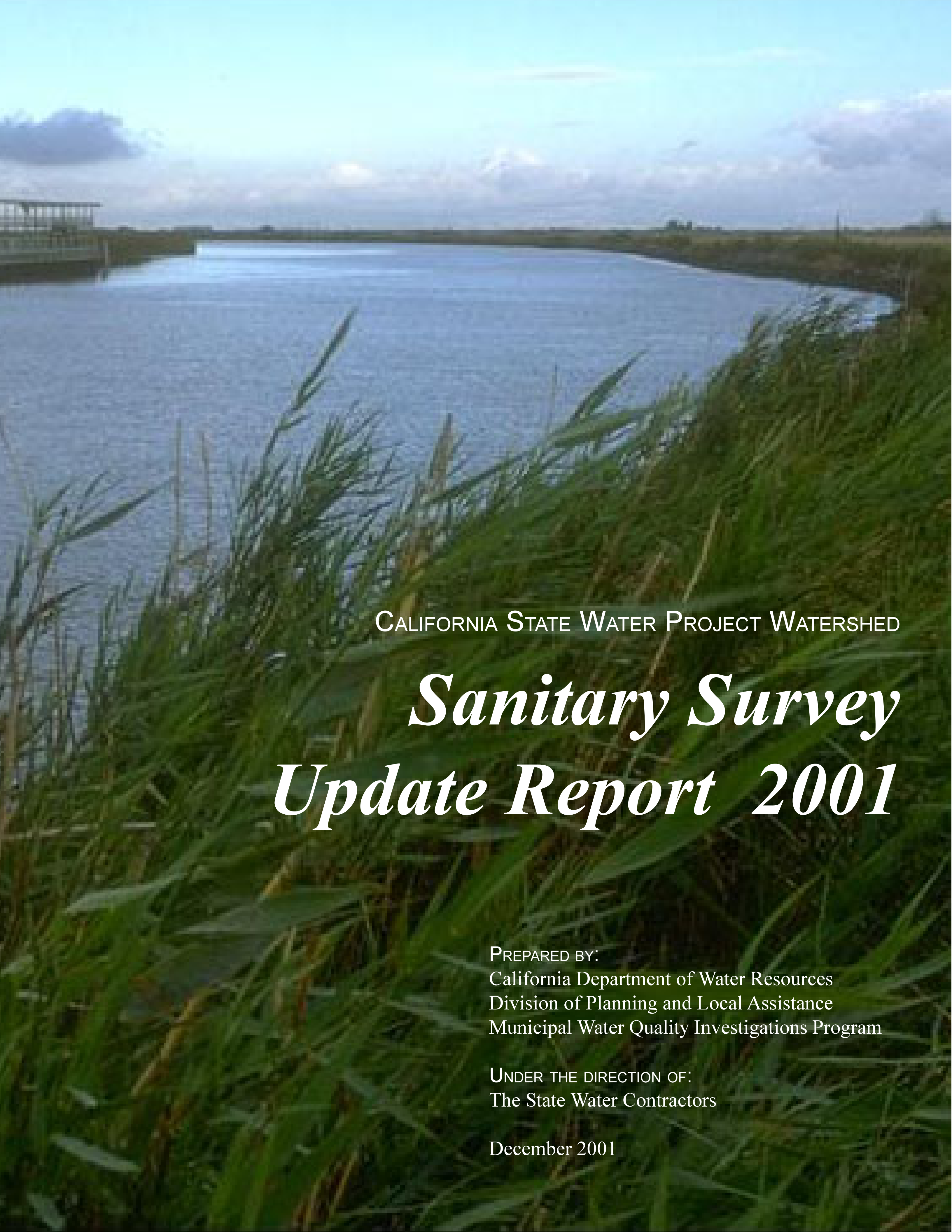

CALIFORNIA STATE WATER PROJECT WATERSHED

Sanitary Survey Update Report 2001

PREPARED BY:
California Department of Water Resources
Division of Planning and Local Assistance
Municipal Water Quality Investigations Program

UNDER THE DIRECTION OF:
The State Water Contractors

December 2001

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Gray Davis Governor State of California	Mary D. Nichols Secretary for Resources The Resources Agency	Thomas M. Hannigan Director Department of Water Resources

Contents

More detailed Contents information along with lists of Figures and Tables are provided at the beginning of each chapter. At the beginning of chapters 3 through 10, which address the State Water Project watersheds and water supply systems, the reader will find significance matrices ranking potential contaminant sources.

WATERSHEDS (CHAPTERS 3 THROUGH 7)

WATER SUPPLY SYSTEMS (CHAPTERS 8 THROUGH 10)

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County of Kings
Crestline-Lake Arrowhead Water Agency
Desert Water Agency
Dudley Ridge Water District
Empire-West Side Irrigation District
Kern County Water Agency
Littlerock Creek Irrigation District
Metropolitan Water District of Southern California
Mojave Water Agency
Napa County Flood Control and Water Conservation District
Oak Flat Water District
Palmdale Water District
Plumas County Flood Control and Water Conservation 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
Tulare Lake Basin Water Storage District

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Introduction and Background

1.1 PURPOSE OF THE WATERSHED SANITARY SURVEY UPDATE

The California Department of Health Services (DHS), under California Surface Water Treatment regulations, requires that all water purveyors perform a sanitary survey of their water source watersheds and update it every 5 years. These regulations implement the federal Surface Water Treatment Rule (SWTR), which became effective on 31 December 1990.

The purpose of a watershed sanitary survey is to:

- Describe control and management practices,
- Describe potential contaminant sources or activities (PCSs) and their effect on drinking water source quality,
- Determine if appropriate treatment is provided, and
- Identify actions and recommendations to improve or control contaminant sources.

1.2 HISTORY OF THE SWP SANITARY SURVEY UPDATE 2001

After completion of the initial State Water Project (SWP) *Sanitary Survey* in 1990, a SWP Sanitary Survey Action Committee (SSAC) was formed. It consisted of staff from the California Department of Water Resources (DWR) and DHS's Drinking Water Program, reprsentatives of the State Water Contractors and consultants. The SSAC's role was to follow up on the report's recommendations. The SSAC's work resulted in the State Water Project Action Plan. This action committee has continued to meet over the years, and although individual membership has changed, the SSAC makeup has remained the same.

The SSAC has taken on the task of providing guidance for the 5-year updates of the *Sanitary Survey*. The *Sanitary Survey Update Report 1996* focused on changes in SWP watersheds and water quality since 1990. The update also provided information from site visits to watersheds—Del Valle, San Luis, Pyramid, Castaic, Silverwood, Perris, Barker Slough/North Bay Aqueduct watershed, and the open channel section of Coastal Aqueduct. An emphasis was placed on the occurrence of coliforms and the pathogens *Giardia* and c*ryptosporidium*. The *Update 1996*, completed in May 1996, included the results of an extensive database search on toxic sites within SWP watersheds.

1.3 COORDINATION WITH STAKEHOLDERS

Preparation for the *Sanitary Survey Update Report 2001* began July 1999 with SSAC meetings to discuss and develop a work plan and scope of work. The SSAC approved a draft work plan and schedule in September 1999 and adopted the final work plan in December 1999.

In May 2000, SSAC members with specific expertise and/or access volunteered to work as a subgroup to expedite the information retrieval, evaluation, and feedback process for the 2001 update. Those seven members represented DHS, SWP contractors, Metropolitan Water District of Southern California (MWDSC), Santa Clara Valley Water District (SCVWD), DWR's Operations and Maintenance Division (O&M), and the California Urban Water Agencies (CUWA).

Following work plan development, DWR's Municipal Water Quality Investigations (MWQI) management and staff, DHS staff, and the SSAC established agreements to help assure adequate progress, the obtainment of necessary information, and feedback on document content quality.

In conjunction with the agreements, this group—SSAC subgroup, MWQI and DHS staff—held frequent and focused meetings and conference calls to track progress, discuss schedule and resource issues, and prioritize tasks.

DHS granted a schedule extension, which was requested because of staffing resource issues and difficulty in obtaining available information. The original delivery date of January 2001 for the final review draft was eventually changed to 4 May 2001. Because of time constraints, not all chapters were reviewed by the SSAC prior to the release of the final review draft. The SSAC, DHS, and DWR staff conducted a thorough review of the final review draft chapters and after a review of the comments, the document was edited to achieve technical accuracy and consistent formatting.

1.4 2001 SANITARY SURVEY ASSESSMENT APPROACH

Sanitary Survey Update Report 2001 offers detailed evaluations of study areas and issues that were selected based on actions and recommendations from previous reports and concerns stemming from new data and information. Findings and recommendations in *Update 1996* led to extensive studies of the Barker Slough watershed and pathogens in source waters. Each of these follow-up activities is covered in detail in its own chapter.

The SSAC work plan specified that *Sanitary Survey Update 2001* would rely on existing data and information from DWR, MWDSC, and other agencies and would require extensive coordination and cooperation to obtain relevant information from several federal, State, and local sources.

During work plan development, it was agreed to provide information in *Sanitary Survey Update 2001* to make it useful for SWP utilities in complying with the California Drinking Water Source Assessment and Protection (DWSAP) Program. The relationship of the *Sanitary Survey Update 2001* to the DWSAP Program is discussed in section 1.8. *Sanitary Survey Update 2001* is not required by the DWSAP Program but much of its PCS information is readily available for incorporation into a source water assessment as required by the DWSAP Program.

A key task in the work plan was the preparation of a sanitary survey questionnaire and its distribution to SWP contractors. This approach was also used for the *Sanitary Survey Update 1996*. The questionnaire was used to obtain information in the most efficient and direct way possible on contaminant sources, available data, and major water quality issues. Of the 29 contractors, 12 responded to the questionnaire (several contractors were not using SWP water at the time).

1.5 SCOPE OF WORK FOR EACH SWP WATERSHED

During the development process for *Sanitary Survey Update 2001*, DWR stated that new field reconnaissance surveys and additional monitoring studies would not be performed specifically for the update. The exception was a 4-year study of the Barker Slough watershed because *Sanitary Survey Update 1996* recommended an investigation.

The major *Sanitary Survey Update 2001* tasks performed for each watershed study include:

- Review and evaluation of the results from the questionnaire sent to SWP contractors,
- Personal communication with staff of various agencies and review of pertinent reports and data about major water quality issues,
- Delineation and mapping of each source watershed area.
- Evaluation of areas and contaminants of known or suspected concern, as directed by DHS and the SSAC,
  - Development of inventories of PCSs and activities in each area.
  - Determination of the susceptibility of the water supplies of each area to those contaminant sources and activities.
- Reports and summaries of the results; identification and rating of significant PCSs and development of recommended actions to reduce the susceptibility of water supplies to existing and future water quality problems.

1.6 SELECTION AND EVALUATION OF POTENTIAL CONTAMINANT SOURCES

The general types of PCSs used in the *Sanitary Survey Update 2001* were developed with SSAC input and the *American Water Works Association Guidance Manual*. They are presented below.

- Recreation
- Wastewater treatment/facilities (includes treatment plant effluent discharges, storage, transport, treatment, disposal to land, and septic systems)
- Urban runoff
- Animal populations (includes grazing, dairies, and wild animal populations)
- Algal blooms
- Agricultural activities (includes agricultural cropland use, pesticide/herbicide use, and agricultural drainage)
- Mining
- Solid or hazardous waste disposal facilities
- Logging

- Unauthorized activity (includes illegal dumping, leaking underground tank)
- Traffic accidents/spills
- Groundwater discharges
- Seawater intrusion
- Geologic hazards (landslides, earthquakes, floods)
- Fires
- Land use changes

Different PCSs can require different approaches and types of data for evaluation. In general, susceptibility to PCSs in a given watershed was determined through the questionnaire and information and data obtained in response to the following criteria:

- Frequency of drinking water regulations (maximum contaminant levels) being actually or nearly exceeded at the water treatment plant intakes, reservoirs, and in the treated water, including complaints about taste and odor.
- Constituents of concern (COC) causing additional water treatment costs or affecting treatment operations (for example, TOC removal requirement).
- Proximity of PCS to source waters (for example, reservoirs, streams) and/or treatment plant intakes.
- Beach closures due to high bacteria counts or wastes or spills associated with certain PCSs (for example, water recreation, sewage spills, septic tank leaks).
- Available water quality data on receiving water downstream of PCS areas and upstream of the nearest water supply diversions. Comparison between these locations, including at the water supply intake.
- The lack of data or the need to do a more thorough assessment of the susceptibility of the watershed to 1 or more PCSs.

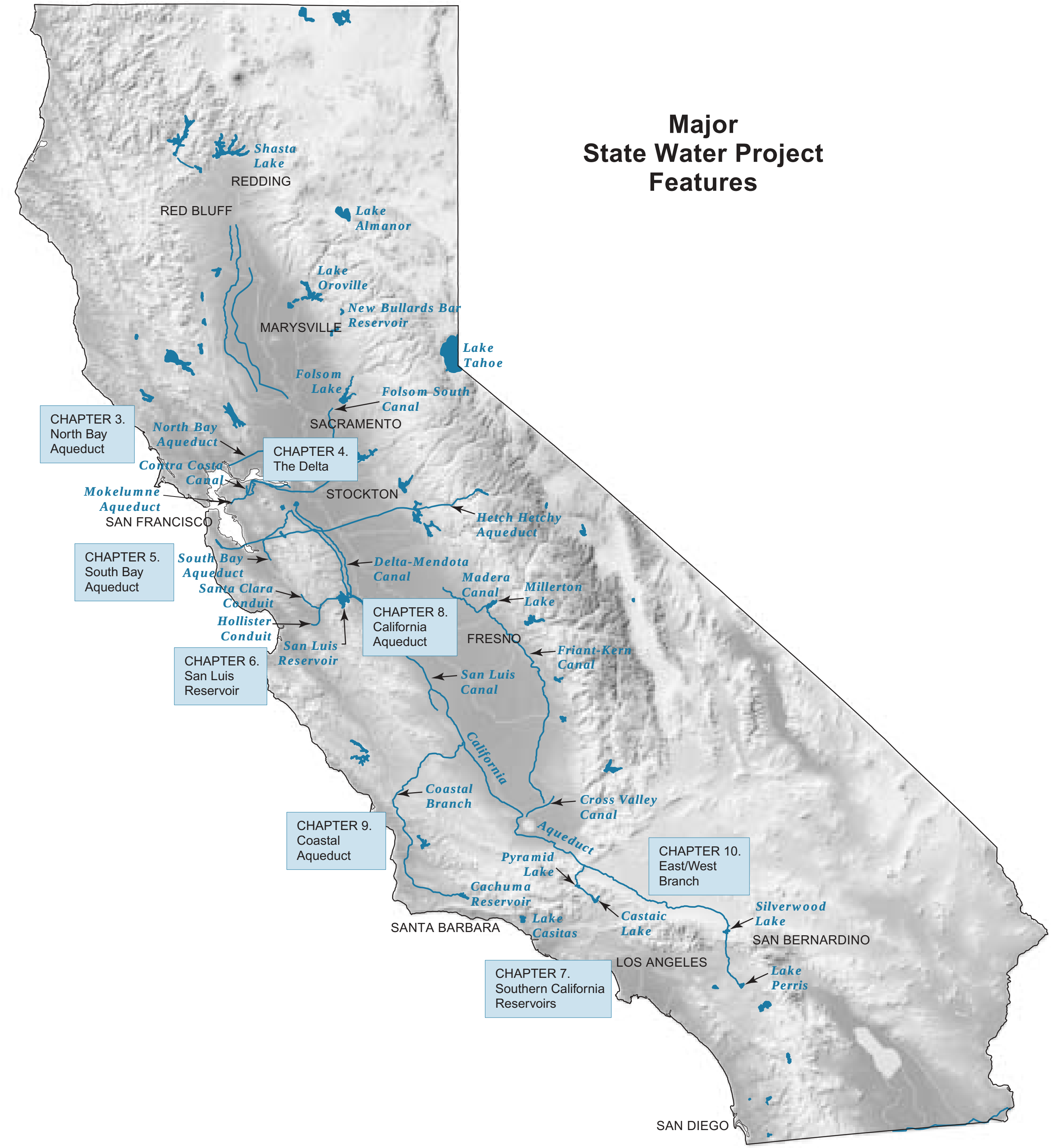
1.7 REPORT ORGANIZATION

1.7.1 CHAPTER PRESENTATION

The *Sanitary Survey Update 2001* watershed chapters are organized by geographical areas, such as the 4 Southern California reservoirs, or by spatial connection, such as the 5 sections of the California Aqueduct. Figure 1-1 shows the approximate geographical location of the watersheds covered in the chapters and their corresponding sections of the SWP. The following SWP structures and their corresponding watersheds are covered in *Sanitary Survey Update 2001*:

- SWP reservoirs
  - Pyramid Lake
  - Castaic Lake
  - Silverwood Lake
  - Lake Perris
  - San Luis Reservoir
  - Lake Del Valle
- SWP aqueducts
  - North Bay Aqueduct (Barker Slough watershed)
  - South Bay Aqueduct
  - California Aqueduct sections:
    - H. O. Banks Pumping Plant to O'Neill Forebay/ Check 13
    - O'Neill Forebay
    - O'Neill Forebay to Avenal
    - Avenal to Kern River Intertie (Check 28)
    - Kern River Intertie to East/West Bifurcation (Check 41)
  - Coastal Branch
  - East Branch and West Branch
- Harvey O. Banks Delta Pumping Plant
  - The Sacramento San Joaquin Delta and watersheds of the Sacramento and San Joaquin rivers

Figure 1-1 Sanitary Survey Chapters and Corresponding Watersheds



At the beginning of each watershed section, a summary matrix shows the assessed threat a PCS poses for that particular watershed and water supply system. The matrix also shows the chapter section where the PCS is presented in detail. The chapter then presents the following information:

- Descriptions of land use, geology and soils, vegetation, and hydrology of each watershed area or descriptions of the SWP aqueduct branches for the water supply system site.
- Identification of PCSs for each area.
- Summary of water quality data.
- Discussion of the significance of the PCS(s) to each area.
- Watershed management practices.

Including this introductory chapter, 5 chapters do not focus on a particular watershed. Chapter 2 summarizes current laws and regulations for drinking water. Chapter 11 describes the SWP Emergency Action Plan and related information. Chapter 12 presents and discusses pathogen data, which DHS and the SSAC considered necessary to include in this report. Chapter 13 contains conclusions and recommendations for the PCSs and water quality issues presented in chapters 3 through 10.

1.7.2 SIGNIFICANCE MATRICES

Significance matrices provide a new approach for the SWP S*anitary Survey* to give the reader a visual summary of the relative importance of PCSs in a watershed. Each watershed chapter begins with a matrix, which operates as a "road map" by providing a quick assessment of the most important PCSs and directing the reader to corresponding chapter sections. The matrices are not absolute ratings of importance. A chapter should be read completely to gain a full understanding of the potential threats to drinking water quality. Each PCS that threatens drinking water contamination of a water supply system was rated as follows:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat.

○ PCS is a minor threat to drinking water quality

In each matrix, symbols represent ratings, and numbers stand for the chapter section in which the PCS is discussed. The ratings were based on data and information collected during research for *Sanitary Survey Update 2001*. Some data provided a clear connection between the PCS and its potential to contaminate drinking water. Some information was anecdotal and based on the collective knowledge and experience of the author investigating a source, as well as other SS Update authors and staff of the DWR Water Quality Assessment Branch.. In some cases, where a PCS was a clear source of the contaminant but the linkage as a threat was unclear, the PCS was given a medium rating. Sometimes a PCS was a clear source of the contaminant, but evidence and data indicated the source was not a threat to drinking water. In these cases, the PCS received a minor threat rating, for example, pesticides in the Delta watersheds.

Chapter headings for PCSs initially were drawn from a master list approved by the SSAC work team in fall 1999. The list had to be varied and expanded because of the extreme variation in geographical areas and settings for each chapter.

1.7.3 DEVELOPMENT OF CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations in chapter 13 were developed at 5 workshops where SSAC and other staff reviewed and discussed authors' drafts and provided extensive input and revision. Detail of the process and content is provided in the introduction to chapter 13. It must be emphasized that chapter 13 is not a "stand-alone" chapter and that each chapter must be reviewed to obtain a complete picture of the status of a particular watershed. Only significant PCSs were included in chapter 13's conclusions and recommendations.

1.8 RELATIONSHIP WITH DHS'S DRINKING WATER SOURCE ASSESSMENT AND PROTECTION (DWSAP) PROGRAM

Under the 1996 reauthorization of the Safe Drinking Water Act (SDWA), all states must complete a source water assessment (SWA) for public water systems by 2003. A SWA document is prepared to determine the existence of PCSs, to determine the appropriate monitoring needed, to inform the public, and to assist in the development of watershed protection programs. The DWSAP Program presents a set of standardized procedures for conducting a SWA. The DHS allows watershed sanitary surveys, like the *Sanitary Survey Update Report 2001*, as alternative methods of determining a water source's vulnerability.

While its requirements are similar, *Sanitary Survey Update Report 2001* contains more information than a SWA. Because of the vast size of the SWP, many subwatersheds interconnect with it. The major tasks of developing this sanitary survey consisted of separate assessments for each of the subwatersheds selected for inclusion. The DWSAP Program assessment and vulnerability summary of sources that are part of the SWP may be based on the information contained in this *Sanitary Survey Update.*

DHS will use the *Sanitary Survey Update Report 2001* as the basis of the DWSAP Program's source water assessment for SWP facilities and for the preparation of vulnerability summaries for those facilities. DHS will work with contractors and water utilities to complete the SWAs. Water utilities then will be required to include information about the assessments and vulnerability summary language in their Consumer Confidence Reports (Walker pers. comm).

There are 6 information requirements that SWP contractors will be required to supply for their DWSAP Program assessments. Contractors will prepare their own DWSAP Program assessments for DHS, based on *Sanitary Survey Update 2001* information, to include the following:

1) Location of Supply Source.
2) Delineation of Source Areas and/or Protection Zones—Watershed will be designated as the source area/protection zone. This sanitary survey will provide the detailed information on the watershed, so each contractor's SWA can refer to the *2001 Sanitary Survey Update Report*.
3) Evaluation of Physical Barrier Effectiveness—DHS will provide standard language on this.
4) Inventory of Possible Contaminating Activities—This is identified in the *2001 Sanitary Survey Update Report.* Water contractors can refer to the update and provide limited description in DWSAP Program document.
5) Vulnerability Ranking—After review of raw water quality data provided by DWR and the water contractors, a consistent approach for each contractor to use in assessing vulnerability will be developed.
6) Assessment Map—*2001 Sanitary Survey Update Report* contains maps of watershed showing major land uses pipelines, any intakes, etc.

Reference

PERSONAL COMMUNICATION

Walker, Leah, Senior Engineer, Department of Health Services, Drinking Water Program. 1999. E-mail to Mike Zanoli, DWR. Nov 23.

Contents

Tables

2

Regulatory Overview

This chapter presents an overview of the following items.

- National and California Department of Health Services (DHS) regulations for treated drinking water and monitoring during the survey period 1996-2000.
- Recent and proposed rules as of February 2001.
- Drinking water quality concerns related to Delta water supplies and contaminants of recent public concern.

Following are abridged excerpts and edited material from federal and State agency publications. Further detailed information about current and proposed drinking water-related rules can be obtained from the Web sites of the US Environmental Protection Agency Office of Water (www.epa.gov/safewater) and DHS (www.dhs.ca.gov/ps/ddwem).

2.1 DRINKING WATER REGULATIONS

2.1.1 PRIMARY AND SECONDARY MCLS AND ACTION LEVELS

There are many contaminants that may be present in source water before it is treated. At certain concentrations, some contaminants can cause harm to human health while others—for example, bromide—can make it difficult for treatment plants to meet treated drinking water standards for disinfection byproducts such as trihalomethanes. These contaminants can be grouped into 5 classes:

1) Inorganic contaminants such as mineral salts and metals from either natural sources or from wastewater discharges, urban storm water runoff, mining, agriculture, and home uses.
2) Organic chemical contaminants such as synthetic and volatile organic chemicals, from manufacturing, petroleum refineries, gasoline and septic tanks, and urban runoff.
3) Agricultural and landscape chemicals (organic and inorganic) such as pesticides and herbicides from farms, homes, and urban drainages.
4) Microbial contaminants such as bacteria and viruses, from septic tanks, sewage treatment plants, livestock, and wildlife.
5) Radioactive materials from natural and industrial sources, for example, mining.

Congress passed the Safe Drinking Water Act (SDWA) of 1974 to set drinking water standards for the protection of human health. The act was amended in 1986 and 1996 to meet additional concerns about unregulated drinking water contaminants.

The major points of the SDWA follow:

- Authorizes the US Environmental Protection Agency (EPA) to set enforceable health standards—for example, maximum contaminant levels (MCLs)—for drinking water contaminants;
- Requires public notification of water systems' violations and annual reports to consumers on the levels of contaminants in their drinking water;
- Establishes a federal-state partnership for enforcement of regulations;
- Includes provisions to protect underground drinking water sources;
- Requires disinfection of surface water and, as necessary, groundwater used for drinking;
- Requires filtration of all surface water supplies except those with pristine, protected sources;
- Establishes a state revolving loan fund for water system improvements; and
- Requires an assessment of all drinking water sources' vulnerability to contamination.

California is a "primacy" state that implements the federal SDWA on behalf of the EPA. California develops and implements its own drinking water standards that must be at least as stringent as federal standards.

The national and California primary drinking water standards, or MCLs, are presented in Tables 2-1 and 2-2, which list MCLs, potential health effects from exposure above the MCL, and common sources of each contaminant in drinking water. Primary MCLs are enforceable regulatory levels under the SDWA and must be met by all public drinking water systems to which they apply. DHS added contaminants to the list and lowered some MCLs.

California has 78 chemical and 6 radioactive contaminants that have primary MCLs. The list of primary MCLs are covered in Title 22 California Code of Regulations (CCR) for inorganic chemicals (§ 64431), trihalomethanes (§ 64439), radioactivity (§ 64441 and § 64443), and organic chemicals (§ 64444). Specific regulations for lead and copper levels at customer taps and in the water distribution system are stated in Title 22 CCR § 64670.

Table 2-1 National and California Primary Drinking Water Standards for Inorganic Chemicals

National Primary MCLs and California Dept. of Health Services (DHS) MCLs are same unless noted. For some contaminants DHS has either established lower MCLs for California or set MCLs not set by EPA.

Contaminant	MCL[a] or TT [b] (mg/L)	Possible Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
Aluminum	1	May be linked to Alzheimer's disease and other dementia; neurotoxic	Discharges from waste sites, manufacturing plants naturally high areas, or
Antimony	0.006	Increase in blood chlolesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0.05 0.01 *effective* 22 Feb 2002*	Skin damage; circulatory system problems; increased risk of cancer	Erosion of natural deposits; runoff from orchards; runoff from glass and electronics production wastes
Asbestos (fibers >10 micrometers)	7 million fiberg per liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2 1 (DHS)	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1 0.05 (DHS)	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	Action Level=l.3; TT[c]	Short term exposure: Gastrointestinal disorders. Long term exposure: Liver or kidney damage. Those with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories

Table 2-1 (continued)

Contaminant	MCL[a] or TT [b] (mg/L)	Possible Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
Fluoride	4.0 2.0 (DHS)	Bone disease (pain and tenderness of the bones) Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	Action Level=0.015; TT[c]	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nickel	0.1 (DHS)	Animal laboratory studies showed genotoxic and carcinogenic effects	Discharges from electroplating plants and metals and machinery manufacturing plants
Nitrate (measured as Nitrogen) Nitrate (measured as Nitrate) Nitrate + Nitrite (measured as sum of Nitrogen)	10 45 (DHS) 10 (DHS)	Infants below the age of 6 months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	Infants below the age of 6 months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites discharge from electronics, glass, and drug factories

Sources: EPA, Office of Water (4606), National Primary Drinking Water Standards, EPA 810-F-94-001, Dec 1999. DHS, MCLs, Action Levels, and Unregulated Chemicals Requiring Monitoring, Updated 13 Nov 2000 http://www.dhs.ca.gov/ps/ddwem/chemicals/MCL/mclindex.htm

[a] Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

[b] Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water,

[c] Lead and copper are regulated using a Treatment Technique that requires systems to control the corrosiveness of their water. The action level serves as a trigger for water systems to take additional treatment steps if exceeded in more than 10% of tap water samples. For copper, the action level is 1.3 mg/L; for lead, 0.015 mg/L.

Table 2-2 National and California Primary Drinking Water Standards for Organic Chemicals, Radionuclides, and Microorganisms

Contaminant	MCL[a] or TT [b] (mg/L)	Potential Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
		Organic Chemicals	
Acrylamide	TT	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor (Alanex)	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine (Aatrex)	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Bentazon (Basagran)	0.018 (DHS)		
Benzene	0.005 0.001 (DHS)	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran (Furadan)	0.04 0.018 (DHS)	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	0.005 0.0005 (DHS)	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	0.002 0.0001 (DHS)	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene (Monochlorobenzene)	0.1 0.07 (DHS)	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
(2,4-Dichlorophenoxy)acetic Acid (2,4-D)	0.07	Kidney, liver, or adrenal gland problems	Herbicide use
Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
l,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene (o-DCB)	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene (p-DCB)	0.075 0.005 (DHS)	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,1-Dichloroethane (1,1-DCA)	0.005	Possible human carcinogen	Discharge from industrial chemical factories
l,2-Dichloroethane (1,2-DCA)	0.005 0.0005 (DHS)	Increased risk of cancer	Discharge from industrial chemical factories
1-1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories

Table 2-2 (continued)

Contaminant	MCL[a] or TT [b] (mg/L)	Potential Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
cis-l, 2-Dichloroethylene	0.07 0.006 (DHS)	Liver problems	Discharge from industrial chemical factories
trans-l,2-Dichloroethylene	0.1(DHS)	Liver problems	Discharge from industrial chemical factories
Dichloromethane (Methylene chloride)	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
l-2-Dichloropropane (Propylene dichloride)	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	General toxic effects or reproductive difficulties	Discharge from chemical factories
Di(2-ethylhexyl) phthalate (DEHP)	0.006 0.004 (DHS)	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	TT	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene (Phenylethane)	0.7	Liver or kidneys problems	Discharge from petroleum refineries
Ethylene dibromide (EDB)	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	0.0004 0.00001 (DHS)	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	0.0002 0.00001 (DHS)	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachloro-cyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories

Table 2-2 (continued)

Contaminant	MCL[a] or TT [b] (mg/L)	Potential Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
Lindane (gamma-BHC)	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	Reproductive difficulties	Runoff leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Molinate (Ordram)	0.02 (DHS)	Under study	Rice herbicide applications and draining rice fields
Methyl tert-Butyl Ether (MTBE)	0.013 (DHS)	Under study	Leaking underground storage tanks and pipelines, spills, emissions from gasoline marine engines, and air deposition
Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories
Picloram	0.5	Liver problems	Herbicide runoff
Simazine (Princep)	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
1,1,2,2-Tetrachloroethane	0.001 (DHS)		
Tetrachloroethylene (PCE)	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Thiobencarb (Bolero)	0.07 (DHS)		Discharge from rice fields
Toluene (Methylbenzene)	10.15 DHS	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfections
Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP(Silvex)	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene (Unsym-Trichlorobenzene)	0.07 (DHS)	Changes in liver, kidneys, and adrenal glands.	Discharge from textile finishing factories.
1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories

Table 2-2 (continued)

Contaminant	MCL[a] or TT [b] (mg/L)	Potential Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
1,1,1- Trichloroethane (1,1,1-TCA)	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2- Trichloroethane (1,1,2-TCA)	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene (TCE)	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Trichlorofluoro-methane (Freon 11)	0.15 (DHS)	Effects on central nervous system	Discharge from metal cleaning sitres.
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	1.2 (DHS)	Effects on central nervous system	Discharge from metal cleaning sitres
Vinyl chloride	0.002 0.0005 (DHS)	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total) Single isomer or sum of isomers	10 1.75 (DHS)	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories
		Radionuclides	
Beta particles and photon emitters	4 millirems per year (mrem/yr)	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation
Gross beta particle activity	50 picocuries per liter (pCi/L)(DHS)		
Gross alpha particle activity	15 (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of naural deposits
Strontium-90	8 pci/L (DHS)	Increased risk of cancer	Erosion of natural deposits
Tritium	20,000 pCi/L (DHS)	Increased risk of cancer	
Uranium	20 pCi/L (DHS) 0.03 mg/L *effective* 8 Dec 2003	Increased risk of cancer	
		Microorganisms	
Giardia lamblia	TT[c]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

Table 2-2 (continued)

Contaminant	MCL[a] or TT [b] (mg/L)	Potential Health Effects from Exposure Above the MCL	Common Sources of Contaminants in Drinking Water
Heterotrophic plate count (HPC)	TT[c]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that is common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system.	HPC measures a range of bacteria that are naturally present in the environment
Legionella	TT[c]	Legionnaire's Disease, a type of pneumonia[d]	Found naturally in water, multiplies in heating systems
Total Coliforms (including fecal coliform and *E. coli*)	5.0% [e]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.	Total coliforms are naturally present in the environment; fecal coliforms and *E. coli* come from human and animal fecal waste.
Turbidity	TT[c]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease- causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	TT[c]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

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[a] Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

[b] Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.

[c] The Surface Water Treatment Rule requires systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or provide the same level of treatment as those who filter. Treatment must reduce the levels of *Giardia lamblia* (parasite) by 99.9%.and viruses by 99.99%. *Legionella* (bacteria) has no limit, but EPA believes that if *Giardia* and viruses are inactivated, *Legionella* will also be controlled. At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU) [systems that filter must ensure that the turbidity is no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples for any single month]; HPC- no more than 500 bacterial colonies per milliliter.

[d] Legionnaire's disease occurs when aerosols containing *Legionella* are inhaled by susceptible persons, not when people drink water containing *Legionella.* Aerosols may come from showers, hot water taps, whirlpools and heat rejection equipment such as cooling towers and air conditioners. Some types of *Legionella* can cause a type of pneumonia called Legionnaire's Disease. *Legionella* can also cause a much less severe disease called Pontiac Fever. The symptoms of Pontiac Fever may include muscle pain, headache, coughing, nausea, dizziness, and other symptoms.

[e] No more than 5.0% of samples may be total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample may be total coliform-positive during a month). Every sample that has total coliforms must be analyzed for either *E. coli* or fecal coliforms to determine whether human or animal fecal matter is present (fecal coliform and *E. coli* are part of the total coliform group).

[f] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

Secondary MCLs, which are set for taste, odor, or appearance of drinking water, are in Title 22 CCR § 64449. Seventeen chemicals or characteristics have secondary MCLs (Table 2-3). Under federal law, secondary MCLs are not enforceable, but California secondary MCLs are enforceable.

Table 2-3 Secondary MCLs

DHS established secondary MCLs for characteristics or constituents and address taste, odor, or appearance of drinking water. Three contaminants have both primary and secondary MCLs: aluminum, MTBE, and thiobencarb.

Chemical or characteristic	Secondary MCL
Aluminum (primary MCL 1 mg/L)	0.2 mg/L
Color	15 units
Copper	1.0 mg/L
Corrosivity	Noncorrosive
Foaming agents (MBAS)	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Methyl tertiary butyl ether (MTBE) (primary MCL 0.013 mg/L)	0.005 mg/L
Odor-threshold	3 units
Silver	0.1 mg/L
Thiobencarb (Bolero) (primary MCL 0.07 mg/L)	0.001 mg/L
Turbidity	5 units
Zinc	5.0 mg/L

	Secondary MCL Ranges		
Constituent	Recommended	Upper	Short Term
Total dissolved solids (TDS)	500 mg/L	1000 mg/L	1500 mg/L
Specific conductance	900 µmhos	1600 µmhos	2200 µmhos
Chloride	250 mg/L	500 mg/L	600 mg/L
Sulfate	250 mg/L	500 mg/L	600 mg/L

Table 2-4 Drinking Water Action Levels for DHS Contaminants of Current Interest

These 15 action level contaminants have been detected in and near water supplies, or are otherwise of current interest to the California Department of Health Services. Updated 9 Jan 2001 from www.dhs.ca.gov

Contaminant	Action Level (mg/L)	Number of positives of number sampled (1984 to Nov 2000)
Boron[a]	1	2,002 of 2,685
Perchlorate	0.018[b]	186 of 2,128
Vanadium[a]	0.015	30 of 69
sec-Butylbenzene	0.26	0 of 10,451
tert-Butylbenzene	0.26	1 of 10,449
2-Chlorotoluene	0.14	1 of 10,467
Dichlorodifluoromethane[a]	1	119 of 14,656
1,4-Dioxane	0.003	0 of 116
Isopropylbenzene (Cumene)	0.77	3 of 10,453
Methyl isobutyl ketone (MIBK)	0.12	0 of 10,197
N-Nitrosodimethylamine (NDMA)	0.00002[c]	0 of 1,229
n-Propylbenzene	0.26	2 of 10,454
Tertiary butyl alcohol[a]	0.012	0 of 0
1,2,3-Trichloropropane[a]	0.000005	25 of 10,466
Napthalene	0.017[d]	4 of 10,544

[a] Updated – Chemical is an unregulated chemical requiring monitoring (Title 22 CCR §64450).
[b] Recommended source removal is greater than 0.04 mg/l for perchlorate.
[c] NDMA AL is 10^{-5} risk and source removal requirement recommendation at greater than 0.0002 mg/L, or 10^{-4} risk.
[d] Established in 2000.

DHS has established action levels (ALs), which are based on health advisory levels for contaminants that have no primary MCLs. The ALs are not enforceable standards, but exceeding them prompts statutory requirements and recommendations by DHS for consumer notice. At higher levels, source removal may be recommended. DHS has 44 ALs—15 for contaminants of current interest (Table 2-4) and 29 for contaminants of historic interest (Table 2-5). The current interest ALs are for contaminants that have been detected in or near water supplies, or otherwise of interest to DHS. Historical interest ALs were developed in the 1980s and 1990s but have been rarely detected. They were developed to address potential contamination of drinking water supplies from hazardous wastes or actual cases of spillages or contamination.

As of December 2000, there were 52 unregulated chemicals that were or may have been required to be monitored, depending on the vulnerability of the drinking water source (Title 22 CCR § 64450). They are listed in Table 2-6. MTBE was added to the unregulated monitored chemicals list in 1997, but a secondary MCL was set in January 1999 and a primary MCL was later set in May 2000. There are no drinking water standards for some of the unregulated chemicals.

The detection limits for purposes of reporting (DLRs) are listed in Title 22 CCR § 64432 and § 64445.1. The DLR is the analytical detection level at which DHS is confident about the quantification of the chemical contaminant's presence in drinking water supplies.

Table 2-5 Drinking Water Action Levels for DHS Contaminants of Historical Interest

Historical action levels (ALs) were established in the 1980s and 1990s, but these contaminants have rarely been detected. Generally, these ALs were developed in anticipation of possible contamination sources (for example, hazardous waste site) or actual events (for example, spillages). Updated 9 Jan 2001 from www.dhs.ca.gov

Contaminant	Action Level (mg/L)	Number positives of number sampled (1984 – November 2000)
Aldicarb (Temik)	0.007	0 of 5,243
Aldrin	0.000002	0 of 5,314
Baygon	0.03	0 of 0
a-Benzene Hexachloride (a-BHC)	0.000015	0 of 1,768
b-Benzene Hexachloride (b-BHC)	0.000025	0 of 1,790
n-Butylbenzene	0.07 [a]	2 of 10,401
Captan	0.0015	0 of 1,240
Carbaryl	0.7	0 of 5,456
Chloropicrin	0.050 (0.037)[b]	0 of 1,479
4-Chlorotoluene	0.14	0 of 10,467
Diazinon	0.006	1 of 1,7124
1,2-Dichlorobenzene	0.6 (0.010)[c]	2 of 14,681
1,3-Dichlorobenzene	0.6 (0.010)[c]	3 of 14,681
Dieldrin	0.000002	0 of 4,988
Dimethoate	0.001	0 of 6,263
2,4-Dimethylphenol	0.1	0 of 1,184
Diphenamide	0.2	0 of 1,184
Ethion	0.004	0 of 583
Formaldehyde	0.1	0 of 16
Isopropyl-N-(3-chlorophenyl) carbamate	0.035	0 of 0
Malathion	0.16	0 of 915
N-Methyl dithiocarbamate (Metam sodium)	0.02[d]	0 of 0
Methylisothiocyanate (MITC)	0.05[d]	0 of 0
Methyl parathion	0.002	0 of 540
Parathion	0.04	0 of 1,485
Pentachloronitrobenzene	0.02	0 of 0
Phenol	4.2 (0.005)[e]	0 of 1,191
2,3,5,6-Tetrachloroterephthalate	3.5	0 of 0
Trithion	0.007	0 0f 0

[a] Revised from 0.045 in 2000.
[b] Taste and odor threshold.
[c] Taste and odor threshold either for a single isomer or the sum of 2 isomers.
[d] Calculated by using standard risk assessment methods but using the child as the endpoint of concern (10 kg body weight, 1 liter per day DWC) and 1.0 RSC.
[e] Taste and odor threshold for chlorinated systems.

Table 2-6 California DHS Unregulated Chemicals Requiring Monitoring, Prior to 3 Jan 2001

List A Unregulated Organic Chemicals

Chemical	Synonym
Bromobenzene	Monobromobenzene
Bromodichloromethane	Dichlorobromomethane
Bromoform	Tribromomethane
Bromomethane	Methyl Bromide
Chlorodibromomethane	Dibromochloromethane
Chloroethane	Ethyl Chloride
Chloroform	Trichloromethane
Chloromethane	Methyl Chloride
2-Chlorotoluene	0-Chlorotoluene
4-Chlorotoluene	p-Chlorotoluene
Dibromomethane	Methylene Bromide
1,3-Dichlorobenzene	m-Dichlorobenzene
Dichlorodifluoromethane	Difluorodichloromethane
1,3-Dichloropropane	
2,2-Dichloropropane	
1,2-Dichloropropene	
1,1,1,2-Tetrachloroethane	
1,2,3-Trichloropropane	Allyl Trichloride

List B Unregulated Organic Chemicals

Chemical	Synonym
Bromacil	HYVAR X, HYVAR XL
Bromochloromethane	Chlorobromomethane
n-Butylbenzene	1-Phenylbutane
Sec-Butylbenzene	2-Phenylbutane
Tert-Butylbenzene	2-Methyl-2-phenylpropane
Chlorothalonil	BRAVO
Dimethoate	CYGON
Diuron	KARMEX, KROVAR
Ethyl-tert-butyl ether	ETBE
Hexachlorobutadienne	Perchlorobutadiene
Isopropylbenzene	Cumene
p-Isopropylbenzene	p-Cymene
Methyl-tert-butyl ether[a]	MTBE
Napthalene	Napthalin
1-Phenylpropane	n-Propylbenzene
Prometryn	CAPAROL
Tert-Amyl-methyl ether	TAME
1,2,3-Trichlorobenzene	Vis Trichlorobenzene
1,2,4-Trimethylbenzene	Pseudocumene
1,2,5-Trimethylbenzene	Mesitylene

Source: 1 Jan 2000, 7th edition, Title 22 of the California Code of Regulations, Tables 64450-A,B,C,D

[a] Monitoring required only for nontransient-noncommunity water systems.

List C Unregulated Organic Chemicals

Chemical	Synonyms
Aldicarb	
Aldicarb sulfone	
Aldicarb sulfoxide	
Aldrin	Aldrec, Aldron
Butachlor	Butanex, Lambast, Machete
Carbaryl	Sevin
Dicamba	Banex, Banvel, Dianat
Dieldrin	
3-Hydroxycarbofuran	
Methomyl	Lannate
Metolachlor	Metelilachlor
Metribuzin	Lexone, Sencor, Sencoral
Propachlor	Albrass, Ramrod

List D Unregulated Inorganic Chemical

Chemical	Synonym
Perchlorate	

Community and nontransient-noncommunity water systems shall monitor for the unregulated chemicals at 5-year intervals by collecting source water samples, or samples from the distribution entry points which are representative of typical operating conditions. For chemicals in Tables 64450-A and 64450-B, surface water systems shall collect 1 year of quarterly samples at each sampling site and groundwater systems shall collect a minimum of 1 sample per sampling site. For chemicals in Tables 64450-C and 64450-D, both surface and groundwater systems shall collect 4 consecutive quarterly samples at each sampling site. For the chemicals ETBE, TAME, and perchlorate, systems may use monitoring data collected any time after 1 January 1993 for sampling sites to meet the initial monitoring requirements. For additional requirements and updates, refer to the latest Title 22 Code of Regulations.

2.1.2 TOTAL COLIFORM RULE

The 1986-amended SDWA required EPA to review the existing standard for total coliform bacteria. EPA reexamined the standard and in November 1987 proposed a new rule. The Total Coliform Rule (TCR) became final in June 1989 and effective 31 December 1990. The rule sets a maximum contaminant level goal (MCLG) for total coliform (including fecal coliform and *E. coli)* of zero and an MCL based on the presence or absence of total coliforms. Monitoring requirements relative to number of monthly samples are based on population served by a community system. For systems that analyze fewer than 40 samples per month, no more than 1 sample per month may be positive for total coliforms.

Routine samples are to be collected from drinking water taps at regular time intervals throughout the month. If a routine sample is positive for total coliforms, the water system must collect a set of repeat samples (3 samples) within 24 hours of being notified of the positive sample:

- One of the repeat samples must be from the same tap as the positive sample,
- One repeat sample must be from a site within 5 service connections upstream of the positive site, and
- One repeat sample must be within 5 service connections downstream of the positive site.

If 1 or more of the repeat samples is coliform-positive, the utility must collect an additional set of repeat samples. All repeat samples are to be collected on the same day. The system operator must repeat this process until no coliforms are detected or be in violation of the coliform rule.

Routine or repeat coliform-positive samples must be analyzed for the presence of fecal coliforms and/or *E. coli*. A laboratory must notify the water system operator within 24 hours after the presence of total coliforms, fecal coliforms or *E. coli* is demonstrated or after a sample is invalidated because of interference problems.

The federal TCR is found in the California Code of Regulations under Title 22, Chapter 15, Article 3. Water system operators were to develop and submit to DHS a sample siting plan for coliform bacteria by 1 September 1992. The sample sites must be representative of water throughout the distribution system, including all pressure zones, and areas supplied by each water source and distribution reservoirs. An updated plan must be submitted to DHS every 10 years. If a system has identified more sample locations than is required, the system can rotate sampling among these sites. California regulations do not state that sample siting plans must be approved by DHS.

- The MCL for total coliforms is as follows:
- For a system collecting more than 40 samples per month, no more than 5.0% of the collected samples may be total coliform-positive.
- For systems collecting fewer than 40 samples per month, a nonacute violation occurs when there is more than 1 positive coliform sample in a given month.

A fecal coliform-positive repeat sample or *E. coli*-positive repeat sample or a total coliform-positive repeat sample, following a fecal coliform or *E. coli*-positive routine sample, constitutes an acute violation of the MCL for total coliforms.

If a system exceeds the MCL for total coliforms, the system operator must notify DHS by the end of the business day when the violation was determined. If the determination is made after the DHS offices close, notification must be made within 24 hours and the system operator must give public notification.

If DHS notifies a system operator that there has been a “significant rise in bacterial count,” the system operator must implement an emergency notification plan. California drinking water regulations define a significant rise in bacterial count as “. . . an increase in coliform bacteria . . . when associated with a suspected waterborne illness or disruption of physical works or operating procedures.” These State regulations list 3 criteria that could indicate a “significant rise in bacterial count”:

1) A system collecting at least 40 samples per month has a total coliform-positive routine sample followed by 2 total coliform-positive samples in the repeat sample set; or
2) A system has a sample that is positive for fecal coliform or *E. coli*; or
3) A system fails the total coliform MCL.

If any of the above criteria exist, the system operator must contact the State by the end of the day or within 24 hours of the result indicating the system exceeded the MCL. The system operator also must submit to DHS information on the current status of the physical works and operating procedures that may have caused the elevated level of bacteria.

A surface water system, or a groundwater system under the influence of surface water, not practicing filtration in compliance with the Surface Water Treatment Rule (SWTR), must collect at least 1 sample near the 1st service connection each day turbidity level of the source water exceeds 1 NTU.

A water system operator can apply for a variance from the total coliform MCL. California regulations include specific criteria to determine if an MCL violation is due to a persistent growth of total coliforms in the distribution system rather than to fecal or pathogenic contamination, a treatment lapse or deficiency, or a problem in the operation or maintenance of the distribution system. California regulations provide criteria a system must meet in order to receive a variance because of coliform regrowth in the distribution system.

2.1.3 SURFACE WATER TREATMENT RULE

The general requirements of the SWTR are to provide treatment to ensure at least " . . . 99.9% (3-log) removal and/or inactivation of *Giardia lamblia* cysts . . . " and at least ". . . 99.99% (4-log) removal and/or inactivation of viruses."

Under the federal SWTR, filtering systems must meet several specific requirements for disinfection and turbidity. Following are the turbidity requirements for conventional filtration systems:

- "The turbidity of representative samples of a system's filtered water must be less than or equal to 0.5 NTU in at least 95% of the measurements taken each month. . . . except that if the State determines that the system is capable of achieving at least 99.9% removal and/or inactivation of *Giardia lamblia* cysts at some turbidity level higher than 0.5 NTU."
- "The turbidity level of representative samples of a system's filtered water must at no time exceed *5* NTU. . . ."

Turbidity measurements are to be performed on representative samples of the system's filtered water every 4 hours (or more frequently). Continuous monitoring can be substituted for grab sampling, if the system validates the continuous measurement for accuracy on a regular basis. Following are the federal SWTR disinfection requirements for systems that filter:

- "The disinfection treatment must be sufficient to ensure that the total treatment processes of that system achieve at least 99.9% (3-log) inactivation and/or removal of Giardia lamblia cysts and at least 99.99% (4-log) inactivation and/or removal of viruses, as determined by the State."
- "The residual disinfectant concentration in the water entering the distribution system . . . cannot be less than 0.2 mg/L for more than 4 hours."
- "The residual disinfectant concentration in the distribution system, measured as total chlorine, combined chlorine, or chlorine dioxide, as specified in 141.74(a)(5) and (c)(3), cannot be undetectable in more than 5% of the samples each month, for any 2 consecutive months that the system serves water to the public. Water in the distribution system with a heterotrophic bacteria concentration less than or equal to 500/mL, measured as heterotrophic plate count (HPC) . . . is deemed to have a detectable disinfectant residual for purposes of determining compliance with this requirement."

The lowest value of disinfectant residual entering the distribution system shall be recorded each day. The residual disinfectant concentration shall be measured at the same points and at the same time that total coliforms are sampled.

The California SWTR is much more detailed and prescriptive than the federal SWTR. To meet the basic 3-log *Giardia* and 4-log virus reduction requirements, utilities must meet the filtration and disinfection performance standards described above. The California SWTR provides design standards for new treatment plants or modifications to existing treatment plants that require permit approval. These design standards include an average daily effluent turbidity goal of 0.2 NTU when using conventional, direct, and diatomaceous earth filtration, provision of filter-to-waste or addition of coagulant chemical to water used for backwashing, among other provisions. System operators must also provide reliability features such as alarm devices, standby replacement equipment, continuous turbidity monitoring, and multiple filter units to replace filter units that fail or are out of service.

The California SWTR also provides maximum flow rates for different filtration treatment plants. DHS can approve higher flow rates if a system demonstrates it can continue to meet SWTR performance requirements at the higher flow rates. When any individual filter in a conventional or direct filtration plant is returned to service following backwashing (or other interruption), the filtered water from that filter shall not exceed any of the following:

- 2.0 NTU;
- 1.0 NTU in at least 90% of the interruption events during any 12-month period; or
- 0.5 NTU after the filter has been in operation for at least 4 hours.

Coagulation and flocculation unit processes are to be used at all times when conventional or direct filtration plants are in operation. The effectiveness of these processes is to be demonstrated by either: at least an 80% reduction through the filters of the monthly average raw water turbidity; or jar testing, pilot testing, or other means to demonstrate that optimum coagulation is being achieved.

Utilities are required to have a DHS-approved operations plan and must report to DHS within 24 hours after any of the following occurs:

- Turbidity of combined filter effluent exceeds 5.0 NTUs at any time;
- More than 2 consecutive turbidity samples of combined filter effluent taken every 4 hours exceeds 1.0 NTU;
- A failure to maintain the 0.2 mg/L disinfectant residual in water being delivered to distribution system (and whether the residual level was restored within 4 hours); or
- An event that could affect the ability of the treatment plant to produce safe, potable water (including, but not limited to spills of hazardous materials and unit treatment process failures).

2.2 RECENT AND PROPOSED RULES

The following information includes updates as of February 2001.

2.2.1 ARSENIC RULE

The SDWA requires EPA to revise the existing 50 parts per billion (ppb) standard for arsenic in drinking water. In January 2001, EPA published a new standard for arsenic in drinking water that would require public water supplies to reduce arsenic to 10 ppb by 2006. EPA is reviewing this standard so that communities that need to reduce arsenic in drinking water can proceed with confidence that the new standard is based on sound science and accurate cost and benefit estimates.

On 19 July 2001, EPA issued a proposal to request comment on whether data and technical analyses associated with the January 2001 arsenic rule support setting the arsenic standard at 3 ppb, 5 ppb, 10 ppb, or 20 ppb. In addition, the agency asks commenters to submit new information for review. The July 2001 notice summarizes 1) the January 2001 arsenic regulations; 2) changes to the effective date; 3) ongoing analyses of health data, cost of compliance estimates, and benefits; and 4) the review of small system implementation issues, including affordability, availability of financial assistance, treatment options, and extended compliance schedules. In fall 2001, EPA is to publish another notice requesting public comment on the reviews that are under way.

The Final Rule for Arsenic in Drinking Water revised the current MCL from 50 µg/L to 10 µg/L and set an MCLG of zero for arsenic in drinking water (EPA 2001). In addition, the rule clarified how compliance is demonstrated for many inorganic and organic contaminants in drinking water.

Both community water systems (CWSs) and nontransient, noncommunity water systems (NTNCWSs) will be required to reduce the arsenic concentration in their drinking water systems to the new MCL. A CWS is a public water system that serves at least 15 locations or 25 residents regularly year round, for example, most cities and towns, apartments, and mobile home parks with their own water supplies. A NTNCWS is a public water system that is not a CWS and serves at least 25 of the same people more than 6 months of the year, for example, schools, churches, nursing homes, and factories.

This final rule also clarified 2 compliance requirements for inorganic contaminants (IOCs), volatile organic contaminants (VOCs), and synthetic organic contaminants (SOCs). When a system fails to collect the required number of samples, compliance averages will be based on the actual number of samples collected. Also, new public water systems and systems using new sources of water must demonstrate compliance within State-specified time and sampling frequencies.

All CWSs and all NTNCWSs that exceed the new MCL will be required to come into compliance by 22 January 2006. Beginning with reports that are due as specified in the new rule, all CWSs will begin providing health information and arsenic concentrations in their annual consumer confidence report (CCR) for water that exceeds one-half of the new MCL.

There has been 2 extensions for the arsenic rule's effective date. In accordance with the 20 January 2001 memorandum from Andrew Card, assistant to the President and Chief of Staff, titled "Regulatory Review Plan," EPA temporarily delayed the effective date for this rule for 60 days, from 23 March 2001 until 22 May 2001. The delay of the effective date was published 23 March 2001. On 23 April, EPA requested public comment on a proposal to delay the effective date for the rule until 22 February 2002. On 22 May, EPA announced that it would delay the effective date for the rule until 22 February 2002, allowing time to complete the reassessment process outlined above and to give the public a full opportunity to provide input.

2.2.2 STAGE 1 DISINFECTANTS AND DISINFECTION BYPRODUCT RULE

In addition to meeting national and State MCLs for treated drinking water, SWP water utilities that use Sacramento/San Joaquin Delta water are concerned about several source water constituents in their water supplies. The Delta is a tidally influenced estuary that is subject to seawater intrusion. It also receives large amounts of agricultural drainage, natural and urban runoff, and municipal wastewater discharges.

Delta source water is high in bromide and total organic carbon (TOC) compared to other drinking water sources.

This poses significant challenges to water utilities in meeting drinking water standards for disinfection byproducts (DBPs) such as trihalomethanes and bromate, depending on the treatment method.

The disinfectants themselves can react with naturally occurring materials in the water to form unintended byproducts that may pose human health risks. Some pathogens, like *Cryptosporidium*, are resistant to traditional disinfection practices. Amendments in 1996 to the SDWA require EPA to develop rules to balance the risks between microbial pathogens and DBPs. The Stage 1 Disinfectants and Disinfection Byproducts (D/DBP) Rule and Interim Enhanced Surface Water Treatment Rule (IESWTR) were announced in December 1998.

The Stage 1 D/DBP Rule applies to all community water systems and NTNCWSs that treat water with a chemical disinfectant for either primary or residual treatment. The rule (Table 2-7) sets maximum residual disinfectant level goals (MRDLGs) and maximum residual disinfectant levels (MRDLs) for 3 chemical disinfectants: chlorine, chloramine, and chlorine dioxide. It also establishes MCLGs and MCLs for total trihalomethanes, haloacetic acids, chlorite and bromate.

Table 2-7 Stage 1 Disinfectants and Disinfection Byproducts Rule Maximum Levels

Updated 26 April 2000 from www.epa.gov/safewater/mdpb/dbp1.html

Disinfectant Residual	MRDLG[a] (mg/L)	MRDL[b] (mg/L)	Compliance based on
Chlorine	4 (as Cl_2)	4.0 (as Cl_2)	Annual average
Chloramine	4 (asCl_2)	4.0 (as Cl_2)	Annual average
Chlorine dioxide	0.8 (as ClO_2)	0.8 (as ClO_2)	Daily samples

Disinfection Byproducts	MCLG (mg/L)	MCL (mg/L)	Compliance based on
Total trihalomethane (TTHM)[c]	N/A	0.080	Annual average
Chloroform			
Bromodichloromethane	0		
Dibromochloromethane	0		
Bromoform	0.06		
Haloacetic acids (five) (HAA5)[d]	N/A	0.060	Annual average
Dichloroacetic acid	0		
Trichloroacetic acid	0.3		
Chlorite	0.8	1.0	Monthly average
Bromate	0	0.010	Annual average

[a] Maximum residual disinfectant level goal.

[b] Maximum residual disinfectant level.

[c] TTHM is sum concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

[d] HAA5 is the sum concentration of mono-,di-, and trichloroacetic acids and mono- and dibromoacetic acids.

Table 2-8 Required Total Organic Carbon Removal by Enhanced Coagulation and Enhanced Softening[a]

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

[a] Systems meeting at least 1 of the alternative compliance criteria in the rule are not required to meet removals in this table.

[b] Systems practicing softening must meet the TOC removal requirement in the last column to the right.

In addition, water systems that use surface or groundwater under the direct influence of surface water and use conventional treatment are required to remove specified percentages of TOC prior to adding disinfectants (Table 2-8). Removal to be achieved through a treatment technique (enhanced softening or coagulation) unless the water system meets alternative criteria. On 16 January 2001, the EPA officially revised the compliance date for large surface water public water systems (PWSs) to meet the Stage 1 D/DBP Rule and IESWTR from December 2001 to January 2002.

2.2.3 LONG TERM 1 ENHANCED SURFACE WATER TREATMENT RULE

Primary purposes of IESWTR are to improve microbial control, especially *Cryptosporidium*, and guard against microbial risk because of the Stage 1 D/DBP Rule. The final IESWTR provisions include the following:

- MCLG of zero for *Cryptosporidium*;
- 2-log *Cryptosporidium* removal requirements for systems that filter;
- Strengthened performance standards and individual filter turbidity monitoring provisions;
- Disinfection benchmark provisions to assure continued levels of microbial protection while facilities take necessary steps to comply with new disinfection byproduct standards;
- Inclusion of *Crytosporidium* in the definition of groundwater under direct influence (GWUDI) of surface water and additional avoidance criteria for unfiltered public water systems;
- Requirements for covers on new finished water reservoirs; and
- Sanitary surveys for all surface water and GWUDI systems regardless of size.

The IESWTR provisions apply to PWSs that use surface water or GWUDI and serve 10,000 or more people, except in primacy states such as California, sanitary surveys are required for all surface water and GWUDI systems regardless of size.

2.2.4 PROPOSED SULFATE RULE

Sulfate is naturally found in drinking water. There are health concerns because diarrhea may be associated with the ingestion of water containing high levels of sulfate. Also, there are population groups that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with higher sulfate concentration (www.epa.gov/safewater/sulfate.html; updated 1 December 2000).

Sulfate in drinking water has a secondary (MCL) of 250 milligrams per liter (mg/L), based on taste and odor. This regulation is not a federally enforceable standard but is provided as a guideline for states and PWSs. EPA estimates that about 3% of the public drinking water systems in the country may have sulfate levels of 250 mg/L or greater. The SDWA, as amended in 1996, directs the EPA and the Centers for Disease Control and Prevention (CDC) to jointly conduct a study to establish a reliable dose-response relationship for the adverse human health effects from exposure to sulfate in drinking water, including the health effects that may be experienced by sensitive subpopulations, for example, infants and travelers. SDWA specifies that the study be based on the best available peer-reviewed science and supporting studies, conducted in consultation with interested states, and completed in February 1999.

Sulfate is 1 of the 50 chemical and 10 microbiological contaminants/contaminant groups included on the Drinking Water Contaminant Candidate List (EPA 1998). SDWA, Section 1412 (b)(12)(B)(ii), directs EPA to include sulfate among the 5 or more contaminants that the agency is to determine by August 2001 whether to regulate. Before making its decision, EPA will evaluate the contaminant candidate list and the National Primary Drinking Water Regulations (NPDWR), analyzing all public comments, reviewing all comments on its previously proposed NPDWR for sulfate (EPA 1994), and reviewing any other information that could have a bearing on its decision of whether to regulate sulfate under NPDWR. In so doing, EPA will be evaluating whether or not the statutory tests provided in Section 1412(b)(1)(A) of SDWA for proceeding with such regulation are met:

> “The contaminant may have an adverse effect on the health of persons; the contaminant

> is known to occur or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and in the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems."

In making this determination, EPA will review—in addition to the dose-response data and information described in the *Federal Register*—a host of applicable risk management factors. They include but are not limited to occurrence data on concentrations of sulfate in PWSs, information relative to treatment technologies (particularly, technologies applicable to small PWSs), availability and costs of analytical methods for sulfate, and overall costs and benefits attributable to any likely rule.

2.2.5 PROPOSED RADON RULE

The EPA is proposing new regulations to protect people from exposure to radon <http://www.epa.gov/OGWDW/radon/fact.html>. The proposed regulations will provide states with flexibility in limiting the public's exposure to radon by allowing the states to focus their efforts on the greatest public health risks from radon—those in indoor air—while reducing the highest risks from radon in drinking water. The framework for this proposal is set out in the SDWA as amended in 1996.

The SDWA directs the EPA to propose and finalize an MCL for radon in drinking water, but also to make available an alternative approach—a higher alternative MCL accompanied by a multimedia mitigation (MMM) program to address radon risks in indoor air. This framework reflects the unique characteristics of radon. In most cases, radon released into indoor air from soil under homes and buildings is the main source of exposure, and radon released from tap water is a much smaller source of radon in indoor air. It is generally more cost-effective to reduce risk from radon exposure from indoor air than from drinking water. EPA strongly encourages states to take full advantage of the flexibility and risk reduction opportunities in the MMM program.

Based on a second 1999 National Academy of Science report on radon in drinking water, EPA estimates that radon in drinking water causes about 168 cancer deaths per year—89% from lung cancer caused by breathing radon released from water, and 11% from stomach cancer caused by drinking radon-containing water.

The proposed radon in drinking water rule applies to all community water systems that use groundwater or mixed ground and surface water, for example, systems serving homes, apartments, and trailer parks. The proposed rule would not apply to CWSs that use solely surface water nor to NTNCWSs or transient public water supplies, for example, systems serving schools, office buildings, campgrounds, restaurants, and highway rest stops.

The rule proposes an MCLG, an MCL, an alternative MCL, and requirements for an MMM program to address radon in indoor air. The proposed rule includes monitoring, reporting, public notification and consumer confidence report requirements and specifies best available technologies and analytical methods.

The proposed MCLG for radon in drinking water is zero. This is a non-enforceable goal. The proposed regulation provides 2 options for the maximum level of radon allowable in CWSs: an MCL of 300 picocuries per liter (pCi/L) or an alternative MCL of 4,000 pCi/L. The drinking water standard that would apply for a system depends on whether the State or the CWS develops an MMM program. CWSs that serve 10,000 or fewer customers have a regulatory expectation to meet the 4,000 pCi/L alternative MCL and be associated with an approved MMM program plan, developed either by the State or the CWS.

2.2.6 UNREGULATED CONTAMINANT MONITORING RULE

In 1996 the SDWA was amended with the Unregulated Contaminant Monitoring Rule (UCMR). The rule requires EPA to establish criteria for a monitoring program for unregulated contaminants and to publish a list of contaminants to be monitored. The list has undergone extensive review and prioritization of a Drinking Water Contaminant Candidate List. The UCMR stipulates the following:

- A list of contaminants for which PWSs must monitor;
- Specific analytical methods to be used;
- Requirements for all large PWSs, and a representative sample of small PWS, to monitor for the listed contaminants with the promulgated methods;
- Submission of the monitoring data to EPA and the states for inclusion in the national Drinking Water Contaminant Occurrence Database; and
- Notification to consumers of the monitoring results.

Table 2-9 Unregulated Contaminant Monitoring Rule Lists

List 1	List 2	List 3
Assessment Monitoring of Contaminants with Available Methods	Screening Survey of Contaminants Projected to have Methods by Date of Program Implementation	Pre-Screen Testing of Contaminants Needing Research on Methods
2,4-dinitrotoluene	Diuron	Cyanobacteria (blue-green algae, other freshwater algae and their toxins)
2,6-dinitrotoluene	Linuron	Echoviruses
Acetochlor	Prometon	Coxsackieviruses
DCPA mono-acid degradate	2,4,6-trichlorophenol	Heliobacter pylori
DCPA di-acid degradate	2,4-dichlorophenol	Mirosporidia
4,4'-DDE	2,4-dinitrophenol	Calciviruses
EPTC	2-methyl-phenol	Adenoviruses
Molinate	Alachlor ESA	Polonium-210
MTBE	1,2-diphenylhydrazine	Lead-210
Nitrobenzene	Diazinon	
Perchlorate	Disulfoton	
Terbacil	Fonofos	
	Tebufos	
	Aeromonas	
	RDX	
	Nitrobenzene	

Source: Update 22 Jan 2001 from www.usepa.gov/safewater/ucmr.html

The UCMR list includes 35 contaminants, which were identified as occurrence priorities on the contaminant candidate list, and 2 radionuclides that emerged during development of the regulations. The UCMR list is divided into 3 lists based on the readiness of analytical methods and current contaminant occurrence data (Table 2-9).

List 1 for assessment monitoring includes 12 chemical contaminants for which analytical methods exist. List 1 monitoring will occur at large PWSs and a representative sample of small PWS beginning in 2001. Surface water systems will monitor quarterly for 1 year and groundwater systems twice per year. List 2 for screening survey will occur at small PWSs selected for the screening survey one in 2001 and at large PWSs selected for screening survey one in 2002. On 11 January 2001, EPA finalized analytical methods for 13 (of the original 16) of the List 2 screening survey contaminants to be monitored and the monitoring schedule for the microbiological contaminant, *Aeromonas* (2003 if the analytical method is promulgated in 2001). The rule also finalizes minor changes to the September 1999 UCMR that affect the implementation of monitoring for List 1 and List 2 contaminants. List 3 for prescreen testing are contaminants that recently have become of concern. Methods for the detection of these contaminants are in the early stages of development. List 3 contaminants will be monitored only after future rulemaking specifies methods to determine whether a listed contaminant occurs frequently in most vulnerable water systems or sampling locations to warrant inclusion in future assessment monitoring or screening surveys.

The monitoring of unregulated contaminants by PWSs informs the public about pollutants not previously measured. This data will help determine if a contaminant frequently occurs and at what levels to warrant further action, which may include more analysis and research on potential health effects and regulation. The major benefit of monitoring unregulated contaminants is early warning of their presence before serious health effects occur.

While the UCMR list contains 35 contaminants, under the SDWA 1996 amendment, EPA is limited to having 30 contaminants monitored in any 5-year cycle. The success of developing analytical methods will determine which 30 contaminants will be monitored in the 5-year cycle.

2.2.7 RADIONUCLIDES (NONRADON) RULE

EPA promulgated the final drinking water standards for (nonradon) radionuclides in drinking water: combined radium-226/-228, (adjusted) gross alpha, beta particle and photon radioactivity, and uranium. This promulgation consisted of revisions to the 1976 rule, as proposed in 1991 (www.epa.gov/safewater/radionuc.html). The standards are: combined radium 226/228 (5 pCi/L); beta emitters (4 mrems); gross alpha standard (15 pCi/L); and uranium (30 µg/L).

CWSs are water systems that serve at least 15 service connections or 25 residents regularly year round. They are required to meet the final MCLs and to meet the requirements for monitoring and reporting. NTNCWS are public water systems that are not a CWS and serve at least 25 of the same people more than 6 months per year, for example, schools and nursing homes. NTNCWS will not be regulated at this time, but EPA will consider this matter and may propose to regulate radionuclides at NTNCWSs in the future. The final rule requires that all new monitoring be conducted at each entry point to the distribution system under a schedule designed to be consistent with the Standardized Monitoring Framework. The framework was promulgated by EPA under the Phase II Rule of the NPDWR and revised under Phase IIB (1991) and Phase V (1992). The framework's goal is to streamline the drinking water monitoring requirements by standardizing them within contaminant groups and by synchronizing monitoring schedules across contaminant groups. The Draft Implementation Guidance for Radionuclides, which details the proposed monitoring requirements, was published in December 2000 (EPA 816-A-00-002).

The rule will become effective 8 December 2003, 3 years after the publication date (7 December 2000). New monitoring requirements will be phased-in between that date and the beginning of the next Standardized Monitoring Framework period, 31 December 2007. "Phased-in monitoring" refers to the requirement by states that some fraction of water systems complete initial monitoring requirements each year between the effective date (8 December 2003) and the beginning of the new cycle (31 December 2007). Water systems will determine initial compliance under the new monitoring requirements using the average of 4 quarterly samples or, at State discretion, using appropriate grandfathered data.

Compliance will be determined immediately based on the annual average of the quarterly samples for that fraction of systems required by the state to monitor in any given year or based on the results from the grandfathered data. Water systems with existing radionuclides monitoring data demonstrating that the system is out of compliance with new provisions will be out of compliance on the effective date of 8 December 2003. Water systems with existing data that demonstrate noncompliance with the current (1976) rule are in violation of the radionuclides National Primary Drinking Water Regulations.

2.2.8 REVISED DHS UNREGULATED CHEMICALS REQUIRING MONITORING

On 3 January 2001, DHS reduced the number of unregulated chemicals requiring monitoring from 52 to 9. The list is presented in Table 2-10. Chromium VI was included among the 9 listed contaminants.

Table 2-10 Revised California DHS Unregulated Chemicals Requiring Monitoring List [a]

Chemical	Number positive sources of number sources sampled from 1984–Nov 2000
Boron [b]	2,000 of 2,685
Chromium VI (Hexavalent chromium)[c]	
Dichlorodifluoromethane (Difluorodichloromethane)[b]	119 of 14,656
Ethyl tertiary butyl ether (ETBE)	0 of 2,083
Perchlorate	186 of 2,128
Tertiary amyl methyl ether (TAME)	0 of 2,997
Tertiary butyl alcohol (TBA) [b]	
1,2,3-Trichloropropane (TCP) [b]	25 of 10,466
Vanadium [b]	30 of 69

Source: Updated 13 Feb 2001 from www.dhs.ca.gov/ps/ddwem/chemicals/MCL/unregulated.htm

[a] Effective as of 3 Jan 2001.

[b] Chemical has a DHS action level.

[c] Chromium VI is regulated under the MCL for total chromium

2.2.9 DHS REVIEW OF MCLS FOR 13 CONTAMINANTS

The CalEPA Office of Environmental Health Hazard Assessment (OEHHA) establishes public health goals (PHGs). PHGs are concentrations of drinking water contaminants that OEHHA considers nonsignificant health risks if consumed for a lifetime.

PHGs are determined strictly from health risk assessment principles, practices, and methods. A PHG is not a drinking water standard but rather a health protective goal to be considered relative to MCLs that may be revised or established. MCLs are health-protective drinking water standards that are adopted by DHS and must be met by PWSs. An MCL is developed from risk management determinations that consider a chemical's health risks, detectability, treatability, and cost of treatment. Health and Safety Code § 16365(a) requires DHS to establish a contaminant's MCL at a level as close as is technically and economically feasible to its PHG, placing primary emphasis on protecting public health.

OEHHA is required to set PHGs for contaminants with MCLs and those contaminants for which DHS intends to adopt MCLs. Each PHG is reviewed and revised at least once every 5 years as necessary, based upon available scientific information. Once OEHHA sets or revises a PHG, DHS determines whether a contaminant's MCL should be reviewed.

DHS has been reviewing MCLs for 13 contaminants. The review process began with an initial screening. The criteria for the screening included the following:

- The relationship between the PHG and both the federal and State MCLs;
- Any changes in treatment techniques for chemical removal that would provide for a materially greater protection of public health; and
- Any new scientific evidence indicating that the substance might present a materially different risk to public health than was previously determined.

In 2 separate lists in 1998 and 1999, DHS designated the following 13 chemicals for a more comprehensive review: cyanide, ethylbenzene, oxamyl, di(2-ethylhexyl)phthalate (DEHP), atrazine, cadmium, chromium, dibromochloropropane (DBCP), 1,2-dichloropropane, methoxychlor, thallium, 1,2,4-trichlorobenzene, and 1,1,2-trichloroethylene (TCE).

The most recent 4 years of analytical data were obtained from DHS' Water Quality Monitoring (WQM) database and analyzed for each chemical to assess chemical occurrence in drinking water sources for the MCL reviews.

DHS established a standardized reporting (quantification) level called the "detection level for purposes of reporting" (DLR) for each chemical in the WQM program. The DLR represents the level at which DHS is confident about the accuracy of the quantity of contaminant being reported. Although any findings below DLRs are considered nondetects and technically are not required to be reported, some laboratories do report lower levels for chemicals.

In the MCL reviews, DHS chose to use the reported values in WQM, regardless of whether or not the values exceeded the DLR. DHS is working with some analytical laboratories participating in a "reporting level workgroup" to evaluate whether any of the existing DLRs should be revised, and, if so, how this should be accomplished. For some chemicals, the DLR may affect the feasibility of revising the MCL.

An update of the MCL reviews for the 13 contaminants designated for MCL review in DHS's 1998 and 1999 lists are presented in Table 2-11. Eight MCL reviews have been completed. DHS has recommended:

- Revising downward the MCLs for 6 contaminants: atrazine, cyanide, ethylbenzene, methoxychlor, oxamyl, and 1,2,4-trichlorobenzene; and
- Not changing the MCLs for 2 contaminants: DEHP and DBCP.

Two contaminants, cadmium and thallium, are undergoing DLR evaluations. Two other contaminants, 1,2-Dichloropropane and TCE, are undergoing comprehensive cost-benefit analyses.

Table 2-11 Status of DHS Reviews of MCLs for 13 Contaminants

Contaminant	MCL, PHG, DLR (µg/L)	DHS Recommendations	Status of review action
Atrazine	DHS/EPA MCL 3 PHG 0.15 DLR 1	MCL 1 DLR 0.5	
Cadmium	DHS/EPA MCL 5 PHG 0.07 DLR 1		Awaiting completion of DLR study
Chromium Total, Cr+3, Cr+6	EPA MCL 100 total Cr DHS MCL 50 total Cr PHG 2.5 total Cr DLR 10 for total Cr	Cr+6 Required unregulated chemical for monitoring until more data are available for review	Monitoring requirement effective 3 Jan 2001
Cyanide	DHS/EPA MCL 200 PHG 150 DLR 1	DHS MCL 150	Revised MCL proposed
Dicbromochloropropane (DBCP)	DHS MCL 0.2 PHG 0.0017	No revision due to high cost-to-benefit ratio	Responses posted for public comment in May-June 2000
1,2-Dichloropropane	DHS/EPA MCL 5 PHG 0.5 DLR 0.5		Analysis of data ongoing
Di(2-Ethylhexyl) Phthalate(DEHP)	DHS MCL 4 EPA MCL 6 PHG 12	No revision	
Ethylbenzene	DHS/EPA MCL 700 PHG 300	DHS MCL 300	Revised MCL proposed
Methoxychlor	DHS/EPA MCL 40 PHG 30	DHS MCL 30	Revised MCL proposed
Oxamyl	DHS/EPA MCL 200 PHG 50	DHS MCL 50	Revised MCL proposed
Thallium	DHS/EPA MCL 2 PHG 0.1		Awaiting completion of DLR study
1,2,4-Trichlorobenzene	DHS/EPA MCL 70 PHG 5 DLR 0.5	DHS MCL 5	Revised MCL proposed
1,1,2-Trichloroethylene (TCE)	DHS/EPA 5 PHG 0.8 DLR 0.5		Awaiting more studies

Source: Last update: 9 Jan 2001 < www.dhs.ca.gov/ps/ddwem/chemicals/PHGs/reviewstatus.htm>
MCL - Maximum Contaminant Level set by DHS or EPA
PHG - Public Health Goal established by CalEPA Office of Environmental Health Hazard Assessement (OEHHA)

2.3 DRINKING WATER QUALITY PARAMETERS OF CONCERN

2.3.1 DELTA WATER QUALITY CONCERNS

Pollutants in Delta waters come from tidal interaction and from point and nonpoint sources in the Delta and tributary watersheds, such as those of the Sacramento and San Joaquin River basins. Pathogens largely come from urban storm water runoff, livestock operations, recreational users, and, potentially, inadequately treated wastewater discharges. Sources of organic matter include runoff from soils, agricultural drainage, urban storm water, tidal wetlands, algae, and wastewater treatment plants.

The primary source of bromide is seawater intrusion and agricultural return water. Other sources of bromide may include geological formations, groundwater influenced by ancient sea salts, and the use of bromine-containing chemicals in the watersheds. Salinity sources, as reflected by total dissolved solids (TDS), include seawater intrusion and, to a lesser extent, from the natural leaching of soils, agricultural drainage, wastewater treatment discharges, and storm water runoff. Nutrient sources include soil erosion, agricultural runoff, livestock operations, urban storm water runoff, and wastewater discharges. Turbidity results from storm events, runoff, resuspended sediments, and phytoplankton. There is insufficient data to clearly establish the relative contributions of pollutants from each of these sources.

In a Comprehensive Monitoring, Assessment, and Research Program (CMARP) Report for the CALFED Bay-Delta Program (CALFED 2000), 7 drinking water parameters of concern were identified:

- TOC and dissolved organic carbon (DOC), which can serve as DBP precursors;
- Bromide, which is a precursor to forming brominated DBPs;
- Pathogenic organisms that can cause serious waterborne diseases;
- Chemical contaminants that can cause violations of drinking water MCLs;
- TDS or salinity that can cause taste and odor problems, corrosion of infrastructure and appliances, and impacts on wastewater reclamation programs, groundwater conjunctive use, and blending projects;
- Nutrients that can enhance nuisance algae blooms that affect water filtration and cause foul taste and odor problems, for example, geosmin and MIB (2-methylisoborneol); and
- Turbidity, which can impact filtration and disinfection treatment processes and requirements.

CALFED Bay-Delta Program actions presented in its *Programmatic EIS/EIR* (CALFED 2000) that could improve Delta water supplies with respect to these concerns would:

- Assure meeting current and future primary and secondary drinking water standards;
- Reduce public concern about the source and quality of drinking water from the Delta;
- Minimize water treatment costs to meet regulations;
- Reduce wide fluctuations in raw water quality with the result of improving the reliability of water treatment plant operations to meet standards and industries requiring consistent good water quality; and
- Reduce industrial pretreatment costs and production costs for industries, for example, electronics and pharmaceutical, that require high water quality.

The proposed CALFED actions are presented in Table 2-12.

Table 2-12 Potential Action Items for Improving Delta Drinking Water Quality

Subject	Potential action for near future implementation
Agricultural drains	Treat drainage, relocate discharge points, release drainage during ebb tides, implement BMPs, modify land management practices to reduce TDS, nutrients, TOC, salinity, and selenium, support land retirement of drainage impaired lands with local sponsorship.
Animal enclosures	Implement BMPs to reduce fecal matter and associate TOC, nutrients, pathogens into water sources.
Treated wastewater effluents	Improve treatment, relocate outfalls, implement watershed management plans, set total maximum daily loads (TMDLs) of pollutants.
Urban runoff	Treat drainage, relocate outfalls, set total maximum daily loads (TMDLs) of pollutants, implement watershed management plans.
Algae control	Treat water to kill or remove algae, control nutrient inputs, evaluate operational procedures.
Boating control	Implement education and enforcement programs to reduce discharges of fecal matter and other wastes to waterways.
Local watershed management	Support community-based watershed efforts to reduce non-point sources of contaminants.
Blending/exchange	Develop a Bay Area blending/exchange project with Bay Area water districts to address water quality and supply reliability. Facilitate water quality exchanges and similar programs to make high-quality Sierra water in the eastern San Joaquin Valley available to urban southern California.
Treatment	Invest in treatment technology demonstration.
Delta Drinking Water Council and Work Groups	Use the Council and its technical work group to develop necessary information on Delta water quality, identify appropriate treatment options, pursue source water exchange opportunities, and make other evaluations to meet CALFED’s goal of continuous improvement in Delta water quality for all users.

Source: *CALFED Final Programmatic EIS/EIR* Jul 2000

2.3.2 CONTAMINANTS OF RECENT PUBLIC CONCERN

Some of the more publicized contaminants of concern during the past 5 years include chromium VI and chemical fuel-related compounds.

2.3.2.1 Chromium (hexavalent)

Total chromium in drinking water is regulated. The DHS MCL is 50 µg/L, which is lower than the EPA MCL of 100 µg/L. The World Health Organization uses 50 µg/L as a guideline for total chromium. These standards are considered protective of public health for both chromium-3 (trivalent) and chromium-6 (hexavalent), which is relatively more toxic. Chromium-3 is a required nutrient with a recommended daily average (RDA) dose of 50 to 200 µg. Chromium-6 can cause cancer in laboratory animals when inhaled. The evidence for carcinogenicity when ingested is not strong. CalEPA's OEHHA lists chromium-6 as a carcinogen, but it is not considered to pose a significant risk by ingestion if the standards are met. OEHHA established a PHG of 2.5 µg/L total chromium in drinking water. Because there is limited data on chromium-6 in drinking water supplies, DHS added chromium-6 to the list of unregulated chemicals for monitoring requirement, effective 3 January 2001. DHS will review the chromium MCL for possible revision when more data are collected.

2.3.2.2 DBCP (1,2-dibromo-3-chloropropane)

The current MCL for DBCP is 0.2 µg/L. The PHG is 0.0017 µg/L. In 1999 DHS began a review of the MCL for DBCP. A cost-benefit analysis was completed in February 2000. The evaluation led DHS to determine that no change in the MCL is required.

2.3.2.3 MTBE (Methyl tertiary butyl ether)

MTBE is a synthetic compound used mainly as a fuel oxygenate. The federal Clean Air Act Amendments of 1990 contained requirements for the use of oxygenated gasoline in areas that exceed the National Ambient Air Quality Standards for carbon monoxide and ozone. The Clean Air Act does not require any specific oxygenate, but MTBE is most commonly used. MTBE is added to gasoline to promote more complete combustion. Reformulated gasoline containing approximately 11% MTBE has been sold in California for many years to meet the state's air quality objectives. Increased MTBE usage has led to an increase in MTBE detections in surface and groundwater. Contamination sources include: leaking underground storage tanks (LUSTs), industrial releases, and emissions from watercraft.

Major potential sources of MTBE in surface waters include motorized recreational watercraft, accidental fuel spills, runoff, and precipitation. Exhaust from recreational watercraft, for example, boats and personal watercraft, is thought to be the major source of MTBE contamination in reservoirs (Dale and others 2000). For the State Water Project, the 2-stroke engine used on some boats and personal watercraft is a major source of MTBE contamination. These engines can expel as much as 25% of the fuel/oil mixture, uncombusted, into the water (DWR 1999).

Conventional water treatment processes do not remove MTBE, but some loss may occur due to volatilization during the treatment process (MWDSC 1998). After MTBE is introduced into a lake, its fate is determined largely by reservoir operation and environmental factors (Dale and others 2000). Volatilization is 1 of the main mechanisms by which MTBE is removed from surface waters, although rate of loss is low and depends on temperature and wind conditions.

In 1991, DHS established an advisory AL for MTBE of 35 µg/L. It was based on nononcogenic effects. In 1999, DHS lowered the AL to 13 µg/L because no health-based drinking water standard existed for MTBE. The EPA has established an AL of 20-40 µg/L in drinking water.

On 25 March 1999, Governor Gray Davis issued an executive order requiring MTBE to be phased out of California's reformulated gasoline by the final day of 2002. Reformulated gasoline will still need to meet the oxygen requirements of the Clean Air Act of 1990. Ethanol is a possible substitute for MTBE. The DHS MCL for MTBE is 13 µg/L in drinking water. DHS also adopted a PHG of 13 µg/L for MTBE. The goal for MTBE is based on oncogenic effects observed in laboratory animals. DHS has a secondary MCL for MTBE of 5 µg/L

Beginning in 2001, new regulations adopted by the California Air Resources Control Board will require manufacturers to reduce emissions from new outboard and personal watercraft engines. These regulations do not affect pre-2001 model year engines. These standards are based on exhaust emissions rather than on engine type. They do not ban 2-stroke engines, although carbureted 2-stroke engines, which can release 20% to 30% of their fuel unburned into the environment, will have a difficult time meeting the new emissions standards. Several 2-stroke direct-injection engines as well as 4-stroke engines are currently available that meet the new regulations (DBW 1999). These engine technologies should reduce the amount of MTBE released into surface waters.

2.3.2.4 NDMA (N-Nitrosodimethylamine)

NDMA is primarily used in research, but in the past it has been used in the production of 1,1-dimethylhydrazine for liquid rocket fuel and other industrial uses: a nematocide, a rubber plasticizer, in polymer synthesis, battery components, a solvent, an antioxidant, and lubricant additive. NDMA has been found in some foods, beverages, drugs, and in tobacco smoke. It also has been detected in polluted air, treated industrial wastewater, public wastewater treatment plant effluents near rocket fuel manufacturing plants, deionized water, high nitrate well water, and chlorinated drinking water.

NDMA is an identified carcinogen. There currently is no standard or approved analytical method for NDMA detection at very low levels. There also are no technologies for large-scale removal of NDMA from drinking water. In April 1998 DHS established an AL of 0.02 µg/L. However, analytical capabilities did not enable detection at that concentration, so any detectable quantity of NDMA exceeded the AL. Therefore, DHS later established a temporary AL of 0.02 µg/L for NDMA in November 1999. Utilities have been advised by DHS about actions that should be taken if the NDMA concentrations exceed the temporary AL.

2.3.2.5 Perchlorate

Perchlorate is a chemical used in a solid rock propellant (ammonium perchlorate) and other industrial applications. In 1997 DHS set a perchlorate AL of 18 µg/L. Since January 1999 perchlorate has been on the list of unregulated chemicals for which monitoring is required. Federal action on perchlorate is being coordinated by the Interagency Perchlorate Steering Committee. Since 1998, the committee has been focusing on analytical methods, treatment technologies, public outreach and communication, and the historical use and distribution of perchlorate, toxicology, risk assessment, and ecological effects.

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Chapter 3 - Barker Slough/North Bay Aqueduct

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters							
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity
Recreation	3.3.1	○	⊙		○	○	⊙	○	⊙
Wastewater Treatment/Facilities	3.3.2								
Urban Runoff	3.3.3	○	○	○	○	○	○	○	○
Animal Populations	3.3.4	○	●			◒	●	○	●
Agricultural Activities	3.3.5	○	◒		○	○		○	◒
Unauthorized Activities	3.3.6								
Geological Sources	3.4.4.3	○	●	○				⊙	●

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

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Barker Slough/North Bay Aqueduct

The *Sanitary Survey Update Report 1996* concluded that the North Bay Aqueduct (NBA) had more water quality problems than any other component of the State Water Project (SWP). Contractors consistently list high total organic carbon (TOC), turbidities, and loss of alkalinity as their major challenges in treating NBA water. Based on the *Sanitary Survey 1996* findings, the Sanitary Survey Action Committee (SSAC) directed the Municipal Water Quality Investigations unit (MWQI) to conduct an in-depth study of the source water to the NBA. Since 1996, the Solano County Water Agency (SCWA), NBA contractors, and an independent consulting firm have worked with the California Department of Water Resources (DWR) to carry out this directive.

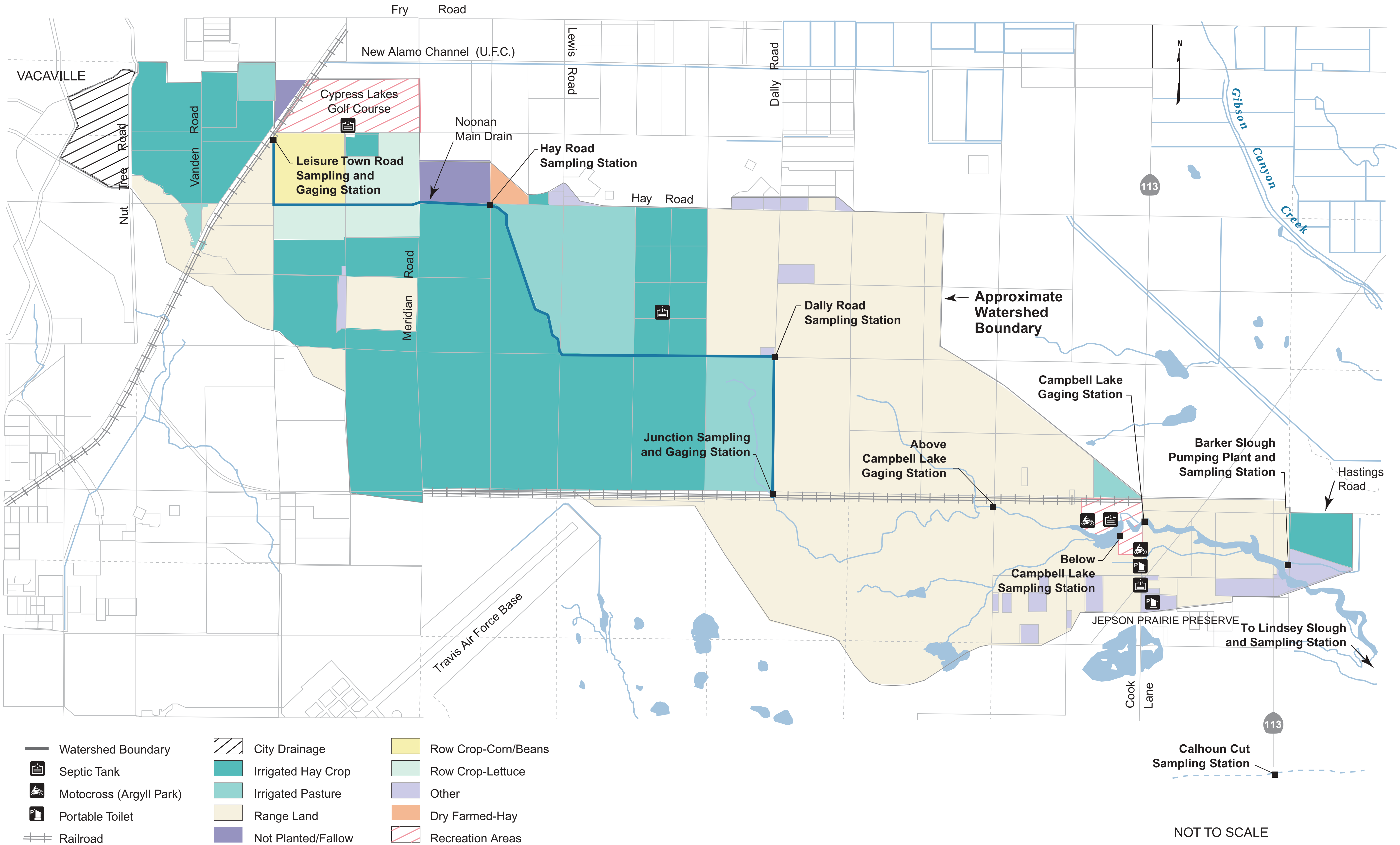
3.1 WATERSHED DESCRIPTION

SCWA field studies have determined the Barker Slough watershed is approximately 14.5 square miles (Figure 3-1). This is about half the 30 square-mile area reported in the *Sanitary Survey Update Report 1996*. Hydro Science, a consulting firm hired by the SCWA to develop Best Management Practice (BMP) options for the watershed, conducted the most recent surveys of the watershed. Although the exact boundary and area of the watershed require refinement, they are not expected to change dramatically.

The lower part of the watershed lies within the northwest section of the Sacramento-San Joaquin Delta (Figure 3-2). Less than 10% of the watershed is within the legal boundaries of the Delta. The watershed is bounded by the City of Vacaville to the west and the Jepson Prairie, University of California Natural Reserve to the southeast. The watershed has a Mediterranean climate, with the majority of the annual rainfall occurring in the winter. Average annual precipitation is 16 inches (DWR 1996). The Barker Slough Pumping Plant, near the terminus of Barker Slough, is the source of water for the NBA. Water is pumped from the slough via the NBA's pipeline and supporting structures to users in the north San Francisco Bay area.

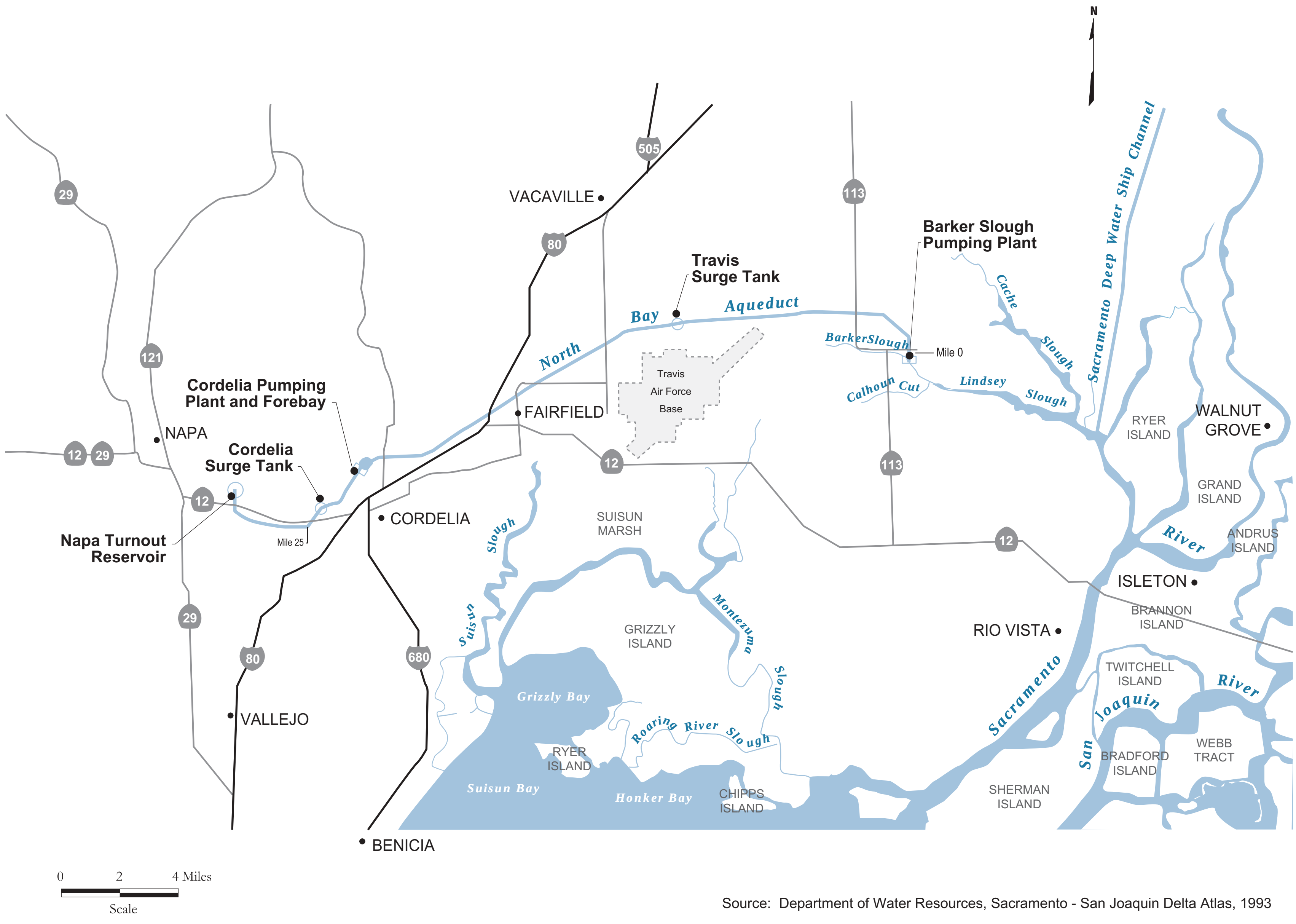
In winter, the Barker Slough watershed is 1 of the dominant influences on water quality at the pumping plant (unpublished DWR data). In summer, water quality appears to be less influenced by the upstream watershed and more heavily influenced by local downstream inputs (DWR 1998).

Figure 3-1 Barker Slough Watershed and Land Use by Parcel as of Fall 2000



NOT TO SCALE

Base map provided courtesy of Solano County Water Agency



Source: Department of Water Resources, Sacramento - San Joaquin Delta Atlas, 1993

Figure 3-2 Location of the North Bay Aqueduct and Barker Slough Pumping Plant

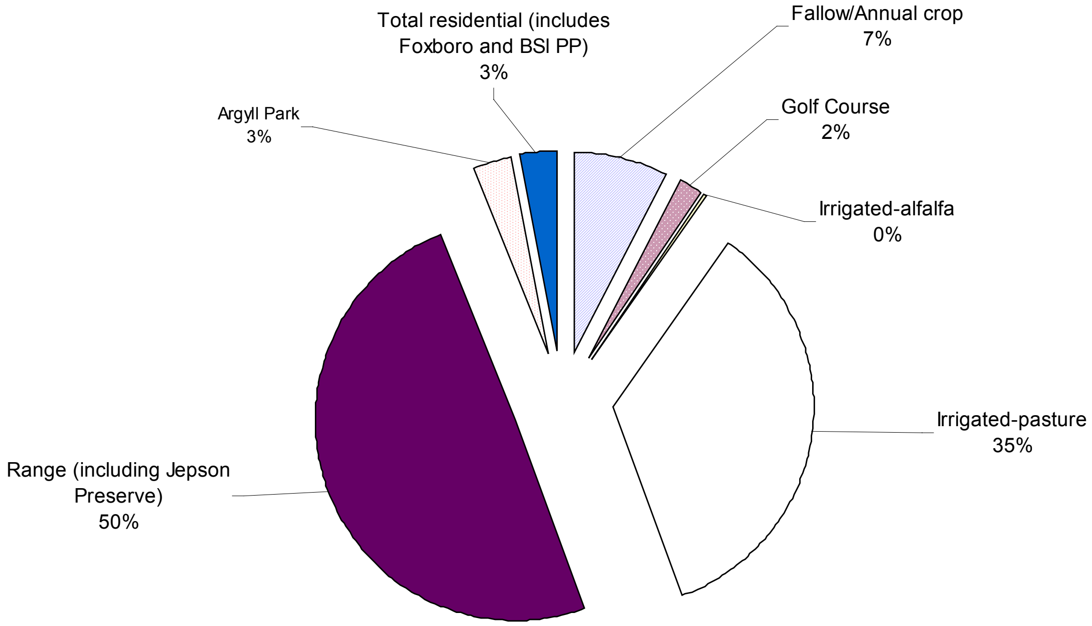
3.1.1 LAND USE

Land use within the Barker Slough watershed (primarily agricultural and divided between crop production and livestock grazing) has changed little since the *Sanitary Survey Update Report 1996* (Scribner pers. comm. 2000). The relatively poor soil conditions have restricted cultivated agriculture to the upper northwest corner of the watershed.

From 1996 to 1998, the California Department of Pesticide Regulation (DPR) documented pesticide use on alfalfa, sorghum, corn, and nursery stock within the watershed. DPR's database only documents crops that require the application of reportable pesticides. Primary exceptions to the full use reporting requirements are home and garden use and most industrial and institutional uses. Additionally, sugar beets, Sudan grass, and safflower have been observed growing in the upper watershed (DWR 1998).

Hydro Science (2000) completed the most recent land use survey of this watershed in fall 2000. Using observations and assessor parcel numbers, the firm divided acreage in the watershed into several land use categories. In at least 1 case—the small area of Vacaville's Foxboro subdivision—acreage is a rough estimate and could be subject to change. According to the survey, approximately 85% of the watershed's land use is rangeland and irrigated pasture (Figure 3-3). The remaining 15% is divided between annual crops and fallow land (7%), and urban and recreational uses (8%). Hydro Science's survey is proportionally similar to previous studies (DWR 1998).

Figure 3-3 Approximate Allocation of Land Use in the Barker Slough Watershed



The Solano County General Plan does not predict any land-use changes before 2010, the next scheduled general plan review. Both the general plan and county zoning designate most of the watershed area for agricultural use (Monske pers. comm. 2000). Although only a small part of its watershed is designated for urban development, Solano County is experiencing considerable growth pressure at its western agricultural boundaires from the City of Vacaville.

Storm drains from a small area in Vacaville's Foxboro subdivision flow into a channel that joins the Noonan Main Drain, a channelized portion of the slough maintained by Solano Irrigation District (SID). About 256 acres of the Foxboro subdivision lies within the Barker Slough watershed (McCall pers. comm. 2000). This represents about 2.5% of the watershed devoted to residential urban land use.

Recreational use includes Argyll Park, a 320-acre motocross track that has operated in the watershed since 1972 (Geier 1994). Argyll Park, which represents about 3% of land use in the watershed, is on Campbell Ranch and about 2 miles upstream of the pumping plant. Along the watershed’s upper northwest boundary is Cypress Lakes Golf Course, which makes up about 2% of the land use. With its docent-led tours in spring, the Jepson Prairie Preserve could be considered a recreational use. The Nature Conservancy transferred ownership of the preserve in 1997 to the Solano County Farmlands and Open Space Foundation. Research and educational use of the preserve is administered through UC Davis (Jepson 1998). About 490 acres of the preserve lie within the southeastern boundaries of the watershed.

3.1.2 GEOLOGY AND SOILS

The Barker Slough watershed, which is fairly uniform in surface geology, is in the Great Valley Geomorphic Province. In general, the watershed is partially filled with clay, silt, sand, and gravel deposited through millions of years of flooding. About 80% of the watershed is composed of alluvium, lake, playa, and terrace deposits, which are consolidated and semiconsolidated (California 1977). The western portion of the watershed contains both marine and nonmarine deposits in the Markley and Tehama Formations (California 1977). The ridge of the Markley Formation extends in a northwest to southeast direction and serves as the western boundary of the watershed. Although groundwater is found in all of the younger sediments, only the more permeable sand and gravel aquifers provide enough water to make wells feasible. These younger sediments overlie older marine sediments containing brackish or saline water (DWR 1998).

