State of California
California Natural Resources Agency
Department of Water Resources

The Municipal Water Quality Investigations Program

Summary and Findings of Data Collected from the Sacramento-San Joaquin Delta Region, October 2007—September 2009

June 2010

Arnold Schwarzenegger
Governor
State of California

Lester A. Snow
Secretary for Natural Resources
Natural Resources Agency

Mark W. Cowin
Director
Department of Water Resources

Previous editions

The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected August 1998 through September 2001.* (Printed by DWR July 2003)

The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected October 2001 through September 2003.* (Printed by DWR June 2005)

The Municipal Water Quality Investigations Program *Summary and Findings of Data Collected from the Sacramento-San Joaquin Delta Region, October 2003 through September 2005.* (Printed by DWR December 2006)

The Municipal Water Quality Investigations Program *Summary and Findings from Data Collected from the Sacramento-San Joaquin Delta Region, October 2005 through September 2007.* (Printed by DWR June 2008)

Foreword

The Sacramento-San Joaquin Delta (Delta) is a major source of drinking water for 25 million people of the State of California. The quality of Delta waters, however, may be degraded by a variety of sources and environmental factors. Close monitoring of Delta waters is necessary to ensure delivery of high quality source waters to urban water suppliers.

The Municipal Water Quality Investigations (MWQI) Program, Division of Environmental Services with the Department of Water Resources is responsible for the monitoring and research of water quality in the Delta. Among all State and local agencies monitoring the Delta and its tributaries, MWQI conducts the only monitoring program mandated to investigate the quality of source waters in the Delta with respect to its suitability for the production of drinking water.

Since 1982, MWQI has been conducting comprehensive and systematic source water monitoring in the Delta region, and regularly prepares biennial or multi-year data summary reports. The previous two-year report (June 2008) summarized data collected October 2005 through September 2007. The current report summarizes and interprets monitoring data collected from October 1, 2007, through September 30, 2009, from 12 MWQI sampling sites. Data and findings are presented for major water quality constituents, including organic carbon, bromide, salinity, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of current interest.

This and other MWQI reports are available online at the MWQI website: http://www.wq.water.ca.gov/mwqi/pubs.cfm. For more information about the MWQI Program, please visit our homepage at: http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm or contact Carol DiGiorgio, Chief of the Municipal Water Quality Investigations Program, (916) 376-9711, or send your request to: MWQI Program, P.O. Box 942836, Sacramento, California 94236-0001.

Dean F. Messer, Chief

Division of Environmental Services

Prepared under the direction of
Eric Oppenheimer
by
Marcia Scavone-Tansey, Project Leader
Theodore Swift
Otome J. Lindsey
Jaclyn Pimental
Sonia Miller

Production services provided by Technical Publications & Communication Media, Statewide Integrated Water Management, Project Support:
Gretchen Goettl, Supervisor of Technical Publications
Dru Dunton, Research Writer
Marilee Talley, Research Writer
Cover design by **Carole Rains**, Research Writer

Maps provided by Graphics Services Branch:
Teresa Chaney, Chief
Joanne Pierce, Graphic Designer

Municipal Water Quality Investigations Program, Office of Water Quality

Carol DiGiorgio, Chief
Marcia Scavone-Tansey, Environmental Scientist

Rachel Pisor, Environmental Scientist

Joseph Christen, Environmental Scientist

Sonia Miller, Environmental Scientist

Jason Moore, Environmental Scientist

Water Quality Special Studies, Office of Water Quality

Theodore Swift, Staff Environmental Scientist

Quality Assurance/Quality Control Group, Office of Water Quality

Bruce Agee, Chief

Murage Ngatia, Environmental Scientist

Field Support Group, Office of Water Quality
Steve San Julian, Chief

Mark Bettencourt, Environmental Scientist

Arin Conner, Environmental Scientist

Steven San Julian, Environmental Scientist

Bryte Laboratory, Office of Water Quality

Sid Fong, Chief

Pritam Thind, Staff Chemist

Maritza Pineda, Chemist

Allan Wong, Chemist

Matt Hicks, Chemist

Elaine Chan, Laboratory Technician

Clint Walker, Business Services Assistant

Richard Hernandez, Chemist

Josie Quiambao, Chemist

Gary Munoz, Chemist

Kelly Pepper, Environmental Scientist

Marilyn Carroll, Laboratory Technician

Report Production

Department of Water Resources Reprographics

Table of Contents

Tables

Figures

Acknowledgments

The authors thank Mr. David Gonzalez, Mr. Steve San Julian, Mr. Mark Bettencourt, Ms. Sonia Miller, and Mr. Arin Conner for sample collections; Mr. Sid Fong and the chemists at the Department of Water Resources's Bryte Chemical Laboratory for sample analyses. We thank Mr. John Coburn of the State Water Contractors, our colleagues Ms. Carol DiGiorgio, Mr. Eric Oppenheimer, Mr. Steven San Julian and Mr. Murage Ngatia for reviewing the draft report and providing us with valuable comments; Mr. Chris Enright, Ms. Kate Le and Ms. Tracy Hinojosa for providing export data; Ms. Cindy Messer for providing valuable information on the history of the Wanger decision and the criteria for pumping curtailment; and the Bay-Delta office for providing the volumetric fingerprint calculations.

We are particularly grateful to Ms. Dru Dunton for her editorial work, which helped improve the readability of this report. Special thanks are also extended to Ms. Joanne Pierce for the maps in this year's report. We thank Ms. Gretchen Goettl for her enthusiastic support of this project. The MWQI Program gratefully acknowledges support from the following urban water agencies:

State Water Project Contractors:

- Alameda County Flood Control and Water Conservation District Zone 7
- Alameda County Water District
- Antelope Valley-East Kern Water Agency
- Castaic Lake Water Agency
- Central Coast Water Authority
- Crestline-Lake Arrowhead Water Agency
- Kern County Water Agency
- Metropolitan Water District of Southern California
- Mojave Water Agency
- Napa County Flood Control and Water Conservation District
- Palmdale Water District
- San Bernardino Valley Municipal Water District
- San Gabriel Valley Municipal Water District
- San Gorgonio Pass Water Agency
- San Luis Obispo County Flood Control and Water Conservation District
- Santa Clara Valley Water District
- Solano County Water Agency

MWQI Program Participant:

- Contra Costa Water District

Executive Summary

Purpose and Scope

The Municipal Water Quality Investigations (MWQI) Program collects and analyzes water samples from the Sacramento-San Joaquin Delta (the Delta) region and reports its findings to the State Water Contractors and the public through annual or multi-year reports. In this report, we summarize and interpret MWQI discrete (grab) sampling data collected from October 2007 through September 2009. In this reporting period, water year (WY) 2008 was a critical water year both for the San Joaquin and Sacramento Valley watersheds. Water year 2009 was a dry water year for the Sacramento Valley and below normal water year for the San Joaquin Valley. The four previous reports presented data from October 1998 through September 2007.

This report presents data from 12 MWQI stations. Four of these 12 stations are on the San Joaquin River (SJR), the Sacramento River, and the American River as they flow into the Delta. Three of these stations are on the American and Sacramento Rivers at or near the north end of the Delta—American River at E.A. Fairbairn Water Treatment Plant (WTP), Sacramento River at West Sacramento WTP Intake, and Sacramento River at Hood. The E.A. Fairbairn WTP represents the water quality of the American River, which is a major tributary of the Sacramento River. West Sacramento WTP Intake represents the water quality of the Sacramento River before it mixes with the American River, and the Sacramento River at Hood reflects the quality of water from the Sacramento River shortly after it enters the Delta. The SJR near Vernalis represents SJR water quality as it enters the Delta. In addition, MWQI monitors an urbanized watershed—Natomas East Main Drainage Canal—which is just upstream of the northern boundary of the Delta.

Seven of the 12 stations are within the Delta or at diversion points in the Delta. Three of the stations—Old River at Station 9, Old River at Bacon Island and Middle River at Union Point—are Delta channel stations that represent the quality of mixed waters primarily from the SJR and Sacramento River. Water is diverted near Old River at Station 9 at the Contra Costa Water District's (CCWD) pumping station. Three of the stations—Banks Pumping Plant, Contra Costa Pumping Plant #1, and Jones Pumping Plant—are diversion points that reflect the quality of water being diverted from the Delta at these points. The last station—the Sacramento River at Mallard Island in the west Delta—is the most susceptible to seawater influence due to its proximity to the San Francisco and Suisun Bays.

Water quality constituents in Delta source waters are presented according to current regulatory priorities and water treatment challenges with organic carbon, bromide, salinity, and nutrients addressed in individual chapters. For each constituent at each station, descriptive plots in the form of temporal graphs show general seasonal patterns. Summary statistics that include range, mean, and median describe general data characteristics. Additionally, this summary report includes a section on the volumetric fingerprinting of source waters at key points in the Delta. Understanding the contribution of different source waters at a site is a useful tool for understanding water quality.

Summary of Findings

Organic Carbon

Organic carbon at 12 MWQI stations in the Delta and its tributaries differed spatially with north Delta stations generally having lower total organic carbon (TOC) concentrations than southern Delta and channel stations. At 1.7 milligrams per liter (mg/L), American River water had the lowest median TOC of any station sampled. Median TOC at the Sacramento River at the West Sacramento WTP was 2.0. Median TOC at Sacramento River at Hood was 2.1 mg/L, which represents organic carbon levels of northern Delta inflows. In contrast, median TOC for the SJR near Vernalis was 3.3 mg/L, about 62% higher than the TOC concentration in the northern inflows. Despite lower organic carbon concentration in northern inflows, median TOC at the six Delta channel and diversion stations ranged from 3.2 to 4.3 mg/L. These results were comparable to the SJR near Vernalis suggesting considerable in-Delta sources of organic carbon. Agricultural drainage and in-channel production are probable sources of in-Delta organic carbon. Mallard Island had a median organic carbon reading of 2.1 mg/L. Because of the dilution from bay waters that have low organic carbon, organic carbon concentrations at Mallard Island were lower than they were at Delta channel and diversion stations. The difference between TOC and dissolved organic carbon (DOC) at Mallard was not significant, which indicated that most organic carbon was in the dissolved form. Compared with the previous four water years, median TOC concentrations at Hood, Vernalis, and Banks did not show large variations. In general, stations experienced elevated carbon levels during the rainy season, which trended downward through the early summer months before reaching their seasonal low during the late summer to early fall. Seasonal patterns of organic carbon concentrations were similar between tributary and channel stations. Seasonal patterns at the five Delta channel and diversion stations were also similar to those at SJR and the Sacramento River stations. Median organic carbon levels at Mallard Island were slightly lower during the current period than during the previous three water years.

Bromide

As expected, bromide concentrations were higher at stations closer to seawater influence. Of the 12 stations, the Mallard Island station is the closest to the Suisun and San Francisco Bays and had the highest median bromide (7.16 mg/L). Median bromide concentrations at the three diversion stations, Banks Pumping Plant, Contra Costa Pumping Plant #1, and Jones Pumping Plant, were 0.29 mg/L, 0.32 mg/L, and 0.29 mg/L, respectively. The SJR near Vernalis had median bromide concentrations of 0.31 mg/L. Elevated bromide in the SJR may be attributable to agricultural drainage returns. Stations at the north end of the Delta are not influenced by seawater; therefore, bromide concentrations were either very low or below the reporting limit of 0.01 mg/L. Bromide to chloride ratios demonstrated that bromide sources were from seawater. The ratio of bromide to chloride in seawater is 0.0034. The ratio of bromide to chloride for the eight central and western Delta stations was 0.00349. Excluding the Mallard Island station, which has the closest proximity to seawater, the ratio was 0.00345.

Salinity

Among the 12 MWQI stations, the lowest electrical conductivity (EC) was found in the American River at E.A. Fairbairn WTP with a median of 64 micro Siemens per liter (µS/cm). Median EC at Natomas East Main Drainage Canal (NEMDC) was 311 µS/cm; however, flows at NEMDC are generally a small percentage of the combined flows of the American and Sacramento rivers for the reporting period. Median EC at Sacramento River at Hood was 176 µS/cm, which represented salinity in northern Delta inflows. Salinity of the San Joaquin River at Vernalis during the reporting period was much greater than the salinity of the Sacramento River at Hood. Median EC at the SJR near Vernalis (679 µS/cm) was the second highest of the 12 monitored stations. High levels of salts in irrigation returns from the San Joaquin Valley and recirculation of salts from the Delta are some of the primary causes of the increased EC levels in this area. EC was significantly lower in the Delta channel and diversion stations than in the SJR due to the dilution effects of water from the Sacramento River. Median EC at the Delta channel stations was 503µS/cm for Old River at Station 9, 550 µS/cm for Old River at Bacon Island and 407µS/cm for Middle River at Union Point. EC was higher at one of the diversion stations, the Banks Pumping Plant, where the median was 524 µS/cm. Of all 12 MWQI sampling stations, Mallard Island had the highest salinity concentration because of its proximity to Suisun Bay, where seawater intrusion to the western Delta is the greatest. Seawater was the primary source of salinity throughout the western Delta as indicated by the high median EC of 6,698 µS/cm at Mallard Island. From the northern rivers to the SJR and throughout the Delta, salinity is affected by watershed runoff, urban discharges, groundwater accretions, and agricultural drainage. Seasonal precipitation during wet months and reservoir releases during dry months decrease salinity by diluting this water with water of lower mineral content. However, salinity loads from the watersheds were significant during the wet months, especially following the first few major rain events.

Nutrients

Nitrogen and phosphorus are critical nutrients to aquatic life but in high concentrations can cause water quality problems. Of the 12 MWQI stations, median inorganic and total nitrogen concentrations ranged from 0.06 to 1.93 mg/L and 0.21 to 2.10 mg/L, respectively; median total phosphorus and orthophosphates ranged from 0.01 to 0.47 mg/L and <0.01 to 0.46 mg/L, respectively. Concentrations of nitrogen and phosphorus were lowest in the American River at E.A. Fairbairn WTP, the West Sacramento WTP Intake and at the Contra Costa Pumping Plant #1. The highest nutrient concentrations were found at the NEMDC station and the San Joaquin River near Vernalis. Although the Hood station receives high quality American River water, it had nitrogen and phosphorus that were more than double the concentration observed at the American River at E.A. Fairbairn WTP and the West Sacramento WTP Intake. This is likely due to urban and wastewater discharges upstream of the monitoring site.

Other Constituents

Other constituents known to cause adverse effects on human health were also monitored to determine whether they exceed the maximum contaminant levels (MCLs). Primary standard constituents have detrimental impacts to the human health, while secondary standard constituents affect the taste, odor, and appearance of finished drinking water. The nine inorganic constituents with primary standards were: arsenic, beryllium, barium, cadmium, chromium, lead, mercury, nickel, and selenium. At Banks, these constituents were always below the MCLs. Other monitored constituents with primary standards included nitrate and nitrate + nitrite. Monitoring for the related unregulated compound ammonia was also conducted. At Banks, the median concentrations for nitrate, nitrate + nitrite and ammonia were 2.4 mg/L, 0.65 mg/L, and 0.04 mg/L, respectively. The monitored constituents with secondary standards were aluminum, copper, iron, manganese, zinc and silver. At Banks, the concentrations of these constituents were always below their MCLs with the exception of manganese, which exceeded the federal MCL of 0.05 mg/L in one of the 24 samples. At NEMDC, all of the primary and secondary constituents were similar to the previous report’s findings of compliance. At NEMDC, aluminum twice exceeded federal MCLs, while iron exceeded its MCL once and manganese exceeded its MCL on four different occasions.

Volumetric and EC Fingerprinting

Volumetric fingerprints were calculated for the Old River on the west side of Bacon Island and Clifton Court Forebay. Overall, the volumetric fingerprint at Old River shows that the majority of its source water originated from the Sacramento River in both water years 2008 and 2009. However, as water continued to the Clifton Court Forebay, the proportion of San Joaquin River source water increased. At Old River, the volumetric contribution of Sacramento River and Martinez (west Delta-Suisun Bay) source waters are greater than their corresponding contributions at Clifton Court Forebay. At Clifton Court, the volumetric contributions of source waters from the SJR, Mokelumne, Cosumnes, and total Delta drainage are increased relative to the Old River volumetric contributions (Figure 2-7 and Figure 2-8). This occurrence reflects the increased influence of the southern, eastern, and interior Delta sources at Clifton Court relative to Old River.

EC fingerprinting was done for the same two sites as the volumetric fingerprinting. The EC fingerprints demonstrated that the San Joaquin River had a stronger influence throughout the year at Clifton Court than it did farther north along the Old River. However, comparisons at both stations between the EC fingerprints and the volumetric fingerprints demonstrated that saltwater from Martinez greatly influenced EC. An increased percentage of Martinez water elevated EC significantly.

Acronyms and Abbreviations

AL(s)	action level(s)
BiOp	biological opinion
CCPP	Contra Costa Pumping Plant #1
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
CDPH	California Department of Public Health
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CSUS	California State University, Sacramento
CVP	Central Valley Project
Delta	Sacramento-San Joaquin River Delta
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
EC	electrical conductivity
FLIMS	Field and Laboratory Information Management System
HORB	temporary barrier constructed at the head of Old River
ICP	inductively coupled plasma optical emission spectroscopy
Jones Pumping Plant	C.W. "Bill" Jones Pumping Plant
L	liters
LCS	laboratory control sample
MCL	maximum contaminant level
MDL	method detection limit
µg/L	micrograms per liter
µm	micrometers
µS/cm	micro Siemens per centimeter
mg/L	milligrams per liter
MWQI	DWR Municipal Water Quality Investigations
NDOI	net Delta outflow index
NEMDC	Natomas East Main Drainage Canal
nm	nanometers
NTU(s)	nephelometric turbidity unit(s)
O&M	Division of Operations and Maintenance

OMR	Old and Middle Rivers
pH	negative log of the hydrogen ion activity
QA/QC	quality assurance/quality control
RPA	reasonable and prudent alternatives
RPD(s)	relative percent difference(s)
SJR	San Joaquin River
SWC	State Water Contractors
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
THMFP	trihalomethane formation potential
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UVA_{254}	ultraviolet absorbance measured at a wavelength of 254 nanometers
VAMP	Vernalis Adaptive Management Plan
WTP	water treatment plant
WWTP	waste water treatment plant
WY	water year

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	Meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	Square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	Square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	Square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	Pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	Meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi) feet head of water	0.14505	6.8948
	kilopascals (kPa)		0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	Degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

Chapter 1 Introduction

Scope

This report summarizes and interprets discrete water quality sampling data collected by the Municipal Water Quality Investigations Program (MWQI) of the Department of Water Resources (DWR) from October 1, 2007 to September 30, 2009. This report is the fifth in a series produced within the last twelve years. The last MWQI report was completed in June 2008 and summarized data collected from October 2005 through September 2007 (DWR, 2008a).

Data presented in this report were collected from 12 MWQI stations in or near the Sacramento-San Joaquin Delta (the Delta). A range of water quality constituents were analyzed for each sample, and this report presents the constituents that are of most concern to drinking water quality. Major water quality constituents examined in this report include organic carbon, bromide, salinity, nutrients, regulated organic and inorganic constituents in drinking water, and a few unregulated constituents of interest. The selection of constituents is based on findings from previous reports and feedback from the MWQI steering committee represented by urban State Water Contractors (SWCs) and Contra Costa Water District (CCWD). Water quality constituents of lesser concern to SWCs are discussed only for selected stations.

Statistical data analyses were limited to simple statistics and illustrations of seasonal patterns. Brief discussions on sources and temporal and spatial patterns of some constituents are presented. All raw data (including hydrologic) are available both online and on a CD-ROM accompanying this report (see Appendix A for Web site address).

This report primarily summarizes monitoring data and presents data in sufficient detail to demonstrate general source water quality conditions in the Delta. At certain Delta diversion stations, some constituents are discussed in the context of existing State and federal drinking water regulations and water quality objectives specified in the long-term water supply contracts between DWR and each SWC. Source waters in the State Water Project (SWP) are not required to meet maximum contaminant levels (MCLs) because source water is not typically regulated to comprehensively meet finished drinking water standards. Therefore, comparisons are made with data collected at diversions stations to provide a relative indication of source water quality. This report does not present the details of the regulations, standards, or contract provisions; the regulations and standards may be found at the websites of the U.S. Environmental Protection Agency and the California Department of Public Health (USEPA, 2010a; CDPH, 2010). The Standard Provisions for Water Supply Contracts between DWR and the SWCs are available from DWR's State Water Project Analysis Office, Project Water Contracts Unit at http://www.swpao.water.ca.gov/wc_b/index.cfm (DWR, 2010c).

Interpretations in this report are primarily based on monthly or biweekly grab sample data. Given the Delta's complex hydrology, results and interpretations from grab sample data, especially monthly data, have limitations in explaining spatial and seasonal patterns in the Delta. MWQI collects real-time data at four stations to enable model-assisted forecasting of water quality conditions. This report includes a section on the modeled volumetric contributions of source waters at key points in the Delta. Understanding the volumetric proportions of source water at a given site can provide insights into the observed water quality. Whenever possible, water quality was related back to modeled results to aid in the interpretation of results. Information pertaining to the models used in developing this report can be found at DWR's Modeling Support Branch, Bay-Delta Office Web site, http://baydeltaoffice.water.ca.gov/modeling/index.cfm (DWR, 2010d). Modeling and MWQI's real-time data are also available through MWQI's daily update for contractors, water agencies, and other interested parties at the MWQI Web site, http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm (DWR, 2010b).

Monitoring Stations and Sampling Frequency

The geographic locations of the 12 monitoring stations are presented in Figure 1-1. During the reporting period, MWQI collected samples at 11 stations, and the Division of Operations and Maintenance (O&M) of DWR collected samples for MWQI at the State Water Project's Harvey O. Banks Pumping Station (Banks Pumping Plant) monitoring station in Alameda County.

Samples were generally collected either monthly or biweekly (Table 1-1). Biweekly samples were collected at two key stations, the Sacramento River at Hood and the San Joaquin River (SJR) near Vernalis. These biweekly samples were scheduled with real-time equipment maintenance trips to both stations. Samples at all other stations were collected monthly.

For discussion purposes in this report, the 12 sampling stations were divided into 5 groups. These are, (1) stations north of the Delta, (2) the Sacramento River at Hood, (3) the San Joaquin River at Vernalis, (4) channel and diversion stations, and 5) Mallard Island (Table 1-1). The stations within each group are either geographically or hydrologically related. In the stations north of the Delta, the Natomas East Main Drainage Canal (NEMDC) was considered separately because it is an urban drainage that is tributary to the Sacrament River. Water quality at NEMDC was also the subject of an MWQI special study (DWR, 2008b).

Modeled volumetric fingerprinting of electrical conductivity (EC) and flow were calculated for Banks Pumping Plant and Bacon Island. (Fingerprinting presents the proportion of each variable, EC or water volume, that contribute to a total at a particular point in the Delta.) These locations were chosen because they are representative of the central and south Delta. No modeling was done for north Delta stations because source waters for these sites come primarily from snow melt and the Sacramento and American rivers.

Program Changes

Beginning in January 2009, grab sampling began at the Central Valley Project's C.W. "Bill" Jones Pumping Station (Jones Pumping Plant) in Tracy. There is a real time carbon analyzer at the pumping plant, and in the future the MWQI plans will include an anion analyzer. The primary purpose of the grab samples was to increase the data record for anions until real time measurements can be made. These samples were taken at the Delta Mendota Canal, approximately one mile downstream from the pumping plant. These samples were collected only for specific analytes.

In March 2009, sampling at the Contra Costa Pumping Plant was modified. Prior to this date, sampling was conducted immediately upstream of the Contra Costa Pumping Plant. Currently, due to access issues, samples are taken at Rock Slough, approximately 5.5 river miles upstream from the original sampling location. This will continue to be the sampling site in the future.

Sample Collection and Laboratory Analysis

Sample collection and laboratory analysis methods were the same as those used for the last MWQI data report. Detailed sample collection procedures and laboratory methods can be found in the MWQI summary report covering October 2001 through October 2003 (DWR, 2005). Sample methods are listed in Table 1-2.

Data Quality

Sample retention is necessary for evaluating and ensuring acceptable results. Once analyses were completed, the remaining sample was kept for 30 to 60 days in storage before being discarded. Bryte Laboratory follows a set of internal quality assurance and quality control (QA/QC) audit procedures, which include evaluation of blank data (laboratory and field), calibration standards, laboratory control samples, etc. The detailed QA/QC procedures and corrective actions have been described in Bryte Laboratory's latest QA technical documentation (Fong and Aylesworth, 2006).

In this report, constituents at concentrations below their reporting limits are treated as a "nondetect", and shown as below the reporting limit. The "nondetect" values are not included in the calculation of averages; however, non-detects were used in the calculations of the median and the minimum and maximum values. For the median, a proxy value less than the detection limit was used. During the reporting period, occasional method changes occurred for some constituents due to adoption of improved techniques, equipment failures, or staff limitations. Constituents that may be analyzed by more than one method are shown in Table 1-2. To minimize the discrepancy between data resulting from method changes, this report includes data from a single method for each constituent.

Statistical Analysis

The following summary statistics are presented in tabular form for each constituent:

Data range: data between the minimum and the maximum concentrations.

Mean: presented mostly for historical reasons. Skewed data of wide variability such as water quality data should not be averaged because the mean is usually strongly influenced by data at both extremes and is often misleading. Non-detects were not included in mean calculations.

Median: more resistant measure for water quality data. The median is thus a generally preferred measure over the mean. Non-detects were included in median calculations.

Much of the water quality data was not normally distributed; therefore, the non-parametric Mann-Whitney test (also called the Wilcoxon Rank-Sum test) was used for comparison of medians among stations or among different time periods, and the Kruskal-Wallis test (followed by a Dunn's Multiple Comparison test) was also used for multiple station or time period comparisons.

Most data are presented in descriptive graphics. Summary statistics were computed using Microsoft Excel. Nonparametric statistical comparisons were calculated using Minitab 14.

Descriptive Plots

Monthly or biweekly data are plotted over time to demonstrate general behavior of the data during the reporting period. Non-detects were not graphed.

Data interpretations are illustrated with bar or scatter plots for seasonal differences, which demonstrate the influences of constituent sources during a given time period.

Box plots are used to illustrate summary statistics of six concurrent water years. In the box plot, the boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentile. The outliers plot the 5th and 95th percentiles as symbols (Figure 1-2).

Fingerprinting

Modeled fingerprinting uses the Delta Simulation Model 2 (DSM2) to estimate the concentrations of a constituent at a specific time and location in the Delta as a function of its source (e.g., tributary rivers, seawater from the west at Martinez, or in-Delta island agricultural drainage returns). A tracer is a measurable constituent or characteristic of a water parcel that can be used to track flow. A conservative tracer remains constant as it moves with the water parcel, whereas a reactive tracer, such as a chemical reacting with its surroundings, may grow or decay over time.) Volumetric contributions from different sources are determined by simulating transport of conservative tracer constituents. These volume contributions can be useful in estimating concentrations of conservative constituents (Anderson, 2002). In this report, historical volumetric and electrical conductance (EC) fingerprinting was modeled.

Frequently used Terms and Abbreviations

A complete list of specialized terms, acronyms, and abbreviations is located at the front of this report. Some frequently used terms and abbreviations are defined here:

Banks Pumping Plant: The Harvey O. Banks Pumping Plant is the headworks monitoring station at the start of the California Aqueduct.

Contra Costa Pumping Plant (CCPP): Contra Costa Water District Pumping Plant #1

Critical Year, Dry Year, Below Normal Year, Above Normal Year, and Wet Year: Runoff year types indicating very low, low, moderately low, moderately high and high total unimpaired runoff in a watershed, respectively, as defined in http://cdec.water.ca.gov/cgi-progs/iodir/wsihist (DWR, 2010e). The Sacramento and San Joaquin basins are defined independently.

Dry months: May 1 to October 31 of each calendar year

NEMDC: Natomas East Main Drainage Canal

p-value and statistical significance: In this report, the p-value, or p in short, 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 declare if a test is statistically significant. The p-value is a measure of the likelihood that the observed pattern is the result of random chance, rather than a genuine effect. The smaller the p-value, the stronger is the evidence supporting statistical significance. This report uses a commonly accepted α value of 5%, or $\alpha = 0.05$. If the p-value is < 0.05, the statistical test is declared significant; otherwise, the test is declared not statistically significant.

Reporting period/Summary period: The period from October 1, 2007 to September 30, 2009, which spans two water years. Thus, “the reporting period” or “the summary period” may also be referred to as “the two water years” throughout the report.

SJR: San Joaquin River

TKN: Total Kjeldahl nitrogen is the sum of total digestible organic nitrogen plus ammonia and ammonium and excludes the inorganic nitrogen species such as nitrate, and nitrite.

VAMP: Vernalis Adaptive Management Plan is mandated by State Water Resources Control Board Decision 1641. From April 22 to May 22 in 2008, and from April 19 to May 19 in 2009, reservoir releases to the SJR are increased, and a temporary barrier was installed at the head of the Old River (Head of Old River Barrier – HORB) to increase the survival of juvenile Chinook salmon in their migration to the ocean.

Water year or WY: The period from October 1 of one calendar year to September 30 of the following calendar year is called a water year. The year number is the latter of the two calendar years; for example, 2005 WY runs from October 1, 2004 to September 30, 2005.

Wet months: November 1 to April 30 of each water year

Table 1-1. MWQI discrete monitoring stations, 2007-2009.

Station	*DWR Station Number*	*Monitoring Frequency*
Stations north of the Delta		
American River at E.A. Fairbairn WTP[a]	A0714010	Monthly
West Sacramento WTP Intake	A0210451	Monthly
Natomas East Main Drainage Canal	A0V83671280	Monthly
Sacramento River at Hood	B9D82211312	Biweekly
San Joaquin River near Vernalis	B0702000	Biweekly
Channel and diversion stations		
Old River at Station 9	B9D75351342	Monthly
Old River at Bacon Island	B9D75811344	Monthly
Jones Pumping Plant	B9C74701355	Variable
Banks Pumping Plant	KA000331	Monthly
Contra Costa Pumping Plant	B9591000	Monthly
Middle River at Union Point	B9D75351292	Monthly
Mallard Island	E0B80261551	Monthly

[a] WTP = water treatment plant

Table 1-2. Analytical methods and reporting limits for included constituents.

Constituent	*Method source*[a]	*Method number*	*Reporting limit*[b]
Total organic carbon (TOC)	Std Methods	5310-D, Wet oxidation, IR, automated	0.5
	USEPA	415.3 Wet oxidation, IR, automated	0.5
Dissolved organic carbon (DOC)	USEPA	415.3 Wet oxidation, IR, automated	0.5
UV absorbance at 254 nm	Std Methods	5910-B UV-absorbing organics	0.001 cm-1
Bromide		300.0 ion chromatography	0.01
Electrical conductivity (EC)	Std Methods	2310-B Wheatstone Bridge	1 µS/cm
	USEPA	120.1 Wheatstone Bridge	1 µS/cm
Total dissolved solids (TDS)	Std Methods	2540-C Gravimetric, dried at 180° C	1
	USEPA	160.1 Gravimetric, dried at 180° C	1
Total suspended solids (TSS)	USEPA	160.2	1
THMFP	DWR	THMFP Buffered	
Chloride	Std Methods	4500-Cl-E Colorimetric, Ferricyanide	1
Sulfate		375.2 Colorimetric, Methythymol Blue	1
		300.0 Ion Chromatography	1
Calcium	USEPA	215.1AA Flame	1
		200.7 ICP	1
Magnesium		242.1 AA Flame	1
		200.7 ICP	1
Potassium	USEPA	200.7 ICP	0.5
Sodium		273.1 AA Flame	1
		200.7 ICP	1
pH	Std Methods	2320-B Electrometric	0.1 pH unit
	USEPA	150.1 Electrometric	0.1 pH unit
Alkalinity	Std Methods	2320-B Titrimetric	1
	USEPA	310.1 Titrimetric	1
Hardness	Std Methods	2340 B total by calculation	1
Turbidity	Std Methods	2130-B Nephelometric	1 NTU
	USEPA	180.1 Nephelometric	1 NTU

Note: Condensed from Appendix A of *Bryte Chemical Laboratory Quality Assurance Manual* (Fong and Aylesworth, 2006).
[a]Std Methods=standard methods as defined in *Standard Methods for the Examination of Water and Wastewater* (Clesceri, et al., 1998).
[b]Unit is mg/L unless otherwise indicated.

Table continued on next page

Table 1-2. continued

Constituent	*Method source* [a]	*Method number*	*Reporting limit* [b]
Aluminum	USEPA	200.7 ICP	0.05
		200.8 ICP/MS	0.01
		200.9 GFAA	0.01
Antimony	USEPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
Arsenic	Std Methods	3114 (4d), AA gaseous hydride	0.001
	USEPA	200.7 ICP	0.05
		200.8 ICP/MS	0.001
Barium	USEPA	200.7 ICP	0.01
		200.8 ICP/MS	0.05
		200.9 GFAA	0.05
		208.2 GFAA	0.05
Boron	USGS	I-2115-85 Colorimetric, Azomethine	0.1
Cadmium	USEPA	200.7 ICP	0.01
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		213.2 GFAA	0.005
Total chromium (all valencies)	USEPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		218.2 GFAA	0.005
Cobalt	USEPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		219.2 GFAA	0.005
Copper	USEPA	200.7 ICP	0.02
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		220.1 AA Flame	0.1
		220.2 GFAA	0.005

Note: Condensed from Appendix A of Bryte Chemical Laboratory Quality Assurance Manual (Fong and Aylesworth, 2006).
[a]Std Methods=standard methods as defined in Standard Methods for the Examination of Water and Wastewater (Clesceri, et al., 1998).
[b]Unit is mg/L unless otherwise indicated.

Table continued on next page

Table 1-2. continued

Constituent	*Method source*[a]	*Method number*	*Reporting limit*[b]
Iron	USEPA	200.7 ICP	0.025
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		236.1 AA Flame	0.1
		236.2 GFAA	0.005
Lead	USEPA	200.7 ICP	0.05
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		239.2 GFAA	0.005
Manganese	USEPA	200.7 ICP	0.01
		200.9 GFAA	0.005
		243.1 AA Flame	0.1
		243.2 GFAA	0.005
Mercury	USEPA	245.1 AA, Flameless, cold vapor	0.001
Molybdenum	USEPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		246.2 GFAA	0.005
Nickel	USEPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		249.1 AA Flame	0.1
		249.2 GFAA	0.005
Selenium	Std Methods	3114B AA gaseous hydride	0.001
	USEPA	200.8 ICP/MS	0.001
Silver	USEPA	200.7 ICP	0.025
		200.8 ICP/MS	0.001
		200.9 GFAA	0.005
		272.2 GFAA	0.005

Note: Condensed from Appendix A of Bryte Chemical Laboratory Quality Assurance Manual (Fong and Aylesworth, 2006).
[a]Std Methods=standard methods as defined in Standard Methods for the Examination of Water and Wastewater (Clesceri, et al., 1998).
[b]Unit is mg/L unless otherwise indicated.

Table continued on next page

Table 1-2. continued

Constituent	*Method source*[a]	*Method number*	*Reporting limit*[b]
Zinc	USEPA	200.7 ICP	0.02
		200.8 ICP/MS	0.005
		200.9 GFAA	0.005
		289.1 AA Flame, Direct	0.1
		289.2 GFAA	0.005
Ammonia	Std Methods	4500-NH_3 B, G Automated Phenate	0.01
	USEPA	350.1 Automated Phenate	0.01
Total Kjeldahl nitrogen	USEPA	351.2 Colorimetric, semi-automated	0.1
Nitrate	Std Methods	4500-NO_3-F Cd-Reduction	0.01
	USEPA	353.2 Cd-Reduction, Automated	0.01
Nitrite + nitrate	USEPA	353.2, Cd-Reduction, Automated	0.01
Orthophosphate	Std Methods	4500-P-E Colorimetric, Ascorbic Acid	0.01
	USEPA	365.1 Colorimetric, Ascorbic Acid	0.01
Phosphorus, total	USEPA	365.4 Colorimetric, semi-automated	0.01

Note: Condensed from Appendix A of Bryte Chemical Laboratory Quality Assurance Manual (Fong and Aylesworth, 2006).
[a]Std Methods=standard methods as defined in Standard Methods for the Examination of Water and Wastewater (Clesceri, et al., 1998).
[b]Unit is mg/L unless otherwise indicated.

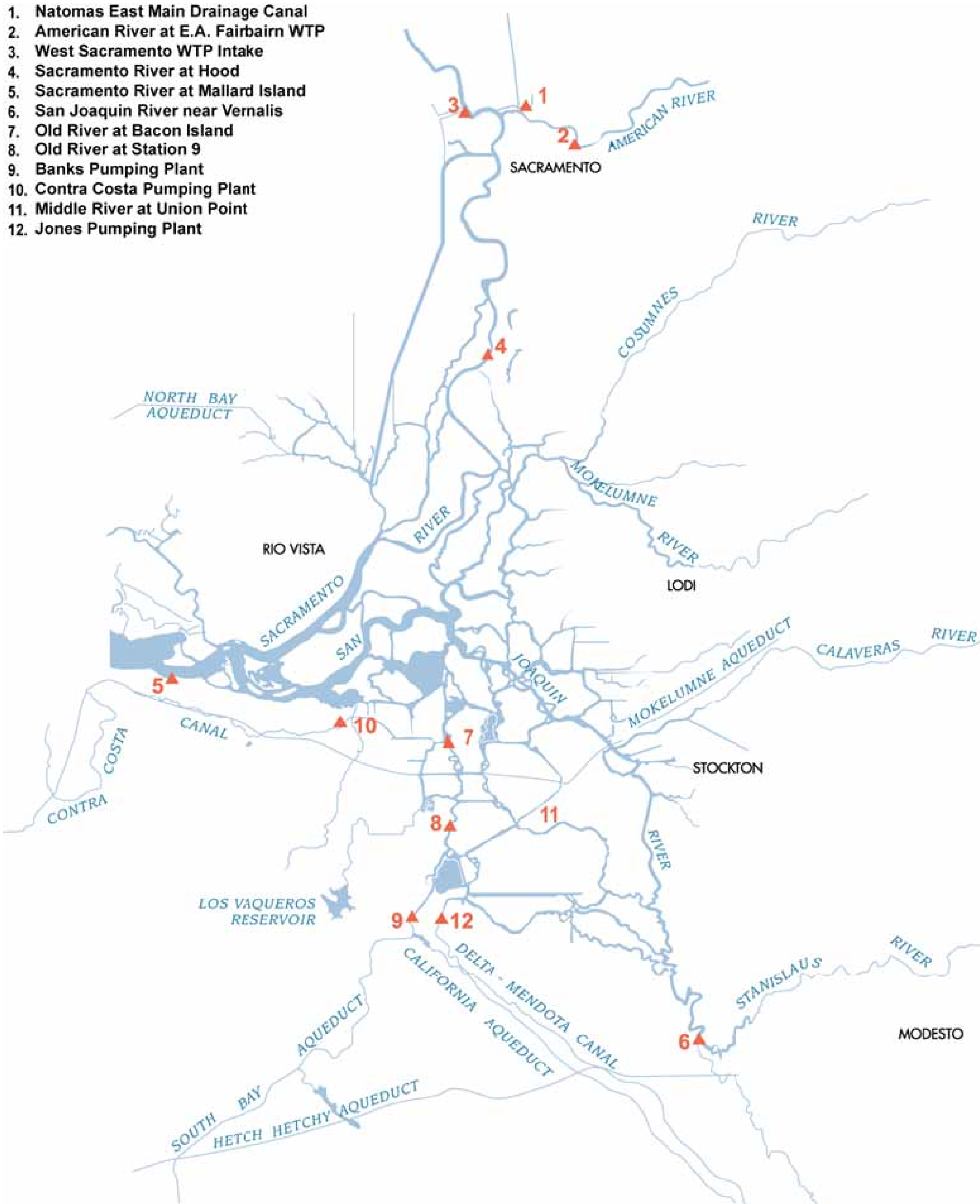


Figure 1-1. MWQI discrete sampling stations, October 1, 2007, to September 30, 2009.

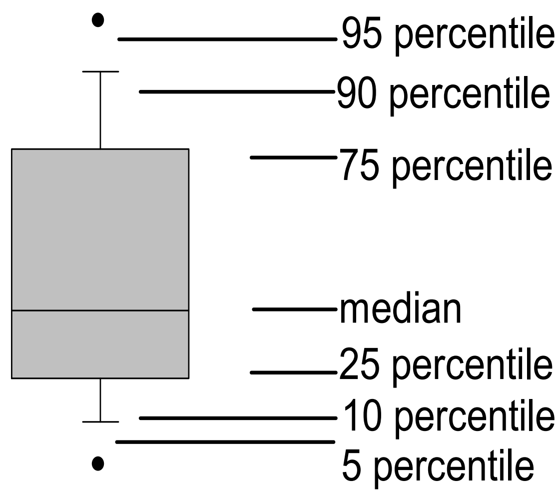


Figure 1-2. Illustrative Box Plot.

Chapter 2 Watershed and Delta Hydrology

Water quality in the Delta is affected by the hydrology of the Delta as well as the hydrologic conditions of the watersheds that contribute water to it. Data presented in this chapter include inflows from the two major rivers, releases from the larger reservoirs, precipitation in the watersheds, and the calculated total Delta outflow. Hydrologic classification indices are also presented for both watersheds for water years (WYs) 2004 through 2009.

Sacramento River Basin

The Sacramento River watershed is greater than 26,000 square miles and is the largest in the state. The major tributaries are the Pit, McCloud, Feather, Yuba, and American Rivers. Although it is not a tributary nor is it in the Sacramento River watershed, some of the Trinity River flow is diverted to the Sacramento River.

Flow in the Sacramento River originates as runoff from six major areas. These are the Sacramento Valley, the Modoc Plateau, plus the mountainous areas of the Coast Range, Klamath Mountains, Cascade Range, and Sierra Nevada. Most of the population in this watershed, as well as the majority of agricultural land, is in the Sacramento Valley; therefore, the greatest use of water in this area is for domestic supply and agricultural purposes.

The major reservoirs in the watershed have a total capacity of approximately 10 million acre-feet. Precipitation in the Central Valley occurs primarily in the winter and spring. Because demand for water is greater in the summer and fall, it is fortunate that much of the precipitation at higher elevations occurs as snow. In this way, these areas act as natural reservoirs holding the water for later use.

San Joaquin River Basin

The San Joaquin River (SJR) is the second largest river in the state with a watershed of approximately 15,200 square miles. The major tributaries are the Merced, Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes rivers. The San Joaquin and its major tributaries have their origin in the Sierra Nevada, and they all have reservoirs. There are nine reservoirs with a capacity equal to or greater than 100,000 acre-feet. Their total capacity is 7.44 million acre-feet.

Precipitation in the Sacramento and San Joaquin Valleys

Data from three weather stations in each valley are presented in this chapter, and the locations of these stations are shown in Figure 2-1. Stations used in the Sacramento Valley are Redding Fire Station, Durham, and California State University at Sacramento (CSUS). Stations used in the San Joaquin Valley are Brentwood, Stockton Fire Station, and Madera.

Data for these stations were obtained from two sources: the California Data Exchange Center (CDEC) and the California Irrigation Management Information System (CIMIS). CDEC provided data for the Redding Fire Station, Stockton Fire Station, and CSUS stations. CIMIS provided data for the Durham, Brentwood, and Madera stations.

Seasonal rainfall patterns were typical for the state, with most occurring during the late fall through early spring and little to none during the summer. In the Sacramento River watershed, Redding Fire Station had the greatest annual rainfall, with 36.92 inches in WY 2008 and 39.32 inches in WY 2009. Out of all six stations monitored in the Sacramento Valley and in the San Joaquin Valley, Redding Fire Station had the maximum amount of rainfall in a month with precipitation recorded at 14.20 inches (Figure 2-2(a)). In the SJR watershed, Stockton Fire Station had the greatest annual rainfall with 10.64 inches in WY 2008 and 11.64 inches in WY 2009 (Table 2-1, Figure 2-2(b)). The cumulative precipitation recorded at the Brentwood station and Stockton Fire Station differed by only 0.18 inches in WY 2008. Due to missing data from March 2009 through June 2009 at the Brentwood station, similar comparisons could not be made for WY 2009.

Water Year Classification

The classification of water years is done using a system developed by the State Water Resources Control Board (SWRCB). The method is found in Water Rights Decision 1641, revised March 15, 2000 (SWRCB, 2000), and is based on the amount of unimpaired runoff at key stream stations in the Sacramento River and SJR watersheds. Under this system there are five water year types: wet, above normal, below normal, dry, and critical.

The Sacramento Valley water year types were critical in WY 2008 and dry in WY 2009 (Table 2-2). The water year types for the San Joaquin Valley were critical in WY 2008 and below normal in WY 2009 (Table 2-2). For the past three water years both valleys total amount of rainfall have been lower than an average year and, therefore, ranged in water years types from below normal to critical.

Releases from Reservoirs

Central Valley reservoirs furnish water for agricultural, municipal, industrial, recreational, and environmental uses. Millions of people in California receive a high percentage of their household water from these reservoirs, and approximately four million acres of cropland are irrigated with water from these sources. Because most of the precipitation occurs in a six-month period, these reservoirs are needed to supply water year-round.

Sacramento Valley

Monthly releases from major reservoirs or tributaries to the Sacramento River are shown in Figure 2-3. Shasta Reservoir release data include water imported from the Trinity River. Releases from Oroville and New Bullards Bar reservoirs combine data from Oroville Reservoir with Englebright Reservoir using source waters originating from the Feather and Yuba rivers. To compensate for less watershed runoff and in order to meet total Delta outflow demands during the dry months, releases from Sacramento reservoirs tended to be greater during the summer than the winter months.

Reservoir releases differed roughly by 56 thousand acre-feet between the two water years (Figure 2-3 and Table 2-2). Total releases from the Sacramento Valley reservoirs were approximately 9.43 million acre-feet for WY 2008 and 10.00 million acre-feet for WY 2009. Total reservoir releases for both water years reflect the lack of snowmelt and precipitation.

San Joaquin Valley

Release data from six major reservoirs in the SJR watershed are presented in Figure 2-4. Data from New Melones, New Hogan, and Camanche reservoirs are included in the top graph. The bottom graph includes data from Millerton Lake, Lake McClure, and Don Pedro Reservoir. Total releases from these reservoirs for the two water years were much lower than those from reservoirs in the Sacramento River watershed. The total release for WY 2008 was approximately 3.68 million acre-feet, and the total for WY 2009 was approximately 3.92 million acre-feet, indicating an estimated year-to-year difference of 24 thousand acre-feet. Total reservoir releases for the San Joaquin Valley for WYs 2008 and 2009 were approximately 7.60 million acre-feet—less than half of the Sacramento Valley.

Delta Outflows/Exports

The Sacramento River, the SJR, and their tributaries provide fresh water inflow to the Delta. Within the Delta, diversions of water reduce the amount of fresh water that flows out of the Delta and into the Suisun and San Francisco Bays. Besides water used locally for irrigation, major diversions that remove water from the Delta include the State Water Project (SWP) and the Central Valley Project (CVP). Collectively, the SWP and the CVP are known as Projects.

Water that is not diverted or does not evaporate from the channels flows out of the Delta and into the bays. The lower the outflow, the more the tides increase the salinity of Delta waters. It is difficult to measure Delta outflow directly; instead, Delta outflows are determined mathematically. The calculated outflows and inflows of the Sacramento and San Joaquin Rivers are presented in Figure 2-5. The outflows tend to be lowest in the late summer and early autumn.

To ensure compliance with Bay-Delta Standards contained in D-1641, exports were coordinated between the Projects (Figure 2-8). The Minimum Delta Outflow, the Habitat Protection Outflow, and the Export and Inflow Ratio listed in the Bay-Delta Standards often restricted the export levels at different times of the years (IEP Newsletter, 2009). However, exports for CVP and SWP were restricted from late December 2007 until June 2008 due to delta smelt concerns, with the exception of parts of April and May of each year when the Vernalis Adaptive Management Plan (VAMP) determined exports (Figure 2-8). Exports for WY 2009, in addition to meeting the Bay-Delta Standards, were also controlled by the 2008 biological opinion's requirements (Figure 2-6) (see the section, "Hydrology and the 2008 Biological Opinion" below). For more information on Delta Water Project Operations, please see the 2009 Spring issue of the IEP Newsletter at http://www.water.ca.gov/iep/newsletters/2009/IEPNewsletter_FINALSpring2009.pdf (Baxter, et al., 2009).

Annual flow and export totals were calculated and compared to those from WY's 2004 through 2009. Annual flows from the Sacramento River, net Delta outflow (NDOI) and the San Joaquin River were lowest in 2008, 2009 and 2007, respectively (Figure 2-7), in comparison to WY 2004 through WY 2009. With increased restrictions, CVP and SWP annual export totals decreased over the past five years; SWP increased slightly in WY 2009 while CVP continued to decrease in both WYs 2008 and 2009.

