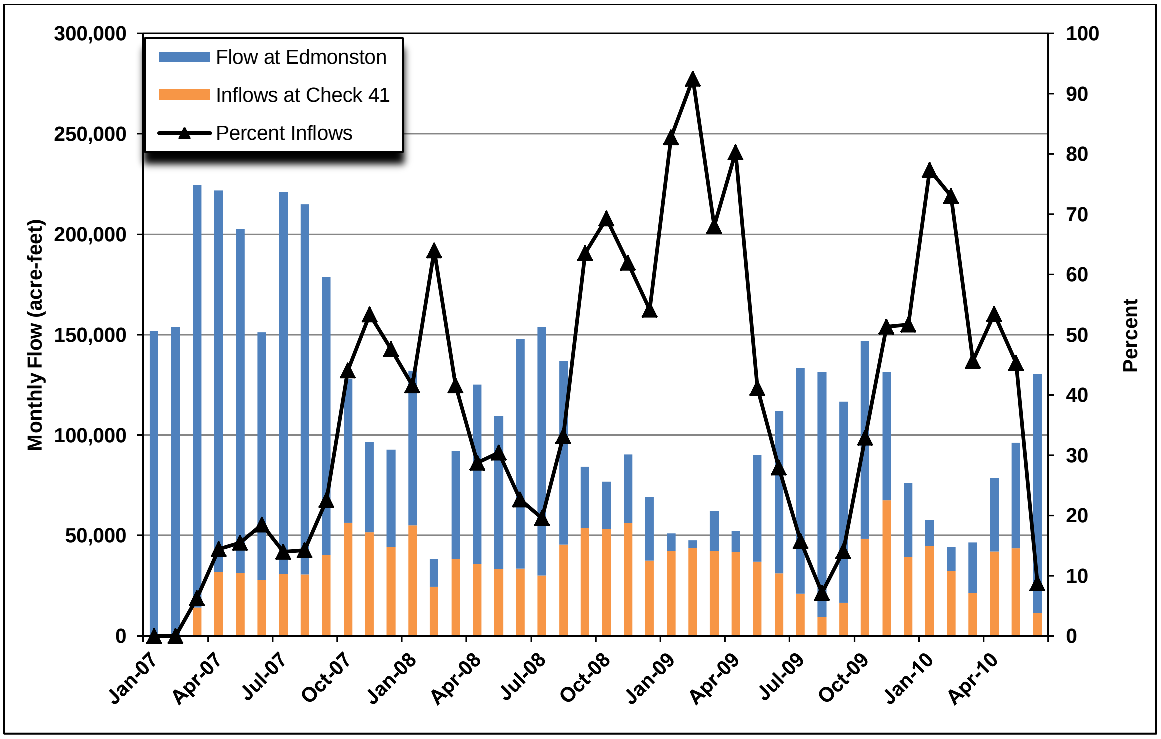


Figure 14-23. Monthly Inflow Volumes Contributing to Aqueduct Flow at Check 41



WATER QUALITY IMPACTS OF NON-PROJECT INFLOWS

As discussed previously, the inflow entities can select from three monitoring program options. The entities contributing substantial amounts of water to the California Aqueduct selected the following monitoring options:

- Kern Water Bank Authority – Option 1, which includes Title 22 testing for all participating wells. Constituents of concern are required for all participating wells at start-up and at the point of discharge to the California Aqueduct on a quarterly basis. It should be noted that these wells are tested for Title 22 inorganics and radioactivity every three years, and Title 22 organics every nine years.

- Pioneer and Berrenda Mesa Projects – Option 1. Kern County Water Agency delivers water through the CVC. It should be noted that KCWA performs a Title 22 test on a third of the wells every three years, leading to a well sampled once every nine years.

- Semitropic – Option 3, which is an individual monitoring program. Semitropic's monitoring program focuses on the point of discharge to the California Aqueduct. The first component of their monitoring program consists of daily (Monday through Friday) monitoring at the point of discharge to the aqueduct for constituents of concern. If daily results vary by less than two standard deviations from the prior twenty laboratory tests, monitoring can be reduced to weekly. If results vary by more than two standard deviations, daily testing will be reinstated until stability is re-established. The second component of their monitoring program consists of weekly Title 22 testing at the point of discharge to the aqueduct. If weekly arsenic results vary by less than two standard deviations from the prior six weeks of testing, monitoring can be reduced to monthly. If monthly results vary by more than two standard deviations, weekly testing will be reinstated until stability is re-established.

- Arvin-Edison – Option 2, which requires that constituents of concern be monitored for all participating wells within two weeks of inflow start-up and Title 22 testing is required for representative wells. Title 22 monitoring is required at the point of discharge to the California Aqueduct at start-up and constituents of concern must be monitored monthly at the point of discharge.

- Wheeler Ridge – Option 1.

Water Quality of the Inflows Prior to Introduction to the California Aqueduct

Tables 14-7 through **14-10** present data from the resultant blend of participating wells and surface inflows for each inflow entity. These samples were collected prior to entering the California Aqueduct. Grab samples are collected by both DWR and the individual inflow entities. The CVC and the KWB Canal are sampled quarterly for constituents of concern and data were provided by Kern County Water Agency. According to the monitoring options selected by the other inflow entities, weekly Title 22 results and daily constituents of concern were collected at the point of entry for Semitropic, monthly constituents of concern were collected at the point of entry for Arvin-Edison, and quarterly constituents of concern were collected for Wheeler Ridge. The monitoring data collected by these entities were not readily available so samples collected by DWR were evaluated. DWR has collected samples for all the inflow entities except for Wheeler Ridge. Wheeler Ridge has multiple inflow locations so a sample representing a blend of its inflow was not available. Semitropic has two locations where inflows enter the California Aqueduct (Semitropic 2 and Semitropic 3). DWR routinely monitors the Semitropic 2 inflows for constituents of concern and the Semitropic 3 inflow for dissolved arsenic. The other constituents are monitored less frequently at Semitropic 3.

Table 14-7. Water Quality of Semitropic 2 Inflows

Date	Dissolved Arsenic (µg/L)	Dissolved Bromide (µg/L)	Dissolved Nitrate (mg/L as NO_3)	TOC (mg/L)	DOC (mg/L)	TDS (mg/L)	Dissolved Sulfate (mg/L)
10/2/07	see Figure 14-24 due to higher sampling frequency for arsenic	535	6.2	1.05	0.6	375	78
11/2/08		620	7.5	0.95	0.5	470	113
12/9/08		670	8.9	<0.5	<0.5	478	101
1/21/09		740	10.3	0.8	0.7	533	125
3/17/09		740	7.4	1.5	1.2	520	116
4/13/09		910	7.4	1.3	0.7	530	109
Min	3	535	6.2	<0.5	<0.5	375	78
Max	15	910	10.3	1.5	1.2	533	125
Median	12	670	7.5	1.0	0.7	499	111
MCL	10	NA	45	NA	NA	500	250

Source: DWR

Table 14-8. Water Quality of KWB Canal Inflows

Date	Dissolved Arsenic (µg/L)	Dissolved Bromide (µg/L)	Dissolved Nitrate (mg/L as NO_3)	TOC (mg/L)	DOC (mg/L)	TDS (mg/L)	Dissolved Sulfate (mg/L)
5/8/08	5	280	9.1	NS	<0.3	250	41
9/4/08	6	110	7.1	NS	0.4	250	51
11/18/08	7	140	8.3	NS	<0.5	260	52
12/30/08	6	130	7.2	NS	<0.5	260	50
3/10/09	7	150	7.4	NS	0.60	250	56
5/19/09*	5	130	5.1	1.2	1.2	205	41
6/15/09	2.6	120	4.6	NS	0.92	170	35
12/1/09	9.1	170	7.1	NS	0.52	260	45
1/29/10	7.3	190	8.4	NS	0.43	270	58
3/15/10	6.4	150	8.1	NS	0.56	260	57
6/7/10	3.7	9	<0.05	NS	3.2	75	5.7
6/11/10*	3	<10	<0.1	NS	3.8	65	6
Min	2.6	<10	<0.05	NA	<0.3	65	5.7
Max	9.1	280	9.1	NA	3.8	270	58
Median	6.0	135	7.2	NA	0.5	250	48
MCL	10	NA	45	NA	NA	500	250

Source: Kern County Water Agency, except for data noted by * from DWR

Table 14-9. Water Quality of CVC Inflows

Date	Dissolved Arsenic (µg/L)	Dissolved Bromide (µg/L)	Dissolved Nitrate (mg/L as NO_3)	TOC (mg/L)	DOC (mg/L)	TDS (mg/L)	Dissolved Sulfate (mg/L)
5/8/08	2	240	7.5	N.S.	<0.3	200	28
9/4/08	3	70	6.8	N.S.	0.6	200	30
11/5/08*	3	120	7.2	0.75	0.6	198	29
11/18/08	4	100	8.4	N.S.	<0.5	210	34
12/9/08*	2	130	6.4	<0.5	<0.5	203	31
12/30/08	3	90	7.3	N.S.	<0.5	210	32
1/21/09*	2	150	7	0.7	0.6	194	30
3/10/09	4	100	7.2	N.S.	0.6	170	30
3/17/09*	4	120	6.8	1.3	1.1	189	29
4/13/09*	3	110	6.4	0.8	0.7	177	26
5/19/09*	4	120	7.2	0.7	0.7	191	29
6/15/09	<2	65	3.2	N.S.	1.4	86	13
12/1/09	6.7	140	7.4	N.S.	0.6	220	29
1/29/10	2.9	47	3.2	N.S.	1.6	92	10
3/15/10	5.2	140	7.1	N.S.	0.5	200	27
6/7/10	5.0	95	5.8	N.S.	1.5	150	19
Min	<2.0	47	3.2	<0.5	<0.3	86	10
Max	6.7	240	8.4	1.3	1.6	220	34
Median	3.0	115	7.1	0.7	0.6	196	29
MCL	10	NA	45	NA	NA	500	250

Source: KCWA, except for data noted by * from DWR

Table 14-10. Water Quality of Arvin Edison Inflows

Date	Dissolved Arsenic (μg/L)	Dissolved Bromide (μg/L)	Dissolved Nitrate (mg/L as NO_3)	TOC (mg/L)	DOC (mg/L)	TDS (mg/L)	Dissolved Sulfate (mg/L)
9/18/07	3	380	2.0	2.1	1.9	326	30
11/5/08	4	120	10.9	0.7	0.5	222	30
1/21/09	9	170	14.1	0.6	1.0	265	42
3/17/09	5	180	9.7	1.9	1.1	278	47
Min	3	120	2.0	0.6	0.5	222	30
Max	9	380	14.1	2.1	1.9	326	47
Median	5	175	10.3	1.3	0.9	272	36
MCL	10	NA	45	NA	NA	500	250

Source: DWR

Based on the available data, Semitropic 2 and Semitropic 3 inflows had the highest arsenic concentrations, with the majority of samples exceeding the MCL of 10 μg/L, as shown in **Figures 14-24** and **14-25**. Although conditions were placed on Semitropic's 2007 project proposal to "attempt to achieve an arsenic concentration of 10 μg/L or less in its pump-in water through full use of its resources", this was not achieved as shown in **Figures 14-24** and **14-25**. The highest medians for bromide, total dissolved solids, and sulfate were also measured in Semitropic 2 inflows. The secondary MCL (500 mg/L) for TDS was also occasionally exceeded at the Semitropic 2 location. The highest median for nitrate was measured at the Arvin-Edison inflow location, but well below the MCL. TOC and DOC concentrations were low for all inflow locations, only exceeding 2 mg/L on two occasions, once at the KWB Canal and once at the Arvin-Edison inflow location.

Water Quality Impacts of the Inflows in the California Aqueduct

In 2001, the Kern County Water Agency developed a model to estimate changes in downstream water quality in the California Aqueduct due to the introduction of non-Project inflows. Today, there are daily, weekly, and annual versions of the model. The annual model is used by the Facilitation Group to evaluate the impacts of proposed non-Project inflows on California Aqueduct water quality. Once the proposal is approved, and the program is initiated, a daily and/or weekly model is used with actual flow data to provide an on-going record of the changes in downstream water quality. It should be noted that although flow data are updated daily, the water quality data for individual wells and for the baseline California Aqueduct water quality is updated much less frequently. As mentioned earlier, DWR staff uses the Kern Aqueduct Blending Model to verify downstream water quality impacts on an on-going basis.

Figure 14-24. Arsenic Concentrations in Semitropic 2 Inflow

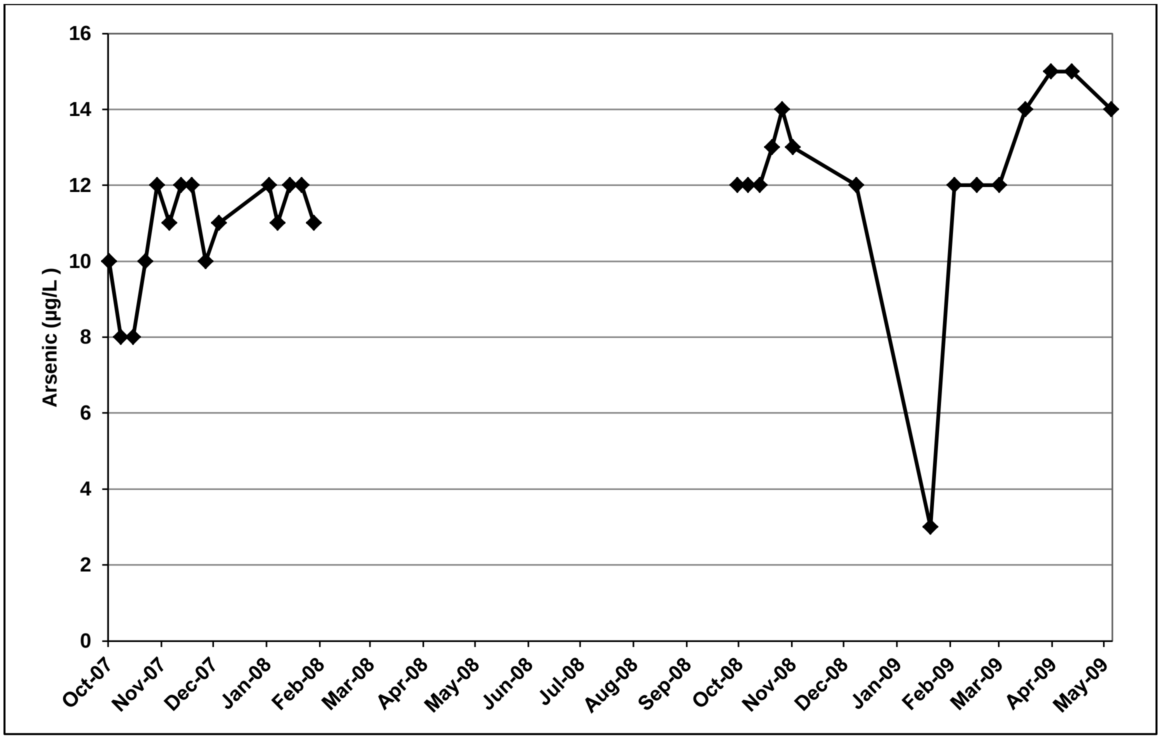
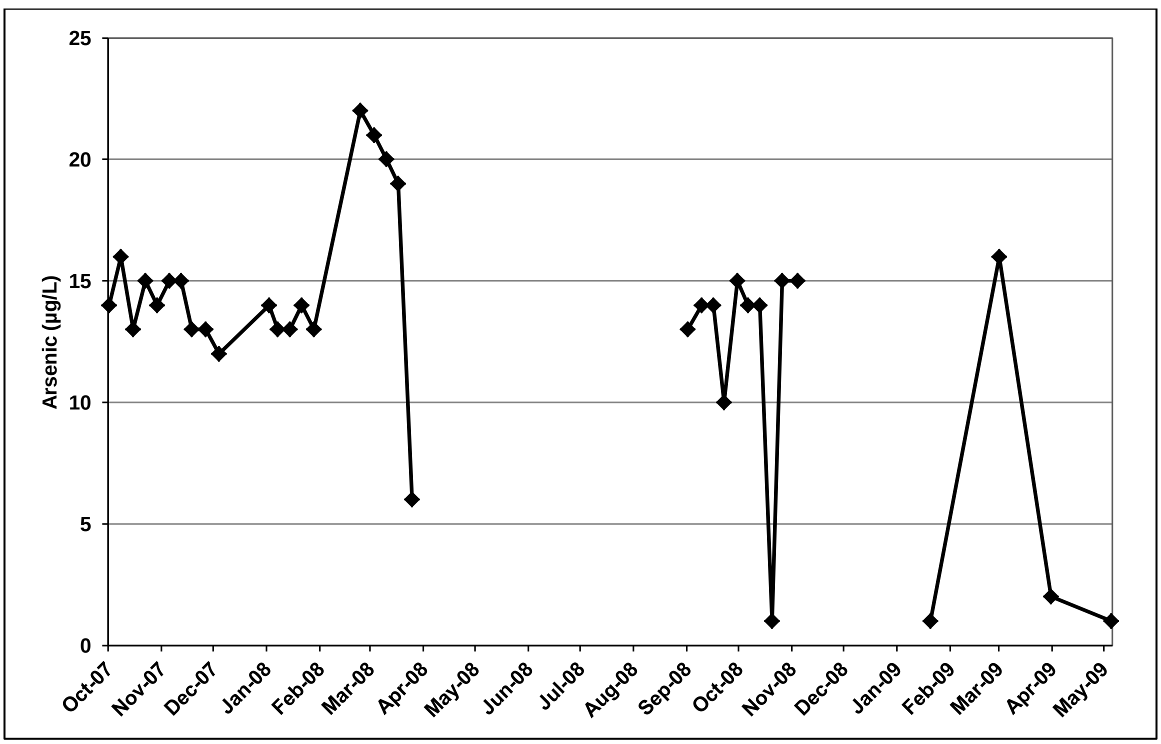


Figure 14-25. Arsenic Concentrations in Semitropic 3 Inflow



According to the Kern Water Bank Authority, the model uses an excel spreadsheet to blend water quality data from the individual wells with the background concentrations in the California Aqueduct. The calculated resultant blend at various points along the aqueduct is based on the flow rate of the aqueduct, the flows of the non-Project water being introduced, and water deliveries being taken out of the aqueduct. The model considers baseline concentration for California Aqueduct water quality (prior to inflows) at O'Neill Forebay Outlet. Although monthly grab samples are taken at O'Neill Forebay Outlet by DWR, these data are not used in the model; rather, historical or long-term seasonal averages are used to define the baseline water quality at O'Neill Forebay Outlet. The use of long-term seasonal averages is considered the best approach when using the model to predict water quality in the future. Non-Project inflow entities sample individual wells, and the grab sample water quality results for individual wells are used in the model. As stated earlier, according to the Implementation Procedures, Title 22 testing for each of the three monitoring options must be repeated every three years or as otherwise acceptable to CDPH. The model focuses on arsenic, bromide, chromium, nitrate, TDS, DOC, sulfate, and uranium.

The Aqueduct Blending Model has become a useful tool to assist in managing the non-Project inflows. Although the daily and weekly models have been used to portray an on-going snapshot of changes in water quality during the active period of the program, the results over the entire reporting period are summarized in this section and modeled results are compared to actual water quality in the California Aqueduct. The model output locations do not match exactly with where DWR monitors water quality in the California Aqueduct. For example, the Aqueduct Blending Model predicts water quality in the California Aqueduct immediately downstream of Semitropic, CVC, KWB Canal, Aquatic Lakes, Arvin-Edison, and Wheeler Ridge. DWR monitors the California Aqueduct at Check 29, which is about 6 miles downstream of the KWB Canal inflow location, and at Check 41, which is about 23 miles downstream of the last Wheeler Ridge inflow location.

A number of figures were developed to compare modeled results with actual California Aqueduct water quality. Two comparisons have been completed; modeled water quality results after KWB Canal and actual water quality at Check 29, and modeled water quality results after Wheeler Ridge and at Check 41. The modeled water quality results after the KWB Canal inflow represent 88 percent of the volume of inflows during the 2007 to 2010 period because Semitropic, CVC and the KWB Canal inflows occur upstream of this point. It is important to keep in mind that these inflows represent water from the Berrenda Mesa and Pioneer Projects, the Kern Water Bank Authority, the City of Bakersfield's 2800 Acres Project, and/or surface water from the Kern River. The modeled water quality results after Wheeler Ridge represent all inflows that occurred during this period. In all of these figures, any samples that were reported as less than the reporting level were set at the reporting level. It is important to note that this only applies to the arsenic and chromium figures.

All figures also include water quality from Check 21, as this location is upstream of all inflows except Westlands and San Luis. In this way, actual upstream and downstream California Aqueduct water quality can be compared, and the modeled versus actual measured results can be compared simultaneously. The impact of the Westlands inflows on downstream water quality is discussed separately in this section, as the upstream and downstream locations were O'Neill

Forebay Outlet and Check 21 for this one-time event. The San Luis inflow was only 384 acre-feet and represented 0.02 percent of the inflow volume. Additionally, although the Kern River Intertie and the Buena Vista 7 have inflow locations between Kern Water Bank and Check 29, there were no flows from these entities during the 2007 to 2010 period. Therefore, Check 29 should represent resultant California Aqueduct water quality, taking into account all inflows prior to and including KWB Canal.

Since California Aqueduct flows are non-continuous, a grab sample collected in the aqueduct may be mostly inflow water rather than a homogeneous mix of aqueduct water and inflows. Therefore, it is likely that there will be instances where grab samples at the check stations may not match modeled results, which represent a blend of inflows and aqueduct water. Also, grab samples at the check stations may not match modeled results because modeled results use long-term averages for background water quality conditions in the model, yet the actual background water quality concentration may vary (higher or lower) from this long-term average.

Table 14-11 presents a summary of the DWR grab sample data collected at Checks 21 and 29 between March 2007 and June 2010 and shows the change in water quality between the two locations during the inflow period. **Table 14-12** presents the same information for Checks 21 and 41. The individual constituents are discussed in the following paragraphs.

Table 14-11. Summary of Aqueduct Water Quality Data for Check 21 and Check 29

Constituent	Check 21 Range	Check 21 Median	Check 29 Range	Check 29 Median	Net Difference from Checks 21 to 29	Percent of the MCL from Checks 21 to 29
TDS (mg/L)	180 - 408	285	111 - 353	269	-16.0	-3.2
Bromide (µg/L)	110 - 430	280	50 - 400	220	-60.0	NA
DOC (mg/L)	2.1 - 7.0	2.9	0.5 - 6.4	2.5	-0.4	NA
Arsenic (µg/L)	2 - 4	2	<1 - 7	3	1	10.0
Chromium (µg/L)	<1 - 3	<1	<1 - 3	1	1	2.0
Nitrate (mg/L as NO_3)	0.3 - 6.9	2.6	0.2 - 7.5	3.0	0.4	0.9
Sulfate (mg/L)	20 - 65	41	16 - 64	42	1	0.4

Table 14-12. Summary of Aqueduct Water Quality Data for Check 21 and Check 41

Constituent	Check 21 Range	Check 21 Median	Check 41 Range	Check 41 Median	Net Difference from Checks 21 to 41	Percent of the MCL from Checks 21 to 41
TDS (mg/L)	180 - 408	285	152 - 349	273	-12.0	-2.4
Bromide (µg/L)	110 - 430	280	100 - 370	220	-60.0	NA
DOC (mg/L)	2.1 - 7.0	2.9	0.7 - 4.5	2.3	-0.6	NA
Arsenic (µg/L)	2 - 4	2	2 - 6	3	1	10.0
Chromium (µg/L)	<1 - 3	<1	1 - 5	1	1	2.0
Nitrate (mg/L as NO_3)	0.3 - 6.9	2.6	0.4 - 8.9	3.5	0.9	2.0
Sulfate (mg/L)	20 - 65	41	19 - 81	44	3	1.2

Total Dissolved Solids

As discussed in Chapter 3, TDS can make drinking water unpalatable, can shorten the life of plumbing fixtures and appliances, and create unsightly mineral deposits on fixtures and outdoor structures. An important economic effect can be the reduced ability to recycle water or recharge groundwater high in TDS. **Figures 14-26 and 14-27** show that inflows reduced TDS concentrations at Checks 29 and 41 compared to Check 21 at times (e.g. early 2009 and early 2010) and at other times there were no substantial differences. As shown in **Tables 14-11 and 14-12**, the median TDS concentration decreased from 285 mg/L at Check 21 to 269 mg/L at Check 29 and 273 mg/L at Check 41. The median TDS concentrations in KWB Canal (250 mg/L), CVC (196 mg/L), and Arvin-Edison inflows (272 mg/L) were lower than concentrations in the California Aqueduct. The median TDS concentration in Semitropic during the inflow period was 499 mg/L, which is considerably higher than aqueduct concentrations. It is useful to compare the inflow data to the aqueduct data but it should be noted that there were far fewer samples collected from the inflows. During early 2009 when TDS concentrations decreased between Check 21 and Checks 29 and 41, Semitropic inflows were declining and there were fairly large volumes of inflows from the KWB Canal and CVC.. In early 2010 when there was also a large decrease along the aqueduct, there were no inflows from Semitropic and large volumes from the KWB Canal and CVC.

As **Figure 14-26** shows, the Aqueduct Blending Model predicts TDS concentrations downstream of the KWB Canal fairly close to measured water quality at Check 29. **Figure 14-27** shows that the model predicts TDS concentrations downstream of Wheeler Ridge fairly close to measured water quality at Check 41.

Figure 14-26. TDS Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

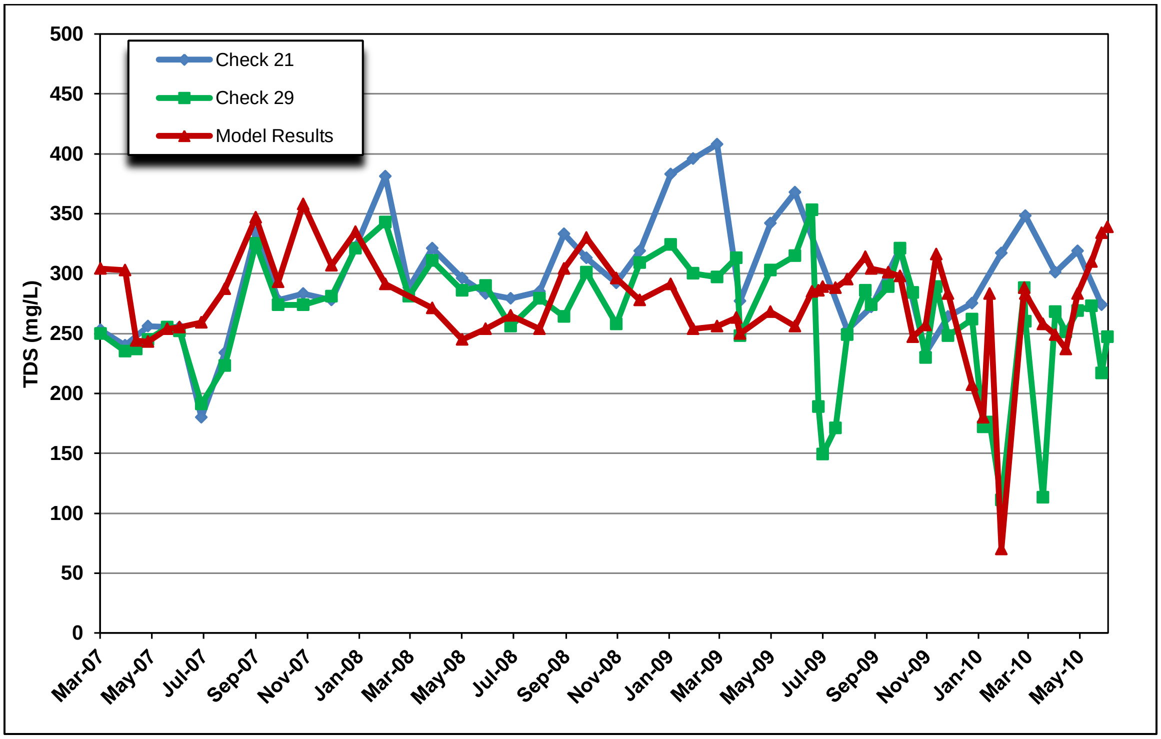
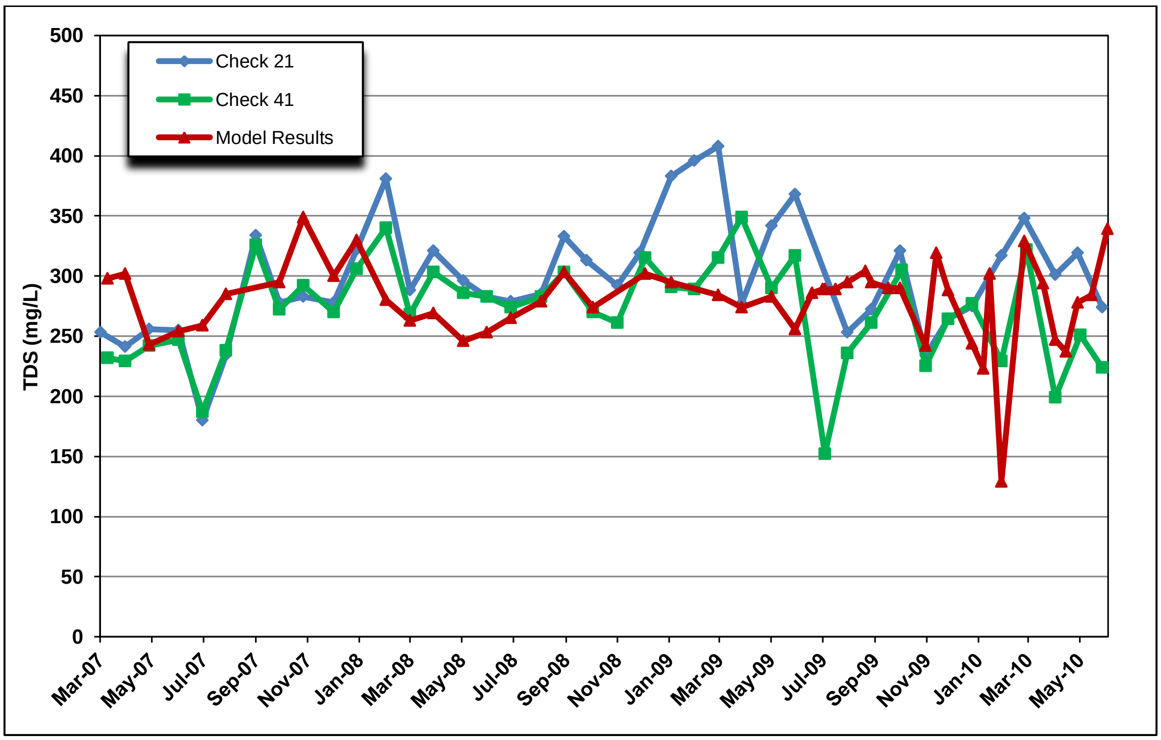


Figure 14-27. TDS Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



Bromide

Bromide is a disinfection byproduct precursor, producing brominated trihalomethanes and haloacetic acids by reacting with chlorine, and bromate by reacting with ozone in water treatment plants. The introduction of non-Project inflows has generally decreased concentrations of bromide in the California Aqueduct. **Figures 14-28 and 14-29** show that bromide concentrations at Checks 29 and 41 were slightly lower than bromide concentrations at Check 21. As shown in **Tables 14-11 and 14-12**, the median concentration of bromide decreased from 280 µg/L at Check 21 to 220 µg/L at Checks 29 and 41. The median bromide concentrations in KWB Canal (135 µg/L), CVC (114 µg/L), and Arvin-Edison (175 µg/L) inflows were lower than background concentrations in the California Aqueduct at Check 21. The median bromide concentration in Semitropic during the inflow period was 670 µg/L, which is considerably higher than aqueduct concentrations.

As **Figure 14-28** shows, the Aqueduct Blending Model tends to predict lower bromide concentrations after the KWB Canal inflow than actual water quality at Check 29. Further examination of the background concentration data used in the model shows that the long-term average for bromide at O'Neill Forebay Outlet is 210 µg/L, yet actual bromide concentrations at this location varied from 80 to 510 µg/L over the reporting period and averaged 270 µg/L. This likely accounts for the lower modeled results compared to actual concentrations at Check 29. The model also predicts lower bromide concentrations at Check 41, again likely due to the variability of actual bromide concentrations at O'Neill Forebay Outlet compared to the model background concentration.

Figure 14-28. Bromide Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

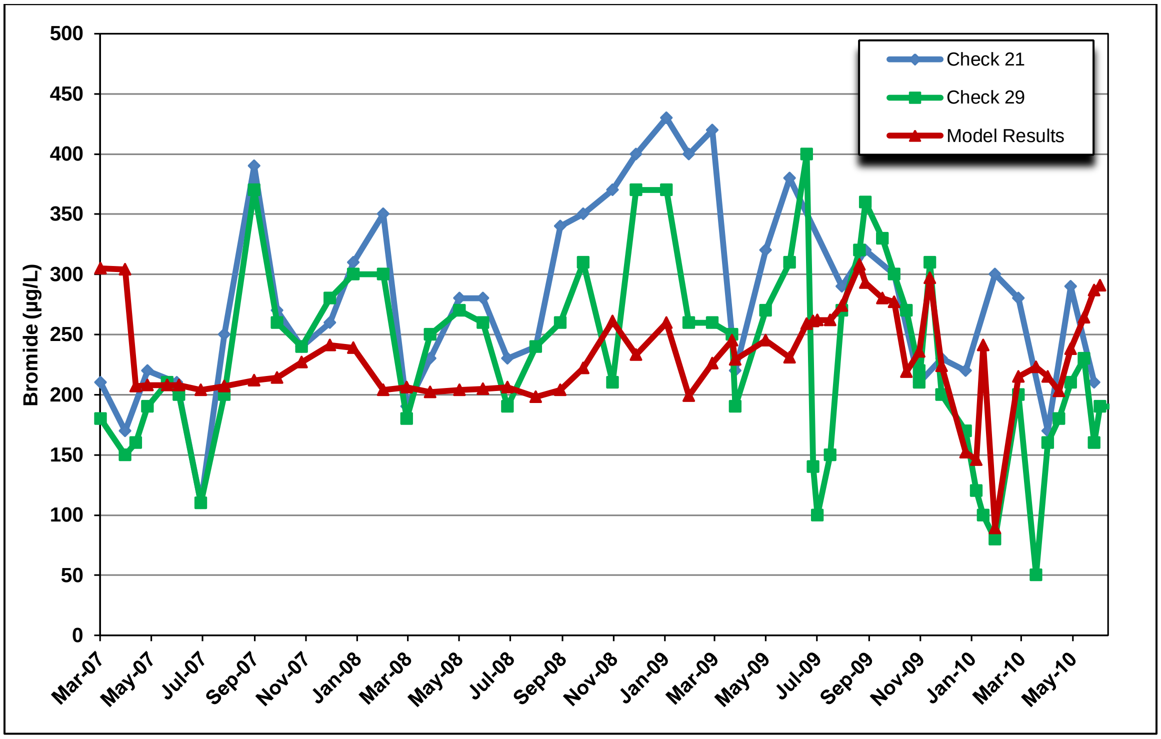
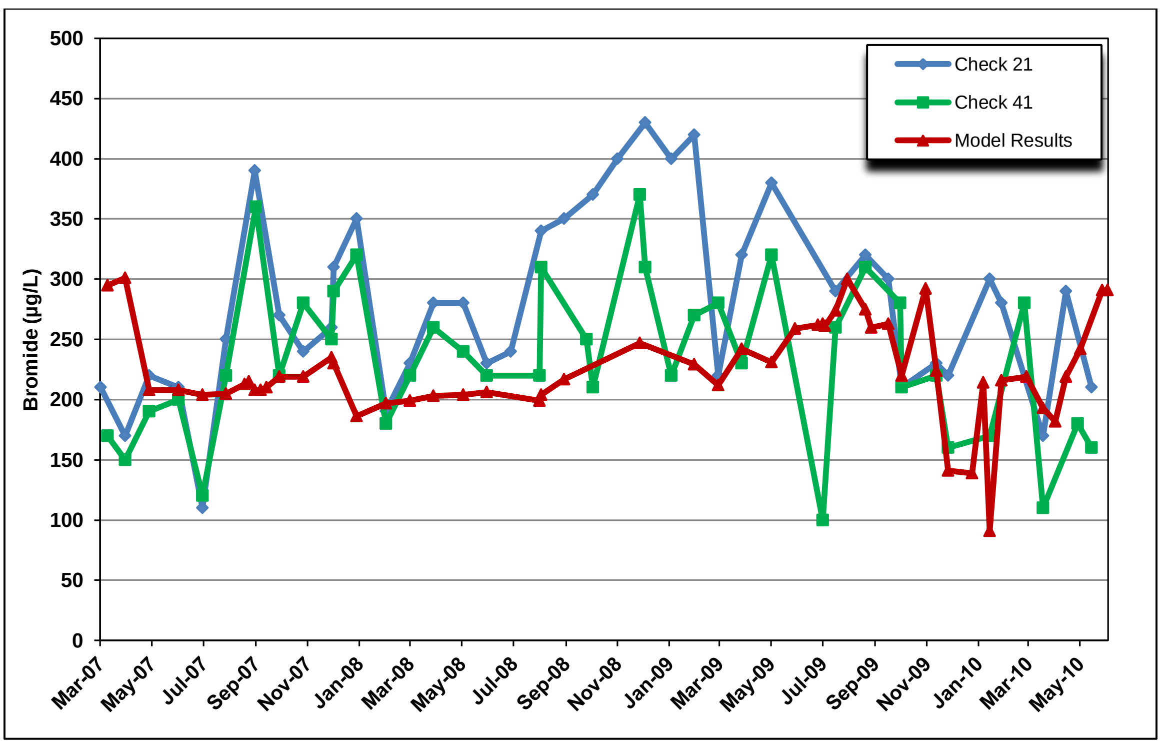


Figure 14-29. Bromide Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



Dissolved Organic Carbon

Organic carbon is a disinfection byproduct precursor that must be removed in water treatment plants. **Figures 14-30 and 14-31** show that Check 21 has higher DOC concentrations than Checks 29 and 41 during inflows. This indicates that the inflows improve water quality in the California Aqueduct for this constituent. The median concentration of DOC decreased from 2.9 mg/L at Check 21 to 2.5 mg/L at Check 29 and 2.3 mg/L at Check 41. As shown previously in **Tables 14-7 to 14-10**, the inflows all had low levels of DOC, with median concentrations ranging from 0.5 to 0.9 mg/L.

As **Figure 14-30** shows, the Aqueduct Blending Model predicts DOC concentrations downstream of the KWB Canal fairly close to the nearest actual measured water quality at Check 29, except in the early stages of the inflow period. **Figure 14-30** shows that on April 20, 2010 the model predicted 3.5 mg/L downstream of the KWB Canal, but the measured concentration at Check 29 was 5.7 mg/L. Similarly, on May 3, 2010, the model predicted 3.3 mg/L, but the measured concentration at Check 29 was 6.4 mg/L. As **Figure 14-31** shows, the Aqueduct Blending Model predicts DOC concentrations downstream of Wheeler Ridge fairly close to the nearest actual measured water quality at Check 41, except in the early stages of the inflow period.

Further examination of the background concentration data used in the model shows that the long-term average for DOC at O'Neill Forebay Outlet is 4.8 mg/L, yet actual DOC concentrations were much higher at this location from February through late April 2010, ranging from 5.2 to 7.7 mg/L. In summary, the model predicts DOC fairly well, but the model may predict slightly different concentrations than actual grab samples when the actual concentrations measured at O'Neill Forebay Outlet vary significantly from the long-term seasonal averages used in the model.

Figure 14-30. Dissolved Organic Carbon Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

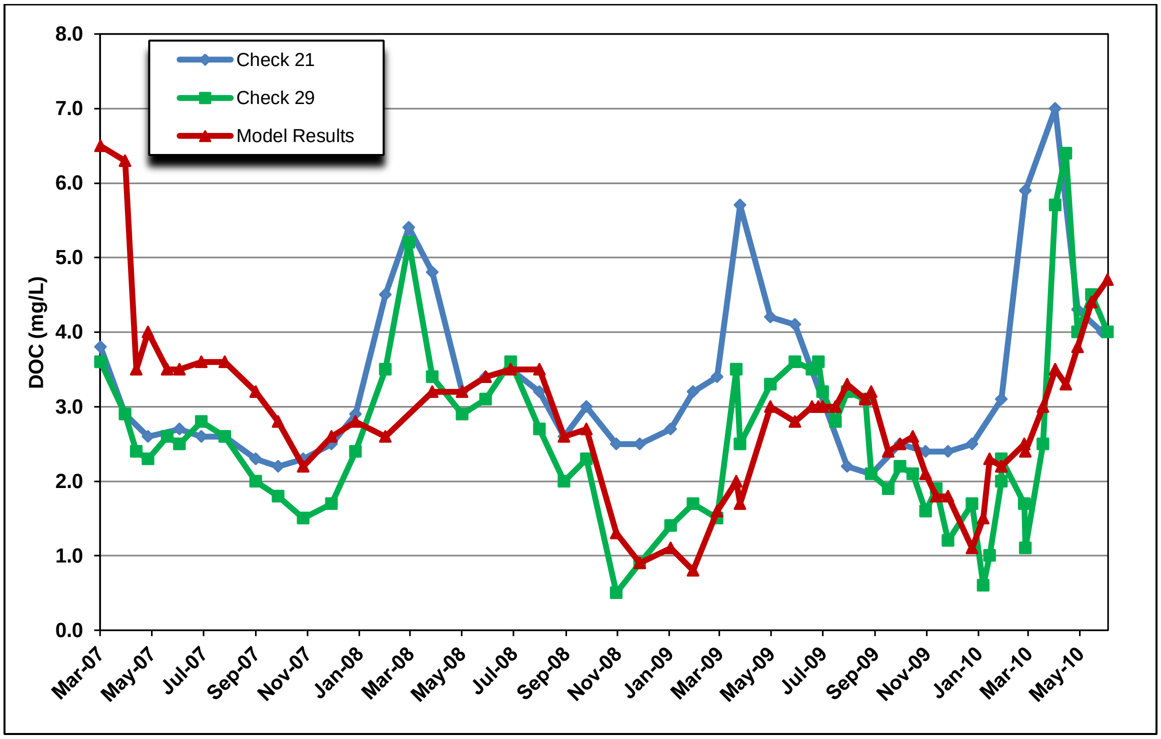
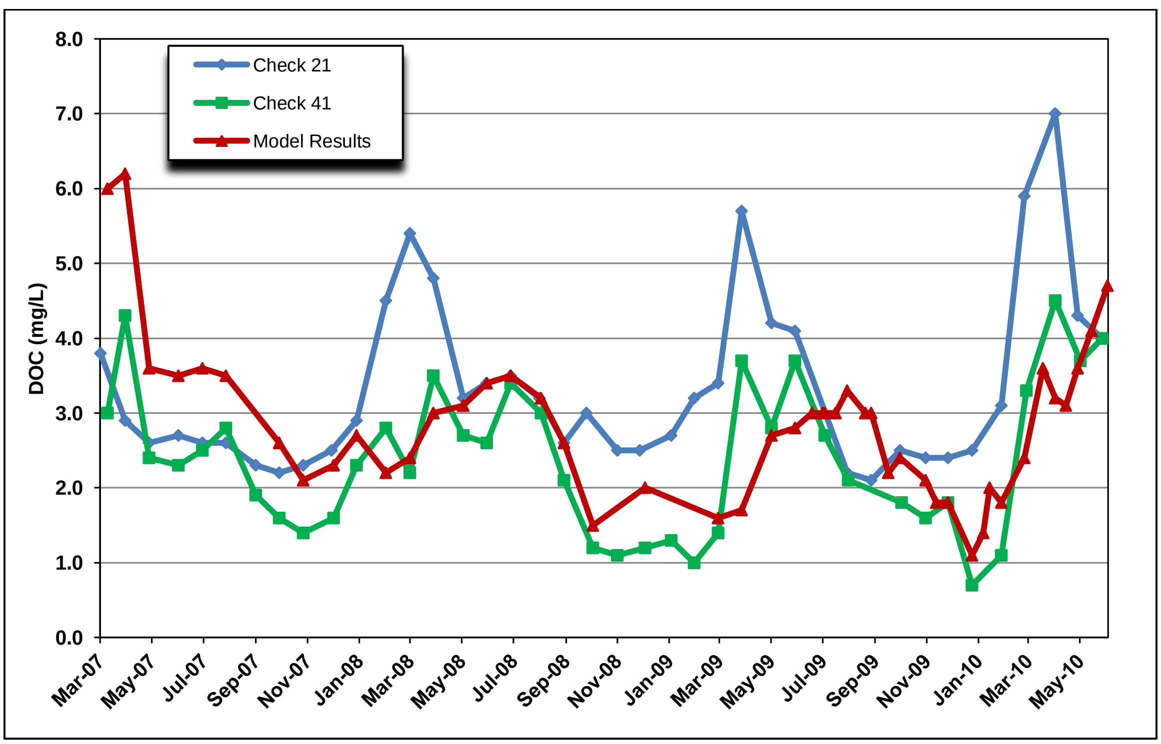


Figure 14-31. Dissolved Organic Carbon Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



Dissolved Arsenic

Arsenic is a human carcinogen with an MCL of 10 µg/L and a Public Health Goal (PHG) of 0.004 µg/L. **Figures 14-32 and 14-33** demonstrate that inflows increase dissolved arsenic concentrations in the California Aqueduct because the dissolved arsenic concentrations at Checks 29 and 41 were higher than at Check 21 during inflows. A summary of the changes from Check 21 to Check 29 and from Check 29 to Check 41 is provided in **Tables 14-11 and 14-12**, respectively. The median concentration of dissolved arsenic over the inflow time period increased from 2.0 µg/L at Check 21 to 3.0 µg/L at both Check 29 and Check 41. **Tables 14-7 to 14-10** show that dissolved arsenic concentrations in all of the major inflows were higher than background concentrations in the California Aqueduct at Check 21. The median concentrations in the inflows ranged from 3.0 µg/L in the CVC to 12.0 µg/L in Semitropic. Although dissolved arsenic concentrations increased in the aqueduct during the inflow period, the concentrations measured at Check 29 and Check 41 did not exceed the MCL for total arsenic of 10 µg/L. While arsenic in groundwater is likely almost 100 percent in the dissolved form, there could be particulate arsenic in surface inflows and in the California Aqueduct. This should be further investigated to ensure that inflows do not result in exceedences of the total arsenic MCL of 10 µg/L.

As discussed previously, the Facilitation Group has a goal of keeping arsenic concentrations in the California Aqueduct below 5 µg/L. There were eleven months when dissolved arsenic concentrations were at or above 5 µg/L at both Checks 29 and 41. Notably, dissolved arsenic was at 6 µg/L for two consecutive months in February and March 2009. **Figure 14-22** shows that a large percent of the water in the California Aqueduct was due to inflows during this time period. In January, 83 percent of the water was due to inflows, in February it was 92 percent and in March it was 68 percent.

As stated earlier, additional conditions regarding arsenic were placed on Semitropic in 2007. The conditions state that Semitropic will operate its pump-in program to achieve an increase in downstream arsenic concentrations of no more than 2 µg/L over background levels in the aqueduct as measured or estimated at the Edmonston Pumping Plant. Background arsenic concentrations will be measured upstream of Semitropic pump-in location. As shown in **Figure 14-33**, background levels increased by more than 2 µg/L in November 2007, February 2009, March 2009, April 2009, January 2010, and February 2010. **Figure 14-33** shows that in November 2007, the dissolved arsenic concentration increased from 2 µg/L at Check 21 to 5 µg/L at Check 41. During February and March of 2009, dissolved arsenic increased from 2 µg/L at Check 21 to 6 µg/L at Check 41. Semitropic inflows were in operation during this time period. **Figure 14-33** also shows that from January to February 2010, dissolved arsenic increased from 2 µg/L at Check 21 to 5 and 6 µg/L at Check 41; however, Semitropic was not releasing water to the aqueduct at this time. During January and February 2010, the arsenic increase was due to KWB Canal and CVC inflows (Personal Communication, Karen Scott, MWDSC). Kern Water Bank identified the high arsenic wells and shut them down.