Soil units found in the watershed are the Antioch-San Ysidro complex, Capay clay loam, Pescadero clay loam, San Ysidro sandy loam, and Solano loam (Bates and others 1977). Except for the San Ysidro soil unit, these soils generally exhibit high soil pH. High soil pH can indicate high levels of sodium and other cations. These conditions create poor soils for agriculture (Singer 1999). With the exception of the Pescadero soil unit, all of the major soils within the watershed are within the "D" US Department of Agriculture's Hydrologic Soil group classification (Bates and others 1977). Pescadero is classified as a "C" soil group. Both soil types exhibit slow or very slow infiltration rates. Soils within the "D" classification are also characterized as heavy clay soils. The combination of high sodium, high clay, and moderate amounts of organic carbon contributes to the slow infiltration rates, the high runoff, and the potentially poor water quality observed in the slough (Singer 1999).

3.1.3 VEGETATION AND WILDLIFE

Where agricultural land uses are absent, the native vegetation has been classified as Valley Grassland, which includes dense to somewhat open bunch grass communities with forbs. Native perennial grasslands and vernal pools are examples of natural habitats native to the Central Valley of California and found in Jepson Prairie Preserve. The preserve has the highest density of vernal pools in Solano County (Barbor and Major 1977). The California Department of Fish and Game has designated vernal pool communities as significant natural communities and monitors their status through the Natural Heritage Program.

The preserve contains many rare and endangered plant and animal species. An inventory of Jepson Prairie flora can be found in the Jepson Prairie Preserve Handbook (Jepson 1998). Within the watershed, beaver and river otters have been observed. Burrowing owls have been observed in the upper reaches of the watershed in the banks of the Noonan Main Drain (Morris pers. comm. 2000).

3.1.4 HYDROLOGY

Headwaters of the Barker Slough watershed begin on a small ridge near the outer edges of the City of Vacaville. The ridge delineates the western boundary of the watershed. Elevations range from 164 feet on some low hills in the southwest portion of the watershed to near sea level at the pumping plant. The average slope of the watershed is about 5 feet per mile toward the east or 0.01% (DWR 1996). Until it was channelized, the upper reaches of Barker Slough probably conveyed water only during winter rainfall months.

Storm drains from the Foxboro subdivision flow into an unnamed channel that probably is the old streambed of the slough. The channel runs through agricultural fields for approximately 2 miles before ending in the Noonan Main Drain (Figure 3-1). SID created this drain in 1961 when it channelized part of the upper portion of Barker Slough to deliver Lake Berryessa irrigation water to local landowners. As the Noonan Main Drain continues down the watershed, it joins the D-1-C spill extension. About half way down the watershed the Noonan Main Drain/D-1-C spill extension ends and continues as an unmaintained drain. This drain gives way to the old slough bed and continues east to a 40-acre impoundment on the Argyll Park property known as Campbell Lake. The combination of irrigation water and irrigation return water can cause the drain to flow for most of the year. However, the movement of irrigation return water out of Campbell Lake appears minimal. Flows in the drain normally drop dramatically in the fall following the end of water deliveries by SID and prior to the winter rainy season

The Campbell Lake dam was constructed for agricultural purposes and engineered by the US Department of Agriculture, Soil Conservation Service (Geier 1994). At the landowner's discretion, water is released through the removal of stacked boards that form the dam barrier. In winter, the boards are often removed to prevent flooding of the property. Although the slough is impounded behind a dam, a portion of it still flows out of Campbell Lake via a pipe with a valve control. Water through the pipe rejoins Barker Slough below the lake before continuing downstream to the pumping plant's forebay. Barker Slough and Calhoun Cut join about 1.5 miles downstream of the pumping plant at Lindsey Slough, which is about 6 miles long. Approximately a mile upstream of the Sacramento River Deep Water Ship Channel, Lindsey and Cache Slough merge. Cache Slough continues for another 2 to 3 miles before joining the Sacramento River.

The lower half of the watershed is prone to extensive flooding during winter months. During major storm events the lower reaches of the unmaintained drain and the slough routinely overtop their banks. Although no longer routinely monitored, DWR groundwater wells indicate that the perched water table is fairly close to the surface (DWR 1994). A shallow perched water table in combination with poorly infiltrated soils is probably a major contributor to seasonal flooding.

In addition to agricultural practices, rainfall, and a small part of the Foxboro subdivision, other sources of runoff are a golf course, uncultivated areas, active and abandoned rail lines, gravel, dirt, and paved roads, and the motocross recreation area.

3.2 WATER SUPPLY SYSTEM

3.2.1 DESCRIPTION OF AQUEDUCT/SWP FACILITIES

The NBA is a 27-mile long, pressurized, underground pipeline providing water to municipal and industrial users in Napa and Solano counties. The aqueduct was constructed in 2 phases. Phase I, built during 1967 and 1968, consisted of permanent and temporary structures. Permanent construction included the Cordelia Surge Tank, the Napa Turnout Reservoir, and a 4-mile long pipeline connecting them. In 1968, contractors began receiving water from Lake Berryessa via the Putah South Canal. Phase II, constructed from 1985 to 1988, extended the pipeline 23 miles from the Cordelia Surge Tank eastward to Barker Slough. The Barker Slough Pumping Plant then began delivering water to NBA contractors (DWR 1996a).

The pumping plant is on the north shore of Barker Slough about a half mile east of State Highway 113 (lat 38º16'534"N, long 121º55'93"W). Nine pumps with a design flow capacity of 224 cfs lift water from Barker Slough into the NBA (Gage pers. comm.). Upon completion of the pumping plant, a test showed a rated flow of 175 cfs (Gage pers. comm. 2000). To date, the maximum flow of the NBA is 142 cfs. Once in the NBA, water flows 9 miles downstream to the Travis Surge Tank. Water is delivered to Travis Air Force Base and to the Solano County communities of Fairfield and Vacaville via 2 turnouts. From the Travis Surge Tank, water flows by gravity to the Cordelia Forebay and Pumping Plant. At the Cordelia Forebay, there are 11 pumps and 3 transmission pipelines. Two of the 3 pipelines serve Benicia and Vallejo; the 3rd carries water to the Cordelia Surge Tank. Water continues from the surge tank through a 4-mile long pipe to the western terminus of the NBA, the Napa Turnout Reservoir. At the reservoir, 2 turnouts deliver water to the cities of American Canyon and Napa. The City of Napa delivers water to Yountville and Calistoga in Napa County.

3.2.2 DESCRIPTION OF AGENCIES USING SWP WATER

There are 2 SWP contractors for NBA water, the SCWA and the Napa County Flood Control and Water Conservation District (DWR 2000). These agencies provide water to a number of utilities. SCWA contracts with Travis Air Force Base and the cities of Benicia, Fairfield, Vacaville and Vallejo. The Napa County district contracts with the cities of American Canyon, Calistoga, Napa, and Yountville. The City of Napa provides treated water to Calistoga and Yountville. The North Bay Regional Water Treatment Plant (NBR WTP) in Fairfield provides treated water to Fairfield and Vacaville. From 1996 through 1999, only the City of Benicia, Travis Air Force Base, and Napa's Jameson Canyon Water Treatment Plant relied principally on NBA water. Depending on NBA water quality, availability, water rights, etc., some state contractors may blend NBA water or switch entirely to other sources.

A brief description of the utilities using NBA water follows. In some cases, storage and/or treatment plants may be shared among several municipalities. In these cases, municipalities were categorized under the municipality providing the storage service or the treated water. The percent of NBA water used by each municipality is shown in Table 3-1.

3.2.2.1 The City of Benicia

The NBA had been the primary source of water for Benicia, but from 1996 to 1999, the municipality occasionally blended NBA water with Lake Berryessa water transported via the Putah South Canal. Lake Berryessa water is of much higher quality and easier and less costly to treat. The Benicia Water Treatment Plant uses a conventional water treatment process involving alum/cationic polymer coagulation-flocculation, dual granular activated carbon (GAC)/sand gravel media filtration, and free chlorine disinfection. Caustic soda for pH adjustment controls corrosion, and fluoride is added for dental protection. The plant is rated hydraulically for 12 million gallons per day (mgd), but the typical annual rate ranges from 3 mgd to 10 mgd.

3.2.2.2 The City of Fairfield

Fairfield and Vacaville jointly own the NBR WTP, which has 2 raw water sources: the NBA and Lake Berryessa via the Putah South Canal. Depending on water quality, the NBR WTP may blend NBA water with Lake Berryessa water or use Lake Berryessa or NBA water exclusively. This flexibility is reflected in the percent of NBA water usage shown in Table 3-1. The NBR WTP's operating range is from 8 mgd to its design capacity of 40 mgd. In the summer, capacity can reach 34 mgd (Fleege pers. comm. 2000c). It uses ozone as the primary oxidant at a pre-ozone contact and has traditional coagulation/flocculation, sedimentation, and filtration. After deep-bed GAC filtration, the NBR WTP uses ozone for disinfection, caustic soda for pH adjustment, fluoride for dental protection, and free chlorine to disinfect the finished water. Like the Travis AFB Water Treatment Plant, the NBR WTP is 1 of the 1st recipients of NBA water.

3.2.2.3 The City of Napa

Napa operates 3 water treatment plants (WTPs): Jameson Canyon (for NBA water), and Hennessey and Milliken (for non-NBA water). The city rotates use of the treatment plants. Typically, the Jameson Canyon WTP operates from mid-November through March and is off-line the remainder of the year. The City of Napa sells treated water to the cities of Calistoga, Yountville, and American Canyon. NBA raw water is delivered from the Napa Turnout Reservoir and treated at the Jameson Canyon WTP, a conventional filtration plant with a capacity of 12 mgd (Walker pers. comm. 2000).

3.2.2.4 The City of American Canyon

American Canyon receives raw NBA water from the Napa Turnout Reservoir and treats it at a conventional treatment plant with a capacity of 2.6 mgd. The city also has interconnections to receive treated water from the City of Napa and the City of Vallejo (Walker pers. comm. 2000).

Table 3-1 Percent of North Bay Aqueduct Water Use Relative to Total Water Use by Each Municipality

	1996	1997	1998	1999
City of Benicia WTP	90	95	95	90
Jameson Canyon WTP-Napa County Flood Control and Water Conservation District	100	100	100	100
North Bay Regional WTP-Cities of Fairfield and Vacaville	54.1	59.1	47.3	56.9
Travis AFB WTP	100	100	100	100
Fleming Hill WTP-City of Vallejo	30	28	30	33

3.2.2.5 The City of Vallejo

The Fleming Hill Water Treatment Plant is the sole source of drinking water for the City of Vallejo. Typically, it treats a 70/30 blend of Lake Berryessa and NBA water, respectively. The WTP's capacity is 42 mgd. Its treatment train consists of: flow blending, pre-ozonation, flash and rapid mixing, flocculation, sedimentation, intermediate ozonation and GAC filtration. Gaseous chlorine is used for disinfection; sodium hydroxide is used for corrosion control; and fluoride is added for dental protection (Rice pers. comm. 2000).

3.2.2.6 Travis AFB WTP

The Travis AFB WTP, a 7-mgd conventional filtration plant with pre-ozone and GAC, is managed and operated by the City of Vallejo. The WTP relies solely on NBA water. The NBR WTP and the Travis AFB WTP are the 1st recipients of NBA water.

3.3 POTENTIAL CONTAMINANT SOURCES (PCSS)

3.3.1 RECREATION

There are 3 main recreational activities in the Barker Slough watershed:

- Argyll Park, a 320-acre multiuse recreational area in the southeastern corner of the watershed that is primarily used for motocross and go-kart racing;
- The Jepson Prairie Preserve, 1,556 acres near Argyll Park and managed by the Solano County Farmlands and Open Space Foundation; and
- Cypress Lakes Golf Course, 210 acres in the northern corner of the watershed and owned by Travis Air Force Base.

Argyll Park has a small concession stand, and some picnicking is allowed. Since the *Sanitary Survey Update 1996*, the only significant change at the park has been the redesign and improvement of its entrance as a condition of its use permit (Parker pers. comm. 2000). No new physical construction was allowed with the new permit except to mitigate for the existing go-kart track, where races occur on many weekends. It appears that motocross use has been declining (Parker pers. comm. 2000). The county does not have an inspection protocol to oversee permit terms (Parker pers. comm. 2000). The Dixon modelers club flies radio-controlled airplanes at Argyll Park and Campbell Lake, a 40-acre lake on the property, for sailing radio-controlled boats. Campbell Lake's primary use is to provide irrigation water for the owner. There is no body-contact recreation allowed in the lake.

At the Jepson Prairie Preserve, docent-led nature tours are conducted in the spring. Since 1983, the University of California, Davis, Natural Reserve System has been administering research and educational use at the preserve (Jepson 1998). Less than a third of the preserve (about 490 acres) lies within the watershed. Recreational activities at Jepson Prairie Preserve are designed to have a minimal impact and promote native vegetation. The impact of the preserve may have less to do with recreation and more to do with the preserve's soils, topography, and proximity to Barker Slough and Calhoun Cut.

From October 1999 to the end of September 2000, 47,000 visitors played a round of golf at the Cypress Lakes Golf Course (Joyce pers. comm. 2000). The golf course has been graded so that runoff enters the drainage ditch along Meridian Road (Joyce pers. comm. 2000). This drainage ditch joins the Noonan Main Drain and the unnamed drain receiving Foxboro runoff at the intersection of Fry and Meridian Roads. In addition to TOC and turbidity, runoff from the golf course could contain fertilizer or pesticides or both.

Activities at the Cypress Lakes Golf Course and the Jepson Prairie Preserve probably have little impact to the high TOC and turbidity levels. Runoff from the golf course may contribute slightly to the overall problem, but the course's area makes up less than 5% of the watershed and its vegetation potentially serves as a filter for runoff.

3.3.2 WASTEWATER TREATMENT/ FACILITIES

3.3.2.1 Septic Systems

Based on information from the Solano County Environmental Management Division, there are about 30 permitted septic systems in the Barker Slough watershed (Bell pers. comm. 2000). The highest concentration of septic systems is on the Box R Ranch. The number of septic system permits and approximate locations are listed in Table 3-2. Figure 3-1 shows approximate locations of septic systems with the exception of those on Hay and Dally Road. Hay and Dally roads also run outside of the watershed's boundaries. There was not enough information to determine if the septic systems were inside or outside the watershed. Although the county issues permits for septic systems, it does not have a water-quality monitoring program. The county would react to a system failure, but none have been reported (Schmidtbauer pers. comm. 2000).

Table 3-2 Location and Number of Permitted Septic Systems in the Barker Slough Watershed

Location	Permitted Septic Systems
Cypress Lakes Golf Course	4
Hay Road[a]	3
Box R Ranch[b]	8
Dally Road[a]	10
Argyll Park (Cook Lane)	2
Cook Lane	3

[a] Some sites may lie immediately outside watershed boundary.

[b] Approximately 1 mile east of Lewis Rd., cross street = Hay Road.

In the recreational areas, Argyll Park and the Jepson Prairie Preserve use chemical toilets for waste disposal. At the Cypress Lakes Golf course, 3 small septic systems are spread throughout the golf course and pumped out monthly. Two years ago, a 2,300-gallon septic system was added to the course and is also pumped out regularly. No leaks have occurred to any of the systems (Joyce pers. comm. 2000).

3.3.3 URBAN RUNOFF

Preliminary loading calculations based on DWR special studies in the area suggest that urban runoff is not a large contributor to the TOC and turbidity problems experienced by the NBA contractors.

An estimated 256 acres of the City of Vacaville's Foxboro subdivision lie within the upper edge of the watershed (McCall pers. comm. 2000). Its storm drains empty into an unnamed channel that joins the Noonan Main Drain downstream. DWR field observations of the urban portion of the drain found that there is generally little measurable flow in the unnamed channel or the drain when SID is not delivering irrigation water. During winter storms, water levels in the upper section of the drain increase and decrease rapidly.

3.3.4 ANIMAL POPULATIONS

3.3.4.1 Livestock Grazing

Grazing animals can contribute pathogens, TOC, nutrients, and increased turbidity resulting from erosion.

Both sheep and cattle graze in the Barker Slough watershed, but cattle comprise the bulk of farmed livestock. Generally, cattle are moved to the hills in spring to take advantage of green feed and moved back to the watershed in summer. The heaviest grazing occurs between November and June (DWR 1996). Although the time of calving has not been fully investigated, it appears to take place normally in the watershed during late summer. Calving also may occur in the hills. Calves have been observed in the watershed in December (Kimball pers. comm. 2000a). Cattle may be present in the watershed for 6 to 8 months of the year.

Fewer sheep are in the watershed, although their number is difficult to determine because they are present only 2 to 3 months of the year. Their shorter residence time is partly because their primary grazing lands are not found within the watershed (Kimball pers. comm. 2000a). As a rough estimate, the watershed may be able to support up to 1,500 sheep (Kimball pers. comm. 2000a).

Within the watershed, irrigated pasture supports approximately 1.25 to 1.3 cattle per acre; nonirrigated, dry rangeland supports less than 0.75 cattle per acre (Morris pers. comm. 2000). Preliminary calculations of potential stocking densities suggest the Barker Slough watershed could support from 2,600 to 2,700 animals annually (Kimball pers. comm. 2000b). These numbers were based on survey work conducted on 1 day in the fall; they tend to agree with UC Cooperative Extension stocking estimates that as many as 3,000 cattle use the watershed annually (Kimball pers. comm. 2000).

There is no known agency that tracks the number of sheep and cattle in township sections or on individual parcels (DaMassa pers. comm. 2000). The Solano County Department of Agriculture publishes an annual crop report that estimates the number of livestock farmed in the county.

Of the areas grazed in the watershed, only the Jepson Prairie Preserve has a range management plan (Morris pers. comm. 2000a). Management of the remaining acreage has not been fully investigated. Dead cows and sheep have been observed in and near the slough. At local meetings, ranchers have said it is too expensive to haul away dead animals. Generally, the slough is the only water source available for livestock. Fencing along much of the slough's length is either nonexistent or poorly maintained, allowing livestock access to the slough. The pumping plant is completely fenced to keep livestock away from the NBA intake. To DWR's knowledge, no studies have examined livestock access below the pumping plant.

3.3.5 AGRICULTURAL ACTIVITIES

3.3.5.1 Pesticide/Herbicide Use

Using herbicides, SID controls vegetation on the banks of the Noonan Main Drain to remove or manage noxious plants such as yellow star thistle, tumbleweed, and fennel, while promoting the growth of grasses to decrease erosion. Weed management is also required for fire control and for maintenance and inspection of the drain. Algae in the drain is controlled to prevent it from clogging screens and slowing the flow. The district also controls rodents that could compromise bank integrity. Most contol measures occur between January and October. Personnel are certified by the State with Qualified Applicator Certificates and must undergo annual training on safety and pesticides application. Training is provided by a State-accredited, licensed pest control adviser. Chemicals used, the approximate period of application, their rate of application, and the reason for application is given in Table 3-3.

SID is phasing out its use of diuron in many locations (for example, along the inside banks of many drains including the Putah South Canal and Noonan Main Drain). The amount of pesticide is reduced substantially if clopyralid is substituted for diuron. The goal is to establish grasses on the sides of the banks that will screen out most of the star thistle. Star thistle will then be controlled by spot applications of herbicide (for example, using 2,4-D amine) (Vale pers. comm. 2000). Grass establishment along drains has been encouraging. After the 2nd year of practicing this form of weed control, grass has grown in some places to shield between 60% and 90% of the newly vegetated area.

SID has standard operating procedures for the application of pesticides. The type of pesticide (post- or pre-emergent) dictates the strategy the applicator must follow in relation to rainfall. Postemergent pesticides are not effective if washed off by rainfall; therefore, the applicator must take into account the time it takes for the pesticide to become "rain-fast," that is, no movement due to rainfall. Improper application of the herbicide defeats the purpose of its application and is costly to SID's weed control program. To ensure that postemergents are applied effectively and that they become rain-fast, SID uses the manufacturers' suggested rain-fast times (generally between 20 minutes and an hour) and applies a safety factor of no rainfall for a minimum of 2 to 4 hours after application (Vale pers. comm. 2000a).

With pre-emergents, a different application strategy is taken to minimize off-site movement due to rainfall. As with postemergents, the application of pre-emergents too soon after rainfall is costly and ineffective. Pre-emergents need to soak into the ground to be effective. Although they can be applied up to the time of rainfall, they are ineffective if the soil is saturated because they cannot penetrate. During the winter, SID generally waits 3 days after a rain event before applying pre-emergents. This allows time for the soil to dry so the pre-emergent can soak into the soil before the next rainfall. Also, application is normally delayed after a rainfall because applicators cannot drive the dirt roads for several days without damaging them. Approximately 90% of SID's access roads are dirt, and in winter, travel on them is reduced to prevent ruts and erosion problems (Vale pers. comm. 2000a).

Table 3-3 Pesticide Use by the Solano Irrigation District
(Post = Postemergent, Pre = Pre-emergent)

Pesticide (chemical name)	When applied	Rate applied	Reason for application
2,4-D amine (Post)	Jan–Apr	32 oz/acre	Broadleaf weed control
R-11 (Post)	As needed year round	64 oz/100 gal. of spray	Spreader-Activator
Aluminum phosphide	Feb–Mar	3-4 Tablets/burrow	Ground squirrel control
Copper Sulfate[a]	Apr–Oct	1-2 lbs/cfs	Algal control
Clopyralid (Mainly Pre)	Jan–Apr	4 to 8 oz/acre	Thistle control
Diuron (Pre)	Nov–Feb	8 lbs/acre	Pre-emergent weed control
Glyphosate (Roundup) (Post)	Usually Feb–Oct	48 oz/acre	Postemergent weed control and brush control.

Source: Mark Vale, Solano Irrigation District.
Pesticide is an umbrella term that includes insecticide, herbicide, and fungicide.
[a] Only applied during water deliveries

SID practices a conservative and responsible weed control program, but it is not known what standard operating procedures are followed for other herbicide applicators in the area. SID applicators have noted herbicide use on the railroad right of way near Leisure Town and along county roads. Weed control is also practiced on Highway 113 that runs through the watershed.

Pesticides and herbicides are used at the Cypress Lakes Golf Club for course maintenance. Round-up (glyphosate) is used for spot weeding. The most heavily applied compound is fertilizer or a fertilizer pre-emergent product. Fairways are normally fertilized 3 to 4 times a year (Goldbronn pers. comm. 2000). Up to 10,000 pounds per application are allowed, although this is the high end of usage. Annually, the 1st application of fertilizer occurs in mid to late February. Application depends on the weather. No compound is applied if the ground is too wet to support a tractor. The last application of fertilizer generally occurs in early November. Depending on weather conditions, fungicide is applied 2 times between August and December but only to the putting greens. The type of fungicide and its application are tied to the weather because different conditions promote the growth of different funguses.

From 1996 through 1998, pesticide use in Solano County remained fairly constant, varying between 1.7 million and 2 million pounds (DPR 1996, 1997, 1998). Within the Barker Slough watershed, irrigated agriculture primarily occurs in the upper half of the watershed. Table 3-4 lists the pounds of active ingredients of all reportable pesticides applied to the upper half of the watershed from 1996 through 1998 (most recent year data were available) (Bartkowiak pers. comm. 2000). During this period, reportable pesticides were applied to alfalfa, sorghum, corn, and nursery stock. Township 06 N Range 01 W Section 36 also reflects compounds applied at Cypress Lakes Golf Club. As noted in Section 3.1.1, Land Use, sugar beets, Sudan grass, and safflower have been previously observed growing in this area of the watershed. Sugar beet crop, along with tomato processing and canning, grapes, and pears, was 1 of the top 5 commodity users of pesticides countywide in 1998 (only year data were available) (DPR 1998). Because of market influences, sugar beets may be farmed less in the future; therefore, the crop's future in Barker Slough watershed may be limited. The top 5 pesticides applied to sugar beets in 1998 were methyl-bromide, metam-sodium, glyphosate, paraquat dichloride, and ammonium sulfate (DPR 1998). Of these substances, DWR monitors for ammonia, glyphosate, and sulfate.

Table 3-4 Pesticide Application, by Crop, (lbs of Active Ingredient) for Upper Section of the Barker Slough Watershed, 1996-1998

TRS	Chemical	Year 1996	1997	1998	Crop
05N01 E05	PETROLEUM HYDROCARBONS	38.44	38.44	38.44	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	PARAQUAT DICHLORIDE	24.04	24.04	24.04	"
	CHLORPYRIFOS	18.53	18.53	18.53	"
	ALKYL OXY-POLYOXYETHYLENE AND ALKYL PHENYLOXY-POLYOXYETHYLENE	9.71	9.71	9.71	"
	PHOSPHORIC ACID	0.36	0.36	0.36	"
	PROPYLENE GLYCOL	0.26	0.26	0.26	"
	TRISODIUM PHOSPHATE	0.11	0.11	0.11	"
	Total	**91.45**	**91.45**	**91.45**	
05N01 E06	CARBARYL	1,197.80	1,197.80	1,197.80	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	OCTYL PHENOXY POLY ETHOXY ETHANOL	69.97	69.97	69.97	"
	METHOMYL	58.76	58.76	58.76	"
	ISOPROPYL ALCOHOL	12.84	12.84	12.84	"
	CITRIC ACID	7.14	7.14	7.14	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	6.56	6.56	6.56	"
	COMPOUNDED SILICONE	3.43	3.43	3.43	"
	PYRETHRINS	1.99	1.99	1.99	"
	ROTENONE, OTHER RELATED	1.66	1.66	1.66	"
	ROTENONE	1.66	1.66	1.66	"
	CALCIUM CHLORIDE	0.86	0.86	0.86	"
	Total	**1,362.66**	**1,362.66**	**1,362.66**	
05N01 E07	CARBARYL	1,026.86	1,026.86	1,026.86	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	METHOMYL	96.27	96.27	96.27	"
	CITRIC ACID	12.41	12.41	12.41	"
	ISOPROPYL ALCOHOL	11.51	11.51	11.51	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	11.40	11.40	11.40	"
	CALCIUM CHLORIDE	1.49	1.49	1.49	"
	Total	**1,159.95**	**1,159.95**	**1,159.95**	
05N01 E08	CARBARYL	538.04	538.04	538.04	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	METHOMYL	60.03	60.03	60.03	"
	CITRIC ACID	45.65	45.65	45.65	"
	ISOPROPYL ALCOHOL	42.38	42.38	42.38	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	41.96	41.96	41.96	"
	CALCIUM CHLORIDE	5.48	5.48	5.48	"
	Total	**733.53**	**733.53**	**733.53**	

Table 3-4 (continued)

TRS	Chemical	Year			Crop
		1996	1997	1998	
05N01 W01	CARBARYL	95.94	95.94	95.94	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	CARBARYL	75.08	75.08	75.08	CORN (FORAGE - FODDER)
	METOLACHLOR	59.38	59.38	59.38	CORN (FORAGE - FODDER)
	OCTYL PHENOXY POLY ETHOXY ETHANOL	10.00	10.00	10.00	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	PHOSPHORIC ACID	1.43	1.43	1.43	CORN (FORAGE - FODDER)
	PROPYLENE GLYCOL	1.05	1.05	1.05	CORN (FORAGE - FODDER)
	ISOPROPYL ALCOHOL	0.89	0.89	0.89	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	COMPOUNDED SILICONE	0.49	0.49	0.49	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	TRISODIUM PHOSPHATE	0.45	0.45	0.45	CORN (FORAGE - FODDER)
	Total	**244.70**	**244.70**	**244.70**	
06N01 W35	PETROLEUM HYDROCARBONS	109.17	109.17	109.17	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	PARAQUAT DICHLORIDE	68.27	68.27	68.27	"
	ALKYL OXY-POLYOXYETHYLENE AND ALKYL PHENYLOXY-POLYOXYETHYLENE	27.56	27.56	27.56	"
	CHLORPYRIFOS	13.14	13.14	13.14	"
	PHOSPHORIC ACID	0.34	0.34	0.34	"
	PROPYLENE GLYCOL	0.25	0.25	0.25	"
	TRISODIUM PHOSPHATE	0.11	0.11	0.11	"
	Total	**218.84**	**218.84**	**218.84**	
06N01 W36	FOSETYL-AL	1,528.03	1,528.03	1,528.03	N-OUTDR CONTAINER/FLD GRWN PLANTS
	MANCOZEB	905.74	863.74	905.74	"
	THIOPHANATE-METHYL	883.20	872.00	672.22	"
	PETROLEUM DISTILLATES, REFINED	867.03	867.03	867.03	"
	ORYZALIN	442.24	432.59	442.24	"
	PCNB	330.42	330.42	330.42	"
	POLY-I-PARA-MENTHENE	291.76	288.27	291.76	"
	OXYFLUORFEN	274.19	274.19	274.19	"
	NAPROPAMIDE	251.13	251.13	251.13	"
06N01 W36	PENDIMETHALIN	204.18	204.18	204.18	"
	COPPER HYDROXIDE	165.31	151.14	165.31	"
	IPRODIONE	163.75	163.75	163.75	"
	ACEPHATE	161.84	160.15	104.09	"
	2-(3-HYDROXYPROPYL)-HEPTA-METHYL TRISILOXANE, ETHOXYLATED, ACETATE	97.82	95.84	97.82	"
	OXADIAZON	85.95	85.95	85.95	"
	METALDEHYDE	64.80	64.80	64.80	"

Table 3-4 (continued)

TRS	Chemical	Year 1996	1997	1998	Crop
	ISOXABEN	47.11	46.95	47.11	"
	CHLOROTHALONIL	46.16	46.16	46.16	"
	METALAXYL	38.50	38.50	11.20	"
	DIAZINON	34.97	34.97	34.97	"
	MALATHION	33.37	33.37	33.37	"
	CARBOFURAN	29.99	29.99	29.99	"
	PHOSPHORIC ACID	14.89	14.89	14.89	"
	CHLORPYRIFOS	14.42	14.42	14.42	"
	BENDIOCARB	13.21	13.21	13.21	"
	CHLORPYRIFOS	12.52	12.52	12.52	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	PROPICONAZOLE	7.54	7.54	7.54	N-OUTDR CONTAINER/FLD GRWN PLANTS
	MANGANESE SULFATE	5.35	5.35	5.35	N-OUTDR CONTAINER/FLD GRWN PLANTS
	PIPERONYL BUTOXIDE	5.17	5.17	5.17	"
	POLYOXYETHYLENE POLYMER	3.52	3.52	3.52	"
	MYCLOBUTANIL	3.48	3.48	3.48	"
	OXYTHIOQUINOX	3.12	3.12	3.12	"
	STREPTOMYCIN SULFATE	3.07	3.07	3.07	"
	COPPER SULFATE (PENTAHYDRATE)	3.03	3.03	3.03	"
	CYFLUTHRIN	2.27	2.27	2.27	"
	TRIADIMEFON	1.89	1.89	1.89	"
	BACILLUS THURINGIENSIS (BERLINER), SUBSP. ISRAELENSIS, SEROTYPE H-14	1.85	1.85	1.85	"
	PIPERONYL BUTOXIDE, TECHNICAL, OTHER RELATED	1.29	1.29	1.29	"
	DIENOCHLOR	0.75	0.75	0.75	"
	ZINC SULFATE	-	0.69	0.69	"
	OCTYL PHENOXY POLY ETHOXY ETHANOL	0.67	0.67	0.67	"
	PYRETHRINS	0.65	0.65	0.65	"
	DODECYLBENZENE SULFONIC ACID	0.57	0.57	0.57	"
	1,3-DICHLOROPROPENE	0.39	0.39	0.39	"
	AVERMECTIN	0.26	0.26	0.26	"
	PHOSPHORIC ACID	0.24	0.24	0.24	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	TRIETHANOLAMINE	0.22	0.22	0.22	N-OUTDR CONTAINER/FLD GRWN PLANTS
	PROPYLENE GLYCOL	0.18	0.18	0.18	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	SODIUM XYLENE SULFONATE	0.18	0.18	0.18	N-OUTDR CONTAINER/FLD GRWN PLANTS
	ISOPROPYL ALCOHOL	0.17	0.17	0.17	"
	DIETHYLAMINE SALT OF COCONUT FATTY ACID	0.13	0.13	0.13	"

Table 3-4 (continued)

TRS	Chemical	Year 1996	1997	1998	Crop
	TETRAPOTASSIUM PYROPHOSPHATE	0.09	0.09	0.09	"
	CHLOROPICRIN	0.08	0.08	0.08	"
	TRISODIUM PHOSPHATE	0.08	0.08	0.08	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	3,7,11-TRIMETHYL-2,6,10-DODECATRIENE-1-OL	0.04	0.04	0.04	N-OUTDR CONTAINER/FLD GRWN PLANTS
	EDTA, TETRASODIUM SALT	0.04	0.04	0.04	"
	3,7,11-TRIMETHYL-1,6,10-DODECATRIENE-3-OL	0.03	0.03	0.03	"
	BACILLUS THURINGIENSIS (BERLINER), SUBSP. KURSTAKI, SEROTYPE 3A,3B	0.02	0.02	0.02	"
	TAU-FLUVALINATE	0.02	0.02	0.02	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	0.02	0.02	0.02	"
	SILICONE DEFOAMER	0.01	0.01	0.01	"
	DIPHACINONE	0.002	0.002	0.002	"
	Total	**7,048.95**	**6,965.31**	**6,753.60**	

Source: Donna Bartkowski, Department of Pesticide Regulation

3.3.6 UNAUTHORIZED ACTIVITY

3.3.6.1 Spills/Illegal Dumping

There are generally no records of illegal dumping or spills in the unincorporated area of the watershed (Eubank pers. comm. 2000).

3.3.6.2 Underground Storage Tanks

The Solano County Division of Environmental Management has no record of any leaking underground storage tanks in the watershed (Eubank pers. comm. 2000). More accurate estimates of the watershed's boundaries have excluded many of the underground storage tanks identified in the *Sanitary Survey Update 1996* (for example, Travis Air Force Base).

3.4 WATER QUALITY SUMMARY

3.4.1 WATERSHED (BARKER SLOUGH PUMPING PLANT)

In this section, comparisons are made between contaminant concentrations in SWP source water and maximum contaminant levels (MCLs) for finished drinking water. Although MCLs are usually applied to finished water, they are useful as conservative indicators of contaminants that concern utilities and that require removal during the treatment process to meet finished water standards. Comparisons also serve to focus on particular PCSs associated with contaminants of concern and to develop appropriate recommendations for actions. It follows that if source water concentrations are below MCLs, then these contaminants are not likely to be of concern to the finished water supplies.

Since 1987, DWR's Operations and Maintenance Division (O&M) has routinely conducted monthly monitoring for organic, inorganic, and miscellaneous compounds at the Barker Slough Pumping Plant. From 1996 through 1999, all conventional parameters and major minerals in the O&M samples were below MCLs for finished drinking water or Article 19 objectives (DWR 1999, 2000a). Conventional parameters include conductivity, hardness, lab pH, suspended solids, suspended volatile solids, field temperature, total dissolved solids, and turbidity. Major minerals include the cations calcium, magnesium, and sodium, and the anions bicarbonate (alkalinity), chloride, nitrate, and sulfate. Selected conventional parameters and major minerals are shown in Table 3-5. Even at its lowest level, turbidity was above the secondary MCL of 5 NTUs. Turbidity patterns are discussed in detail in Section 3.3.3, Key Constituents of Concern to NBA Contractors.

Minor elements include metals such as copper, zinc, and iron, and nonmetals such as arsenic and selenium. They are called minor elements because concentrations are usually below 1 part per million in natural surface waters. From 1996 through 1999, dissolved aluminum, iron, and manganese were detected above primary or secondary MCLs. These metals are discussed further in Section 3.3.2.1, Title 22 Constituents. The remaining minor elements were below the MCLs for finished drinking water or Article 19 objectives (DWR 1999, 2000a).

Table 3-5 Barker Slough Pumping Plant, Jan 1996 to Dec 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	16	16	7	26	9.0 - 22	1.0	51/51
Chloride	21	18	6	47	10.0- 36	1.0	51/51
Total Dissolved Solids	183	176	90	300	126 - 262	1.0	51/51
Hardness (as CaCO3)	97	95	46	162	56 - 146	1.0	51/51
Alkalinity (as CaCO3)	101	101	37	167	63 - 139	1.0	83/83
Conductivity	312	303	126	501	186 - 460	1.0	52/52
Magnesium	14	14	7	24	8.0 - 21	1.0	51/51
Sulfate	24	20	5	53	9.0 - 44	1.0	51/51
Turbidity (NTU)	65	45	18	256	23 - 157	1.0	106/106
Minor Elements (dissolved) (mg/L)							
Aluminum	0.02	0.01	< 0.01	0.438	0.01 - 0.011	0.01	12/81
Arsenic	0.00	0.002	0.001	0.004	0.002 - 0.003	0.001	49/49
Barium	0.05	0.05	< 0.05	0.08	0.05 - 0.06	0.05	14/48
Boron	0.21	0.2	0.1	0.4	< 0.1 - 0.38	0.1	48/51
Chromium	0.01	0.005	< 0.005	0.011	0.005 - 0.007	0.005	18/49
Copper	0.004	0.004	0.005	0.005	0.002 - 0.005	0.001	31/49
Managanese	0.03	0.019	< 0.005	0.358	0.008 - 0.044	0.005	78/81
Zinc	0.01	0.005	< 0.005	0.05	0.005 - 0.05	0.005	5/48
Nutrients (mg/L)							
Total ammonia	0.95	0.7	0.4	2	0.5 - 1.72	0.01	29/29
Total Kjeldahl Nitrogen(as N)	0.9	0.7	0.4	2	0.5 - 1.7	0.1	29/29
Nitrate (as NO3)	0.4	0.4	0.4	0.4	0.4 - 0.4	0.1	1/1
Nitrate+Nitrite (as N)	0.38	0.3	0.08	3.5	0.13 - 0.53	0.01	50/50
Total Phosphorus	0.23	0.21	0.1	0.43	0.15 - 0.35	0.01	51/51
Orthophosphate	0.09	0.1	0.01	0.15	0.07 - 0.12	0.01	51/51
Misc.							
Bromide (mg/L)	0.05	0.04	0.01	0.10	0.02 - 0.08	0.01	51/51
Total Organic Carbon (mg/L)	7.2	5.6	1.0	38.0	2.9 - 13.6	0.1	117/117
pH (pH unit)	7.5	7.6	6.9	8.2	7.1 - 8	0.1	21/21
UVA (uS/cm)	0.462	0.328	0.112	0.99	0.121 - 0.952	0.001	20/20

Source: DWR O&M Division database, May 2000

Notes: All metals Jan 1996 through Dec 1999.

Turbidity data from Jun 1996 through Dec 1999.

Total Kjeldahl Nitrogen(as N) and total ammonia data collected from Jun 1996 through Mar 1998.

Only one sample collected for Nitrate. All other nutrient data from Jan 1996 through Dec 1999.

Bromide and TOC data from Jan 1996 through Dec 1999.

pH and UVA data from Feb 1998 through Dec 1999.

Nutrients enhance plant growth in surface waters and include nitrogen and phosphorus compounds. Primary MCLs exist for nitrite and nitrate as nitrogen as well as nitrate and nitrite as nitrogen. No standards or objectives exist for the other nutrients. Concentrations for selected nutrients monitored by O&M from 1996 through 1999 are shown in Table 3-5. Nutrient levels were below all MCLs for finished drinking water. In 1996 and 1997, O&M examined seasonal nutrient trends. Although data were not extensive, nitrogen compounds flucuated seasonally and increased during periods of rainfall (DWR 1999). Additionally, organic nitrogen was correlated with TOC, while nitrate was not. By definition, organic nitrogen is organically bound to compounds such as proteins, peptides, nucleic acids, urea, and other organics present in animal fecal material. In contrast, nitrates in surface water can originate from a number of sources including animal waste, fertilizers, and nitrification. Nitrates are also more likely than organic nitrogen to percolate through soil, reducing the amount available for transport via runoff.

O&M monitors pesticides and organic chemicals at the pumping plant 3 times a year, usually in March, June, and October (DWR 1999). Samples are analyzed for chlorinated organics, chlorinated phenoxy acid herbicides, glyphosate, volatile organics (including MTBE), and carbamates (DWR 2000a). From 1995 to 1999, the MWQI unit has analyzed Barker Slough Pumping Plant samples for pesticides 12 times. Samples were collected in December 1995, March and June 1996, twice in September 1996, October 1996, twice in December 1996, twice in March 1997, once in June 1997, and again in June 1999.

Based on DPR data, Table 3-6 lists the top 2 pesticides applied in terms of pounds within the township-ranges encompassing areas of the upper Barker Slough watershed. Table 3-7 shows pesticide concentrations at the Barker Slough Pumping Plant of pesticides that were either applied by SID or were 1 of the top 2 pesticides applied in the upper watershed, according to DPR use reports. Of DPR-reported compounds, DWR monitors for carbaryl and methomyl. Neither was detected 1996 through 1999. With respect to the compounds applied by SID, DWR monitors for 2,4-D, aluminum, copper, diuron, glyphosate, and sulfate. Of the organic pesticides applied by SID, only diuron has been detected. Diuron concentrations ranged from below the detection limit to 4.24 µg/L. There is no MCL for this compound.

Table 3-6 Top 2 Pesticides (in Terms of lbs) Applied in Townships, Ranges, and Sections Encompassing Irrigated Lands in the Upper Barker Slough Watershed, 1996 to

Township, Range, Section	Top 2 pesticides applied (as lbs) from 1996-1998	Pounds Applied	Crop Application
05N01E05	PETROLEUM HYDROCARBONS	38.44[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
	PARAQUAT DICHLORIDE	24.04[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
05N01E06	CARBARYL	1197.8[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	OCTYL PHENOXY POLY ETHOXY ETHANOL	69.97[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
05N01E07	CARBARYL	1026.86[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	METHOMYL	96.27[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
05N01E08	CARBARYL	538.04[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	METHOMYL	60.03[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
05N01W01	CARBARYL	95.94[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	CARBARYL	75.08[a]	CORN (FORAGE - FODDER)[b]
06N01W35	PETROLEUM HYDROCARBONS	109.17[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
	PARAQUAT DICHLORIDE	68.27[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
06N01W36	FOSETYL-AL	1528.03[a]	N-OUTDR CONTAINER/FLD GRWN PLANTS[b]
	MANCOZEB	905.74[c]	N-OUTDR CONTAINER/FLD GRWN PLANTS[d]
	THIOPHANATE-METHYL	872.00[e]	N-OUTDR CONTAINER/FLD GRWN PLANTS

Information provided courtsey of Donna Bartkowiak, Department of Pesticide Regulation

[a] Same number of pounds applied in 1996, 1997, and 1998

[b] Applied to same crop in 1996, 1997, and 1998

[c] Only applied in 1996 and 1998. Same number of pounds applied in both years.

[d] Applied to same crop in 1996 and 1998

[e] One of 2 of the top pesticides used in 1997

Table 3-7 Selected Pesticides Detected at the Barker Slough Pumping Plant, 1996 to [a]

		MWQI		O & M	
	MCL	mean	range	mean	range
2,4-D (μg/L)	70	< 0.1		< 0.1	
Carbaryl (μg/L)	-	< 2		< 2	
Diuron (μg/L)	-	0.89	< 0.25 - 4.24	0.26	< 0.25 - 0.26
Glyphospate (μg/L)	700	< 100		< 100	
Methomyl (μg/L)	-	< 2		< 2	

[a] Pesticides were either applied by SID or, based on DPR use reports, were 1 of the top 2 pesticides applied in upper watershed.

With respect to individual constituents of inorganic pesticides, monthly samples for dissolved copper as well as sulfate concentrations were below MCL or Article 19 objectives (DWR 1999, 2000a). According to quarterly Title 22 analyses, total copper has consistently been below the detection limit, but concentrations of total aluminum are routinely detected above its primary MCL (DeAlbidress pers.

comm. 2000). Aluminum is discussed in Section 3.3.2.1, Title 22 Constituents. Finally, of the 962 pesticide analyses conducted by MWQI, only 6 pesticides have been detected from 1996 through 1999 (Table 3-8). With the exception of simazine, no MCLs have been established for any of these pesticides. All simazine detections were below the MCL.

Table 3-8 Pesticides Detected at the Barker Slough Pumping Pumping Plant from MWQI Studies

Pesticide	Sample Date	MCL	Result (µg/L)
bis(2-Ethylhexyl) phthalate	9/5/96	-	4.0
Diazinon	9/30/96	-	.01
Diazinon	9/30/96		.05
Diazinon	12/30/96		.01
Diuron	12/30/96	-	.75
Diuron	3/31/97		4.24
Formetanate hydrochloride	6/6/96	-	100
Methidathion	6/16/97	-	.07
Simazine	3/7/96	4	1.3
Simazine	12/30/96		.62
Simazine	3/31/97		.14

Note: Samples collected Dec 1995 and quarterly in 1996. Samples also collected in Mar 1997, Jun 1997, and Jun 1999

Bromide concentrations at the Barker Slough Pumping Plant from 1996 to 1999 ranged from 0.1 to 0.95 mg/L and averaged 0.46 mg/L (Table 3-5). These concentrations were frequently above the 0.05 mg/L level desired by utilities. Unlike organic carbon, bromide concentrations do not increase during the rainy season, instead increases are usually observed during spring and early summer (Figure 3-4) (DWR 1998, 1999, 2000a).

At Lindsey Slough, which is closer to the Sacramento River, bromide concentrations reflect seawater intrusion. In the absence of other sources, bromide concentrations at Lindsey Slough should be the same or higher than bromide concentrations upstream at the pumping plant. However, comparisons between samples collected at Lindsey Slough and the Barker Slough Pumping Plant show bromide concentrations at the pumping plant are the same or higher than bromide concentrations downstream at Lindsey Slough (Figure 3-5). Bromide concentrations between the 2 sites are also significantly different (one-tailed t-test, $p < 0.05$); samples were not necessarily collected at high tide at either sampling point.

With these caveats, 1 hypothesis for these results may be the movement of bromide by groundwater. Because groundwater movement will be much slower than surface runoff, groundwater impacts may not occur until after the rainy season. Within the watershed, the Markley Formation may contain ancient marine sediments, which could leach bromide into the groundwater. Another hypothesis is that the evaporation of irrigation water could create a buildup of salts, including bromide (DWR 1998). No formal studies have been conducted to verify either of these hypotheses.

Figure 3-4 Average Monthly Bromide Concentration (mg/L) at the Barker Slough Pumping Plant, 1996 to 1999

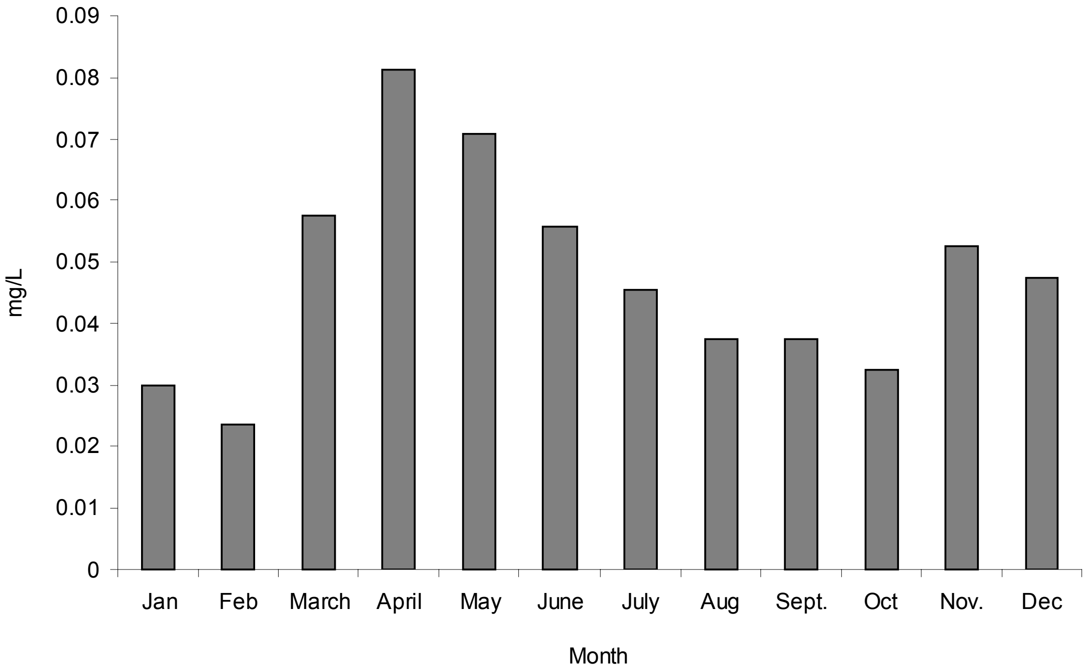


Figure 3-5 Comparison of Bromide Concentrations between the Barker Slough Pumping Plant and Lindsey Slough, Jun 1996 to Jul 1997

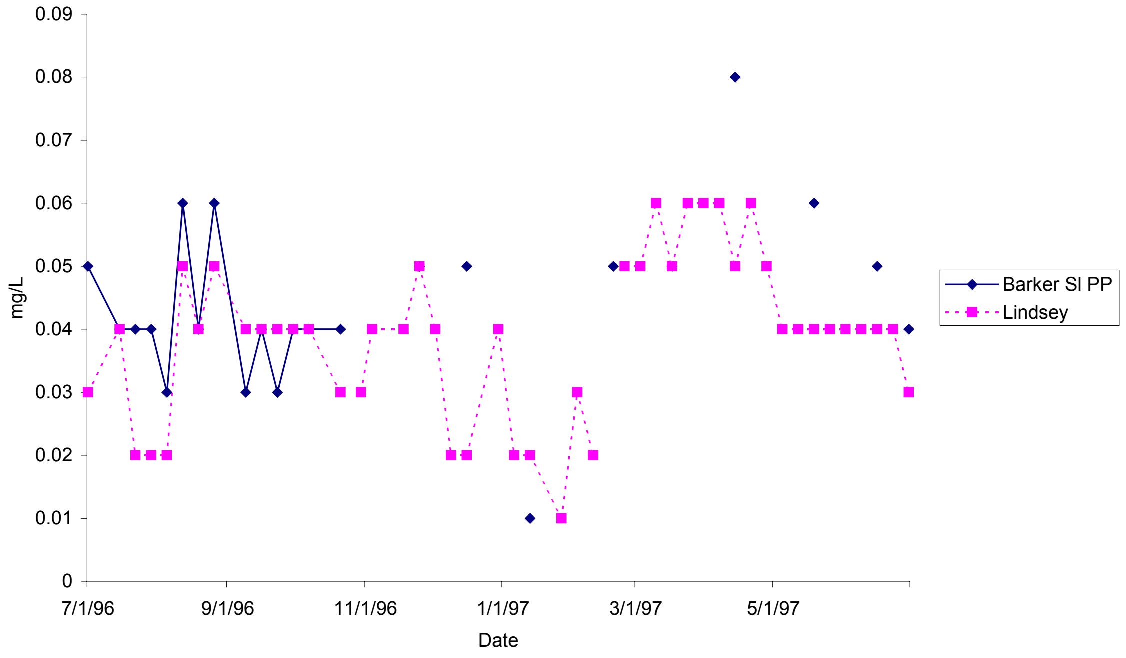


Table 3-9 Summary of Title 22 Violations (primary and secondary) for Quarterly Samples of Barker Slough Pumping Plant Analyzed by NBR, 1996 to 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Total Aluminum	4.41	3.12	0.979	11.4	1.63 - 9.90	0.05	16/16
Total Iron	3.04	2.555	0.771	7.68	0.94 - 5.8	0.1	16/16
Total Managanese	0.09	0.082	0.046	0.271	0.06 - 0.11	0.03	15/16

3.4.2 WATER SUPPLY SYSTEMS

Treatment difficulties using NBA source water generally occur with winter storm events and heavy watershed runoff. Contractors consistently list high TOCs, turbidities, and loss of alkalinity as their major challenges in treating NBA water. In order not to exceed finished water turbidity and TOC standards, contractors have been forced to shut down plants that are unable to blend or switch to an alternate water source. Another challenging problem with storm events is the sudden, rapid changes in turbidity and TOC, which can force plants to shut down until enough jar tests can be performed to determine proper chemical dosages. The instability of NBA water quality requires frequent adjustments to chemicals and treatment schemes and requires continuous laboratory analytical testing. Rapidly changing turbidities also create problems in optimizing turbidity for pathogen control. When turbidities are fairly stable, contractors are able to meet the 2-log removal of *Cryptosporidium* at a filter effluent turbidity of 0.3 nephelometric turbidity unit (NTU). When turbidities change rapidly, the inability to calculate chemical dosages may compromise pathogen removal (Fleege pers. comm. 2000a).

Travis AFB WTP and the NBR WTP are the 1st to receive NBA water from the pumping plant. The cities of Benicia, Napa, and Vallejo are farther downstream and may benefit from potential settling out of contaminants due to distance and the presence of the Cordelia Forebay and Surge Tank. In the case of Vallejo, NBA water is conveyed through city-owned pipes from the Cordelia Forebay to Cordelia and Summit Reservoir, where more settling is possible. Because Vallejo blends its water (Table 3-1), it does not encounter the same problems with NBA water as some of the other contractors and was not included in this discussion.

3.4.2.1 Title 22 Constituents

As part of a cooperative agreement approved by the California Department of Health Services (DHS), NBR WTP staff conduct quarterly sampling for most Title 22 constituents (see Chapter 2) on NBA raw water for all NBA contractors. Exceptions include radionuclides, nonvolatile synthetic organic chemicals (SOCs), and asbestos. Radionuclide samples are collected at NBR WTP quarterly every 3 years. SOCs are sampled twice a year, once in the dry season and once in the wet season. Asbestos is sampled and analyzed once every 9 years. Organic and radionuclides data are used for compliance by all NBA contractors. NBA contractors sample and analyze their own treated water for all inorganic Title 22 constituents and may conduct their own in-house analyses on specific Title 22 compounds. NBA contractors use NBR WTP's raw water analyses to determine compliance for organics and radionuclides and their own treated water analyses to determine compliance for the remaining Title 22 compounds. The 1 exception is Napa at Jameson Canyon, which also uses NBR WTP's analyses of raw NBA water for inorganic compliance. Raw water analyzed by NBR WTP staff is collected at the Barker Slough Pumping Plant.

With the exception of Napa, there have been no Title 22 violations for any of the NBA contractors. Napa uses raw water to compare metal concentrations to the MCL. Aluminum has consistently exceeded the primary MCL of 1 mg/L. Following treatment, Napa's aluminum concentrations have never violated the MCL. Iron and manganese also routinely violate secondary MCLs. Again, after the water is treated, there have been no violations for either of these metals. Title 22 organic compounds are monitored quarterly by NBR WTP staff. From 1996 through 1999, no organic Title 22 compounds were detected (DeAlbidress pers. comm. 2000). Samples collected by O&M have only detected Dacthal (DCPA) once at 0.05 µg/L (DWR 1999, 2000a).

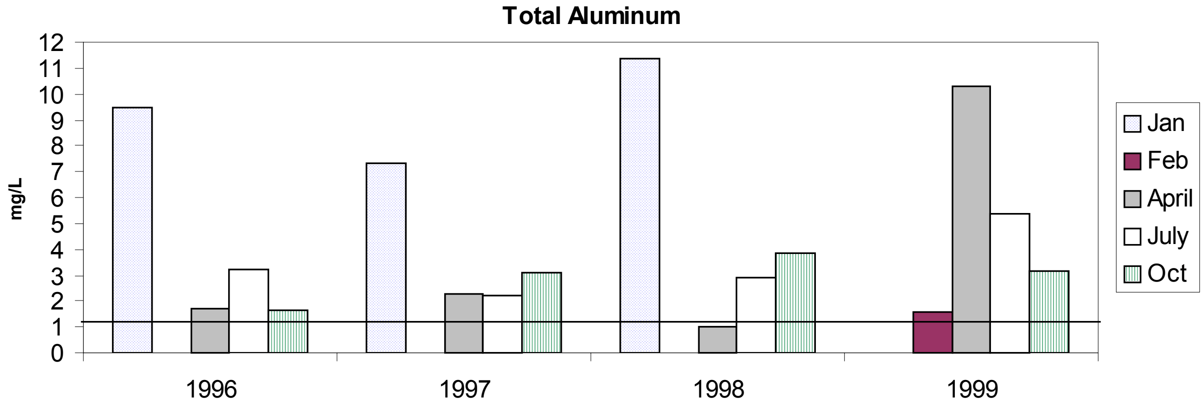
Table 3-9 and Figure 3-6 summarize NBR WTP's quarterly Title 22 analyses of aluminum, iron, and manganese. Iron or manganese showed no seasonal pattern. DWR data were not used to examine patterns because the majority of samples analyzed were for dissolved aluminum and more than 80% were below the detection level. Only 1 of the 16 samples collected in spring 1998 was below the primary MCL. Highest concentrations were generally detected in winter. With no other data, causes for the elevated aluminum concentrations are speculative. Aluminum phosphide is used for rodent control, but it is applied inside the rodent hole and should have minimal off-site movement (Vale pers. comm. 2000a). Aluminum concentrations may be highest in the winter due to the increased solubility of Al in lower pH rainwater. Also, increased particulates may result in the adsorption of Al resulting in elevated metal concentrations.

3.4.3 KEY CONSTITUENTS OF CONCERN TO NBA CONTRACTORS

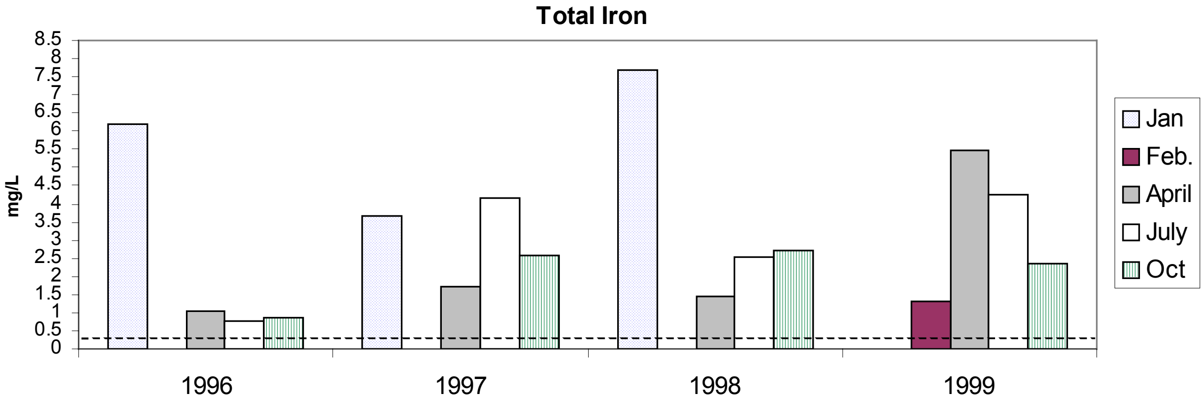
3.4.3.1 Total Organic Carbon (TOC) and Alkalinity

Organic carbon levels are strongly influenced by the wet season. TOC influent data were pooled by month from 1996 through 1999 for several major NBA contractors and the Barker Slough Pumping Plant (Figure 3-7). Because data collected by utilities and DWR vary by sample date, time, and frequency, the pooled monthly averages cannot be compared directly. However, the data verify that for each utility, highest TOC concentrations primarily occur between December and April. Bracketing TOC concentrations between 2 and 4 mg/L—the lowest TOC range of source water requiring treatment under the Disinfectants and Disinfection Byproducts (D/DBPs) Rule (EPA 1998)—found that on average pumping plant and utility influent water always exceeded 2 mg/L TOC.

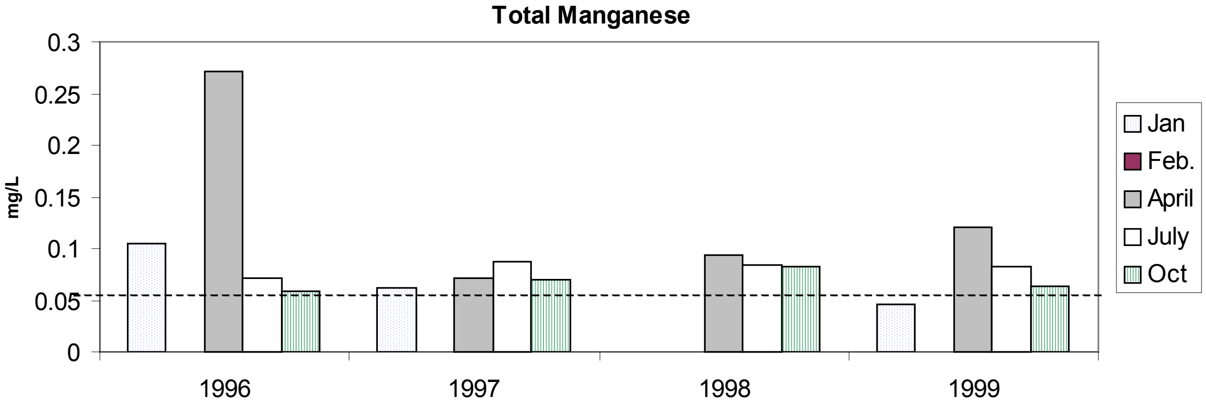
Figure 3-6 Quarterly Concentrations of Minor Elements in Raw Water Exceeding Title 22 Concentrations



Total Aluminum



Total Iron



Total Manganese

(Primary MCL shown as solid horizontal line; secondary MCL shown as horizontal dashed line)

Figure 3-7 Average Monthly TOC Concentrations for Selected NBA Contractors, 1996 to 1999

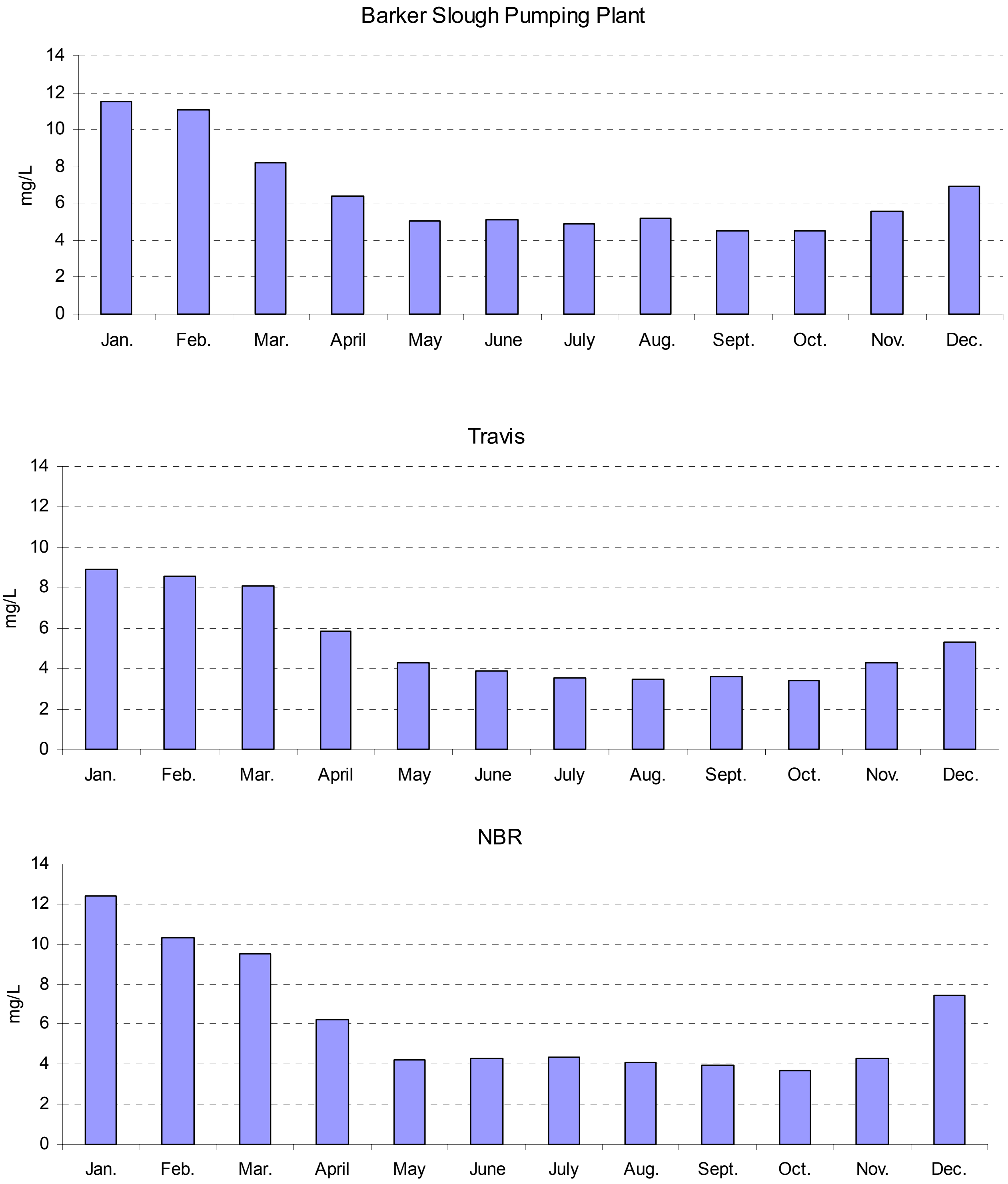
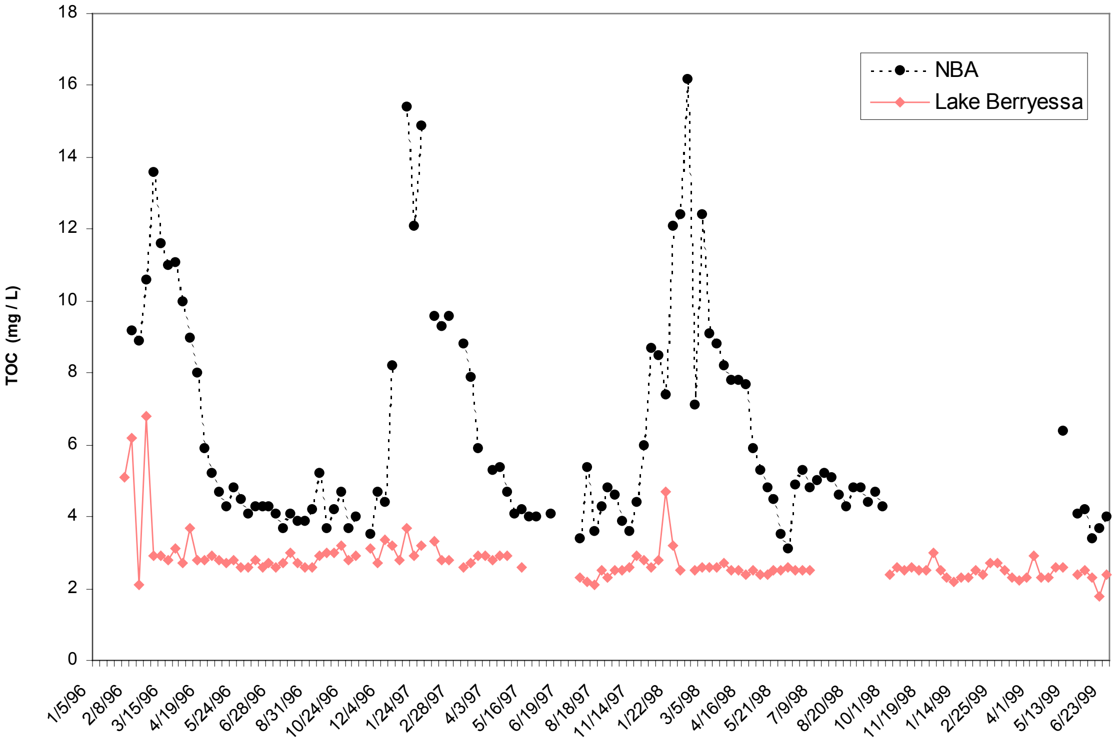


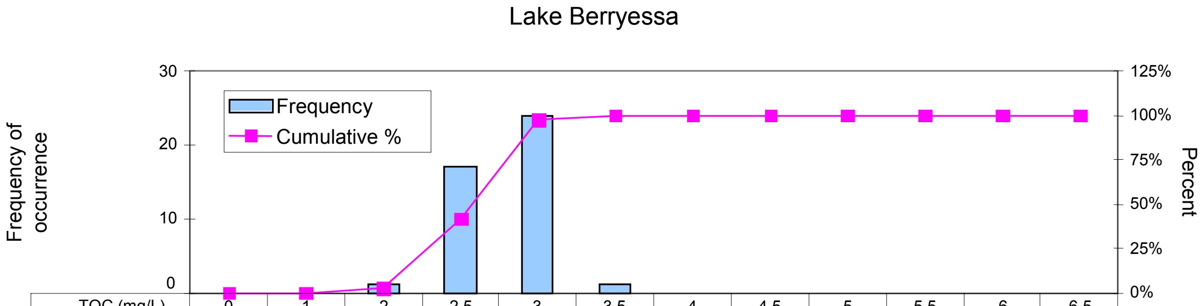
Figure 3-8 TOC Comparisons between North Bay Aqueduct Water at the North Bay Regional Water Treatment Plant and Lake Berryessa, 1996 to 1999



A comparison between NBA and Lake Berryessa TOC concentrations underscores the dramatic differences in water quality between the 2 sources (Figure 3-8). NBR WTP data were used to examine differences between NBA and Lake Berryessa water quality. Except when a source is not being used, NBR WTP staff maintains weekly TOC records for both NBA and Lake Berryessa water. Regardless of the season, NBA's TOC concentrations were consistently higher than those from Lake Berryessa water. In summer, Lake Berryessa TOC concentrations were less than 4 mg/L, whereas more than half of the NBA samples collected on the same date as those taken from Lake Berryessa were over 4 mg/L (Figure 3-9). Additionally, winter peaks in NBA TOC concentrations remained elevated over a longer period of time relative to Lake Berryessa water and were at higher concentrations than at the lake. For example, from November to April, more than 90% of influent Lake Berryessa TOC concentrations were less than 4 mg/L; for NBA waters, more than 90% were greater than 4 mg/L (Figure 3-10). Average weekly data do not show the rapid, unexpected peaks of TOC experienced during winter storms, but Figure 3-8 does illustrate the twofold jumps in concentration that NBA water can experience during the winter

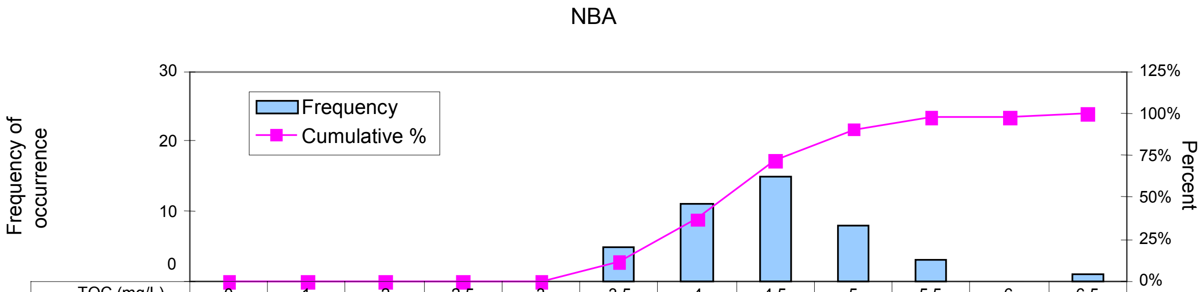
Figure 3-9 Cumulative Probability Distribution of Summer TOC Values at Lake Berryessa and North Bay Aqueduct from NBR Data

Lake Berryessa



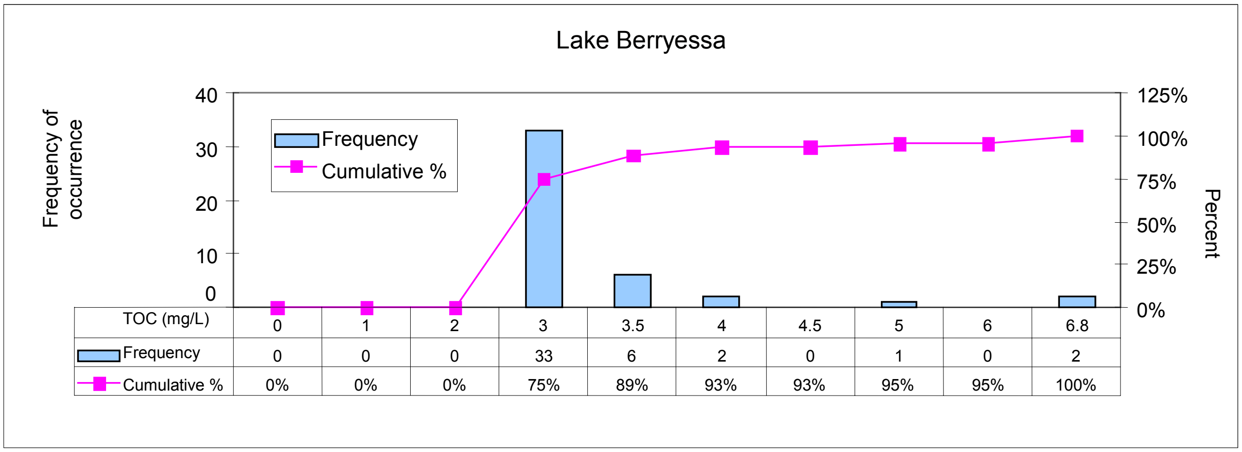
TOC (mg/L)	0	1	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Frequency	0	0	1	17	24	1	0	0	0	0	0	0
Cumulative %	0%	0%	2%	42%	98%	100%	100%	100%	100%	100%	100%	100%

NBA

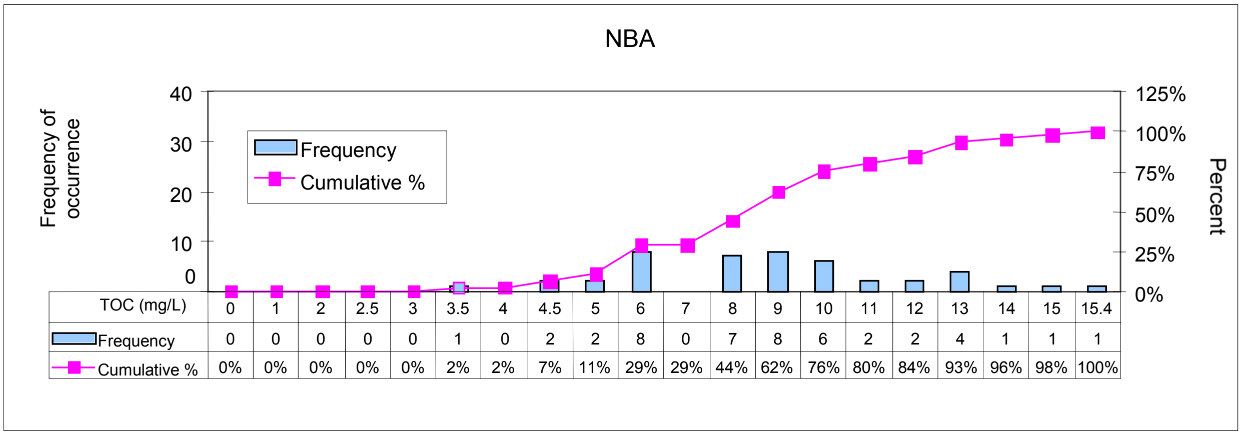


TOC (mg/L)	0	1	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Frequency	0	0	0	0	0	5	11	15	8	3	0	1
Cumulative %	0%	0%	0%	0%	0%	12%	37%	72%	91%	98%	98%	100%

Figure 3-10 Cumulative Probability Distribution of Winter TOC Values at Lake Berryessa and North Bay Aqueduct from NBR Data

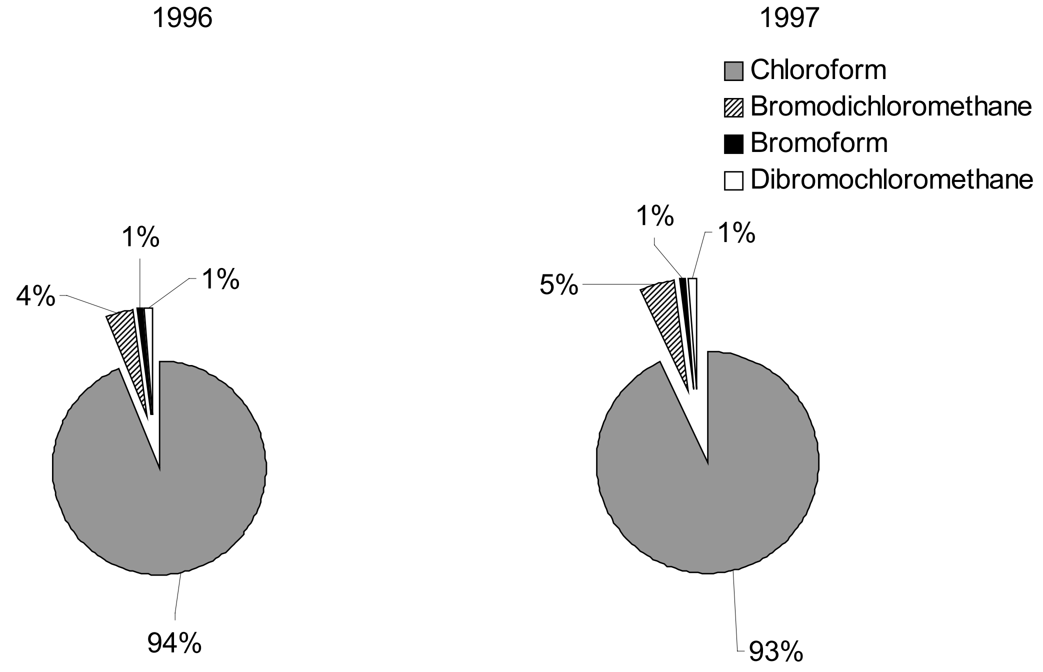


TOC (mg/L)	0	1	2	3	3.5	4	4.5	5	6	6.8
Frequency	0	0	0	33	6	2	0	1	0	2
Cumulative %	0%	0%	0%	75%	89%	93%	93%	95%	95%	100%



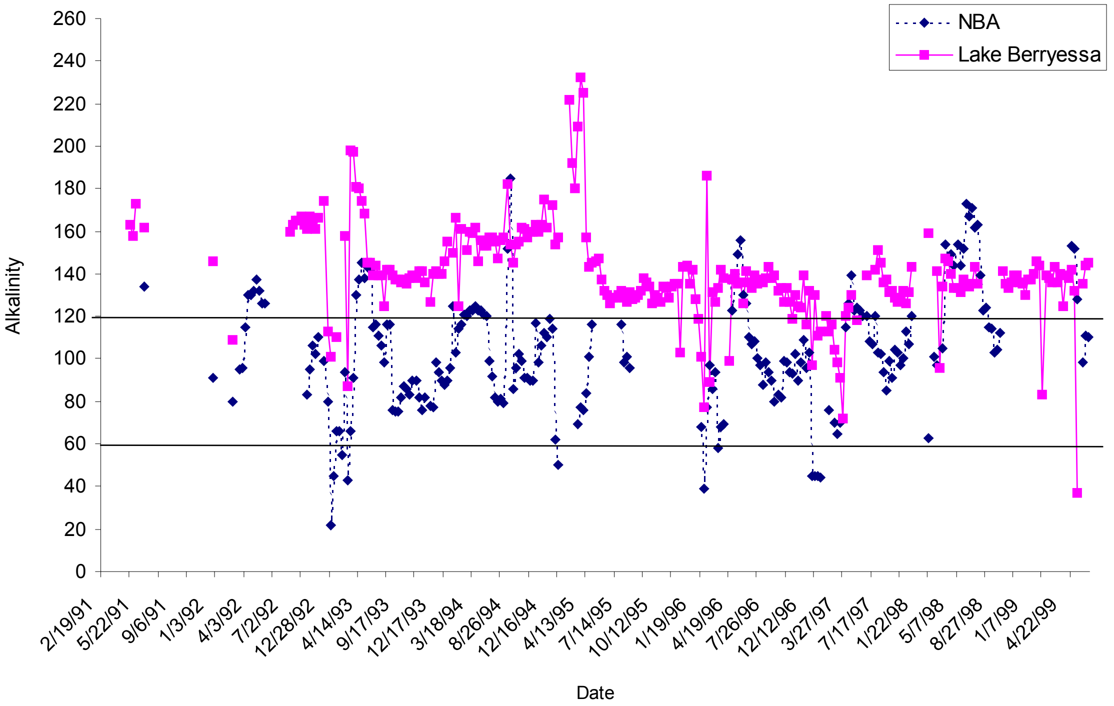
TOC (mg/L)	0	1	2	2.5	3	3.5	4	4.5	5	6	7	8	9	10	11	12	13	14	15	15.4
Frequency	0	0	0	0	0	1	0	2	2	8	0	7	8	6	2	2	4	1	1	1
Cumulative %	0%	0%	0%	0%	0%	2%	2%	7%	11%	29%	29%	44%	62%	76%	80%	84%	93%	96%	98%	100%

Figure 3-11 Relative Proportion of Individual Trihalomethanes Composing TTHMFP at the Barker Slough Pumping Plant



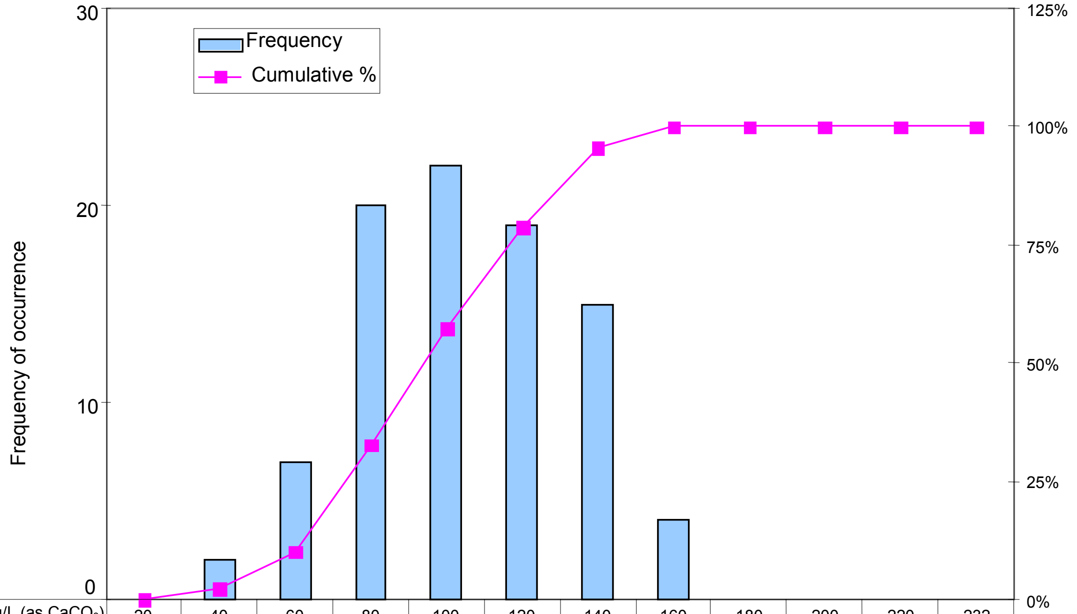
Trihalomethane precursors include organic carbon and bromide. Monthly samples show distinct seasonal patterns for each constituent. Peak concentrations of TOC are consistently observed in the winter. Concentrations have ranged from 1.0 to 38 mg/L, with an average of 7.2 mg/L (Table 3-5). Comparisons between median TOC concentration and its percentile ranges illustrate the skew of the data toward higher concentrations. When organic carbon from the pumping plant is subjected to chlorine oxidation, the majority of trihalomethane production is in the form of chloroform. In 1996 and 1997, more than 90% of the total trihalomethane formation potential was chloroform, followed by 4% to 5% bromodichloromethane with the remainder composed of dibromochloromethane and bromoform (Figure 3-11) (DWR 1999). These results suggest that from year to year the composition of the watershed's organic carbon may be relatively constant.

Figure 3-12 Comparison of Weekly Alkalinities between NBA and Lake Berryessa Water, 1991-1999 (NBR Raw Water Plant Influent)



Regardless of season, alkalinity in the NBA was lower than alkalinity in Lake Berryessa (Figure 3-12). Using NBR WTP data, the majority of NBA alkalinity values collected from 1991 through 1999 ranged between 60 and 120 mg/L, whereas the majority of Lake Berryessa water ranged between 120 and 180 mg/L. Based on TOC removal requirements under the D/DBP Rule, source water alkalinities between 0 and 60 mg/L will require the highest percentages of TOC removal (EPA 1998). Similarly, at TOCs greater than 8 mg/L, a level not uncommon to some NBA utilities, alkalinities between 60 and 120 mg/L also will require substantial percentage removals. According to NBR WTP data, the alkalinity concentrations of approximately 80% of the NBA water sampled between November and April were less than 120 mg/L (Figure 3-13). In the same time period, more than 50% of measured TOC concentrations were greater than 8 mg/L (Figure 3-10). This situation will make it difficult for WTPs that rely solely on NBA water. Elevated winter TOC levels create the potential for higher trihalomethane disinfection byproducts (DBPs). Low alkalinities make it difficult to remove enough TOC to meet MCLs of Stage 1 D/DBPs Rule. All NBA contractors are currently meeting these levels through a combination of strategies including increased coagulant usage, and blending or switching to another source. WTPs that cannot blend or switch to an alternate winter source are concerned that they will be unable to meet the Stage 2 D/DBP Rule (for example, Benicia, Napa, Travis). In the case of Stage 1 D/DBP Rule, Travis will need to practice enhanced coagulation. In some cases, these plants may not be able to meet Stage 2 D/DBP Rule and, therefore, total trihalomethane formation potential (TTHMFP)/haloacetic acids (five) (HAA5) limits.

Figure 3-13 Cumulative Probability Distribution of Winter Alkalinity – NBA Influent into NBR WTP



Alk. mg/L (as $CaCO_3$)	20	40	60	80	100	120	140	160	180	200	220	232
▭ Frequency	0	2	7	20	22	19	15	4	0	0	0	0
■ Cumulative %	0%	2%	10%	33%	57%	79%	96%	100%	100%	100%	100%	100%

The low alkalinities associated with stormwater make it difficult for WTPs to reduce TOC/turbidity using alum as their primary coagulant. Some plants switch to more expensive or less effective coagulants; others add chemicals for alkalinity substitution so that their coagulants will work. Because of the high turbidities and TOC associated with NBA water, the water requires more alum, caustic, and ozone or other oxidant. The addition of more chemicals creates more sludge volume. NBR WTP staff estimates that about 935 pounds per day of extra sludge are generated at their plant when using NBA water in winter. Additional backwashing is required to handle the increased turbidity loading of the NBA. All of these factors lead to increased costs for treating NBA water. NBR WTP staff estimate that the cost of treating NBA water is nearly $200 per million gallons, approximately more than 2 to 4 times than for Lake Berryessa water.

3.4.3.2 Turbidity

High turbidities, including sudden unexpected peaks, generally occur in winter. At Barker Slough Pumping Plant, average daily on-line turbidities can change by more than a factor of 4 within 24 hours (Figure 3-14). All treatment plants that rely solely on NBA water experience the sudden changes in turbidity. Monthly turbidity ranges at the plants reflect the large turbidity changes (Table 3-10), but monthly averages and ranges do not show the rapid changes in NBA source water turbidity. For example, in January 1997 at the NBR WTP, influent NBA turbidities rose from 60 to 400 NTUs in fewer than 8 hours (Fleege pers. comm. 2000a).

Table 3-10 Average Monthly Winter Turbidity Levels for Selected Utilities, 1996 to 1999 (Ranges Shown in Parentheses)

Utility	Nov	Dec	Jan	Feb	March	April
Benicia[ab]	40 (18-298)	82 (20-274)	106 (18-280)	149 (99-228)	51 (14-181)	22 (12-41)
NBR WTP	52 (21.5-317.8)	80.8 (19.6-260)	144.5 (102-206)	160.1 (87.9-236)	65.9 (45-168)	34.5 (20.8-58.9)
Napa[b]	44 (21-428)	84.7 (21-344)	62.8 (20.3-105.2)	108.3 (27.1-189.5)	77.2 (52.3-130)	27.1 (19.2-32.2)
Travis	34 (18-321)	54.4 (15-236)	73.1 (14-273)	95 (15-221)	64.8 (30-181)	30.6 (13-59)

[a] No electronic data available for 1996.

[b] Averages calculated from maximum daily turbidities.

Figure 3-14 Average Daily Turbidity at the Barker Slough Pumping Plant, 1996 to 1999

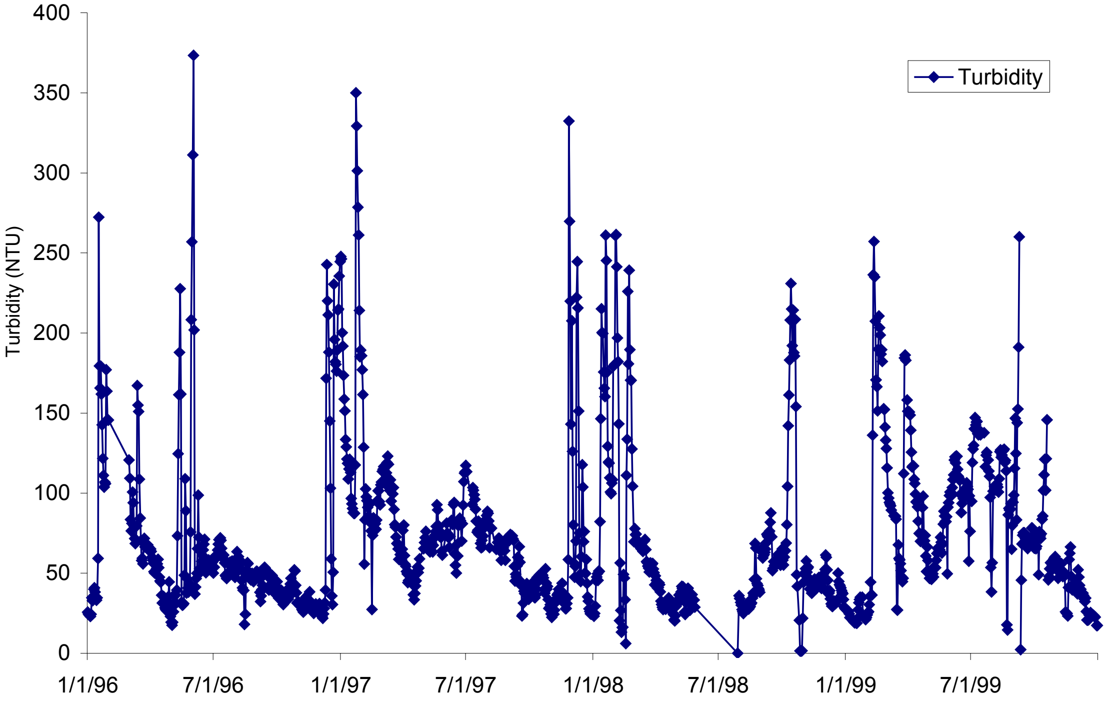
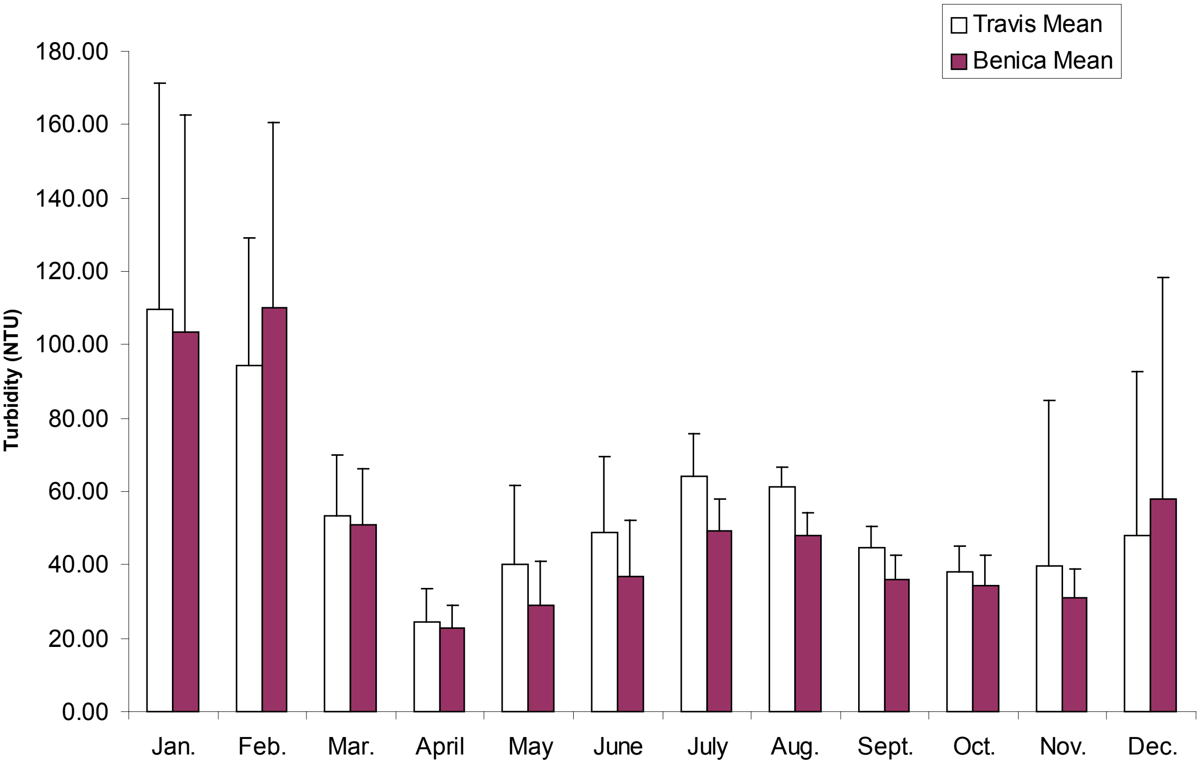


Figure 3-15 Comparison of Average Monthly Turbidities (+1sd) between Travis AFB and Benicia Water Treatment Plants, 1997 to 1998



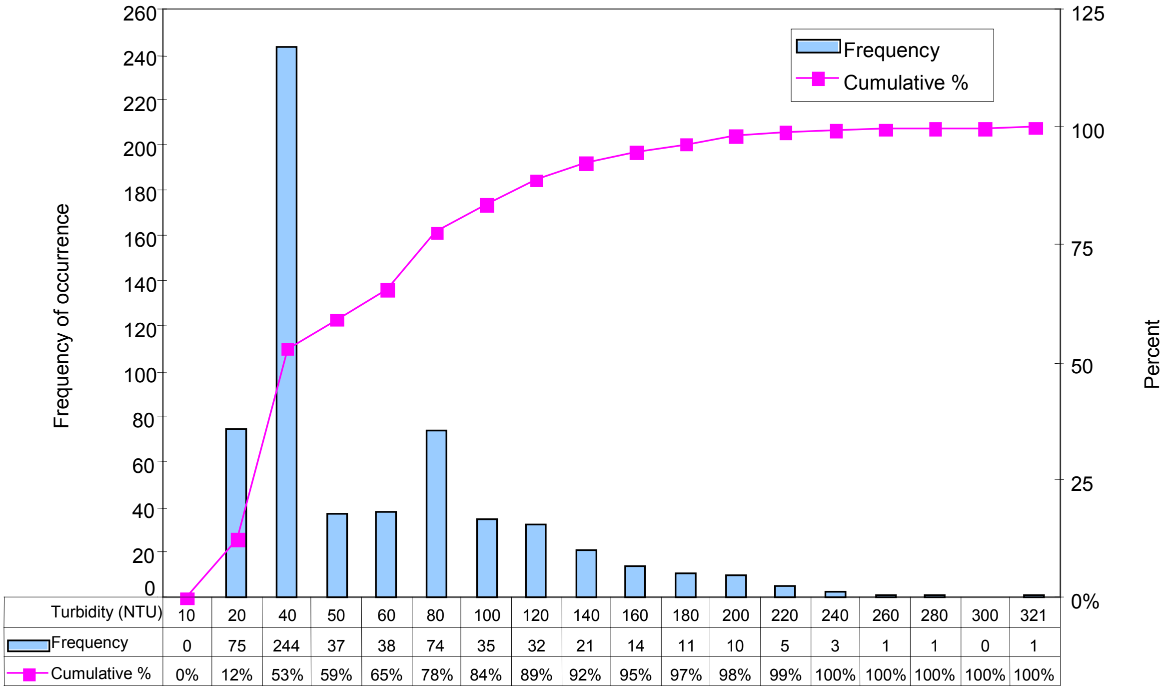
Turbidity comparisons between 1 of the WTPs closest to the Barker Slough Pumping Plant and the WTP farthest from the pumping plant suggested that particles responsible for plant turbidity do not settle out with distance. The influent line into Travis AFB WTP is approximately 10 miles from the pumping plant, whereas the influent line into the City of Benicia's WTP is approximately 34 miles away. In 1997 and 1998, more than 90% of the water used by both plants came from the NBA. Not only were turbidity patterns identical between the 2 plants (Figure 3-15), turbidity differences between the 2 plants never varied by more than 15 NTUs. While only 2 years of data were compared, the nearly identical turbidity readings from plants separated by more than 20 miles of pipeline suggested that the particles associated with turbidity never settled out of the pipeline. The large standard deviations associated with winter turbidities also shows the wide range of turbidities experienced by the 2 plants during winter months

Daily average turbidities for each month from 1996 to 1999 also show 2 seasonal turbidity peaks (Figure 3-16). In this figure, data between the 5 plants are not directly comparable. In some cases, utilities either blended or stopped using NBA water. In other cases, the plant shut down, electronic data were not available, or daily peak turbidity values were reported. However, given these caveats, all plants showed the same turbidity patterns. During late spring/early summer, turbidities increased steadily until July. Following July, turbidities decreased steadily until large jumps were observed in winter rainy season. This steady increase in turbidity was not as pronounced at the pumping plant, but average turbidities did increase by almost 40 NTUs between April and June. Increases in summer turbidity could be the result of irrigation return water or algal blooms.

Unlike turbidity, TOC concentrations did not steadily increase in summer. This may be due to the lower sampling frequency associated with TOC measurements. Plants normally reported a weekly TOC value, but turbidity values were based on daily averages calculated from turbidity measurements reported every 2 to 4 hours.

Figure 3-16 Average Monthly Turbidity for Selected NBA Contractors

Figure 3-17 Cumulative Probability Distribution of Average Winter Daily Turbidities at the Travis AFB WTP, 1996 to 1999



Turbidity (NTU)	10	20	40	50	60	80	100	120	140	160	180	200	220	240	260	280	300	321
Frequency	0	75	244	37	38	74	35	32	21	14	11	10	5	3	1	1	0	1
Cumulative %	0%	12%	53%	59%	65%	78%	84%	89%	92%	95%	97%	98%	99%	100%	100%	100%	100%	100%

Contractors for NBA water would prefer to treat water with daily average turbidities of not more than 50 NTUs with spikes not greater than 200 NTUs (Fleege 2000). At Travis AFB WTP, which relies solely on NBA water, approximately 60% of the daily winter turbidity values averaged 50 NTUs or less (Figure 3-17). Not accounting for sudden spikes in turbidity, this still leaves a significant percentage of days when daily turbidities averaged over 50 NTUs.

3.4.3.3 Pathogens

For a discussion of pathogen issues in the North Bay Aqueduct, refer to Chapter 12.

3.4.4 RESULTS OF WATERSHED SPECIAL STUDIES

Based on the difficulties in treating NBA water and the recommendations in DWR's *Sanitary Survey Update 1996*, MWQI began a series of special studies in 1996 to understand the relative contributions of different surface waters to water quality in the NBA. The summary of these studies focuses on several key constituents that affect WTP operation, namely turbidity and organic carbon.

3.4.4.1 1996/1997 Special Studies

The 1st year of watershed studies focused on inputs from all the major water sources to the Barker Slough Pumping Plant (DWR 1996). Samples were collected weekly from July 1996 to June 1997 from 4 sites (Figure 3-1):

- Lindsey Slough near the Sacramento River,
- Calhoun Cut (approximately a mile downstream of the plant),
- Barker Slough at Cook Lane, and
- Barker Slough Pumping Plant.

Results from this yearlong sampling confirmed that the majority of water quality problems at the pumping plant occurred during winter rainy season. For example, dissolved organic carbon (DOC) and turbidity increased at all sites in winter (Figures 3-18 and 3-19), while alkalinity values fell (Figure 3-20).