Delta Cross Channel Operations

The Delta Cross Channel is a gated channel that connects the Sacramento River to Snodgrass Slough, which opens into the Mokelumne River. It is a facility of the U.S. Bureau of Reclamation (USBR) and is operated in accordance with the State Water Resources Control Board Decision 1641 (Figure 2-8) (SWRCB, 2000). When the gates are open, water from the Sacramento River has a more direct route and shorter distance to the major diversion pumps in the southern Delta. This, therefore, improves the quality of water being diverted by lowering the electrical conductivity (EC) and salinity.

The gates are closed during fish migration to avoid confusing migrating fish. They are also closed during high flows in the Sacramento River to reduce flood risks along the Mokelumne River and lower SJR. The timing of the opening and closing of the gates depends on the period of fish migration and the flows in the Sacramento River (Figure 2-8).

Hydrology and the 2008 Biological Opinion

In WY 2009, due to a sharp population decline in the endangered delta smelt, the California Department of Water Resources (DWR) and USBR implemented the 2008 biological opinion, discussed below, which affected exports and flows during WY 2009.

Previously, in 2005 the U.S. Fish and Wildlife Service's (USFWS) biological opinion (BiOp) found that the Central Valley Project (CVP) and State Water Project (SWP) combined would not endanger or jeopardize the survival of the delta smelt. However, the BiOp was challenged. On May 25, 2007, Judge Oliver Wanger of the United States District Court, Eastern District, ruled that the 2005 BiOp failed to analyze significant information, which rendered the finding in the BiOp on the threatened delta smelt arbitrary. Consequently, USBR and DWR were ordered to develop a new biological assessment. They submitted the new biological assessment to USFWS for consultation on August 20, 2008. USFWS issued its biological opinion on December 15, 2008. The 2008 USFWS BiOp found that the impact of coordinated CVP-SWP operations would jeopardize the survival of delta smelt through entrainment and/or by adversely modifying delta smelt critical habitat. Within the 2008 BiOp, USFWS developed Reasonable and Prudent Alternatives (RPAs) (consistent with the regulations implementing the Environmental Protection Act), which imposed operating restrictions for the projects (USFWS, 2008, p. 279). USBR and DWR provisionally accepted and began implementing the RPAs within the BiOp; however, this matter remains in litigation due to suits filed in court by various plaintiffs.

The Reasonable and Prudent Alternatives (RPAs) consist of five components:

Component 1: Protection of the Adult Delta smelt Life Stage

Component 2: Protection of Larval and Juvenile Delta smelt

Component 3: Improve Habitat for Delta smelt Growth and Rearing

Component 4: Habitat Restoration

Component 5: Monitoring and Reporting

Out of the five components, components 1 and 2 involve average combined flow in Old and Middle rivers (OMR) and have three actions associated with the components that directly affected export pumping during WY 2009 (Figure 2-6). Figure 2-9 and Figure 2-10 show the periods and actions that occur during components 1 and 2. For more information on the 2008 BiOp's RPA's, please see pages 279-285 and Attachment B (USFWS, 2008).

Vernalis Adaptive Management Plan

The Vernalis Adaptive Management Plan (VAMP) is a 12-year experiment designed to protect juvenile Chinook Salmon migration from the San Joaquin Basin and determine how salmon survival rates change in response to alternations in San Joaquin river flows and State Water Project (SWP) and Central Valley Project (CVP) exports with the installation of the Head of Old River Barrier (HORB). The normal VAMP period is from April 15 through May 15, but it can be a different 31-day period based on the time of the migration. In years of lower flows, releases from the major reservoirs in the San Joaquin watershed are increased. At the same time, combined pumping at the Banks and Tracy pumping plants are reduced to 1,500 cubic feet per second (cfs). In years of higher flows, the combined pumping can be higher. Because the VAMP program is adaptively managed and adjusted based on the hydrology of the particular year, specific levels of pumping corresponding to various levels of flow cannot be forecast until the spring of that year. In addition to the limited pumping during VAMP, a temporary barrier is constructed at the HORB. This barrier causes the migrating smolts to follow the SJR through the Delta, thereby avoiding SWP and CVP diversions.

To help guard against the potential impacts to the delta smelt, the HORB was not installed for WYs 2008 and 2009. In WY 2009, the VAMP project tested a new measure to deter juvenile Chinook salmon from migrating down Old River by using a fish guidance system composed of underwater lights, sounds, and bubbles. Information about the VAMP period can be found in two issues of the San Joaquin Basin Update published by FishBio (April 24, 2008 and June 11, 2009) as well as in the VAMP 2008 technical report (SJRGA, 2009).

Actions associated with the VAMP for WY 2008 began April 22 and ended on May 22, 2008. The Vernalis target flow was 3,200 cfs with combined exports of 1,500 cfs. Mean daily pumping at the federal pumps at C.W. Jones Pumping Plant ranged between 839 cfs and 2,617 cfs. State mean daily pumping at the Harvey O. Banks Pumping Plant ranged between 488 cfs and 2,819 cfs. Combined state and federal pumping during the VAMP period ranged between 1,327 cfs and 4,654 cfs (SJBU, 2008).

In WY 2009, actions associated with the VAMP began April 19 and ended on May 19, 2009. Vernalis target flow was 2,200 cfs with combined exports of 1,500cfs. Mean daily pumping at the federal pumps at C.W. Jones Pumping Plant ranged between zero cfs and 1,807 cfs. State mean daily pumping at the Harvey O. Banks Pumping Plant ranged between zero cfs and 2,447 cfs. Combined State and federal pumping during the VAMP period ranged between zero cfs and 3,553 cfs (SJBU, 2009).

Volumetric Fingerprinting

Volumetric fingerprinting of water at the west side of Bacon Island (Old River) and Clifton Court Forebay is shown in Figure 2-11 and Figure 2-12, respectively. Volumetric fingerprints calculate and track the relative volumetric contributions of various water sources in a column of water to create a percentage contribution from each source water at a specified location in the Delta. The methodology and applications of volumetric fingerprinting using the Delta Simulation Model 2 (DSM2) can be found in several publications (Anderson, 2002; Anderson and Wilde, 2005; Mierzwa and Wilde, 2004). Fingerprinted locations were chosen to facilitate explanations between observed water quality in the central and south Delta and the volumetric sources of water. Modeled fingerprints of source water are also valuable in interpreting changes in electrical conductance (EC) and explaining how hydrology affected the movement of water. DWR's Bay-Delta office provided all of the volumetric fingerprint calculations. In Chapter 5, volumetric and EC fingerprints of source water are analyzed for correlations with EC variability.

The volumetric fingerprint at Old River, Figure 2-11, shows that the majority of its source water originated from the Sacramento River for both WYs 2008 and 2009. However, on its way to the Clifton Court Forebay (Figure 2-12), the SJR source water increased considerably in both water years, especially in WY 2008. One of the most important aspects shown by volumetric fingerprints is how the San Joaquin River can dominate water quality at Clifton Court during certain seasons of the year. In the spring of WY 2008, San Joaquin River water accounted for close to 80% of the source water at Clifton Court Forebay. The following water year it was less than 20%. As discussed in the following chapters, this phenomenon can have significant consequences for water quality (Figure 2-11 and Figure 2-12). During other periods of the water years, the Sacramento River dominated source waters at the pumps; however, increases in other source waters can affect water quality as discussed in the following chapters.

Table 2-1. Summary of monthly precipitation (inches) at six weather stations.

Station	Reporting months	Months rained	Monthly precipitation			Cumulated precipitation in water year[b]	
			Range[a]	Mean[a]	Median[a]	2008	2009
Sacramento Valley							
Redding Fire Station	24	21	0.00–14.20	3.18	0.88	36.92	39.32
Durham	24	15	0.28–6.18	2.16	1.88	15.23	17.14
Sacramento State University	24	18	0.00–7.43	1.31	0.85	14.73	16.79
San Joaquin Valley							
Stockton Fire Station	24	17	0.00–5.80	0.93	0.48	10.64	11.64
Brentwood[c]	18	12	0.01–5.58	1.04	0.49	10.46	1.97
Madera	24	17	0.01–3.77	0.90	0.47	8.08	7.25

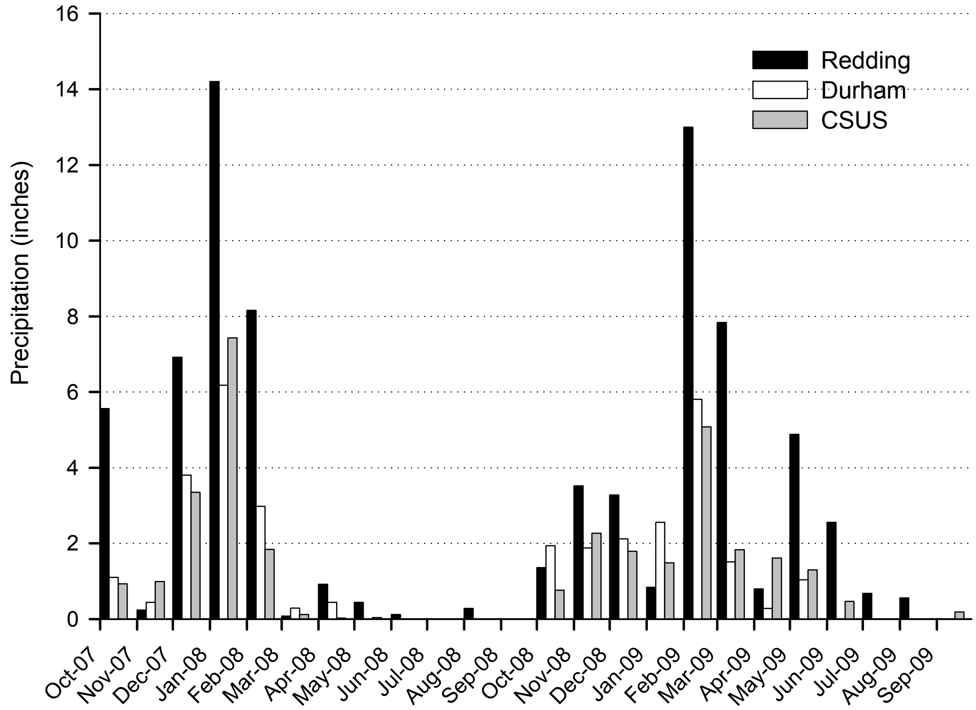
[a] Calculated with data from months with rain.
[b] Water year runs from October 1 to September 30; for example, the 2008 water year runs from October 2007 through September 2008.
[c] CMIS station San Francisco Bay – Brentwood -#47 had missing data from March 2009 through July 2009.

Table 2-2. Hydrologic index classification based on measured unimpaired runoff at selected rivers.

Water year	*Sacramento Valley*	*San Joaquin Valley*
Previous summary period		
2004	Below Normal	Dry
2005	Above Normal	Wet
2006	Wet	Wet
2007	Dry	Critical
Current Summary Period		
2008	Critical	Critical
2009	Dry	Below Normal

Figure 2-1. Location of selected weather stations.

(a)



(b)

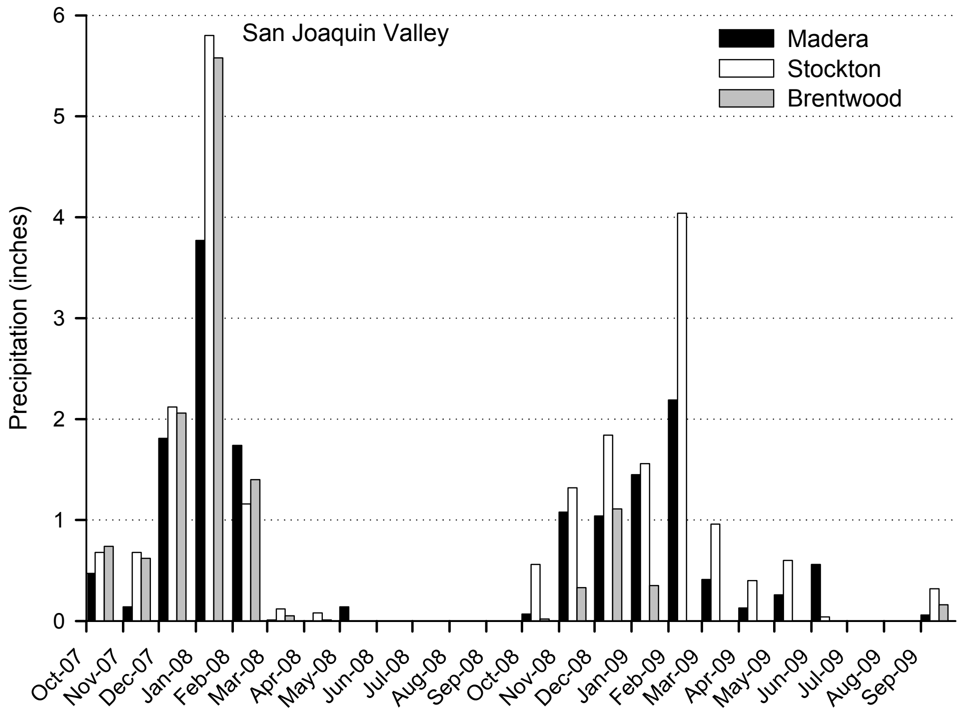


Figure 2-2. Monthly precipitation at 6 stations in the Sacramento-San Joaquin River watersheds. a. Sacramento Valley. b. San Joaquin Valley.

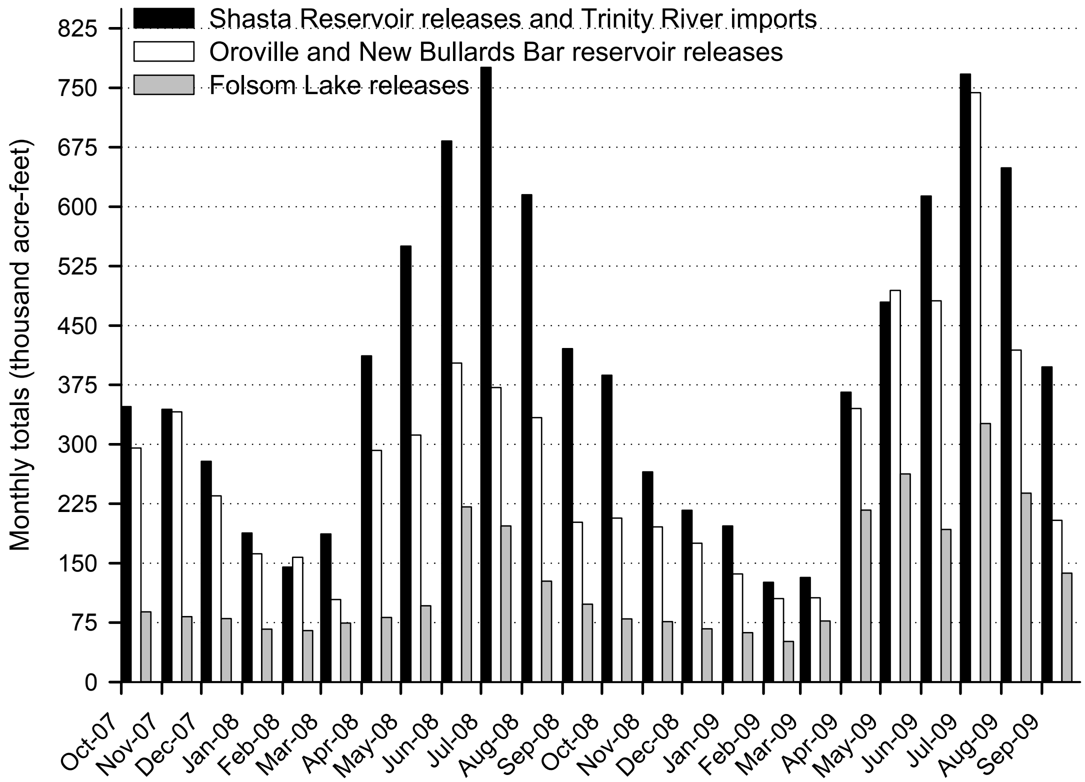
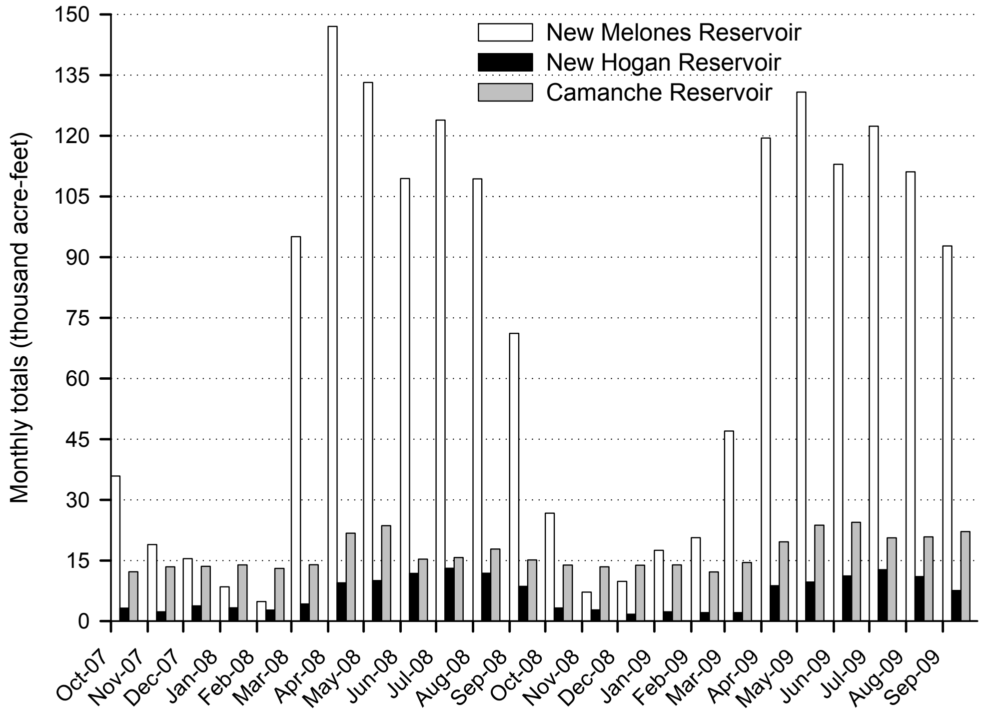


Figure 2-3. Sacramento River watershed reservoir releases.

(a)



(b)

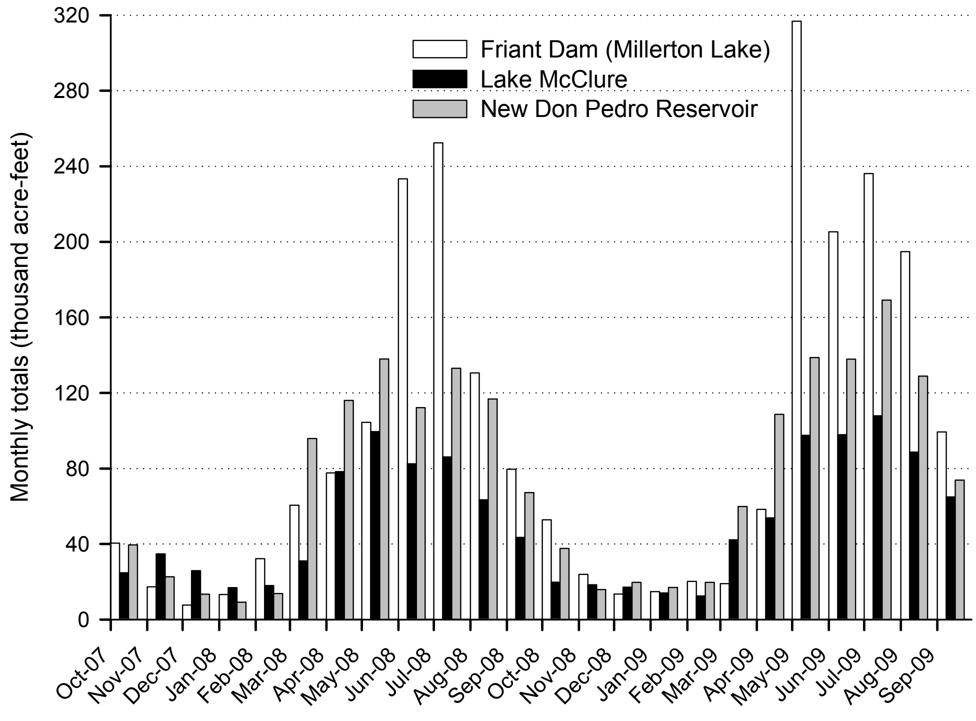


Figure 2-4. San Joaquin River watershed reservoir releases. a. New Melones, New Hogan, and Camanche reservoirs. b. Friant Dam (Millerton Lake), Lake McClure, and New Don Pedro Reservoir.

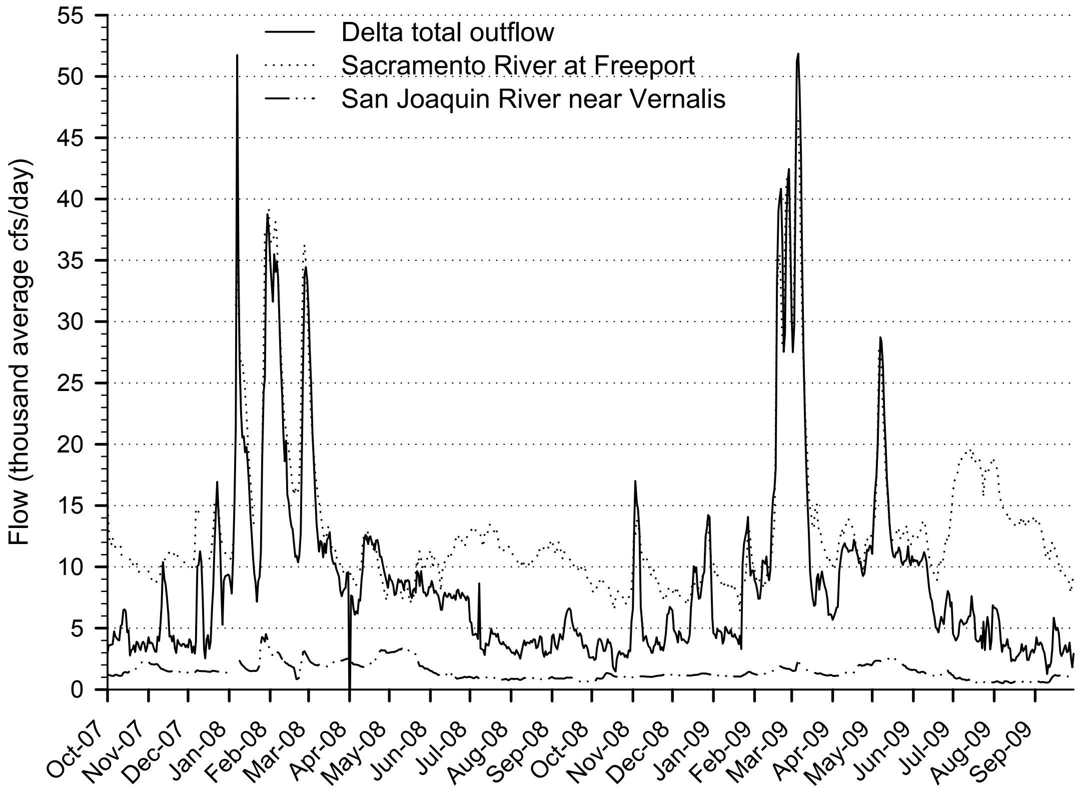


Figure 2-5. Delta total outflow and major river inflows (WYs 2008 and 2009).

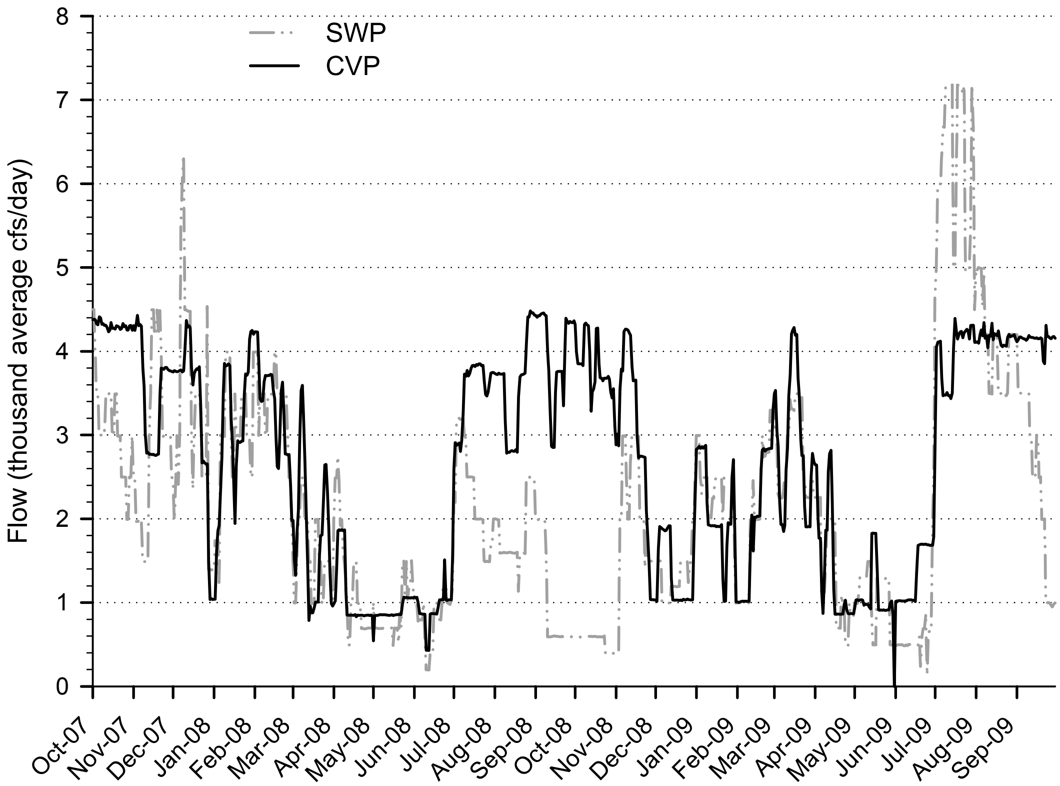


Figure 2-6. SWP and CVP daily average exports during WY 2008 and 2009.

Source: Interagency Ecological Program (IEP) Newsletter

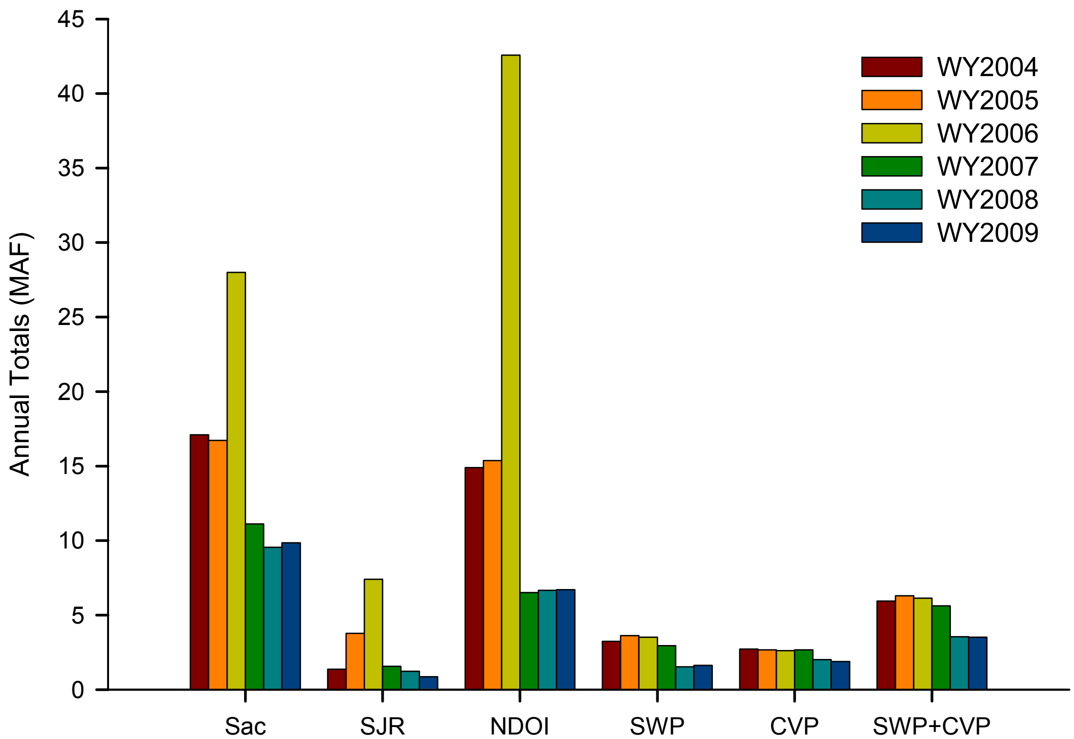
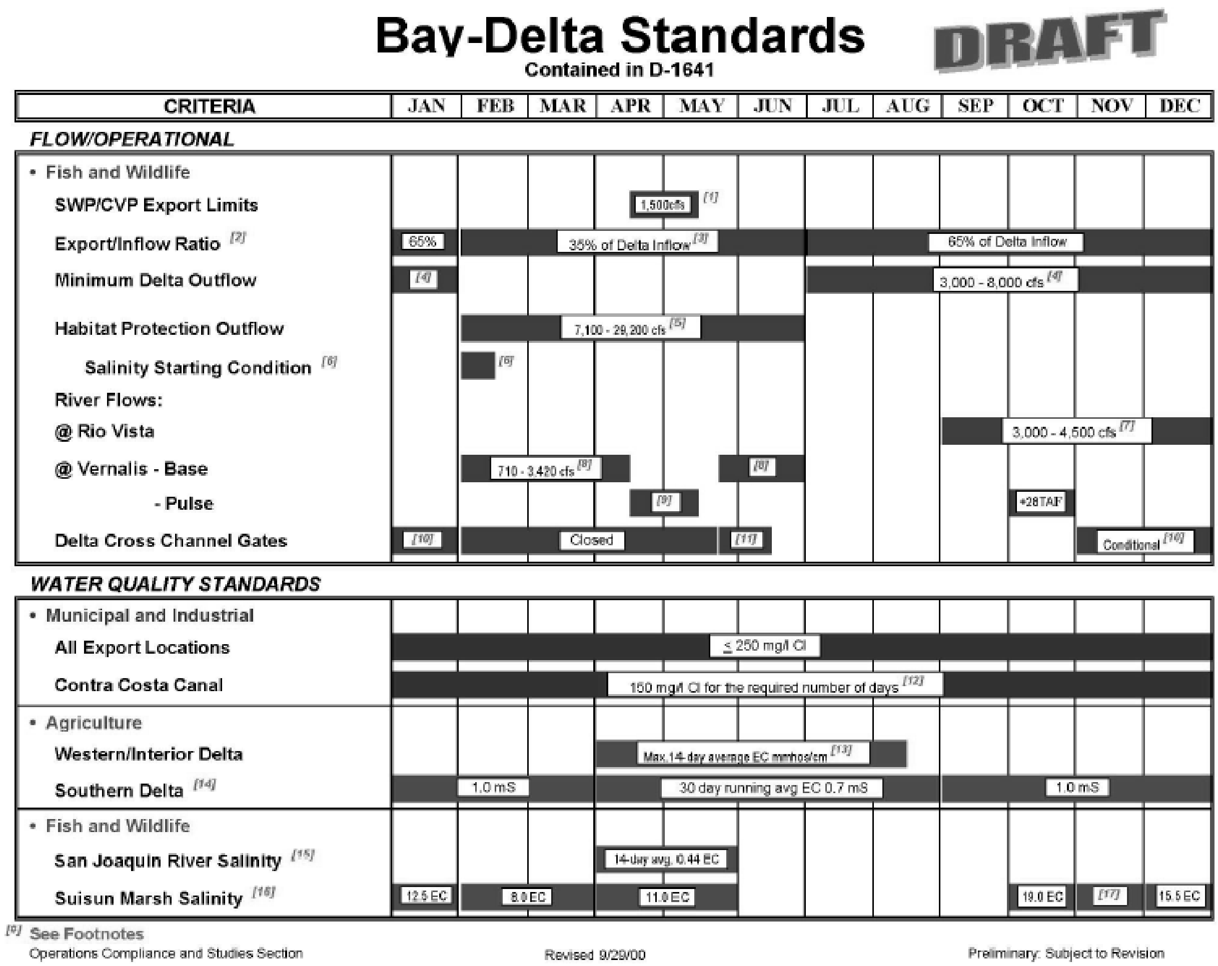


Figure 2-7. Annual discharge and export totals for water years 2004 through 2009.

Source: Interagency Ecological Program (IEP) Newsletter, Volume 22, Issue 2, p. 8.



For footnote information see http://swpoco.water.ca.gov/cmplmon/bay_deltastandards.htm

Figure 2-8. Summary of D-1641 Bay-Delta Standards.

Source: Interagency Ecological Program (IEP) Newsletter, Volume 22, Issue 2, p. 7.

Figure 2-9. RPA Action 1a and 1b.

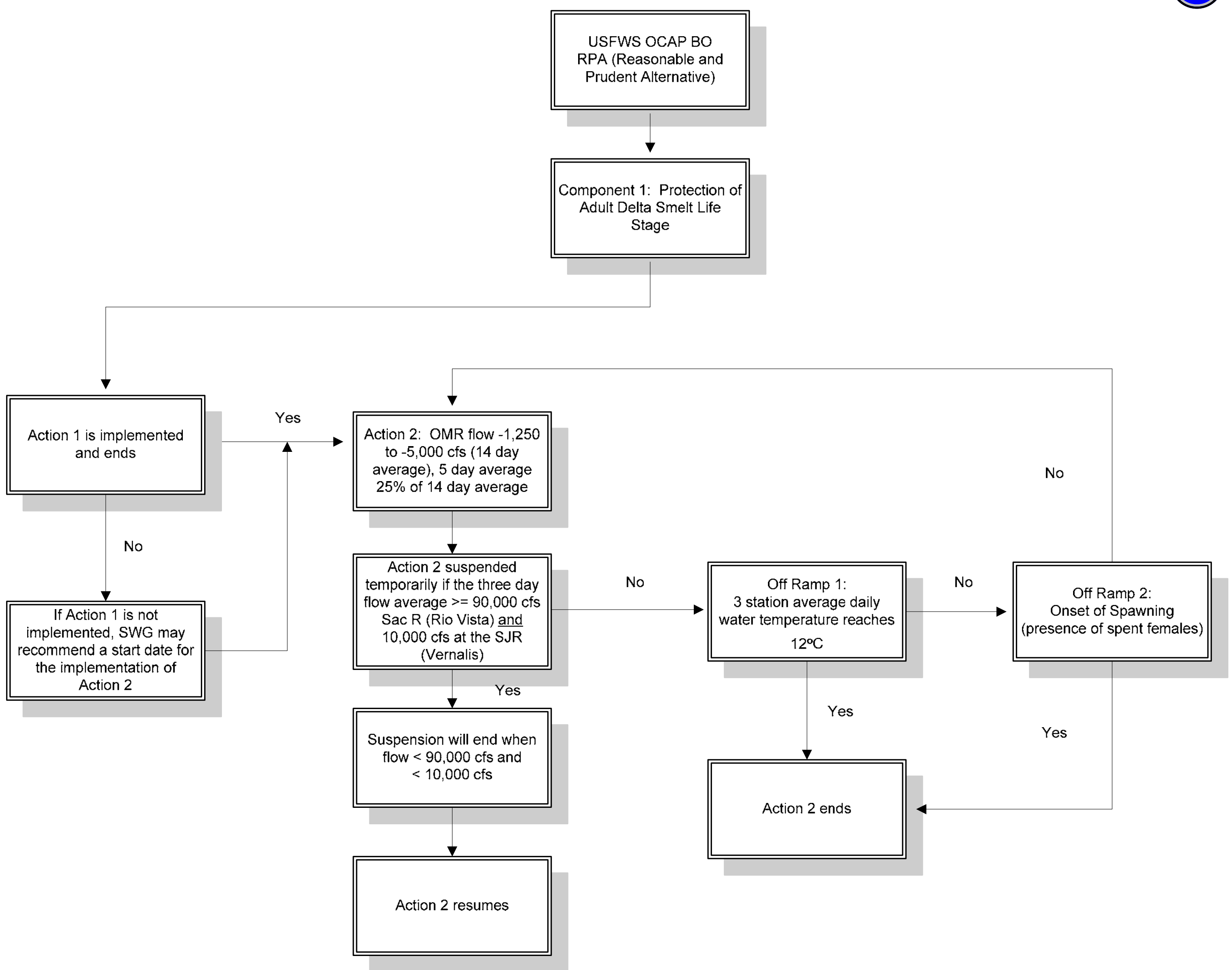


Figure 2-10. RPA Action 2.

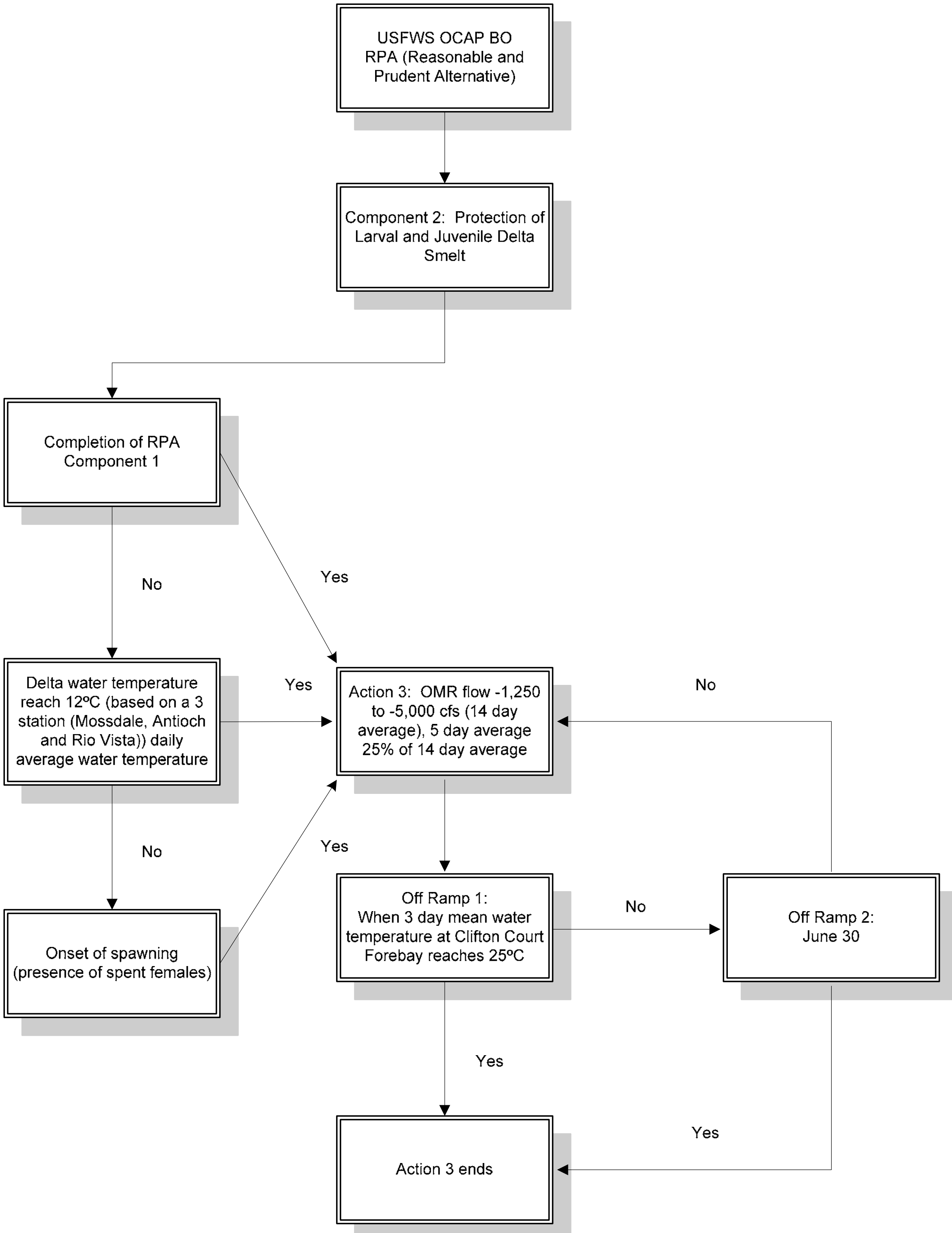


Figure 2-11. RPA Action 3.

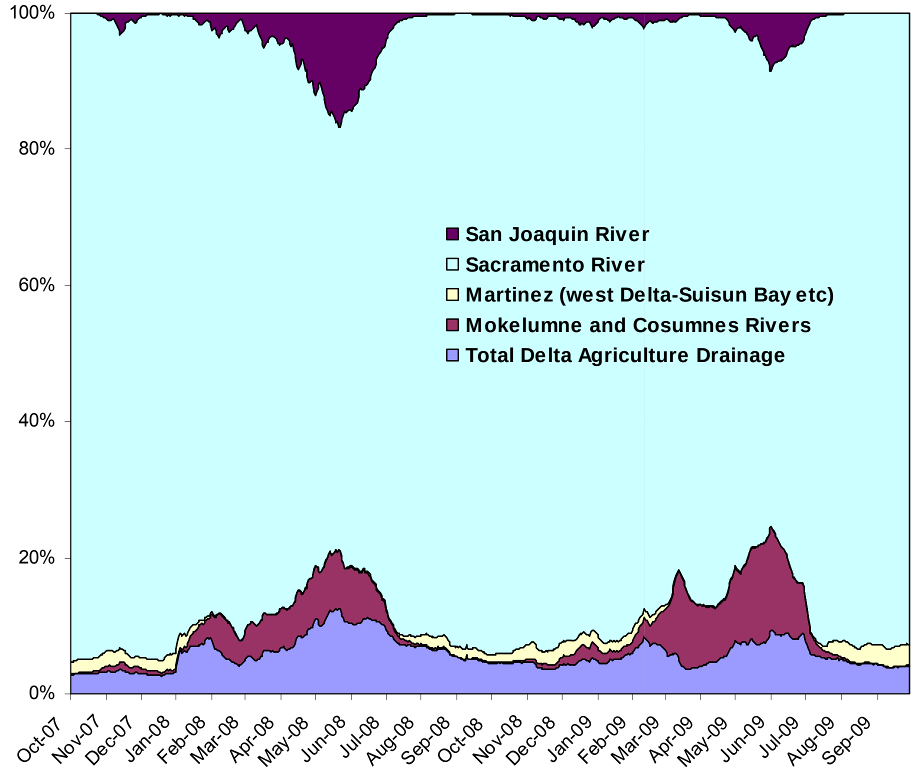


Figure 2-12. Volumetric fingerprint at Old River.

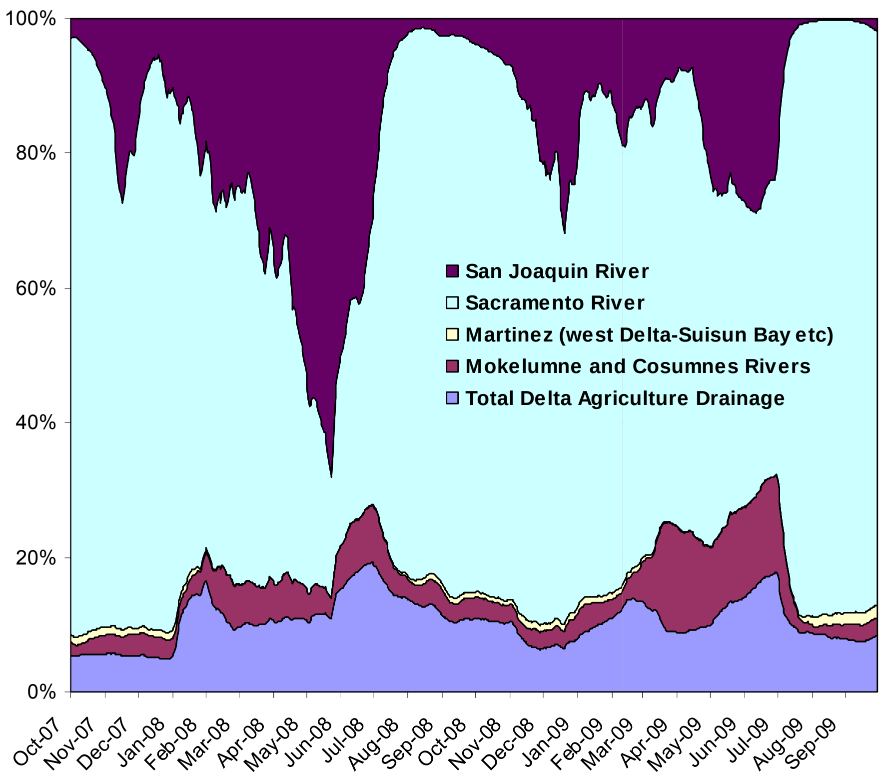


Figure 2-13. Volumetric fingerprint at Clifton Court Forebay.

Chapter 3 Organic Carbon

Organic carbon reacts with disinfectants in the water treatment process to form disinfection bi-products such as haloacetic acids and trihalomethanes. Haloacetic acids potentially increase the risk of cancer, and trihalomethanes may cause liver, kidney, or central nervous system problems and increase the risk of cancer (USEPA, 2010b). Organic carbon occurs in natural waters in both dissolved and particulate forms, usually measured as dissolved organic carbon (DOC: all that passes through a 0.45 um filter) and total organic carbon (TOC: all organic carbon in an unfiltered sample).

Organic carbon can be viewed as a wide range of plant, microbial and animal organic chemical molecules in various stages of decomposition and transformation (Wetzel, 2001). Sources include land and aquatic plants, animals and bacteria. There is no maximum contaminant level (MCL) for dissolved organic carbon, although there are regulations for total organic carbon (TOC) in finished drinking water dependent on source water alkalinity (USEPA, 2010c). For finished drinking water, the MCL for haloacetic acid is 0.060 mg/L and the MCL for total trihalomethanes is 0.080 mg/L (USEPA, 2010a).

This chapter summarizes grab sample data for organic carbon collected at 12 stations in the Sacramento-San Joaquin Delta (Delta) from October 1, 2007, to September 30, 2009. The samples were collected twice a month from the Sacramento River at Hood, the San Joaquin River near Vernalis, and the Banks Pumping Plant. At the remaining stations, samples were collected monthly. A new monitoring station at the Jones Pumping Plant became active in January 2009. For the Banks Pumping Plant, Jones Pumping Plant, and Hood and Vernalis stations, additional samples were collected during the reporting period. These four stations have real-time monitoring equipment installed; quality assurance/quality control (QA/QC) and maintenance visits were made weekly or biweekly. During these QA/QC trips, additional discrete samples were collected. Note that only four samples were collected at the Jones Pumping Plant; therefore, no graphs or trend analyses were conducted for this station.

Organic carbon data were acquired by two laboratory analytical methods. One method, commonly referred to as the combustion method, oxidizes organic carbon at high temperature in a small chamber within the instrument; the other method, commonly referred to as the wet oxidation method, oxidizes organic carbon with chemical oxidants. Ngatia and Pimental (2007) found that the two methods are equivalent. The samples reported here were analyzed by the wet oxidation method. Basic summary statistics, including range, median, and averages, are presented. Brief discussions on seasonality at individual stations and some limited spatial comparisons are made.

Stations North of the Delta

MWQI sampled three stations near the northern boundary of the Delta. These stations are the American River at the E. A. Fairbairn Water Treatment Plant (WTP) intake, the Sacramento River at the West Sacramento WTP intake, and Natomas East Main Drainage Canal (NEMDC) (Figure 3-10). Water quality at these stations represents inflows to the Delta from the American and Sacramento rivers, as well as urban drainage from a heavily populated urban watershed (NEMDC).

American River at the E. A. Fairbairn Water Treatment Plant

With the exception of the rainy period in March 2009, organic carbon concentrations were generally at or below 2 milligrams per liter (mg/L) (Figure 3-1). During the rainy season, heavy rains in the Delta watershed tend to bring additional organic carbon into tributaries such as the American River, increasing carbon levels there to between 2 and 3 mg/L.

Both TOC and DOC ranges were quite similar, while median and average TOC and DOC concentrations differed by only 0.1 mg/L (Table 3-1). Such small differences suggest that organic carbon was mostly in a dissolved form, with seasonal differences generally associated with the rainy season (Figure 3-1).

American River water generally exhibits low turbidity (see Chapter 7, Other Water Quality Constituents), suggesting that particulate carbon (as a difference between TOC and DOC) concentrations were small.

Organic carbon fluctuations were generally small, except during the October through April rainy months (Figure 3-1). In response to rainfall events, organic carbon increased slightly between February and March 2008 and in March 2009, but elevated organic carbon levels did not persist. Water Year (WY) 2008 was classified as critically dry in the Sacramento Valley and 2009 was classified dry, with shorter runoff periods and lower river discharge than the long-term average (Table 2-2).