As **Figure 14-32** shows, the dissolved arsenic concentrations predicted by the Aqueduct Blending Model downstream of the KWB Canal are fairly close to measured concentrations at Check 29. Similarly, **Figure 14-33** shows the arsenic concentrations predicted by the model downstream of Wheeler Ridge are fairly close to measured water quality at Check 41.

Figure 14-32. Dissolved Arsenic Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

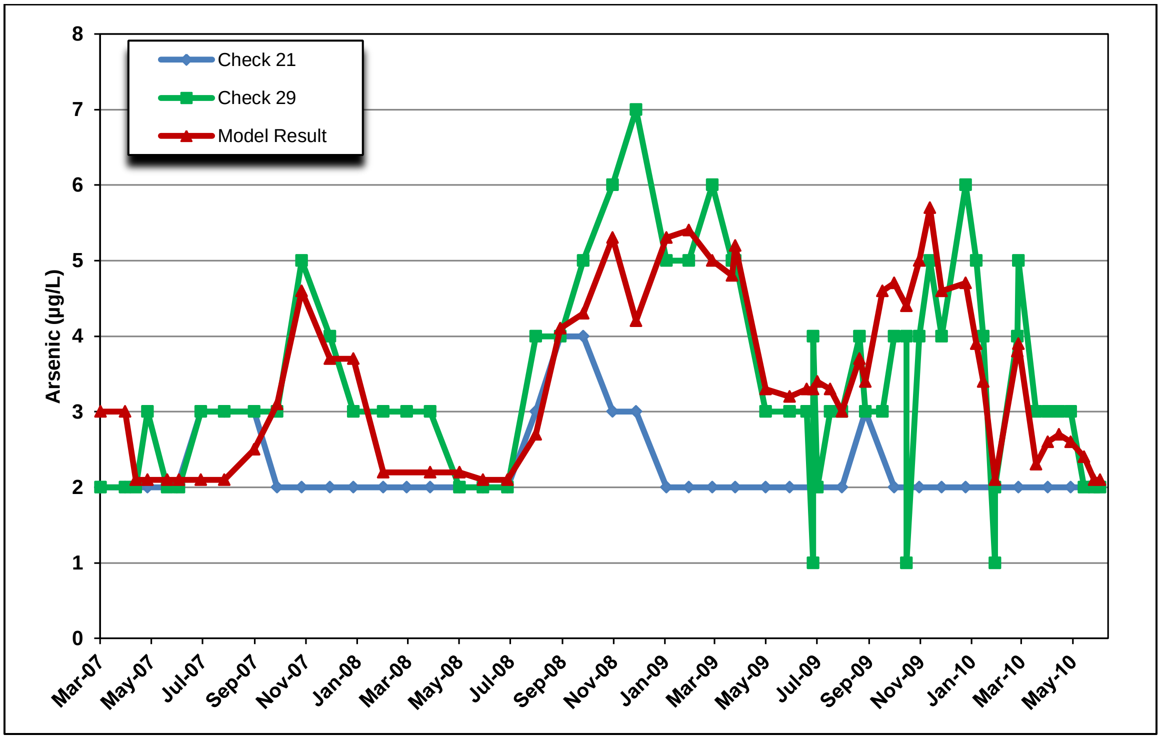
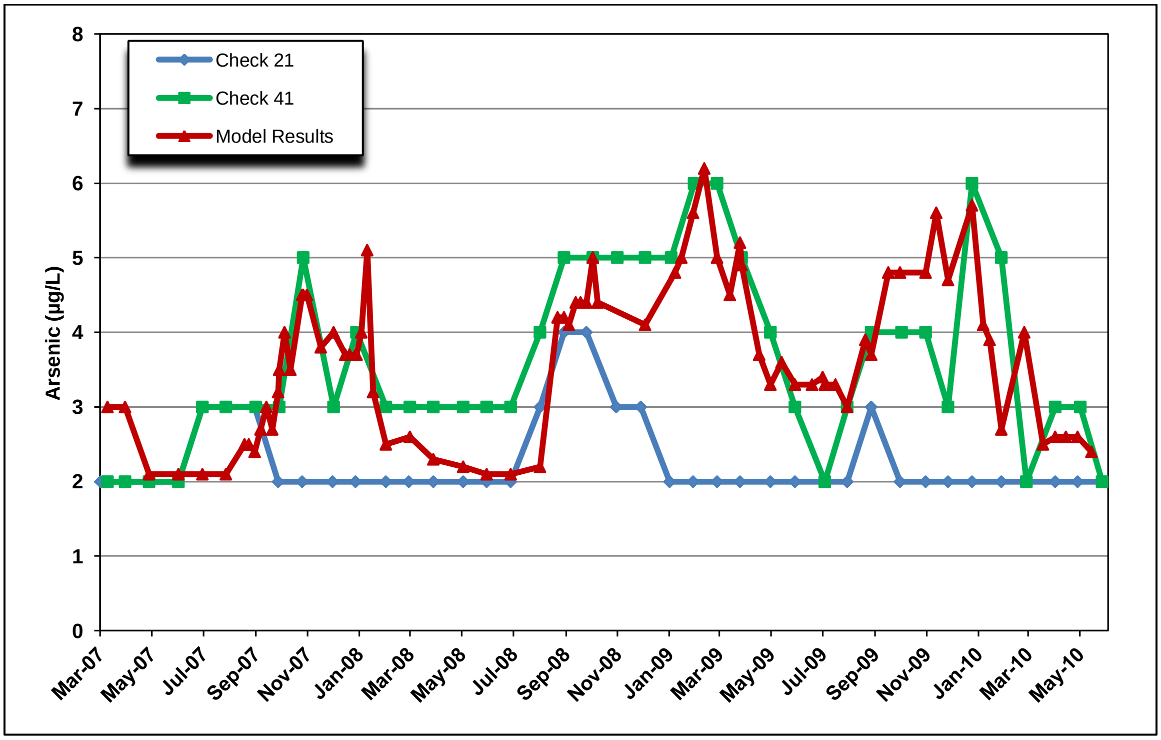


Figure 14-33. Dissolved Arsenic Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



Dissolved Chromium

Chromium (VI), or hexavalent chromium, causes acute gastritis when ingested in high doses and is an established human lung carcinogen when inhaled. Hexavalent chromium is currently regulated as part of the 50 µg/L MCL for total chromium. In July 2011, the Office of Environmental Health Hazard Assessment (OEHHA) published a final PHG for hexavalent chromium of 0.02 µg/L. CDPH is developing an MCL with a draft expected in 2014 and a final in 2015. California Aqueduct samples were not analyzed for hexavalent chromium during the inflow period so total dissolved chromium is discussed in this section.

As **Figure 14-34 and 14-35** show, Check 21 occasionally has lower dissolved chromium concentrations than Checks 29 and 41 during inflows, indicating that the non-Project inflows slightly increase dissolved chromium concentrations in the aqueduct at times. There were limited data on the concentrations of dissolved chromium in the inflows. As shown in **Tables 14-11 and 14-12**, the median dissolved chromium concentration increased from <1 µg/L at Check 21 to 1 µg/L at Checks 29 and 41. This is a trivial increase compared to the MCL of 50 µg/L for total chromium. Information is needed on hexavalent chromium concentrations in the future.

The Aqueduct Blending Model tends to predict higher dissolved chromium concentrations after the KWB Canal inflow than the actual concentrations at Check 29. The model also predicts higher chromium concentrations after the Wheeler Ridge inflow than actual concentrations at Check 41. Further examination of the background concentration data used in the model shows that the long-term average for chromium at O'Neill Forebay Outlet is 1 µg/L, yet actual chromium concentrations at this location varied from <1 to 3 µg/L over the reporting period and averaged <1 µg/L. In fact, most of the samples collected at O'Neill Forebay Outlet did not have detectable chromium concentrations during the 2007 to 2010 period. This likely accounts for the higher modeled results compared to actual concentrations at Check 29. The model also predicts higher chromium concentrations after the Wheeler Ridge inflow than actual concentrations at Check 41, again likely due to the difference between actual chromium concentrations at O'Neill Forebay Outlet (non-detectable) and the model background concentration of 1 µg/L.

Figure 14-34. Dissolved Chromium Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

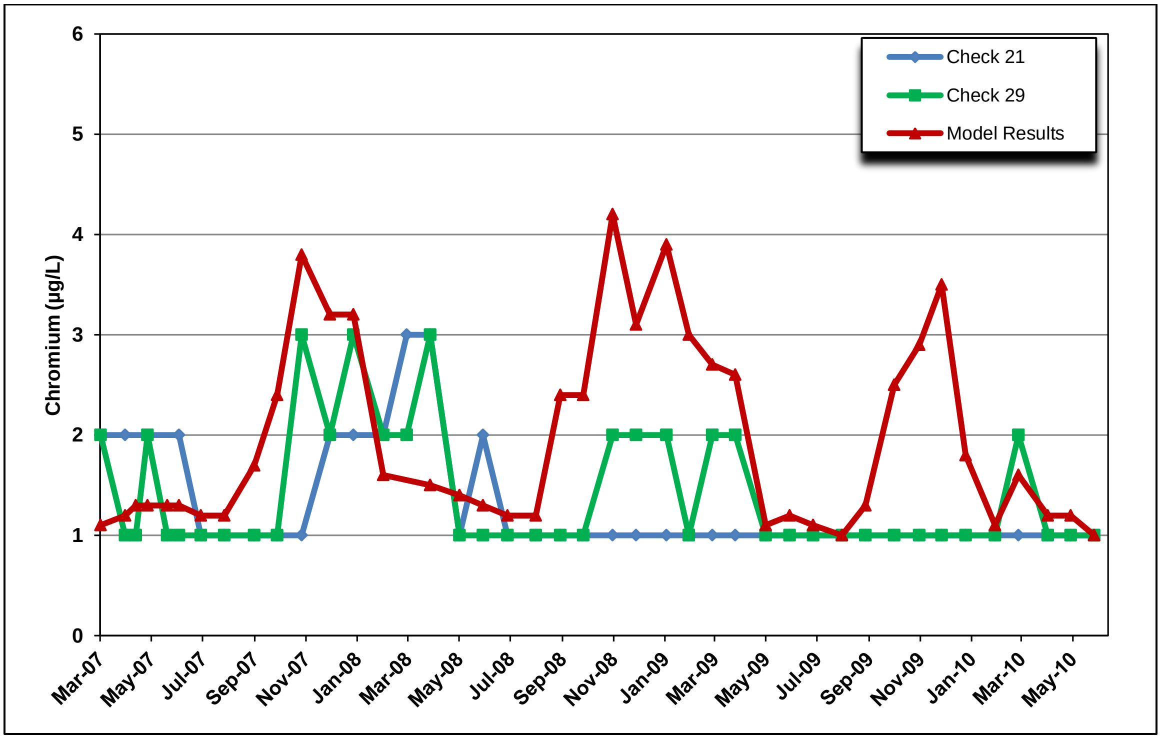
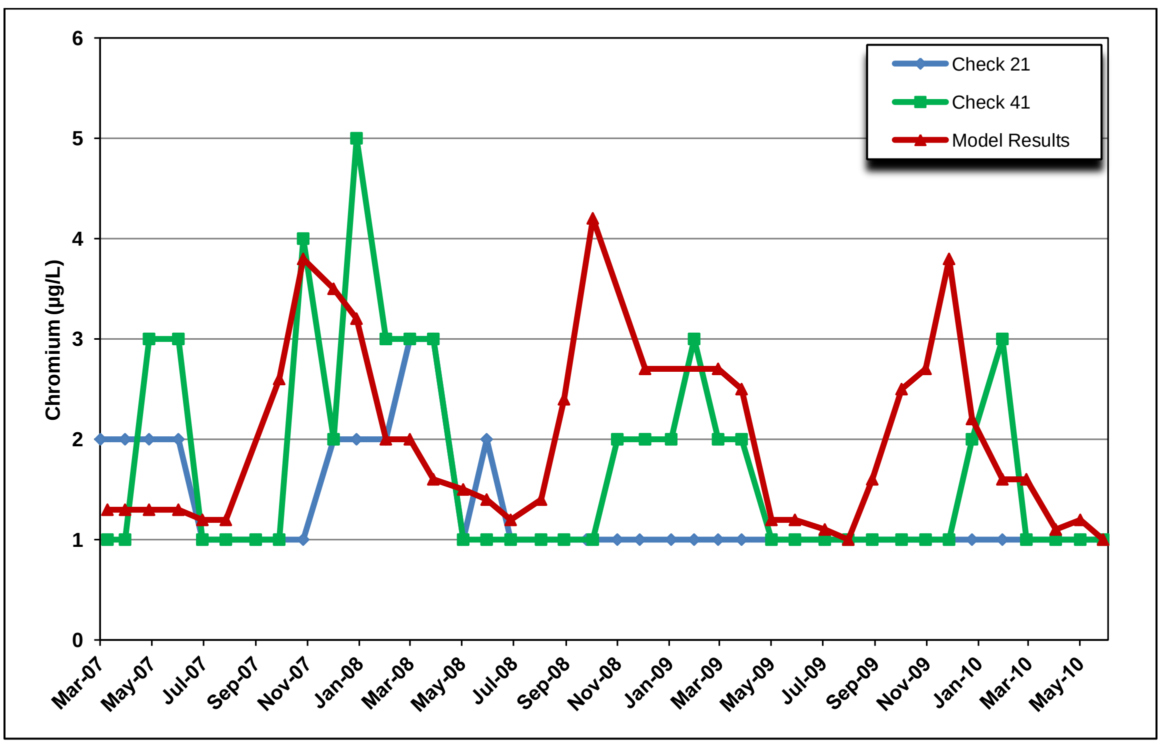


Figure 14-35. Dissolved Chromium Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



Nitrate

Although nitrate concentrations in the SWP never approach the MCL or PHG of 45 mg/L as NO_3, nitrate is a nutrient that stimulates algal growth leading to T&O problems, physical obstruction of water conveyance and treatment facilities, and increased treatment costs. **Figures 14-36 and 14-37** demonstrate that inflows increase nitrate concentrations in the California Aqueduct because the nitrate concentrations at Checks 29 and 41 were higher than at Check 21 during inflows. The median concentration of nitrate during the inflow time period increased from 2.6 mg/L as NO_3 at Check 21 to 3.0 mg/L as NO_3 at Check 29 and 3.5 mg/L as NO_3 at Check 41. **Tables 14-7 to 14-10** show that nitrate concentrations in all of the major inflows were higher than background concentrations in the California Aqueduct at Check 21. The median concentrations in the inflows ranged from 7.1 mg/L as NO_3 in the CVC to 10.3 mg/L as NO_3 in Arvin-Edison. Although nitrate concentrations increased in the aqueduct during the inflow period, the concentrations measured at Checks 29 and 41 did not exceed the MCL of 45 mg/L as NO_3.

As **Figure 14-36** shows, the Aqueduct Blending Model tends to predict higher nitrate concentrations after the KWB Canal inflows than actual water quality at Check 29. The model also predicts higher concentrations at Check 41. Further examination of the background concentration data used in the model shows that the long-term average for nitrate at O'Neill Forebay Outlet is 3.5 mg/L as NO_3, yet actual nitrate concentrations at this location varied from 0.2 to 7.1 mg/L as NO_3 over the reporting period and averaged 2.9 mg/L as NO_3. This likely accounts for the higher modeled results, compared to Check 29.

Figure 14-36. Nitrate Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

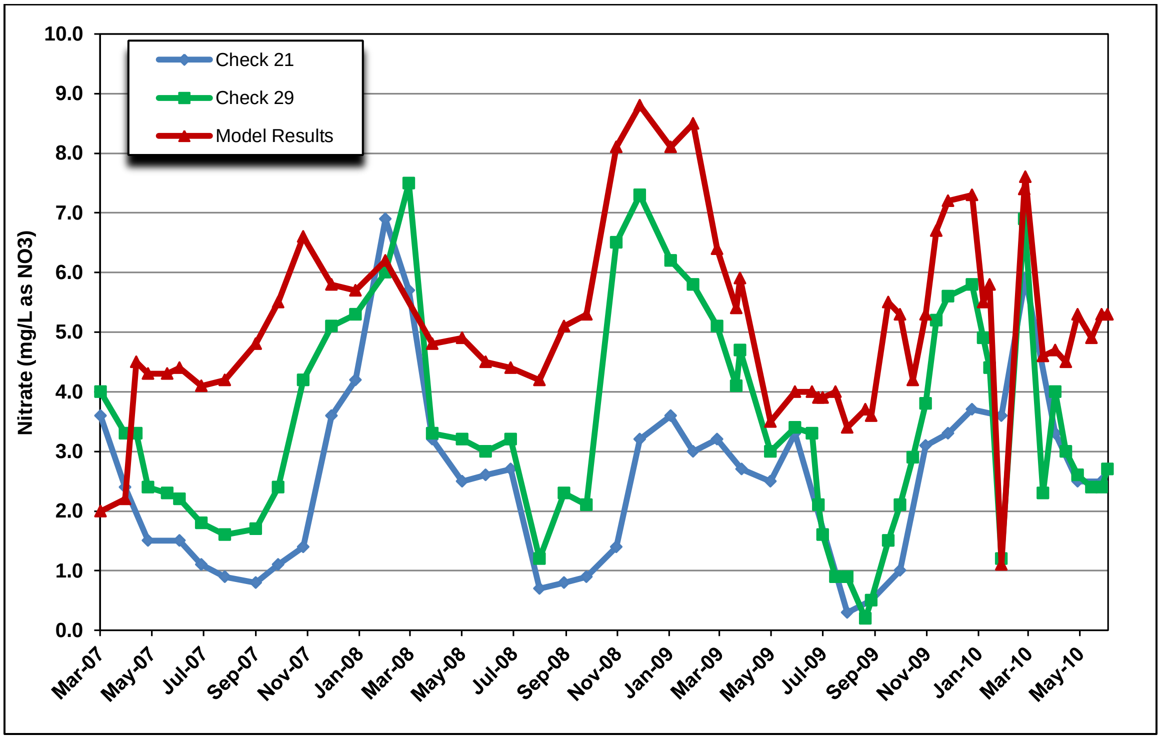
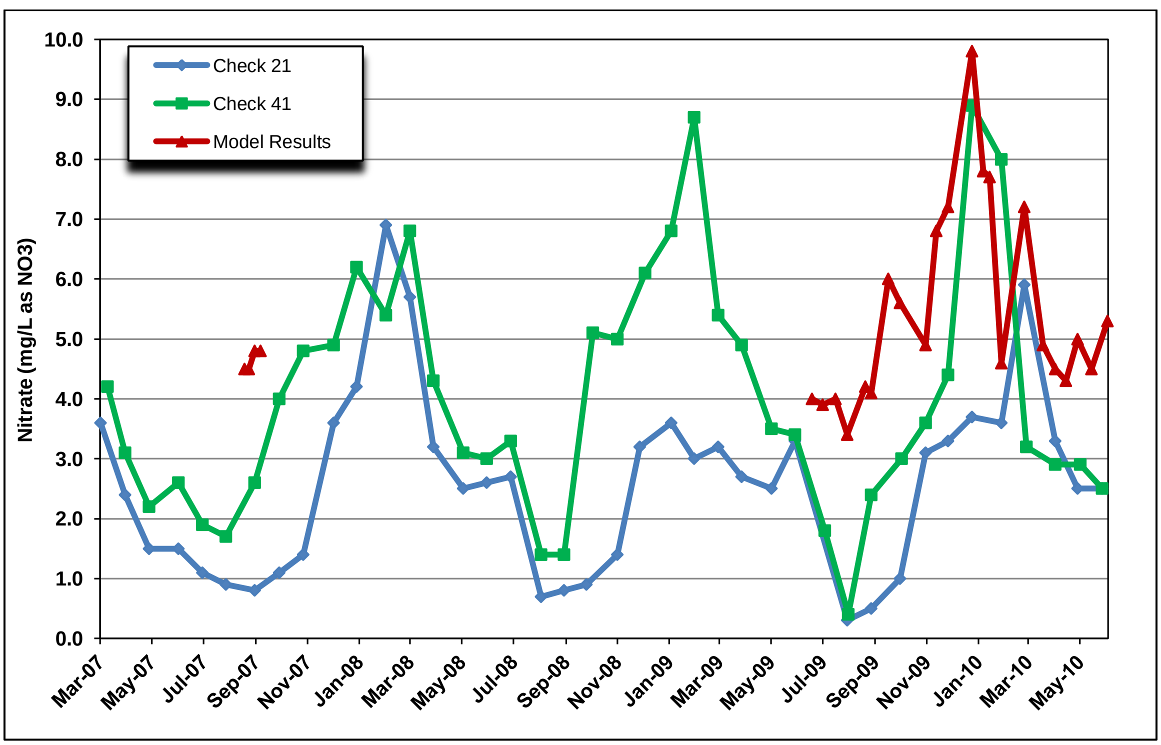


Figure 14-37. Nitrate Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



Sulfate

Sulfate occurs naturally in drinking water supplies and has a secondary MCL of 250 mg/L based on aesthetic effects. The sulfate concentrations at Checks 29 and 41 are generally higher than the concentrations at Check 21 during the fall and early winter months as shown in **Figures 14-38 and 14-39**. The reverse is true during the spring months. This pattern results in very little overall change in sulfate concentrations when the median concentration at Check 21 (41 mg/L) is compared to the median concentration at Check 29 (42 mg/L) and Check 41 (44 mg/L). The seasonal differences are due to the periods when different inflows are entering the California Aqueduct. Semitropic inflows, with a median of 111 mg/L, were discharged to the aqueduct during the fall and early winter months when sulfate concentrations increased in the aqueduct. The decrease in sulfate concentrations along the aqueduct during the spring months was due to a combination of low inflows from Semitropic and higher inflows from the CVC, with a median of 29 mg/L. The KWB Canal inflows (median of 48 mg/L) and the Arvin-Edison inflows (median of 36 mg/L) were similar to the sulfate concentrations in the aqueduct.

As **Figure 14-38** shows, the Aqueduct Blending Model both under predicts and over predicts sulfate concentrations after the KWB Canal inflows when compared to actual sulfate concentrations at Check 29. The model performs in a similar manner downstream of the Wheeler Ridge inflows. Further examination of the background concentration data used in the model shows that the long-term average for sulfate at O'Neill Forebay Outlet is 43 mg/L, yet actual sulfate concentrations at this location varied from 14 to 70 mg/L over the reporting period and averaged 42 mg/L.

Figure 14-38. Sulfate Concentrations at Check 21 and Check 29 and Model Results in Aqueduct after the KWB Canal

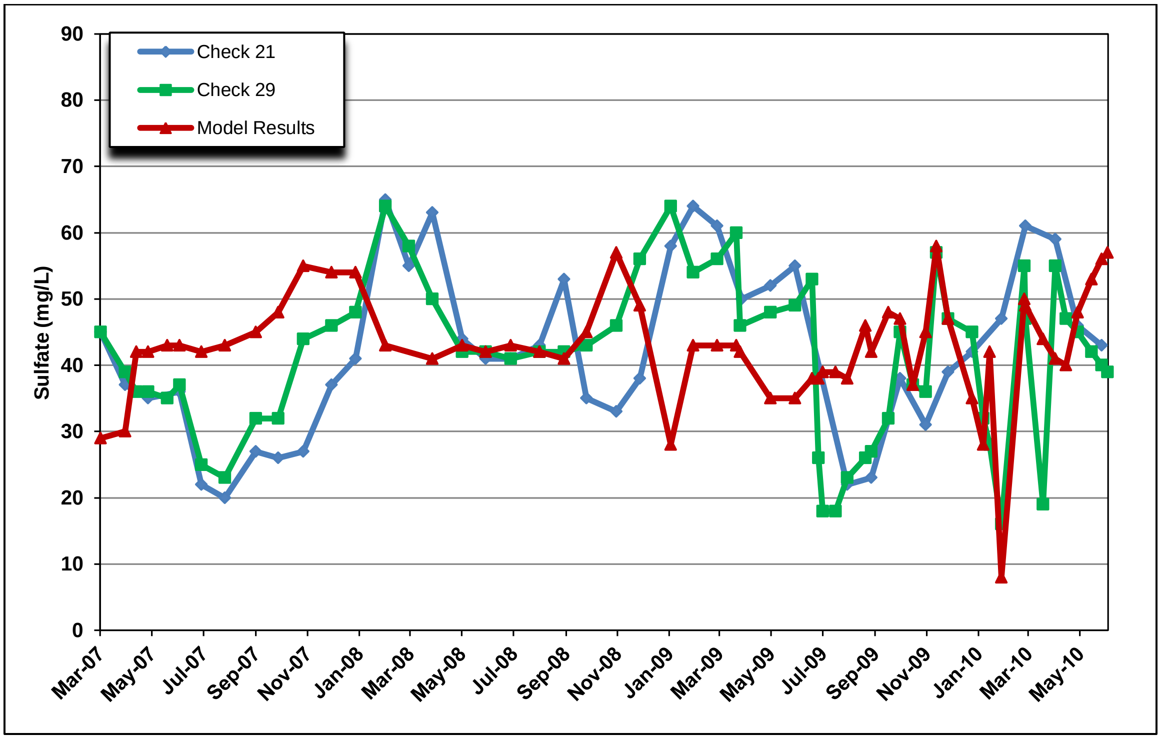
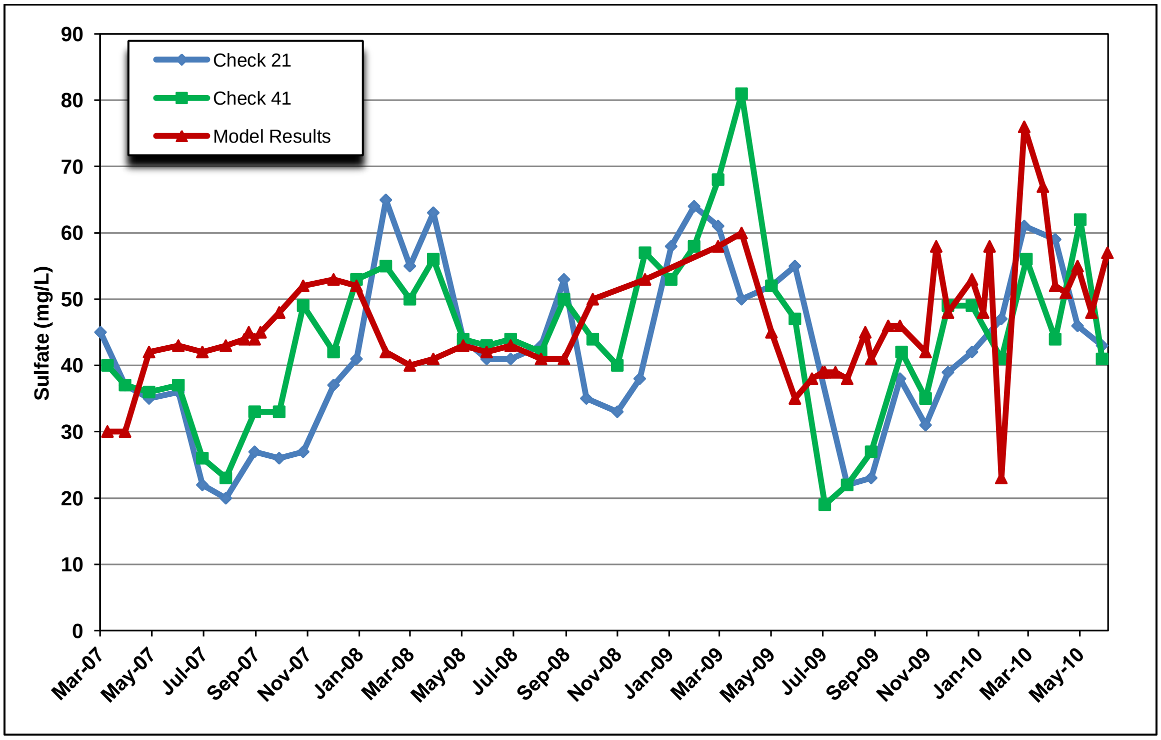


Figure 14-39. Sulfate Concentrations at Check 21 and Check 41 and Model Results in Aqueduct after Wheeler Ridge



SPECIAL TOPICS

Semitropic Arsenic Removal System

Semitropic began evaluating methods to remove arsenic from a number of wells located in the northern part of the district that contribute to Semitropic's groundwater banking project. Bench-scale studies were completed from 2005 to 2006, and a conceptual design for a 400 cfs treatment facility employing iron coagulation with membrane filtration was developed. Construction cost estimates ranged from $20 million for a 50 cfs facility, to $88 million for a 500 cfs facility.

In anticipation of extracting stored groundwater, a pilot facility was constructed primarily within an existing canal, and began operation in November 2007. This facility is referred to as the Raw Water Processing Facility and is shown in **Figure 14-40**. The treatment system consisted of injection of four chemicals (sodium hypochlorite, sulfuric acid, ferric sulfate, and polymer) across a canal, mixing in the canal through installation of K-rails, and settling of floc in the forebay prior to being pumped to the aqueduct. This was a simple, low cost system which could handle flows from 40 to 160 cfs. The treatment facility is unique in that it will operate infrequently (only in dry or drought years), but when operational it will have to treat a very large flow rate for a period of several months and will then be possibly shut-down for several years.

Figure 14-40. Construction of Semitropic Water District Raw Water Processing Facility

The pilot facility was operated from November 2007 to November 2009 and treated a total of 61,665 acre-feet at a cost of $1.8 million. The average arsenic removal was 12 percent, as measured by samples sent to an outside certified laboratory. Semitropic analyzed samples using a bench-top analyzer which showed much higher arsenic removal rates.

The operation of the pilot facility was considered to be successful in removing arsenic at a fairly low cost with a simple treatment system. Semitropic will develop a long-term facility “off-stream”, as the demonstration facility is “in-stream” on one of Semitropic’s main conveyance canals. Semitropic will build a 40 acre spillway basin to accumulate and capture sediment before the groundwater is pumped into the California Aqueduct. Operational recommendations that were completed after the pilot facility was shut down in November 2009 were: 1) replacing the Mazzei injectors with metering pumps for injecting chemicals and 2) installing an automatic pH controller to vary the sulfuric acid dose to maintain more consistent pH. These two improvements have been implemented, however they have not been tested since there have been no inflows since the end of 2009. Due to these improvements, Semitropic expects more consistent removal levels when the Raw Water Processing Facility is operational again.

Westlands Water District

Westlands was approved to wheel their groundwater on a one-time basis from June to September 2008 by a Governor’s Executive Order addressing the drought. Westlands is not a SWP Contractor. Due to the Governor’s Executive Order, Westlands was allowed to begin pumping groundwater into the San Luis Canal portion of the California Aqueduct prior to any evaluation of the groundwater quality. From June to September 2008, 12,581 acre-feet was pumped into the San Luis Canal portion of the California Aqueduct. The contract executed between DWR and Westlands allowed Westlands to pump up to 20,000 acre-feet of local groundwater originating from wells in the Westlands service area.

Due to the complexity of the system, there was not a centralized location to monitor water quality immediately prior to introduction into the California Aqueduct. Therefore, sampling of individual wells was conducted by DWR and by private well owners. From June 2008 to September 2008, DWR sampled approximately 58 wells for arsenic, selenium, nitrate, sulfate, chloride, TDS, pH, conductivity, TOC, bromide, and boron. In addition, a modified Title 22 analysis was required by individual well owners.

The contract specified that if any tested groundwater was found to be at, or within, ten percent of the maximum acceptable concentrations listed in **Table 14-13** for the constituents of concern, DWR would resample that well. If a second test did not meet the acceptable concentration, Westlands would have to remove the well from the inflow program. Similarly, if any well was found to not meet the modified Title 22 requirements during the operation, that well would be shut down immediately.

Although the contract specified these requirements, the Governor’s Executive Order bypassed the water quality testing requirements, and Westlands was allowed to begin pumping prior to any evaluation. According to DWR, two wells were shut down based on high concentrations of TDS and sulfate found after the wells were placed into service. Therefore, some unacceptable water was introduced into the California Aqueduct during this four-month time period.

Table 14-13. Maximum Acceptable Concentrations for Constituents of Concern Identified for 2008 Westlands Emergency Pump-in

Constituent	Acceptable Concentration
Arsenic (µg/L)	10
Boron (mg/L)	2.0
Bromide (µg/L)	Reviewed on a case by case basis
Nitrate (mg/L)	45
Sulfate (mg/L)	600
TDS (mg/L)	1100

Since the Westlands inflow lasted for a four month time period, from June to September 2008, a limited water quality comparison was conducted to determine downstream impacts. **Table 14-14** shows that median concentrations did not change very much from O'Neill Forebay Outlet to Check 21. There were no other pump-in entities between O'Neill Forebay Outlet and Check 21 from June to September 2008.

Table 14-14. Water Quality in the California Aqueduct during 2008 Westlands Emergency Pump-in

Constituent	O'Neill Forebay Outlet Jun-Sep 2008 Median	Check 21 Jun-Sep 2008 Median
Arsenic (µg/L)	2.5	2.5
Bromide (µg/L)	265	260
Nitrate (mg/L)	1.5	1.7
DOC (mg/L)	3.4	3.3
Sulfate (mg/L)	38	42
Chromium (µg/L)	<1	<1
TDS (mg/L)	293	284

As stated in the contract dated August 8, 2008 between DWR and Westlands, Westlands has committed that they will not propose similar programs in response to future water supply shortage conditions, unless those programs are accompanied by completed CEQA documentation, comply with DWR pump-in policies and demonstrate that economic effects resulting from subsidence associated with the increased groundwater pumping or any water quality degradation for SWP Contractors are either fully mitigated or compensation is provided.

SUMMARY

- Volume of Inflows – Non-Project inflows introduced into the California Aqueduct totaled 1,490,164 acre-feet from 2006 to 2010, which was a substantial increase over the 360,000 acre-feet for the 2001 to 2005 period.

- Quality of Inflows – Water quality data collected at the points of entry to the California Aqueduct show that all four major inflows contained lower concentrations of DOC and higher concentrations of dissolved arsenic and nitrate compared to the background quality in the California Aqueduct at Check 21. Semitropic inflows also had higher concentrations of TDS, bromide, and sulfate. KWB Canal, CVC, and Arvin-Edison inflows had lower concentrations of TDS and bromide than those found in the aqueduct.

- TDS – Inflows reduced TDS concentrations at Checks 29 and 41 compared to Check 21 at times (e.g. early 2009 and early 2010) and at other times there were no substantial differences. The median net reduction between Checks 21 and 41 was 12 mg/L, which is a relatively small reduction compared to the median concentration of 285 mg/L in the California Aqueduct at Check 21. The median net reduction of 12 mg/L represents 2.4 percent of the secondary drinking water MCL of 500 mg/L. The Aqueduct Blending Model performed well in predicting TDS concentrations downstream of the inflows during the 2006 to 2010 period.

- Bromide – The introduction of non-Project inflows generally decreased concentrations of bromide in the California Aqueduct. The median net reduction between Checks 21 and 41 was 60 µg/L, which is a substantial reduction compared to the median concentration of 280 µg/L at Check 21. The model predicted lower bromide concentrations than actual concentrations in the California Aqueduct. This is likely due to the variability of actual bromide concentrations at O'Neill Forebay Outlet compared to the background concentrations used in the model.

- DOC – Inflows reduced DOC concentrations between Checks 21 and Check 41. The median net reduction between Checks 21 and 41 was 0.6 mg/L, which is a substantial reduction compared to the median concentration of 2.9 mg/L at Check 21. The model performed well in predicting DOC concentrations downstream from the inflows except during the first few months of the inflow period.

- Dissolved Arsenic – Non-Project inflows increased dissolved arsenic concentrations in the California Aqueduct between Checks 21 and 41. The median net increase was 1 µg/L, which is substantial compared to the 2 µg/L median concentration at Check 21. However, it is important to keep in mind that a net increase of 1 µg/L represents 10 percent of the drinking water MCL of 10 µg/L. The model performed well in predicting arsenic concentrations downstream of the inflows during the 2006 to 2010 period. The Facilitation Group has an informal goal of keeping arsenic concentrations below 5 µg/L and this group required that Semitropic strive to achieve an increase in downstream arsenic concentrations of no more than 2 µg/L. There were eleven months when arsenic levels were measured at or above 5 µg/L at both Checks 29 and 41, exceeding the informal goal of keeping arsenic concentrations below 5 µg/L. In addition, there were six months when arsenic concentrations increased by more than 2 µg/L from background levels. Although dissolved arsenic concentrations increased in the aqueduct during the inflow period, the concentrations measured at Check 29 and Check 41 did not exceed the MCL for total arsenic of 10 µg/L. While arsenic in groundwater is likely almost 100 percent in the dissolved form, there could be particulate arsenic in surface inflows and in the California Aqueduct. This should be further investigated to ensure that inflows do not result in exceedences of the total arsenic MCL of 10 µg/L.

- Dissolved Chromium – Hexavalent chromium was not monitored in the California Aqueduct during the inflow period so the analysis was conducted on total dissolved chromium. Inflows increased the median concentration of dissolved chromium from <1 mg/L at Check 21 to 1 mg/L at Check 29. This is a 2.0 percent increase compared to the MCL of 50 mg/L. Hexavalent chromium should be sampled in the future. The model predicted higher concentrations of dissolved chromium than actual concentrations downstream of the inflows.

- Nitrate – Nitrate concentrations increased in the California Aqueduct as a result of the inflows. The median concentration increased from 2.6 mg/L as NO_3 at Check 21 to 3.5 mg/L as NO_3 at Check 41. While this increase of 0.9 mg/L represents only 2 percent of the MCL of 45 mg/L as NO_3, nitrate is also a concern because it is an algal nutrient. The model predicted higher nitrate concentrations than actual concentrations in the California Aqueduct. This is likely due to the variability of actual nitrate concentrations at O'Neill Forebay Outlet compared to the background concentrations used in the model.

- Sulfate – The sulfate concentrations at Checks 29 and 41 were generally higher than the concentrations at Check 21 during the fall and early winter months and lower during the spring months. This pattern resulted in a median net increase of 3 mg/L between Check 21 (41 mg/L median concentration) and Check 41 (44 mg/L median concentration). The model both under predicted and over predicted sulfate concentrations in the aqueduct. This is likely due to the variability in sulfate concentrations at O'Neill Forebay Outlet compared to the background concentrations used in the model.

- Semitropic's Arsenic Removal System – Semitropic operated an arsenic removal pilot facility from November 2007 to November 2009 that treated 61,665 acre-feet at a cost of $1.8 million. The average arsenic removal was 12 percent, as measured by samples sent to an outside certified laboratory. Semitropic analyzed samples using a bench-top analyzer which showed much higher arsenic removal rates. Semitropic plans to develop a long-term facility.

- Westlands – Westlands pumped 12,581 acre-feet of water into the San Luis Canal portion of the California Aqueduct over a four month period from June 2008 to September 2008. Due to a Governor's Executive Order, the water was allowed into the aqueduct before water quality testing was conducted. A comparison of upstream water quality measured at O'Neill Forebay Outlet to downstream water quality measured at Check 21 showed little to no change during the four months.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan included one action item related to non-Project inflows:

Improve Monitoring of Inflows and California Aqueduct Water Quality

This action item was prioritized as immediate, indicating that the issue was of critical nature. The action item suggested that more frequent and more representative data should be collected at the inflows at the point of discharge to the California Aqueduct and at the checks on the aqueduct so the actual impact of inflows can be evaluated. In addition, the action item stated it would be worthwhile to consider installing analyzers to gather real-time data for the constituents of concern at checks 21, 29, and 41.

Due to the development of the Aqueduct Blending Model, the ability to assess downstream water quality impacts has greatly improved. Therefore, it appears that the installation of real-time water quality analyzers is not needed at this time. However, the previous recommendation to have more frequent and representative data at the point of discharge to the California Aqueduct is needed and justifiable, and will be included as a recommendation for this report.

POTENTIAL ACTIONS

O&M should Prepare an Annual Review of the Program

The 2001 Implementation Procedures state that “DWR will prepare an annual report of water quality impacts in the SWP from Non-Project water and make all water quality data available to interested parties.” The annual reviews have not been completed on a regular or timely basis (the last annual review was completed by O&M in July 2008) due to staffing resource constraints. The annual review should be considered a high priority activity and should be completed within four months of the end of the water year. If O&M does not have the staff to complete the annual reviews, inflow entities should assist with resources.

O&M should Conduct Quarterly Sampling of Inflows

O&M should conduct quarterly sampling at each inflow location. O&M has conducted sampling at all of the inflow locations, except for Wheeler Ridge. The data collected are summarized in Tables 14-7 through 14-10. It is apparent that the data are not collected consistently from year to year. O&M should conduct quarterly sampling at each inflow location and enter the data in the Water Data Library so it is available for the SWP Contractors to review within two weeks of sampling.

O&M should Continue to Conduct Monthly Monitoring of the California Aqueduct and Disseminate Data Promptly

O&M should continue to conduct monthly monitoring of the California Aqueduct for all constituents of concern at O’Neill Forebay Outlet and Checks 13, 21, 29, and 41 during the active non-Project inflow period. The data collected during the 2007 to 2010 inflow period were valuable for assessing the impacts of inflows on aqueduct water quality. This monitoring should continue. Prompt dissemination of the data will allow the data to be used in evaluating downstream water quality impacts using the Kern Aqueduct Blending Model.

O&M should Add Total Arsenic and Hexavalent Chromium to the Monitoring Program

O&M currently monitors for dissolved arsenic and total dissolved chromium. Total arsenic data are needed for the inflows at the point of entry to the California Aqueduct and at the check structures in the aqueduct for comparison to the MCL which is based on total arsenic. OEHHA finalized the PHG for hexavalent chromium in July 2011 and CDPH will develop an MCL by 2014. O&M should initiate hexavalent chromium monitoring to establish a data base for comparison to the future MCL.

O&M should Enter Monitoring Data Collected by Inflow Entities in the Water Data Library

Inflow entities currently provide electronic water quality data to the Facilitation Group. However, it would be beneficial to have these entities also submit electronic data to O&M, and to have O&M enter the data in the Water Data Library. This will allow O&M to ensure that inflow entities are adhering to the required monitoring programs specified in the project proposals and will make the data accessible for review by O&M and the SWP Contractors. If O&M does not have the staffing capability to do this, inflow entities should assist with resources.

Consider Additional Use of Monthly Measured Water Quality Data at O'Neill Forebay Outlet to Define Background Water Quality During Active Inflow Period

The Aqueduct Blending Model currently uses historical averages for aqueduct background concentrations. The primary advantage of using these averages is not having a moving target when both forecasting expected changes from proposed programs and monitoring ongoing programs. Thus, historical averages provide a level of certainty for both project proponents and downstream stakeholders with respect to program changes as compared to typical aqueduct conditions. However, actual background concentrations for some constituents may at times vary significantly from historical averages, and the Aqueduct Blending Model does not then accurately predict "instantaneous" changes in water quality. Predicting these changes may be important to some model users, and consideration should be given to providing a mechanism to model using both historical averages and recent actual data.

SUBSIDENCE ALONG THE AQUEDUCT

BACKGROUND

Land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs.

Subsidence in the San Joaquin Valley is caused by fluid withdrawal, namely groundwater. It should be noted that subsidence in the Delta is caused by oxidation of peat soils, which is a completely different process than subsidence in the San Joaquin Valley. By the mid-1970s, nearly 30 feet of subsidence had been measured in the San Joaquin Valley due to pumping of groundwater.

Recently, there has been a renewed interest in subsidence in the San Joaquin Valley due to increased groundwater pumping, caused by a reduction of available imported surface water deliveries due to drought and fish-protection measures. A recent study found that from October 2003 to March 2010, aquifers in the Central Valley were drawn down by 25 million acre-feet (Famiglietti, 2011, University of California Irvine). In 2007 alone, there was a 150 foot decline in groundwater elevation, which caused subsidence. Generally, the occurrence of subsidence decreases when groundwater levels increase, and conversely the occurrence of subsidence increases when groundwater levels decrease.

Subsidence in the San Joaquin Valley is caused by compaction of aquitards (clay and silt). **Figure 14-41** shows how compaction in the deep aquifer causes subsidence in the San Joaquin Valley. The cross-section on the left shows the aquifer prior to groundwater pumping, and it is important to note the random orientation of the clayey soils in the close-up picture. Once groundwater pumping is initiated, the water in the pore spaces in clayey soils is withdrawn (as shown on the right cross-section), and the clayey soils re-orientate themselves in a “stacked” configuration, and are subsequently compacted. This compaction causes land subsidence and it also reduces the storage capacity of the aquifer. Once subsidence has occurred, the effects are irreversible. Generally, when groundwater levels fall below historical lows, there will be inelastic (irreversible) compaction.

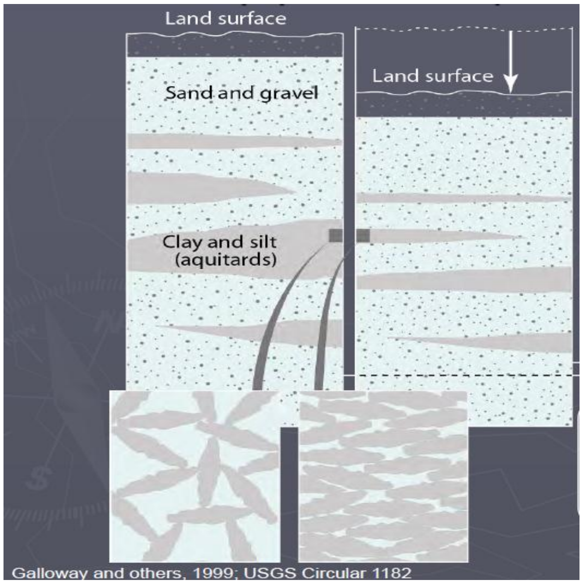
OCCURRENCE OF SUBSIDENCE ALONG CALIFORNIA AQUEDUCT

Since subsidence occurs at different rates, damage to the State Water Project and associated infrastructure has occurred. According to DWR staff at the San Luis Field Division, damage has occurred at the turnout structures, check sites, canal lining, and bridges. The worst subsidence damage has occurred near Coalinga (Personal Communication, Mandeep Bling, DWR). The amount of subsidence ranges from one to two feet. DWR staff plans to start repair work in the immediate future. In addition to structural damage, there has been a reduction in aqueduct capacity, as water cannot flow at levels in the aqueduct that are above the canal liner.

As more water districts develop groundwater banking programs adjacent to the California Aqueduct, the occurrence of land subsidence may increase. As discussed in this Non-Project Inflows section, there were seven individual entities which pumped banked groundwater into the

California Aqueduct from 2006 to 2010. Additionally, the volume of groundwater pump-ins has increased from the 2005 to 2010 time period, compared to the groundwater volume pumped in from 2000 to 2004.

Figure 14-41. Aquifer Compaction and Land Subsidence Processes in the San Joaquin Valley



CURRENT STUDIES

The U.S. Geological Survey (USGS) is currently conducting a study on behalf of DWR to gain a better understanding of how land subsidence is affecting the California Aqueduct. DWR would like to prevent future subsidence and minimize damage to existing structures. The current study area is focused on the Westlands area, as this is where the most damage from subsidence has occurred to date along the California Aqueduct. DWR also initiated this project due to the potential for future subsidence from groundwater pumping by Westlands. A similar study is being conducted on behalf of Reclamation for the CVP, from Tracy to Kettleman City. It is expected that both projects will be completed in September 2012.

The objectives of the USGS study are to:

- Determine the location, extent, and magnitude of changes in land-surface elevation along the California Aqueduct from 2003 to 2010.
- Develop and implement an approach to use permanent scatterer Interferometric Synthetic Aperture Radar (InSAR) to monitor subsidence in the Westlands area.
- Improve the understanding of groundwater conditions and land subsidence.

- Utilize an existing groundwater flow and land subsidence model to help manage and limit future land subsidence in the Westlands area.