Figure 3-18 Dissolved Organic Carbon Results for NBA Watershed Study, 1 Jul 1996 to 30 Jun 1997

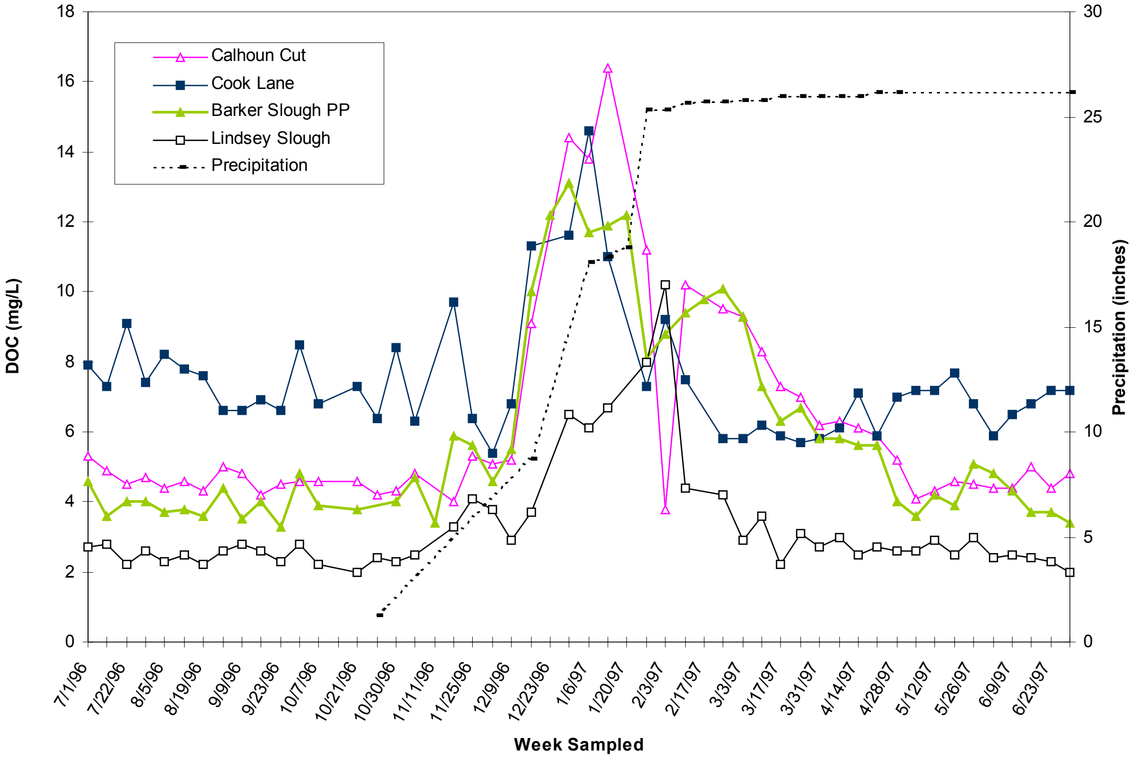


Figure 3-19 Turbidity Results for NBA Watershed Study Sampling Sites, 1 Jul 1996 to 30 Jun 1997

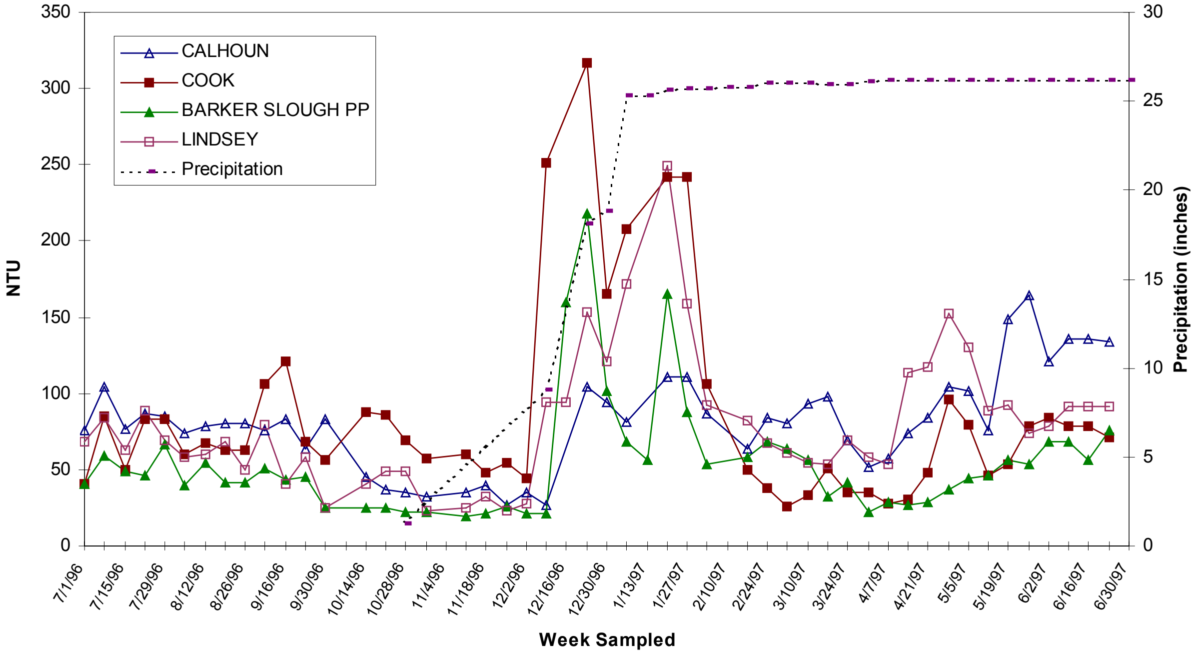
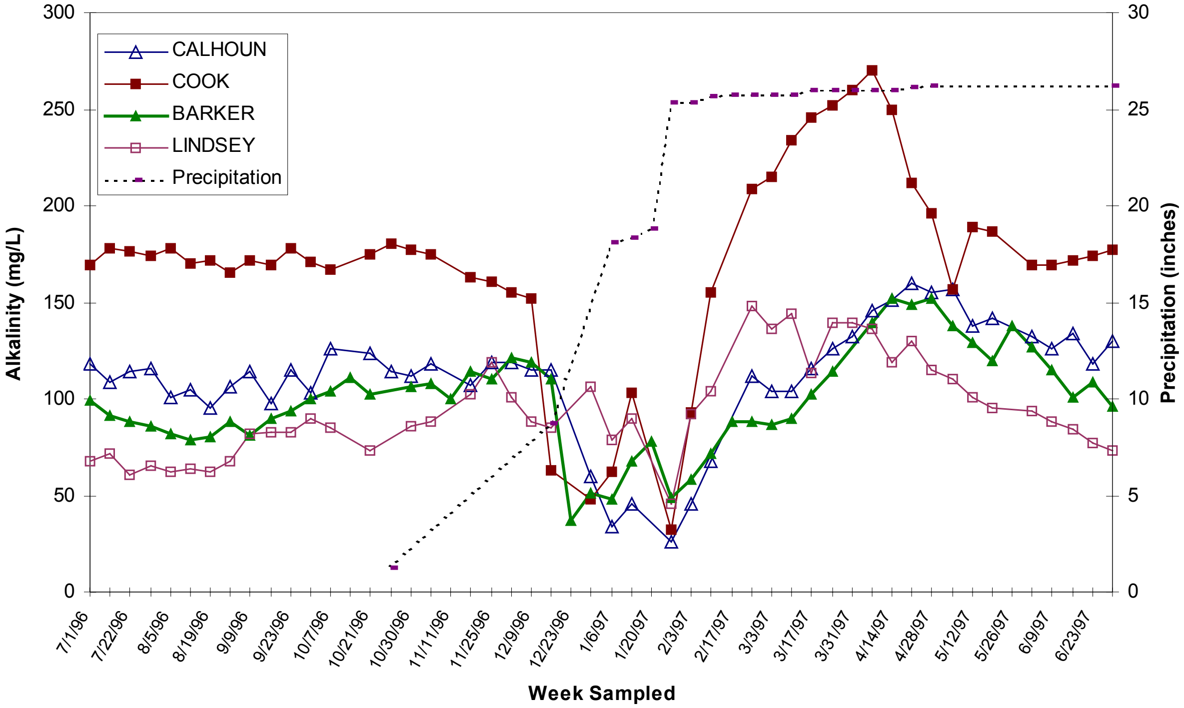


Figure 3-20 Alkalinity Values for NBA Watershed Study Sampling Sites, 1 Jul 1996 to 30 Jun 1997



The influence of upstream and downstream sites on organic carbon concentrations at the pumping plant appeared to be seasonal. In the winter, with respect to organic markers (DOC and THMFP), the Sacramento River did not appear to influence water quality at the pumping plant. For example, during the winter rainy season, DOC concentrations upstream of Lindsey Slough were twice as high as those detected at Lindsey Slough (Table 3-11). In summer, DOC concentrations at the pumping plant generally fell between those concentrations observed at Lindsey Slough and at Calhoun Cut (Figure 3-18). Unlike the other sites sampled, Cook Lane's average summer DOC concentrations remained elevated at winter levels, suggesting that upstream sites had little impact on summer pumping plant water quality. Experiments conducted in following years began examining the sources of contaminant loading from the upper reaches of the watershed. Since summer organic carbon and turbidity levels are manageable for the treatment plants, subsequent studies focused on watershed dynamics in the winter.

Table 3-11 Average Annual Summer and Winter DOC Concentrations near the Barker Slough Pumping Plant, Jul 1996 to Jun 1997 (mg/L ± sd)

Site	Yearly	Summer	Winter
Lindsey Slough	3.3 ± 1.7	2.5 ± 0.27	4.2 ± 0.44
Calhoun Cut	6.1 ± 2.9	4.6 ± 0.29	7.9 ± 0.74
Barker Sl PP	6.0 ± 2.8	4.0 ± 0.47	7.8 ± 0.55
Cook Lane	7.5 ± 1.8	7.3 ± 0.75	7.7 ± 0.53

Yearly average = Jul 1996 to Jun 1997
Summer average = May to Oct
Winter average = Nov to Apr

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Table 3-12 Average Concentrations of Turbidity, TOC and DOC by Site and Rainfall Period for the 1997/1998 Winter Sampling Season (Ranges Given in Parentheses)

	Turbidity (NTUs)		TOC (mg/L)		DOC (mg/L)	
Sample Site	Baseline (pre-rainfall)	Wet	Baseline (pre-rainfall)	Wet	Baseline (pre-rainfall)	Wet
Lindsey Slough	32.5 (31-35)	68.8 (38-162)	3.0 (2.7-3.2)	5.5 (3.8-6.2)	2.2 (2-2.3)	5.0 (4-5.5)
Calhoun Cut	45.2 (37-54)	73.6 (43-112)	6.3 (6.2-6.3)	15.3 (11.3-20.7)	4.8 (4.4-5.2)	12.3 (10.3-15.9)
Barker Sl PP	46.7 (44-51)	176.2 (102-256)	6.1 (5.5-7)	14 (12 -20.3)	4.8 (3.4-6)	9.5*
Cook Lane	111.4 (95-128)	366.2 (304-469)	9.4 (8.8-10)	17.7 (13.9-20.5)	6.2 (6-6.4)	11.6 (9.9-12.8)
Dally Road	60 (50-70)	192.8 (49-436)	8.8 (4.8-12.8)	16.1 (11.2 -20)	7.7 (4-11.4)	12.4 (9.6-15)
Hay Road	32.7 (18-47)	354 (23-608)	9.4 (3.7-15.1)	13.4 (10.8-17.4)	9.1 (3.4-14.8)	9.8 (6.1-16.1)

Baseline = Sep 1997 to Nov 1997; Wet = Dec 1997 to Feb 1998
* Only 1 sample analyzed

3.4.4.2 1997/1998 Special Studies

Follow-up experiments confirmed that water quality from the Sacramento River via Lindsey Slough did not impact the winter water quality at the Barker Slough Pumping Plant. In winter, turbidity, TOC, and DOC were generally higher at all sites above Lindsey Slough (Table 3-12). In addition, turbidity and TOC data showed that water quality did not improve upstream in the watershed. For example, some of the highest average turbidities were observed at sampling points farthest upstream.

During this 2nd year of study, when stream and weather conditions permitted, flow measurements were collected by DWR staff. The goal was to understand the loading contributions of different sites in the watershed Over the course of a single day, concentration and flow data were collected from the uppermost sampling site to the lower boundary of the watershed. Based on loading, the pounds of carbon entering the slough increased over 30-fold from the uppermost site sampled (Hay Road) to the Cook Lane site approximately a mile above the pumping plant (Table 3-13). This showed that there were many sources of organic carbon throughout the watershed with the largest carbon inputs occurring in the lower half of the watershed.

Table 3-13 Flow and TOC Loading in the Barker Slough Watershed from the Uppermost to Lowermost Site in the Watershed, 17 Dec 1997

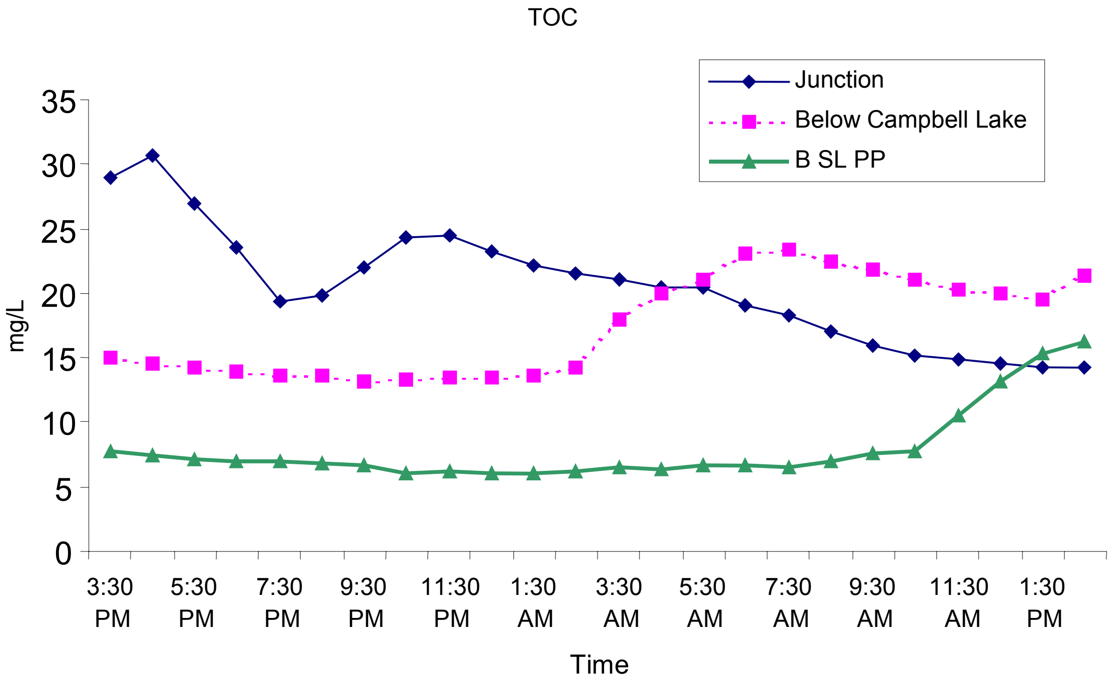
Site	cfs	TOC (mg/L)	Loading (lbs/day)
Hay Road	0.26	10.9	15.24
Dally Road	1.03	11.2	62.07
Cook Lane	5.26	19.3	546.23

3.4.4.3 1998/1999 Special Studies

In the 1998/1999 winter sampling season, DWR staff collaborated with a number of NBA contractors to examine the dynamics of turbidity and TOC during storm events in the upper watershed. Using loading, the objective was to determine the relative inputs of TOC, DOC, and turbidity from different land use areas in the watershed. Sampling points isolated key land uses in the watershed and/or inputs to the system from a particular area of interest. On-line flow, turbidity, and rain gauges and remotely triggered autosamplers were installed at the sites. In addition, weekly grab samples were collected at the pumping plant to validate patterns seen in previous studies and to examine patterns of water quality between storm events.

In the 1998/1999 winter sampling season, 2 dynamics were observed in the watershed. Autosampler results generally showed a strong spatial and temporal component associated with TOC and turbidity (Figure 3-21). Autosampler data suggested that the progression of peak concentrations of TOC and turbidity were related to a storm's intensity and/or the saturation level of soils. For example, in December, peaks of TOC and turbidity were observed during a small rainfall event at the uppermost site. Downstream, below Campbell Lake and at the pumping plant, no TOC or turbidity peak was observed. In February, during 1 of the largest storms of the season, the turbidity/TOC peak moved down the watershed and was recorded by the pumping plant's on-line turbidity meter, suggesting that the upstream watershed was influencing the pumping plant water quality.

Figure 3-21 Autosampler TOC and Turbidity Progression, Feb 1999



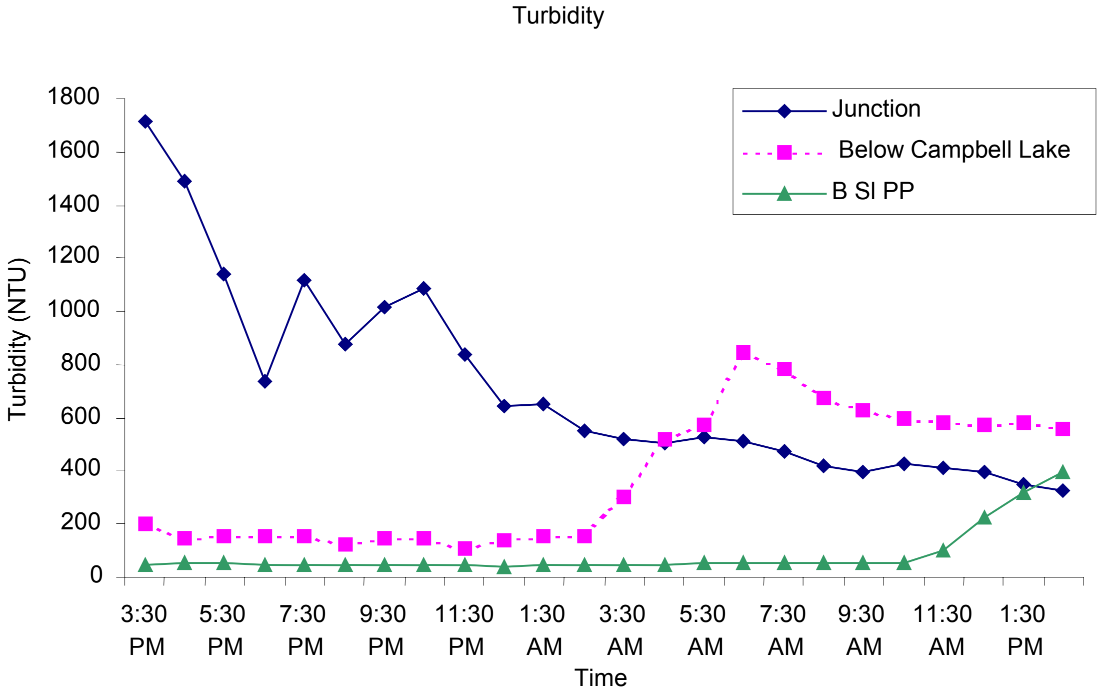
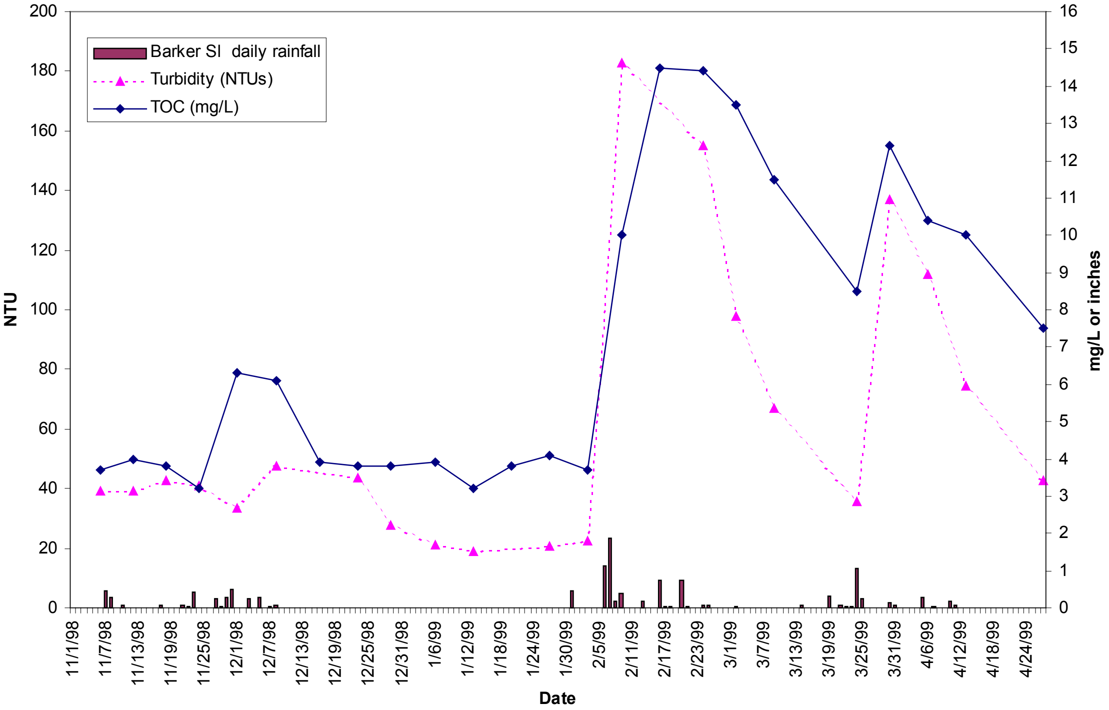


Figure 3-22 Weekly Turbidity and TOC at Barker Slough vs. Rainfall, Nov 1998 to Apr 1999



The weekly grab samples collected at the pumping plant highlighted a separate phenomenon that was not directly tied to a rainfall event. Grab samples collected weekly at the pumping plant showed that TOC and turbidity levels remained elevated at the pumping plant for a 3-month period, regardless of rainfall activity (Figure 3-22). For example, in the first 3 weeks of March, the pumping plant received less than 0.5 inches of rain, yet TOC concentrations averaged 11 mg/L. In comparison, the pumping plant in February received over 5 inches of rain with TOC concentrations averaging 9.3 mg/L.

Unfortunately, loading inputs relative to each of the sample sites could not be calculated over a whole sampling event. In all cases, due to inherent physical difficulties with the streambed's morphology, flow measurements were not calculated for water leaving Campbell Lake. In 1 case, TOC measurements were not collected because the storm damaged the sampling equipment.

A literature search of the soil characteristics in the watershed suggested that shallow groundwater and alkaline clay soils in the area could account for the high TOC and turbidity levels. Soil surveys conducted by the US Department of Agriculture showed that many of the watershed's soils contain high levels of sodium (Bates and others 1977). Soils high in sodium (sodic soils) may influence water quality in 2 ways: 1) Sodium ions are large monovalent ions that enhance clay swelling and dispersion, leading to higher turbidity. 2) Sodium tends to raise a soil's pH, increasing dispersion of organic carbon (US Salinity Laboratory Staff 1954, Sposito 1989, Shainberg 1990, Singer 1999, Goldberg and others 2000). The clay subsoils and the shallow groundwater level that create the area’s vernal pools may also be responsible for the widespread ponding and flooding observed in the watershed.

Special studies continued into the 1999/2000 sampling season. Results are not covered in-depth in this report. However, when loads could be calculated, those at the uppermost site (representing urban and some row cropping land use) were between 4.5 and 100 times lower than loads exiting Campbell Lake. Like the 1998/1999 sampling season, following the saturation of the watershed, TOC concentrations remained elevated in weekly pumping plant samples even in the absence of rainfall.

Loading calculations suggest that, in the absence of rainfall, excessive loading of these constituents into the forebay may be the cause of the pumping plant's elevated TOC and turbidity levels. Using the plant's average pumping rate and the pounds per day of carbon exiting Campbell Lake, sample collections in Table 3-14 show the pounds per day pumped by the pumping plant. For 3 weeks the carbon load exiting Campbell Lake was well above the load exported by the pumping plant. This indicates a possibility that during and after large storm events, large quantities of TOC and turbidity continue to feed the plant's forebay. As the 1996/1997 study showed, Lindsey Slough water has little influence on winter water quality. One hypothesis is that the lack of winter flushing between the pumping plant and Lindsey Slough occurs from the formation of a hydrologic plug from the Yolo Bypass. Additionally, points downstream of the forebay (for example, Calhoun Cut) may contribute to the reservoir of carbon at the forebay because their outflow would also be blocked. In the absence of rainfall, the pumping plant would continue to pump from this TOC reservoir until the high TOC/turbidity was exhausted and/or hydrologic conditions changed.

Table 3-14 Organic Carbon Load Exiting Campbell Lake vs. Organic Carbon Load Pumped at the Barker Slough Pumping Plant

	Camp Lk (lbs/day)	BSI (lbs/day)	Percent
Jan 26	1,727	5,162	33
Feb 2	131	1,860	7
Feb 9	223	1,149	19
Feb 16	4,064	1,397	290
Feb 23	9,104[a]	2,057	443
Mar 1	3,054	1,928	158
Mar 8	833	930	90
Mar 15	268	1,016	26
Mar 22	221	4,494	5
Mar 29	189	1,690	11

Shaded area: Load from Campbell Lake exceeded load pumped by the pumping plant

[a] Estimated load using flow from Junction. Slough overtopped its banks at Campbell Lake gaging station

3.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

NBA water often exceeds primary MCLs for aluminum. Levels are generally highest in the winter and may be caused by the increased metal solubility in low pH waters, the increase in particulates associated with winter storms, or the potential lack of flushing of the forebay during the winter. Concentrations may reflect natural background levels in the watershed. With no other data, the cause for elevated aluminum concentrations is speculative. NBA water also often exceeds secondary MCLs for iron and manganese. This cause also is unknown, but as with aluminum, the elevated concentrations may be tied to the natural physical-chemical dynamics of the watershed itself.

The main water quality issues consistently challenging NBA contractors are the high levels and/or rapidly changing levels of organic carbon and turbidity. Of the PCSs examined—recreational use, septic systems, livestock grazing, pesticide/herbicide usage, underground storage tanks, and unauthorized activity—only recreational use and livestock grazing had the potential to have an impact on TOC and turbidity.

Of the 3 recreation sites, Argyll Park has the strongest impact on turbidity and TOC. The large dirt motocross area drains into a small pond near Campbell Lake. The pond is generally more turbid than the lake. It is not known how the pond is operated. However, the water released from this pond can join with Barker Slough downstream of the outlet from Campbell Lake. Campbell Lake, which is minimally used for recreation, plays a role in the high TOC and turbidity levels because of its location on Barker Slough. The lake could serve as a sink for larger particle sizes, but data suggest this shallow lake may serves more as a holding area for high turbidity water than as a settling basin for the finer silt that makes up a large component of the turbidity. Until a storm of sufficient intensity allows runoff to pass through Campbell Lake, impacts from the Barker Slough watershed may not be felt at the pumping plant.

Livestock grazing has the most obvious influence on organic carbon and turbidity in the watershed. Cattle more than sheep have the greatest potential to affect the watershed's water quality because of their greater numbers, their longer residence time in the watershed, and their habit of wading in the stream. Sheep generally do not wallow or stand in watercourses for any length of time.

Cattle standing in the slough also are a direct source of pathogens and organic carbon. Fecal material on land can be transported during storm events and serve as a potential source of carbon and/or pathogens. If calves are present in the watershed during winter, then the potential for Cryptosporidium and Giardia contamination increases because both organisms retain their infectivity under cool, damp conditions (Olson and others 1999) and because young animals shed more pathogens than adults.

The lack of proper fencing leaves much of the slough accessible to livestock. Areas around streams are highly disturbed and susceptible to erosion. In summer, the slough may be the only source of water for livestock; in winter, the paths leading into the slough are devoid of vegetation and more susceptible to erosion.

A 2nd source of erosion may be the Noonan Main Drain, as well as the majority of access roads that are unpaved. The drain is mostly unlined and in the past has been kept clear of vegetation. Present weed control practices are changing, and revegetation of the bank may lessen erosion. However, grasses cannot prevent bank scouring during high flows or prevent bank slumping. Where no vegetation is present along the banks of the drain, rivulets have been observed.

In addition to livestock disturbances, physical properties of the soil also may be a large contributor to the TOC and turbidity problems. It has been suggested that the high sodium content within the horizons exposed by channel incisions, etc. is the single most important factor in creating the type of persistent turbidity associated with runoff from the Barker Slough watershed (Hydro Science 2000). Based on limited data, Hydro Science concludes that the channel system, and not the contiguous disturbed areas, produces most of the sediment load. In addition to the physical-chemical properties of the soils, the hydrologic conditions that develop in the winter may prevent stormwater from the Barker Slough watershed and points downstream from moving away from the pumping plant. This appears to result in the pumping plant drawing from a “pool” of high TOC water until hydrologic conditions change.

3.6 WATERSHED MANAGEMENT PRACTICES

With the exception of the program at Jepson Prairie Preserve, range management practices of area landowners are unknown. Local meetings have been poorly attended, and landowners in the area may not trust inquiries from outside agencies. Campbell Lake, which is under the control of the owners of Argyll Park, is not managed to control outflow in the winter when most of the problems occur. The landowner noted that he dams the lake in summer to provide irrigation water and removes the boards in the winter to prevent flooding.

In late 1999, the SCWA was awarded a grant from the State Water Resources Control Board to conduct pilot BMPs in the watershed. There are obvious BMPs that can be put into place that promote good land stewardship, for example, fencing cows out of the slough and moving livestock water supplies away from the slough. In July 2000, the SCWA hired Hydro Science to recommend and evaluate the potential effectiveness of traditional BMPs in addressing contractors’ concerns. Hydro Science proposed and ranked 21 different BMPs and concluded that there were more opportunities available to reduce turbidity than organic carbon (Table 3-15). At the time of this report, the firm’s recommendations had just been released. Contractors had not reviewed and discussed the results. No grant-related activities are anticipated until after the recommendations are reviewed.

Table 3-15 Ranking of Proposed Best Management Practices for the Barker Slough Watershed

BMP	Primary Removal (DOC or Sediment)	Cost Effectiveness	Technical Feasibility	Implementation Feasibility	Long Term Reliability
Off-Channel Stock Watering	Both	H	H	H	M
Installation of Fencing to Mid-Point of the Watershed	Both	H	H	M	L
Installation of Fencing from Mid-Point of the Watershed to the Pumping Plant	Both	H	H	H	L
Lay Back Slopes and Revegetate	Sediment	L	H	M	M
Control of Tailwater	DOC	H	H	L	L
Restoration of Channel above Campbell Lake	Sediment	M	M	M	H
Noonan Drain Wetland Creation	Sediment	L	M	L	M
Campbell Lake Low Water Bypass	DOC	H	H	M	H
Spillway Canal to Calhoun Cut	Both	L	H	L	M
Campbell Lake Flow Management	Both	H	H	L	M
Concrete Lining of Noonan Main Drain	Both	L	H	M	H
Stormwater Detention	Sediment	L	M	L	M
Urban Runoff Erosion Control	Sediment	H	H	M	M
Vegetative Filter Strips	Sediment	M	M	L	L
Winter Wheat Early Planting	Sediment	M	H	L	L
Conversion of Annual Cropland	Sediment	H	H	L	M
Elimination of Late Season Irrigation	DOC	H	H	L	L
Create Retention Storage	DOC	H	H	L	L
Deep Ripping	DOC	M	M	M	L
Gypsum Treatment	Both	M	M	H	H
Campbell Ranch Erosion Control	Sediment	H	H	M	L

Note: H = High; M = Medium; L = Low
Technical Feasibility = feasibility based on physical aspects of implementation
Implementation Feasibility = willingness of landowners to adopt a BMP

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Chapter 4 - The Delta

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters							
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	MTBE
Recreation	4.2.1		○			○	◒		○
Wastewater Treatment/Facilities	4.2.2	◒	⊙		○	⊙	⊙	○	
Urban Runoff	4.2.3	○	◒		○	◒	◒	○	
Livestock Grazing	4.2.4	○	○			◒	◒		
Confined Animal Feeding Operations	4.2.5	◒	⊙			●	◒		
Agricultural Drainage-Delta	4.2.6.2	◒	●	◒ [1]	○	◒	⊙		
Agricultural Drainage-Sacramento River	4.2.6.3	◒	◒		○	◒	⊙		
Agricultural Drainage-San Joaquin River	4.2.6.4	●	●	● [1]	○	◒	⊙		
Geologic Hazards	4.2.7	●	○	●				○	
Seawater Intrusion	4.2.8	●	⊙	●		⊙		○	

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. See Seawater Intrusion, Section 4.3.7

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The Delta

The Sacramento-San Joaquin Delta is the most critical junction for water in California. Two major rivers, the Sacramento and the San Joaquin, provide the majority of water into the Delta (Figure 4-1). Two-thirds of Californians receive a portion of their drinking water from the Delta. Water passing through the Delta from the Sacramento and San Joaquin rivers is subjected to additional loading of drinking water contaminants from land uses, natural processes, and recreation within the Delta. The State Water Project (SWP) exports water from the southern Delta. The extensive farmland of the Central Valley also relies on water pumped from the Delta through the State and federal water projects.

The Delta also supports extensive farmland within its boundaries, as well as an ecosystem that is critical for various species of concern, including anadromous species such as salmon, striped bass, and steelhead. This chapter discusses land use, soils and geology, vegetation, and hydrology for the Delta and its 2 main watersheds of the Sacramento and San Joaquin rivers.

4.1 ENVIRONMENTAL SETTING

4.1.1 DELTA REGION

4.1.1.1 Land Use

The Legal Delta (Figure 4-2) is divided into 2 areas, the uplands and lowlands. The uplands are those lands above the 5-foot contour elevation that are served by the lowland Delta channels. The Delta lowlands lie at or below the 5-foot contour elevation. Within the lowland areas used for agriculture, about 33% have a north mineral soil type; 16 percent, a south mineral type; and 51 percent, a middle organic type.

Agriculture in the Delta Region began in the mid-1800s and consisted primarily of dry land farming or agriculture irrigated by artesian wells, groundwater pumping, and creek-side diversions. Extensive Delta development began in late 1850 when the federal Swamp Lands Act promoted the conversion of swamp and overflow lands to agricultural production. During the early 1900s, a series of levees and waterways were developed to enhance future agricultural and urban development.

Between 1920 and 1950, land use in the Delta began to shift from agricultural to urban. As in other parts of California, private water development projects by cities and utilities assisted in the urban expansion.

Between 1976 and 1993, the total amount of agricultural land in the Delta was reduced by about 14,500 acres. This was largely due to conversion of agricultural land to urban uses in the Brentwood and Oakley areas of Contra Costa County, the Pocket area in Sacramento County, the West Sacramento area in Yolo County, and the Stockton and Tracy areas in San Joaquin County. During this 17-year period about 12,000 of 83,000 acres of native land were developed for urban uses. The California Department of Water Resources (DWR) defines native land as land that has all native vegetation, is barren, or is riparian. This brings the total increase of urban land in the actual Delta between 1976 and 1993 to 26,500 acres. By 1993, urban land use in the Delta Region covered 44,000 acres.

Urban expansion continues in the Delta with most of the development on the periphery of the region in Sacramento, San Joaquin, and Contra Costa counties. Much of this urbanization has occurred within incorporated cities, such as Antioch, Brentwood, Isleton, Pittsburgh, Rio Vista, Sacramento, and West Sacramento. Fourteen unincorporated communities also are in the Delta Region: Discovery Bay, Oakley, Bethel, Courtland, Freeport, Hood, Ryde, Walnut Grove, Byron, Terminous, Thornton, Hastings Tract, and Clarksburg.

Figure 4-1 Delta Waterways

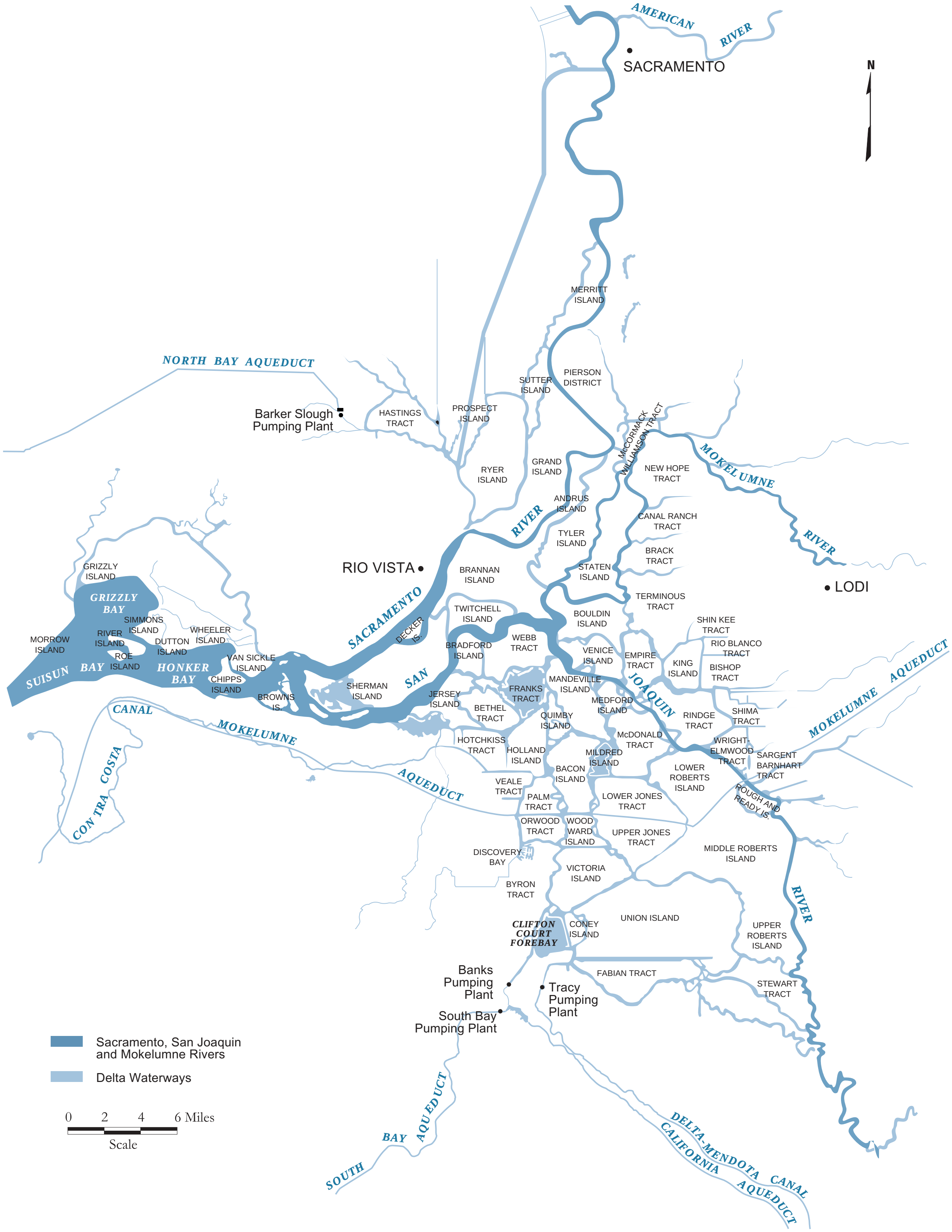
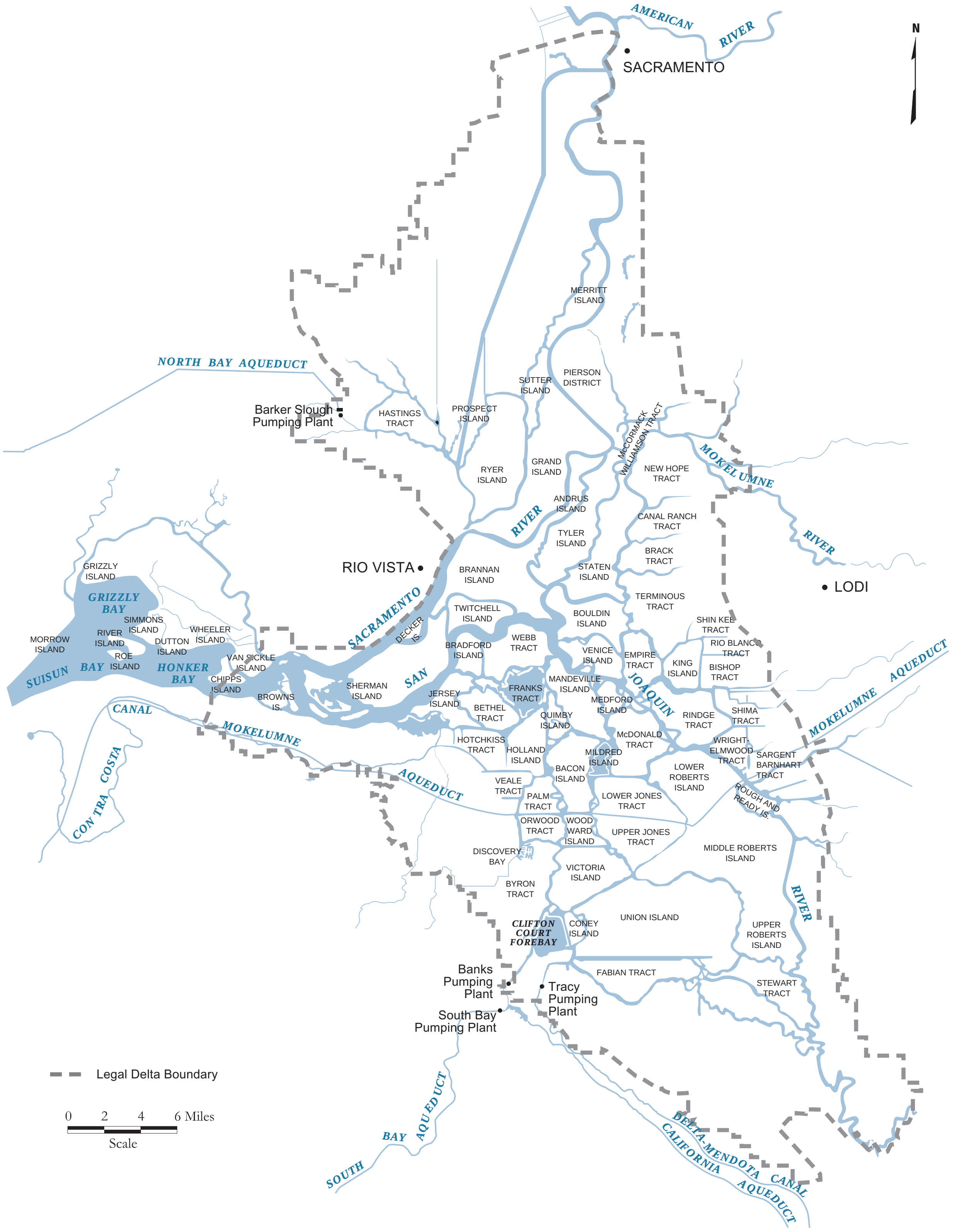


Figure 4-2 Legal Delta Boundary



Today, of the nearly 750,000 acres in the Delta, about 542,000 acres are farmed. Most of this area is classified as prime and unique farmland, with high statewide significance for agricultural production. Principal crops include corn, grain, sugar beets, alfalfa, pasture, tomatoes, asparagus, fruit, safflower, and nuts. Soil loss is one of the problems occurring to the organic rich peat soils of the Delta lands. When exposed to aerobic conditions by farm cultivation, the soil oxidizes and erodes. This process has dropped land surface elevations to several feet below sea level throughout much of the Delta.

4.1.1.2 Geology and Soils

A triangular-shaped network of channels and islands, the Delta is the meeting point for the Sacramento, San Joaquin, and Mokelumne rivers. Its islands have been reclaimed for agricultural use because of their fertile soils. Conversion of the Delta wetlands to farmlands began in 1850 when the federal government transferred ownership of "swamp and overflow" lands to the states. Substantial reclamation was accomplished between 1880 and 1920. By 1930, the Delta essentially was developed to its current configuration.

The fertility of the region is attributed to the millions of years of sediment deposition from upstream river flows and tidal action. Thick organic soil, commonly referred to as peat, was formed as native plants became buried by the tons of sediment deposits. In the mid-1800s, peat soil thickness was up to 60 feet deep.

The soils of the Delta margin are mainly mineral in character with variable admixtures of organic matter. The mineral soils were developed from valley plain materials and for the most part represent a transition between organic soils of the flat and depressed river delta basin and the better drained soils of the alluvial fans and valley floor. The organic soils occupy the larger aggregate acreage (about 250,000 acres) than the mineral soil areas. Most of the central Delta has Staten and Venice peat muck soil that have 60% to 70% organic matter. Most areas that have the intermediate organic type soils (Ryde silty clay loam) have 30% to 50% organic matter.

Decades of peat oxidation enhanced by farming and wind erosion have caused rapid subsidence of the islands and tracts. Lands that were above sea level in the mid-1800s are now at 20 feet below mean sea level. Elevation measurements from 1921 to 1988 showed 1 to 3 inches of subsidence per year. Because peat was also used to build the levees, breaching has occurred and resulted in flooding of some islands.

Development of the islands resulted in subsidence of the island interiors and greater susceptibility of the topsoil to wind erosion. Subsidence, as it relates to Delta islands, refers generally to the falling level of the land surface that results primarily from the process of peat soil oxidation. Levee settlement may be partially caused by peat oxidation if land adjacent to levees is not protected from subsidence.

Subsidence of the Delta's organic soils and highly organic mineral soils continues to be a concern and could present a threat to the present land use of the Delta islands. The threat includes levee failure that could impact water quality through increased seawater intrusion. Interior island subsidence is attributable primarily to biochemical oxidation of organic soil material as a result of long-term drainage and flood protection. The highest rates of subsidence occur in the central Delta islands, where organic matter content in the soil is highest. Loss of these soils through oxidation results in high levels of organic carbon in the surface and subsurface water on these islands. The effect of this carbon is discussed in section 4.2.6, Agricultural Drainage.

Increasing soil salinity has been a recognized problem in the San Joaquin Valley since the late 1800s. A rapid increase in irrigated acreage coincided with increasingly poor drainage (caused by elevated shallow groundwater table levels) and elevated soil salinity levels in the western and southern portions of the San Joaquin Valley.

Dissolved salts in irrigation water can lead to high soil salinity, an unfavorable condition for agricultural crop production. High soil salinity is a concern in the south Delta area, the west Delta area (primarily Sherman and Twitchell islands), and in Suisun Marsh. North and east Delta areas receive relatively low salinity water from the Sacramento River and east-side tributaries, and do not experience salinity problems.

The concentration of salts in shallow groundwater and the salt mass contained in Delta soils are direct consequences of the quality of the irrigation water drawn from Delta channels. Discharge of salts, including bromide, are discussed in sections 4.2.6, Agicultural Drainage, and 4.2.8, Seawater Intrusion.

The large quantities of sediment transported by the rivers into the Delta move primarily as suspended load. Of the estimated 5 million tons per year of sediment inflow into the Delta, about 80% originates from the Sacramento River and San Joaquin River drainages; local streams contribute the remainder. About 15% to 30% of the sediment is deposited in the Delta; the balance moves into the San Francisco

Bay system or out through the State and federal water projects. Transport of sediment in the State Water Project leads to elevated turbidities, nutrient loading, and physical interference with the operation of the project and downstream water treatment plants.

Sediment circulation within the Bay-Delta system is complex because of the numerous interconnected channels, tidal flats, and bays within which the interaction of freshwater flows, tides, and winds produce an ever-changing pattern of sediment suspension and deposition. Pumping at the Central Valley Project (CVP) and SWP Delta facilities alters sediment movements within the system and may cause erosion of the bed and banks by inducing higher water velocities in some channels. The discharges and velocities in the channels south of the San Joaquin River are influenced significantly by exports at the CVP and SWP pumping plants. Sediment deposition and gain from local drainage alter the amount and composition of the sediment transported in the channels. In addition, degradation or aggradation, and widening or narrowing of certain channels may be occurring because of the higher velocities caused by pumping.

4.1.1.3 Vegetation and Habitats

Agricultural lands and adjacent wildlands are the dominate habitats in the Delta Region. Agricultural lands occupy approximately 85% of the total land in the region. The remaining portions of the region contain mostly open-water, wetland, and riparian habitats. Years of agriculture and development in the Delta Region have resulted in the reduction or elimination of many natural habitats and species, especially those associated with native grasslands and tidal wetlands.

Until the early 1800s, the Delta Region was dominated by approximately 400,000 acres of tidal marshland. The more than 60 large islands of the Delta were mostly marshy, with some riparian areas and upland shrubs. Prior to the mid-1800s, agriculture in the Delta Region consisted primarily of dry land farming and agriculture irrigated by artesian wells, groundwater pumping, and some creek canals. By 1900, about one-half of the Delta's historical wetland areas had been reclaimed. Extensive reclamation continued through the 1930s.

As of 1985, only about 18,000 acres of the original tidal marshland remained. Historically, native grasslands and vernal pools were found in the Delta Region but were never common. As leveed lands and agriculture increased, non-native grasslands emerged in unfarmed areas and abandoned agricultural fields. Today, the Delta Region contains approximately 641,000 acres of agricultural land in the lowland areas. Other dominant habitats in the region include valley foothill riparian and fresh and saline emergent wetlands.

Hundreds of miles of waterways divide the Delta Region into islands, some of which are 25 feet below sea level. The Delta Region relies on more than 1,000 miles of levees to protect these islands. Many species occurring in the Delta Region have survived changes and reductions to their habitats, including reductions in their ranges and breeding populations. Many species have adapted to agricultural land uses, although agricultural lands often do not supply all life-cycle requirements

Grassland and ruderal habitats are present throughout the Delta Region. Although typically small, these habitats can provide relatively high wildlife values because intensive and extensive agriculture have greatly reduced the available natural upland habitats. The extent of use by wildlife depends on the type of vegetation present and the adjacent land uses. Vernal pools that occur in grasslands along the fringes of the Delta Region support a wide diversity of native plants and invertebrates. In particular, the Jepson Prairie Preserve contains vernal pools that support several special-status species. Riparian scrub and woodland areas typically occur on channel islands on levees and along unmaintained, narrow channel banks of Delta Region creeks, waterways, and major tributaries.

The major rivers of the Delta Region include the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras. About 7,000 acres of riparian vegetation occur primarily on the levees of Delta islands and along the Cosumnes and Mokelumne rivers. The riparian zone along leveed islands is usually very narrow, but more extensive riparian areas occur along the San Joaquin River just below its confluence with the Stanislaus River and along the Cosumnes River.

Seasonal freshwater wetlands include inland marshes that maintain surface water during only a portion of the year and vernal pools that are associated with grasslands. Seasonal wetland conditions also are created when harvested cornfields are flooded in the Delta Region during fall and winter to reduce soil salinity and control weeds. Large seasonal wetlands managed for waterfowl are located in the northwestern part of the Delta Region in the Yolo Bypass, west of the Sacramento Deep Water Ship Channel. These wetlands are of great importance to migratory waterfowl and shorebird populations for the forage that they provide during fall, winter, and spring when bird populations in the Delta increase dramatically.

Nontidal freshwater marsh occurs on the landward side of Delta Region levees and in the interiors of

Delta Region islands, mostly in constructed waterways and ponds in agricultural areas. Dominant nontidal freshwater marsh species include tule, bulrush, cattail, watergrass, and nutgrass.

Common floating aquatic species include pretty-water smartweed and water weed. Tules and cattails, with common-reed, buttonbush, sedges, and rushes dominate tidal freshwater and brackish-water emergent marsh habitat. This habitat occurs on instream islands and along mostly unleveed, tidally influenced waterways. Tidal emergent marsh provides habitat for many species, including the following special-status species: Mason's lilaeopsis, California hibiscus, Delta tule pea, California black rail, and tricolored blackbird.

Open water in the Delta Region includes sloughs and channels in the Delta, flooded islands, ponds, and bays. Deep, open water areas are largely unvegetated; beds of aquatic plants occasionally occur in shallower open water areas. Typical aquatic plant species include water hyacinth, a non-native noxious weed, and water milfoil. Open water provides resting and foraging habitat for water birds, including loons, pelicans, gulls, cormorants, and diving ducks. These species forage primarily on invertebrates and fish.

4.1.1.4 Hydrology

Several important water management facilities are located in the Delta. These include the CVP Pumping Plant at Tracy, the Delta Cross Channel (DCC) at Walnut Grove, the SWP's Clifton Court Forebay (CCF) and Harvey O. Banks Pumping Plant (Banks PP), the SWP North Bay Aqueduct (NBA) Pumping Plant, and the Contra Costa pumping plants at Rock Slough and Old River.

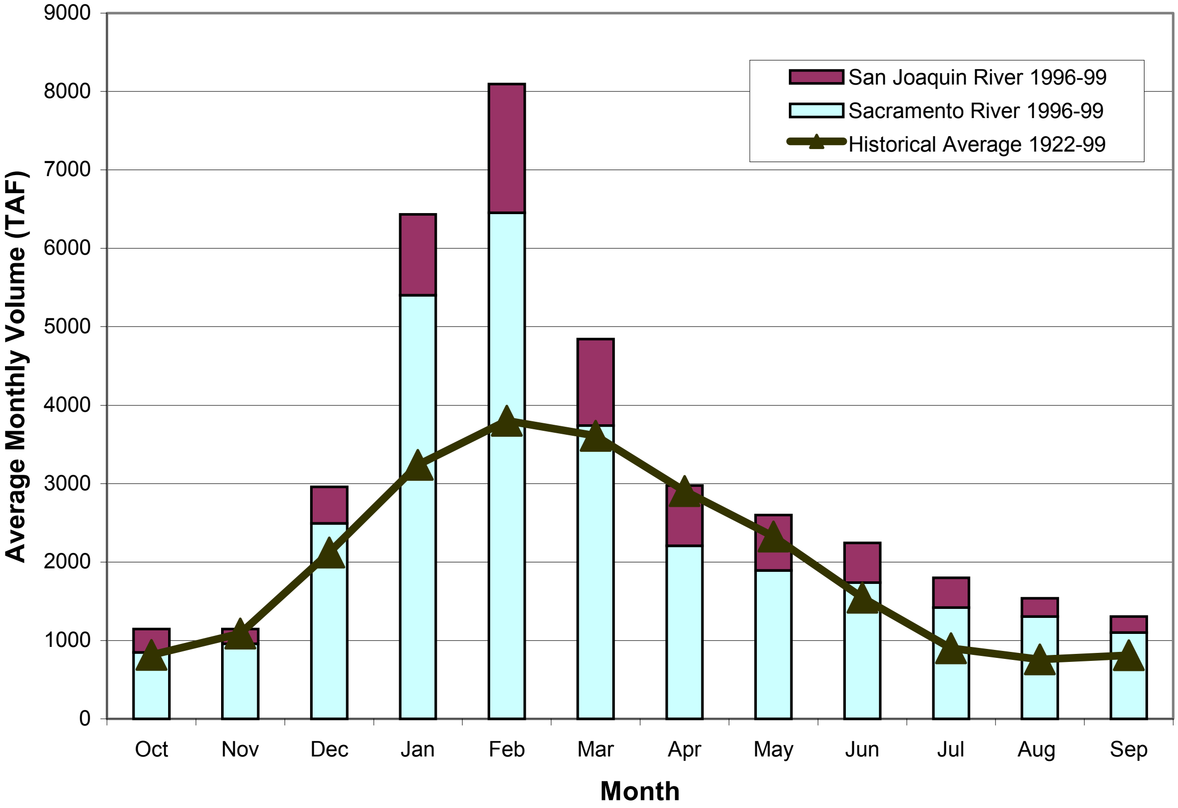
The CVP Tracy pumping plant has a maximum capacity of about 4,600 cubic feet per second (cfs), the nominal capacity of the Delta-Mendota Canal (DMC) at the pumping plant. The SWP Banks PP supplies water for the South Bay Aqueduct (SBA) and the California Aqueduct, with an installed capacity of 10,300 cfs. Under current operational constraints, exports from Banks PP are generally limited to a maximum of 6,680 cfs, except between 15 December and 15 March, when exports can be increased by 33% of San Joaquin River flow (if greater than 1,000 cfs).

The SWP also pumps water from Barker Slough into the NBA for use in the North Bay Region. While the maximum pumping capacity at Barker Slough is 175 cfs, the average annual pumping rate is approximately 70 cfs.

Contra Costa Water District (CCWD) recently completed construction of the Los Vaqueros Reservoir and a 2nd pumping plant on Old River. These facilities will provide CCWD with access to improved water quality and emergency water supplies. Los Vaqueros will be refilled by diversions only when source-water chloride concentration is less than 65 milligrams per liter (mg/L). Los Vaqueros water will be used for delivery during low Delta outflow periods, when chloride concentration at Rock Slough and Old River is greater than 65 mg/L.

Delta inflow from the tributary basins is allocated to supply in-Delta diversions for agricultural and municipal water use, provide minimum Delta outflow required to satisfy 1995 Water Quality Control Plan (WQCP) and CVP Project Improvement Act objectives, and allow Delta exports within the WQCP export/inflow ratio and the permitted pumping capacity. Inflow that exceeds these uses contributes to total Delta outflow. The average monthly Sacramento San Joaquin Delta inflows from 1996 through 1999 are plotted against the historical monthly average inflows from 1922 through 1999 in Figure 4-3. Some Delta exports are used for direct deliveries to satisfy water supply demands, and some of the exports are stored in San Luis Reservoir (or other local water storage facilities) for later delivery.

Figure 4-3 Sacramento/San Joaquin Delta Inflows 1996 to 1999 vs. Historical Average



4.1.2 SACRAMENTO RIVER REGION

4.1.2.1 Land Use

Using GIS and ground-truthing, DWR has mapped almost 2 million acres of cropland from 1998 data for the Sacramento River Region. Table 4-1 shows the breakdown of cropland in the region. Rice continues to be the dominant crop, representing more than 25% of the total crop acreage. Pasture and alfalfa total 457,000 acres, and fruit and nut crops total 358,000 acres. Hundreds of thousands of additional acres are used for grazing, although an exact areal estimate is not available.

Table 4-1 1998 Crop Land Use by Acre in Sacramento River Region

Crop	Acres	Percent of total
Rice	502,300	25.3%
Pasture	312,800	15.7%
Other deciduous	239,400	12.1%
Grain	154,800	7.8%
Alfalfa	144,200	7.3%
Processing tomatoes	130,500	6.6%
Almond/Pistachio	118,600	6.0%
Corn	108,800	5.5%
Safflower	78,000	3.9%
Other field	49,500	2.5%
Cucurbits	34,200	1.7%
Subtropical	31,700	1.6%
Dry beans	30,700	1.5%
Vineyard	29,000	1.5%
Sugar beets	14,700	0.7%
Other truck	13,300	0.7%
Cotton	9,400	0.5%
Onion and garlic	1,700	0.1%
Fresh tomatoes	1,100	0.1%
Potato	-	0.0%
Total Crop Acres	2,004,700	
Multiple Crops	18,100	
Total Land Acres	1,986,600	

Source: DWR Unpublished Land Use Data 2000

Agriculture and open space historically have comprised most of the land use in the Sacramento River Region. Since the 1970s, urban land uses in the greater metropolitan Sacramento area have begun to supplant some agricultural uses. Except for Sacramento County, the region contains large quantities of parkland, forests, and other open space, and has preserved its traditionally rural nature.

Urban development accounts for approximately 863,000 acres (about 4%) of total land use in the region. Land uses in the Sacramento River Region are still principally agricultural and open space, with urban development focused in and around the City of Sacramento. More than half the region's population lives in the greater metropolitan Sacramento area. Other fast-growing communities include Vacaville, Dixon, Redding, Chico, and several Sierra Nevada foothill towns. Urban development along major highway corridors in Placer, El Dorado, Yolo, Solano, and Sutter counties has taken some irrigated agricultural land out of production. Suburban ranchette homes on relatively large parcels surround many of the urban areas and often include irrigated pastures or small orchards.

4.1.2.2 Geology and Soils

The upper watersheds of the Sacramento River Region include drainages above Shasta Reservoir (as well as a portion of the Trinity River watershed, from which flows are diverted into the Bay-Delta system), the Clear Creek drainage basin west of Redding, the Colusa Basin, Cache Creek and Putah Creek watersheds on the west side of the valley, and the Feather River and American River watersheds in the Sierra Nevada. Hydraulic mining on the western slopes of Sierra Nevada between 1853 and 1884 dramatically increased the sediment budgets of central Sierra streams and rivers. The addition of abundant coarse material overwhelmed the capacity of the rivers, resulting in temporary storage of the sediment in channels and floodplains and in widespread flooding of Central Valley towns and farms. Since the end of hydraulic mining more than 100 years ago, most rivers have reestablished their original gradients, aided by the trapping of mining sediment behind dams and the scouring of channels promoted by levees built along the rivers.

The Sacramento River's hydrology has been profoundly altered by reservoir construction. The average annual flood flow has been lowered, reducing the energy available to transport sediment in the Sacramento River. Moreover, the sediment supply to the river has been reduced by sediment trapping in reservoirs; by mining of sand and gravel from channel beds; and from artificial protection of riverbanks. Erosion of riverbanks had supplied sediment to the channel.

Rates of bank erosion and channel migration have declined since 1946, presumably because of change in flow and blockage of upstream sediment supply as a result of Shasta Dam, and because of construction of downstream bank protection projects. The channel sinuosity (ratio of channel length to valley length) also has decreased.

The Sacramento River Region contains 4 major landform types (each with its own characteristic soils): 1) floodplain, 2) basin rim/basin floor, 3) terraces, and 4) foothills and mountains. Floodplain alluvial soils make up some of the best agricultural land in the state. Basin landforms consist of poorly drained soils, and saline and alkali soils in the valley trough and on the basin rims. These soils are used mainly for pasture, rice, and cotton. Areas above the valley floor have terrace and foothill soils, which are primarily used for grazing and timberland.

The upper watersheds of the Sacramento Valley are mainly foothill soils. These soils are found on the hilly to mountainous terrain surrounding the Sacramento Valley and are formed in place through the decomposition and disintegration of the underlying parent material. Deep soils occur in the high rainfall zones at the higher elevations in the mountains surrounding the Sacramento Valley. These soil areas support timberlands and are characterized by acid reaction and depths to bedrock of 3 to 6 feet.

Shallow soils occur in the medium-to-low rainfall zones at lower elevations. The soils range from calcareous brown stony clay (for example, Lassen soils) to noncalcareous brown loam (for example, Vallecitos soils) and are used principally for grazing. Very shallow soils are found on steep slopes, often at high elevations. They consist of stony clay loam or stony loam and are not useful for agriculture or timber because of their very shallow depth, steep slopes, and stony texture. As such, they are also rated very low for grazing purposes.

The geologic provinces composing the Sacramento River Region include the Klamath Mountains, the Coast Ranges, the Cascade Range/Modoc Plateau, the Sierra Nevada, and the Central Valley. Downstream of Red Bluff, the Sacramento River flows within a meander belt of recent alluvium. The river is characterized by an active channel, with point bars on the inside of meander bends, and is flanked by active floodplain and older terraces. While most of these features consist of easily eroded, unconsolidated alluvium, there are also outcrops of resistant, cemented alluvial units.

In the channel itself, the bed is composed of gravel and sand (less gravel with distance downstream), and point bars are composed of sand. The bottomlands flanking the channel consist of silts and sands (deposited from suspended load in floodwater), commonly overlying channel gravels and sands. Higher, older surfaces consisting of (often-cemented) Pleistocene deposits also are encountered. The river channel migrates (maintaining roughly constant dimensions) across the floodplain to the limits of the meander belt, constrained only by outcrops of resistant units or artificial bank protection.

As meander bends grow, they may become unstable and form cutoffs. Since the construction of Shasta Dam in the early 1940s, flood volumes on the river have been reduced, which has reduced the energy available for sediment transport. Straightening and reduced meander migration rate of the river may be associated with flow regulation of Shasta Dam. The reduction in active channel dynamics is compounded by the physical effects of riprap bank protection structures, which typically eliminate shaded bank habitat and associated deep pools, as well as halt the natural processes of channel migration.

Sediment loads in the streams draining the upper watersheds have been artificially increased by past and current logging and grazing practices. Both practices remove soil-stabilizing vegetation, create preferential drainage pathways, and promote localized soil compaction. Erosive overland flow is enhanced by the loss of vegetation and by compacted soils. Larger amounts of sediment are delivered to the streams from increased rates of soil erosion and from enhanced rates of mass movement, such as landslides.

During high runoff events, the sharp increases in sediment yields can lead to widespread channel aggradation, which in turn can lead to lateral migration of the channels and increased frequency of landslide. Where dams have created reservoirs, most of the sediment is trapped behind the dam and, during the life of the reservoir, will not be transported downstream of the dam. Where such sediment traps are not in place, the sediment load will be transferred downstream.

Aggregate mining occurs within many streams in the western foothills of California and in the lower foothills of the Sierra Nevada. Because of their convenient proximity to the ground surface and their location on flat land, these deposits have been mined for many years. In-stream gravel mining can cause significant water quality and habitat problems with the increased release of sediments in the river as well as removal of soils in the areas of mining activities.

4.1.2.3 Vegetation and Habitats

The Sacramento River Region contains the watershed of the Sacramento River and its tributaries and extends from Collinsville in the south to the Oregon border in the north. The Sacramento River Region contains a large diversity of both lowland and upland habitats and species. Along most of the Sacramento River and its tributaries, remnants of riparian communities are all that remain of a once very productive and extensive riparian ecosystem. However, along the upper reaches of the Sacramento River, more riparian vegetation is still intact.

Wetlands occupy many areas along Sacramento River Region waterways but are not as extensive as wetlands found in the Delta Region. On the other hand, grasslands and wooded upland communities are more abundant in this region than in the Delta Region. Agricultural lands also occupy a significant portion of the Sacramento River Region. Open-water areas occur mainly on the larger waterways, where waterways converge, and in reservoirs. Conifers and hardwoods dominate the higher elevations in the Sacramento River Region. These areas have sustained some development and logging but have suffered less of a decline than the other communities in the region.

The most drastic difference between historical and existing conditions in the Sacramento River Region is the reduction of lush, unbroken riparian areas. Development, dams, agriculture, and fuel needs have removed and fragmented most riparian areas, especially in the mid-19th through mid-20th centuries. Native perennial grasslands once covered vast areas in the region but have been farmed or invaded by non-native annuals. Low-lying areas in the region routinely flooded, replenishing nutrients and providing water to many portions of the region not situated along waterways. These processes have been altered by diking and construction of levees to protect agricultural lands and residential areas, and many former communities dependent on regular floods have disappeared. Marshes and emergent wetlands were never as abundant in the Sacramento River Region as in the Delta and Bay regions because of inherent differences in their geomorphology. Vernal pools are important wetland resources that were historically abundant and have decreased dramatically with agriculture and development in the last 2 centuries.

4.1.2.4 Hydrology

The Sacramento River Region (26,960 square miles) contains the entire drainage area of the Sacramento River and its tributaries and extends almost 300 miles from Collinsville in the Delta north to the Oregon border (Figure 4-4). Average annual precipitation is 36 inches, and average annual runoff is about 22 million acre-feet (maf). The most intensive runoff occurs in the upper watershed of the Sacramento River above Lake Shasta and on the rivers originating on the west slope of the Sierra Nevada; these watersheds produce an annual average of 1 thousand acre-feet (taf) to more than 2 taf of runoff per square mile.

Figure 4-4 Sacramento River Hydrologic Region

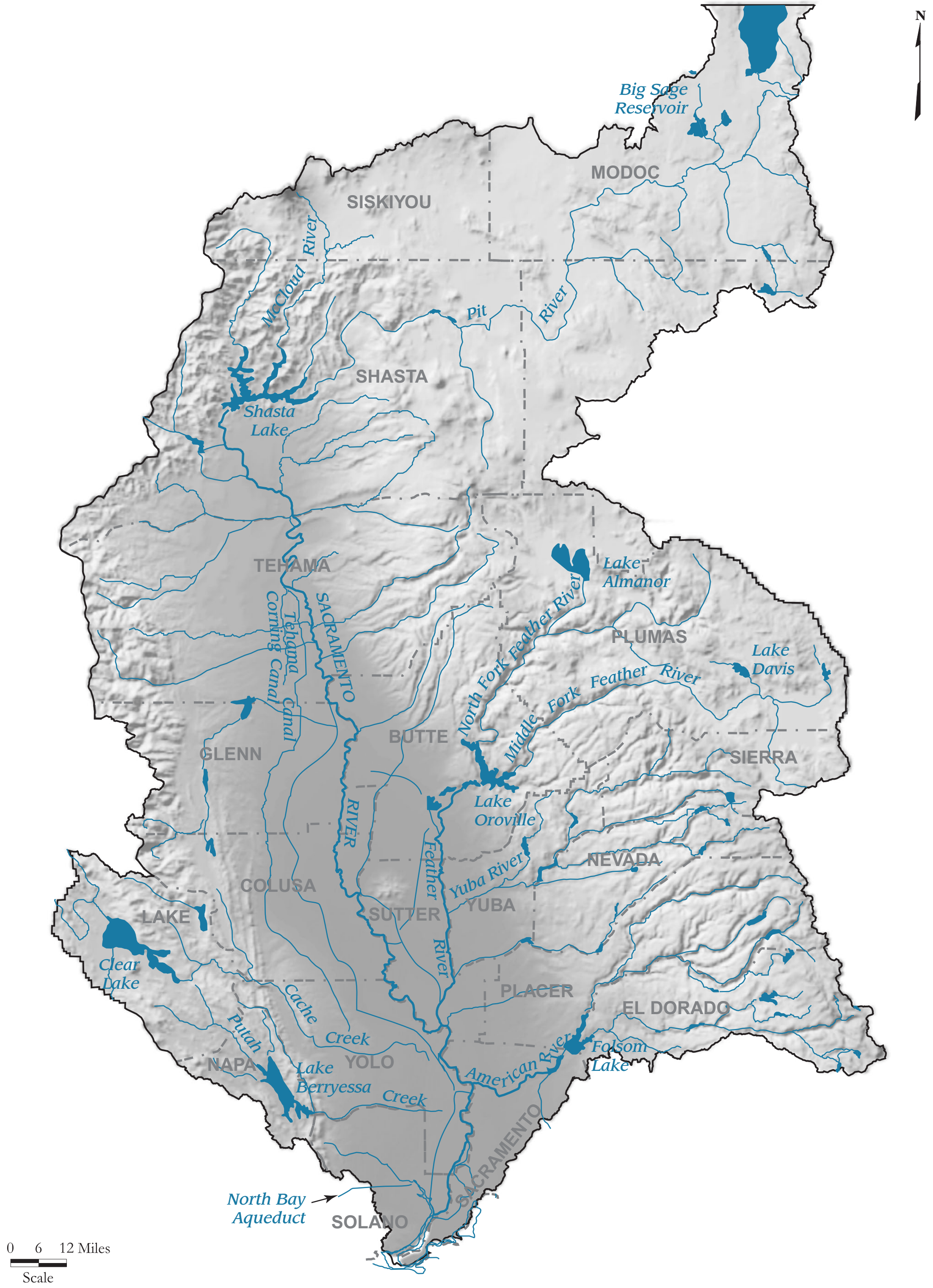
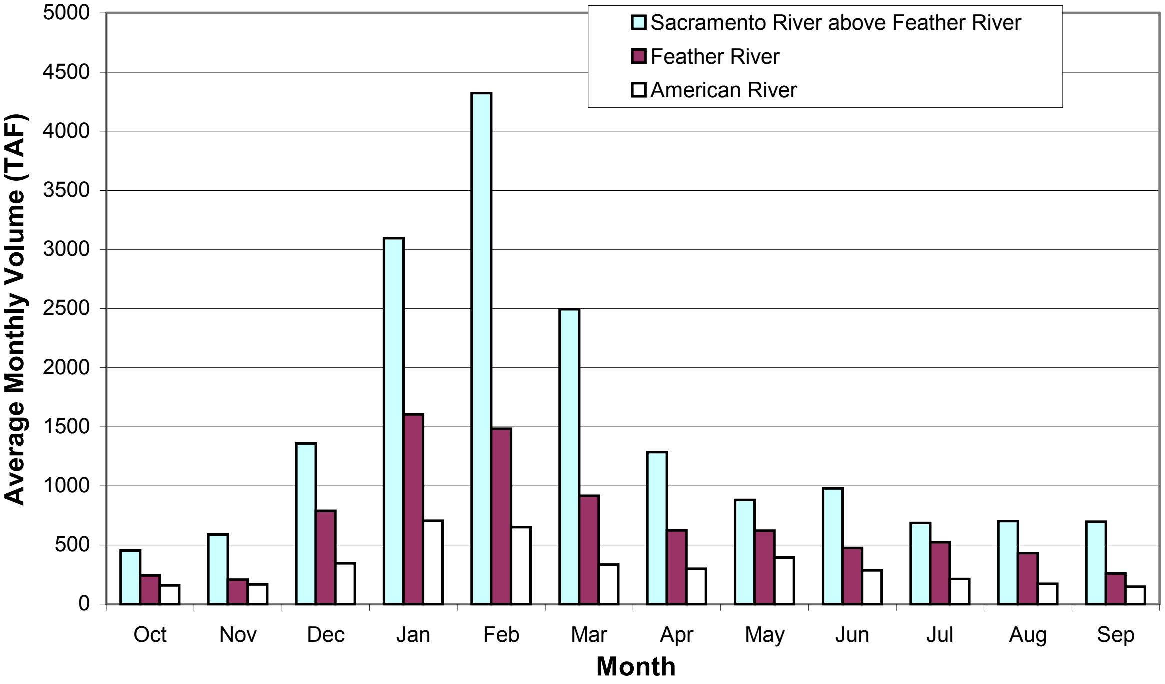


Figure 4-5 Major Upper Sacramento River Tributary Inflows 1996 to 1999



Notes: Sacramento River above Feather River includes Yolo Bypass flows plus Colusa Basin Drain and RD1500.
Feather River includes flows measured on the Feather River near Gridley plus measured flows on the Bear and Yuba rivers.

The 2 major tributaries to the Sacramento River along its lower reach are the Feather River (which includes flows from the Yuba River) and the American River. The combined flows of the Feather River and Sutter Bypass enter the Sacramento River near Verona. The American River joins the Sacramento River north of downtown Sacramento. Figure 4-5 shows the average monthly tributary inflows from 1996 through 1999 for the 3 main tributaries.

Other sources of discharge that have the potential to contribute contaminants to the Sacramento river include:

- Natomas Cross Canal, draining the area south of the Bear River drainage;
- Natomas East Main Drain, which drains 180 square miles of a rapidly urbanizing watershed—the drain discharges to the Sacramento River at low flows and into the American River at high flows;
- Colusa Basin Drain, which drains the west side of the Sacramento Valley from near Willows south to Knights Landing; and
- Sacramento Slough, which receives discharge from the agricultural lands within Reclamation District 1500, as well as from Butte Creek, Butte Slough, and the Sutter Buttes.

The Sacramento River Region contributes the majority of Delta inflow. Unimpaired flow from the 4 major rivers in the Sacramento River Region (Sacramento, Feather, Yuba, and American rivers) averaged 17.9 maf and ranged from 5.1 maf to 37.7 maf during the 1906 to 1996 period. Of this, the Sacramento River (at Red Bluff) averaged 8.4 maf, the Feather River above the Yuba River averaged 4.5 maf, the Yuba River averaged 2.4 maf, and the American River averaged 2.6 maf.

Since 1900, numerous reservoirs have been constructed in or have affected this region. They include Shasta, Oroville, Trinity, Berryessa, Folsom and New Bullards Bar, as well as numerous smaller reservoirs. Total reservoir capacity in or affecting the Sacramento River Region is more than 18 maf. Historically, these reservoirs have been operated to provide agricultural and domestic water supplies, flood control capacity, recreation, and water to sustain riverine ecosystems.

4.1.3 SAN JOAQUIN RIVER REGION

4.1.3.1 Land Use

The Spanish settled the San Joaquin Valley area for cattle ranching in the 1700s. By the mid-1800s, gold mining to the north and east created a demand for agricultural products and led to the 1st large irrigation developments in the region. Large areas of wetlands, such as Tulare Lake, were reclaimed for agriculture; and the advent of the railroad expanded agricultural markets to the rest of the nation. Many early irrigation developments were private; but in the 1930s and 1940s, the federal government played a larger role by developing multipurpose projects on the east-side rivers and valley floor.

Although agriculture and food processing are still the region's major industries, expansion from the San Francisco Bay area and Sacramento over the past 30 years has created major urban centers throughout the San Joaquin River Region. Open-space uses—including national forest and parkland, state parks and recreational areas, and U.S. Bureau of Land Management and military properties—historically comprised about one-third of the region.

Between 1946 and 1950, in terms of irrigated acres, cotton and grains were the most important crops in the San Joaquin River Region, accounting for 22% and 20% of the total irrigated acres, respectively. In 1998 almost 2 million acres of cropland were identified within the hydrologic region of the San Joaquin watershed (Table 4-2) (DWR unpublished land use data October 2000), an area similar to the total acreage found in the Sacramento River Region**.** Fruit and nut crops accounted for 23% of the total crops grown. Alfalfa and pasture equaled 22% of the acreage. Corn, vineyards, cotton and grain were next in order of total acreage, ranging from 8% to 13% for each type. Thousands of additional acres are used for grazing; the actual number of total acres of grazing is not available.

Land uses in the San Joaquin River Region are predominantly grazing and open space in the mountain and foothill areas and agricultural in the San Joaquin Valley area. Urban land use in 1996 totaled approximately 375,000 acres. Urban areas include the cities of Stockton, Modesto, Merced, and Tracy, as well as smaller communities such as Lodi, Galt, Madera, and Manteca. The western side of the region, south of Tracy, is sparsely populated. Small farming communities provide services for farms and ranches in the area, all relatively close to Interstate 5. Prior to the 1960s, land uses in the San Joaquin River Region were principally agriculture and open space, with urban uses limited to small farm communities. Although agriculture and food processing are still the region's major industries, expansion from the San Francisco Bay area and local industrial growth over the past 30 years have resulted in the creation of major urban centers throughout the region.

Table 4-2 1998 Crop Land Use by Acre in San Joaquin River Region

Crop	Acres	Percent of total
Almond/Pistachio	285,500	14.5%
Corn	260,400	13.2%
Alfalfa	236,300	12.0%
Vineyard	221,100	11.2%
Pasture	189,300	9.6%
Cotton	177,000	9.0%
Other deciduous	167,200	8.5%
Grain	153,400	7.8%
Processing tomatoes	83,100	4.2%
Other truck	64,700	3.3%
Dry beans	50,400	2.6%
Cucurbits	46,100	2.3%
Safflower	29,300	1.5%
Fresh tomatoes	21,900	1.1%
Sugar beets	21,800	1.1%
Rice	18,600	0.9%
Other field	13,100	0.7%
Onion and garlic	8,100	0.4%
Subtropical	7,100	0.4%
Potato	3,800	0.2%
Total crop acres	2,058,200	
Multiple crops	88,800	
Total land acres	1,969,400	

Source: DWR Unpublished Land Use Data 2000

4.1.3.2 Geology and Soils

Storage of floodwater behind Friant Dam has resulted in a decline in flood magnitudes on the mainstem of the San Joaquin River. Similar reductions have occurred on major tributaries, such as the Merced River. Less frequent flooding has reduced the energy available to transport sediments. Sediment supply to the river system has been reduced by catchment and trapping in reservoirs; mining of sand and gravel from channel beds; and artificial protection of riverbanks, the erosion of which had historically supplied sediment to the channel.

The floodplains of the San Joaquin River and its tributaries have been extensively modified for agricultural development, with elimination of many acres of slough and side-channel habitat. Gravel extraction has been both extensive and intensive from the upper mainstem and the major tributaries. The combined effects of sediment trapping by upstream reservoirs and, to a lesser extent, reduced bank erosion from riprapping, have resulted in a condition of sediment-starvation. In addition, excavation of pits for aggregate production has directly transformed many reaches of the San Joaquin River and its tributaries from flowing rivers to quiescent lakes.

The San Joaquin River Region contains 4 major landform types (each with its own characteristic soils):

1) Floodplain,
2) Basin rim/basin floor,
3) Terraces, and
4) Foothills and mountains.

Floodplain lands contain 2 main soil types: alluvial soils and aeolian soils. The alluvial soils make up some of the best agricultural land in the state, whereas the aeolian soils are prone to wind erosion and are deficient in plant nutrients. Basin lands consist of poorly drained soils, and saline and alkali soils in the valley trough and on the basin rims. These soils are used mainly for pasture, rice, and cotton. Areas above the valley floor contain terrace and foothill soils, which are primarily used for grazing and timberland. The upper watersheds of the Sacramento and San Joaquin valleys mainly drain foothills soils, which are found on the hilly to mountainous topography surrounding the San Joaquin Valley.

Moderate depth (20 to 40 inches) to bedrock soils occur on both sides of the northern part of the San Joaquin Valley, where the annual rainfall is intermediate to moderately high. Deep (> 40 inches) soils are the important timberlands of the area and occur in the high rainfall zones at the higher elevations in the Sierra Nevada. Shallow (< 20 inches) soils, used for grazing, occur in the medium- to low-rainfall zone at lower elevations on both sides of the valley. Very shallow (< 12 inches) soils are found on steep slopes, mainly at higher elevations. These soils are not useful for agriculture, grazing, or timber because of their very shallow depth, steep slopes, and stony texture.

The geologic provinces composing the San Joaquin River Region include the Coast Ranges, Central Valley, and Sierra Nevada. The mainstem San Joaquin River meanders within a meander belt of recent alluvium. The river is characterized by an active channel, with point bars on the inside of meander bends, flanked by an active floodplain and older terraces. While most of these features consist of easily erodible, unconsolidated alluvial deposits, there are also outcrops of resistant, cemented alluvial units such as the Modesto and Riverbank formations. Within the channel itself, the bed is composed of gravel and sand (less gravel with distance downstream), and point bars are composed of sand.

The bottomlands flanking the channel consist of silts and sands (deposited from suspended load in floodwater), commonly overlying channel gravels and sands. Higher, older surfaces consisting of (often-cemented) Pleistocene deposits also are encountered. The river channel migrates (maintaining roughly constant dimensions) across the floodplain to the limits of the meander belt, constrained only by outcroppings of resistant units or artificial bank protection. As meander bends grow, they may become unstable and form cutoffs, leaving oxbow lakes like those visible along lower reaches of the mainstem. Sediment loads in streams draining the upper watersheds of the San Joaquin River Region are similar to those described for the Sacramento River Region.

After nearly 2 decades of little or no land subsidence, significant land subsidence recently has been detected in the San Joaquin Valley along the DMC because of increased groundwater pumping during the 1987 to 1992 drought. It was not until the 1920s that deep well pumping lowered the water table below the root zone of plants on the east side of the valley. Dry-farming practices were replaced with irrigated agriculture on the west side in the l940s, leading to the spreading and worsening of drainage problems on the west side of the valley and near the valley trough in the 1950s. As a result of heavy pumping, groundwater levels declined by more than 300 feet in certain areas during the 1940s and 1950s. The groundwater level declines resulted in significant land subsidence over large areas. Significant historical land subsidence caused by excessive groundwater pumping has also been observed in the Los Banos-Kettleman Hills area.

High soil salinity caused by irrigation has been identified in the western and southern portions of the San Joaquin Valley. Most soils in this region were derived from marine sediments of the Coast Ranges, which contain salts and potentially toxic trace elements such as arsenic, boron, molybdenum, and selenium. Soil salinity problems in the San Joaquin Valley have been, and continue to be, intensified by poor soil drainage, insufficient water supplies for adequate leaching, poor-quality (high-salinity) applied irrigation water, high water tables, and an arid climate. A 1984 study estimated that about 2.4 million of the 7.5 million acres of irrigated cropland in the Central Valley were adversely affected by soil salinity.

Selenium in soils is primarily a concern on the west side of the San Joaquin Valley. When these soils are irrigated, selenium (along with other salts and trace elements) dissolves and leaches into the shallow groundwater. Over the past 30 to 40 years of irrigation, soluble selenium has been leached from the soils into the underlying shallow groundwater aquifers. Subsurface drainage systems transported selenium into the agricultural drainage sloughs. Transportation of selenium to the Kesterson Reservoir led to the well publicized mutation of waterfowl and other bird species, and resulted in the closing of the San Luis Drain. The original plans to have the San Luis Drain discharge to the Delta were rejected. Currently, Mud and Salt Sloughs carry much of this drainage to the San Joaquin River.

4.1.3.3 Vegetation and Habitats

Ecosystems in the San Joaquin River Region have many similarities to the Sacramento River Region, including terrain, climate, habitats, and species. Historical and present differences between the 2 regions do exist, however. For example, the San Joaquin River Region's riparian zones are not and have never been as extensive as those found in the Sacramento River Region. Many San Joaquin riparian communities were lost when historical waterways ran dry as water was diverted through irrigation channels and artificial drainages.

Isolated riparian communities exist in the lower portions of the San Joaquin River Region, and more intact communities can be found along the eastern reaches in the region. Wetlands are situated in the northern and western reaches in the region but are less abundant in other parts of the region.

As with the Sacramento River Region, the San Joaquin River Region has lost most of its historical riparian areas, mostly to agriculture. Agriculture developed early and quickly in the region and has remained the dominant land use. Historically, the lowlands were a large floodplain of the San Joaquin River that supported vast expanses of permanent and seasonal marshes, lakes, and riparian areas. Almost 70% of the lowlands have been converted to irrigated agriculture, with wetland acreage reduced to 120,300 acres.

Upland shrubs and oak woodlands that surround the San Joaquin River Region to the east, west, and south are less intact today than they were prior to the twentieth century. Development and water diversions adversely affected some communities in these areas. Wetland areas were once very common in the northern, southern, and parts of the western reaches of the San Joaquin River Region; but since the mid-19th century, wetlands have been reduced to a fraction of their historical acreage by minerals, salts, pesticides, diversions, and reclamation activities.

4.1.3.4 Hydrology

The San Joaquin River Region includes the Central Valley south of the watershed of the American River and Morrison Creek down to the northern boundary of the Tulare Lake Basin (Figure 4-6). It is generally drier than the Sacramento River Region, and flows into the Delta from the San Joaquin River are considerably lower than those into the Delta from the Sacramento River (Figure 4-3). The region is also subject to extreme variations in flow, as exemplified by flooding that occurred during January 1997.

Figure 4-6 San Joaquin River Hydrologic Region

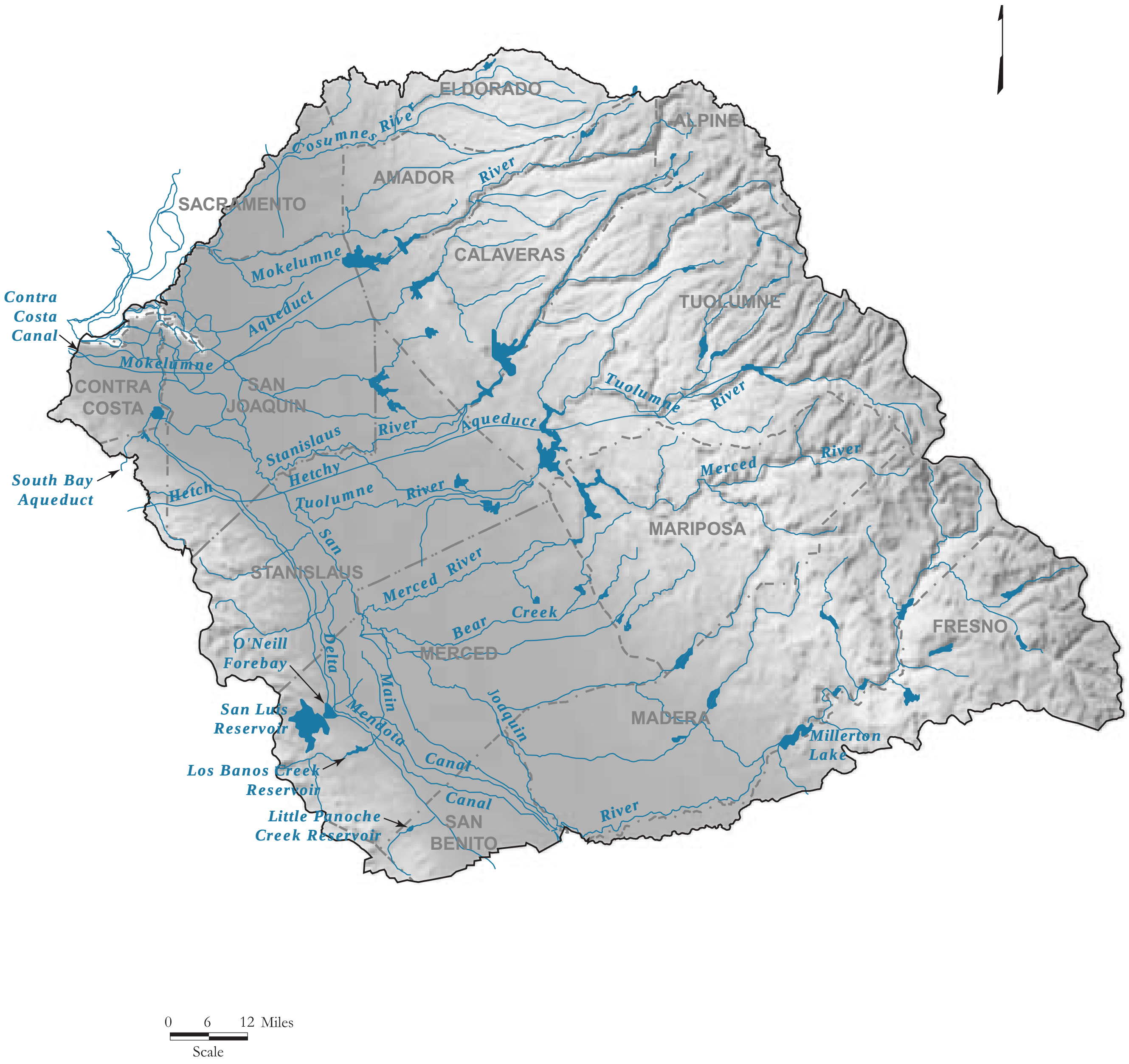
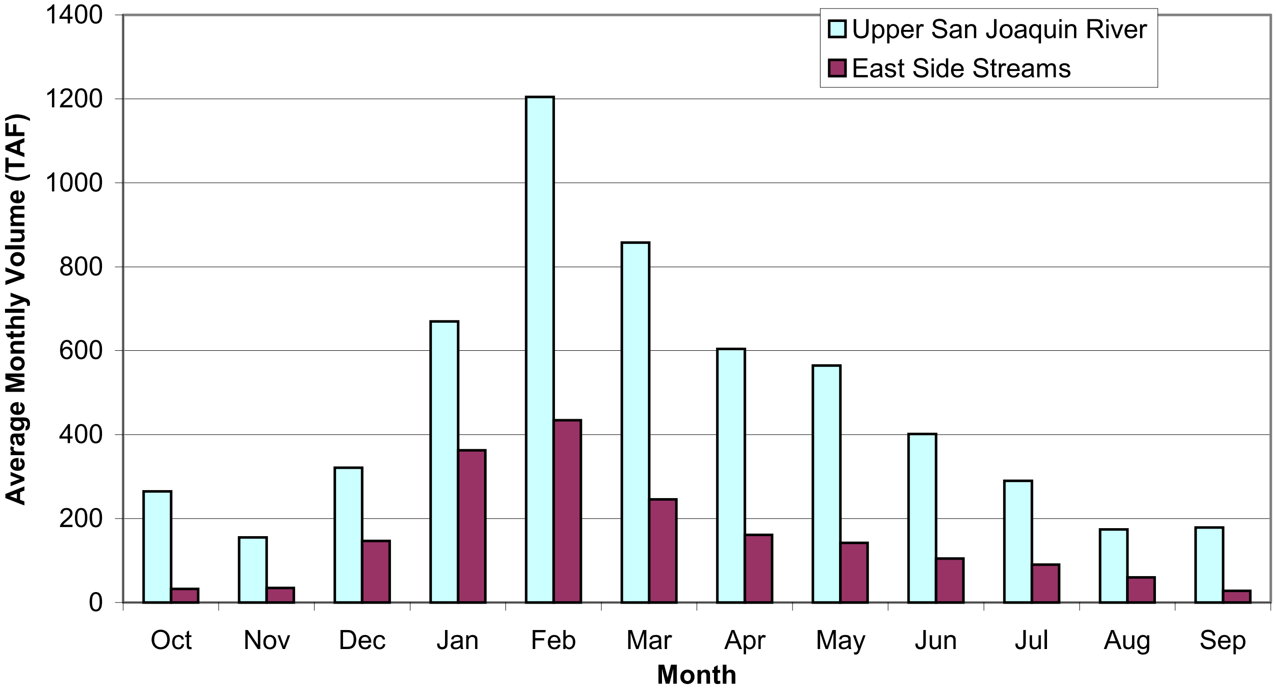


Figure 4-7 Major San Joaquin River Tributary Inflows 1996 to 1999



Note: East Side Streams includes the Mokelumne and Cosumnes rivers, miscellaneous inflows such as Calaveras River, Bear Creek, and others.

The drainage area of the San Joaquin River above Vernalis is 13,356 square miles, including 2,100 square miles of drainage contributed by the James Bypass. Most of the inflow to the San Joaquin River Region originates from the upper watershed tributary streams between the Mokelumne River and the San Joaquin River, on the west slope of the Sierra Nevada (Figure 4-**7).** The San Joaquin River has 3 major tributaries that drain the Sierra Nevada. In downstream order, they are the Merced (drainage area 1,270 square miles, average flow 1,350 cfs), Tuolumne (1,884 square miles, average flow 2,254 cfs), and Stanislaus (980 square miles, average flow 1,400 cfs) rivers. Another major river, the Mokelumne, enters the east Delta along with minor tributaries (including the Cosumnes and Calaveras rivers), joining the San Joaquin River prior to its confluence with the Sacramento River.

Runoff intensity averages less than 1 taf per square mile in this region. Inflows from the Merced, Tuolumne, and Stanislaus rivers historically contribute more than 60% of the flows in the San Joaquin River as measured at Vernalis.

Precipitation is predominantly snow above 4,000 feet in the Sierra Nevada and rain in the middle and lower elevations of the Sierra Nevada and Coast Ranges. As a result, the natural hydrology reflects a mixed runoff regime of summer snowmelt and winter-spring rainfall runoff. Average annual precipitation in the lower reach of the river ranges from 10 to 12 inches per year. The upper watershed of the San Joaquin River Region has historically been less developed than that of the Sacramento River Region, although the same general process of development has occurred, including mining, logging, housing construction, industrial development, and dam construction. As in the Sacramento River Region, the upper watershed contains major parks and wilderness areas. Most development has occurred in the lower foothills, near or below the snow line.

Annual average unimpaired runoff from the San Joaquin, Stanislaus, Tuolumne, and Merced rivers is about 5.5 maf. Numerous dams and diversions have been constructed on these rivers and other rivers in this system. Of the 5.5 maf of unimpaired runoff, about 3.5 maf is diverted from the major rivers of the San Joaquin system. An average of about 3 maf annually reaches Vernalis and contributes to Delta inflows.

4.2 POTENTIAL CONTAMINANT SOURCES

4.2.1 RECREATION

Recreation is a multimillion dollar industry for the Sacramento, San Joaquin and Delta regions and encompasses a wide variety of activities including boating, waterskiing, personal watercraft (PWC), fishing and hunting. Fishing and boating are the most popular activities and account for approximately 70% of total use (CALFED 2000d). While most of the navigable waterways in the Delta are public, most of the land is privately held; this lack of public lands serves to limit the use of the Delta for recreation. Public use of the Delta is concentrated in a few areas where marinas and other facilities provide access to the Delta waterways. There are more than a hundred private marinas that provide most of the recreation opportunities in the Delta, but few public parks. Some of the recreation areas are only accessible by boat, further limiting public access. The Delta's 1,100 miles of improved levees are also popular with bank anglers; however, because much of the levee system is privately owned, the public must trespass to gain access. Hunting occurs mainly on private property and on State-owned land and water (California State Parks 1997).

Of the 7 constituents (bromide, dissolved solids, microbial pathogens, natural organic matter, nutrients, salinity, and turbidity) identified by a panel of CALFED drinking water experts as constituents of concern in Delta waters (CALFED 2000), only microbial pathogens are directly associated with recreational use. Pathogen contamination can be caused by discharge of raw or partially treated sewage from sport boats or by body-contact recreation such as swimming or water skiing. Bank fishing from levees is a popular Delta activity; however, few of the sites possess garbage receptacles or restroom facilities, which increases the risk of pathogen contamination (California State Parks 1997). Additionally, boats and other personal watercraft can introduce MTBE and hydrocarbons into the Delta. Land-based activities such as hiking, horseback riding, and offroad vehicle travel can accelerate erosion and increase water turbidity.

4.2.1.1 Recreational Use Surveys

The Delta is a popular destination for recreators from the Sacramento metropolitan area, San Francisco Bay area and the cities of Stockton, Tracy, and Modesto (DBW 2000). Delta boundaries include portions of Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties. Recreation in the Delta currently exceeds 12 million user-days (recreation-days) annually and is expected to increase concurrent with the populations of surrounding areas (DBW 2000). Recreational use is measured in "recreation days," defined as 1 user visiting the recreation area during part of a 1-day period. The population of the 5 counties adjoining the Delta is projected to increase to 5.2 million by the year 2005 (California State Parks 1997), and recreational pressures are likely to increase in the future.

The Delta contains approximately 50,000 acres of water surface and nearly 1,100 miles of leveed shoreline (DBW 2000). The network of interconnected islands translates into approximately 700 miles of waterway (Delta Protection Commission 1995). Recreational facilities are predominately in the northern and western Delta; however, recreational facilities are found throughout the region. Current Delta use patterns indicate that a majority of the visitors stay in the Delta a single day or less. The peak recreation period occurs from May through September. Spring and summer (March to September) account for about 75% of total annual use (CALFED 2000d).

Estimates of Delta recreational use are hard to come by and can vary considerably. A recent survey conducted for the Delta Protection Commission estimated recreational use to be about 40 million visitor days, but other studies concluded use was substantially lower (see above). Currently, few up-to-date recreational use surveys exist for the Delta or the Sacramento and San Joaquin rivers and environs (Archibald & Wallberg and others 1995). Ancillary information such as length of visit, dollars spent per visitor day, age, sex or ethnic background of visitors, or type of facilities needed to meet present and future visitor needs for the Delta are even more sparse (Delta Protection Commission 1995). When studies were conducted, they tended to focus on only a few recreational activities or on smaller regions. For example, a study commissioned in 1995 by the Delta Protection Commission (California State Parks 1997) only addressed boating and fishing, and a 1993 DWR survey was restricted to Delta areas north of Brannan Island (DWR 1997). One of the few comprehensive and extensive surveys of recreational use on the Sacramento River (DWR 1982) is now 20 years old (Rischbieter pers. comm.2000). A search of current literature found no recreation use surveys for the lower San Joaquin River. Accurate tallies of total public use of the Delta are difficult to obtain because public access to the Delta is not restricted to a single entrance and there is no central agency that collects use data from the public and private recreation areas within the Delta (Cox pers. comm. 2000).

The Delta Protection Commission conducted one of the most recent Delta use surveys in 1995. Registered boat owners and holders of fishing licenses were surveyed on their use of the Delta. The survey found that boating activity was split nearly evenly between the weekday and weekend, whereas fishing activity was concentrated on the weekend (California State Parks 1997). Both boating and fishing activities were concentrated in the summer months.

The study subdivided the Delta into 6 recreation use areas or zones (Figure 4-8). The eastern Delta includes portions of the city of Stockton. The zones in the northern Delta include the Sacramento River from Courtland south to State Route 12 and all stretches of the Mokelumne and Cosumnes rivers that lie within the Delta. The west Delta (zone D), which includes the lower Sacramento and San Joaquin rivers and the Brannan Island State Recreation Area (SRA), was the most popular area for boating, fishing, and swimming. The eastern and northern Delta (zones E and C, respectively) were the next most popular recreational areas. The area of the Delta that receives the least use from boaters and fishermen is zone B, which includes the Yolo Bypass, Cache Slough, and the Sacramento River Deep Water Ship Channel. Relative popularity of the different zones is shown below in Table 4-3. Figure 4-9 shows the location of public and private marinas and boat launches in zone D.

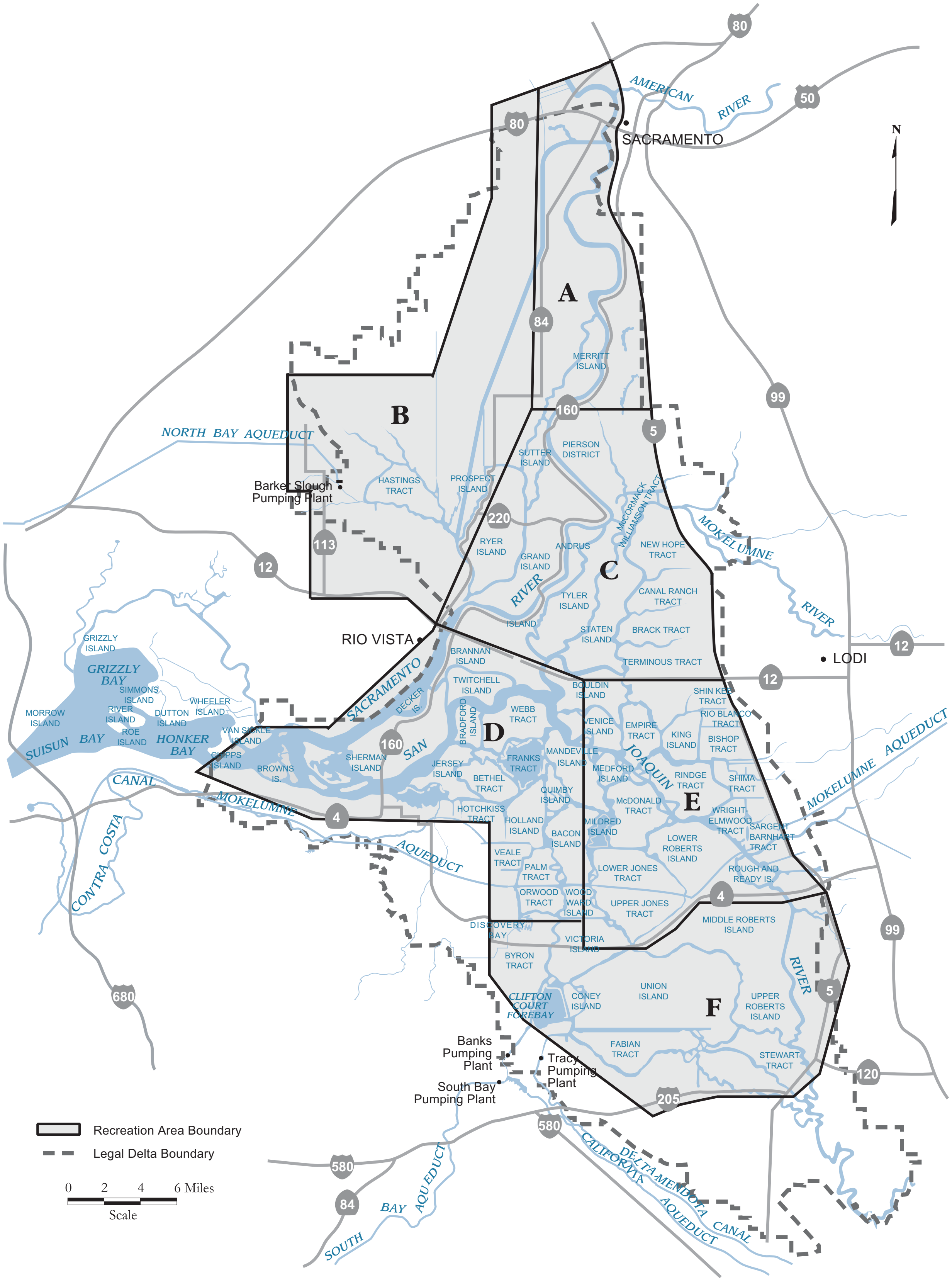
Table 4-3 Popularity of Boating and Fishing Activities in the Delta by Zone[a]

Activity	
Boating (includes fishing from boat)	Fishing (includes fishing from boat)
D	D
E	E (tie)
C	C (tie)
A	A
F	F
B	B

Adapted from California State Parks 1997

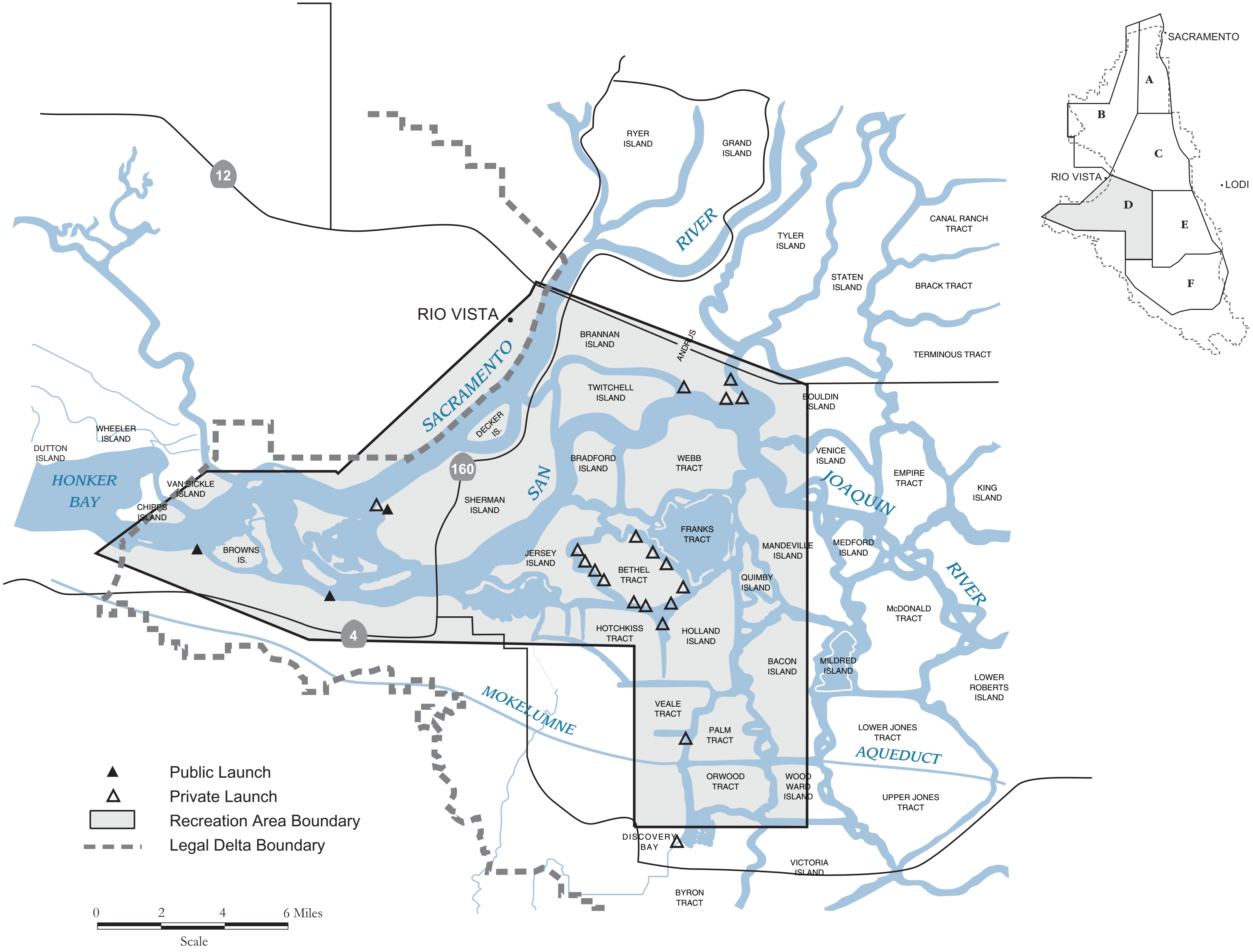
[a] Zones ranked in descending order from most to least popular

Figure 4-8 Recreation Zones in the Delta



Adapted from California State Parks Sacramento - San Joaquin Delta Recreation Survey, 1997

Figure 4-9 Most Frequently Used Boating and Fishing Zones



Adapted from California State Parks Sacramento - San Joaquin Delta Recreation Survey, 1997

California State Parks Visitor Attendance Reports for fiscal year 1998/1999 reinforce the Delta Protection Commission's 1995 survey: Brannan Island in the northwest corner of the Delta was the most heavily used State-run facility (Table 4-4). Bethany Reservoir had the fewest boat launching of any SWP reservoir where boating is allowed. Recreational use of Bethany Reservoir was primarily for bank fishing (Hardcastle pers. comm. 2000), and restroom facilities are available on-site.