Sacramento River at the West Sacramento WTP intake

The West Sacramento WTP intake is about 2.5 miles (4.0 km) upstream of the confluence of the American and the Sacramento rivers (Figure 3-10). Water quality at this station reflects the quality of Sacramento River before mixing with inflows from the American River and NEMDC and before entering the Delta. Organic carbon concentrations were generally between 1 and 3 mg/L, with concentrations increasing to above 3 to 5 mg/L during periods of high river flow correlated to rain events (Figure 2-2 and Figure 3-2). The median levels of TOC and DOC for the reporting period were 2.0 and 1.9 mg/L, respectively (Table 3-1). Like the concentrations of TOC and DOC in the American River, TOC and DOC concentrations were higher in the Sacramento River during the wet months than during the dry months. The lack of differences between TOC and DOC in individual monthly values (Figure 3-2) indicated that organic carbon was mostly in the dissolved form.

Natomas East Main Drainage Canal (NEMDC)

NEMDC at El Camino Avenue in north Sacramento is an urban drainage canal that discharges water to the Sacramento River. It collects drainage waters from a rapidly urbanizing and highly populated watershed that lies on the north side of the city of Sacramento. NEMDC was the subject of a Municipal Water Quality Investigations (MWQI) special study that monitored loads, seasonality of organic carbon, coliform bacteria, and other constituents of concern (DWR, 2008b). While the intensive sampling involved with that study was suspended, MWQI has continued to collect monthly water quality samples as part of the routine north Delta monitoring program.

Among the three MWQI stations north of the Delta, organic carbon concentrations at NEMDC were consistently two to four times greater than those at the American River WTP intake, two to three times greater than the West Sacramento WTP intake, and higher than any other MWQI station (Table 3-1). Carbon concentrations were generally higher during the wet months than during the dry months, but the range between wet and dry was not as pronounced during the past two severely dry and dry years as was found in the 2008 MWQI biennial report. That report found that, after initial heavy rainfall events in the watershed, organic carbon concentrations were as high as 25 to 35 mg/L (DWR, 2008a, Table 3-1). Similar concentrations have occurred only after the first significant rainfall event following a long dry period (DWR, 2005). As found in the 2008 biennial report, organic carbon, during the dry months, ranged between 4 and 6 mg/L.

During the two-year period covered in this report, TOC and DOC concentrations tended to vary closely with each other. Median DOC was 5.1 mg/L; median TOC was 5.4 mg/L. These results suggest that organic carbon was primarily in the dissolved form (Figure 3-3). Since WY 2008 was critically dry in the watershed and WY 2009 was a dry year, the organic carbon time series for the two years were similar.

Sacramento River at Hood

Water at the Hood station is primarily a mixture of the Sacramento and American rivers, with smaller contributions from NEMDC and the Sacramento Regional Wastewater Treatment Plant shortly after their combined flows enter the legal Delta. Because of its key location, MWQI monitors water quality at Hood on a weekly to biweekly basis. During the reporting period, organic carbon concentrations ranged from

1.3 to 5.0 mg/L for TOC and 1.2 to 4.6 mg/L for DOC (Table 3-1). Median concentrations of TOC and DOC (2.1 and 2.0 mg/L, respectively) were not statistically different (Mann-Whitney, p=0.302), suggesting again that most of the organic carbon occurred in the dissolved form.

A clear discharge-driven seasonal pattern was observed at the Hood station, related to winter precipitation-driven flows (Figure 3-4). Organic carbon was elevated during the wet months and generally ranged between 2 and 5 mg/L; whereas during the dry months, organic carbon was between 1.0 and 2.5 mg/L with only small fluctuations. Taking into account the wet-and-dry-month seasonal patterns (comparing month to month), there was no evidence of an increase in organic carbon between water years (Mann-Whitney test, TOC: p=0.41 and DOC: p=0.67).

San Joaquin River near Vernalis

The San Joaquin River (SJR) monitoring station near Vernalis represents the water quality conditions at the point where the SJR enters the Delta from the southeast. As with the Hood station on the Sacramento River, water quality near Vernalis was monitored either weekly or biweekly during the reporting period. Organic carbon concentrations generally varied between 2 and 4 mg/L, but were as high as 7.4 mg/L (TOC) for the February 2008 sample (Figure 3-5). Median concentrations of TOC and DOC were 3.3 and 2.8 mg/L, respectively (Table 3-1). Differences between DOC and TOC were significant (Mann-Whitney, p=0.0013), indicating the presence of particulate organic carbon in the water. Differences between TOC and DOC occurred in the summer months, but not the winter (Figure 3-5), suggesting that algal production or other agriculturally influenced changes were responsible for shifts in the TOC/DOC ratio. Particulate organic carbon (as TOC minus DOC) ranged from zero to 2.8 mg/L (median 0.30 mg/L).

As with north Delta stations, organic carbon concentrations reached their annual maximum during the wet season (Figure 3-5). However, unlike northern Delta stations, where organic carbon concentrations during the dry seasons were relatively low, concentrations at Vernalis were often elevated during the dry months. This may be due to in-river algal production and upstream irrigation discharge. This occurrence was especially noticeable during the two drought years of this report: during the current reporting period, WYs 2008 and 2009 were classified as critically dry and below normal runoff years, respectively, for the San Joaquin River watershed (Figure 2-2). As Figure 3-5 shows, TOC and DOC diverge between June and August, reaching maximal values of 2.3 mg/L in June 2008 and 2.8 mg/L in July 2009. In contrast, TOC and DOC concentrations were generally lowest between April and May of each year due to increased river flows as part of the Vernalis Adaptive Management Plan (VAMP). During these dry water years, organic carbon concentrations increased as soon as the VAMP releases ended (Figure 3-5).

As noted earlier, the higher organic carbon concentrations during the dry months are likely attributed to a combination of in-river algal growth and agricultural drainage returns into the SJR. High dissolved nutrient concentrations, shallow depth and slow water flow conditions produce an environment conducive to algae production. Algae appear as high chlorophyll concentrations measured by other DWR *in-situ* sensors at Vernalis and, downstream, at Mossdale (CDEC, data not shown; Michael Dempsey, DWR, pers. comm.). Also, agricultural drainage enters the SJR during the May to October growing season, resulting in increased organic carbon concentrations in the river (Figure 3-5). Low organic carbon concentrations in October 2007 were probably due to decreased agricultural drainage entering the SJR at the end of the growing season coupled with cooler temperatures, which tend to reduce algal production. MWQI field staff has often seen this pattern between September and November.

Channel and Diversion Stations

Old River Stations

Two stations were sampled along Old River: one at Bacon Island (Bacon) and the other near Pumping Station 9 off of Highway 4 (Station 9) (Figure 3-6). These stations are approximately 9 stream miles apart. Ten agricultural return sites from five islands or tracts—Holland, Bacon, Orwood, Woodward, and Victoria—drain to this section of Old River. In addition, the Woodward and North Victoria canals and Indian Slough merge with this section of the river.

Organic carbon at Old River stations comes from multiple sources, including waters from the San Joaquin River, the Sacramento River, and Delta island drainage. With the exception of the SJR at Vernalis, seasonal patterns of organic carbon at these stations were similar to those at other stations. Unlike the Vernalis station on the SJR, organic carbon concentrations were much lower during dry summer months than during wet months (compare Figure 3-5 and Figure 3-6).

Water quality at the two Old River stations is strongly affected by both seasonal natural river hydrology and by pumping at the federal and State projects to the south. Inflows of high organic carbon water from tributary and agricultural sources tend to increase organic carbon concentrations in Old River. When large volumes of relatively low carbon from Sacramento River water are drawn to the export projects, it tends to dilute other relatively high-carbon sources. During the summer months, when tributary organic carbon is relatively low and export pumping is relatively high, volumetric fingerprinting shows that during periods when a large percentage of Sacramento River water is moving through Old River, organic carbon levels tend to be lower (Figure 2-7 and Figure 3-6). At the Old River stations, both factors appear to contribute to the observed seasonal organic carbon levels.

As reported in previous MWQI reports (DWR, 2003; 2005; 2006; 2008a), the temporal patterns of TOC and DOC at both stations were almost identical during the sampling period reported here (Figure 3-6). At both sites, little difference was found between TOC and DOC, suggesting that organic carbon was almost entirely in the dissolved form. Given the hydrologically driven similarities between these two stations, and if these similarities persist following recent changes in export patterns, it may be worthwhile to evaluate whether one of these two stations could be removed from the sampling program.

Middle River at Union Point

The Middle River at Union Point station was added to MWQI's monthly monitoring in July 2006 during the last biennial reporting period. It was added due to concerns that Middle River water, by way of Victoria Canal, could affect water quality at the State Water Project (SWP) pumps. Monitoring at this location helps provide data to model Middle River inputs to the SWP.

The temporal patterns and concentrations of organic carbon on Middle River were quite similar to the Old River stations. Concentrations peaked during the wet season before trending downward through summer and mid-autumn. Dry season concentrations ranged between 2 and 3 mg/L (Figure 3-6(c)). Over the sampling period, median TOC and DOC were 4.0 mg/L and 3.8 mg/L, respectively (Table 3-1). TOC and DOC concentrations did not differ significantly (Mann-Whitney, $p=0.700$), suggesting that the majority of organic carbon in the river was in the dissolved form.

Banks Pumping Plant

Samples were collected at the Banks Pumping Plant Headworks (a SWP facility), in the canal immediately uphill from the pumping plant itself. Organic carbon concentrations at this station represent the quality of Delta water at its point of entry into the California Aqueduct. TOC and DOC ranges at Banks were similar to other channel and diversion stations (Table 3-1). Higher concentrations were found mostly during the wet months, but a secondary peak in concentrations occurred during early summer in both water years (Figure 3-7(a)). This period corresponds to the return to higher pumping rates after the VAMP period (Figure 3-8). It may reflect a buildup of carbon in Delta channels while low-carbon Sacramento River water is not being drawn across the Delta. Organic carbon concentrations varied between 4 and 8 mg/L during the wet months. During the dry months, concentrations were less variable than in the winter and were generally between 2 and 3 mg/L. The increase in organic carbon during the wet months was attributable to increased loads from tributary watersheds and in-Delta island runoff.

Median TOC and DOC concentrations were 3.2 and 3.1 mg/L, respectively (Table 3-1), which were not statistically different (Mann-Whitney, p=0.564). This indicates that particulate organic carbon was a small fraction of total organic carbon in the water at Banks.

At many stations, TOC concentrations tend to increase with increases in flow. However, this is not necessarily true at Banks because flow rate is influenced by pumping and is less affected by watershed events such as rainfall or dam releases. Increased pumping does not necessarily lead to higher organic carbon concentrations unless pumping occurs at a time when high organic carbon concentrations are present in Clifton Court Forebay and the Delta channels that feed it. Historically, pumping is high during the summer months, drawing low-carbon Sacramento River water across the Delta to the pumps. During this reporting period, summer pumping was affected by recent court decisions limiting maximum pumping rates during various times of the year. Pumping was relatively low during May and June of each of the past two years (April usually has lower pumping rates due to the VAMP program) (Figure 3-8). When pumping rates increased in July of each year, organic carbon concentrations generally decreased, most notably in July 2009.

For both water years, organic carbon decreased during the dry season (Figure 3-7). The decrease in organic carbon during this period was probably due to a combination of factors, including the opening of the Delta Cross Channel gates (thus bringing more Sacramento River water across the Delta), implementation of VAMP in the San Joaquin Valley, increased reservoir releases into the Sacramento and San Joaquin rivers, and the absence of storm and Delta island runoff. Releases from reservoirs in both watersheds were generally highest from May to August.

Contra Costa Pumping Plant

Samples near the Contra Costa Pumping Plant were collected from two separate locations during the two-year period of the report. From October 2007 to February 2009 samples were collected at the pumping plant intake. Due to construction near the pumping plant, beginning in March 2009, samples were collected from Rock Slough approximately 5.5 river miles upstream from the original Contra Costa Pumping Plant site. This sampling location was chosen because it combined ease of access with a continued data stream related to the quality of waters available for pumping at the pumping plant.

The median values for TOC and DOC were 3.9 mg/L and 3.6 mg/L, respectively. The highest concentrations of organic carbon occurred during the wet months and peaked at 6.2-6.3 mg/L of TOC (Figure 3-7(b)). Like the Banks station, TOC and DOC concentrations at the Contra Costa Pumping Plant were not significantly different (Mann-Whitney, p=0.542), suggesting low particulate organic carbon in the water (the difference between TOC and DOC ranged from 0.0 to 0.40 mg/L, with a median of 0.20 mg/L). Seasonal patterns at the Contra Costa Pumping Plant were similar to those at Banks Pumping Plant (Figure 3-7(a) and (b)) and those at the Old River stations (Station 9 and Bacon Island) (Figure 3-6). As with those sites, organic carbon concentrations at Contra Costa were influenced by the ratio of Sacramento River water present in Old River (Figure 3-6 and Figure 3-7).

Mallard Island Station

Water at the Mallard Island station, the MWQI monitoring station farthest west in the Delta (Figure 3-10), comes from all upstream sources, including the San Joaquin River, the Sacramento River, drainage from Delta islands, and numerous municipal and industrial discharges, plus tidally-mediated saline water from the San Francisco Bay to the west. Because of dilution from bay waters that have low organic carbon and the large percentage of Sacramento River water at this point, organic carbon concentrations at Mallard Island were lower than they were at Delta channel and diversion stations (Table 3-1). Median TOC and DOC concentrations were 2.1 and 1.9 mg/L, respectively, which were consistently less than those found at channel and diversion stations (Table 3-1). However, Mallard Island organic carbon values were generally higher than those at Hood (median ratio 1.18), suggesting that, for most months of the year, Mallard was receiving additional organic carbon from other sources than the Sacramento River. The difference between TOC and DOC at Mallard Island was not significant (Mann-Whitney, p=0.322), which indicated that most organic carbon was in the dissolved form.

Organic carbon concentrations were elevated during wet months like the other stations, with maximal concentrations varying from 4 to 6 mg/L (Figure 3-9). These variations were smaller than those at the river and channel stations.

Comparisons between the Current Reporting Period and Previous Periods

Sacramento River at Hood Station

Over the last six water years, median organic carbon concentrations have varied slightly. The range for the WYs 2008-2009 reporting period was slightly greater than the ranges of the prior reporting periods (Table 3-2). This is of interest given how dry the past two years have been compared to the previous four years. Mean monthly organic carbon concentrations for WYs 2008 and 2009 were not statistically different from each previous water year from 2004 to 2007 (Kruskall-Wallis test, TOC, $p > 0.28$ and DOC, $p > 0.23$ for all pairings). Taking into account the comparisons of the years described above, there is no evidence of an increasing trend in organic carbon. The relatively short period from 2004 to 2009, however, may be indicative of long-term conditions.

San Joaquin River near Vernalis Station

Over the last six water years, median organic carbon concentrations decreased slightly. The 2008-2009 reporting period had the lowest median of the three reporting periods, and it was lower than the median for all six water years (Table 3-2). In the previous biennial report, this difference was ascribed to greater summer reservoir releases into the San Joaquin River made possible by consecutive wet years in 2005 and 2006. However, 2008 and 2009 have been dry years, suggesting that some other mechanism is at work. High flows in winter would tend to increase concentrations. Reservoir releases during the VAMP period tend to lower concentrations.

Channel and Diversion Stations

At Station 9 and Old River stations, the ranges and medians from the current period differed slightly from those found during the previous four water years. Comparing each water year from 2005 to 2009, annual median organic carbon at Station 9 and Union Island was fairly elevated, though the period is too short to draw statistical conclusions. The Bacon Island station had a smaller increase in annual mean organic carbon. Data for the Middle River at Union Point station was added to the monitoring program in July 2006, so no prior reporting period comparisons can be made.

Annual median DOC and TOC concentrations have varied slightly over the past five years at Banks, though there is not a discernable long-term trend in the variation. Median annual organic carbon concentrations were highest in WY 2005 (TOC=3.5 mg/L; DOC=3.3 mg/L).

At the Contra Costa Pumping Plant, the ranges for both TOC and DOC were similar to each other (Table 3-1) and varied slightly over the five water years. In WY 2009, both TOC and DOC were lower than any of the previous four years.

Mallard Island

Median organic carbon levels were slightly lower during the current period than during the previous three water years (Table 3-1). WY 2009 was a dry year in both tributary watersheds.

Summary

Organic carbon at 12 MWQI stations in the Delta and its tributaries differed spatially, with north Delta stations generally having lower organic carbon concentrations than south Delta and channel stations (Figure 3-10 and Table 3-1). The American River station had the lowest median TOC of 1.7 mg/L. Median TOC at the Sacramento River at the West Sacramento WTP intake was 2.0 mg/L. Median TOC at Sacramento River at Hood was 2.1 mg/L. In contrast, median TOC for the SJR near Vernalis was 3.4 mg/L, which was about 62% higher than the TOC concentration of the northern inflows. The median TOC at Mallard Island was 2.3 mg/L, which, when compared to the median TOC concentrations at Hood and Vernalis, reflected the multiple sources of water at this station.

The five Delta channel and diversion stations (Old River at Station 9, Old River at Bacon Island, Middle River at Union Point, Banks Pumping Plant, and Contra Costa Pumping Plant #1) receive water from both the San Joaquin and Sacramento rivers, and vary seasonally with natural and anthropogenic effects. Despite the dilution effects of water from the Sacramento River, median TOC concentrations for these stations ranged from 3.2 to 4.0 mg/L. These results suggest a considerable in-Delta influence, as well as the influence from the Sacramento and San Joaquin rivers. Median TOC concentrations of most stations did not show large variations over the five years examined here. Seasonal patterns of organic carbon concentrations were similar between tributary and channel stations. Seasonal patterns at the five Delta channel and diversion stations were also similar to those at the San Joaquin and Sacramento rivers. In general, stations experienced elevated carbon levels during the rainy season, which trended downward through the early summer months before reaching their seasonal low during the late summer to early fall.

Table 3-1. Summary of organic carbon at 12 MWQI stations.

Station	TOC[a] (mg/L)				DOC[a] (mg/L)			
	Samples	Range	Average	Median	Detects	Range	Average	Median
Stations north of the Delta								
American River at E.A. Fairbairn WTP	24	1.2–2.7	1.7	1.7	24	1.2–2.7	1.6	1.6
West Sacramento WTP Intake	24	1.2–5.2	2.2	2.0	24	1.1–4.5	2.1	1.9
Natomas East Main Drainage Canal	21	4.3–8.5	5.4	5.0	21	4.1–7.7	5.1	4.8
Sacramento River at Hood	48	1.3–5.0	2.3	2.1	48	1.2–4.6	2.1	2.0
San Joaquin River near Vernalis	50	2.1–7.4	3.7	3.3	50	1.8–7.3	3.1	2.8
Channel and diversion stations								
Old River at Station 9	24	2.1–7.1	4.0	3.9	24	2.0–6.9	3.9	3.8
Old River at Bacon Island	24	1.8–7.0	3.6	3.4	24	1.8–6.7	3.5	3.3
Banks Pumping Plant	42	2.2–7.9	3.8	3.2	42	2.1–7.9	3.6	3.1
Jones Pumping Plant	4	2.5–7.8	4.7	4.3	4	2.5–7.5	4.6	4.2
Contra Costa Pumping Plant [b]	22	2.2–6.5	3.9	3.9	22	1.9–6.2	3.7	3.6
Middle River at Union Point	24	2.2–8.0	4.3	4.0	24	2.1–7.8	4.2	3.8
Mallard Island	24	1.1–5.8	2.6	2.1	24	1.0–5.1	2.3	1.9

[a] Both TOC and DOC were determined by the wet oxidation method (Water Data Library code PS-3).
[b] Contra Costa Pumping Plant includes data from Contra Costa at Rock Slough from 3/2009 to 9/2009.

Table 3-2. Summary of organic carbon during six consecutive water years.

Station	*Water Years*	***TOC (mg/L)***			***DOC (mg/L)***		
		Range	*Average*	*Median*	*Range*	*Average*	*Median*
Sacramento River at Hood	2008–2009	1.3–5.0	2.3	2.1	1.2–4.6	2.1	2.0
	2006–2007	1.5–4.3	2.4	2.2	1.4–4.0	2.1	2.0
	2004–2005	1.2–4.9	2.2	1.9	1.0–4.3	2.1	1.7
Summary	2004–2009	1.2–5.0	2.3	2.1	1.0–4.6	2.1	1.9
San Joaquin River near Vernalis	2008–2009	2.1–7.4	3.7	3.3	1.8–7.3	3.1	2.8
	2006–2007	2.4–5.9	3.4	3.4	2.1–5.9	3.0	3.0
	2004–2005	2.2–10.5	4.1	3.8	2.1–9.2	3.6	3.2
Summary	2004–2009	2.1–10.5	3.8	3.4	1.8–9.2	3.3	3.0
Banks Pumping Plant	2008–2009	2.2–7.9	3.8	3.2	2.1–7.6	3.6	3.1
	2006–2007	2.2–5.1	3.3	3.2	2.2–4.8	3.1	3.1
	2004–2005	2.2–8.4	3.5	3.1	2.2–8.2	3.3	2.9
Summary	2004–2009	2.2–8.4	3.6	3.3	2.1–8.2	3.4	3.2

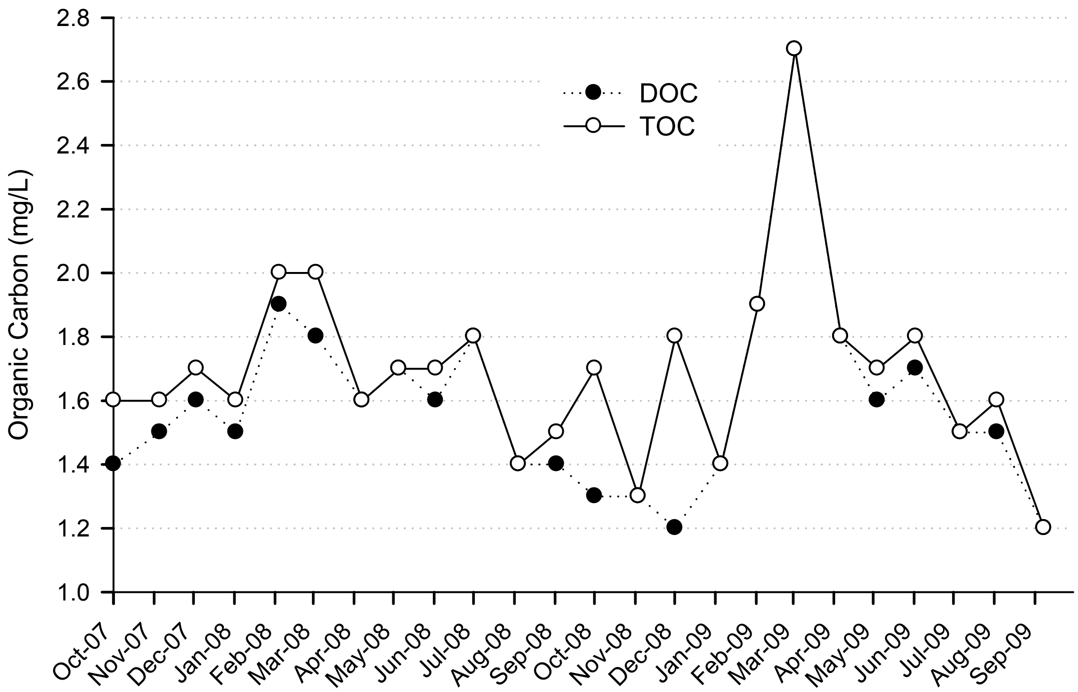


Figure 3-1. Organic carbon at the American River WTP intake.

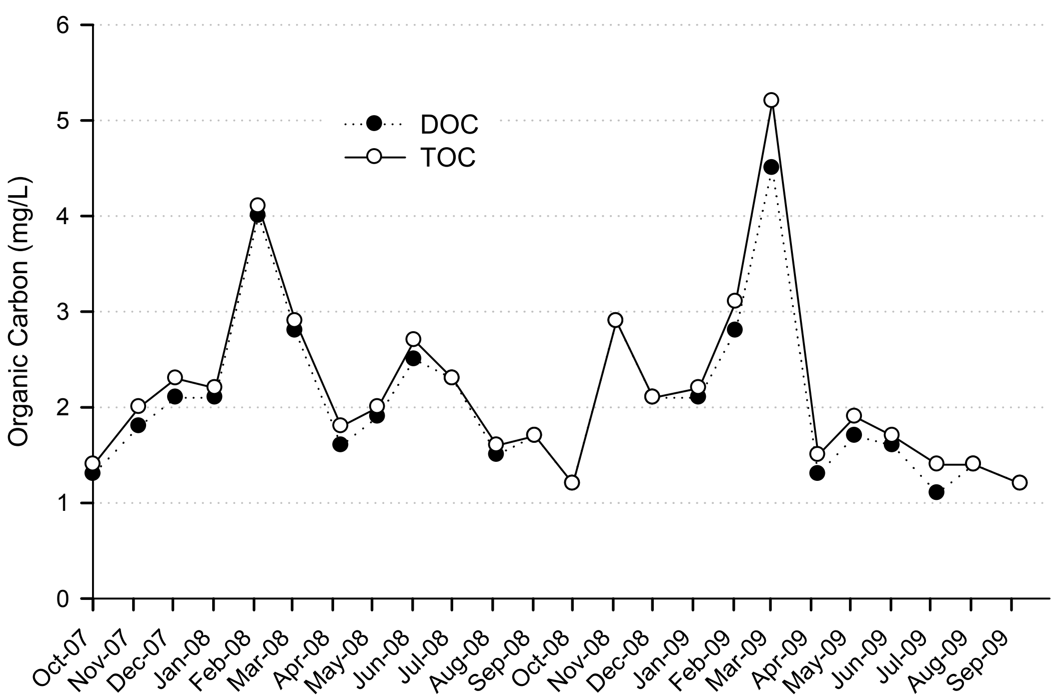


Figure 3-2. Organic carbon at West Sacramento WTP intake.

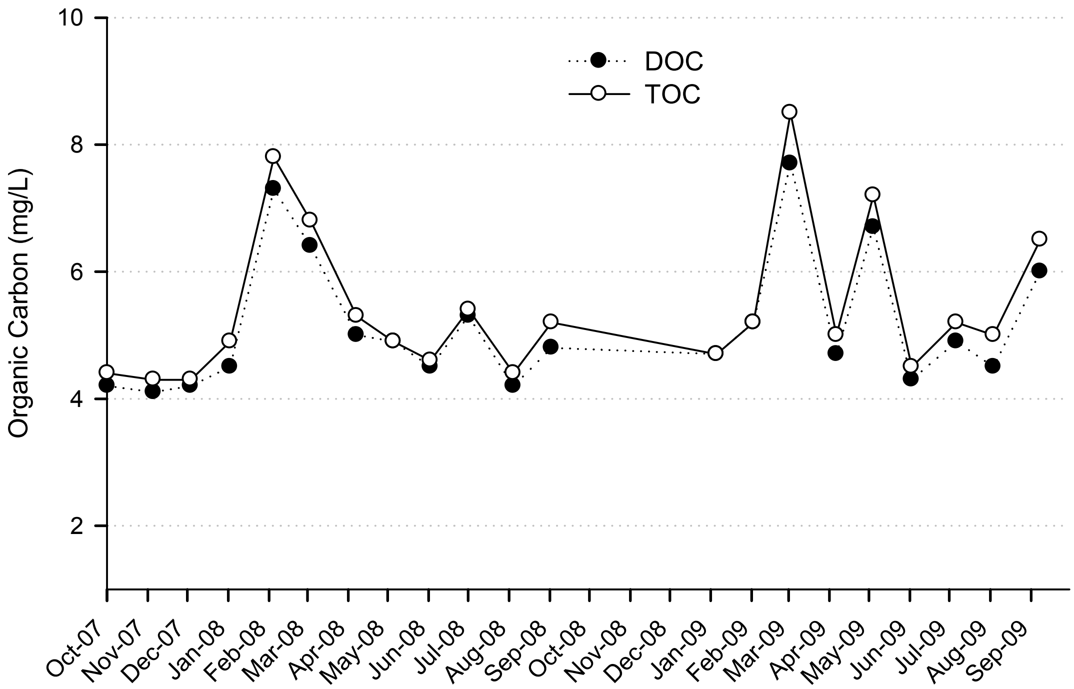


Figure 3-3. Organic carbon at Natomas East Main Drainage Canal at El Camino Blvd, Sacramento.

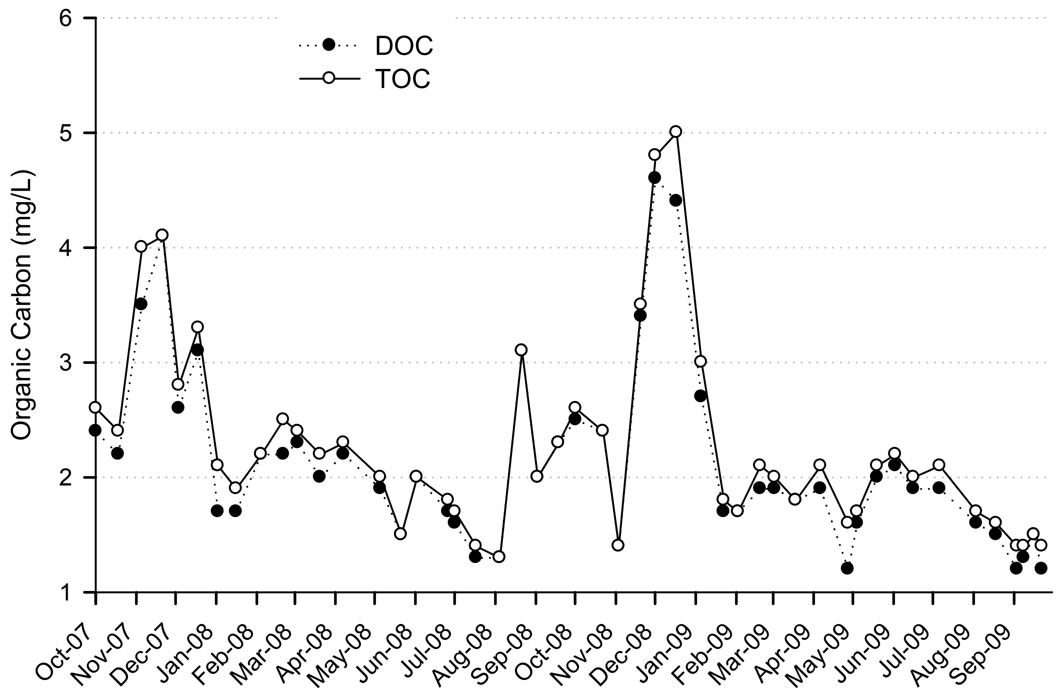


Figure 3-4. Organic carbon at Sacramento River at Hood.

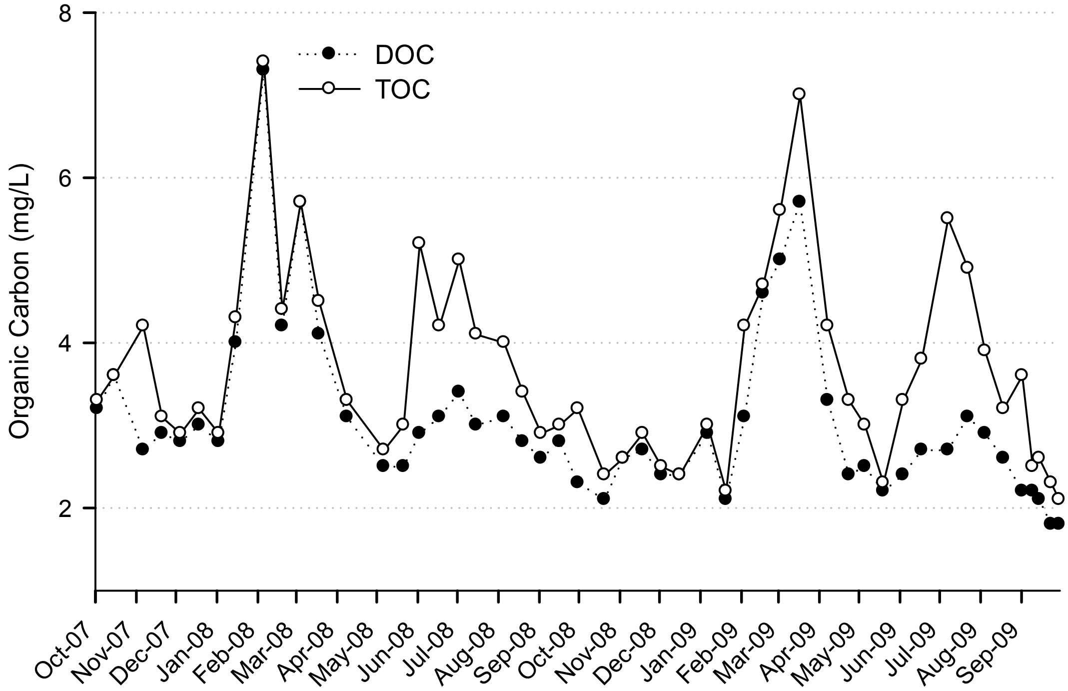


Figure 3-5. Organic carbon at the San Joaquin River near Vernalis.

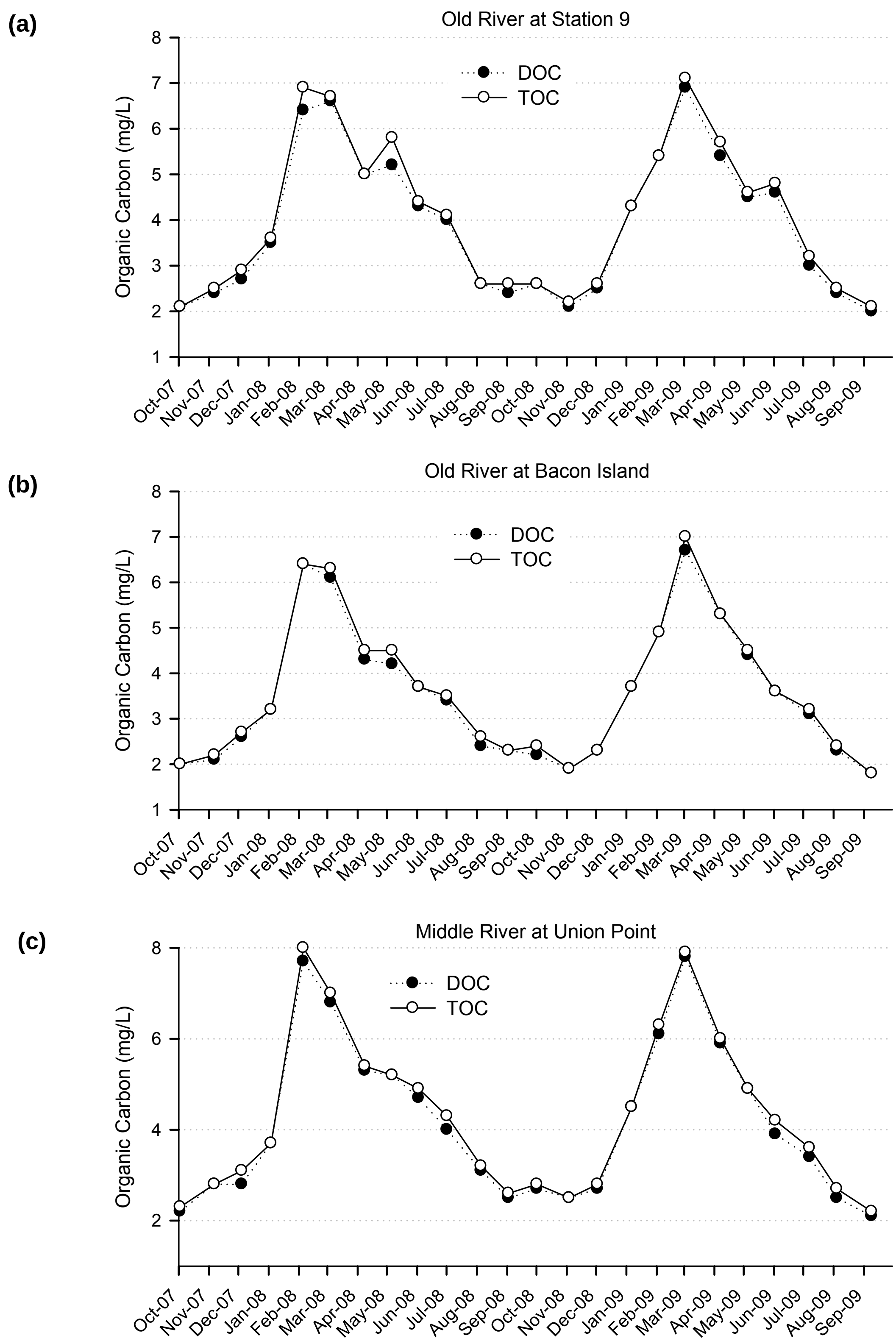
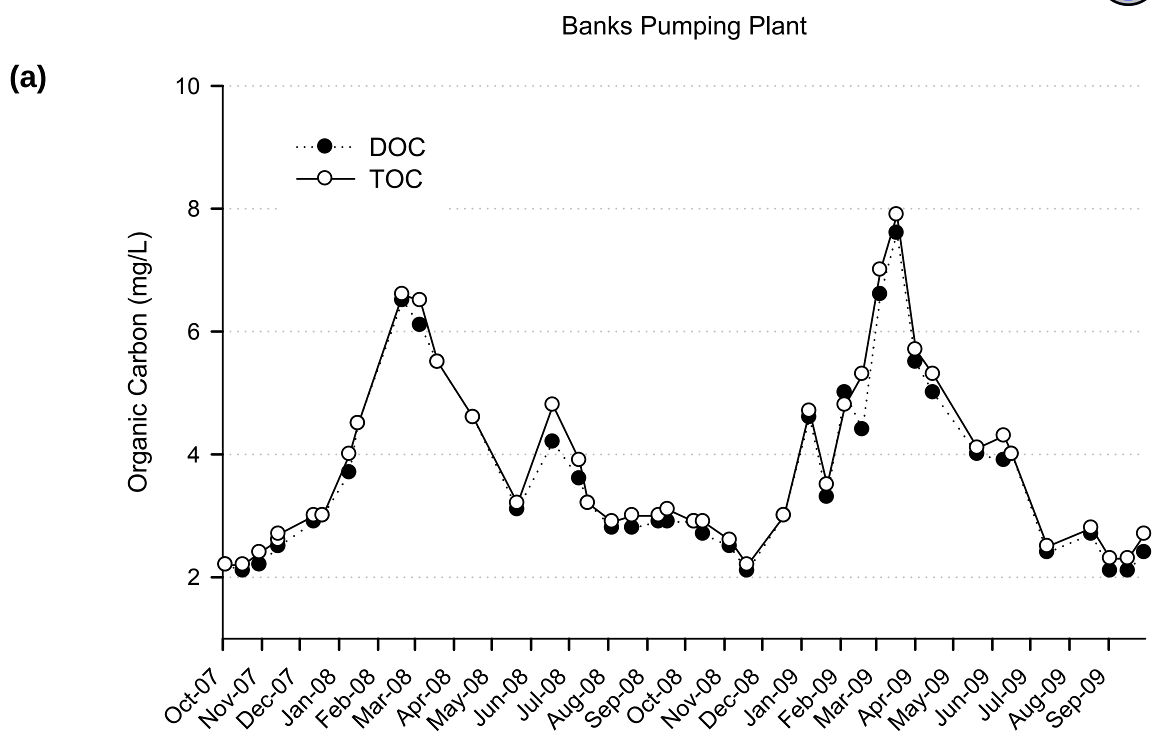


Figure 3-6. Organic carbon at Old and Middle River stations. a. Old River at Station 9. b. Old River at Bacon Island. c. Middle River at Union Point.



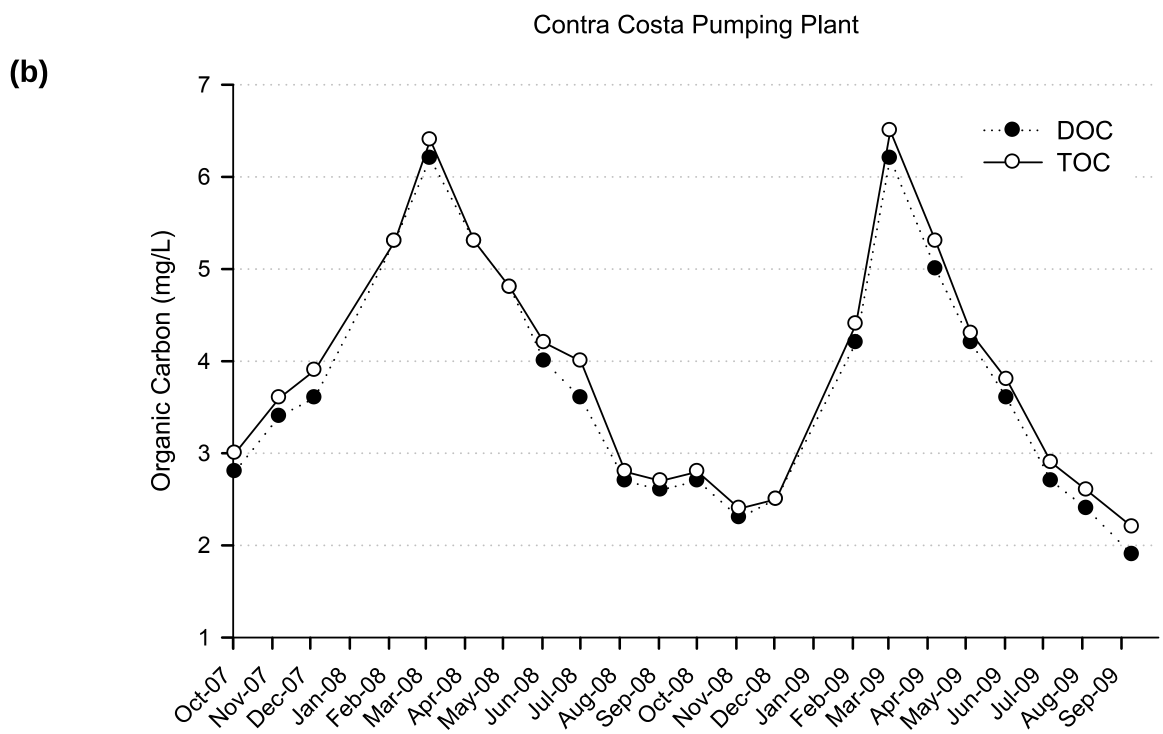


Figure 3-7. Organic carbon at two Delta diversion stations.
a. Banks Pumping Plant. b. Contra Costa Pumping Plant.

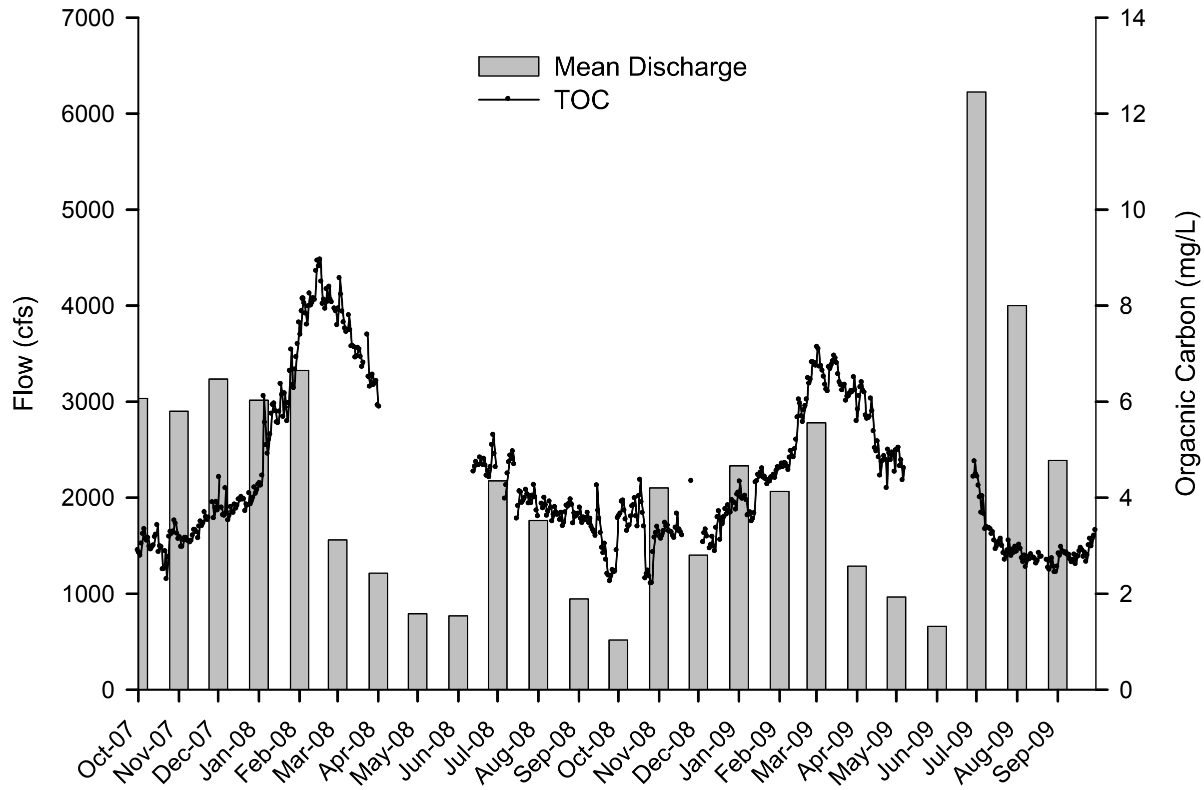


Figure 3-8. Banks Pumping Plant average monthly discharge rate compared to TOC concentration.

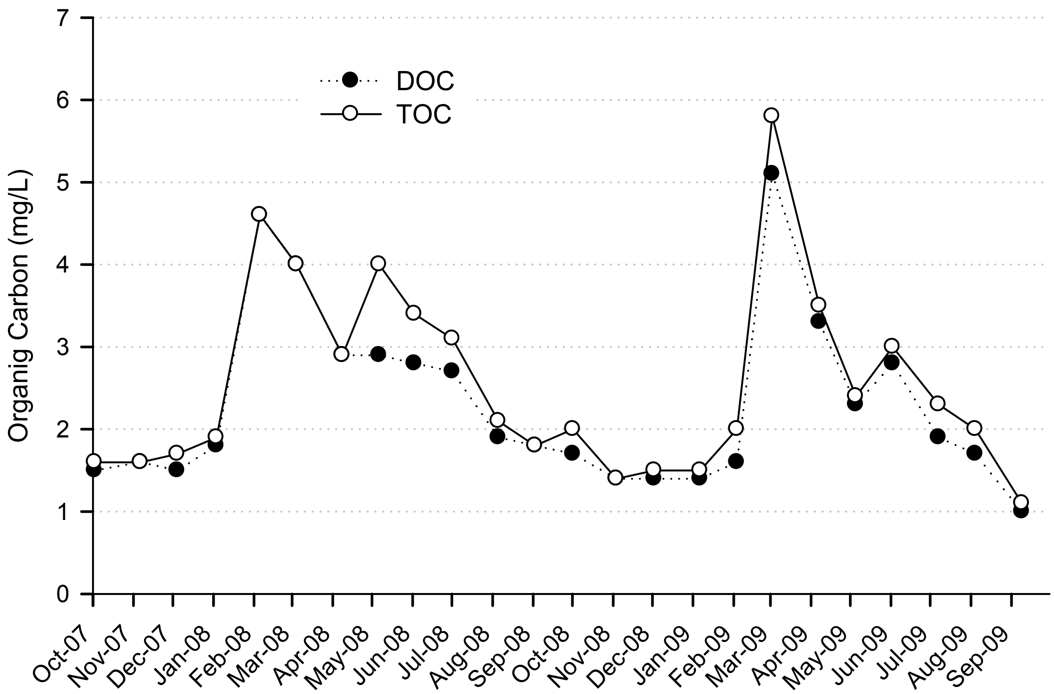


Figure 3-9. Organic carbon at Mallard Island.