InSAR is the processing of individual satellite radar images of the same area to make a map of changes in vertical land-surface elevations at selected locations in the San Joaquin Valley.

According to USGS, there will be no recommendations at the conclusion of the study, in order to remain unbiased and objective, per USGS policy. However, the USGS hopes to define the preconsolidation stress(es), which is essentially the water level at which inelastic subsidence initiates. Therefore, this will provide valuable information in preventing/managing future subsidence, as subsidence will not occur if groundwater levels are kept above the preconsolidated stress.

POTENTIAL ACTIONS

DWR should Evaluate the Need to Monitor Subsidence along the California Aqueduct

When the current USGS study is completed, DWR should assess the need to monitor land subsidence outside and beyond the Westlands area, as there are active groundwater inflow programs downstream along the California Aqueduct. These additional assessments may be important to further protect the aqueduct from damage caused by subsidence.

PYRAMID LAKE

Pyramid Lake is the second reservoir on the West Branch of the California Aqueduct. Pyramid Lake is located in the Angeles and Los Padres National Forests, about 60 miles northwest of downtown Los Angeles. Water from the SWP flows into the lake at the end of the Peace Valley Pipeline or via the improved Gorman Creek channel when the Warne Power Plant capacity is insufficient to meet demands. **Figure 14-42** shows the facilities along the West Branch. The reservoir has a storage capacity of about 171,200 acre-feet, and provides regulatory storage for the Castaic Powerplant, normal regulatory storage for water deliveries from the SWP West Branch, emergency storage in the event of a shutdown of the SWP to the north, recreation opportunities, and incidental flood protection. This section contains an update on the 2005 oil spill that was discussed in the 2006 Update and a discussion of a fire that occurred in 2006.

OIL SPILL

Background

The 2006 Update contains a discussion of an oil spill that occurred on March 23, 2005 into Posey Canyon, approximately 1.3 miles upstream of Pyramid Lake. As a result, the 2007 State Water Project Action Plan included one action item for follow up. As there were no spills during the 2006 to 2010 reporting period, this section contains a discussion of the previous action item and follow-up action taken. Additional action taken by the responsible party, Pacific Pipeline Systems, LLC (Pacific), in regards to the 2005 oil spill is also discussed.

Current Status

On September 4, 2008, Plaintiff United States of America, on behalf of the United States Environmental Protection Agency filed a complaint alleging that Pacific violated Sections 301 (a) and 311 (b) of the Clean Water Act when 3,393 barrels of crude oil were discharged from Pacific's Line 63 pipeline on March 23, 2005 into Pyramid Lake and Posey Canyon Creek. Pacific's Line 63 is an underground pipeline that runs from Bakersfield to Los Angeles.

Pacific has agreed to pay a $1.3 million civil penalty and discontinue the use of approximately 70 miles of the Line 63 pipeline. The pipeline can be reused if Pacific performs specific actions to relocate the pipeline into more geologically stable areas or improve its resistance to earth movement. The actions required of Pacific in a Consent Decree are:

- By November 30, 2009 Pacific shall purge and remove all oil in a 70 mile section of Line 63.
- Pacific shall select, subject to USEPA's approval, an independent third party to review work plans and maintain work consistent with industry standards.
- Pacific shall relocate above-ground sections of Line 63 at specific locations into permanent below-ground locations, as these locations were temporarily installed after prior landslides.

Figure 14-42. West Branch of the California Aqueduct

- Pacific shall make appropriate repairs to Old Ridge Road.

- Pacific shall relocate and bury 250 feet of buried pipe, Pacific shall lower or relocate sections of exposed pipe, Pacific shall repair and cover 28 feet of exposed pipe in a creek bed, Pacific shall lower 240 feet of exposed pipe and Pacific shall relocate 700 feet of exposed pipe at the bottom of a steep ravine.

- Pacific will perform increased oversight to address risks to Line 63 by conducting increased aerial inspection frequency following significant rain events, increased ground inspection by field personnel, and monitoring of cumulative rainfall and weather conditions to determine if Line 63 should continue to operate or be shut down (as the integrity of the line could be at risk from landslides due to accumulated rainfall).

Before the Consent Decree was issued, Pacific performed permanent relocation of Line 63 at Posey Canyon using horizontal directional drilling to route 1,110 feet of the pipeline 30 feet below the landslide plane. Additional repairs and relocations were conducted after the spill at Grapevine Creek, Castaic Creek, Vista Del Lago, Gun Club Creek, and Windage. The Consent decree also notes that Pacific conducts emergency training exercises and has included lessons learned from the March 2005 landslide event in its response drills.

Pacific has developed a work plan to address the above ground section of Line 63. Therefore, it appears that Pacific is in the process of completing the actions required in the Consent Decree to reuse Line 63.

PYRAMID LAKE DAY FIRE

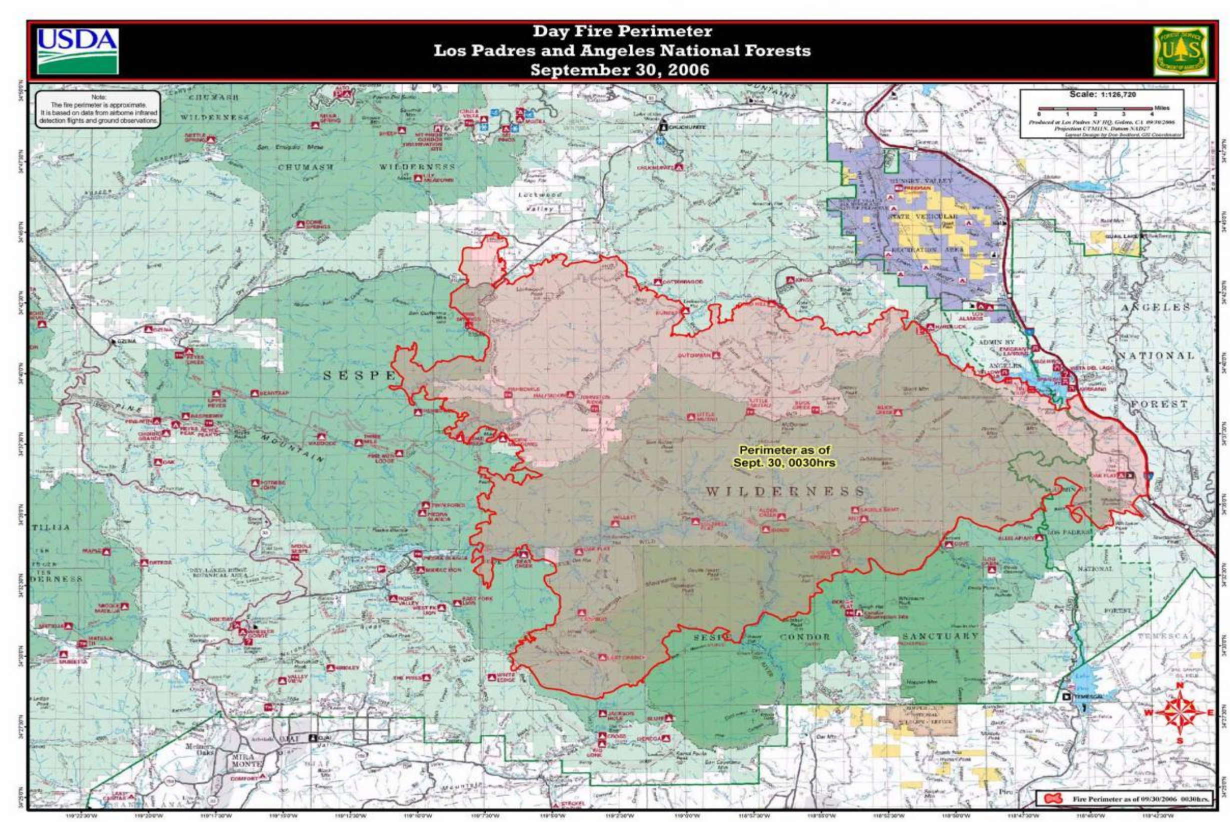
Description of Event

The Day Fire started on September 4, 2006 and was contained on October 2, 2006. The fire burned a total of 163,908 acres, of which 152,908 acres were on National Forest System lands and the remainder private lands. As shown in **14-43**, the Day Fire is bounded on the east by Interstate Highway 5, on the north by Lockwood Creek and Piru Creek, on the west by the headwaters of Piru Creek and Sepse Creek and on the south, along the Sepse Wilderness boundary.

The Day Fire burned five hydrologic unit code watersheds: Upper Cuyama River, Lower Piru Creek, Sepse Creek, Lower Santa Clara River, and Upper Piru Creek. It should be noted that of the Day Fire burn area, only Upper Piru Creek is tributary to Pyramid Lake. Approximately 38 percent of the 291.1 square mile Upper Piru Creek watershed was located within the perimeter of the Day Fire. Approximately 0.44 percent of the Upper Piru Creek watershed burned with high burn severity, 23 percent burned with moderate severity, with the remaining area at low to no burn severity.

A Burn Area Emergency Rehabilitation (BAER) report was prepared by the National Forest Service to document potential threat to both life and property down slope of the burn area (National Forest Service, 2006). The BAER report identified increased sediment and water discharge into Pyramid Lake as a threat that could reduce the storage capacity of the reservoir. The amount of sediment expected to be deposited in Pyramid Lake during the year immediately following the fire was estimated at 868,567 cubic yards, which is an increase of 800 percent from pre-fire conditions. Runoff flows to the lake were expected to increase by 22 percent.

Figure 14-43. Day Fire Perimeter – Los Padres and Angeles National Forests



Actions Taken

The BAER report concluded that there are no practical or effective on site treatments to reduce the effects of flooding, debris flow and sedimentation to impacted water bodies. Seeding and other watershed treatments were considered but eliminated because of the low percentage of high burn intensity and the steep, rocky slopes within the fire perimeter. Therefore, most of the post-fire action taken by the Forest Service focused on area closures to protect the public from flood hazards, trail and hazard tree identification, cleaning and repairing drainage structures, and removal of hazard trees. According to DWR staff, a weather station was installed by the U.S. Forest Service to monitor rainfall in the subsequent winters after the fire. The weather station has been dismantled.

DWR installed debris log booms at key locations on Pyramid Lake to contain any floating debris. However, the ash and debris flow expected after the fire did not occur due to moderate rains. DWR continued to install the debris boom for three consecutive winters after the fire, yet there was no debris accumulation on the lake surface. DWR staff also continued to monitor the lake as part of their routine monitoring for turbidity and Secchi depth. As there were no heavy rains in the winter of 2006, turbidity levels in the lake did not become elevated from post-fire watershed runoff (Personal Communication, John Kemp, DWR).

Castaic Lake was also potentially vulnerable to elevated turbidity from Pyramid Lake, as Castaic Lake had been lowered for required maintenance on the Elderberry Forebay dam at the time of the fire. However, according to MWDSC staff, there were no changes in influent water quality to the Jensen WTP during the winter of 2006 as a result of the fire (Personal Communication, David Dean, MWDSC).

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following action related to the Pyramid Lake oil spill:

SWPCA and DWR should Work with Oil Companies to Identify Measures Needed to Protect Water Quality.

This action item was prioritized as long-term, indicating that the issue was of a non-critical nature that will be reassessed periodically. Although not related to Pyramid Lake, DWR is initiating an effort to protect the SWP from oil spills. DWR O&M Headquarters Civil Maintenance has tentatively decided to reroute a pipeline crossing the California Aqueduct. DWR is currently renegotiating the agreement with Conoco Phillips related to the repair activities. Once a final decision is made regarding this location, MWQI will work with the SWP Contractors to decide upon the appropriate course of action in evaluating the risks and costs associated with other oil pipeline crossings along the aqueduct.

POTENTIAL ACTIONS

None

CASTAIC LAKE

Castaic Lake, located about 45 miles northwest of downtown Los Angeles, is the terminal reservoir of the West Branch of the California Aqueduct, as shown previously in **Figure 14-42**. Castaic Lake is supplied by the SWP from Pyramid Lake, and has a maximum storage of 323,700 acre-feet. Castaic Lake supplies water to MWDSC, Castaic Lake Water Agency, and the Ventura County Flood Control and Water Conservation District. The Ventura County Flood Control and Water Conservation District water is routed directly to the Santa Clara River and is not treated for potable use. This section contains an update on the high *E. coli* levels discussed in the 2006 Update and a description of a wastewater spill that occurred in 2008.

HIGH *E. COLI* LEVELS

Background

The 2006 Update discussed contaminant sources which may have contributed to high *E. coli* levels during the winters of 2000 and 2001. Potential sources of *E. coli* were cattle grazing, gull roosting, and general watershed runoff. The previous watershed sanitary survey also discussed the actions taken by both DWR and MWDSC to address these issues which were:

- 3.5 miles of new fence was installed in 2003 to protect the entire west side of Elderberry Forebay.

- MWDSC obtained grant funding from the State Water Board through the Costa-Machado Water Act of 2000 (Proposition 13) to complete a limited microbial source tracking study to determine the relative contribution of cows, gulls, and tributary creeks to the seasonal *E. coli* contamination within Castaic Lake. The final report was submitted to the State Water Board in March 2007.

- MWDSC hired an ornithologist to track the number of gulls and their behavior patterns on Castaic Lake. This work also included developing a list of potential best management practices to reduce gull roosting on Castaic Lake.

Results of the limited microbial source tracking study and the gull surveys were discussed in detail in the 2006 Update.

Current Status

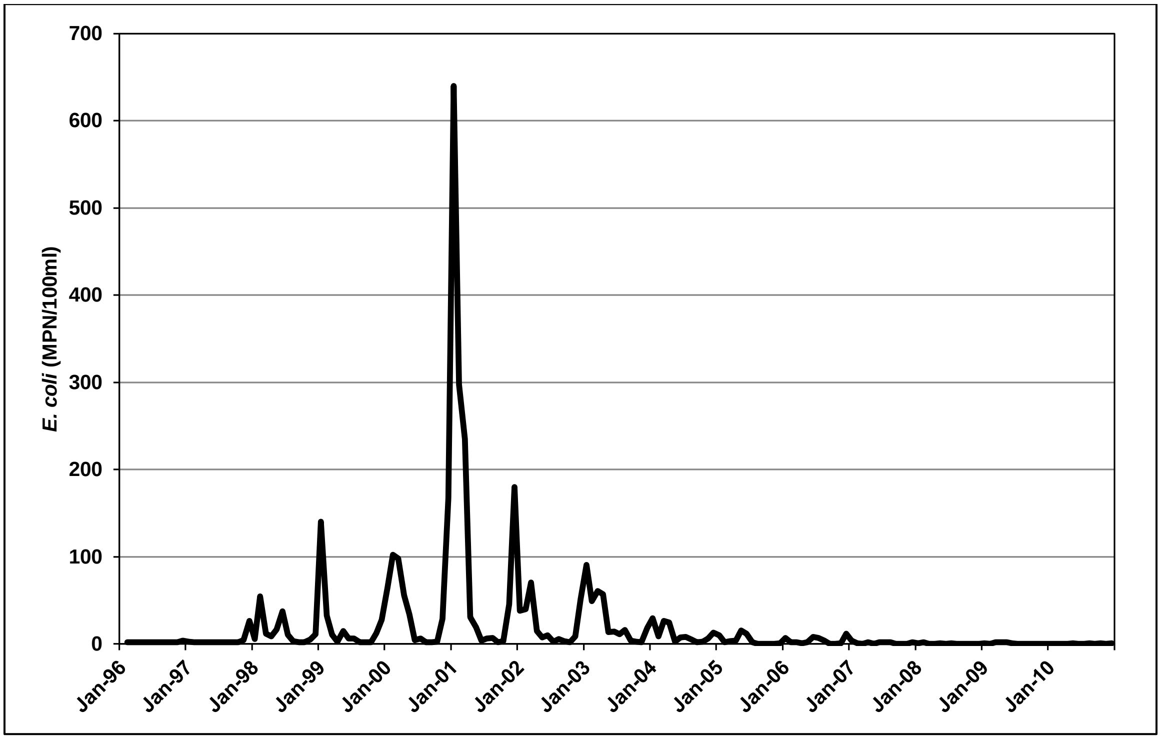
Since the studies have been completed, two best management practices have been implemented to discourage gull roosting on the lake. Pilot scale gull management exercises were conducted in January and February 2007 with limited success. Gulls were chased off the lake surface using a motorized boat for four consecutive nights. The percentage of gulls successfully removed from the lake each night ranged from 15 to 64 percent.

A brochure was also developed to educate the general public on the hazards of feeding the gulls at the Castaic lagoon or lake. This brochure was distributed at the main gate to the Castaic Lake Recreational Area by the Los Angeles County Department of Parks and Recreation (LACDPR) in 2007, as shown in **Figure 14-44**. However, it is no longer being distributed. Although the LACDPR acknowledge the continued presence of gulls on both Castaic Lake and the lagoon, the LACDPR do not feel that they have a problem with the general public feeding gulls (Personal Communication, Lori Bennett, Regional Park Superintendent, LACDPR).

Figure 14-44. Gull Feeding Brochure for Castaic Lake State Recreation Area

As shown in **Figure 14-45**, monthly average *E. coli* levels at the Jensen WTP have been on the decline since the winters of 2000 through 2002. Therefore, there has not been a need to consider further gull management techniques. As stated in the previous watershed sanitary survey, these techniques were to work with the Los Angeles County Department of Health Services to inform local businesses to keep dumpsters closed, or to inform local landfills to discourage gull presence.

Figure 14-45. Monthly Average *E. coli* Levels at Jensen WTP



WARM SPRINGS SEWAGE SPILL

Description of Event

On April 22, 2008 a 5,000 gallon sewage spill originated from the Warm Springs Rehabilitation Center in Castaic, California. The facility has a small wastewater treatment plant adjacent to Elizabeth Lake Canyon Creek. Elizabeth Lake Canyon Creek is one of two main tributaries to Castaic Lake. According to information provided by the Los Angeles County Health Department, the switching pump station electrical switch failed and wastewater was not pumped from the pump station to the wastewater plant. The spill was diked and contained in front of the station and subsequently removed.

The design capacity of the wastewater treatment plant is 30,000 gallons a day, and normally all secondary treated wastewater is disposed of by irrigation on seven acres of land near the facility owned by the U.S. Forest Service. No drainage or disposal is allowed in or near the creek.

The MWDSC and the Castaic Lake Water Agency were informed of the spill on April 23, 2008 in the morning by both DWR and CDPH. Upon further investigation of the Warm Springs Rehabilitation Center that afternoon, it was determined by the Los Angeles County Health Department that the sewage did not enter Elizabeth Lake Canyon Creek or Lake Castaic.

Actions Taken

On April 24, 2008 the DWR collected samples near the outlet tower and the Elizabeth Lake Canyon Creek shoreline, where the creek enters Castaic Lake. The samples were analyzed by the Castaic Lake Water Agency. All of the samples ranged from <2 MPN/100mL to 4 MPN/100mL for *E. coli*.

MWDSC also collected two pathogen samples at the Foothill Feeder Control Structure on April 24, 2008 and the samples were negative for both *Cryptosporidium* and *Giardia*. DWR Southern Field Division staff inspected the Elizabeth Lake Canyon Creek Arm, and reported no visible sewage in Elizabeth Canyon Creek where it enters Castaic Lake.

The Warm Springs Rehabilitation Center repaired the switching station electronics and also installed a back-up mechanical float valve to ensure continued pumping at the site due to potential failure of the electrical system.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains the following action related to the high *E. coli* levels in Castaic Lake:

Determine if Any Other Locations along the SWP May Benefit from Gull Management Programs.

This action item was prioritized as long-term, indicating that the issue was of non-critical nature. As there have not been gull problems at other SWP reservoirs/facilities, this action item has been completed.

POTENTIAL ACTIONS

SWPCA Should Confirm that a Backup Mechanical Float Valve Was Installed.

SWPCA should confirm with Warm Springs Rehabilitation Center that a backup mechanical float valve was installed at the pump station to ensure continued pumping if electrical failures occur in the future.

HESPERIA MASTER DRAINAGE PLAN

BACKGROUND

The East Branch of the California Aqueduct traverses the incorporated City of Hesperia and portions of the County of San Bernardino, as shown in **Figure 14-46**. Natural runoff in this area is in a northeasterly direction towards the Mojave River. When the East Branch was constructed, the natural drainage pattern was interrupted so overchutes and culverts were constructed by DWR to convey drainage over and under the California Aqueduct. Within the Hesperia watershed, there are seven overchutes and 12 culverts. There is also a two mile stretch of the aqueduct where urban runoff is discharged into the aqueduct through 45 drop inlets. The inlets were installed by DWR to prevent flooding of the urban area adjacent to the aqueduct on the southwest side. **Figure 14-47** shows a drop inlet along the aqueduct. As the Hesperia watershed becomes increasingly urbanized with residential and commercial developments, the volume of urban runoff into the aqueduct via the drop inlets is expected to eventually increase.

Figure 14-46. East Branch of California Aqueduct near the City of Hesperia

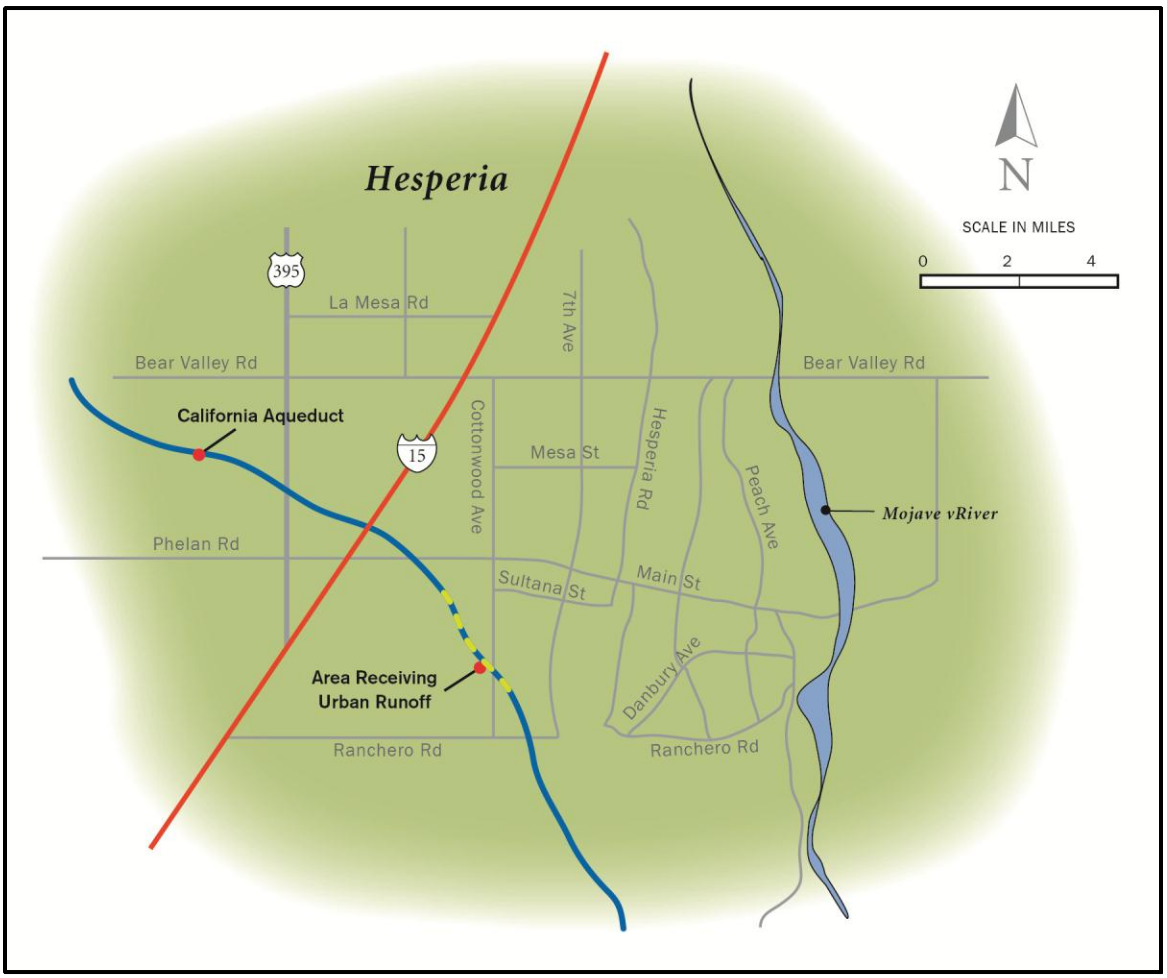


Figure 14-47. Drop Inlets Along the California Aqueduct in Hesperia

Note: This figure shows the end of a drop inlet pipeline leading into the California Aqueduct. The pipeline collects drainage from the other side of the embankment and discharges into the aqueduct.

There are a number of SWP Contractors that have turnouts downstream of this area, as shown in **Table 14-15**. **Table 14-15** shows the approximate distance from the Hesperia drop inlets to the various downstream SWP Contractors. The Mojave Water Agency, the San Gabriel Valley Water District, and the San Gorgonio Pass Water Agency use SWP deliveries for groundwater recharge. The Desert Water Agency and the Coachella Valley Water District do not receive water directly from the SWP, but participate in a wheeling exchange with MWDSC. Crestline Lake Arrowhead Water Agency, San Bernardino Valley Municipal Water District, and MWDSC receive water from the SWP for subsequent treatment and delivery to their member agencies or consumers.

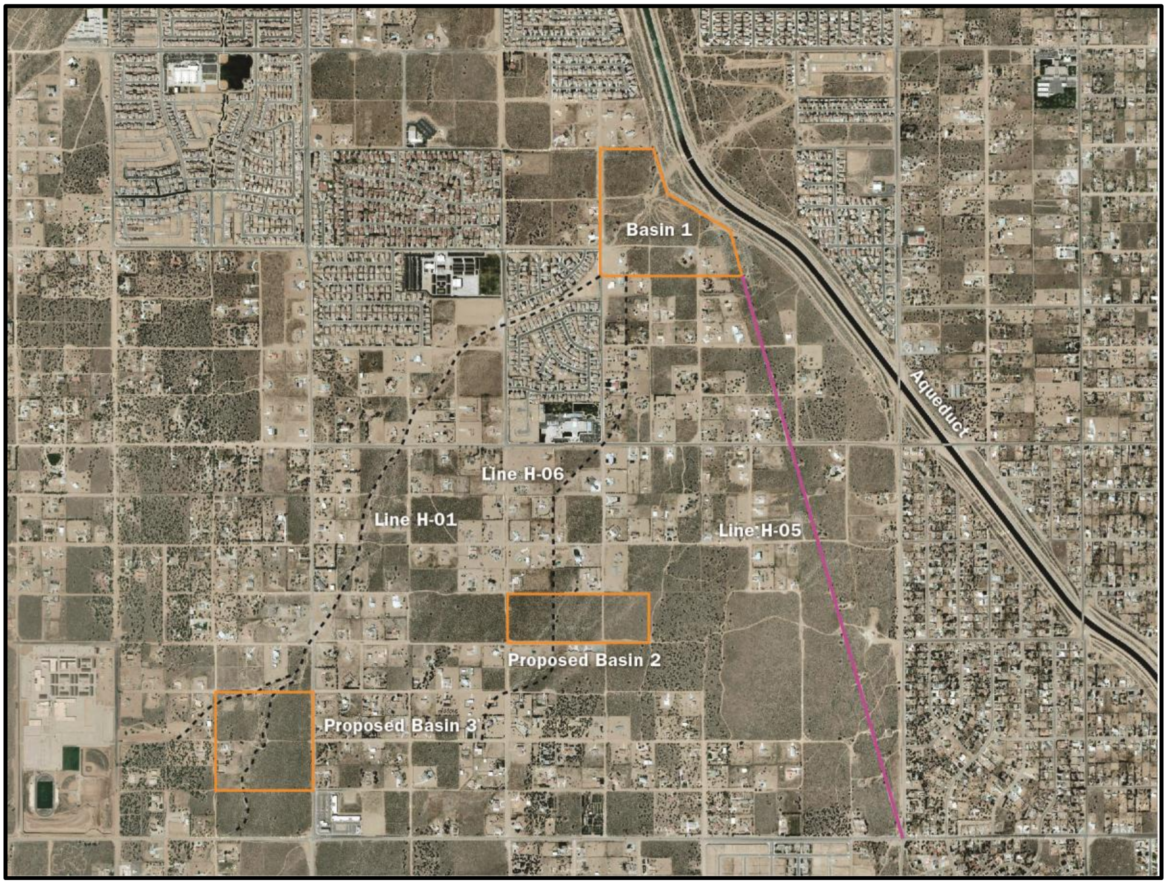
Table 14-15. Turnouts Downstream of Hesperia Drop Inlets

SWP Contractor	Turnout Location	Approximate Distance from Hesperia Drop Inlets (miles)
Mojave Water Agency	California Aquduct	4
Crestline Lake Arrowhead Water Agency	Silverwood Lake	11
MWDSC	Devil Canyon Afterbay	16
Desert Water Agency	Devil Canyon Afterbay	16
San Gabriel Valley Municipal Water District	Devil Canyon Afterbay	16
Coachella Valley Water District	Devil Canyon Afterbay	16
San Bernardino Valley Municipal Water District	Devil Canyon Afterbay	16
San Gorgonio Pass Water Agency	Devil Canyon Afterbay	16
MWDSC	Santa Ana Valley Pipeline	43
MWDSC	Lake Perris	46

The 2006 Update contained a discussion of the 1996 Master Plan of Drainage and communication between DWR and San Bernardino County through 2006. This information is summarized in this section to provide context for activities in the last five years.

The County developed a Master Plan of Drainage in May 1996 for the City of Hesperia to address the management of storm water flows in the watershed (San Bernardino County Flood Control District, 1996). As shown in **Figure 14-48**, there are three drainage lines (H-01, H-06, and H-05). Currently, H-01 and H-06 are natural drainages which lead to an overchute that carries drainage over the California Aqueduct. As the combined 100-year peak flow at full build out for H-01 and H-06 is calculated at 4,887 cfs, and the capacity of the overchute is 2,115 cfs, excess flows not conveyed across the overchute pond along the California Aqueduct and may eventually flow through the drop inlets. To address the undersized overchute at, the County proposed a single detention basin to attenuate peak flows contributed by H-01 and H-06. The Hesperia Basin report prepared by the County in 2006 contained a variety of alternatives for the single detention basin design (San Bernardino County, 2006a). The report proposed three detention sizes to control flows and convey runoff for a 100-year storm event.

Figure 14-48. Key Facilities near the California Aqueduct



According to the 2006 report, the largest size detention basin was designed to attenuate not only the natural drainage leading to the overchute, but to also contain additional flows if the 45 drop inlets were eliminated. All of the flow would be redirected to the detention basin. According to the County, the cost of the large detention basin, which would eliminate the 45 drop inlets, is approximately $45 million in 2010 dollars, and the cost of the detention basin to only attenuate flow leading to the one overchute (and not including flows through the 45 drop inlets) is $30 million. Therefore, the cost differential to eliminate flows through the drop inlets leading into the California Aqueduct is $15 million.

DWR has not officially written a comment letter on the County's 2006 Hesperia Basin Report. DWR and the SWP Contractors reviewed preliminary drawings and submitted comments to the County in 2005 (DWR, 2005). The letter maintains that the continued use of the drop inlets is unacceptable because: 1) the drop inlets were constructed in 1971 as temporary drainage measures until the County completed its Hesperia Master Plan of Drainage, and 2) impounding water against the California Aqueduct embankment within DWR right of way is problematic.

CURRENT STATUS

This section contains an update on the County's plans to address drainage in the vicinity of the California Aqueduct and an analysis of water quality data conducted to determine if there is any direct evidence of the impact of the drainage on aqueduct water quality.

Proposed Project

There have been a number of developments since the 2006 Update, which are presented in chronological order. In May 2008, a tour of the area was attended by representatives of DWR and the State Water Contractors. The group viewed the overchute, two drop inlets, site of the proposed detention basin, and damage to the California Aqueduct embankment and concrete panels caused by stormwater flows coming down Main Street. DWR personnel mentioned that streets crossing the aqueduct in the area (Main Street, Maple Avenue, Mesquite Street, and Cottonwood Avenue) were serving as floodways and were allowing flood water to enter the aqueduct.

At this meeting, DWR's position was that any solution proposed by the County must keep all surface runoff out of the California Aqueduct and there should be no use of DWR right of way. DWR was also waiting for a final legal opinion from their Legal Office regarding the SWP legal obligations and liabilities related to the drainage. At the time, the plan explained by DWR staff was to finalize the legal opinion, meet with their management, and then meet with the SWP Contractors. To date, DWR has not set-up a meeting with the SWP Contractors, and the legal opinion has not been finalized.

A meeting between DWR staff and the County was held in the spring of 2010, as a number of power poles were destroyed on DWR property due to flooding near the California Aqueduct. According to the County, DWR staff indicated during the meeting that funding was not available for the construction of the larger detention basin. As a result of this meeting, the County has decided to move forward with a smaller Hesperia detention basin, as well as two additional detention basins as shown in **Figure 14-48**. As the size of the Hesperia basin was reduced, it will not eliminate flows to the aqueduct via the 45 drop inlets, but there will be a reduction in flow through the drop inlets.

The County is planning for a phased construction, where lines H-01 and H-06 and the first detention basin (Hesperia Basin) will be constructed first, and line H-05 and detention basins 2 and 3 following. Currently, the construction of the Hesperia detention basin is scheduled for 2017-2018, pending funding by the County. According to the County, construction of line H-05 is at least ten years away, and will not be considered a high priority until the area is more developed. The County's first priority is to construct lines H-01 and H-06, and the Hesperia detention basin.

As part of the project, H-01 will be converted into a concrete and rip-rap lined trapezoidal channel, and H-06 will be converted into a rip-rap lined trapezoidal channel. Line H-05 is a proposed riprap channel alignment which is designed to capture the flows that currently sheet flow in a northeast direction and eventually terminates at the California Aqueduct and flows through the drop inlets. Line H-05 is being designed to capture 1,200 cfs of runoff flows.

The County is planning to complete design of the three detention basins by the end of 2011. The smaller Hesperia basin will be 580 acre-feet, covering approximately 40 acres. As shown in **Figure 14-48**, the approximate location for the Hesperia detention basin is proposed to be just south of the California Aqueduct, between Bandicoot Trail and the Edison easement, in the unincorporated area of San Bernardino County. According to the County, the size of this basin is not large enough to contain the 100-year peak flows from lines H-01 and H-06, and it will not be able to store flows from H-05 once constructed. Therefore, basins 2 and 3 will be needed at a later date to contain these excess or additional flows.

The County has been in communication with DWR's Division of Safety of Dams and the Lahontan Regional Water Quality Control Board, and the County does not anticipate it will be required to complete an EIR. However, they will need to complete a siting study as required by the Lahontan Regional Water Quality Control Board.

In summary, the County is moving forward with the design of three detention basins and channels in the Hesperia watershed as part of their Master Plan of Drainage. Construction of the three detention basins and the three channels (H-01, H-06, H-05) will reduce the flows currently flowing through the drop inlets. However, construction of line H-05, which provides the greatest direct benefit to reducing flows through the drop inlets is at least ten years away. The County's first priority is to construct lines H-01 and H-06, and the Hesperia detention basin.

Water Quality Impacts

Typical pollutants found in urban stormwater runoff are nutrients, suspended solids, organic carbon, bacteria, hydrocarbons, trace metals, and pesticides. Urban runoff occurs on a year-round basis and includes wet and dry weather discharges. Wet weather runoff results from seasonal storms, while dry weather runoff results from activities such as lawn irrigation and car washing. Wet weather runoff is of relatively short duration and can have highly variable pollutant concentrations. Typically, the highest wet weather pollutant load occurs after a first-flush event. The County has no data on the quality of the runoff water entering the California Aqueduct. DWR staff reports that one sample was taken in the winter of 1993. This sample contained elevated levels of suspended solids and organic carbon was measured at 11.9 mg/L. Concentrations of metals or minerals detected were not considered to be elevated.

Since urban stormwater runoff contains various pollutants, downstream water users remain concerned about impacts to source water quality. Pollutant loading to the California Aqueduct from the drop inlets is unknown since not enough information is available for both the quality and quantity of urban runoff discharged through the drop inlets. The County has not performed any flow computations or direct flow measurements through the drop inlets.

Continuous turbidity and EC data measured at Check 66 were analyzed to determine if levels increased during periods of heavy rainfall. The nearest precipitation gauge for the Hesperia watershed is located in Victorville. Analysis of rainfall data from 2004 to 2010 showed that the years of highest cumulative rainfall were the winters of 2004 to 2005, 2007 to 2008, and 2009 to 2010. The winter of 2004 to 2005 had the highest cumulative rainfall of 18.6 inches, the winters of 2007 to 2008 had only 4.4 inches and the winter of 2009 to 2010 had 9.9 inches. Average annual rainfall in Victorville is 6.2 inches so the winter of 2004 to 2005 was extremely wet.

Figures 14-49 through 14-51 show turbidity levels at Check 66 for each of the respective winters and **Figures 14-52 through 14-54** show EC levels at Check 66 for the same time periods. **As Figures 14-49 through 14-51** show, there are instances when an increase in turbidity can be related to an increase in precipitation. However, there are also instances when turbidity increases without a corresponding increase in precipitation. It appears that turbidity and rainfall are more often correlated during winters of higher cumulative rainfall, as in the winter of 2004 to 2005. Therefore, based on the current amount of development in the watershed, flow through the drop inlets is likely impacting downstream water quality only under extreme storm conditions, as during the winter of 2004 to 2005.

Figures 14-49 through 14-51 show EC at Check 66 and rainfall as measured at Victorville. Electrical conductivity appears to be less correlated to rainfall compared to turbidity.

Figure 14-49. Continuous Turbidity at Check 66 and Precipitation at Victorville Station, Winter 2004 to 2005

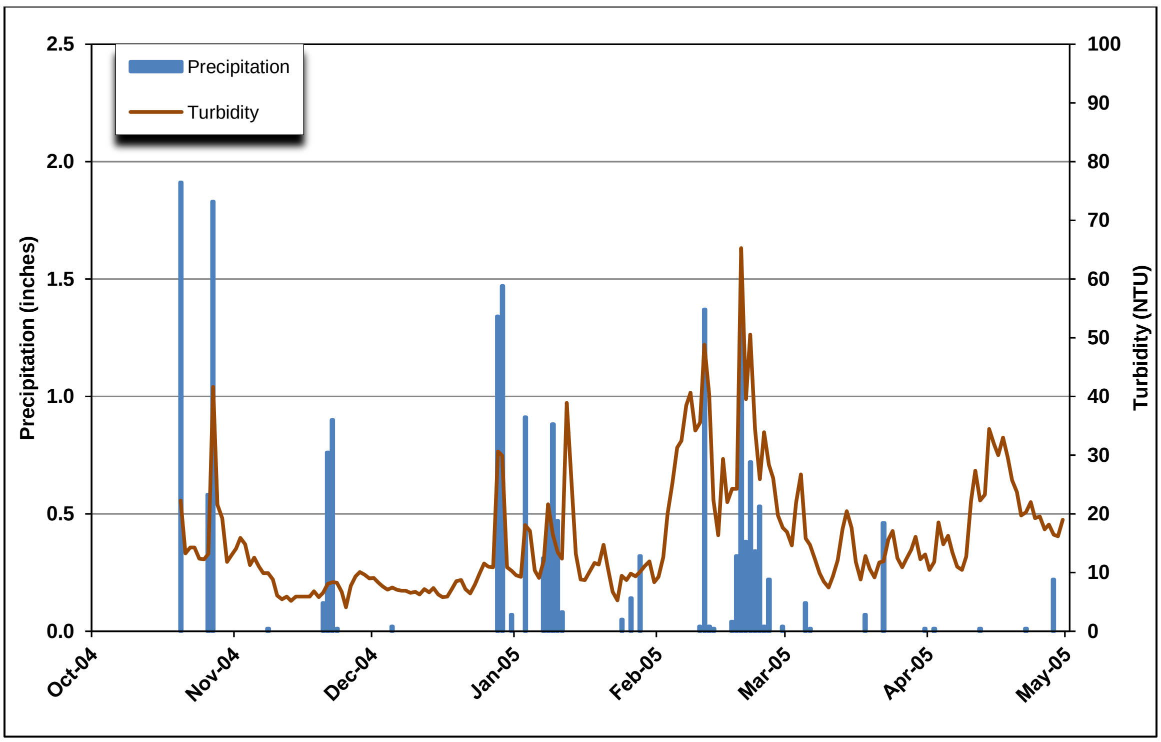


Figure 14-50. Continuous Turbidity at Check 66 and Precipitation at Victorville Station, Winter 2007 to 2008

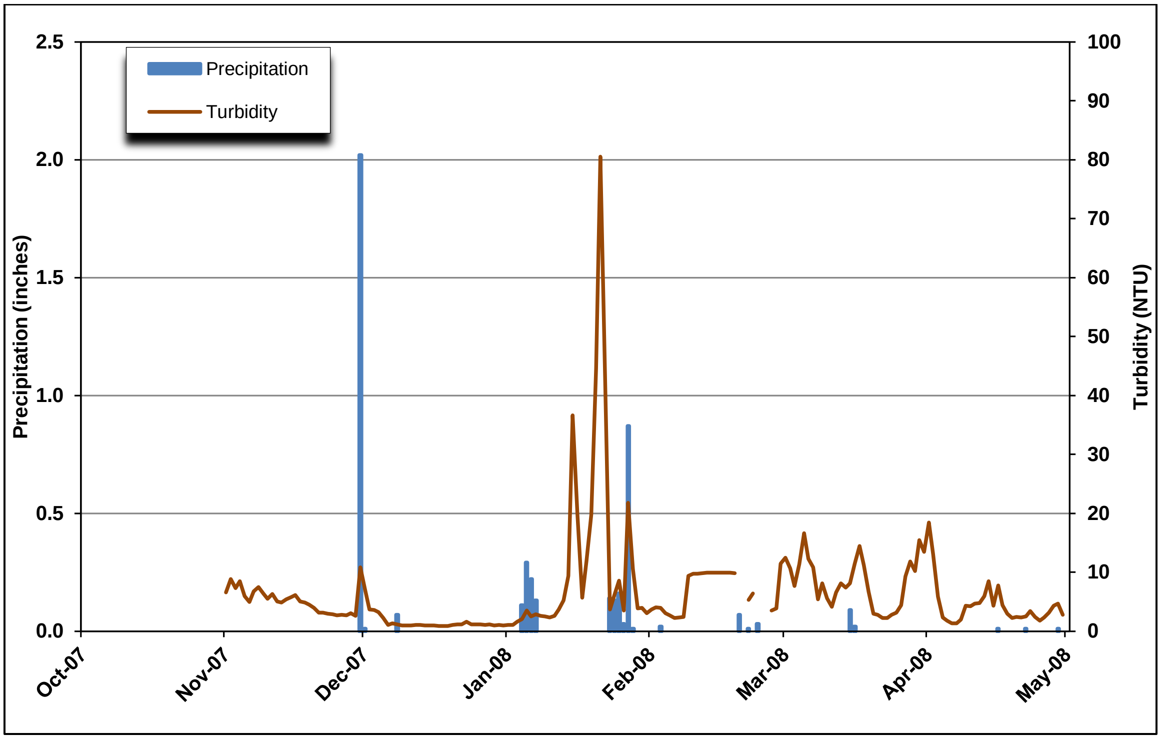


Figure 14-51. Continuous Turbidity at Check 66 and Precipitation at Victorville Station, Winter 2009 to 2010

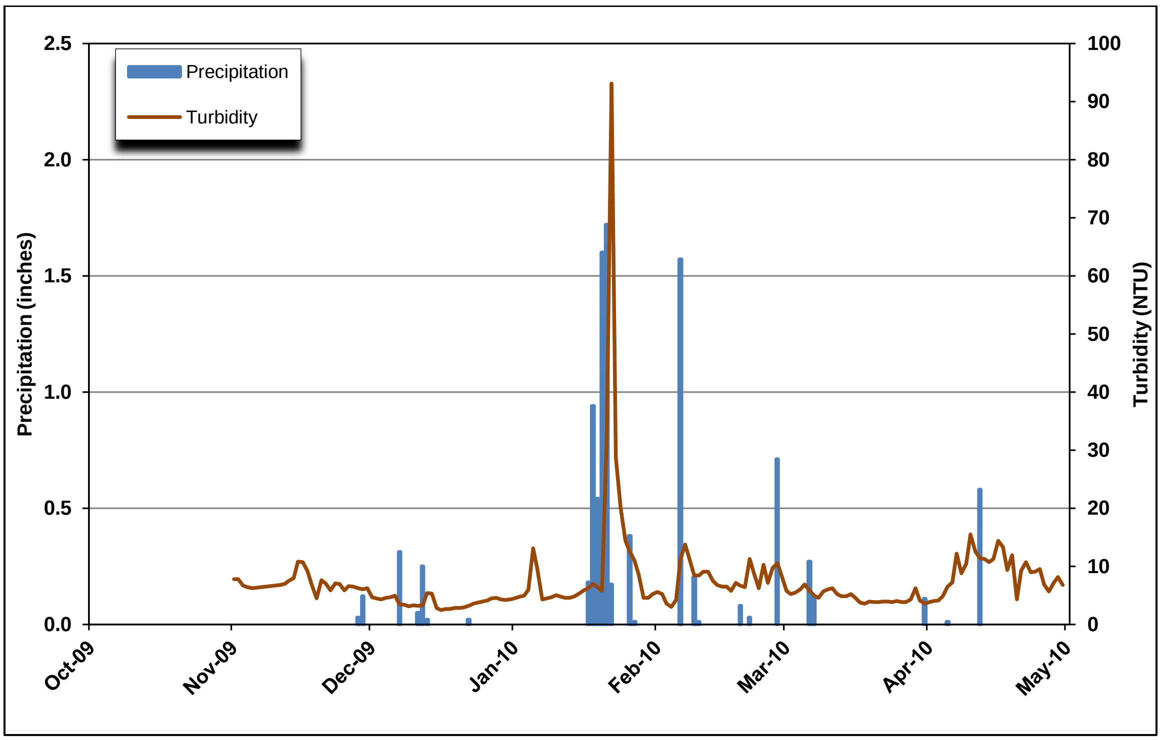


Figure 14-52. Continuous Electrical Conductivity at Check 66 and Precipitation at Victorville Station, Winter 2004 to 2005

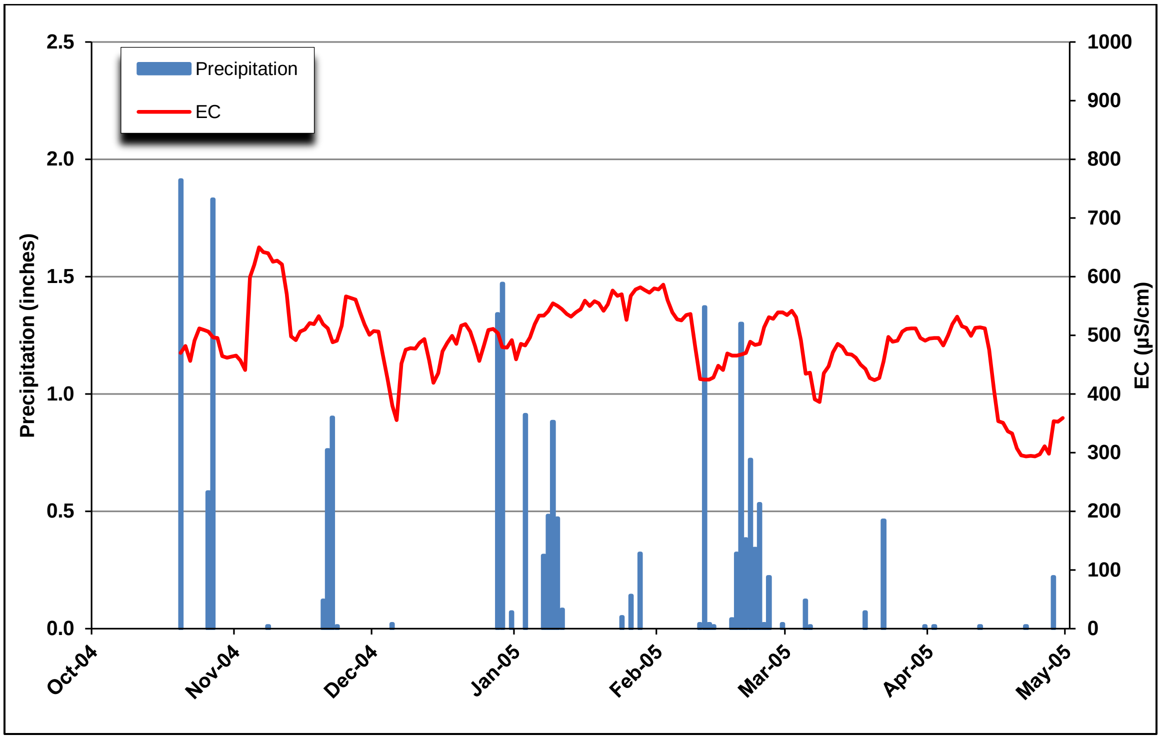


Figure 14-53. Continuous Electrical Conductivity at Check 66 and Precipitation at Victorville Station, Winter 2007 to 2008

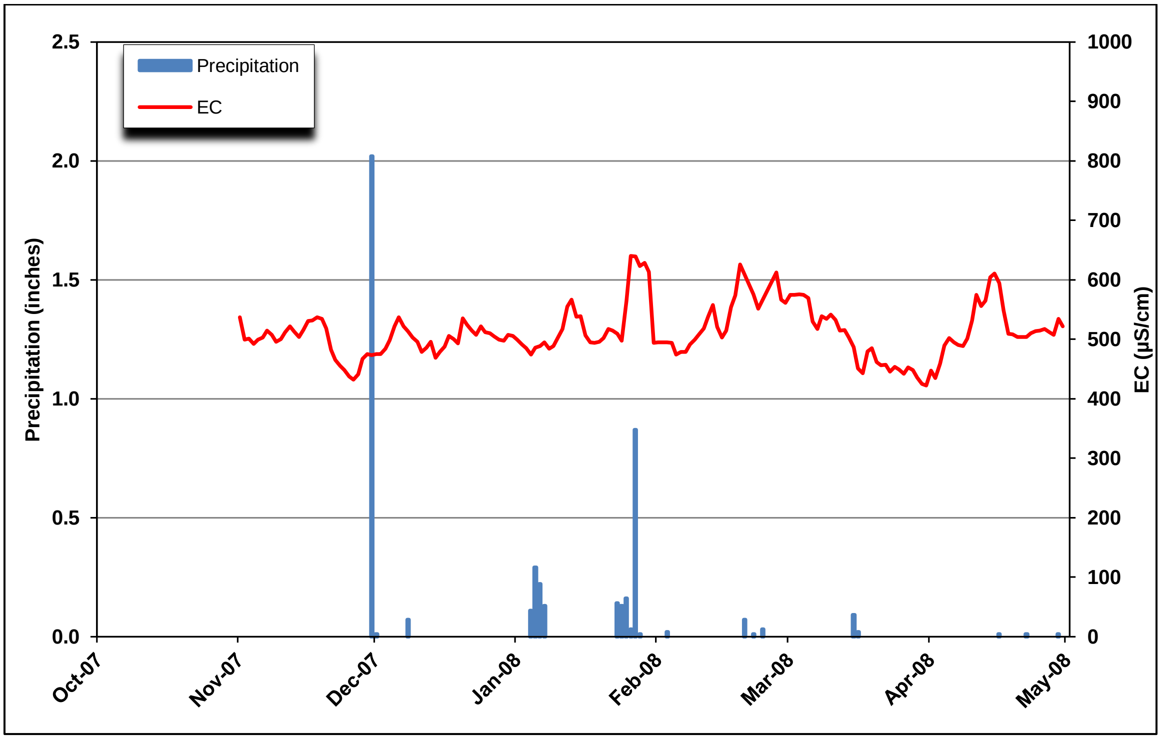
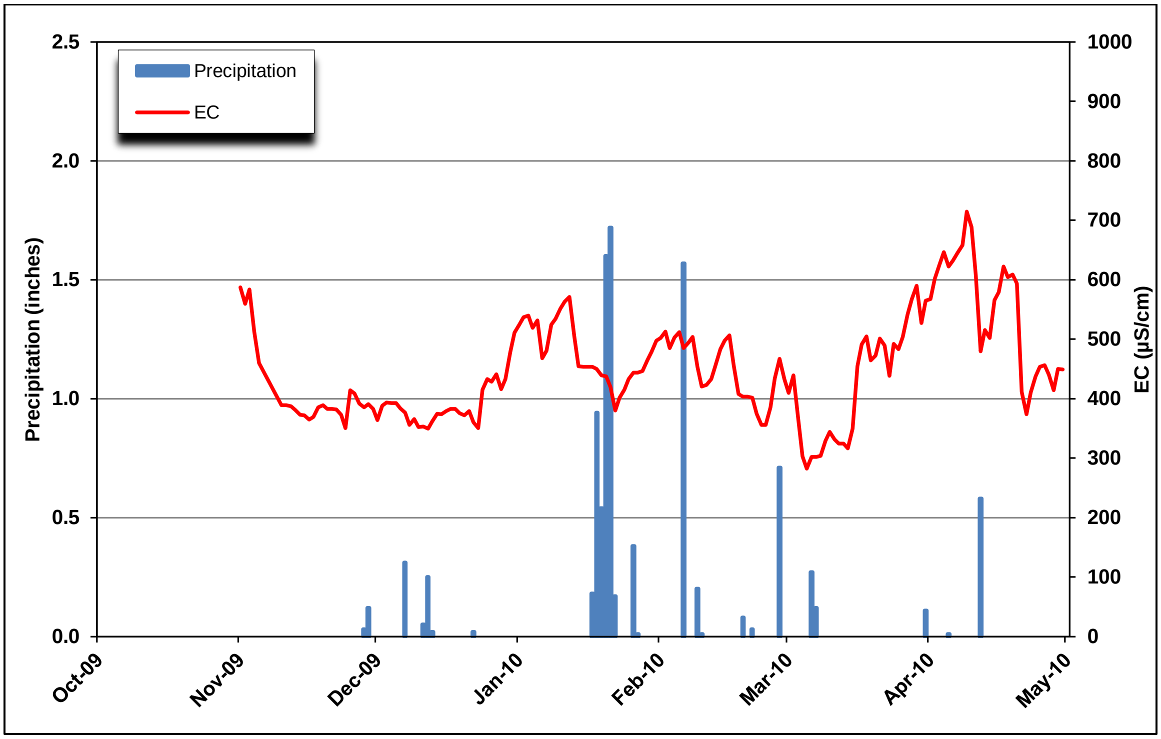


Figure 14-54. Continuous Electrical Conductivity at Check 66 and Precipitation at Victorville Station, Winter 2009 to 2010



STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan included two action items for follow up which were:

Monitor Hesperia Urban Runoff Discharged to the California Aqueduct.