Table 4-4 Number of Vehicles (day use[a]) and Number of Boats Launched in State Recreation Areas or State Parks for Fiscal Year 1998/99

Recreation Area	# of Vehicles	Boats Launched
Colusa-Sacramento SRA	26,599	3,062
Bethany Reservoir SRA	13,950	292
Bidwell-Sacramento SRA	85,966	5,989
Brannan Island SRA	92,329	9,913
Delta Meadows SP	5,166	-
Frank's Tract SRA	9,013	-

[a] Paid or free day use

A 1980 survey conducted by DWR (1982) is still one of the best surveys available for estimating recreation use along the Sacramento River (Rischbieter pers. comm. 2000). The survey covered the reach between Keswick Dam and the city of Sacramento and found that fishing was the most popular activity (39%), followed by relaxing (17%) and powerboating/waterskiing (11%). Swimming and beach use comprised 9% of the recreational use. Fishing was found to be the primary activity along all reaches of the Sacramento River except near Redding, Red Bluff, and Sacramento, where relaxing was the predominant activity. Table 4-5 shows the 3 most heavily used river reaches for recreational activity based on recreation hours on the Sacramento River. With the exception of relaxing, most activities occurred in the lower Sacramento from river reach 10 to 13. These reaches include Discovery and Miller parks in the city of Sacramento.

Table 4-5 Dominant Recreation Activities along the Sacramento River Identified by River Reach of Occurrence

Activity	Top 3 River Reaches by Activity
Boat fishing	1) Miller Park to Paintersville Bridge below Courtland 2) Hamilton Bend to Meridian Bridge 3) Feather River to north end of Discovery Park
Shore fishing	1) Miller Park to Paintersville Bridge below Courtland 2) Eldorado Bend to mouth of the Feather River 3) Discovery Park to south end of Miller Park
Boating[ab]	1) Miller Park to Paintersville Bridge below Courtland 2) Discovery Park to south end of Miller Park 3) Feather River to north end of Discovery Park 4) Eldorado Bend to mouth of the Feather River
Relaxing	1) Discovery Park to south end of Miller Park 2) Keswick Dam to North Street Bridge in Anderson 3) Jelly's Ferry Bridge to Red Bluff Diversion Dam
Swimming/Beach Use	1) Discovery Park to south end of Miller Park 2) Eldorado Bend to mouth of the Feather River 3) Feather River to north end of Discovery Park

Adapted from DWR 1982

[a] Includes personal watercraft, sailing, pleasure boating and waterskiing.

[b] More than 3 river reaches identified based on lumping of all boating activities.

A California Department of Fish and Game (DFG) survey of sport-fish catch inventory found that fishing activity during fiscal years 1989 and 1990 was heaviest between Sacramento and the Carquinez Bridge (California State Parks 1997). This mirrors the survey conducted for the Delta Protection Commission, which found that zone D (western Delta) was the most popular section of the Delta for fishing. The DFG study also found that the number of recreational anglers declined during 1989 to 1990 at least in part because of a declining population of anadromous fish and poor river conditions associated with the consecutive critically dry years (California State Parks 1997).

The San Joaquin River Region contains reservoirs, rivers, and wildlife refuges, which support a variety of recreational activities. Eight major streams and 22 minor streams flow into the San Joaquin River providing opportunities for a number of different recreational activities. Recreation use in the region has been rising since the 1940s. Historical use trends at some of the major reservoirs and lakes in the region show substantial increases during the 1970s and 1980s particularly at San Luis Reservoir, Lake McClure, and New Hogan Lake (CALFED 2000d). Overall, water-dependent activities in these areas generated approximately 3 million visitor days in 1992. Recreation use is measured by counting a single user visiting the recreation area during part of a 1-day period. Because 1992 was a dry year, it is probable that this figure underestimates the level of activity that occurs in most years (CALFED 2000d).

It is difficult to determine more recent use figures for the San Joaquin River Basin because no single agency is responsible for measuring recreational activities in the area (Hardcastle pers. comm. 2000). A recreation inventory of public and private recreation facilities, areas, access points, and routes along the various river corridors was recommended in the 1995 *San Joaquin River Management Plan* (Hoffman-Floerke pers. comm. 2000).

Besides the San Joaquin River, there are 3 other rivers used for recreation in the San Joaquin Valley: Merced, Stanislaus, and Tuolumne. All of these rivers have historically supported salmon fisheries; however, current sportfishing data are limited (CALFED 2000d). In 1962, DFG estimated that the Stanislaus River Chinook salmon run supported an average annual use of 10,000 angler days of sportfishing. No other use-data for the Stanislaus River or other important rivers in the San Joaquin River Region are available (CALFED 2000d).

4.2.1.2 Boating and Pathogen Contamination

In 1992, Congress passed the Clean Vessel Act, a $40 million grant program to fund construction/renovation of pump-out stations and to educate boaters about proper disposal of vessel sewage. Congress found that “sewage discharged from recreational vessels because of an inadequate number of pump-out stations is a substantial contributor to localized degradation of water quality in the U.S.” The Water Quality Control Plan for the Central Valley region also prohibits the discharge of toilet wastes from all rental houseboats on the Delta (CVRWQCB 1998). Chapter 6 of the Harbors and Navigation Code mandates that all marinas have pump-out facilities (Atkinson pers. comm. 2000). However, many marinas lack these facilities, and because of staffing limitations at the Central Valley Regional Water Quality Control Board (CVRWQCB), this regulation is minimally enforced (Atkinson pers. comm. 2000).

Table 4-6 Marina Pump-Out Facilities by County

County	Total Marinas in County	Pump-out Sewage Facility
Contra Costa	41	10
Sacramento	27	10
San Joaquin	23	7
Solano	6	3
Yolo	2	0
Total	99	30

Adapted from DBW *1998*

Within the Delta, there are approximately 100 marinas with a total of almost 11,000 berths (Delta Protection Commission 1995). Marinas are not equally distributed throughout the Delta. The most heavily used areas include Bethel Island in Contra Costa County and Lower Andrus Island in Sacramento County (CALFED 2000d). Only 29% of the marinas in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties maintained pump-out facilities (DBW 1998). Similarly, only 2 of the 12 marinas on Bethel Island and 2 of the 11 marinas on Andrus Island had a pump-out facility (DBW 1998, 1999). A 1996 water quality assessment of the Sacramento River between the Sacramento River water treatment plant and the Freeport Bridge noted 8 marinas, only 1 of which had a pump-out facility (Archibald & Wallberg and others 1996). The number of marinas and pump-out facilities by county are shown in Table 4-6. The lack of pump-out facilities increases the chances that boaters will release raw or partially treated sewage directly into the Delta.

The problem of sewage disposal is compounded by the fact that the majority of the most popular boating vessel (powerboats) do not contain a Marine Sanitation Device (MSD). The 1995 Boating Use Survey found that only 15% of surveyed powerboat owners had MSDs onboard (California State Parks 1997). In contrast, the survey found that over 80% of the houseboats and 68% of the sailboats had toilets. Houseboats may have a greater potential to generate onboard waste (due to greater passenger capacity), but these crafts represented only 4% of surveyed boat owners in 1995, and because most are equipped with MSDs, houseboats may pose less of a threat to water quality than the more numerous, small watercraft. In the year covered by the study, the rental of houseboats had declined due to the recession in the early 1990s and to changes in the tax code that reduced profits for the owners (California State Parks 1997). However, the economic climate has changed considerably since the early 1990s; therefore, it is possible that houseboating has again gained in popularity.

In addition to fecal contamination, some of the chemicals used for MSD disinfectants, which include chlorine, ammonia, and formaldehyde, are also discharged when boaters empty an MSD directly into the water.

4.2.1.3 Body-Contact Recreation and Pathogens

In the Delta, most body-contact recreation is waterskiing and windsurfing (Aramburu pers. comm. 2000). Waterskiing is one of the most popular recreation uses of the Delta. Discussions of boating use in Section 4.2.1.2 include waterskiing. DWR surveyed windsurfing and the use of PWC in the northern Delta and found that both activities comprised about 1% of the area's recreation hours (DWR 1997).

Because of a lack of public beaches, swimming from shore is uncommon in the Delta; however, swimming from boats is a popular alternative (California State Parks 1997). Twenty-two percent of respondents in a 1980 use survey indicated they used the Delta for swimming (Cajucom 1980). Most swimming beaches are located in the west Delta—the lower Sacramento and San Joaquin rivers and the Brannan Island SRA (California State Parks 1997). However, a 1993 recreation use study of the northern Delta (which included Brannan Island SRA) found only 4% of the respondents used the north Delta for swimming (DWR 1997). The Delta Protection Commission's 1995 survey also found that swimming from boats was most common in zone D.

Although these use-figures suggest that the impacts of swimming may be relatively minor, bacterial-loads may have a more substantial impact on local water quality. For example, before the 2000 Labor Day weekend, Discovery Park, a popular recreation area at the confluence of the Sacramento and American rivers was closed to swimming due to high fecal coliform levels. The cause of the bacterial contamination increase was unknown (Knight pers. comm. 2000). Coliform numbers began rising prior to the weekend holiday and, based on repeat sampling, peaked at 2,400 MPN/100 ml (Knight pers. comm. 2000). This is the 1st time that coliform levels precipitated a voluntary closure of the park to swimming by California State Parks. Sampling of Sacramento's public beaches has been sporadic, and in some summers no sampling has occurred (Hackett pers. comm. 2000). This lack of monitoring can be traced to the lack of regulations for coliform levels at inland public beaches. The California Department of Health Services (DHS) is in the process of researching regulations that will require monitoring of public freshwater beaches (McGuirk pers. comm. 2000).

The number of restroom facilities on Delta shores appears to be inadequate. In the boating portion of the Delta Protection Commission 1995 survey, 40% of the boaters indicated that the number of restrooms was somewhat inadequate and another 20% rated them as very inadequate. Similar results were found in the fishing portion of the survey. Fifty-five percent of fishing respondents viewed public restroom availability as somewhat or very inadequate (California State Parks 1997).

4.2.1.4 Delta Recreation and MTBE

Another potential contaminant associated with recreational use of the Delta is MTBE. MTBE is a fuel additive used to boost octane and make gasoline burn more efficiently. Almost all existing PWC and most outboard motorboats use carbureted 2-stroke engines. In the 5 counties that comprise most of the Delta, 14,544 PWC and 120,679 boats were registered in 1999 (Standard pers. comm. 2000). Because 2-stroke engines discharge up to 25% of their fuel/oil mixture into the surface water, these engines are a significant source of hydrocarbon and MTBE pollution (DWR 1999). MTBE is very soluble in water (approximately 5 g/L) and highly persistent in water if not exposed to air. Based on its potential to be a human carcinogen, the DHS recently issued a primary maximum concentration level (MCL) for MTBE of 13 μg/L; the secondary MCL is 5 μg/L (DHS 2001).

Beginning in 2001, new regulations adopted by the California Air Resources Control Board take effect.

Instead of carbureted 2-stroke engines, either 2-stroke direct-injection engines or 4-stroke engines will be sold (DBW 2000a). Direct injection engines are significantly more efficient than carbureted 2-stroke engines, while 4-stroke engines are more efficient than direct-injection 2-stroke models. Owners of pre-2001 model year engines are not required to retrofit or purchase a new engine; therefore, although MTBE is being phased out of gasoline by 2002, conventional 2-stroke engines could continue to release MTBE formulated fuel into the Delta until then. The phaseout of MTBE is also dependent on changes to federal laws that require oxygenates in fuel. If these changes do not occur, MTBE may continue to be discharged into Delta waters beyond the 2002 target date. In a recent Delta water-quality assessment, MTBE was determined to be of limited significance to drinking water quality owing to relatively low concentrations in Delta waters (CALFED 2000).

4.2.2 WASTEWATER TREATMENT FACILITIES

The Clean Water Act prescribes performance levels to be attained by municipal wastewater treatment plants in order to prevent the discharge of harmful quantities of waste into surface waters and to ensure that residual biosolids meet environmental quality standards. The Act authorizes the principal federal program to aid wastewater treatment plant construction. In the Sacramento/San Joaquin watersheds, the CVRWQCB implements the Clean Water Act and the State's Porter-Cologne Act through National Pollutant Discharge Elimination Systems (NPDES) permits and Waste Discharge Requirements (WDRs), respectively. The permits set the effluent water quality to be maintained but do not specify the methods to ensure compliance. The limits and prohibitions in the permit are developed individually for each facility based on the water quality objectives of the receiving water as described in the water quality control plan for that region. The permits also describe how biosolids from the facility will be stored, transported, and disposed. Commonly used disposal methods for sludge include incineration, disposal to landfill or spreading on land.

In the past, land application of biosolids was primarily regulated for heavy metals. Increased concern over eutrophication of water bodies has added nutrients to the list of concerns. Application of biosolids is currently calculated to achieve "agronomic rates." The goal is to apply only enough biosolids to match the biological needs of the crops being grown (Lee and Jones-Lee 2000). However, Lee and Jones-Lee have pointed out that not all the organic nitrogen in the biosolids is mineralized during the growing season and about 30% can be carried over to the next season. These excess nutrients can then end up in storm water runoff. The ability for wastewater facilities to dispose of biosolids on land is increasingly being restricted in California. The San Joaquin Valley has been a major disposal area, especially for biosolids from Southern California which have been used to grow animal feed or fiber crops such as alfalfa and cotton. Recently, Kern, Fresno, Tulare, and Kings counties drafted ordinances to either ban or severely limit the practice of using biosolids as fertilizer. The counties are worried about consumer perception that waste is being used to grow human food-crops, which would undermine the public's confidence in produce from those counties (Russell 2000).

A wastewater facility's size and point of discharge determine its NPDES classification. A plant that has a design flow of 1 million gallons per day (mgd) or more is a major discharger. Less effluent volume may be classified as a major discharge if the outfall is into an environmentally sensitive water body or near a drinking water intake. The NPDES permit specifies the types of monitoring and reporting that each facility is required to provide to CVRWQCB. Wastewater facilities have not been mandated to monitor some of the constituents important to drinking water such as total organic carbon (TOC), dissolved organic carbon (DOC), and bromide. The permits are supposed to be reviewed and updated every 5 years; however, lack of resources at CVRWQCB has resulted in delay of renewal for many permits (Tansey 2000).

Wastewater quality is determined by the type of wastes treated (domestic, industrial, agricultural etc.), the efficiency and degree of treatment (primary, secondary, or tertiary), and season (the type and concentration of some constituents may vary with season). The receiving water flow rate and the permitted wastewater effluent rate dictate available dilution (dilution and mixing ratios) where data are available. Where data are not available at the time the NPDES permit and WDR are adopted, CVRWQCB may require the discharger to collect the data and perform further analyses. The CVRWQCB may modify the permit once new data are available.

Though the effluent may be a source of pathogens such as *Cryptosporidium*, *Giardia,* and coliforms, only the latter have been monitored in the past. Wastewater effluent may contain suspended solids, total dissolved solids (TDS), disinfection byproducts (DBPs) precursors (organic carbon), trace elements, biochemical oxygen demand (BOD), priority pollutants and nutrients that can further impact water quality. Wastewater treatment plants can accidentally release untreated sewage, which can have a negative impact on water quality.

The US Environmental Protection Agency (EPA) Pretreatment Program was designed to reduce the level of pollutants discharged by industries and other nondomestic wastewater sources into municipal sewer systems, thereby reducing the amount of pollutants released into the environment through wastewater. All publicly owned treatment works (POTWs) over 5 mgd are required to implement the pretreatment program. The program aims to protect POTWs from pollutants that may interfere with plant operations, damage the collection system, injure workers or the public. The program also prevents pass-through of pollutants into receiving waters . Contributing industries may be required to pretreat their effluent before discharging into municipal sewer systems. Industries may also utilize other techniques such as recycling and product substitution to reduce their waste streams.

4.2.2.1 Priority Pollutants

Priority pollutants are a group of toxic chemicals that are listed under section 307(a)(1) of the Clean Water Act of 1977. This list was established to provide guidelines for regulating industrial effluent discharge to protect public health. In 1992, EPA promulgated the National Toxics Rule, which established numeric criteria for toxic pollutants to protect aquatic and human health.

Section 303(c)(2)(B) of the Clean Water Act requires states to adopt numeric criteria for those priority toxic pollutants that could reasonably be expected to interfere with the beneficial use of water. In 1991, California's State Water Resources Control Board (SWRCB) adopted the Inland Surface Waters Plan (ISWP) to comply with the Clean Water Act. However, a court ruling rescinded the ISWP in 1994. California then was not in compliance with the Clean Water Act until March 2000 when the SWRCB adopted the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries. This policy implements the California Toxics Rule, promulgated by the EPA in May 2000. The policy will standardize the regulation of toxic pollutants through NPDES permits and WDRs. Priority pollutants from wastewater discharges will be evaluated under the Toxics Rules utilizing pollutant objectives contained in SWRCB Basin Plans. In theory, dischargers are required to submit effluent data including dilution and mixing studies so that contaminants can be evaluated for their "reasonable potential" to impact the receiving waters. In reality, many wastewater treatment plants have not completely collected these data at the time they apply for the permits, and interpretation of the data is site specific.

Priority pollutant evaluation is a complex process. First, the ambient background concentration of influent water is determined. Next, the most stringent receiving water quality criterion or objective is established. Effluent data are then used to determine the maximum allowable pollutant concentration. If the adjusted effluent concentration of the pollutant is greater than the water quality objective of the receiving water, taking into consideration the pollutant's ambient level, then an effluent limitation may be required. Other information taken into consideration are discharge type, solids loading, and available mixing zones for dilution of the effluent.

Although priority pollutant data were available from Sacramento Regional Wastewater Treatment Plant (SRWTP) and Stockton in this sanitary survey update, "reasonable potential" analysis had only been completed by the Regional Board for Stockton Regional Wastewater Control Facility (RWCF).

In general, wastewater treatment plants have the potential to cause contamination from the following:

- Discharges of contaminated effluent due to inadequate treatment;
- Discharge through cracks in wastewater treatment tanks;
- Leaks or releases from wastewater delivery system and infrastructure; and
- Leaching of contaminants from sludge in on-site storage areas.

The most common occurrence at a wastewater treatment plant is the discharge of contaminated effluent. Effluent is typically handled in either of 2 ways: 1) the treated effluent is discharged to surface water and/or groundwater, or 2) the effluent is sprayed on land. Wastewater effluent generated at the end of the treatment process is supposed to be "clean"; however, if the plant encounters any problems in the treatment process, the effluent may contain contaminants, which then enter the receiving surface water, groundwater or soils. Problems that can upset the treatment process include:

- A treatment process breakdown;
- Untreatable contaminants; or
- Excess volume from combined sewer overflows, resulting in treatment bypass.

Subsequently, the contaminated effluent can cause surface water, groundwater, and/or soil contamination. If contaminated effluent enters a surface water body, the following effects could occur:

- Fish kills;
- Harm to human health if the surface water body is used for recreational purposes such as swimming, boating and fishing;
- Contamination of a drinking water supply source; or
- Detriment to agricultural uses.

Accidental discharge of contaminated effluent can be costly for a wastewater plant. In the event that a stream was contaminated by effluent, local residents could sue for bodily injury and also file a property damage suit for loss of stream use under the Clean Water Act. CVRWQCB can levy considerable fines for these discharges.

4.2.2.2 Wastewater Treatment Plants In Sacramento/San Joaquin Watersheds

Wastewater treatment plants in the Sacramento/San Joaquin valleys that discharge 1 million gallons per day (mgd) or more are shown in (Table 4-7). Some facilities with a discharge of 1 mgd or more were not included in the table because they have insignificant impacts on tributaries of the Delta. For example, Fresno, the largest city in the valley, discharges to land and, therefore, has no direct impact into the San Joaquin River. Wastewater flow was evaluated by researching the facilities' files at the Regional Water Quality Control Board, consulting with board staff, and contacting the facilities for additional information. Where available, information on any past and/or ongoing treatment problems and water quality data were obtained. Although NPDES permits are required to be renewed every 5 years, not all facilities have had their permits updated by the regional boards because of insufficient personnel resources (Tansey 2000). Table 4-7 is broken down into the San Joaquin and Sacramento watersheds.

The dry weather flows in the Sacramento watershed were estimated at 223.5 mgd. SRWTP contributed about 74% of this flow. The cumulative dry weather flows for the facilities in San Joaquin watershed were estimated as 105.1 mgd. The bulk of this was from Modesto (18%) and Stockton (25%). Approximate locations of these facilities are shown in Figure 4-10**.**

SRWTP and Stockton RWCF were selected as surrogates of the industry and are presented in more detail due to their significant impacts in their respective watersheds. Also described are a number of other wastewater treatment plants that have a likelihood of affecting water quality in the SWP because of their location in the south Delta. Special focus was directed to geographical areas that are close to SWP pumps and that have a projected high population growth in the future such as the cities of Tracy, Mountain House, and Lathrop (Figure 4-11).

Table 4-7 Major Wastewater Treatment Facilities Discharging into the Sacramento and San Joaquin Rivers

Facility Name	Design flow	Average dry weather flow (mgd[a])	Comments
	Sacramento Watershed		
Beale AFB	5.0	0.7	
Chico WWTF	9.0	6.0	
City of Anderson	2.0	1.4	
City of Davis	5.3	4.5	
Olivehurst PUD	1.8	1.2	
Oroville SCOR	6.5	3.0	
Red Bluff	2.5	1.3	
Redding Clear Creek WWTP	8.8	7.5	
Redding Stillwater WTP	4.0	2.7	
Roseville WWTP	18.0	12.5	
Sacramento Regional	181.0	165.0	
City of Sacramento combined wastewater collection system			Potential 130 mgd wet weather CSS[b] over flow
University of California Davis	2.5	1.6	
Vacaville Gibson Canyon Creek	1.4	0.3	
Vacaville Easterly	10.0	7.4	
West Sacramento	18.0	7.0	
Total Average Dry Weather Flow for Basin		223.5	
	San Joaquin Watershed		
Atwater WWTF	6	3	
Brentwood	2.2	5	
Discovery Bay	1.3	1.1	
EID Deer Creek	2.5	2.3	
Galt	3.0	1.5	
Lodi	6.2	5.9	Annual average
Manteca	7.0	5.3	Annual average
Merced WWTF	10.0	7.4	
Modesto WWTP	56.7	25	Annual average
Mountain House	5.4	2.8	
Stockton Main	40.0	29.8	
Tracy Sewage TP	9.0	5.9	
Turlock WWTP	20.0	10.1	
Total Average Dry Weather Flow for Basin		105.1	

[a] MGD= million gallons per day

[b] CSS= Combined sewer service

Figure 4-10 Wastewater Treatment Plants in the Sacramento-San Joaquin Delta and Tributaries

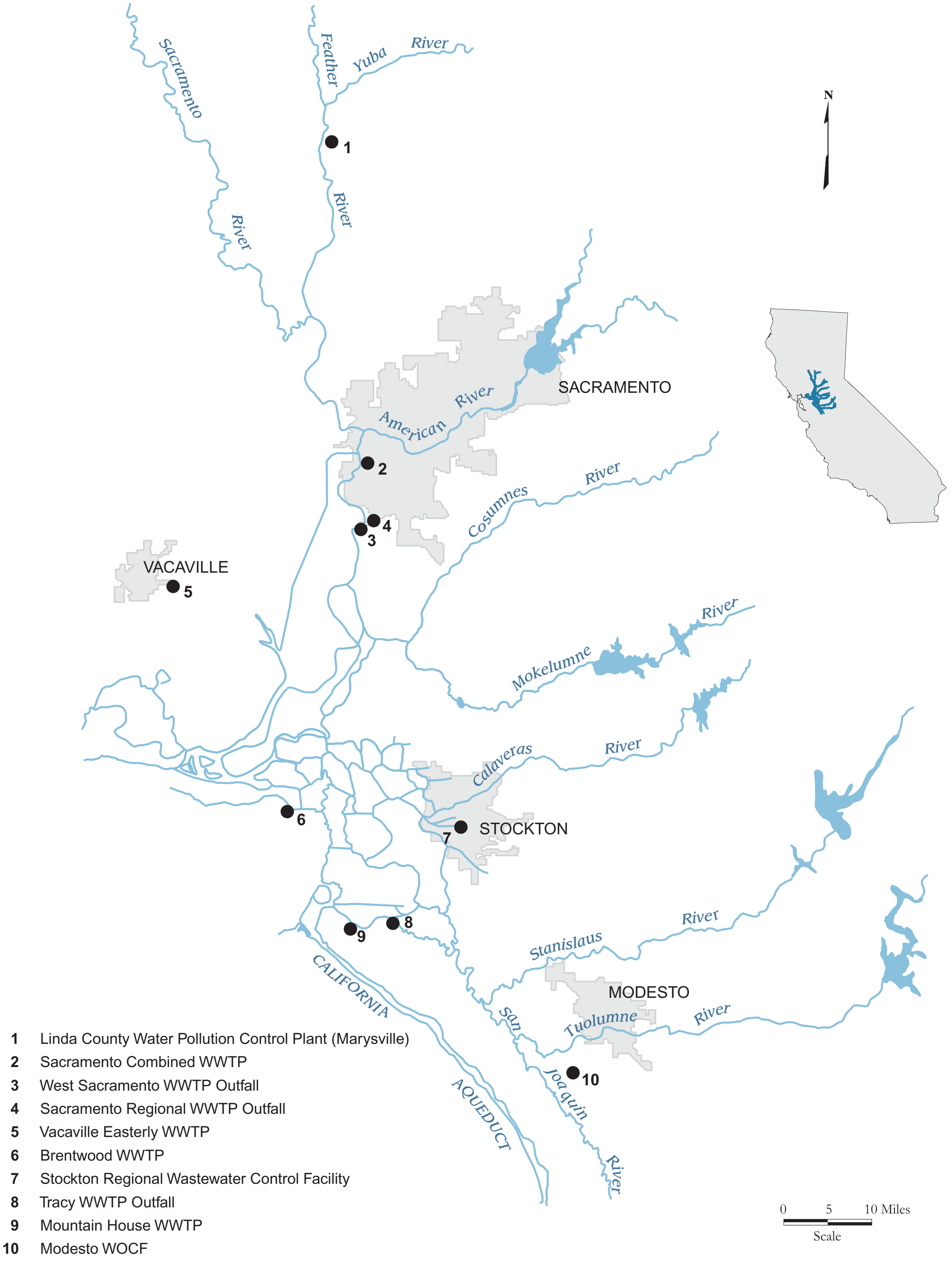
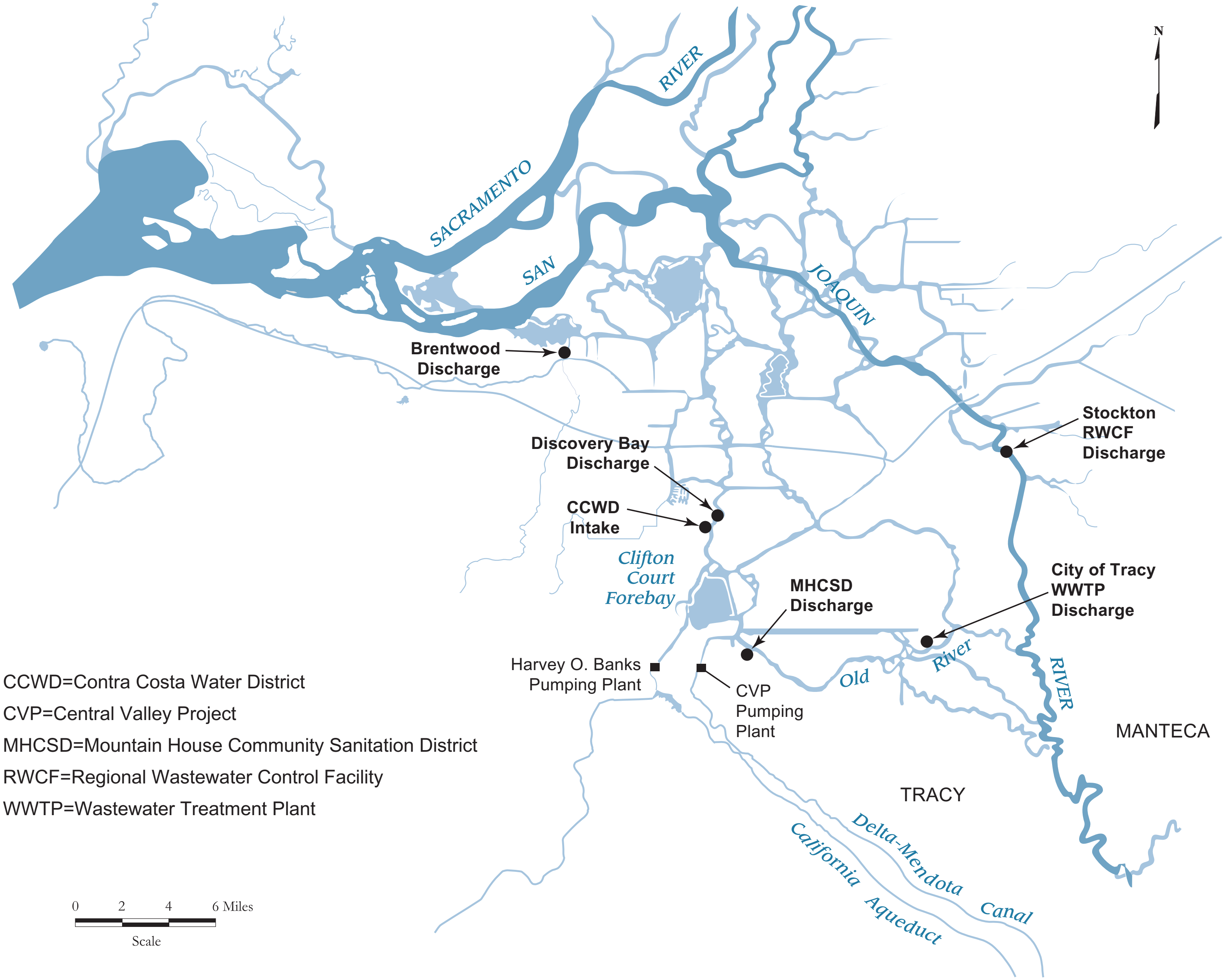


Figure 4-11 Wastewater Treatment Plant Discharge in the South Delta



CCWD=Contra Costa Water District

CVP=Central Valley Project

MHCSD=Mountain House Community Sanitation District

RWCF=Regional Wastewater Control Facility

WWTP=Wastewater Treatment Plant

Sacramento

SRWTP is operated by the Sacramento Regional County Sanitation District (SRCSD) and is the largest facility in the Delta watershed. SRCSD provides wastewater treatment for several agencies including the County Sanitation District 1 (CSD-1) serving most of the unincorporated areas in Sacramento County, the city of Sacramento, the city of Folsom and the city of Citrus Heights. SRWTP occupies 900 acres off Franklin Boulevard in Elk Grove and serves about 1 million people (SRWTP 2000). The facility owns an additional 2,500 acres of surrounding land which act as buffer to nearby residential areas (SRWTP 2000). Some of the buffer lands are part of the Stone Lakes National Wildlife Refuge. An updated NPDES permit (No. CA0077682) and a WDR (Order No. 5-00-188) were revised and adopted by the CVRWQCB on 4 August 2000. The new permits still do not provide effluent limitations or monitoring for *Giardia*, *Cryptosporidium*, or TOC.

The SRCSD sewer system contains about 2,455 miles of sewer mains within a service area of 229 square miles (SRWPT 2000). The system serves the urbanized unincorporated areas of Sacramento County, the cities of Sacramento, Citrus Heights, Elk Grove, and the city of Folsom. Each agency is responsible for maintaining its own sewer collection system. The SRWTP dry weather flow is 165 mgd and can increase to 400 mgd during wet weather. The facility provides primary and secondary treatment before discharging into the Sacramento River. It has an oxygen generation plant that can produce about 200 tons per day for use in the activated sludge process that produce about 30,000 tons of biosolids per year. The biosolids are treated in solids-storage basins for up to 5 years and then injected into the ground. SRWTP operated a landfill for disposing of biosolids until it was closed in 1994. SRWTP is building a water reclamation plant with a 5 mgd capacity and will market the reclaimed water for nonpotable uses such as landscape irrigation by neighboring landowners (SRWTP NPDES Permit).

The city of Sacramento operates a combined sewer system (CSS) which carries both sewage and storm water runoff. Most of downtown, east Sacramento and Land Park are served by a combined sanitary sewage and storm water pipeline. The combined sewer service area is approximately 7,500 acres. An additional 3,600 acres of the city contribute only sanitary sewage (Archibald & Wallberg and others 1995). The CSS is old, and in most areas it is in need of rehabilitation (CVRWQCB NPDES Permit). Overflows have occurred over the years when rainfall events exceed the carrying capacity of the system. Both the combined sewer overflow structure and the discharge from the structure are referred to as combined sewer outflows (CSOs). The EPA has proposed a rule to require sewer collection systems to have their own NPDES permits. If this rule is implemented, the cities of Folsom and Citrus Heights will be required to obtain NPDES permits. The proposed regulation will also require municipal sanitary sewer collection infrastructure systems (the pipes, sumps, etc.) to control accidental discharges. These discharges occur due to deteriorating, improperly maintained, or undersized sewers. SWRCB has initiated a project to investigate the extent of this problem in the state and to work with stakeholders to develop workable regulations (Gonzales pers. comm. 2000).

The Sacramento CSS conveys sewage to Sump 2 at the Combined Wastewater Treatment Plant (CWTP) near 37th Street and operated by the city. The CWTP has 2 storage basins at 42nd Street and R Street near the UC Medical Center. The city has contracted with the SRCSD for SRWTP to treat the first 60 mgd from the CSS. When flow exceeds 60 mgd, the city operates the CWTP to treat the next 130 mgd, which receive primary treatment and disinfection before being discharged into the river. If flows exceed 190 mgd, the next 28 mgd are pumped into Pioneer Interceptor and Reservoir. Pioneer Reservoir consists of 3 chambers connected in a serpentine configuration. The reservoir utilizes a slow flow-through process to remove floating solids. In previous years during wet weather, the CWTP would discharge any additional flows directly into the Sacramento River without any treatment. In the last year or so, operational changes, including a 90-inch inline storage, have been added such that, according to the plant operator, no untreated waste is likely to be discharged unless flows exceed 540 mgd (Batha pers. comm. 2000). The wastewater through Pioneer is now being chlorinated and dechlorinated before being discharged. There were only 2 instances where the CSS discharged directly into the river between 1996 and 1999. These instances were February 1996 (13.5 million gallons) and January 1997 (226.75 million gallons).

SRWTP must expand in the future to accommodate anticipated population growth in its service area. Starting 1997, SRCSD retained a contractor to prepare a 2020 Wastewater Master Plan. The master plan update is still in progress with input from stakeholders to address changes in population served, new treatment technologies, future regulations, projected facility financial needs, etc. A summary of the alternative scenarios was prepared and presented to the SRCSD Board of Directors on 26 July 2000. The SRWTP is also negotiating with the city of West Sacramento to connect that city's wastewater system to SRCSD's proposed 17.7-mile pipeline from the Natomas area through West Sacramento to the SRWTP.

As part of the 2020 Master Plan studies, SRCSD has performed modeling analyses of the SRWTP's effluent impact on the water quality at Clifton Court Forebay under different scenarios. Seven scenarios were evaluated:

- Base Case: Existing SRWTP treatment level
- Base Case + water conservation + source control
- Base Case + water conservation + source control + chlorine enhanced primary treatment
- Base Case + water conservation + source control + filtration
- Base Case + water conservation + source control + filtration + reuse
- Base Case + water conservation + source control + filtration + reverse osmosis
- Base Case + water conservation + source control + filtration + nonstructural (waste minimization, source controls, water conservation)

The simulated fraction of water at Clifton Court Forebay originating from SRWTP ranged from about 0.5% (baseline conditions) to 1.5% under the different scenarios (SRWTP 2000).

Another impact on water quality in Sacramento River may originate from population growth in south Placer County. Currently, Roseville's Dry Creek Wastewater Treatment Plant (WWTP) treats about 12.5 mgd from the cities of Roseville, Granite Bay, Rocklin, Loomis and Sunset Industrial Area and discharges into Dry Creek, a tributary of Natomas East Main Drain that discharges to the Sacramento River. According to the SWRCB database, the plant had some chlorine violations in its effluent in 1999; residual chlorine can negatively impact aquatic life. To accommodate anticipated growth, the city of Roseville has started construction of the new 12 mgd Pleasant Grove WWTP to be completed by 2003. The impact of this new plant on water quality in the Sacramento River is unknown but will probably be minimal.

Stockton Regional Wastewater Control Facility (RWCF)

The original Stockton RWCF was constructed in 1922. Since then, the facility has been upgraded several times to keep pace with growth in the area and currently has a dry weather flow of about 40 mgd. The area serviced has a population of 300,000, and the waste stream includes both residential and industrial sources. The Stockton facility has approximately 630 acres of oxidation ponds, which provide secondary treatment. RWCF accepts wastewater from about 40 industrial users accounting for about 5.3 mgd or 16% of the average flow (CVRWQCB Draft Fact Sheet). Historically, the facility has had problems with ammonia in its effluent. A tertiary facility with a capacity of 55 mgd was constructed in 1978 to augment secondary treatment during the canning season. It has been estimated that Stockton RWCF's effluent can contribute significant volume to San Joaquin River flows at Stockton during some periods of the year (Lee and Jones-Lee 2000a). Flows near Rough and Ready Island have been estimated by the US Geological Survey (USGS) utilizing ultrasound velocity meters (UVMs). The river near Stockton is tidally influenced, and flow is problematic to measure. The Stockton RWCF effluent to San Joaquin River ratios were especially high in fall 1999. The effluent is a significant source of the oxygen demand in the Stockton Deep Ship Channel (Lee and Jones-Lee 2000a).

Stockton RWCF operates according to the seasonal water quality fluctuations of its influent. In general, the facility performs primary, secondary and tertiary treatment. Canneries are the major wastewater contributors during summer and fall, which are the periods of maximum effluent flow from the facility. During the peak algal period between July and October, the facility's dissolved air filtration and mixed media filtration operate at full capacity to ensure that the plant does not exceed its total suspended solids (TSS) effluent limitations. In September 2000, the SWRCB approved a $9.68 million grant from Proposition 13 money toward the staged expansion of the secondary facility.

San Joaquin River in the vicinity of the Stockton RWCF continues to experience low oxygen levels that violate the SWRCB Salinity Plan. It is estimated that Stockton RWCF contributes 43% of the oxygen demand during San Joaquin River low flows (NPDES Permit). The regional board has proposed tightening the effluent dissolved oxygen (DO) limitations in the future. DHS has also been concerned about viral infection from water-contact recreation owing to inadequate dilution ratios during periods when San Joaquin River discharge is low (NPDES Permit).

4.2.2.3 Population Growth and Wastewater Impacts in the South Delta

As with many areas in the Central Valley, the south Delta is experiencing rapid population growth (Table 4-8), and this growth may have a significant impact on water quality because of its proximity to SWP and CVP intake pumps. The following are some of the fast growing areas and their projected wastewater discharges that may impact the SWP.

Table 4-8 Population Estimates for Cities in the Stockton Area

Urban Area	Est. Pop. (2000)	Projected Pop. (2020)	Percent Increase
Lathrop	9, 974	20, 627	103
Manteca	49, 306	77, 699	58
Stockton	250, 576	369, 070	47
Tracy	51, 631	117, 788	114

Accessed on the web 25 Oct 2000 :
http://www.sjcog.org/RFC/pop.htm

City of Tracy

The City of Tracy is in San Joaquin County at the intersection of Interstates 5, 205 and 580. The Tracy Planning Area (TPA) consists of land within the city boundaries plus unincorporated areas in the county that the city has determined to be within its influence. There are about 14,117 acres within the city and 58,453 acres in the county (Pacific Municipal Consultants 1997). The TPA is one of the fastest growing areas in the state with the population of 41,405 in 1990 projected to grow to 117, 788 in 2020. A lot of this development is occurring in the southwest part of the TPA. Some of the larger projects are Tracy Hills Specific Plan, South Schulte Planning Area and some portions of North Schulte Planning Area. The California Aqueduct crosses the TPA at the northeast corner. The DMC parallels the aqueduct in the same area.

The current Tracy WWTP has a collection system that segregates domestic and industrial wastewater. The 2 wastewater streams receive separate primary treatment, are combined for secondary treatment, and then discharged into Old River (Pacific Municipal Consultants 1997). The WWTP has a design capacity of 9.0 mgd, and there are plans to expand it to 12.2 mgd. The wastewater discharge may amount to 1% of the San Joaquin River during low flows. The facility has an emergency storage pond and 5 storage ponds. The TPA is projected to generate more wastewater than the current WWTP can handle. The TPA has, therefore, proposed to construct a wastewater reclamation facility (WRF) that will treat the excess amount and use land disposal of effluent. The plant will be built over 30 to 40 years and ultimately have a capacity of 5.2 mgd. Disposal on land may still have an indirect impact on Old River from storm water runoff from the disposal area.

In 1994, the City of Tracy updated its storm water management with the Storm Drainage Master Plan. The plan is a series of 5 drainage systems delineated by topography and outfall points. The 5 systems are Westside Channel System, the Eastside Channel System, Lammers System, I-205 Specific Plan system and the Banta Area System. Some of the storm water will be disposed by percolation into the ground, and some, like the Westside Channel System, will drain into Old River. According to the draft environmental impact report (EIR), the storm water will not adversely affect water quality in Old River (Pacific Municipal Consultants 1997).

Mountain House New Community

Mountain House is a new 4,700-acre development, which is proposed in San Joaquin County between Highway 205 and Old River. It is about 3 miles west of Tracy. The developer has proposed 6 neighborhoods. When completed, the community will have approximately 45,000 residents and will require a wastewater treatment plant with an average flow of 5.4 mgd occupying 30 acres. The facility will discharge tertiary treated effluent into Old River about 2 miles upstream of Clifton Court Forebay (NPDES No. CA 0084271). The CVRWQCB has stipulated that the combined flow from Tracy and Mountain House cannot exceed 5% of Old River flows; however, the project poses a potential threat to drinking water quality because of its proximity to the SWP intake pumps.

There has been concern from various stakeholders about the Mountain House wastewater discharge impacts on water quality in Old River. The developer has applied for a 3-phase wastewater treatment plant. California Urban Water Agencies (CUWA) and DWR commented on the draft EIR and recommended a more rigorous monitoring program to ensure water quality is protected. These recommendations were not adopted by SWRCB. The 1st permit has been tentatively issued by the CVRWQCB (NPDES order No. 98-192). This 1st permit allows a treatment plant with a 0.5 mgd capacity. The wastewater will get secondary treatment using an aerated lagoon-pond system and then will be used to irrigate animal feed crops. The plant will operate during the initial phase of the development, estimated at 1,400 dwelling units, which was approved in early 2000. The 2nd permit (not yet approved) will allow winter discharge into the San Joaquin River and land disposal the rest of the time. The 3rd permit will be for tertiary treatment with some or all the effluent being discharged into Old River. The wastewater facility is forecast to generate about 5,150 tons of solid waste per year in phase 1; about 70% of this waste will be disposed at Foothill Landfill in eastern San Joaquin County.

Cities of Lathrop and Manteca

Manteca and Lathrop share some of their wastewater treatment facilities. The city of Lathrop is growing rapidly and will need to upgrade its wastewater treatment plants in the future. Some of the city's wastewater is treated at Manteca's Wastewater Quality Control Facility (WQCF) where Lathrop has an allocation of 1.02 mgd. Manteca has 2 WQCF. One is in design stage to increase its capacity to 9.87 mgd. The Manteca WQCF discharges into the San Joaquin River. It has frequently discharged elevated levels of ammonia above its WDRs and is under cease and desist orders from the CVRWQCB.

Lathrop's own current discharge from its wastewater plant is only 0.6 mgd. The anticipated population growth will increase wastewater discharge to about 9.3 mgd. About 5 mgd will be discharged into the San Joaquin River only during August through May (Lathrop 2000). It is not clear whether the regional board will issue the permit because the CVRWQCB is not issuing any new permits to discharge into the river until a total maximum daily loading (TMDL) study of the river is completed.

The main Manteca WQCF provides secondary treatment for the city and portions of Lathrop. Some of the effluent receives primary treatment and then is used to irrigate 360 acres. In 1998/1999 the facility had problems with ammonia exceeding toxicity limits in its permit, and the regional board issued cease and desist orders. The city has proposed expanding the current capacity by 2.92 mgd to an average daily flow of 9.87 mgd. The plant will discharge to land during spring and summer and into the San Joaquin River in winter. Manteca's Crosslands WWTP is a smaller facility with a build-out capacity of 0.60 mgd. According to SWRCB database, the plant had some acute aquatic toxicity problems in 1999.

City of Brentwood

The city of Brentwood in eastern Contra Costa County has a wastewater treatment plant that serves about 11,500 households. The current capacity has an annual dry weather flow of 2.2 mgd and discharges into infiltration ponds. An extraction system then collects a portion of the infiltrated secondary effluent and discharges the water into Marsh Creek which is a tributary of the San Joaquin River (Brentwood 1998). The volume of this discharge into the San Joaquin River is unknown. According to SWRCB database, the plant had BOD violations in 1999.

The city has proposed constructing new treatment facilities that will increase the capacity by 10 mgd. Disposal will still be on Jersey Island land. It does not appear that the planned expansion will have a major impact on the San Joaquin River; however, runoff could still enter the river.

Discovery Bay

Discovery Bay is another rapidly growing urban area. The wastewater treatment plant's capacity is only 0.88 mgd per day; wastewater is discharged into a reclamation canal and then pumped into the Old River. According to SWRCB, the plant has had numerous problems with copper, and the regional board has issued a number of cease and desist orders. The plant was still out of compliance in early 2000.

4.2.3 URBAN RUNOFF

Major pollutants found in runoff from urban areas include sediment, nutrients, oxygen-consuming substances, road salts, heavy metals, petroleum hydrocarbons, and pathogens. Suspended sediments constitute the largest mass of pollutant loading from urban areas to receiving waters. Construction is a major source of sediment erosion. Petroleum hydrocarbons result mostly from automobile sources. Nutrient and bacterial sources include garden fertilizers, leaves, grass clippings, pet wastes, and sanitary sewer overflows. As population densities increase, a corresponding increase in pollutant loading generated from human activities follows. Many of these pollutants enter surface waters via runoff without undergoing treatment. However, in some cases drainage areas may have detention basins, where the runoff collects and contaminants may absorb onto particulate matter and settle before discharge (SWRCB 1998).

Urban runoff occurs year round. Storm water runoff results from seasonal storms, while dry weather runoff occurs from a number of outdoor water uses such as irrigation. Storm water is conveyed through gutters, then to drains and sumps, which discharge to a receiving water body. According to Larry Walker Associates, in the Sacramento area over the course of a year, about an equal volume of dry weather and storm runoff is discharged to the river (Archibald & Wallberg and others 1995). During any storm event, the highest concentrations of pollutants are observed in the 1st few hours of the storm. As the storm continues, pollutants become washed away or diluted. Another phenomenon associated with storm water monitoring is the “1st flush” effect. In the absence of rainfall, pollutants build up in the urban environment. When the 1st storm of the season occurs, these built-up pollutants are washed into storm drains or creeks resulting in a spike in pollutant concentrations in receiving waters. A similar phenomenon may occur in the winter rainy season if the period between storm events is of a long enough duration. Because of the large impermeable areas often associated with urban areas, storm water runoff volumes are greater than in natural or agricultural areas where soil infiltration of rainfall is higher. In addition, a narrower range of contaminants are often observed from dry weather runoff than from wet weather runoff.

The 1972 amendments to the federal Clean Water Act prohibit the discharge of any pollutant from a point source into waters of the United States, unless permitted under the National Pollutant Discharge Elimination System (NPDES). Storm water and urban runoff discharges that occur through discreet conveyance systems are considered point sources subject to NPDES requirements. In 1987, Congress enacted a 2-phased program under the Clean Water Act. Its 1987 amendments mandated the EPA to publish regulations establishing permit requirements for storm water discharges associated with industrial activities, and large and medium municipal storm sewer systems. In the early 1980s, the EPA conducted an intensive Nationwide Urban Runoff Program (NURP) monitoring 28 urban areas. The NURP study led to the formulation of the EPA runoff regulations implemented in the 1990s under the NPDES program.

In California, the SWRCB and 9 RWQCBs administer the NPDES storm water permit program. The 1st phase of the NPDES regulations requires storm water permits for municipal separate storm sewer systems serving populations of 100,000 or more and for certain construction and industrial activities. Implementation of the 2nd phase is scheduled for March 2003. The 2nd phase will include regulation of smaller population centers.

As part of the permit requirements, all permittees must submit to the regional board a Storm Water Management Program that outlines how the permittees will assess the effectiveness of their storm water program in reducing pollutants in storm water discharges to the maximum extent practicable. The control of urban nonpoint source pollution focuses on the prevention of pollutant loadings through Best Management Practices (BMPs). Monitoring programs are used to characterize storm water runoff and help evaluate the effectiveness of BMP control measures.

The CVRWQCB requires storm water permits within the Delta and the Central Valley from the following agencies: the county of Sacramento and its associated co-permittees, Contra Costa County and its associated permittees, the city of Stockton and its co-permitee, the Port of Stockton, and the city of Modesto. Sacramento and Stockton storm water programs were examined in detail. Storm water quality was not examined for the city of Modesto based on the distance between the city and the Banks Pumping Plant. Contra Costa County storm water data was also not examined (Brown and Caldwell and others 1995). Table 4-9 lists the permit holders, the NPDES Storm Water Permit Number, the date of the most recently issued storm water permit, and its expiration date. Storm water permits are renewed every 5 years. Storm water permits for both the Sacramento and Stockton storm water programs are currently in the review and/or renewal processes. When Sacramento’s permit is renewed, the cities of Citrus Heights and Elk Grove will be included as co-permittees.

Table 4-9 Municipalities Covered by NPDES Storm Water Permits in the Delta Region

Entity	Permittees Listed on Permit	Permit Number	Date of Approval	Renewal Date
Contra Costa County (CCC) Clean Water Program	Portions of CCC	CA 0083313	Jun 1998	Jun 2000
	City of Antioch			
	City of Brentwood			
	City of Oakley			
	CCC Flood Control District			
Sacramento Stormwater Program	County of Sacramento	CA 0082597	May 1996	May 2001
	City of Sacramento			
	City of Folsom			
	City of Galt			
Stockton Stormwater Program	City of Stockton	CA 0083470	Feb 1995	Jul 2001
	County of San Joaquin			
Port of Stockton Stormwater Program	None	CA0084077	Feb 1997	Feb 2002

In addition to a separate storm drain system, the city of Sacramento's Combined Sewer Collection System conveys both sanitary sewage and storm water in the same pipeline and encompasses approximately 9,900 acres in the downtown and nearby areas (Sacramento Utilities Department 1995). Discharge from this facility is regulated under a POTW NPDES permit. The combined sewer collection system is discussed in more detail in Section 4.2.2.2.

4.2.3.1 Projected Urban Growth

A very substantial level of urban growth and expansion is anticipated in the Delta region over the next 20 years. This growth increase will result in more urban runoff impacting receiving waters. Between 1998 and 1999, both Sacramento and San Joaquin counties were ranked among the top 10 counties for population growth in California. In 1998 to 1999, Placer County, a portion of which contributes urban runoff to the Sacramento River via the Natomas East Main Drainage Canal (NEMDC), was 1 of 2 counties posting the state's highest growth rate (DOF 2000).

Tables 4-10 and 4-11 show the projected population increases expected between the year 2000 and 2020 for most of the urban areas covered by the Sacramento and Stockton Storm Water Management Program. Between the year 2000 and 2020, the city of Sacramento's population is projected to increase by 26% from 404,701 people in 2000 to 511,000 in 2020, while the population of the city of Elk Grove, which will become a co-permittee when the Sacramento permit is renewed, is projected to increase by more than 100% (SACOG 2000; Butler pers. comm. 2000). In the southern Delta, the city of Stockton is projected to increase from 250,576 people in 2000 to 369,070 people in 2020, an increase of nearly 50% (SJCOG 2000). Outside the city of Stockton, some of the most dramatic growth in the southern Delta is occurring in the cities of Lathrop and Tracy; populations in both cities will increase more than 100%. Storm water discharge from the city of Tracy will find its way to the San Joaquin River via the Old River. Storm water effluent from Lathrop will likely be discharged directly to the San Joaquin.

Table 4-10 Population Estimates for Cities in the Sacramento Area

Urban Area	Current Estimated Pop. (2000)	Projected Pop. (2020)	Percent Increase
Citrus Heights	88,201	92,949	5
Elk Grove	72,600	158,710	109
Galt	19,000	31,450	66
Folsom	50,884	76,333	50
Loomis	6,106	10,304	69
Rocklin	32,297	64,002	98
Roseville	79,102	106,806	35
Sacramento	404,701	511,000	26
Sacramento County	1,203,899	1,620,931	35

Sources: Sacramento Area Council of Governments; Elk Grove Chamber of Commerce, pers. comm Deborah Butler, 10 Oct 2000

Table 4-11 Population Estimates for the Stockton Area

Urban Area	Current Estimated Pop. (2000)	Projected Pop. (2020)	Percent Increase
Lathrop	9,974	20,627	103
Manteca	49,306	77,699	58
San Joaquin County	564,539	821,835	46
Stockton	250,576	369,070	47
Tracy	51,631	117,788	114

Source: San Joaquin Council of Governments, http://www.sjcog.org/RFC/pop.htm; Accessed 25 Oct 2000

Within the Sacramento area, there are 4 major drainage systems that convey urban runoff to the Sacramento River: the American River, the NEMDC, the Natomas Main Drain (composed of east and west branches), and Morrison Creek (Figure 4-12). The American River forms a convenient north-south dividing line for the Sacramento urban area with the northern Sacramento urban area draining into the American River, NEMDC, and Natomas Main Drain, while the southern area drains into the American River and Morrison Creek. Contour maps were used to estimate the approximate drainage paths for several urban centers within the Sacramento urban area (Table 4-12). No maps are available from the city and county of Sacramento that delineate drainage areas within different community boundaries. The approximate number of sumps and detention basins are not readily available, but the county of Sacramento estimated that the county is responsible for about 30 pump stations and 15 catchment basins (Gaines pers. comm. 2000).

Figure 4-12 Sacramento Urban Runoff Areas

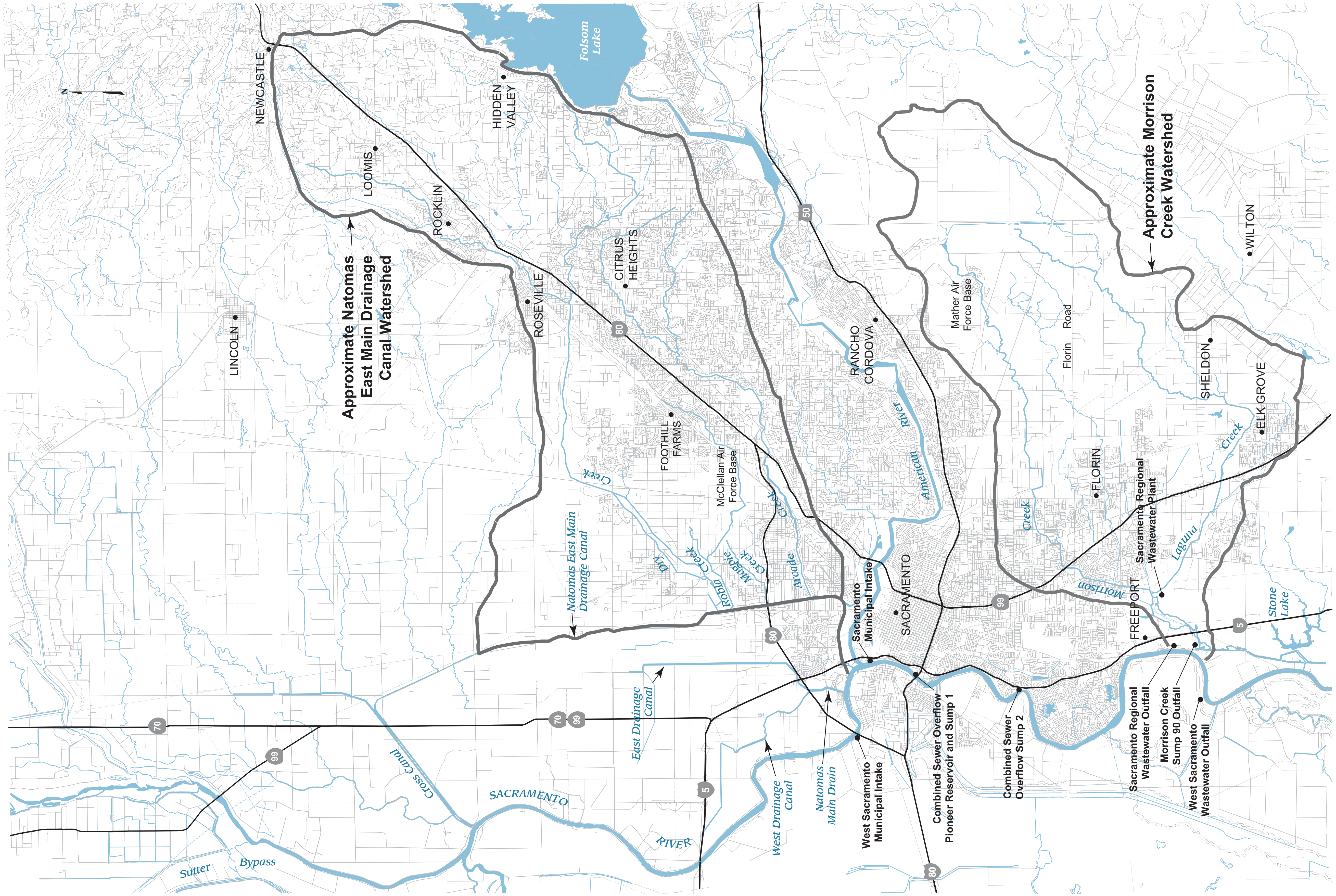


Table 4-12 Approximate Urban Drainage Sources to the Sacramento/San Joaquin River in the Sacramento Urban Area

Main Urban Drainage	Urban Area	Tributary Drainage to Main Urban Drainage
NEMDC	Citrus Heights	Tributaries to Arcade Creek
	Loomis	Tributaries to Dry Creek
	McClellan AFB	Tributaries to Robla (Linda) Creek
	Newcastle	Tributaries to Dry Creek
	North Highlands	Tributaries to Dry Creek and Robla (Linda) Creek
	Rio Linda	Tributaries to Dry Creek
	Rocklin	Tributaries to Dry Creek
	Roseville	Tributaries to Dry Creek
	Sacramento	Lower Magpie Creek
Natomas Main Drainage Canal	Natomas Commercial/Residential Development & Agriculture	Drainages to East or West branch of Main Drainage Canal
American River	Carmichael	Minor tributaries to American River
	Fair Oaks	Minor tributaries to American River
	Folsom	Lake Natomas to American River
	Orangevale	Lake Natomas to American River
	Rancho Cordova	Minor tributaries to American River
	Rosemont	Minor tributaries to American River
	Sacramento	Minor tributaries to American River
Morrison Creek	Elk Grove	Laguna Creek tributary to Morrison Creek
	Florin	Tributaries to Morrison Creek
	Mather AFB	Discharges directly to Morrison Creek
	Sacramento	Tributaries to Morrison Creek
San Joaquin River	Galt	Dry Crk tributary to the Consumnes River, tributary to the Mokelumne, tributary to the San Joaquin River

Contour maps were also used to calculate approximate drainage areas. In the northern Sacramento area, the drainage area discharging into NEMDC encompasses approximately 180 square miles. Creeks discharging directly into NEMDC include Arcade, Robla, and Dry Creek. NEMDC also receives runoff via Robla Creek from the McClellan Air Force Base. In addition to urban runoff, the canal receives agricultural runoff from the northwestern part of the county. At times of high flow, the east branch of the Natomas Main Drain is also pumped into the NEMDC. Of the drainage areas in the Sacramento urban area, the Natomas Main Drain receives the largest percentage of agricultural drainage, primarily from rice. As the Natomas area develops, it is likely that it will convey a higher percentage of urban runoff to the Sacramento River. The approximate drainage area for the Natomas Main Drain was not estimated because it was not known what geologic feature served as its northernmost hydrologic boundary.

In the southern area, the drainage area discharging into Morrison Creek encompasses approximately 125 square miles. Below the American River, in the southern urban area of Sacramento, Morrison Creek receives urban runoff from several tributary streams. Mather Air Force Base discharges directly to Morrison Creek. Contour lines could not be used to approximate the urban drainage area for the American River because contour lines were not resolvable in urban areas; however, Archibald & Wallberg and others (1995) estimated the acreage drained by the lower American River at 45,940 acres.

In less than a 20-mile stretch of river, these 4 drainage systems discharge to the Sacramento River (Figure 4-12). The NEMDC discharges into the Sacramento River immediately above the confluence of the American and Sacramento rivers. The Natomas Main Drain discharges into the Sacramento River downstream of the city of West Sacramento's Drinking Water Intake but upstream of NEMDC's discharge into the Sacramento River. Morrison Creek discharges into the Sacramento River approximately 1 mile below the Sacramento Regional Water Treatment Plant's discharge at Freeport and approximately 2.5 miles above the city of West Sacramento outfall.

In the Stockton area, several drainage systems convey urban runoff to the San Joaquin River. In the northern Stockton urban area, Disappointment Slough, Fourteen Mile Slough, and the Calaveras River receive urban discharge. In the southern Stockton urban area, French Camp Slough, Mormon Slough, and runoff from Rough and Ready Island discharge to the surrounding channels and the San Joaquin River (Figure 4-13). Actual drainage areas were not calculated because of the difficulty of resolving contour lines within Stockton's urban areas. However, contour maps were used to estimate drainage paths for the few urban centers within the Stockton urban area (Table 4-13). The Stockton NPDES permit noted that 63 major outfalls were identified for the City of Stockton (CVRWQCB 1995). At the time of issuance, outfalls within the urbanized area of the county had not been counted.

Figure 4-13 Stockton Urban Runoff Areas

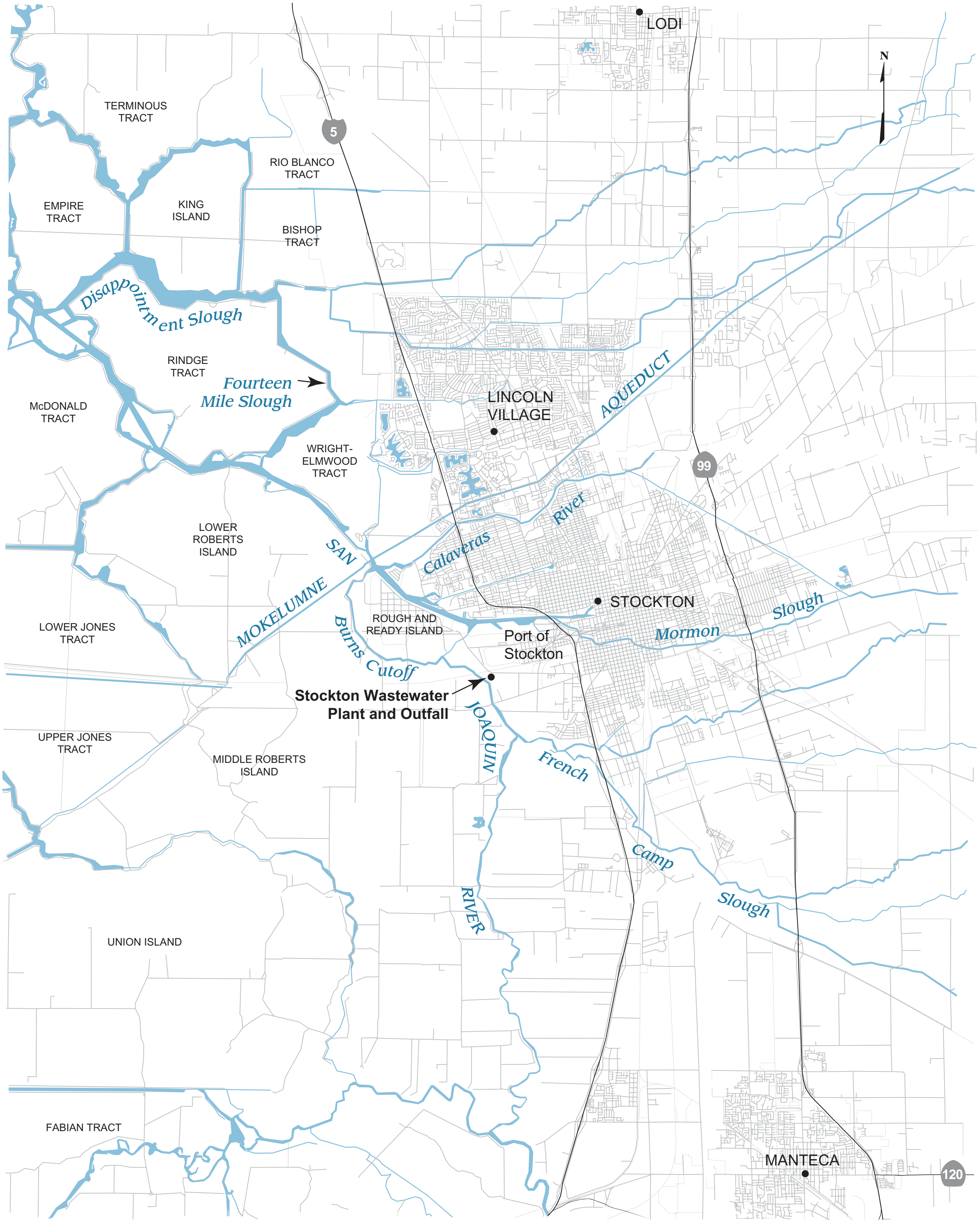


Table 4-13 Major Urban Drainage Sources to the San Joaquin River in the Stockton Urban Area

Main Urban Drainage	Urban Area	Tributary Drainage
San Joaquin River	Northern Stockton and Lincoln Village	Fourteen Mile Slough
		Disappointment Slough
		Calaveras River
	Rough and Ready Island	Channels surrounding R&R Island
	Central and Southern Stockton	French Camp Slough
		Morman Slough

Urban runoff from the Port of Stockton is discharged directly to the port's channel. Urban runoff from the city of Stockton can occur from roads, and there is the potential for accidental intermittent discharges from the city's wastewater treatment plant (Jahangiri pers. comm. 2000).

4.2.4 LIVESTOCK GRAZING

In the Sacramento River Region, irrigated pasture and orchards account for approximately 20% of water use in the region (CALFED 2000d). Land use in the San Joaquin River Region is predominantly grazing and open space in the mountain and foothill areas (CALFED 2000d).

Livestock grazing can impact drinking water quality in several ways. Fecal matter can contaminate waterways with bacteria, *Cryptosporidium*, *Giardia*, and other pathogens. Grazing removes protective vegetative cover and can compact the soil, processes that can lead to high surface runoff, polluting waters with sediment, nutrients, pathogens, and organic carbon. Livestock standing in streams or grazing along the bank result in higher erosion; turbidity increases the likelihood that pathogenic organisms and organic carbon will enter the water body.

Information from the US Department of Agriculture's National Agricultural Statistics Service was used to determine changes in the number of acres grazed and the number of livestock found in the 5 counties encompassed by the legal Delta (USDA 1997). The census of agriculture is conducted every 5 years; the most recent year available was 1997. The census includes the entire county while only part of the county may be included within the legal boundaries of the Delta (for example, Alameda and Contra Costa counties). It is also unknown how many herds of livestock are in locations that could directly impact drinking water supplies.

In most cases, the number of acres within the 5 county area devoted to pasture and grazing declined slightly or remained relatively constant (Table 4-14). The one exception was Solano County where acreage grazed nearly doubled between 1992 and 1995. Of the 5 counties, San Joaquin County had the most acreage devoted to pasture and grazing. With the exception of San Joaquin and Solano counties, livestock numbers also declined slightly or remained relatively constant. In the case of San Joaquin County, all livestock, excluding sheep and lambs, showed steady increases in numbers with each 5-year census. Large gains in the number of cattle and calves in Solano County were also observed; however, all other listed livestock in this county showed a pattern of decline with each census. The greatest numbers of cattle, calves, and beef cows were found in San Joaquin County. The greatest numbers of sheep and lambs were found in Solano County.

Table 4-14 Inventory of Livestock Grazed in Counties Encompassed within the Boundaries of the Legal Delta[a]

County	1987	1992	1997
Alameda			
Cattle and Calves	34, 123	27, 213	30, 442
Beef Cows	13, 460	11, 952	12, 511
Milk Cows	25	60	127
Sheep and Lambs	1, 211	1, 047	1, 212
Contra Costa			
Cattle and Calves	36, 125	30, 050	27, 351
Beef Cows	14, 126	Not available	Not available
Milk Cows	2, 367	Not available	Not available
Sheep and Lambs	637	734	286
Sacramento			
Cattle and Calves	111, 565	93, 011	69, 362
Beef Cows	22, 075	23, 078	17, 457
Milk Cows	21, 919	18, 383	18, 762
Sheep and Lambs	10, 148	5, 674	4, 239
San Joaquin			
Cattle and Calves	183, 636	196, 627	218, 515
Beef Cows	22, 496	23, 153	27, 174
Milk Cows	68, 237	76, 003	86, 148
Sheep and Lambs	29, 104	21, 549	21, 944
Solano			
Cattle and Calves	27, 416	25, 494	33, 252
Beef Cows	9, 397	10, 414	9, 458
Milk Cows	2, 047	2, 525	1, 632
Sheep and Lambs	77, 031	65, 234	57, 032
Yolo			
Cattle and Calves	15, 709	22, 003	18, 963
Beef Cows	Not available	Not available	7, 224
Milk Cows	702	Not available	Not available
Sheep and Lambs	24, 052	34, 462	22, 850

Source: USDA-National Agricultural Statistics Service, 1997 Census of Agriculture. http://www.nass.usda.gov/census/census97/highlights/ca/ca.htm. Accessed on 27 Nov 2000

[a] Livestock numbers were reported for the entire county, including livestock grazed beyond the boundaries of the Legal Delta.

Using data from Table 4-14, estimates of livestock grazing density were calculated (Table 4-15). Because more than one type of livestock may be using the same acreage, these numbers should not be used literally; however, it appeared that nearly twice as many livestock per acre were found in San Joaquin County when compared with other counties in the Legal Delta.

Table 4-15 Estimates of Number of Livestock/Acre in 1997 in Counties Encompassed within the Boundaries of the Legal Delta

County	1997 *Livestock numbers	1997 Acreage Used for Pasture & Grazing	Number of livestock/ acre
Alameda	44,165	26,818	1.65
Contra Costa	27,637	Not available	Not available
Sacramento	91,058	24,365	3.74
San Joaquin	267,633	38,932	6.87
Solano	99,742	31,410	3.18
Yolo	49,037	18,119	2.71

*Livestock = Cattle and calves, beef cows, and sheep and lamb

4.2.5 CONFINED ANIMAL FEEDING OPERATIONS

Dairies comprise the vast majority of confined animal feeding operations (CAFOs) of concern in the Sacramento and San Joaquin River watersheds. Other types of CAFOs (for example, poultry or other fowl, feed lots, hogs, horses, etc.) are not discussed in this chapter because their numbers are small and their activities are unlikely to be significant sources of contamination to the SWP.

There are 2 major types of dairies based upon the products that they produce. Grade A dairies produce milk for liquid consumption, and Grade B dairies produce milk for manufacturing other products such as cheese, butter, and powdered milk. More than 95% of the dairies in the Central Valley are Grade A, and they tend to be larger than the Grade B dairies; Grade B average only 200 animals per operation. Because there are fewer and they are smaller in size, the Grade B dairies pose less of a risk to the SWP; thus only Grade A dairies will be examined in this chapter.

4.2.5.1 Constituents of Concern

Potential water quality impacts resulting from dairy operations include accidental or intentional discharge of animal wastes to surface waters or infiltration to groundwater. Surface water contamination can result from poor facility design and/or construction, poor management, inadequate waste pond storage, proximity to surface waters, lack of tailwater recovery, and inadequate sump operations. Inadequate storage capacity can lead to waste being spilled into adjacent drains or creeks. Some dairies outgrow their waste handling capabilities, while others may not have enough cropland to dispose of solid waste. Poor construction resulting from use of inferior materials and design can lead to off-site waste discharges.

Constituents in dairy discharges that can adversely affect water quality include coliform bacteria, the microbial pathogens *Cryptosporidium* and *Giardia*, TOC, nutrients, and salts (mostly potassium). Nutrients include phosphates and several forms of nitrogen, including organic nitrogen, ammonia, and urea. High biochemical oxygen demand (BOD) can result in surface waters contaminated with manure organic matter, which can also be a source of TOC. Nutrients can lead to eutrophication and algal blooms in agricultural drains and streams used as source water to the SWP and are a potential source of taste and odor compounds that increase water treatment costs. Dairy wastes may also be a source of hormones, antibiotics and pesticides, constituents with unknown, but potentially negative human health effects. The quantities, fate, and transport of these contaminants are not well known, and the USGS has implemented a national reconnaissance program (with 1 sampling site in the Delta) to collect baseline information on these contaminants.

The state of the knowledge regarding water quality impacts resulting from dairy operations in the Central Valley is incomplete. Like other nonpoint urban and agricultural discharges, as well as municipal point sources such as wastewater treatment plants, very little is known about the transport and fate of TOC, pathogen, and organic loading from these sources. Therefore, the magnitude of the potential impacts of these nonpoint source discharges on drinking water quality in the Delta and SWP is hard to assess with current data and points to the need for more thorough study in the future. In the following sections us a discussion of the potential for dairies to impact water quality in the SWP, along with a presentation of some limited monitoring data.

4.2.5.2 Location of Major Dairy Activity

Data on locations and numbers of dairies were based on reports from the California Department of Food and Agriculture (CDFA). Data were available for 1996, 1997, and 1999, but the CVRWQCB uses the 1997 data because the 1999 data were only recently available and not yet reviewed by staff (Menke pers. comm. 2000). There are approximately 2,100 Grade A dairies in California and about 1,700 are in the Central Valley region regulated by the CVRWQCB (Region 5: Sacramento and Fresno offices). The Fresno area includes dairies in Madera and Fresno counties, which are unlikely to discharge to tributaries of the San Joaquin River. Dairies in these counties pose a greater threat to groundwater than surface water quality and, therefore, are not discussed here.

This chapter focuses on dairies within Sacramento, San Joaquin, Stanislaus, Merced and Madera counties that have a much higher potential for contamination of runoff to the Delta and SWP. Distribution maps of dairies in each county (except Madera) are provided in Section 4.2.5.5, Regulatory Status. The largest numbers of dairies are in the San Joaquin River watershed, which includes parts of southern Sacramento County that drain to Dry Creek and the Mokelumne River.

4.2.5.3 Number and Location of Central Valley Dairy Facilities

There are about 969 Grade A and 50 Grade B dairies in Sacramento, San Joaquin, Stanislaus, Merced and Madera counties. The number of Grade A dairies in each county, based on data provided by CVRWQCB staff, for 1997 are presented in Table 4-16. A comparison of 1996, 1997, and 1999 data from CDFA showing the number of cows and dairies in each county is shown in Table 4-17.

Table 4-16 Central Valley Dairies (Grades A and B) by County

County	# of Dairies
Sacramento	59
Stanislaus	332
San Joaquin	159
Merced	368
Madera	51

Table 4-17 Number of Grade A Dairies and Dairy Cows in 5 Central Valley Counties

	1996[a]		1997[a]		1999[b]	
County	Number of cows	Number of dairies	Number of cows	Number of dairies	Number of cows	Number of dairies
Madera	25,293	50	26,299	51	35,507	52
Merced	163,493	348	171,721	368	185,130	338
Sacramento	15,844	60	17,687	59	17,193	56
San Joaquin	86,593	162	89,073	159	88,778	154
Stanislaus	140,032	340	142,799	332	146,285	323

[a] CDFA 1998

[b] CDFA 2000 Web database, www.cdfa.ca.gov

According to the data available from CDFA (1997), the number of milk cows increased in 4 of the 5 counties between 1987 and 1997. Sacramento County is the exception with a decline that started around 1993. Between 1987 and 1997, milk cows decreased by about 30% in Sacramento, whereas there were increases of 27% in Madera, 49% in Merced, 35% in San Joaquin and 33% in Stanislaus Counties (CDFA 1997).

DWR staff contacted the planning departments of the 5 counties to get information on the level of expected growth of dairies. Except for Madera County, there was very little information on proposed new dairies. Madera County Planning Department provided information that new dairies were increasing up to about mid-1999. At that time, the California State Office of the Attorney General warned several San Joaquin Valley counties, including Madera, that their permitting process for dairy projects may be in violation of the California Environmental Quality Act (CEQA). Since then, Madera has tightened its requirements, which now can require an applicant to prepare an EIR. This has slowed down the applications for new dairy permits tremendously in the San Joaquin Valley (Motta pers. comm. 2000).

A comparison of 1996, 1997, and 1999 dairy data from CDFA did not indicate significant growth in the number of dairies in the 5 counties (see Table 4-17). Madera County Planning Department staff indicated that dairies are growing more in Kings and Tulare Counties. The number of dairies in Kings County is 155, and the number in Tulare County is 298, based on 1999 CDFA data. The number of milk cows grew by 50% in Kings County and by 100% in Tulare County between 1987 and 1997 (CDFA 1997). However, these counties are not considered to have a direct impact on surface waters that drain into the Delta.

4.2.5.4 Regulatory Background

Various county, State and federal agencies regulate the overall operation of dairies. At the federal level, construction of a new dairy or expansion of an existing one may require approval of the US Fish and Wildlife Service if the activity will impact wildlife or habitat. If the construction will involve streambed modifications, the US Army Corps of Engineers would have to approve it.

At the State level, the CDFA is delegated the responsibility of enforcing the California Food and Agricultural Code. Water supplied to the milk house and dairy barn must conform to the bacterial quality standards for public supplies of drinking water set by the DHS. County departments of health may have their own requirements that dairies have to comply with, and county planning departments may or may not have zoning requirements. For example, Sacramento and Stanislaus counties do not have permit requirements as long as the dairy is in an approved agricultural zone. San Joaquin County Planning Department only requires a site approval and public hearing. Merced County requires a conditional use permit, and since 1999, Madera County is also requiring conditional use permits. This came about when the California Attorney Generals' Office questioned whether the county's dairy permitting process complied with CEQA regulations.

The EPA regulates dairies that have 700 milk cows (1,000 animal units) to ensure that operations are in compliance with the Safe Drinking Water Act and the NPDES requirements of the Clean Water Act. The CVRWQCB enforces compliance with state regulations for animal waste management under the Porter-Cologne Water Quality Control Act. The CVRWQCB is the primary regulatory agency for dairy waste discharges in the Sacramento and San Joaquin River watersheds. Under SWRCB regulations for confined animal facilities, dairies are not allowed to discharge their wastewater to surface waters; therefore, NPDES permits such as those for a wastewater treatment plant are not required.

Dairies are not allowed to discharge any waste into surface or groundwater and may be required to obtain and follow WDRs set by the CVRWQCB. There are 2 basic types of surface water discharges from dairy operations, wastewater discharges resulting from milk processing and operations, which are not allowed as described above, and storm water runoff from rainfall events.

Historically, the Central Valley RWQCB has had insufficient staff to cover the large number of dairies and other CAFOs in the region, and, consequently, many dairies in the region have never been inspected. Some dairies are covered by the General Industrial Storm water permit approved for the State for this type of activity. Under the storm water regulation, facilities with 1,000 or more animal units are considered CAFOs, and facilities with between 300 and 1,000 animal units can be CAFOs, depending on site-specific and operating conditions. However, "regardless of size, a dairy does not need an NPDES storm water permit if it is managed such that discharges to surface water occur only during storm events greater than the 25-year, 24-hour storm event" (CVRWQCB).

Although dairies can operate without an NPDES storm water permit, some of them chose to obtain one as a protective strategy to avoid fines and/or penalties, according to CVRWQCB staff (Menke pers. comm. 2000). This is because the "NPDES permit allows a properly operated dairy to discharge from its waste management system during periods of continuous rain or catastrophic events in order to prevent overtopping of the pond or other waste system failure" (CVRWQCB). In the past, Notices to Comply with the storm water permits were sent by the CVRWQCB to dairies with greater than 700 milk cows; however, only about half have responded to the notice.

Given that CVRWQCB staff and resources are very limited for the large number of facilities, the board adopted a waiver policy. Simply stated, if there are no known or reported problems with a dairy, then the CVRWQCB does not require WDRs to be obtained. New and/or expanding dairies require review and possible permitting. For facilities with waivers or permits, if the CVRWQCB finds a problem or violation at a facility, then that facility can be referred for enforcement action directly to a Special Task Force consisting of State and federal attorneys. The California State Office of the Attorney General may also prosecute violators and depending on the results of their investigation, enforcement actions can include abatement actions, fines, and even imprisonment.

4.2.5.5 Regulatory Status

Evaluation Methods

CVRWQCB records were reviewed and evaluated in an attempt to determine the impact of dairies on surface water quality. In order to investigate the potential effects of dairies on Delta water quality, dairies that were known or suspected to have discharged into tributaries of the Sacramento or San Joaquin rivers are discussed. An attempt was made to focus on the potential for contaminants to move from the discharge location downstream to the Sacramento or San Joaquin River. Waste discharges into surface waters that were not tributary to the Sacramento or San Joaquin River were not included.

The CVRWQCB maintains records of all dairies that it inspects, and DWR staff compiled a list of problem dairies, based on past inspections. As such, CVRWQCB records include only those dairies that have been inspected. Some dairies did not have files, or if the dairy was under investigation for possible legal action, the file was sealed in order not to jeopardize the case. CVRWQCB records often include follow-up inspections reporting modifications to facilities or management practices that were needed to eliminate waste discharges. CVRWQCB records indicate that if dairies failed to make the required modifications, these dairies were identified as ongoing problem dairies.

Information in available files was obtained when violations occurred. It included where a dairy discharged in relation to a tributary of either river and any enforcement action taken by the CVRWQCB. Waste discharges were evaluated using best professional judgment, based on the magnitude and the frequency of releases. Some dairies displayed a pattern of illegal waste discharges spanning several years. Most illegal discharges were discovered after anonymous phone calls to various regulatory agencies or neighbors' complaints. Some dairies were labeled as "problems" based on special considerations, such as proximity to a major waterway. These dairies were given special consideration as frequent dischargers. Records of waste discharges occurring before *Sanitary Survey Update 1996* were also included if the dairy showed either frequent or ongoing discharge problems.

Results

A summary of the numbers of dairies, dairy files at CVRWQCB, and a breakdown of problem dairies in each county are provided in Table 4-18. The table includes the total number of known dairies, those with files, and those considered problem facilities.

Table 4-18 Numbers of Dairies, Central Valley Regional Water Quality Control Board Files, and Problem Dairies by County

	County			
Category	Merced	Sacramento	San Joaquin	Stanislaus
Number of dairies (CDFA data)	368	59	159	332
Dairies with files at CVRWQCB	180	17	83	120
Dairies with history of discharge problems, according to CVRWQCB staff[a] (that is, potential problem dairies)	15	22	37	58
Potential problem dairies with files available	14	11	31	49
Potential problem dairies with recent significant violations	12	11	18	13

[a] Based on complaints or violations or both (CVRWQCB).

Those facilities that have violations and have been referred for further enforcement action are considered by the CVRWQCB to be the most serious potential threats to water quality. CVRWQCB staff estimates 400 dairies could impact surface waters draining into the Sacramento-San Joaquin Delta.

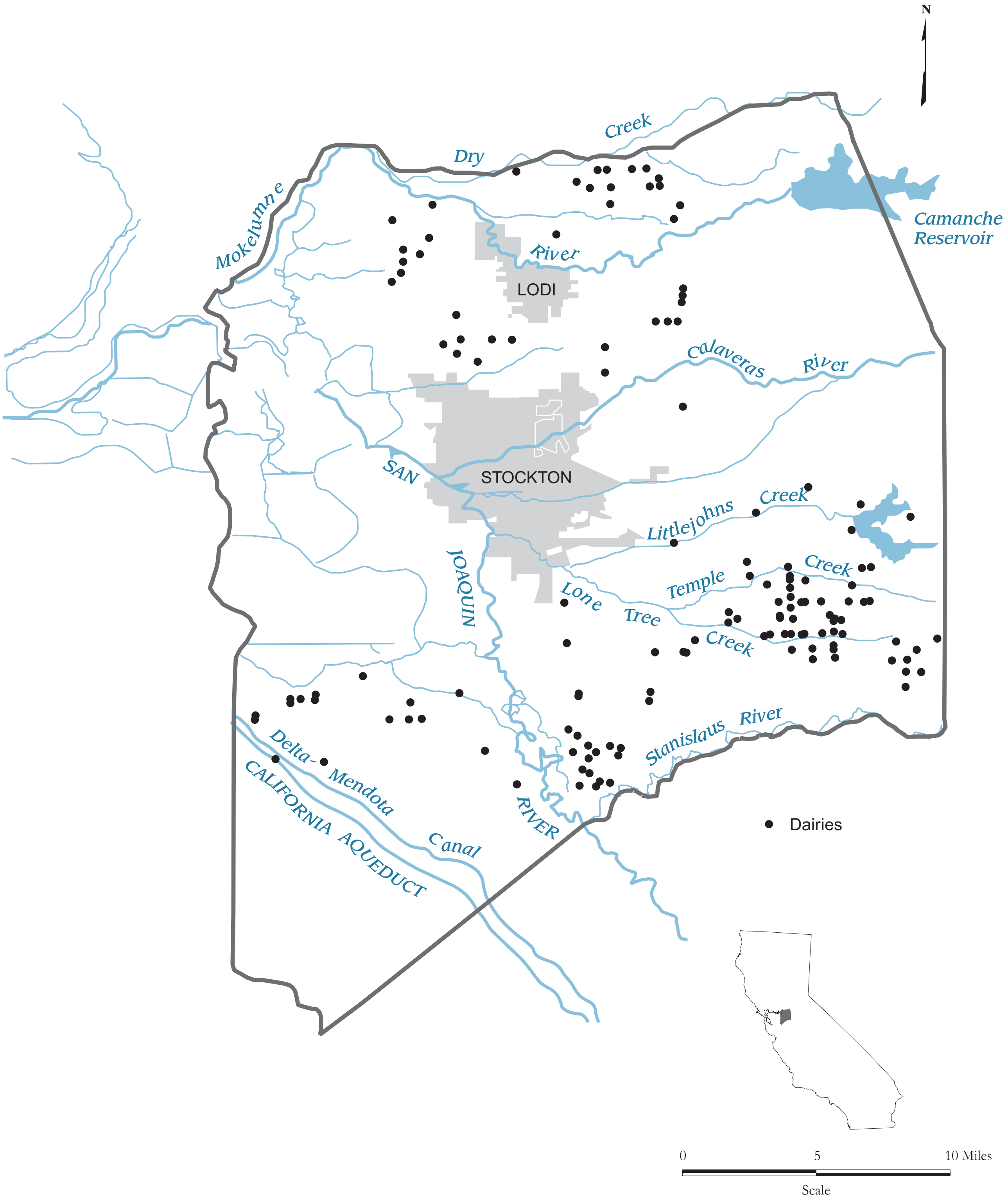
A summary of the results of the file reviews for each county follows. Distribution maps depicting locations of dairies in each county are also provided. The maps only show approximate locations of dairies because not all dairies are known and not all could be mapped because some street addresses could not be located on available base maps.

SACRAMENTO COUNTY. The distribution of known dairies in Sacramento County is shown in Figure 4-14. DWR staff reviewed the only 17 files for the 59 dairies in Sacramento County. Sacramento County had 11 problem dairies, 3 of which discharged waste into irrigation drains tributary to Stone Lakes. One dairy disposed waste into Badger Creek, which is tributary to the San Joaquin River. Three other dairies discharged wastewater into irrigation ditches and creeks tributary to the Sacramento River. One dairy had a problem containing winter storm water runoff. The runoff flowed over manured areas and then into a dry creek that runs through the property and drains to Laguna Creek in the winter. Sacramento County also included 1 dairy operator who was recently indicted for a long series of violations dating back to 1975. Wastewater from this dairy drained into Stone Creek, tributary to the Sacramento River.

SAN JOAQUIN COUNTY. The distribution of known dairies in San Joaquin County is shown in Figure 4-15. There were 18 problem dairies noted in the county. Of these, 6 have been fined in the last 2 years for illegally disposing wastewater. Most of the discharges occurred in local irrigation ditches and drains that are tributary to the San Joaquin River, Stanislaus River, or Mokelumne River. Several dairies discharged wastewater into sloughs and drains that are within the southern portion of the Sacramento-San Joaquin Delta. One dairy discharged waste into Red Bridge Slough, which is tributary to the San Joaquin River just south of Vernalis.

Figure 4-14 Dairies in California—Sacramento County

Figure 4-15 Dairies in California—San Joaquin County



At least 4 dairies discharged waste into Temple Creek or Lone Tree Creek. These creeks are on the 1998 303(d) list of impaired water bodies created by the CVRWQCB, as required by EPA under the Clean Water Act. These streams have been listed as impaired since the early 1990s because of discharges from dairies containing ammonia, electrical conductivity (EC), and BOD (Lone Tree Creek only) (SWRCB 1998a; Schnagl pers. comm. 2000). Lone Tree Creek is tributary to the San Joaquin River near the city of Stockton. Wastewater discharges to the 2 creeks were the result of design problems at 2 or more of the 4 dairies. One of these dairies has a wastewater pond only a few feet from Lone Tree Creek. During periods of heavy rainfall the wastewater overflowed the pond and discharged into Lone Tree Creek.

There have been numerous complaints of dairy waste discharges in Temple and Lone Tree Creeks or drains tributary to them. The only known available data on dairy discharges are from limited sampling conducted by the CVRWQCB in 1987 to 1988 in response to the complaints. Only a few measurements were made of EC, BOD, and ammonia. In December 1987, EC in samples collected from Lone Tree Creek ranged from 1,500 to 3,700 µS/cm, indicating that dairy wastes were present, according to field notes on file at the CVRWQCB. BOD levels in both creeks at this time ranged from 22 to 126 mg/L. In January 1988, BOD ranged from 30 to 40 mg/L with EC ranging from 500 to 600 µS/cm. In February 1988, BOD ranged from 13 to 68 mg/L and EC ranged from 700 to 2,500 µS/cm. In August and September 1988 and early 1989, samples collected at different locations from the 2 creeks generally had similar EC and BOD ranges. Ammonia values ranged from <0.2 mg/L to 12 mg/L; ammonia concentrations above 5 mg/L may be toxic to fish.

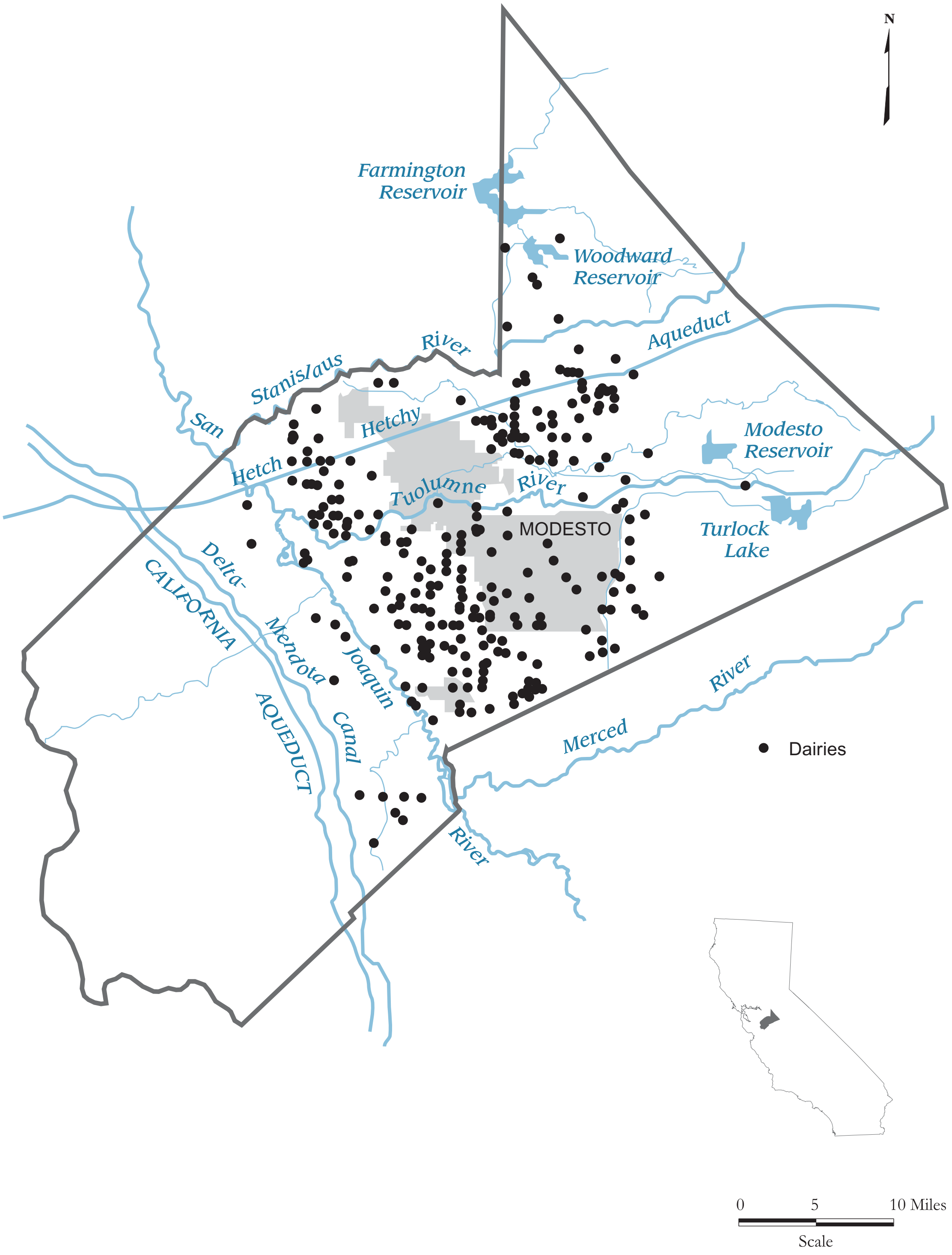
These data also indicated occasional spikes of EC and BOD in samples collected downstream of dairies relative to sites above the dairies. However, the sampling program was very limited in scope, and quality control problems with analytical laboratories were noted. Nevertheless, the data indicated that wastewater discharges at least occasionally impacted these surface waters, and the dairies were, therefore, placed on the 303(d) list.

Water bodies listed as impaired on the 303(d) list will eventually be required to have TMDLs prepared to allocate pollutant loadings among sources to improve water quality. These are the only 2 streams known to be listed solely because of dairy discharges.

Another dairy received several complaints throughout the 1970s and 1980s for discharging wastewater into a local irrigation ditch. The CVRWQCB inspector who investigated these complaints indicated that the dairy does not have enough adjoining cropland on which to distribute its manure waste. This caused a buildup of waste in the retention pond. Two of the wastewater discharges that were investigated resulted in fish kills in nearby sloughs and irrigation ditches. Without enough cropland on which to spread the waste, the dairy discharges the wastewater off the property.

STANISLAUS COUNTY. The distribution of known dairies in Stanislaus County is shown in Figure 4-16. There were 28 problem dairies in Stanislaus County, most of which discharged wastewater into local irrigation district ditches which are tributary to the San Joaquin River south of Vernalis. Two dairies disposed of wastewater in Lone Tree Creek, which also flows in the northeastern portion of the county into San Joaquin County and is tributary to the San Joaquin River.

Figure 4-16 Dairies in California—Stanislaus County

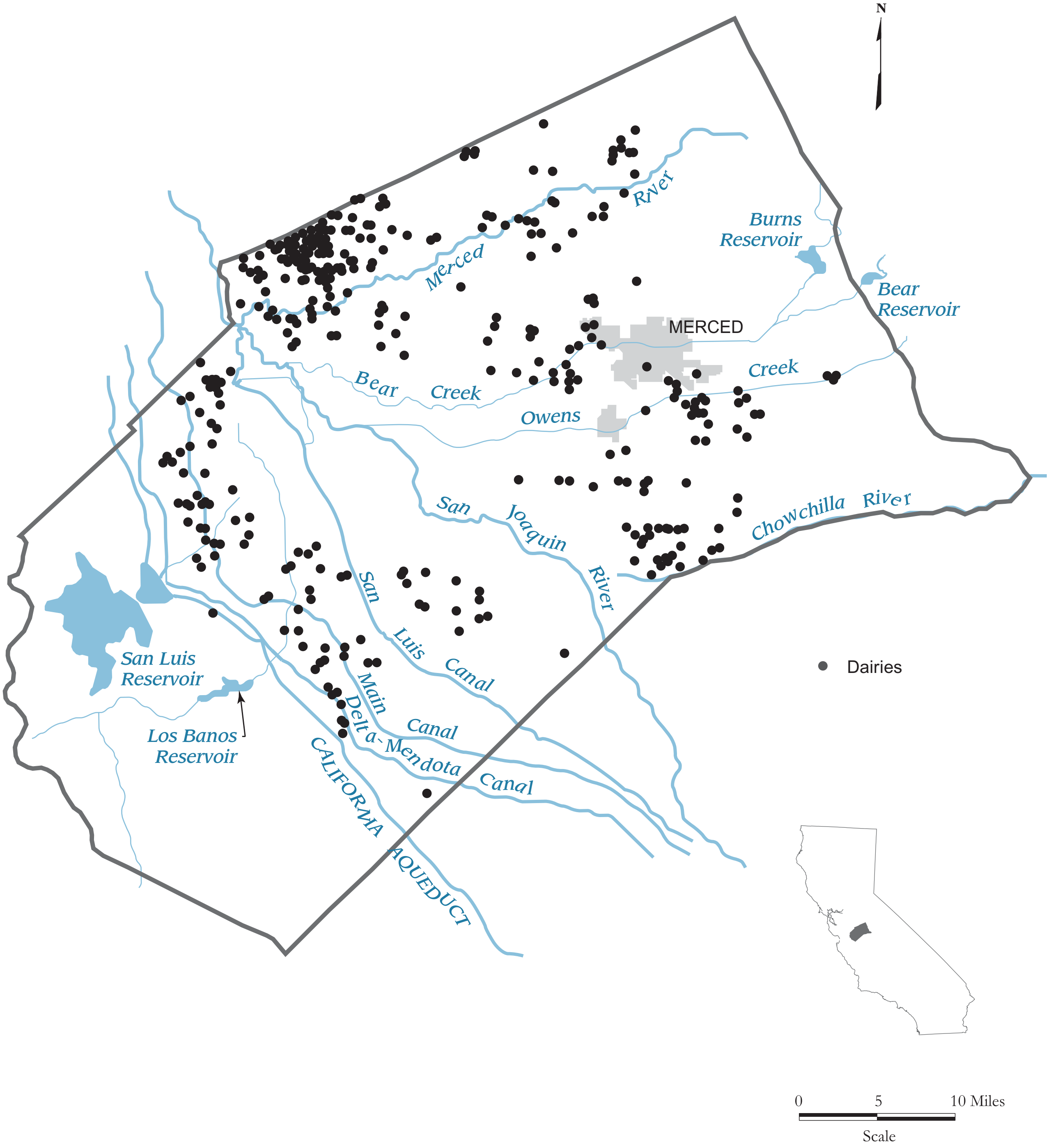


Four of the problem dairies received fines for illegal waste discharges since 1998. The EPA is currently investigating 1 more dairy, and the file is in confidential status. A 1996 CVRWQCB inspection of 1 dairy revealed that not only was that dairy illegally discharging manured wastewater, but 6 other neighboring dairies were also discharging wastewater. On a separate visit, an inspector actually observed a dairy owner operating a pump that was moving water from the waste retention pond into a neighboring irrigation drain. Although there were instances of wastewater discharge in Stanislaus County, these discharges pose a lower threat to Delta water quality than discharges in San Joaquin County because of the greater distance between the irrigation district drains and the Delta pumps. Also, high percolation rates in the sandy soil in many areas of Stanislaus County suggest that dairy ponds may pose a greater risk for groundwater contamination than for surface waters (Menke pers. comm. 2000).