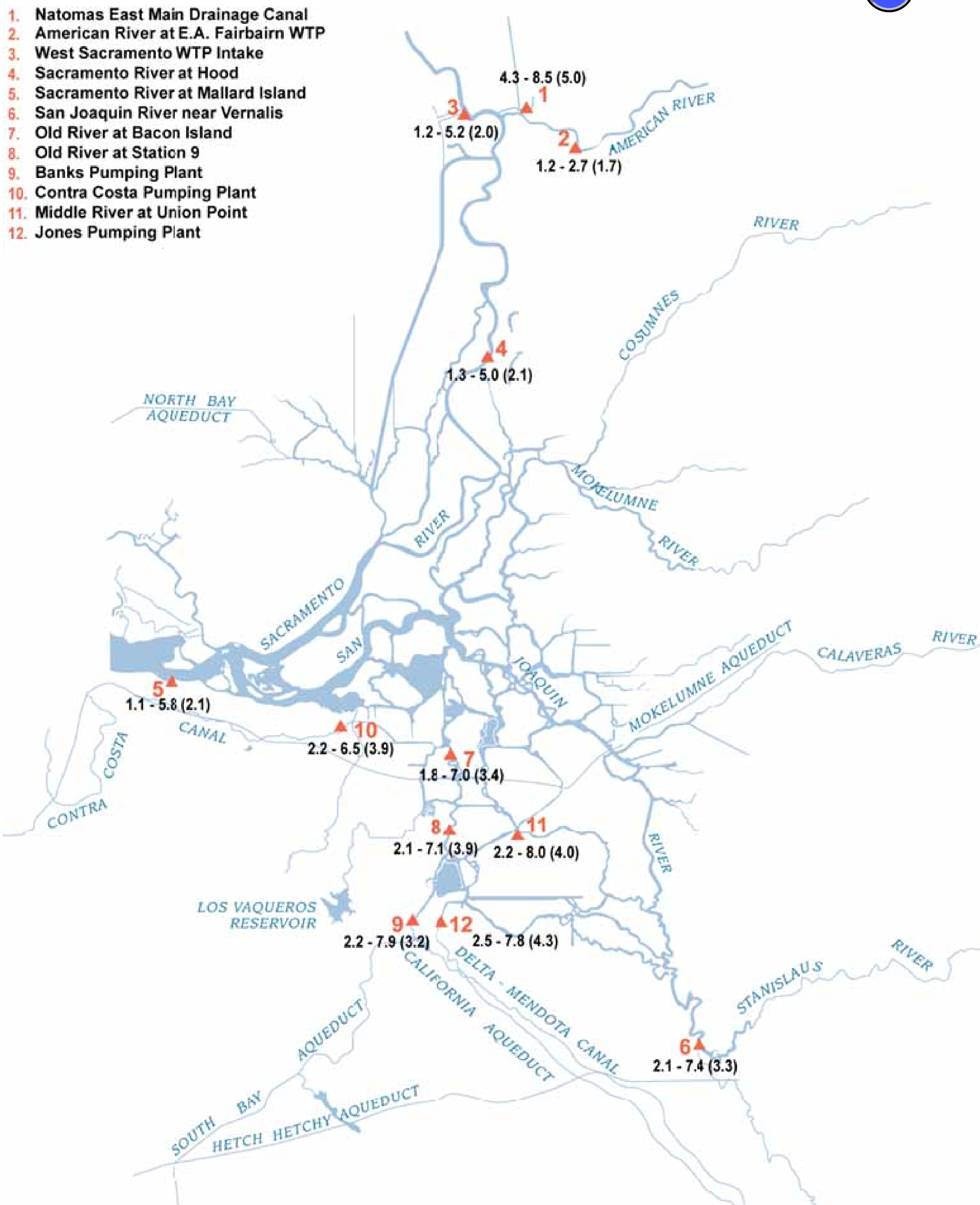


Figure 3-10. Total organic carbon: Range (median) in mg/L.

Chapter 4 Bromide

Depending on the disinfection process used, carcinogenic bromide compounds can be formed in two ways during drinking water disinfection. If chlorine is used for disinfection, the chlorination of water containing bromide and organic carbon leads to the formation of brominated trihalomethanes, which may cause liver, kidney, or central nervous system problems and may increase the risk of cancer (USEPA, 2010b). If ozone is used, bromate is formed, which is a potential carcinogen (USEPA, 2010b). The U.S. Environmental Protection Agency (USEPA) has not developed a maximum contaminant level (MCL) for bromide. In finished drinking water, the MCL for bromate is 0.01 and the MCL for total trihalomethanes is 0.080 (USEPA, 2010b).

This chapter summarizes bromide data collected at 12 stations in the Delta region from October 1, 2007 to September 30, 2009. A brief discussion of seasonal trends and spatial comparisons is also made for six seawater-affected stations.

Stations North of the Delta

During the reporting period, MWQI sampled one station on the American River at the E.A. Fairbairn Water Treatment Plant (WTP), one station on the Sacramento River at the West Sacramento WTP Intake, and an urban drainage canal, Natomas East Main Drainage Canal (NEMDC).

Of the 24 samples collected at the American River at E.A. Fairbairn WTP, bromide was never detected (Table 4-1). At the West Sacramento WTP Intake, 67% of the samples had bromide above the method detection limit (MDL) of 0.01 mg/L. Concentrations ranged from less than the reporting limit of 0.01 to 0.02 mg/L with average and median concentrations of 0.02 mg/L (Table 4-1, Figure 4-1).

Bromide concentrations at NEMDC were higher than those found at the American River station and the West Sacramento WTP Intake (Table 4-1, Figure 4-1). Bromide was reported above the reporting limit for all samples. Bromide concentrations ranged from 0.02 to 0.07 mg/L (Table 4-1). Both average and median concentrations were 0.04 mg/L. Higher bromide levels at NEMDC were most likely due to urban sources.

Sacramento River at Hood Station

Water at the Hood sampling station is a mixture of inflows shortly after they enter the legal Delta. Most inflows come from the American and Sacramento Rivers. Like the American River at E.A. Fairbairn WTP and the Sacramento River at West Sacramento WTP Intake, bromide concentrations at the Sacramento River at Hood were near the reporting limit, with bromide concentrations below the reporting limit in 26% of the 46 samples (Table 4-1, Figure 4-2). For samples where bromide was detected, bromide concentrations ranged from less than 0.01 to 0.03 mg/L (Table 4-1). Both the average and median bromide concentrations were 0.02 mg/L (Table 4-1).

San Joaquin River Station near Vernalis

Of the 51 samples collected at the San Joaquin River (SJR) near Vernalis, bromide concentrations ranged from 0.10 to 0.54 mg/L with an average of 0.30 mg/L and a median of 0.31 mg/L (Table 4-1).

Seasonal patterns of bromide in the SJR reflect both rainfall and agricultural practices in the watershed. The San Joaquin Valley is mostly irrigated agricultural land. Much of the irrigation water for the area comes from the Delta-Mendota Canal (DMC), which diverts water from the south Delta. Water from the DMC is a considerable source of bromide loading to the Valley (DWR 2003, 2005, 2006, 2008a). When irrigation water is applied, bromide concentrates on the soil surface through evapotranspiration. Following either irrigation or rainfall, runoff returns previously accumulated bromide from the soil surface to the SJR. In addition to irrigation water adding bromide to the system, some soils in the area developed from marine deposits containing high levels of bromide. Bromide in these soils is transported into the river during wet months or through agricultural runoff and drainage. In some areas, shallow groundwater also carries high levels of bromide, which can reach the SJR through seepage. Freshwater inflows from the Sierra Nevada watershed can significantly dilute bromide concentrations in the SJR; however, the degree of dilution that occurs is influenced by water year type. For example, during dry years, winter freshwater inflows are mostly trapped behind upstream reservoirs for flood control or storage purposes, resulting in less dilution downstream. Consequently, bromide concentrations in the lower part of the river can remain high during the winter months. This pattern was generally observed during the critical WY 2008 and below normal WY 2009.

Bromide concentrations were generally higher during the wet months of November through March. This condition was in evidence from December to March in WY 2008 and from November through March in WY 2009 (Figure 4-3). Bromide concentrations were the lowest from mid-April to mid-May of WY 2008 and mid-April to mid-June of WY 2009 (Figure 4-3), which coincided with the Vernalis Adaptive Management Plan (VAMP) period (see Chapter 2). In both water years, bromide concentrations increased after the VAMP period to approximately their average values during the remainder of the growing season portion of the water year (Figure 4-3).

Delta Channel and Diversion Stations

Channel stations

MWQI monitored bromide at 3 channel stations—Old River at Station 9, Old River at Bacon Island and Middle River at Union Point. Bromide was detected in every sample collected (Table 4-1). Median concentrations of bromide were 0.28 mg/L at Station 9, 0.31 mg/L at Bacon Island and 0.16 mg/L at Union Point (Table 4-1).

Temporal patterns were similar for all channel stations (Figure 4-4) and were similar to those of organic carbon (Figure 3-5 and Figure 3-6). Bromide concentrations generally began to increase in late summer or early fall and remained high until February. This pattern resulted from the complex interplay between total Delta outflow, the timing and source of San Joaquin River water and seawater intrusion. For example, beginning in July or August, Delta outflows decreased by almost half (Figure 2-5). With fewer outflows, higher bromide Martinez water began to appear in late summer at both the Old River and at Clifton Court (Figure 2-12 and Figure 2-13), which reflects the increased bromide concentrations at the sampled channel locations. As shown by EC (electrical conductivity) and volumetric fingerprints (Figure 5-9 and Figure 5-10), a small fraction of seawater had a large impact on salinity. Similarly, high total Delta outflow from approximately January through July (Figure 2-5), contributed to lower bromide concentrations at the channel stations. With high Delta outflows, a greater volume of low bromide Sacramento River water is present in the channels. Additionally, the VAMP period, between April and May, would also contribute to lower bromide waters. As shown in Figure 2-12 and Figure 2-13, VAMP flows between April and May resulted in a higher proportion of San Joaquin water in the Old River and at Clifton Court. This low bromide water from reservoir releases, in conjunction with high Delta outflows, potentially resulted in low bromide waters at channel sampling sites.

Diversion Stations

Samples from three Delta diversion stations—Banks Pumping Plant, Contra Costa Pumping Plant #1, and Jones Pumping Plant—were collected during the reporting period. The median bromide concentration at Banks Pumping Plant was 0.29 mg/L, the median concentration at the Contra Costa Pumping Plant was 0.32 mg/L, and the median bromide concentration at Jones Pumping Plant was 0.29 mg/L. The medians of these stations were comparable, though the range was wider at the Contra Costa Pumping Plant, resulting in a higher average bromide concentration at the Contra Cost Pumping Plant than at the Banks

Pumping Plant and Jones Pumping Plant (Table 4-1). Higher bromide concentrations at the Contra Costa Pumping Plant were potentially due to seawater influences (Figure 4-12).

Seasonal patterns were similar between channel and diversion stations (Figure 4-4 and Figure 4-5). This comparison excludes Jones Pumping Plant data because only two samples over a six month period were collected at this station. WY 2008 was a drier year than WY 2009 for both the Sacramento and San Joaquin valleys (Table 2-2). Due to increased river inflows in WY 2009, bromide concentrations were high at the beginning of the wet months, but were diluted through the rest of the wet months. As a result, concentrations at Banks and at the Contra Costa Pumping Plant #1 remained low from April to July of WY 2009 (Figure 4-5, Figure 5-9, Figure 5-10). The increases in bromide concentrations from October to January in WY 2008 were due to reduced releases from peripheral reservoirs and decreased inflows to the Delta. In response to the drier runoff and lower river inflows to the Delta, bromide concentrations at both diversion stations increased from July to September of the WY 2008. These seasonal patterns were different from those observed at the SJR station near Vernalis (Figure 4-3), reflecting the influences of multiple sources at the diversion pumps.

Mallard Island Station

The Mallard Island station is more heavily influenced by seawater than the other stations. Water at this station is a mixture of water from rivers and channels in the Delta as well as water from the Bay. A total of 24 monthly samples were collected at this station during the current summary period. Concentrations ranged from 0.08 to 18.4 mg/L, making it the most widely variable of all 12 stations (Table 4-1). The average and median bromide concentrations were 7.97 and 7.20 mg/L, respectively.

Seasonal bromide concentrations reflected Delta outflow patterns. Reduced total Delta outflow increased the influence of seawater intrusions resulting in rising bromide concentrations in August and September (Figure 2-5 and Figure 4-6). Conversely, increased Delta outflows lowered bromide concentrations.

Relationship between Bromide and Chloride

Bromide concentrations were very low at four of the 12 MWQI grab sampling stations. These stations included the three stations north of the Delta and the Sacramento River at Hood in the northern Delta (Table 4-1). Water at these stations originates in the Sacramento Valley watershed, which includes both the Sierra and Cascade mountain ranges. These waters contain very low levels of bromide. Although there were wastewater discharges upstream of the Hood station, their size or distance has only a minor influence on bromide concentrations.

Bromide levels at the other eight stations were much higher than natural freshwater background levels. Bromide at these stations comes either directly or indirectly from seawater. A detailed discussion on the origin of bromide and seawater influence on these eight stations has been presented in a previous data summary report (DWR, 2005). As discussed in that report, bromide and chloride are strongly correlated and their relationship mimics that found in seawater. Seawater contains approximately 65 mg/L of bromide and 19,000 mg/L of chloride. Therefore, the bromide/chloride ratio in seawater is roughly 0.0034. Like chloride, bromide is a conservative constituent and does not degradate or react with its environment. This ratio should be seen in Delta waters if seawater is the sole source of bromide and chloride.

During the current summary period, a total of 286 grab samples from eight stations were analyzed for both bromide and chloride. A near perfect linear relationship was found between bromide and chloride (Figure 4-7). This linear relationship can be described by the following linear regression equation:

Bromide = 0.00345 * Chloride – 0.0164, [$r^2 = 0.977$, $p < 0.000$]

In Figure 4-7, all bromide values greater than 0.70 mg/L were from the Mallard Island station, which is more influenced by seawater intrusion. Excluding data from Mallard Island (Figure 4-8), the relationship between bromide and chloride remained linear and was represented by the following equation:

Bromide = 0.00349 * Chloride – 0.0231, [r2 = 0.968, $p < 0.000$]

From these two equations, the bromide/chloride ratio in waters of the eight central and western Delta stations was from 0.00345 to 0.00349, which is the same as the ratio found in seawater, indicating that bromide and chloride in central and western Delta waters came primarily from seawater.

Bromide of Delta Waters between the Current Reporting Period and Previous Reports

Stations North of Delta

At the American River, the median and range concentrations during the current reporting period were comparable to those found during the previous four water years. At this site, bromide concentrations continued to be below the report limit. The West Sacramento Intake and NEMDC medians had no significant differences when compared to the values from the previous four water years. For these stations, the p-values were 0.128 and 0.918, respectively (using Dunn's Multiple Comparison test).

Sacramento River at Hood

The median and range of bromide concentrations for this reporting period were comparable to those found during the previous four water years (Table 4-2). Over the last six water years, the median bromide concentrations showed little variability or statistical difference. The only statistical difference occurred when WY 2004 and WY 2006 were compared with WY 2008, which had a relatively high median bromide concentration. P-values for these comparisons were 0.0003 and 0.0005, respectively (Dunn's Multiple Comparison test). Figure 4-9 shows summary box plots for all six water years.

San Joaquin River near Vernalis

The bromide concentrations for this reporting period were less variable than those measured during the previous four water years (Table 4-2). The 2006-2007 reporting period had the lowest median concentrations of all six water years (Figure 4-10, Table 4-2). Bromide concentrations for WY 2005 were statistically different from WYs 2004, 2008 and 2009, and bromide concentrations for WY 2006 were statistically different from WYs 2004, 2007, 2008 and 2009. The p-values for all significant differences were less than 0.000 (Dunn's Multiple Comparison test). All other year comparisons were found to be insignificant.

Banks Pumping Plant

At the Banks station, the median and range for the current reporting period were higher than the median and range of the prior four water years (Figure 4-11, Table 4-2). Comparisons of WYs 2004, 2005, and 2006 with WY 2009, were statistically different (p=0.0096, 0.0028, and 0.0001, respectively). Bromide concentrations were also statistically different between WY 2006 and WY 2008 (p=0.0023, Dunn's Multiple Comparison test).

Summary

Bromide concentrations were highest at those stations with the most seawater influence (Figure 4-12). Of the 12 stations sampled, Mallard Island is the closest to the Bay and had the highest median bromide concentrations (7.16 mg/L) (Figure 4-12). Median bromide concentrations at the three diversion stations were similar, ranging between 0.29 and 0.32 mg/L. The SJR near Vernalis had median bromide concentrations of 0.31 mg/L. Elevated bromide in the SJR was potentially attributable to agricultural drainage returns, which are indirectly influenced by seawater. Lower concentrations were observed during the VAMP period with larger releases of freshwater from upstream reservoirs.

At the stations north of the Delta, median bromide concentrations were 0.01 and 0.04 mg/L for the West Sacramento Intake and NEMDC stations, respectively. The American River median bromide concentrations were below the reporting limit of 0.01 mg/L. The stations north of the Delta are not influenced by seawater; therefore, bromide concentrations are expected to be lower than the tidally influenced stations.

Compared with the previous four water years, median bromide concentration at the Hood station for this report period was equivalent to WYs 2004 and 2005, and higher than the median for WYs 2006 and 2007. Vernalis station and Banks Pumping Plant median bromide concentrations were higher for this reporting period (Table 4-2). At the stations north of the Delta, median bromide concentrations were comparable to those from the four previous water years. Like previous years, the American River had bromide concentrations below the reporting limit.

Bromide to chloride ratios indicated bromide in central and western Delta waters came primarily from seawater.

Table 4-1. Summary of bromide at 12 MWQI stations.

	Br (mg/L)			
Station	*Detects[a]/Samples[b]*	*Range*	*Average*	*Median[c]*
Stations north of the Delta				
American River at E.A. Fairbairn WTP	0/24	-	-	<0.01
West Sacramento WTP Intake	16/24	<0.01–0.02	0.02	0.01
Natomas East Main Drainage Canal	21/21	0.02–0.07	0.04	0.04
Sacramento River at Hood	34/46	<0.01–0.03	0.02	0.02
San Joaquin River near Vernalis	51/51	0.10–0.54	0.30	0.31
Channel and diversion stations				
Old River at Station 9	24/24	0.09–0.56	0.28	0.28
Old River at Bacon Island	72/72	0.05–0.69	0.30	0.31
Banks Pumping Plant	27/27	0.10–0.54	0.28	0.29
Jones Pumping Plant	2/2	0.26–0.32	0.29	0.29
Contra Costa Pumping Plant[d]	48/48	0.07–0.79	0.33	0.32
Middle River at Union Point	24/24	0.10–0.39	0.19	0.16
Mallard Island	24/24	0.08–18.40	7.97	7.16

[a] Detects = Includes only samples above reporting limit
[b] Samples = Number of samples collected
[c] Medians are calculated using values below the detection limit
[d] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2009

Table 4-2. Summary of bromide during six consecutive water years.

	Bromide (mg/L)			
Station	*Water Years*	*Range*	*Average*	*Median*
Sacramento River at Hood	2008–2009	<0.01-0.03	0.02	0.02
	2006–2007	<0.01–0.02	0.01	0.01
	2004–2005	<0.01–0.04	0.02	0.02
Summary	2004–2009	<0.01-0.04	0.02	0.01
San Joaquin River near Vernalis	2008–2009	0.10-0.54	0.30	0.31
	2006–2007	0.02–0.35	0.18	0.18
	2004–2005	0.02–0.62	0.26	0.24
Summary	2004–2009	0.02-0.62	0.23	0.24
Banks Pumping Plant	2008–2009	0.10-0.54	0.28	0.29
	2006–2007	0.03–0.38	0.15	0.12
	2004–2005	0.05–0.31	0.13	0.11
Summary	2004–2009	0.03-0.54	0.20	0.17

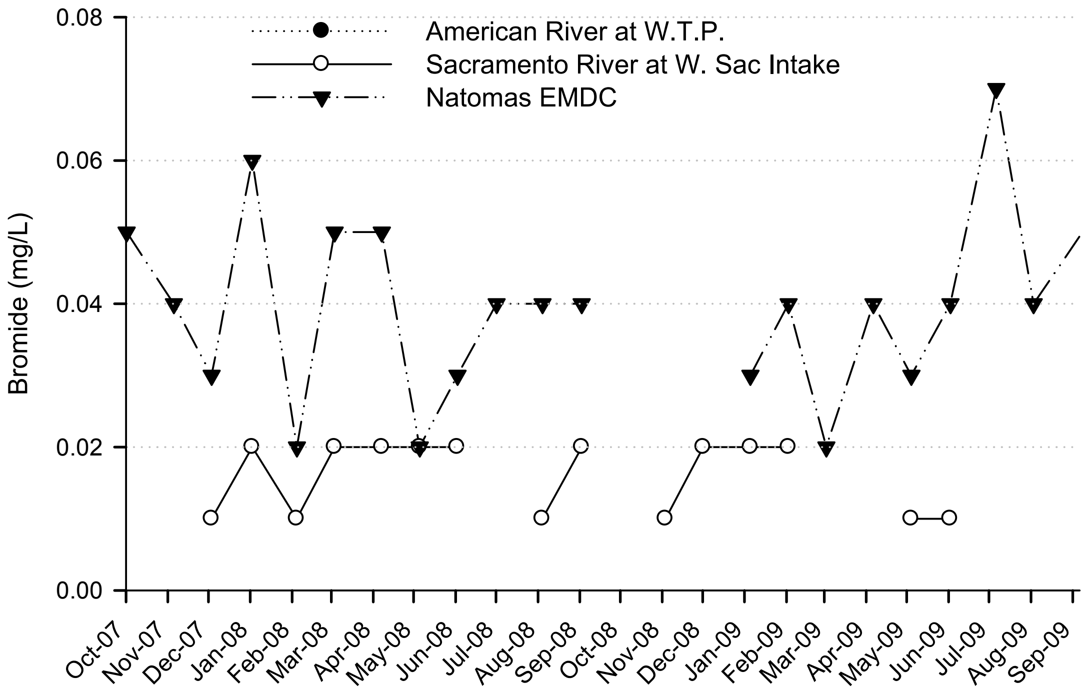


Figure 4-1. Bromide concentrations at stations north of Delta.

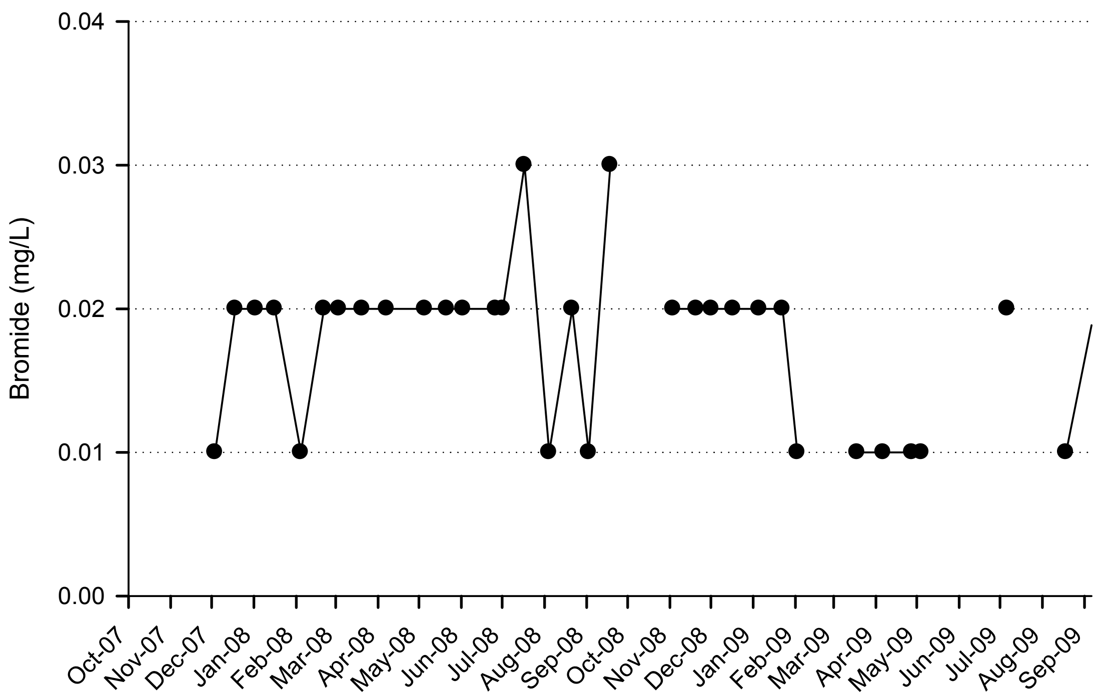


Figure 4-2. Bromide concentrations at Sacramento River at Hood.

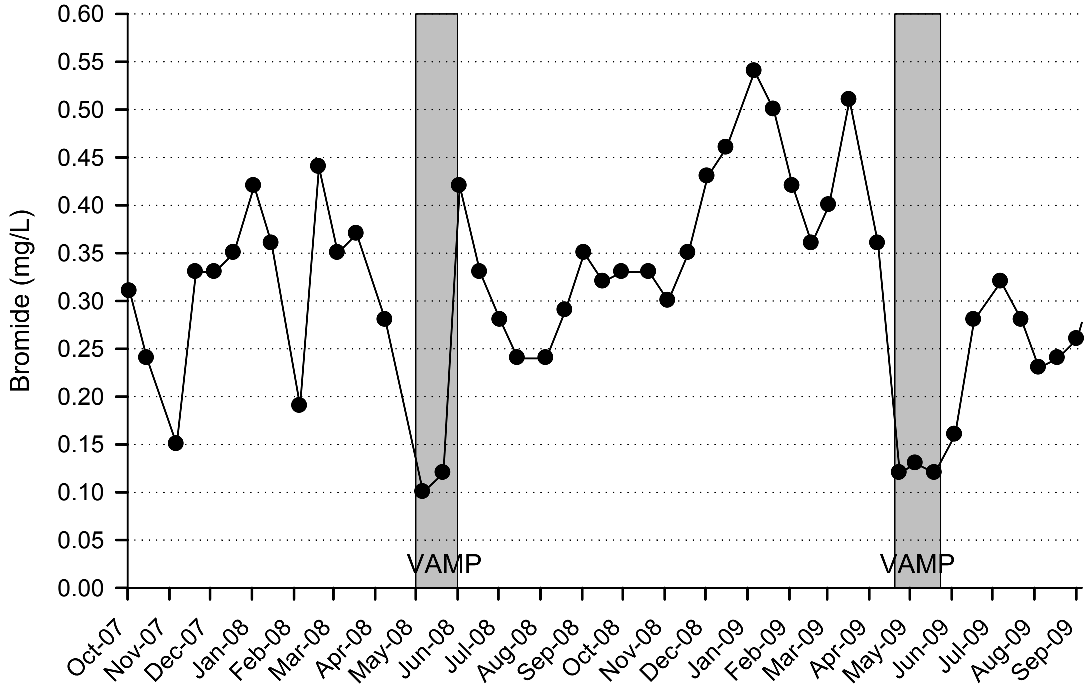


Figure 4-3. Bromide concentrations at the San Joaquin River near Vernalis.

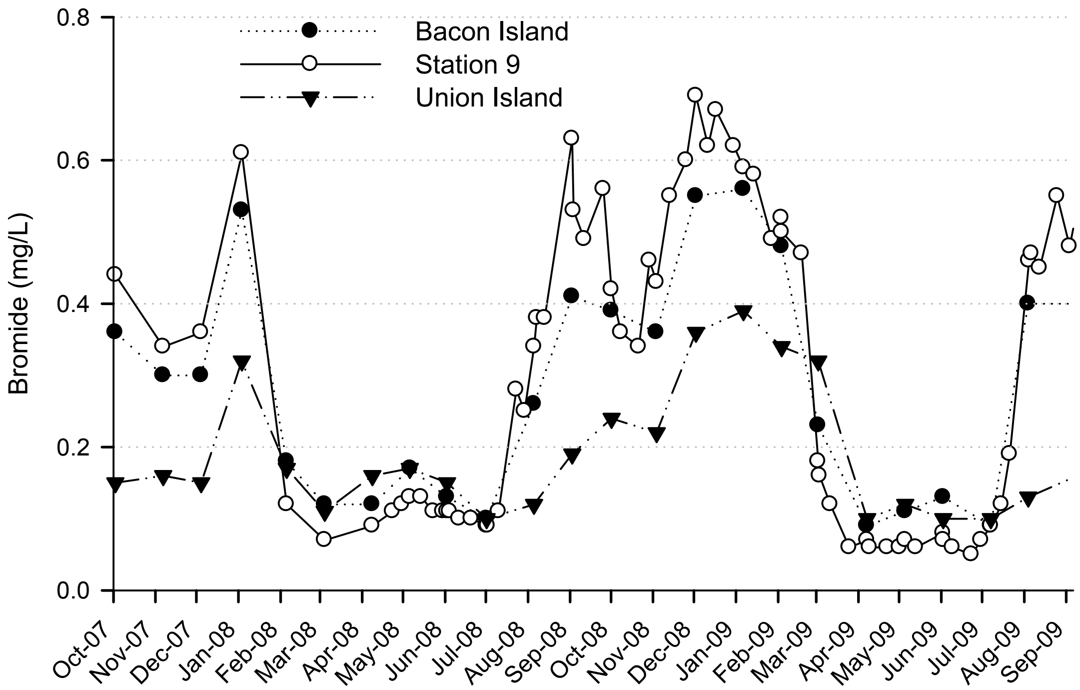


Figure 4-4. Bromide concentrations at Delta Channel Stations.

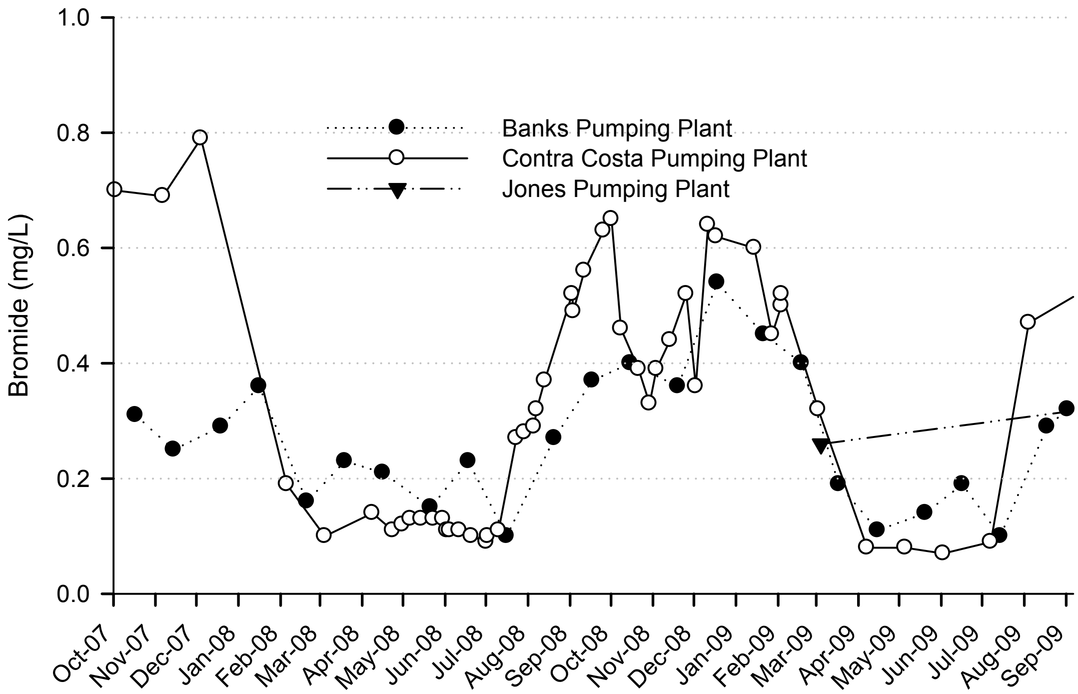


Figure 4-5. Bromide concentrations at the diversion station.

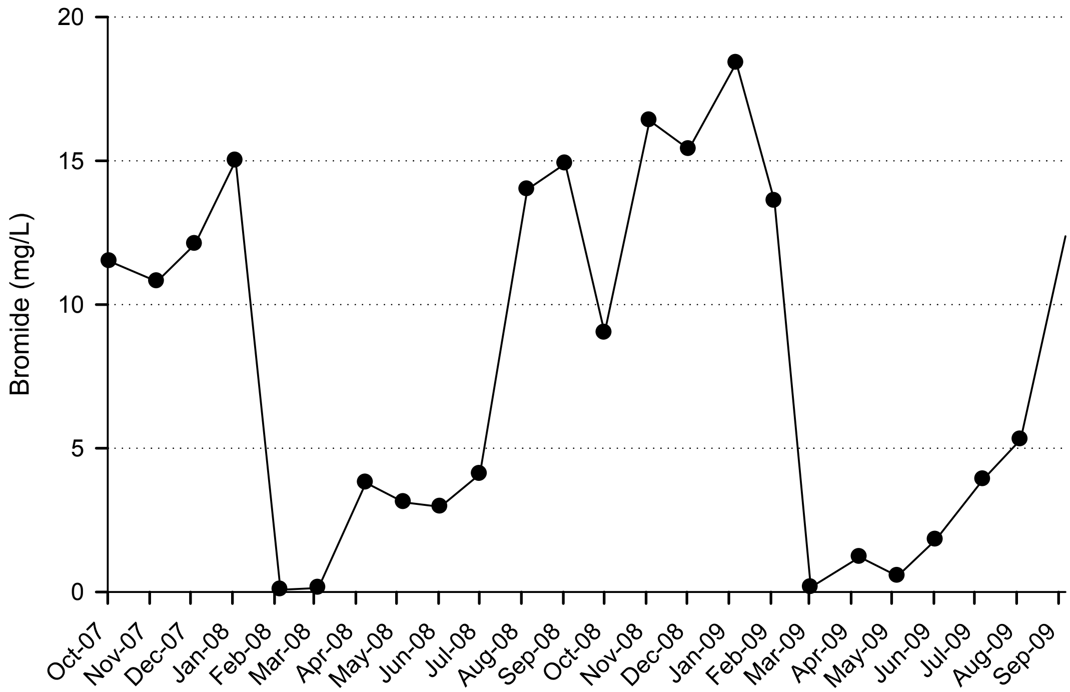


Figure 4-6. Bromide concentrations at the Mallard Island station.

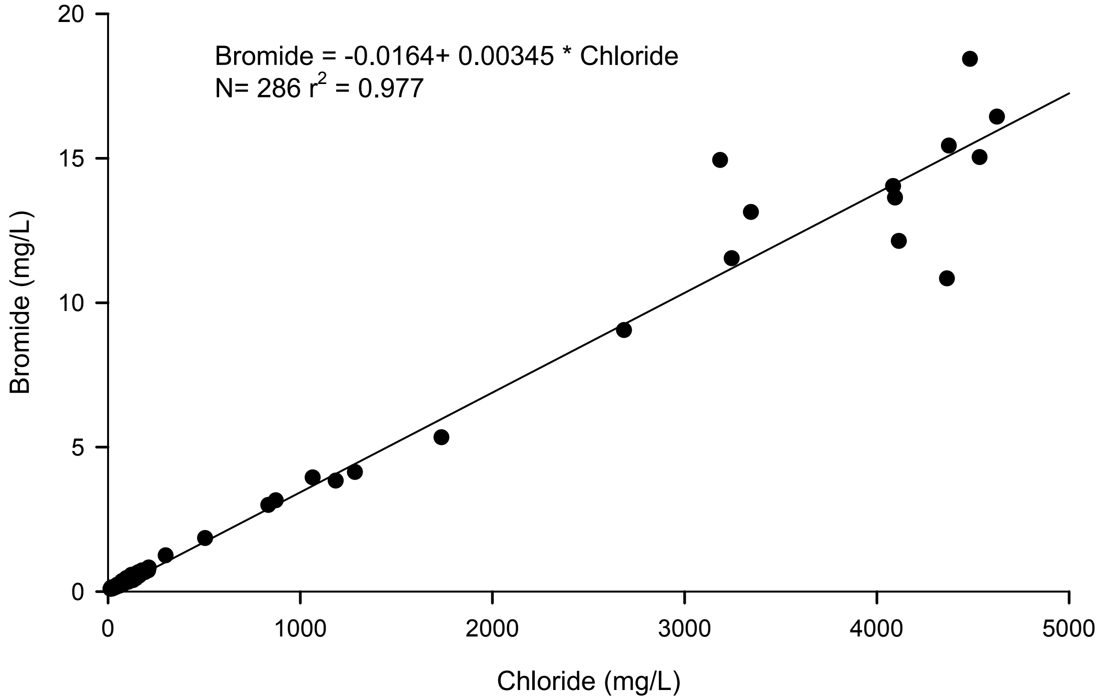


Figure 4-7. Relationship between bromide and chloride at eight stations including Mallard Island station.

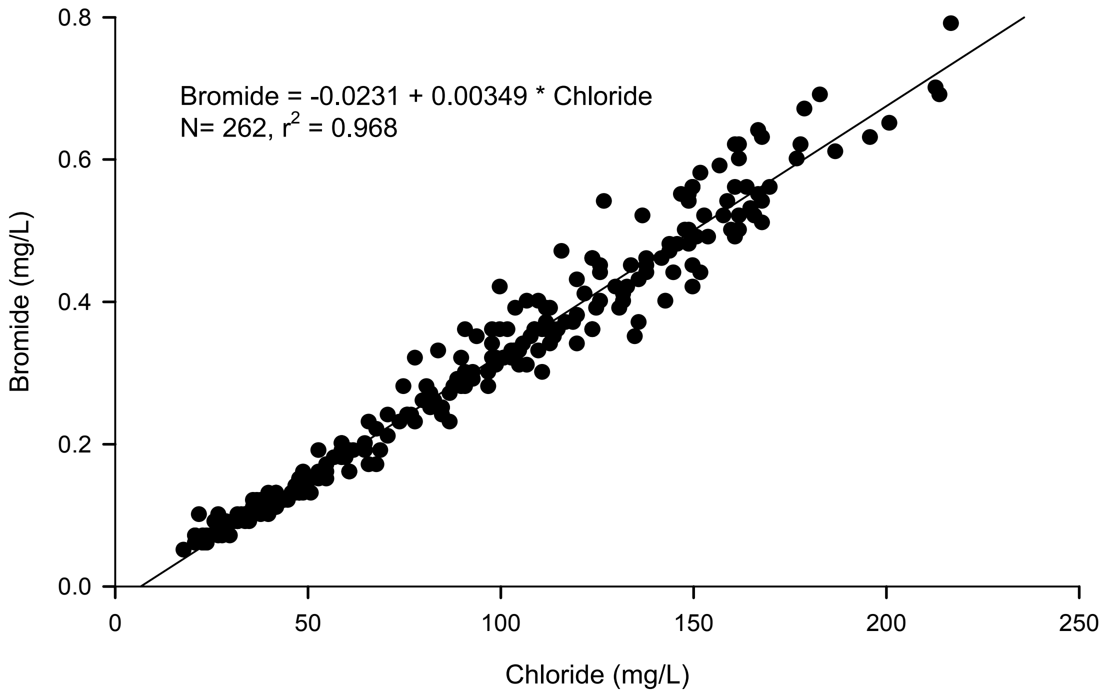


Figure 4-8. Relationship between bromide and chloride at seven stations excluding Mallard Island station.

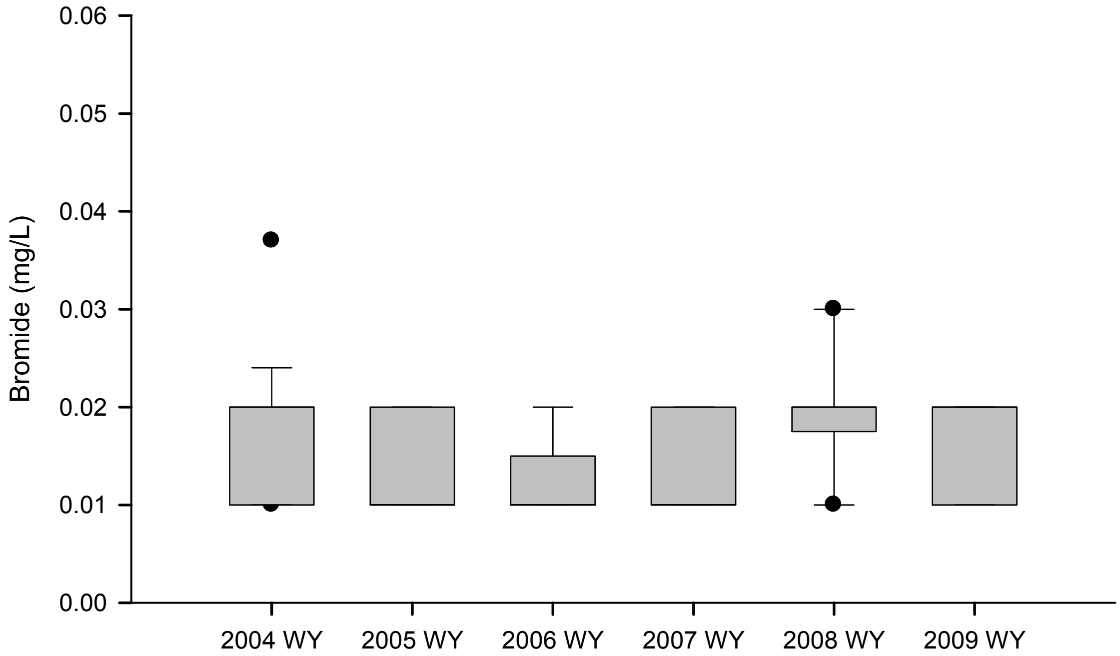


Figure 4-9. Bromide concentrations at Hood, WY 2004 to WY 2009.

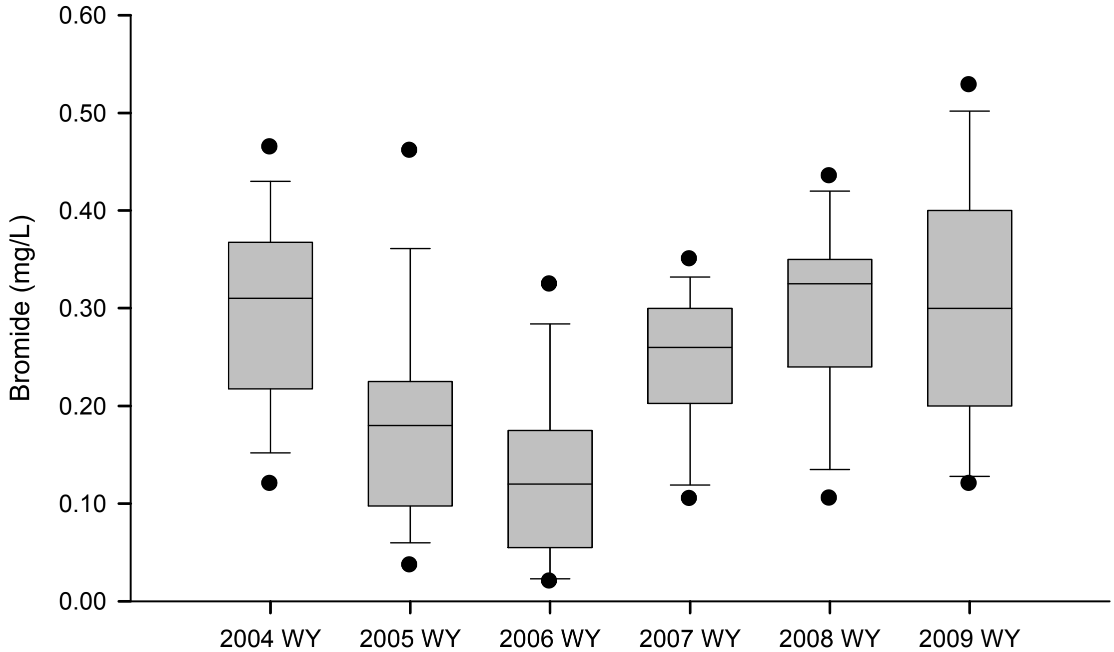


Figure 4-10. Bromide concentrations in the San Joaquin River near Vernalis, WY 2004 to WY 2009.

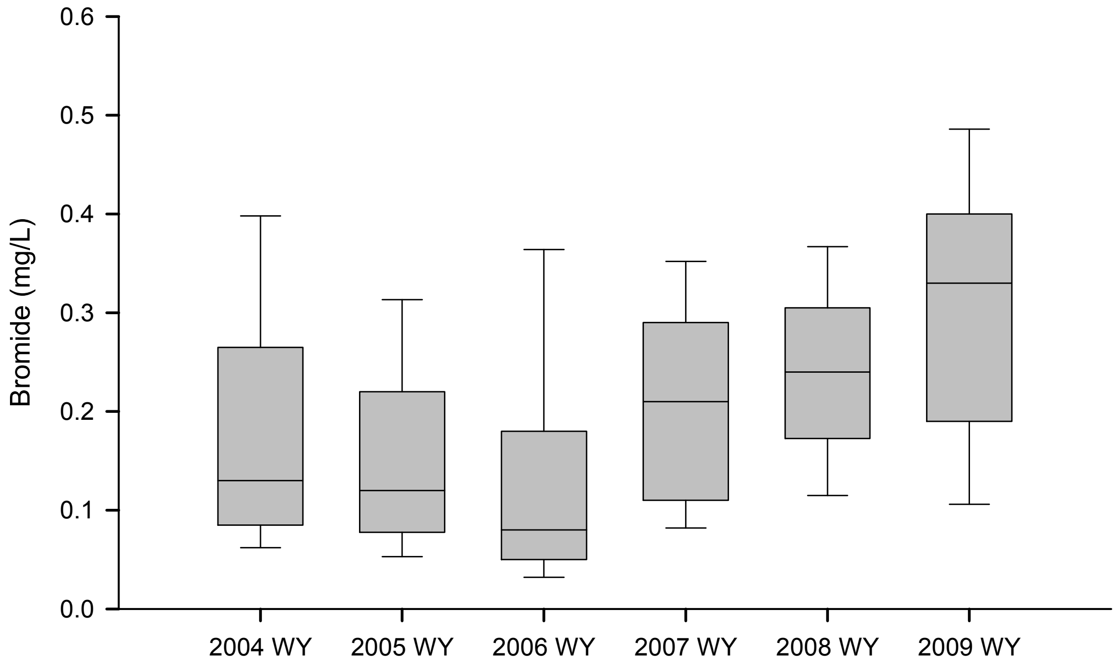


Figure 4-11. Bromide concentrations in the Sacramento River at Banks, WYs 2004 to 2009.

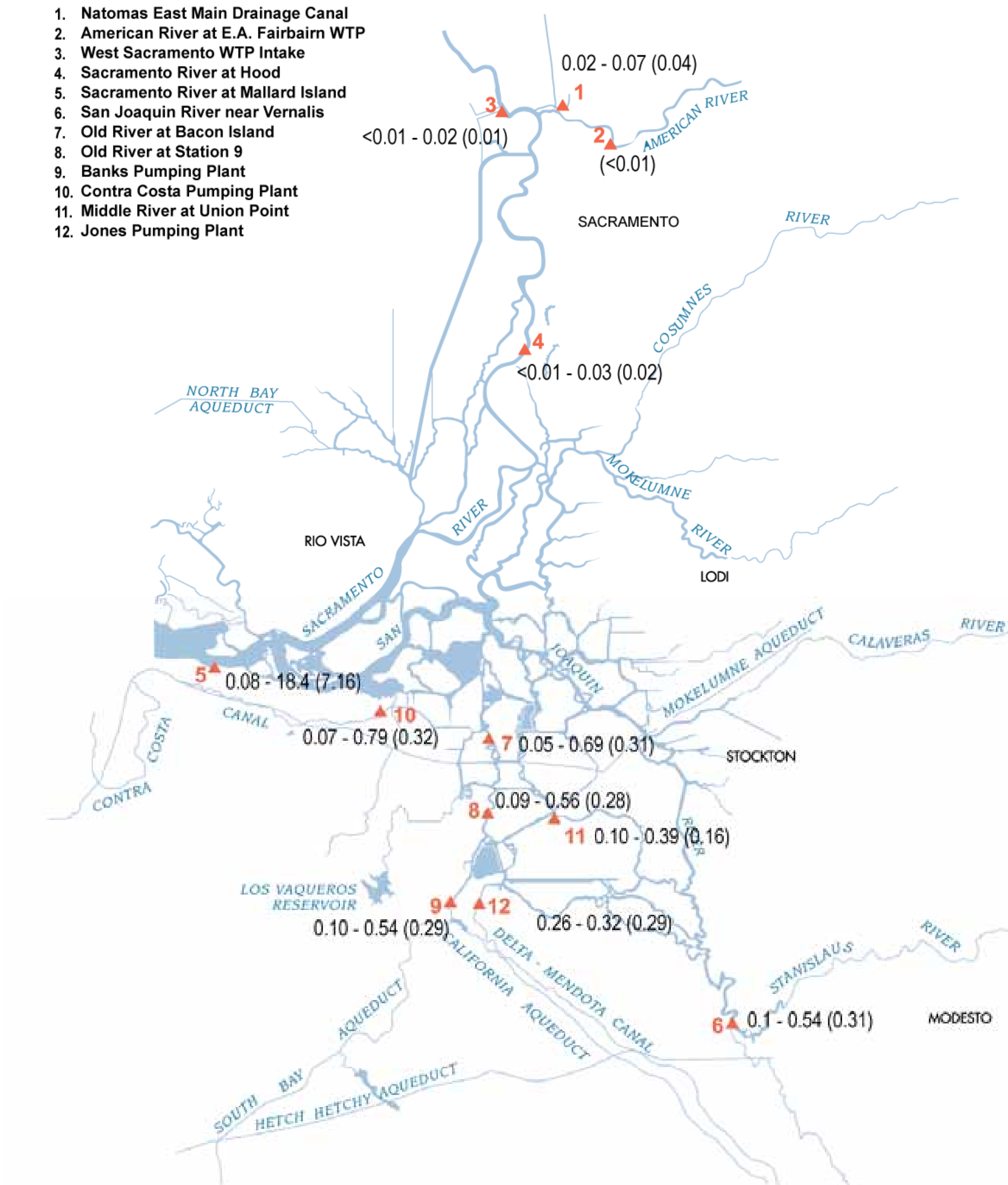


Figure 4-12. Bromide: range, median (mg/L).