This action item was prioritized as immediate, indicating that the issue was of a critical nature and would not require significant staff time. As mentioned earlier, a tour of the area was held in May 2008. The MWQI Specific Projects Committee decided it was not feasible to conduct monitoring due to the infrequent storm events and the difficulty of allocating resources to sample a storm event on short notice.

Develop Coordinated Plan to Address Hesperia Urban Runoff.

This action item was prioritized as near-term, indicating that it is less important than the immediate actions and will be addressed as the immediate actions are completed. The objective of this action item was for SWPCA and DWR to meet with the eight Contractors that have turnouts downstream of Hesperia to make sure that all Contractors are aware of the issue. DWR conducted a tour of the area with the affected SWP Contractors in May 2008. At the meeting, DWR staff indicated that the plan of action was to finalize the legal opinion, meet with their management, and then meet with the SWP contractors. To date, DWR has not set-up a meeting with the SWP Contractors, a coordinated plan has not been developed, and the legal opinion has not been finalized.

POTENTIAL ACTIONS

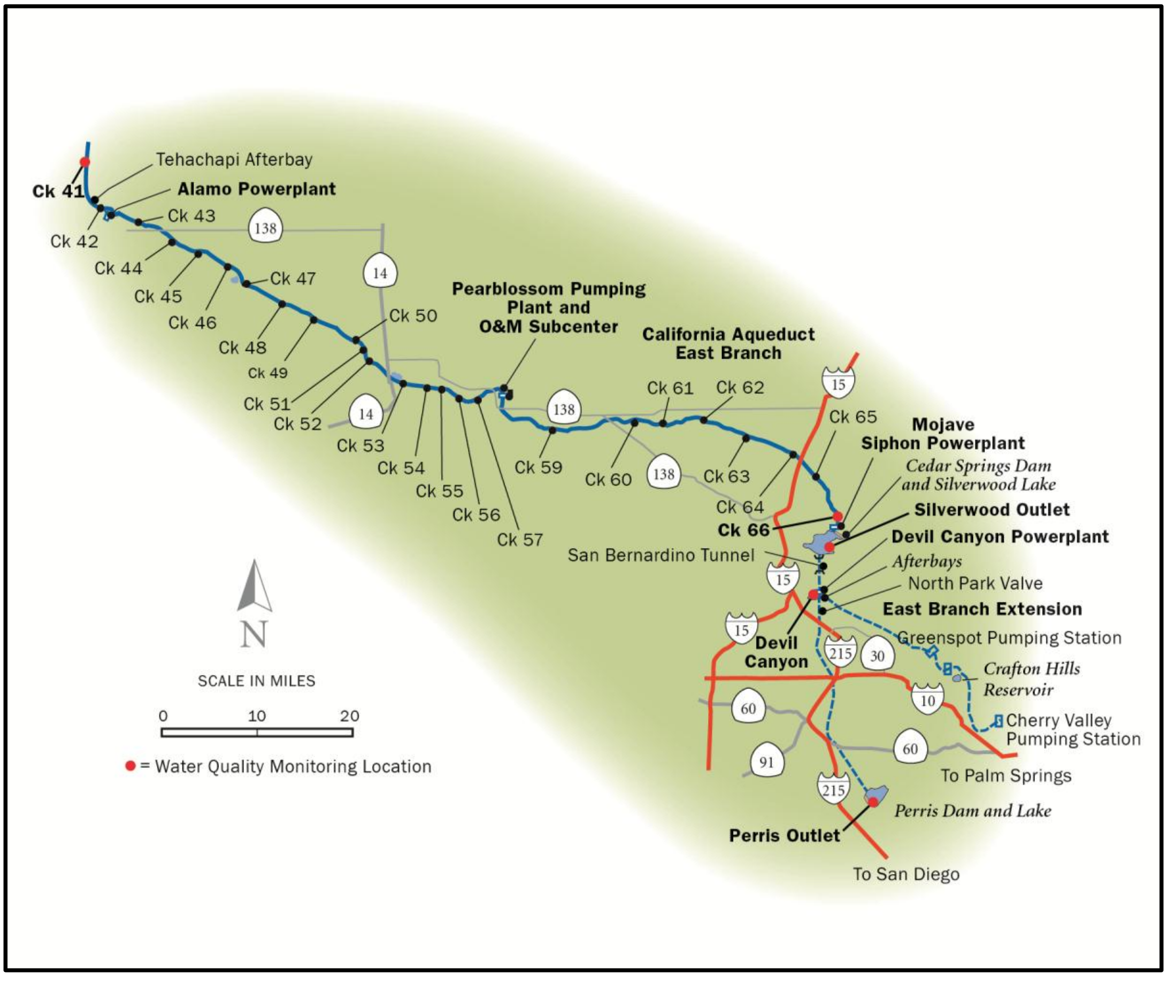
SWPCA should Contact DWR to Develop a Course of Action to Work with the San Bernardino County Flood Control District to Eliminate the Drop Inlets and Stop Urban Runoff from Entering the California Aqueduct.

DWR and the SWP Contractors have not met regarding this issue since 2008. At that time, the plan explained by DWR staff was to finalize the legal opinion regarding the SWP legal obligations and liabilities related to the drainage, meet with DWR management, and then meet with the SWP Contractors.

SILVERWOOD LAKE

Silverwood Lake, approximately 30 highway miles north of the city of San Bernardino, is the first reservoir on the East Branch of the California Aqueduct and is located in the San Bernardino National Forest. Water from the SWP flows into the lake through the Mojave Siphon Power plant and flows out of the lake and into the San Bernardino Tunnel, which leads to the Devil Canyon Powerplant. The reservoir has a storage capacity of about 74,970 acre-feet, and provides regulatory and emergency storage, recreation, and wildlife habitat. . The East Branch facilities are shown in **Figure 14-55**.

Figure 14-55. East Branch of the California Aqueduct



The 2006 Update discussed three wastewater spills and a fire in the Silverwood Lake watershed which occurred over the 2000 to 2005 time period. As there were no incidents (wastewater spills, sewer line breakage, fires, or high runoff events) during the 2006 to 2010 reporting period, this section contains an update on the wastewater spills and the fire.

WASTEWATER SPILLS

Background

The Crestline Sanitation District's (CSD) effluent outfall line transports chlorine-disinfected secondary treated wastewater effluent from all three of CSD's wastewater treatment plants (Cleghorn, Seely, and Huston) to the Las Flores Ranch, located in Summit Valley, just outside the Silverwood Lake watershed. Portions of the effluent outfall line are located near the shoreline of Silverwood Lake. During heavy winter rains, the effluent outfall line is vulnerable to damage, and treated wastewater spills have occurred. There have also been spills of untreated wastewater from the California Department of Parks and Recreation (Parks and Recreation) collection system.

Current Status

The 2006 Update mentioned that the CSD is considering upgrading their wastewater treatment plants to tertiary treatment. This would be beneficial for the Silverwood Lake watershed, as less water would be transported through the effluent outfall, as tertiary treated water could be used locally. According to CSD staff, future plans for tertiary treatment for CSD's three wastewater treatment plants are still in the planning stages, primarily due to funding issues. However, they hope to upgrade their main Huston plant to tertiary treatment in four to five years (Personal Communication, Mark Pattison, CSD).

OLD FIRE AND HIGH TURBIDITY

Background

As discussed in the 2006 Update, the Silverwood Lake watershed was impacted by the Old Fire in 2003 and Silverwood Lake was temporarily impacted by high runoff in the winter of 2004 to 2005, which increased turbidity and possibly pathogens and/or pathogen indicators in the source water.

On December 25, 2003 the Silverwood watershed received over five inches of rain within a 24-hour period, causing mudslides and high runoff within the watershed. Large amounts of debris entered the lake, as this was the first heavy rain since the October 2003 Old Fire. Hourly turbidity data at Devil Canyon showed that turbidity peaked at 236 NTU on December 26, 2003. Water quality was also impacted during the winter of 2004 to 2005, due to high runoff. Turbidities at Devil Canyon Afterbay remained above 20 NTU for one month, from the end of December 2004 to the end of January 2005, peaking at 322 NTU on January 11, 2005.

Current Status

As stated above, there have been no fires or high runoff events during the reporting period. Continuous turbidity data measured at Devil Canyon Headworks was reviewed from January 2006 to March 2010. Turbidities reached 20 NTU for one day in January 2006, and again for three days in January 2010. Other than these two time periods, turbidity was less than 10 NTU.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contained a broad action item related to spills and emergency response:

- Request DWR Revise Emergency Planning and Response Documents to Better Address Water Quality Concerns

The Action Plan contains a specific recommendation under the broader emergency response action to address wastewater spills and fires.

SWPCA should Recommend that DWR Develop a Separate Emergency Response Procedure for Wastewater Spills in the Field Divisions' Emergency Action Plans.

Wastewater spills are different than a general hazardous spill response in terms of containment and clean-up. SWPCA and DWR should clarify the needed resources to respond to a wastewater spill, and what supporting roles the SWP Contractors could provide.

In response to the broad action item above, MWQI staff completed a draft report of Emergency Planning and Response documents to integrate the MWQI Program into this area. The draft report is currently undergoing internal DWR review. It should be noted that O & M has separate emergency response documents that include and address water quality. Additionally, MWQI staff met with State Water Board staff to clarify agency roles during extraordinary emergency situations associated with natural disasters or human-caused emergencies. The 2009 State of California Emergency Plan states that the State Water Board is to "provide technical environmental staff to evaluate potential impact to water quality from emergencies". Thus, DWR is not legally responsible for evaluating water quality impacts from emergencies.

Track Crestline Sanitation District's Future Plans for Wastewater Facilities in the Watershed.

This action item was prioritized as long-term, indicating that the issue was of non-critical nature that will be reassessed periodically. The Action Plan also indicated that MWDSC will periodically check with CSD on any future plans to upgrade their secondary WWTPs in the Silverwood watershed.

SWPCA should Request that DWR Play an Active Role Whenever there is a Fire within the Watersheds of the SWP.

Although DWR may not have the specific expertise to assess a fire-burned watershed, DWR can work with agencies such as the National Resource Conservation Service or the various BAER teams when they are assembled to assess watershed conditions. If there are any proactive measures which can be taken to lessen erosion and protect water quality, these measures should be presented to the impacted SWP Contractors for consideration.

As stated earlier, MWQI staff completed a draft report of Emergency Planning and Response documents in order to integrate the MWQI program into this area. The draft report is currently under internal DWR review.

POTENTIAL ACTIONS

None.

LAKE PERRIS

Lake Perris, the terminal reservoir of the East Branch of the California Aqueduct, is an artificial impoundment that was created by the construction of Perris Dam in the early 1970's. Lake Perris is located in western Riverside County, about 13 miles southeast of the City of Riverside. Lake Perris is supplied by the SWP from Silverwood Lake through the Santa Ana Valley Pipeline, and has a maximum storage of 131,450 acre-feet. It is a multi-use facility, providing water storage, recreation, and fish and wildlife habitat.

MWDSC is the only SWP Contractor requesting deliveries from Lake Perris. Although Coachella Valley Water District and Desert Water Agency have contractual rights to use Lake Perris for water supply, these agencies have not as yet constructed physical delivery facilities and take water only by exchange. Lake Perris supplies water to MWDSC's Mills WTP (via pumpback), Diamond Valley Lake, and Lake Skinner. It also supplies water directly to the Skinner WTP and MWDSC member agencies. Historically, key water quality concerns such as pathogens, T&O compounds, algal toxins, and anoxia in the hypolimnion have limited MWDSC's ability to withdraw their full entitlement from the lake.

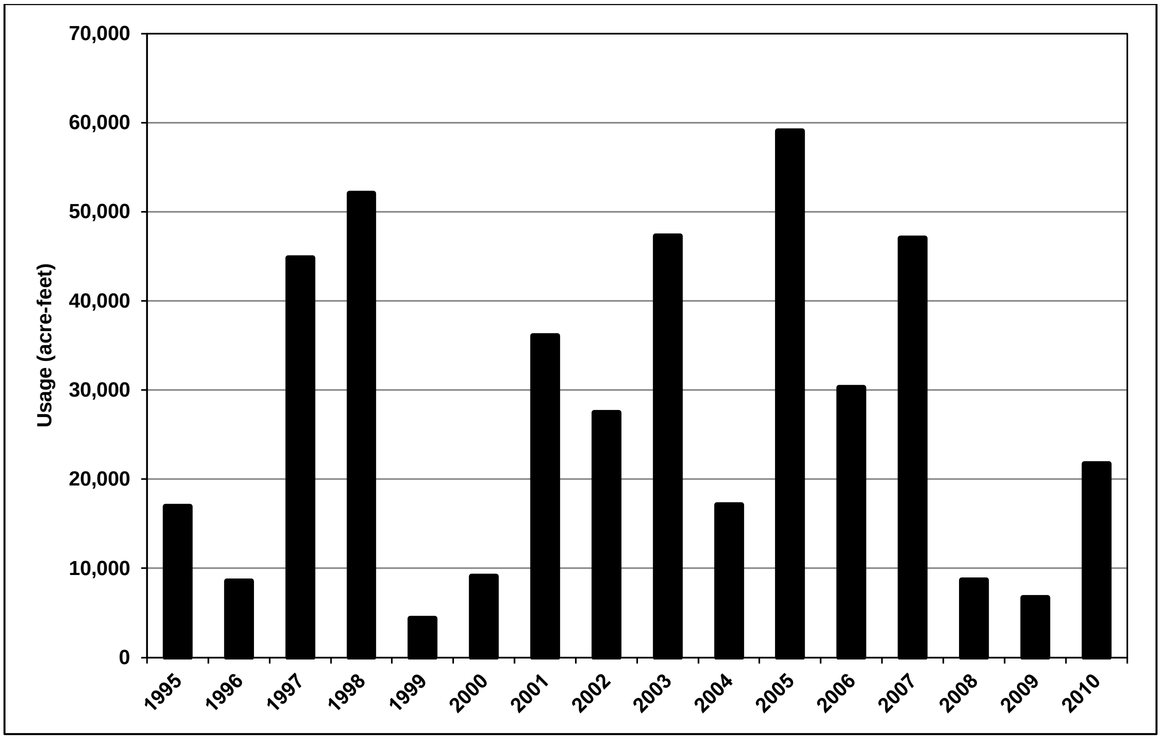
To address some of these concerns, the MWDSC applied for grant funding from the State Water Board through the Costa-Machado Water Act of 2000 (Proposition 13) and was awarded $1,370,800 for the Lake Perris Pollution Prevention and Source Water Protection Program in December 2003, as well as $3,000,000 for the Lake Perris Dissolved Oxygen Enhancement Project in May 2005. The water quality technical studies associated with both of these projects were discussed in detail in the 2006 Update. Back in 2006, the next steps were final design for voluntary swimming alternatives for the Lake Perris Pollution Prevention and Source Water Protection Program, and final design and construction for a hypolimnetic oxygenation system for the Lake Perris Dissolved Oxygen Enhancement Project.

Since the last watershed sanitary survey was completed in 2006, use of Lake Perris by MWDSC has been reduced due to regulatory restrictions on pumping from the Bay-Delta and limitations to protect recreation and endangered species resulting from a 25-foot lake level drawdown due to dam safety concerns. **Figure 14-56** shows the amount of water withdrawn from Lake Perris by MWDSC from 1995 to 2010. A notable decrease is seen in years 2008 and 2009.

As such, MWDSC has decided not to proceed with the implementation of voluntary swimming alternatives (i.e. swim lagoons, water play areas and other water features) to address body-contact recreation, nor the construction of a hypolimnetic oxygenation system. Given the regulatory pumping restrictions from the Delta, MWDSC, Desert Water Agency, and Coachella Valley Water District do not currently view Lake Perris as a reliable source of SWP supply to justify the cost to construct these facilities.

The purpose of this section is to update the three key issues associated with Lake Perris from the 2006 Update which are recreational usage, anoxic hypolimnion, and seismic hazard. As MWDSC has decided not to proceed with a solution to address body-contact recreation or a hypolimnetic oxygenation system, the discussion of these issues is brief and the primary focus of this section is the Lake Perris Dam Remediation to address seismic hazard.

Figure 14-56. Usage of Lake Perris by MWDSC



Source: MWDSC

SEISMIC HAZARD

Background

DWR released a seismic study of Perris Dam in June 2005. It was determined that a portion of the embankment and foundation is underlain by thin layers of low-plasticity and clayey sands that are potentially susceptible to liquefaction and severe loss of strength during a large earthquake event. With the lake filled to its design capacity, this could result in overtopping of the dam during a large earthquake event. In 2005, Lake Perris was lowered to elevation 1,563 feet (25 feet below normal maximum level) to mitigate the seismic risk while a permanent solution is being determined. This reduction in surface elevation reduced the storage capacity of the lake by approximately 40 percent.

A reduced lake elevation leads to a reduced hypolimnetic volume, which means that there is less oxygen mass, and the hypolimnion will become anoxic much quicker. This will reduce operational flexibility if water cannot be drawn from the hypolimnion. Additionally, there has been an increase in T&O problems from benthic algae since the lake was lowered. Additional details on significant T&O events since the lake was lowered are provided at the end of this section.

Current Status

In 2006, DWR prepared a Perris Dam Reconnaissance study which evaluated eight reservoir options, ranging from permanently emptying the reservoir to increasing the normal reservoir level to 1,814 feet for a total volume of 1 million acre-feet. A weighted evaluation was performed, and the highest rated option was the 1,588 feet (as-designed) elevation, with 1,640 feet elevation as the second highest rated. The normal maximum operating level on the lake is 1,588 feet above mean sea level.

In January 2010, DWR prepared a Draft EIR for the Perris Dam Remediation Program. The proposed dam remediation plan includes upgrading the dam by replacing the foundation material and reinforcing it with a stability berm placed on top of the improved foundation. It is anticipated that approximately 15,000 cubic yards of dam material under underlying loose silty sand would be excavated and recompacted (DWR, 2010). On September 29, 2011 the Final EIR was completed.

The DEIR evaluated the following six dam remediation alternatives: 1) increased dam capacity alternative (above 1588 feet), 2) keeping normal operating level (at 1588 feet), 3) reduced dam capacity alternative (at 1563 feet), 4) recreation alternative (at 1,542 feet), 5) dam decommissioning alternative (draining the lake), and 6) no project alternative. Under the increased dam capacity alternative, two new saddle dams would need to be constructed. Under the recreational alternative, the reservoir would be used for recreation purposes only, not for water storage, and the dam would not need to be remediated. The decommissioning of Perris Dam would require draining the reservoir, removing the outlet tower, and retrofitting the dam to prevent impounding storm water runoff. MWDSC would continue to serve its customers via the Santa Ana pipeline, but would not be able to use the reservoir for emergency storage.

The Final EIR selected the recreation alternative as the environmentally superior alternative due to the lack of environmental impacts from construction of the dam remediation.

MWDSC, Coachella Valley Water District, and Desert Water Agency submitted comment letters for the Perris Dam Remediation Project on July 2, 2007, September 28, 2007, and April 12, 2010. Some of the major comments were that the Draft EIR failed to account for the ecosystem problems in the Bay-Delta and their adverse effect on the supply and delivery of SWP water. The three agencies also expressed that the process used to screen and evaluate alternatives resulted in "an inadequate range of viable alternatives being considered in the DEIR", and believes that "a more detailed analysis of possible alternatives should be conducted by DWR." These agencies are currently in the process of reviewing the Final EIR.

Impacts on Water Quality since the Lowering of Lake Perris

In 2005, the water elevation of Lake Perris was reduced from elevation 1,588 feet to 1,563 feet due to concerns regarding the seismic stability of the dam as discussed earlier. This essentially reduced the volume of the lake by 40 percent, and it has remained at this lower volume since 2005. Lowering the lake has impacted water quality, as the most severe T&O event caused by benthic algae on record occurred in 2006.

At this lowered lake elevation, nutrient rich sediments previously in the dark are now exposed to sunlight thereby greatly increasing the potential for problematic growth of benthic algae. Prior to the drawdown, benthic copper sulfate treatments were never allowed in Lake Perris because of potential impacts on spawning game fish. Given the exceptional measures to reduce dam safety risks and the need to sustain a high quality drinking water source, the California Department of Fish and Game agreed to allow benthic treatments after review of the individual plans.

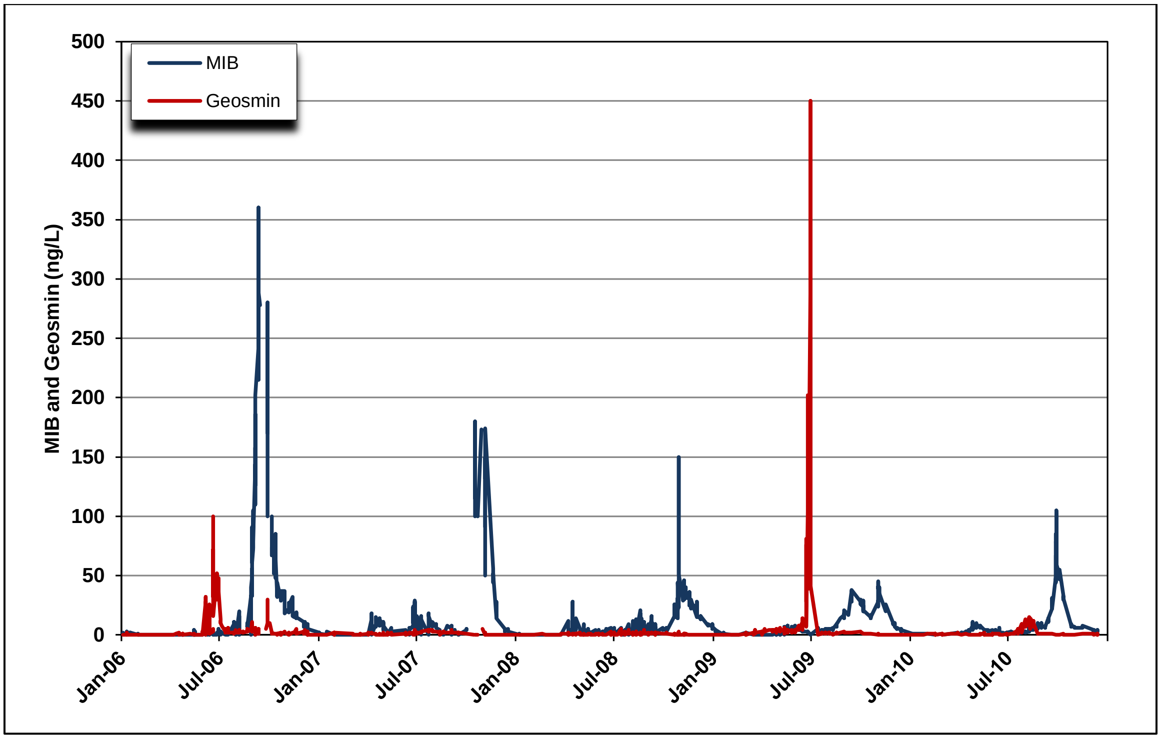
Since 2006, there have been seven significant cyanobacteria (blue-green algae) T&O events, four planktonic and three from benthic species. As shown in **Table 14-16**, four of the events required treatments, with one in September of 2006 requiring a second treatment. Treatments were not conducted for the other events because there was no operational need for the water at those times. This is consistent with MWDSC's strategy to avoid treatments if alternative operational options are available. **Figure 14-57** shows levels of geosmin and MIB at Lake Perris from 2006 to 2010. MIB and geosmin samples were collected from three profile stations located near the inlet, outlet tower, and reservoir center. The dataset also includes benthic samples collected at various lake locations during T&O events.

Table 14-16. Significant Taste and Odor Events at Lake Perris from 2005 through 2010

Year	Month	T&O Compound	Maximum Concentration (ng/L)	CuSO4 Treatment (Tons)	Comments
2006	Jun	Geosmin	100	–	Planktonic – no operational need to treat
2006	Sep	MIB	360	2 + 3	Benthic (two treatments: 9/12 & 9/26)
2007	Oct	MIB	260	4	Planktonic
2008	Oct	MIB	150	3.5	Benthic (east end)
2009	Jul	Geosmin	450	4	Planktonic
2009	Sep	MIB	49	–	Planktonic – no operational need to treat
2010	Sep	MIB	105	–	Benthic – No operational need to treat

Source: MWDSC

Figure 14-57. MIB and Geosmin Concentrations at Lake Perris



Source: MWDSC

Lowering the lake also constrains the depths at which lake water can be withdrawn. For example, when Lake Perris has full storage at elevation 1,588 feet, all five tier depths at the outlet tower can be utilized. When the lake elevation is lowered to 1,563 feet, only the bottom four tier depths are available.

RECREATIONAL USAGE

Background

The Lake Perris SRA, which opened in 1974, fulfills the mandate that all SWP facilities provide recreational amenities and opportunities. Body-contact recreation includes swimming, water skiing, and personal watercraft riding. Non-body-contact recreation at Lake Perris includes camping, picnicking, horseback riding, sail and power boating, fishing, hiking, bicycling, hunting, and rock climbing.

Current Status

Of the four Southern California SWP reservoirs, Lake Perris receives the heaviest recreational use with an average of 1.1 million visitors each year (Lake Perris SRA website). However, attendance at the Lake Perris SRA has declined since the drawdown of the lake in 2005. The peak attendance in 2005 was in July with 277,463 visitors. The peak attendance in 2010 was in July with 150,636 people. Prior to the drawdown, the peak monthly attendance was approximately 500,000 to 600,000 people. According to the Lake Perris SRA, they have had to reduce the maximum allowable number of boats on the lake from 500 to 250 for safety reasons after the drawdown.

Since the 1980's, there has been a history of bacteriological and pathogen contamination at the swimming beaches. During the recreation season (Memorial Day through Labor Day), Lake Perris SRA staff collects samples on either Saturdays or Sundays along the heavy-recreational beaches and coves. When a fecal coliform sample exceeds 400 MPN/100mL, the beach is closed until subsequent samples show fecal coliform levels below the trigger level. **Table 14-17** shows the location and duration of the areas that were closed from 2005 to 2010. It should be noted that samples are taken at the lifeguard towers which are spaced approximately 100 yards apart. If a sample exceeds the trigger level, only that portion of the beach will be closed. There were eleven beach closures at Lake Perris from 2005 to 2010, with no beach closures in 2008 and 2010. During the 2001 to 2005 period there were seven beach closures.

Table 14-17. Beach Closure Locations at Lake Perris, 2005-2010

Year	Location	Duration of Closure
2005	Perris Beach – Tower 3	2 weeks on 2 different occasions
2005	Perris Beach – Tower 5	3 days
2006	Perris Beach – Tower 3	3 days on 2 different occasions
2006	Perris Beach – Tower 5	3 days
2007	Perris Beach – Tower 2	3 days
2007	Perris Beach – Tower 6	3 days
2007	Moreno Beach – Tower 8	3 days
2009	Perris Beach – Tower 1	1 day
2009	Perris Beach – Tower 3	1 day
2009	Perris Beach – Tower 5	1 day
2009	Moreno Beach – Tower 7	1 day

Source: Parks and Recreation Lake Perris, SRA

The presence of fecal coliforms or *E. coli* is a concern for Lake Perris as a drinking water reservoir since it is an indication that fecal contamination is occurring. Enteric pathogens may be shed into reservoir waters during body-contact recreation from residual fecal material and from accidental fecal releases. These inputs increase pathogen concentrations in the reservoir, water treatment costs, as well as gastrointestinal illness risks for swimmers.

MWDSC completed various water quality studies from 2003 through 2005 to address microbial contamination from body-contact recreation occurring at Lake Perris. The studies undertaken by MWDSC were a multi-pronged approach to determine the potential impact of swimming on Lake Perris water quality (MWDSC, 2005). The multi-pronged approach consisted of: 1) fecal coliform and *E. coli* sampling at eleven locations and at multiple lake depths for a period of 18 months; 2) fingerprinting analysis by repetitive- polymerase chain reaction of *E. coli* isolates from the beaches and the outlet tower; 3) hydraulic modeling of Lake Perris under five different scenarios of body-contact recreational use and lake conditions; and 4) risk assessment modeling to determine impacts to downstream consumers of water from Lake Perris using a well-established dose response model.

As a result of the studies, and to reduce the risk of waterborne pathogens at Lake Perris, MWDSC proposed the implementation of voluntary swimming alternatives (i.e. swim lagoons, water play areas and other water features) to swimming in the reservoir. MWDSC developed design plans for voluntary swimming alternatives in cooperation with California State Parks. MWDSC also prepared a Final EIR in July 2006. The grant funding from the State Water Board was for the water quality technical studies and design of voluntary swimming alternatives, but grant funds did not include monies for construction. After the EIR was prepared, MWDSC desired to seek additional grant funding for the construction of the voluntary swimming alternatives but was not able to apply for grant funding without California State Parks as an official project partner. Although California State Parks desired to have these additional recreational facilities, they felt they could not be named as an official project partner due to a lack of funding to cover operational and maintenance costs. In turn, MWDSC would not be able to solely financially support the project, although numerous water quality benefits would be obtained. It is hoped that California State Parks may be able to eventually fund the project and use the design that was jointly developed by MWDSC and California State Parks.

ANOXIC HYPOLIMNION

Background

Thermal stratification occurs as a natural process at Lake Perris beginning in April and lasting to November. In the spring Lake Perris stratifies as sunlight heats the upper layers of the water, making this water less dense than the colder water on the bottom. The upper less-dense and mixed stratum of water is called the epilimnion, the cooler more-dense bottom layers are called the hypolimnion and the transition-strata from cold, dense hypolimnetic water to warm, buoyant epilimnetic water are called the metalimnion. The metalimnion density gradient resists vertical mixing and isolates the hypolimnion from the oxygenated epilimnion and atmosphere (the oxygen source). From the on-set of stratification the hypolimnion begins to lose oxygen as a result of decomposition of organic matter sinking from the upper layers and in the sediments. Dying dense algal blooms are important contributors to the hypolimnetic oxygen demand in Lake Perris. Typically the hypolimnion near the sediments becomes anoxic (also known as anaerobic) by the end of June and will become completely anoxic by mid-August or sooner.

Under anaerobic conditions reduced compounds such as metals, sulfides, ammonia, and methane accumulate in the hypolimnion as do reduced T&O producing compounds such as hydrogen sulfide, polysulfides and organosulfides. These reduced compounds are problematic for drinking water treatment because, in addition to objectionable T&O, they exert a significant oxidant demand in the treatment process. Lastly, under anaerobic conditions phosphorus, in the form of -PO4, is released to the water by decomposition. During destratification the phosphorus and nitrogen compounds accumulated in the hypolimnion are mixed throughout the water column and fertilize the lake adding to further algal growth.

During thermal stratification, Lake Perris has two recurring problems; hypolimnetic anaerobic conditions and algal produced T&O in the epilimnion. Cyanobacteria blooms in Lake Perris can produce either MIB or geosmin to problematic levels. As these two conditions can occur simultaneously during the stratified period, there are times when the entire lake is unacceptable as a source of drinking water, hindering MWDSC's ability to obtain full access to its allotment stored in Lake Perris.

Current Status

To prevent low oxygen levels in the hypolimnion and the resulting water quality degradation, two methods have been traditionally used: 1) hypolimnetic oxygenation and 2) artificial reservoir destratification. Various alternatives were reviewed by MWDSC, and the diffused oxygenation system, or hypolimnetic oxygenation system was selected. A Final EIR and design plans and specifications were developed for the project in 2006. MWDSC also received grant funding to assist with a portion of the project construction.

On an interim basis DWR has been using a pneumatic mixer to destratify Lake Perris and maintain aerobic conditions. However, the system is undersized and can only keep up with oxygen demand by continuously withdrawing approximately 100 cfs from the lower outlet tier (Personal Communication, Rich Losee, MWDSC).

With the Wanger decision in 2007, reliability of SWP supplies was severely impacted with regulatory restrictions on pumping from the Bay-Delta. Under this new operating scenario, MWDSC reexamined the cost benefit ratio of constructing the hypolimnetic oxygenation system and the costs were determined too high for a water supply source with reduced reliability. The cost to construct the hypoliminion oxygenation system was also significantly higher than expected, due to the rising cost of stainless steel.

In addition, the current uncertainty regarding how the Perris Dam will be remediated for seismic hazard also played a role in MWDSC's decision to not construct the hypolimnetic oxygenation system. Various alternatives for the Perris Dam Remediation project were presented in the 2010 Draft EIR for the Perris Dam Remediation Program. The recreation alternative was identified as the environmentally superior alternative in the Final EIR. With this alternative, the lake would not be used for water storage; therefore a hypolimnetic oxygenation system would not be needed.

STATUS OF ACTION ITEMS

The 2007 State Water Project Action Plan contains one near-term action related to both the potential changing lake levels associated with the seismic hazard and the anoxic hypolimnion and one action related to recreational usage of Lake Perris.

Conduct Additional Water Quality Monitoring of Lake Perris

Monitoring was recommended to address possible water quality changes associated with the hypolimentic oxygenation system which was scheduled to be on-line by March 2008. Monitoring was also recommended to address possible water quality changes associated with the potential increase or decrease in the depth of water due to the seismic alternatives. The existing monitoring program was not expanded because the reliability of Lake Perris was reduced due to pumping restrictions in the Delta and the hypolimentic oxygenation system was put on hold.

SWPCA Should Lobby and/or Seek Funding to Construct Alternative Swimming Facilities at Lake Perris

Plans to construct alternative swimming solutions and an EIR have been prepared by MWDSC. After the EIR was prepared, MWDSC sought additional grant funding for the construction of the voluntary swimming alternatives but were not able to apply for grant funding without California State Parks as an official project partner. Unfortunately, California State Parks decided they could not be named as an official project partner due to a lack of funding to cover operational and maintenance costs. Given the current budget crisis in California, it is unlikely that California State Parks will be able to obtain funding to cover on-going operating and maintenance costs for an alternative swimming facility.

POTENTIAL ACTIONS

DWR should Investigate Increasing the Size of the Aeration System to Adequately Mix Lake Perris to Prevent Anoxia from Forming.

On an interim basis DWR has been using a pneumatic mixer to destratify Lake Perris and maintain aerobic conditions; however, the system is undersized and its capacity should be increased.

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Personal Communication

Zamora, Harold, County of San Bernardino Department of Public Works, Flood Control Planning.

Morshed, Monty, County of San Bernardino Department of Public Works, Public, Works Engineer.

SILVERWOOD LAKE

Personal Communication

Pattison, Mark, Crestline Sanitation District.

LAKE PERRIS

Personal Communication

Losee, Rich, Metropolitan Water District of Southern California.

CHAPTER 15 STATE WATER PROJECT FACILITY OPERATIONS VULNERABILITIES

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CHAPTER 15 STATE WATER PROJECT FACILITY OPERATIONS VULNERABILITIES

The California Department of Public Health (CDPH), the State Water Project (SWP) Contractors, and the Department of Water Resources (DWR) worked together to determine the SWP vulnerabilities and contaminant sources to be addressed in the California State Water Project Watershed Sanitary Survey, 2011 Update (2011 Update). This chapter contains a discussion of the following topics:

- Impacts of Operational Changes on Drinking Water Quality – This chapter contains a description of the potential drinking water quality impacts of the biological opinions issued by the U.S. Fish and Wildlife Service (USFWS) for delta smelt and the National Marine Fisheries Service (NMFS) for salmon. There is also a discussion of the 2-Gates Fish Protection Demonstration Project and the Head of Old River Non-Physical Barrier.

- Impacts of Drought on Drinking Water Quality – The water quality data discussed in previous chapters are analyzed to determine if there are any identifiable impacts of drought on drinking water quality.

IMPACTS OF OPERATIONAL CHANGES ON DRINKING WATER QUALITY

This section contains a description of the impacts on drinking water quality of the biological opinions issued by the USFWS for delta smelt and by NMFS for salmon, the proposed 2-Gates Fish Protection Demonstration Project, and the head of Old River non-physical barrier.

BIOLOGICAL OPINIONS

Chapter 2 contains a description of the biological opinions issued by the USFWS for delta smelt and by NMFS for salmon. The Wanger Decision is also described in Chapter 2. The biological opinions are currently being rewritten by the fisheries agencies so this analysis is based on the Reasonable and Prudent Alternatives (RPAs) contained in the previous biological opinions. The potential impacts on Sacramento-San Joaquin Delta (Delta) exports and possible impacts on drinking water quality are described in this section.

Impacts on Delta Exports

Figure 15-1 compares average monthly diversions at the Harvey O. Banks Delta Pumping Plant (Banks) from 1998 to 2006 and from 2007 to 2010. Between 1998 and 2006, diversions at Banks were governed by the State Water Resources Control Board (State Water Board) 1995 Bay-Delta Plan (D-1641). The Bay-Delta Plan established new water quality objectives for the Delta that resulted in lower diversions of water from the Delta in the spring and higher diversions in the fall, starting in 1998. Delta operations changed again in 2007 when DWR voluntarily reduced exports in the spring to reduce entrainment of delta smelt. The SWP operated under the Wanger Interim Remedial Order in 2008 and under the terms of the biological opinions in 2009 and 2010.

Figure 15-1. Average Monthly Diversions at Banks

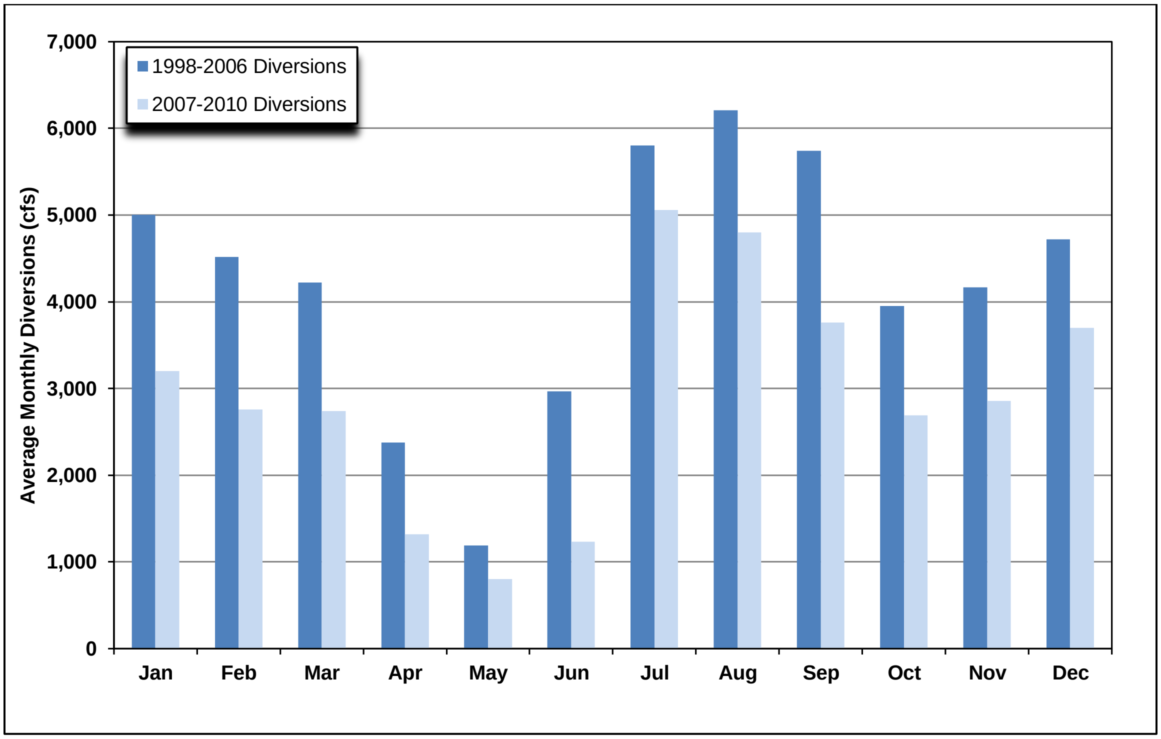
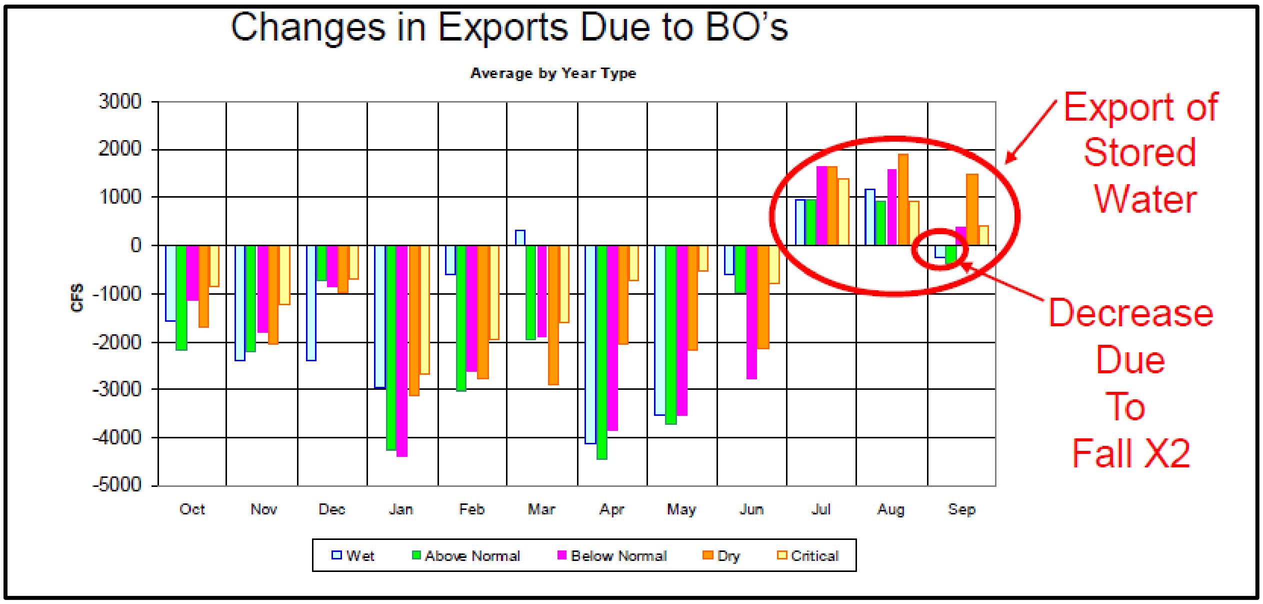


Figure 15-1 shows that Delta exports were reduced in all months of the year between 2007 and 2010 compared to the prior period. The greatest reduction was in June. It is difficult to separate the impacts of the biological opinions from the impacts of hydrology. The 1998 to 2006 period had more wet years than dry years, whereas the later period was predominantly dry.