A notice of violation was issued to 1 dairy in Oakdale in December 1998 for discharge of high conductivity wastewater to the Mootz Drain, tributary to the Stanislaus River. Another dairy had ponded water in the manure storage area flowing into the Cleveland Drain, which flows to the Modesto Irrigation District Main Canal, which is also tributary to the Stanislaus River.

MERCED COUNTY. Distribution of known dairies in Merced County is shown in Figure 4-17. There were 12 problem dairies in Merced County, most of which discharged manured wastewater into irrigation ditches, sloughs, or creeks that are tributary to either the Merced River or the San Joaquin River. A dairy in the Atwater area discharged wastewater to Bear Creek, tributary to the Merced River and only 3 miles upstream of the San Joaquin River. Seven of the 12 problem dairies are repeat offenders, and their files contain records of several violations. One of these dairies has had several cleanup and abatement orders levied against it, often for the same violation and even after several inspections. One dairy discharged wastewater to a creek through a 12-inch pipe, which had been illegally constructed for the purpose of waste disposal.

Figure 4-17 Dairies in California—Merced County



Another dairy was found discharging manured water that entered drains flowing to Mud Slough, tributary to the San Joaquin River. A similar situation was found at a dairy discharging to the Jones Drain, tributary to the Merced River. Animals at a dairy constructed on the banks of the Merced River had access to the river. Three other dairies are undergoing legal proceedings against them, and as such, portions of their records are sealed for confidentiality.

MADERA COUNTY. There were 51 known dairies in Madera County. The number of problem dairies is unknown. There have been complaints (illegal discharges and odor) but no known prosecutions, according to CVRWQCB staff in the area (Raley pers. comm. 2000). Most of the dairies appear to be in a relatively small area west of Highway 99 and east of the Chowchilla Canal Bypass, which is several miles west of the San Joaquin River. Drainage from these dairies has the potential to flow to either the Chowchilla River in the north, the Fresno River and Lone Willow or Berenda sloughs in the central area, or the San Joaquin River.

TILE DRAINAGE. Dairies in southern Stanislaus County and Merced County are considered more of a threat to groundwater than to surface water (Menke pers. comm. 2000). Many of these dairies have the potential to discharge wastes that can enter subsurface agricultural drains via groundwater. CVRWQCB staff indicated that dairy wastewater in tile drainage might have a bigger impact on surface water than direct surface discharges because tile drainage in San Joaquin, Stanislaus and Merced counties commonly empties into irrigation district canals that discharge into tributaries of the San Joaquin River. With the low flows that occur in the San Joaquin River, tile drainage contributes a significant amount of salts and solids that is not quantified.

4.2.6 AGRICULTURAL DRAINAGE

The Delta receives water containing agricultural drainage from more than 4.5 million acres of cropland in the San Joaquin and Sacramento Valley watersheds and from within the Delta itself. Large quantities of agricultural petrochemicals in the form of pesticides and fertilizers are applied to this acreage. Contamination from pesticides receives the greatest publicity; and in the case of ecosystem concerns, there is merit to this concern. In the realm of drinking water quality, pesticides are of a lesser concern compared to other parameters. Salts, including bromide, nutrients, and organic carbon have a more serious impact on drinking water quality. CAFOs in the San Joaquin Basin are sources of pathogens, as well as nutrients and salts and are discussed in Sections 4.2.5 and 4.3.5. This section focuses on agricultural drains that represent discharge from irrigated cropland combined with other natural sources and discuss agricultural drainage as a potential contaminant source.

Previous surveys for the SWP and the city of Sacramento have included many of the studies of pesticides from the 1980s and early 1990s. The studies focused primarily on ecosystem concerns, for which the concentrations of the pesticides have a potentially serious impact. In *Sanitary Survey Update 2000*, statewide pesticide-use trends are initially discussed. Next, agricultural drainage in the Delta and the Sacramento River and the San Joaquin River basins are examined separately. The presence of priority contaminants such as salts, carbon, and pesticides in the major drains of each of the 3 regions are included in the discussion.

4.2.6.1 Statewide Pesticide Use and Trends

In the 1980s, concentrations of rice herbicides in the Sacramento River created taste and odor problems in the Sacramento city water supply. In response, several State and local agencies successfully implemented a rice herbicide reduction program. However, negative public reaction to pesticide presence was not as easily mitigated, despite assurances that the pesticide levels had little or no known health implications. Since the rice herbicide episode, there have been very few investigations of pesticide levels and sources in relation to drinking water supply. Therefore, it is essential to evaluate current trends of pesticide usage in order to evaluate potential problems caused by an increase in the use of pesticides.

Table 4-19 shows 1998 statewide pesticide use ranked by total pounds for pesticides used on the crops found in the San Joaquin and Sacramento valleys and Delta region, according to information from California Department of Pesticide Regulation (DPR) Pesticide Use Reporting. Table 4-20 lists the top pesticide use statewide for crops found in each of the 3 regions by crop. In this report, top pesticides are defined as those applied in excess of 100,000 pounds per region. In the case where all the active ingredients for a crop did not exceed 100,000 pounds, the top 5 pesticides used for that crop were included. It should be noted that the totals represent the number of pounds used statewide on the listed crops, and not just what was used within the 3 regions. Breakdown by regions is problematic because watershed boundaries for the 3 basins cut across a number of counties within each basin. Based on crop acreage totals, a significant portion of the pesticides listed was applied in the 3 regions.

Table 4-19 1998 Statewide Pesticide Use on Crops in the 3 Regions (Ranked by Pounds)

PESTICIDE	AMOUNT (lbs)
SULFUR PRODUCTS TOTAL	38,232,340
PETROLEUM PRODUCTS TOTAL	7,013,159
COPPER PRODUCTS TOTAL	4,201,139
METAM-SODIUM TOTAL	3,142,049
SODIUM CHLORATE	2,305,593
MINERAL OIL	2,032,733
CRYOLITE	1,700,428
GLYPHOSATE TOTAL	1,454,966
CAPTAN TOTAL	1,061,404
METHYL BROMIDE TOTAL	1,034,468
PROPARGITE TOTAL	1,029,028
ZIRAM TOTAL	1,013,151
MOLINATE	1,004,827
CHLORPYRIFOS TOTAL	895,877
TRIFLURALIN TOTAL	875,353
MANGANESE PRODUCTS TOTAL	790,930
THIOBENCARB	724,712
ETHEPHON	703,058
PARAQUAT DICHLORIDE TOTAL	686,622
PROPANIL	523,373
ALDICARB	513,949
S,S,S-TRIBUTYL PHOSPHOROTRITHIOATE	438,890
ORYZALIN TOTAL	383,728
CHLOROTHALONIL	349,014
MALATHION	265,865
CYANAZINE	244,159
UREA DIHYDROGEN SULFATE	243,770
PROMETRYN	226,050
DIURON	221,613
SODIUM TETRATHIOCARBONATE	220,102
DICOFOL	211,947

The following excerpt from the DPR's Report on Pesticide Use Analysis summarized findings on pesticide use trends from 1991 to 1996 (Ross and others 1999; Wilhoit and others 1999):

> "Reported pesticide usage in California declined from 1995 to 1996. A total of 189 million pounds of pesticides were reported in 1996, compared to 196 million pounds in 1995. Agricultural pesticide use declined to 174 million pounds in 1996 from 179 million pounds in 1995. (These figures do not include adjuvants, although these also must be reported in California. Adjuvants are ingredients that cause a pesticide to stick, spread, or dissolve in the appropriate manner.)"

Pesticide use was lower in 1996 as measured by total pounds of active ingredient applied, cumulative number of acres treated, and number of applications. At the same time, DPR's analysis underscored the fact that 1 year of data does not signify a trend: Pesticide use increased from 1991 to 1995. Overall pesticide use varies from year to year, depending upon pest problems, weather, crops, and other factors. From 1991 to 1996, sulfur, a natural fungicide favored by both conventional and organic growers, was the single most used agricultural pesticide in pounds used, applications, and cumulative acres. Sulfur accounted for 36% of all active ingredient pounds used, about 9% of applications, and 11% of acres treated. Due to sulfur's irritant properties and extensive use, it is also the most frequently reported source of pesticide-related injury (primarily skin rashes).

Four pesticides (sulfur, oil, metam-sodium, and methyl bromide) accounted for 68% of all pounds applied in production agriculture in 1996. Thirty-one agricultural pesticides (out of approximately 800) comprised 85% of all pounds applied and accounted for most of the application increase from 1991 to 1996. While these 31 pesticides range widely in toxicity, a number are generally acknowledged as reduced-risk pesticides.

DPR's analysis found that 19 crops accounted for 83% of all production agricultural pesticide use, 71% of all applications, and 82% of all acres treated in 1996. Ranked by pounds applied, crops with the highest pesticide use statewide were grapes (wine, raisin, and table), followed by tomatoes, almonds, cotton, oranges, strawberry, carrots, rice, and sugar beets. Grapes, tomatoes, almonds, cotton and rice represent significant acreage in the Sacramento and San Joaquin valleys and Delta Region.

Table 4-20 1998 Statewide Pesticide Use for Crops Found in the 3 Regions (Ranked by Pounds)

CROPS	DELTA BASIN CROP	SACRAMENTO BASIN CROP	SAN JOAQUIN BASIN CROP	PESTICIDE	AMOUNT (lbs)
ALMOND		x	x	1,3-DICHLOROPROPENE	109,414.87
WHEAT	x	x	x	2,4-D, DIMETHYLAMINE SALT	128,247.88
COTTON			x	ALDICARB	513,949.09
COTTON			x	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	130,483.71
WHEAT	x	x	x	BROMOXYNIL OCTANOATE	46,732.57
CORN		x	x	BUTYLATE	64,114.80
ALMOND		x	x	CAPTAN	1,061,377.18
STONE FRUITS		x	x	CAPTAN	26.39
				CAPTAN TOTAL	1,061,403.57
TOMATO	x	x		CHLOROTHALONIL	349,013.69
COTTON			x	CHLORPYRIFOS	327,464.35
ALMOND		x	x	CHLORPYRIFOS	291,055.89
ALFALFA	x	x	x	CHLORPYRIFOS	277,356.97
				CHLORPYRIFOS TOTAL	895,877.21
ALMOND		x	x	COPPER HYDROXIDE	660,305.80
TOMATO	x	x		COPPER HYDROXIDE	525,626.11
GRAPES	x		x	COPPER HYDROXIDE	434,472.10
PISTACHIO		x	x	COPPER HYDROXIDE	90,982.18
STONE FRUITS		x	x	COPPER HYDROXIDE	66.22
GRAPES	x		x	COPPER OXYCHLORIDE SULFATE	223,417.95
RICE		x		COPPER SULFATE (PENTAHYDRATE)	2,266,268.49
				COPPER PRODUCTS TOTAL	4,201,138.85
COTTON			x	COTTONSEED OIL	161,781.19
GRAPES	x		x	CRYOLITE	1,700,428.22
COTTON			x	CYANAZINE	244,158.79
ALMOND		x	x	DIAZINON	114,416.93
WHEAT	x	x	x	DICLOFOP-METHYL	24,465.71
COTTON			x	DICOFOL	211,946.98

Table 4-20 (continued)

CROPS	DELTA BASIN CROP	SACRAMENTO BASIN CROP	SAN JOAQUIN BASIN CROP	PESTICIDE	AMOUNT (lbs)
ALFALFA	x	x	x	DIURON	221,612.51
ALFALFA	x	x	x	EPTC	129,191.45
CORN	x	x	x	EPTC	70,233.91
				EPTC TOTAL	199,425.36
COTTON			x	ETHEPHON	703,058.38
ALMOND		x	x	GLYPHOSATE, ISOPROPYLAMINE SALT	649,893.16
COTTON			x	GLYPHOSATE, ISOPROPYLAMINE SALT	368,912.21
GRAPES	x		x	GLYPHOSATE, ISOPROPYLAMINE SALT	195,181.38
TOMATO	x	x		GLYPHOSATE, ISOPROPYLAMINE SALT	134,009.69
PISTACHIO		x	x	GLYPHOSATE, ISOPROPYLAMINE SALT	78,713.12
WHEAT	x	x	x	GLYPHOSATE, ISOPROPYLAMINE SALT	28,246.56
STONE FRUITS		x	x	GLYPHOSATE, ISOPROPYLAMINE SALT	10.12
				GLYPHOSATE TOTAL	1,454,966.24
GRAPES	x		x	HYDROGEN CYANAMIDE	100,177.23
ALMOND		x	x	IPRODIONE	169,805.64
GRAPES	x		x	LIME-SULFUR	157,853.63
ALFALFA	x	x	x	MALATHION	265,864.90
TOMATO	x	x		MANCOZEB	189,099.62
GRAPES	x		x	MANCOZEB	138,337.50
ALMOND		x	x	MANEB	463,492.91
				MANGANESE PRODUCTS TOTAL	790,930.03
WHEAT	x	x	x	MCPA, DIMETHYLAMINE SALT	144,983.05
TOMATO	x	x		METAM-SODIUM	2,640,871.97
COTTON			x	METAM-SODIUM	414,502.04
CORN	x	x	x	METAM-SODIUM	86,675.44
				METAM-SODIUM TOTAL	3,142,049.45
COTTON			x	METHAMIDOPHOS	114,377.31

Table 4-20 (continued)

CROPS	DELTA BASIN CROP	SACRAMENTO BASIN CROP	SAN JOAQUIN BASIN CROP	PESTICIDE	AMOUNT (lbs)
ALFALFA		x	x	METHOMYL	148,568.64
ALMOND		x	x	METHYL BROMIDE	459,259.98
TOMATO	x	x		METHYL BROMIDE	301,372.24
GRAPES	x		x	METHYL BROMIDE	273,835.75
				METHYL BROMIDE TOTAL	1,034,467.97
CORN	x	x	x	METOLACHLOR	85,905.86
ALMOND		x	x	MINERAL OIL	2,032,733.23
RICE		x		MOLINATE	1,004,827.29
COTTON			x	NALED	129,567.49
ALMOND		x	x	ORYZALIN	194,728.11
GRAPES	x		x	ORYZALIN	111,217.81
PISTACHIO		x	x	ORYZALIN	77,781.96
				ORYZALIN TOTAL	383,727.88
COTTON			x	OXAMYL	119,565.43
ALMOND		x	x	OXYFLUORFEN	105,115.85
COTTON			x	PARAQUAT DICHLORIDE	329,592.29
ALMOND		x	x	PARAQUAT DICHLORIDE	146,167.10
GRAPES	x		x	PARAQUAT DICHLORIDE	105,456.89
ALFALFA	x	x	x	PARAQUAT DICHLORIDE	105,406.08
				PARAQUAT DICHLORIDE TOTAL	686,622.36
TOMATO	x	x		PEBULATE	168,674.37
COTTON			x	PENDIMETHALIN	183,592.93
ALFALFA	x	x	x	PETROLEUM HYDROCARBONS	131,195.76
COTTON			x	PETROLEUM HYDROCARBONS	105,580.32
RICE		x		PETROLEUM HYDROCARBONS	87,615.86
ALMOND		x	x	PETROLEUM OIL, UNCLASSIFIED	5,980,106.90
PISTACHIO		x	x	PETROLEUM OIL, UNCLASSIFIED	533,850.13
GRAPES	x		x	PETROLEUM OIL, UNCLASSIFIED	174,724.91
STONE FRUITS		x	x	PETROLEUM OIL, UNCLASSIFIED	85.23
				PETROLEUM PRODUCTS TOTAL	7,013,159.11

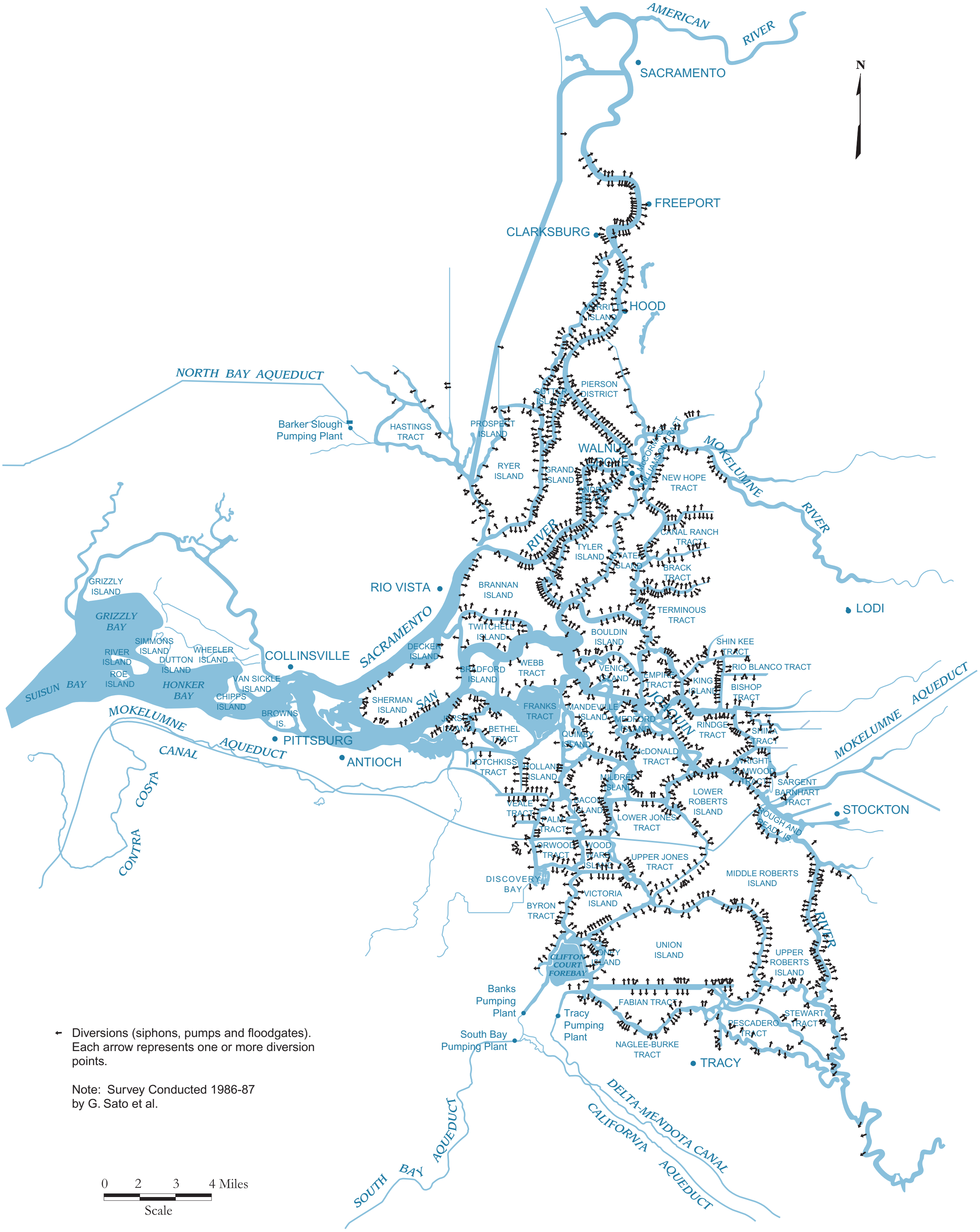
Table 4-20 (continued)

CROPS	DELTA BASIN CROP	SACRAMENTO BASIN CROP	SAN JOAQUIN BASIN CROP	PESTICIDE	AMOUNT (lbs)
ALMOND		x	x	PHOSMET	106,222.30
ALMOND		x	x	POLY-I-PARA-MENTHENE	141,808.64
COTTON			x	PROMETRYN	226,050.13
RICE		x		PROPANIL	523,372.52
ALMOND		x	x	PROPARGITE	382,533.26
CORN	x	x	x	PROPARGITE	366,409.21
GRAPES	x		x	PROPARGITE	165,142.59
COTTON			x	PROPARGITE	114,943.01
				PROPARGITE TOTAL	1,029,028.07
COTTON			x	S,S,S-TRIBUTYL PHOSPHOROTRITHIOATE	438,889.50
GRAPES	x		x	SIMAZINE	164,147.04
COTTON			x	SODIUM CHLORATE	2,305,593.21
GRAPES	x		x	SODIUM TETRATHIOCARBONATE	220,101.97
GRAPES	x		x	SULFUR	28,942,675.47
TOMATO	x	x		SULFUR	6,844,088.31
TOMATO	x	x		SULFUR	687,119.52
ALFALFA	x	x	x	SULFUR	564,133.88
ALMOND		x	x	SULFUR	438,647.64
PISTACHIO		x	x	SULFUR	409,788.36
COTTON			x	SULFUR	177,146.82
GRAPES	x		x	SULFUR DIOXIDE	168,740.24
				SULFUR PRODUCTS TOTAL	38,232,340.24
RICE		x		THIOBENCARB	724,712.06
ALFALFA	x	x	x	TRIFLURALIN	626,097.56
COTTON			x	TRIFLURALIN	249,255.09
				TRIFLURALIN TOTAL	875,352.65
COTTON			x	UREA DIHYDROGEN SULFATE	243,769.71
COTTON			x	VEGETABLE OIL	113,884.79
ALMOND		x	x	ZIRAM	1,013,130.37
STONE FRUITS		x	x	ZIRAM	20.52
				ZIRAM TOTAL	1,013,150.89

4.2.6.2 Delta Agricultural Drainage

Over 1,800 siphons are used in the Delta to withdraw water from the adjacent channels for irrigation (Figure 4-18). These diversions collectively exceed 4,000 cfs during peak summer irrigation season. Irrigation water is siphoned into ditches about 10 feet wide that parallel the levee about 100 feet inside the inner toe and then discharge into lateral ditches 4 feet wide that divide the island into checks ranging from 20 to 50 acres. The water then flows from these laterals into smaller temporary spud ditches, about 10 inches wide and about 20 inches deep, which parallel the crop rows at intervals of 50 to 100 feet. Winter rainfall also contributes to irrigation of winter crops. Some of this water is lost to evaporation and transpiration by growing crops, and the remainder percolates through the soils to the deeper island drainages. Water also enters and leaves the islands as underground seepage because of the high porosity and looseness of the peat soil in the land and levees. The drain water collects into open drainage ditches (6 to 10 feet deep) downslope of the irrigated fields. Drainage is periodically pumped out into the channels. The drainage pump motors are electrically powered and activated by float switches, which operate the pumps whenever drainage reaches a specified water level at the base of the pump station platform, which sits above the drain terminus. The drainage is finally pumped out to the adjacent channels through large pipes buried through the levees. There are over 260 pump stations, most with more than 1 pump, that return agricultural drain water to the Delta (Figure 4-19).

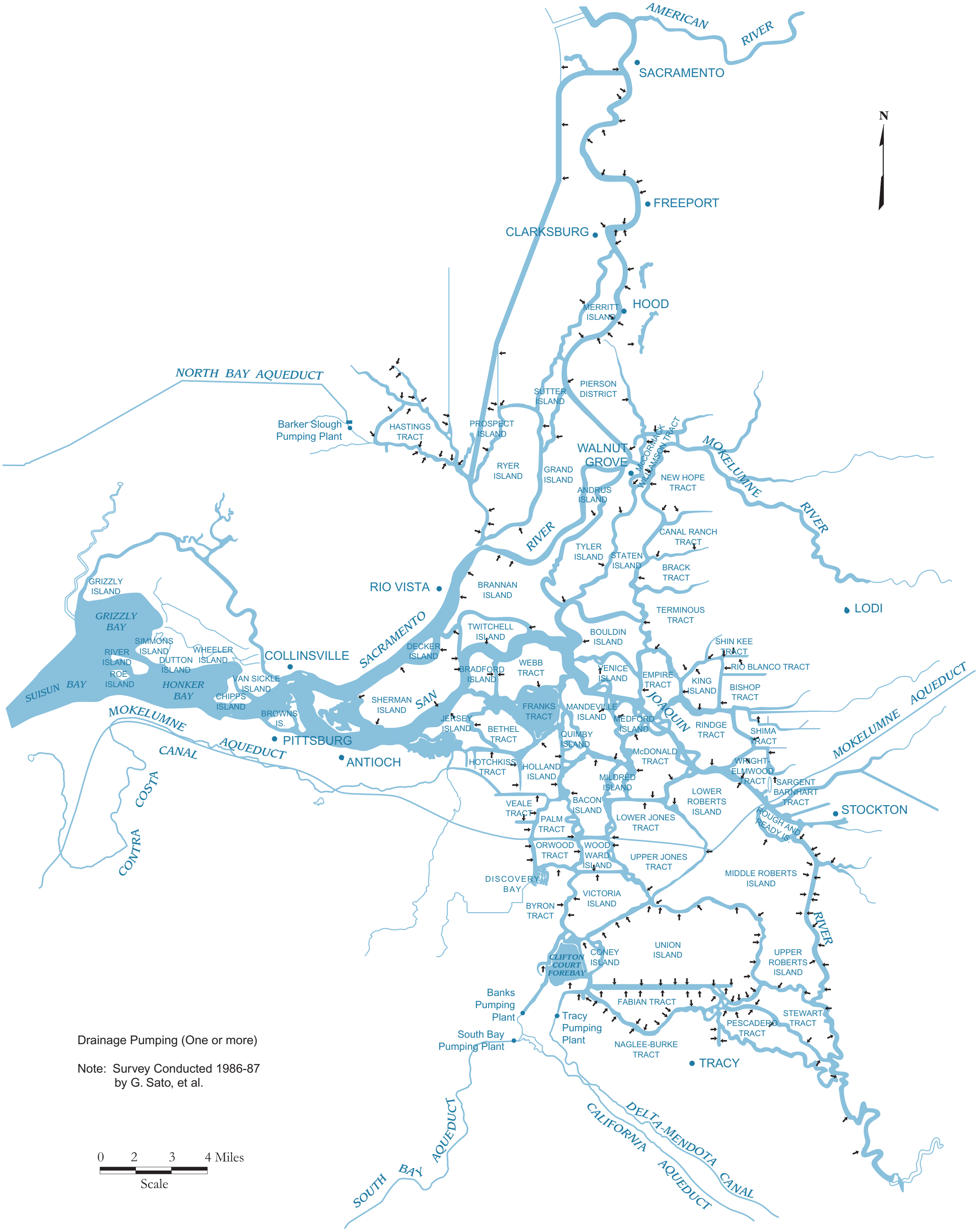
Figure 4-18 Irrigation Diversions



← Diversions (siphons, pumps and floodgates). Each arrow represents one or more diversion points.

Note: Survey Conducted 1986-87 by G. Sato et al.

Figure 4-19 Agricultural Drainage Returns

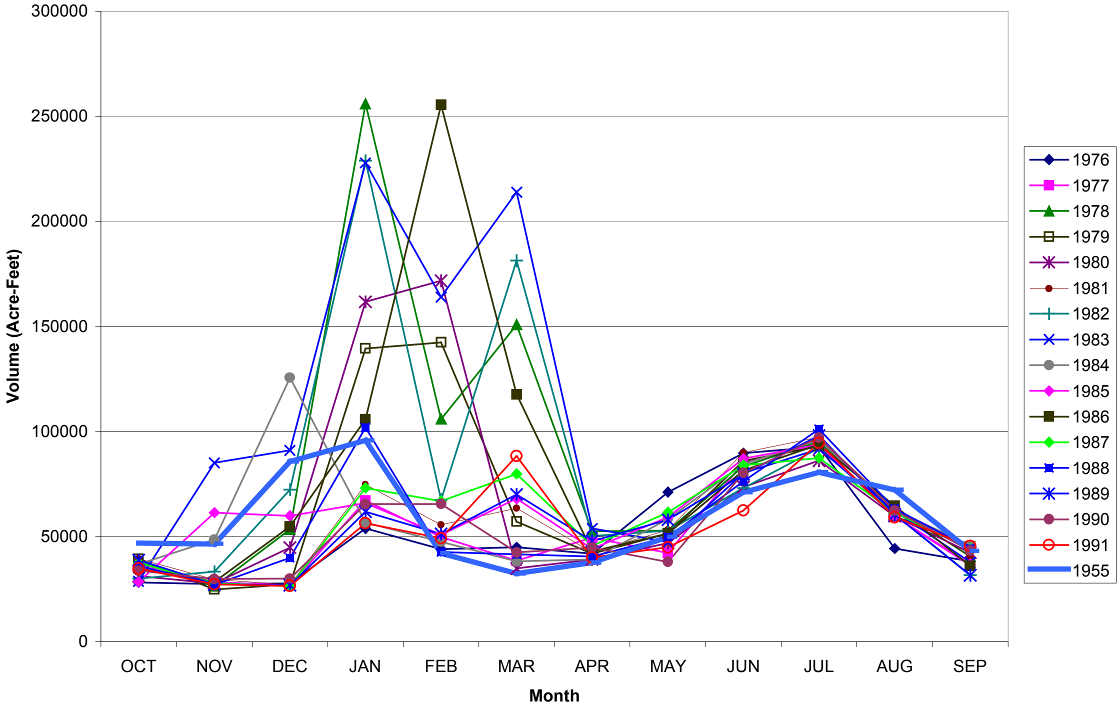


Note: Survey Conducted 1986-87 by G. Sato, et al.

Peaks in discharge of drainage waters in the Delta typically occur in the summer (June through August) when irrigation is high and in winter peak when fields are leached and the rain season occurs. There were 2 studies that estimated the drainage volume of lowland discharges based on a combination of power use records, pump efficiency tests, and extrapolations of computed volumes (DWR 1956; Templin and Cherry 1997). Attempts by DWR to access the drains to conduct more measurements of discharge volume and quality have been unsuccessful. Most of the Delta islands and tracts are privately owned, and individual power use records are not public record.

DWR developed a computer model named the Delta Island Consumptive Use (DICU) to provide monthly drainage estimates based on land use, rooting depths, seepage, soil moisture, irrigation season, evapotranspiration, and precipitation. A comparison of the model results to the limited measured data (1954 to 1955) showed general agreement on the seasonal trends but not numeric values (Figure 4-20). Refinement of the model is continuing with reassessments of the Municipal Water Quality Investigations(MWQI) drainage quality data to model baseline and historic water quality conditions in the Delta (Jung 2000). The model is also being used to study the CALFED Bay-Delta alternatives for water storage and transport in the Delta.

Figure 4-20 Lowland Drainage Estimates



Source: Water years 1976 to 1991 estimates from DICU Model Run
Water Year 1955 data from DWR Report No. 4, 1956

4.2.6.3 Sacramento River Basin

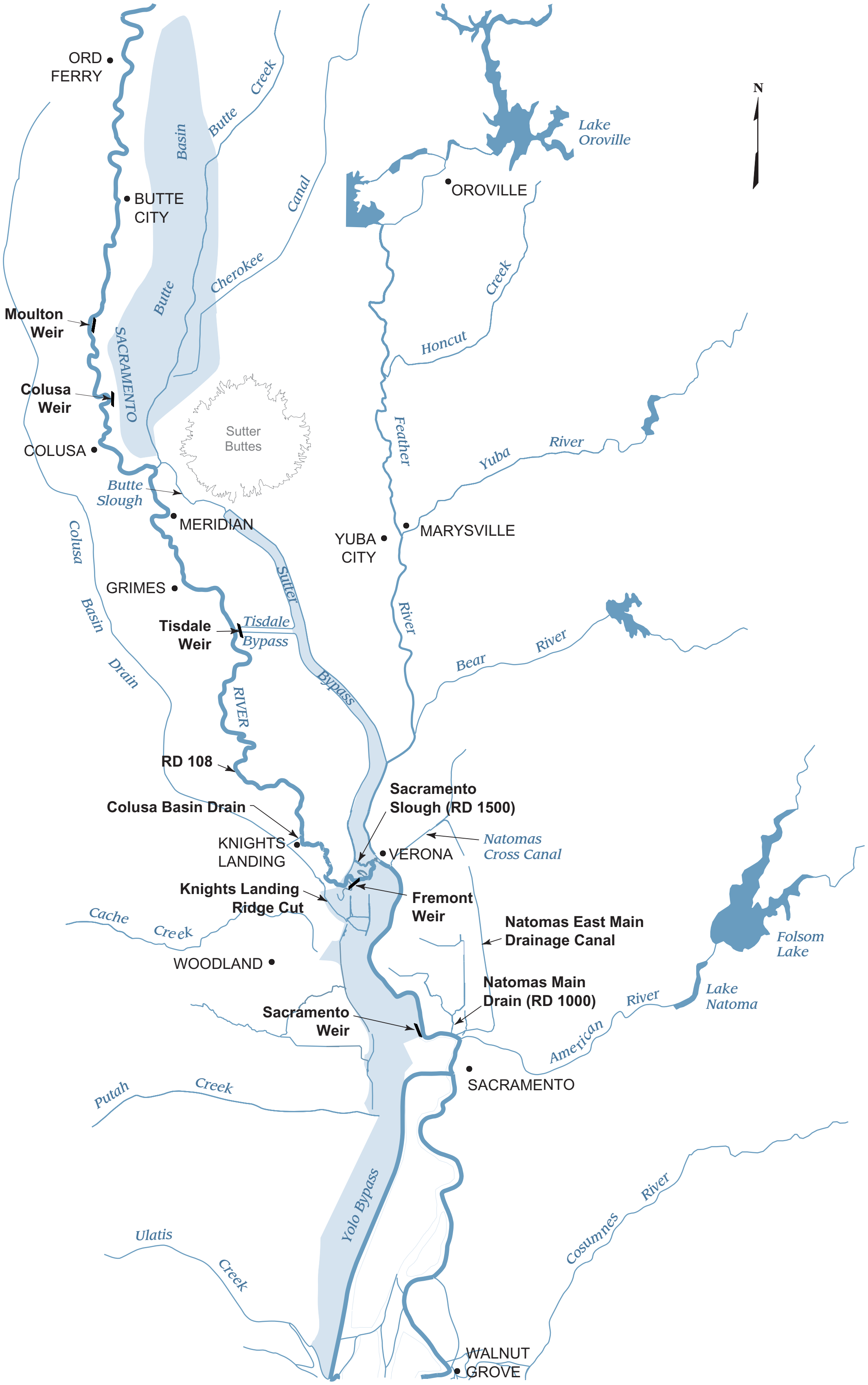
Historically, the Colusa Basin Drain, Sacramento Slough, and Butte Slough contribute up to 80% of the agricultural drainage into the Sacramento River (Table 4-21). Reclamation District 1000 has historically contained drains from agricultural cropland just north of the cities of Sacramento and West Sacramento, although some of the agricultural land has been converted to commercial and residential use. The NEMDC receives discharges from Reclamation District 1000 during late-summer rice field drainage and during winter high flow periods. However, the majority of its watershed is from urban areas east of the drain; for this sanitary survey, the East Main Drain is considered an urban drain.

Table 4-21 Main Agricultural Drains in the Sacramento Basin (Ranked by Percent of Total Historical Discharge)

Agricultural Drain	Percent of Total Historical Discharge
Colusa Basin Drain	27-41%
Sacramento Slough	9-26%
Butte Slough	8-15%
R.D. 108	10-13%
R.D.787	<2%
R.D 1000	<2%
R.D. 70	<2%

The Colusa Basin Drain (CBD1) and the Sacramento Slough carry two-thirds of the agricultural runoff into the Sacramento River. The CBD1 captures drainage from the west side of the Sacramento River (Figure 4-21). During periods when the Sacramento River is high, the CBD1 gates are closed to prevent water flooding from the river back into the basin. During this period, flows from the Colusa Basin flow south through the Knights Landing Ridge Cut toward the Yolo Bypass. This makes calculations of the drainage of this basin difficult, because the diverted flows are not measured. Waters diverted into the Ridge Cut do not enter the Delta until they reach the lower end of the Yolo Bypass above Cache Slough. In 1997, the CBD1 gates were closed in January. The total discharge into the Sacramento River from the CBD1 for 1997 was 284,000 acre-feet.

Figure 4-21 Sacramento River Watershed Agriculture Drains



The Sacramento Slough originates as a toe drain in the Sutter Bypass to the east of the Sacramento River. At Karnak Pumping Plant, Reclamation District 1500 pumps its agricultural drainage over the levee into the toe drain. From that point, the combined waters are referred to as the Sacramento Slough. It travels southeast across the width of the Sutter Bypass, entering the Sacramento River just above the confluence of the Sacramento and the Feather River. During flood events, the Sacramento River and Sutter Bypass flows overwhelm the Sacramento Slough, and Reclamation District 1500 discharge enters the commingled waters east of the levee.

Agricultural Land Use and Cultural Practices

During 1998, DWR delineated about 2 million acres of cropland in the Sacramento River watershed. Table 4-1 shows the breakdown of cropland in the region. The 1998 data show that rice was the major crop grown, representing over 25% of the total crop acreage. Pasture and alfalfa together total 457,000 acres (23%), and fruit and nut crops total 358,000 acres (18%) (DWR 2000). Cultural practices used for producing these major crops contribute significantly to the seasonality of contamination by agricultural drainage. Pesticides, fertilizers, and crop residues find their way into agricultural drains and into the Sacramento River. Some of this transport occurs through irrigation water while rainfall and runoff provides another vehicle for transport. Table 4-20, discussed earlier, shows statewide totals for major pesticide use on crops found in the region.

PESTICIDES. Dormant sprays control insects and diseases on fruit and nut crops. Rainfall after an application can carry these pesticides into the agricultural drains. Pesticides and fertilizers applied during growing season to fruit and nut orchards can be transported in irrigation water where flood irrigation is used. Residual pre-emergent herbicides used to maintain clean orchard floors and ditch banks can be transported in irrigation water and winter runoff. Copper products used as fungicides during the dormant season can be transported off site during rainstorms.

Alfalfa and pastures often receive little fertilization. Alfalfa is a nitrogen-fixing plant eliminating most fertilization after start-up. Alfalfa pest-control can include controlling alfalfa weevil in the early spring and several lepidopterous pests during the summer. Crops such as alfalfa and pasture receive less insecticide than other crops because they are grown for feed, reducing the need for cosmetic protection. Herbicides are used to control certain problem weeds in alfalfa fields. Healthy stand establishment is a major cultural goal to provide competition for weed species.

Wheat often is treated for broadleaf weeds. Traditionally 2-4,D has been used for this purpose in late winter/early spring. Phenoxy compounds such as 2.4-D can drift and cause contamination of adjacent waterways. Insecticide use for aphid control also is an early-season practice. Subsequent spring rains following treatment can cause transport of these pesticides to waterways.

Rice is a major crop in the valley, and both flooding and pesticides are used for pest control. Both paddy rice (for human consumption) and rice for seed are grown in the Sacramento basin. Rice grown for seed requires extra effort to avoid contamination by paddy rice seed; weed species not only reduce yields but also diminish the value of the seed rice through weed-seed contamination.

Rice can be grown without standing water, but water is used to control weeds by maintaining a flooded environment after seedling establishment. This cultural practice has resulted in the development of weeds that can thrive in the aquatic environment. The use of aquatic rice herbicides such as molinate, thiobencarb, and propanil, and the problems caused by transport of these herbicides was discussed in detail in previous sanitary surveys (SWP Sanitary Survey Update 1990, 1996**;** Archibald & Wallberg and others 1995). Rice-herbicide problems have been largely resolved through efforts of growers and government agencies. The use of 30-day holding periods where fields containing herbicides are not allowed to discharge while the herbicides are volatilized and degraded has sharply reduced herbicide concentrations of ordram and molinate in the Sacramento River.

Control of rice water weevil takes place during stand establishment in early spring and introduces insecticides directly into the aquatic environment of the rice field. Pesticide use reports also show large applications of copper sulfate on rice for control of algae.

Rice field discharge of pesticides is of concern May through July, after the holding periods for herbicides are completed. Following this, rice field irrigation may continue to provide transport, because water is moved through rice paddies to maintain fresh water. The next period of concern is late summer/fall when the fields are drained completely to prepare for harvest; this coincides with lower flows in the Sacramento River. Transport of pesticides is less of an issue during post-harvest period, but other parameters of concern such as salts and carbon are transported during this time.

NUTRIENTS. Nitrates and nitrites are regulated under State and federal primary maximum contaminant levels (MCL). The EPA has set criteria for nitrate and ammonia but not for phosphorus. The MCL for nitrate in drinking water is 10 milligrams per liter as nitrogen (mg/L as N) or 45 mg/L as nitrate (EPA 1986). Nutrients in general may induce algal growth, which can lead to physical clogging of facilities. The breakdown of algae can increase carbon levels, and certain types of algae cause taste and odor problems.

Sacramento Valley agriculture utilizes petrochemical fertilizers on the majority of crops. Mature orchards receive a controlled amount of fertilizers, which are often applied to the surface and watered in. This can lead to transport off-site. Rice receives a soil preplant application of fertilizer and may receive an early application of water-run fertilizer.

SALTS. Despite similar agricultural acreage totals for both the Sacramento and San Joaquin basins, the concentrations of salts, organic carbon and nutrients are lower in the Sacramento River than in the San Joaquin River. The Sacramento River has the benefit of Lake Shasta and Lake Oroville to provide more dilutional flows to the agricultural drainage entering the river, resulting in lower salt concentrations.

ORGANIC CARBON. The Sacramento Basin contains more than 2 million acres of irrigated cropland, as well as thousands of acres of nonirrigated rangeland. A number of State and federal refuges have restored former agricultural land to native habitats, including wetlands. Riparian habitat also is found extensively along the Sacramento River and certain tributaries, although these are just a remnant of historic wetlands. The majority of the riparian areas outside the immediate river and stream courses have been converted to cultivated agriculture. All of these land-use changes have increased the organic carbon load to the river. As discussed for the previous parameters, the dilutional flows from the Shasta and Oroville reservoirs provide a low carbon source to reduce carbon concentrations during summer and fall.

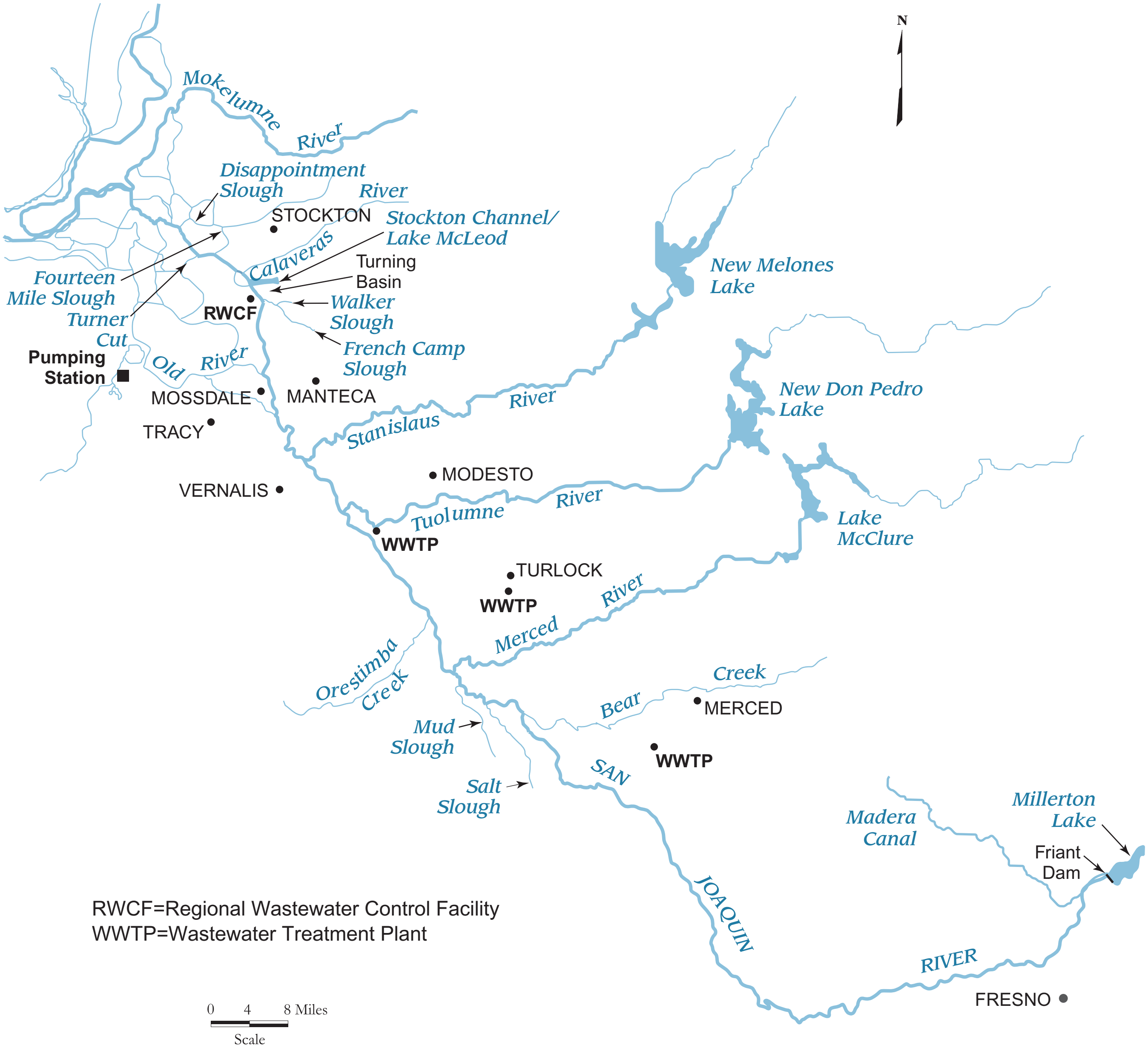
A half-million acres of rice generates a significant amount of organic carbon available for degradation and transport. The mandated reduction of rice straw burning to meet air quality goals has changed the way rice straw is disposed of, especially in the area of water management. The water quality impacts of these new disposal mandates are unknown. Besides crop residues, other vegetation and organisms are available for decomposition and transport into the drain water. An increasing amount of rice acreage is flooded in the fall following harvest. The economics of waterfowl hunting has also encouraged increased rice-field flooding. Some reclamation districts practice recirculation to avoid discharge to the Sacramento River, but this is done primarily to reduce rice herbicide discharge. No studies have been conducted to track the effects of these changes in cultural practices on carbon loading amount and timing.

4.2.6.4 San Joaquin River Basin

The San Joaquin Valley is a segment of California's Great Central Valley and is divided into 2 parts (USDA 1998). The Tulare Lake Basin comprises the southern part and has little or no impact on the water quality flowing into the Delta. Documents such as the CALFED environmental impact statement/environmental impact report (EIS/EIR) combine both basins in their discussion of land use in the San Joaquin Valley. The San Joaquin River and its tributaries occupy the northern section and are discussed further in this section.

The drainage area of the San Joaquin River above Vernalis is 13,356 square miles, including 2,100 square miles of drainage contributed by the James Bypass (Figure 4-22). Most of the inflow to the river originates from the upper watershed tributary streams between the Mokelumne River and the San Joaquin River on the west slope of the Sierra Nevada. Roughly 70% of the annual flow comes from the east-side tributaries—the Stanislaus, Tuolumne and Merced rivers—and is low in most contaminants of interest for drinking water. The remainder of the flow comes from tailwater runoff, drainage from Mud and Salt Sloughs, and groundwater accretions (UC 1999).

Figure 4-22 San Joaquin River Watershed from the Upper San Joaquin River to the Deep Water Ship Channel



RWCF=Regional Wastewater Control Facility
WWTP=Wastewater Treatment Plant

Base map provided by Lee, G.F. and R.A. Jones-Lee. 2000a

There are 57 major reservoirs in the eastern tributaries' watershed, 4 of which have a storage capacity of more than 1 million acre-feet: New Melones on the Stanislaus River, New Don Pedro on the Tuolumne River, Lake McClure on the Merced River, and Millerton Lake on the San Joaquin River mainstem.

Surface water quality is degraded in the valley from various sources. The main sources are agricultural return water, confined animal facilities, wastewater discharges, riparian runoff and groundwater discharges. There are little data on pathogens. The exact allocation of contaminant loads to these various sources is unknown but is being studied by various agencies.

The San Joaquin River near Vernalis is the southern boundary of the Legal Delta. Upstream of the station, there is no tidal influence, and the water quality (except bromide and perhaps minor atmospheric deposition) is mainly influenced by natural and anthropogenic activities in the watershed. The water quality at Vernalis is strongly influenced by San Joaquin River inputs into the southern Delta.

Agricultural Land Use and Cultural Practices

Almost 2 million acres of irrigated cropland in the San Joaquin River watershed were delineated by DWR in 1998. Table 4-2 shows the crop acreage in the watershed. Agriculture pesticides and fertilizers that end up in the runoff from cropland are discharged to the San Joaquin River and its tributaries. Besides pesticides and nutrients, salts, bromide, selenium, and boron are discharged through agricultural drainage. Although there are little data on total loads, organic carbon is generated from agricultural activities and likely contributes significantly to the loading of carbon into the Delta.

Despite the large quantity of pesticides used within the basin, the loading of carbon, salts, bromide, and nutrients from agricultural drains to the San Joaquin River is considered the main source of degradation to water quality.

PESTICIDES. Pesticides are applied based on acceptable practices, and the timing of such applications also determines the potential for contamination in runoff. Studies have found that some pesticides are detected during the irrigation season, indicating that pesticides are being transported in irrigation runoff (Kratzer and Shelton 1998.) Twenty-two percent of the cropland in the basin is almonds and other deciduous crops. The use of dormant spray oils and organophosphate insecticides as a BMP in orchards has led to runoff of dormant-season insecticides during rainstorms (Kratzer and Shelton 1998).

NUTRIENTS. Fertilizers are widely used in the valley for agriculture. In 1990, Fresno, Kern, and Tulare counties were the top 3 counties in fertilizer usage in the nation (Kratzer and Sheldon 1998). However, nutrient loads contributed by agricultural sources have not been quantified for the Delta. Consumption of oxygen due to algal growth/decomposition has reduced dissolved oxygen levels in the lower San Joaquin River (near Stockton) below levels required to sustain aquatic life.

SALTS. The major water quality problems in the San Joaquin River are caused by the high loading of salt, selenium, and boron in the displaced groundwater and surface return irrigation water discharged to the river. Both federal and State water quality objectives have been developed to protect fish and wildlife, to protect riparian agricultural irrigation diverters in the south Delta, and to protect municipal and industrial water agencies and users that divert water from the Delta (UC 1999).

Salt contributions from the San Joaquin River drainage are mainly the result of recirculated seawater in irrigation surface and subsurface drainage. The source water for irrigation on the west side of the San Joaquin is from pumped Delta water containing seawater and agricultural runoff from the Delta and Sacramento River, as well as recirculated San Joaquin River water. This coupled with the shallow water table and naturally occurring minerals found in the soils has led to higher concentrations of selenium, and boron, and other salts entering the San Joaquin River.

Additional sources of salt include wastewater discharges, fertilization, and CAFO drainage. Commercial agriculture is made possible by supplemental irrigation with surface and groundwater (UC 1999). Leaching of salts and trace elements occurs as the water percolates through the soil. In certain areas that are underlain by low permeability clay soils, the shallow water table (5 to 10 feet) rises and may cause water logging in the root zone. As the water evaporates, salts and trace elements become more and more concentrated reducing crop productivity, unless artificial drainages (tile drains) are installed.

Salt concentrations of San Joaquin River near Vernalis has doubled since the 1940s. This has been due to construction of reservoirs on east-side tributaries and substitution of poorer quality Delta water in lieu of San Joaquin River water to irrigate west-side agricultural lands (CVRWQCB 1998). San Joaquin River flow upstream of the Merced River is dominated by agricultural return flows for most of the year (USBR and others 1996). The agricultural flows are a combination of surface runoff flows (tailwaters) and subsurface agricultural drainage (CVRWQCB 2000) (Figure 4-23). The Grasslands watershed is a 370,000-acre subbasin of the San Joaquin Valley, west of the San Joaquin River. Soils in the area have a high salt content, low permeability, and a high water table. About 100,000 acres in the watershed are wetland refuges. The Grassland Bypass Project collects drainage from approximately 100,000 acres of irrigated land (Figure 4-24). The project was started in 1996 to divert agricultural tile drainage away from the wetlands and wetland water supply channels. In addition, the Grassland Bypass Project avoids discharges to Salt Slough and a portion of Mud Slough; discharges enter the lower portion of Mud Slough, 6 miles upstream of the San Joaquin River.

Figure 4-23 Discharge of San Joaquin River Tributaries as Percentage of Mean Annual Total

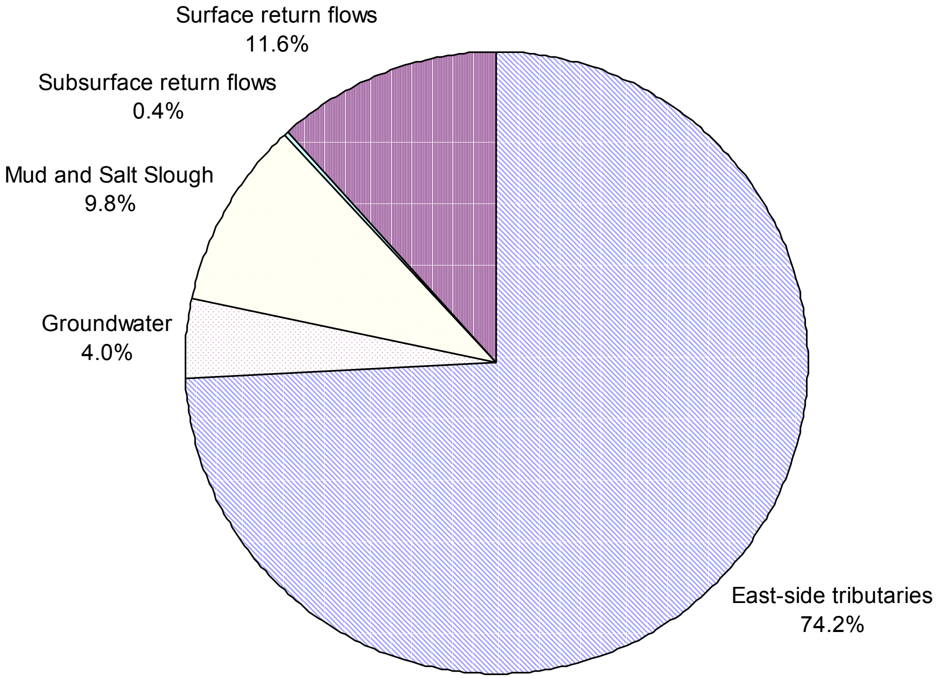
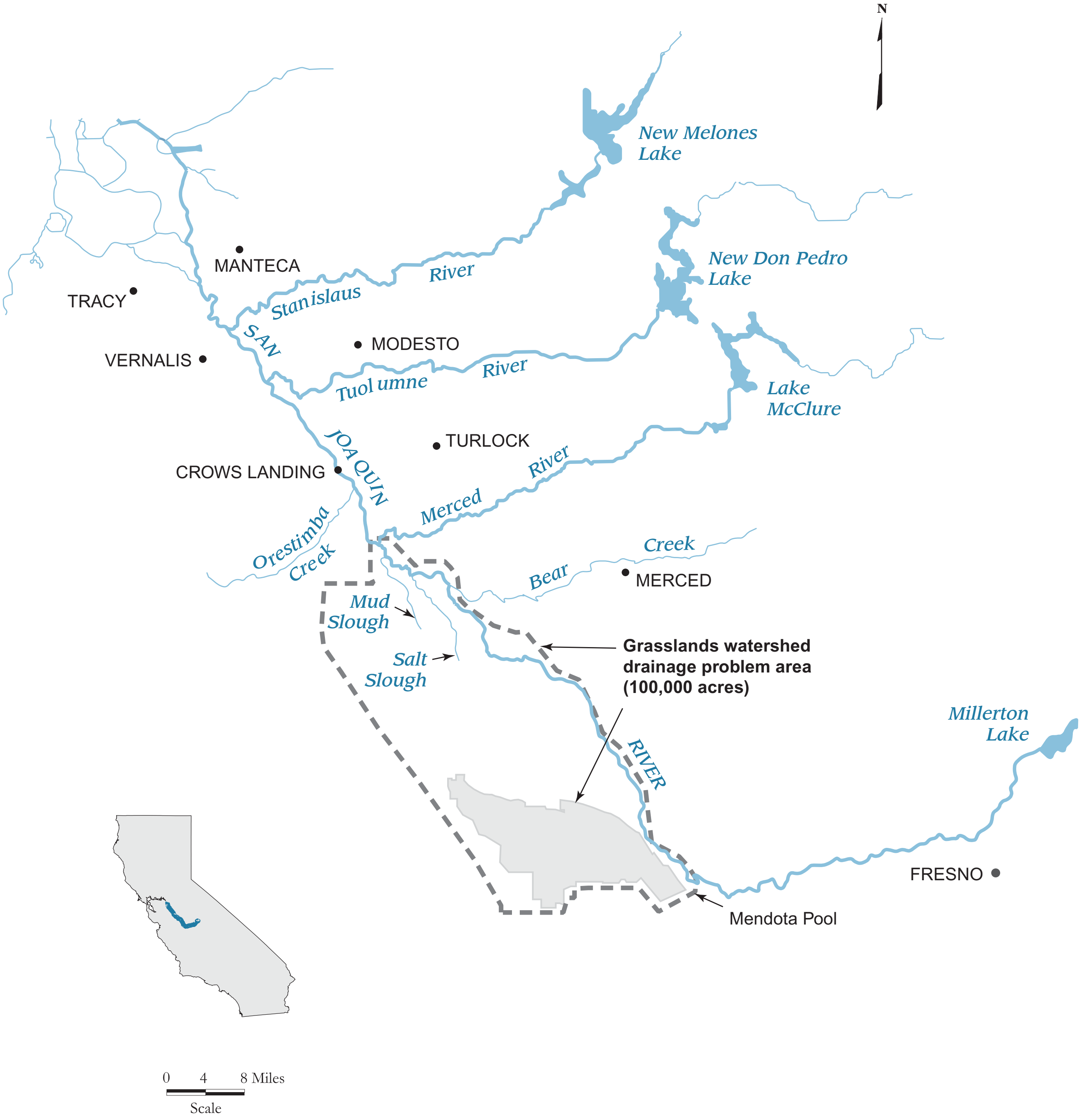


Figure 4-24 San Joaquin River Watershed from Mendota to Vernalis



The Grasslands Water District provides water to the area that eventually drains into Mud and Salt sloughs, which flow north into the San Joaquin River (CRWQCB 2000a). The area has a shallow water table that requires artificial subsurface systems (tile drains) in order to control soil salinity in the plant root zone. Disposal of tile drainage poses a serious problem because of high concentrations of contaminants such as selenium, boron, molybdenum, and salts. In 1977 the 2 sloughs contributed about 43% of the total salt load into the San Joaquin River. This was about 450,000 tons of salt (UC 1999). During water year 1998, the project accounted for less than 1% of the San Joaquin River flow but 8% of the salt load, 25% of the boron load and 55% of the selenium load at Vernalis (CRWQCB 2000b).

ORGANIC CARBON. Almost no TOC or DOC data exist for sites in the watershed of the San Joaquin River basin, except at Vernalis. Potential sources include the wildlife refuges and agricultural runoff from the Grasslands drainage area, as well as east-side agricultural runoff, urban runoff, dairies, and wastewater treatment plants. The lack of organic carbon data in the San Joaquin River watershed indicates a need for studies to be conducted with salt reduction programs because runoff control could also benefit water quality for carbon loading.

4.2.7 GEOLOGIC HAZARDS

The California State Legislature mandates that the physical characteristics of the Delta remain essentially in their present form (CALFED 2000c). This mandate is necessary to protect the beneficial uses of the Delta. The key to preserving the Delta's physical characteristics is its levee system.

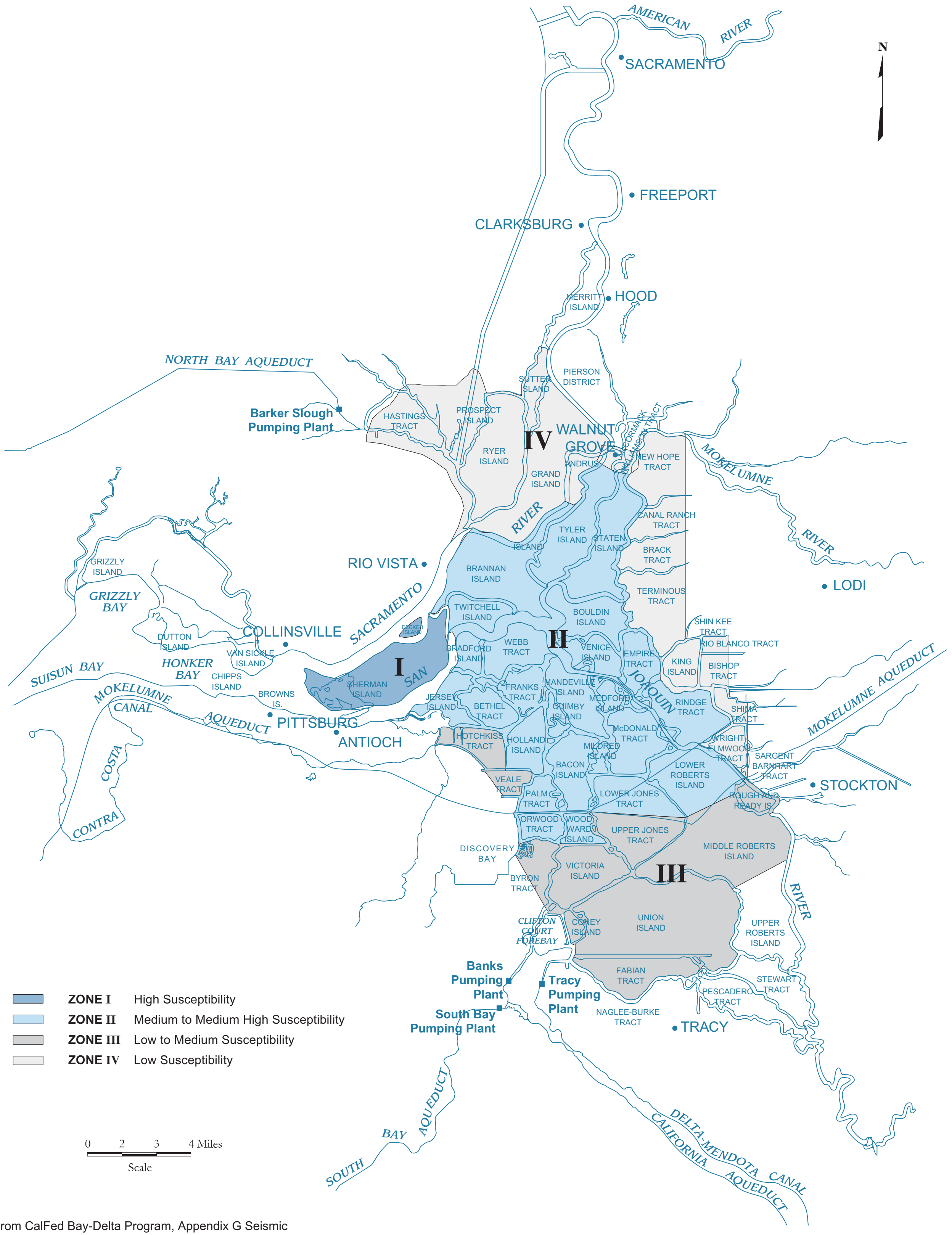
The vulnerability of the Delta levee system, especially during earthquakes, or periods of high runoff, is an abiding concern. Earthquakes pose a catastrophic threat to Delta levees. Seismic forces can cause multiple levee failures in a short period. Along with numerous other impacts, a levee failure in the central or western Delta could disrupt or interrupt water supply deliveries to urban and agricultural users. If a levee failed in a dry or critically dry water year and one or more key western or central Delta islands flooded, inundation would allow salinity to intrude farther upstream into the Delta. Collapsed islands can cause longer seawater residence-time in the Delta by reducing dilution and flows to retard salinity. Drinking water quality could be impaired by high TDS and bromide from seawater and higher TOC/DOC released from flooded peat-soil islands. The salinity intrusion could result in water supply interruption for in-Delta and export use by both urban and agricultural users until the saltwater could be flushed from the Delta. In order to lower salinity in the Delta to acceptable levels and restore ecological balance, flushing flows would need to be released from upstream reservoirs. As a result, water supplies in these reservoirs could be seriously depleted, and the ability to respond to other demands would be compromised.

This doomsday scenario has historical precedent. In the summer of 1972, the southern levee protecting Andrus Island gave way. Normal releases from upstream reservoirs were incapable of maintaining the hydraulic barrier against salinity intrusion in the Delta, and saltwater moved up into the Delta. Both the SWP and the CVP immediately reduced exports until increased releases from upstream reservoirs could restore the hydraulic barrier. Salinity in the western Delta fell. In the central and southern Delta, flushing effects were less effective, and saltwater was removed by local and export pumping, causing adverse effects on domestic water supplies (CALFED 2000c).

The primary seismic threat to the Delta is levee failure resulting from lateral displacement and deformation, with resultant breaching or mass settlement caused by ground shaking and liquefaction of levee materials. Many levees include sandy sections with low relative density and high susceptibility to liquefaction. Therefore, the seismic risk to Delta levees varies significantly across the Delta, depending on proximity to the source of the earthquake and the conditions of the levee and levee foundation.

There has never been a levee failure caused by a seismic event; however, no appreciable seismic activity has occurred in the Delta with the levees at their current size. In 1998, a Seismic Vulnerability Subteam began a seismic risk assessment of Delta levees (CALFED 2000a). The team was composed of seismic experts and geotechnical engineers with experience in the Delta. The study subdivided the Delta into 4 damage potential zones (Figure 4-25). Seismic vulnerability was highest in Zone 1, Sherman Island, because of poor levee embankment and foundation soils and higher exposure to seismic shaking at the western edge of the Delta. Zone II, the Central Delta, had the next highest overall level of seismic levee fragility and exposure to seismic shaking. Levees in the southern and western periphery of the Delta as well as on the northern and eastern periphery of the Delta were determined to have low to medium susceptibility to seismic movement.

Figure 4-25 Damage Potential Zones Within the Delta



From CalFed Bay-Delta Program, Appendix G Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees

Currently, the greatest threat to levee stability is overtopping and seepage during flood flows (CALFED 2000c). Since their reclamation, numerous islands have flooded, often more than once, and some of the flooded islands have never been reclaimed. Since the beginning of the 20th century, the rate of sea level rise has been between 1 and 3 mm/year. If sea level continues to rise in response to climate change at the present rate, levees will become further inundated and threatened by increased water surface levels, wave erosion, and associated problems. Because much of the Delta is at or near sea level, it is likely to be directly affected by rising sea levels. Levee heights may need to be increased to prevent levee overtopping and subsequent failure (CALFED 2000c). The EPA projects a sea level rise of 6.5 inches by 2050 in the San Francisco Bay area. Other calculations estimate sea level rise between 3 and 6 inches by 2050 at the Golden Gate Bridge. Using the upper range of sea level rise would produce an increase of 4 inches in surface water elevation near Venice Island in the mid-Delta. A sea level rise of 3 inches would produce a 2-inch water-surface rise in the Delta (CALFED 2000c).

4.2.8 SEAWATER INTRUSION

Seawater intrusion has the greatest effect on Delta water quality, especially on salinity, TDS, EC, and bromide concentrations. Most of the bromide that is introduced into the Delta and lower Sacramento and San Joaquin rivers comes from seawater. The EC of seawater is approximately 50,000 µS/cm and contains approximately 66.8 mg/L bromide, more than 1,300 times the 0.05 mg/L CALFED target concentration for Delta export waters. DBPs are formed from the interaction of bromide with disinfectants, such as chlorine or ozone, during water treatment. This interaction produces unwanted, potentially carcinogenic compounds. Bromate, a DBP, may have the highest cancer-causing potential of the measured DBPs (CALFED 2000). Bromate is an inorganic byproduct formed by the ozonation of water containing bromide. While seawater intrusion is considered a major source of salinity in the Delta system, salts can also be discharged to source water from urban and agricultural discharges, confined animal facilities, and wetlands and mines (CALFED 2000b). Salt levels in municipal water supplies can result in reduced opportunities for water recycling and groundwater replenishment, economic impacts to both industrial and residential consumers because of corrosion of appliances and plumbing, and lack of consumer acceptance because of salty taste (CALFED 2000). Since the CALFED program calls for significantly more water recycling and reuse to stretch scarce supplies, the saltiness of water supplies will directly affect the ability to meet the CALFED goals in this area.

Seawater intrusion is generally not a drinking water problem for the main stem of the Sacramento River because of high flows and the narrow channel. The northern Delta region has better water quality than the southern Delta because of the upstream releases of high quality freshwater down the Sacramento River (CALFED 2000d). When compared to the secondary MCL for TDS of 500 mg/L, or the proposed bromide target level at the export pumps of 50 µg/L, the Sacramento River meets these values. The water contains relatively low TDS concentrations (about. 100 mg/L) and little bromide (about 20 µg/L) (Amy and others 1998). During drought conditions, the Sacramento River may be the only freshwater source for the Delta (DWR 1994). Agricultural drainage can also be a source of salts to the Sacramento River. However, when compared to the San Joaquin River, the generally higher quality of river water and the higher river flows results in substantial dilution of drainage and relatively little adverse impact on Sacramento River water quality. Water in the Sacramento River (at Freeport) is of much higher quality compared to the San Joaquin River (near Vernalis). The 340 µs/cm CVRWQCB objective for the Sacramento River at the I Street Bridge was never exceeded between water years 1986 and 1997 (CALFED 2000b).

In the Delta, seawater intrusion is the major source of salinity and bromide (CALFED 2000d) and a major problem during periods of low Delta outflow (CALFED 2000). Although, the average annual freshwater flow from the Sacramento makes up approximately 62% of the inflow into the Delta, this inflow is volumetrically small in comparison to tidal exchange with San Francisco Bay (Amy and others 1998). In general, the quality of water in the west Delta is strongly influenced by exchange with the Bay. In the south Delta, water quality tends to be poorer because of the combination of inflows of poorer water quality from the San Joaquin River, discharges from Delta islands, and the effects of diversions that can sometimes increase seawater intrusion from the bay (CALFED 2000d). Agricultural drainage, particularly from the San Joaquin Valley, is also an important source, especially in the south Delta. However, as discussed below, much of the San Joaquin River salt reflects recirculation of salts from the agricultural irrigation water obtained from the DMC, and the bromide loads appearing in the San Joaquin are mainly due to seawater intrusion and the recycling of ocean-derived bromide from areas irrigated with Delta water (CALFED 2000d).

A panel of drinking water experts convened by CALFED cited bromide, dissolved solids, and salinity as constituents of concern in Delta waters (CALFED 2000). A nationwide survey found that bromide levels in Delta waters are typically in the 90th to 95th percentile of levels found nationwide (DWR internal report). This means 90% to 95% of the nation's drinking water sources have bromide levels lower than levels typically found in the Delta. The results of seawater intrusion are reflected in the water quality delivered through the California Aqueduct. For example, DWR's Division of Operations and Maintenance (O&M) attributed increases in California Aqueduct bromide and TDS levels at the end of 1997 and 1998 to seawater intrusion (DWR 1999a, 2000a).

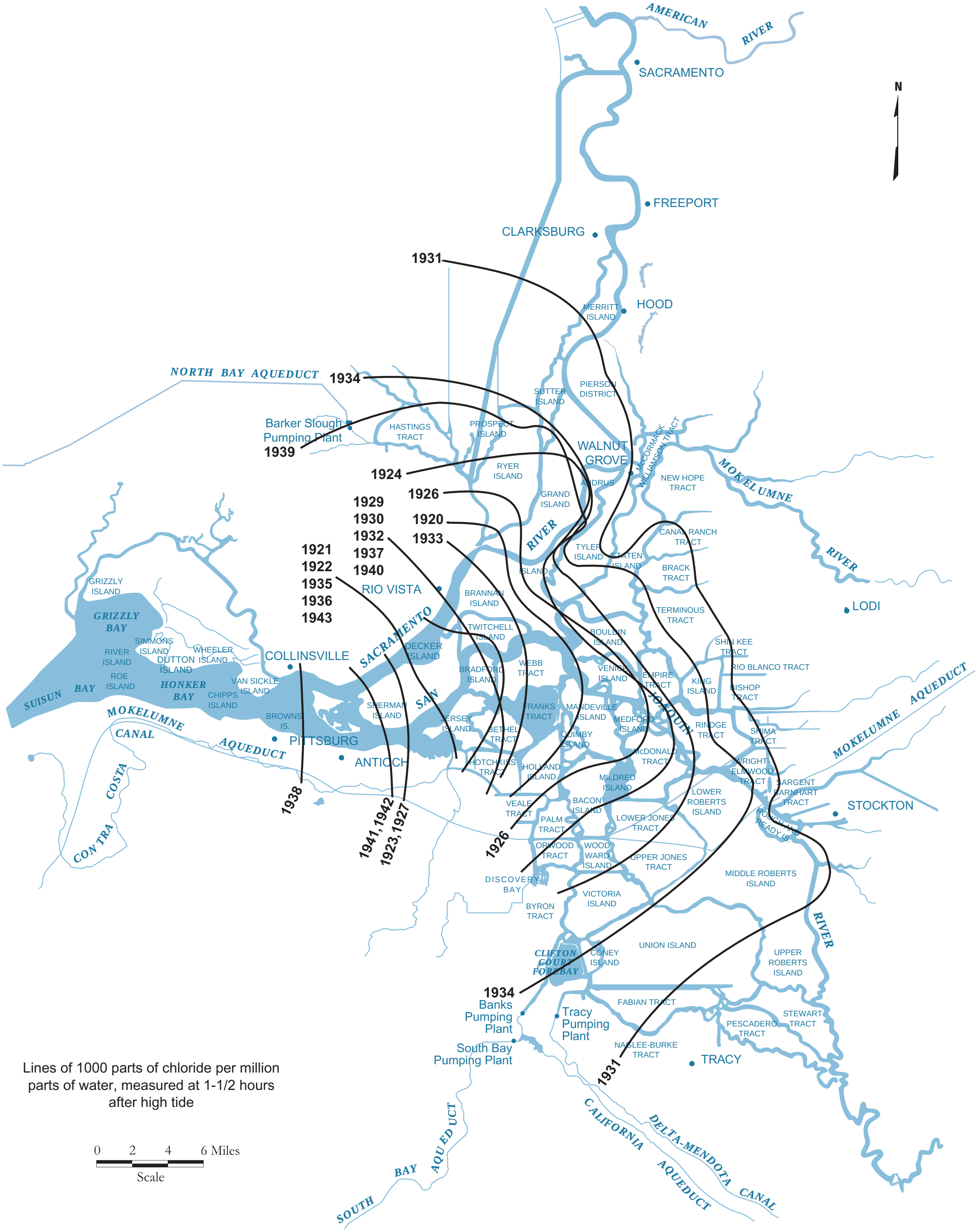
In addition to seawater and recycling of agricultural drainage water from the Delta, other sources of bromide in the Delta include methyl bromide used for fumigation and connate waters (ancient seawater) beneath some Delta islands (for example, Empire Tract), discharges from olive-processing facilities, municipal wastewater treatment plants, and disinfectants used in spas (Amy and others 1998; CALFED 2000). Relative to seawater, olive processing facilities, municipal wastewater treatment plants, and disinfectants used in spas are minor sources of bromide to the Delta (Amy and others 1998).

The relative loads of bromide in the system and the ionic ratios between bromide and chloride indicate that most of the bromide load in the San Joaquin River is from seawater intrusion (CALFED 2000). However, when compared to the Sacramento River Basin, salinity issues in the San Joaquin River are complex. If the study area is expanded to include the San Joaquin and Tulare basins, about 38% or 2.7 million acre-feet is imported into the area from the Sacramento-San Joaquin Delta through the California Aqueduct and the DMC (federal CVP) (Gronberg and others 1998). Water imports into the San Joaquin River Basin have higher salt concentrations and loads because the water source is the Delta (CALFED 2000b).

Central Valley farmers manage salt buildup in their arid soils by leaching salt from the soils. This practice results in highly saline agricultural drainage being discharged into the San Joaquin River, which is the conduit for removal of salt from the San Joaquin watershed (CALFED 2000). The CVP pumps at Tracy receive the highest percentage of San Joaquin River water because the plant operates continuously (CALFED 2000). Most of this water, diverted to the DMC, is used for irrigation in the San Joaquin watershed. Thus, a combination of "new" Delta water and recirculated San Joaquin/Delta water is reintroduced back into the valley for irrigation and salt leaching. This reuse of return agricultural drainage through the San Joaquin River creates a cycle by which salts are moved from the Delta into the San Joaquin Valley, back to the Delta, and back to the valley again. Thus, some of the salt and bromide load leaving the valley via the San Joaquin River was originally introduced to the valley from the Delta as a result of seawater intrusion (CALFED 2000).

Prior to the operation of Shasta Dam in 1943, the upper edge of the seawater gradient in drier years moved well up into the northern and southern Delta reaching as far as Courtland and beyond in the northern Delta and as far as Stockton in the southern Delta (Figure 4-26). Today, seawater intrusion in the Delta is primarily controlled by operating the SWP and the CVP to create a hydrostatic barrier against tidal influences. The extent of seawater intrusion from 1944 to 1990 was less than in preproject years (Figure 4-27). However, the Delta is operated in an ever more complex manner in an attempt to meet a growing list of criteria (see Section 4.5.3). The criteria are primarily contained in Water Rights Decision 1641 and Decision 1422 promulgated by the SWRCB, the Winter-run and Delta Smelt Biological Opinions, and the Cooperative Operations Agreement between the CVP and the SWP. Operations of the SWP and CVP facilities, both upstream and in the Delta, are often constrained by flow and water quality standards throughout the year with flow and water quality criteria factored into their delivery capabilities during any given year. Operations are adjusted as needed to ensure that flow and water quality standards are met. Additionally, the SWP and the CVP operate under numerous water rights and agreements with local agencies such as North Delta and South Delta Water agencies. The water quality standards protect water quality for municipal and industrial use, agricultural uses, and fish and wildlife.

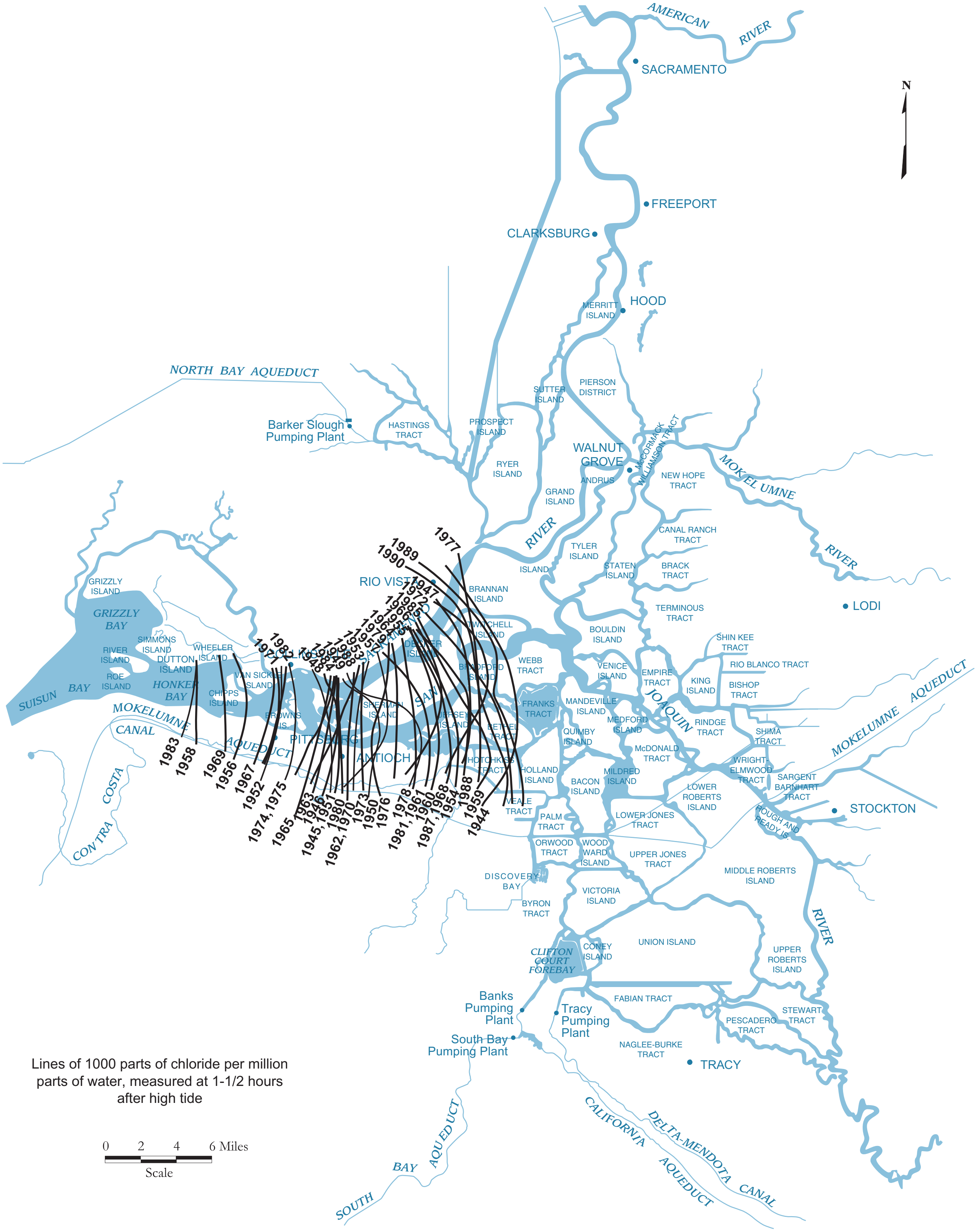
Figure 4-26 Maximum Salinity Intrusion, 1921-1943



Lines of 1000 parts of chloride per million parts of water, measured at 1-1/2 hours after high tide

Source: Department of Water Resources, Sacramento - San Joaquin Delta Atlas, 1993

Figure 4-27 Maximum Salinity Intrusion, 1944-1990



Lines of 1000 parts of chloride per million parts of water, measured at 1-1/2 hours after high tide

Source: Department of Water Resources, Sacramento - San Joaquin Delta Atlas, 1993

Currently, EC and chloride are the only drinking water criteria considered in operating reservoirs and Delta facilities. Municipal and industrial uses are directly protected by limiting chloride, which must not exceed 250 mg/L at all export locations. Chloride at the Contra Costa Canal must not exceed 150 mg/L for a specified number of days. Standards for the protection of agriculture and fish and wildlife are based on EC. These also serve to protect municipal and industrial sources.

The effects of year type (dry or wet) combined with pumping demands often create a difficult balancing act with respect to seawater intrusion. Seawater intrusion becomes most critical during periods of drought. The highest demands on pumping at Banks Pumping Plant generally occur in summer and late winter. In summer, water is required for environmental, municipal, industrial, and agricultural users. In winter, SWP operations may take advantage of winter rains to refill depleted reservoirs. Under low rainfall conditions, most available rainwater may be directed toward storage, with less runoff available to help maintain the hydrostatic barrier in the Delta. This leads to increased concentrations of bromide and salinity in Delta exports. While the increase in seawater, both in summer and winter, may still meet statutory EC and chloride requirements, unregulated bromide concentrations may increase. In contrast, during wet years, there is sufficient fresh water to meet both environmental and municipal demands in the summer, refill depleted reservoirs in the winter, adequately meet or exceed minimum EC and chloride requirements, and maintain a strong hydrostatic barrier against seawater intrusion.

4.2.9 ORGANIC CARBON

Natural organic matter has many origins in the Delta including organic soils and sediments, algal growth, agricultural activities, animal waste, storm water runoff from both urban and natural sources, riparian growth along channels, wetlands and wastewater treatment plants (Brown and Caldwell and others 1995). Soils with high organic carbon content, such as peat, are more significant contributors of organic carbon than are mineral soils. Drainage discharges from Delta peat soil islands are sources of DOC in the Delta. Organic carbon is created primarily by plant photosynthesis. Decaying crop material, becoming humus, is another organic carbon source (Brown and Caldwell and others 1995). When vegetation decays, large humic and fulvic acid molecules are produced that subsequently enter watercourses. It is these complex organic compounds that are believed to contribute most to the presence of DBP in drinking water supplies (Woodard 2000).

Organic carbon is the basic and essential precursor in the formation of potential cancer causing DBPs. The Surface Water Treatment Rule requires that all systems treating surface water disinfect the raw water. Oxidants, such as chlorine used in the disinfection of drinking water react with organic carbon to form trihalomethanes (THMs) and haloacetic acids (HAAs). Total trihalomethanes refers to the sum of 4 varieties of THMs. Haloacetic acid 5 is the sum of 5 haloacetic acid compounds. In the presence of bromide and free chlorine, organic carbon reacts to form brominated DBPs. Some brominated DBPs may also be carcinogenic, and certain DBPs (for example, chloroform) can be formed in the absence of bromide, but not in the absence of carbon. DBPs are a public health concern that will be more stringently regulated in the near future (CALFED 2000).

CALFED has reviewed Delta water quality issues and has identified organic carbon as a parameter of concern; however, there is limited knowledge of baseline TOC conditions at key Delta locations and tributaries. There is also limited understanding of TOC loads in the system (CALFED 2000d). The same could be said for DOC.

Data show that most of the organic carbon in the Delta is in the dissolved form (CALFED 2000d). By operational definition, DOC is the fraction that passes through a 0.45 µm pore sized filter. TOC consists of both the dissolved phase and particulate organic carbon fraction, which does not pass through the 0.45 µm pore sized filter. Studies conducted by DWR found that approximately 94% of the TOC measured in the fresh water inflows to the Delta from the American, Sacramento, and San Joaquin rivers were composed of DOC (Woodard 2000). DOC concentrations in drinking water diversions from the Delta are nearly twice those in the Sacramento River, reflecting inputs from many sources. The North Bay Aqueduct (NBA), which is outside the legal boundaries of the Delta but is connected to the Sacramento River via Lindsey and Cache sloughs, experiences some of the highest TOC and DOC concentrations of any of the SWP facilities.

At a drinking water plant, most of the organic carbon that reacts with oxidants to form DBPs is in the dissolved form (CALFED 2000d). Particulate organic carbon is reduced by several pretreatment drinking water procedures designed to remove particulate matter (for example, coagulation, sedimentation, and filtration). The removal of organic matter prior to disinfection reduces the production of DBPs. To some extent, DOC can be removed through the treatment process; however, its removal is not as efficient as that of particulate organic carbon (Woodard 2000). Moreover, DOC is typically more reactive than TOC in forming DBPs. Therefore, DOC concentrations are more reliable predictors of DBP-forming capacity than are TOC concentrations. That is why DWR has historically focused on collecting DOC data. Water purveyors are concerned about TOC concentrations because federal and State drinking water regulations regulate TOC levels (EPA 2001). Direct measurement of DBP precursors is not practical; therefore, TOC concentrations are the proposed surrogate measurement. EPA has proposed percentage removals for TOC based on the source water TOC and alkalinity (EPA 2001).

Besides serving as a DBP precursor component, organic carbon affects drinking water treatment in 2 additional ways: 1) Pathogens may adhere to particulate organic carbon and be shielded from disinfection; and 2) oxidative disinfectants do not preferentially attack pathogenic organisms. The result is that more disinfectant is needed to oxidize the higher concentrations of organic matter and provide disinfection (CALFED 2000). As more disinfectants are used, or the contact time is lengthened, the levels of DBP formed will increase. The level of organic carbon also affects the economics associated with particle removal. Organic carbon, in and of itself, does not affect the physical removal process, but TOC levels affect the degree of coagulation, flocculation, and sedimentation required. For example, increases in TOC also increase the coagulant demand of the water, thus requiring more coagulant to effectively remove the turbidity. Enhanced coagulation for TOC removal is then required. The major factors affecting physical removal processes for Delta water in warm months are the presence and types of algae, water temperature, and pH (CALFED 2000).

Water purveyors who use Delta water have carefully analyzed the problems of meeting stringent new EPA drinking water standards. They have developed criteria for raw water contaminant levels that would enable them to meet the new EPA criteria without costly changes to treatment systems. Based on its proposals, CALFED has set a target for TOC not to exceed 3 mg/L at the export pumps (DWR 2000.).

4.3 WATER QUALITY SUMMARY

4.3.1 RECREATIONAL CONTAMINANT SOURCES

4.3.1.1 Pathogens

No data are available that quantify pathogen numbers in the Delta with recreation use. Even if sewage originates from a human source, it is difficult to know whether it comes from a boat, a malfunctioning septic system, or a sewage treatment plant. Under these circumstances, the best strategy may be prevention through installation of MSD, pump-out facilities, and restrooms.

There are 3 types of MSDs. A Type I and II treat the sewage for overboard discharge. The most common MSD, a type III, is basically a holding tank that must be pumped out at an onshore pump-out station. Boats frequently have a “Y” valve that allows boaters to direct wastes into the holding tank or directly overboard. Boats operating in the Delta or other inland waters must secure the “Y” valve handle in the closed position with a wire tie or padlock. Overboard discharges frequently are caused by intentional or unintentional misuse of the “Y” valve.

The most popular boats found on the Delta (powerboats) do not contain MSDs, whereas the majority of recreation boats have a Type III MSD. In a 1995 Boating Use Survey conducted by the Delta Protection Commission, only 15% of surveyed powerboat owners had pump-out facilities onboard (California State Parks 1997). In contrast, the survey found that more than 80% of the houseboats and 68% of the sailboats had pump-out toilets. Houseboats may have a greater potential to generate waste; however, the survey found that only 4% of surveyed boat owners owned houseboats and that the rental of houseboats had declined in recent years because of the recession in the early 1990s and changes in the tax code that reduced profits for owners (California State Parks 1997). The economic climate has changed considerably since the early 1990s; therefore, it is possible that houseboating has again gained popularity.

Although small in volume, boat sewage is highly concentrated. The California Department of Boating and Waterways (DBW) estimates that a single weekend boater flushing untreated sewage into the water produces the same amount of bacterial pollution as 10,000 people whose sewage passes through a treatment plant (DBW).

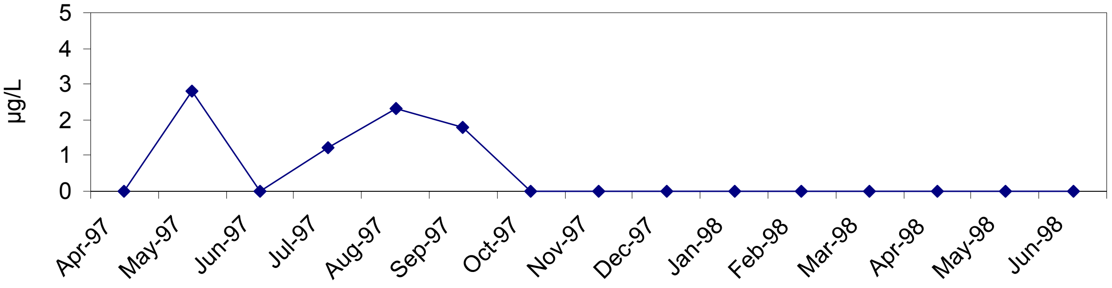
Without accurate use numbers and only sporadic coliform sampling by local agencies at Delta recreation areas, it is not possible to draw conclusions on body-water contact and pathogens. However, accidental fecal release (AFR) from body-contact sports has been estimated at 1 AFR per 1,000 recreators, with 50 to 200 grams of material released per event, according to DHS unpublished data.

4.3.1.2 MTBE

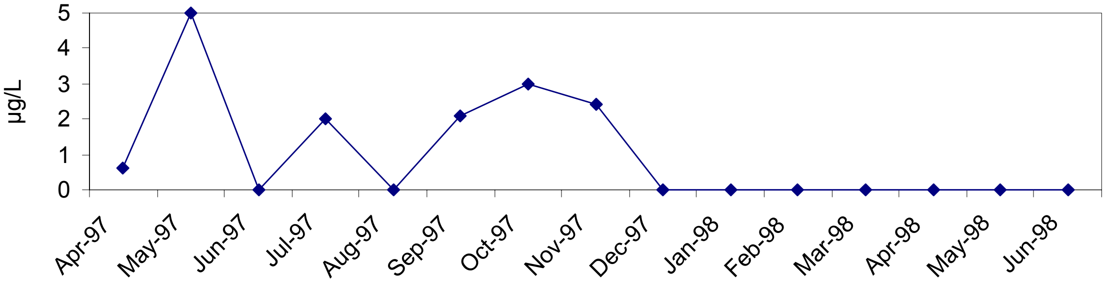
Very little information exists on MTBE and recreational boating in the Delta. From January 1997 through July 1998, DWR’s MWQI analyzed monthly samples collected from the Sacramento River at the West Sacramento Water Treatment Plant intake, from Greenes Landing/Hood, and the San Joaquin River near Vernalis. In April, MTBE was detected once in the Sacramento River at the secondary MCL. In all other cases, MTBE concentrations were below the secondary MCL of 5 µg/L (Figure 4-28). In the Sacramento River, MTBE was detected throughout spring and summer when the heaviest recreational boat use would be expected. However, MTBE was also detected as late as November. The following year, through the termination of the sampling program in June, MTBE was not detected in any month sampled. Samples collected near Vernalis showed a different pattern. Nearly identical concentrations were detected once in December, when recreational boating use would be expected to be low, and once in May when recreational boating use would be expected to be increasing.

Figure 4-28 MTBE Occurrences in the Delta

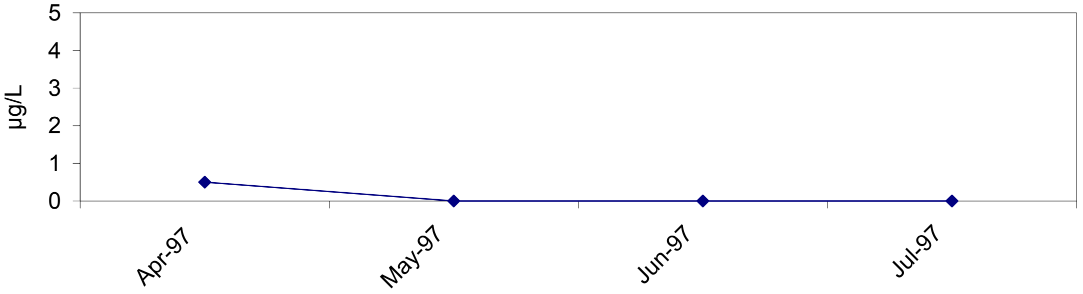
West Sacramento Intake



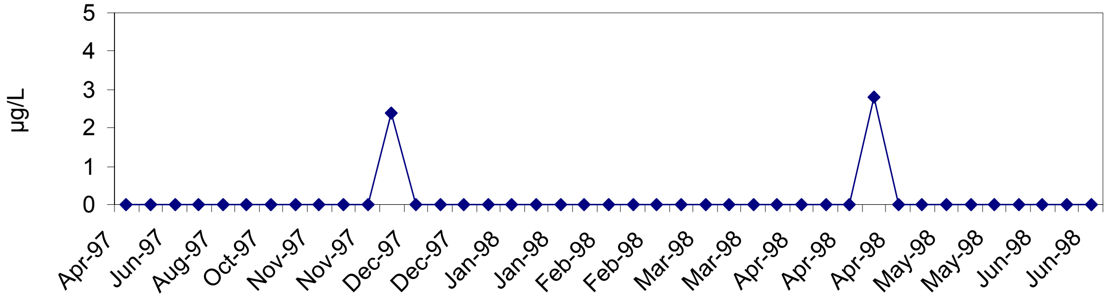
Greenes Landing/Hood



Banks Pumping Plant



Vernalis



Values less than the detection limit reported as 0.

Table 4-22 Methyl Tert-Butyl Ether Concentrations in µg/L during Heavy Boating Use, Summer 1997

	Memorial Day		Fourth of July		Labor Day	
Site	Pre-holiday use 23 May 1997	Post-holiday use 27 May 1997	Pre-holiday use 1 Jul 1997-2 Jul 1997	Post-holiday use 7 Jul 1997-9 Jul 1997	Pre-holiday use 28 Aug 1997	Post-holiday use 2 Sep 1997-3 Sep 1997
Contra Costa Pumping Plant 1	3.3	3.3	<1	5.6	<1	1.9
Station 9 (South Delta)	3.9	3.3	1.7	4.2	<1	2.7
DMC	2.4	4.2	1.6	5.6	<1	4.6

In addition to monthly sampling, DWR has also collected samples before and after major summer holidays to assess the impacts of recreational watercraft on MTBE levels. With input from DWR's Division of Planning, sites were chosen based on potential impacts from recreational watercraft. Sites were confined to the south Delta at Station 9 (Byron), Contra Costa Pumping Plant Number 1, and the DMC. Results for samples collected on Memorial Day, 4th of July, and Labor day weekends are shown in Table 4-22. At all sites sampled, prior to the holiday weekend MTBE levels were below the secondary MCL of 5 µg/L. After the holiday weekend, MTBE levels generally increased. In all cases, MTBE was never detected near the primary MCL of 13 µg/L; however, following the 4th of July weekend, MTBE concentrations exceeded the secondary MCL at the Contra Costa Pumping Plant Number 1 and DMC sampling stations.

Studies have shown that MTBE is highly volatile and has a very short half-life. Volatilization half-lives of MTBE from streams and rivers have been estimated to be approximately 3.5 to 9.5 hours, respectively (EPA 1993). This could account for the lower post holiday MTBE levels at Station 9. The potential for volatilization of the compound also highlights the importance of timing sample collection to capture the compound. All of these effects—rapid mixing, volatilization, and sample timing—are variables that affect the observed sample concentrations. The results suggest, however, that under heavy use conditions, MTBE is not as important a factor to Delta drinking water quality as it is in confined reservoirs and groundwater.

As part of a monthly mercury screening program, the CVRWQCB has also begun collecting MTBE samples from several sites in the Sacramento-San Joaquin Delta. The program is scheduled to run until March 2002. Samples are collected from sites flowing into the Delta (Sacramento River at Greenes Landing, San Joaquin River near Vernalis), in Suisun Bay between Chipps Island and Martinez, and for water flowing out of the Delta (near Bethany Reservoir and Mountain House) (Smith pers. comm. 2000). Table 4-23 lists MTBE concentrations detected in regional board sampling. MTBE is generally detected at low levels in the Sacramento River, but not in the San Joaquin. MTBE concentrations in the Sacramento River were highest in May and lowest in July and August. Because summer months are peak boating months, the lower MTBE levels may be an artifact of sampling or reflect the increased volatilization of MTBE in warmer waters. MTBE has also been detected at the Mountain House and the sampling site near Bethany. MTBE has never been detected at the sampling point between Chipps Island and Martinez. To date all concentrations have been below the secondary MCL. The data set is still too small to draw any conclusions of MTBE patterns.

Table 4-23 Monthly Concentrations of MTBE (µg/L) at Selected Sites in the Sacramento/San Joaquin Delta

Date Sampled	Sacramento River @ Greenes Landing	San Joaquin River near Vernalis	Delta 1[a]	Delta 2[b]	Delta 3[c]
4 Apr 2000	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)	ND (<5.0)
5 May 2000	3.6	0.53	ND (<0.5)	1.4	0.98
6 Jun 2000	2.6	ND (<0.5)	ND (<0.5)	2.5	ND (<0.5)
24 Jul 2000	1.4	ND (<0.5)	ND (<0.5)	2.1	1.3
21 Aug 2000	1.2	ND (<0.5)	ND (<0.5)	1.1	2.3

Samples collected monthly by the CVRWQCB as part of a mercury screening program in the Delta. The program runs from March 2000 to March 2002.

[a] Delta 1--Samples collected between Martinez and Chipps Island.

[b] Delta 2-- Samples collected at Mountain House Road.

[c] Delta 3-- Samnples collected near Bethany.

4.3.2 WASTEWATER CONTAMINANT SOURCES

4.3.2.1 Sacramento Regional Wastewater Treatment Plant

Water quality data from Sacramento Regional Wastewater Treatment Plant (SRWTP) were obtained from the plant operators as well as from the regional board. Available effluent data from the self-monitoring program required under the NPDES permit and priority pollutants data from the Pretreatment Program are presented. In general wastewater plants are not required to collect all the constituents important in drinking water, especially TOC, DOC, and nutrients. There were limited TOC and nutrient data from SRWTP effluent. They are presented. Other data are presented for background information only because mixing zone analysis to evaluate their potential impacts from this facility has not been completed. The updated NPDES permit adopted by the SWRCB on 4 August 2000 requires the facility to conduct localized impact studies and complete them within 36 months from the issuance date.

Effluent Discharges

The SRWTP flow discharges are regulated according to standards established in the SRWTP 1990 Plan of Operation. The plan requires that Sacramento River flow be at least 1,300 cfs and a river-effluent flow ratio of at least 14:1 be attained before SRWTP can discharge. The treatment plant will hold back effluent if these conditions are not met unless there are emergency conditions beyond the facility's control. In the 1996 to 1999 period, effluent flow ratios were not a problem with the lowest river to effluent ratio being 44:1 (Table 4-24). For the period 1996 to 1999, SRWTP effluent data were compiled and evaluated to show the contribution of the facility to the Sacramento River flows and contaminant loadings. Average plant effluent flow was 252 cfs, with a flow range of 217 and 375 cfs. SRWTP's maximum contribution to the Sacramento River flow was a low 2.3%. The average SRWTP effluent contribution to Sacramento flows was 1.1% with a range 0.3% to 2.3% (Table 4-24).