Chapter 5 Salinity

Salinity is the concentration of dissolved salts in a given volume of an aqueous solution. High levels of salinity can cause an unpleasant taste, making it less suitable for drinking water purposes. Salinity also creates scale build-up in water delivery pipes, causes deterioration of residential and industrial appliances, and reduces usefulness of the water for blending with other source waters. Moreover, once salts enter the water supply it is difficult and expensive to remove. The State of California has established enforceable secondary maximum contaminant levels (MCLs) for salinity (Appendix A).

In an aqueous solution, dissolved salts exist as charged ionic species and increase the electrical conductivity of water. As a result, the electrical conductivity (EC) of a solution is used as an indirect measure of its salinity. A more direct measure of salinity is the weight of the total dissolved solids (TDS) present in a sample. The California Department of Public Health (CDPH) has set recommended MCLs for EC and TDS of 900 micro Siemens per centimeter (µS/cm) and 500 mg/L, respectively.

Stations North of the Delta

American River at the E.A. Fairbairn Water Treatment Plant (WTP)

Previous reports have documented that, regardless of season, the American River station has had the least saline water of all sampled stations. The results presented during this reporting period are consistent with that pattern (Table 5-1). EC and TDS values ranged from 52 to 95 µS/cm and 32 to 57 mg/L, respectively, for the 24 samples taken during the reporting period. Median EC was 64 µS/cm and median TDS was 41 mg/L (Table 5-1). Both water years covered in this report were very dry, and this resulted in elevated EC and TDS ranges compared to those in previous reports. Seasonally, EC and TDS were highest in the winter and lowest in the summer (Figure 5-1).

Sacramento River at West Sacramento WTP Intake

The West Sacramento WTP intake is just upstream from the confluence of the Sacramento and American rivers on the Sacramento River. For the 23 samples collected, EC and TDS ranged from 134 to 237 µS/cm and 78 to 137 mg/L, respectively (Table 5-1, Figure 2-2). Median EC for the two-year period was 176 µS/cm and median TDS was 110 mg/L (Table 5-1). Conductivity and TDS were, again, generally higher in the two dry water years (WYs) reported here than in the previous wet or dry years (WYs 2006 and 2007, respectively). EC and TDS were highest in the winter and lowest during the summer. This station had the least variation around the median of all stations sampled: EC ranged from -24% to +35% of the median; TDS ranged from -29% to +25% of the median.

Natomas East Main Drainage Canal

The Natomas East Main Drainage Canal (NEMDC) collects runoff from an urbanized watershed of mixed land use areas, as well as a wastewater treatment plant. This urban runoff, combined with NEMDC's small discharge volumes, resulted in elevated EC and TDS values relative to the nearby sampled stations.

During the reporting period, 21 samples were collected at NEMDC. EC values ranged from 189 to 418 µS/cm and TDS ranged from 113 to 240 mg/L (Table 5-1). The lowest EC and TDS values were observed during and after storms in February 2008 and March 2009 (Figure 5-3). Median EC and TDS were 311 µS/cm and 187 mg/L, respectively, for the two-year period (Table 5-1). Median EC and TDS were slightly lower than in the previous biennial report, in which median EC and TDS were 314 µS/cm and 193 mg/L, respectively, for the two-year period 2006-2007.

Sacramento River at Hood

Salinity patterns at the Sacramento River at Hood station were similar to the salinity patterns at the Sacramento River at West Sacramento WTP (Figure 5-2 and Figure 5-4). For the 46 samples collected, EC and TDS ranged from 115 to 234 µS/cm and 68 to 138 mg/L, respectively. EC values at the Hood site were statistically similar to those of the West Sacramento WTP Intake site (Mann-Whitney, p=0.854, p=0.917, WYs 2006 and 2009, respectively). Median EC was 177 µS/cm and median TDS was 104 mg/L (Table 5-1).

San Joaquin River near Vernalis

The water years 2008 and 2009 covered in this report were classified as critically dry and below normal, respectively, for the San Joaquin River. The Vernalis station generally had high EC and TDS values except when there was heavy rainfall (e.g., February of both years) or large releases from upstream reservoirs (e.g., March-April releases as part of the Vernalis Adaptive Management Plan (VAMP), Figure 5-5). The high mineral content of the soils of the San Joaquin Valley, saline irrigation return water, and recirculation of salts contributed to the elevated salinity of the San Joaquin River. Median EC and TDS values were higher for the Vernalis station than any other MWQI monitoring station except the Mallard Island station, which experiences seawater influences (Table 5-1). Forty-seven samples were collected during the sampling period. EC values ranged from 292 to 1,077 µS/cm with a median of 679 µS/cm. TDS concentrations ranged from 161 to 672 mg/L with a median of 394 mg/L.

Channel and Diversion Stations

Channel Stations

MWQI has historically sampled two Delta channel stations along the Old River: Station 9 and Bacon Island. Beginning in July 2006, samples were also collected from a third channel station, on the Middle River at Union Point. The three channel stations are relatively close to each other geographically and hydrologically, and as such, EC and TDS values were similar between stations (Table 5-1, and

Figure 5-6(a)-(c)). Of the three channel stations, median EC for the two-year period was highest at Bacon Island and lowest at Union Point. The range of EC values was also largest at Bacon Island and smallest at Union Point. The pattern of EC results suggests that seawater intrusion most heavily impacts Station 9 and the Bacon Island site, while the diluting effects of the Sacramento River at Union Point produced a lower median and narrower range of observed EC.

The EC fingerprints demonstrated that the San Joaquin River had a stronger influence throughout the year at Clifton Court Forebay than it did further north along the Old River (Figure 5-9 and Figure 5-10). Additionally, a comparison of the volumetric fingerprints to the EC fingerprints demonstrated the large effect water from the Martinez had on EC during these dry years (Figure 5-9 and Figure 5-10).

Figure 5-6(a) shows a time-series graph of the EC in the Old River at Bacon while Figure 5-9 (a and b) show EC and volumetric fingerprint graphs of the Old River near Bacon Island. When compared, the graphs illustrate that the highest EC values occurred when there was an increase in the percentage of Martinez water.

Diversion Stations

Samples were taken from the two Delta diversion stations at the Harvey O. Banks and the Contra Costa County pumping plants. For the 22 samples taken during the reporting period, EC at the Contra Costa Pumping Plant #1 (CCPP) ranged from 222 to 1,212 µS/cm, with a median of 518 µS/cm. TDS ranged from 140 to 674 mg/L, with a median of 299 mg/L (Table 5-1). At Banks, 23 samples were taken during the reporting period. EC ranged from 215 to 730 µS/cm with a median of 524 µS/cm. TDS concentrations at the Banks station ranged from 129 to 428 mg/L with a median of 295 mg/L.

During both years CCPP and Banks were influenced by saltwater intrusion from the west. This was especially noticeable in the late fall and early winter when Delta outflow was low, pumping was still significant, and tides were strong (Figure 5-7 and Figure 2-5). A comparison of Figure 5-7(b) to the volumetric fingerprint of Clifton Court Forebay (Figure 5-10) showed that seasonal high EC values occurred at Banks when Martinez water was present in Clifton Court Forebay waters. The same pattern was exhibited for the CCPP in which EC values were elevated when an increased percentage of Martinez water was present at the Old River near Bacon Island (Figure 5-7(a), Figure 5-9). In the spring and early summer months, river flows and curtailed pumping resulted in relatively lower EC and TDS at Clifton Court and Old River (Figure 2-5, Figure 5-9, and Figure 5-10). During this period, EC at Banks and the CCPP were at their lowest values.

In both water years, the salinity of the south Delta waters peaked in the early winter. EC at Banks decreased during spring rain events, VAMP, the opening of the Delta Cross Channel gates, and the initial onset of higher pumping rates in July of each year. This occurrence was due to the movement of less saline water from the north Delta flowing south (upstream) through the Middle River. Because Banks often had higher EC due to Martinez seawater entrained down the Old River, EC values between Banks and Middle River at Union Point were significantly different for the two year period (p=0.019, Mann-Whitney).

Mallard Island

Mallard Island is just downstream of the confluence of the Sacramento and San Joaquin rivers. It is the station farthest west and closest to Suisun Bay. Of all the sampled stations, it is the most heavily influenced by seawater intrusion. During the reporting period, 24 samples were collected. EC ranged from 289 to 13,580 µS/cm with a median of 6,698 µS/cm. TDS ranged from 165 to 8,220 mg/L with a median of 3,830 mg/L. Due to the persistent drought conditions in Delta tributaries, conductivity and TDS ranges and medians were much higher than those reported for the previous two water years (Figure 5-8, Table 5-1).

Chloride and Sulfate

Chloride and sulfate are among the salt ions that contribute to the salinity of Delta waters. Elevated concentrations of chloride and sulfate can give finished drinking waters an unpleasant taste. Municipal water suppliers report increased taste and odor complaints from customers when chloride concentrations exceed 100 mg/L. The California Department of Public Health (CDPH) has enforceable secondary MCLs for chloride and sulfate; the recommended maximum contaminant level for both constituents is 250 mg/L.

State Water Resources Control Board (SWRCB) Water Right Decision D-1641 includes a year-round 250 mg/L chloride objective that is in effect at the Delta export locations (Contra Costa Canal Pumping Plant #1, Clifton Court Forebay, Jones Pumping Plant, Cache Slough at the City of Vallejo intake, and Barker Slough) (SWRCB, 2000, revised). An additional municipal and industrial water quality objective for chloride at the Contra Costa Canal Intake near Rock Slough specifies that, depending upon the water year classification, chloride levels must be below 150 mg/L for a given number of days during the year.

With the exception of Mallard Island, concentrations of chloride and sulfate for the monitored stations were well below the CDPH MCLs. Due to seawater influence accentuated by the dry years (i.e., low flows), 83% of the samples from Mallard Island had chloride concentrations greater than 250 mg/L. Salinity at Mallard varied dramatically with Delta outflow and was especially low during outflow February-March 2008, and March and May 2009. Median chloride concentration over the two-year period was 2,215 mg/L with a range from 30 to 4,630 mg/L. Sulfate concentrations at Mallard ranged from 18 to

639 mg/L with a median of 288 mg/L. There were no exceedances of the CDPH MCLs for chloride or sulfate at any of the other 10 MWQI monitored stations. Fourteen of 49 samples at CCPP were above the narrower 150 mg/L chloride limit, generally in late fall and early winter. However, since these were monthly grab-samples, they do not necessarily reflect the total number of days during which chloride concentrations at CCPP were above 150 mg/L (Table 5-2).

The American River at Fairburn WTP had very low chloride and sulfate concentrations; the maximum values were 4 mg/L and 5 mg/L, respectively. At the Sacramento River at West Sacramento WTP and on the Sacramento River at Hood, chloride concentrations did not exceed 12 mg/L, and sulfate was less than 15 mg/L during the reporting period. At the NEMDC, chloride concentrations ranged from 12 to 37 mg/L with a median of 29 mg/L, and sulfate ranged from 10 to 27 mg/L with a median of 18 mg/L.

Median values of chloride for Bacon Island, Station 9, and Union Point stations were 93, 87, and 55 mg/L, respectively. Median values for sulfate concentrations at these three channel stations were 26, 30, and 28 mg/L, respectively. Contra Costa Pumping Plant had some elevated levels of chloride in comparison to the channel stations, perhaps due to a greater amount of seawater intrusion and local agriculture runoff. Chloride concentrations at CCPP ranged from 25 to 217 mg/L with a median of 101 mg/L. Sulfate, often used as a marker for seawater, was similar among the channel and the diversion stations Jones and Banks. Median sulfate was highest at Jones Pumping Plant (49 mg/L), followed by CCPP at 34 mg/L. However, the highest sulfate concentrations were detected at the CCPP in December 2007 (136 mg/L). Sulfate values at CCPP and Banks had very similar minima, means, and medians, though CCPP had a higher range, probably due to several very high sample readings in the fall of 2007. WY 2008, which includes Oct-Dec 2007, is classified as critically dry for both the Sacramento and San Joaquin Rivers. A Mann-Whitney test indicated that Banks and CCPP chloride and sulfate were not significantly different (chloride, $p=0.509$; sulfate, $p=0.429$.) The San Joaquin River at Vernalis had chloride concentrations that ranged from 36 to 168 mg/L with a median of 96 mg/L. Sulfate ranged from 31 to 165 mg/L with a median value of 79 mg/L.

Salinity of Delta Waters between Current Reporting Period and Previous Reports

Sacramento River at Hood

The salinity of the Sacramento River at Hood varied between and within seasons, but in general, the median EC and median TDS concentrations were lower in years that received more than an average amount of precipitation. Between WYs 2004 and 2009, 2006 was the only wet water year. The lowest median EC was recorded during this period (Table 5-3).

San Joaquin River at Vernalis

Salinity of the San Joaquin River at Vernalis tends to be relatively high in comparison to other Delta tributaries, yet decreases sharply with high flows. This was most noticeable in the 2006 to 2007 reporting period, when heavy rains in WY 2006 resulted in sustained high river discharge and lower median EC and TDS levels than any other recent reporting period (Table 5-3). Water year 2004 was dry; WYs 2005 and 2006 were wet; WYs 2007 and 2008 were critically dry; and 2009 was below normal.

Banks Station

Samples from the past six years did not exceed the MCLs for EC or TDS. Changes in EC values were seasonal with increases in EC during the fall months when Delta outflow was low, and decreases in EC during winter or spring months when Delta outflow was high. For the current reporting period, median EC (524 µS/cm) and median TDS (295 mg/L) were considerably higher than in the previous two reporting periods (Table 5-3).

Summary

Salinity throughout the Delta and its source rivers can be affected by watershed runoff, reservoir releases, natural sources in the watershed, urban discharges, agricultural drainage, and, at some stations, seawater intrusion and recirculation of salts in supply water. The effect of each factor on salinity varies between stations and over time.

During the reporting period (from October 2007 to September 2009), between 302 and 388 samples were collected from 12 stations, depending on the station. EC values ranged from 52 µS/cm to 13,580 µS/cm and TDS values from 32 mg/L to 8,220 mg/L. Approximately 84% of the samples had EC values of less than 750 µS/cm; approximately 89% were less than 900 µS/cm. All samples with EC values greater than 1212 µS/cm were collected from the Mallard Island station, the station with the greatest seawater influence. Table 5-1 summarizes the range, average, and median of EC and TDS values by station.

Of the 12 MWQI sampling stations, the American River had the lowest range of EC values and the lowest median EC of 64 µS/cm (Table 5-1). The Sacramento River at the West Sacramento WTP upstream of the confluence of the American and Sacramento rivers had a median EC of 176µS/cm (Table 5-1). In contrast, the NEMDC station, which discharges into the Sacramento River less than two miles downstream of the West Sacramento station, had an elevated median EC of 311µS/cm (Table 5-1). NEMDC flows, however, were a small percentage of the combined flows of the American and Sacramento rivers for the reporting period. Median EC on the Sacramento River at Hood, more than 15 miles downstream of the West Sacramento station and the NEMDC confluence, was comparable to median EC and other ion parameters at the West Sacramento WTP Intake (Table 5-1 and Table 5-2). Median EC at the Sacramento River at Hood during the reporting period was 176 µS/cm. The salinity of the San Joaquin River at Vernalis during the reporting period was much greater than the salinity of the Sacramento River at Hood. The median EC at Vernalis, of 679 µS/cm, was the second highest EC value of the 12 MWQI stations, after Mallard Island's 6,698 µS/cm. The high salinity of the San Joaquin River is usually attributed to irrigation returns, upstream diversions, recirculation of salts from the Delta, and the highly mineralized soils of the west side of the San Joaquin Valley.

Despite Delta island drainage, municipal discharges, and seawater intrusion, the channel and diversion stations had median EC values lower than that of the San Joaquin Vernalis station. This occurrence was most likely due to the influence of fresh water from the north Delta. EC values increased during the fall months when inflow to the Delta was low. EC values of the channel and diversion stations decreased during months with high Delta inflows and outflows, though these sometimes lagged behind the flushing effect seen at Mallard Island. They also tended to decrease when the Delta Cross Channel gates were open and project pumping was elevated, drawing low-salinity Sacramento River water across the Delta. Comparisons of the volumetric and EC fingerprints showed the seasonal influence of operations, seawater, and agricultural drainage on salinity.

Water at Mallard Island typically exhibits a high degree of seawater intrusion due to its proximity to Suisun Bay and the straits leading to San Francisco Bay. Eighty-three percent of the samples at Mallard Island had EC values greater than 1,000 µS/cm (up from 60% in the last biennial report). Median EC at Mallard Island during the reporting period was 6,698 µS/cm; WY 2006-2007 median was 3,374 µS/cm. When Delta outflows were high in spring 2006, Mallard Island EC ranges were as low as any of the other channel and diversion monitoring stations.

Table 5-1. Summary of EC and TDS data at 12 MWQI stations, October 2007 through September 2009.

	EC (µS/cm)				TDS (mg/L)			
Station	*Samples*	*Range*	*Average*	*Median*	*Samples*	*Range*	*Average*	*Median*
Stations north of the Delta								
American River at E.A. Fairbairn WTP	24	52–95	68	64	24	32–57	43	41
West Sacramento WTP Intake	23	134–237	181	176	24	78–137	106	110
Natomas East Main Drainage Canal	21	189–418	316	311	21	113–240	189	187
Sacramento River at Hood	46	115–234	177	176	46	68–138	103	104
San Joaquin River near Vernalis	47	292–1077	690	679	47	161–672	399	394
Channel and diversion stations								
Old River at Station 9	24	232–755	507	503	24	134–420	284	279
Old River at Bacon Island	24	236–819	514	550	24	135–460	288	305
Banks Pumping Plant	23	215–730	499	524	23	129–428	284	295
Contra Costa Pumping Plant [a, b]	22	222–1212	571	518	22	140–674	324	299
Middle River at Union Point	24	228–633	416	407	24	135–350	233	225
Mallard Island	24	289–13,580	7,015	6,698	24	165–8,220	4,223	3,830

[a] Samples for this station were not collected.
[b] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 3/2009 to 9/200

Table 5-2. Summary of chloride and sulfate data, October 2007 through September 2009.

	Cl (mg/L)				SO_4 (mg/L)			
Station	*Samples*	*Range*	*Average*	*Median*	*Samples*	*Range*	*Average*	*Median*
Stations north of the Delta								
American River at E.A. Fairbairn WTP	24	2–4	2	2	24	2–5	3	2
West Sacramento WTP Intake	24	3–11	7	6	24	4–14	8	8
Natomas East Main Drainage Canal	21	12–37	27	29	21	10–27	18	18
Sacramento River at Hood	46	4–11	8	8	46	5–14	8	8
San Joaquin River near Vernalis	50	36–168	94	96	50	31–165	86	79
Channel and diversion stations								
Old River at Station 9	24	26–165	89	87	24	13–57	31	30
Old River at Bacon Island	72	18–187	92	93	24	12–39	27	26
Banks Pumping Plant	27	27–132	85	89	27	12–83	38	33
Jones Pumping Plant [a]	2	83–103	92	93	2	46–49	48	48
Contra Costa Pumping Plant [b]	49	25–217	102	101	22	12–136	39	34
Middle River at Union Point	24	22–113	60	55	24	12–54	30	28
Mallard Island	24	30–4,630	2,305	2,215	24	18–639	319	288

[a] Jones Pumping Plant data are derived from two samples collected on two dates: 3/4/09 and 9/15/09.
[b] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 3/2009 to 9/2009.

Table 5-3. Summary of EC and TDS during six consecutive water years.

		EC (µS/cm)			TDS (mg/L)		
Station	*Water Years*	*Range*	*Average*	*Median*	*Range*	*Average*	*Median*
Sacramento River at Hood	2008–2009	115–234	177	176	68–138	103	104
	2006–2007	73–189	144	147	46–115	87	89
	2004–2005	111–240	161	154	69–140	97	93
Summary	2004–2009	73–240	161	163	46–140	96	96
San Joaquin River near Vernalis	2008–2009	292–1,077	690	679	161–672	399	394
	2006–2007	99–776	476	492	64–456	278	285
	2004–2005	120–1,170	679	710	75–635	330	347
Summary	2004–2009	99–1,170	575	621	64–672	324	348
Banks Pumping Plant	2008–2009	215–730	499	524	129–428	284	295
	2006–2007	125–567	342	337	74–345	196	191
	2004–2005	196–671	377	350	108–378	218	204
Summary	2004–2009	125–730	412	416	74–428	236	243

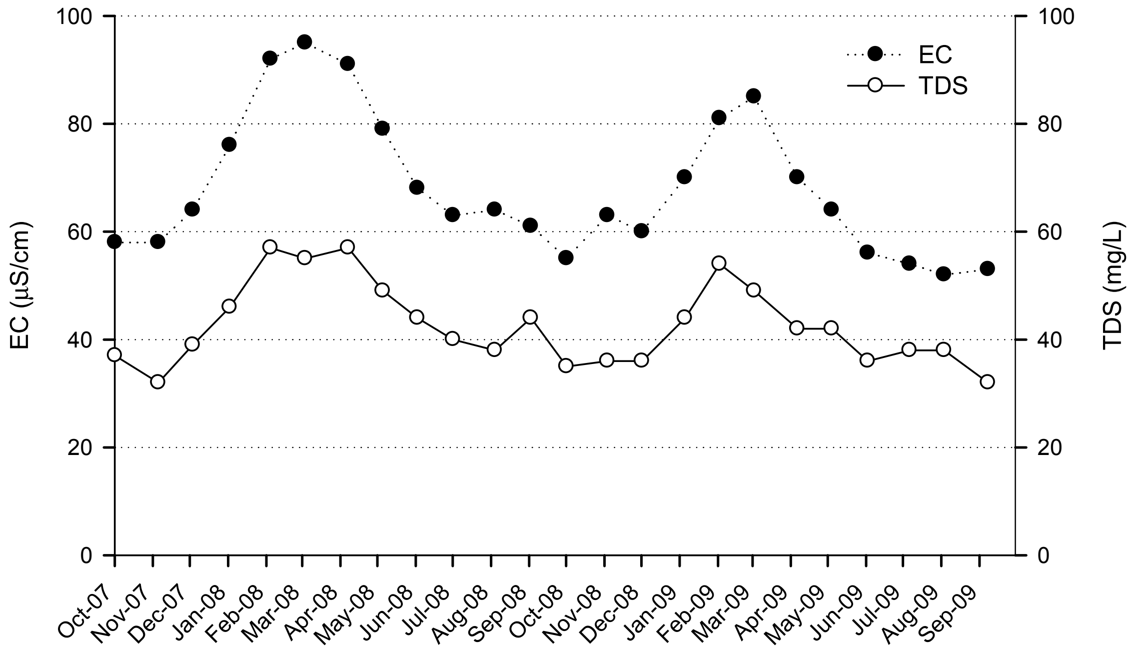


Figure 5-1. EC and TDS at E.A. Fairbairn WTP Intake.

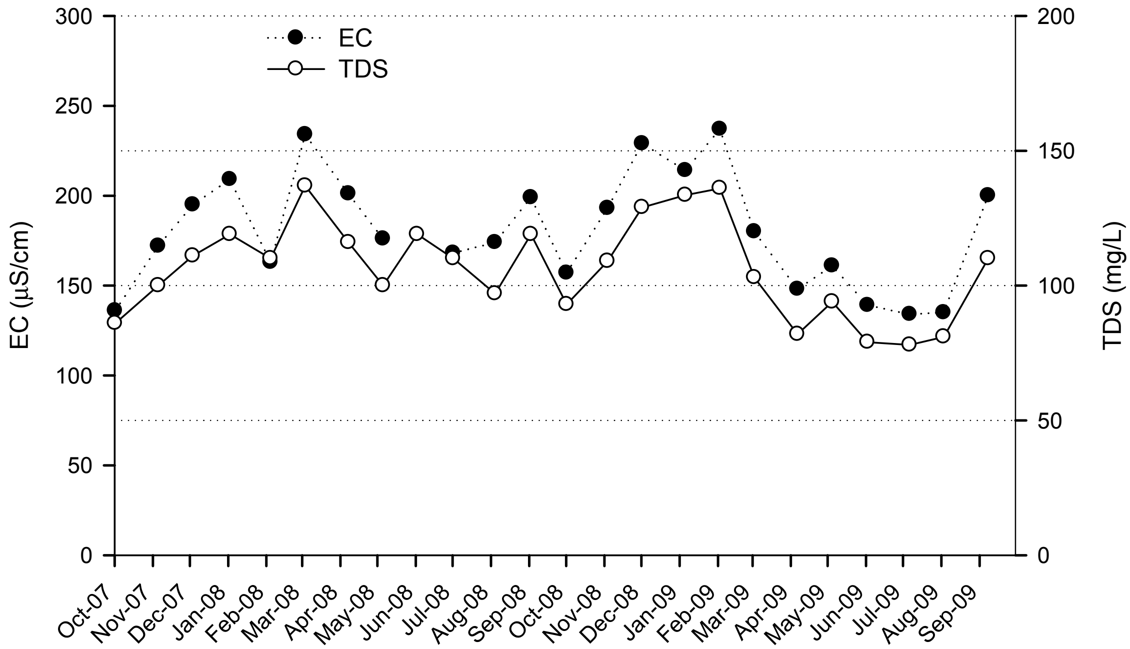


Figure 5-2. EC and TDS at West Sacramento WTP Intake.

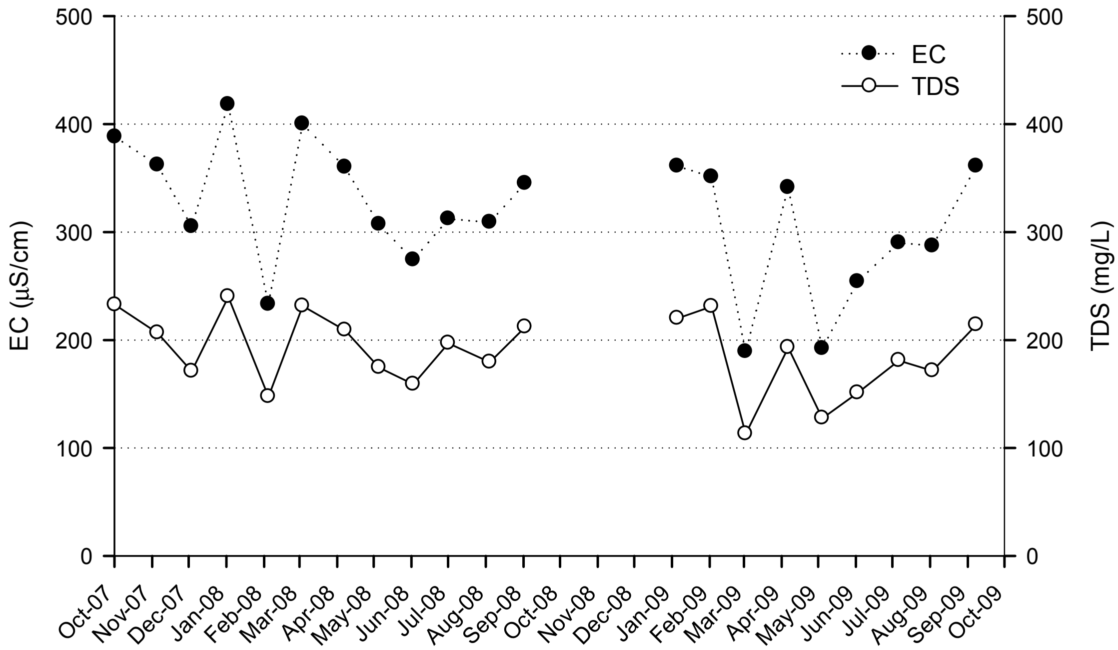


Figure 5-3. EC and TDS at the NEMDC station.

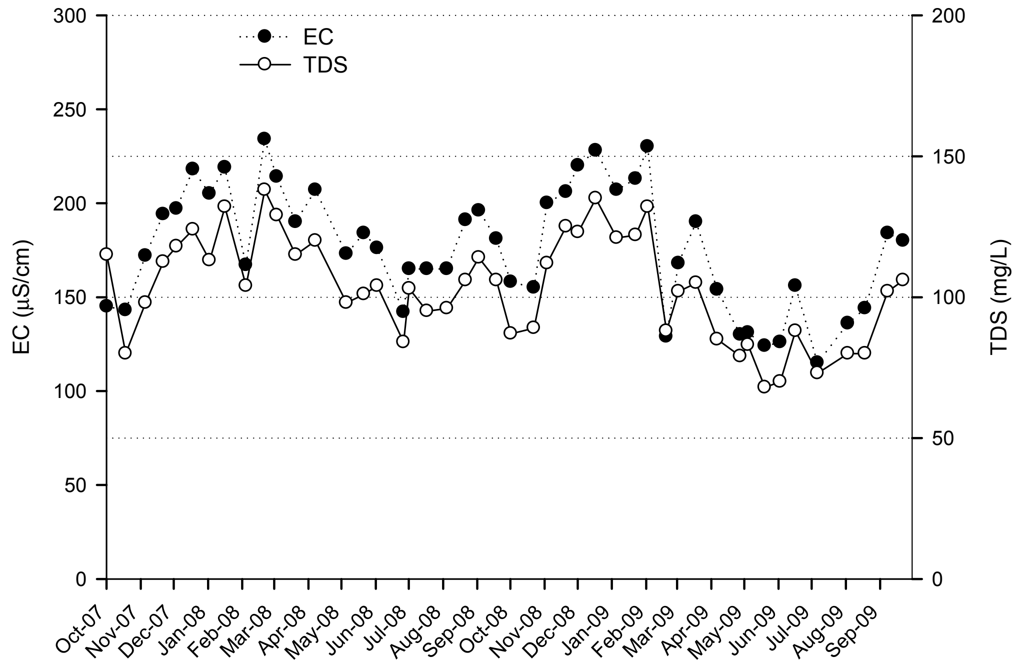


Figure 5-4. EC and TDS at Sacramento River at Hood.

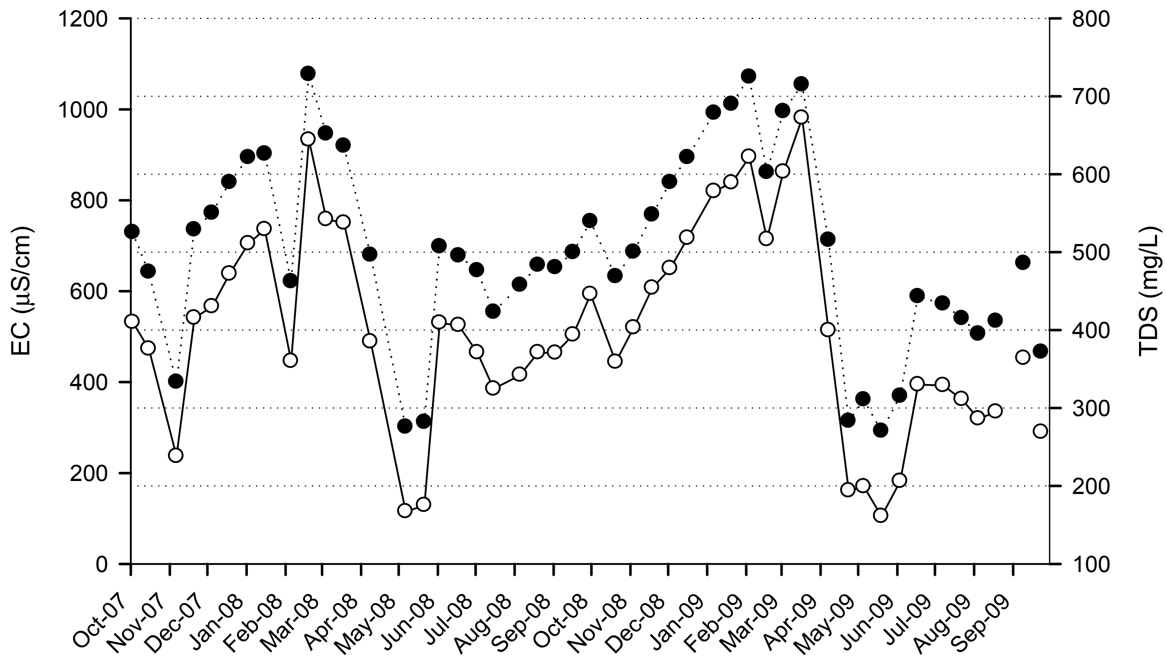


Figure 5-5. EC and TDS at the San Joaquin River near Vernalis.

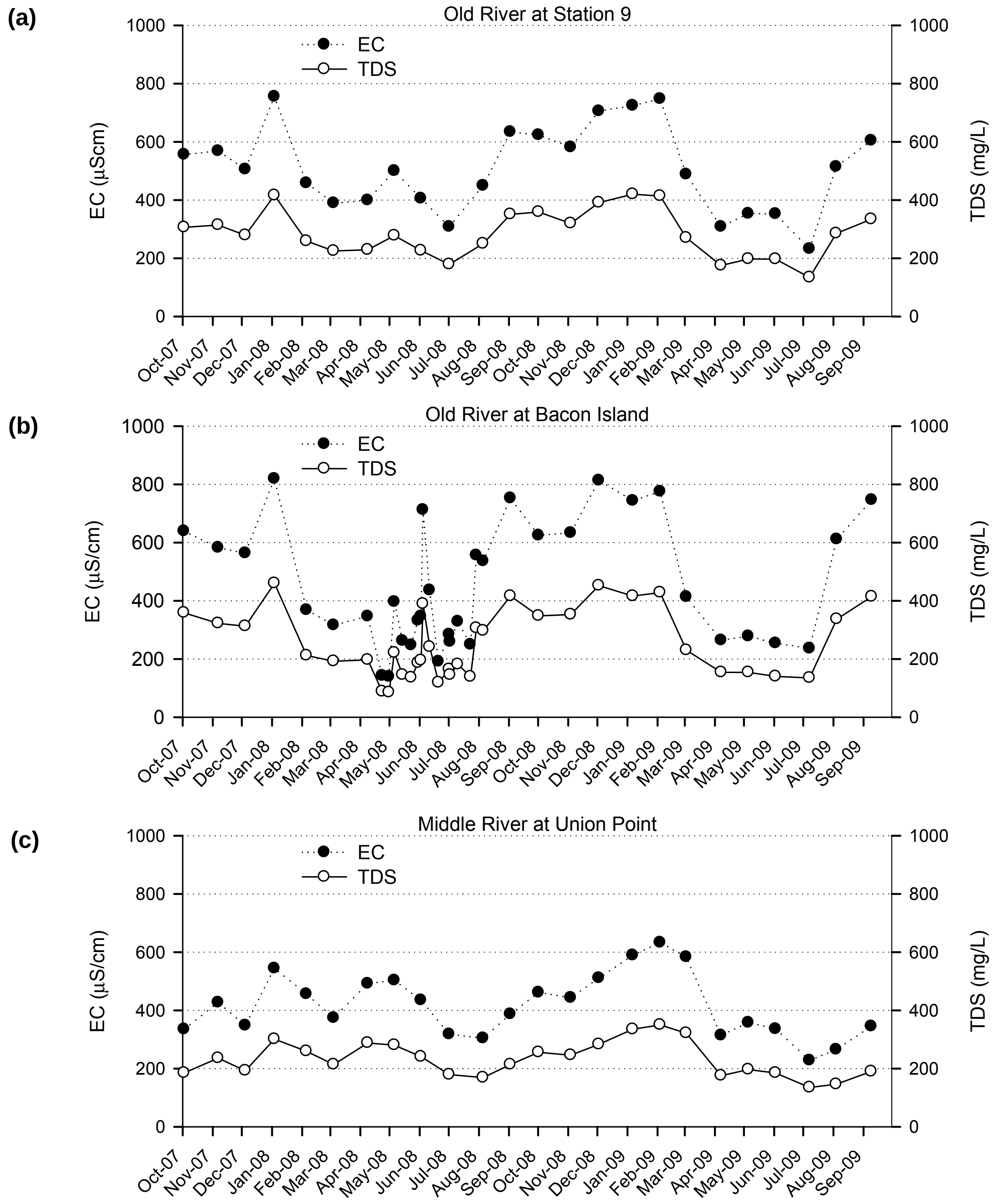
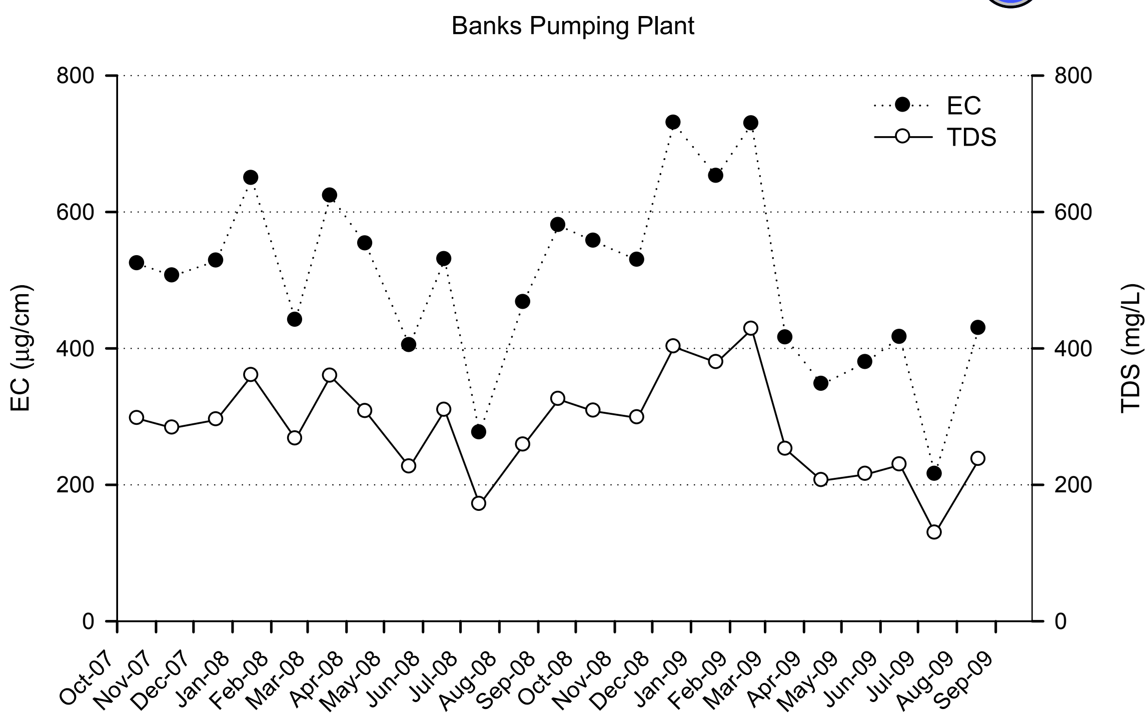


Figure 5-6. EC and TDS at the Delta channel stations. a. Old River at Station 9. b. Old River at Bacon Island. c. Middle River at Union Point.

(a)



(b)

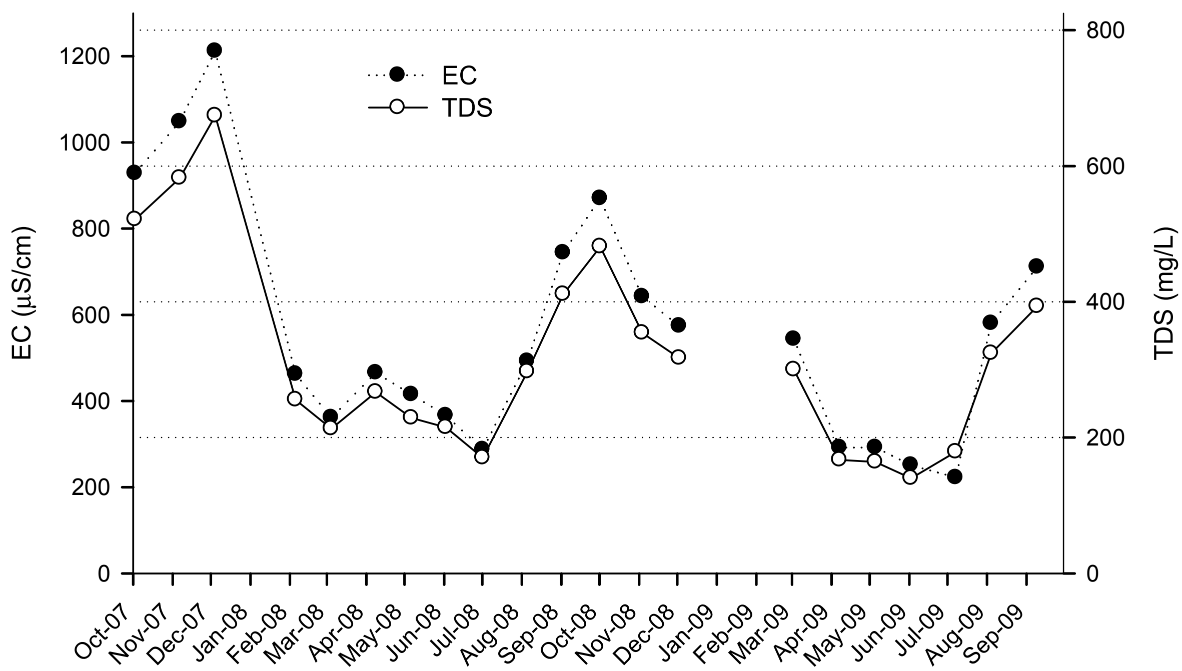


Figure 5-7. EC and TDS at Delta diversion stations. a. Banks Pumping Plant. b. Contra Costa Pumping Plant.

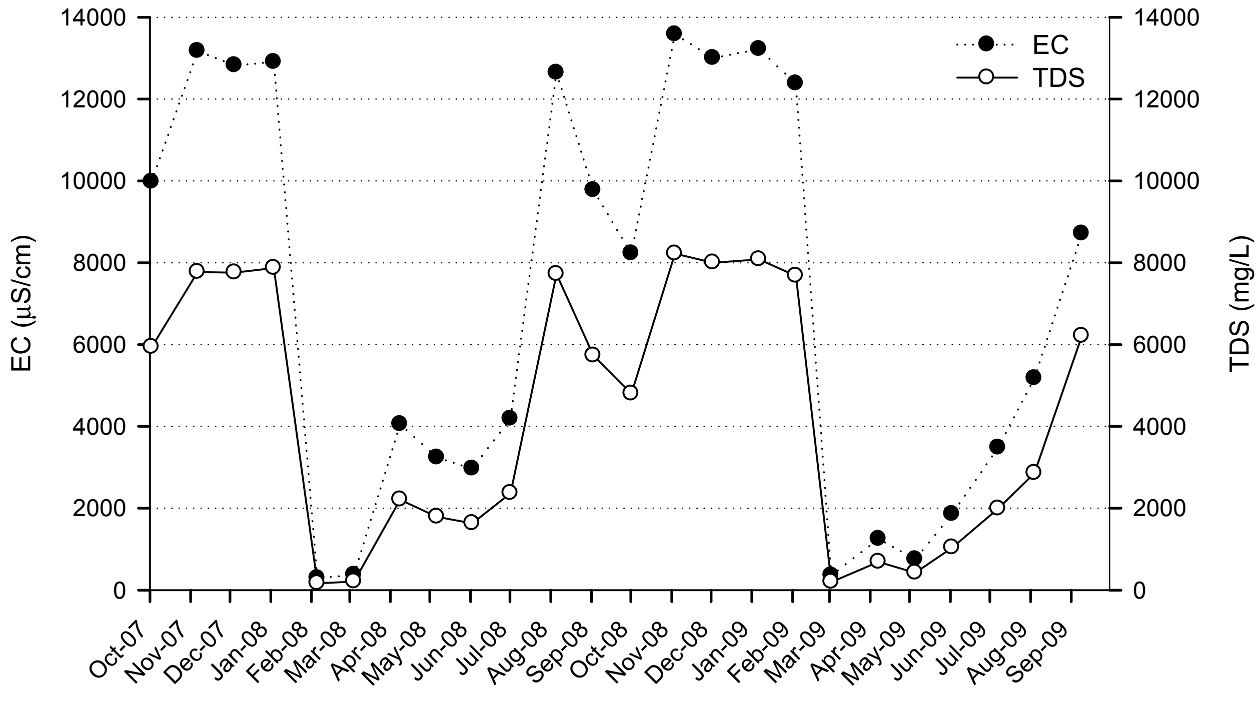
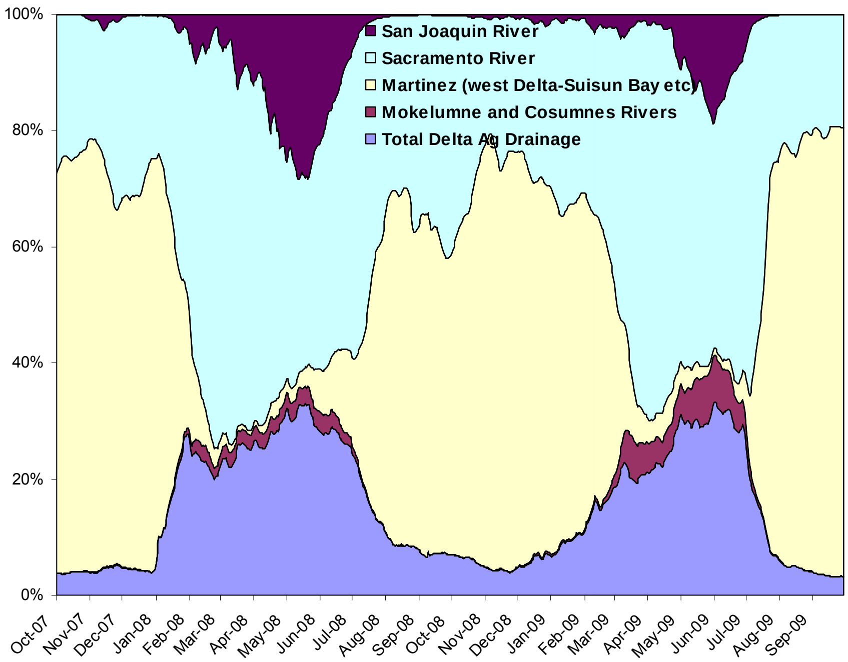


Figure 5-8. EC and TDS at Mallard Island station.

(a)



(b)

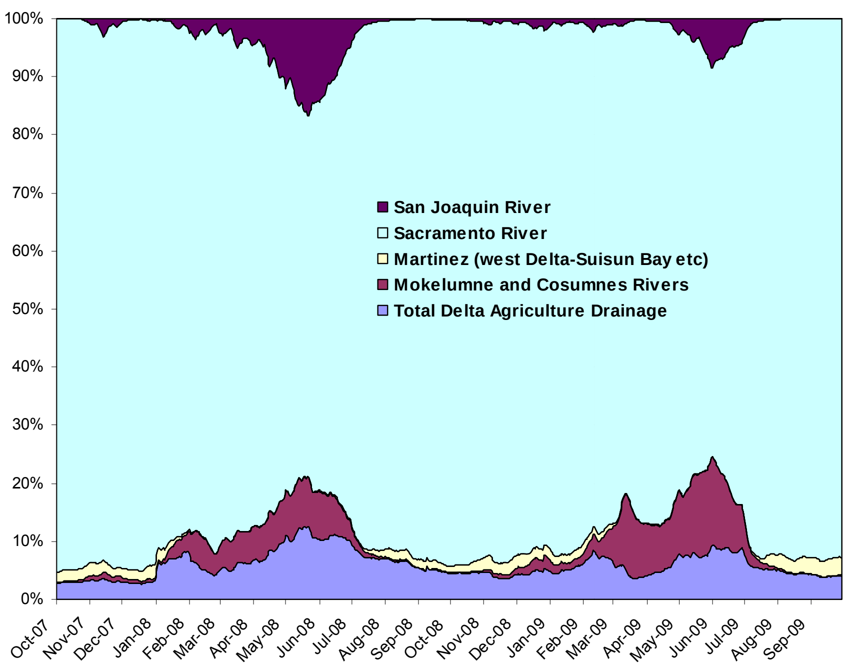
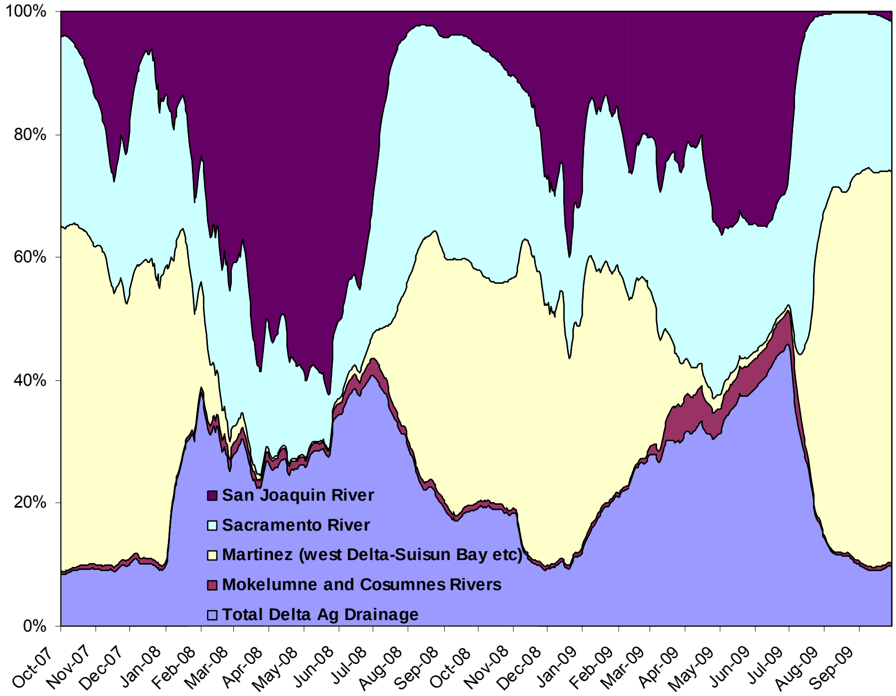


Figure 5-9. Fingerprints at the Old River. a. Electrical Conductivity (EC) fingerprints. b. Volumetric fingerprints.