The Wanger Interim Remedial Order and the USFWS and NMFS biological opinions require exports to be limited to reduce reverse flows in the Old and Middle rivers (OMR) between December and June. The intent of this action is to prevent entrainment of delta smelt at the export pumps. The other RPA action contained in the biological opinions (but not in the Wanger Interim Remedial Order) with the potential to impact drinking water quality is the requirement to increase Delta outflow in wet and above normal years during the fall months to move the low salinity zone near Suisun Marsh, which is thought to improve delta smelt survival. This is referred to as the Fall X2 Action. X2 is shorthand for the position in the estuary where monthly average salinity is 2 parts per thousand (ppt). The biological opinions' export restrictions, OMR flow requirements, fall Delta outflow requirements, and a number of other actions specific to various reservoirs and stream reaches have been incorporated into a CALSIM run to model the impacts on water supply.

The CALSIM results were presented at a September 7, 2011 California Water and Environmental Modeling Forum briefing on the biological opinions (Walter Bourez, MBK Engineers). These results were also submitted to the State Water Board as testimony in the hearings on Delta flow requirements. As shown in **Figure 15-2**, the modeling studies show that operations to meet the conditions of the biological opinions will result in less Delta water exported during the October to June period and more water exported during the July to September period. **Figure 15-3** shows the pattern of Delta outflow under the D-1641 operating rules and the changes in Delta outflow as a result of the biological opinions. These changes in Delta exports and outflow are used to estimate potential impacts on drinking water quality.

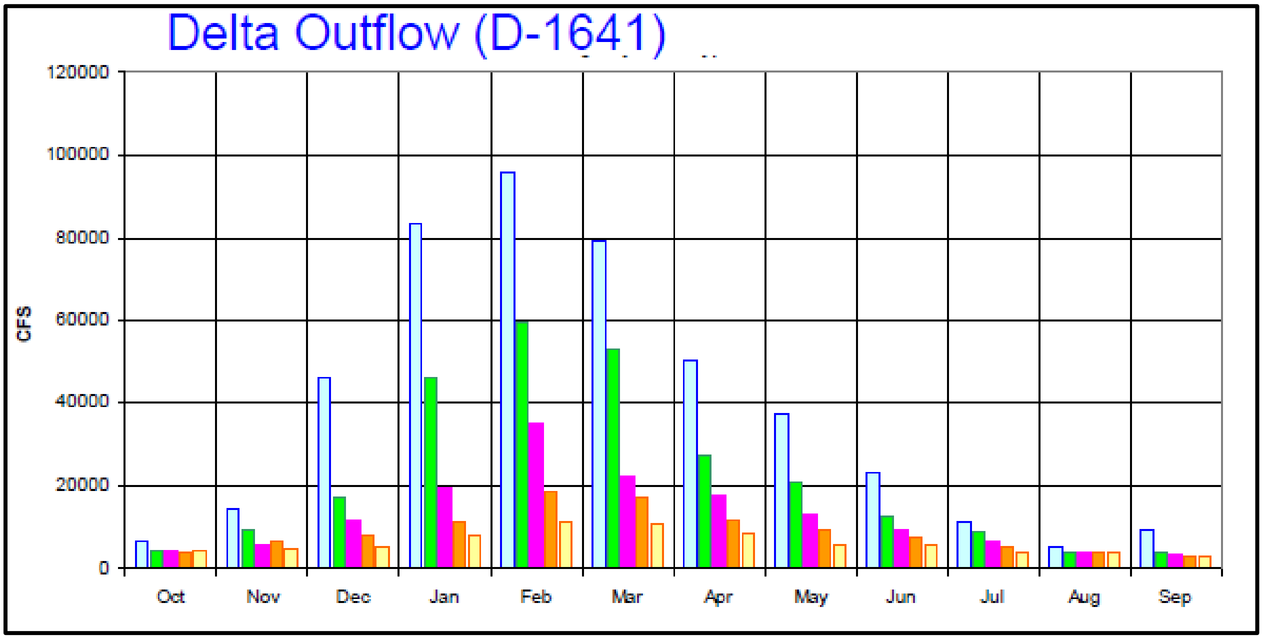
Figure 15-2. Impacts of Biological Opinions on Timing of Exports

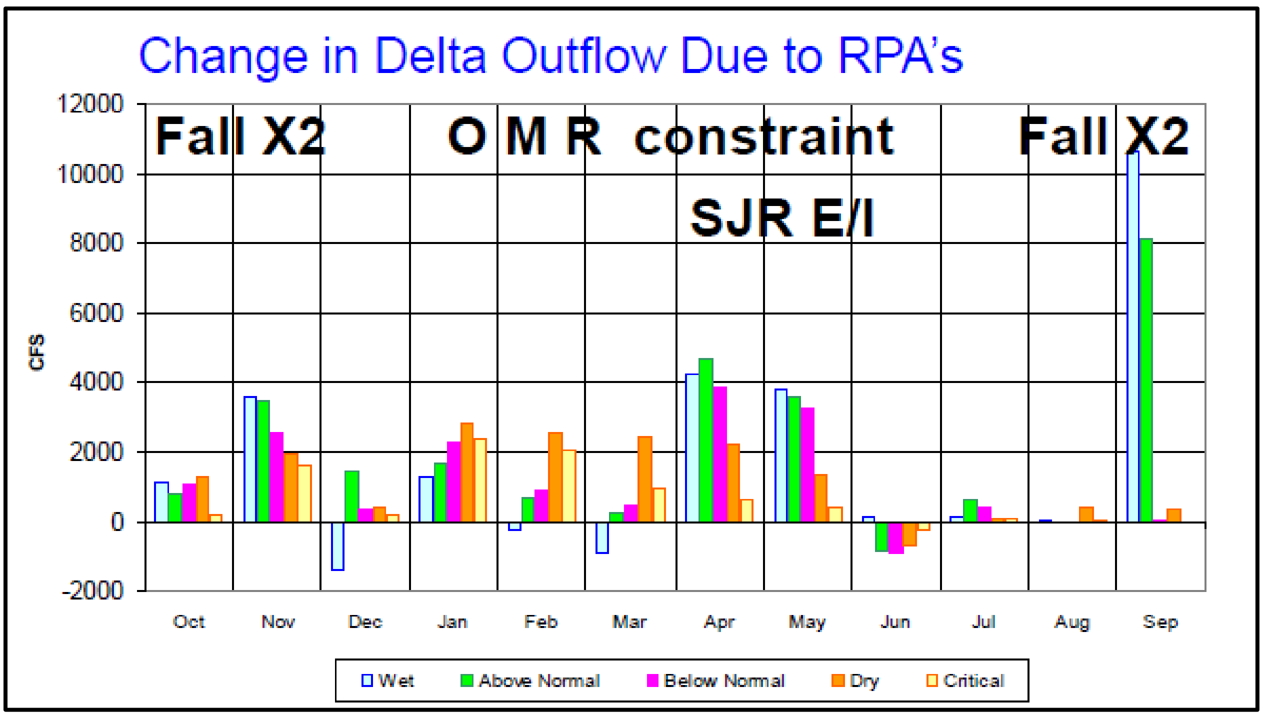


Source: Walter Bourez, MBK Engineers

Note: Fall X2 refers to the requirement to increase Delta outflow during the fall months to move the low salinity zone (2 ppt) near Suisun Marsh.

Figure 15-3. Changes in Delta Outflow Required by the Biological Opinions





Source: Walter Bourez, MBK Engineers

Note: Fall X2 refers to the requirement to increase Delta outflow during the fall months to move the low salinity zone (2 ppt) near Suisun Marsh.

Potential Drinking Water Quality Impacts

The drinking water quality impacts of the biological opinions have not been evaluated with modeling studies (Personal Communication, Tara Smith, DWR); however, DWR conducted modeling studies on the impacts of the OMR reverse flow restrictions contained in the Wanger Interim Remedial Order issued in December 2007. This section contains a qualitative analysis of the potential impacts on drinking water quality due to a couple of the biological opinion RPA actions that would likely affect drinking water quality. The qualitative analysis is compared to the modeling study results. The OMR reverse flow restrictions in the Wanger Interim Remedial Order that were modeled and the corresponding reverse flow restrictions in the biological opinions are as follows:

- Wanger Interim Remedial Order – Achieve a daily average OMR flow of between -750 and -5,000 cubic feet per second (cfs) on a seven day running average.
- Biological Opinions – Achieve a daily average OMR flow of between -1,250 and -5,000 cfs based on a 14 day running average.

These flow restrictions apply during the period of December to June and are triggered when there are indicators that delta smelt are spawning or larval smelt are present in the south and central Delta

<u>Impacts on Percent of Sacramento River at South Delta Pumping Plants</u>

The DWR modeling of the Wanger Interim Remedial Order evaluated the impacts of both the -750 cfs and -5,000 cfs net upstream flow in OMR at Clifton Court Forebay (Clifton Court) and the C.W. “Bill” Jones Pumping Plant (Jones). **Figure 15-4** shows these two locations and other key locations discussed in the following paragraphs. **Figures 15-5 and 15-16** show the impacts of the two flow restriction scenarios on the percent of high quality Sacramento River water at Clifton Court and at Jones. This figure shows that during the January to June period, the volume of Sacramento River water at Clifton Court is greatly reduced if OMR flows are restricted to -750 cfs and slightly reduced if OMR flows are restricted to -5,000 cfs. The same pattern is seen at Jones; however the volume of Sacramento water is much lower at Jones than at Clifton Court.

Figure 15-4. Key Water Quality Monitoring and Modeling Locations

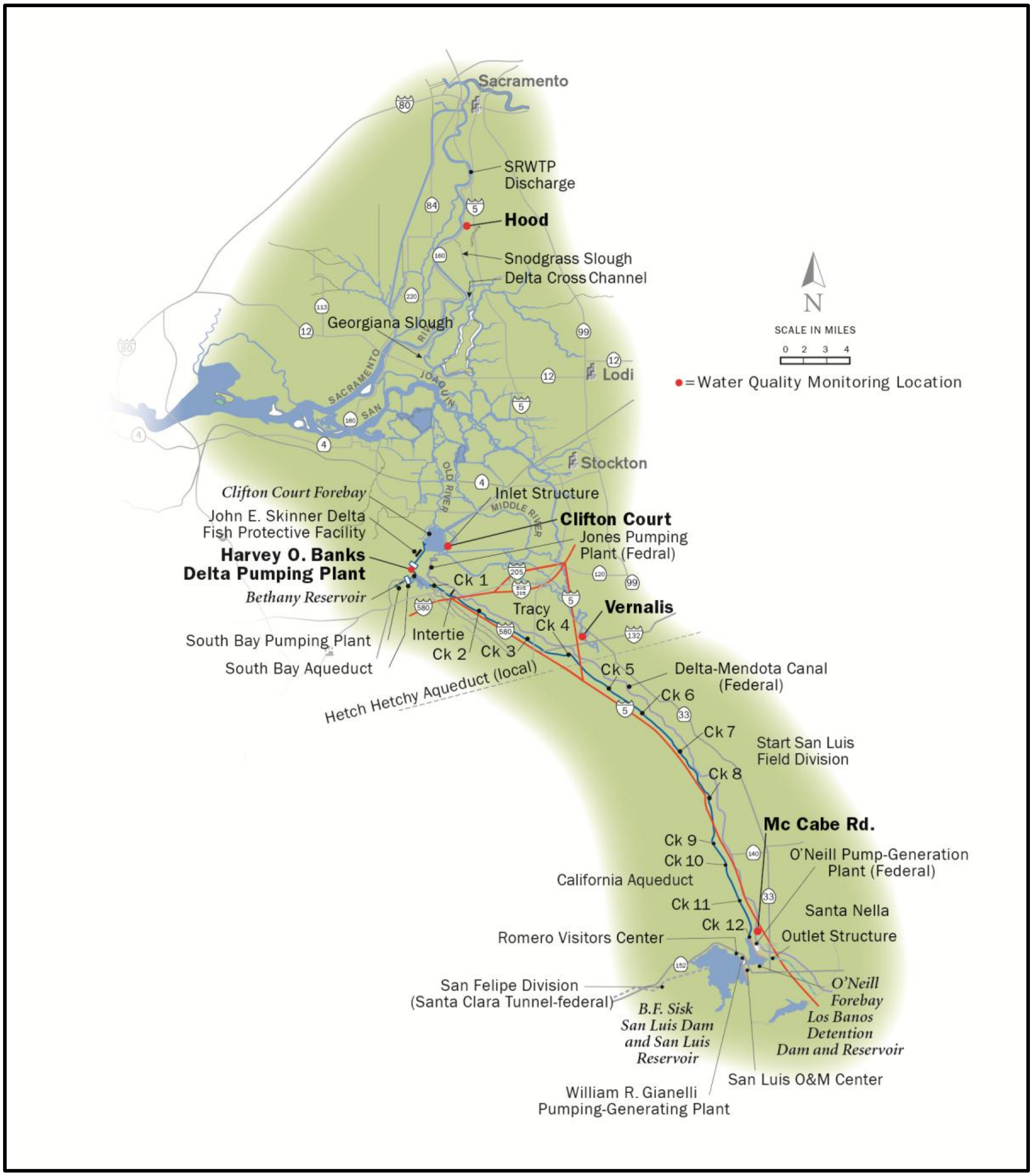
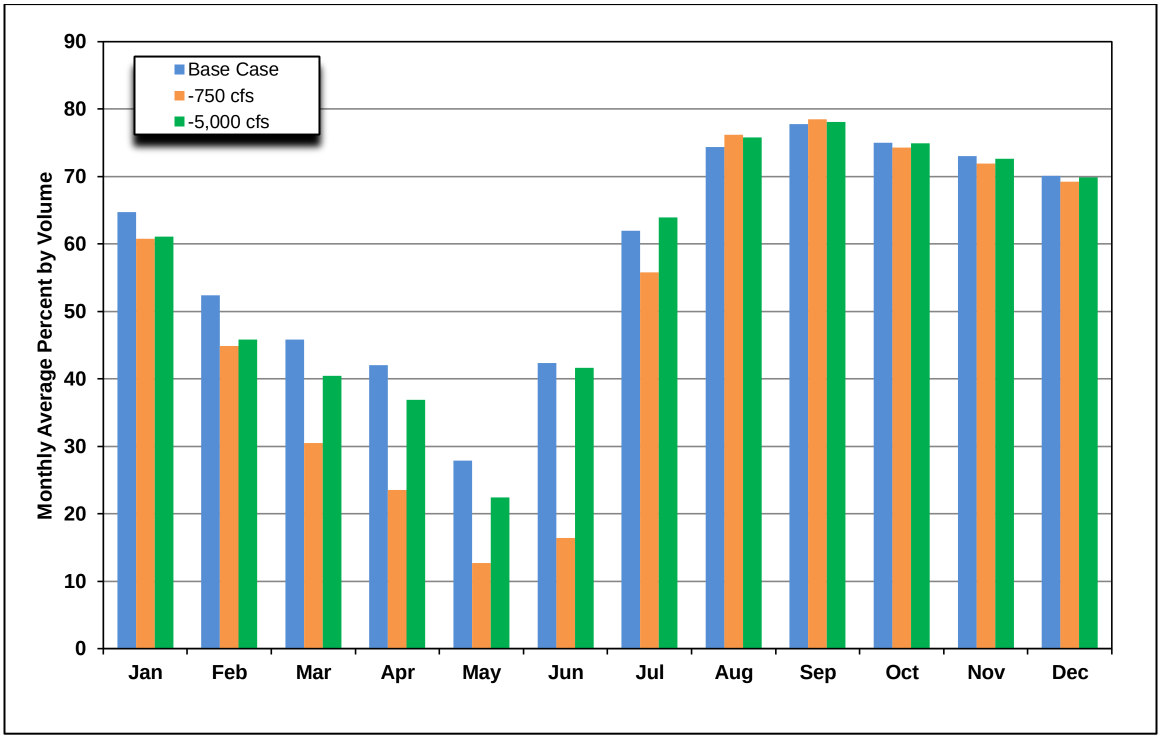
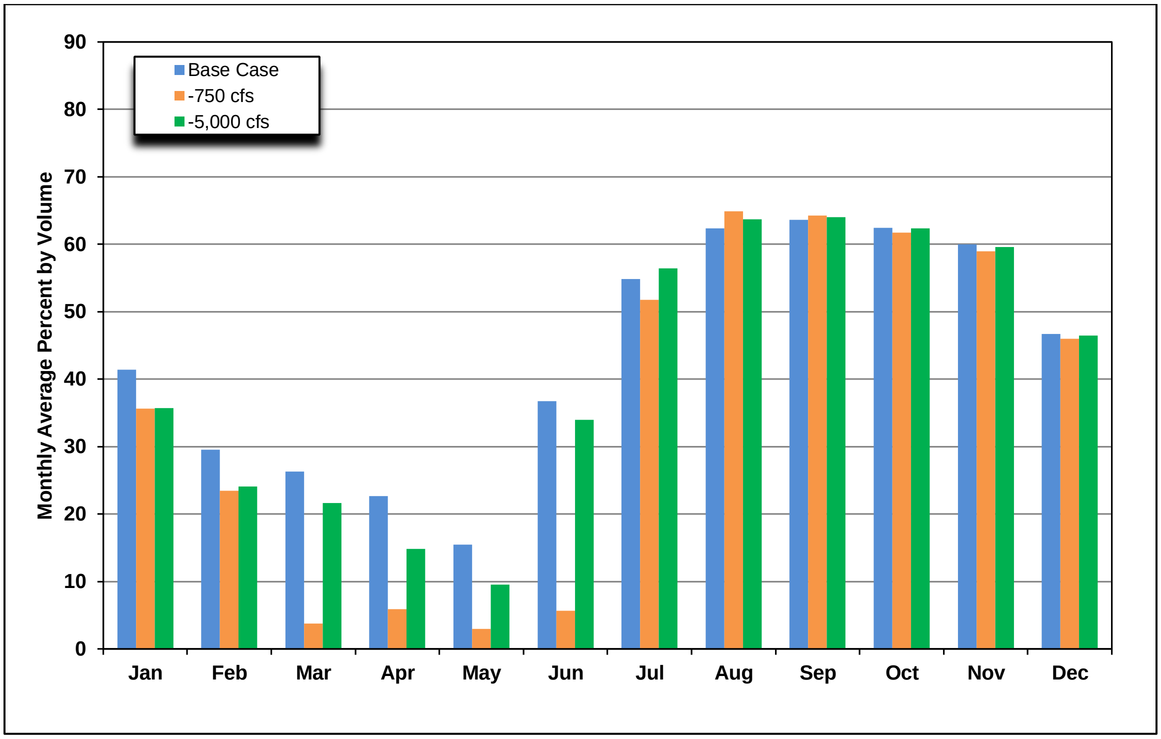


Figure 15-5. Impact of OMR Flow Restrictions on Percent of Sacramento River Water at Clifton Court



Source: Bob Suits, DWR. Presentation at April 9, 2008 MWQI Workshop.

Figure 15-6. Impact of OMR Flow Restrictions on Percent of Sacramento River Water at Jones



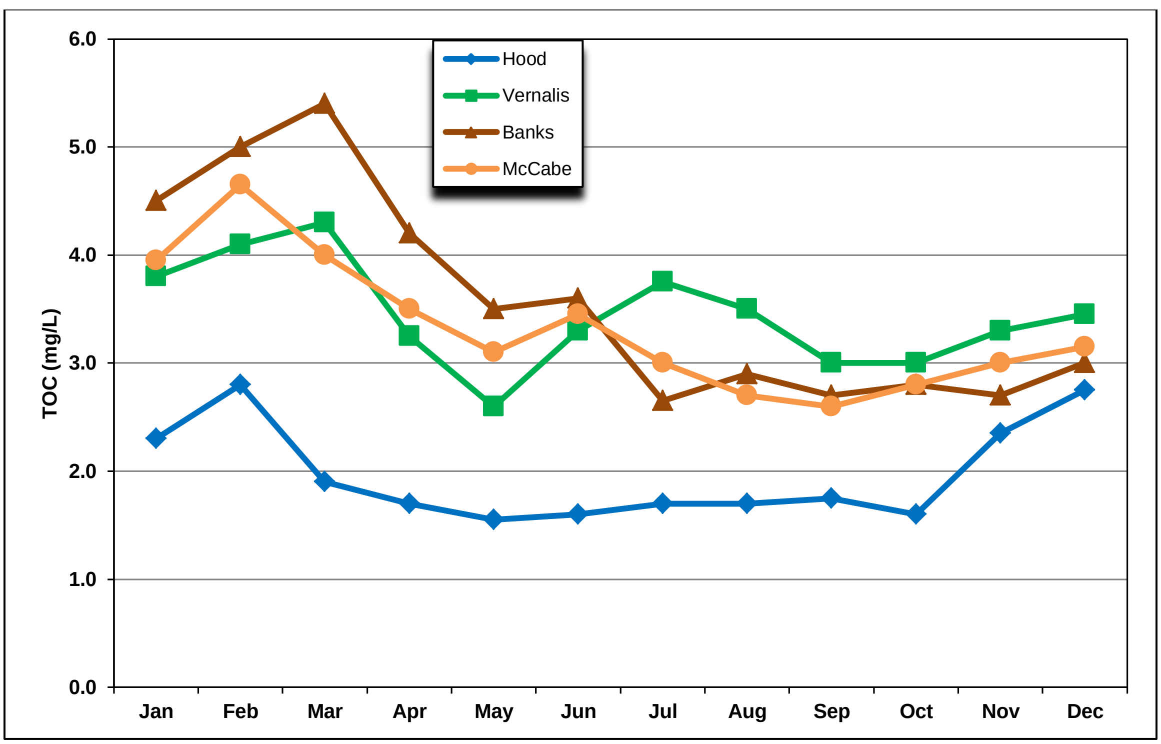
Source: Bob Suits, DWR. Presentation at April 9, 2008 MWQI Workshop.

Organic Carbon

OMR Flow Restrictions

The requirement to reduce exports to reduce reverse flows in OMR between December and June will shift the timing of diversions and increase the influence of the San Joaquin River during the months that reverse flows are reduced. **Figure 15-7** presents the monthly median total organic carbon (TOC) concentrations between 1998 and 2010 for the Sacramento River at Hood (Hood), the San Joaquin River at Vernalis (Vernalis), McCabe Road (McCabe) on the Delta-Mendota Canal (DMC), and Banks. Banks represents the quality of water entering the Governor Edmund G. Brown California Aqueduct (California Aqueduct) and McCabe represents the quality of water entering O'Neill Forebay from the DMC. The historical data show that during the December to June period, the low TOC concentrations in the Sacramento River dilute the higher TOC concentrations in the San Joaquin River and in Delta agricultural drainage when Sacramento River water is mixed with the other sources in the central and south Delta. If pumping is reduced to prevent reverse flows in OMR, the San Joaquin River and Delta agricultural drainage would likely not be diluted by Sacramento River water. This could potentially result in higher TOC concentrations at the south Delta pumping plants because the TOC concentrations in the San Joaquin River are 1.0 to 2.0 mg/L higher than the TOC concentrations in the Sacramento River. This higher TOC water would accumulate in the south Delta with lower pumping rates and then have to be pumped out of the south Delta when pumping restrictions are lifted in July.

Figure 15-7. Monthly Median TOC Concentrations, 1998 to 2010



As discussed previously, exports would increase in the July through September period and decrease in all other months under the operating rules of the biological opinions. **Figure 15-7** indicates that TOC concentrations have historically been lower in July through September and higher during the winter months. This indicates that more water with lower TOC concentrations could be exported in the summer months.

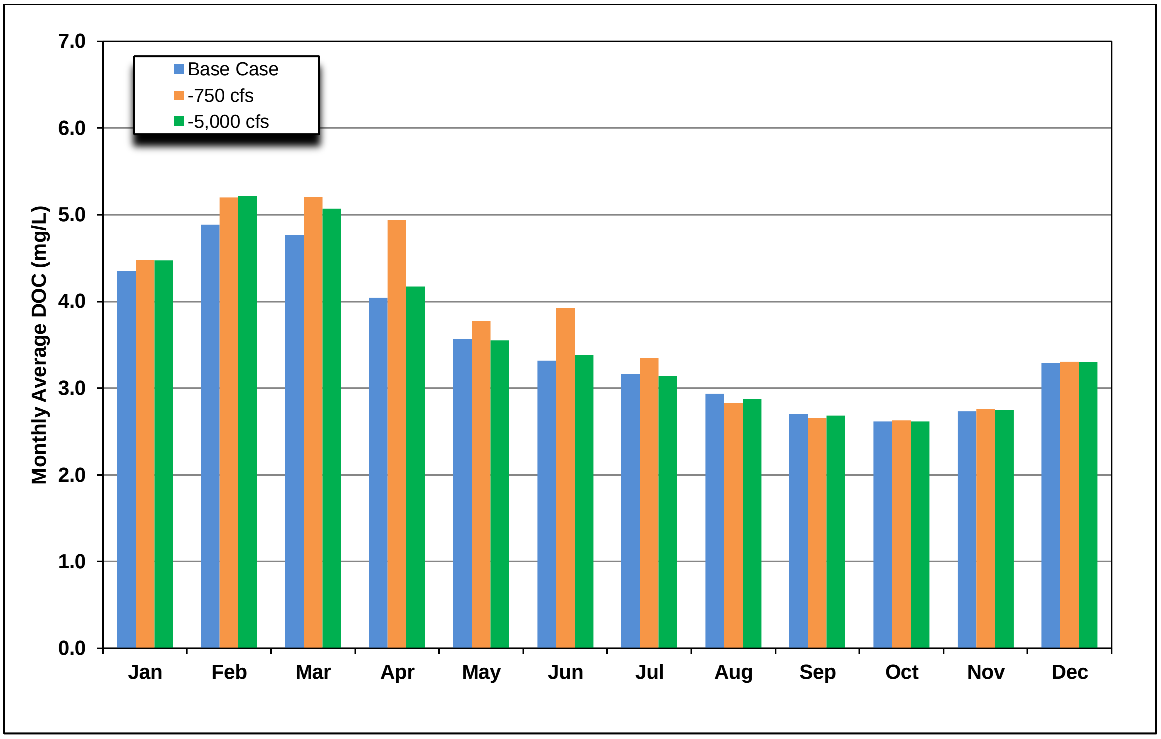
The modeling results for the impact of the Wanger Interim Remedial Order OMR flow restrictions on DOC concentrations at Clifton Court and Jones are shown in **Figures 15-8 and 15-9**. DOC concentrations at Clifton Court are predicted to be substantially higher during the spring months if OMR flows are restricted to -750 cfs and slightly increased if OMR flows are restricted to -5,000 cfs. The Jones DOC concentrations remain virtually the same as the base case.

<u>Increased Delta Outflow</u>

The other major effect of the new operations is that Delta outflow will increase in most months of the year with the most significant increases in September of wet and above normal years. This will likely result from increased releases from Oroville and Folsom reservoirs, and to some extent, from Lake Shasta. This may be combined with lower exports to meet the outflow requirements. In wet years, September Delta outflow will increase on average from about 10,000 cfs to 20,000 cfs as shown in **Figure 15-3**. Note that the first part of **Figure 15-3** shows Delta outflow under the D1641 operating rules and the second part shows the change in Delta outflow. For example, under D1641 September Delta outflow is about 10,000 cfs (first part of **Figure 15-3** and the change (shown on the second part of **Figure 15-3**) is about 10,000 cfs. This means that September Delta outflow will be 20,000 cfs with the operating rules of the biological opinions.

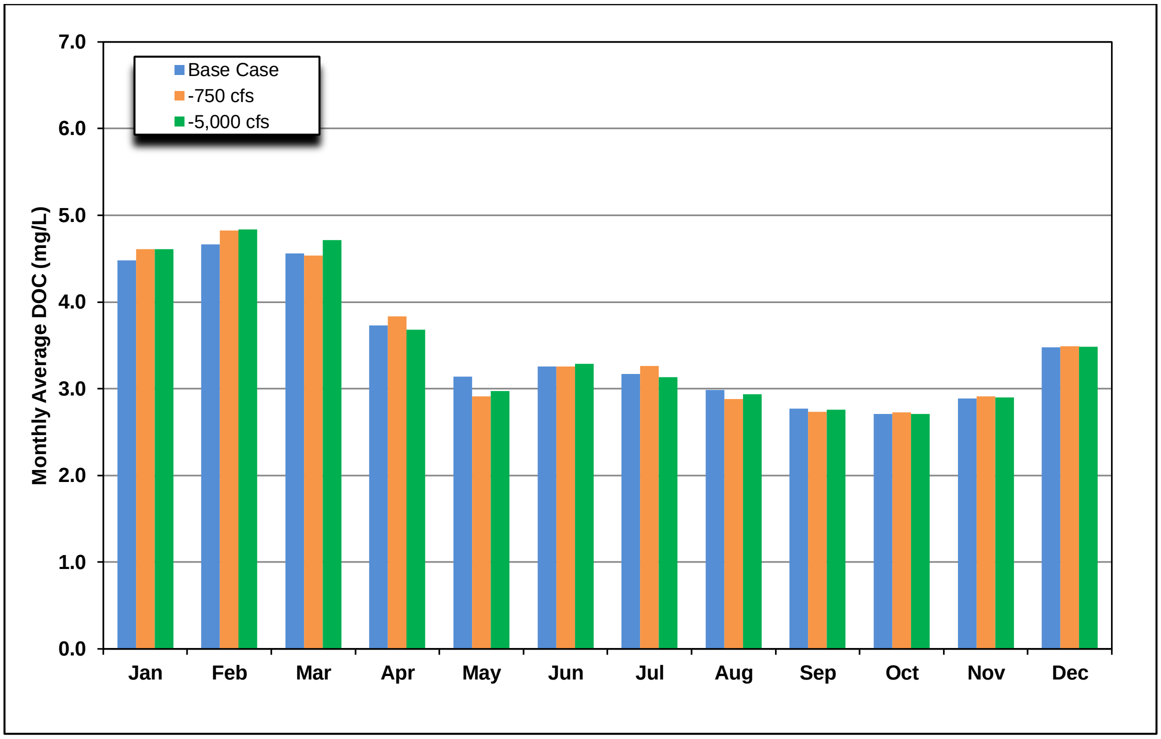
In an attempt to understand the impacts of this increased Delta outflow on TOC concentrations at Banks, the TOC data and the Delta outflow data for wet and above normal years were plotted in **Figure 15-10**. Data are only presented for periods when Delta outflow is below 20,000 cfs since this is likely the upper range of fall flows. This figure shows that TOC concentrations at Banks are in the range of 2.0 to 4.5 mg/L when Delta outflow is less than 10,000 cfs and between 2.7 and 4.0 mg/L at flows between 10,000 and 20,000 cfs. It is difficult to draw any conclusions on whether the increased Delta outflow will have any impact on TOC concentrations at Banks in the fall months. If the increased outflow is due to releases of high quality water from reservoirs rather than early season storm flows, TOC concentrations could decrease in the Sacramento River and this may result in lower concentrations at Banks, unless pumping is restricted and the Sacramento River water is not pulled into the Delta.

Figure 15-8. Impact of OMR Flow Restrictions on DOC at Clifton Court



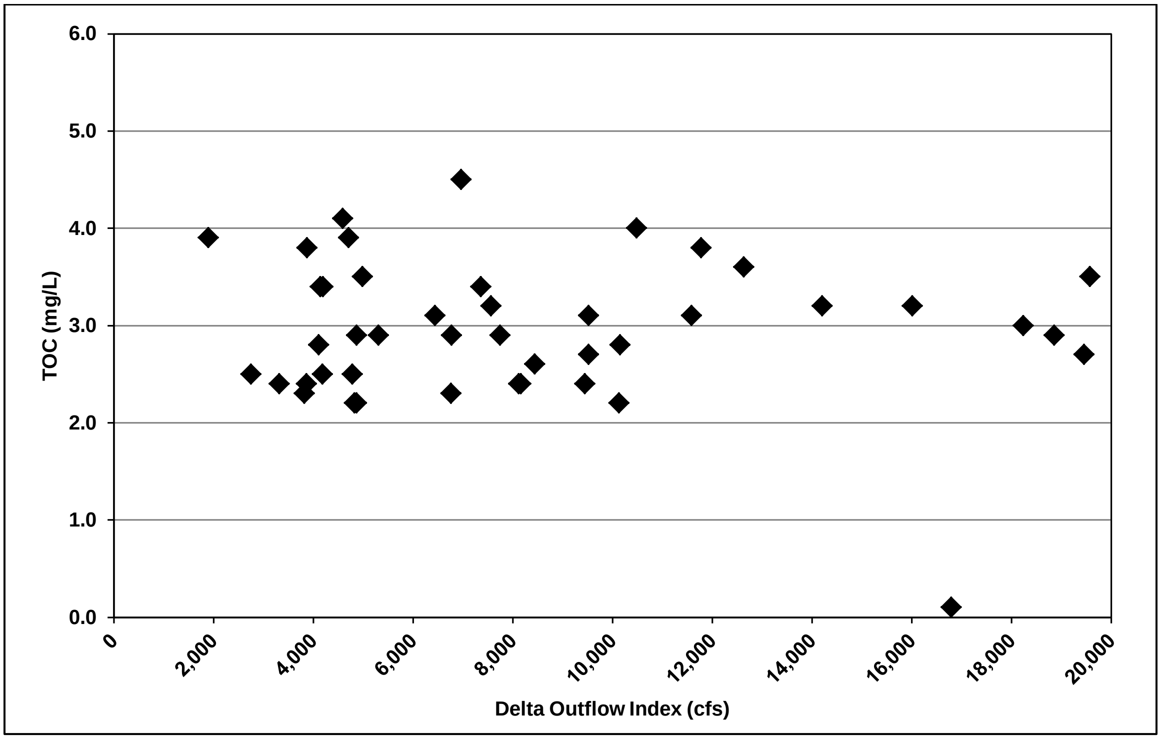
Source: Bob Suits, DWR. Presentation at April 9, 2008 MWQI Workshop.

Figure 15-9. Impact of OMR Flow Restrictions on DOC at Jones



Source: Bob Suits, DWR. Presentation at April 9, 2008 MWQI Workshop.

Figure 15-10. TOC at Banks and Delta Outflow Index in Wet and Above Normal Water Years



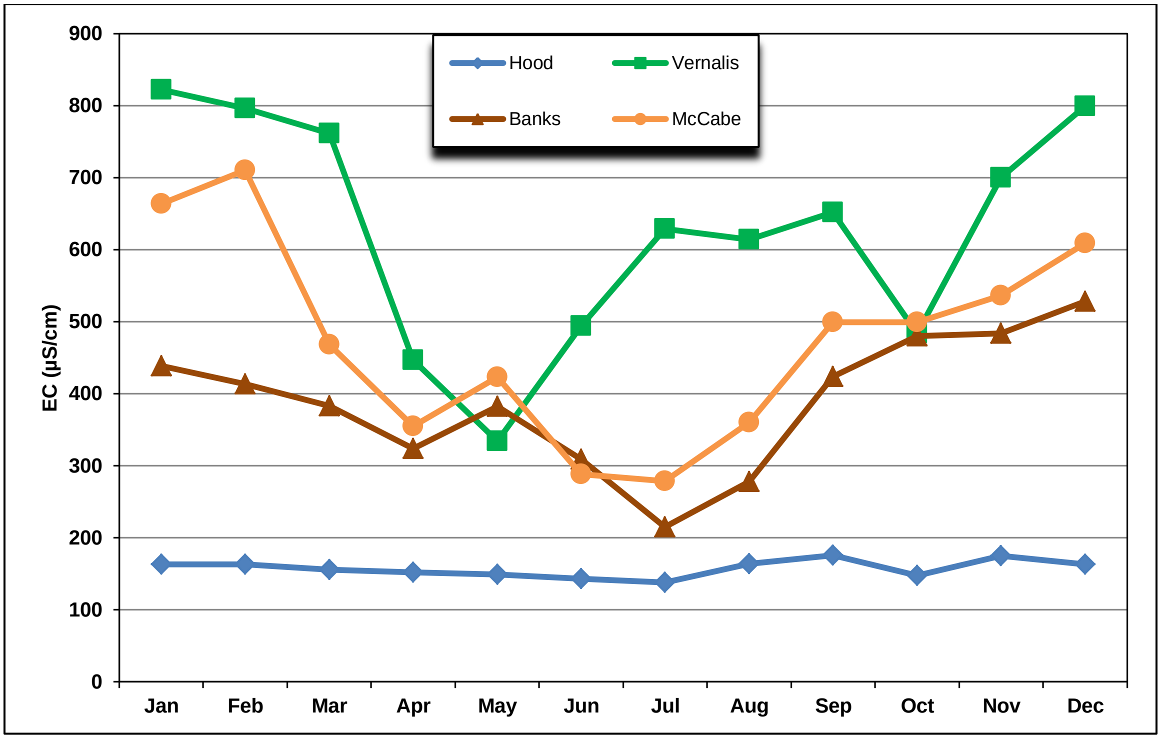
Note: This graph contains data for the wet years of 1998, 1999, and 2006 and the above normal years of 2000, 2003, and 2005.

Salinity

OMR Flow Restrictions

Figure 15-11 presents the monthly median electrical conductivity (EC) levels between 1998 and 2010 at Hood, Vernalis, McCabe, and Banks. During the December to June period when OMR restrictions would be in place, historical EC levels on the San Joaquin River are much higher than the levels on the Sacramento River and for most of this time, higher than historical levels at Banks and McCabe. The lower EC levels of the Sacramento River dilute the high EC levels in the San Joaquin River when Sacramento River water is mixed with other sources in the central and south Delta. When pumping is reduced to prevent reverse flows in OMR, the San Joaquin River and Delta agricultural drainage would likely not be diluted by Sacramento River water. This could potentially result in much higher EC levels at the south Delta pumping plants since EC levels at Vernalis can be more than 600 µS/cm higher than at Hood. This higher salinity water would accumulate in the south Delta with lower pumping rates and then have to be pumped out of the south Delta when pumping restrictions are lifted in July.

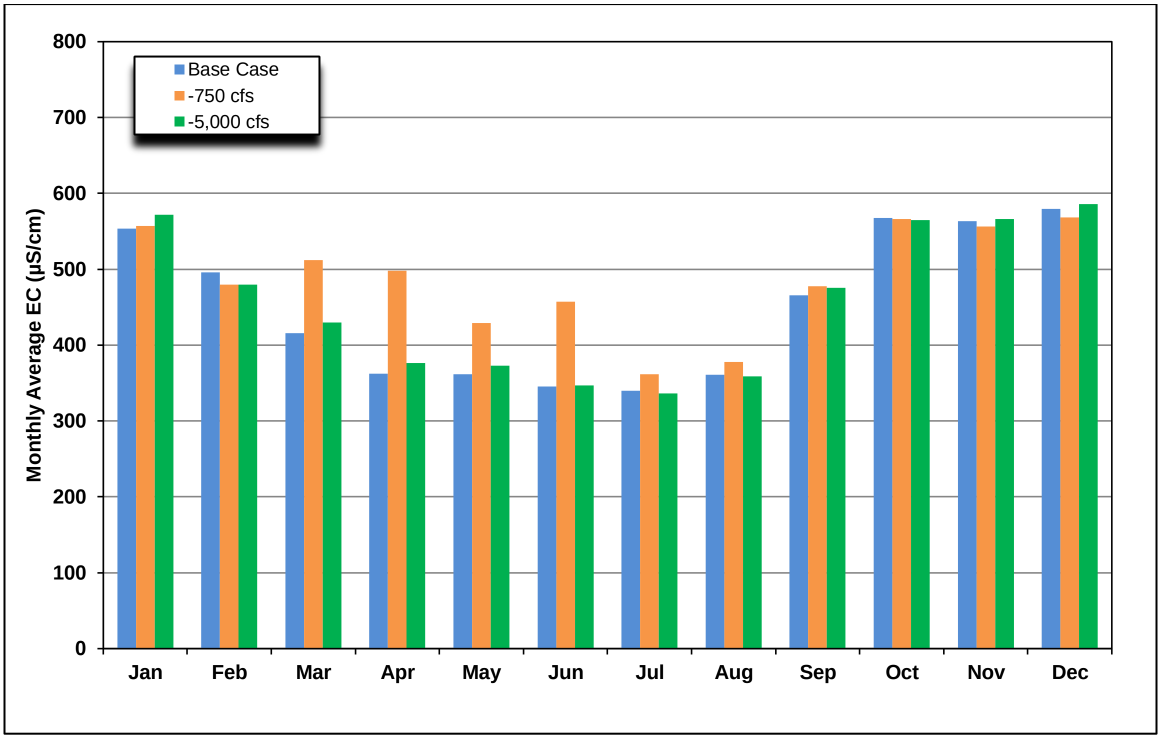
Figure 15-11. Monthly Median EC Levels, 1998 to 2010



The historical data show that EC levels at Banks and McCabe are low in July and then start increasing in August and September when exports would increase under the operating rules for the biological opinions. The EC levels in September are lower than the levels found October through January at Banks and November through February at McCabe. There may be some minor reductions in the salinity of water exported since exports are predicted to increase the most in July and August and decrease the most in the January through May period (see **Figure 15-2**).

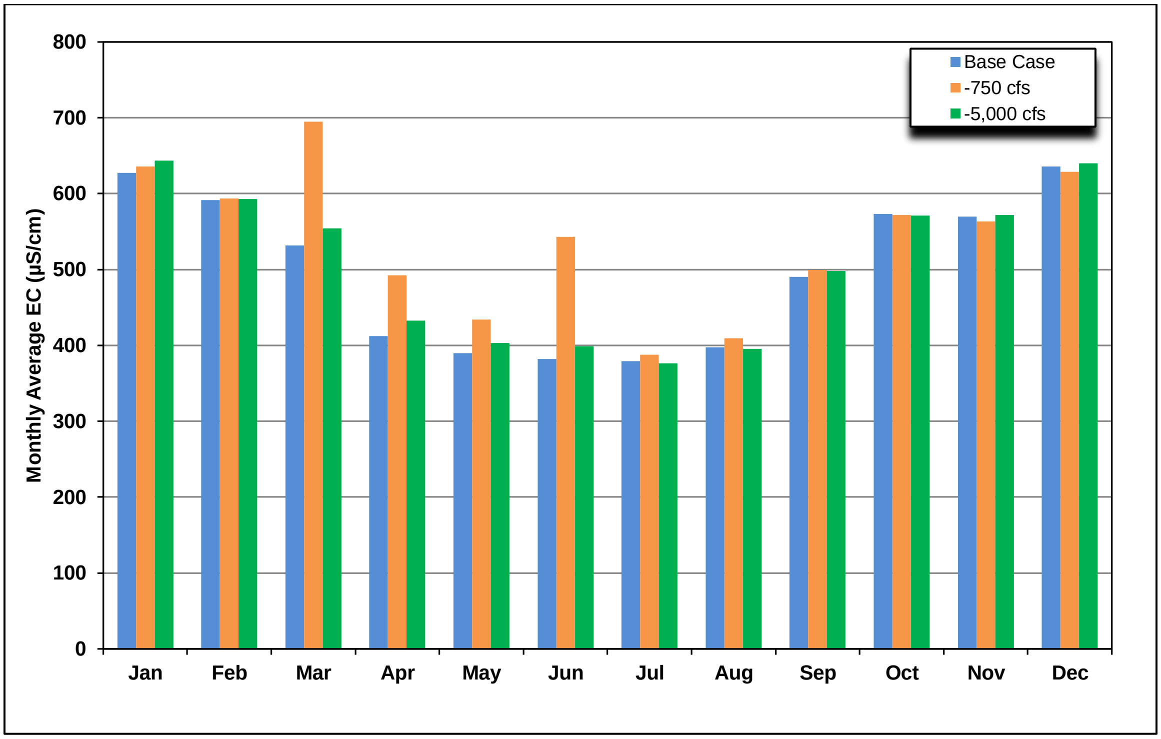
The modeling results for the impact of the Wanger Interim Remedial Order OMR flow restrictions on EC levels at Clifton Court and Jones are shown in **Figures 15-12 and 15-13**. EC levels at Clifton Court and Jones are predicted to be substantially higher during the spring months if OMR flows are restricted to -750 cfs and slightly increased if OMR flows are restricted to -5,000 cfs.

Figure 15-12. Impact of OMR Flow Restrictions on EC at Clifton Court



Source: Bob Suits, DWR. Presentation at April 9, 2008 MWQI Workshop.

Figure 15-13. Impact of OMR Flow Restrictions on EC at Jones

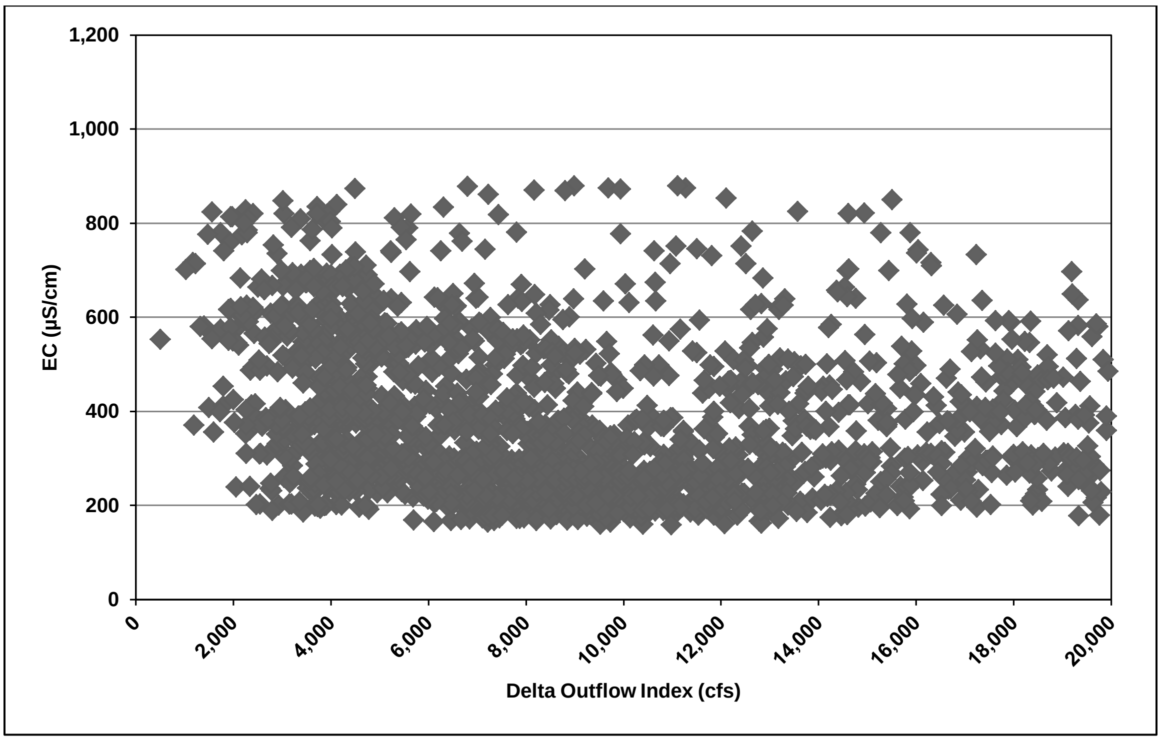


Source: Bob Suits, DWR. Presentation at April 9, 2008 MWQI Workshop.