Table 4-24 Sacramento Regional Wastewater Treatment Plant Total Dissolved Solids and Effluent Contribution to the Sacramento River

Date	TDS (ppm)	Plant Effluent (cfs)	Sacramento River Flow (cfs)	Ratio of Sacramento River Flow to Effluent Flow	Effluent Flow to Sacramento R. Flow
1/22/1996	565	258.5	49175	190	0.5%
2/22/1996	602	305.7	91513	299	0.3%
3/24/1996	579	270.9	44558	164	0.6%
5/25/1996	540	236.1	66016	280	0.4%
6/25/1996	488	218.7	18792	86	1.2%
7/26/1996	509	217.3	20077	92	1.1%
8/26/1996	512	228.6	21634	95	1.1%
9/26/1996	489	233.0	14195	61	1.6%
11/27/1996	544	243.8	18811	77	1.3%
12/28/1996	590	285.7	81911	287	0.3%
1/28/1997	716	333.7	95053	285	0.4%
2/28/1997	600	258.2	36690	142	0.7%
3/31/1997	540	234.8	18294	78	1.3%
4/1/1997	536	224.3	18035	80	1.2%
5/1/1997	534	225.7	10725	48	2.1%
6/1/1997	502	227.5	13333	59	1.7%
8/2/1997	513	233.0	20725	89	1.1%
9/2/1997	442	224.6	16389	73	1.4%
10/3/1997	491	226.0	14034	62	1.6%
11/3/1997	528	244.6	10813	44	2.3%
12/4/1997	544	256.8	27066	105	0.9%
1/4/1998	595	309.1	18937	61	1.6%
2/4/1998	706	375.1	94129	251	0.4%
3/7/1998	628	280.6	68062	243	0.4%
4/7/1998	594	268.2	69053	258	0.4%
5/8/1998	570	263.5	48851	185	0.5%
6/8/1998	490	251.1	63488	253	0.4%
7/9/1998	525	238.7	29283	123	0.8%
8/9/1998	513	234.1	24720	106	0.9%
9/9/1998	466	241.8	15324	63	1.6%

Table 4-24 (continued)

Date	TDS (ppm)	Plant Effluent (cfs)	Sacramento River Flow (cfs)	Ratio of Sacramento River Flow to Effluent Flow	Effluent Flow to Sacramento R. Flow
10/10/1998	553	243.4	16285	67	1.5%
11/10/1998	538	255.8	15792	62	1.6%
12/11/1998	508	249.6	59400	238	0.4%
1/4/1999	554	254.2	20694	81	1.2%
2/4/1999	572	297.6	34812	117	0.9%
3/7/1999	516	266.6	72905	273	0.4%
4/7/1999	517	241.8	27268	113	0.9%
5/8/1999	498	231.0	21231	92	1.1%
6/8/1999	510	232.5	20257	87	1.1%
7/9/1999	477	235.6	21016	89	1.1%
8/9/1999	447	238.7	18917	79	1.3%
9/9/1999	428	243.4	16312	67	1.5%
10/10/1999	498	238.4	14349	60	1.7%
11/10/1999	466	245.0	13010	53	1.9%
12/11/1999	428	232.8	17755	76	1.3%
Mean	532	252.3	33993.1	128.8	1.1%
Median	525	243.4	20725.0	89.2	1.1%
Low	428	217.3	10725.0	44.2	0.3%
High	716	375.1	95053.0	299.4	2.3%
Count	45	45	45	45	45

Total Organic Carbon and Biochemical Oxygen Demand

The SRWTP outfall is about 10 miles upstream of the Greenes Landing benchmark station. Historical MWQI data from Greenes Landing indicate a TOC range of 1.2 to 6.1 mg/L with a median of 1.7 mg/L. There are no flow measurements at this location, and so it is difficult to calculate loading. Upstream, SRWTP is only required to monitor BOD and not TOC in its effluent, but some limited TOC data were available. An attempt was made to develop a predictive equation utilizing BOD to estimate TOC, which if successful would have produced a larger TOC dataset. However, regression analysis showed an R^2 of 0.092 and, therefore, no ability for BOD to predict TOC of the effluent. Loads and seasonal distribution of TOC and BOD loads are shown in Tables 4-25, 4-26, 4-27, and 4-28. TOC and BOD loads in effluent are highest in winter. BOD exceeded the NPDES limit 19 March 1997. All other values were below the regulatory limits. Seasonal variation is shown on Figure 4-29.

Table 4-25 Sacramento Regional Wastewater Treatment Plant Effluent TOC and BOD Concentrations, 1996 to 1998

	TOC (mg/L)	BOD (mg/L)	TOC (lbs/day)	BOD (lbs/day)
Mean	15.7	9.8	20,478	13,249
Minimum	7.0	5.7	10,275	7,706
Maximum	27.0	17.0	31,750	22,983
Number of Analyses	50	52	50	52

Table 4-26 Average Monthly Loading of Sacramento Regional Wastewater Treatment Plant Effluent TOC and BOD[a]

Month	No. of analyses	Min TOC (lbs/day)	Max TOC (lbs/day)	Avg TOC (lbs/day)	Min BOD (lbs/day)	Max BOD (lbs/day)	Avg BOD (lbs/day)
Jan	4	14,719	27,980	23,593	4,904	42,467	21,567
Feb	4	13,672	23,972	20,540	13,411	21,017	17,278
Mar	18	15,512	32,594	23,782	6,047	48,172	18,622
Apr	4	13,740	17,029	14,625	7,106	33,093	19,874
May	4	13,566	21,467	16,077	4,203	14,945	8,916
Jun	18	3,295	27,622	18,985	6,505	24,186	12,539
Jul	5	13,059	31,750	17,589	3,027	18,815	10,190
Aug	5	12,163	24,186	15,925	5,630	12,093	9,461
Sep	14	11,101	27,497	16,449	5,046	22,068	10,249
Oct	5	9,277	23,135	15,117	5,087	12,252	8,682
Nov	5	11,649	23,352	16,802	6,155	17,614	10,650
Dec	12	10,275	21,318	16,629	6,630	24,244	10,673

[a] The current NPDES permit limits BOD to a monthly average of 30 mg/L or 45,286 lbs/day

Table 4-27 Sacramento Regional Wastewater Treatment Plant Effluent Monthly Average Water Quality

Date	Effluent Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Total Coliform (MPN/100 ml)	Total Kjeldahl Nitrogen (mg/L)	Nitrate (mg/L)	Total Phosphorus (mg/L)
Jan-96	166.8	7	5	Median <2	20	1.5	4.4
Feb-96	197.2	9	5	Median <2	16	2.0	1.8
Mar-96	174.8	10	5	Median <2	17	2.9	4.6
Apr-96	156.6	12	6	Median <2	17	0.8	4.5
May-96	152.3	9	6	Median <2	20	0.1	1.9
Jun-96	141.1	12	7	Median <2	17	0.4	2.0
Jul-96	140.2	14	6	Median <2	18	0.6	2.6
Aug-96	147.5	10	11	Median <2	13	0.7	3.0
Sep-96	150.5	8	10	Median <2	13	1.4	2.5
Oct-96	148.4	12	9	Median <2	15	0.2	1.9
Nov-96	157.3	9	7	Median <2	18	0.2	2.4
Dec-96	184.3	8	6	Median <2	22	0.5	2.4
Jan-97	215.3	9	6	Median <2	16	0.4	2.0
Feb-97	166.6	13	9	Median <2	17	0.3	2.2
Mar-97	151.5	14	7	Median <2	19	0.1	2.3
Apr-97	144.7	9	6	Median <2	19	0.2	2.4
May-97	145.6	12	5	Median <2	21	0.4	3.0
Jun-97	146.1	17	8	Median <2	18	0.5	2.8
Jul-97	146.8	9	8	Median <2	18	0.3	2.3
Aug-97	150.3	9	7	Median <2	18	0.1	2.5
Sep-97	144.9	7	7	Median <2	15	0.4	2.1
Oct-97	145.8	7	7	Median <2	18	0.2	2.2
Nov-97	158.8	6	7	Median <2	22	0.2	2.7
Dec-97	165.7	7	7	Median <2	22	0.2	2.0
Jan-98	199.4	7	7	Median <2	20	2.1	2.1
Feb-98	242.8	9	9	Median <2	13	1.0	1.6
Mar-98	180.7	8	7	Median <2	20	0.1	2.0
Apr-98	173.0	8	7	Median <2	18	<0.1	2.2
May-98	169.6	9	7	Median <2	21	<0.1	2.3
Jun-98	162.2	7	5	Median <2	22	<0.1	2.1

Table 4-27 (continued)

Date	Effluent Flow (MGD)	BOD (mg/L)	TSS (mg/L)	Total Coliform (MPN/100 ml)	Total Kjeldahl Nitrogen (mg/L)	Nitrate (mg/L)	Total Phosphorus (mg/L)
Jul-98	154.1	6	5	Median <2	16	<0.1	1.9
Aug-98	150.7	10	6	Median <2	17	<0.1	2.2
Sep-98	155.8	6	6	Median <2	17	<0.1	2.0
Oct-98	156.6	7	6	Median <2	17	<0.1	2.3
Nov-98	164.9	12	8	Median <2	NS	<0.1	NS
Dec-98	160.5	7	7	Median <2	17	<0.1	1.6
Jan-99	164.0	12	8	Median <2	19	<0.2	2.2
Feb-99	192.4	15	10	Median <2	18	<3.0	1.8
Mar-99	172.1	11	7	Median <2	17	<0.1	1.9
Apr-99	156.1	12	7	Median <2	17	<0.1	2.0
May-99	148.8	15	7	Median <2	26	<0.1	1.9
Jun-99	154.5	13	7	Median <2	23	<0.1	2.9
Jul-99	152.1	12	6	Median <2	22	<0.1	2.6
Aug-99	154.5	7	6	Median <2	15	<0.1	2.2
Sep-99	155.6	9	8	Median <2	20	<0.1	2.2
Oct-99	153.8	11	8	Median <2	18	<0.1	2.0
Nov-99	158.0	9	8	Median <2	20	<0.1	2.3
Dec-99	150.2	11	9	Median <2	18	<0.1	2.0
Minimum	140.2	5.7	4.8		12.7	0.1	1.6
Maximum	242.8	17.0	10.7		25.5	2.9	4.6
Average	162.1	9.8	7.0		18.3	0.7	2.4

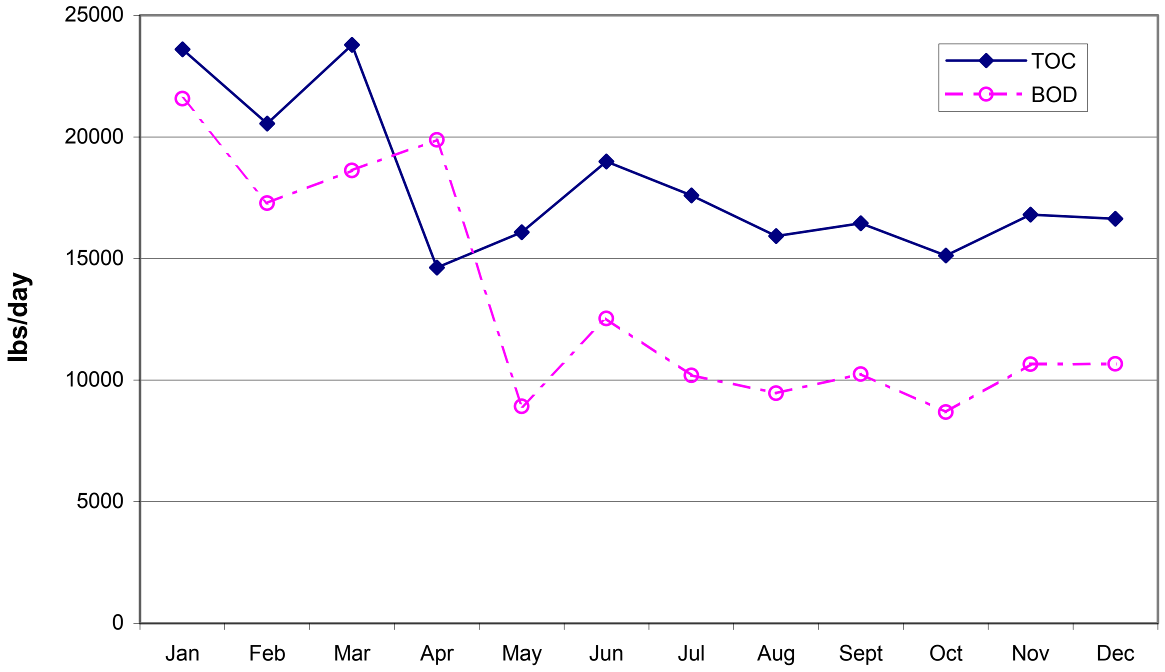
Table 4-28 Sacramento Regional Wastewater Treatment Plant Monthly Average Loading (lbs/day)

Date	Effluent Flow (MGD)	BOD	TSS	Total Kjeldahl Nitrogen	Nitrate	Total Phosphorus
Jan-96	166.8	9738	7525	27822	2087	6121
Feb-96	197.2	14802	8399	26314	3289	2960
Mar-96	174.8	14578	7708	24783	4228	6706
Apr-96	156.6	15673	7384	22203	1045	5877
May-96	152.3	11432	7318	25404	127	2413
Jun-96	141.1	14121	8363	20005	471	2354
Jul-96	140.2	15922	7346	21287	673	3041
Aug-96	147.5	12462	13151	15668	888	3689
Sep-96	150.5	10214	12480	16316	1762	3138
Oct-96	148.4	15129	11257	18871	264	2351
Nov-96	157.3	11150	8815	23349	280	3148
Dec-96	184.3	11851	8806	33816	740	3689
Jan-97	215.3	15525	11151	28732	754	3609
Feb-97	166.6	18063	12505	23621	417	3057
Mar-97	151.5	17689	8845	24007	126	2906
Apr-97	144.7	10861	7241	22929	241	2896
May-97	145.6	14572	6072	25500	486	3643
Jun-97	146.1	20714	9748	21933	609	3412
Jul-97	146.8	11019	9794	22038	367	2816
Aug-97	150.3	11282	8775	22563	125	3134
Sep-97	144.9	8459	8459	18127	483	2538
Oct-97	145.8	8512	8512	21887	243	2675
Nov-97	158.8	7946	9271	29137	265	3576
Dec-97	165.7	9674	9674	30403	276	2764
Jan-98	199.4	11641	11641	33260	3492	3492
Feb-98	242.8	18225	18225	26324	2025	3240
Mar-98	180.7	12056	10549	30141	151	3014
Apr-98	173.0	11543	10100	25971	144	3174
May-98	169.6	12730	9901	29704	141	3253
Jun-98	162.2	8795	6860	29766	135	2841
Jul-98	154.1	7338	6214	20820	129	2416

Table 4-28 (continued)

Date	Effluent Flow (MGD)	BOD	TSS	Total Kjeldahl Nitrogen	Nitrate	Total Phosphorus
Aug-98	150.7	12207	7263	21876	126	2766
Sep-98	155.8	8273	7389	21700	130	2599
Oct-98	156.6	9447	7322	22673	131	2978
Nov-98	164.9	17012	10404		138	
Dec-98	160.5	8720	9286	22616	134	2141
Jan-99	164.0	15798	11019	25855	274	3051
Feb-99	192.4	23441	16712	29046	4814	2889
Mar-99	172.1	16249	10647	24540	144	2727
Apr-99	156.1	15272	9731	22127	130	2603
May-99	148.8	18777	9229	31649	124	2358
Jun-99	154.5	17092	9405	29632	129	3672
Jul-99	152.1	14772	7930	27399	127	3298
Aug-99	154.5	9101	7891	19452	129	2834
Sep-99	155.6	11206	10224	25571	130	2856
Oct-99	153.8	14192	9926	23089	128	2565
Nov-99	158.0	12390	10114	26110	132	3031
Dec-99	150.2	13496	10829	22548	125	2505
Minimum	140.2	7338	6072	15668	124	2141
Maximum	242.8	23441	18225	33816	4814	6706
Average	162.1	13149	9529	24651	698	3166

Figure 4-29 SRWTP Monthly Average TOC-BOD, 1996 to 1998



The 1991/92 MWQI DOC monthly average data from Greenes Landing were used to estimate potential for SRWTP to contribute TOC at this benchmark station. The estimate was calculated assuming that DOC is 75% of TOC. The results are shown in Table 4-29. The results indicate that during dry years, SRWTP may contribute about 8% to 12% of TOC at Greenes Landing during spring and summer months.

Table 4-29 Estimated Percent SRWTP Contribution to Total Organic Carbon at Greenes Landing Assuming a TOC:DOC Ratio of 0.75

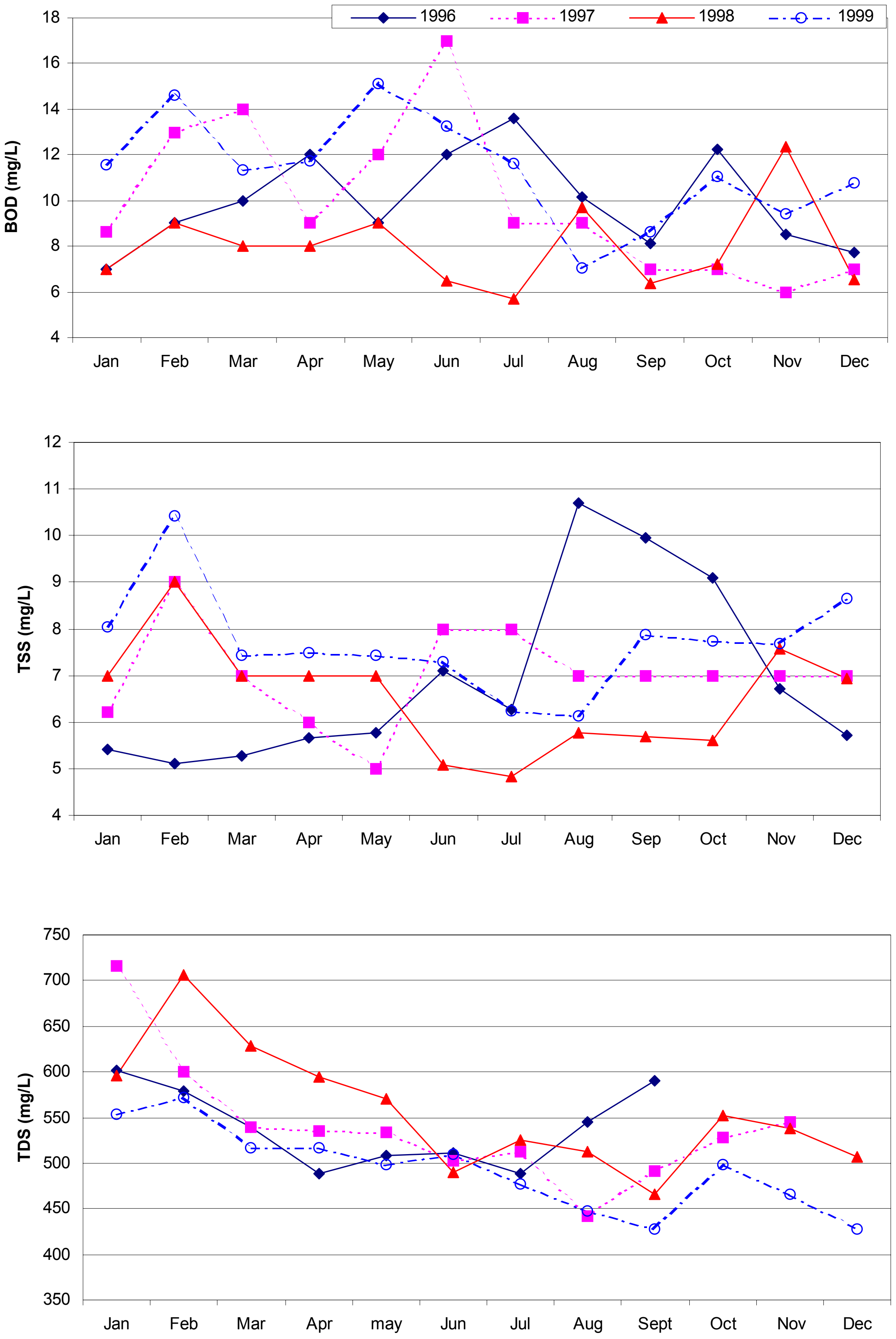
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991									8.1	7.1	9.9	7.2
1992	7.8	2.3	3.1	6.7	11.8	8.6	8.3	7.1	6.1	8.3	6.6	5.3
1993	1.0	0.8	1.5	1.4	2.1	0.9	2.9	2.8				

Limited TOC data at Clifton Court Forebay indicate a median concentration of 3.2 and a range of 2.1 to 4.7 mg/L. Preliminary and unpublished modeling analyses performed as part of the SRWTP 2020 Master Plan have estimated that, as currently operated, there is a 50% probability that SRWTP can contribute a median 0.3 mg/L of TOC at Clifton Court Forebay. This would make up almost 10% of TOC at Clifton Court. The probability of SRWTP contributing 0.5 mg/L or more TOC to Clifton Court was estimated at equal to or less than 10%.

Total Dissolved Solids

Average TDS in effluent from SRWTP was 532 mg/L and ranged from 428-716 mg/L, Table 4-24, Figure 4-30. TDS levels were higher in early winter (January, February) probably due to high loads in the 1st large-scale storm events of the wet season. The lowest concentrations (428 mg/L) were in December 1999, probably due to a moderately sized storm that did not have a lot of runoff. As expected, TDS levels were well correlated with effluent flow—the higher the effluent flow the higher the TDS loads. The higher SRWTP effluent flows coincided with higher Sacramento River flows, which would make the effluent impacts less significant.

Figure 4-30 Sacramento Regional Wastewater Treatment Plant Monthly Average BOD, TSS and TDS



Historical MWQI data indicate that TDS concentrations at Greenes Landing are low, and so the loads from SRWTP do not seem to have a large impact on the Sacramento River. Preliminary unpublished evaluation performed as part of the 2020 Master Plan estimated that there is a 50% probability that SRWTP can contribute an additional 6 mg/L above the averge to TDS loads at Clifton Court Forebay. Assuming an average TDS concentration of 200 mg/L at Clifton Court, SRWTP contribution would be only 3%. The model estimated that the probability SRWTP could contribute 10 mg/L or more was 10% or less.

Total Suspended Solids

SRWTP has an effluent limitation on TSS of 45,286 lbs/day, which was never exceeded in the 1996 to 1999 period. TSS levels were relatively low compared to the NPDES effluent limits (Table 4-27, Figure 4-30). Loading ranged between 6,072 and 18,225 lbs/day with an average of 9,529 lbs/day.

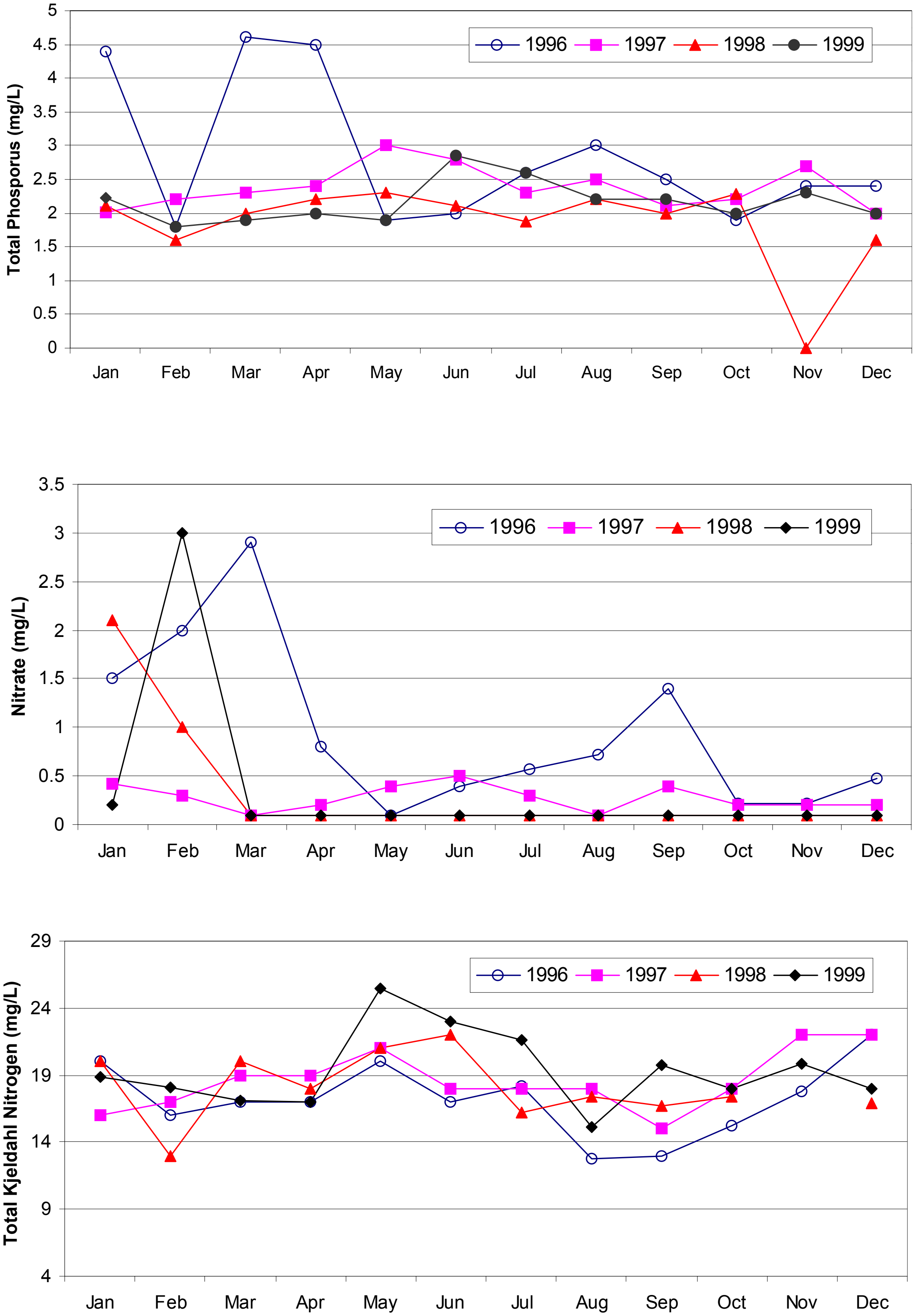
Pathogens

The only pathogen data available were monthly averages of total coliforms (Most Probable Numbers (MPN), Table 4-27). Most of the data were below the reporting limit. The exceptions were January 1996, October 1999, and December 1999 when the median occurrence was 2, which was still below the NPDES permit limit of 23 MPN. According to SRWTP staff, *Cryprosporidium* and *Giardia* data were not ready for dissemination because the analytical method is still under development. The updated NPDES permit does not have effluent limitations for these pathogens.

Nutrients

Nutrient data available were total Kjeldahl nitrogen (TKN), nitrate and total phosphorus, Table 4-27, Figure 4-31. Nutrient limitations are not included in the SRWTP NPDES permit. Nitrate and total phosphorus were relatively low compared to EPA drinking water standards of 10 mg/L. However, the level of these nutrients may be high enough to cause nuisance algal growth if not well diluted.

Figure 4-31 SRWTP Effluent Monthly Average Nutrient Concentrations, 1996 to 1999



TKN levels were many times higher than the other nutrients. It is possible that the high TKN levels may contribute to algal growth. With proper dilution TKN would be below the drinking water levels for nitrates. It will not be possible to evaluate the true impacts of nutrients until the dilution/mixing studies prescribed in the updated NPDES permit are completed.

Priority Pollutants

Effluent limitations are established by considering the assimilative capacity of the receiving waters and water quality objectives contained in the basin plan. The process involves modeling and dynamic analyses of mixing zones downstream from the discharge. Guidelines for evaluating priority pollutants impact on receiving water quality are contained in the California Toxics Rule (CTR). SRWTP has not finished conducting mixing zone analyses required to utilize the CTR (SWRCB NPDES Permit). SWRCB has set up a time schedule for SRWTP to conduct these studies. Based on historical data from 1994 to 1998, SWRCB concluded that there is a reasonable potential for copper, lead, silver, zinc and cyanide to exceed CTR aquatic life criteria. Effluent limits based on monthly averages have not been set for these pollutants (Table 4-30).

HEXAVALENT CHROMIUM (CR6+) From limited data, average hexavalent concentrations in the effluent were about 20 µg/L. The impact of Cr^{6+} in drinking water is under evaluation by DHS. There are no effluent limitations in the permit and further evaluation must await the dilution/mixing studies.

Table 4-30 SRWTP Priority Pollutant Metals

Constituent	Number of analyses	Average (lbs/day)	Median (lbs/day)	Minimum (lbs/day)	Maximum (lbs/day)	10-90% Percentile
Antimony, total	35	0.43	0.41	0.28	0.95	0.32-0.54
Arsenic, total recoverable	94	2.93	2.82	1.00	5.96	1.89-4.25
Arsenic, dissolved	66	2.47	2.32	1.04	5.71	1.69-3.33
Beryllium, total recoverable	14	0.03	0.03	0.03	0.03	0.03-0.03
Beryllium, dissolved	14	0.03	0.03	0.03	0.03	0.03-0.03
Cadmium, total recoverable	35	0.05	0.05	0.02	0.10	0.03-0.08
Cadmium, dissolved	41	0.05	0.05	0.01	0.12	0.02-0.08
Chromium, total recoverable	52	1.16	1.11	0.27	3.02	0.85-1.51
Chromium, dissolved	59	0.95	0.95	0.40	1.72	0.64-1.31
Chromium 6, dissolved	19	25.14	24.65	20.37	27.36	23.71-27.12
Copper, total recoverable	80	7.43	6.73	3.74	21.78	4.62-11.04
Copper, dissolved	98	6.16	5.72	3.45	18.17	4.00-8.57
Cyanide, total	87	7.21	6.55	5.09	31.96	6.07-8.33
Lead, total recoverable	79	0.72	0.68	0.08	2.14	0.45-0.97
Lead, dissolved	94	0.41	0.36	0.19	1.30	0.25-0.58
Manganese, total recoverable	14	105.77	89.16	69.23	253.97	76.53-148.16
Manganese, dissolved	14	100.79	86.98	39.52	221.07	74.06-165.14
Mercury, dissolved	110	0.010	0.000	0.000	0.020	0.000-0.01
Molybdenum, total recoverable	38	3.52	2.19	0.31	10.61	0.81-8.21
Molybdenum, dissolved	45	3.33	2.28	0.25	10.35	0.63-8.02
Nickel, total recoverable	37	2.84	2.84	0.31	4.71	1.42-3.96
Nickel, dissolved	44	2.70	2.72	0.25	6.09	1.36-3.48
Selenium, dissolved	14	0.47	0.44	0.21	0.77	0.36-0.66
Silver, total recoverable	37	0.38	0.38	0.14	0.68	0.20-0.54
Silver, dissolved	44	0.10	0.09	0.03	0.19	0.06-0.14
Thalium, total recoverable	14	0.34	0.35	0.32	0.36	0.32-0.35
Thalium, dissolved	14	0.34	0.35	0.32	0.36	0.32-0.35
Zinc, total recoverable	45	39.65	40.29	5.85	84.94	31.5-46.97
Zinc, dissolved	52	36.61	36.73	16.04	58.61	22.52-47.11

Table 4-31 RWCF Effluent Limitations (RWCF NPDES Permit No. CA0079138)

Constituent	Time period	Units	Monthly Average	Weekly Average	Daily Max
CBOD[a]	1 Dec to 31 Mar	mg/L	20	30	50
CBOD[a]	1 Apr to 31 Oct	mg/L	10	20	25
Ammonia	1 Apr to 31 Oct	mg/L	2	4	5
CBOD[a]	1 Nov to 30 Nov	mg/L	15	23	30
Ammonia	1 Nov to 30 Nov	mg/L	10	15	--
TSS	Not applicable	mg/L	30	45	60
Total coliforms	Not applicable	MPN	23 (median)	--	500

[a] Carbonaceous biochemical oxygen demand.

4.3.2.2 Stockton Regional Wastewater Control Facility

The Stockton RWCF effluent is regulated seasonally because of change in its water quality, Table 4-31.

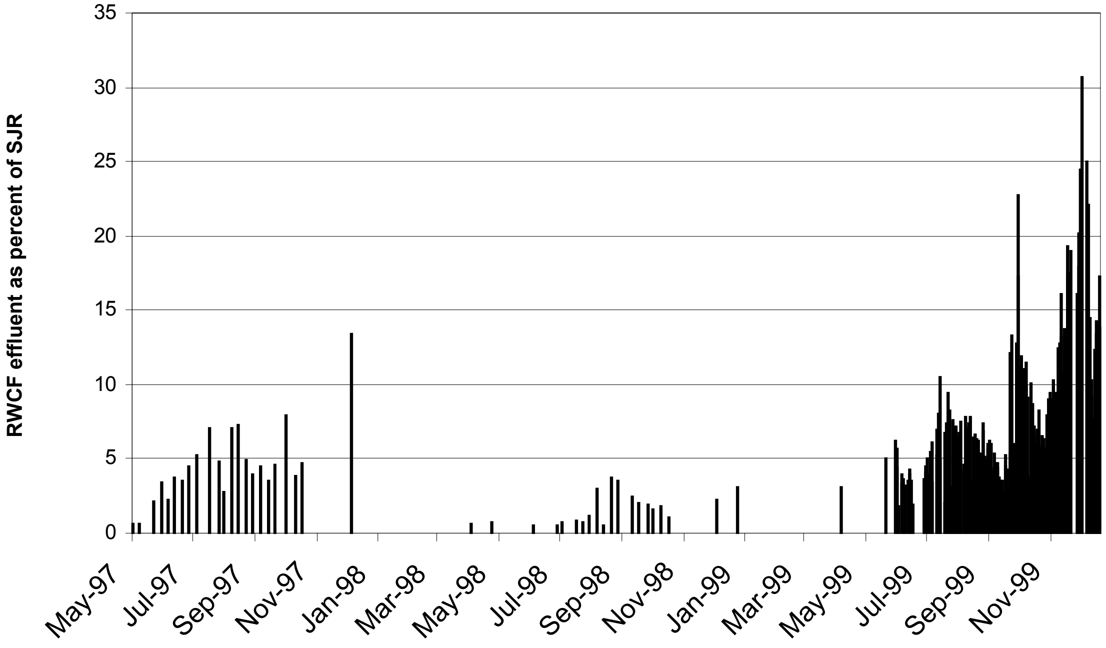
Most studies of the impacts of the RWCF on San Joaquin River water quality have been to address the low dissolved oxygen problem in the Stockton Deep Water Ship Channel (DWSC). The CVRWQCB, city of Stockton, and other stakeholders are in the process of developing a TMDL to address the sources of the oxygen demand. In the early 1990s, the city sponsored the development of the Stockton San Joaquin River Dissolved Oxygen Model to assess the impacts of the wastewater treatment plant discharge on the river (Lee and Jones-Lee 2000a).

Summary of the RWCF discharge characteristics from 1997 to 1999 are shown in Table 4-32. Unlike most other wastewater facilities, the RWCF monitors carbonaceous biochemical oxygen demand (CBOD), which may be more conservative than BOD.

Table 4-32 Stockton RWCF Daily Average Effluent Characteristics from 1997 to 1999 (mg/L)

	Flow (mgd)	CBOD	TSS	Settlable solids	EC (umhos/cm) at 25C	NH3-N	Total Coliforms (MPN)	Oil & Grease	Alkalinity	Hardness (Total $CACO_3$)
Average	32.1	6.3	17.3	0.0	1307.4	15.1	13.5	0.8	139.7	154.5
Median	31.8	5.6	17.0	0.0	1312.0	17.6	2.0	0.0	144.0	155.0
Minimum	0.5	0.0	2.1	0.0	1024.0	0.2	2.0	0.0	60.0	107.0
Maximum	54.2	30.0	44.0	0.0	1648.0	25.8	350.0	50.0	204.0	201.0
10th percentile	20.9	3.4	8.0	0.0	1174.0	3.4	2.0	0.0	90.0	126.7
90th percentile	44.0	10.0	28.0	0.0	1453.0	23.0	16.0	1.3	189.0	181.0
Count	915	883	897	893	195	488	51	107	71	68

Figure 4-32 Stockton Wastewater Effluent as Percent of San Joaquin River Flow



Effluent Discharge

The USGS has measured San Joaquin River flows at Stockton utilizing UVMs. The flow near Stockton is influenced by tides and can be difficult to measure. The RWCF contribution to San Joaquin River flow ranged from 0.5% to 62% with a median value of 6% (Figure 4-32). The higher RWCF contributions were in the fall and early winter of 1999. The estimated San Joaquin River flow was especially low in fall of 1999 when the RWCF contributions were high. It is not clear what caused the below-normal San Joaquin River flows. Water exports from the SWP and DMC pumps in the south Delta seemed to have some effect with the low flows near Stockton. The data indicate that the RWCF can have a significant impact on the San Joaquin River near Stockton. Currently, the CVRWQCB and stakeholders are in the process of developing a DO TMDL for the Deep Water Ship Channel. The process will provide more information on the impacts from various sources of pollution into the San Joaquin River including the RWCF.

CBOD

The RWCF effluent CBOD and ammonia are regulated seasonally because of the seasonal variability of influent composition especially from cannery operations (Table 4-31). There was only 1 daily maximum exceedance that occurred in October 1998. CBOD appears to have small spikes in midwinter, Figure 4-33. The loading ranged between 924 to 3636 lbs/day (Table 4-33). The Deep Water Ship Channel continues to experience low DO, and it is possible that the RWCF effluent CBOD will be regulated more in the future.

Figure 4-33 Stockton Regional Wastewater Control Facility Water Quality Charts

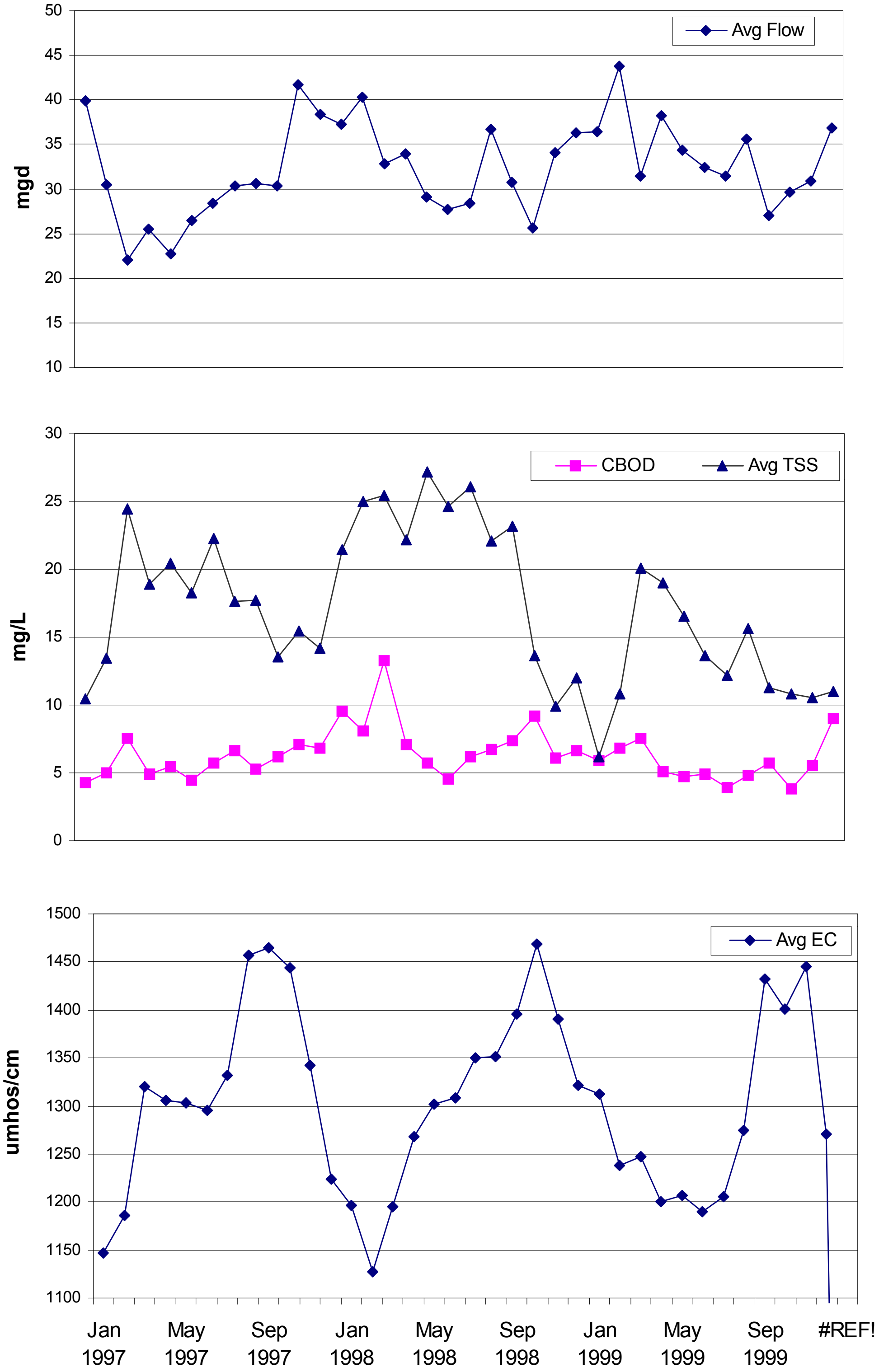


Table 4-33 Stockton RWCF Monthly Average Loading from 1997 to 1999

Date	Flow (MGD)	CBOD (lbs/day)	TSS (lbs/day)	Settleable Solids (lbs/day)	NH3-N (lbs/day)	Oil & Grease (lbs/day)	Alkalinity (lbs/day)	Hardness (lbs/day)
Jan-97	39.9	1416.9	3496.0	33.3	6093.1	1664.8	52773.5	48778.0
Feb-97	30.5	1267.8	3438.8	25.5	4287.0	1273.6	48779.9	43940.1
Mar-97	22.1	1368.1	4503.1	18.4	2388.8	920.9	34811.7	36008.9
Apr-97	25.6	1052.1	4034.5	21.3	103.3	1066.0	20148.1	39869.8
May-97	22.7	1030.7	3871.6	18.9	43.9	946.4	14321.9	32744.8
Jun-97	26.5	991.7	4045.4	22.1	44.2	1104.8	17346.0	39000.9
Jul-97	28.5	1317.3	5290.4	23.7	99.3	1186.4	21473.8	41761.1
Aug-97	30.3	1685.9	4462.3	25.3	2704.3	1265.3	29228.2	46309.6
Sep-97	30.7	1384.7	4533.7	24.6	4614.6	1279.3	41832.2	45670.0
Oct-97	30.3	1575.7	3413.2	25.3	4874.3	1263.5	43211.1	41947.6
Nov-97	41.7	2478.5	5372.1	32.3	7072.4	1740.1	52900.3	49420.0
Dec-97	38.4	2179.9	4557.6	32.1	6039.5	1602.8	38788.7	42154.7
Jan-98	37.3	2958.3	6678.5	31.1	5522.6	1554.5	43836.0	39794.4
Feb-98	40.4	2721.3	8430.1	33.7	4737.5	4713.9	48485.8	45792.1
Mar-98	32.8	3635.6	6952.8	27.3	2343.4	1366.8	45650.5	47974.0
Apr-98	34.0	2016.8	6288.3	28.3	283.3	1456.8	32999.5	50561.4
May-98	29.1	1391.8	6612.6	24.3	295.1	1214.6	35586.3	42509.3
Jun-98	27.8	1045.1	5695.6	23.2	46.3	1157.6	24773.7	37855.1
Jul-98	28.4	1440.6	6201.4	23.7	47.5	1245.7	23964.2	39149.4
Aug-98	36.7	2071.8	6768.6	30.6	61.2	1530.3	41470.6	46367.5
Sep-98	30.8	1894.2	5935.7	25.6	2543.7	338.6	42918.0	39327.2
Oct-98	25.6	1998.6	2914.0	21.4	4442.0	439.3	37052.6	31072.9
Nov-98	34.0	1668.6	2803.3	28.4	6608.3	425.9	46569.5	34075.2
Dec-98	36.3	2000.6	3624.2	30.3	6813.4	303.0	60438.6	32718.7
Jan-99	36.5	1795.6	1873.4	30.4	7024.1	511.3	57976.6	35912.0
Feb-99	43.8	2503.1	3951.0	36.5	7844.2	401.7	70109.6	46922.3
Mar-99	31.5	1971.5	5269.9	26.2	5063.2	262.4	41335.3	37661.1
Apr-99	38.2	1610.9	6055.3	31.9	1802.1	318.7	39678.4	48602.0
May-99	34.3	1360.7	4731.5	28.6	785.1	286.3	23190.6	41943.5
Jun-99	32.4	1336.7	3693.6	27.1	202.9	270.6	26112.5	43565.9

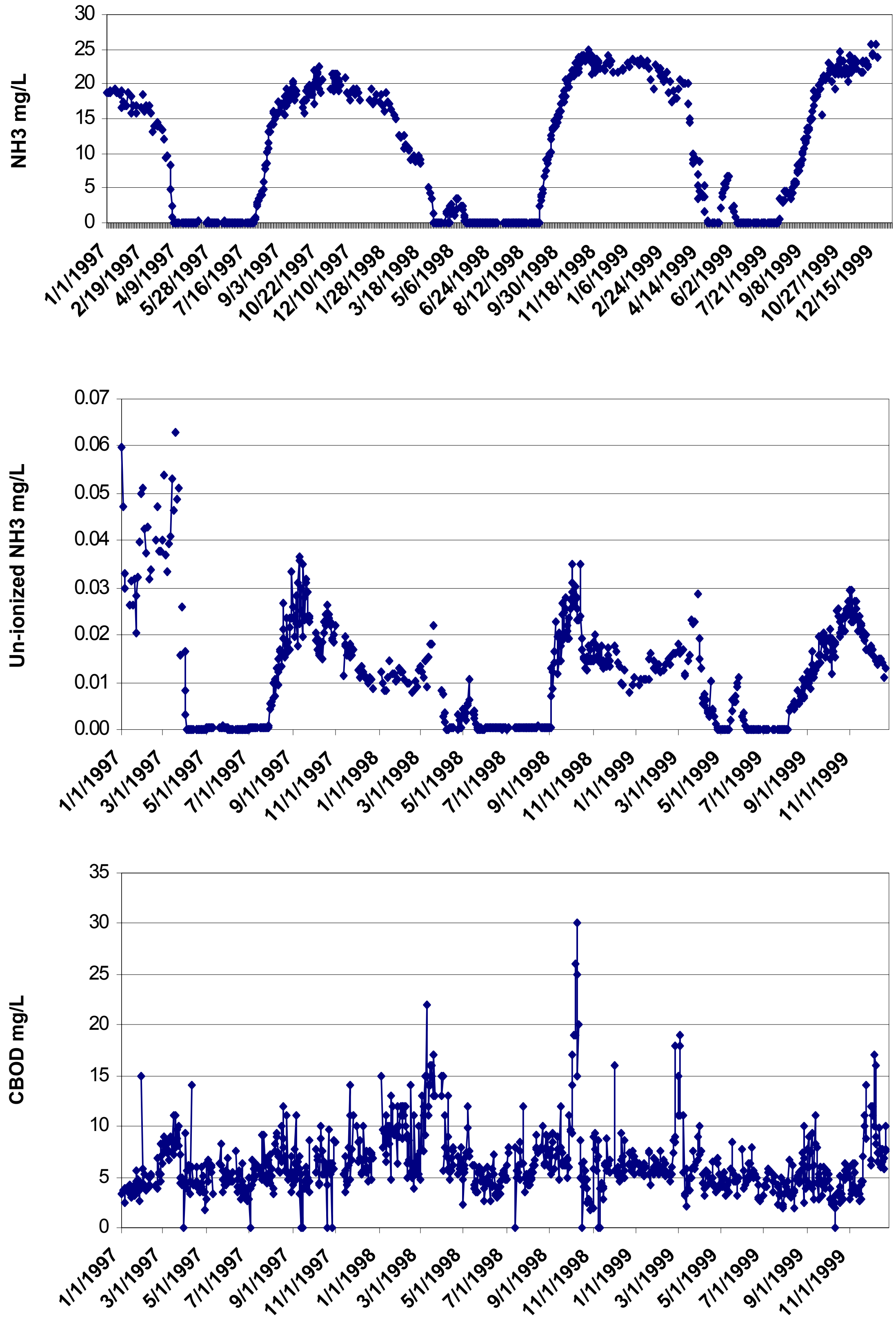
Table 4-33 (continued)

Date	Flow (MGD)	CBOD (lbs/day)	TSS (lbs/day)	Settleable Solids (lbs/day)	NH3-N (lbs/day)	Oil & Grease (lbs/day)	Alkalinity (lbs/day)	Hardness (lbs/day)
Jul-99	31.4	1021.6	3197.9	26.2	131.0	261.9	25670.4	42958.6
Aug-99	35.6	1439.6	4634.1	29.6	1150.8	296.5	40174.8	46549.4
Sep-99	27.1	1293.1	2545.8	22.6	2972.7	225.6	29783.7	34070.8
Oct-99	29.6	923.5	2680.7	24.7	5281.6	246.9	39836.4	35062.6
Nov-99	30.9	1432.9	2711.1	25.8	5767.5	293.8	47160.8	33502.2
Dec-99	36.8	2772.1	3377.9	30.7	7290.1	1525.2	57731.5	36235.7
Minimum	22.1	923.5	1873.4	18.4	43.9	225.6	14321.9	31072.9
Maximum	43.8	3635.6	8430.1	36.5	7844.2	4713.9	70109.6	50561.4
Average	32.5	1723.7	4573.5	27.0	3261.8	998.9	38836.7	41049.7

Ammonia

Historically, the RWCF has had problems with ammonia in its effluent (Table 4-32 and Figure 4-34). High concentrations occurred from about September to April. There were permit limit exceedances in daily maxima as well as monthly averages, especially in late August through November, and a well-defined seasonal fluctuation, which is associated with the canning season. Loading ranged from 44 to 7,822 lbs/day (Table 4-33). CALFED has funded a 1-year study to develop the data needed for a DO TMDL assessment.

Figure 4-34 Stockton Regional Wastewater Control Facility Effluent Nutrient and CBOD, 1997 to 1999



A complex set of factors such as influent quality and quantity, algae, and temperature probably influenced the seasonal fluctuation of ammonia. The ammonia levels are lowest in late spring and summer during the time of peak algal growth—algae assimilate nitrates thereby preventing reduction to ammonia by bacteria. Algal growth may also provide an alternative source of the oxygen needed by bacteria and other microorganisms. The rise in temperature could also lead to low solubility and vaporization of any ammonia produced by microorganisms. In late fall and winter, the process is reversed with little algal growth and, therefore, high ammonia concentrations. Nutrients and algal growth data were not available to confirm this hypothesis. During peak algal growth periods, the RWCF operates the filtration units at full capacity to reduce TSS. Algal growth products can be a source of trihalomethane precursors (DOC), which could affect drinking water quality.

Pathogens

Limited total coliform data were available (Table 4-32). Total coliforms were all within the NPDES monthly, weekly, and daily limits. However, DHS has indicated concern that there may be significant viral infection risks from water contact recreation when dilution ratios are minimal during San Joaquin River low flows. A comprehensive risk assessment has been ordered by the CVRWCQB, but results were not yet available (NPDES Permit).

Other Regulated Constituents

TSS and oil and grease are the other regulated constituents. Their concentrations in the effluent did not exceed the permit limitations in the period (Tables 4-31 and 4-32). Conductivity, alkalinity, and hardness are not regulated in the permit. EC exhibits seasonal variation but not as pronounced as ammonia (Table 4-33 and Figure 4-33). Alkalinity ranged from 14,321 to 70,109 lbs/day. These seasonal variations may be due to changes in influent quality.

4.3.3 URBAN RUNOFF CONTAMINANT SOURCES

There are no numeric limits in the NPDES permits for the storm water and nonstorm water effluent discharges of the 3 permit holders (CVRWQCB 1995, 1996, 1997). Effluent limitations are narrative and rely on the implementation of BMPs identified in the municipalities' respective Storm Water Management Programs to control and abate the discharge of storm water pollutants and ensure that receiving water limitations are achieved. Receiving water limits are based upon beneficial uses, 303(d) listed constituents likely to be present in urban or storm water runoff, and water quality objectives and standards (primarily for the protection of aquatic life) contained in the regional board's basin plan. Identification of parameters of concern for monitoring is analyzed by the regional board on a case-by-case basis. There are some constituents of concern, for example, hydrocarbons, that are generally required for monitoring in most storm water programs (Berchtold pers. comm. 2000).

Storm water pollutant control is a multistepped process: Storm water effluents are monitored, yearly monitoring uncovers consistent reoccurrence of certain pollutants at levels of concern, BMPs are designed to potentially control pollutant discharge, and subsequent monitoring evaluates BMP effectiveness. Therefore, it may require many years for pollutant sources to be fully identified and for management practices to be developed, implemented, and evaluated.

Storm water programs for both the cities of Sacramento and Stockton include monitoring of general water quality constituents plus metals, organic compounds, and coliform bacteria. Neither program includes pathogen monitoring for *Cryptosporidium* or *Giardia*. The EPA test methods for these pathogenic organisms are expensive and have yielded poor recoveries that lead to dubious interpretations and conclusions (Larry Walker Associates 1999). Furthermore, the Port of Stockton is not required to monitor for TOC, coliform bacteria, or *Cryptosporidium* and *Giardia* as it is primarily an industrial facility.

The Sacramento Storm Water Monitoring Program began in 1990/91 following the issuance of the NPDES Permit to the Permittees in 1990 (Larry Walker Associates 1999). From 1996 to 1999, the storm water program has analyzed water quality from 3 urban sites (1 drain and 2 sumps). The first 3 years of the monitoring program showed the following (Larry Walker Associates 1999):

- No significant differences in runoff water quality among the sites;
- No clear spatial trends in river chemistry or toxicity;
- Evidence of some toxic impacts from urban runoff and upstream sources, and
- An indication that storm water may cause toxicity in urban creeks.

Special studies have been conducted on pesticide residues in local creeks, sediment uptake of pollutants in detention basins, and the effectiveness of different control measures. Water quality in the surrounding rivers has been a joint effort between the State and local agencies through the Coordinated

Monitoring Program. Both dry and wet weather periods have been sampled; however, the frequency of sampling has changed yearly based on evaluation of the data and the focus of new studies. Dry weather data are limited. In the past 10 years, only 8 samples have been collected. Future monitoring may include more dry weather sampling.

The Stockton urban area storm water program was implemented in 1995. The co-permittees for the Stockton urban area are required to sample at least 3 storm events each year. The goal is to get a 1st flush event and 2 storms separated by at least 30 days. Five sites representative of commercial, industrial, and residential land uses are sampled throughout the Stockton urban area (Murdoch pers.comm. 2000; Stockton 2000). Dry weather flows are not routinely monitored, but the city annually surveys 20% of the major outfalls to identify any new dry weather flows (Stockton 2000). The Stockton storm water permit identified a total of 63 major outfalls for the city of Stockton. When the permit was issued, additional major outfalls in the surrounding urbanized areas of the county had not yet been identified.

The Port of Stockton is required to sample 3 representative events. Rainfall of more than 0.1 inch or a storm lasting at least an hour and producing sufficient runoff for analytical testing is considered an event. Monitoring occurs at 11 sites interspersed throughout the port, 5 storm water discharge sites, 3 interior conveyance points, and 3 receiving water points (Port of Stockton 2000). Additional monitoring may be conducted for activities uniquely associated with the port, for example, maritime operations with possible release of contaminants into the receiving water.

Water quality data were examined for 2 permit holders in the Delta: 1) the city of Sacramento and its co-permittees, and 2) the city of Stockton and its co-permittee. Monitoring data were not readily available from the Port of Stockton, so this municipality was not included in any data analysis. However, the Port of Stockton's storm water program has identified ammonia, nitrate, nitrite, and TSS as the highest priority potential constituents of concern for its baseline source identification (Port of Stockton 2000).

Selection of the examined storm water data was based on several criteria:

- Parameters of concern for drinking water, such as TOC and coliform bacteria as well as TDS, and nutrients were examined for each storm water program.
- The analytes determined by the Sacramento Storm Water Program as potentially causing receiving water impacts were examined. The Sacramento Storm Water Program's procedure for determining these constituents was based on 9 years of monitoring data.

The summary was calculated by using data compiled for each storm water monitoring location. The data included 7 dissolved metals and total mercury, 4 pesticides, 7 semivolatile organics (1 phenol and 6 phthalates), 3 polynuclear aromatics, and fecal coliform. These data were used to calculate the probability of measured constituents meeting the lowest relevant water quality criteria. If available, water quality criteria from the California Toxics Rule—adopted 18 May 2000—or the CVRWQCB Basin Plan objectives were used for comparisons. If these criteria were not available, other applicable criteria were used, including Safe Drinking Water Act MCLs, DHS guidance levels, EPA criteria for the protection of aquatic life, and California Department of Fish and Game guidance levels (Larry Walker Associates 1999).

Constituents identified from this summary as potentially impacting the American and Sacramento rivers were diazinon, lead, mercury and fecal coliform (Larry Walker Associates 1999). With the exception of diazinon, which does not have a drinking water MCL, these analytes were included for comparison from both storm water programs. Metals in general do not appear to be a concern from Sacramento storm water discharges (Archibald & Wallberg and others 1995); however, they have not been examined from Stockton storm water runoff. Both chlorinated pesticides and semivolatile organics were not included. For the Stockton Storm Water Program, the CVRWQCB authorized elimination of requirements to analyze semivolatile organic compounds and chlorinated pesticides. This was due to the infrequency of detection and detections occurring at the method's detection level (Kinnetic Laboratories 1998). The Sacramento Storm Water Program did not identify either of these compound groups as potentially impacting receiving waters.

The data from the storm water discharges were compared to drinking water MCLs and receiving water quality levels found at the NEMDC and at the Harvey O. Banks Pumping Plant. The comparisons were made to assess the potential of storm water discharges on the untreated drinking water quality at Banks and to treated drinking water quality standards. The comparisons were not fully conclusive because some constituents were collected by the programs at different times. There have been no studies on the effects of urban runoff on water quality at the Banks Pumping Plant.

4.3.3.1 Pathogens

Pathogen monitoring in urban runoff varies widely throughout California. However, since pathogens from urban runoff are thought to be one contributor behind the increase in beach closures in Southern California, pathogen monitoring is beginning to be looked at more consistently as part of storm water monitoring (Berchtold pers. comm. 2000a). In the case of the Sacramento storm water program, a coliform/pathogen issues work plan has been developed to guide the permittee's activities and efforts toward progress on microbiologic urban runoff over the next few years (Larry Walker Associates 1999). The draft work plan includes several items:

- Educating the public about pet waste disposal,
- Identifying livestock operations and areas in Sacramento County,
- Surveying Sacramento area veterinarians on *Cryptosporidium* and *Giardia* in Sacramento pet populations,
- Consulting with local health authorities and hospitals on microbiological diseases in the human population in Sacramento,
- Tracking the efforts of other storm water programs and other agency efforts with regard to microbiological characterization and control of urban runoff,
- Developing a situation statement of the nature and degree of the concerns,
- Developing a sampling plan for microbiological parameters, and
- Developing a work plan for following years.

Total and fecal coliform levels are regulated along public saltwater beaches. When coastal beaches are used by at least 50,000 people annually, and a storm drain discharges into the receiving water in the summer, then the geometric mean of 5 weekly samples cannot exceed 1,000 MPN/100mL total coliform or 200 MPN/100 ml fecal coliform. There are no regulations for inland freshwater beaches, but DHS has published draft guidelines for freshwater inland beaches (DHS 2000). Storm water samples were not collected in a manner that allowed direct comparison to coastal water regulations, that is, median computed from 5 samples/month and compared to a standard.

An examination of total coliform counts for both urban areas found that storm water bacterial counts can range from below 10^3 MPN/100 ml to 10^7 MPN/100 ml (Tables 4-34 and 4-35). Both the median and range of total coliform counts from Sacramento storm water runoff are higher than those recorded for Stockton, however the reasons for this difference are unknown.

Table 4-34 Water Quality Comparisons between Sacramento Storm Water Runoff (all sites) and the Sacramento River at Greenes Landing/Hood for Selected Constituents

	Sacramento Area Stormwater Runoff				Sacramento River @ Greenes Landing/Hood			Banks
Contaminant	Drinking Water Standard	Range	Median[a]	Detected/ Total # of Samples	Range	Median[a]	Detected/ Total # of Samples	Range
DBP Precursor (mg/L)								
Total Organic Carbon	3 mg/L proposed target level	2.9 – 42[b]	9	34/34	1.3 - 4.2[c]	1.7	201/201	0.1 - 5.2[d]
Metals (µg/L)[e]								
Arsenic	50[f]	0.54 - 5.3[g]	na	49/55	< 1 – 2[h]	1	22/28	< 1 – 3[i]
Cadmium	5[f]	0.071 - 0.65[g]	na	32/70				
Chromium	50[f]	0.37 – 18[g]	na	39/67				
Copper	1300[f]	1.0 – 25[g]	na	73/73				
Lead	15[f]	0.32 – 8.5[g]	na	46/73				
Mercury	2000[f]	3.63 – 1137.9[g]	na	15/15				
Nickel	100[f]	1.0 - 9.1[g]	na	27/45				
Zinc	5000[f]	6.1 – 550[g]	na	70/73				
Microbiological Contaminants (MPN/100mL)								
Total Coliforms	-	240 - 2.3E+07[j]	1.6E+05	90/90	13 - 8.0E+03	300	44/44	7 – 3000[k]
Fecal Coliforms	-	240 - 9.0E+06[j]	1.6E+05	91/91	4 - 8.0E+03	30	43/43	4 – 300[k]
E. coli	-	ns	ns	ns	< 1- 50.4[l]	6.25	8/12	3.1-238[m]
Minerals (mg/L)								
TDS	500[n]	20 - 497[j]	68	115/115	50 – 374[o]	94	114/114	101 – 416[p]
Nutrients (mg/L)								
Nitrate + Nitrite as N	10	0.6-7.5[q]	1.4	16/16			2 samples collected in 10 years	0.23 - 1.8[r]
Total Phosphorus	-	< 0.05 - 3.6[s]	0.36	98/104			1 sample collected in 10 years	0.05 - 0.26[t]
Pesticides (µg/L)								
Diazinon	-	0.05 - 1.10[g]	na	42/58	ns	ns	ns	< DL[u]

Samples collected at Sacramento River at Freeport by Sacramento Coordinated Monitoring Program (CMP), Samples collected fall 1996 – Aug 2000; source Sacramento CMP database.

[a] Medians calculated with substitution of the DL for values < DL.

[b] Samples collected between 2/95-1/98; source--City of Sacramento Storm Water database report

[c] Samples collected between 10/97-12/99; source--MWQI database

[d] Samples collected between 7/97-12/99; source MWQI database.

[e] with the exception of mercury, all metal values are dissolved

[f] Metal MCLs are for total metals

[g] Samples collected between 1990 and 1999; source--Tables B-5 through B-8; 1998/99 Annual Monitoring Report and Comprehensive Evaluation, 1990-1999, Dec 1999, Larry Walker Assoc.

DL = Detection Limit
na = unable to analyze from
ns = not sampled

[h] samples collected monthly between 1/96-8/98; source MWQI database

[i] Samples collected between 7/91-12/99; source MWQI database.

[j] Samples collected between 10/91-1/98; source--City of Sacramento Stormwater database

[k] Samples collected monthly between 4/96 and 5/98; source O&M Web site

[l] Samples collected between 11/96 - 4/98; source MWQI database.

[m] Samples collected between 11/96-7/97; source MWQI database

[n] Secondary MCL

[o] samples collected between 10/91-1/98.

[p] Samples collected between 10/91-1/98; source MWQI and O & M databases.

[q] Samples collected from 2 storm events 12/90 and 2/91; source--City of Sacramento Stormwater database

[r] Samples collected quarterly in 95/96. No samples used for 1997. Samples collected monthly 1998-1999.; Source MWQI and O&M databases.

[s] Samples collected between 2/90-1/98; source--City of Sacramento Stormwater database

[t] Samples collected between 2/90-1/98; source: O&M databases.

[u] Samples collected twice in 1999; source MWQI database

Table 4-35 Water Quality Comparison between Stockton Storm Water Runoff (all sites) and the San Joaquin River near Vernalis/Mossdale

	Stockton Area Urban Runoff Water Quality				San Joaquin River near Vernalis/Mossdale			Banks
Contaminant	Drinking Water Standard	Range	Median[a]	Detected/ Total # of Samples	Range	Median[a]	Detected/ Total # of Samples	Range
DBP Precursor (mg/L)								
Total Organic Carbon	3 mg/L proposed target level	4.9 – 60[b]	9.2	71/71	2 - 8.5[c]	2.9	77/77	0.1 - 5.2[d]
Metals (µg/L)[e]								
Arsenic	50	ns	ns	ns	< 1 – 3[f]	2	74/79	< 1 – 3[g]
Cadmium	5	< 0.1- 2.7[b]	0.3	54/72				
Chromium	50	< 1 – 65[b]	3	57/73				
Copper	1,300	2.2 – 48[b]	10	69/69				
Lead	15	< 1 – 50[b]	8.5	65/73				
Mercury	2,000	ns	ns	ns				
Nickel	100	< 2 – 66[b]	5	67/73				
Zinc	5,000	14 - 1900[b]	120	73/73				
Microbiological contaminants (MPN/100mL)								
Total Coliforms	-	900 - 1.3E + 07[b]	8.0E + 04	70/70	ns	ns	ns	7 – 3000[h]
Fecal Coliforms	-	240 - 2.2E + 06[b]	1.0E + 04	66/66	ns	ns	ns	4 – 300[h]
E. coli	-	ns	ns	ns	< 1- 3440[i]	78	21/24	3.1 – 238[j]
Fecal Streptococcus	-	1,100 - 2.3E + 06[b]	3.0E + 04	65/65	ns	ns	ns	ns
Minerals (mg/L)								
TDS	500[k]	10.0 - 260[b]	50	71/71	83 – 578[l]	261	143/143	85-399[l]
Nutrients (mg/L)								
Nitrate + Nitrite as N	10	<0.2 - 1.9[b]	0.5[a]	31/37	ns	ns	ns	0.23 - 1.8[m]
Total Phosphorus	-	<0.1 - 1.5[b]	0.35[a]	64/70	ns	ns	ns	0.07-0.22[n]
Pesticides (µg/L)								
Diazinon	-	0.03 - 2.3[b]	0.39[a]	57/75	<DL[o]	<DL	<DL[o]	< DL[p]

[a] Medians calculated with substitution of the DL for values < DL.

[b] Samples collected between 1995-2/00; data compiled and analyzed from--City of Stockton 1995-1996 NPDES Storm Water Monitoring Program, Aug 1996, Tables 7-16, Kinnetic Laboratories, Inc.; City of Stockton 1997-1998 Storm Water Monitoring Program, Aug 1998, Tables 6-14, Kinnetic Laboratories, Inc.; Storm Water Management Program 1998/99 Annual Report and Program Effectiveness Evaluation Report, Jul 1999, Appendix M1, Larry Walker and Assoc.; City of Stockton Department of Municipal Utilities Storm Water Division 1999/2000 Annual Report, Aug 2000, Table 2. No author cited.

[c] Samples collected between 9/98 and 2/00 ; source MWQI database

[d] Sample collected between 7/97-12/99; source MWQI database

[e] All values represent Total Metal Concentrations and MCLs

[f] Samples collected monthly between 1/96-8/98; source MWQI database

[g] Samples collected between 1/98-12/99; source MWQI database

[h] Samples collected monthly between 4/96 and 5/98; source O&M Web site.

[i] Samples collected between 11/96 - 4/98; source MWQI database.

[j] Samples collected between 11/96-7/97; source MWQI database.

[k] Secondary MCL.

[l] Samples collected 1/96-12/99; source MWQI & O&M databases.

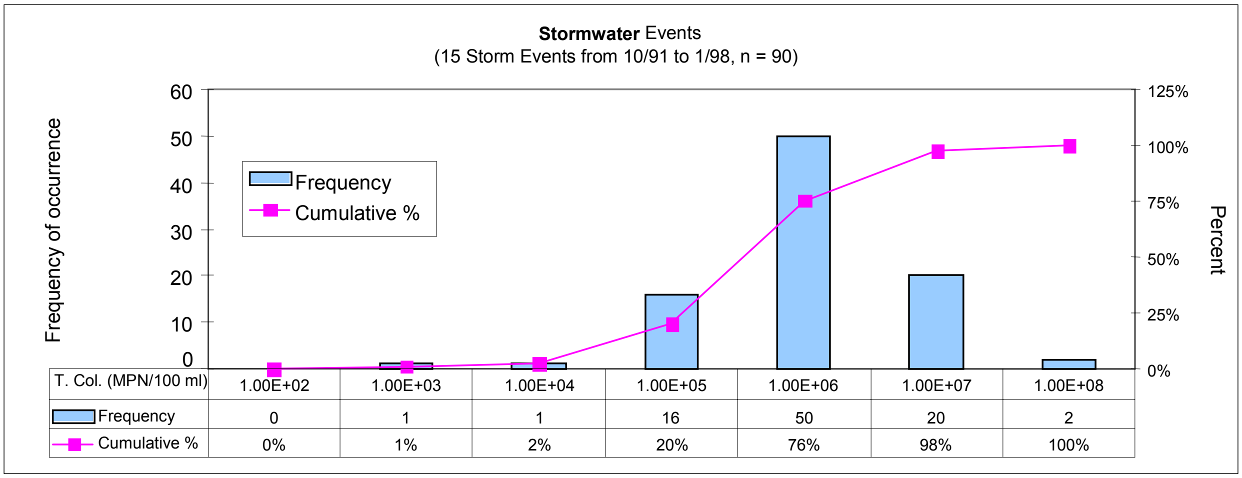
[m] Samples collected quarterly in 1995/1996. No samples used for 1997. Samples collected monthly 1998-1999. ; source MWQI and O&M databases.

[n] Samples collected 1/96-12/99; source MWQI & O&M databases.

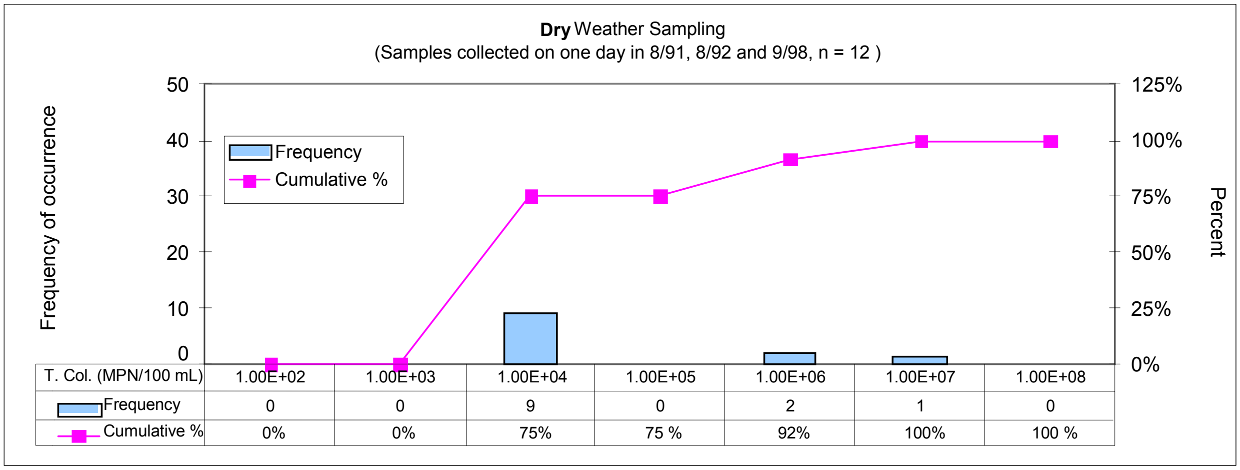
[o] Samples collected monthly between 9/96-9/97; source MWQI database.

[p] Samples collected twice in 1999; source MWQI database.

Figure 4-35 Cumulative Probability Distribution of Total Coliform from Sacramento Urban Runoff



T. Col. (MPN/100 ml)	1.00E+02	1.00E+03	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08
Frequency	0	1	1	16	50	20	2
Cumulative %	0%	1%	2%	20%	76%	98%	100%



T. Col. (MPN/100 mL)	1.00E+02	1.00E+03	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08
Frequency	0	0	9	0	2	1	0
Cumulative %	0%	0%	75%	75 %	92%	100%	100 %

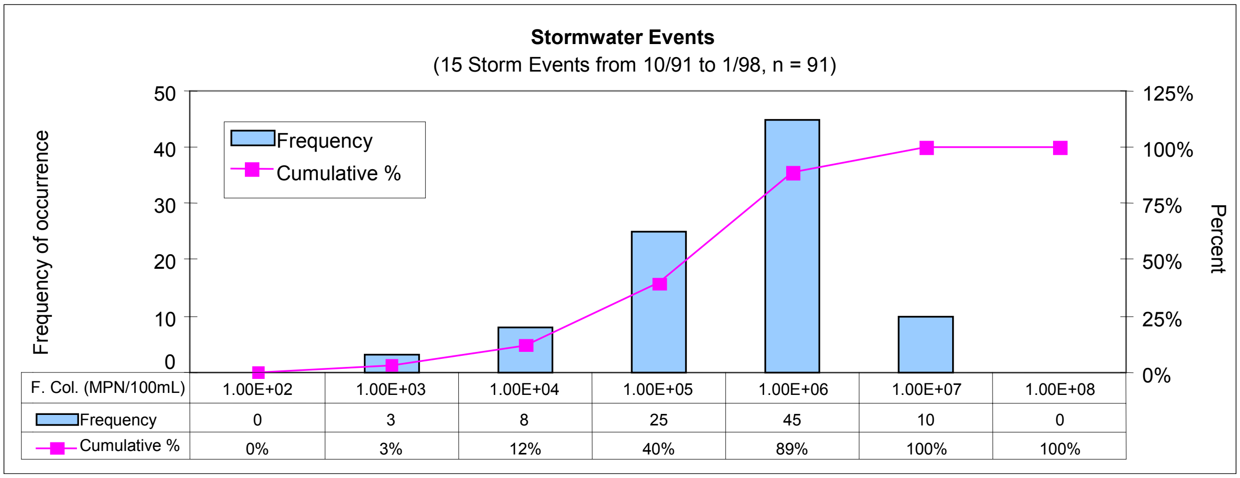
As illustrated by cumulative probability graphs, more than 50% of the total coliform counts in Sacramento storm water runoff lie between 10^5 and 10^6 MPN/100mL (Figure 4-35). During dry weather conditions, the majority of total coliform densities fall by an order of magnitude to 10^4 MPN/100 ml or less. Median densities were 2 orders of magnitude higher in wet weather than in dry weather (Table 4-36). The few samples indicate coliform numbers often increase following storm water events.

Table 4-36 Water Quality of Selected Constituents from Sacramento Area Runoff Storm Water Collection Sites. Comparison between Wet Weather and Dry Weather Samples.

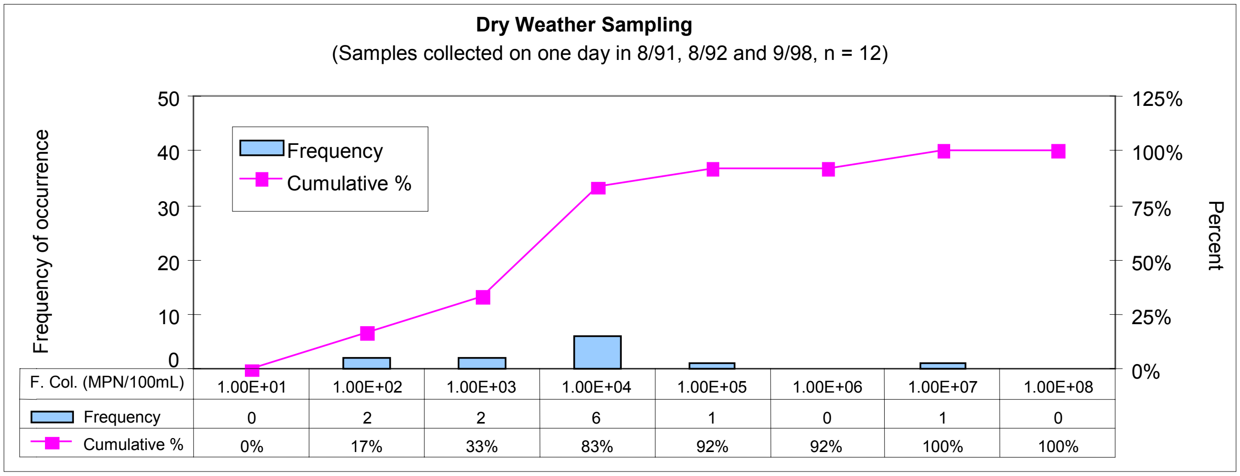
	Sacramento Wet Weather Runoff				Sacramento Dry Weather Runoff		
Contaminant	Drinking Water Standard	Range	Median[a]	Detected/ Total # of Samples	Range	Median[a]	Detected/ Total # of Samples
DBP Precursor (mg/L)							
Total Organic Carbon	3 mg/L proposed target level	2.9 – 42[b]	9	34/34	6.9 – 38[c]	9	9/9
Nutrients (mg/L)							
Total Phosphorus	-	< 0.05 - 3.6[d]	0.36	98/104	0.05-0.87[e]	0.49	18/18
Microbiological Contaminants (MPN/100mL)							
Total Coliforms	-	240 - 2.3E+07[f]	1.6E+05	90/90	1.6E+03 - 1.6E+06[a]	1.60E+03	12/12
Fecal Coliforms	-	240 - 9.0E+06[f]	1.6E+05	91/91	80 - > 1.6E+06[a]	1.60E+03	12/12
Minerals (mg/L)							
TDS	500[g]	20 – 497[f]	68	115/115	120 – 333[h]	240	18/18

[a] Samples collected on one day in 8/91, 8/92, and 9/98; source--City of Sacramento Stormwater database.
[b] Samples collected between 2/95-1/98; source--City of Sacramento Stormwater database.
[c] Samples collected 3/98, 5/98, and 9/98.
[d] Samples collected between 2/90-1/98; source--City of Sacramento Stormwater database.
[e] Samples collected 8/90 and 91, 3/98, 5/98, and 9/98.
[f] Samples collected between 10/91-1/98; source--City of Sacramento Stormwater database.
[g] Secondary MCL.
[h] Samples collected 8/91 and 92, 3/98, 5/98 and 9/98; source--City of Sacramento Stormwater database.

Figure 4-36 Cumulative Probability Distribution of Fecal Coliform from Sacramento Urban Runoff



F. Col. (MPN/100mL)	1.00E+02	1.00E+03	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08
Frequency	0	3	8	25	45	10	0
Cumulative %	0%	3%	12%	40%	89%	100%	100%



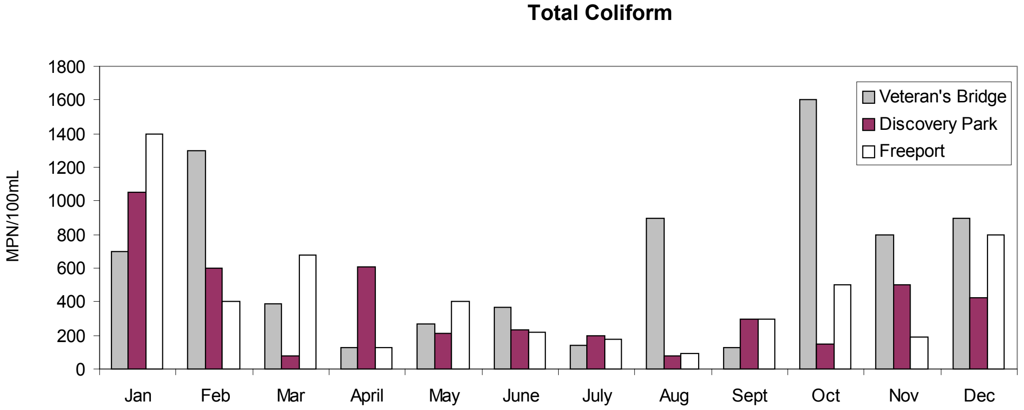
F. Col. (MPN/100mL)	1.00E+01	1.00E+02	1.00E+03	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08
Frequency	0	2	2	6	1	0	1	0
Cumulative %	0%	17%	33%	83%	92%	92%	100%	100%

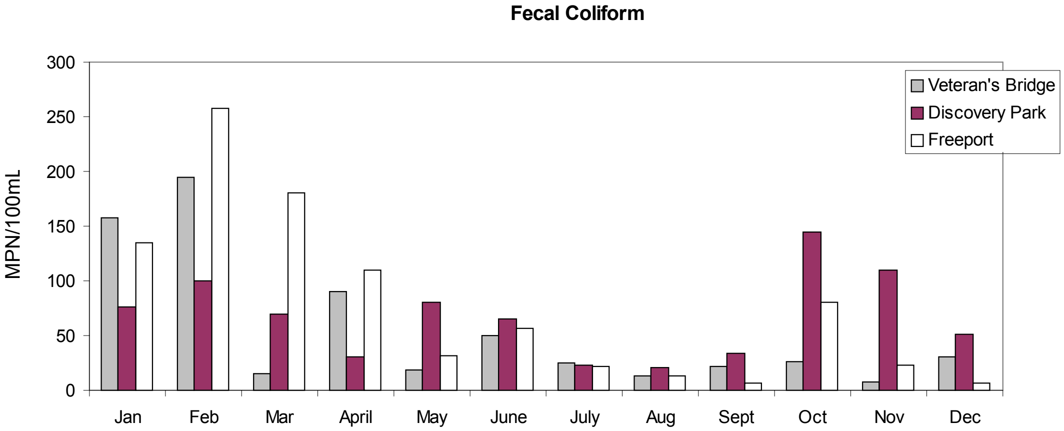
Similar comparisons between the Sacramento Storm Water Program's wet and dry sampling were made for fecal coliforms (Figure 4-36). Patterns for fecal coliforms were similar to patterns observed for total coliforms. Like total coliforms, at least half of all fecal coliforms detected were between 10^5 and 10^6 MPN/100mL. Similarly, under dry weather conditions, the majority of fecal coliform counts fell to 10,000 MPN/100 mls or less. Like total coliforms, median fecal coliform densities were 2 orders of magnitude higher under wet weather conditions than in dry (Table 4-36), however, with so few dry weather samples, it would be premature to make judgments on wet versus dry patterns.

It was not possible to evaluate the impacts of Sacramento bacterial storm water discharges to the Sacramento River farther downstream of the city. DWR's MWQI program only monitors for *E. coli* at Greenes Landing/Hood, and this parameter was not monitored by the Sacramento storm water program. However, bacteriological data are collected by the Sacramento Coordinated Monitoring Program (CMP). Sampling sites include a site on the Sacramento River upstream from Sacramento urban input (Veteran's Bridge), the confluence of the American River with the Sacramento River (Discovery Park), and the Sacramento River at Freeport above the Sacramento RWTP. Total and fecal coliform data have generally been collected monthly from these sites from fall 1996 to August 2000, the last date data were available electronically from the program.

To examine seasonal trends, the monthly median for total and fecal coliform data were calculated for the 3 CMP sampling sites. Monthly bacterial sampling is not adequate to fully characterize this highly dynamic variable. To increase the sample size, all data from all years were combined at each site.

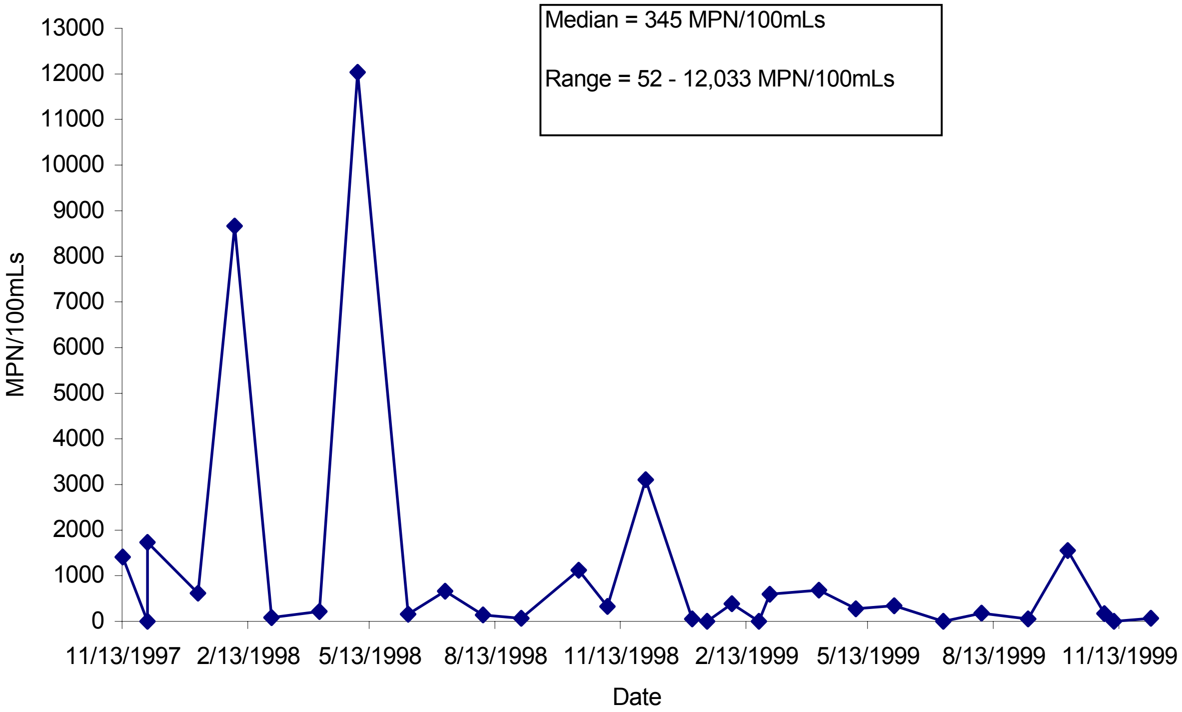
Figure 4-37 Median Total and Fecal Coliform Densities by Month for Receiving Waters in the Sacramento Urban Area, Fall 1996 to Summer 2000


Total Coliform


Fecal Coliform

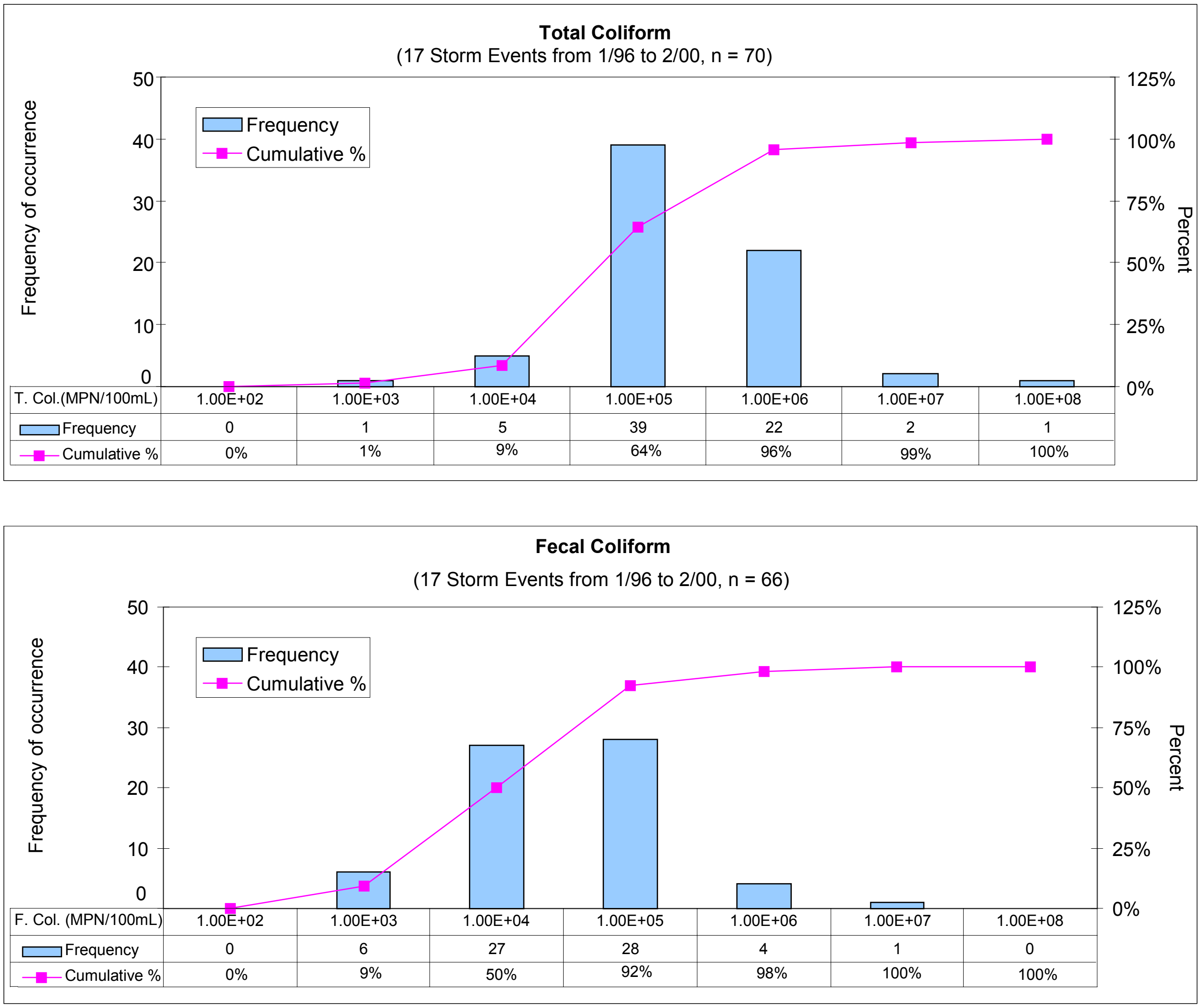
With respect to monthly patterns, most increases in coliform numbers in the Sacramento and American rivers occurred between October and March (Figure 4-37). In the remaining months, bacteria numbers were generally lower. Based on a single grab sample, the draft DHS guidance for freshwater public beaches recommends local health officials post warning signs if total or fecal coliforms exceed 10,000 per 100 mLs or 400 per 100 mLs, respectively (DHS 2000). Monthly grab samples never exceeded these limits at any of the sites analyzed. However, monthly sampling would not be expected to capture the impacts of storm water urban runoff on river water quality.

Figure 4-38 Monthly *E. Coli* Counts in the Natomas East Main Drain, Jan 1997 to Dec 1999



Patterns associated with *E. coli* levels in NEMDC were not conclusive. In winter 1998, *E. coli* levels were generally high. However, *E. coli* numbers collected in winter 1999 were not much different from those observed during the summer (Figure 4-38). This may be an artifact of sampling. Spikes in coliform numbers could easily be missed with monthly sampling. Low sample frequency may also explain why the highest *E. coli* numbers observed over a 2-year period occurred in May 1998. Although the overall median for the 2-year period was 345 MPN/100 mLs, samples collected once a month did not allow a monthly median to be calculated.

Figure 4-39 Cumulative Probability Distribution of Total and Fecal Coliform from Stockton Storm Water Program



T. Col.(MPN/100mL)	1.00E+02	1.00E+03	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08
Frequency	0	1	5	39	22	2	1
Cumulative %	0%	1%	9%	64%	96%	99%	100%

F. Col. (MPN/100mL)	1.00E+02	1.00E+03	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08
Frequency	0	6	27	28	4	1	0
Cumulative %	0%	9%	50%	92%	98%	100%	100%

Monthly total and fecal coliform were collected from the Banks Pumping Plant between April 1996 and May 1998. Monthly total coliform ranges were much wider than those observed at any of the Sacramento or American River sites, while fecal coliform numbers generally fell within the same range observed by the CMP.

Cumulative probability graphs of total and fecal bacterial counts were also examined for Stockton storm water runoff (Figure 4-39). At least half of the total and fecal coliform densities fell an order of magnitude lower than those observed in Sacramento storm water discharge. For example, in the case of total coliforms, more than 50% of Stockton's bacterial counts fell at or below 10^5 MPN/100 mLs. In the case of Sacramento, this point occurred between 10^5 and 10^6 MPN/100 mLs. Similar differences between the 2 storm water programs were observed with fecal coliforms. For example, approximately 50% of Stockton's fecal coliform counts occurred at 10^4 MPN/100 mLs or less, whereas at least 50% of Sacramento's fecal coliforms were detected an order of magnitude higher. Dry weather sampling data were not available from the Stockton storm water co-permittees.

It was not possible to evaluate the impacts of Stockton bacterial storm water discharges to downstream receiving water. DWR's MWQI program only monitors for *E. coli* at the San Joaquin River near Vernalis and at Mossdale; both stations are upstream of Stockton. Monthly total and fecal counts were available for the Banks Pumping Plant between April 1996 and May 1998. However, it is not possible to determine the effects of Stockton storm water discharges on coliform levels at the pumping plant without more data and sampling locations between Banks and Stockton.

4.3.3.2 Metals

Direct comparisons between urban runoff metal concentrations and drinking water method detection limits (MDLs) must be viewed with caution as dissolved metals were measured by the storm water programs while MDLs are measured as total metal concentrations. With this caveat, copper, lead, and zinc have been noted as constituents of concern by both storm water programs; however, the dissolved metal levels for these as well as other monitored metals, including mercury, were well below drinking water MCL or action levels (ALs) (Tables 4-34 and 4-35). Because all metals were below drinking water MCLs, they were not compared to levels in the Sacramento or San Joaquin rivers. The 1995 sanitary survey conducted for the cities of Sacramento and West Sacramento concluded that metals from the area's storm water runoff were of little significance to the drinking water quality of the Sacramento River (Archibald & Wallberg and others 1995). The survey considered mine drainage to be the most significant source of metals to the river.

The total arsenic MCL for treated drinking is 50 µg/L. The highest dissolved arsenic concentration reported in Sacramento storm water discharge was 5 µg/L. Dissolved arsenic was analyzed monthly from January 1996 to August 1998 (total arsenic was not analyzed) from the Sacramento River at Greenes Landing/Hood. During this time, dissolved levels were never higher than 2 µg/L. These results are inconclusive because the effects of pulsed storm events may be missed with monthly sampling. Although arsenic was not sampled by the Stockton storm water program, values were examined in San Joaquin River receiving water (Table 4-35). Dissolved arsenic concentrations were similar to those observed in the Sacramento River at Greenes Landing/Hood, ranging from below the detection limit to 3 µg/L. However, like samples collected from the Sacramento River, arsenic samples were only collected monthly. Beginning in 1990, arsenic samples have been collected monthly at the Banks Pumping Plant. Again, monthly sampling is too infrequent to capture pulsed storm water discharges, however, over a 9-year period, dissolved arsenic concentrations at the Banks Pumping Plant have never exceeded 3 µg/L. The data indicate the high likelihood that discharges from either urban area are not impacting arsenic levels at the pumps.

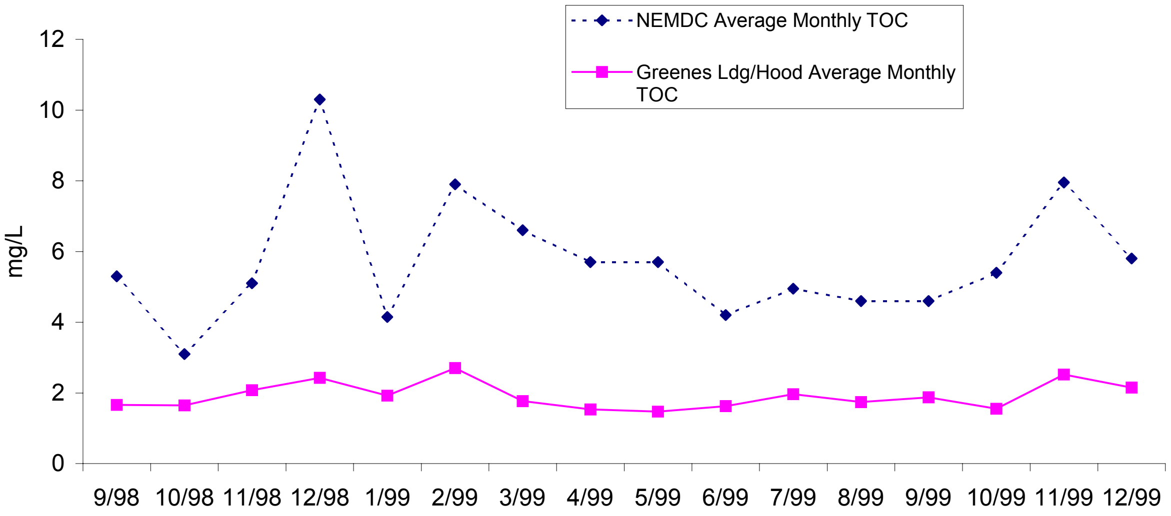
4.3.3.3 Total Organic Carbon

Total organic carbon levels in Sacramento and Stockton urban area storm water discharges, at downstream receiving water stations, and the Banks Pumping Plant are shown in Tables 4-34 and 4-35, respectively.

TOC ranges associated with Sacramento urban runoff were considerably wider than ranges observed in the Sacramento River (Table 4-34). TOC concentrations in Sacramento storm water were 2.9 to 42 mg/L, while downstream at the Sacramento River at Greenes Landing/Hood sites, TOC concentrations were 1.3 to 4.2 mg/L. The wide TOC ranges in storm water runoff may reflect the influence of 1st flush effects or the impacts from different land use areas sampled by the program. Although samples were collected from 2 mutually exclusive programs and true comparisons are problematic, some tentative conclusions may be drawn from the data. Over a 2-year period, TOC was never higher than 4.2 mg/L in weekly samples collected from the Sacramento River at Greenes Landing/Hood stations. Depending on the intensity of the storm and the storm water discharge volume, this frequency of sampling could potentially capture some of the storm water discharge. If this assumption is true, then the lower TOC concentrations in the river, downstream of storm water discharges, suggests that the impacts of urban storm water on TOC concentrations were minimal. Alternatively, the impacts of urban storm water on TOC concentrations could have been missed entirely with this frequency of sampling. At the Banks Pumping Plant, TOC is generally collected monthly. Total organic carbon at the pumping plant ranged from 2.3 to 6.7 mg/L. Monthly sampling is too infrequent to capture pulsed storm water discharges.

Dry weather samples were collected from the same sumps and drains sampled during wet weather events. Although not compared statistically, there appeared to be little difference in TOC concentrations between dry and wet weather samples (Table 4-36). Dry weather events have been less sampled than wet weather. More data are needed to support this observation as a conclusion.

Figure 4-40 Comparisons between Monthly Average TOC at Natomas East Main Drainage Canal and the Sacramento River at Greenes Landing/Hood



Monthly TOC samples from NEMDC have only been collected since fall 1998. When compared over the same time period, TOC concentrations at NEMDC were consistently higher than the average TOC levels in the Sacramento River at Greenes Landing/Hood (Figure 4-40, Table 4-37). Although TOC concentrations at both sites showed a threefold difference between their lowest and highest TOC concentrations; the highest TOC concentration recorded at Greenes Landing/Hood was 3.6 mg/L, while the highest value recorded at NEMDC was 10.6 mg/L. In general, monthly TOC patterns were similar between the sites. Both sites experienced the highest TOC concentrations in winter months; however, monthly changes in NEMDC winter TOCconcentrations were more variable than those observed in the Sacramento River. These results are likely due to different sampling frequencies. Samples were collected weekly and averaged at Greenes Landing/Hood, while samples from NEMDC were generally collected once a month. Although changing the frequency of the sampling might decrease the variability observed in monthly NEMDC values, this still would not affect the conclusion that TOC levels are consistently higher in the drain than in the river. No samples are collected at the point where NEMDC discharges into the Sacramento River. Therefore, it is unknown what effects the drain has locally. However, based on concentration data, it appears to be well diluted when it reaches the Greenes Landing/Hood sites.

Table 4-37 TOC Summary Statistics for Natomas East Main Drainage Canal and the Sacramento River at Greenes Landing/Hood

	TOC (mg/L)			
	Range	Median	Mean	Detected/ Total Number of Samples
Natomas East Main Drainage Canal (NEMDC)	3.1 – 10.3	5.4	5.9	19/19
Sacramento River at Greenes Landing/Hood	1.4 – 3.6	1.6	1.8	144/144

TOC concentrations from storm water runoff from the Stockton urban area were also compared to water quality in the San Joaquin River stations near Vernalis and at Mossdale (Table 4-35). Similar to Sacramento storm water runoff, TOC ranges recorded for Stockton storm water discharges were much greater than those observed in the river. From 1995 and February 2000, TOC concentrations in Stockton storm water runoff have ranged from 4.9 to 60 mg/L. In the San Joaquin River near Vernalis, TOC concentrations between 1998 and February 2000 ranged between 2 and 8.5 mg/L. At Banks Pumping Plant, TOC is generally collected monthly. TOC concentrations ranged from 2.3 to 6.7 mg/L. Sampling frequencies at the pumping plant were too low to be able to make comparisons between urban discharge and the pumping plant.

4.3.3.4 Nutrients

Nitrate plus nitrite as N and total phosphorus were examined from storm water runoff in both urban areas (Tables 4-34 and 4-35). In the case of nitrate plus nitrite, median values and ranges for both urban areas were below the drinking water MCL of 10 mg/L. Median concentrations were higher in Sacramento storm water runoff; however, only 16 samples were collected by Sacramento, while Stockton collected twice that number. Brown and Caldwell and others (1995) estimated that the nitrate plus nitrite load from Sacramento urban discharge to the Sacramento River at Freeport was between 0% and 11%. Similar calculations were not done for the storm water discharge to the San Joaquin River. This constituent has rarely been sampled at Greenes Landing/Hood or Vernalis/Mossdale. It has also not been sampled in the Sacramento River by the CMP or by DWR at NEMDC. However, nitrate plus nitrite has been collected monthly since 1998 at the Banks Pumping Plant. Nitrate plus nitrite concentrations at the Banks Pumping Plant have ranged from 0.23 to 1.8 mg/L. This frequency of sampling would not be expected to capture pulsed storm water events, but these values fall below the drinking water MCL. Nitrate plus nitrite concentrations have not been analyzed in Sacramento's dry weather sampling.

No MCLs have been established for total phosphorous. Median values were nearly identical between the 2 urban areas (0.36 and 0.35 mg/L for Sacramento and Stockton, respectively) (Tables 4-34 and 4-35). However, based on the wider range of concentrations, total phosphorous appeared more variable in Sacramento storm water discharges. Not enough samples were collected from either the Sacramento River at Greenes Landing/Hood or the San Joaquin River near Vernalis/Mossdale to make meaningful comparisons of receiving water impacts from storm water discharges. Total or dissolved phosphorous was also not analyzed at NEMDC. The CMP also does not collect samples for total phosphorous. At Banks, total phosphorous is analyzed once a month. In the case of both urban areas, the upper range of total phosphorous exceeded the ranges observed at the Banks Pumping Plant. However, given the frequency of sampling at the pumping plant, pulsed storm water events would probably not be captured. Brown and Caldwell and others (1995) estimated that the total phosphorous load from Sacramento urban discharge to the Sacramento River at Freeport was between 0% and 4%. Similar calculations were not done for storm water discharge to the San Joaquin River.

Total phosphorous concentrations from Sacramento dry weather sampling were not as variable as those associated with wet weather events; however, fewer samples were collected during dry weather (Table 4-36). Under dry weather conditions, total phosphorous was detected in every sample analyzed. Total phosphorous was usually detected in storm water discharges; however, there were several occasions when concentrations were below the detection limit. Although less variable than storm water discharges, median total phosphorus concentrations were higher than median levels under storm water conditions.

4.3.3.5 TDS

TDS concentrations for storm water runoff from the Sacramento and Stockton urban areas are shown in Tables 4-34 and 4-35. An examination of Sacramento's storm water data between 1991 and 1998 found that TDS levels above 200 mg/L occurred during 1 storm event in October 1991. All other storm events captured by the storm water program have never exceeded 150 mg/L TDS. Archibald & Wallberg (1995) and others in their 1995 sanitary survey for the cities of Sacramento and West Sacramento also concluded that TDS from Sacramento storm water discharge was not of concern. Both the median concentration and the range of TDS concentrations from Stockton storm water discharges were well below those detected upstream in the San Joaquin River near Vernalis/Mossdale. Although not all storm water events were captured by the program, the data suggest that storm water discharges from the Stockton co-permittees may have a minimal impact on drinking water MCLs. Although collected only monthly, TDS ranges at Banks were similar to ranges observed in the San Joaquin River. The secondary drinking water MCL for TDS is 500 mg/L.