(a)



(b)

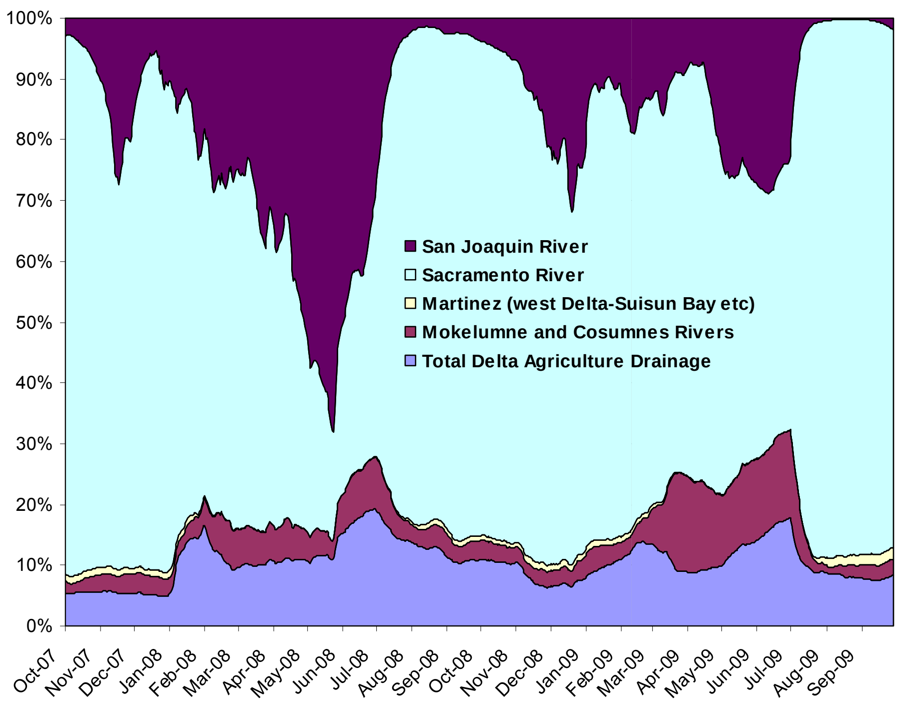


Figure 5-10. Fingerprints at the Clifton Court Forebay.
a. Electrical Conductivity (EC) fingerprints. b. Volumetric fingerprints.

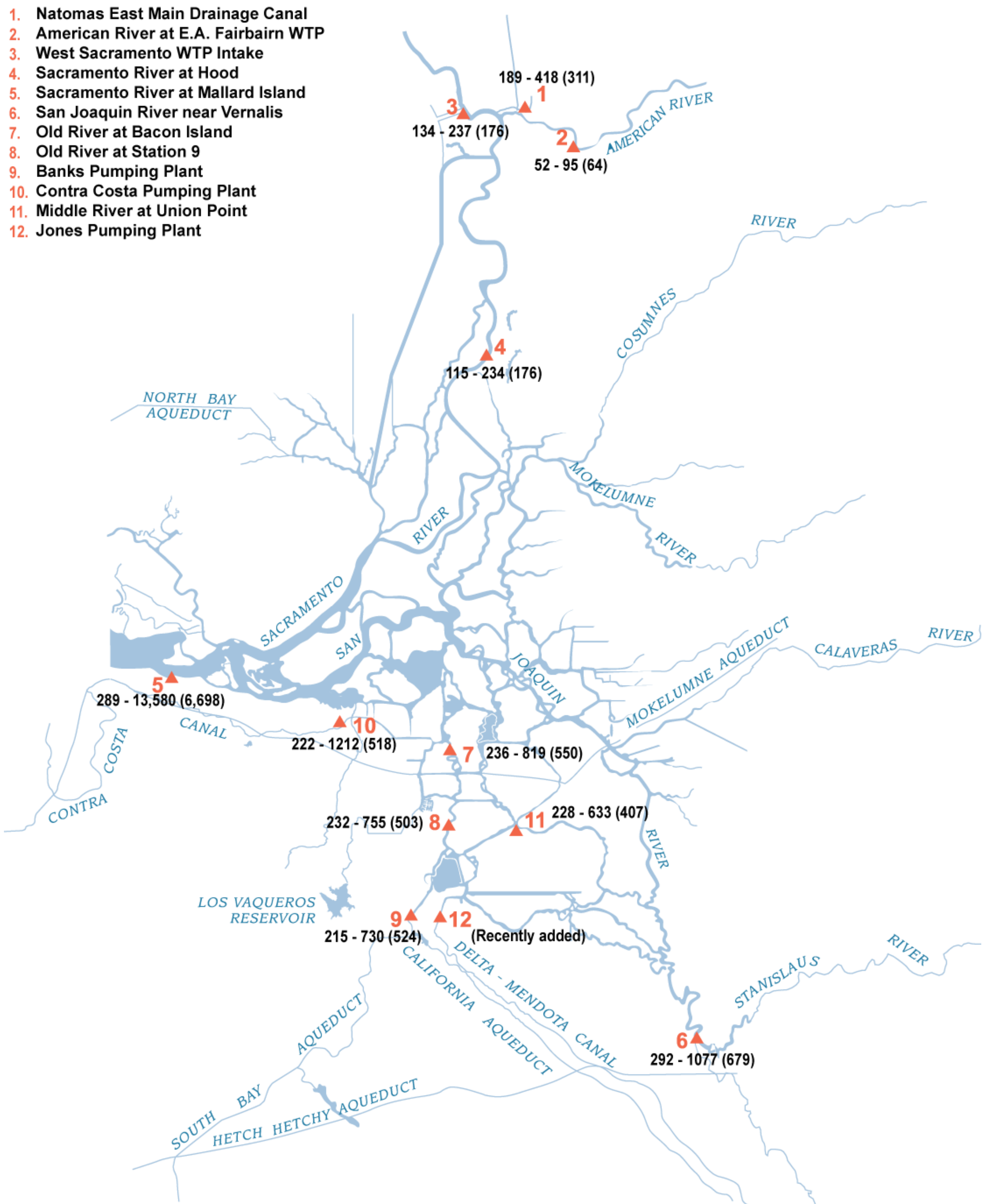


Figure 5-11. Electrical conductivity: Range (median) µS/cm.

Chapter 6 Nutrients

Nutrient concentrations indicate the potential for algal and vascular plant growth throughout the Delta. Excess nutrients can lead to significant water quality problems, including harmful algal blooms, hypoxia, and deterioration in taste, odor, and other aesthetic qualities. The U.S. Environmental Protection Agency (USEPA) has been working on the development and adoption of national nutrient criteria for water quality standards since 2001. In drinking water, the USEPA has established primary maximum contaminant levels (MCLs) for nitrate of 10 mg/L measured as nitrogen (as N), 10 mg/L as N for nitrate plus nitrite, and 1 mg/L as N for nitrite. No federal or State drinking water standards have been developed for phosphorus. Since these MCLs are for finished drinking water, these MCLs are not directly applicable to concentrations reported in this investigation.

MWQI monitored nutrients including dissolved nitrate, combined nitrate and nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, and orthophosphates. In this report, total nitrogen was calculated as the sum of TKN plus nitrate plus nitrite, while inorganic nitrogen was calculated as the sum of ammonia plus nitrate plus nitrite. Total phosphorus is composed of the particulate and dissolved phase of phosphorus; orthophosphates are soluble, inorganic fractions of phosphorus. Orthophosphate is the only form that is generally available for algal and plant uptake, but total phosphorus is a better indicator of the productivity of a system (Archibald Consulting, 2007). Of the 12 stations monitored, nutrients were not analyzed at the Jones Pumping Plant.

Stations North of the Delta

The lowest median concentrations of nutrients were found at the American River at E.A. Fairbairn Water Treatment Plant (WTP) Intake and at the West Sacramento WTP Intake. These stations had the lowest inorganic, TKN and total nitrogen medians as well as the lowest concentrations of phosphorus and orthophosphates (Table 6-1). Nitrogen concentrations at both stations followed regular seasonal patterns of biological uptake during the spring and summer, and increased nitrogen concentrations during the fall and winter. Increases in the fall and winter occurred as nitrogen was mobilized from the soil during runoff and sediment releases from inflows and precipitation (Figure 2-2 and Figure 6-1). Concentrations of total phosphorus and orthophosphates followed seasonal patterns similar to those for nitrogen (Figure 6-1). Phosphate concentrations were low in the summer due to biological activity. In the winter, concentrations increased due to runoff.

With the exception of the Vernalis station for inorganic and total nitrogen, the Natomas East Main Drainage Canal (NEMDC) had the second highest median concentrations of nitrogen, and highest median concentration for total phosphorus, and orthophosphates (Table 6-1 and Table 6-2). Unlike the nearby Sacramento and American River stations, concentrations of inorganic nitrogen at NEMDC were often higher than concentrations of TKN (Figure 6-2). Most of the total phosphorus was present as dissolved orthophosphate indicating little particulate phosphorus (Figure 6-2). This elevation in inorganic nutrients may be attributed to nitrogen and phosphorus fertilizers used in some areas of the watershed. NEMDC collects water from a variety of sources, including surface drainage from a highly populated watershed, small amounts of agricultural drainage, and a wastewater treatment plant.

Statistically, seasonal differences were detected at NEMDC for total nitrogen, but not for total phosphorus. The median total nitrogen for the wet and dry season was 1.80 and 1.56 mg/L, respectively with a p-value of 0.0289. The median total phosphorus for the wet and dry season was 0.47 and 0.57 mg/L, respectively with a p-value of 0.4177.

Sacramento River at Hood

Due to a wastewater treatment plant and an active marina discharge upstream from the Hood station, median concentrations of inorganic nitrogen, total nitrogen, and phosphorus were higher at Hood than at upstream sites (Table 6-1, Table 6-2, Figure 6-3). Unlike water year (WY) 2009, there were not pronounced seasonal differences in nutrient concentrations in WY 2008. As WY 2008 was a critical year, this may have led to less mobilization of nutrients in the winter months and less freshwater flushing from reservoir releases in the summer months.

San Joaquin River near Vernalis

Among all stations, the highest median inorganic and total nitrogen concentrations were found at the San Joaquin River (SJR) near Vernalis (Table 6-1). Nutrient seasonality at this station was complicated by application of nitrogen and phosphorus fertilizers on agricultural lands along the SJR and its tributaries. Fertilizer applications are potentially responsible for the high levels of inorganic nitrogen observed at this location (Figure 6-4). Also shown in Figure 6-4, nutrient concentrations dropped between April and May while the Vernalis Adaptive Management Plan (VAMP) was in effect. Nutrient concentrations fell during this period in response to freshwater releases from upstream reservoirs. Increased concentrations during the dry months were associated with the growing season and more specifically with the agricultural drainage inflows to the river. Similar to the NEMDC station, total nitrogen data for the wet and dry seasons were significantly different with a p-value of 0.035. Medians for total nitrogen for wet and dry seasons were 2.20 and 1.81 mg/L, respectively.

As shown in Figure 6-4, organic phosphates constituted a significant proportion of the total phosphates. Organic phosphates are formed primarily by biological processes as well as by the breakdown of organic pesticides in a wastewater treatment plant (WWTP). Drier years between WY 2007 and 2009 had lower precipitation and snowmelt, resulting in less runoff of particulate or orthophosphates found in fertilizer. TKN, orthophosphates, and total phosphorus concentrations at Vernalis were lower than those found at NEMDC, but higher than the stations north of the Delta.

Channel and Diversion Stations

Water at the channel and diversion stations is derived from multiple sources. Therefore, volumetric fingerprints presented in Chapter 2 were used to help explain nutrient water quality patterns. At channel and diversion stations, maximum concentrations were generally higher than those observed at Hood; however, median concentrations were similar to those found at Hood, but less than those found at Vernalis (Table 6-1 and Table 6-2). Total nitrogen and phosphorus concentrations were generally higher during the wet months and lower during the dry months of each water year (Figure 6-5 and Figure 6-6). Increased algal activities in the rivers and channels of the Delta could explain lower nitrogen concentration during the dry months. Higher concentrations of nutrients occurred from December to March in response to precipitation and increased reservoir releases (Figure 2-4). Cyclical patterns of seasonal change were less obvious for both total phosphorus and orthophosphates. Concentrations at the channel stations on Middle River at Union Point and Old River at Station 9 were comparable to those at the diversion station at Banks Pumping Plant (Figure 6-5). Looking at the volumetric fingerprint for these three stations (Figure 2-12), nutrients levels generally increased or decreased based on the relative contribution of high nutrient San Joaquin River water. Contra Costa Pumping Plant #1 (CCPP) is a diversion station that pumps water from Rock Slough. From a source water standpoint, waters at this site are influenced by water from Old River (Figure 1-1 and Figure 2-12). Although the Contra Cost Pumping Plant #1 and Bacon Island are both influenced by Old River, median concentrations of total nitrogen and phosphorus were statistically different.

Mallard Island

Nitrogen and phosphorus concentrations at the Mallard Island station were comparable to those at the channel and diversion stations (Table 6-1 and Table 6-2). Low nutrient concentrations at Mallard Island may be attributed to several factors, including seawater influence, water diversion through pumping, and biological consumption of nutrients within the Delta. Of all the stations surveyed, Mallard Island is the most susceptible to tidal and seawater influences. Seawater, with its low nitrogen concentrations, diluted nitrogen concentrations at Mallard Island (Figure 6-7). In addition, when water passes through the biologically diverse and complex Delta, much of the nitrogen may be consumed before it reaches the Mallard Island station.

Summary

Figure 6-8 and Figure 6-9 show summary box plots by station for nitrogen and phosphorus. Of the 11 stations monitored for nitrogen and phosphorus, median inorganic and total nitrogen concentrations ranged from 0.06 to 1.93 mg/L and 0.21 to 2.10 mg/L, respectively. Median total phosphorus and orthophosphates ranged from 0.01 to 0.47 mg/L and <0.01 to 0.46 mg/L, respectively. The lowest nutrient concentrations were found at the American River at E.A. Fairbairn WTP, the West Sacramento WTP intake, and the Contra Costa Pumping Plant (Table 6-1 and Table 6-2). The highest inorganic nitrogen and total nitrogen concentrations were found at the SJR near Vernalis and NEMDC (Figure 6-8 and Table 6-1), while the highest total phosphorus and orthophosphate concentrations were found at NEMDC (Figure 6-9 and Table 6-2). Although the Hood station is near the north boundary of the Delta and receives high quality water from the American River, nutrient concentrations were much higher than at nearby stations. Elevated concentrations are possibly due to urban loads and wastewater discharges upstream. Nutrient concentrations at most Delta channel and diversion stations were comparable to those at the Hood station. Due to the diluting influences of seawater, concentrations at the Mallard Island station were comparable to the Delta channel and diversion stations.

Even during the critical water year of 2008, low levels of rainfall diluted high nutrient concentrations. This effect was least pronounced at NEMDC and the Vernalis stations, which already had higher nutrient concentrations during the summer due to agricultural and/or urban runoff. Concentrations remained high throughout the winter with only a modest decrease in concentrations June through September.

Table 6-1. Summary of inorganic, organic, and total nitrogen at 12 MWQI stations.

	Inorganic N [a, c] (mg/L)			*Total Kjeldahl nitrogen (mg/L)*			*Total nitrogen [b, c] (mg/L*		
Station	*Range*	*Average*	*Median*	*Range*	*Average*	*Median[d]*	*Range*	*Average*	*Median*
Stations North of the Delta									
American River at E.A. Fairbairn WTP	0.01–0.20	0.08	0.06	<0.1–0.3	0.2	0.2	0.12–0.46	0.23	0.21
West Sacramento WTP Intake	0.03–0.37	0.18	0.19	<0.1–0.8	0.3	0.2	0.12–1.15	0.38	0.32
Natomas East Main Drainage Canal	0.53–2.33	1.12	1.04	0.1–1.2	0.7	0.7	1.01–3.00	1.73	1.64
Sacramento River at Hood	0.25–0.94	0.60	0.59	0.2–1.2	0.7	0.7	0.30–1.44	0.82	0.77
San Joaquin River near Vernalis	1.41–2.99	2.13	1.93	<0.1–1.3	0.6	0.5	0.60–3.66	2.08	2.10
Channel and diversion stations									
Old River at Station 9	0.10–1.84	0.64	0.57	0.2–0.9	0.5	0.4	0.30–2.60	1.07	1.02
Old River at Bacon Island	0.13–1.44	0.57	0.57	0.1–0.9	0.4	0.4	0.24–2.21	0.89	0.85
Banks Pumping Plant	0.08–1.82	0.71	0.67	0.2–0.8	0.4	0.4	0.26–2.44	1.11	1.08
Jones Pumping Plant									
Contra Costa Pumping Plant [e]	0.04–1.27	0.47	0.48	0.2–0.6	0.5	0.5	0.42–1.79	0.92	0.92
Middle River at Union Point	0.13–2.15	0.77	0.71	0.2–1.0	0.5	0.5	0.31–3.00	1.20	1.13
Mallard Island	0.28–0.89	0.59	0.60	0.3–0.8	0.5	0.5	0.64–1.46	0.99	0.99

[a] Inorganic N includes ammonia, nitrate and nitrite.
[b] Total nitrogen includes TKN and nitrate and nitrite.
[c] Calculation for Inorganic N and Total nitrogen doesn't include samples below the detection limit.
[d] Medians for TKN are calculated using values below the detection limit.
[e] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2009.

Table 6-2. Summary of total phosphorus and orthophosphates at 12 MWQI stations.

Station	Total Phosphorus (mg/L)				Orthophosphates (mg/L)			
	Detects[a]/ Samples[b]	Range	Average	Median[c]	Detects[a]/ Samples[b]	Range	Average	Median[c]
Stations North of the Delta								
American River at E.A. Fairbairn WTP	17/24	<0.01–0.02	0.01	0.01	3/24	<0.01–0.01	0.01	<0.01
West Sacramento WTP Intake	24/24	0.03–0.20	0.05	0.04	24/24	0.01–0.06	0.03	0.03
Natomas East Main Drainage Canal	21/21	0.26–1.02	0.55	0.47	21/21	0.12–1.04	0.46	0.46
Sacramento River at Hood	45/45	0.06–0.22	0.10	0.10	45/45	0.03–0.12	0.07	0.07
San Joaquin River near Vernalis	47/47	0.08–0.33	0.16	0.15	47/47	0.02–0.21	0.08	0.07
Channel and diversion stations								
Old River at Station 9	24/24	0.06–0.14	0.09	0.08	24/24	0.03–0.09	0.06	0.06
Old River at Bacon Island	24/24	0.06–0.12	0.08	0.08	24/24	0.04–0.09	0.06	0.06
Banks Pumping Plant	24/24	0.06–0.16	0.11	0.10	24/24	0.05–0.12	0.08	0.08
Jones Pumping Plant								
Contra Costa Pumping Plant [d]	22/22	0.04–0.12	0.07	0.06	22/22	0.02–0.09	0.04	0.03
Middle River at Union Point	24/24	0.05–0.17	0.09	0.08	24/24	0.03–0.13	0.06	0.06
Mallard Island	24/24	0.09–0.13	0.11	0.11	24/24	0.04–0.10	0.07	0.07

[a] Detects = Only samples above the reporting limit.
[b] Samples = Above and below the reporting limit.
[c] Medians are calculated using values below the detection limit.
[d] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2009.

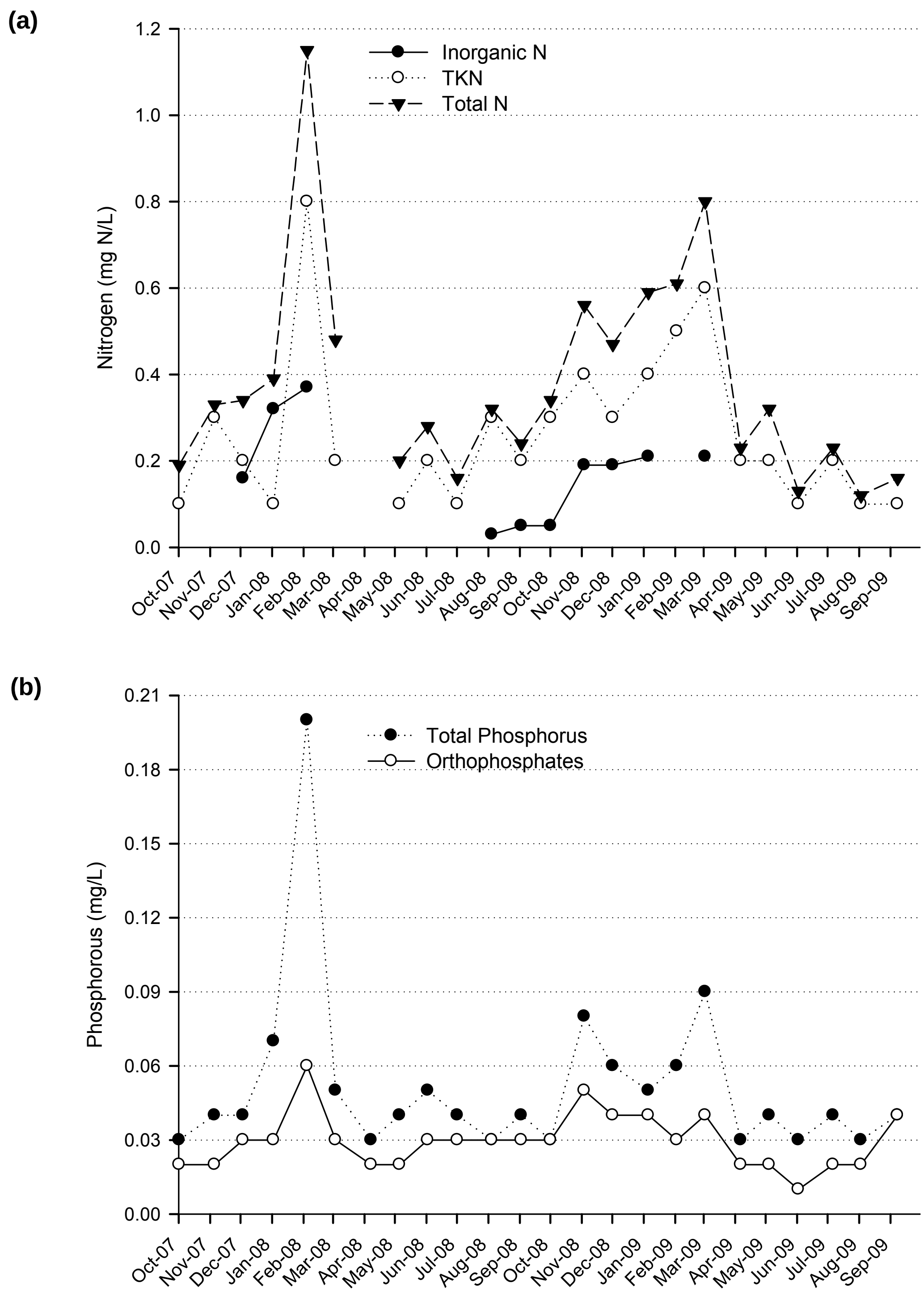


Figure 6-1. Nutrient concentrations at West Sacramento WTP Intake.
a. Nitrogen. b. Phosphorus.

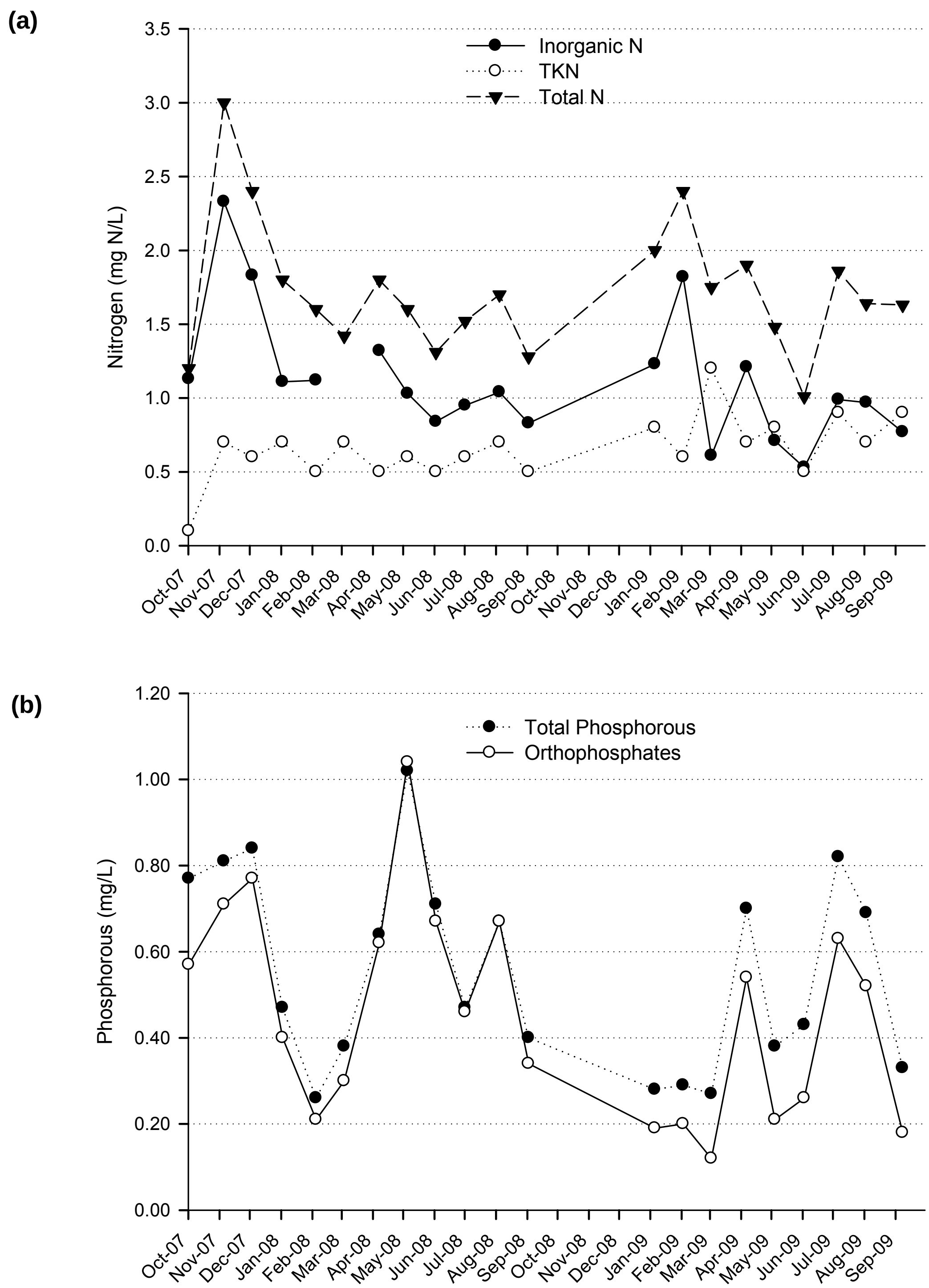
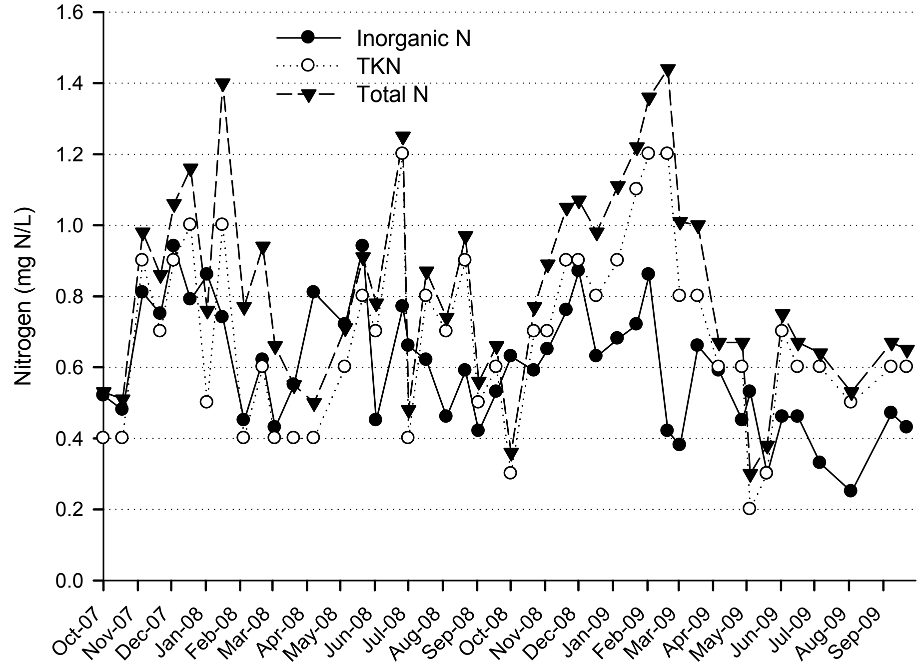


Figure 6-2. Nutrient concentrations at Natomas East Main Drainage Canal. a. Nitrogen. b. Phosphorus.

(a)



(b)

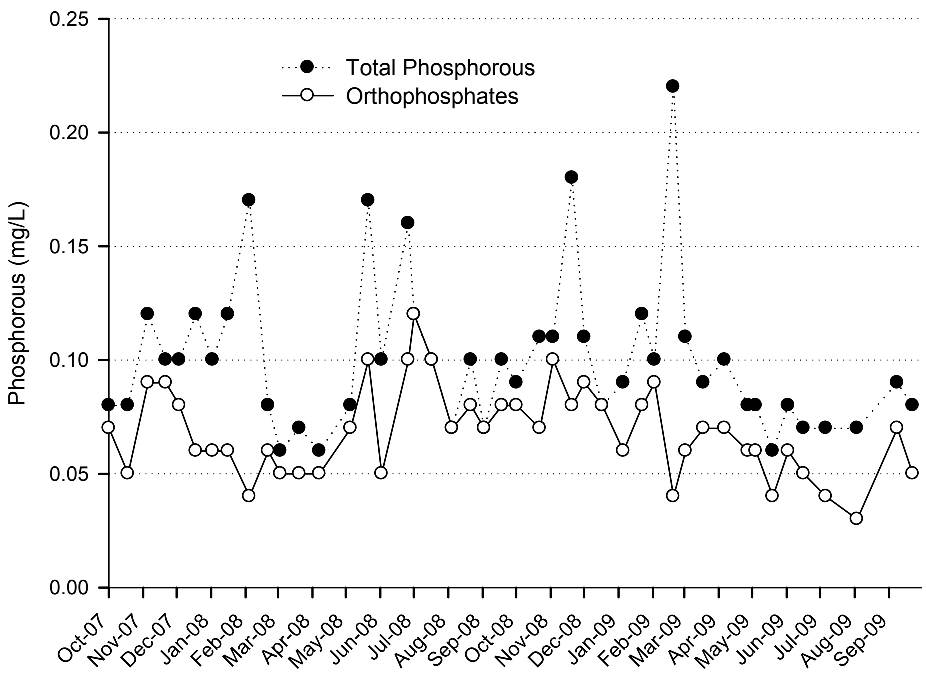


Figure 6-3. Nutrient concentrations at Sacramento River at Hood.
a. Nitrogen. b. Phosphorus.

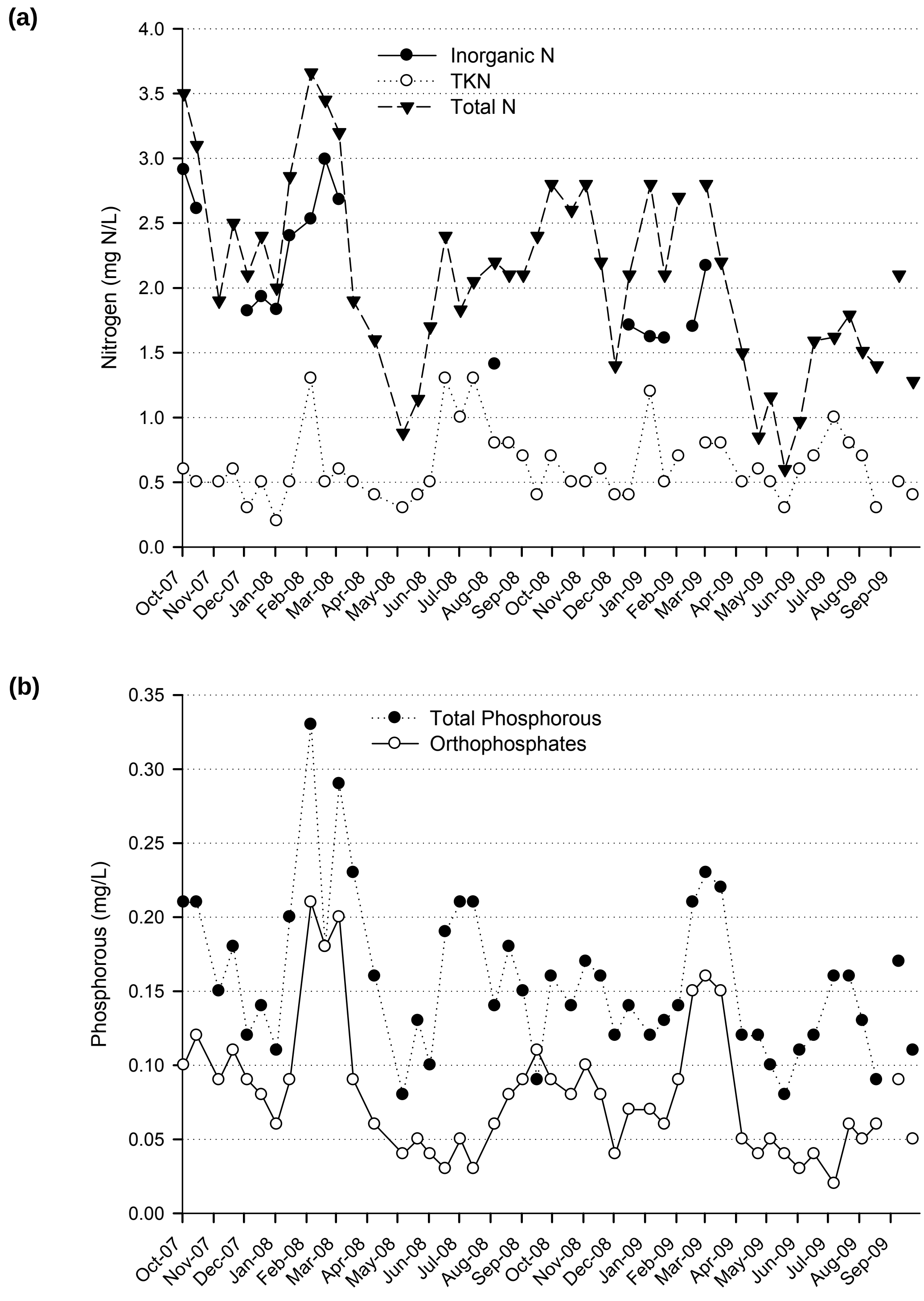
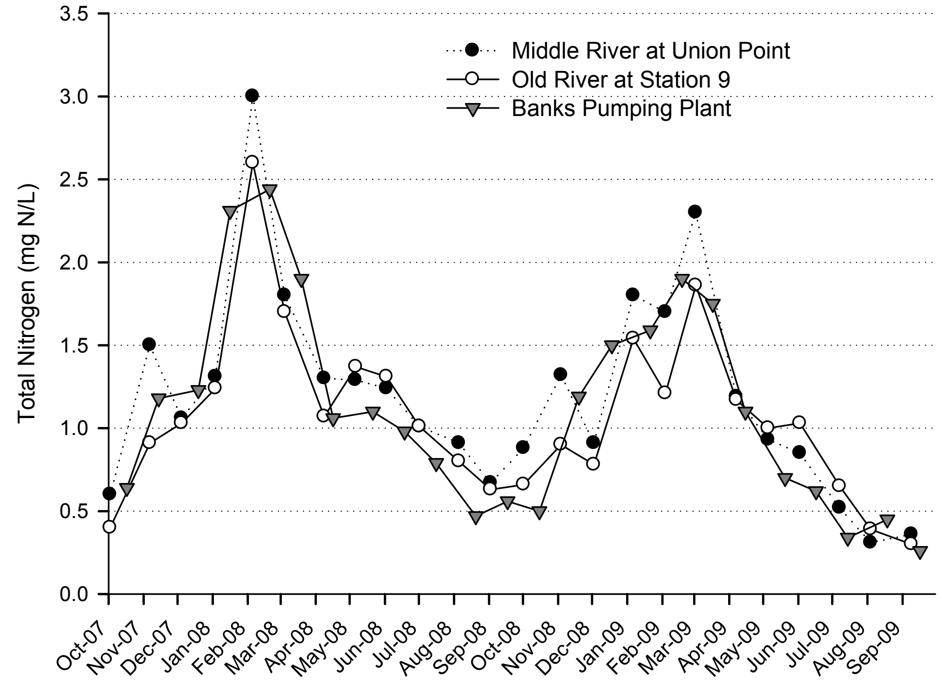


Figure 6-4. Nutrient concentrations at San Joaquin River near Vernalis. a. Nitrogen. b. Phosphorus.

(a)



(b)

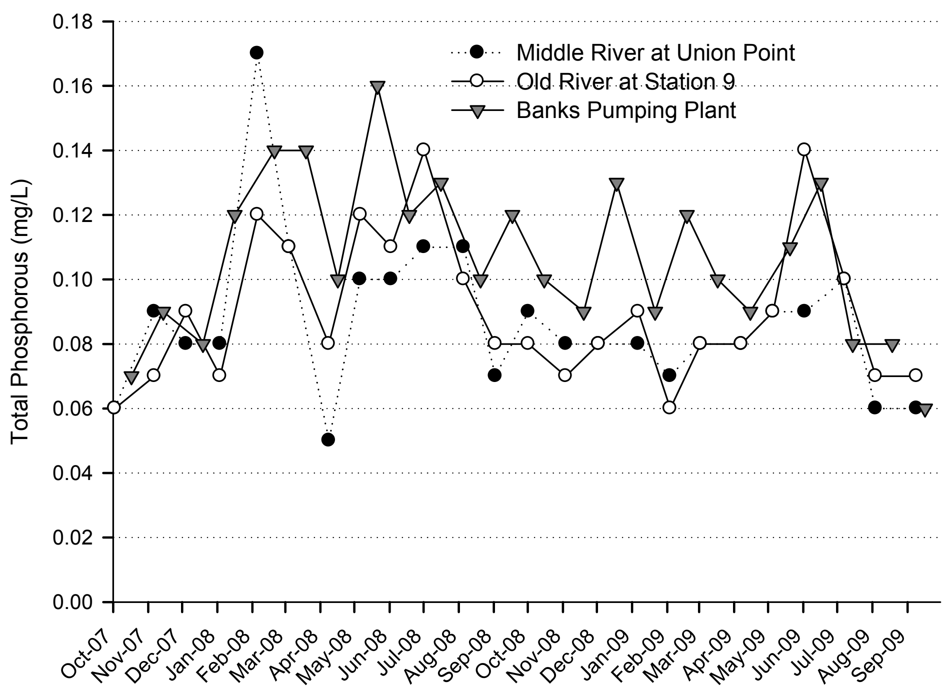
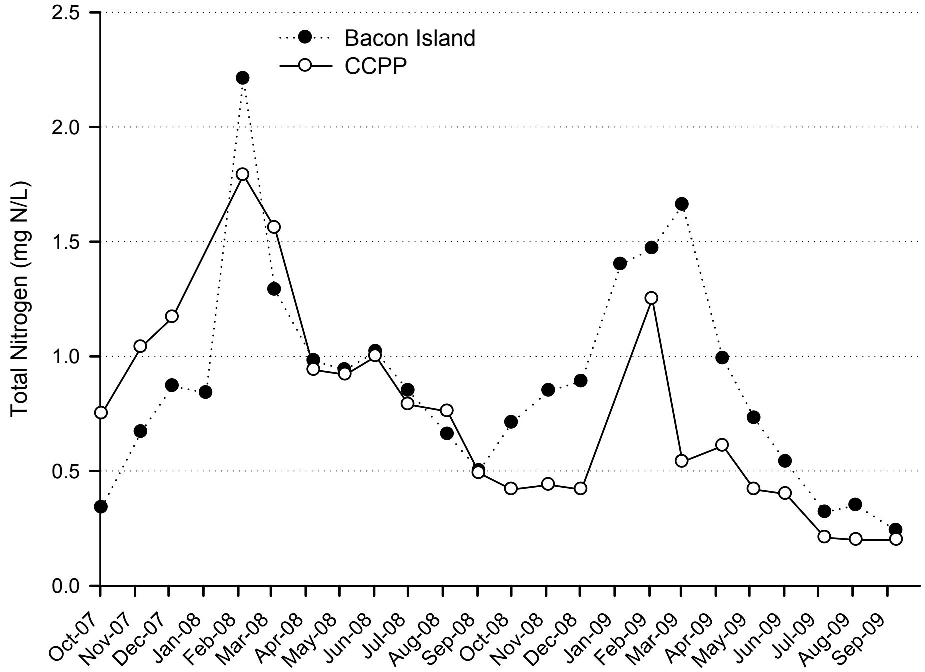


**Figure 6-5. Nutrient concentrations at stations near Clifton Court Forebay.
a. Total Nitrogen. b. Total Phosphorus.**

(a)



(b)

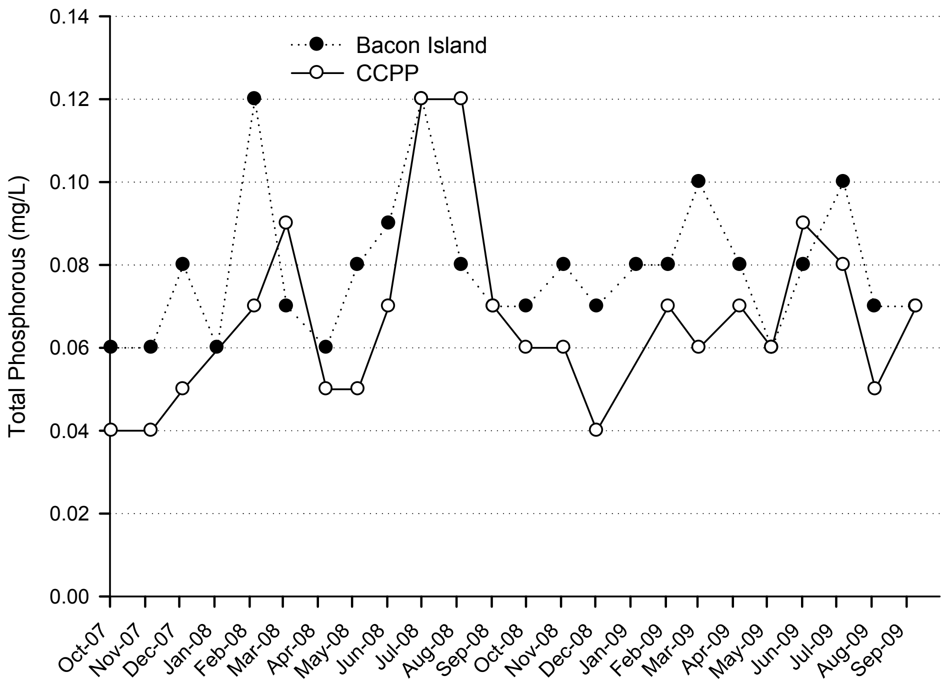


Figure 6-6. Nutrient concentrations at Old River at Bacon Island and Contra Costa Pumping Plant. a. Total Nitrogen. b. Total Phosphorus.

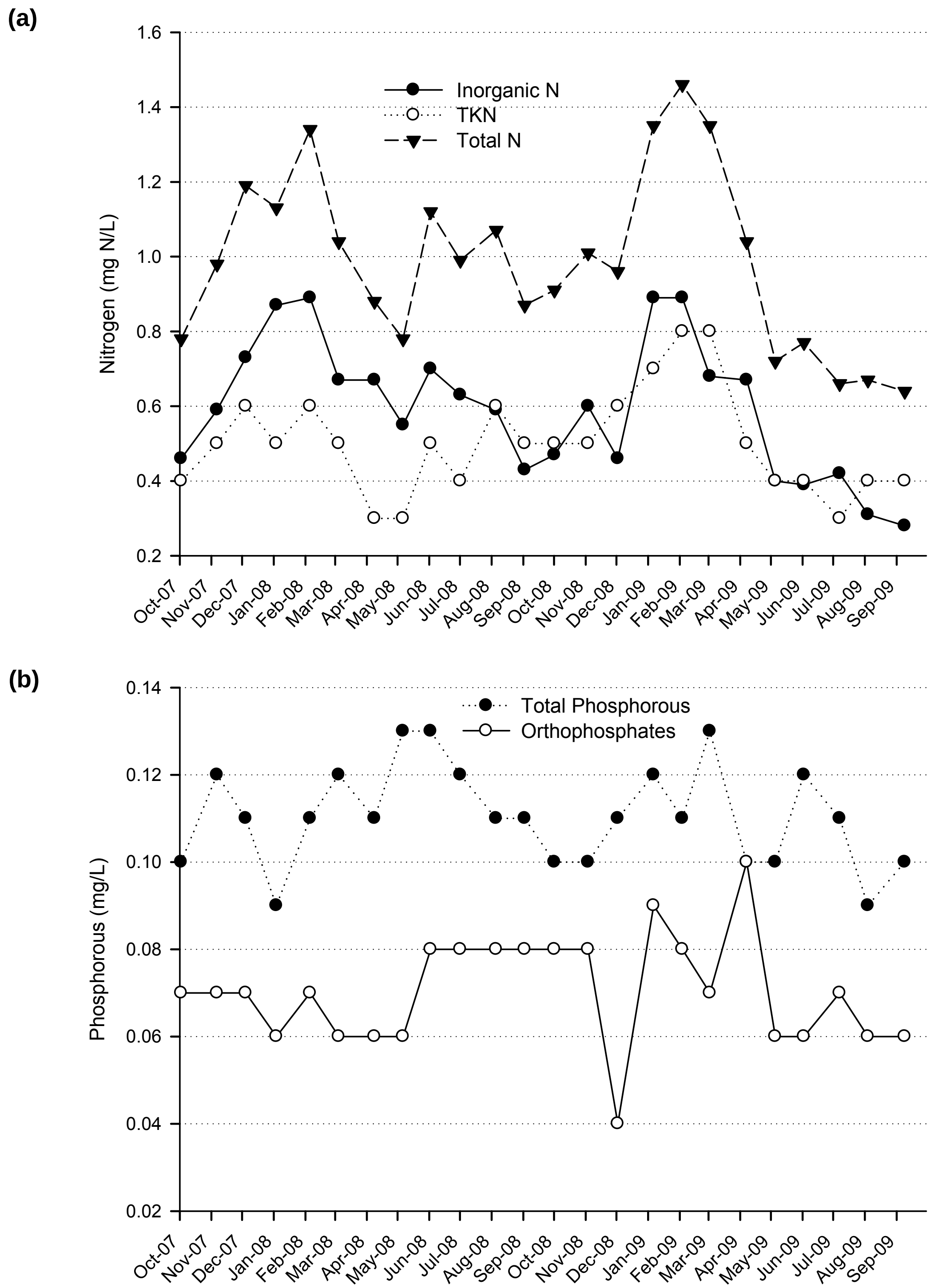


Figure 6-7. Nutrient concentrations at Mallard Island.
a. Nitrogen. b. Phosphorus.