Increased Delta Outflow

The real-time EC data at Banks and the Delta outflow data for wet and above normal years are shown in **Figure 15-14**. Data are only presented for periods when Delta outflow is below 20,000 cfs since this is likely the upper range of fall flows. This figure shows that EC levels at Banks are not related to Delta outlow at flows in this range. There appears to be a slight decrease in EC levels when Delta outflow reaches about 16,000 cfs. It doesn't appear that the increased fall Delta outflow will have an impact on EC levels at Banks. If pumping is restricted to maintain Delta outflow, and San Joaquin River water accumulates in the south Delta, EC levels at the pumping plants could potentially increase during the fall months.

Figure 15-14. EC at Banks and Delta Outflow Index during Wet and Above Normal Years



Note: This graph contains data for the wet years of 1986, 1995 to 1999, and 2006 and the above normal years of 1993, 2000, 2003, and 2005.

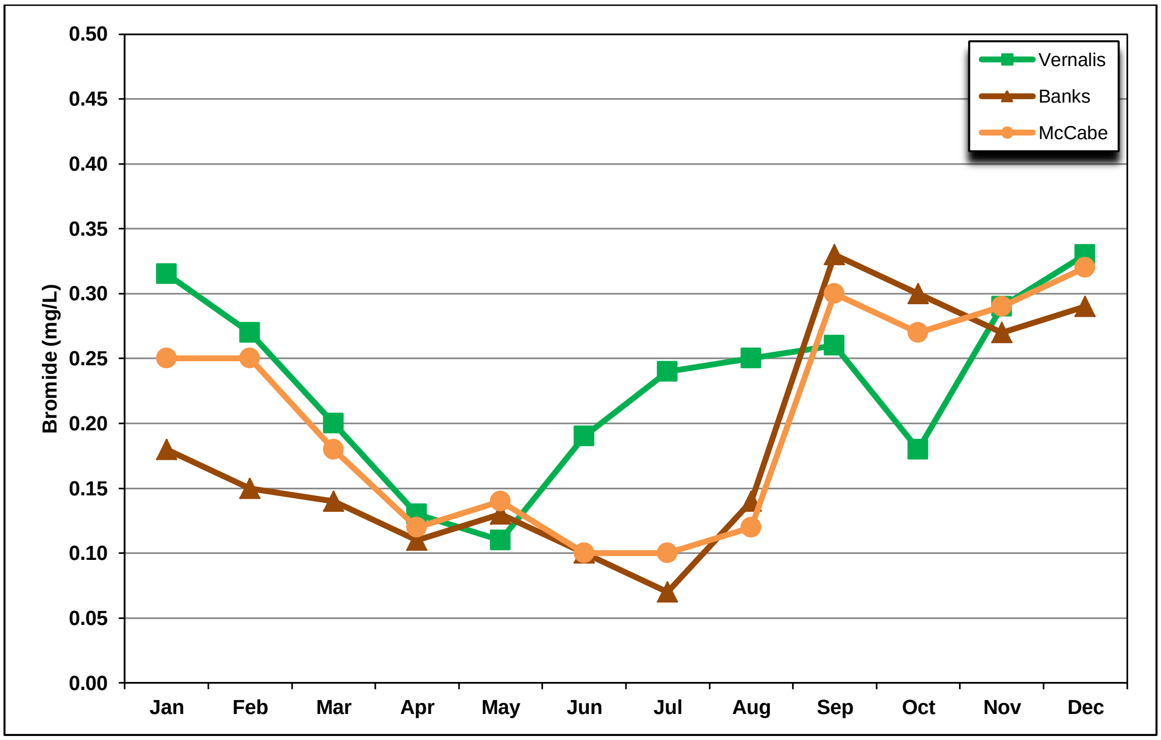
Bromide

OMR Flow Restrictions

Figure 15-15 shows the monthly median bromide concentrations at Vernalis, McCabe, and Banks between 1998 and 2010. Hood is not shown on this figure because bromide concentrations are consistently at or near the detection limit of 0.01 mg/L. During the December to June period when OMR restrictions would be in place, bromide concentrations in the San Joaquin River are typically above 0.20 mg/L except during the spring when flows are high on the San Joaquin

River. The impact of the Sacramento River is seen in the summer months when the bromide concentrations at the pumping plants are much lower than the concentrations seen in the San Joaquin River. When pumping is reduced to prevent reverse flows in OMR, the San Joaquin River would likely not be diluted by Sacramento River water in the south and central Delta. This could potentially result in much higher bromide concentrations at Banks since bromide concentrations at Vernalis can be more than 0.30 mg/L higher than at Hood. The concentrations at McCabe have historically been similar to the concentrations in the San Joaquin River and are an indication of what the concentrations could be at Banks. This higher bromide water would accumulate in the south Delta with lower pumping rates and then have to be pumped out of the south Delta when pumping restrictions are lifted in July.

Figure 15-15. Monthly Median Bromide Concentrations, 1998 to 2010

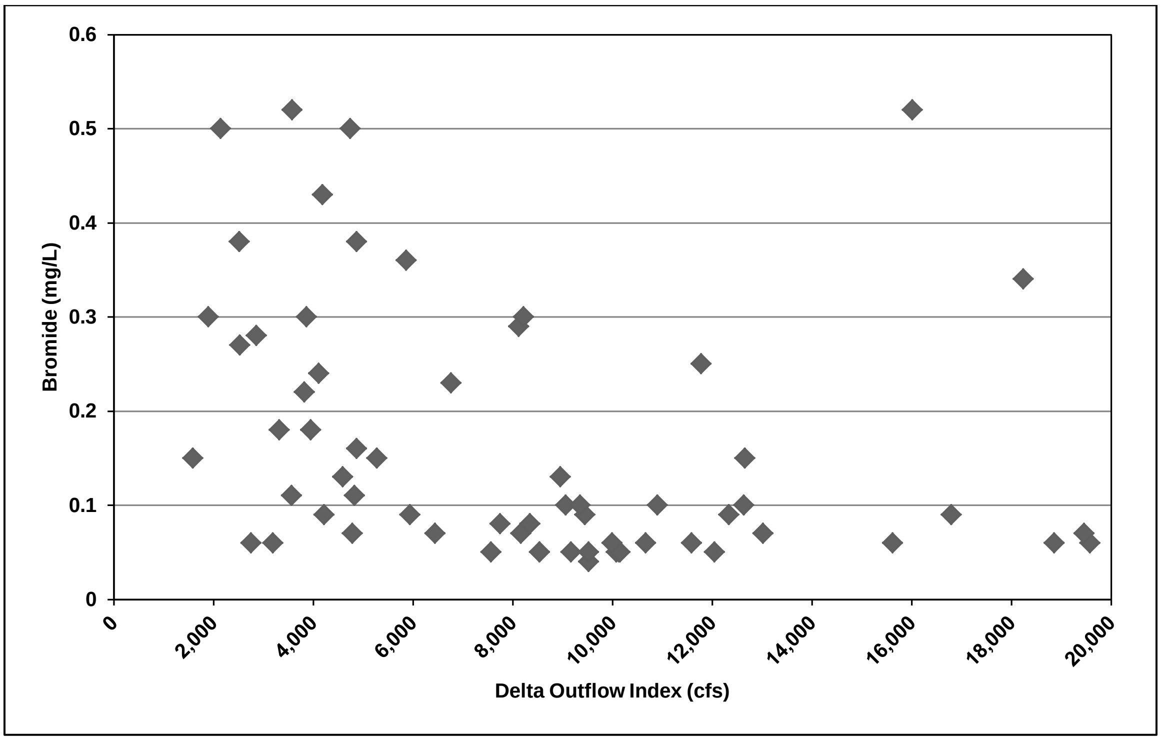


The historical data show that bromide concentrations at Banks and McCabe are low in July and then start increasing in August and September when exports would increase under the operating rules for the biological opinions. September has historically had the highest bromide concentrations at Banks and high concentrations at McCabe. Shifting more pumping to the July to September period and reducing pumping in the March to May period may result in higher concentrations of bromide being exported.

Increased Delta Outflow

The bromide data at Banks and the Delta outflow data for wet and above normal years are shown in **Figure 15-16**. Data are only presented for periods when Delta outflow is below 20,000 cfs since this is likely the upper range of fall flows. There are more data points in the low end of the Delta outflow range that are higher but there are also some high bromide concentrations at the upper end of the Delta outflow range. This analysis shows that historically higher Delta outflow in the range likely to be seen in September will not impact bromide concentrations at Banks. However, as stated previously for EC, if pumping is restricted and San Joaquin River water accumulates in the south Delta, bromide concentrations could potentially increase.

Figure 15-16. Bromide at Banks and Delta Outflow during Wet and Above Normal Years



Conclusions on the Impacts of the Biological Opinions on Drinking Water Quality

While modeling studies have been conducted to examine the impacts of the biological opinions on water supply, there have not been any modeling studies to evaluate the impacts on drinking water quality. The impacts of the Wanger Interim Remedial Order on drinking water quality were modeled. Historical data were examined and the results of the modeling studies on the Wanger Interim Remedial Order were reviewed in an attempt to determine if any conclusions could be drawn on the likely impacts. Delta hydrology is extremely variable, Delta operations are highly complex, and the operations rules to comply with the actions in the biological opinions will change the way the Delta has historically been operated. It is not possible to reach firm conclusions on the impacts of the biological opinions without conducting modeling studies; however it appears that the greater influence of the San Joaquin River during the periods that OMR reverse flows are regulated will result in higher levels of TOC, DOC, EC, and bromide at the south Delta pumping plants. Shifting exports to the July to September period may result in more water with lower TOC and possibly EC being exported. Bromide concentrations may be lower in July but would increase to high levels by September. Increased fall Delta outflow, in the range that would likely occur in September, does not appear to have any impact on drinking water quality at the pumping plants.

Potential Actions

Modeling Studies should be Conducted on the Impacts of the Biological Opinions on Water Quality.

Both the USFWS and NMFS biological opinions are currently being revised. When they are reissued, DWR should conduct modeling studies on the impacts on both water supply and water quality at the Delta pumping plants.

2-GATES FISH PROTECTION DEMONSTRATION PROJECT

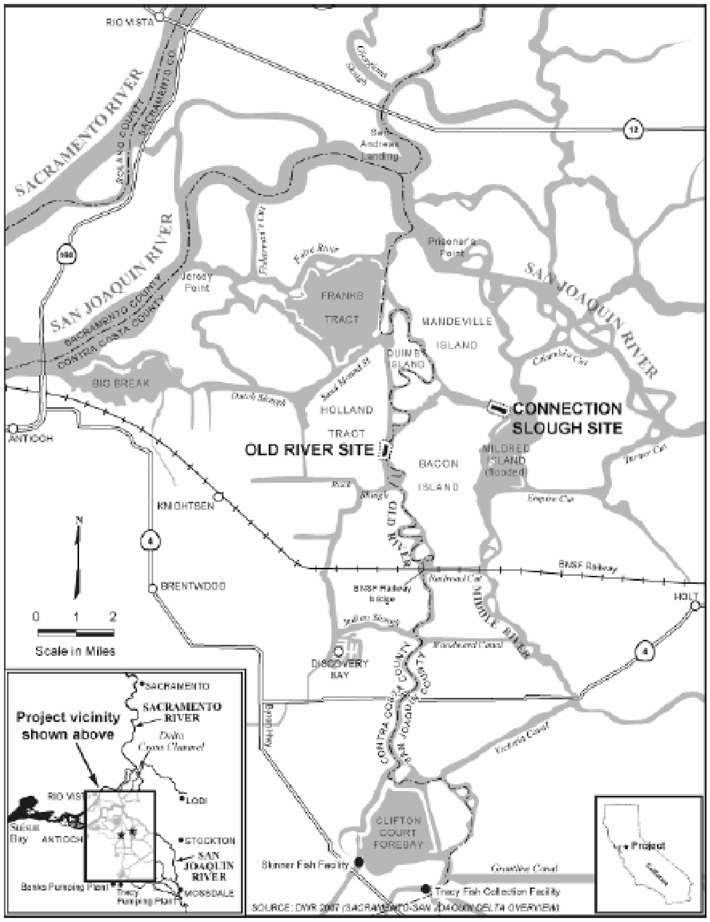
Metropolitan Water District of Southern California (MWDSC) and the San Luis & Delta-Mendota Water Authority proposed the 2-Gates Project to test alternative ways of protecting delta smelt while lessening the impact on water supply reliability of the biological opinion. A demonstration project was proposed to determine if placing operable gates on Connection Slough near the Middle River and on the Old River between Holland Tract and Bacon Island could reduce entrainment of delta smelt at the south Delta pumping plants. **Figure 15-17** shows the proposed locations of the gates. Research suggests that the pre-spawning migration of delta smelt from Suisun Bay into the central Delta is tied to turbidity. The gates would be operated to manipulate the flow of turbid water to keep it away from the Central Valley Project (CVP) and SWP export facilities. The hypothesis is that the smelt that are in the turbid water would also be kept away from the pumps. The gates would be closed for short periods December through February to control adult delta smelt movement and for moderate periods March through June to control larvae/juvenile delta smelt movement.

The Bureau of Reclamation (Reclamation) is the lead agency for the project and DWR is providing technical assistance. Reclamation released the draft Environmental Assessment in October 2009. This document contained an analysis of the water quality impacts of the proposed project. Modeling studies conducted for Reclamation did not identify any water quality impacts on the SWP and CVP. The studies found that there could be minor changes in salinity at Contra Costa Water District's Rock Slough intake (Reclamation, 2009). This project is no longer being actively pursued (Personal Communication, Paul Hutton, MWDSC).

Potential Actions

None

Figure 15-17. Proposed Locations of Gates

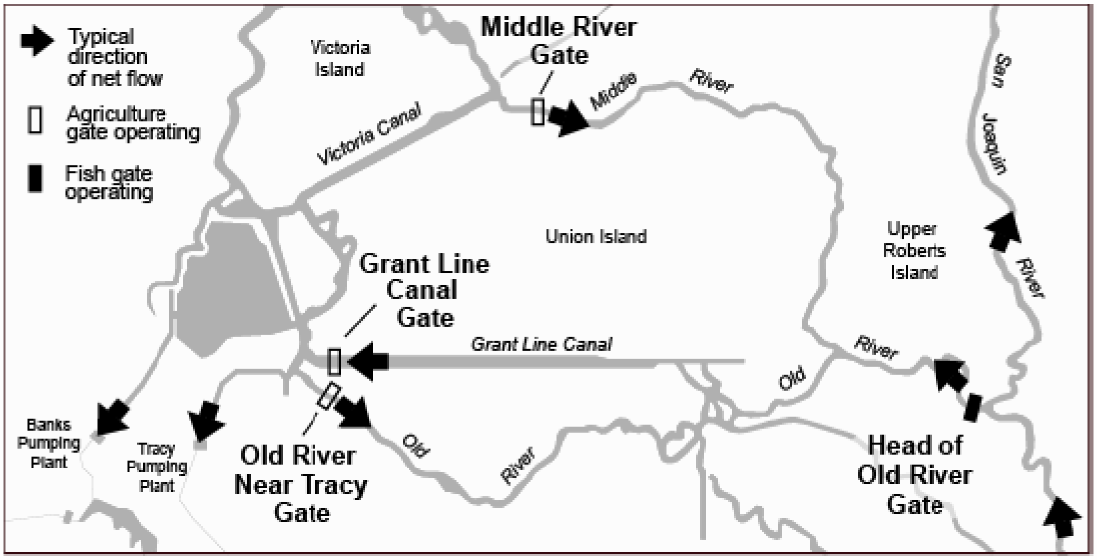


Source: Reclamation (2009)

HEAD OF OLD RIVER NON-PHYSICAL BARRIER

The South Delta Temporary Barriers Project was initiated in 1991. The project consists of four rock barriers across south Delta channels. The barriers on Old River near Tracy, Middle River, and Grant Line Canal are installed each year to maintain water levels and water quality conditions in south Delta channels to benefit agricultural water users. The Head of the Old River Barrier (HORB) is installed to keep migrating salmon in the San Joaquin River and to prevent them from entering the Old River and being drawn towards agricultural diversions and the south Delta pumping plants. The locations of the barriers are shown in **Figure 15-18**.

Figure 15-18. South Delta Temporary Barriers



Source: DWR 2006.

Historically the HORB was a 200-foot long barrier constructed by placing rock in the main channel bed along with overflow weirs and gated culverts. The barrier is installed in the spring, generally from mid-April to mid-May during the Vernalis Adaptive Management Plan (VAMP) flows and again in the fall. The physical barrier effectively blocks most flow from the San Joaquin River into the Old River. As a result of the delta smelt biological opinion, participants in the VAMP program suggested testing a non-physical barrier as an alternative to the rock barrier, since the physical barrier may have adverse impacts on delta smelt. A non-physical barrier was installed in the Old River in the spring of 2009 as an experimental project to determine if migrating salmon and steelhead would avoid the barrier and stay in the San Joaquin River rather than entering the Old River. The non-physical barrier combines a strobe-lit curtain of bubbles and low-frequency sound generators to create an underwater wall of light and sound. The sound system and strobe light flash rates can be tuned to known sensitivities of various fish species (DWR, 2009). The non-physical barrier does not change Delta hydrodynamics, so San Joaquin River water can flow toward the south Delta pumping plants via the Old River. The non-physical barrier was installed again in the spring of 2010 but high flows on the San Joaquin River prevented it from being installed in the spring of 2011.

The water quality impacts of the non-physical barrier have not been modeled. The non-physical barrier allows San Joaquin River water to flow toward the south Delta export pumps during the mid-April to mid-May period, whereas the rock barrier prevented this. Exports are curtailed during the April to May VAMP period when the rock barrier was historically installed so any water quality impacts during this period would not be as significant as during periods when export pumping is high. The water quality data at Vernalis and Banks were evaluated to determine if it is possible to determine the impacts of the non-physical barrier. No barrier was installed in the spring of 2008 due to concerns over impacts on delta smelt, and the non-physical barrier was installed in 2009 and 2010. This period was selected to represent water quality with a non-physical barrier. These years were classified as critical (2008), below normal (2009), and above normal (2010) for the San Joaquin Basin. A similar period was found between 2002 and 2004 to represent water quality with the physical barrier installed. These years were classified as dry (2002 and 2004), and below normal (2003). Data from April and May in these two periods are compared in the following sections.

Organic Carbon

Figure 15-7, presented previously, shows the monthly variability in TOC at Vernalis and Banks. TOC concentrations are low at Vernalis in April and May, with May having the lowest concentrations (median of 2.6 mg/L) of any month of the year. The historical data show that April and May are transition months at Banks with TOC concentrations declining from the high levels found in the winter but not as low as the TOC concentrations found during the summer months. **Figure 15-19** compares the April and May TOC concentrations at Vernalis and Banks during the 2002 to 2004 physical barrier period to the concentrations during the 2008 to 2010 non-physical barrier period. The median concentration of 3.0 mg/L at Vernalis during the 2002 to 2004 period is not statistically significantly different from the median of 3.3 mg/L during the 2008 to 2010 period (Mann-Whitney, p=0.0878). However, the median concentration at Banks was 3.3 mg/L when the physical barrier was installed and 4.5 mg/L when there was no physical barrier restricting the flow of San Joaquin River water into the Old River. The medians are statistically significantly different (Mann-Whitney, p=0.0082). Since the Banks TOC concentration was higher than Vernalis during the 2008 to 2010 period, the higher TOC concentration at Banks could not have come from the San Joaquin River. The higher TOC concentration at Banks without a physical barrier suggests that organic matter may be added to San Joaquin River water as it passes through Old River and the south delta. Some potential sources of TOC in the south delta are agricultural inputs, growth of aquatic and wetland plants and benthic and planktonic algae

Salinity

Figure 15-11, presented previously, shows that EC levels at Vernalis are declining from the high winter levels in April and are at their lowest in May (median of 334 µS/cm). EC levels at Banks have historically been low in April and May compared to the August to March period. **Figure 15-20** compares the April and May EC concentrations at Vernalis and Banks during the 2002 to 2004 period and the 2008 to 2010 period. The median EC of 314 µS/cm at Vernalis during the 2008 to 2010 period is statistically significantly lower than the median of 453 µS/cm during the 2002 to 2004 period (Mann-Whitney, p=0.0055), indicating that the water quality on the San Joaquin River was substantially different during these two periods. Despite the lower EC levels in the San Joaquin River when the non-physical barrier was employed, the median EC level at Banks during the 2008 to 2010 period (391 µS/cm) was higher than during the 2002 to 2004 period (348 µS/cm), although the difference is not statistically significant (Mann-Whitney, p=0.2298). The higher EC level at Banks without a physical barrier suggests that salinity may be added to San Joaquin River water as it passes through Old River and the south delta. Some potential sources of salinity in the south delta are agricultural inputs and wastewater discharges.

Figure 15-19. TOC Concentrations at Vernalis and Banks in April and May

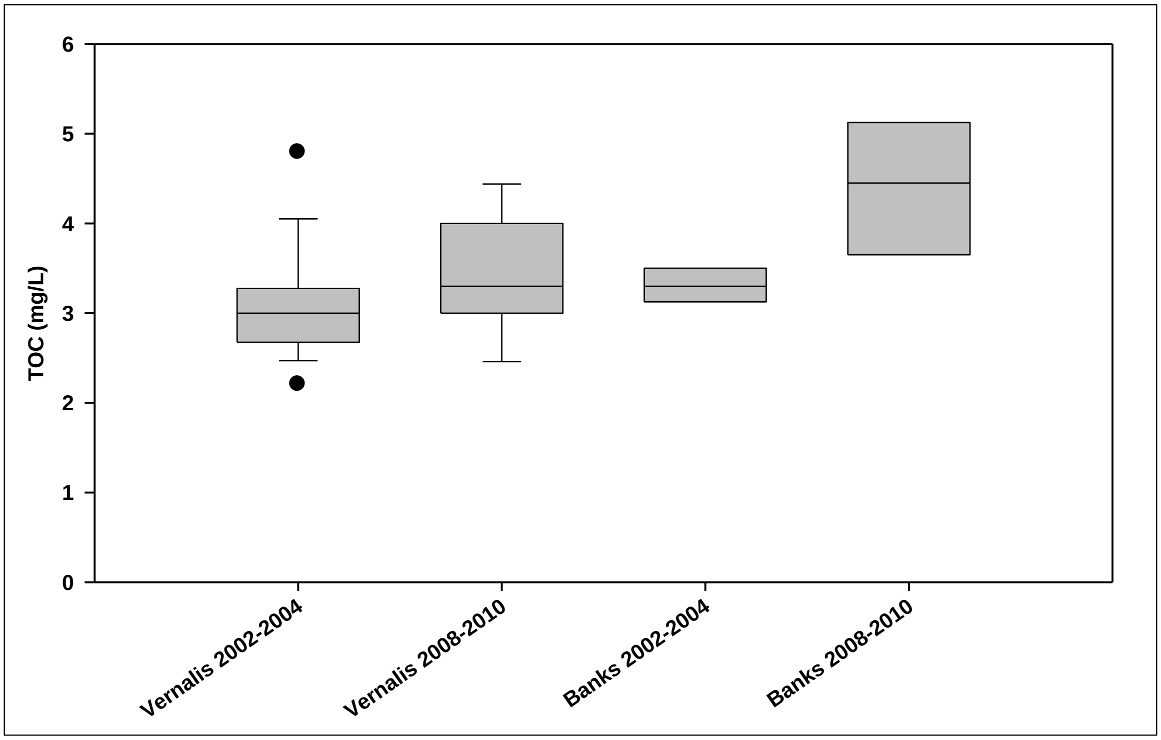
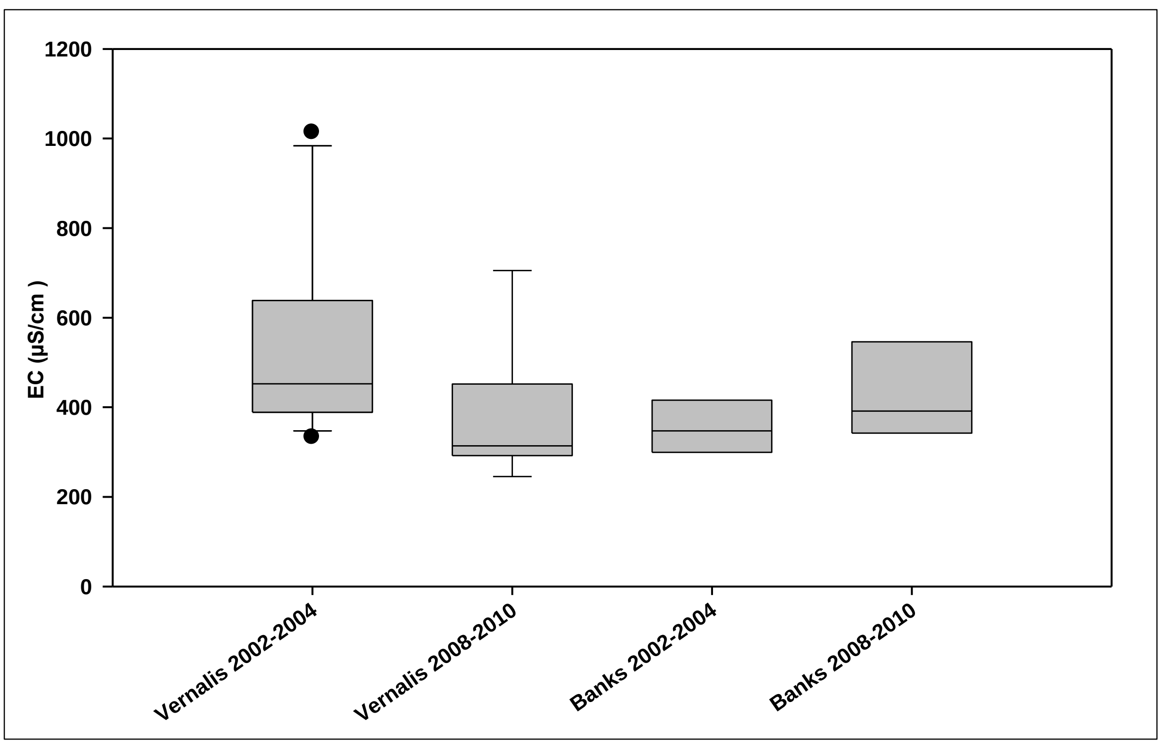


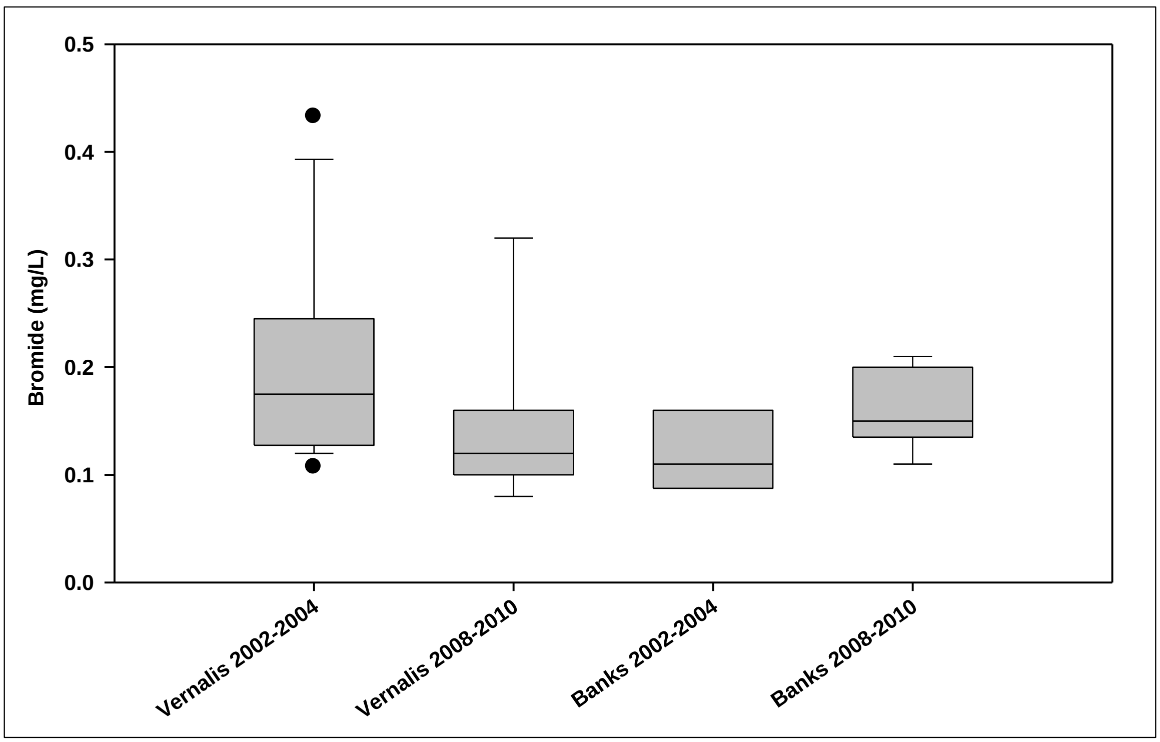
Figure 15-20. EC Levels at Vernalis and Banks in April and May



Bromide

Bromide concentrations are lowest at Vernalis in April and May, as shown previously in **Figure 15-15**. **Figure 15-15** also shows they are low at Banks during these months. **Figure 15-21** compares the April and May bromide concentrations at Vernalis and Banks during the 2002 to 2004 period and the 2008 to 2010 period. Bromide follows the same pattern as EC. The median bromide concentration at Vernalis in 2008 to 2010 (0.12 mg/L) is statistically significantly lower than the median of 0.18 mg/L in 2002 and 2004 (Mann-Whitney, p=0.0091). Despite the lower bromide concentration in the San Joaquin River when the non-physical barrier was employed, the median bromide concentration at Banks during the 2008 to 2010 period (0.15 mg/L) was higher than during the 2002 to 2004 period (0.11 mg/L), although the difference is not statistically significant (Mann-Whitney, p =0.0771). The higher bromide concentration at Banks without a physical barrier suggests that bromide may be added to San Joaquin River water as it passes through Old River and the south delta.

Figure 15-21. Bromide Concentrations at Vernalis and Banks in April and May



Conclusions on the Impacts of the Non-Physical Barrier on Drinking Water Quality

DSM2 modeling studies have shown that the head of the Old River physical barrier prevents the San Joaquin River from entering the Old River when it is in place. There have not been any studies on the impacts on water quality of replacing the physical barrier with a non-physical barrier. It would seem logical that the San Joaquin River would have a greater influence on water quality at the south Delta pumping plants with a non-physical barrier. Water quality data were compared for two relatively dry periods: 2002 to 2004 when the physical barrier was in place and 2008-2010 when there was no physical barrier. The Delta hydrodynamics are too complex to draw any conclusions from the examination of these limited data.

Potential Actions

DWR should Conduct Modeling Studies on the Impacts of the Non-Physical Barrier.

If DWR decides to permanently install a non-physical barrier, rather than the rock barrier that has historically been installed at the head of the Old River, DWR should conduct modeling studies on the impacts on water quality.

IMPACTS OF DROUGHT ON DRINKING WATER QUALITY

The Water Quality chapters contain a comparison of dry years and wet years for TOC, EC, bromide, turbidity, total nitrogen, and total phosphorus at each of the key monitoring locations in the watershed and in the SWP. The impact that dry years has on water quality is examined in more detail for the North Bay Aqueduct (NBA) and Banks. These two locations were selected because they reflect the quality of water pumped from the north and south Delta in different year types. After entering the California Aqueduct, water quality is affected by other factors such as inflows at O'Neill Forebay from the DMC, storage in reservoirs, and non-project inflows.

As described in Chapter 3, wet years are defined as those that are classified as wet and above normal. Dry years are defined as those that are classified as below normal, dry, and critical. The data were divided by year type and then by month so that wet years and dry years could be compared on a monthly basis.

NORTH BAY AQUEDUCT

Table 15-1 presents a summary of the wet year/dry year comparison for each constituent discussed in the Water Quality chapters. The dry year median levels of TOC and turbidity are statistically significantly lower than the wet year median levels. The dry year TOC and turbidity medians are both 28 percent lower than during wet years. There were no statistically significant differences between wet years and dry years for the remaining constituents when all of the wet year data were compared to all of the dry year data.

The data were examined on a monthly basis to determine if there are times of the year when drought conditions have more of an impact on water quality pumped from the Delta than at other times. Individual wet month medians are compared to individual dry month medians to determine if there are statistically significant differences. The monthly comparisons were made using the Mann-Whitney test.

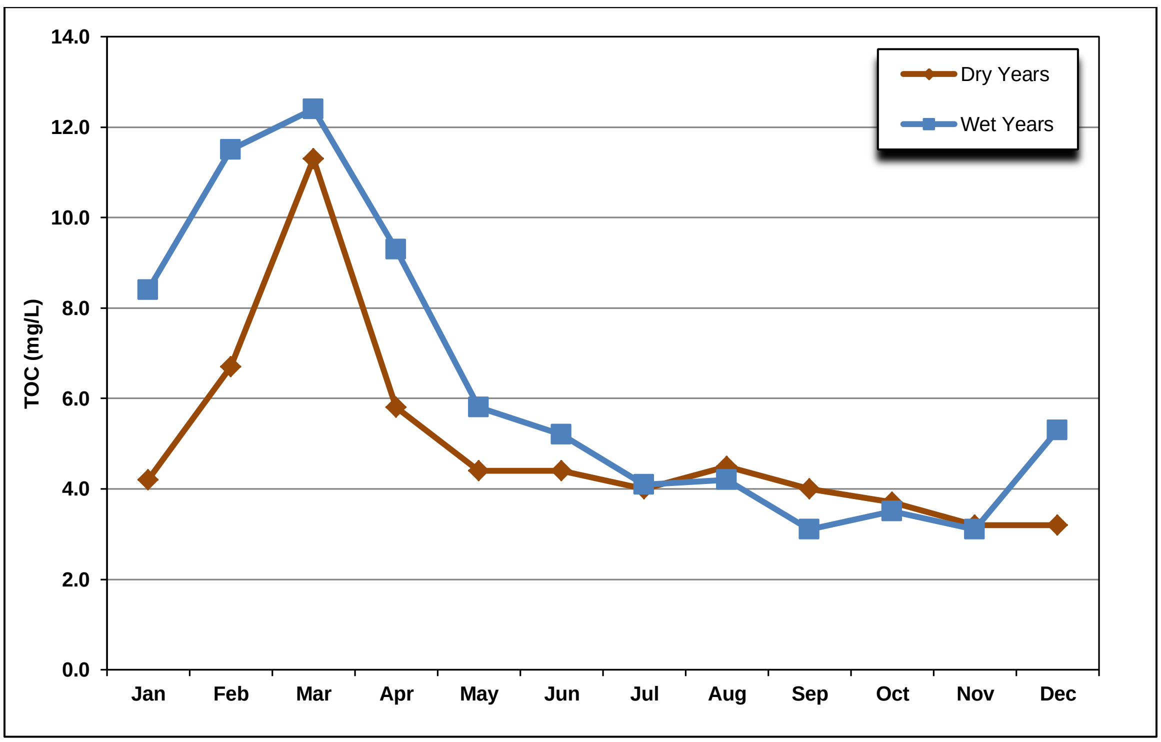
Table 15-1. Summary of Wet Year/Dry Year Analysis at Barker Slough

Constituent	Median Concentration		Comment
	Wet Years	Dry Years	
TOC (mg/L)	5.8	4.2	Significant (*p* =0.0228)
EC (µS/cm)	283	298	Not significant (*p* =0.0626)
Bromide (mg/L)	0.04	0.04	Not significant
Turbidity (NTU)	39	28	Significant (*p* =0.0000)
Total N (mg/L)	0.84	0.82	Not significant (*p* =0.4221)
Total P (mg/L)	0.12	0.18	Not significant (*p* =0.3474)

Organic Carbon

Figure 15-22 presents the monthly median TOC concentrations for wet and dry years. TOC concentrations are generally lower in dry years than in wet years; however, the only months in which the differences are statistically significant are April (*p*=0.0028) and December (*p*=0.0206).

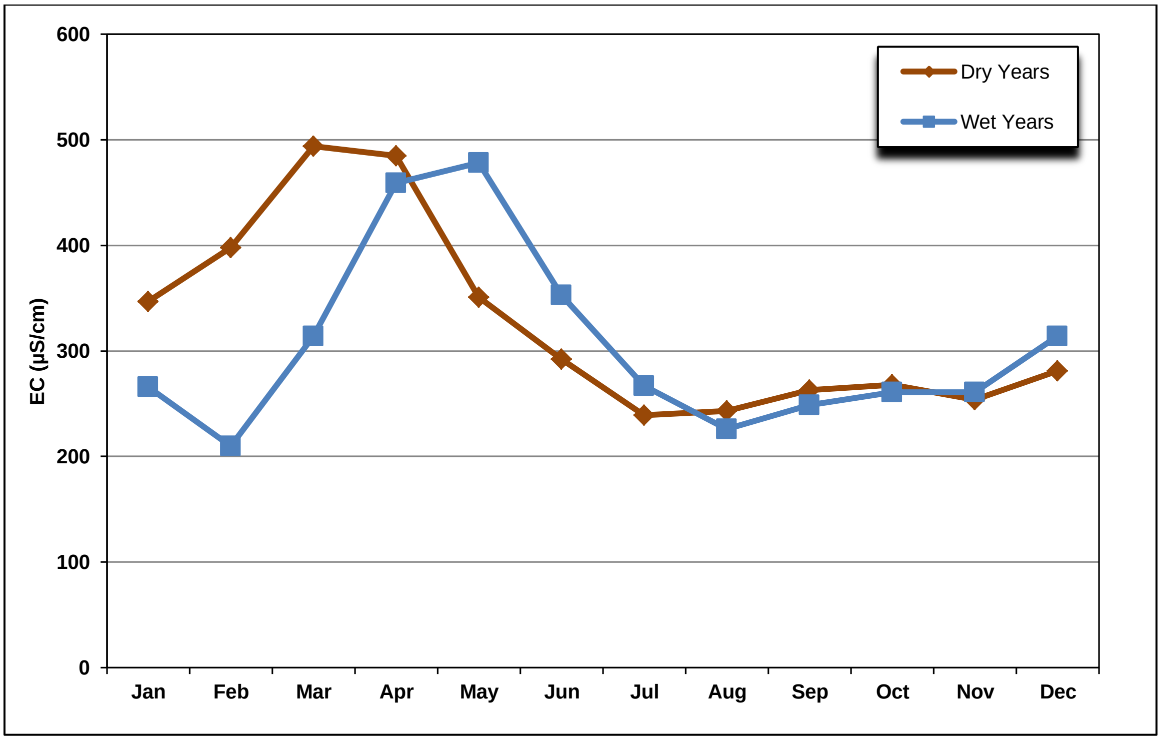
Figure 15-22. Median TOC Concentrations at Barker Slough



Salinity

Figure 15-23 presents the EC data. For the months of January through April, the median EC levels during dry years are statistically significantly higher than during wet years (p=0.0021 to p=0.0409). The opposite is true for May and June when the wet year median levels are statistically significantly higher than the dry year medians. There are no statistically significant differences between wet years and dry years for the months of July through December.

Figure 15-23. Median EC Levels at Barker Slough



Bromide

The bromide monthly median data are shown in **Figure 15-24**. The dry year medians in May and December are statistically significantly lower than the wet year medians (p=0.0120 and p=0.0237, respectively). There are no statistically significant differences in the other months.

Turbidity

Figure 15-25 presents the turbidity data for Barker Slough. The dry year monthly median turbidity is statistically significantly lower than the wet year monthly median turbidity during the wet season months of December through April (p=0.0000 to p=0.0140). There are no statistically significant differences in the monthly medians for the remaining months of the year.

Figure 15-24. Median Bromide Concentrations at Barker Slough

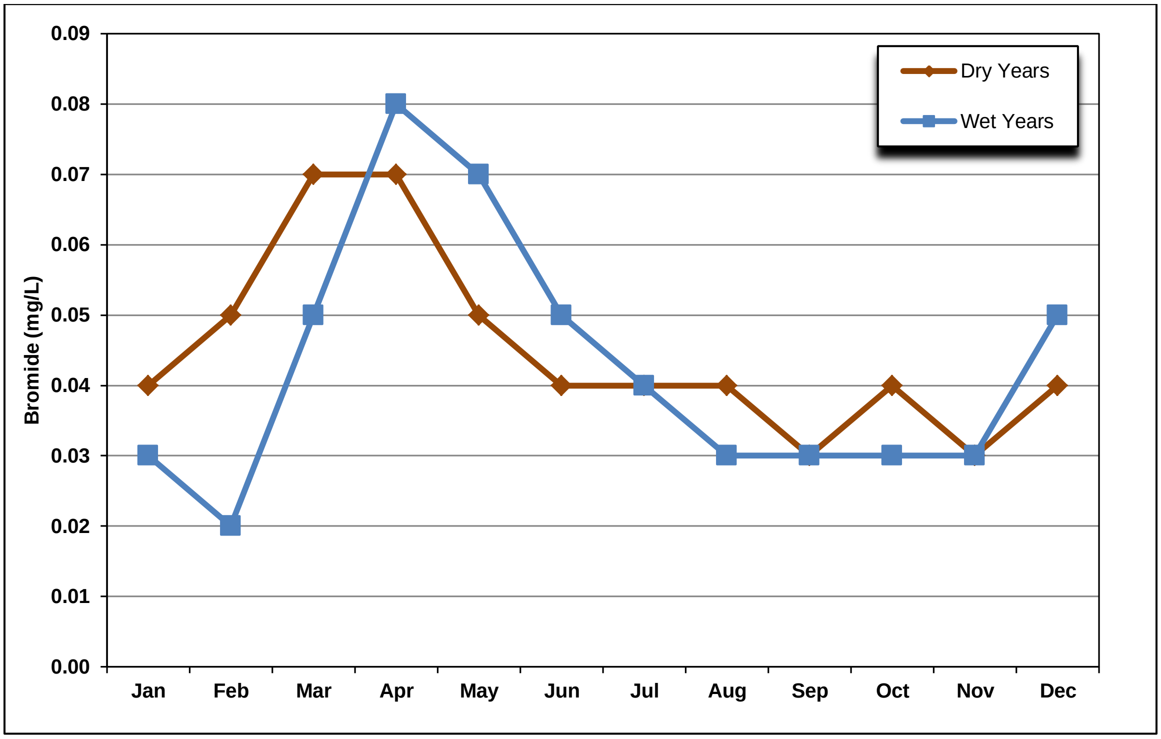
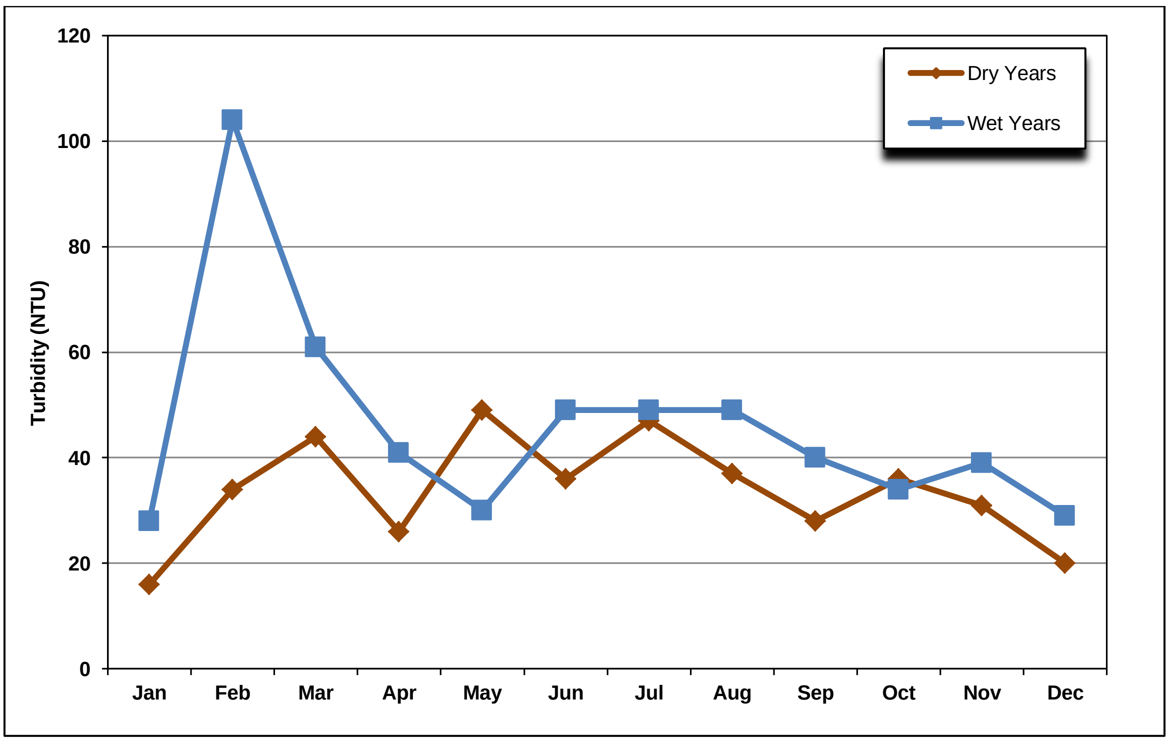


Figure 15-25. Median Turbidity at Barker Slough



Nutrients

The total N and total P data are shown in **Figure 15-26** and **Figure 15-27**, respectively. There are no statistically significant differences between the monthly median concentrations of total P in dry and wet years. August is the only month in which the total N median concentration in dry years is statistically significantly lower than the total N median concentration in wet years (Mann-Whitney, p=0.0266).

Conclusions on the Impacts of Drought on NBA Water Quality

When examined on a monthly basis, there are few statistically significant differences between wet and dry year monthly medians for TOC, bromide, and nutrients. During dry years, EC levels are higher during the wet months of January through April and turbidity levels are lower during the December to April period.

BANKS PUMPING PLANT

Table 15-2 presents a summary of the wet year/dry year comparison for each constituent discussed in Chapter 3. The dry year median levels of EC and bromide are statistically significantly higher than the wet year medians. The dry year median EC is 59 percent higher than during wet years and the median bromide concentration is 125 percent higher. These substantial differences have implications for water treatment and water management. The median turbidity is slightly lower in dry years but the 2 NTU difference does not have any meaningful impact on drinking water treatment. TOC, total N, and total P were not statistically significantly different when all of the wet year data were compared to all of the dry year data. The data were examined on a monthly basis to determine if there are times of the year when drought conditions have more of an impact on water quality pumped from the Delta than at other times.