In the Sacramento urban area, median TDS concentrations were higher for samples collected in dry weather. Ranges, however, were lower in dry weather than in wet. As mentioned previously, with the exception of 1 storm in a 9-year period, all Sacramento storm water TDS samples were at or below 150 mg/L. Therefore, the comparison between these sets of seasonal ranges can be misleading. Although very few dry weather samples have been collected, TDS levels would be expected to be higher in summer.

4.3.4 LIVESTOCK GRAZING CONTAMINANT SOURCES

There are no water quality data available that specifically address the impacts of livestock grazing on water quality in the Sacramento and San Joaquin rivers or the Delta Region.

4.3.5 CONFINED ANIMAL FEEDING OPERATIONS SOURCES

Very limited water quality data on CAFO sources are presented in Section 4.2.5.5. Other than that, there are no water quality data available that specifically address the impacts of CAFOs on water quality in the Sacramento and San Joaquin rivers or the Delta Region.

4.3.6 AGRICULTURAL DRAINAGE WATER QUALITY

4.3.6.1 Delta Region

DWR has studied Delta drainage and its impacts on drinking water quality since 1982. The following summaries are from publications of the Interagency Delta Health Aspects Monitoring Program (1982-1989), Delta Island Drainage Investigation (1986-1989), and MWQI Program (1990–2000), and consultant’s reports (1998-2000).

Pesticides

Delta drainage has not been sampled for pesticide contaminants for many years. Data collected in 1983 to 1987 both in the channels and drains showed that most (96%) concentrations were below the reported detection limits and far below drinking water MCLs (Table 4-38). The selection scheme for pesticide analyses was based on usage patterns and environmental behavior. The protocol produced a site and time-specific target list of pesticides for monitoring in the channels and drains to improve the chances of detecting any chemicals in the water and to eliminate the need for broad scans for hundreds of chemicals (DWR 1986). The data led to the conclusion that the levels of pesticide contaminants in the Delta were not a significant drinking water concern (DWR 1989).

Table 4-38 Pesticide Monitoring Results, 1983 to 1987, Interagency Delta Health Aspects Monitoring Program

Chemical	Highest concentration (ug/L)	Location (Found Above Detection Limit Once At Each Location Unless Noted)	Current MCLs (ug/L)
2,4-D	1.0	BR, BN, L, AGE(2), CS	70
4,4'-DDD	1.0	V	
4,4'-DDE	1.0	V, RS	
Atrazine	1.0	AGE	3
Bentazon	1.0	GR(2), AGE, V, BN(2). RS, AGT	18
BHC-alpha	0.003	V, DMC, CS, CC	
BHC-beta	0.006	V, DMC,CC	
BHC-gamma	0.006	L, GR, DMC, RS(2), CS, MO(2), H(2), NB, CC(2)	
Bolero (thiobencarb)	1.7	AGG, V	70
Carbofuran	1.33	V, CS	18
Dacthal	0.15	AGG	
Diazinon	0.1	V, BN, DMC, RS(2), CS, NB, CC	
Dieldrin	0.005	V, DMC, CC	
Dimethoate	0.046	V	
Endosulfan 01	0.004	V	
Endosulfan 02	0.005	DMC, RS, CS, CC	
Endosulfan	0.01	V, RS	
Glyphosate	10.0	AGE	700
Guthion	0.02	RS	
Methyl Parathion	2.5	V(2),DMC, RS, CS, CC	
Ordram (Molinate)	1.4	MA, L, GR, AGG, AGE(2), V(2), BN(2), DMC, RS(2), MI	20
Paraquat	74.0	V(2)	
Parathion	0.035	V, DMC, RS(2), CS, CC	
Simazine	0.36	DMC(2)	

LOCATION ABBREVIATIONS

AGE = Agricultural Drain at Empire Tract
AGG = Agricultural Drain at Grand Island
AGT = Agricultural Drain at Tyler Island
BN = Banks Pumping Plant
BR = Barker Slough
CC = Clifton Court
CS = Cache Slough
DMC = Delta-Mendota Canal
GR = Greenes Landing
H = Honker Cut
L = Lindsey Slough
MA = Mallard Island
MI = Middle River
MO = Mokelumne River
NB = North Bay Pumping Plant
RS = Rock Slough
V = San Joaquin River near Vernalis

Table 4-39 Harvey O. Banks Pesticide Detects, Jun 1995 to Dec 1996

Sample Site	Constituent Detected	Date Detected	Result (ug/L)	Federal MCL (ug/L)	State MCL (ug/L)
Banks Pumping Plant	Arsenic	Sep 1995	2	50 (10 proposed)	50 (10 proposed)
		Dec 1995	2		
		Mar 1996	1		
		Sep 1996	2		
		Dec 1996	1		
	Barium	Jun 1995	130	2,000	1,000
	Copper	Dec 1995	8	1,300 (Action Level)	1,000 (SMCL)
	2,4-D	Jun 1995	1	70	1000
	Dalapon	Dec 1996	2	200	200
	Manganese	Sep 1995	9	50 (SMCL)	50 (SMCL)
		Dec 1995	8		
		Mar 1996	33		
		Jun 1996	26		
		Sep 1996	12		
		Dec 1996	14		
	Zinc	Sep 1995	8	5,000 (2000 proposed)	5,000
		Dec 1995	10		
		Mar 1996	12		
		Jun 1996	4,330		
		Sep 1996	7		

HARVEY O. BANKS PUMPING PLANT PESTICIDE DETECTIONS The MWQI Program conducted the New Parameters Study from June 1995 to December 1996. It consisted of quarterly sampling within the Delta for proposed or newly regulated constituents. In addition, DWR O&M has conducted quarterly sampling from 1996 to 1999. The results for Banks PP and the DMC are shown in Tables 4-39 and 4-40. The years 1995 through 1999 were considered wet years for the Sacramento and San Joaquin basins. These studies did not sample during the heavy runoff months of January and February. This could have led to more dilution of pesticides being transported to the Delta pumping plants. Conversely, if storm water measurements had been taken, there may have been more pesticides detected, or at greater concentrations, especially following dormant spray periods.

Table 4-40 DMC Pesticide Detects

Sample Site	Constituent Detected	Date Detected	Result (ug/L)	Federal MCL (ug/L)	State MCL (ug/L)
DMC	Cyanazine	Mar 1997	0.12		
	2,4-D	Sep 1996	0.29	70	1000
		Jun 1997	0.13		
		Sep 1998	0.10		
	Dacthal (DCPA)	Mar 1996	0.04		
	Diuron	Mar 1996	0.13		
	Diazinon	Jun 1996	0.03		
		Jun 1997	0.03		
	Simazine	Mar 1996	0.06		4
		Jun 96	0.04		
		Mar 1997	0.06		

Results for the Banks PP showed that only herbicide active ingredients were detected in both studies. The herbicides detected were cyanazine, 2,4-D, dacthal, dalapon, diuron, and simazine. None of the herbicides detected exceeded federal or State MCLs. MCLs relate to finished drinking water standards, so the low detected concentrations reinforce the concept of low risk from pesticides entering the SWP.

Copper, zinc, and manganese were also detected below existing and proposed regulatory levels. These elements can be found in a number of natural sources but are also found in a number of fungicides. Copper-containing pesticides are used heavily on many of the crops found in the San Joaquin Basin and Sacramento Basin. Statewide, more than 4 million pounds of copper-based pesticides were applied in 1998. Rice production utilizes copper compounds to combat algal growth within the rice fields. Copper was also mined in the upper watershed of the Sacramento River, and runoff may transport remnant copper deposits into the river. Banks PP had a detection of copper in December 1995 of 0.008 mg/L as part of the New Parameters Study.

Manganese and zinc were detected frequently at both Banks PP and the DMC as part of the New Parameters Study. Grapes and tomatoes statewide received more than 327,000 pounds of manganese-containing mancozeb and maneb in 1998. More than 1 million pounds of zinc-containing ziram was applied statewide in 1998. There are no studies that show these pesticides are the source of the copper, manganese, and zinc found at Banks PP.

Salts

There are strong linear correlations (R^2 0.98) between measured EC and TDS in Delta drain water (Jung 2000). Drainage TDS and EC vary with the regional mineral content of the applied water used for irrigation and with the seasonal farming activities on the islands or tracts (Figure 4-41). Irrigation water in the north Delta is lowest in TDS and EC because its origin is the Sacramento River. Areas in the west Delta have water quality that is greatly influenced by seawater intrusion by daily tides and low upstream river flows. Therefore, irrigation and drain water in this area will generally have the highest EC, TDS, bromide, and chloride concentrations. In the southeast Delta, the TDS and EC are less affected by seawater because of blending with Sacramento River water. The EC range is between the average drainage EC seen in the north and west Delta regions (Figures 4-42 and 4-43).

Figure 4-41 Bulletin 123 Delta Subregions

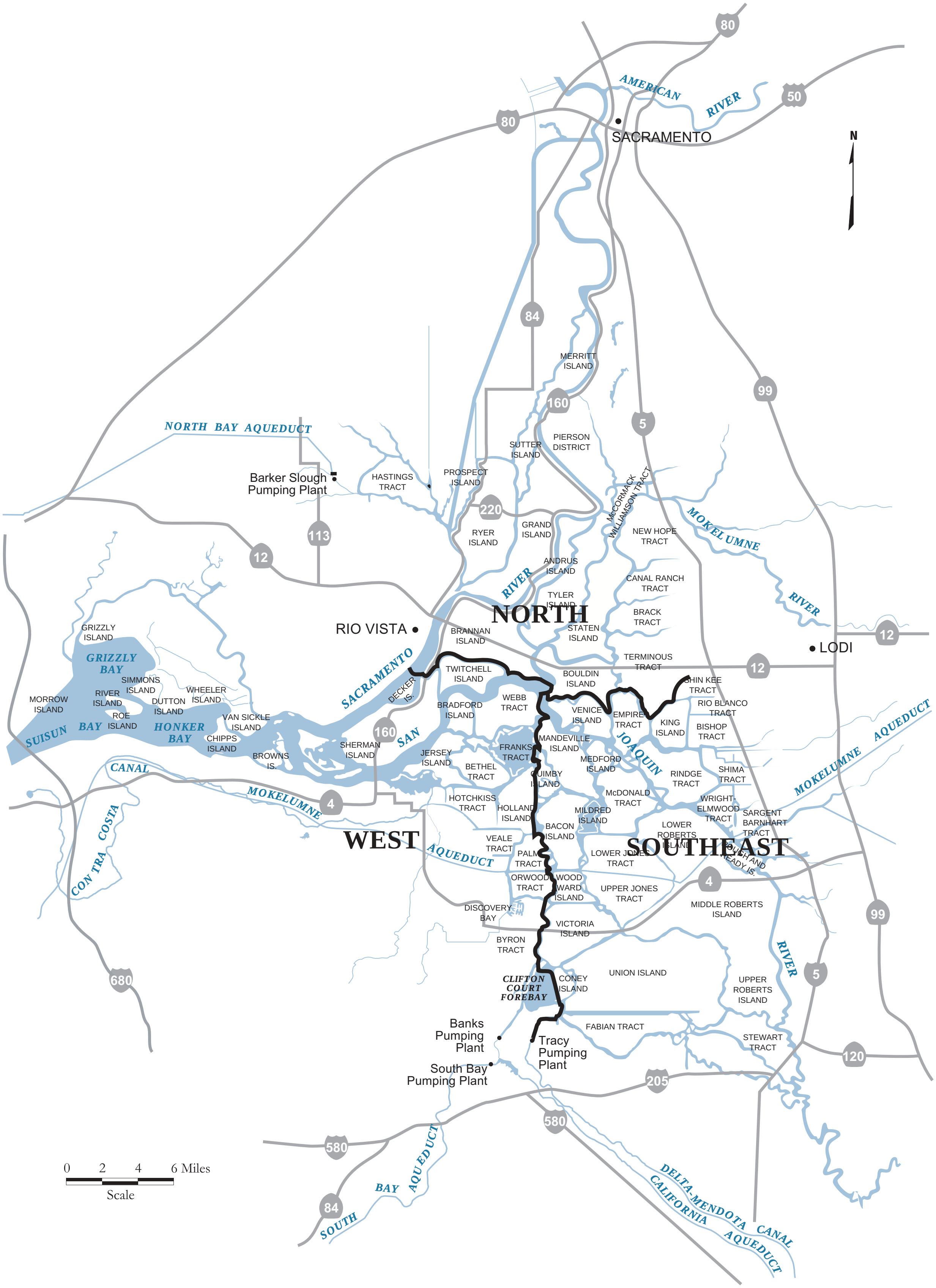


Figure 4-42 Average Monthly EC Values in Delta Drainage

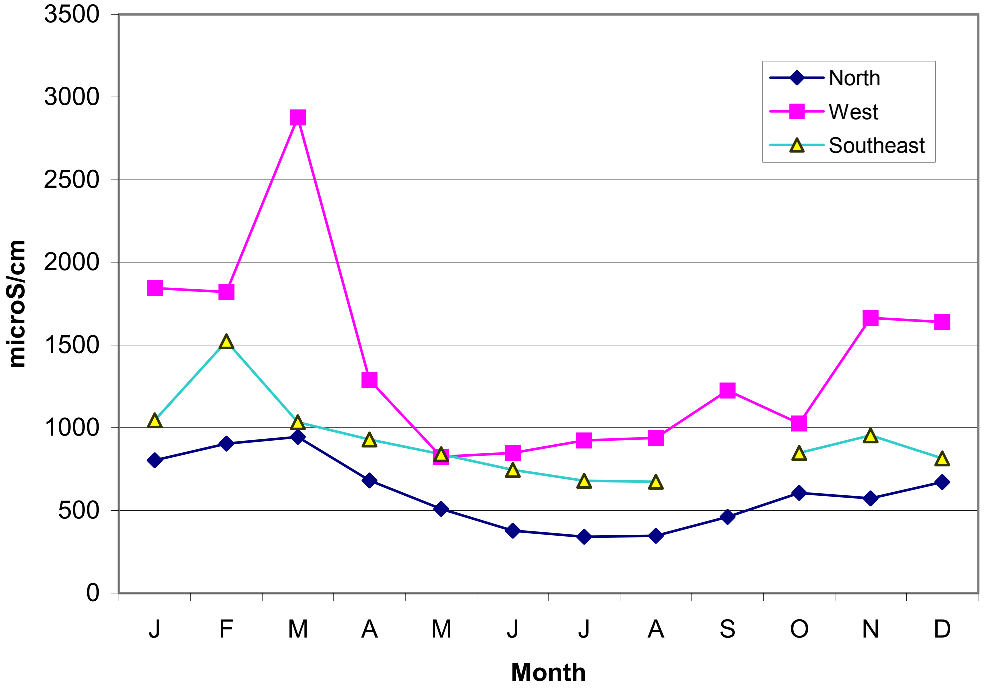


Figure 4-43 Average TDS in Delta Drainage

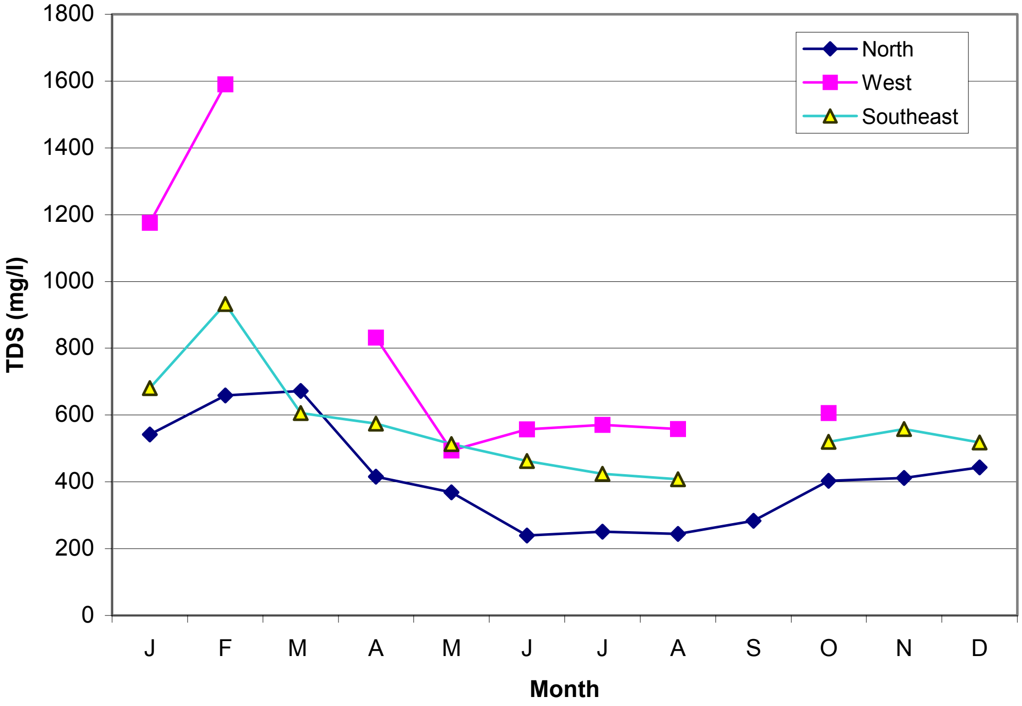
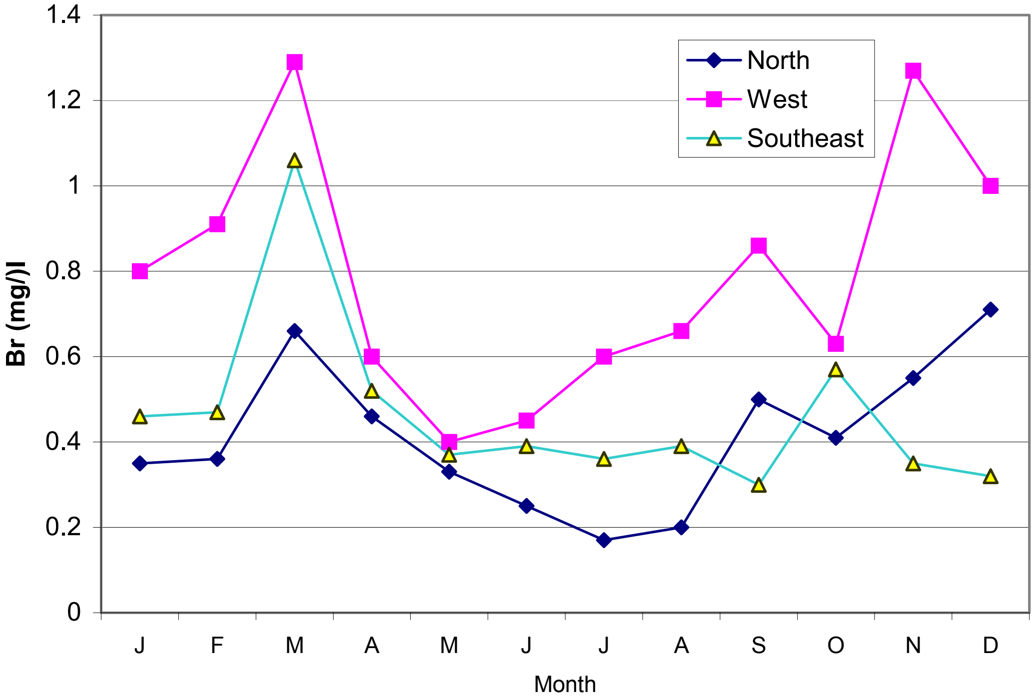


Figure 4-44 Average Monthly Bromide Concentrations in Delta Drainage



Drain water TDS and EC are typically lowest during the long warm summer. During late fall and early winter, the drainage TDS and EC increases significantly when the fields are ponded and leached to remove the salt residues from the previous irrigation season that would harm the next planting of crops. Prolonged heavy rainfall, which usually occurs in January through March, also aids in further dissolution and removal of the salts in the fields to the drains. The highest drainage TDS and EC values occur during this period.

Organic Carbon and Bromide

The monthly average bromide concentrations in Delta drainage are presented in Figure 4-44**.** Bromide sources on the islands include seawater ions in the irrigation water (west Delta), dissolution of evaporites, decaying plant matter, connate water, for example, Empire Tract, and thermal springs, for example, Byron Tract near Clifton Court Forebay.

The small drainage that discharges into Clifton Court Forebay is high in EC and other minerals from local underground hot springs. However, the discharge volume is considered to be small and has no discernible impact on the water quality at the Banks PP based on data collected at the drain, inside the forebay, and at the plant.

The rich organic peat soil and decaying crop residues contribute large amounts of TOC/DOC in the drains. There are both regional and seasonal differences in the concentration patterns. The regional range of DOC concentrations appears to be related to soil type and land surface elevations. Drainage from mineral soil areas, such as in the periphery of the Delta, had the lowest DOC concentrations. Figure 4-45 shows these regional differences based on the historic monthly maximum DOC. Areas overlying peat soil have higher levels of DOC. It also appears DOC concentrations are associated with land surface elevations, in particular, the below mean sea level heights. Islands with the lowest elevations often have the highest range of DOC concentrations. This could be attributed to longer water saturation time between soil and water before the drainage is pumped off and from higher seepage because of the greater height between the land elevation and adjacent channel water heights.

The seasonal drainage DOC concentration patterns for the Delta are shown in Table 4-41**.** The low DOC range subareas are primarily in mineral soil areas that have a lower soil organic carbon content. The mid range and high range DOC subareas overlie peat soil areas, and most of the high range areas have the lowest land surface elevation.

Figure 4-45 Delta Island Consumptive Use Model Subareas Based on the Highest Monthly Drainage DOC Concentrations, 1982 to 1997

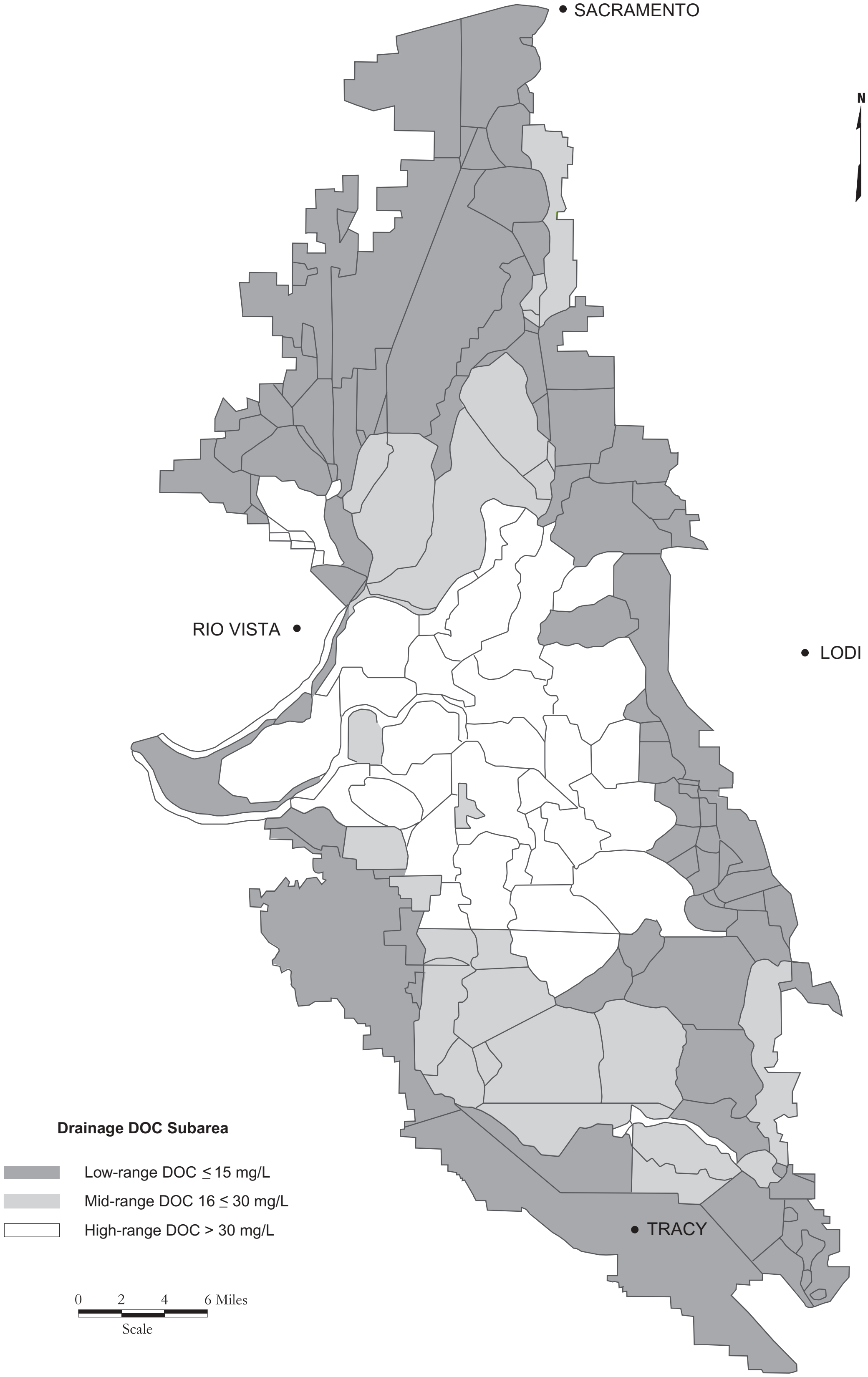


Table 4-41 Summary Descriptive Statistics for Delta Drainage DOC

Summary Statistics for Monthly DOC Concentrations for High Range Subarea in Delta

Month	Count	Min	Max	Range	Median	Mean	95% Upper CI	95% Lower CI	Std. Dev.
1	178	5.4	118.5	113.1	32	32.3	35.1	29.6	18.4
2	56	6.2	71	64.8	36.6	35.5	40.1	31	16.9
3	82	7.6	75.2	67.6	34.5	33.8	37.4	30.3	16.3
4	177	3.1	89	85.9	20.8	22	20.1	23.8	12.7
5	59	5.3	84.5	79.2	18	20.6	16.9	24.2	13.9
6	154	4.1	59	54.9	12.2	15.3	13.8	16.8	9.9
7	177	3.5	76	72.5	13	15.4	16.8	14	9.8
8	147	4.7	57	52.3	15	15.5	16.8	14.2	8.2
9	40	3	96	93	7.7	12	16.8	7.3	14.9
10	144	5.3	96	90.7	13	17.8	20.4	15.3	15.4
11	45	5.9	67.5	61.6	12	17.5	22	13	14.9
12	57	7.1	85	77.9	23.7	28.5	33.3	23.7	18.1

Summary Statistics for Monthly DOC Concentrations for Mid Range Subarea in Delta

Month	Count	Min	Max	Range	Median	Mean	95% Upper CI	95% Lower CI	Std. Dev.
1	57	1.9	29.5	27.6	7.9	10.5	12.6	8.4	8
2	12	3.2	20	16.8	16.3	12.8	17	8.6	6.6
3	31	1.5	37	35.5	10	11.8	15	8.5	8.9
4	57	1.7	17	15.3	7.7	8.3	9.3	7.4	3.4
5	21	3.4	17	13.6	6	7.4	9.1	5.7	3.7
6	42	1.6	18	16.4	6.7	7.3	8.2	6.4	2.8
7	51	3	18	15	6.7	7.5	8.4	6.7	3.1
8	48	3.1	18	14.9	6.9	7.7	8.8	6.7	3.5
9	9	4.7	14.8	10.1	8.2	9	11.4	6.6	3.2
10	46	2.5	18.7	16.2	7.1	8	9.1	6.8	4
11	9	1.7	14	12.3	6.7	7.5	10.8	4.1	4.4
12	10	3.4	19.6	16.2	12	11.6	15.6	7.6	5.6

Table 4-41 (continued)

Summary Statistics for Monthly DOC Concentrations for Low Range Subarea in Delta

Month	Count	Min	Max	Range	Median	Mean	95% Upper Cl	95% Lower Cl	Std. Dev.
1	12	3.2	8	4.8	4.8	5.1	6	4.2	1.5
2	2	4.3	4.4	0.1	4.4	4.4	5	3.7	0.07
3	14	4.2	6.9	2.7	5.4	5.5	6	5	0.8
4	14	3.3	8.1	4.8	5.9	5.7	6.5	4.9	1.5
5	7	3.5	6.9	3.4	5.7	5.6	6.7	4.5	1.2
6	7	2.1	11	8.9	3.7	4.8	7.6	1.9	3.1
7	7	3.1	13	9.9	3.6	5.3	8.6	2.1	3.6
8	5	2.3	5.9	3.6	4.1	4.3	6.1	2.4	1.5
9									
10	7	3.4	9.7	6.3	6	6.1	8.1	4.1	2.2
11									
12	3	5.5	6.1	0.6	5.8	5.8	6.6	5.1	0.3

The assessment of the impact of Delta drainage on the TOC/DOC concentrations at the diversions (NBA, CCWD, Banks, DMC) have been computer-simulated using the DICU and DWRSM2 models. Organic carbon mass load estimates for subregions of the Delta were computed, based on the estimated monthly average drainage volumes and average TOC/DOC concentrations, to identify which areas contribute the most organic carbon. The estimated TOC loads are shown in Table 4-42. Using a scoring scheme that considered proximity to Clifton Court Forebay, summer Delta flow patterns, and the mass load of discharged TOC/DOC, the subregions were ranked on their potential of affecting the TOC levels at the diversions. These subregions were identified as candidate regions for treatment to reduce organic carbon loads (Figure 4-46).

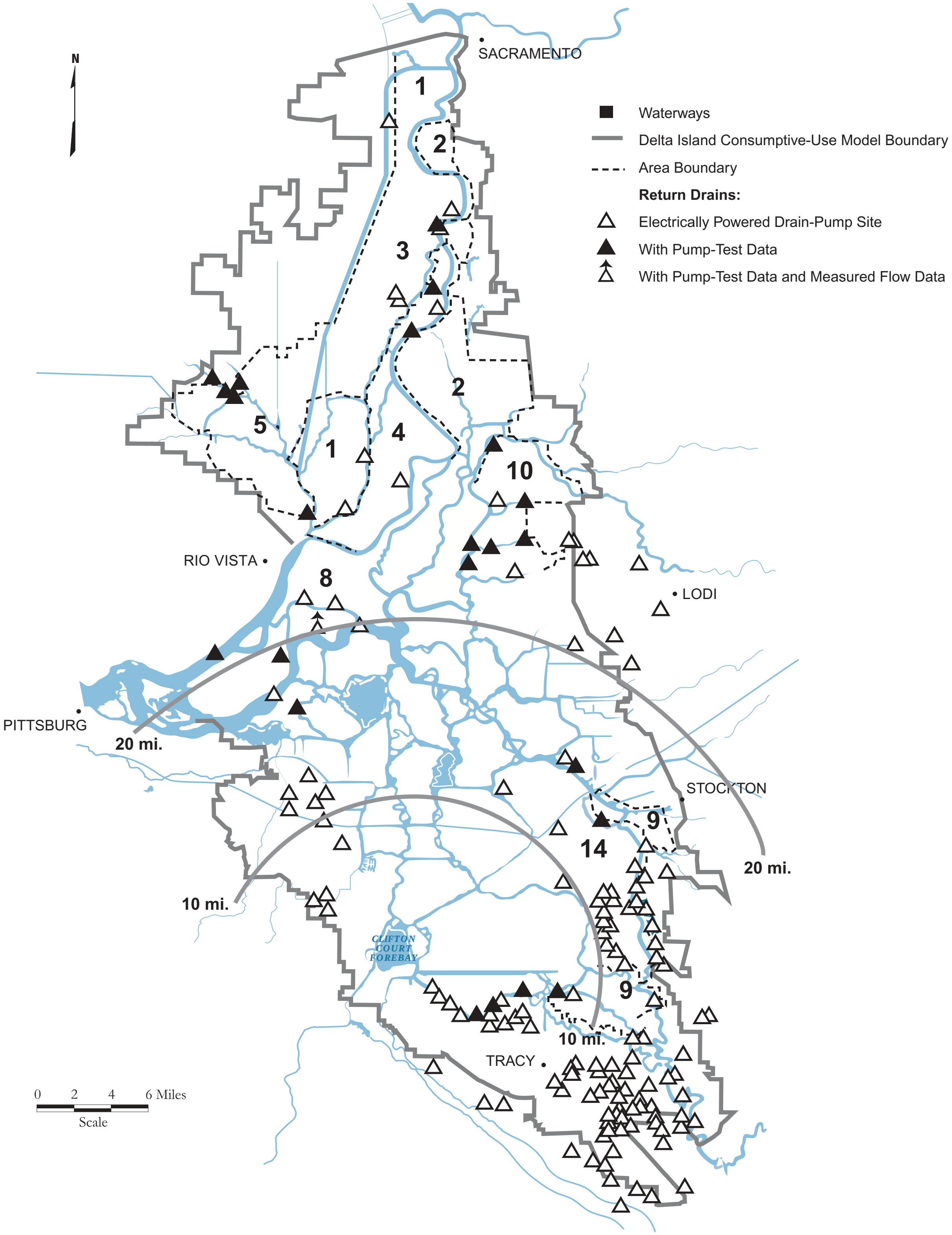
Table 4-42 Estimated Monthly Average Mass Loads of DOC

USGS[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	790	903	568	406	376	716	650	397	278	298	237	390
3	3,489	5,252	1,600	381	291	151	144	60	70	193	705	824
4	8,069	8,226	4,153	2,104	1,532	2,255	2,014	2,209	1,271	809	1,669	2,252
5	2,064	1,731	2,856	2,315	2,442	1,243	1,737	1,410	1,020	2,105	1,476	1,476
6	13,639	22,194	20,542	5,053	10,249	27,550	15,908	9,612	6,358	7,012	9,589	13,487
7	7,687	14,961	16,301	7,053	4,943	2,785	2,598	2,456	2,054	1,532	1,271	1,685
8	12,342	12,799	13,384	3,808	2,411	2,109	3,112	2,294	1,872	1,805	2,053	3,557
9	1,825	1,330	3,394	1,553	1,210	993	1,571	1,391	270	418	91	775
10	25,265	17,842	9,001	3,785	9,071	5,267	11,532	7,294	5,289	5,294	5,878	10,282
11	33,570	27,123	11,501	5,416	16,067	15,238	14,788	9,012	26,360	4,924	16,406	18,456
12	30,096	31,315	17,708	5,366	9,542	11,399	10,739	7,726	4,910	3,124	4,227	9,659
13	15,985	6,117	11,180	936	2,069	1,928	1,947	1,751	1,195	1,463	1,928	4,601
14	12,411	6,462	10,904	1,083	2,115	1,800	1,906	1,664	1,358	1,097	1,533	4,403
15	4,973	4,141	10,409	1,289	2,149	1,658	2,403	1,584	1,087	494	532	1,884

Average daily mass load of DOC discharged in pounds per day

[a] Location of the numbered sections are shown in Figure 4-46.

Figure 4-46 Candidate Regions for Modeling Impacts



Note: Numbers represent aggregated areas of the delta island consumptive-use model. Drains outside the boundary of the delta island consumptive-use model are used to pump water into the channels that serve the delta lowlands and uplands.

In a bench scale jar study of the treatment of Delta drainage from Twitchell Island to reduce organic carbon (Brown and Caldwell 1997a, 1997b, 1997c), ferric chloride coagulation removed up to 60% of the TOC/DOC in the drain water samples. Extrapolated costs from this study, yielded estimates of more than $400 million (20-year life project) for constructing and operating treatment plants at the candidate region islands and tracts (Jung and Tran 1999). The model simulation showed that the CALFED target of 3 mg/l TOC at the SWP and DMC intakes could be met 6 months of the year on average if TOC loads were reduced by 60% at these candidate regions. Under simulated existing conditions, the model showed the target could not be met, according to Jung's unpublished data.

4.3.6.2 Sacramento River Basin

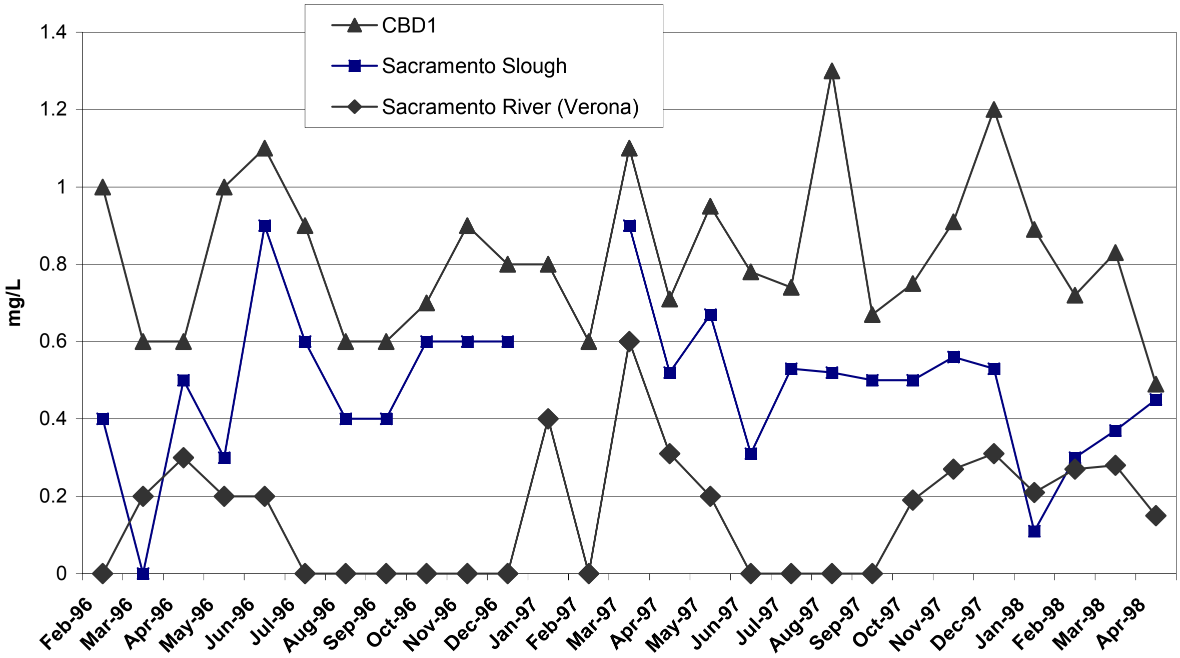
Pesticides

Much of the historical work done on pesticides in the Sacramento River has focused on ecosystem impacts as documented in previous sanitary surveys. The USGS National Water Quality Assessment (NWQA) study provides new data for major drains and tributaries feeding the Sacramento River (Domagalski 2000). Additionally, pesticide data have been accumulated in the California Department of Pesticide Regulation surface water database. Results for the 2 main agricultural drains (the CBD1 and Sacramento Slough), the Sacramento River at Verona (downstream of the Feather River), and the Sacramento River downstream of Sacramento (Freeport) are provided in Table 4-43**.** Estimated values were included in the calculation of the minimum and maximum values. All values were converted to µg/L.

Table 4-43 Pesticides Detected in the Sacramento River and Inflow, USGS NWQA Study Nov 1996 to Apr 1998

	CBD1 USGS		Sacramento Slough		Sacramento River Verona		Sacramento River Freeport		Pesticide	MCL
Pesticide	Min (ug/L)	Max (ug/L)	Min (ug/L)	Max (ug/L)	Min (ug/L)	Max (ug/L)	Min (ug/L)	Max (ug/L)	Type*	(ug/L)
2,4-D	0.11	0.78							H	70
Alachlor	0.011	0.012							H	2
Atrazine	0.002	0.005			0.001	0.001	0.001	0.002	H	3
Bentazon	0.05	0.13					0.002	0.002	H	18
Carbaryl	0.009	0.1	0.007	0.441	0.023	0.084	0.03	0.06	I	
Carbofuran	0.01	0.4	0.007	0.282	0.009	0.063	0.01	0.04	I	18
Chlorpyrifos	0.007	0.016	0.011	0.011			0.003	0.003	I	
Cyanazine	0.005	0.44					0.01	0.02	H	
Dacthal	0.001	0.0086					0.002	0.002	H	
Desethyl Atrazine	0.003	0.004					0.001	0.001	H (RESIDUE)	
Diazinon	0.002	0.098	0.006	0.017	0.001	0.097	0.002	0.046	I	
Diuron	0.04	0.69					0.004	0.12	H	
EPTC	0.003	0.72					0.001	0.022	H	
Fonofos			0.009	0.009					I	
Malathion	0.0055	0.054	0.01	0.092	0.008	0.013	0.004	0.004	I	
Methidathion					0.002	0.087			I	
Metolachlor	0.004	0.39	0.008	0.076	0.001	0.02	0.002	0.026	H	
Metribuzin	0.013	0.031							H	
Molinate	0.009	19	0.03	8.46	0.016	0.964	0.002	1.6	H	20
Napropamide	0.004	0.43							H	
Pebulate	0.011	0.011	0.007	0.007			0.0056	0.0056	H	
Prometon	0.005	0.01							H	
Propanil	0.045	0.045					0.029	0.029	H	
Propargite	0.052	0.052							I	
Pronamide	0.0094	0.035							H	
Simazine	0.003	0.15	0.002	0.036	0.006	0.006	0.003	0.02	H	4
Tebuthiuron	0.009	0.013							H	
Thiobencarb	0.014	4.4	0.014	0.646	0.001	0.125	0.004	0.17	H	70
Trifluralin	0.002	0.016	0.002	0.009					H	
Tryclopyr	0.22	1.1					0.03	0.03	H	

Figure 4-47 Total Kjeldahl Nitrogen as N (mg/L)



The majority of pesticides detected are herbicides used in the production of rice, control of weeds in orchards, or weed control along rights of way and fallow areas. Insecticides detected are mainly associated with rice, orchard, and alfalfa pest management, which is consistent with crop and pesticide use information. None of the recorded concentrations exceeded the MCLs for drinking water. As stated previously, MCLs only apply to finished drinking water and are only shown as reference values.

As expected, rice pesticides are present in the agricultural drains, especially CBD1. The peak molinate concentration was detected 24 May 1997 during the normal annual period of peak discharge following application. The concentration was 19ug/L (Domagalski 2000). For a reference point, the MCL for molinate is 20 µg/L, which is enforced only for finished, treated drinking water. The peak carbofuran (insecticide) concentration was in April, which is the time period when carbofuran is applied for rice water weevil. Carbofuran is also used in alfalfa for alfalfa weevil control in late winter/early spring. Dyfonate® (fonofos) was detected in Sacramento Slough and is used for control of soil-borne pests of corn.

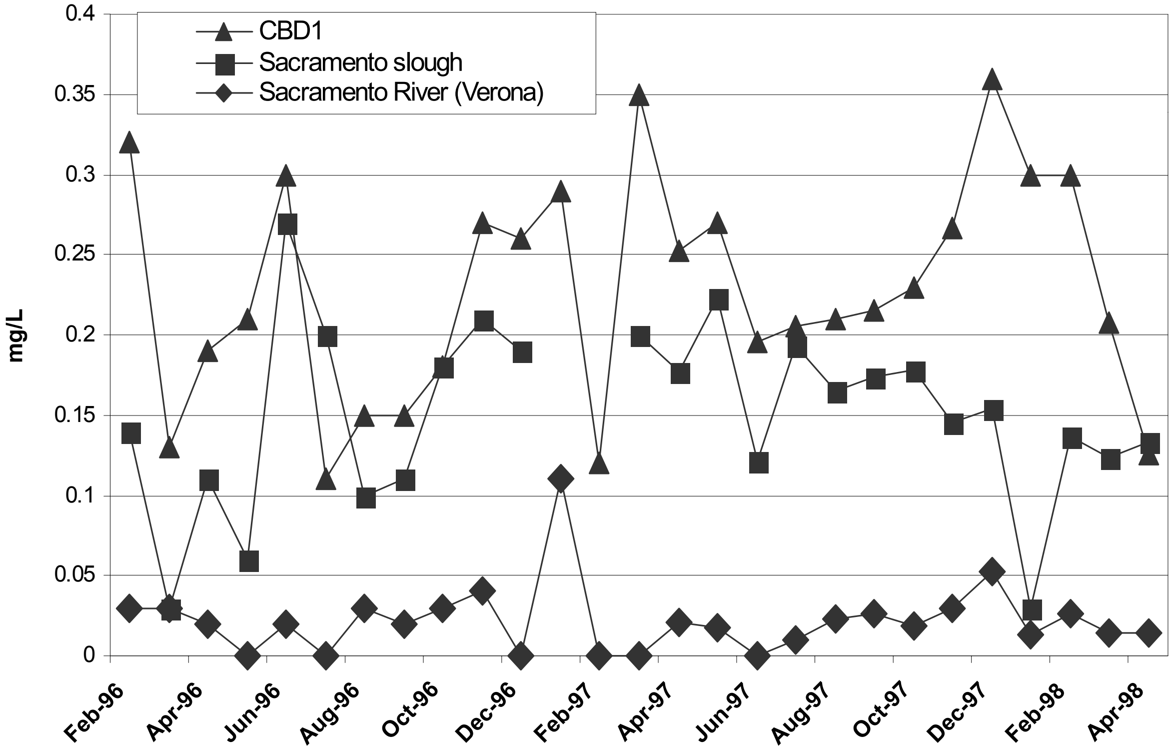
Nutrients

Figure 4-47 shows Kjeldahl nitrogen as mg/L of nitrogen in the 2 main drains and in the Sacramento River at Verona (below the confluence of the Feather River). Seasonal patterns are inconsistent within each drain, as well as between drains. The traditional wet season contaminant runoff pattern is partially evident in CBD1 with elevated nitrogen during the runoff periods of 1996 and 1997, but the values fluctuate through the year, with high levels in early and midsummer months that drop suddenly and then climb up again in the fall. One pattern that is unexplained is the low level of nitrogen for CBD1 that occurred in April of every year. This could be due to a spring algal bloom or use of nitrogen by macrophytes in the drainage basin.

Sacramento Slough data show a June peak and a summer drop-off similar to the pattern at CBD1 in 1996. There was also a peak in March 1997 that coincided with a peak in CBD1. One condition that contributes to the variability in the data is the nonconservative nature of the nutrients, which are subject to changes through both organic and inorganic processes.

Concentrations at Verona were generally lower than in either drain. The Verona values were always lower than the corresponding values at CBD1, and in only 2 months were the values greater than the ones at Sacramento Slough. However, the data from the Verona station also show a pattern of fluctuations that are difficult to explain because of the nonconservative nature of the nutrients.

Figure 4-48 Total Phosphorus (mg/L as P)



Phosphorus concentrations are shown in Figure 4-48. Phosphorus values at CBD1 mirror some of the nitrogen concentration patterns found in CBD1. The March drop in phosphorus in 1996 and 1998 is similar to the March nitrogen drop in CBD1. Sacramento Slough mirrors the CBD1 pattern, except in the winter of 1998. Verona phosphorus concentration patterns appear not as strongly correlated with seasonal peaks in the drains.

Table 4-44 shows the mean Kjeldahl nitrogen, phosphorus, and nitrate values for key stations in the Delta, including the Sacramento River. The Sacramento River contains lower nutrient concentrations than the San Joaquin River for 3 reasons:

1) The irrigation water is lower in initial nutrients, unlike the San Joaquin where the west side of the valley uses Delta waters already enriched with nutrients.
2) There are significantly more dairies and POTWs to be found in the San Joaquin drainage.
3) There is more dilutional flow in the Sacramento River from low nutrient sources.

Table 4-44 Mean Nutrient Values in the Sacramento River, the San Joaquin River, and at Banks Pumping Plant

Source	Site	Conc (mg/L)	Loading (tons/day)
Kjeldahl Nitrogen			
San Joaquin River	Vernalis	2.47	22
Sacramento	Freeport	0.84	45
Total Phosphorus			
San Joaquin River	Vernalis	0.26	2.44
Sacramento	Freeport	0.09	6
Nitrate			
San Joaquin River	Vernalis	6.1	66
Sacramento River	West Sac Intake (Feb 1997 to Dec 1998)	0.58	
Sacramento River	West Sac Intake	0.53	
Sacramento	Hood/Greenes Landing	1.41	65
Delta Islands		9.5	20
Banks Pumping Plant		2.94	
DMC		3.76	

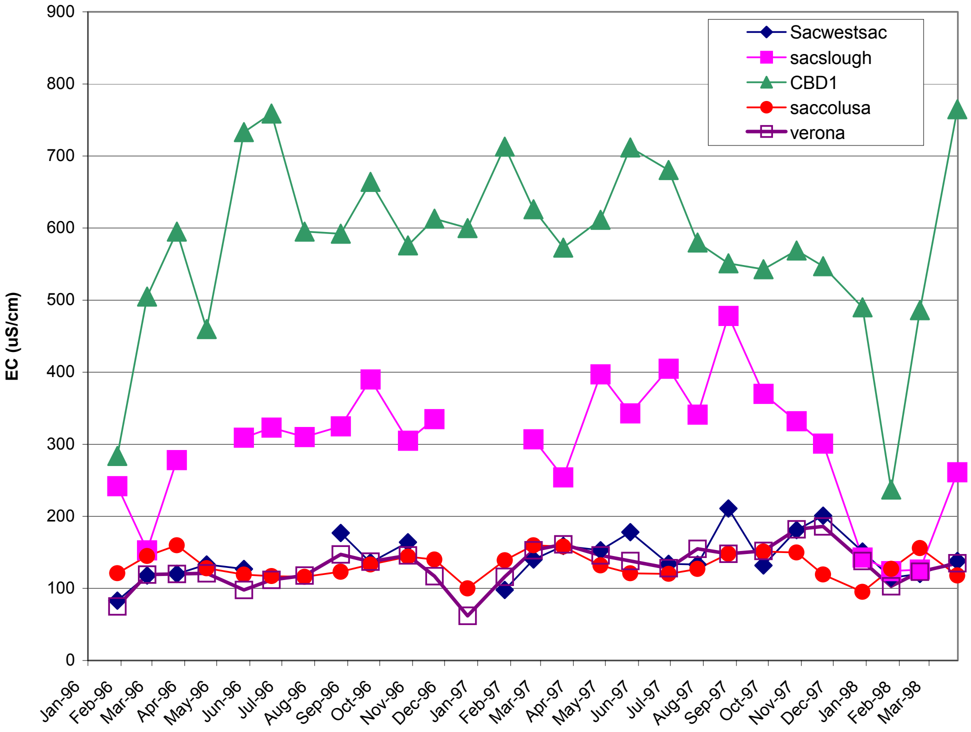
Source: Woodard 2000

Even though the mean concentrations of nutrients transported in the Sacramento River are lower, the mass loading of nutrients to the Delta is higher than the San Joaquin River, given the larger volume of flow. The exception is nitrate, where high concentrations in the San Joaquin River translate into an almost equal daily loading of nitrate compared to the Sacramento River.

A comparison of the historical mean value for nitrate in the Sacramento River at the West Sacramento intake with data from February 1997 to December 1998 shows a slightly higher value for the more recent data (0.58 mg/L compared to 0.53 mg/L) (Woodard 2000). When comparing the historical mean values in the Sacramento River at the West Sacramento intake to Greenes Landing (Sacramento River below Sacramento), there is almost a threefold increase. The 2 historical data sets contain differing amounts of sample data that were used to calculate these means, which does not allow for exact comparisons. The increase can likely be attributed to additional nitrates contributed from urban and agricultural sources in the Sacramento area, though this is not supported by historical concentrations recorded at the main inflow sites (Woodard 2000). These include the Natomas Main and East Main Drains, as well as storm water runoff, and discharges from POTWs. Once again, the historical data sets are not synchronous in terms of sample dates and total number of samples.

For both nitrogen, and phosphorus, all concentrations found in the drains and in the Sacramento River are well above what is considered limiting for algal growth (Woodard 2000). These waters are exposed to additional nutrient loading in the Delta from agricultural and urban sources containing nutrients.

Figure 4-49 Electrical Conductivity in the Sacramento River and at Agricultural Drains



Salts

Figure 4-49 shows EC values for selected Sacramento River and drain sites (Domagalski, and others 2000, Domagalski and Dileanis 2000). CBD1 has the highest readings, often more than double that of Sacramento Slough and 4 times that of the main Sacramento River sites. Seasonal patterns are inconsistent, except for a general increase during the summer months, and a drop during high runoff flows. Sacramento Slough does not mirror the CBD1 pattern.

Figure 4-50 shows only the EC for the Sacramento River sites at Colusa and Verona. The monthly total acre-feet of flow is also shown. Both sites show an inverse relationship of EC to flow as expected. When Verona EC is lower than Colusa EC, Verona flows are most influenced by the winter inflow complex of CBD1, Sacramento Slough, and the Feather River, with the Feather River providing most of the inflow with low EC values. When Verona EC rises above Colusa EC, it is during a period of low runoff and inflow from the agricultural drains has the highest influence on water quality.

As with much of the water quality data examined in this section, monthly grabs only represent 1 point in time. Salinity is 1 parameter that shows some of the greatest fluctuations over a short period of time. Synaptic review of daily EC values for the fall confirm a more direct influence of agricultural drain salinity on the Sacramento River during the low-flow periods.

Figure 4-50 Flows and EC in the Sacramento River at Colusa and Verona

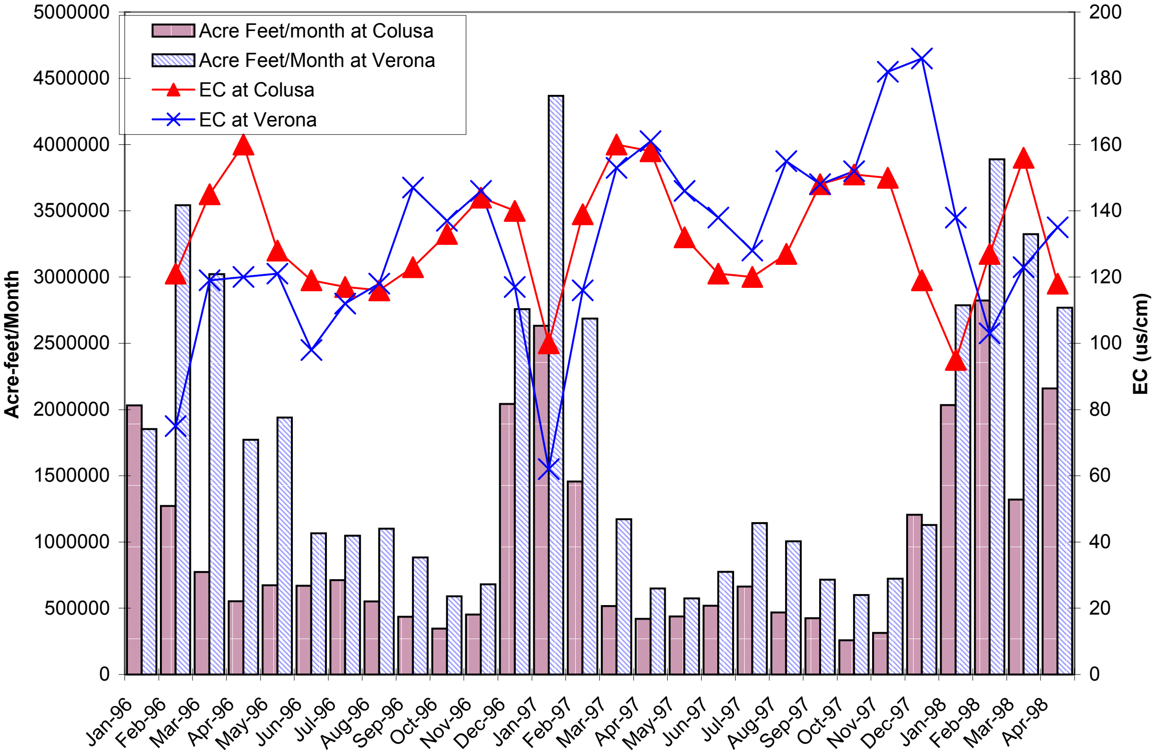
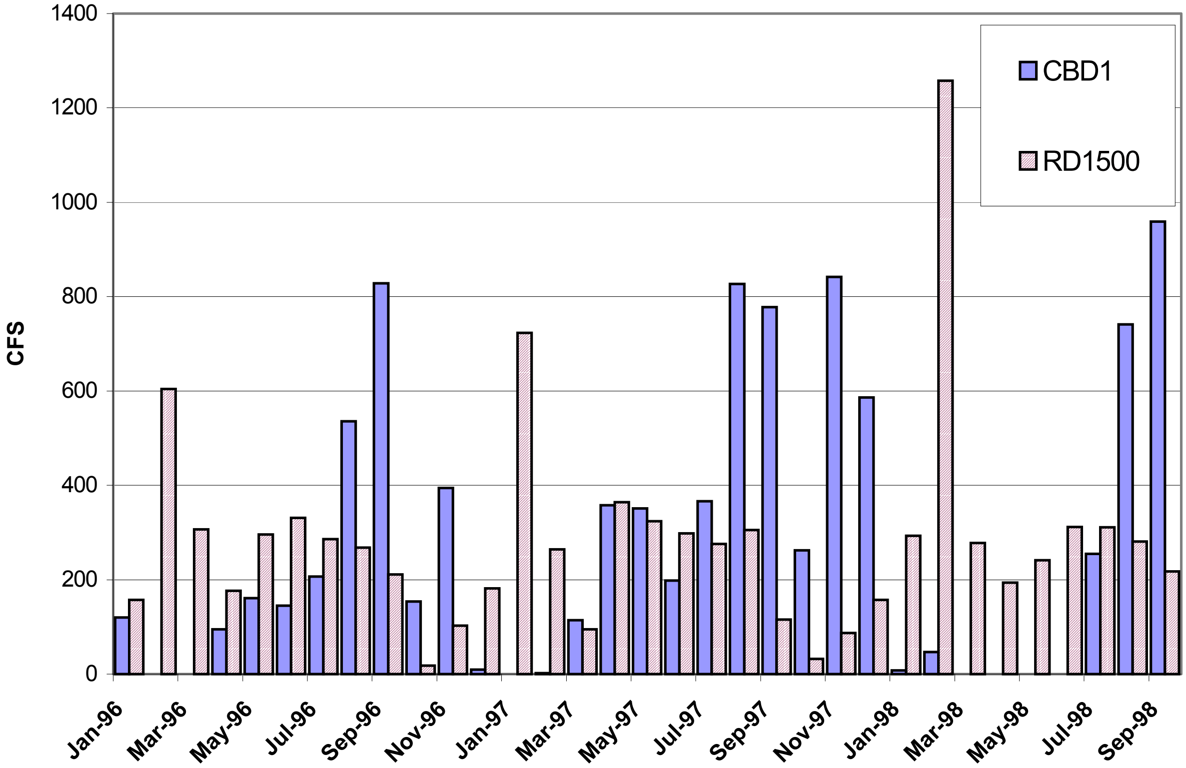


Figure 4-51 Monthly Average Discharge from Colusa Basin Drain (CBD1) and RD1500



Organic Carbon

CBD1 and Sacramento Slough are 2 of the largest main agricultural drains discharging into the Sacramento River. A significant portion of the Sacramento Slough water volume during the irrigation and fall season comes from Reclamation District 1500. Figure 4-51 shows the seasonality of discharge in cfs from these 2 drains. The lack of CBD1 winter discharge into the Sacramento River during certain winter months was explained previously. Because during high runoff periods Sacramento Slough becomes inundated with backflow from the Sacramento River, Reclamation District 1500 data are provided to show the seasonality of discharge. Both drains show typical irrigation season increases in discharge. But in late summer into fall, CBD1 continues to show significant discharge. This is due to continuing rice irrigation and the subsequent discharge of water to drain the fields in preparation of harvest. Because of the many different varieties of rice grown and the extended planting season, rice field maturation may vary significantly, leading to a long period (3 months) where rice fields are drained and harvested.

USGS NWQA data were analyzed along with DWR flow data to calculate pounds of carbon transported per month (Domagalski 2000). Once again, it is noted that these are monthly grab sample data and do not measure accurately the loading estimate. The value of these analyses is the visualization of trends in seasonal loading.

Figure 4-52 TOC Loading and Transport (lbs. of carbon/month) in the Sacramento River above Verona

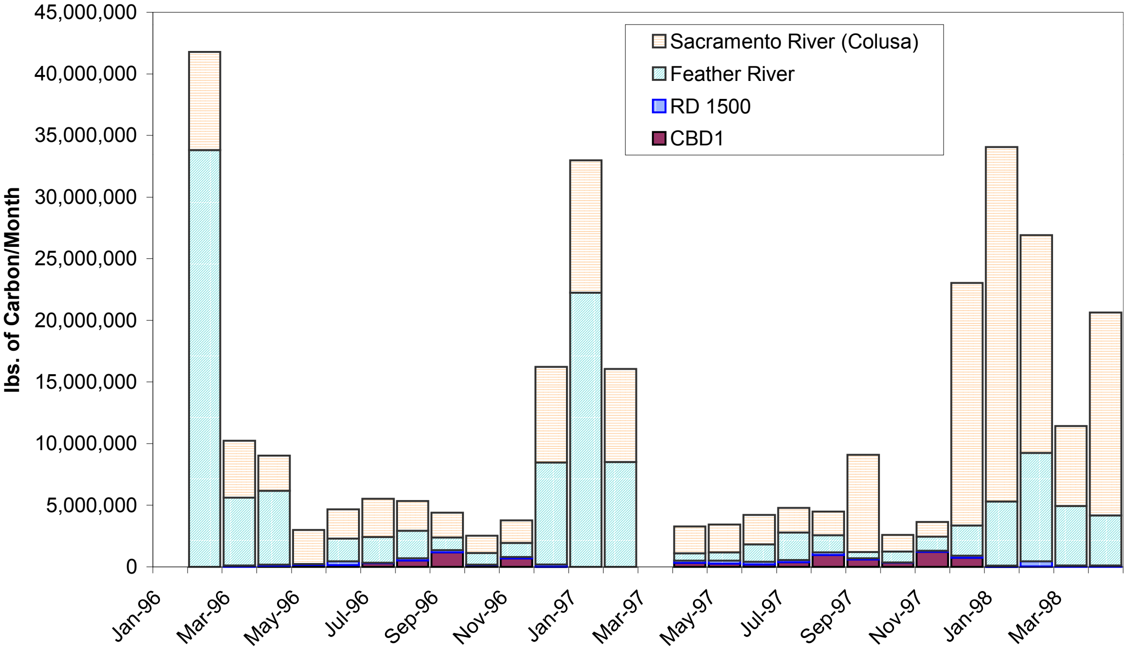


Figure 4-52 shows the loading of pounds of carbon based on TOC into the Sacramento River above Verona. Despite low average concentrations in the Sacramento River above the agricultural drains (Colusa) and the low concentrations in the Feather River, the shear volume of flow during winter runoff provides the majority of carbon transported in the river above Sacramento. Figure 4-53 adjusts the monthly TOC loading by sources to percentage of the total load. This emphasizes the months when agricultural drains provide significant loading to the river. This demonstrates that during the irrigation season, carbon loading from the drain sources increases. CBD1 continues to provide a significant portion (as high as 25% to 30% of the total load) through the fall and into early winter.

Figure 4-53 Percent of Total TOC Loading and Transport (lbs. of carbon/month) in the Sacramento River above Verona

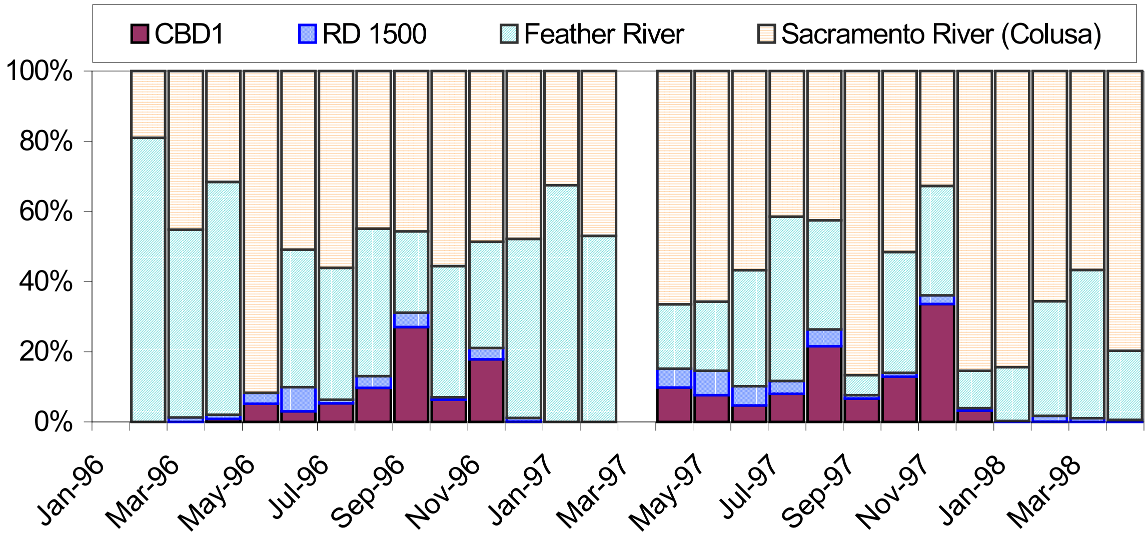
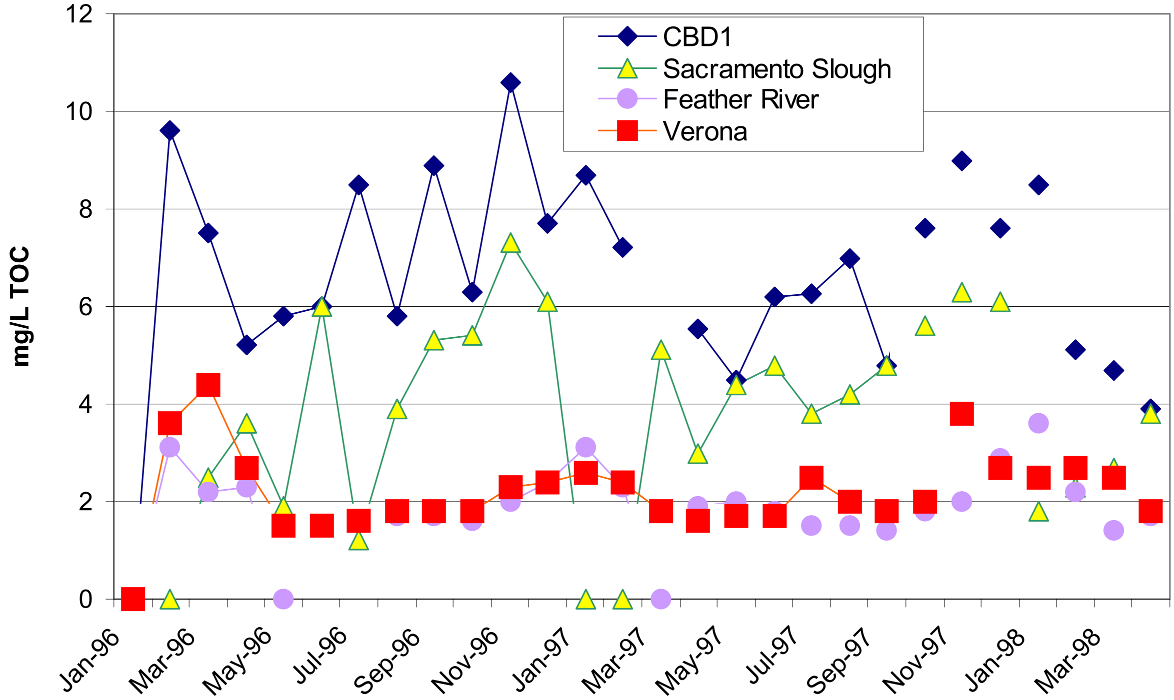
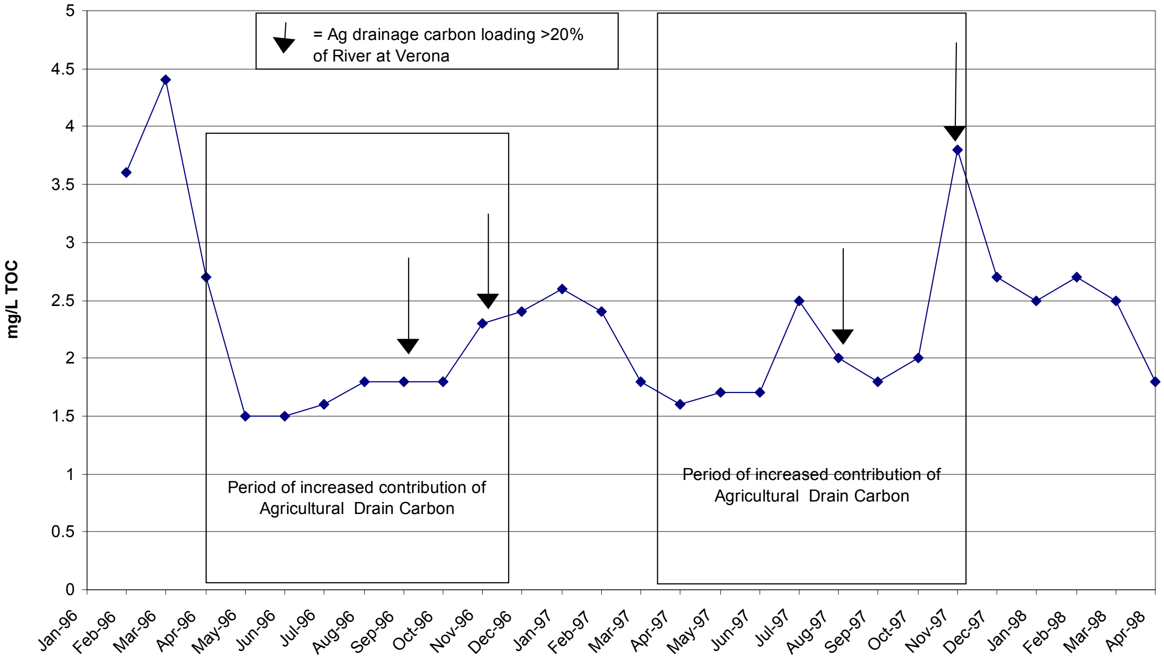


Figure 4-54 TOC Concentrations in the Sacramento River, the Feather River, and Agricultural Drains



Concentrations of TOC in the drains and in the river are shown in Figure 4-54**.** As expected, CBD1 contains the highest concentrations of TOC, with Sacramento Slough the 2nd highest. The Feather River concentrations are significantly lower, which aids in dilution of the agricultural drain concentrations. In order to examine more closely the effect the drain complex has on the Sacramento River, the TOC concentrations at Verona are plotted in Figure 4-55**.** Boxes bracket the period of time when the agricultural drains are contributing an increasing amount of TOC. The arrows indicate the months when agricultural drains contribute at least 20% of the load into the river. The figure shows that agricultural drainage increases carbon concentrations in the river at Verona during the summer, fall, and winter months. At these times, carbon concentrations and flows from the Sacramento River above the drain complex and the Feather River are low, so the corresponding increase at Verona can be attributed solely to increased concentrations from the drains.

Figure 4-55 TOC Concentrations in the Sacramento River at Verona



4.3.6.3 San Joaquin River Basin

Pesticides

Various agencies, including the California Department of Pesticide Regulation and the USGS, have conducted pesticide studies. Most of the San Joaquin River Basin studies were conducted from 1991 to 1995.

The California Department of Pesticide Regulation surface water database contains results from 1991 to 1993 for Mud and Salt sloughs, 2 main agricultural drains that discharge into the San Joaquin River. Results show that no detected pesticide exceeded its MCL (Table 4-45). MCLs are set for finished drinking water, so concentrations of pesticides in the agricultural drains will undergo further dilution and degradation before reaching the treatment plants.

Table 4-45 Pesticide Detects and Maximum Contaminant Levels

Sample Date	Pesticide Name	Min (µg/Ll)	Max (µg/L)	MCL (µg/L)	Secondary MCL or Action Level (µg/l)
Mud Slough (trib. to SJR)					
4/2/91 to 2/8/1993	chlorpyrifos	<DL	0.01		
4/26/91 to 2/8/93	diazinon	<DL	0.17		14
4/2/91 to2/8/93	endosulfan sulfate	<DL	0.019		
1/27/92 to 8/28/93	methomyl	<DL	0.13		
Salt Slough (Trib. to SJR at Highway 165)					
3/18/1993 to 11/17/93	2,4-D	<DL	1.2	70	70
1/20/1993 to 11/17/93	2,6-diethylaniline	<DL	0.003		
1/20/1993 to 11/17/93	alachlor	<DL	0.03	2	
1/20/1993 to 11/17/93	atrazine	<DL	0.036	3	
1/20/1993 to 11/17/93	butylate	<DL	0.005		
1/27/92 to 11/17/93	carbaryl	<DL	0.078		60
3/16/1992 to 11/17/93	chlorpyrifos	<DL	0.12		
1/20/1993 to 11/17/93	chlorthal-dimethyl	<DL	0.045		
1/20/1993 to 12/28/93	cyanazine	<DL	1.3		
1/20/1993 to 11/17/93	dde-	<DL	0.005		
1/20/1993 to 11/17/93	deethyl-atrazine	<DL	0.005		
4/21/1991 to 11/17/93	diazinon	<DL	0.33		14
3/18/93 to 11/17/1993	dichlorprop	<DL	0.11		
4/2/91 to 11/17/93	diuron	<DL	1.9		
4/2/91 to 2/8/93	endosulfan sulfate	<DL	0.018		
1/20/1993 to 11/17/93	eptc	<DL	2.2		
1/2/93 to 11/17/93	linuron	<DL	0.29		
4/2/91 to 11/17/93	malathion	<DL	0.39		160
1/27/1992 to 11/17/93	methomyl	<DL	0.67		
1/20/1993 to 11/17/93	metolachlor	<DL	0.053		
1/20/93 to 11/17/93	molinate	<DL	4	20	
1/20/1993 to 11/17/93	Napropamide	<DL	0.036		
3-18-93 to 11/17/93	Norflurazon	<DL	0.44		
1/27/92 to 12/28/93	oxamyl	<DL	0.27	200	
1/20/1993 to 11/17/93	pebulate	<DL	0.043		

Table 4-45 (continued)

Sample Date	Pesticide Name	Min (µg/Ll)	Max (µg/L)	MCL (µg/L)	Secondary MCL or Action Level (µg/l)
1/20/93 to 11/17/93	prometon	<DL	0.006		
1/20/93 to 11/17/93	propanil	<DL	0.004		
1/20/93 to 11/17/93	propargite--	<DL	0.095		
1/20/1993 to 11/17/93	propyzamide-	<DL	0.022		
1/20/1993 to 11/17/93	simazine	<DL	0.085	4	
1/20/1993 to 11/17/93	tebuthiuron-	<DL	0.004		
1/20/1993 to 11/17/93	thiobencarb-	<DL	0.51	70	1
1/20/1993 to 11/17/93	trifluralin-	<DL	0.11		

In other studies conducted from 1991 to 1995, the USGS reported the frequent detection of pesticides below drinking water MCLs and ALs in the San Joaquin River Basin. Table 4-46 shows the most frequently detected pesticides in the San Joaquin River Basin by the USGS from 1992 to 1995. Though these studies have shown pesticides to exceed criteria for aquatic life toxicity, the levels measured in the San Joaquin have been below MCLs for drinking water (Domagalski 2000).

In summary, pesticides are detected in the San Joaquin runoff, but studies show that the levels detected are significantly lower than finished drinking water standards.

Table 4-46 Most frequently Detected Pesticides in the San Joaquin River Basin, 1992 to 1995

Herbicides	Insecticides
simazine	Diazinon
dacthal	Chlorpyriphos
EPTC	Metolachlor
Trifluralin	
DCPA	

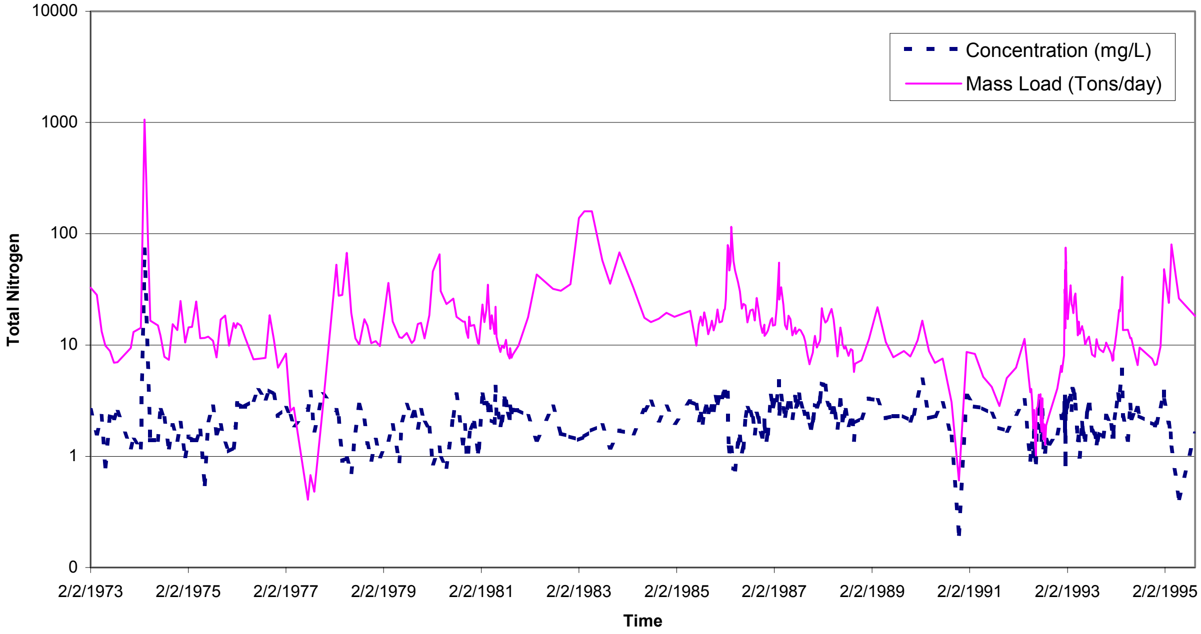
Nutrients

The EPA has set criteria for the nitrate and ammonia forms of nitrogen, but not for phosphorus. The MCL for nitrate in drinking water is 10 milligrams per liter as nitrogen (mg/L as N) (EPA 1986). Despite a long-term increase of nitrate concentrations in the San Joaquin River, they are still well below the EPA drinking water standard (Kratzer and Shelton 1998).

Nutrient concentrations in the lower San Joaquin River are determined primarily by relatively concentrated inputs from west-side agricultural drainage, east-side wastewater-treatment plants, runoff from dairies, and relatively dilute inputs from major east-side tributaries. Mud and Salt sloughs receive a part of their flow from subsurface drains that drain about 100,000 acres of agricultural land. Although the sloughs account for only about 10% of the streamflow in the San Joaquin River near Vernalis, the subsurface drainage is very high in nitrate (about 25 mg/L as N), and the sloughs contribute nearly one-half the nitrate in the San Joaquin River (Kratzer and Shelton 1998).

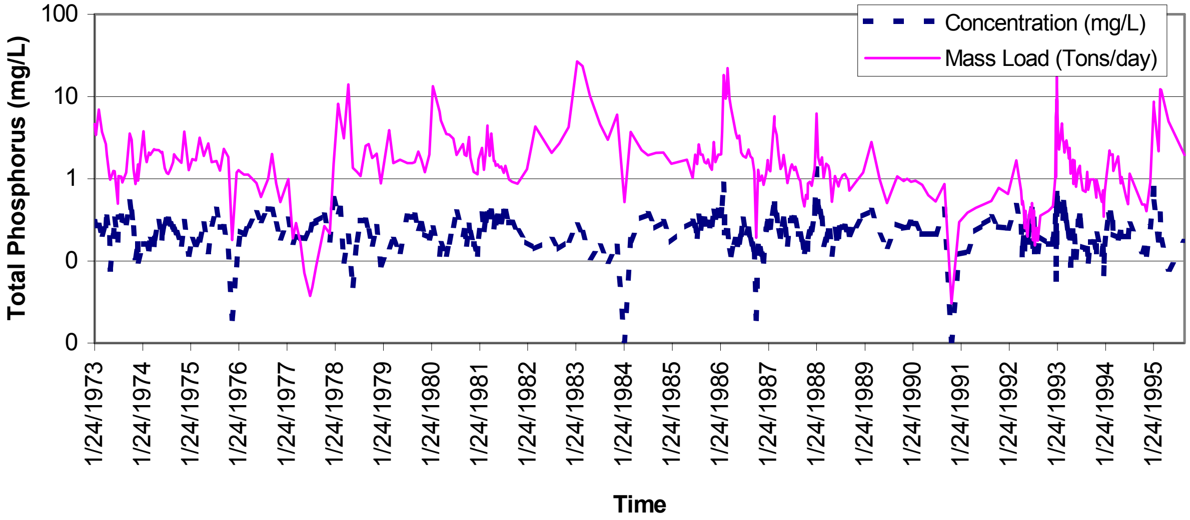
The nitrate transported in the San Joaquin River during a wet year (1986) was about 50% more than that transported in a dry year (1988) (MWQI internal draft report, data assessment project [DAP], 23 May 2000). The highest levels of Kjeldahl nitrogen, nitrate, and phosphorous transport occur in the wet months of wet years (Woodard 2000). Figure 4-56 shows a historical timeline of total nitrogen concentrations and mass transport in the San Joaquin River at Vernalis. The drought years of the late 1980s and early 1990s resulted in lower transport of nitrogen in tons per day than in the wet years. Figure 4-57 shows phosphorus transport. The seasonal patterns are very similar for phosphorus transport and nitrogen transport (Woodard 2000).

Figure 4-56 Total Nitrogen in the San Joaquin River near Vernalis



Source: Woodard 2000

Figure 4-57 Total Phosphorus in the San Joaquin River near Vernalis



Source: Woodard 2000

Figure 4-58 Mean Annual Loading of TDS to San Joaquin River for Water Year 1985 to 1995: 1-Million Tons Based on Historical and SJRIO Model Data

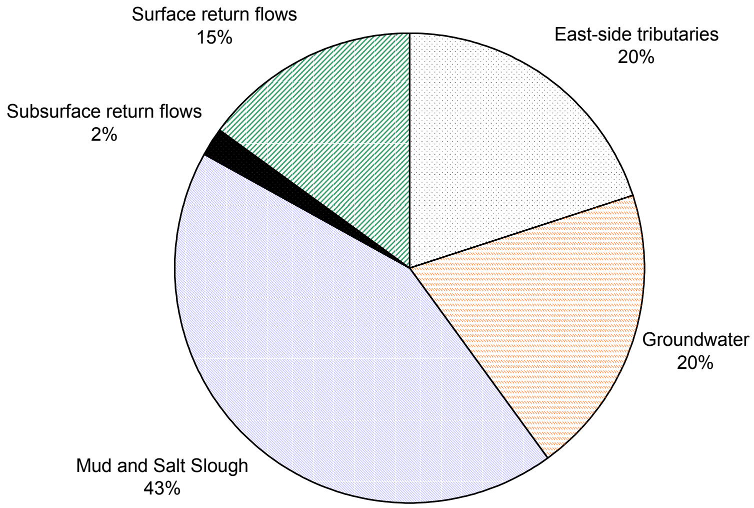
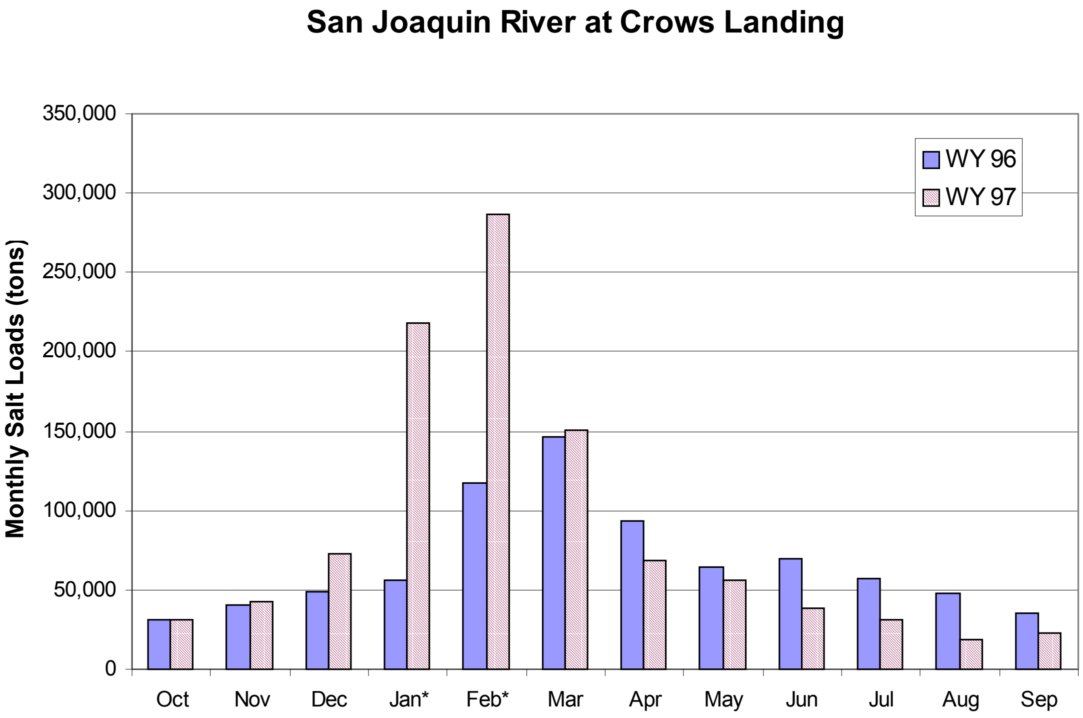


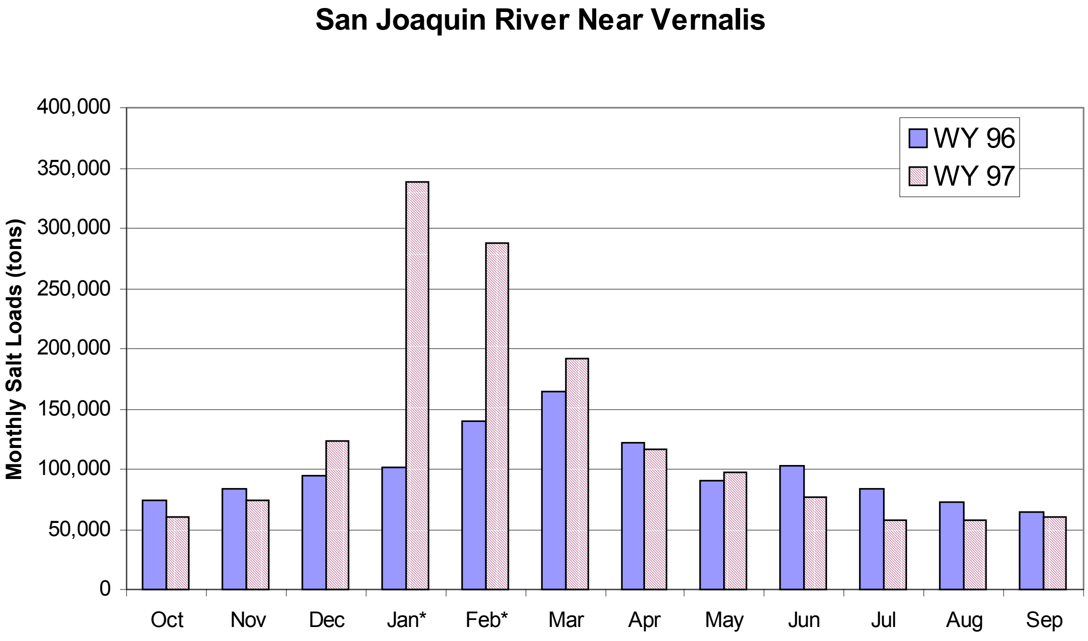
Table 4-44 provides a summary of the mean values of nutrients at key locations within the Delta. The San Joaquin River has higher historical mean concentration values for total nitrogen, total phosphorus, and nitrate. The mean nitrate levels found at Banks PP and in the DMC are not explained by Sacramento River quality. Both the San Joaquin River and Delta island drains have higher levels of nitrate that contribute to the higher nitrate levels at the pumping plants. Although the actual source of water in the DMC is a blend of Sacramento River water, San Joaquin River water, and Delta island drainage, the historical mean is 3.76 mg/L compared to 2.94 mg/L at Banks PP. One possible explanation is that the DMC receives a greater portion of the San Joaquin River water and, consequently, would receive higher concentrations of nitrate from that source.

Salts

Salt loading to the San Joaquin River is primarily the result of agricultural drainage from the west side of the valley. The concentration of salt and boron in the lower San Joaquin River exceeds the water quality objectives set up by the SWRCB and is on the State 303 (d) list. There are no regulatory MCLs for salinity in drinking water, but a secondary MCL of 500 mg/L TDS or 900 :S/cm EC has been adopted by federal and State regulatory agencies. (The regional board uses a 0.65 multiplier to convert EC to TDS for the lower San Joaquin River.) Figure 4-58 shows the sources of TDS loading in the lower San Joaquin River from 1985 to 1995. The mean annual loading of TDS into the lower San Joaquin River is 1-million tons (UC 1999). Figure 4-59 shows the monthly salt loads in tons measured at Crows Landing and Vernalis for water years 1996 and 1997 (Chilcott and others 1998). Both of these water years were classified as wet years for the San Joaquin River basin.

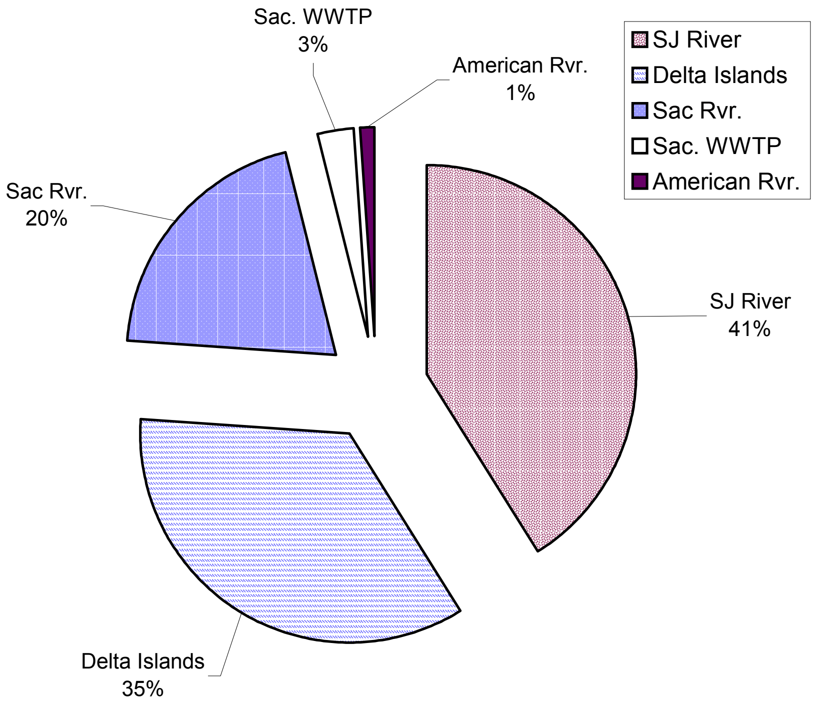
Figure 4-59 Monthly Salt Loads in the SJR at Crows Landing and Vernalis, Water Years 1996 and 1997





*Load data estimated for Jan and Feb 1997 due to flood flow estimates, overland flows and limited water quality data availability.

Figure 4-60 Percent Bromide Loading to the Sacramento/San Joaquin Delta



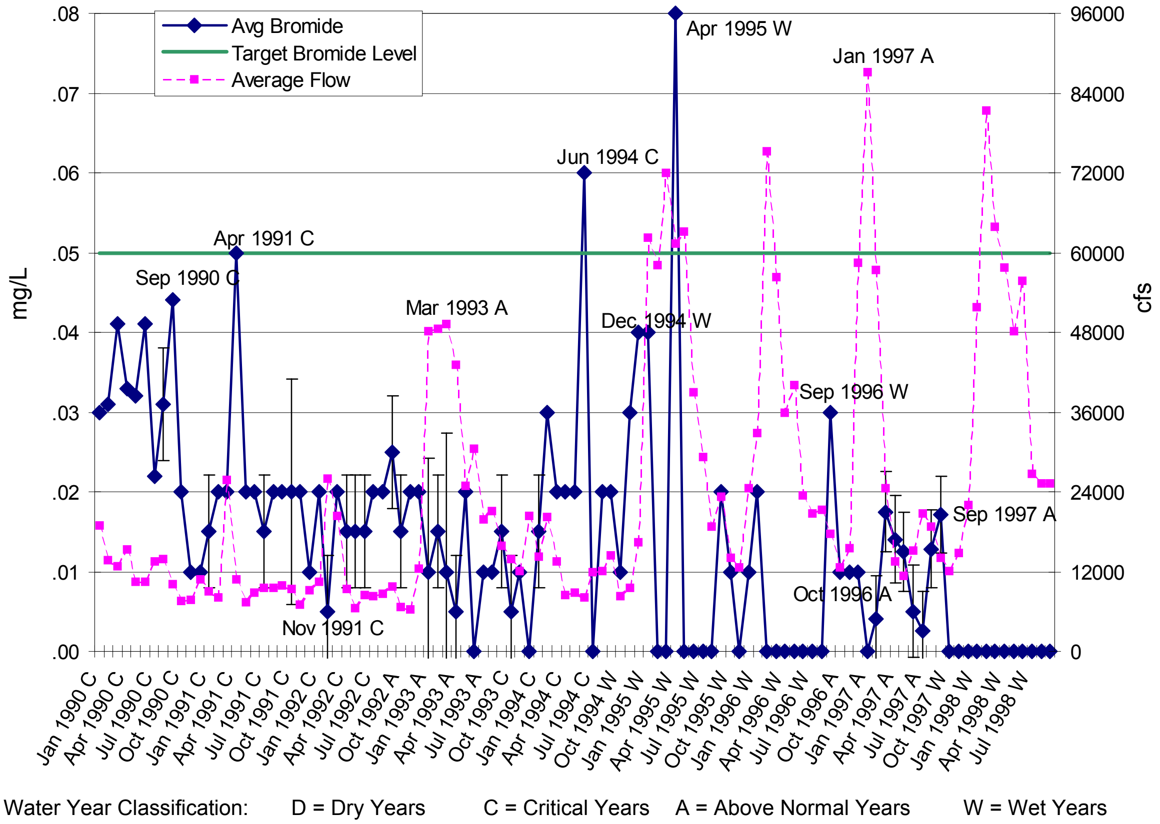
Source: Woodard 2000

4.3.7 SEAWATER INTRUSION

4.3.7.1 Bromide

The relative contributions of bromide by major inflows and discharges to the Sacramento-San Joaquin Delta are shown in Figure 4-60. The San Joaquin River and Delta islands are the largest contributors of bromide to the system; however, both the San Joaquin River and drainages from Delta islands return bromide that is already in the system (Woodard 2000). For example, approximately 80% of the bromide load that appears in the San Joaquin River near Vernalis is supplied through the DMC (CALFED 2000). The Sacramento River may contribute up to 20% of the bromide load to the Delta, but in terms of concentration, bromide levels are not an issue for drinking water. Figure 4-61 illustrates average monthly bromide levels for the Sacramento River at Greenes Landing or Hood between January 1990 and July 1998. With 3 exceptions, average bromide levels never exceeded the CALFED proposed target level of 0.05 µg/L. To meet stringent EPA drinking water standards, CALFED has proposed that bromide levels at the export pumps not exceed 0.05 mg/L.

Figure 4-61 Sacramento River at Greenes Landing/Hood - Monthly Average Bromide Concentrations (± 1 std. dev.) with Sacramento River Flow



Unlike the Sacramento River, the Delta is influenced by seawater intrusion. As shown in Table 4-47, four parameters that can indicate seawater intrusion are highest in the west Delta and in southern Delta channels where the effects of recirculated bromide from the San Joaquin and the direct effects of seawater intrusion would be felt the most. Again, the northern Delta, which can be more heavily influenced by Sacramento River runoff, shows considerably less impact (CALFED 2000d).

Table 4-47 Mean Concentration of Several Selected Seawater Intrusion Constituents

Delta Zone	Location	Bromide (mg/L)	Chloride (mg/L)	EC (µS/cm)	TDS (mg/L)
North	Sacramento River at Greenes Landing	0.018	6.8	160	100
	North Bay Aqueduct at Barker Slough	0.051	26	332	192
South	SWP Clifton Court Forebay	0.269	77	476	286
	San Joaquin River at Vernalis	0.313	102	749	459
West	Contra Costa Intake at Rock Slough	0.455	109	553	305

Source: CALFED 2000d.
Period of record varies with constituent, but generally is between 1990 and 1998.

Geographic differences in seawater intrusion can also be seen by the frequency that different areas of the Delta exceed CALFED's recommended bromide target level of 0.05 mg/L at the pumps. Water quality data were analyzed by DWR's MWQI unit for a number of water quality parameters. Location of the stations are shown in Figure 4-62. Figures 4-63 through 4-66 show the cumulative probability of bromide concentrations at 4 geographical locations in the Delta. Although samples were not necessarily collected on the same day, the data represent samples often collected within a few days of each other over an 8-year period. In the northern Delta on the Sacramento River at Greenes Landing/Hood, 98% of the samples collected were below this proposed target level. In contrast, 88% of the samples collected in the southern Delta (San Joaquin River near Vernalis/Mossdale) and 87% of the samples collected in the western Delta (Station 9) exceeded the CALFED target of 0.05 mg/L bromide. Since seawater contains approximately 66.8 mg/L bromide, more than 1,300 times the 0.05 mg/L export target, it takes relatively little seawater to increase bromide levels. This can ultimately be seen at Banks where more than 90% of the samples exceeded the proposed target level. It is important to note that during this 8-year period, there were more wet than dry years. Roughly twice as many samples were collected in wet years as in dry.