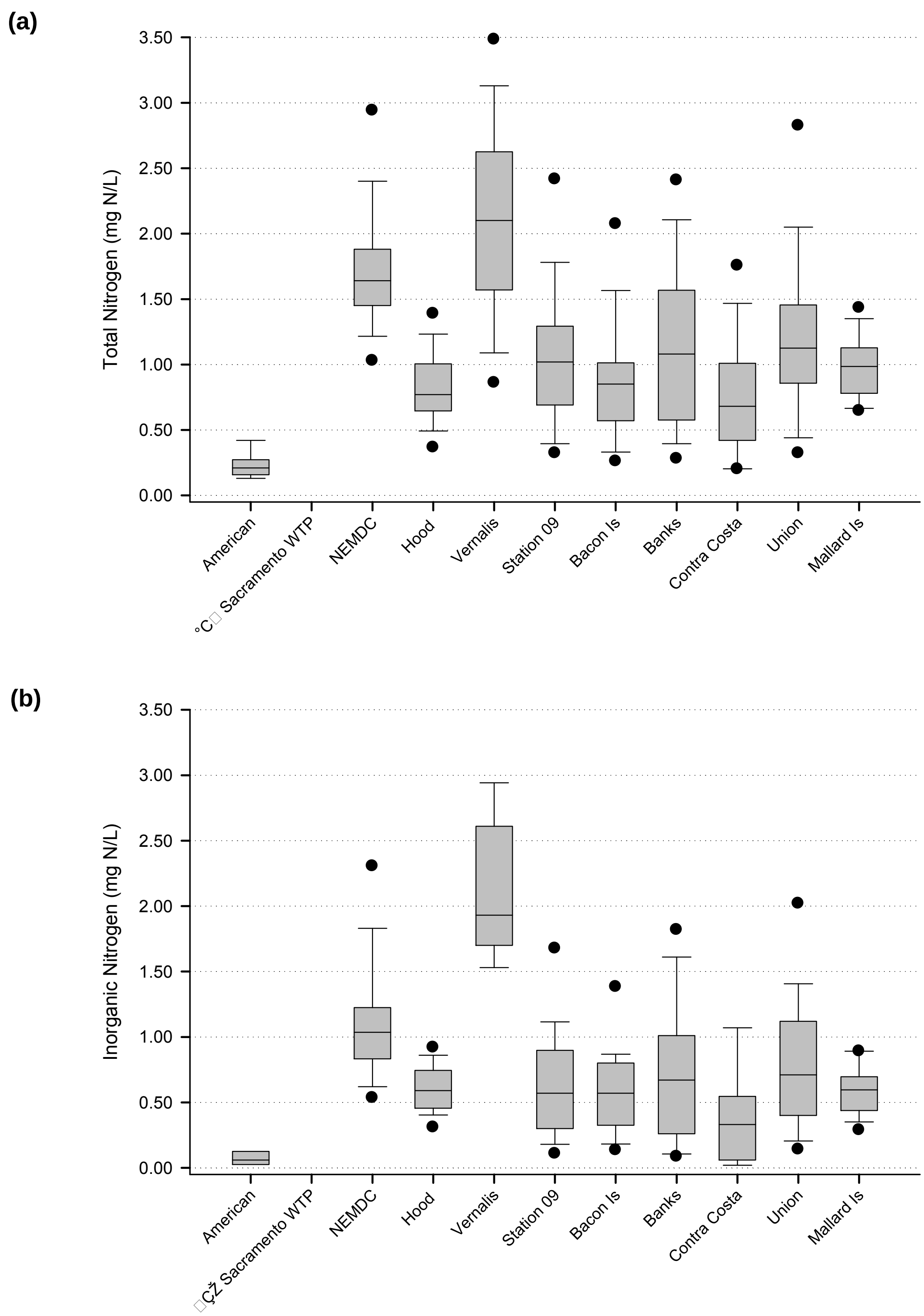


Figure 6-8. Nitrogen concentrations at sampling stations.
a. Total Nitrogen. b. Inorganic Nitrogen.

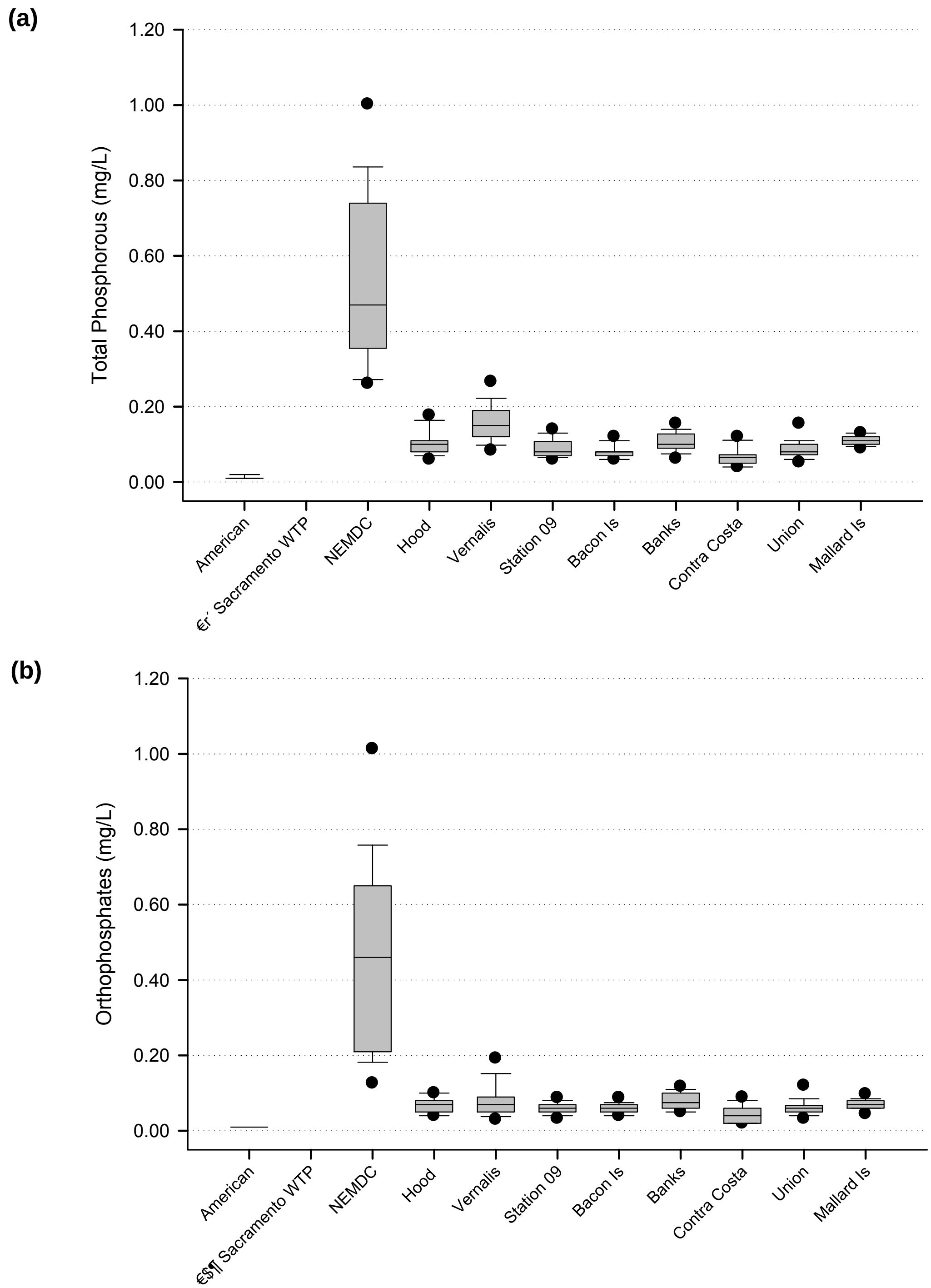


Figure 6-9. Phosphorus concentrations at sampling stations.
a. Total Phosphorus. b. Orthophosphates.

Chapter 7 Other Water Quality Constituents

This chapter summarizes the data for monitored parameters and constituents with primary and secondary drinking water standards that were not discussed in the previous chapters. These constituents can either have health impacts or affect the taste, odor, and appearance of drinking water. Note that ambient waters, such as those analyzed in this report, do not need to meet primary or secondary drinking water maximum contaminant levels (MCLs). Ambient water concentrations of regulated drinking water parameters are provided for comparative purposes. In this chapter, there is no data for any water quality constituent at the Jones Pumping Plant. Therefore, there will be no discussion of Jones Pumping Plant in this chapter.

Constituents with Primary Standards

Constituents with primary standards are known to have risks associated with human health when present in drinking water at concentrations greater than their MCLs. For all samples, metals with primary standards were at or below their respective MCLs (Figure 7-1). Nine inorganic metals with primary standards—arsenic, beryllium, barium, cadmium, chromium, lead, mercury, nickel, and selenium—were monitored at the H.O. Banks Pumping Plant by the Water Quality Section of the Division of Operations and Maintenance, California Department of Water Resources. Beryllium, cadmium, lead, and mercury were not detected in any of the 24 samples collected over the two-year period, whereas barium was detected once at a level of 0.05 in February of 2009. Chromium was detected in a third of the samples while nickel and selenium were detected in approximately three quarters of the 24 samples.

Arsenic was one of the primary standard constituents to be monitored at both the Banks station and at the Natomas East Main Drainage Canal (NEMDC) station. Arsenic was detected in all samples taken at these stations. However, arsenic concentrations in all samples were always below the MCL of 0.01 mg/L. The median concentration at both stations was 0.002 mg/L (Table 7-1). The other primary standards that are monitored, ammonia, nitrate and combined nitrate and nitrite, will be discussed in the next section.

Nutrients- Ammonia, Nitrate, and Combined Nitrate and Nitrite

There are federal and State enforceable standards for nitrate, nitrite, and combined nitrate-nitrite concentrations in drinking water. Nitrate is converted into nitrite in the human body. Elevated levels of nitrite have the potential to cause adverse health effects. Furthermore, nitrite can react with other substances and form nitrosamines, which have been demonstrated to be carcinogenic. The California Department of Public Health (CDPH) has set a MCL of 45 mg/L as NO_3 for nitrate. The U.S. Environmental Protection Agency (USEPA) and CDPH have a MCL of 10 mg/L as N for combined nitrate-nitrite (USEPA, 2010d; 2010e).

MWQI monitored for nitrate as NO_3 and combined nitrate-nitrite as N at 11 sampling stations. Nitrate and nitrite was detected at all stations well below their respective MCLs (Table 7-2). The highest concentrations were at the Vernalis and NEMDC stations. Nitrate concentrations were 5 mg/L and 2.1 mg/L as NO_3, respectively.

Ammonia, as a drinking water constituent, is not regulated by primary or secondary standards. The USEPA recommends, however, that ammonia be considered as a potential source of nitrates in drinking water (USEPA, 2010a). Primary sources of ammonia in surface waters are fertilizers, sewage, and livestock manure (USEPA, 2010a). Of the 11 sampling stations, the Sacramento River at Hood had the highest concentrations of ammonia (Table 7-2). The relatively elevated ammonia concentrations at Hood may be due to the upstream proximity of the Sacramento Regional Wastewater Treatment Plant.

Constituents with Secondary Standards

Municipal drinking water that is aesthetically displeasing or odious might cause a consumer to resort to a more expensive or unhealthy source of water. As such, the State of California has enforceable secondary standards for constituents that can affect the taste, odor, and appearance of finished drinking water. The constituents with secondary MCLs are aluminum, copper, iron, manganese, zinc and silver.

Of the metallic constituents with secondary MCLs, aluminum and copper both have adverse effects on human health while iron and manganese have adverse effects on taste, odor, or appearance. Silver and zinc were monitored at Banks, but neither constituent was detected in any of the 24 samples. The other four secondary constituents were monitored at the Banks and NEMDC stations. When detected, copper and iron concentrations at Banks were below their respective MCLs (Table 7-3). Aluminum was not detected at Banks, while manganese was detected in 23 of the 24 samples, exceeding the federal MCL of 0.05 mg/L once in October of 2008 (Table 7-4).

Concentrations of aluminum, iron, and manganese were elevated at NEMDC in comparison with Banks (Table 7-3 and Table 7-5). Manganese concentrations exceeded the MCL of 0.05 mg/L at NEMDC in four samples and ranged from 0.052 to 0.071 mg/L. Aluminum concentrations exceeded its MCL twice (0.261 and 0.299 mg/L) while iron concentrations exceeded its MCL in one sample during the reporting period (0.396 mg/L). Copper concentrations at NEMDC were low throughout the reporting period. The relatively elevated concentrations of metals at NEMDC are not a concern for regional water exports due to the NEMDC's relatively low flows; however, elevated levels of metals may be cause for concern regarding protection of the local beneficial uses of water.

Boron

Boron is an unregulated constituent; however, CDPH requires it to be monitored in drinking water. Exposure to high levels of boron has been linked to reproductive and developmental harm in mice (USEPA, 2010c). Compounds that contain boron occur naturally and have been found in Sacramento aquifer groundwater (USEPA, 2010c). Industrial products such as insecticides and textiles also contain boron. CDPH has set an Action Level (AL) of 1 mg/L for dissolved boron in drinking water. It was only at Mallard Island that eight samples had boron concentration values at 1 mg/L or over. The AL for boron is at 1 mg/L. Seawater typically has a boron load of 5 mg/L. Concentrations at Mallard Island ranged from 0.1 to 1.1 mg/L in 23 of the 24 samples in which boron was detected.

Concentrations of boron in all other samples were either low or not detected. On eight occasions boron was detected at the detection limit in the American River at the E.A. Fairbairn water treatment plant (WTP). At the reporting limit, boron was detected seven times in the Sacramento River at the West Sacramento Water Treatment Plant. The NEMDC station had low concentrations (median 0.1 mg/L) during the reporting period. Boron was detected at Hood in approximately one-fourth of the samples. Boron concentrations at the San Joaquin River at Vernalis ranged from 0.1 to 0.7 mg/L. Among the channel and diversion stations, Banks had the most detects. Concentrations of boron at the channel and diversion stations, including Banks, were at or below 0.4 mg/L for all samples (Table 7-6).

pH

Precipitation and dissolution of carbonates in an aqueous solution are influenced by pH. There are no enforceable regulations for pH in finished drinking water. The pH for all stations ranged from 6.8 to 9.1 (Table 7-7). The majority of samples tended to be slightly alkaline, and the median pH at all 11 stations ranged between 7.4 and 8.0. The American River at E.A. Fairbairn WTP had the lowest pH of 6.8. Vernalis had the highest pH of any sample at 9.1.

The pH values have an effect on what form the nitrogen takes. Algae have to convert nitrate (NO_3), which is the main form of nitrogen in the water, into ammonium (NH_4) before they can use it. When the pH of water is acidic (<6.9) or neutral (7.0), the majority of the nitrogen is ionized ammonium (NH_4+). When the pH increases over 8.0, the nitrogen is mostly unionized ammonia (NH_3), which is toxic. Dinoflagellates and cyanobacteria, like *Mycrocystis*, prefer ammonium to nitrate, while diatoms prefer nitrate.

Alkalinity

Alkalinity is the concentration of $CaCO_3$ measured in mg/L and derived from a measure of the sum of all titratable bases (Clesceri, et al., 1998). Alkalinity is unregulated in drinking water. However, requirements for removal of organic carbon from source waters for drinking purposes are based on organic carbon concentrations and alkalinity (USEPA, 2010b).

Total alkalinity as mg/L of $CaCO_3$ ranged from 20 to 155 mg/L (Table 7-7). The American River had the lowest median alkalinity at 26 mg/L as $CaCO_3$ and the least variability (20 to 36 mg/L as $CaCO_3$) (Table 7-7). Alkalinity at the NEMDC station was highly variable with a median of 86 mg/L as $CaCO_3$ and a range of 58 to 137 mg/L as $CaCO_3$ (Figure 7-1 (c), Table 7-7). The Sacramento River near Hood had a median alkalinity of 66 mg/L as $CaCO_3$ (Figure 7-1 (b), Table 7-7). The highest median alkalinity occurred at the San Joaquin River (SJR) near Vernalis (108 mg/L as $CaCO_3$). Vernalis also had the highest variability, with concentrations ranging between 48 to 155 mg/L as $CaCO_3$. The channel and diversion stations had median values of alkalinity from 70 to 82 mg/L as $CaCO_3$ (Figure 7-2). Mallard Island had a median alkalinity value of 82 mg/L as $CaCO_3$ (Figure 7-2).

Hardness

Hardness in this report is calculated and defined as the sum of the calcium and magnesium concentrations expressed as calcium carbonate ($CaCO_3$) in mg/L (Clesceri, et al., 1998). Hard water reduces the solubility of soaps and detergents and contributes to scaling in boilers and industrial equipment. General guidelines for classification of waters are: 0 to 60 mg/L as $CaCO_{3,}$ soft; 61 to 120 mg/L, moderately hard; 121 to 180 mg/l, hard; and more than 180 mg/L, very hard.

The lowest hardness of the 11 monitored stations was in samples from the American River at E.A. Fairbairn WTP (Figure 7-3 (a), Table 7-8). The median hardness of the samples from the American River was 23 mg/L as $CaCO_3$ (Table 7-8). Waters with the greatest hardness were from the Mallard Island station, which is heavily influenced by seawater intrusion (Figure 7-4). For the two-year period, median hardness as $CaCO_3$ at Mallard Island was 696 mg/L. The Sacramento River at the West Sacramento WTP and near Hood had similar ranges and median values of hardness (Table 7-8); the range of hardness values as $CaCO_3$ for these stations was 50-90 mg/L and 36-90 mg/L, respectively (Figure 7-3 (b)). Median values were 68 and 63 mg/L as $CaCO_3$ for West Sacramento and Hood, respectively. NEMDC had a median hardness of 90 mg/L as $CaCO_3$ (Figure 7-3 (b), Table 7-8). Waters of the San Joaquin River near Vernalis were relatively hard, with a median hardness of 157 mg/L as $CaCO_3$ and a range of 70 to 247 mg/L as $CaCO_3$ (Figure 7-4). Channel stations had median hardness values greater than the Sacramento River and less than the San Joaquin River (Figure 7-4). The median hardness values for the three channel stations ranged from 99 to 106 mg/L as $CaCO_3$. Median hardness at the Contra Costa Pumping Plant #1 (CCPP) and at Banks was 118 and 107 mg/L as $CaCO_3$, respectively.

Turbidity

Turbidity is an optical measurement of the opacity of water. Suspended particulate matter in a body of water impairs the transmission of light through the water. As such, turbidity is a general indirect measurement of the concentration of particulate matter suspended in the water column. High values of turbidity in riverine systems are usually seen following storm events, which increase the sediment loads.

Over the two-year reporting period the turbidity ranged from <1 to174 nephelometric turbidity unit (NTU) (Figure 7-6 (a), (b), and (c), Table 7-8). The lowest median turbidity value of 1 was from the E. A. Fairbairn WTP. The stations along the Sacramento River had median turbidities higher than the channel and diversion stations as well as the highest turbidity values. Potentially, high turbidities were due to elevated turbidities following storm events. West Sacramento at the WTP had a median value of 11 NTU and a range of 4 to 170 NTU (Table 7-8). Sacramento River at Hood had a median value of 9 with turbidity ranging from 3 to 174 NTU (Figure 7-5). Both of Hood's readings above 100 NTU occurred in February of both reporting years; similarly, the highest turbidity at the West Sacramento site was also recorded in February of 2008 (Figure 7-5). NEMDC had the second highest median value of 13 NTU. The San Joaquin River near Vernalis had a median value of 12 NTU (Figure 7-6 (a)). Compared to Vernalis or the Sacramento River stations, channel and diversion stations had lower turbidity values and less variability. The channel stations had medians that ranged from 5 to 7 NTU (Figure 7-6 (b) and (c)). The median at Banks was 7 NTU and Contra Costa had a median value of 8 NTU. Mallard Island had the highest median value of all of the stations at 21 NTU (Figure 7-6 (c)).

Summary

The regulated primary constituents for Banks remained at low or below detection levels. When compared to the data from 2005 to 2007, the number of detections, the ranges and the medians at Banks showed little divergence. This trend was also true for concentrations of nitrate, nitrate + nitrite and ammonia. The exception to this tendency was manganese, which once exceeded the federal MCL of 0.05 mg/L. Concentrations of secondary MCL constituents at Banks were also similar within this reporting period and between this and the previous reporting period from 2005 to 2007 (DWR, 2008a).

At NEMDC, concentrations and ranges of primary and secondary MCL-regulated compounds were similar to concentrations reported from 2005 to 2007 (DWR, 2008a). At NEMDC, aluminum twice exceeded the federal MCLs, while iron MCLs were exceeded once. Manganese exceeded standards on four different occasions.

The values of ammonia and nitrate + nitrite at the other stations were similar to data from 2005 to 2007. It is worth mentioning that median ammonia concentrations at the Sacramento River at Hood were more than ten times higher than those found at all of the other stations. Although boron is not yet regulated, at nearly every station it was detected in more samples, but the averages and medians were relatively unchanged. The range of pH at all the stations was more alkaline, yet the median values remained nearly identical to the prior report. Hardness at all stations diverged in the range, average, and median values from previous years. The median values were almost all larger and most of the ranges were larger. Turbidity values also differed from the previous years. Overall the ranges were larger, and the largest values were much higher than the earlier report. Median values, however, remained comparable.

Table 7-1. Summary of regulated primary constituents.

Constituents	*Detection Limits (mg/L)*	*MCL[a] (mg/L)*	*Detects[b]/Sample Number[c]*	*Range*	*Median[d]*
Banks					
Arsenic	0.001	0.01	24/24	0.002-0.004	0.002
Beryllium	0.001	0.004	0/24	<0.001	<0.001
Barium	0.05	1.0	1/24	<0.05-0.05	<0.05
Cadmium	0.001	0.005	0/24	<0.001	<0.001
Chromium	0.001	0.05	8/24	<0.001-0.004	<0.001
Lead	0.001	0.015	0/24	<0.001	<0.001
Mercury	0.0002	0.002	0/24	<0.0002	<0.0002
Nickel	0.001	0.1	19/24	<0.001-0.002	<0.001
Nitrate[e]	0.1	45	25/26	<0.1-7.0	2.4
Nitrate + Nitrite[f]	0.01	10	24/24	0.05-1.74	0.65
Selenium	0.001	0.05	18/24	<0.001-0.002	0.001
NEMDC					
Arsenic	0.001	0.01	21/21	0.002-0.004	0.002
Nitrate[e]	0.1	45	21/21	2.5-10.8	4.5
Nitrate + Nitrite[f]	0.01	10	21/21	0.51-2.30	1.00

a. Maximum Contaminant Levels
b. Detects = Includes only samples above the reporting limit.
c. Samples = Number of samples collected.
d. Medians are calculated using values below the detection limit.
e. mg/L as NO_3
f. mg/L as N

Table 7-2. Summary of ammonia, nitrate and nitrate + nitrite at 11 MWQI stations.

Station	***Ammonia (mg N/L)***[a]			***Nitrate (mg N/L)***[b]			***Nitrate + Nitrite (mg N/L)***[c]		
	Detects[d]*/ Samples*[e]	*Range*	*Median*[f]	*Detects*[d] */ Samples*[e]	*Range*	*Median*[f]	*Detects*[d] */ Samples*[e]	*Range*	*Median*[f]
Stations North of the Delta									
American River at E.A. Fairbairn WTP	7/24	<0.01-0.04	<0.01	14/24	<0.1-0.7	0.2	16/24	<0.01-0.16	0.03
West Sacramento WTP Intake	10/24	<0.01-0.03	<0.01	22/24	<0.1-1.4	0.4	24/24	0.02-0.35	0.09
Natomas East Main Drainage Canal	20/21	<0.01-0.06	0.03	21/21	2.5-10.8	4.5	21/21	0.51-2.30	1.00
Sacramento River at Hood	45/45	0.08-0.83	0.46	45/45	0.1-1.6	0.5	45/45	0.03-0.40	0.11
San Joaquin River near Vernalis	15/47	<0.01-0.20	<0.01	50/50	1.2-12.1	6.4	47/47	0.25-2.95	1.40
Channel and diversion stations									
Old River at Station 9	24/24	0.01-0.14	0.04	24/24	0.5-6.8	2.3	24/24	0.09-1.70	0.54
Old River at Bacon Island	21/24	<0.01-0.13	0.03	24/24	0.2-5.3	2.0	24/24	0.04-1.31	0.52
Banks Pumping Plant	24/24	0.01-0.11	0.04	25/26	<0.1-7.0	2.4	24/24	0.05-1.74	0.65
Jones Pumping Plant[g]									
Contra Costa Pumping Plant [h]	17/22	<0.01-0.09	0.02	20/22	<0.1-4.8	1.3	21/22	<0.01-1.19	0.29
Middle River at Union Point	23/24	<0.01-0.15	0.03	24/24	0.7-8.3	2.7	24/24	0.11-2.00	0.64
Mallard Island	24/24	0.02-0.24	0.09	24/24	1.2-3.6	2.2	24/24	0.24-0.74	0.50

a. Detection limit 0.01 mg/L
b. Detection limit 0.1 mg/L as NO_3
c. Detection limit 0.01 mg/L as N
d. Detects = Includes only samples above the reporting limit.
e. Samples = Number of samples collected.
f. Medians are calculated using values below the detection limit.
g. Samples for this station were not collected.
h. Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2009.

Table 7-3. Summary of secondary constituents.

Constituents	Detection Limit (mg/L)	Banks (mg/L)				NEMDC (mg/L)[e]			
		MCL[a] (mg/L)	Detects[b] / Samples[c]	Range	Median[d]	MCL[a] (mg/L)	Detects[b] / Samples[c]	Range	Median[d]
Aluminum	0.01	0.2	0/24	<0.01	<0.01	0.2	19/21	<0.01-0.30	0.03
Copper	0.001	1.0	24/24	0.0010-0.003	0.002	1	21/21	0.002-0.004	0.002
Iron	0.005	0.3	21/24	<0.005-0.068	0.013	0.3	21/21	0.015-0.396	0.078
Manganese	0.005	0.05	23/24	<0.005-0.058	0.015	0.05	21/21	0.015-0.071	0.036
Silver	0.001	0.1	0/24	<0.001	<0.001	0.1	---	---	---
Zinc	0.005	5.0	0/24	<0.005	<0.005	5	---	---	---

a. Maximum Contaminant Levels
b. Detects = Includes only samples above the reporting limit.
c. Samples = Number of samples collected.
d. Medians are calculated using values below the detection limit.
e. Silver and Zinc were not analyzed at NEMDC

Table 7-4. Summary of primary and secondary regulation compliance constituents for Banks from October 2007 through September 2009.

Constituents	*Findings*[a]	*Regulation compliance*[b]
Constituents with adverse effects on human health		
Aluminum[h]	Never Detected	Never exceeded State or federal MCL of 0.2 mg/L
Arsenic[f]	Detected in all 24 samples range: 0.002-0.004 mg/L median: 0.002 mg/L	Never exceeded federal MCL of 0.01 mg/L
Barium[i]	Detected in 1 out of 24 samples value: 0.05	Never exceeded federal MCL of 1 mg/L
Beryllium[f], cadmium[f], lead[f] and mercury[e]	Never Detected	Never exceeded federal MCL of 1 mg/L
Chromium[f] (total)	Detected in 8 out of 24 samples range: <0.001–0.004 mg/L median: <0.001 mg/L	Never exceeded federal MCL of 0.1 mg/L or State MCL of 0.05 mg/L
Copper[f]	Detected in all 24 samples range: 0.001–0.003 mg/L median: 0.002 mg/L	Never exceeded State or federal MCL of 1.0 mg/L
Nickel[f]	Detected in all 19 of 24 samples range: <0.001–0.002 mg/L median: 0.001 mg/L	Never exceeded State MCL of 0.1 mg/L
Nitrate[c j]	Detected in 25 out of 26 samples range: <0.1-7.0 mg/L median: 2.4 mg/L	Never exceeded State MCL of 45 mg/L
Nitrate+Nitrite (as N)[d h]	Detected in all 24 samples range: 0.05-1.74 mg/L median: 0.65 mg/L	Never exceeded State MCL of 10 mg/L
Selenium[f]	Detected in 18 of 24 samples range: <0.001–0.002 mg/L median: 0.001mg/L	Never exceeded federal MCL of 0.05 mg/L
Constituents with adverse effects on taste, odor, or appearance		
Iron[g]	Detected in 21 of 24 samples range: <0.005–0.068mg/L median: 0.013 mg/L	Never exceeded federal MCL of 0.3 mg/L
Manganese[g]	Detected in 23 of 24 samples range: <0.005–0.058 mg/L median: 0.015 mg/L	Once exceeded federal MCL of 0.05 mg/L (0.058 in 10/08)
Silver[f]	Never detected	Never exceeded federal secondary MCL of 0.1 mg/L
Zinc[g]	Never detected	Never exceeded federal secondary MCL of 5 mg/L

a. Detects = Includes only samples above the reporting limit. Samples = Number of samples collected.
b. Maximum Contaminant Level
c. mg/L as NO3
d. mg/L as N
e. Detection limit 0.0002 mg/L
f. Detection limit 0.001 mg/L
g. Detection limit 0.005 mg/L
h. Detection limit 0.01 mg/L
i. Detection limit 0.05 mg/L
j. Detection limit 0.1 mg/L

Table 7-5. Summary of primary and secondary regulation compliance constituents for NEMDC from October 2007 through September 2009.

Constituents	*Findings*[a]	*Regulation compliance*[b]
Constituents with adverse effects on human health		
Aluminum[g]	Detected in 19 of 21 samples range: <0.01-0.30 mg/L median 0.03 mg/L	Twice exceed federal MCL of 0.20 (0.261 and 0.299)
Arsenic[e]	Detected in all 21 samples range: 0.002-0.004 mg/L median: 0.002 mg/L	Never exceeded federal MCL of 0.01 mg/L
Copper[e]	Detected in all 21 samples range: 0.002-0.004 mg/L median: 0.002 mg/L	Never exceeded State or federal MCL of 1.0 mg/L
Nitrate[c,h]	Detected in all 21samples range: 2.5-10.8 mg/L median: 4.5 mg/L	Never exceeded State MCL of 45 mg/L
Nitrate+Nitrite (as N)[d,g]	Detected in all 21 samples range: 0.51-2.30 mg/L median: 1.00 mg/L	Never exceeded State MCL of 10 mg/L
Constituents with adverse effects on taste, odor, or appearance		
Iron[f]	Detected in all 21 samples range: 0.015-0.396 mg/L median: 0.078 mg/L	Exceeded federal MCL of 0.3 mg/L in 3/09 with a value of 0.396
Manganese[f]	Detected in all 21samples range: 0.015-0.071 mg/L median: 0.036 mg/L	Exceeded federal MCL of 0.05 mg/L on 4 occasions in 2008 range 0.052-0.71 mg/L

a. Detects = Includes only samples above the reporting limit. Samples = Number of samples collected.
b. Maximum Contaminant Levels
c. mg/L as NO_3
d. mg/L as N
e. Detection limit 0.001 mg/L
f. Detection limit 0.005 mg/L
g. Detectiion limit 0.01 mg/L
h. Detection limit 0.1 mg/L

Table 7-6. Summary of boron data at 12 MWQI stations from October 2007 through September 2009[a].

Station	Boron (mg/L)			
	Detects[b] / Samples[c]	*Range*	*Average*	*Median[d]*
Stations North of the Delta				
American River at E.A. Fairbairn WTP	0/24	<0.01	<0.01	<0.01
West Sacramento WTP Intake	6/24	<0.1-0.1	0.1	<0.01
Natomas East Main Drainage Canal	19/21	<0.1-0.2	0.1	0.1
Sacramento River at Hood	15/45	<0.1-0.1	0.1	<0.01
San Joaquin River near Vernalis	47/47	0.1-0.7	0.3	0.3
Channel and diversion stations				
Old River at Station 9	22/24	<0.1-0.3	0.1	0.1
Old River at Bacon Island	16/24	<0.1-0.2	0.1	0.1
Banks Pumping Plant	23/24	<0.1-0.3	0.2	0.2
Jones Pumping Plant [e]				
Contra Costa Pumping Plant [f]	13/15	<0.1-04	0.2	0.1
Middle River at Union Point	19/24	<0.1-0.2	0.1	0.1
Mallard Island	23/24	<0.1-1.1	0.6	0.5

a. Boron is currently an unregulated constituent that requires monitoring.
b. Detects = Only samples above the reporting limit of 0.01
c. Samples = Above and below the reporting limit.
d. Medians are calculated using values below the detection limit.
e. Samples for this station were not collected.
f. Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2010.

Table 7-7. Summary of pH and alkalinity at 12 MWQI stations.

Station	***pH***			***Alkalinity (mg/L as $CaCO_3$)***			
	Samples	*Range*	*Median*	*Samples*	*Range*	*Average*	*Median*
Stations North of the Delta							
American River at E.A. Fairbairn WTP	24	6.8–7.6	7.4	24	20–36	26	26
West Sacramento WTP Intake	24	7.4–8.5	7.8	24	54–94	73	72
Natomas East Main Drainage Canal	21	7.2–8.0	7.6	21	58–137	90	86
Sacramento River at Hood	45	7.1–7.9	7.6	45	44–88	67	66
San Joaquin River near Vernalis	47	7.5–9.1	8.0	47	48–155	104	108
Channel and diversion stations							
Old River at Station 9	24	7.5–8.2	7.8	24	49–85	73	74
Old River at Bacon Island	24	7.5–8.8	7.9	24	48–84	70	70
Banks Pumping Plant	24	7.5–8.3	7.9	24	53–102	76	76
Jones Pumping Plant[a]							
Contra Costa Pumping Plant[b]	15	7.6–8.7	7.9	15	63–126	81	82
Middle River at Union Point	24	7.4–8.0	7.7	24	49–89	74	75
Mallard Island	24	7.5–8.2	7.7	24	54–93	75	77

[a] Samples for this station were not collected.
[b] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2009.

Table 7-8. Summary of hardness and turbidity data at 12 MWQI stations.

	Hardness (mg/L as $CaCO_3$)				Turbidity (NTU)			
Station	*Samples*	*Range*	*Average*	*Median*	*Samples*	*Range*	*Average*	*Median*
Stations North of the Delta								
American River at E.A. Fairbairn WTP	24	19–36	26	23	24	<1–4	2	1
West Sacramento WTP Intake	24	50–90	68	68	24	4–170	20	11
Natomas East Main Drainage Canal	21	65–143	94	90	21	7–32	15	13
Sacramento River at Hood	45	36–90	63	63	45	3–174	18	9
San Joaquin River near Vernalis	47	70–247	159	157	47	6–54	15	12
Channel and diversion stations								
Old River at Station 9	24	65–150	104	106	24	3–20	9	7
Old River at Bacon Island	24	64–144	101	101	24	2–30	8	5
Banks Pumping Plant	24	68–164	111	107	24	2–17	7	7
Jones Pumping Plant [a]								
Contra Costa Pumping Plant [b]	15	79–213	122	118	15	1–21	9	8
Middle River at Union Point	24	57–140	100	99	24	2–17	5	5
Mallard Island	24	79–1,534	788	696	24	7–69	26	21

[a] There is no data available for Jones Pumping Plant
[b] Contra Costa Pumping Plant includes data from Contra Costa @ Rock Slough from 03/2009 to 09/2009

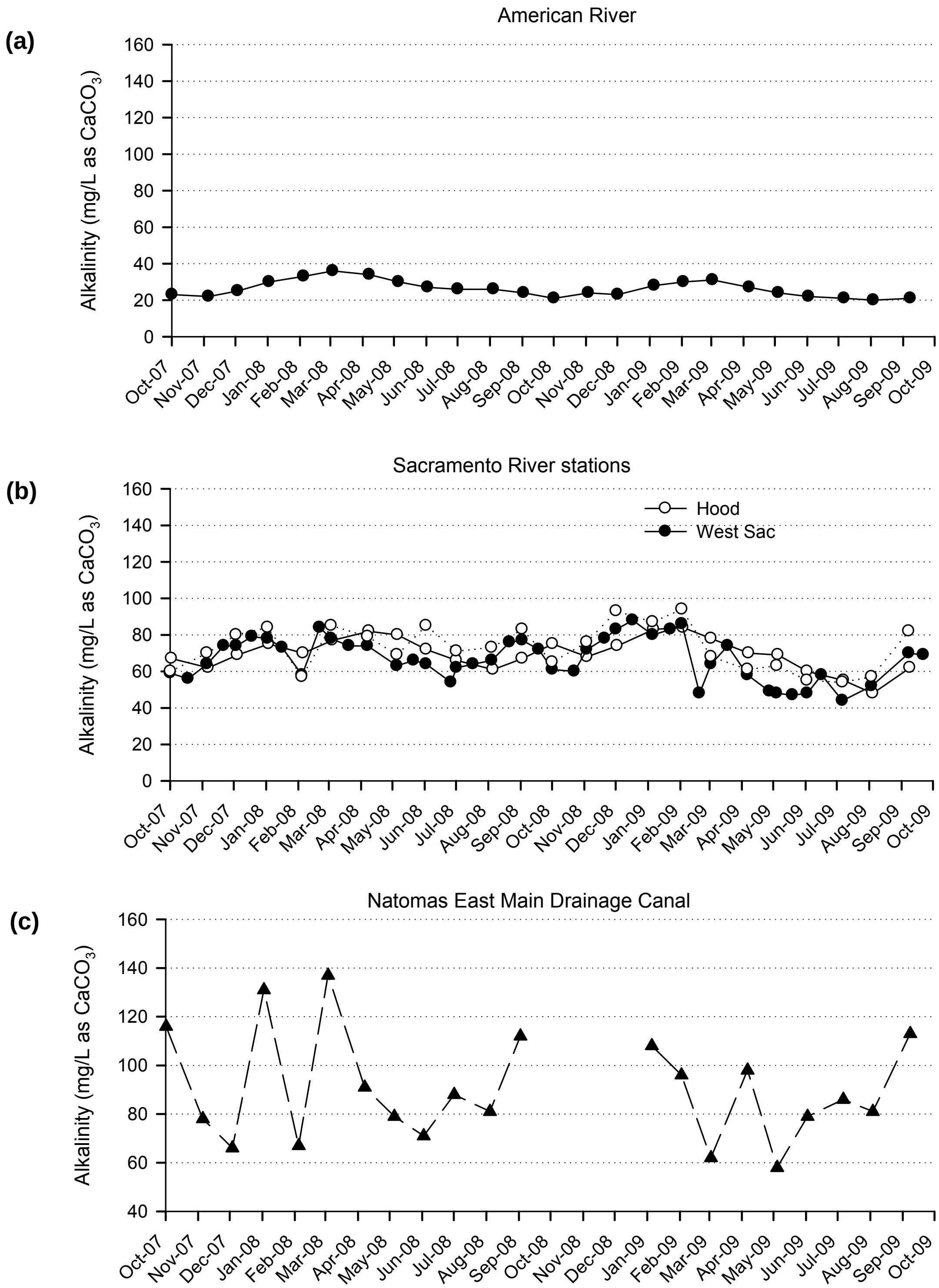


Figure 7-1. Alkalinity north of the Delta. a. American River. b. Sacramento River stations. c. Natomas East Main Drainage Canal.

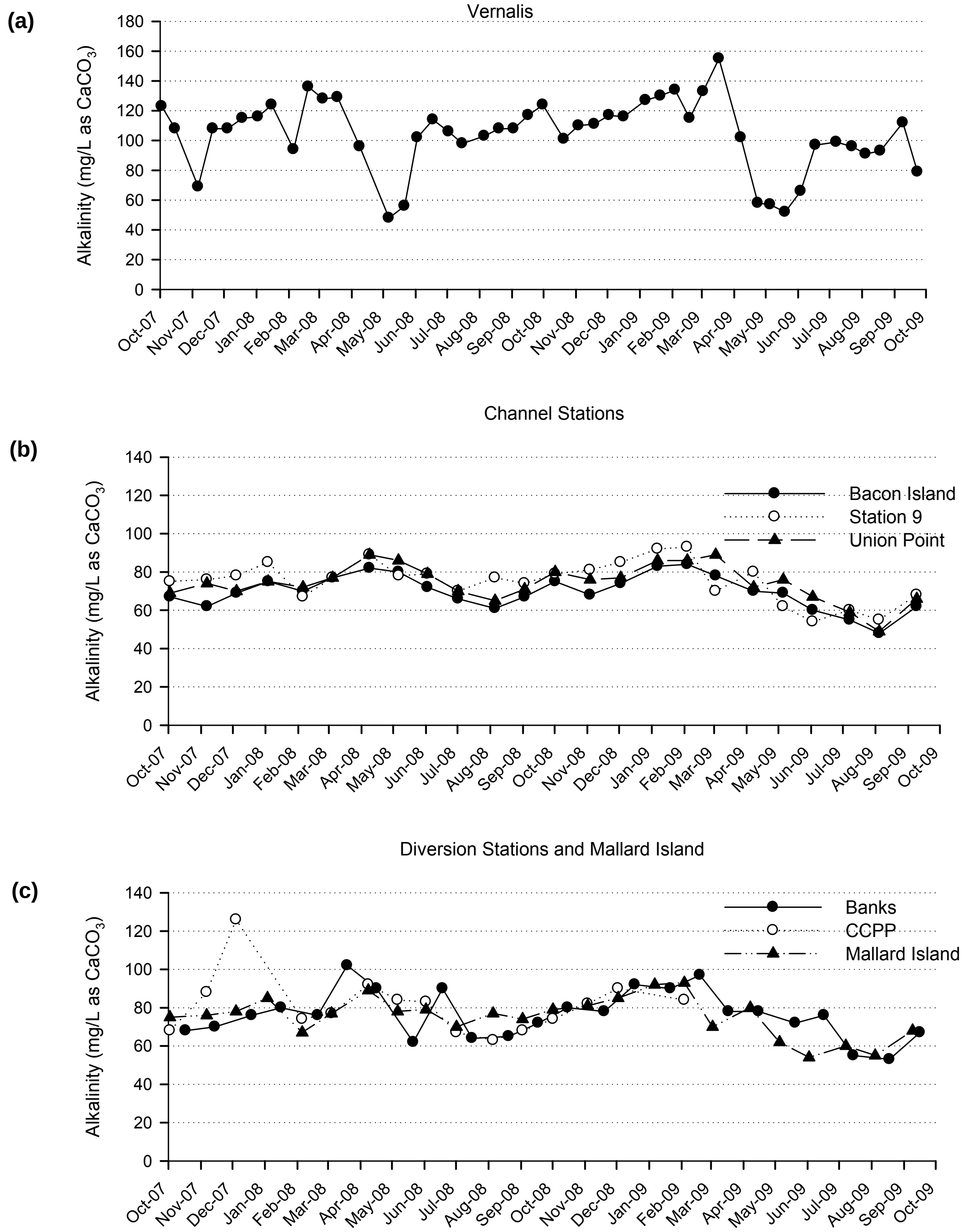


Figure 7-2. Alkalinity at (a) Vernalis, (b) Channel Stations, and (c) Diversion Stations and Mallard Island.

(a)
(b)
(c)

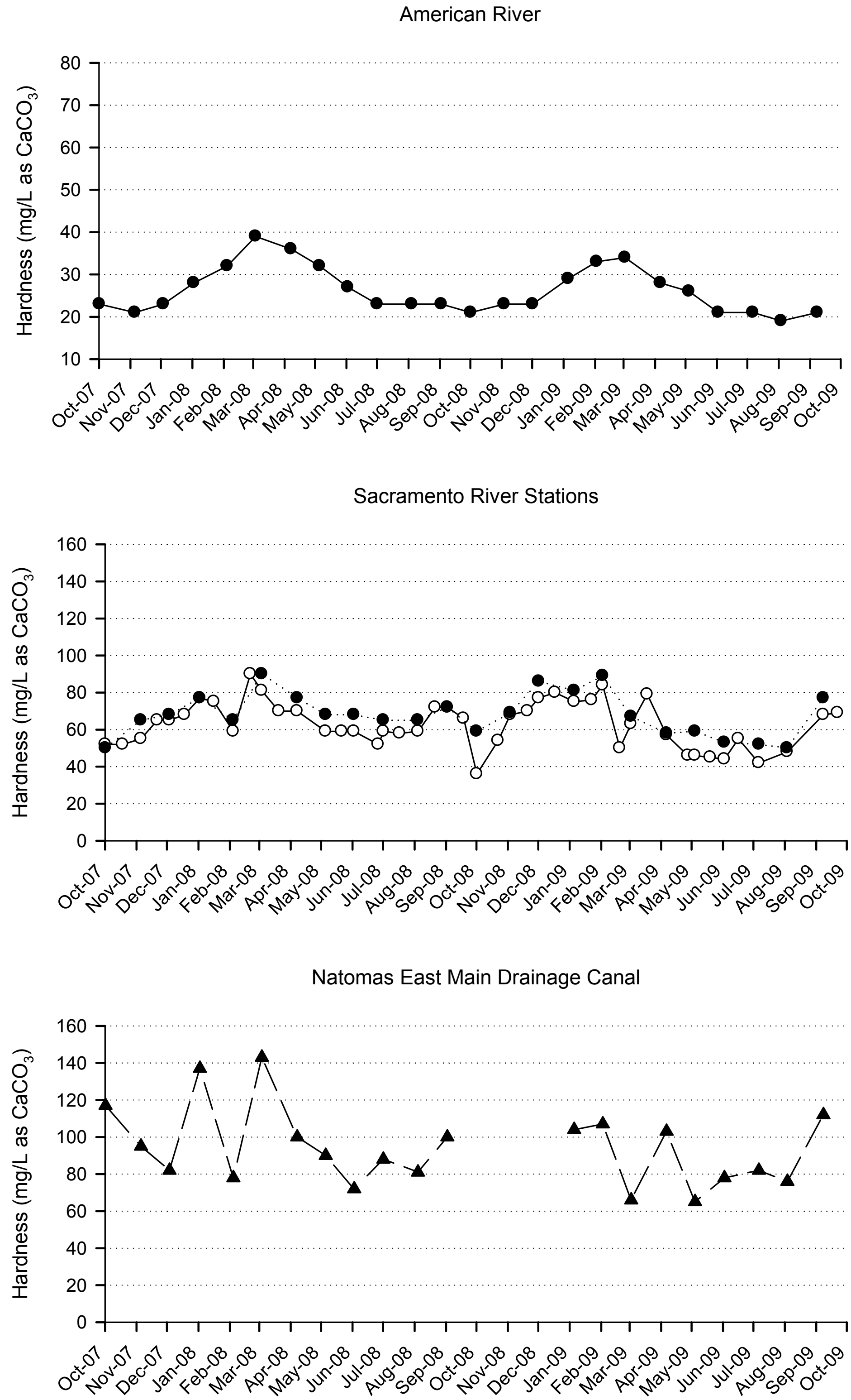


Figure 7-3. Hardness north of the Delta. a. American River. b. Sacramento River Stations. c. Natomas East Main Drainage Canal.

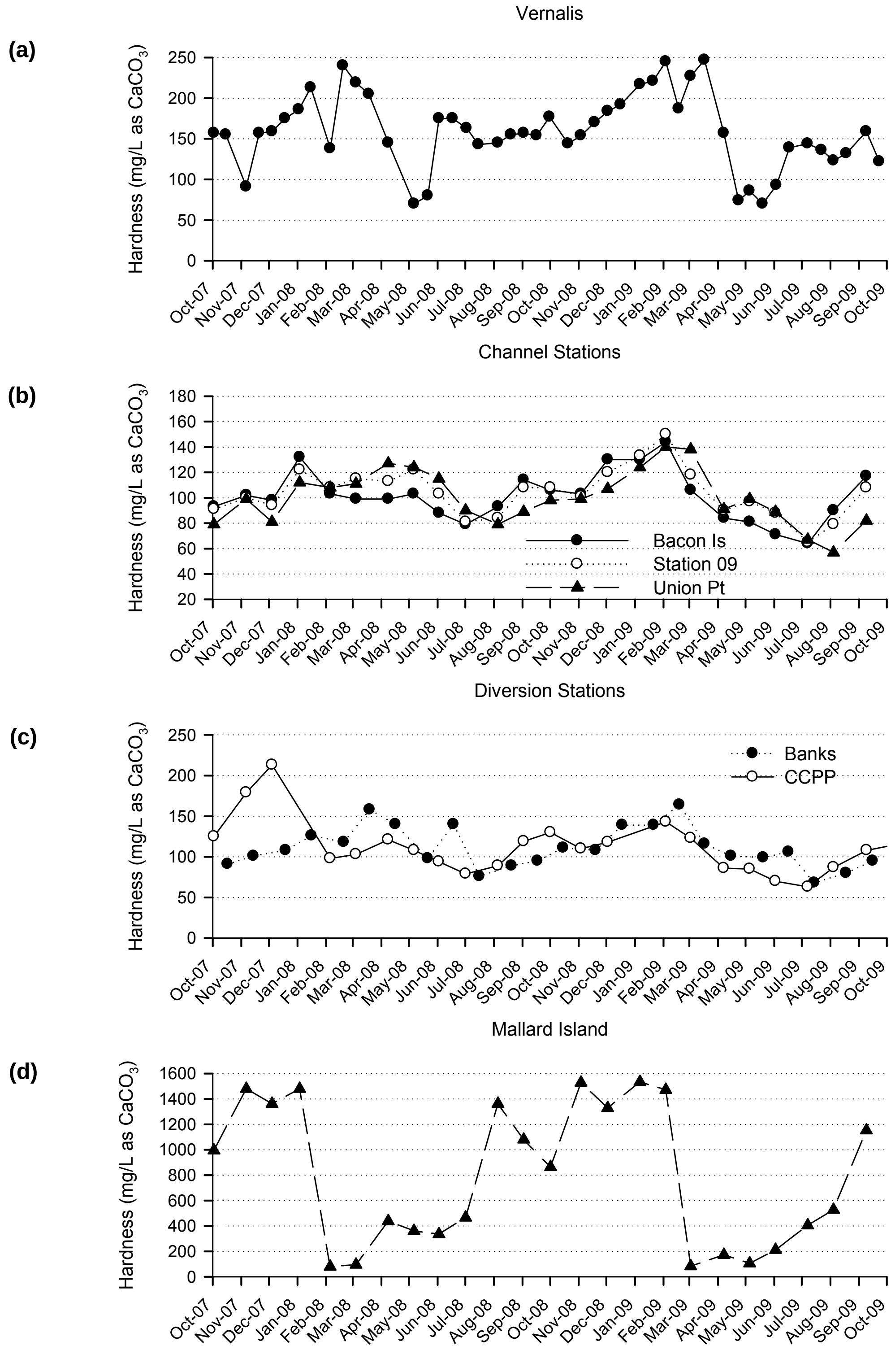


Figure 7-4. Hardness at (a) Vernalis, (b) Channel Stations, (c) Diversion Stations, and (d) Mallard Island.