Table 15-2. Summary of Wet Year/Dry Year Analysis at Banks

Constituent	Median Concentration		Comment
	Wet Years	Dry Years	
TOC (mg/L)	3.2	3.2	Not significant
EC (µS/cm)	312	497	Significant (p=0.0000)
Bromide (mg/L)	0.12	0.27	Significant (p=0.0000)
Turbidity (NTU)	10	8	Significant (p=0.0053)
Total N (mg/L)	0.82	0.99	Not significant
Total P (mg/L)	0.10	0.10	Not significant

Figure 15-26. Median Total Nitrogen Concentrations at Barker Slough

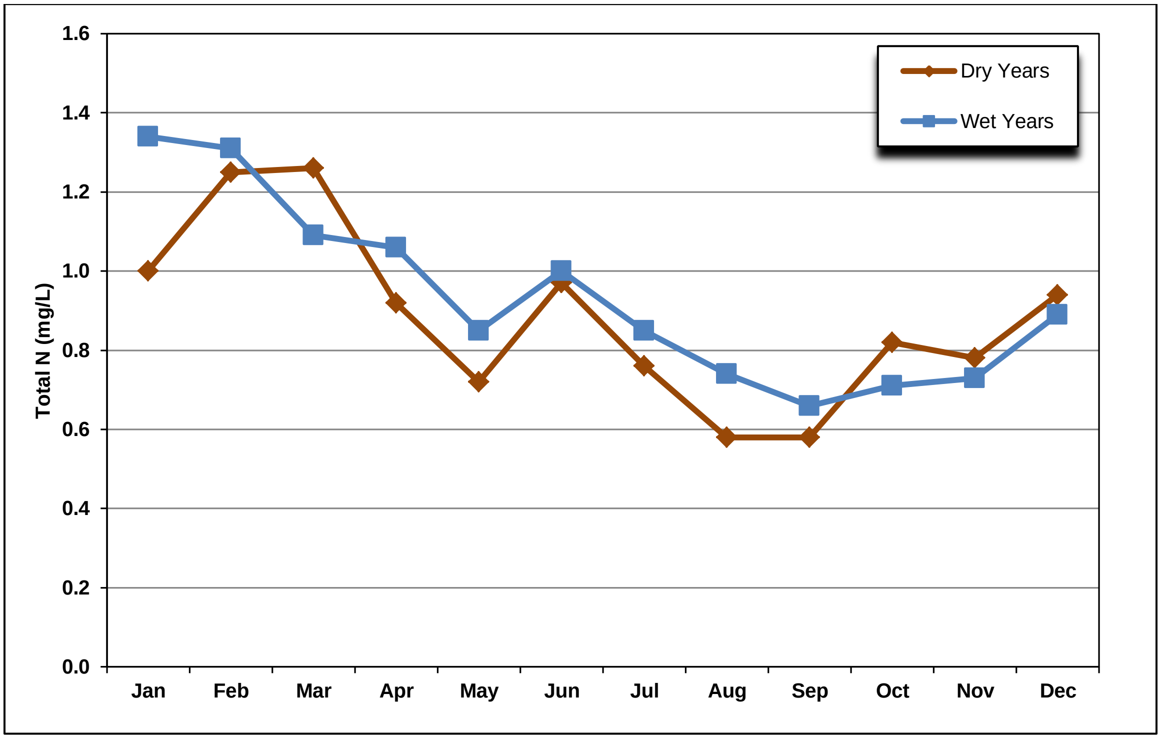
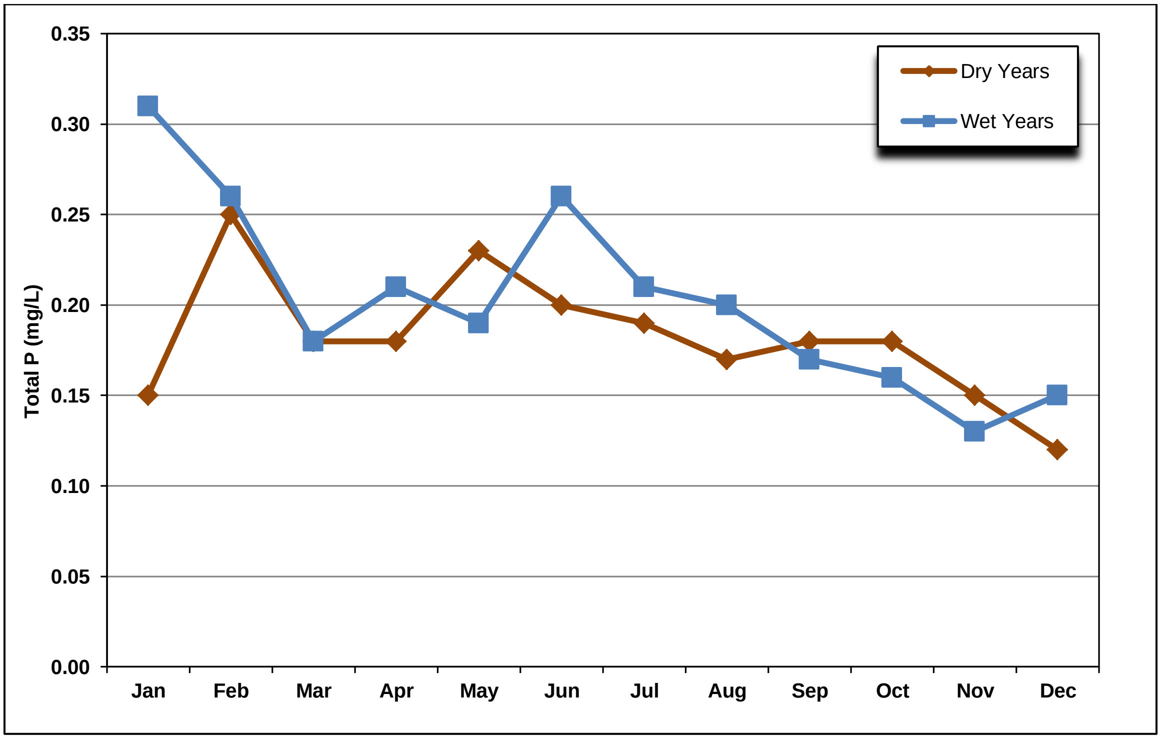


Figure 15-27. Median Total Phosphorus Concentrations at Barker Slough



Organic Carbon

Figure 15-28 presents the monthly median TOC concentrations for wet and dry years. The monthly median TOC concentrations in dry years are generally higher than or about the same as the monthly medians during wet years. The monthly medians during March, June, and September are statistically significantly higher during dry years than wet years (p=0.0164, 0.0416, and 0.0434). The wet year medians are statistically significantly higher in October (p=0.0420) and November (p=0.0354).

Salinity

EC levels are higher in every month of the year during dry years, as shown in **Figure 15-29.** The greatest differences occur during the July to September period when exports have historically been highest. This will continue to be the period when pumping will be highest under the operating rules of the biological opinions. The dry year median concentrations are statistically significantly higher from January through March and from June through September (p=0.0000 to p=0.0017). In April and May, the EC levels increase slightly over the levels found in March in wet years, whereas there is a decrease in EC during these months in dry years. This is due to the increasing flow on the San Joaquin River during the VAMP months. Seawater intrusion results in increasing levels of EC in both wet and dry years during the fall months.

Bromide

Figure 15-30 shows that bromide concentrations are much higher during the summer months of dry years. The monthly median bromide concentrations in January, February, and June through September of dry years are statistically significantly higher than the median concentrations in wet years (p=0.0000 to p=0.0180). The other six months of the year are not statistically significantly different.

Turbidity

Figure 15-31 presents the turbidity data for Banks. The dry year monthly median turbidity is statistically significantly lower than the wet year monthly median turbidity during July, August, and September (p=0.0030 to p=0.0211). There are no statistically significant differences in the monthly medians for the remaining months of the year.

Nutrients

The total N and total P data are shown in **Figure 15-32** and **Figure 15-33**, respectively. There are no statistically significant differences between the monthly median concentrations of total P in dry and wet years. September is the only month in which the total N median concentration in dry years is statistically significantly lower than the total N median concentration in wet years (Mann Whitney, p=0.0449).

Figure 15-28. Median TOC Concentrations at Banks

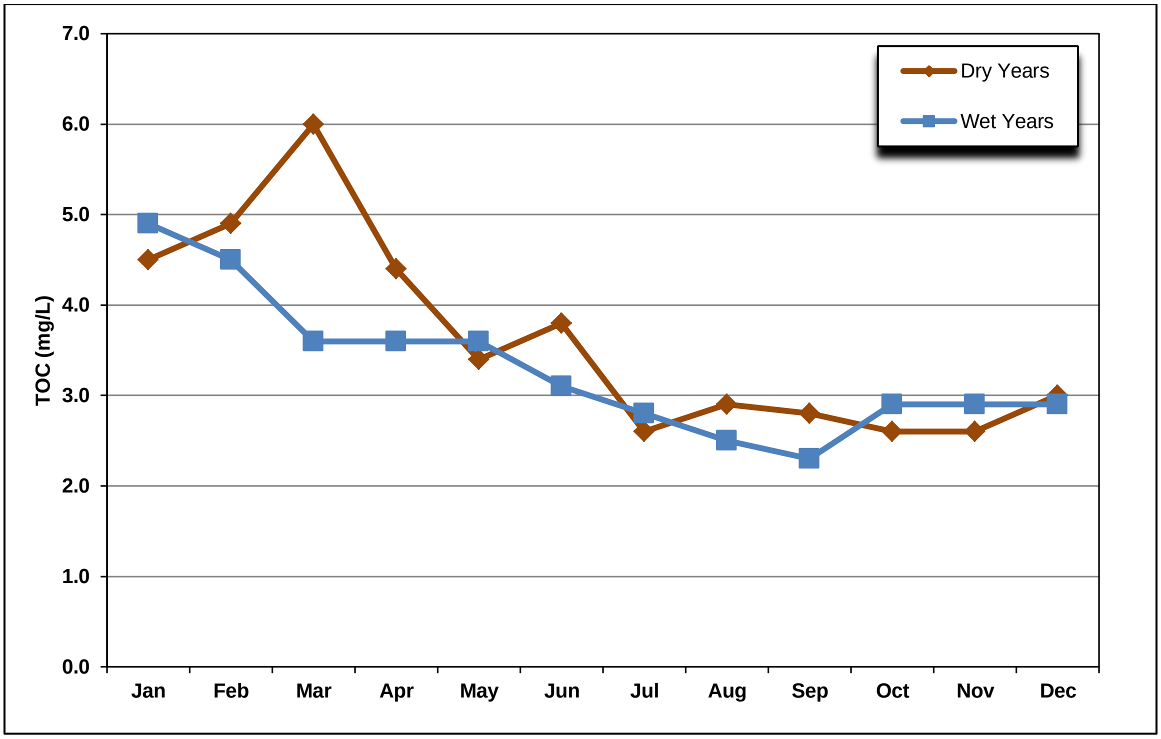


Figure 15-29. Median EC Levels at Banks

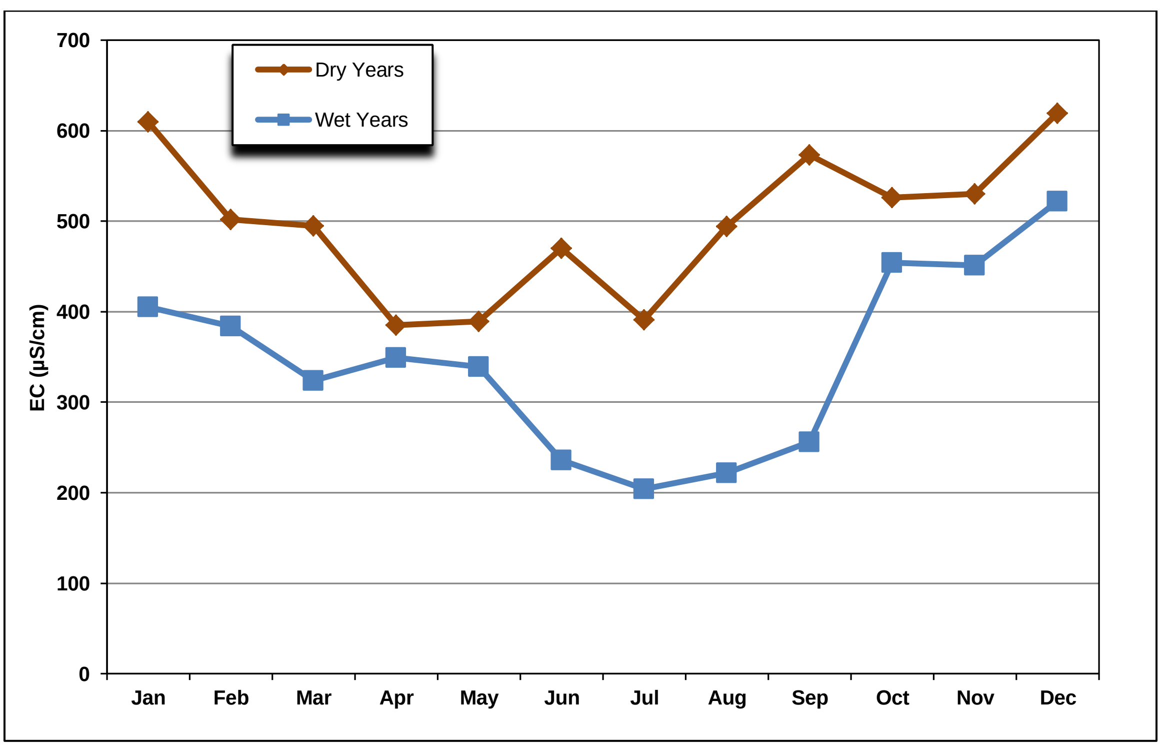


Figure 15-30. Median Bromide Concentrations at Banks

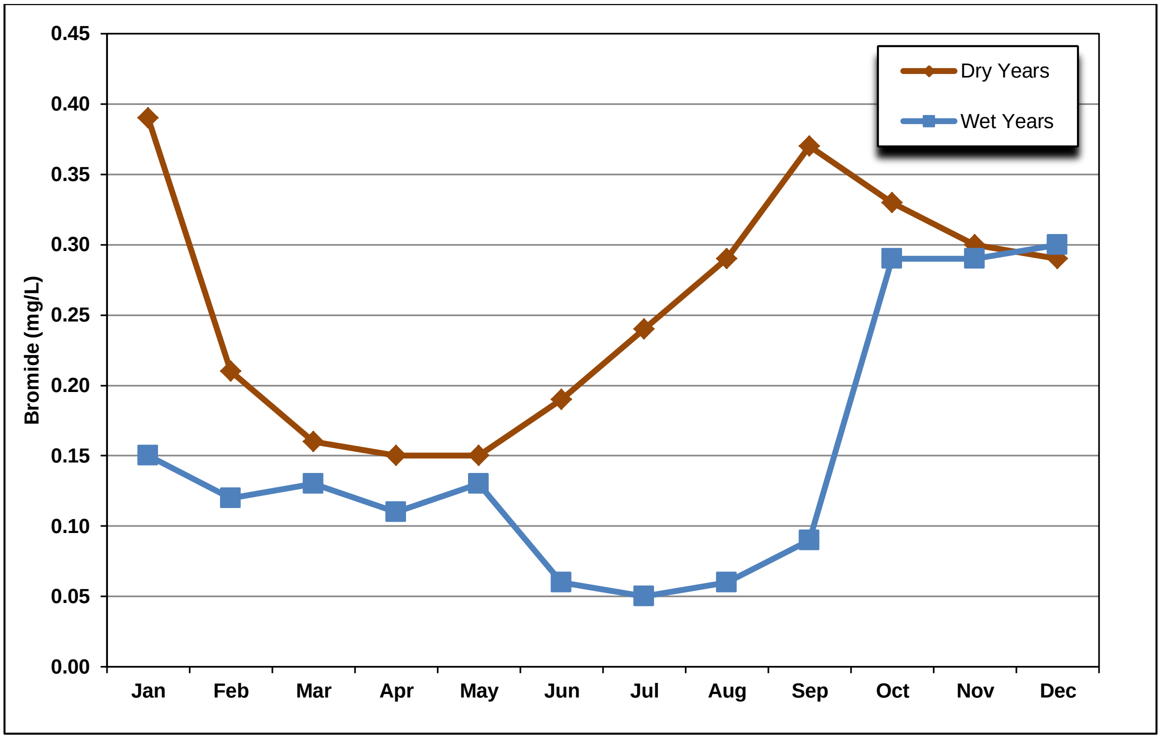


Figure 15-31. Median Turbidity at Banks

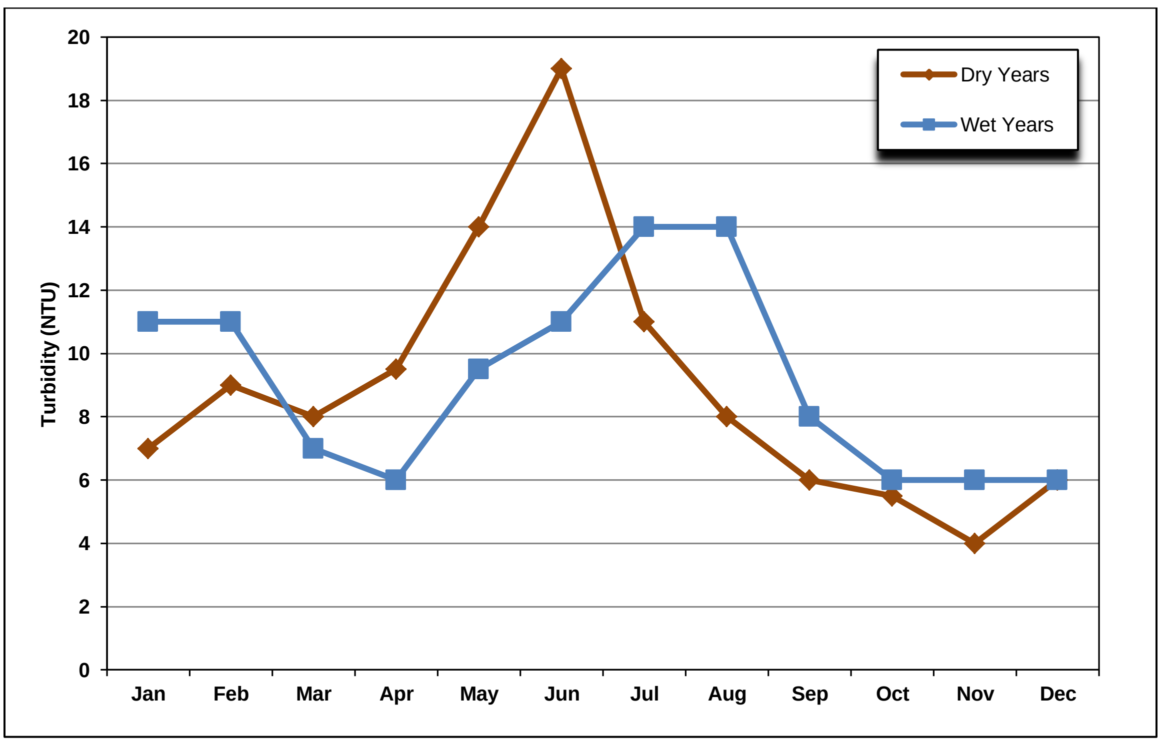


Figure 15-32. Median Total Nitrogen Concentrations at Banks

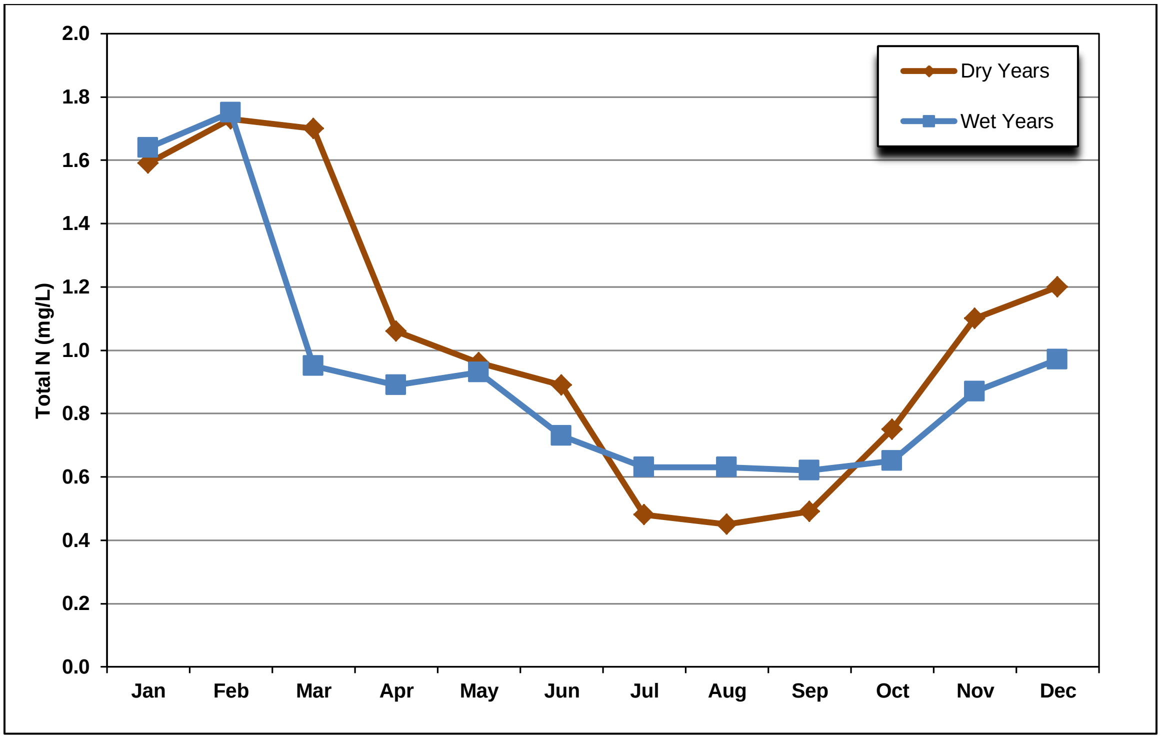
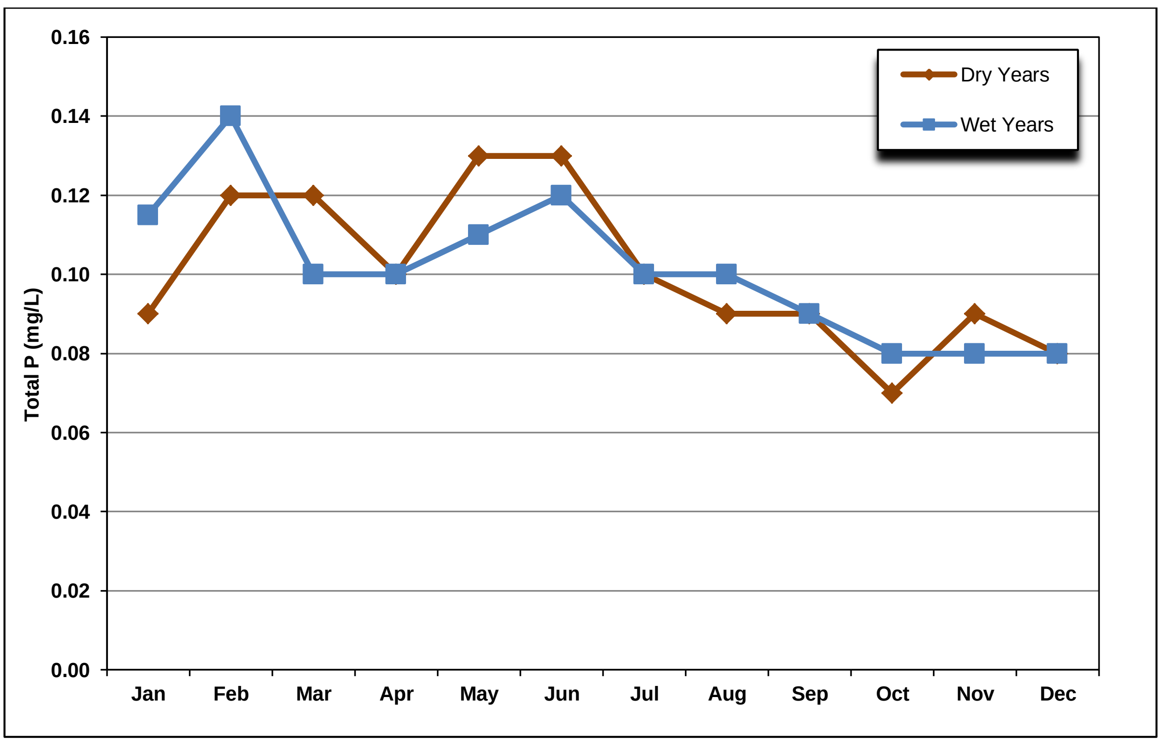


Figure 15-33. Median Total Phosphorus Concentrations at Banks



Conclusions on the Impacts of Drought on Banks Water Quality

When examined on a monthly basis, the substantial impact of dry years on EC and bromide are evident. During dry years, EC and bromide are statistically significantly higher in the summer months when exports are highest and in the winter months. Turbidity levels are statistically significantly lower during the summer months of dry years. TOC concentrations are higher during a few months of dry years and lower during other months, with no clear pattern. Nutrient concentrations are not statistically significantly different in dry years and wet years.

Potential Actions

None

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CHAPTER 16 FINDINGS AND RECOMMENDATIONS

CONTENTS

TABLES

CHAPTER 16 FINDINGS AND RECOMMENDATIONS

This chapter contains a discussion of the key findings from the System Environment, Water Quality, and Vulnerabilities chapters. The recommendations presented in this chapter are draft potential actions for consideration by the State Water Project (SWP) Contractors, the California Department of Public Health (CDPH) and the Department of Water Resources (DWR) Municipal Water Quality Investigations (MWQI) Program and the Division of Operations and Maintenance (O&M). These agencies will work with the consulting team to rank the draft recommendations and determine if, and how, they will be implemented. An Action Plan will be developed by September 2012 that describes each action in more detail, identifies the responsible entity, and lays out the schedule for implementation.

SYSTEM ENVIRONMENT

The System Environment chapter contains a discussion of drinking water regulations and source water protection regulations. This chapter also contains a discussion of the biological opinions and the various programs aimed at restoring the Sacramento-San Joaquin Delta (Delta) ecosystem while enhancing water supply reliability. Key findings and recommendations from the System Environment chapter are presented in this section.

DRINKING WATER REGULATIONS

Findings

The U.S. Environmental Protection Agency (USEPA) finalized a number of key drinking water regulations in the last five years, including the Stage 2 Disinfectants and Disinfection Byproducts Rule and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Key federal regulations that are being developed are:

- The Unregulated Contaminant Monitoring Rule 3 – This rule is scheduled to be finalized in 2012.
- The USEPA Health Effects Assessments – Health effects assessments are being completed for acrylamide, trichloroethylene, and tetrachloroethylene.
- USEPA Drinking Water Strategy – In February 2011 the USEPA announced that it will move forward with development of regulatory standards for a group of 16 carcinogenic volatile organic compounds. The USEPA also announced that the second group of contaminants to be addressed will be nitrosamine disinfection byproducts.
- Perchlorate – In February 2011, USEPA announced that it will develop a regulation for perchlorate under the Safe Drinking Water Act. A proposed rule is expected in early 2013 with a final rule by mid-2014.

In the last five years, CDPH reduced the arsenic Maximum Contaminant Level (MCL) from 50 to 10 µg/L and the Office of Environmental Health Hazard Assessment (OEHHA) published a chromium (VI) Public Health Goal (PHG). Key California regulations that are being developed are:

- Perchlorate – OEHHA proposed a revised PHG of 1 µg/L in January 2011. OEHHA published the results of an external peer review in November 2011 and is currently developing a revised draft PHG for public review. OEHHA currently does not have a schedule for issuing the final PHG

- Chromium (VI) – OEHHA released the final PHG of 0.02 µg/L in July 2011. CDPH will establish a MCL in the next several years.

- Total Trihalomethanes (TTHM) – OEHHA issued a draft PHG of 0.8 µg/L for TTHM in September 2010. OEHHA is in the process of establishing the final PHG but does not yet have a schedule for completing the process.

Recommendations

<u>Individual SWP Contractors and CDPH should keep MWQI informed of regulatory developments that may impact the MWQI monitoring program or lead to special studies</u>.

Individual SWP Contractors, CDPH, and water organizations such as the Association of California Water Agencies (ACWA) and California Urban Water Agencies (CUWA) track regulatory development for their members. While there is no need for the State Water Project Contractors Authority (SWPCA) to track the pending regulations, individual SWP Contractors and CDPH should keep MWQI apprised of any developments that could impact the monitoring program or special studies.

SOURCE WATER PROTECTION REGULATIONS

Findings

Source water protection is a key component of the multi-barrier approach to protecting drinking water quality. California has adopted many regulations to protect source water quality and there are several source water protection regulations that are under development. Key regulations that are being developed are:

- Industrial Stormwater General Permit – The State Water Resources Control Board (State Water Board) has proposed changes to the Industrial Stormwater General Permit. The State Water Board staff is responding to comments submitted in April 2011.

- Irrigated Lands Regulatory Program – The Central Valley Regional Water Quality Control Board (Central Valley Regional Water Board) is developing a long-term regulatory program to replace the interim program.

- Proposed Statewide Nutrient Policy – The State Water Board is developing a new regulatory program for nutrients in inland surface waters.

- Total Maximum Daily Loads (TMDLs) – The Central Valley Regional Water Board is currently developing mercury and DO TMDLs and a Central Valley TMDL for diazinon and chlorpyrifos The board is planning to work on a Central Valley TMDL for pyrethroid pesticides in the near future.

- Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) – This is a multi-year effort to address salt, boron, and nitrate in the Central Valley.

- Central Valley Drinking Water Policy – This is a multi-year effort to develop a policy to protect source water quality for key drinking water constituents. The Drinking Water Policy is currently under development and will be considered by the Central Valley Regional Water Board in July 2013.

Recommendations

<u>MWQI and CDPH should participate in regulatory development and provide comment letters on source water protection programs and regulations, when feasible.</u>

Individual SWP Contractors and water organizations such as ACWA and CUWA track regulatory development for their members. While there is no need for SWPCA to track the pending regulations, SWPCA, MWQI, and CDPH staff should lend support to organizations such as CUWA. CUWA has historically notified MWQI and CDPH when critical permits and regulatory programs are being developed in which MWQI and CDPH staff can contribute based on their knowledge of drinking water issues, the Delta, and the SWP watershed. MWQI and CDPH should continue to participate in these processes, when feasible.

BIOLOGICAL OPINIONS

Findings

The U.S. Fish and Wildlife Service (USFWS) is required to issue biological opinions on projects that have the potential to impact federally listed threatened and endangered species. Similarly, the National Marine Fisheries Service (NMFS) is required to issue biological opinions on projects that have the potential to impact federally listed marine and anadromous fish species. Biological opinions have been issued for delta smelt by the USFWS and for winter-run and spring-run Chinook salmon, steelhead, green sturgeon, and killer whales by NMFS. The biological opinions were challenged by the State Water Contractors (SWC) and other water organizations and were revised and challenged again. Both USFWS and NMFS are currently revising the biological opinions.

Recommendations

None.

The SWC has historically taken the lead on tracking and responding to the biological opinions. There is no need for SWPCA or MWQI to track and comment on the revised biological opinions when they are reissued by USFWS and NMFS.

POLICY SETTING

Findings

In the last five years there have been numerous activities and programs aimed at restoring the Bay-Delta ecosystem and improving water supply reliability. The key ongoing activities that address water quality or could impact water quality in the Delta are:

- The Delta Stewardship Council's Delta Plan – The Delta Plan is scheduled for adoption in the fall of 2012.

- The Delta Conservancy's Strategic Plan – The Strategic Plan is scheduled for completion by early 2013.

- The Bay Delta Conservation Plan (BDCP) – A public review draft BDCP is expected to be completed by September 2012. Following a public review period, a final BDCP will be prepared. The impacts of the plan on environmental and drinking water quality will be evaluated in the Environmental Impact Report/Environmental Impact Statement (EIR/EIS) which is on the same schedule as the BDCP.

- USEPA Advanced Notice of Proposed Rulemaking (ANPR) – USEPA Region 9 issued an ANPR on February 10, 2011. This ANPR initiates an assessment of the effectiveness of current programs designed to protect ecosystem water quality and aquatic species habitat in the Bay Delta Estuary. USEPA expects to release a synthesis report in the spring of 2012 and then determine if new regulations are needed.

- San Joaquin River Restoration Program – The effort to restore the San Joaquin River involves restoring flows to about 60 miles of dry river bed and significant improvements to channels, levees, and fish passages. There have not been any studies done on the impact of the increased flows on water quality in the San Joaquin River and at the Delta pumping plants.

- Delta Wetlands Project – The Delta Wetlands Project involves creating storage reservoirs on Webb Tract and Bacon Island and creating wetlands and wildlife habitat on Bouldin Island and Holland Tract in the central Delta. The Final EIR on the project was certified in September 2011. Delta Wetlands Properties is currently pursuing a water right permit with the State Water Board.

Recommendations

SWPCA and MWQI should continue to track projects that could impact Delta water quality.

SWPCA and MWQI have historically tracked projects that could impact Delta water quality and have provided comments to the appropriate regulatory agency. This effort should continue. High priority activities with the most potential to impact water quality include the BDCP and the Delta Wetlands Project.

SWPCA and MWQI should review the Draft BDCP EIR/EIS and submit comments on the Water Quality Section and Appendices.

The Draft BDCP EIR/EIS is scheduled to be released in September 2012. SWPCA and MWQI should review these documents and submit comments on the water quality sections to ensure that the impacts on drinking water quality have been adequately addressed.

WATER QUALITY IN THE WATERSHEDS AND THE STATE WATER PROJECT

The Water Quality chapters (3 through 11) contain a discussion of organic carbon, electrical conductivity (EC), bromide, nutrients, taste and odor (T&O) incidents and algal toxins, turbidity, pathogens, and organic chemicals and trace elements at a number of key locations along the SWP. Chapter 12 contains a discussion of the latest research on constituents of emerging concern (CECs). Key findings and recommendations from the Water Quality chapters are presented in this section.

MONITORING PROGRAM

Findings

DWR's MWQI Program and the O&M Division conduct a comprehensive water quality monitoring program of the Delta and the SWP facilities. The long period of record at many locations allows the data to be analyzed for spatial trends, long-term trends, and seasonal trends. Most of the data has been entered into DWR's Water Data Library. This online database is a valuable tool that provides easy access to the data shortly after it has been collected.

Recommendations

MWQI, O&M, and other DWR divisions should continue to enter data analyzed at other laboratories in the Water Data Library, when feasible.

When data are analyzed by outside laboratories, the data are not automatically entered into the Water Data Library. For example, the 2-methylisoborneol (MIB) and geosmin data analyzed by Metropolitan Water District of Southern California (MWDSC) are transmitted to the SWP Contractors in Excel files to provide quick access to the data. This should be continued; however, the data should subsequently be entered into the Water Data Library to provide a permanent record. Bacteria and pathogen data are another example of data that should be entered into the Water Data Library. Analytical methods, detection limits, and all other information normally included for samples analyzed at DWR's laboratory should also be included when data from other laboratories are entered into the Water Data Library.

<u>O&M should enter all historical data collected on the SWP in the Water Data Library</u>.

MWQI conducted an analysis of all of its data in 2011 to determine if it had been entered into the Water Data Library. The O&M Division has conducted a similar analysis and has plans to enter all remaining data; however, it is currently not a high priority due to limited staff resources. Examples of missing data include total organic carbon (TOC) data at the Harvey O. Banks Delta Pumping Plant (Banks) between 1989 and 1998 and data collected at the check structures along the Governor Edmund G. Brown California Aqueduct (California Aqueduct) prior to December 1997. The SWP Contractors should consider providing financial assistance to ensure that the data are entered into the Water Data Library.

REAL-TIME MONITORING

Findings

The real-time monitoring equipment operated by MWQI and O&M provides valuable data on the quality of water in the Delta and the SWP. The real-time equipment provides more information on the day-to-day variability in water quality that is not always captured with the grab sample monitoring. There is good correspondence between the real-time data and grab samples collected on the same day in most instances. There are a few locations where there are anomalies when comparing the real-time and grab sample data. A rigorous statistical analysis of the data was beyond the scope of this effort; however, **Table 16-1** lists the locations and constituents which appear to be problematic. In some cases, there are long periods of time when an instrument was clearly providing erroneous readings (e.g. EC at Castaic Outlet for 2008 and 2009).

Recommendations

<u>O&M should evaluate the real-time and grab sample data to determine if the apparent anomalies are real, and if they are, determine what corrective action is needed</u>.

O&M should conduct a more rigorous analysis of the real-time and grab sample data listed in **Table 16-1** to determine if there are problems with the real-time instruments that can be corrected with more frequent maintenance.

<u>O&M and the SWP Contractors should review the real-time data frequently to allow instrument malfunctions to be detected and quickly corrected</u>.

In some cases, there are long periods of time when an instrument was clearly providing erroneous readings. These problems could be caught and corrected by reviewing the real-time data on a regular basis

Table 16-1. Real-time Equipment Anomalies

Location	Constituent	Issue
Vernalis	EC	The real-time sampler does not often measure the peak levels above 1,000 µS/cm that are measured in the grab samples.
Banks	EC	The real-time sampler peak levels are often higher than grab samples collected on the same day.
Cordelia	EC	The real-time measurements are generally lower than the grab samples.
Devil Canyon	EC	The real-time measurements are often higher than the grab samples.
Banks	Turbidity	The real-time measurements are systematically higher than the grab samples.
Barker	Turbidity	The real-time measurements are routinely higher than the grab samples.
Cordelia	Turbidity	The real-time measurements are routinely higher than the grab samples.
DV Check 7	Turbidity	The real-time measurements are often substantially higher than the grab samples.
O'Neill Forebay Outlet	Turbidity	The real-time measurements are often substantially higher than the grab samples.
Devil Canyon	Turbidity	The real-time measurements are often lower than the grab samples.

INFLUENCE OF THE SAN JOAQUIN RIVER

Findings

The volumetric, dissolved organic carbon (DOC), and EC fingerprints produced by DWR's Modeling Section are valuable tools that help to interpret the water quality conditions in the Delta. The fingerprints show that at times, the San Joaquin River greatly influences the quality of water at the C.W. "Bill" Jones Pumping Plant (Jones) and at Banks. The San Joaquin River contains statistically significantly higher levels of TOC, EC, bromide, turbidity, and nutrients than the Sacramento River.

Recommendations

<u>MWQI should conduct a review of literature and data collected on the San Joaquin watershed</u>.

This review should identify the sources of key drinking water contaminants in the watershed and identify any data and information gaps. This information will be valuable in evaluating the results from the Watershed Analysis and Risk Management Framework (WARMF) model for the San Joaquin watershed which is under development. This effort should be coordinated with CV-SALTS to determine if the necessary information on salt and nitrate has been developed through that effort.

WATER QUALITY TRENDS

Findings

All available water quality data at a number of locations in the watersheds, the Delta, and along the SWP facilities were evaluated for the SWP Watershed Sanitary Survey 2011 Update. The data were evaluated to determine if there are long-term trends, spatial trends, and differences between wet and dry years.

Long-term Trends

There are no apparent long-term trends in the water quality data at any of the locations evaluated for this project. In 2009, MWQI staff conducted a long-term trend analysis for the Sacramento River at Hood (Hood), the San Joaquin River at Vernalis (Vernalis), and Banks. Trends were analyzed for the entire period of record through 2008 at each location and for the 1999 to 2008 period. Different results were obtained for the different periods of time. For example, the analysis showed a declining trend in DOC at all three locations during the longer period and an increasing trend at Hood and Vernalis and no trend at Banks during the more recent period. This analysis showed that trends are very much a function of the hydrology of the system during the starting and ending points of the analysis. Another TOC trend analysis conducted at Banks between 1990 and 2003 by O&M staff reached the same conclusion. O&M staff conducted an assessment of long-term salinity trends at Banks using data from 1970 to 2002 and concluded that the salinity in SWP exports has neither increased nor decreased over that period. Visual inspection of time series graphs for a number of other constituents and locations also shows that water quality trends can be explained by evaluating the hydrologic conditions at the start and end of the trend analysis period.

Spatial Trends

The data were analyzed to determine if water quality changes as the water flows down the California Aqueduct and is stored in reservoirs. Factors that could potentially affect water quality include:

- NBA – The NBA is an enclosed pipeline so water quality should not change between Barker Slough and the water treatment plant intakes.
- Banks to South Bay Aqueduct (SBA) Terminal Tank – Water from Lake Del Valle enters the SBA below Del Valle Check 7 (DV Check 7). This primarily affects SBA water quality in the fall months when releases are made to the SBA.
- Banks to O'Neill Forebay – There are no inputs to the California Aqueduct in this reach.
- O'Neill Forebay and San Luis Reservoir – Water from the Delta-Mendota Canal (DMC) mixes with water from the California Aqueduct in O'Neill Forebay. Storage in San Luis Reservoir and the timing of filling and releases from the reservoir can potentially impact water quality.

- San Luis Canal Reach of the California Aqueduct – Local streams that run eastward from the Coastal Range Mountains bisect the aqueduct at various points. During storms, water from some of these streams enters the aqueduct.

- Coastal Branch of the California Aqueduct – The Coastal Branch is 115 miles long; the first 15 miles are open aqueduct and the remainder is a pipeline. No drainage enters the open canal section.

- California Aqueduct between Check 21 and Check 41 – This reach of the aqueduct is used to convey both surface water and groundwater acquired through transfers and exchanges among local agencies. The quality of the non-Project inflows can affect the quality of the water in the aqueduct. This topic is addressed in Chapter 14.

- West Branch of the California Aqueduct – Pyramid and Castaic lakes provide almost 500,000 acre-feet of storage, which greatly reduces the fluctuations in water quality seen in the aqueduct. Natural inflow from the watersheds of the reservoirs can affect water quality during substantial storm events.

- East Branch of the California Aqueduct – Silverwood Lake has a capacity of only 74,970 acre-feet and does not moderate water quality the way the West Branch reservoirs do. Natural inflow from its watershed can affect water quality at times.

This analysis included an evaluation of all of the data at each monitoring location. The data collected during comparable periods of time at all locations were analyzed to draw conclusions about spatial trends. The data were statistically analyzed using the non-parametric Mann-Whitney test which determines if the data sets being compared are statistically different. The median concentrations are representative of the entire data set. The key findings are:

- Median TOC concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct when data collected during comparable periods of time are aggregated and analyzed. The median TOC concentrations along the aqueduct range from 3.0 to 3.2 mg/L. San Luis Reservoir and Castaic Lake have less variability in TOC concentrations than the aqueduct due to the dampening effect of reservoir mixing. The dampening effect is not seen in Silverwood Lake on the East Branch due to its limited hydraulic residence time. When examined on a finer time scale, differences in TOC occur between O'Neill Forebay Outlet and Check 21. The peak concentrations of TOC at Check 21 occurred approximately one month later than at O'Neill Forebay Outlet in 2008, 2009, and 2010 and the peak concentrations were about 1 mg/L lower at Check 21. The shift in the timing of the peak is likely due to low flows in the aqueduct during this period. The lower TOC concentrations at Check 21 compared to O'Neill Forebay Outlet during the 2007 to 2010 period are inexplicable. A small amount of groundwater (12,581 acre-feet) was pumped into this reach of the aqueduct by Westlands Water District (Westlands) in the summer of 2008, but that does not explain the differences during the spring of 2008, 2009, and 2010. Changes in TOC concentrations are apparent in the aqueduct during periods when non-Project inflows are introduced between Checks 21 and 41.

- Although, there are no apparent differences in median TOC concentrations when all available data are aggregated, the quality of organic carbon changes. Water in San Luis Reservoir has a greater propensity to form disinfection byproducts during the spring and summer months (Krause et al., 2011). This is the period when most water is released from the reservoir and flows south in the California Aqueduct.

- Changes to EC in the California Aqueduct and SWP reservoirs are complex. There is a statistically significant increase of 63 µS/cm between Banks and O'Neill Forebay Outlet due to storage in San Luis Reservoir and to mixing with water from the more saline DMC in O'Neill Forebay. However, there is not a significant change in EC between O'Neill Forebay Outlet and Check 21. There is a statistically significant decrease in EC between Check 21 and Check 41 of 16 µS/cm. This is likely due to non-Project inflows of lower EC water in recent years. The median EC at Castaic Lake Outlet (Castaic Outlet) is 57 µS/cm higher than at Check 41 but there is no significant change between Check 41 and Devil Canyon Afterbay (Devil Canyon).

- There is a statistically significant increase in bromide concentrations between Banks (median of 0.18 mg/L) and O'Neill Forebay Outlet (median of 0.22 mg/L) due to the release of water from San Luis Reservoir that has high bromide concentrations (median of 0.25 mg/L). Bromide does not change significantly between O'Neill Forebay Outlet and Check 21. The median bromide concentration of 0.21 mg/L at Check 41 is not statistically different from the median bromide concentration of 0.22 mg/L at Check 21. However, during periods when non-Project inflows are introduced to the aqueduct, the bromide concentrations at Check 41 are lower than the concentrations at Check 21. The median bromide concentration at Castaic Outlet of 0.21 mg/L is the same as at Check 41. The median bromide concentration at Devil Canyon of 0.19 mg/L is not statistically different from the median bromide concentration of 0.21 mg/L at Check 41.

- Turbidity levels are quite variable as water moves down the aqueduct but the impact of settling in reservoirs is quite apparent in that median turbidity levels in the reservoirs are 1 to 2 NTU.

- Nutrient concentrations do not change as water flows from the Delta through the SBA and the California Aqueduct. Median total nitrogen (total N) concentrations are about 1.0 mg/L and median total phosphorus (total P) concentrations are about 0.1 mg/L throughout the system. Nutrient concentrations are substantially lower in Castaic Lake and Lake Perris.

Wet Year and Dry Year Trends

The data were analyzed to determine if there are water quality differences between wet years and dry years. Wet years are defined as those that are classified as wet and above normal. Dry years are defined as those that are classified as below normal, dry, and critical.

- There are no statistically significant differences between median TOC concentrations in dry years and wet years at many of the locations along the aqueduct.

- EC levels during dry years are statistically significantly higher than EC levels during wet years at all locations except Barker Slough and Castaic Outlet. There were no statistically significant differences between year types at these two locations. The higher levels during dry years are due to less dilution of agricultural drainage, urban runoff, and wastewater discharged to the rivers and Delta during low flow periods and to seawater intrusion in the Delta during periods of low Delta outflow.

- Bromide concentrations during dry years are statistically significantly higher than bromide concentrations during wet years at all locations except Barker Slough. There were no significant differences between year types at this location. The median bromide concentrations during dry years are 50 to 100 percent higher than the median concentrations during wet years. This is due primarily to seawater intrusion in the Delta during periods of low Delta outflow.

- Turbidity levels are statistically significantly lower during dry years than wet years at most locations that were included in this analysis. At several locations, including San Luis Reservoir and Castaic Lake, there was no significant difference between dry and wet years.

- Comparison of nutrient concentrations in dry years and wet years does not produce a consistent pattern throughout the system. At many locations, there are no differences between dry and wet years. At Hood and Vernalis, total P concentrations are not statistically different between dry years and wet years but total N concentrations are statistically significantly higher during dry years. This may be due to the greater influence of the Sacramento Regional Wastewater Treatment Plant (SRWTP) at Hood and to agricultural drainage at Vernalis. At Pacheco Pumping Plant in San Luis Reservoir (Pacheco), both total N and total P are statistically significantly lower in dry years. This is likely due to algal uptake and settling in the reservoir since samples are collected in the epilimnion of the reservoir more frequently during dry years when water levels are lower. The pattern at Castaic Lake is different with both total N and total P being statistically significantly higher in dry years. Check 41 and Devil Canyon show the same pattern of higher total N concentrations in dry years and lower total P concentrations in dry years. This may be related to non-Project inflows that occur more frequently in dry years.

- Median total P concentrations in dry years and wet years are the same at most locations. Dry year total P medians are statistically significantly lower than wet year medians at Pacheco, Check 41, Castaic, and Devil Canyon. Dry year total N medians are statistically significantly higher than wet year medians at about half of the locations and the same at the other locations.

Recommendations

O&M should conduct an analysis of the changes in water quality between O'Neill Forebay Outlet and Check 21.

The analysis should include a review of TOC and other constituents to examine the seasonal patterns. The changes between O'Neill Forebay Outlet and Check 21 should be related to flows in the aqueduct, inflows to the aqueduct, and any other factors that could affect water quality between the two locations.

TASTE AND ODOR INCIDENTS AND ALGAL TOXINS

Findings

Monitoring of MIB and geosmin was initiated at a number of locations in the SWP between 2001 and 2005. Monitoring was initiated for the NBA in 2009. The samples are quickly analyzed and email reports are sent to the SWP Contractors alerting them to potential T&O problems.