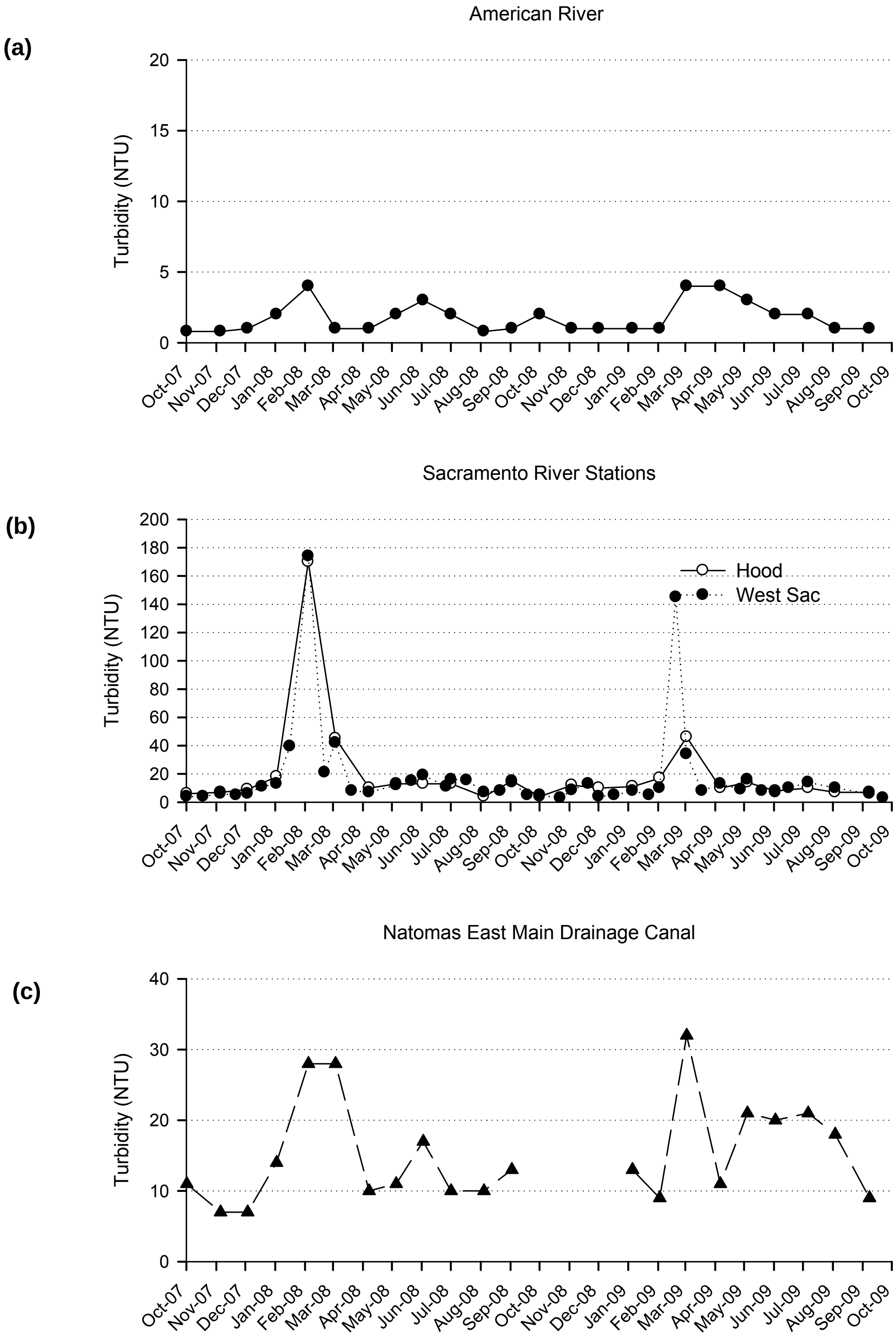


Figure 7-5. Turbidity north of the Delta. a. American River. b. Sacramento River Stations. c. Natomas East Main Drainage Canal.

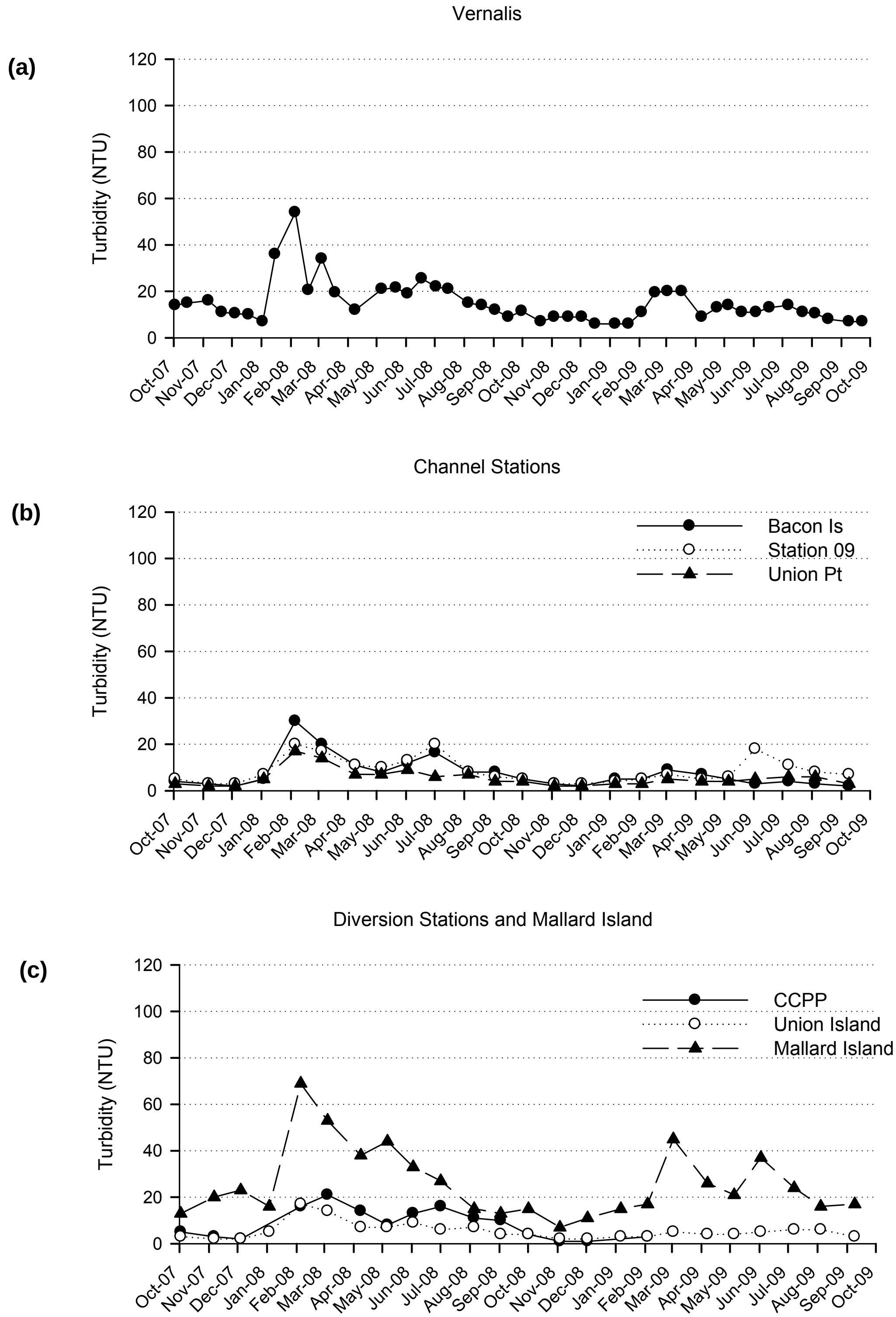


Figure 7-6. Turbidity at (a) Vernalis, (b) Channel Stations, (c) Diversion Stations and Mallard Island.

Chapter 8 Data Quality Control

Overview

This data quality review covers the reporting period from October 1, 2007, through September 30, 2009. Data from 12 stations were collected through the Municipal Water Quality Investigations (MWQI) Program during this reporting period.

The data review was performed using the available quality control (QC) data stored in the California Department of Water Resources' (DWR) Bryte Laboratory - Field and Laboratory Information Management System (FLIMS) database (Fong and Aylesworth, 2006). This database was used to retrieve the data and flag the analyses that were outside established control limits. The Bryte Laboratory is certified by the Environmental Protection Agency and the Department of Public Health's Environmental Laboratory Accreditation Program since 1978 (Fong and Aylesworth, 2006).

The data quality review indicated that the 2007-2009 MWQI project data were of acceptable quality overall. A few analyses were outside the control limits, but they were not considered to have a significant impact on the overall data quality of the project. The results of the review are presented below.

Field Procedures Quality Control

Field Duplicates

Field duplicates are replicate samples taken at a randomly selected station during each field run to evaluate precision of field and laboratory procedures. The results of field duplicate analyses are evaluated by calculating relative percent differences (RPDs) and comparing the RPDs with established control limits. The equation for expressing precision is:

$$RPD= (D1-D2)/[(D1+D2)/2] \times 100,$$

where D1 is the first sample value and D2 is the second (replicated) sample value. During the study period, 1,429 field-replicated analyses were performed and 89 (6.2%) of the RPDs exceeded the acceptable control limits (Table 8-1). These duplicate results indicate that field and laboratory procedures were of acceptable precision for the project.

Field Blanks

Field blanks monitor contamination originating from the collection, transport, and storage of environmental samples. Filtered blanks help check for contamination from field sample processing procedures. Unfiltered blanks check for contamination from containers and preservatives. The results for blanks are compared to the reporting limit for the particular analyte. If the result was greater than the reporting limit, it was flagged as being over the control limit. In the study period, 1,229 field blank analyses were performed, and 77 (6.3%) field blanks exceeded the control limit (Table 8-2).

Internal Quality Controls

Internal QC measurements are performed by the laboratory to ensure that the analytical process is in statistical control. Environmental samples are grouped in "batches," with approximately 20 samples per batch. Generally, one of each QC measure, such as method blank, matrix spike, etc., is performed with each batch to confirm that the analytical method is in control. In some cases, the laboratory performs more than one of each of the QC measures to ensure the quality of the batch. The total number of internal QC analyses performed per analyte is shown in Table 8-3. The following is a review of the internal QC for the project.

Sample Holding Times

Holding time is the period during which a sample can be stored after collection and preservation without significantly affecting the accuracy of its analysis. If any analyte exceeds holding time limits, the results of the specific analysis should be interpreted with caution. During the 2007-2009 reporting period, there were no reported analyses that exceeded the holding time limit.

Method Blanks

Method blanks are analyzed with every sample set and are used to determine the level of contamination that exists in the analytical procedure. A total of 2,566 method blanks were analyzed from October 2007 through September 2009, and two (0.08%) exceeded the control limits.

The analytes with method blank contamination are shown in Table 8-4. Elimination of blank contamination is more difficult for some analytical methods; therefore, each method has its own specific level of acceptance. Table 8-5 shows the frequency of method blank contamination for these analytes, but the frequency of method blank contamination was low for all of the analytes in question.

Laboratory Control Samples and Duplicates

A laboratory control sample (LCS) is a standard made from a different source than the calibration standard and spiked into blank water. The LCS is then analyzed, and the results are compared to the laboratory's control limits. When environmental matrix spike recoveries exceed the control limits, LCS results are useful to confirm that the analytical method was still under control. During the reporting period, 4,208 LCS analyses were performed, and four LCSs exceeded the control limits (Table 8-6). The frequency with which the LCS was outside the control limits was very low (Table 8-7), but whenever the results fall outside the control limits, sample results are deemed unacceptable. Once it is corrected and the LCS is within limits, the samples are reanalyzed. There were 2,078 LCS duplicates performed during the study period (Table 8-8) and two duplicates exceeded the control limits (Table 8-9).

Matrix Spike Recovery

Matrix spike recoveries are used to monitor matrix interferences. The results of matrix spike recoveries indicate the accuracy of analysis given any interference from the sample matrix. Matrix spikes are prepared by adding a known concentration of analyte to an environmental sample with known background concentration. The percent recovery must fall within acceptable limits. During the study period, 5,474 matrix spike recoveries were performed, and 31 (0.56%) exceeded the control limits. The batches with matrix spike recoveries outside the control limits are shown in Table 8-10. The analytes that had matrix spike exceedances were boron, bromide, Kjeldahl nitrogen, nitrate + nitrite, and phosphorus. Phosphorus had an exceedance frequency of 4% and Kjeldahl nitrogen 8.6% (Table 8-11). Some of the recoveries were high, but the RPDs and LCSs for those batches were within limits; therefore, the batch is considered in control. Recoveries that were lower than the control limits can be attributed to matrix interference, but the LCS for those batches were in control.

Matrix Spike Duplicates

Matrix spike duplicate results indicate the precision of the analytical method in a given matrix. The difference between the duplicate samples is reported as an RPD. This difference is compared against the laboratory's control limits as a conservative approach to determining precision. During the study period, 2,590 matrix spike duplicates were performed. Only nine matrix spike duplicate batches exceeded the control limits (0.35%), as shown in Table 8-12. The analytes were Kjeldahl nitrogen and phosphorus and the frequency of exceedance is shown in Table 8-13. These analytes were out of recovery limits for the matrix spikes as well as the spike duplicates, which suggest matrix interference. The LCS recoveries are within limits for these analytes; therefore, the batch is considered in control.

Summary

This review was performed to determine if MWQI's environmental monitoring data met the program's quality objectives during the study period. Based on the field and laboratory quality control measures evaluated, MWQI's data were ascertained to be of acceptable quality.

Table 8-1. Field duplicates.

Analyte	*Collection date*	*Sample number*	*Sample duplicate*	*Result 1*	*Result 2*	*Units*	*RPD (%)*	*RPD Limit (%)*
Dissolved Ammonia	8/5/2008	CC0808B2121	CC0808B2123	0.04	0.03	mg/L as N	29	20
Dissolved Ammonia	10/1/2007	CC1007B0886	CC1007B0888	0.04	0.03	mg/L as N	29	20
Dissolved Ammonia	11/13/2008	CD1108B2185	CD1108B2190	0.05	0.04	mg/L as N	22	20
Dissolved Ammonia	2/3/2009	CI0209B0460	CI0209B0464	0.03	0.04	mg/L as N	29	20
Dissolved Ammonia	7/28/2009	CI0709B0946	CI0709B0947	0.03	0.02	mg/L as N	40	20
Dissolved Ammonia	9/17/2008	CI0908B0094	CI0908B0098	0.03	0.02	mg/L as N	40	20
Dissolved Boron	3/4/2008	CC0308B1313	CC0308B1315	0.1	0.2	mg/L	67	20
Dissolved Boron	11/6/2007	CC1107B1012	CC1107B1016	0.2	0.1	mg/L	67	20
Dissolved Boron	2/3/2009	CI0209B0460	CI0209B0464	0.2	0.1	mg/L	67	20
Dissolved Boron	4/8/2008	CC0408B1427	CC0408B1429	0.1	0.14	mg/L	33	20
Dissolved Boron	10/1/2007	CC1007B0886	CC1007B0888	0.04	0.05	mg/L	22	20
Dissolved Hardness	10/1/2008	CI1008B0115	CI1008B0119	34.0	59.0	mg/L as CaCO3	54	20
Dissolved Nitrate + Nitrite	8/3/2009	CA0809B0023	CA0809B0027	0.01	0.02	mg/L as N	67	20
Dissolved Nitrate + Nitrite	8/4/2009	CA0809B0033	CA0809B0037	0.14	0.11	mg/L as N	24	20
Dissolved Nitrate + Nitrite	11/3/2008	CB1108B0011	CB1108B0013	0.5	0.04	mg/L as N	170	20
Dissolved Nitrate + Nitrite	6/2/2009	CI0609B0850	CI0609B0851	0.04	0.05	mg/L as N	22	20
Dissolved Nitrate + Nitrite	7/27/2009	CI0709B0955	CI0709B0958	0.04	0.05	mg/L as N	22	20
Dissolved Nitrate + Nitrite	7/7/2009	CI0709B1022	CI0709B1023	0.47	0.36	mg/L as N	27	20
Dissolved Nitrate	11/3/2008	CB1108B0011	CB1108B0013	2.2	0.2	mg/L	167	20

Analyte	*Collection date*	*Sample number*	*Sample duplicate*	*Result 1*	*Result 2*	*Units*	*RPD (%)*	*RPD Limit (%)*
Dissolved Organic Carbon	1/2/2008	CC0108B1151	CC0108B1152	1.5	1.8	mg/L as C	18	15
Dissolved Organic Carbon	1/27/2009	CI0109B0423	CI0109B0427	4.9	4.1	mg/L as C	18	15
Dissolved Ortho-phosphate	8/4/2009	CA0809B0033	CA0809B0037	0.05	0.03	mg/L as P	50	20
Dissolved Ortho-phosphate	11/3/2008	CB1108B0011	CB1108B0013	0.06	0.03	mg/L as P	67	20
Dissolved Ortho-phosphate	2/4/2008	CC0208B1229	CC0208B1233	0.04	0.06	mg/L as P	40	20
Dissolved Ortho-phosphate	7/1/2008	CC0708B1889	CC0708B1890	0.09	0.12	mg/L as P	29	20
Dissolved Ortho-phosphate	7/15/2008	CC0708B2089	CC0708B2092	0.09	0.05	mg/L as P	57	20
Dissolved Ortho-phosphate	10/1/2007	CC1007B0886	CC1007B0888	0.72	0.57	mg/L as P	23	20
Dissolved Ortho-phosphate	1/5/2009	CI0109B0322	CI0109B0326	0.03	0.04	mg/L as P	29	20
Dissolved Ortho-phosphate	1/26/2009	CI0109B0415	CI0109B0418	0.06	0.08	mg/L as P	29	20
Dissolved Ortho-phosphate	6/3/2009	CI0609B0860	CI0609B0865	0.04	0.03	mg/L as P	29	20
Dissolved Ortho-phosphate	9/17/2008	CI0908B0094	CI0908B0098	0.07	0.04	mg/L as P	55	20
Dissolved Ortho-phosphate	10/1/2008	CI1008B0105	CI1008B0111	0.09	0.06	mg/L as P	40	20
Dissolved Ortho-phosphate	10/14/2008	CI1008B0166	CI1008B0169	0.03	0.04	mg/L as P	29	20
Dissolved Potassium mg/L	10/1/2008	CI1008B0115	CI1008B0119	1.6	1.3	mg/L as P	21	20
Dissolved Sodium	2/4/2008	CC0208B1229	CC0208B1233	9.0	7.0	mg/L	25	20
Dissolved Sodium	10/1/2008	CI1008B0115	CI1008B0119	7.0	9.0	mg/L	25	20
pH	11/5/2007	CC1107B1002	CC1107B1006	7.3	8.1	pH Units	10	10
Total Dissolved Solids	3/2/2009	CD0309B0564	CD0309B0567	316.0	270.0	mg/L	16	15
Total Kjeldahl Nitrogen	8/12/2008	CA0808B0025	CA0808B0027	0.4	0.3	mg/L as N	29	25

Analyte	*Collection date*	*Sample number*	*Sample duplicate*	*Result 1*	*Result 2*	*Units*	*RPD (%)*	*RPD Limit (%)*
Total Kjeldahl Nitrogen	8/3/2009	CA0809B0023	CA0809B0027	0.2	0.1	mg/L as N	67	25
Total Kjeldahl Nitrogen	8/4/2009	CA0809B0033	CA0809B0037	0.3	0.2	mg/L as N	40	25
Total Kjeldahl Nitrogen	2/4/2008	CC0208B1229	CC0208B1233	0.5	0.8	mg/L as N	46	25
Total Kjeldahl Nitrogen	4/8/2008	CC0408B1427	CC0408B1429	0.7	0.4	mg/L as N	55	25
Total Kjeldahl Nitrogen	7/1/2008	CC0708B1889	CC0708B1890	0.7	0.4	mg/L as N	55	25
Total Kjeldahl Nitrogen	7/1/2008	CC0708B1899	CC0708B1901	0.4	0.3	mg/L as N	29	25
Total Kjeldahl Nitrogen	7/15/2008	CC0708B2089	CC0708B2092	1.3	1.7	mg/L as N	27	25
Total Kjeldahl Nitrogen	7/16/2008	CC0708B2097	CC0708B2098	0.3	0.5	mg/L as N	50	25
Total Kjeldahl Nitrogen	10/1/2007	CC1007B0886	CC1007B0888	0.7	0.1	mg/L as N	150	25
Total Kjeldahl Nitrogen	3/2/2009	CD0309B0564	CD0309B0567	0.7	0.9	mg/L as N	25	25
Total Kjeldahl Nitrogen	5/6/2008	CD0508B0123	CD0508B0126	0.4	0.6	mg/L as N	40	25
Total Kjeldahl Nitrogen	11/13/2008	CD1108B2185	CD1108B2190	0.3	0.4	mg/L as N	29	25
Total Kjeldahl Nitrogen	9/2/2008	CF0908B0001	CF0908B0002	0.7	0.5	mg/L as N	33	25
Total Kjeldahl Nitrogen	1/6/2009	CI0109B0342	CI0109B0348	0.5	0.7	mg/L as N	33	25
Total Kjeldahl Nitrogen	1/27/2009	CI0109B0423	CI0109B0427	0.8	<	mg/L as N	156	25
Total Kjeldahl Nitrogen	2/2/2009	CI0209B0450	CI0209B0452	0.8	0.6	mg/L as N	29	25
Total Kjeldahl Nitrogen	5/4/2009	CI0509B0751	CI0509B0753	0.6	0.8	mg/L as N	29	25
Total Kjeldahl Nitrogen	6/2/2009	CI0609B0850	CI0609B0851	0.5	0.7	mg/L as N	33	25
Total Kjeldahl Nitrogen	7/27/2009	CI0709B0955	CI0709B0958	1.3	0.9	mg/L as N	36	25
Total Kjeldahl Nitrogen	7/6/2009	CI0709B1012	CI0709B1013	0.4	0.6	mg/L as N	40	25

Analyte	*Collection date*	*Sample number*	*Sample duplicate*	*Result 1*	*Result 2*	*Units*	*RPD (%)*	*RPD Limit (%)*
Total Kjeldahl Nitrogen	9/17/2008	CI0908B0094	CI0908B0098	0.3	0.4	mg/L as N	29	25
Total Kjeldahl Nitrogen	10/1/2008	CI1008B0115	CI1008B0119	0.2	0.3	mg/L as N	40	25
Total Kjeldahl Nitrogen	10/14/2008	CI1008B0166	CI1008B0169	1.3	0.8	mg/L as N	48	25
Total Kjeldahl Nitrogen	12/2/2008	CI1208B0256	CI1208B0262	0.4	0.3	mg/L as N	29	25
Total Phosphorus	8/4/2009	CA0809B0033	CA0809B0037	0.08	0.06	mg/L	29	25
Total Phosphorus	3/3/2008	CC0308B1303	CC0308B1304	0.1	0.06	mg/L	50	25
Total Phosphorus	4/7/2008	CC0408B1417	CC0408B1421	0.04	0.03	mg/L	29	25
Total Phosphorus	5/5/2008	CD0508B0103	CD0508B0106	0.02	0.01	mg/L	67	25
Total Phosphorus	10/15/2008	CD1008B2172	CD1008B2176	0.16	0.12	mg/L	29	25
Total Phosphorus	9/2/2008	CF0908B0001	CF0908B0002	0.1	0.07	mg/L	35	25
Total Phosphorus	1/27/2009	CI0109B0423	CI0109B0427	0.11	0.08	mg/L	32	25
Total Phosphorus	5/4/2009	CI0509B0751	CI0509B0753	0.29	0.38	mg/L	27	25
Total Phosphorus	5/5/2009	CI0509B0761	CI0509B0764	0.12	0.09	mg/L	29	25
Total Phosphorus	6/2/2009	CI0609B0850	CI0609B0851	0.06	0.08	mg/L	29	25
Total Phosphorus	7/27/2009	CI0709B0955	CI0709B0958	0.38	0.28	mg/L	30	25
Total Phosphorus	7/6/2009	CI0709B1012	CI0709B1013	0.05	0.07	mg/L	33	25
Turbidity	8/3/2009	CA0809B0023	CA0809B0027	6.0	7.0	N.T.U.	15	15
Turbidity	8/3/2009	CA0809B0023	CA0809B0027	6.0	7.0	N.T.U.	15	15
Turbidity	8/4/2009	CA0809B0033	CA0809B0037	5.0	6.0	N.T.U.	18	15
Turbidity	11/3/2008	CB1108B0011	CB1108B0013	3.0	1.0	N.T.U.	100	15

Analyte	*Collection date*	*Sample number*	*Sample duplicate*	*Result 1*	*Result 2*	*Units*	*RPD (%)*	*RPD Limit (%)*
Turbidity	8/4/2008	CC0808B2111	CC0808B2112	6.0	7.0	N.T.U.	15	15
Turbidity	10/2/2007	CC1007B0896	CC1007B0897	10.0	13.0	N.T.U.	26	15
Turbidity	10/2/2007	CC1007B0896	CC1007B0897	10.0	13.0	N.T.U.	26	15
Turbidity	9/2/2008	CF0908B0001	CF0908B0002	12.0	14.0	N.T.U.	15	15
Turbidity	9/2/2008	CF0908B0021	CF0908B0024	7.0	6.0	N.T.U.	15	15
Turbidity	4/6/2009	CI0409B0599	CI0409B0600	10.0	13.0	N.T.U.	26	15
Turbidity	5/5/2009	CI0509B0761	CI0509B0764	5.0	6.0	N.T.U.	18	15
Turbidity	12/1/2008	CI1208B0246	CI1208B0247	3.0	4.0	N.T.U.	29	15
Turbidity	12/1/2008	CI1208B0246	CI1208B0247	3.0	4.0	N.T.U.	29	15
UV Absorbance	7/16/2008	CC0708B2097	CC0708B2098	0.102	0.113	abs/cm @ 254 nm	10	10

Table 8-2. Field blanks.

Analyte	*Sample number*	*Result*	*Reporting limit*	*Units*
Dissolved Ammonia	CB1108B1215	0.66	0.01	mg/L as N
Dissolved Ammonia	CI0109B0409	0.02	0.01	mg/L as N
Dissolved Organic Carbon	CC0208B1286	0.9	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1516	0.7	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1523	0.6	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1548	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1555	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1560	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1567	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0608B1574	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0708B1922	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0708B1954	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0708B1961	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CC0708B1966	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CD0508B0147	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CD0508B0150	0.6	0.5	mg/L as C
Dissolved Organic Carbon	CD0508B0160	0.5	0.5	mg/L as C
Dissolved Organic Carbon	CI0609B0912	0.6	0.5	mg/L as C
Total Kjeldahl Nitrogen	CA0808B0032	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CA0908B0105	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CB1108B0010	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CB1108B0020	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CB1108B1200	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CB1108B1215	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC0608B1554	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC0708B1960	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC0808B2120	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC0808B2130	0.2	0.1	mg/L as N

Analyte	*Sample number*	*Result*	*Reporting limit*	*Units*
Total Kjeldahl Nitrogen	CC0808B2157	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC0808B2162	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC1107B1021	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CC1107B1051	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CD1008B2171	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CD1108B2192	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CF0908B0010	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CF0908B0062	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CF0908B0069	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0109B0331	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0109B0351	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0109B0414	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0109B0422	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0209B0459	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0209B0469	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI0709B0954	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI1008B0114	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI1008B0124	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI1008B0181	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI1008B0194	0.2	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI1208B0295	0.1	0.1	mg/L as N
Total Kjeldahl Nitrogen	CI1208B0312	0.2	0.1	mg/L as N
Total Organic Carbon	CC0408B1485	1	0.5	mg/L as C
Total Organic Carbon	CC0408B1486	1.5	0.5	mg/L as C
Total Organic Carbon	CC0608B1497	0.5	0.5	mg/L as C
Total Organic Carbon	CC0608B1498	0.6	0.5	mg/L as C
Total Organic Carbon	CC0608B1514	0.5	0.5	mg/L as C
Total Organic Carbon	CC0608B1515	0.8	0.5	mg/L as C

Analyte	*Sample number*	*Result*	*Reporting limit*	*Units*
Total Organic Carbon	CC0608B1521	0.5	0.5	mg/L as C
Total Organic Carbon	CC0608B1522	0.6	0.5	mg/L as C
Total Organic Carbon	CC0608B1559	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B1896	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B1897	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B1906	0.6	0.5	mg/L as C
Total Organic Carbon	CC0708B1920	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B1921	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B1928	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B1964	0.5	0.5	mg/L as C
Total Organic Carbon	CC0708B2093	0.5	0.5	mg/L as C
Total Organic Carbon	CD0508B0110	0.5	0.5	mg/L as C
Total Organic Carbon	CD0508B0135	0.5	0.5	mg/L as C
Total Organic Carbon	CD0508B0159	0.5	0.5	mg/L as C
Total Organic Carbon	CI0609B0898	0.7	0.5	mg/L as C
Total Organic Carbon	CI0609B0903	0.6	0.5	mg/L as C
Total Phosphorus	CC1107B1048	0.01	0.01	mg/L
Total Phosphorus	CC1107B1051	0.01	0.01	mg/L
Total Phosphorus	CI0109B0414	0.02	0.01	mg/L
Total Phosphorus	CI0709B0954	0.02	0.01	mg/L

Table 8-3. Total internal quality control batches grouped by analyte.

Analyte	*Method*	*LCS recovery*	*RPD-LCS duplicate*	*Matrix spike*	*RPD- Matrix spike duplicate*	*Method blank*
Minor Elements						
Alkalinity	Std Method 2320 B	152	76	190	95	75
Aluminum	EPA 200.8	40	20	49	19	20
Arsenic	EPA 200.8	40	20	67	26	20
Barium	EPA 200.8	20	10	13	3	10
Boron	EPA 200.7	130	63	216	99	121
Beryllium	EPA 200.8	20	10	11	3	10
Cadmium	EPA 200.8	20	10	12	3	10
Chromium	EPA 200.8	22	11	17	4	11
Copper	EPA 200.8	40	20	54	19	20
Iron	EPA 200.8	40	20	50	19	20
Lead	EPA 200.8	20	10	15	3	10
Manganese	EPA 200.8	40	20	50	19	20
Mercury	EPA 200.8					
Nickel	EPA 200.8	20	10	11	3	10
pH	Std Method 2320 B					75
Selenium	EPA 200.8	26	13	27	4	13
Silver	EPA 200.8	20	10	12	3	10
Turbidity	EPA 180.1	128	60			130
Zinc	EPA 200.8	20	10	13	3	10
Calcium	EPA 200.7	130	63	230	106	121
Magnesium	EPA 200.7	130	63	232	107	121
Potassium	EPA 200.7	130	63	196	90	121

Analyte	*Method*	*LCS recovery*	*RPD-LCS duplicate*	*Matrix spike*	*RPD- Matrix spike duplicate*	*Method blank*
Sodium	EPA 200.7	130	63	236	108	121
Bromide						
Bromide	EPA 300.0 28d Hold	348	172	613	299	128
Organic Carbon and UVA						
Dissolved Organic Carbon (DOC)	EPA 415.1 (D) Ox	188	93			108
Total Organic Carbon (TOC)	EPA 415.1 (T) Ox	190	95			112
Total Organic Carbon (TOC)	EPA 415_1 (T) Cmbst	136	69			74
Organic Carbon (Dissolved) by Combustion	EPA 415.1 (D) Cmbst	136	66			73
UV Absorbance @254nm	Std Method 5910B	98	48			91
Salinity						
Conductance (EC)	Std Method 2510-B					76
Chloride	EPA 300.0 28d Hold	358	177	876	428	129
Sulfate	EPA 300.0 28d Hold	358	177	778	381	129
Total Dissolved Solids (TDS)	Std Method 2540-C					77
Hardness	Std Method 2340 B					
Nutrients						
Nitrate	EPA 300.0 28d Hold	358	177	658	322	129
Nitrite+Nitrate	Std Method 4500-NO3-F 28 d	146	73	192	96	73
Ammonia	EPA 350.1	146	73	198	99	73
Kjeldahl Nitrogen	EPA 351.2	140	69	124	62	71
Ortho-phosphate	EPA 365.1 (DWR Modified)	146	73	210	105	73
Phosphorus	EPA 365.4	142	71	124	62	71
Totals:		4208	2078	5474	2590	2566

Table 8-4. Method blank exceedances.

Analyte	*Method*	*Batch number*	*Result*	*Reporting limit*	*Units*
Kjeldahl Nitrogen	EPA 351.2	27222	0.1	0.1	mg/L as N
Nitrate + Nitrite	Std Method 4500-NO3-F (28Day)	28316	0.01	0.01	mg/L as N

Table 8-5. Number of batches with method blank exceedances.

Analyte	*Method*	*Total batches*	*Batches with method blanks out of limits*	*Frequency of samples out of limits*
Kjeldahl Nitrogen	EPA 351.2	71	1	1.4
Nitrate + Nitrite	Std Method 4500-NO3-F (28Day)	73	1	1.4

Table 8-6. LCS recovery exceedances.

Analyte	*Method*	*Batch number*	*Recovery (%)*	*Control limits (%)*
Kjeldahl Nitrogen	EPA 351.2	26911	72	80-120
Kjeldahl Nitrogen	EPA 351.2	27440	128	80-120
Kjeldahl Nitrogen	EPA 351.2	27440	123	80-120
Kjeldahl Nitrogen	EPA 351.2	28860	67	80-120

Table 8-7. Frequency of QC batches with LCS recovery exceedances.

Analyte	*Total laboratory control samples*	*LCS recoveries out of limits*	*Frequency of samples out of limits (%)*
Kjeldahl Nitrogen	140	4	2.8

Table 8-8. LCS duplicate recovery exceedances.

Analyte	*Method*	*Batch number*	*Recovery (%)*	*Control limits (%)*
Kjeldahl Nitrogen	EPA 351.2	26538	21	20
Kjeldahl Nitrogen	EPA 351.2	28860	35	20

Table 8-9. Number of LCS duplicate recovery exceedances.

Analyte	*Total LCS duplicates*	*LCS duplicate recoveries out of limits*	*Frequency of samples out of limits (%)*
Kjeldahl Nitrogen	69	2	2.8

Table 8-10. Matrix spike recovery exceedances.

Analyte	*Method*	*Batch number*	*Recovery (%)*	*Control limits (%)*
Boron	EPA 200.7 (D)	26148	97	80–120
Boron	EPA 200.7 (D)	26204	111	80–120
Boron	EPA 200.7 (D)	26204	100	80–120
Boron	EPA 200.7 (D)	28031	91	80–120
Boron	EPA 200.7 (D)	28031	93	80–120
Boron	EPA 200.7 (D)	28296	97	80–120
Boron	EPA 200.7 (D)	28338	106	80–120
Boron	EPA 200.7 (D)	28338	106	80–120
Boron	EPA 200.7 (D)	28932	190	80–120
Boron	EPA 200.7 (D)	28932	180	80–120
Boron	EPA 200.7 (D)	29005	106	80–120
Boron	EPA 200.7 (D)	29005	106	80–120
Bromide	EPA 300.0 28d Hold	29622	67	80–120
Kjeldahl Nitrogen	EPA 351.2	25961	134	70–130
Kjeldahl Nitrogen	EPA 351.2	26407	63	70–130
Kjeldahl Nitrogen	EPA 351.2	26455	132	70–130
Kjeldahl Nitrogen	EPA 351.2	27125	164	70–130
Kjeldahl Nitrogen	EPA 351.2	27328	68	70–130
Kjeldahl Nitrogen	EPA 351.2	27547	66	70–130
Kjeldahl Nitrogen	EPA 351.2	27754	37	70–130
Kjeldahl Nitrogen	EPA 351.2	28321	-100	70–130
Kjeldahl Nitrogen	EPA 351.2	28499	133	70–130
Kjeldahl Nitrogen	EPA 351.2	28941	142	70–130
Kjeldahl Nitrogen	EPA 351.2	28941	137	70–130
Nitrate + Nitrite	Std Method 4500-NO3-F (28Day)	25778	118	85–115
Nitrate + Nitrite	Std Method 4500-NO3-F (28Day)	25778	118	85–115
Phosphorus	EPA 365.4	25654	78	80.7–121
Phosphorus	EPA 365.4	25915	78	80.7–121
Phosphorus	EPA 365.4	27127	160	80–120
Phosphorus	EPA 365.4	27330	75	80–120
Phosphorus	EPA 365.4	28322	-131	70–130

Table 8-11. Frequency of QC batches with matrix spike recovery exceedances.

Analyte	*Total matrix spikes*	*Matrix spike recoveries out of limits*	*Frequency of samples out of limits (%)*
Boron	216	12	5.5
Bromide	613	1	0.16
Kjeldahl Nitrogen	124	11	8.8
Nitrate + Nitrite	192	2	1
Phosphorus	124	5	4

Table 8-12. Matrix spike duplicate RPD exceedances.

Analyte	*Method*	*Batch number*	*Recovery (%)*	*Control limits (%)*
Kjeldahl Nitrogen	EPA 351.2	26538	21	0-20
Kjeldahl Nitrogen	EPA 351.2	28860	35	0-20
Kjeldahl Nitrogen	EPA 351.2	27125	49	0-30
Kjeldahl Nitrogen	EPA 351.2	27518	38	0-30
Kjeldahl Nitrogen	EPA 351.2	27547	47	0-30
Kjeldahl Nitrogen	EPA 351.2	27754	86	0-30
Kjeldahl Nitrogen	EPA 351.2	28321	4124	0-30
Phosphorus	EPA 365.4	27127	55	0-25
Phosphorus	EPA 365.4	28322	13	0-25

Table 8-13. Number of matrix spike duplicate recovery exceedances.

Analyte	*Total matrix spike duplicates*	*Matrix spike duplicate recoveries out of limits*	*Frequency of samples out of limits (%)*
Kjeldahl Nitrogen	62	7	11.3
Phosphorus	62	2	3.2

Chapter 9 References

General

Anderson, J. 2002. Chapter 14: DSM2 Fingerprinting Methodology. **In:** Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 23rd Annual Progress Report. Sacramento (CA): California Department of Water Resources, Bay-Delta Office. 26 p. Available at: http://modeling.water.ca.gov/delta/reports/annrpt/2002/2002Ch14.pdf

Anderson, J; Wilde, J. 2005. Chapter 6: Fingerprinting: Clarification and Recent Applications. **In:** Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 26th Annual Progress Report. Sacramento (CA): California Department of Water Resources, Bay-Delta Office. 18 p. Available at: http://modeling.water.ca.gov/delta/reports/annrpt/2005/2005Ch6.pdf

Archibald Consulting; Richard Woodard Water Quality Consultants; Palencia Consulting engineers. 2007. California State Water Project Watershed Sanitary Survey. 2006 Update. The State Water Project Contractors Authority. 519 p. Available at: http://www.water.ca.gov/pubs/waterquality/municipal_wq_investigations/mwqi_reports/california_state_water_project_watershed_sanitary_survey_2006_update/awconsultingreport-final.pdf

Baxter, RD; Sommer, Ted; Hrodey, Pete; Chotkowski, Mike; Gehrts, Karen; Cornelius, P, editors. 2009. IEP Newsletter. **[Internet].** (Interagency Ecological Program for the San Francisco Estuary). Sacramento (CA): California Department of Water Resources; State Water Resources Control Board; California Department of Fish and Game; U.S. Bureau of Reclamation; U.S. Army Corps of Engineers; U.S. Fish and Wildlife Service; U.S. Geological Survey; U.S. Environmental Protection Agency; National Marine Fisheries Service. [cited: 2009 Dec 22]. 44 p. 22(2). Available at: http://www.water.ca.gov/iep/newsletters/2009/IEPNewsletter_FINALSpring2009.pdf

[DWR]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. 2003. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected August 1998 through September 2001. Sacramento (CA): California Department of Water Resources. 200 p. Available at: http://www.wq.water.ca.gov/docs/mwqi_pubs/FullReport.pdf

[DWR]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. 2005. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected October 2001 through September 2003. Sacramento (CA): California Department of Water Resources. 206 p. Available at: http://www.wq.water.ca.gov/docs/mwqi_pubs/MWQI.SummRep.Fulldoc.pdf

[DWR]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. 2006. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected from the Sacramento-San Joaquin Delta Region, Oct 2003—Sep 2005. Sacramento (CA): California Department of Water Resources. 148 p. Available at: http://www.wq.water.ca.gov/docs/wqs_pubs/fguo/SummRpt2003-05.pdf

[DWR, 2008a]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. 2008. The Municipal Water Quality Investigations Program Summary and Findings from Data Collected from the Sacramento –San Joaquin Delta Region, October 2005 to September 2007. Sacramento (CA): California Department of Water Resources. 178 p. Available at: http://www.wq.water.ca.gov/docs/mwqi_pubs/MWQIsummRep05-07.pdf

[DWR, 2008b]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. 2008. Steelhead Creek Water Quality Investigation. Final Technical Report. Sacramento (CA): California Department of Water Resources. 140 p. Available at: http://www.water.ca.gov/pubs/waterquality/municipal_wq_investigations/mwqi_reports/steelhead_creek_water_quality_investigation/steelhead_creek_water_quality_investigation._february_2008.pdf

Clesceri, LS; Greenberg, AE; Eaton, AD; (managing editor) Franson, MAH, editors. 1998. Standard methods for the examination of water and wastewater. 20th ed. Washington (DC): American Public Health Association, American Water Works Association, Water Environment Federation. 1 v.

Fong, S; Aylesworth, S. 2006. Bryte Chemical Laboratory Quality Assurance Manual. Sacramento (CA): California Department of Water Resources, Environmental Services Division, Water Quality Assessment Branch, Bryte Chemical Laboratory. 21 p. Quality Assurance Technical Document 8. Available at: http://www.wq.water.ca.gov/docs/bryte_pubs/Bryte_QA_Manual_2006.pdf

Mierzwa, M; Wilde, J. 2004. Chapter 9: using QUAL Fingerprinting Results to Develop DOC Constraints in CALSIM. **In:** Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 25th Annual Progress Report. Sacramento (CA): California Department of Water Resources, Bay-Delta Office. 16 p. Available at: http://modeling.water.ca.gov/delta/reports/annrpt/2004/2004Ch9.pdf

Ngatia, M; Pimental, J. 2007. San Francisco Estuary and Watershed Science. **[Internet].** Berkeley (CA): CALFED Science Program; California Digital Library's eScholarship service; University of California—Davis John Muir Institute of the Environment. [cited: 2010 Feb 18]. 5(2):art 3. Available at: http://escholarship.org/uc/item/5h2074wx

[SJBU]. 2008. San Joaquin Basin Update. **[Internet].** Oakdale (CA): Fishbio Environmental. [cited: 2010 Jan 3]. 2(12):2008 Apr 24. Available at: http://sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html

[SJBU]. 2009. San Joaquin Basin Update. **[Internet].** Oakdale (CA): Fishbio Environmental. [cited: 2010 Jan 3]. 3(13):June 11, 2009. Available at: http://sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html

[SJRGA]. San Joaquin River Group Authority. 2009. San Joaquin River Agreement Vernalis Adaptive Management Plan 2008 Annual Technical Report. 2009 Jan. Modesto (CA): San Joaquin River Group Authority. 81 p. Available at: http://www.sjrg.org/technicalreport/2008/complete-2008.pdf

[SWRCB]. State Water Resources Control Board. 2000. Revised Water Right Decision 1641. 2000 Mar 15. Sacramento (CA): State Water Resources Control Board. 213 p. Available at: http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1641_1999dec29.pdf

[USFWS]. U.S. Deparment of the Interior, Fish and Wildlife Service. 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP). 2008 Dec 15. Sacramento (CA): U.S. Fish and Wildlife Service. 81420-2008-F-1481-5. Available at: http://www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf

Wetzel, RG. 2001. Limnology: lake and river ecosystems. 3rd ed. San Diego: Academic Press. 1006 p.

Web sites

[CDPH]. California Department of Public Health. Upcoming Regulations for Drinking Water. **[Internet].** 2010. Sacramento (CA): California Department of Public Health. [cited: 2010 Jan]. Available at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Regulations.aspx

[DWR, 2010a]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. MWQI - Publications. **[Internet].** 2010. Sacramento (CA): California Department of Water Resources. Available at: http://www.wq.water.ca.gov/mwqi/pubs.cfm

[DWR, 2010b]. California Department of Water Resources, Division of Environmental Services, Office of Water Quality. Municipal Water Quality Investigations. **[Internet].** 2010. Sacramento (CA): California Department of Water Resources. Available at: http://www.wq.water.ca.gov/mwqi/mwqi_index.cfm

[DWR, 2010c]. California Department of Water Resources, State Water Project Analysis Office. Water Contracts Branch. **[Internet].** 2010. Sacramento (CA): California Department of Water Resources. Available at: http://www.water.ca.gov/swpao/wc_b.cfm

[DWR, 2010d]. California Department of Water Resources, Bay-Delta Office. Modeling Support Branch Web site. **[Internet].** 2010. Sacramento (CA): California Department of Water Resources. Available at: http://baydeltaoffice.water.ca.gov/modeling/index.cfm

[DWR, 2010e]. California Department of Water Resources. California Data Exchange Center, Water Supply Index History (WSIHIST). **[Internet].** 2010. Sacramento (CA): California Department of Water Resources. Available at: http://cdec.water.ca.gov/cgi-progs/iodir/wsihist

[DWR, 2010f]. California Department of Water Resources. Water Data Library. **[Internet].** 2010. Sacramento (CA): California Department of Water Resources. Available at: http://www.water.ca.gov/waterdatalibrary/index.cfm

[USEPA, 2010a]. U.S. Environmental Protection Agency. Drinking Water Standards. **[Internet].** 2010. Washington (DC): U.S. Environmental Protection Agency. [cited: 2010 Jan]. Available at: http://www.epa.gov/safewater/standards.html

[USEPA, 2010b]. U.S. Environmental Protection Agency. Drinking Water Contaminants. **[Internet].** 2010. Washington (DC): U.S. Environmental Protection Agency. [cited: 2010 Jan 2]. Available at: http://www.epa.gov/safewater/contaminants/index.html

[USEPA, 2010c]. U.S. Environmental Protection Agency. Stage 2 Disinfectants and Disinfection Byproduct Rule (Stage 2 DBP rule). **[Internet].** 2010. Washington (DC): U.S. Environmental Protection Agency. [cited: 2010 Jan 29]. Available at: http://www.epa.gov/OGWDW/disinfection/stage2/index.html

[USEPA, 2010d]. U.S. Environmental Protection Agency. Basic Information about Nitrate in Drinking Water. **[Internet].** 2010. Washington (DC): U.S. Environmental Protection Agency. [cited: 2009 Dec 23]. Available at: http://www.epa.gov/safewater/contaminants/basicinformation/nitrate.html

[USEPA, 2010e]. U.S. Environmental Protection Agency. Basic Information about Nitrite (Measured as Nitrogen) in Drinking Water. **[Internet].** 2010. Washington (DC): U.S. Environmental Protection Agency. [cited: 2009 Dec 23]. Available at: http://www.epa.gov/safewater/contaminants/basicinformation/nitrite.html

Appendix A Current State and Federal Drinking Water Standards

Available online at

http://www.wq.water.ca.gov/owq_content/regulations.cfm

or on CD inserted in report

Appendix B Data Files

Available online at

http://www.wq.water.ca.gov/mwqi/pubs.cfm#program%20reports

or on CD inserted in report