- The NBA Contractors experienced a severe T&O episode in February 2009 that resulted in numerous customer complaints when geosmin concentrations quickly increased to over 300 ng/L. The likely T&O producer was *Aphanizomenon gracile*. The NBA had to be shut down for over six weeks, resulting in a significant loss of Delta water for the NBA Contractors. The Solano County Water Agency works with DWR to monitor T&O compounds and to periodically treat Campbell Lake, a small impoundment upstream of the Barker Slough Pumping Plant. The combination of monitoring to detect problems and treatments has been effective since the NBA users have had no further customer complaints.

- Problematic levels of MIB and geosmin occur in the Delta, along the California Aqueduct, and in southern California reservoirs. MIB and geosmin peaks in excess of 10 ng/L have occurred at Clifton Court every summer since monitoring was initiated in 2003. Geosmin concentrations have exceeded 10 ng/L every year and MIB concentrations have exceeded 10 ng/L in five of the ten years that monitoring has been conducted at Banks.

- The peak levels of MIB and geosmin at Banks are quickly transported to the SBA. MIB and geosmin concentrations at DV Check 7 exceeded 10 ng/L every summer between 2003 and 2007 and again in 2010. MIB from the Delta is transported down the California Aqueduct to O'Neill Forebay Outlet but the concentrations decrease with distance down the aqueduct. Castaic Lake has extremely high levels of geosmin every summer (up to 830 ng/L) and occasional MIB peaks greater than 10 ng/L. Silverwood Lake has peaks of both compounds that exceed 10 ng/L but do not reach the high levels found in Castaic Lake.

DWR has monitored *Microcystis aeruginosa* blooms for their ecological consequences for a number of years. Monitoring for microcystins in drinking water supplies started in 2006.

- *M. aeruginosa* blooms have occurred routinely in the summer months in the Delta since 1999. While blooms are found throughout the Delta, the highest cell densities are routinely found in the south Delta in the Old River and the Middle River.

- DWR conducted cyanotoxin monitoring at various locations in the SWP for four years. In 2007, microcystin-LR was detected at all locations that were monitored, except Barker Slough. It was below the reportable limit of 1 µg/L.

Recommendations

<u>The SBA Contractors should consider analyzing T&O samples from Banks and the SBA in their laboratories</u>.

Due to the proximity of the SBA to Banks Pumping Plant, water moves quickly into the SBA and T&O issues occasionally arise in the SBA before the weekly email reports reach the SBA Contractors. While the SBA Contractors can monitor general trends in MIB and geosmin over the course of several weeks, there can be times when the concentrations increase rapidly. O&M currently ships the samples to MWDSC for analysis in its laboratory. If the SBA Contractors analyzed the Banks and SBA samples, the information could be available to them within 24 hours of sample collection rather than several days after the samples are collected.

PATHOGENS

Findings

All SWP Contractors have completed their LT2ESWTR monitoring and all have been classified in Bin 1, meaning *Cryptosporidium* levels are low (running annual average of less than 0.075 oocysts/L), so no additional action related to *Cryptosporidium* is required at this time. An evaluation of the total coliform, fecal coliform, and *E. coli* data indicates that 2-log *Cryptosporidium*, 3-log *Giardia*, and 4-log virus removal and inactivation is the appropriate level of treatment for all SWP Contractors.

There were limitations in conducting statistical analysis of the coliform data at some sampling locations due to peak values being reported as greater than an upper limit, rather than being enumerated. This is due to insufficient dilution of the samples.

Recommendations

<u>SWP Contractors should consider using *E. coli* as the fecal indicator organism</u>.

Most SWP Contractors are using *E. coli* as the fecal indicator organism. Two agencies (City of Fairfield and Palmdale Water District) are using fecal coliforms. These agencies should consider converting to or adding *E. coli* as their source water fecal indicator. *E. coli* has been determined by USEPA to be a better indicator of the potential presence of protozoa and is used under the LT2ESWTR.

Coliform samples should be adequately diluted to allow enumeration of peak values.

The SWP Contractors should review their coliform data results to determine if and when peak values exceeded enumeration limits (results reported as greater than an upper limit) and if so, develop a plan to require dilution by the lab during periods that are projected to have elevated coliform levels to provide enumerated values for coliform.

CONSTITUENTS OF EMERGING CONCERN

Findings

Studies on the occurrence, fate, and transport; health effects; analytical methods; and removal of CECs in drinking water and wastewater have been completed in the last five years. The five most frequently detected chemicals in surface water in a recent nationwide study were cholesterol, metolachlor, cotinine, β-sitosterol, and 1,7-dimethylxanthine (Focazio et al., 2008). Another study showed the five most frequently detected chemicals in raw waters were sulfamethoxazole, carbamazepine, atrazine, phenytoin, and meprobamate (American Water Works Research Foudation, 2008).

In 2010, the National Water Research Institute, MWDSC, and Orange County Water District completed a source, fate, and transport study of endocrine disrupting compounds (EDCs), pharmaceuticals, and personal care products (PPCPs) that included eleven sampling sites associated with the SWP (Guo et al., 2010). Of the 49 PPCPs and organic wastewater contaminants analyzed, 21 analytes were detected at or above the minimum reporting level, whereas the other 28 were not detected at all locations with the existing minimum reporting levels. The six most frequently detected CECs were carbamazepine, diuron, sulfamethoxazole, caffeine, primidone, and tris (2-chloroethyl) phosphate (TCEP). The highest concentrations of many of the most frequently detected compounds were found in samples from the San Joaquin River at Holt Road, just downstream of the Stockton Regional Wastewater Control Facility (Stockton WWCF). Certain PPCPs (carbamazepine, primidone, gemfibrozil, and sulfamethoxazole) are highly attenuated as water moves downstream along the California Aqueduct. However, detectable levels of some PPCPs were found at terminal reservoirs in southern California. The NWRI study concluded there is no evidence of human health risk from low levels of the commonly detected EDCs and PPCPs in drinking water or drinking water supplies; however, more toxicological studies are needed.

MWDSC and MWQI completed a two-year study in April 2010 of the sources and occurrence of N-nitrosodimethylamine (NDMA), other nitrosamines, and their precursors in the Delta (DiGiorgio et al., 2010). The only instantaneous nitrosamine detected was NDMA, once at the Mossdale sampling location at 4.2 ng/L, and once at the Vernalis sampling location at 2.5 ng/L. NDMA formation potential concentrations were generally two to four times higher downstream of the SRWTP and the Stockton WWCF). The second phase of this study began in early 2011.

The State Water Board convened a CEC Science Advisory Panel to develop guidance for the establishment of monitoring programs to assess potential CEC threats from water recycling activities. The final report identified four indicator compounds based on their toxicological relevance for groundwater recharge projects: NDMA, 17 beta-estradiol, caffeine, and triclosan.

Four additional CECs were identified as viable performance indicators (N,N-Diethyl-meta-toluamide (DEET), gemfibrozil, iopromide, and sucralose).

Recommendations

SWPCA should track on-going research on PPCPs and EDCs.

The Water Research Foundation has a number of CEC-related studies in progress regarding analytical methods, planning monitoring programs, statistical tools, and consumer perceptions towards EDCs and PPCPs. Some of the SWP Contractors are participating in these studies. The SWP Contractors should stay apprised of recent research. Some of the ongoing studies to track are:

- Evaluation of Analytical Methods for EDCs and PPCPs via Inter-Laboratory Comparison #4167
- Water Utility Framework for Responding to Emerging Contaminant Issues - #4169
- Building a National Utility Network to Address EDC/PPCP Issues - #4261
- EDC/PPCP Benchmarking and Monitoring for Drinking Water Utilities - #4260
- Consumer Perceptions and Attitudes Toward EDCs and PPCPs in Drinking Water #4323

In addition, the USEPA Endocrine Disruptor Screening Program is underway and will determine which chemicals are of greatest risk for endocrine disruption to the environment and to human health.

SWPCA should work with both the City of Sacramento and the County of Sacramento on proper disposal instructions.

Controlling these contaminants at the source will likely be most cost-effective and will result in benefits to drinking water and aquatic organisms. The websites for the City and the County do not clearly address disposal of medications. The SWP Contractors should work with the City and the County to ensure information on proper disposal of unused PPCPs and locations where residents can safely dispose of medications is available on their respective websites. Many consumers are advised by their pharmacists to dispose of unneeded drugs by flushing them down the toilet or pouring them down the drain.

KEY WATER QUALITY VULNERABILITIES OF THE SACRAMENTO-SAN JOAQUIN DELTA

Chapter 13 contains a discussion of the key water quality vulnerabilities of the Delta. The findings and recommendations for each of the specific topics discussed in Chapter 13 are presented in this section.

WASTEWATER TREATMENT PLANTS

Findings

There are 12 wastewater treatment plants that discharge directly to the Delta and many others that discharge to tributaries of the Delta. Wastewater treatment plants in the SWP watershed currently discharge 346 million gallons per day (mgd) based on average dry weather flow. The current average dry weather flow design capacity of wastewater treatment plants in the Central Valley is 560 mgd, indicating that wastewater agencies are planning for growth and increased volumes of wastewater.

The DWR Modeling Section has recently developed a fingerprint that includes wastewater volumes from three of the largest treatment plants that discharge to the Delta. These three wastewater plants represent 82 percent of the wastewater volume discharged to the Delta so the fingerprints are a good estimation of the overall percent of wastewater at Delta pumping plants. The wastewater contribution at Clifton Court and Jones ranges from zero to about three percent.

Regulatory management of wastewater dischargers has increased significantly through implementation of more stringent National Pollutant Discharge Elimination System (NPDES) permit effluent limits and special study requirements. Most wastewater dischargers have upgraded to tertiary treatment and several other facilities are required to upgrade within the next ten years.

There are limited data on the concentrations of key drinking water constituents in wastewater effluent because NPDES monitoring programs do not include many of the key drinking water constituents.

There were few spill events at the wastewater treatment plants, but numerous collection system failures resulted in discharges to receiving waters. Most were related to sewer line blockage or failure.

Recommendations

<u>SWPCA, MWQI, and CDPH should continue to comment on waste discharge permits, EIRs, and the Triennial Review of the Basin Plan.</u>

While many wastewater treatment plants have upgraded to tertiary treatment, or are required to upgrade, there are still several wastewater treatment plants in the Delta that are at secondary treatment and several dischargers, including the Sacramento Regional County Sanitation District (SRCSD), have appealed their permits. The comments of the SWP Contractors, MWQI, and CDPH on past permits have been considered by the Central Valley Regional Water Board. In addition, data collected by MWQI has been used in evaluating permit conditions. It is important to continue these efforts and to continue commenting on EIRs on wastewater treatment plant expansion projects and on the Triennial Review of the Basin Plan. SWPCA, MWQI, and CDPH should continue to request that key drinking water constituents (pathogens, organic carbon, nutrients, and salinity) be included in the monitoring programs.

SWPCA should track development of special studies required by the NPDES permits for Delta dischargers.

The Central Valley Regional Water Board often requires dischargers to conduct special studies as conditions of their permits. For example, in the recently issued permit for the SRWTP, the Central Valley Regional Water Board required a Salinity Evaluation and Minimization Plan and a special monitoring study for perchlorate. The recently issued permit for the City of Sacramento's Combined Sewer System requires the City to prepare a Water Quality Assessment. SWPCA should track these studies and other studies required in future permits and prepare comments as needed.

The NBA and SBA Contractors should continue to work with Contra Costa Water District to model wastewater spills.

Contra Costa Water District (CCWD) has set up a modeling procedure to determine the impacts of spills occurring within the Delta at Delta water intakes, including CCWD's intakes, Clifton Court Forebay, and the NBA. The NBA and SBA Contractors should work with CCWD on a mechanism for disseminating the modeling results each week. This information could be posted on the MWQI website if a process for doing so is established.

URBAN RUNOFF

Findings

Urban runoff from Sacramento, Stockton, eastern Contra Costa County, and a number of small communities is discharged to the Delta. A number of other communities discharge urban runoff to Delta tributaries.

Urban runoff in the Central Valley and Delta is regulated by the Central Valley Regional Water Board through Municipal Separate Storm Sewer System NPDES permits. These permits require large (greater than 250,000 population) and medium (100,000 to 250,000 population) municipalities (designated as Phase I permittees) to develop stormwater management plans and conduct monitoring of stormwater discharges and receiving waters. Small communities (less than 100,000 population) are Phase II permittees. They are required to develop management plans but historically did not have to conduct monitoring. Monitoring may be required when the new Phase II permit is issued later this year. The permits require the communities to implement best management practices (BMPs) and conduct special studies. The permits for the larger Phase I permittees require low impact development for new development, which involves designing and maintaining facilities to manage urban runoff onsite to maintain runoff volumes at pre-development levels.

Urban runoff levels of bacteria, nutrients, and organic carbon are much higher than the receiving waters. Generally, these constituents are seen at higher levels during wet weather events.

The stormwater permits do not contain effluent limitations for specific water quality constituents but do require municipalities to reduce urban runoff pollution to the maximum extent practicable through implementation of BMPs. There are limited data on the effectiveness of BMPs in reducing drinking water constituents of concern, such as organic carbon, nutrients, and pathogens. Based on the limited studies that have been conducted, retention and detention ponds seem most effective at reducing drinking water constituents of concern. Data from a new retention basin in Sacramento support this finding.

Recommendations

SWPCA, MWQI, and CDPH should comment on stormwater permits.

Stormwater permits are renewed every five years. SWPCA, MWQI, and CDPH should provide comments on the permits for the large and medium systems that discharge to the Delta. Since there are limited data on the effectiveness of BMPs in controlling key drinking water constituents, such as organic carbon, nutrients, and pathogens, SWPCA, MWQI, and CDPH should request that the permits contain special studies to evaluate the effectiveness of BMPs in removing drinking water constituents. Drinking water constituents should also be included in the monitoring programs required by the permits.

SWPCA should track development of special studies required by the stormwater permits for Delta dischargers.

The Central Valley Regional Water Board often requires dischargers to conduct special studies as conditions of their permits. For example, Contra Costa County is required to conduct a special monitoring program to evaluate the presence of CECs in urban runoff. This is being conducted over the next few years to be incorporated into the next permit. SWPCA should track this study and other studies required in future permits and prepare comments as needed.

DELTA LAND CONVERSIONS

Findings

There are a number of habitat restoration projects that are underway or being planned in the Delta. Conversion of agricultural lands to tidal marsh is called for by the Ecosystem Restoration Program's Conservation Strategy for Sacramento-San Joaquin Delta Ecological Management Zone (California Department of Fish and Game, 2010) and by the BDCP. Other ecosystem restoration projects may occur through the Sacramento-San Joaquin Delta Conservancy, and the Delta Wetlands project (discussed in Chapter 2). DWR currently has three habitat restoration projects underway.

There is consensus that DOC production will increase as a result of converting agricultural land into tidal wetlands. Recent studies have also shown that an expansion of wetlands has the potential for raising Delta DOM concentrations in spring and early summer. Therefore, restoration may shift the overall DOC peak towards spring and summer, later than the current winter peak. This temporal shift in DOC loading may affect the overall loading to drinking water since more water is typically pumped during the spring and summer than during the winter.

Conversion of the Delta's traditional cultivated fields to managed wetlands or rice crops shows potential for stopping and reversing the effects of subsidence as well as potentially serving as a means of carbon sequestration. DWR and the U.S. Geological Survey (USGS) are jointly working on two major types of pilot projects on Delta islands to assess their effectiveness for subsidence reversal and carbon sequestration. These projects are part of the DWR Interim Delta Actions to continue incremental improvements in the Delta until a long-term solution is in place. These projects include managed wetlands and rice cultivation, both of which include flooding Delta islands.

Studies conducted to date indicate that there is great opportunity for subsidence reversal and carbon capture through wetlands and rice cultivation in the Delta. It is still uncertain if widespread implementation of these projects will occur in the Delta. The studies have included evaluation of the potential impacts to receiving waters, in particular the contribution of DOC. Wetlands and rice cultivation have been shown to both contribute elevated amounts of DOC in the drainages, particularly in the seepage flows through shallow groundwater. The highest loading of DOC from both wetlands and rice occurred during the summer months. Additional studies on the managed wetlands and rice crops will further examine the amount, extent, and potential factors influencing the transport of DOC to receiving waters.

Recommendations

SWPCA and MWQI should track carbon sequestration and subsidence reversal projects being conducted by USGS and DWR.

SWPCA and MWQI should track these projects to ensure that the impacts on drinking water quality are fully evaluated. The funding for monitoring for drinking water constituents has been substantially reduced. SWPCA should contact DWR and USGS to recommend that drinking water constituents be included in the monitoring programs. If needed, SWPCA should send a letter to DWR requesting that drinking water constituents be included in the monitoring program.

RECREATIONAL USE OF THE DELTA

Findings

The Delta Protection Commission has estimated that there are over 12 million visitors to the Delta annually, including about 500,000. This includes shoreline recreation (picnicking, hiking, camping, and hunting), boating, fishing, water-skiing, and other recreational activities along the Delta’s 57,000 acres of navigable waterways. All of these activities have the potential to impact water quality in the Delta. Recreational use of the Delta is projected to increase in the future as population increases. Recreational users may not be aware of the significance of the Delta as a drinking water source.

The California Department of Parks and Recreation (Parks and Recreation) prepared a Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh in May 2011. This plan will be included with the Delta Plan that will be finalized in the fall of 2012. The plan calls for creation of wildlife habitat and passive recreational facilities at Barker Slough, creation of an upland recreation area in the South Delta, possibly in the Old River area, development of floating campsites/day use areas and expanded waterfowl hunting programs (boat-in and longer-term), and potentially increasing the recreational use of SWP facilities.

There are a number of boater education programs that provide information on boating safety, proper disposal of hazardous wastes, and proper sewage handling facilities, but their effectiveness is uncertain. Although there are numerous pumpout and restroom facilities located throughout the Delta, it is uncertain how frequently they are used.

Vessel abandonment is a significant activity in the Delta which has direct impacts on source water quality. There are three key state programs that address the issue of abandoned vessels; however, two of these programs require local agencies to provide ten percent matching funds. Many local agencies cannot provide the matching funds due to budget constraints.

Recommendations

SWPCA should track Delta recreational management plans and proposals.

There are a number of activities in the Recreation Proposal, developed by Parks and Recreation, that could potentially impact Delta water quality. This plan will be incorporated into the Delta Plan that is scheduled to be completed in the fall of 2012. SWPCA should track plans for various recreation projects and provide comments on EIRs and other documents on the need to protect drinking water quality when recreational projects are developed.

SWPCA should support the Delta Protection Commission's efforts to develop a matching fund program for removal of abandoned vessels.

Establishing a fund that could be used by local agencies to provide the required ten percent matching funds would allow more of the state's funding to be used to remove abandoned vessels in the Delta. SWPCA should support the Delta Protection Commission in development of a matching fund program.

KEY WATER QUALITY VULNERABILITIES OF THE STATE WATER PROJECT

Chapter 14 contains a discussion of the key water quality vulnerabilities of the SWP. The findings and recommendations for each of the specific topics discussed in Chapter 14 are presented in this section.

NORTH BAY AQUEDUCT

Findings

The NBA Contractors have taken a multifaceted approach to improving the quality of water delivered to their customers. They have conducted studies in conjunction with MWQI on the water quality of the Barker Slough watershed, installed real-time monitoring equipment to provide advanced warning of water quality problems, installed fencing and alternative water supplies to exclude cattle from Barker Slough, evaluated the impacts of Campbell Lake operations on Barker Slough water quality, and conducted hydrodynamic modeling of the watershed to better understand the sources of water at the Barker Slough watershed under varying hydrologic conditions. In addition, the NBA Contractors evaluated treatment options and water exchanges as methods of improving water quality. The NBA Contractors are currently pursuing an alternate intake on the Sacramento River. The alternate intake would be operated in conjunction with the existing intake at Barker Slough to provide operational flexibility and improve water quality.

Recommendations

None.

The NBA Contractors are pursuing a comprehensive program to improve water quality. No other actions are recommended.

CLIFTON COURT FOREBAY

Findings

While developing the scope of work for the 2006 Update, the SBA Contractors expressed concerns that sedimentation of Clifton Court Forebay has resulted in a shallow water body that encourages algal and vascular plant growth that result in T&O problems. The 2006 Update contains an analysis of real-time water quality monitoring data that could potentially be used to detect algal blooms. The scope of work for the 2011 Update did not include any further analysis of the impact of sedimentation in Clifton Court on algal growth and T&O problems or of the ability of monitoring equipment to detect algal blooms. The status of action items from the 2006 Update was reviewed.

Recommendations

Two action items from the 2007 SWP Action Plan were not completed and should be continued in the next several years.

MWQI should evaluate current equipment capabilities to detect algal blooms.

This action item was classified as near-term in the 2007 SWP Action Plan pending completion of an evaluation of the in-situ monitoring equipment. The MWQI New Technologies Subcommittee is tracking work being conducted by the Interagency Ecological Program and MWDSC on fluorometric quantification of planktonic algae. The results of these studies should be reported to the MWQI Committee and a decision made on the usefulness of these methods in detecting algal blooms in Clifton Court Forebay.

The SBA Contractors should consider continuous measurement of dissolved oxygen to detect algal blooms.

This action item was classified as near-term in the 2007 SWP Action Plan pending completion of an evaluation of the in-situ monitoring equipment. It is currently on hold pending discussions between the SBA Contractors and the Delta Field Division. The SBA Contractors should determine if continuous measurement of dissolved oxygen would be helpful in detecting algal blooms in Clifton Court Forebay.

SOUTH BAY AQUEDUCT

Findings

The SBA Contractors have engaged in a number of activities to improve water supply reliability and water quality of the SBA. The SBA Improvement and Enlargement Program is nearing completion. The Watershed Protection Program Plan was completed in 2008 and the SBA Contractors conducted several workshops and developed public education materials on protecting drinking water quality in Bethany Reservoir and Lake Del Valle. The SBA Contractors previously expressed concern over a proposed trail along the SBA but that project does not currently have funding and appears to not be of any immediate concern.

Cattle grazing in the Bethany Reservoir watershed remains a major concern. DWR leases a 115-acre parcel on the southwestern shoreline that drains to Bethany Reservoir and two parcels on the northeast side, most of which do not drain to the reservoir. The leases require that good grazing practices be used so the property is not over-grazed and allow DWR to inspect the property to determine if the land is being over-grazed. The leases also require that fences be constructed and maintained to prevent cattle from entering the property of adjacent property owners but there are no requirements for fencing to keep cattle out of Bethany Reservoir. Stormwater monitoring conducted by the SBA Contractors showed that the Bethany Headlands drainage on the western side of Bethany Reservoir contained high levels of *Giardia* and *Cryptosporidium* relative to other sources of water to the SBA. Cattle are the likely source of these pathogens because cattle grazing is the primary use of this land and cattle are known carriers of these pathogens.

Recommendations

SWPCA should work with the DWR Division of Engineering Real Estate Branch to evaluate options for restricting cattle access to Bethany Reservoir.

A limited number of cattle on property managed by DWR currently have access to Bethany Reservoir. If DWR discontinued the lease on the southwestern side of the reservoir, cattle from the much larger privately-owned part of the watershed that is upstream of DWR property in the Bethany Reservoir watershed may still have access to the reservoir. The leases require that fences between state-owned property and private property be maintained by the lessees but the condition of those fences is unknown. The first step should be to inspect the fences to determine if discontinuing the lease would solve the problem of cattle having direct access to the reservoir.

The second consideration is that DWR has no control over activities on private property, which includes most of the Bethany Headlands drainage. SWPCA and the Real Estate Branch should explore options for communicating with the small number of large property owners in the watershed to determine if there are opportunities for better managing the grazing and the access of the cattle to the drainage courses.

DELTA-MENDOTA CANAL/CALIFORNIA AQUEDUCT INTERTIE

Findings

Construction was completed on an intertie between the California Aqueduct and the DMC in April 2012. The intertie will allow water pumped at the Jones Pumping Plant to be conveyed in the California Aqueduct to O'Neill Forebay. The Central Valley Project (CVP) water reaching O'Neill Forebay may be pumped into San Luis Reservoir, released to the San Luis Canal and the Dos Amigos Pumping Plant, or released through the O'Neill Pump-Generating Plant to the lower DMC and Mendota Pool.

The Final EIS did not evaluate the impacts on the quality of water in the California Aqueduct, O'Neill Forebay, or San Luis Reservoir as a result of the intertie. The intertie will be operated mainly between September and March when EC levels and bromide concentrations are highest in the South Delta. However, the volume of water pumped from the DMC into the California Aqueduct (maximum of 467 cubic feet per second) is relatively small compared to the flows in the California Aqueduct so there may not be a change in EC or bromide levels.

Recommendations

SWPCA should work with MWQI and the DWR Modeling Section to use the Aqueduct Extension Model to evaluate the water quality impacts of the intertie.

The Aqueduct Extension Model should be used to evaluate the water quality impacts of the intertie, whenever it is being used, to provide early warning to downstream SWP Contractors of increases in EC and bromide levels resulting from pumping water from the DMC into the California Aqueduct.

SAN LUIS RESERVOIR

Findings

The U.S. Bureau of Reclamation (Reclamation), Santa Clara Valley Water District, and San Luis and Delta-Mendota Water Authority have conducted a number of studies and held public scoping meetings for the San Luis Low Point Improvement Project. The three agencies are currently preparing a Feasibility Report and companion EIS/EIR which will present three alternatives: 1) Lower San Felipe Intake Comprehensive Plan, 2) Pacheco Reservoir Comprehensive Plan, and 3) the Combination Comprehensive Plan. It is anticipated that the Feasibility Report and Draft EIS/EIR will be completed in July 2012 and the Final EIS/EIR will be completed in January 2013.

SWPCA, MWQI, and O&M are currently addressing cattle grazing in the Cottonwood Bay area of the San Luis Reservoir. Efforts are underway to coordinate among the cattle owner, the land owner (Reclamation) and the San Luis Field Division to prevent the cattle from accessing the water. Three potential fencing alignments have been developed to date.

Recommendations

<u>SWPCA and DWR should continue their efforts to exclude cattle from San Luis Reservoir.</u>

CDPH has identified this as a high priority action.

COASTAL BRANCH

Findings

Over the last five years, the Central Coast Water Authority (CCWA) has implemented a number of measures to address T&O issues that may be attributed to sediment accumulation in the Coastal Branch forebays and canals. These measures include: 1) cooperating with and encouraging O&M to implement a routine sediment removal program from the open channel canal, forebays, and storage tanks, 2) implementing a MIB Monitoring Program/Response Plan at the Polonio Pass Water Treatment Plant (PPWTP) influent; Devil's Den, Bluestone, and Polonio Pass pumping plant forebays; and selected canal locations, 3) conducting an experiment using the SolarBee to evaluate its effectiveness in minimizing sediment accumulation and prevention of blue-green algae blooms in a pumping plant forebay, and 4) investigating alternative theories that may explain the high MIB levels.

Sediment accumulation in the pumping plant forebays is still occurring and remains a concern despite an active sediment removal program developed by O&M. In addition, elevated ammonia levels are routinely observed in the PPWTP influent just prior to the O&M annual winter shutdown, as water levels in the canal are reduced.

Through the examination of sediment removal records and water quality sampling along the Coastal Branch over the past five years, CCWA staff has not been able to confirm that greater amounts of sediment will lead to greater T&O incidents. However, there have been no major sustained T&O incidents from 2006 to 2010 at either Banks or the PPWTP.

Recommendations

<u>O&M should provide adequate monitoring and data reporting for T&O compounds at O'Neill Forebay Outlet</u>.

A review of the 2003 to 2010 O&M Water Quality Taste and Odor Report (distributed to SWP Contractors) revealed that O'Neill Forebay Outlet data were not widely available until 2008. In addition, O'Neill Forebay Outlet samples are not collected as frequently as the Banks sample location. The number of sampling events at Banks compared to O'Neill Forebay Outlet is shown in **Table 16-2**.

Table 16-2. Comparison of T&O Sampling Frequencies

Year	Number of Samples Collected at Banks	Number of Samples Collected at O'Neill Forebay Outlet	Percent Missed Sampling Opportunities at O'Neill Forebay Outlet
2008	51	38	25.5
2009	50	30	40.0
2010	51	35	31.4

<u>CCWA and O&M should endeavor to develop data interpretation techniques for MIB production along the California Aqueduct</u>.

MIB samples collected at the same time but at different locations along the California Aqueduct do not address whether or not MIB is being produced within the aqueduct itself. Data interpretation techniques should involve the concept of "same parcel" sampling, where the goal is to understand how the MIB concentration is changing within a given "parcel" of water as it makes its way from the source to the treatment plant.

<u>O&M should provide additional operational data when MIB samples are collected at O'Neill Forebay Outlet</u>.

When interpreting the O'Neill Forebay Outlet MIB data, it is important to know the blend ratio between releases from San Luis Reservoir and Banks. This information is helpful in understanding whether or not MIB production is occurring within O'Neill Forebay. O&M should: 1) provide information on the operating conditions during sample collection (i.e. stating if releases from San Luis Reservoir occurred prior to sample collection), or 2) develop a sampling protocol where samples are collected during times when the blending condition is known.

<u>O&M should sample more frequently and disseminate data promptly when MIB concentrations are increasing</u>**.**

Weekly sampling for MIB when levels are increasing in the California Aqueduct does not provide enough information to properly manage and/or prevent a T&O event. Sampling frequencies should be agreed upon by the impacted SWP Contractors and O&M.

<u>O&M and CCWA should continue to study the relationship between operations and maintenance activities in the Coastal Branch with water quality observations</u>**.**

The occurrence of MIB has a range of causes. MIB may be produced at the source water, produced in the conveyance system, or there may be a delayed cell lysis issue. Likewise, the reduction in MIB may be due to blending or through some form of degradation.

O&M and CCWA should continue to work together on good canal/forebay/tank maintenance.

O&M and CCWA staff should continue to work together to develop an alternative cleaning strategy to lessen the impact on source water quality during the annual winter shutdown.

NON-PROJECT INFLOWS

Findings

Non-Project inflows introduced into the California Aqueduct totaled 1,490,164 acre-feet from 2006 to 2010, which is a substantial increase from the 360,000 acre-feet previously introduced from 2001 to 2005. During certain months in the 2006 to 2010 period, inflows contributed a substantial percentage of the aqueduct flow. In February 2009, inflows contributed 87 percent of the flow at Check 29, and 92 percent of the flow at Check 41. This is an increase over the 2001 to 20005 period, as the highest monthly percentage at Check 41 was 40 percent.

Groundwater quality data from the resultant blend of participating wells for each project proponent, prior to entering the California Aqueduct, were examined. Based on the available data, Semitropic Water Storage District (Semitropic) inflows had the highest arsenic concentrations, with the majority of samples exceeding the drinking water MCL of 10 µg/L. Although conditions were placed on Semitropic's 2007 project proposal to "attempt to achieve an arsenic concentration of 10 µg/L or less in its pump-in water through full use of its resources", this was not achieved. Although one of the conditions placed on Semitropic is stated as above, it should be noted that the Semitropic inflow was actually evaluated as one component of the Kern program that also included Kern Water Bank, Kern County Water Agency, and the Wheeler Ridge-Maricopa Water Storage District (Wheeler Ridge). As such, the weighted average of all of the Kern program inflows was evaluated by the Facilitation Group and could not exceed any drinking water MCLs. Therefore, Semitropic was allowed to pump-in water with arsenic concentrations greater than 10 µg/L as long as the weighted average of other Kern inflows and Semitropic inflows was less than 10 µg/L. Semitropic also had the highest medians for bromide, total dissolved solids (TDS), and sulfate. The highest median for nitrate (10.3 mg/L) was measured at the Arvin-Edison inflow location, but it was well below the MCL of 45 mg/L.

Modeling results from the Kern County Water Agency Aqueduct Blending Model were also compared to grab samples taken along the aqueduct. The model predicts arsenic, DOC, and TDS concentrations fairly close to measured water quality at Check 29 and Check 41. The model tends to predict lower bromide concentrations and higher chromium and nitrate concentrations compared to measured water quality at both Check 29 and Check 41. This is because modeled results use long-term averages as the background concentrations at O'Neill Forebay Outlet, yet the actual water quality at this location may vary higher or lower from the long-term average. Overall, the Aqueduct Blending Model has become a useful tool in managing the non-Project inflows and assessing downstream water quality impacts.

The introduction of non-Project inflows has generally decreased the concentrations of bromide and DOC and increased the concentrations of nitrate and arsenic in the California Aqueduct downstream of the inflows. Specifically, there were eleven months when arsenic levels were measured at or above 5 µg/L at Check 29 and Check 41. Notably, arsenic levels were 6 µg/L for two consecutive months in February and March 2009 at Check 41. The percent of inflow volumes was high during this time period, averaging 83 percent in January 2009, 92 percent in February 2009, and 68 percent in March 2009. In addition, there were six non-consecutive months when the change in arsenic concentration from upstream to downstream of the Semitropic inflows was greater than 2 µg/L. This is notable as one of the conditions placed on Semitropic in 2007 was "Semitropic will operate its inflow program to achieve an increase in downstream arsenic concentrations of no more than 2 µg/L over background levels in the California Aqueduct." Further information is provided in Chapter 14. Only slight changes were observed for TDS and sulfate.

Semitropic constructed a demonstration facility to remove arsenic from groundwater. The demonstration facility was operated from November 2007 to November 2009 and treated a total of 61,665 acre-feet at a cost of $1.8 million.

Westlands was approved to convey their groundwater on a one-time basis from June to September 2008 by a Governor's Executive Order addressing the drought. During this period Westlands pumped 12,581 acre-feet of groundwater into the San Luis Canal portion of the California Aqueduct. The Governor's Executive Order bypassed water quality testing requirements that were specified in the contract between DWR and Westlands, so Westlands was allowed to begin pumping groundwater prior to any evaluation. According to DWR, two wells were shut down based on high levels of TDS and sulfate found after the wells were placed into service. Therefore, some unacceptable water was introduced into the San Luis Canal portion of the California Aqueduct during this four-month time period.

Recommendations

<u>O&M should prepare an annual review of the program</u>.

The 2001 Implementation Procedures state that "DWR will prepare an annual report of water quality impacts in the SWP from Non-Project water and make all water quality data available to interested parties." The annual reviews have not been completed on a regular or timely basis (the last annual review was completed by O&M in July 2008) due to staffing resource constraints. The annual review should be considered a high priority activity and should be completed within four months of the end of the water year. If O&M does not have the staff to complete the annual reviews, inflow entities should assist with resources.

<u>O&M should conduct quarterly sampling of inflows</u>.

O&M should conduct quarterly sampling at each inflow location. O&M has conducted sampling at all of the inflow locations, except for Wheeler Ridge. The data collected are summarized in Chapter 14 (Tables 14-7 through 14-10). It is apparent that the data are not collected consistently from year to year. O&M should conduct quarterly sampling at each inflow location and enter the data in the Water Data Library so it is available for the SWP Contractors to review within two weeks of sampling.

O&M should continue to conduct monthly monitoring of the California Aqueduct and disseminate data promptly.

O&M should continue to conduct monthly monitoring of the California Aqueduct for all constituents of concern at O'Neill Forebay Outlet and Checks 21, 29, and 41 during the active non-Project inflow period. The data collected during the 2007 to 2010 inflow period were valuable for assessing the impacts of inflows on aqueduct water quality. This monitoring should continue. Prompt dissemination of the data will allow the data to be used in evaluating downstream water quality impacts using the Kern Aqueduct Blending Model.

O&M should add total arsenic and hexavalent chromium to the monitoring program.

O&M currently monitors for dissolved arsenic and total dissolved chromium. Total arsenic data are needed for the inflows at the point of entry to the California Aqueduct and at the check structures in the aqueduct for comparison to the MCL which is based on total arsenic. OEHHA finalized the PHG for hexavalent chromium in July 2011 and CDPH will develop an MCL by 2014. O&M should initiate hexavalent chromium monitoring to establish a data base for comparison to the future MCL.

O&M should enter monitoring data collected by inflow entities in the Water Data Library.

Inflow entities currently provide electronic water quality data to the Facilitation Group. However, it would be beneficial to have these entities also submit electronic data to O&M, and to have O&M enter the data in the Water Data Library. This will allow O&M to ensure that inflow entities are adhering to the required monitoring programs specified in the project proposals and will make the data accessible for review by O&M and the SWP Contractors. If O&M does not have the staffing capability to do this, inflow entities should assist with resources.

Consider additional use of monthly measured water quality data at O'Neill Forebay Outlet to define background water quality during active inflow period.

The Aqueduct Blending Model currently uses historical averages for aqueduct background concentrations. The primary advantage of using these averages is not having a moving target when both forecasting expected changes from proposed programs and monitoring ongoing programs. Thus, historical averages provide a level of certainty for both project proponents and downstream stakeholders with respect to program changes as compared to typical aqueduct conditions. However, actual background concentrations for some constituents may at times vary significantly from historical averages, and the Aqueduct Blending Model does not then accurately predict "instantaneous" changes in water quality. Predicting these changes may be important to some model users, and consideration should be given to providing a mechanism to model using both historical averages and recent actual data.

SUBSIDENCE ALONG THE AQUEDUCT

Findings

There has been renewed interest in subsidence in the San Joaquin Valley due to increased groundwater pumping, caused by a reduction of available imported surface water deliveries due to drought and fish-protection measures. In 2007, there was a 150 foot decline in groundwater elevation, which caused subsidence. Damage to the SWP due to subsidence has occurred at the turnout structures, check sites, canal lining, and bridges. The worst subsidence damage has occurred within the jurisdiction of the San Luis Field Division near Coalinga.

USGS is currently conducting a study on behalf of DWR to better understand the occurrence of land subsidence along the California Aqueduct. The study is focused on the Westlands area and will determine the location and extent of changes in land surface elevation along the California Aqueduct. A similar study is being conducted for the CVP, and both projects are expected to be completed in September 2012. USGS hopes to define a groundwater level that will prevent/manage future subsidence.

Recommendations

DWR should evaluate the need to monitor subsidence along the California Aqueduct.

When the current USGS study is completed, DWR should assess the need to monitor land subsidence outside and beyond the Westlands area, as there are active groundwater inflow programs downstream along the California Aqueduct. These additional assessments may be important to further protect the aqueduct from damage caused by subsidence.

PYRAMID LAKE

Findings

Pacific Pipeline Systems LLC (responsible party) has completed repairs and relocations of Line 63 which was damaged and resulted in a March 2005 oil spill. They have increased ground and aerial inspection of the pipeline after rain events, and conducted emergency training exercises. Pacific Pipeline Systems was also required to pay a $1.3 million civil penalty and is currently completing additional specific actions to relocate or improve resistance to movement for Line 63.

The Upper Piru Creek portion of the Pyramid Lake watershed was impacted by the Day Fire which began on September 4, 2006 and was contained on October 2, 2006. The majority of the burn area tributary to Pyramid Lake burned at a low intensity. Although sediment loading and runoff was predicted to increase post-fire, ash and debris flow did not occur due to moderate rains that winter. According to MWDSC staff, there were no changes to influent water quality at the Jensen Water Treatment Plant as a result of the fire.

Recommendations

None.

CASTAIC LAKE

Findings

MWDSC has completed necessary best management practices to discourage gull roosting on the lake. Two pilot scale gull management exercises were conducted in 2007 with limited success. A brochure was developed by MWDSC and distributed at the Castaic Lake Recreation Area to discourage gull feeding by the general public. Monthly average *E. coli* levels at the Jensen Water Treatment Plant have declined since 2002.

On April 22, 2008, a 5,000 gallon sewage spill originated from the Warm Springs Rehabilitation Center in Castaic, California. The wastewater pump station experienced an electrical failure and wastewater spilled in front of the pump station. The Los Angeles County Health Department determined that the sewage did not enter Castaic Lake or any tributaries to the lake. *Cryptosporidium* and *Giardia* were not detected in samples collected by MWDSC and *E. coli* and fecal coliforms were either not detected or were present at low levels in samples analyzed by Castaic Lake Water Agency.

Recommendations

SWPCA should confirm that a backup mechanical float valve was installed.

SWPCA should confirm with Warm Springs Rehabilitation Center that a backup mechanical float valve was installed at the pump station to ensure continued pumping if electrical failures occur in the future.

HESPERIA MASTER DRAINAGE PLAN

Findings

Urban runoff from the City of Hesperia is discharged to the California Aqueduct through 45 drop inlets. This issue was identified in the 1990 SWP Watershed Sanitary Survey and has not been resolved in over 20 years. The San Bernardino County Flood Control District has developed a plan to address local drainage concerns but does not plan to address the discharge of urban runoff into the aqueduct unless DWR agrees to help fund the project.

Continuous turbidity and EC data measured at Check 66 were analyzed to determine if levels increased during periods of heavy rainfall. Based on the current amount of development in the watershed, flow through the drop inlets is likely impacting downstream water quality only under extreme storm conditions.

Recommendations

SWPCA should contact DWR to develop a course of action to work with the San Bernardino County Flood Control District to eliminate the drop inlets and stop urban runoff from entering the aqueduct.

DWR and the SWP Contractors have not met regarding this issue since 2008. At that time, the plan explained by DWR staff was to finalize the legal opinion regarding the SWP legal obligations and liabilities related to the drainage, meet with DWR management, and then meet with the SWP Contractors.

SILVERWOOD LAKE

Findings

During the reporting period, there have been no incidents such as wastewater spills, sewer line breakages, fires, or high runoff events. There have been no high turbidity events in the source water, with the exception of one day in January 2006, and three days in January 2010 when turbidities reached 20 NTU. Other than these two time periods, turbidity was less than 10 NTU.

Recommendations

None.

LAKE PERRIS

Findings

Since the 2006 Update was completed, use of Lake Perris by MWDSC has been reduced due to regulatory restrictions on pumping from the Delta and limitations to protect recreation and endangered species due to the Lake Perris drawdown. Lake Perris has been lowered by 25 feet below the normal maximum level to mitigate seismic risk while a permanent solution is being determined by DWR. Although MWDSC was proceeding with the procurement of a hypolimnetic oxygenation system and the design of voluntary swimming alternatives (i.e. swim lagoons, water play areas and other water features), MWDSC does not currently view Lake Perris as a reliable enough source of SWP supply to justify the cost to construct these facilities. As such, MWDSC has discontinued their efforts to implement these projects.

In January 2010, DWR prepared a Draft EIR for the Perris Dam Remediation Program to address seismic hazard. The Draft EIR evaluated the following dam remediation alternatives: 1) increased dam capacity alternative (above 1,588 feet), 2) normal dam capacity (at 1,588 feet), 3) reduced dam capacity alternative (at 1,563 feet), 4) recreation alternative (at 1,542 feet), 5) dam decommissioning alternative (draining the lake), and 6) no project alternative. The Final EIR was completed in September 2011. For the Final EIR, DWR concluded that the recreation alternative is the environmentally superior dam remediation alternative.

MWDSC, Coachella Valley Water District, and Desert Water Agency submitted comment letters on the Draft EIR, and commented that there was an inadequate range of alternatives considered, and that a more detailed analysis of possible alternatives should have been conducted. These agencies are in the process of reviewing the Final EIR.

Recreational attendance at the Lake Perris SRA has declined since the drawdown of the lake in 2005. However, attendance increased by 40,000 visitors from 2010 to 2011. The maximum number of allowable boats on the lake has been reduced from 500 to 250 for safety reasons. There were eleven beach closures from 2005 to 2010 based on *E. coli* levels exceeding standards for recreational usage.

Recommendations

DWR should investigate increasing the size of the aeration system to adequately mix Lake Perris to prevent anoxia from forming.

On an interim basis DWR has been using a pneumatic mixer to destratify Lake Perris and maintain aerobic conditions; however, the system is undersized and its capacity should be increased.

STATE WATER PROJECT FACILITY OPERATIONS VULNERABILIITIES

Chapter 15 contains a discussion of the key operational vulnerabilities of the SWP. The key findings and recommendations for each of the specific topics discussed in Chapter 15 are presented in this section.

BIOLOGICAL OPINIONS

Findings

Both the USFWS and NMFS biological opinions require exports to be limited to reduce reverse flows in the Old and Middle rivers between December and June. The intent of this action is to prevent entrainment of delta smelt at the export pumps. The other action with the potential to impact water quality is the requirement to increase Delta outflow in wet and above normal years during the fall months to move the low salinity zone near Suisun Marsh, which is thought to improve delta smelt survival. While modeling studies have been conducted to examine the impacts of the biological opinions on water supply, there have not been any modeling studies to evaluate the impacts on drinking water quality. The impacts of the Wanger Interim Remedial Order on drinking water quality were modeled. Historical data were examined and the results of the modeling studies on the Wanger Interim Remedial Order were reviewed in an attempt to determine if any conclusions could be drawn on the likely impacts. Delta hydrology is extremely variable, Delta operations are highly complex, and the operations rules to comply with the actions in the biological opinions will change the way the Delta has historically been operated. It is not possible to reach firm conclusions on the impacts of the biological opinions without conducting modeling studies; however, it appears that the greater influence of the San Joaquin River during the periods that Old and Middle River reverse flows are regulated will result in higher levels of TOC, DOC, EC, and bromide at the south Delta pumping plants. Shifting exports to the July to September period may result in more water with lower TOC and possibly EC being exported. Bromide concentrations may be lower in July but would increase to high levels by September. Increased fall Delta outflow, in the range that would likely occur in September, does not appear to have any impact on drinking water quality at the pumping plants.

Recommendations

DWR should conduct modeling studies on the impacts of the biological opinions on water quality.

Both the USFWS and NMFS biological opinions are currently being revised. When they are reissued, DWR should conduct modeling studies on the impacts on both water supply and water quality at the Delta pumping plants.

HEAD OF OLD RIVER BARRIER

Findings

The head of Old River barrier (HORB) is installed to keep migrating salmon in the San Joaquin River and to prevent them from entering the Old River and being drawn towards agricultural diversions and the south Delta pumping plants. Historically the HORB was a 200-foot long barrier constructed by placing rock in the main channel bed along with overflow weirs and gated culverts. The physical barrier effectively blocks most flow from the San Joaquin River into the Old River. As a result of the delta smelt biological opinion, participants in the VAMP program suggested testing a non-physical barrier as an alternative to the rock barrier, since the physical barrier may have adverse impacts on delta smelt. A non-physical barrier was installed in the Old River in the spring of 2009 as an experimental project to determine if migrating salmon and steelhead would avoid the barrier and stay in the San Joaquin River rather than entering the Old River.

Modeling studies using the Delta Simulation Model 2 (DSM2) have shown that the physical barrier prevents the San Joaquin River from entering the Old River when it is in place. There have not been any studies on the impacts on water quality of replacing the physical barrier with a non-physical barrier. It would seem logical that the San Joaquin River would have a greater influence on water quality at the south Delta pumping plants with a non-physical barrier. Water quality data were compared for two relatively dry periods; 2002 to 2004 when the physical barrier was in place and 2008 to 2010 when there was no physical barrier. The Delta hydrodynamics are too complex to draw any conclusions from the examination of these limited data.

Recommendations

DWR should conduct modeling studies on the impacts of the non-physical barrier.

If DWR decides to permanently install a non-physical barrier, rather than the rock barrier that has historically been installed at the head of the Old River, DWR should conduct modeling studies on the impacts on water quality.

IMPACTS OF DROUGHT ON WATER QUALITY

Findings

The water quality impacts of dry years at the Barker Slough and Banks Pumping Plants were evaluated. These two locations were selected because they reflect the quality of water pumped from the north and south Delta in different year types.

When examined on a monthly basis, there are few significant differences between wet and dry year monthly medians at Barker Slough for TOC, bromide, and nutrients. During dry years, EC levels are higher during the wet months of January through April and turbidity levels are lower during the December to April period.

When examined on a monthly basis, the substantial impact of dry years on EC and bromide is evident at Banks. During dry years, EC and bromide are statistically significantly higher in the summer months, when exports are highest, and in the winter months. Turbidity levels are statistically significantly lower during the summer months of dry years. TOC concentrations are higher during a few months of dry years and lower during other months, with no clear pattern. Nutrient concentrations are not significantly different between dry years and wet years.

Recommendations

None.

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