Figure 4-62 MWQI Delta Sampling Locations

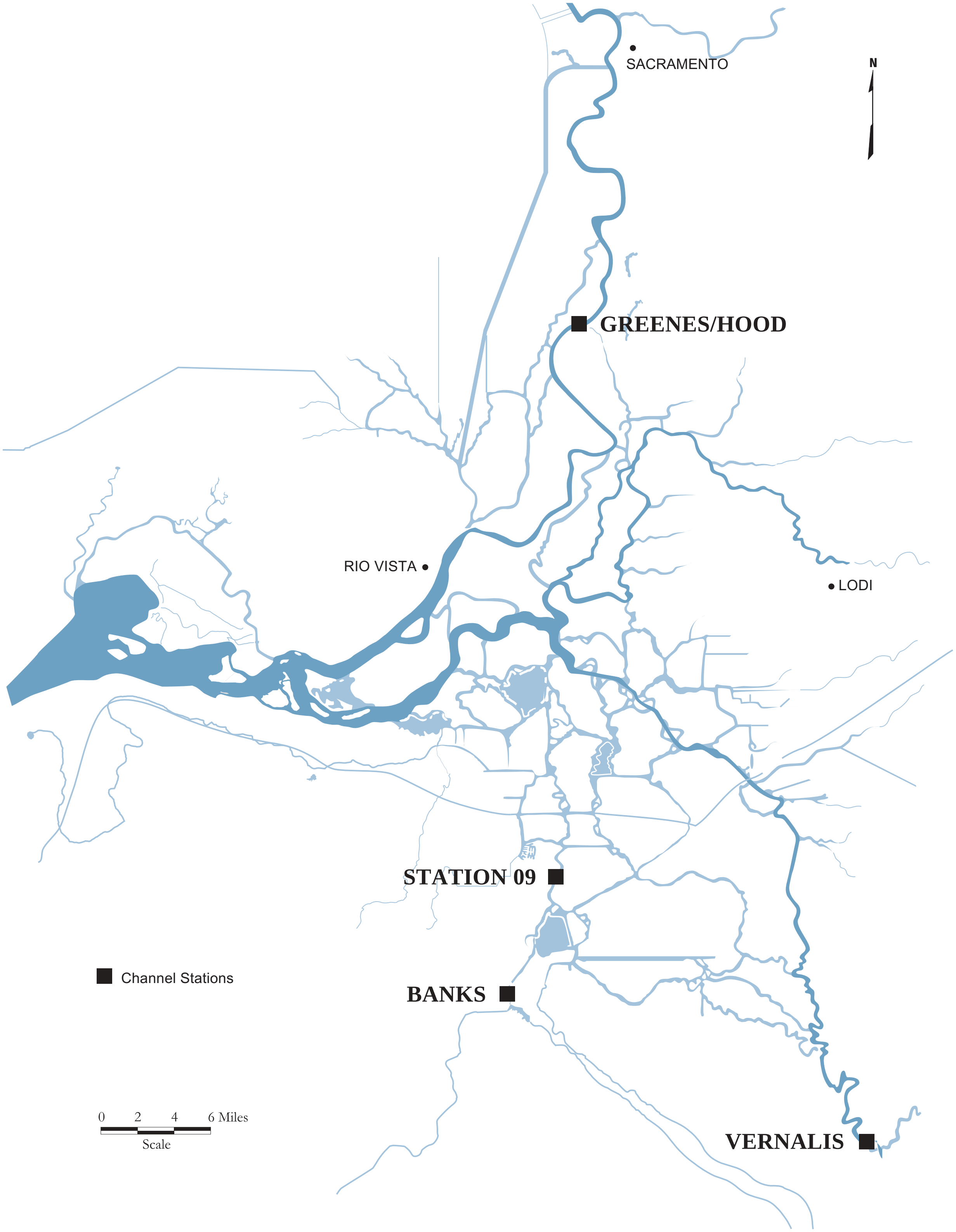
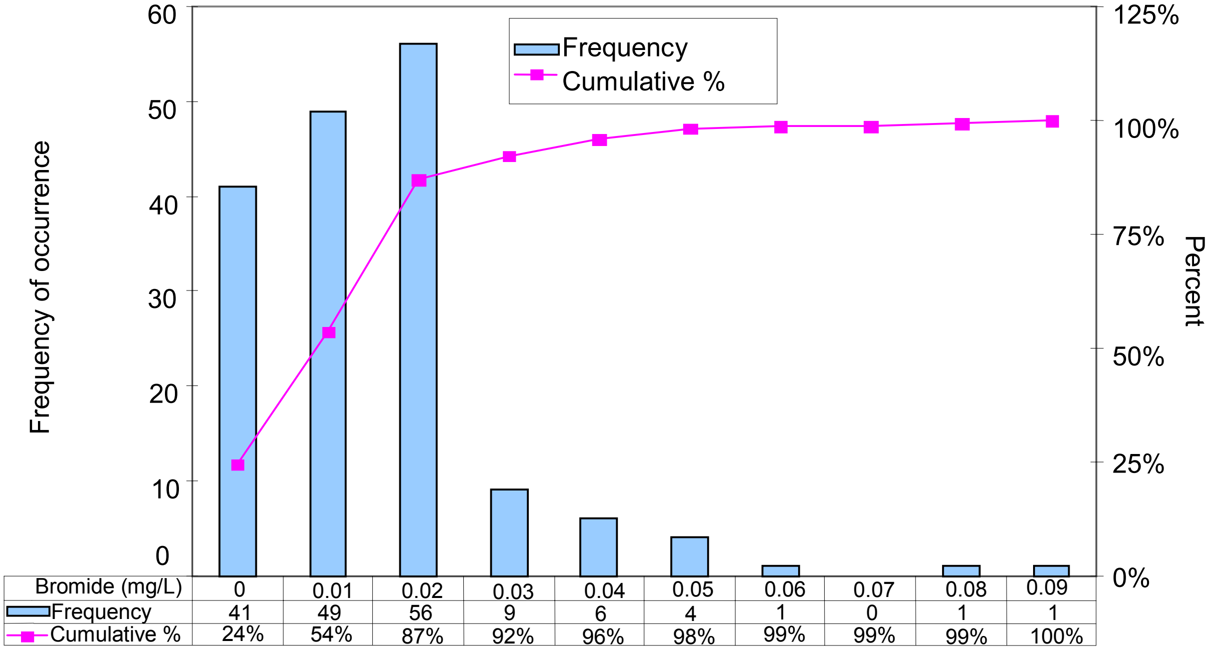
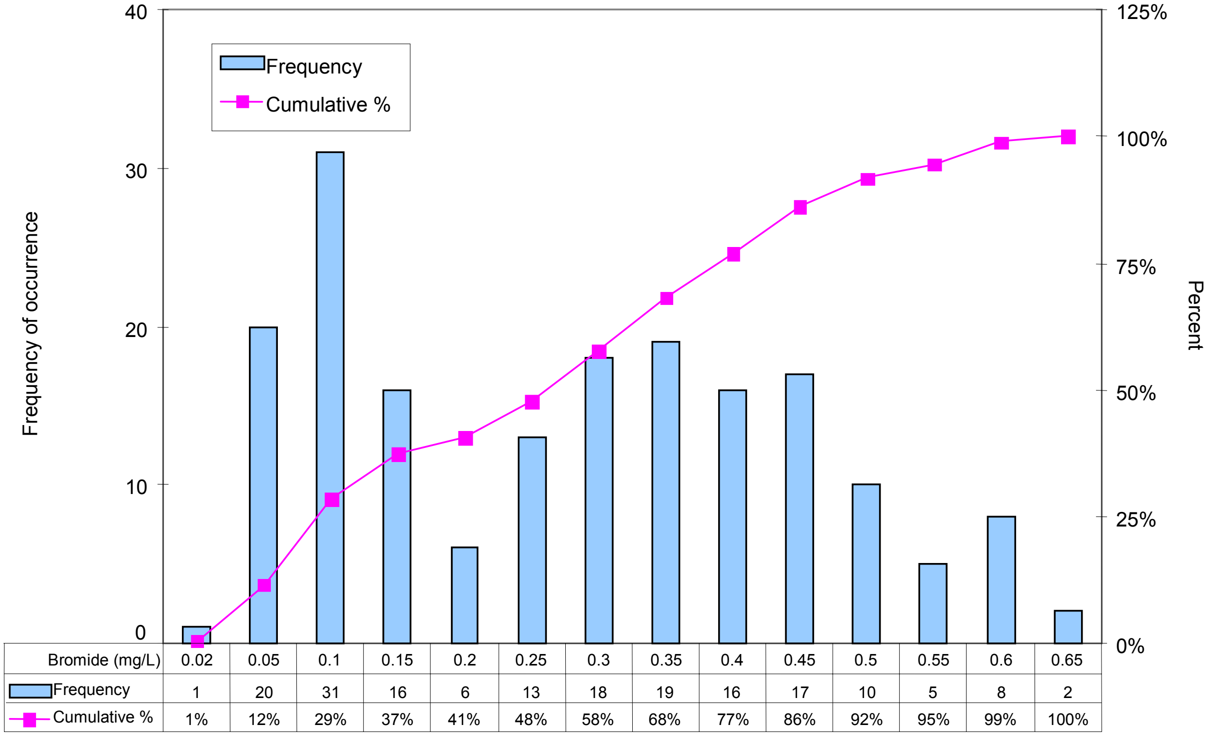


Figure 4-63 Cumulative Probability Distribution of Bromide (mg/L) in the Sacramento River at Greenes Landing/Hood, 1990 to 1998



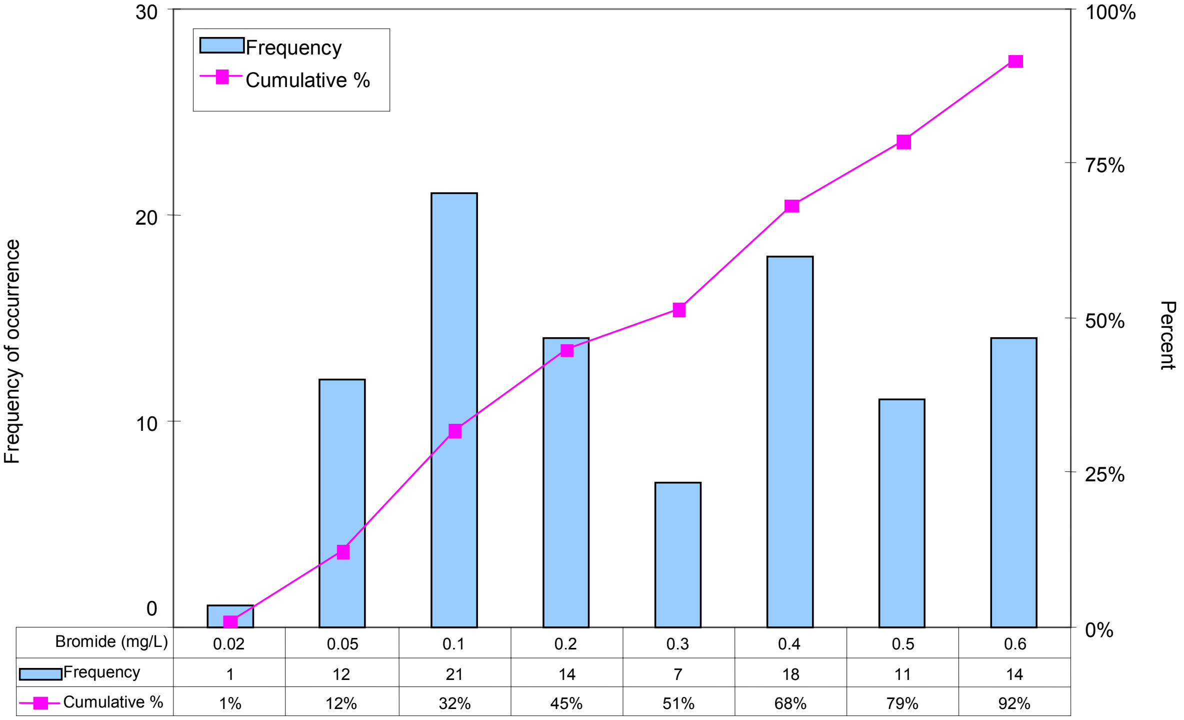
Bromide (mg/L)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
Frequency	41	49	56	9	6	4	1	0	1	1
Cumulative %	24%	54%	87%	92%	96%	98%	99%	99%	99%	100%

Figure 4-64 Cumulative Probability Distribution of Bromide (mg/L) at Vernalis/Mossdale, Jan 1990 to Sep 1998



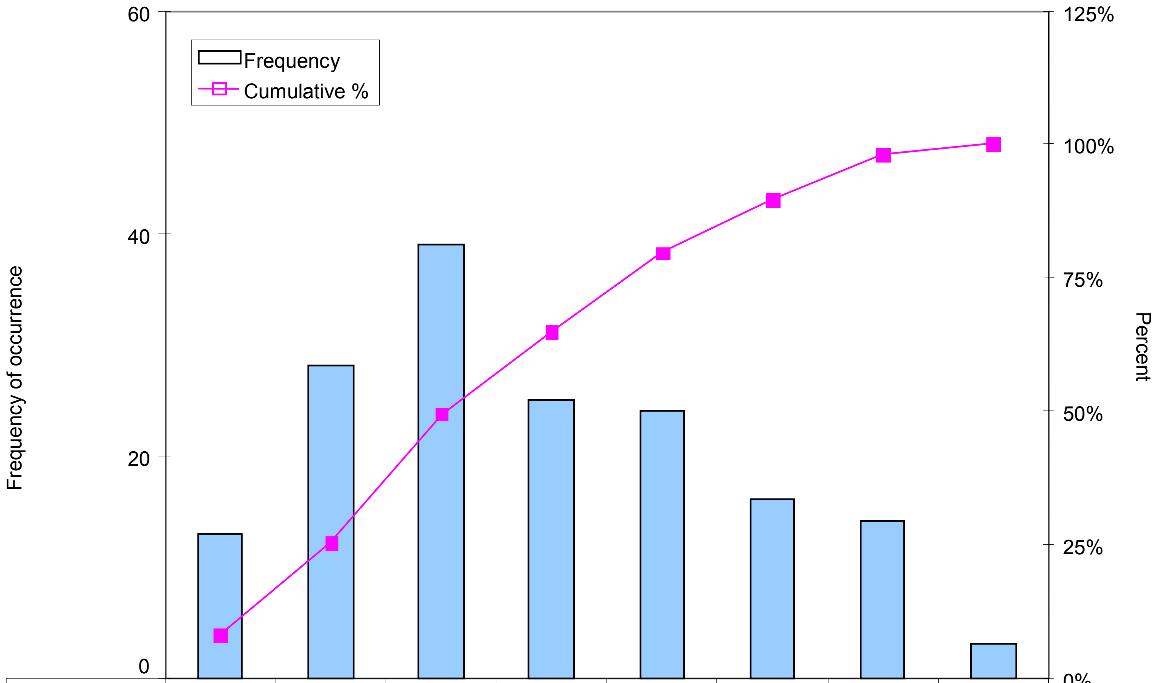
Bromide (mg/L)	0.02	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65
Frequency	1	20	31	16	6	13	18	19	16	17	10	5	8	2
Cumulative %	1%	12%	29%	37%	41%	48%	58%	68%	77%	86%	92%	95%	99%	100%

Figure 4-65 Cumulative Probability Distribution of Bromide (mg/L) at Station 9, Jul 1990 to Sep 1998



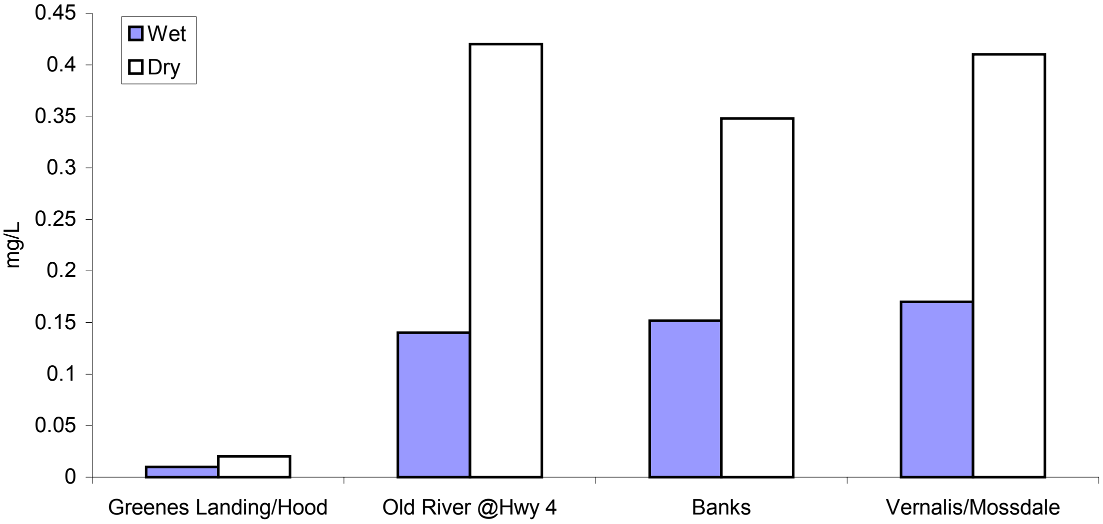
Bromide (mg/L)	0.02	0.05	0.1	0.2	0.3	0.4	0.5	0.6
Frequency	1	12	21	14	7	18	11	14
Cumulative %	1%	12%	32%	45%	51%	68%	79%	92%

Figure 4-66 Cumulative Probability Distribution of Bromide (mg/L) at Banks Pumping Plant, Jan 1990 to Sep 1998



Bromide (mg/L)	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.64
Frequency	13	28	39	25	24	16	14	3
Cumulative %	8%	25%	49%	65%	80%	90%	98%	100%

Figure 4-67 Average Bromide Concentrations (mg/L) by Year Type at Selected Sites in the Sacramento/San Joaquin Delta

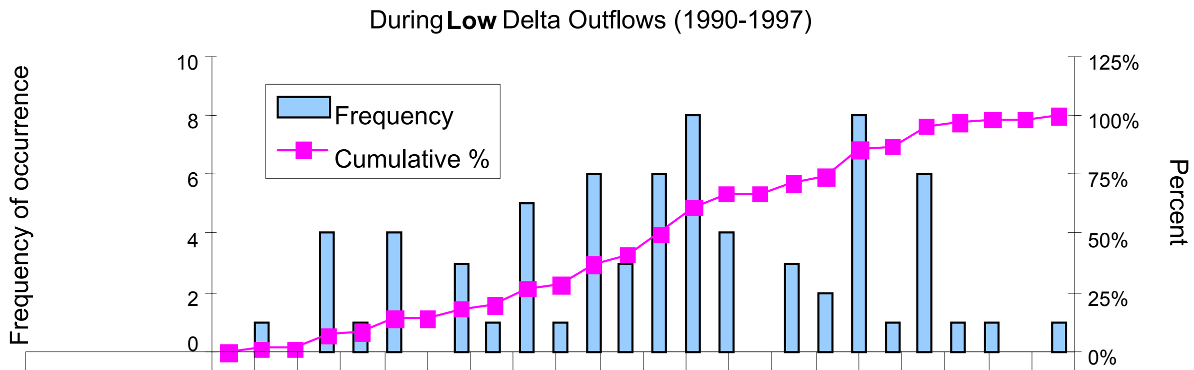


Data adapted from DWR 2000
See text for year type definitions
Most samples collected monthly between 1990-1998

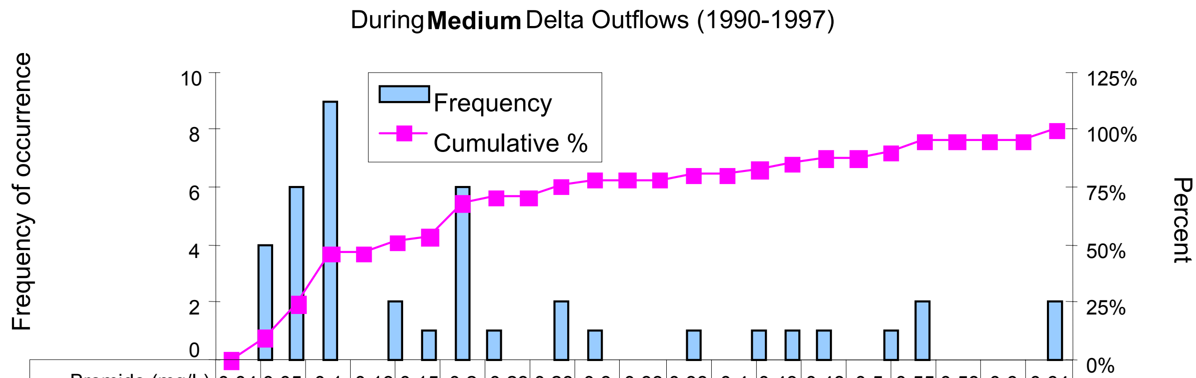
In the Delta, water year has a strong influence on bromide concentration. Figure 4-67 illustrates the average bromide concentrations from about 1990 to 1998 at 4 sites within the Delta. Samples analyzed according to year type (wet year type combines wet and above normal water years, while dry year type combines dry and critical water years) found that in all cases, bromide concentrations were significantly higher in dry than in wet years.

In addition to water year, the level of water outflow (that is, water available for dilution of bromide or salts) also plays a significant role in observed bromide concentrations. A comparison between bromide concentration and average Delta outflow on the Sacramento River at Greenes/Hood, the San Joaquin River near Vernalis/Mossdale, and at the Banks Pumping Plant consistently found that bromide levels were consistently higher under low flow conditions than at medium or high Delta outflow (DAP). This can be seen in Figures 4-68. For example, at Banks Pumping Plant, under low flow conditions, about 50% of the bromide concentrations fell below 0.38 mg/L. Under medium and high flow conditions, about 50% of the bromide concentrations fell below 0.15 mg/L

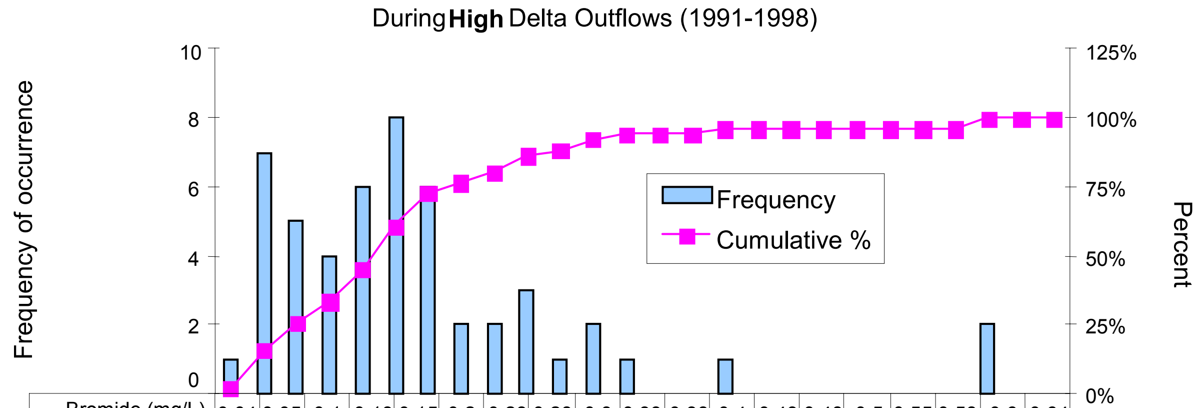
Figure 4-68 Cumulative Probability Distribution of Bromide (mg/L) at the Banks Pumping Plant



Bromide (mg/L)	0.04	0.05	0.1	0.13	0.15	0.2	0.23	0.25	0.28	0.33	0.35	0.38	0.43	0.45	0.48	0.53	0.55	0.58	0.6	0.64
Frequency	0	1	4	1	4	3	1	5	1	3	6	8	0	3	2	1	6	1	1	1
Cumulative %	0%	1%	7%	9%	14%	19%	20%	27%	29%	41%	50%	61%	67%	71%	74%	87%	96%	97%	99%	100



Bromide (mg/L)	0.04	0.05	0.1	0.13	0.15	0.2	0.23	0.28	0.3	0.33	0.38	0.4	0.43	0.48	0.5	0.55	0.58	0.6	0.64
Frequency	0	4	9	0	2	6	1	2	1	0	1	0	1	1	0	2	0	0	2
Cumulative %	0%	10%	46%	46%	51%	68%	71%	76%	78%	78%	80%	80%	83%	88%	88%	95%	95%	95%	100



Bromide (mg/L)	0.04	0.05	0.1	0.13	0.15	0.2	0.23	0.28	0.3	0.33	0.38	0.4	0.43	0.48	0.5	0.55	0.58	0.6	0.64
Frequency	1	7	4	6	8	2	2	1	2	1	0	1	0	0	0	0	0	2	0
Cumulative %	2%	16%	33%	45%	61%	76%	80%	88%	92%	94%	94%	96%	96%	96%	96%	96%	96%	100	100

Table 4-48 Comparison between Bromide Concentrations at Selected Stations in the State Water Project

Bromide (mg/L)	Banks Pumping Plant	Check 13	Check 41	Castaic	Silverwood
Mean	0.15	0.15	0.15	0.13	0.11
Median	0.12	0.15	0.14	0.13	0.11
Low	0.04	0.05	0.01	0.12	0.09
High	0.52	0.43	0.38	0.15	0.14
Number of Detects/Samples	48/49	48/48	43/47	4/4	3/3

Source: DWR O&M Division and MWQI database, May 2000
Bromide Detection limit = 0.01 mg/L.
Samples from Banks and Check Stations Collected between 1996 and 1999.
Samples at Lake Stations collected between Feb and Aug 1999.

Bromide is imported into the California Aqueduct. Mean, maximum, and minimum concentrations remain relatively consistent from Banks Pumping Plant to the bifurcation of the SWP at Check 41 (Table 4-48). This suggests that the strongest bromide influence on the delivery of aqueduct water still remains seawater intrusion and that the effects of evaporation are relatively minor. Although included for completeness, the bromide data set for the 2 southern California destination reservoirs that receive only SWP water is very small. Therefore, it is difficult to make meaningful comparisons or examine patterns with these 2 sites.

Drainage from Delta islands contains high concentrations of bromide. Based on 1,000 samples, the average bromide drainage concentration from 15 Delta islands was 0.713 mg/L (Woodard 2000). In general, bromide concentrations in Delta island drainages spike in fall or winter, regardless of year type, and are probably attributable to the release of residual irrigation water (Woodard 2000). Because agricultural practices on the islands concentrate dissolved solids in the applied water, it is not certain whether significant, intrinsic sources of bromide exist on some islands or whether the bromide appearing in the drainage water is mostly from the concentration of channel water. For a more in-depth examination of Delta drainages on bromide concentration, see Section 4.3.6, Agricultural Drainage Water Quality.

Connate (trapped seawater groundwater of ancient origins) does not appear to play a significant role in Delta bromide levels (CALFED 2000). Empire Tract drainage contains groundwater that is thought to be of connate origin. According to data from a 1990 DWR report that was analyzed by Metropolitan Water District of Southern California (MWDSC), drainage from Empire Tract accounted for less than 3% of the total drainage volume from Delta lowlands.

Most of the bromide from the San Joaquin Valley originates from seawater, but some have suggested that methyl bromide, a soil fumigant used in agriculture, could be contributing to the loading in the San Joaquin watershed. Based on 135 samples collected by DWR between 1990 and 1995, the ratio of bromide to chloride did not vary significantly from a seawater ratio. If methyl bromide were a significant contributor of bromide to the river system, the bromide to chloride ratio should have been higher as bromide from the fumigant would not have contributed chloride. The lack of an evident ratio shift indicates that bromide from methyl bromide use is not an important source of bromide loading to the system. Use of methyl bromide for soil fumigation is expected to end in 2005 by decree of the EPA (CALFED 2000).

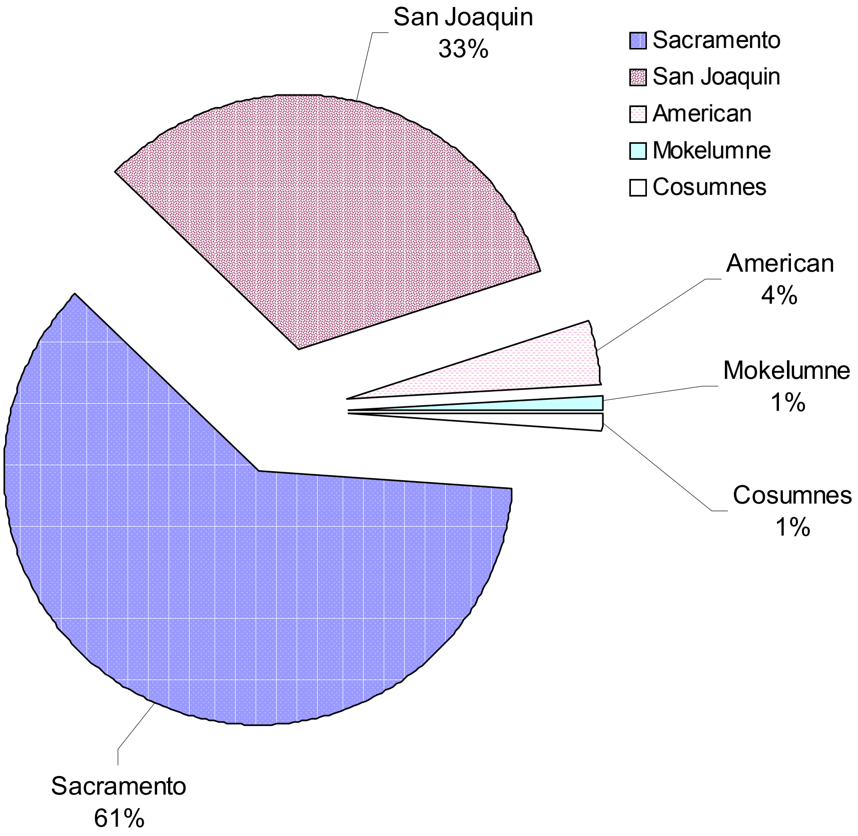
4.3.7.2 Salinity/TDS/EC

Scientists measure salt concentrations in a number of different ways. Salinity is a measure of the mass fraction of salts (measured in parts per thousand [ppt]), whereas TDS is a measure of the concentration of salts (measured as mg/L). Since EC generally changes proportionately to changes in dissolved concentrations, it is a convenient surrogate measure for TDS.

Both CALFED and the Comprehensive Monitoring Assessment and Research Program for Drinking Water have identified seawater intrusion as the major source of TDS to the Delta (CALFED 2000, CALFED 1998). However, the majority of data examined, quantified TDS in the tributaries to the Delta, and discussed TDS sources in terms of agricultural drainages, urban runoff, wastewater discharges, and discharges from confined animal facilities. With the exception of monitoring stations that are under the direct influence of tidal action (for example, Mallard Island), data analyses quantifying only the contribution of seawater intrusion to TDS concentrations are scarce. However, because the EC of seawater is approximately 50,000 µS/cm—about 70 to 80 times above the daily average EC range at Banks that can signal the department to consider allowing more fresh water into the system—it takes relatively little seawater to increase TDS or EC levels.

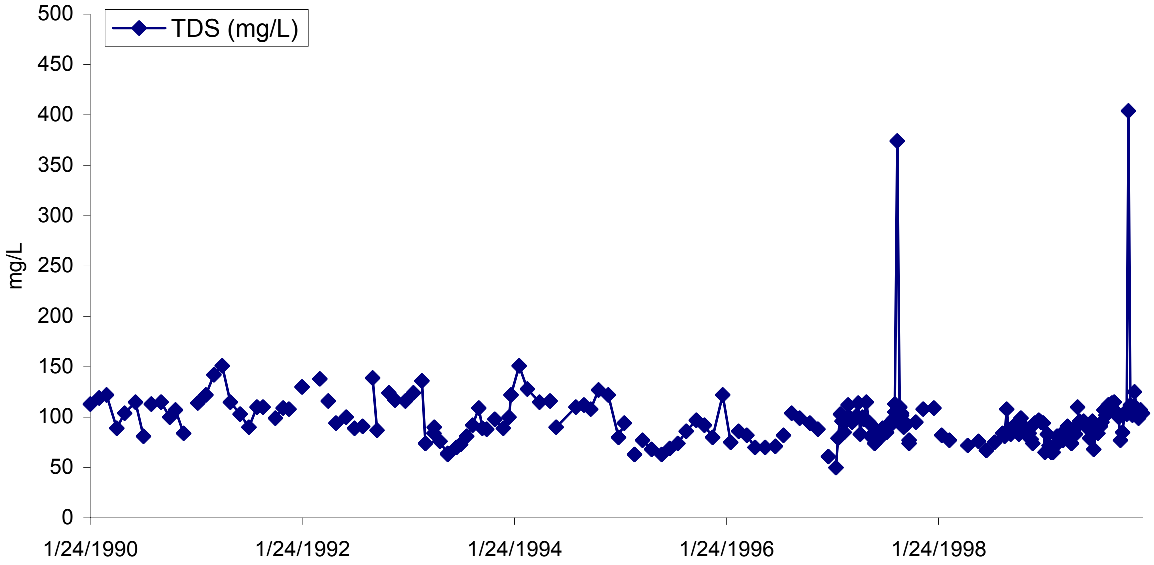
Figure 4-69 shows the relative contributions to TDS of tributaries into the Delta. The relative concentrations of TDS are low in the Sacramento River, but because of its large volume, the river contributes the majority of the TDS load to the Delta. Although actual flows from the San Joaquin River are lower than the Sacramento River, the TDS of San Joaquin River water averages 7 times that of the Sacramento. The San Joaquin River provides about one-third of the TDS load to the Delta. TDS concentrations in Delta island drainages are similar overall to those seen in the San Joaquin River. Because Delta island drainages are not considered a tributary to the system, their loading impact is not shown. However, Woodard estimated that loading from Delta island drainages was approximately 40% of the TDS loads contributed by the San Joaquin River. A number of island drains are near the diversion locations, and their drainage can have a disproportionately large influence on the water quality diverted to State and federal facilities (Woodard 2000).

Figure 4-69 Percent TDS Contribution in Tributary Inflows



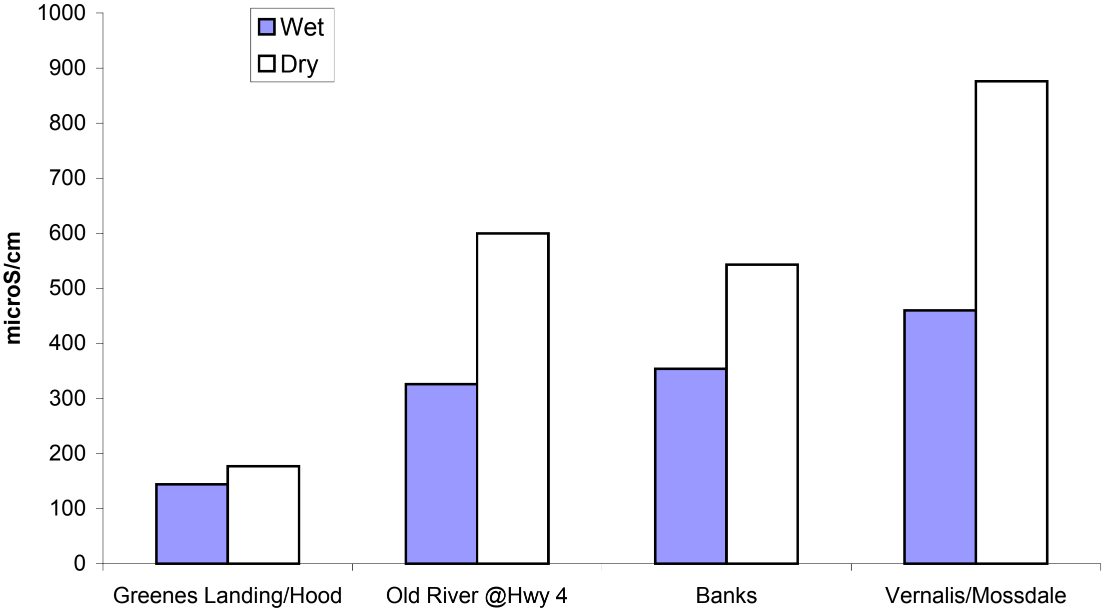
Source: Woodard 2000

Figure 4-70 TDS (mg/L) at Greenes Landing/Hood, 1991 to 1999



Brown and Caldwell and others (1995) estimated that of the total TDS loads observed in the Sacramento River, 26 to 33% came from agricultural drainage while 6% came from the combined loading of urban runoff, sewer overflow, and the SRWTP. By far, the greatest contributor to Sacramento River TDS loads came from unknown sources. It is unknown how large a role seawater intrusion plays in this fraction, however, if bromide measurements can be used as a marker of seawater intrusion, then seawater intrusion may play a minor role in the total TDS loading observed in the Sacramento River at Greenes Landing/Hood. Regardless of its source, TDS concentrations at this site are consistently below the secondary MCL of 500 mg/L (Figure 4-70). A 1996 survey concluded that there would be no treatment issues associated with mineral constituents if a drinking water facility was located at Freeport (Archibald & Wallberg and others 1996). A cumulative probability graph of raw water TDS for the Sacramento Water Treatment Plant found that 99.99% of the samples collected had a TDS < 170 mg/L (Archibald & Wallberg and others 1996).

Figure 4-71 Average Electrical Conductivity Values (µS/cm) by Year Type at Selected Sites in the Sacramento/San Joaquin Delta



See text for year type definitions.
Most samples collected monthly between 1990-1998.
Data adapted from DWR DAP report.

Salinity patterns observed in the Delta are similar to patterns observed with bromides. For example, like bromide, TDS concentrations are highest in the west Delta and the south Delta channels affected by the San Joaquin River (Table 4-47). Like bromide, salinity measurements are significantly higher in dry years. In some cases, average EC measurements in dry years are double those collected in wet years (Figure 4-71). Similarly, a DWR project report found that EC levels are generally higher during low Delta outflows as compared to medium or high flows (DWR 2000). However, unlike with bromide, Delta island drainages show higher levels of TDS under high flow conditions. Patterns associated with agricultural and Delta island drainages are covered in detail under PCS section, Section 4.2.6 Agricultural Drainage. However, this probably reflects the seasonal leaching of salts from Delta islands. As mentioned previously, there are other sources of salinity in the Delta, including agricultural drainage, urban runoff, and confined animal facilities.

Between 1996 and 1999, TDS levels at Banks Pumping Plant never exceeded the secondary MCL of 500 mg/L (Table 4-49). The same findings were true for samples collected on the Sacramento River at Hood, and in the western Delta at Old River at Station 9. The 1 exception occurred with samples collected from the San Joaquin River near Vernalis. At this station, the TDS of 6 of the 146 samples (2%) was above the secondary MCL. However, even at this site, more than 90% of the samples collected were at or below the secondary MCL (Figure 4-72). It is important to note that TDS measurements do not measure the relative amount of each of the dissolved solids. Therefore, while the TDS secondary MCL of 500 mg/L may be achieved, individual constituents may still exceed MCL or Article 19 objectives. This was observed at the Banks Pumping Plant in December 1999. Because of seawater intrusion in the south Delta, TDS concentrations at Banks met MCL or Article 19 objectives, while sodium and chloride did not. (DWR 2000a).

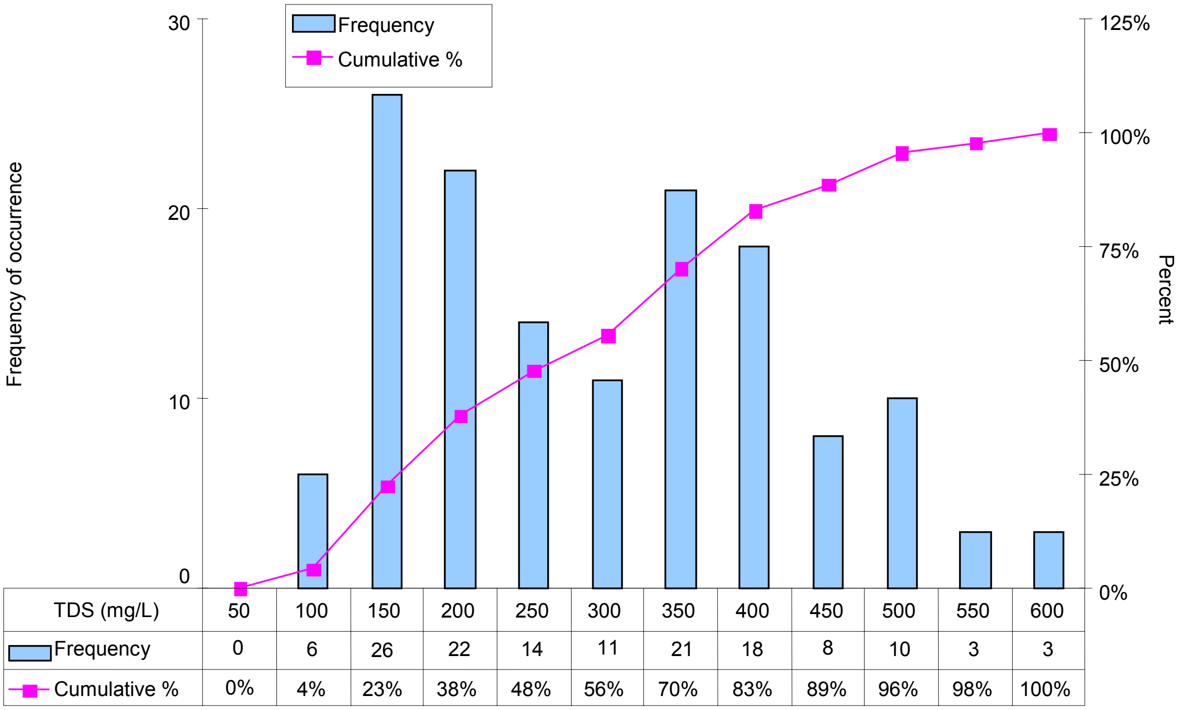
Table 4-49 Comparison between Total Dissolved Solids Concentrations at Selected Stations in the Delta

TDS (mg/L)	Sac River @ Greenes/Hood	Old River @ Station 9	Banks Pumping Plant	SJR Near Vern/Mossdale
Mean	95	200	195	273
Median	92	173	182	261
Low	50	107	116	83
High	404	450	388	578
Number of Detects/Samples	131/131	40/40	27/27	143/143

Source: DWR MWQI database
TDS Detection limit = 1.0 mg/L

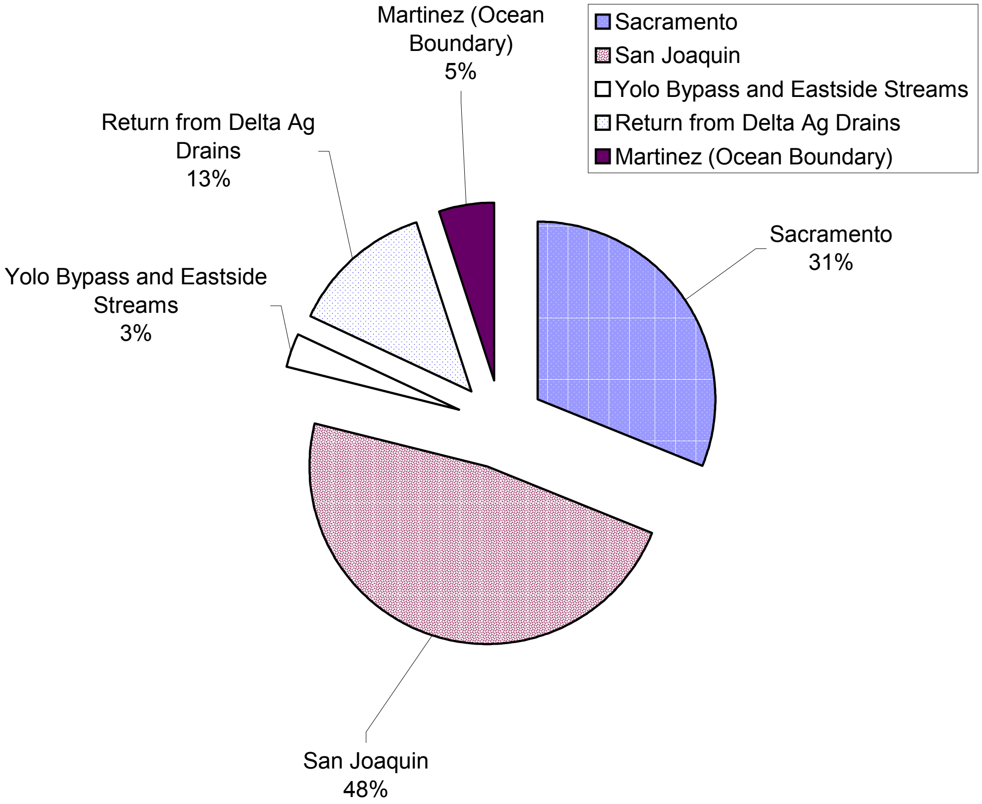
Samples collected between 1996 and 1999.

Figure 4-72 Cumulative Probability Distribution of TDS (mg/L) at Vernalis/Mossdale, 1996 to 1999



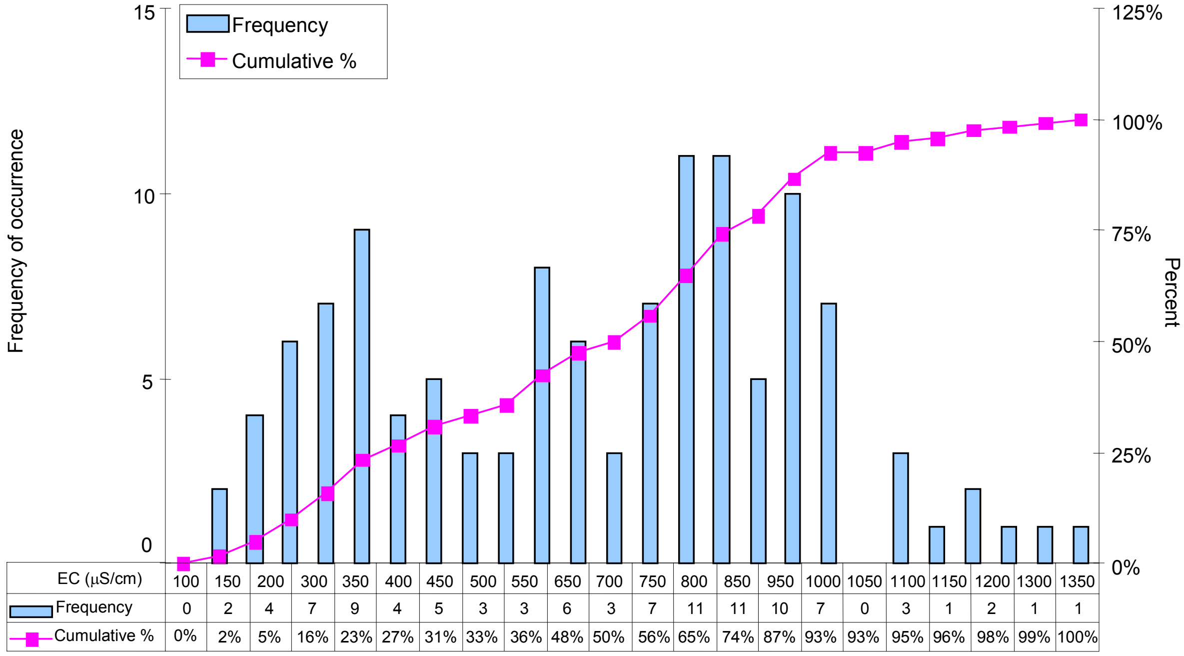
TDS (mg/L)	50	100	150	200	250	300	350	400	450	500	550	600
Frequency	0	6	26	22	14	11	21	18	8	10	3	3
Cumulative %	0%	4%	23%	38%	48%	56%	70%	83%	89%	96%	98%	100%

Figure 4-73 EC Contribution at Banks Pumping Plant (by Percent) based on DSM2 Model, May to Oct 1996



In the southern Delta, agricultural drainage from the San Joaquin is an important salinity source as are Delta island drainages. Separating the relative contributions of "new" salt originating from seawater intrusion and that from agricultural drainage, however, is complex. No studies were found that portioned the relative contributions of the 2. Because of the flow pattern that causes San Joaquin River water to flow to the diversion pumps, the influence of the San Joaquin River is disproportionately large at the southern Delta diversions. For example, the Department's Delta Simulation Model predicted that in the summer months of 1996, the San Joaquin River contributed nearly 50% of the EC level measured at Banks Pumping Plant (Figure 4-73). It is important to note that elevated salinity in the San Joaquin River near Vernalis frequently exceeds the SWRCB salinity objectives of 700 µS/cm to protect agricultural beneficial uses in the south Delta (CALFED 2000b). However, for drinking water, the recommended secondary MCL is 900 µS/cm. Between 1996 and 1999, only 4% of the monthly average EC samples collected by MWQI at the San Joaquin River near Vernalis/Mossdale exceeded this secondary drinking water MCL (Figure 4-74). Because the water years during this period were classified as either wet or above normal, it is not surprising that the majority of samples fall below secondary MCLs. In contrast, in the early 1990s during the prolonged drought, the number of samples that averaged 900 µS/cm or above also increased (Figure 4-75). The effects of flow and EC levels are also evident in Figure 4-76. During summer, when flow in the San Joaquin is primarily derived from agricultural return water, EC increases. However, during higher flow periods (about January through March), EC levels often drop. It is illustrative to note that some of the lowest flows often occur in late fall and early winter from October to December.

Figure 4-74 Cumulative Probability Distribution of Average Monthly Electrical Conductivity (µS/cm) at San Joaquin River near Vernalis/Mossdale, 1990 to 1999



EC (µS/cm)	100	150	200	300	350	400	450	500	550	650	700	750	800	850	950	1000	1050	1100	1150	1200	1300	1350
Frequency	0	2	4	7	9	4	5	3	3	6	3	7	11	11	10	7	0	3	1	2	1	1
Cumulative %	0%	2%	5%	16%	23%	27%	31%	33%	36%	48%	50%	56%	65%	74%	87%	93%	93%	95%	96%	98%	99%	100%

Figure 4-75 Monthly Average Electrical Conductivity Values (±1 std. dev.) for the SJR Near Vernalis/Mossdale, 1990 to 1999

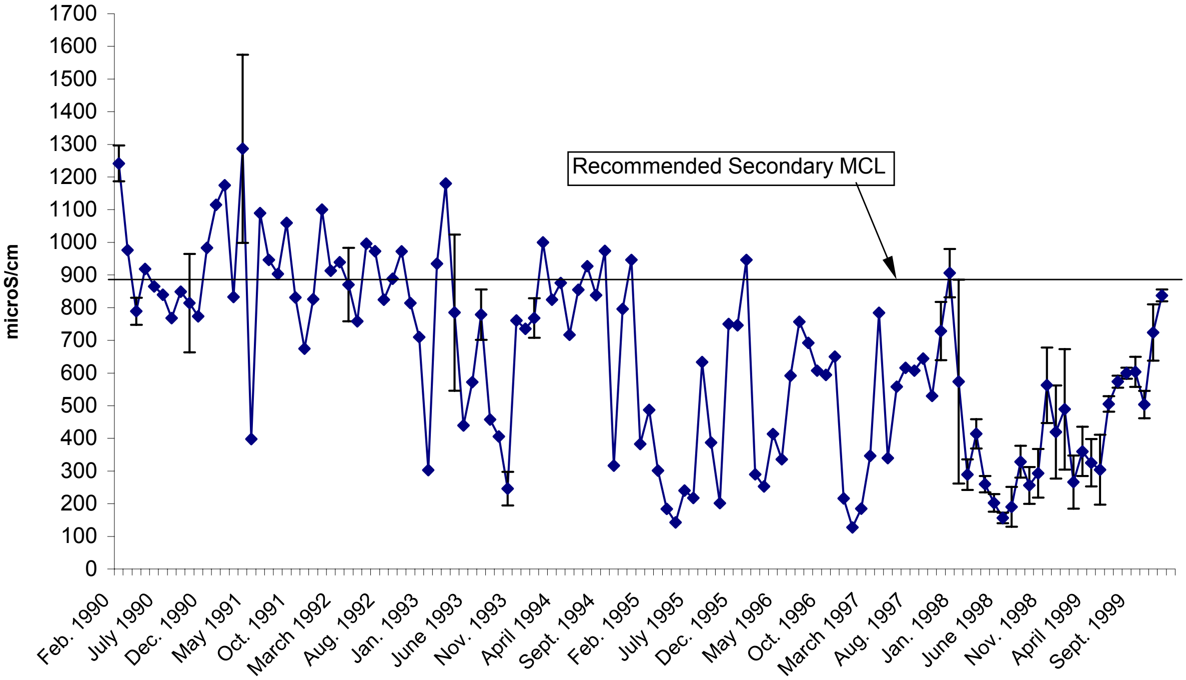
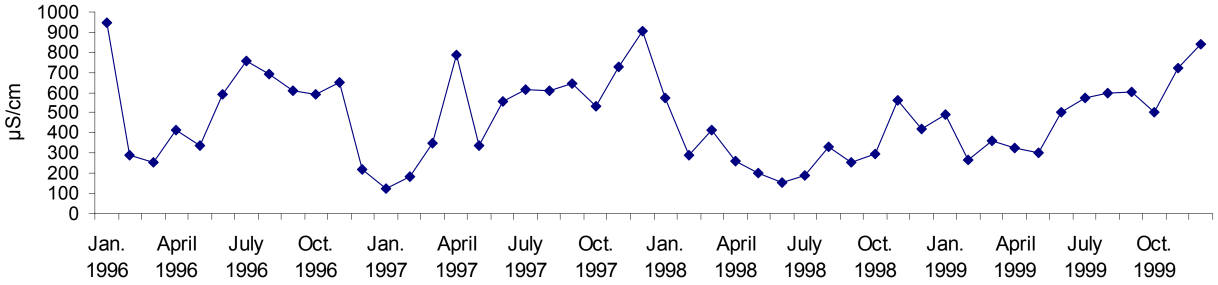


Figure 4-76 Average Monthly Electrical Conductivity Levels (µS/cm) at the San Joaquin River near Vernalis/Mossdale and Average Flow of the San Joaquin River by Month


Average Monthly EC levels at the SJ Rvr. near Vernalis/Mossdale (96-99)

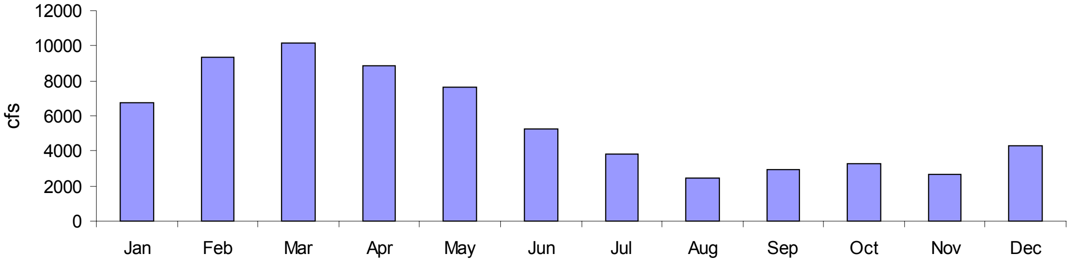

Avg. Flow of the San Joaquin by Month (1980-1998)

Table 4-50 Comparison between Total Dissolved Solids Concentrations at Selected Stations in the State Water Project

TDS (mg/L)	Banks Pumping Plant	Check 13	Check 41	Castaic	Silverwood
Mean	195	214	208	315	198
Median	182	211	218	313	202
Low	116	126	73	266	148
High	388	295	345	406	246
Number of Detects/Samples	27/27	48/48	46/46	19/19	16/16

Source: DWR MWQI and O&M databases
TDS Detection limit = 1.0 mg/L
Samples collected between 1996 and 1999.

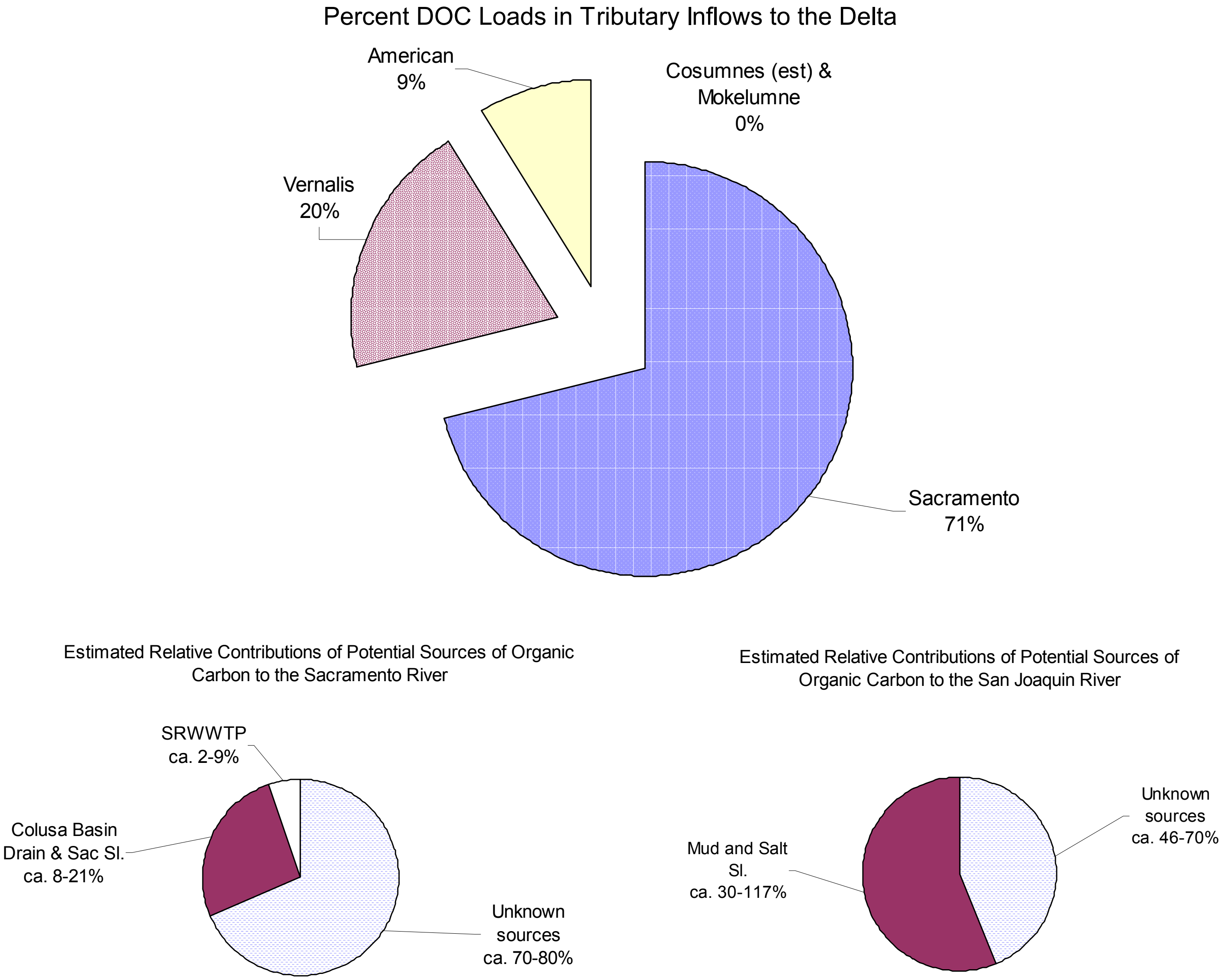
Although slightly more variable than bromide, TDS levels in the California Aqueduct appeared relatively similar from Banks Pumping Plant down through the bifurcation of the aqueduct at Check 41, and even the highest detected samples did not exceed secondary MCLs (Table 4-50). However, with respect to Castaic and Pyramid, the TDS concentrations of both lakes are quite different from that of the SWP. As discussed in the Castaic and Silverwood water quality section, TDS concentrations of these lakes are influenced by input from a local water body, Piru Creek.

4.3.8 ORGANIC CARBON

Water quality data in this section is discussed in terms of both DOC and TOC. Data was obtained primarily from the DWR MWQI database. In this database, the most complete records were generally for DOC. In general, during periods of low runoff TOC and DOC values are similar. However, a greater discrepancy between the 2 measurements is usually observed during high flows. Under these circumstances turbidities can increase dramatically because of increased particulate matter (for example, sediment, plant matter) from surface runoff. TOC levels will rise as particulate organic carbon increases. During high flows, DOC also increases, but in general not as pronounced as particulate organic carbon concentrations. For these reasons, MWQI DOC data may underestimate TOC levels during rainfall or high runoff events.

CALFED has reviewed Delta water quality issues and has identified organic carbon as a parameter of concern; however, there is limited knowledge of baseline conditions of TOC at key Delta locations and tributaries. There is also limited understanding of TOC loads in the system (CALFED 2000d). The same could be said for DOC.

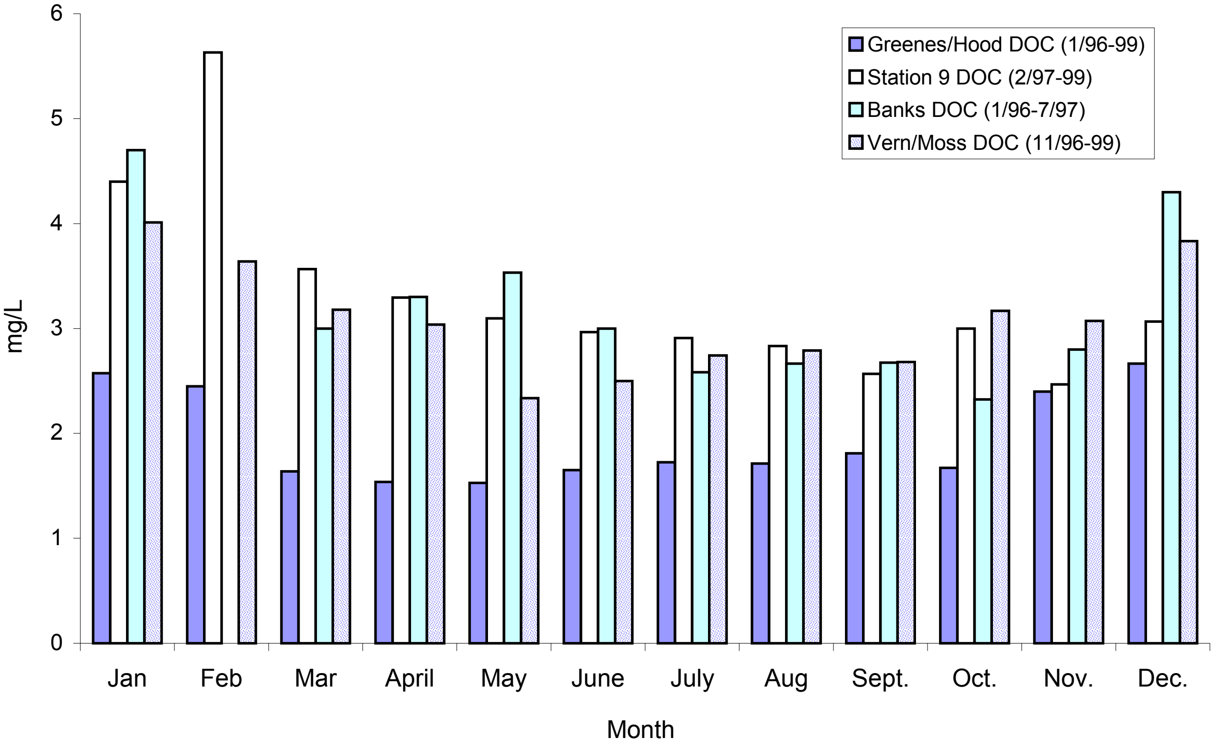
Figure 4-77 Estimates of Mass Loads and Relative Sources of Dissolved Organic Carbon to the Delta



Source: Upper figure adapted from Woodard 2000; lower figures adapted from Brown & Caldwell and others 1995

A large proportion of the carbon sources in the Sacramento and San Joaquin River watersheds are not known. Figure 4-77 shows the estimated DOC carbon input from tributaries to the Delta. The Sacramento River is a major contributor to the Delta carbon load because although its carbon concentrations are relatively low, approximately three-quarters of the inflow into the Delta comes from the Sacramento River. Based on mass load estimates of known carbon inputs, Brown and Caldwell and others (1995) estimated that, depending on the year type and the season, between 70% and 80% of the carbon load in the Sacramento River came from unknown sources (Figure 4-77). Similarly, depending on the season and year type, up to 70% of the carbon load observed in the San Joaquin was of unknown origin.

Figure 4-78 Average Monthly DOC Concentrations at Selected Sites within the Delta



Drainage from Delta islands, particularly from islands with highly organic peat soils, contributes significantly to the DOC load in the Delta. Studies conducted by DWR estimated that during the summer irrigation months, island drainage contributed 40% to 45% of the DBP carbon reacting in Delta water supplies. During winter, Delta island drainages may contribute from 38% to 52% of the DBP-forming carbon (Woodard 2000). Woodard estimated that carbon loading from Delta islands is about 36 tons per day. It is important to note that not all of this carbon is necessarily produced on the islands themselves. Water diverted onto Delta islands contains DOC that may be concentrated by evaporation and plant transpiration (Woodard 2000). For a more complete discussion of Delta island contributions to organic carbon, see Section 4.3.6.1, Delta Region.

Seasonal DOC trends from 1996 to 1999 were examined for 4 sites within the Delta. Samples collected from the Sacramento River near Greenes Landing/Hood were used to examine DOC inputs from the northern Delta. Samples collected from the San Joaquin River near Vernalis/Mossdale were used to examine DOC inputs from the southern Delta. Samples collected from Station 9 were used to examine DOC inputs from the western Delta. DOC concentrations were also examined at the Banks Pumping Plant.

Monthly averages of DOC at the 4 sites are shown in Figure 4-78. Strict comparisons between the sites were not possible as sampling frequency varied with the station (Greenes Landing/Hood and Vernalis/Mossdale were generally sampled weekly, while Station 9 and Banks were generally sampled monthly) and the period of record was not always complete for all stations. In the case of Banks, data were only available from January 1996 to July 1997 so averages could not be computed for all months. With these caveats, individual DOC patterns for each station generally showed increases in DOC levels over winter months.

Statistically, DOC concentrations in the Delta are influenced by season (winter or summer), not year type (wet versus dry). One project compared changes in DOC concentrations between 1990 and 1998 by season (winter = November to April, summer = May to October) and by year type (wet = above normal or wet, dry = below normal, dry, and critical) (DWR 2000). At the 4 sites examined in this report, DOC concentrations were significantly higher in winter than in summer. At a given site, DOC concentrations were not significantly different between wet and dry year types. This pattern was opposite the one observed for bromide. In the case of bromide, concentrations varied significantly with year type, not season. In addition to the 4 sites of this report, the project also examined DOC concentrations at 8 other sites in the Delta (DWR 2000). With 1 exception, DOC concentrations showed the same pattern of significant differences with the season but not the year type. The exception—the North Bay Aqueduct—showed significant differences not only by season, but by year type as well. For a full discussion of North Bay Aqueduct studies, see Chapter 3. TOC data were not always available at the 4 key sites for statistical analysis; however, 1 project found that TOC concentrations at the Banks Pumping Plant also varied significantly by season (DWR 2000).

Although comparison of trends between these 4 sites with this dataset is problematic, the lowest DOC concentrations were observed in the Sacramento River (Table 4-51). These results are consistent with a number of other studies (for example, DWR 2000; Brown and Caldwell and others 1995; Woodard 2000). The highest DOC and TOC values observed at Greenes Landing/Hood were below the highest concentrations observed at the Banks Pumping Plant. Therefore, it is unlikely that the Sacramento River is responsible for the elevated concentrations observed at the pumping plant. Because the Sacramento River is the largest freshwater tributary to the Delta, it is likely that the river improves organic carbon water quality at the pumps.

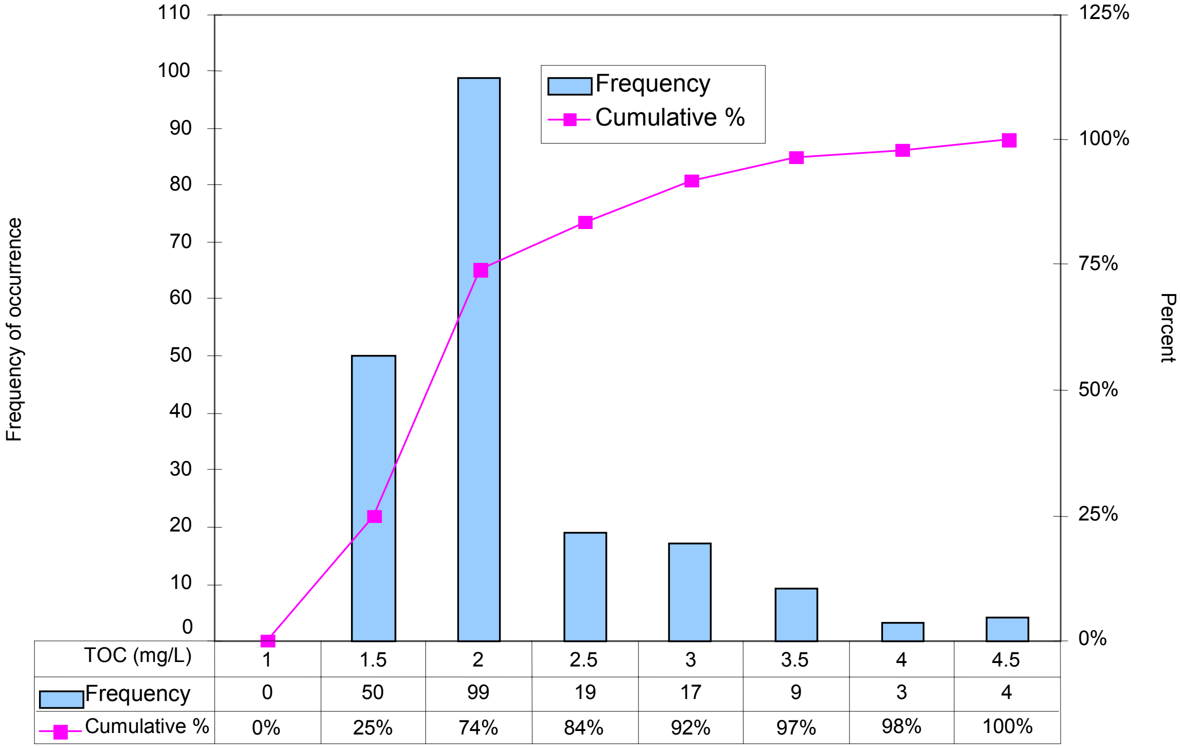
On average DOC concentrations in the western and southern Delta were higher than those observed in the northern Delta. Average DOC and TOC concentrations in the San Joaquin River and at Station 9 were approximately 50% to 60% higher than those found at the Sacramento River at Greenes Landing/Hood (Table 4-51). At Station 9, mean, median, minimum, and maximum DOC and TOC concentrations were the highest of any of the 4 sites. Although not examined statistically, average DOC and TOC concentrations at the Banks Pumping Plant were between those observed in the western and southern Delta. Note that the maximum DOC concentration recorded at Vernalis/Mossdale was greater than its maximum recorded TOC value. This discrepancy occurred because of a lack of correspondence between DOC and TOC values. The DOC value was recorded in 1996, a year before TOC collection began.

Table 4-51 Comparison between Dissolved and Total Organic Carbon Concentrations (mg/L) at Selected Stations in the Sacramento/San Joaquin Delta

DOC (TOC)	Sac River @ Greenes Ldg/Hood	Station 9	SJR Near Vernalis/Mossdale	Banks Pumping Plant
Mean	1.9 (1.9)	3.3 (3.5)	3.1 (2.9)	2.8 (3.5)
Median	1.7 (1.7)	3.1 (3.1)	2.8 (2.9)	2.7 (3.2)
Low	1.2 (1.3)	2.2 (2.2)	1.9 (2.0)	1.7 (2.3)
High	6.1 (4.2)	8.4 (9.8)	8.1 (4.3)	4.9 (6.7)
Number of Detects/Samples	310/310 (201/201)	36/36 (27/27)	134/134 (69/69)	66/66 (48/48)

DOC Samples collected between 1996 and 1999.
TOC Samples Collected at Greenes Landing/Hood and Station 9 collected from late 1997 to 1999
TOC Samples Collected at Vernalis/Mossdale from Sep 1998 to Dec 1999.
TOC Samples Collected at Banks Pumping Plant from 1996 to 1999.

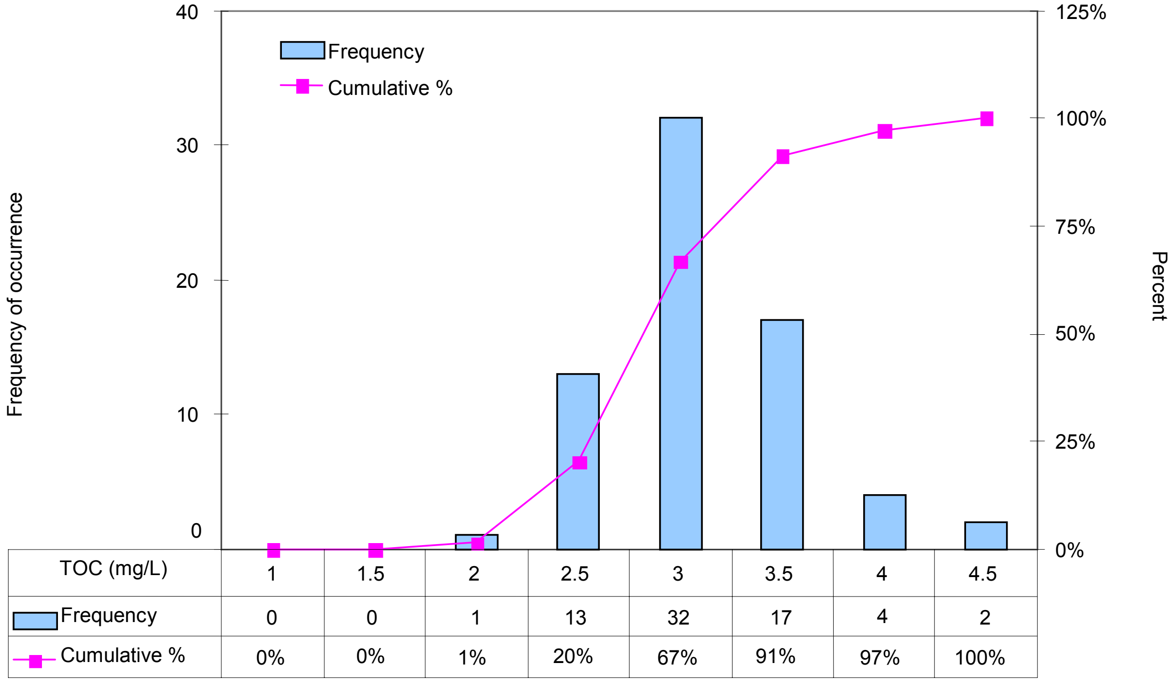
Figure 4-79 Cumulative Probability Distribution of TOC in the Sacramento River at Greenes Landing/Hood, Oct 1997 to 8 Feb 1999



TOC (mg/L)	1	1.5	2	2.5	3	3.5	4	4.5
Frequency	0	50	99	19	17	9	3	4
Cumulative %	0%	25%	74%	84%	92%	97%	98%	100%

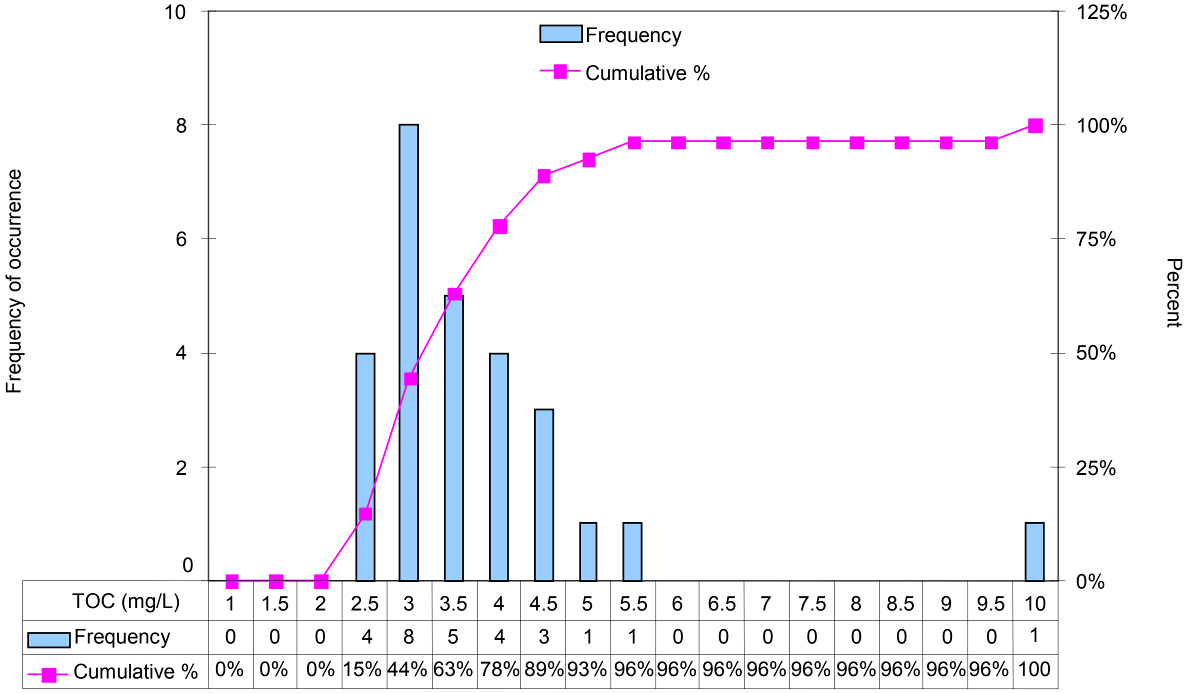
Using the CALFED proposed target level of 3 mg/L, frequency distributions for TOC were examined at the 4 representative sites. With the exception of the Banks Pumping Plant, TOC samples were not collected over the entire period of record of this report. From October 1997 to December 1999, 90% of the TOC samples analyzed in the Sacramento River at Greenes Landing/Hood were at or below the target level (Figure 4-79). Total organic carbon was analyzed in the San Joaquin River near Vernalis/Mossdale for a little more than a year (September 1998 to December 1999). Nearly 70% of the samples collected in this time period fell at or below 3 mg/L. Ninety percent were at or below 3.5 mg/L (Figure 4-80). With such a short period of record, it is difficult to make meaningful comparisons between this site and the others. At Station 9, one sample as high as 10 mg/L was detected; however, the majority of samples were detected at 5.5 mg/L or less (Figure 4-81). Less than half occurred at 3 mg/L or less. Although collected monthly, TOC was analyzed at the Banks Pumping Plant from 1996 to 1999. Frequency distributions of this data found that only 35% of the samples were detected at 3 mg/L or less. The majority of detections occurred between 3 and 3.5 mg/L. More than 90% of the samples were detected at 5 mg/L or less (Figure 4-82).

Figure 4-80 Cumulative Probability Distribution of TOC in the San Joaquin River near Vernalis/Mossdale, Sep 1998 to Dec 1999



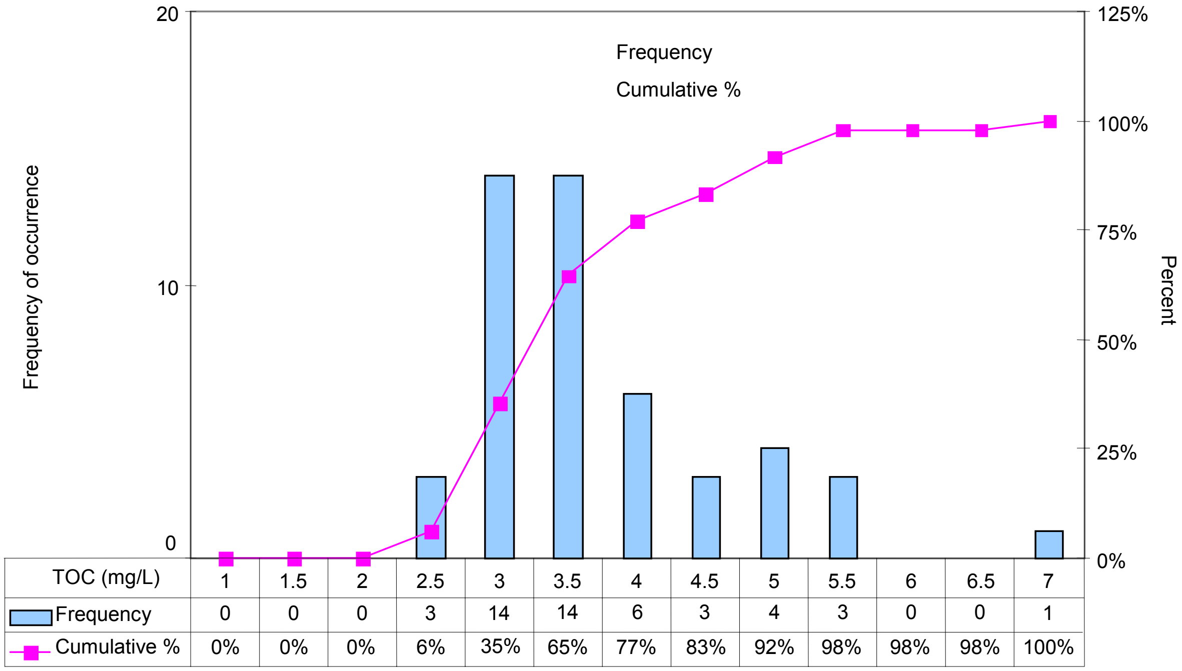
TOC (mg/L)	1	1.5	2	2.5	3	3.5	4	4.5
Frequency	0	0	1	13	32	17	4	2
Cumulative %	0%	0%	1%	20%	67%	91%	97%	100%

Figure 4-81 Cumulative Probability Distribution of TOC at Station 9, Oct 1997 to Dec 1999



TOC (mg/L)	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
Frequency	0	0	0	4	8	5	4	3	1	1	0	0	0	0	0	0	0	0	1
Cumulative %	0%	0%	0%	15%	44%	63%	78%	89%	93%	96%	96%	96%	96%	96%	96%	96%	96%	96%	100

Figure 4-82 Cumulative Probability Distribution of TOC at Banks Pumping Plant, Jan 1996 to Dec 1999



TOC (mg/L)	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
▭ Frequency	0	0	0	3	14	14	6	3	4	3	0	0	1
■ Cumulative %	0%	0%	0%	6%	35%	65%	77%	83%	92%	98%	98%	98%	100%

4.4 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Seawater intrusion is the largest source of TDS, salts and bromide to the Delta. Freshwater inflows to the Delta from the Sacramento and San Joaquin rivers, while substantial, are volumetrically small in comparison to tidal exchange with the San Francisco Bay. Daily tidal fluctuations have a large effect on water quality at the Delta pumping plants and other areas in the western and southern Delta. When feasible, inputs to Clifton Court Forebay are timed to avoid periods of greatest tidal influence on water quality. The extent of seawater intrusion into the Delta is also a function of current inputs from the Sacramento and San Joaquin rivers, the rate of export at the SWP and CVP intakes, and the operation of various control structures such as the Delta Cross-Channel Gates and Suisun Marsh Salinity Control System. In general, drinking water quality standards are not the primary objectives for SWP operations in the Delta. The main determinants of Delta operations are standards based on flow criteria that support wildlife and maintain adequate water quality for agricultural purposes. Widespread failure of Delta island levees could occur during earthquakes and also lead to extensive seawater intrusion, interrupting water deliveries in the SWP and CVP. Levee system integrity is currently being evaluated, and necessary steps will be taken to protect levees from failure.

Discharge from wastewater treatment plants within the Delta and along its major tributaries contribute TDS, salts, pathogens and nutrients to the Delta and, in turn, affect water quality in SWP and CVP exports. Population growth is likely to increase both urban runoff and wastewater discharges. Wastewater treatment plants and urban runoff appear to pose a minor to moderate threat to drinking water quality in the Delta; however, the potential for sewage spills still exists at some facilities and future urban growth may increase the loading of pathogens, TOC/DOC, and industrial pollutants to the Delta. For example, the city of Sacramento operates an outdated, combined sewer system which carries both sewage and storm water runoff to the water treatment plant. Sewage spills into the Sacramento River have occurred when storm runoff exceeded the carrying capacity of the plant. Water quality data currently collected by wastewater treatment plants within the Delta watershed are generally insufficient for a complete evaluation of the impacts of discharges on drinking water quality. In particular, there is need for increased effluent-monitoring of DBP precursors such as TOC/DOC, human pathogens, and trace constituents such as chromium 6 and mercury.

Agricultural activities, including dairies, contribute substantial amounts of TDS, salt, and nutrients to the Sacramento and San Joaquin rivers and the Delta. Lower flows in the San Joaquin result in less dilution of inputs from agricultural drains than occurs along the Sacramento River and within the Delta. Given the proximity of the Tracy Pumping Plant to the San Joaquin confluence, a significant proportion of the TDS, nutrient, salt, and perhaps TOC/DOC load in the DMC originates in the San Joaquin River Basin. While sources of salt to the Delta and its major tributary rivers are well defined and quantified, there are few data to assess nutrient and pathogen loads from agricultural sources. Dairies in particular are a large potential source for nutrients and pathogens where little water quality data are available. In addition to contamination from surface runoff from these facilities, there may be significant, negative water-quality effects from land disposal of dairy biosolids and wastewater. Baseline data on the number and spatial distribution of CAFO facilities in the Delta watershed will also be needed to fully gauge CAFO impacts on drinking water quality in the SWP and CVP.

Delta island drainage is a significant source of organic carbon in the SWP and CVP, because of both the native peat soils and the fact that agricultural runoff from these islands enters the Delta near the pumping plants. Agricultural drainage from Delta islands is also high in TDS, bromide, and other salts owing to evapoconcentration of irrigation water and inputs from connate water. More study is needed of the drinking water quality impacts from Delta island drainage, especially in regard to TOC/DOC quantity and quality and loading to the SWP.

A serious lack of toilets and marina pump-out facilities has been documented in the Delta and poses a moderate risk of pathogen contamination in the SWP and CVP. As many as 70% of all Delta marinas may not have adequate facilities to handle sewage generated by boaters. Poor access to toilet facilities increases the risk for fecal contamination of Delta waterways and beaches along the Sacramento and San Joaquin rivers. A dearth of recreational use surveys in the Delta and tributary rivers hinders solutions for these problems. Moreover, available pathogen data are inadequate to link incidences of contamination to sources or judge the relative importance of these sources to the total pathogen load of the Delta. More study will be needed in order to fully understand the scale of the problem and design useful and cost-effective mitigation measures.

4.5 WATERSHED MANAGEMENT PRACTICES

4.5.1 SACRAMENTO RIVER BASIN

Extensive efforts have been made to control the contamination of the Sacramento River by rice herbicides. Other efforts have focused on controlling mine contamination. The CALFED program ecosystem restoration program has funded a number of investigations and programs aimed at improving ecosystem water quality. In this effort, drinking water quality also benefits when its parameters of concern are identical with those of the ecosystem.

The Sacramento River Watershed Program (SRWP) is composed of government and private volunteer entities linked by activities and mandates within the Sacramento watershed. Activities that are funded and established include a coordinated monitoring program and an educational outreach program. Workshops are held for coordination and educational purposes.

The SRWP mission is "To ensure that current and potential uses of the watershed's resources are sustained, restored, and where possible, enhanced, while promoting the long-term social and economic vitality of the region."

Its goals are:

- To develop an effective process of improving water quality and protecting beneficial uses that meets the interests of all stakeholders, not just regulatory agencies,
- To collect better information through monitoring,
- To ensure solutions are based on good, solid information,
- To develop an effective process that meets the interest of regulatory bodies, so that a locally driven process can be effective,
- To develop a stewardship approach.

The SRWP is currently funded through an EPA grant. It is proposed to establish the program as a nonprofit corporation. Draft bylaws are under review. The majority of participants rely upon their own funding sources and mandates to participate in and support the SRWP. A number of participants receive some funding from the SRWP to carry out elements of the SRWP work plan.

4.5.2 SAN JOAQUIN RIVER BASIN

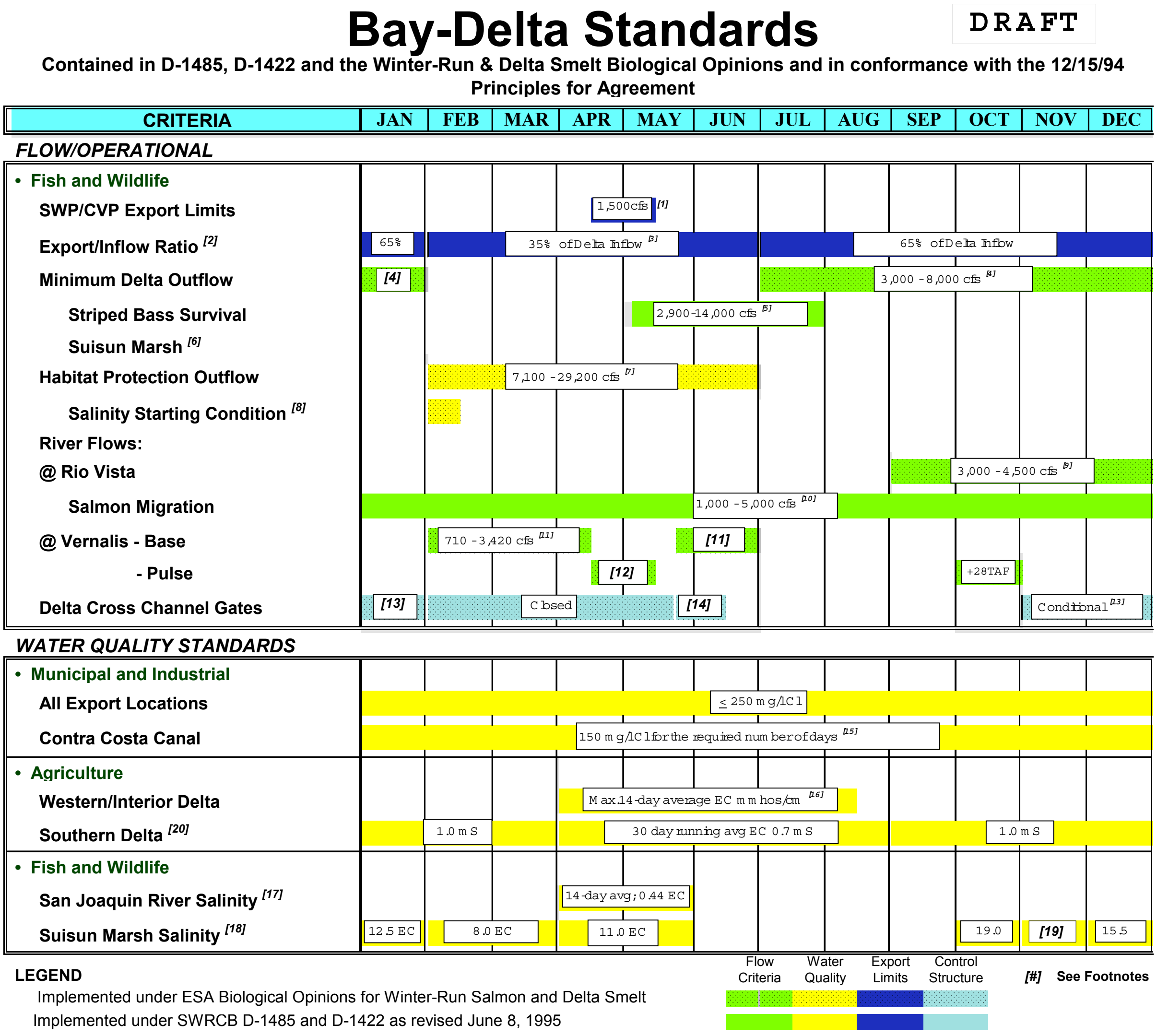
In 1990, the San Joaquin Valley Drainage Program (SJVDP) recommended a plan to manage the drainage problem in the Grasslands Basin. One of the options was to pump tile drainage water into the San Joaquin River based on the river's ability to assimilate the discharges without exceeding water quality standards. A revised management plan was signed in 1995, and the project commenced in 1996. This project known as the Bypass Project consists of diverting agricultural drainage in a separate canal into a 28-mile section of the old San Luis Drain, which would then drain into a short northern section of Mud Slough and into the San Joaquin River. This prevents commingling of tile drainages with tailwater, maintaining the quality of the latter to improve its agricultural recycling potential.

Removing the flow of tile drainage into wetlands reduces selenium impacts on wildlife in the refuges. The bypass also provides better management control of the volume and timing of tile drainage discharges that is based on the calculated ability of the San Joaquin River to assimilate the discharges without impairing water quality. The plan would also eliminate all tile drainage discharges into Salt Slough and a large portion of Mud Slough, which improves their water quality (UC 1999). The project required a (WDR), which was issued by the CVRWQCB in July 1998 to expire in 2010 with the main focus of limiting selenium loads into the San Joaquin River at 8,000 pounds. The project has not yet produced the desired results, and water quality objectives are still being exceeded. These have been due to the difficulty of timing drainage discharges to coincide with reservoir releases. A new real time management system is being pilot tested to fine-tune the system and make coordination more efficient.

4.5.3 DELTA REGION

State and federal management of agricultural, industrial and municipal pollution sources is important to the protection of water quality in the Delta. Of even greater importance, however, is the regulatory management of the diversion of water for export from the Delta. An extensive and complex set of regulatory requirements and controls have been established with regards to these diversions. A thorough discussion of these regulations and their impacts on water quality are beyond the scope of this chapter. An abbreviated summary of the major Delta controls and requirements are presented in Figure 4-83.

Figure 4-83 Bay-Delta Standards



Source: Personal communication: Curtis Creel, 28 Apr 2001, e-mail attachment

For several years the primary regulations for operation of the Delta export facilities were part of the SWRCB Decision 1485 (D-1485), which was adopted in 1978. D-1485 was quite comprehensive and covered many aspects of the hydrology, ecology, and water quality of the Delta; however, it became evident that there were aspects that had not been included or were inadequately covered. This situation resulted in the revision of D-1485 by the SWRCB plus the adoption by the board of the 1995 Bay-Delta Plan. In December 1999, the board adopted Decision 1641, which covers many of the export regulations. Other State and federal agencies have also adopted regulations affecting the operation of export facilities. Readers are encouraged to consult the documents listed above for more information.

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Chapter 5.3.1 - South Bay Aqueduct

Potential Contaminant Source or Watershed Activity	**Report Section**	**Water Quality Parameters**								
		TDS/ Salts	**Organic Carbon**	**Bromide**	**Pesticides**	**Nutrients**	**Pathogens**	**Trace Elements**	**Turbidity**	**T&O**
Recreation	5.3.1.1									
Wastewater Treatment/Facilities	5.3.1.2		○			○	○		○	
Urban Runoff	5.3.1.3	○	○		○	○	○	○	○	
Animal Populations	5.3.1.4					◒	◒		○	
Algal Blooms	5.3.1.5								●	●
Agricultural Activities	5.3.1.6									
Traffic Accidents/Spills	5.3.1.7									
Geologic Hazards	5.3.1.8					○	○		○	

<u>Rating symbols:</u>

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Chapter 5.3.2 - Lake Del Valle

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Recreation	5.3.2.1						◒		◒		● [1]
Wastewater Treatment/Facilities	5.3.2.2		◒			◒	◒				
Urban Runoff	5.3.2.3				○	○	○		○		
Animal Populations	5.3.2.4					○	◒		○		
Algal Blooms	5.3.2.5								◒	◒	
Agricultural Activities	5.3.2.6				○						
Mines	5.3.2.7	○						○			
Unauthorized Activity	5.3.2.8										
Traffic Accidents/Spills	5.3.2.9										
Geologic Hazards	5.3.2.10					○	○		○		
Fires	5.3.2.11										
Land Use Changes	5.3.2.12								●		● [2]

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. MTBE
2. Threat of erosion from development,grading, etc

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South Bay Aqueduct and Lake Del Valle

This chapter addresses the South Bay Aqueduct (SBA) and Lake Del Valle as separate but highly related State Water Project (SWP) features. Discussion of potential contaminant sources (PCSs) for the SBA focuses on the aqueduct's open portions, which include about 10.7 miles of open canal. A separate discussion of Lake Del Valle's PCSs is warranted because its watershed and activities call for distinct evaluation and development of conclusions and recommendations.

5.1 WATERSHED DESCRIPTION

The SBA begins at Bethany Reservoir along the western edge of the San Joaquin Valley, traverses the hills surrounding Altamont Pass and descends into the Livermore Valley. The SBA flows along the eastern and southern edges of the valley, south of the City of Livermore and the Lawrence Livermore National Laboratory. Through much of the Livermore Valley, the aqueduct is an open canal. The SBA has approximately 10.7 miles of open canal sections, which present the greatest potential for contamination.

Lake Del Valle is approximately 11 miles from the City of Livermore, which has a population of 74,303 as of January 2000 (DOF 2000). The watershed of Lake Del Valle encompasses approximately 130 square miles (95,300 acres) of rugged, hilly terrain. The reservoir has an extensive watershed with a number of significant tributary streams that contribute substantial annual runoff to the SBA supply. Precipitation in the area is typical of the Coast Ranges in this vicinity and occurs mainly as rainfall between the months of October and May. Average annual precipitation in the Lake Del Valle watershed varies with elevation, ranging from 16 inches at lake elevation to 36 inches in the higher elevations surrounding Mount Eylar (DWR 1974).

5.1.1 LAND USE

5.1.1.1 South Bay Aqueduct

The vast majority of Alameda County's agricultural land is used as rangeland (Livermore 1997). Grazing is the main agricultural practice in the upland areas. Land surrounding the open canal sections is undeveloped and used as rangeland. In Livermore Valley, orchards, rangeland, and vineyards typify the area's agriculture. Approximately 2,100 acres of vines grow in the south Livermore Valley, and several commercial wineries operate in the vicinity of the SBA. The SBA skirts the southern edge of the valley, an area that is experiencing rapid urban expansion. Most of the Livermore Valley land immediately surrounding the SBA is governed by Williamson Act contracts, which restrict land use to agriculture for a minimum period of 10 years (Livermore 1997).

5.1.1.2 Lake Del Valle

Much of the Lake Del Valle watershed remains in a natural, undeveloped state. Major land uses are recreation associated with Lake Del Valle and cattle-grazing in the upland areas. There are no other significant land uses, and very little has changed since the Del Valle Dam was built in 1968 (Budzinski pers. comm. 2000).

The watershed contains about 95,000 acres, including about 4,000 for the park area. Much of the land surrounding the lake and within the watershed is privately owned, with many of the parcels divided into large plots. In 1974, 73% of the basin (about 70,000 acres) were owned by 30 landowners, each with more than 640 acres (DWR 1974). Naftzger-N3 Cattle Company, the largest landowner in the watershed, operates a ranch southeast of the recreation area surrounding Lake Del Valle. Naftzger lands extend farther southeast into the watershed, constituting a large portion of the area along Arroyo Valle. Patterson Trust owns a substantial portion of the land immediately adjacent to the Lake Del Valle State Recreation Area (SRA) also has operations adjacent to the northern edge of the lake. Other significant private landowners are the Walker, Sachau, and Minoggio families. In 1990, there were reported to be approximately 160 private residences in the upper portion of the watershed (Brown and Caldwell 1990).

5.1.2 GEOLOGY AND SOILS

5.1.2.1 South Bay Aqueduct

Soils near open SBA canals are somewhat similar to the Lake Del Valle watershed, consisting of both valley and upland types. Soil types include Clear Lake clay and Danville clay loam in the flatter areas and Zamora, Positas, and Diablo silt and clay loams in sloped areas (Livermore 1997). The SBA is surrounded by some relatively flat areas and numerous rolling hills with slopes ranging from gentle to steep. Runoff potential in sloped areas ranges from medium to rapid with moderate to severe erosion hazards.

5.1.2.2 Lake Del Valle

Lake Del Valle's watershed lies within the Diablo Range and encompasses several rock types in both the Great Valley Geomorphic Province and the California Coast Ranges. The dam and a majority of the lake are on the Upper Cretaceous Panoche Formation of the Great Valley Geomorphic Province (DWR 1996). The upper watershed overlies the Franciscan Formation composed of Gray Wacke, minor clay shale, and chert interbeds with some metamorphic rocks (DWR 1979). Soils in this watershed can be broken into 2 main types—upland soils and valley soils. Upland soils cover the majority of the watershed and are predominately Gaviota, Vallecitos, Parrish, Shedd, and Henneke series (DWR 1974). Valley soils, which occur mainly in the San Antonio and Upper San Antonio valleys in the upper portion of the Arroyo Valle drainage basin, are composed of various types of alluvium, including the Yolo, Hillgate, Garretson, San Ysidro, Cortina, Zamora, Clear Lake, and Positas series (DWR 1974).

Elevation in the Lake Del Valle watershed ranges from about 700 feet to more than 4,000 feet. A substantial portion of the watershed has slopes greater than 30% (DWR 1974). Soils in the area are generally shallow. Depth of the upland soils ranges from approximately 6 to 42 inches. With its shallow soils and steep slopes, the land in the Del Valle drainage basin is highly erodible. About 80% of the land has severe erosion hazards. Landslides in various stages cover approximately 77% of the Lake Del Valle watershed (DWR 1974). About 20% of the drainage basin lie in flat areas around the lake and the San Antonio Valley.

There are several active faults in the SBA and Lake Del Valle areas. The Livermore fault intersects the SBA near mile marker 18, passes within 800 feet of the Del Valle Dam, and then continues south approximately 3 miles, skirting the eastern edge of the lake. The Williams and Valle faults are in the area (DWR 1979). Active faults in the area include the Greenville fault, 6 miles east of Lake Del Valle; the Calaveras fault, 8 miles west of Lake Del Valle; the Hayward fault, 20 miles west of Lake Del Valle; and the San Andreas Fault, 55 miles west of Lake Del Valle (DWR 1996a).

5.1.3 VEGETATION AND WILDLIFE

Regional vegetation is predominately foothill woodlands and grasses (DWR 1996). The riparian areas and north-facing slopes support stands of California live oak, blue oak, valley oak, and digger pines (DWR 1974). Cottonwood and sycamore trees are found along portions of the Arroyo Valle drainage. Native needle grass and spear grass occupy the areas between wooded stands.

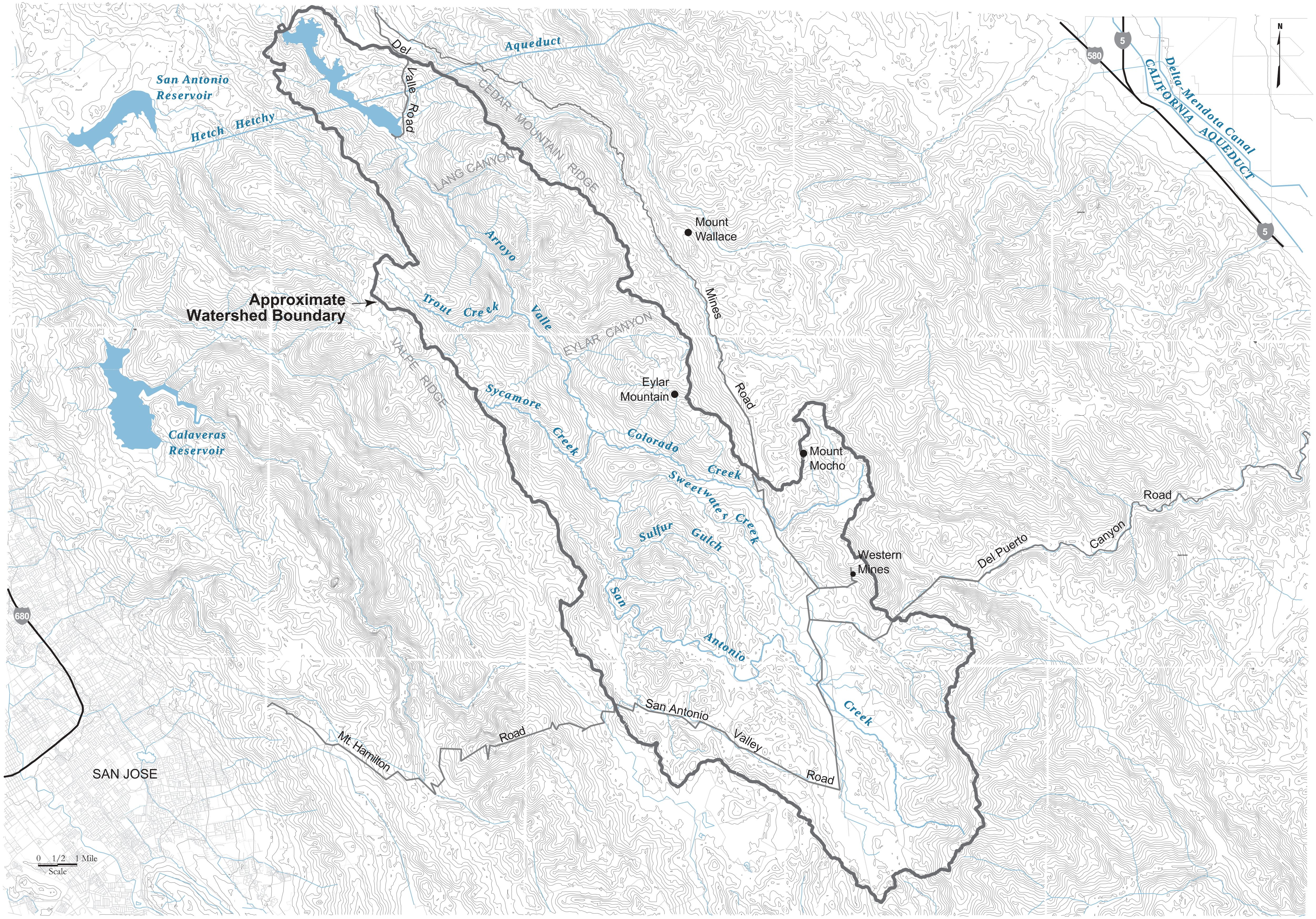
The region is home to many avian, mammalian, amphibian, and reptilian species. The extensive expanses of relatively unspoiled habitat provide for large populations of some species. Mammalian species common in the region include blacktailed deer, feral goats, wild pig, rabbits, hares, and ground squirrels (DWR 1974). Other small mammals include weasels, skunks, gray fox, coyotes, badgers, and bobcats. Mountain lions and opossum are also found in the region. Avian species include the game birds quail and doves, which frequent the stands of oak surrounding Lake Del Valle. Woodpeckers, swallows, jays, wrens, warblers, blackbirds, and finches are all found in the region.

5.1.4 HYDROLOGY

Two sources of inflow—SWP water from the SBA and natural inflows from the watershed—supply Lake Del Valle. During summer months, SWP water is pumped into the reservoir to maintain reservoir elevations suitable for recreational uses; and in the fall, the water is released to provide flood control capacity. SBA inflows and outflows from 1996 to 1999 are discussed in Section 5.2, Water Supply System.

The major stream draining Lake Del Valle's watershed is Arroyo Valle, which drains an area of approximately 130 square miles. Since most of the precipitation occurs in the winter, Arroyo Valle flows from October through July in normal rainfall years (DWR 1996). Important stream tributaries to Arroyo Valle include Trout Creek, Sycamore Creek, Colorado Creek, Sweetwater Creek, and San Antonio Creek (Figure 5-1). Colorado and Sweetwater creeks drain the southeastern portion of the watershed farther down Mines Road, where there are magnesium mines containing high hardness and alkalinity levels.

Figure 5-1 Lake Del Valle Watershed Area



Natural inflows constituted a large portion of the total inflow to Lake Del Valle (Table 5-1). From 1996 to 1999, natural inflows were between 74% and 100% of the total lake inflow. A considerable amount of year-to-year variation in natural inflow volume can be explained by the heavy precipitation during the El Niño storms of 1998. However, annual variation can be observed in historical data. The flow in Arroyo Valle near the damsite prior to its construction in 1958 was 80,780 acre-feet. In 1961, the flow dropped to 807 acre-feet (DWR 1974).

Table 5-1 Total Annual Natural Inflows to Lake Del Valle (acre-feet)

1996	1997	1998	1999
60,806	47,276	87,265	15,375

Source: DWR, Division of Operations and Maintenance, SWP Operations Data 1996 to 1999

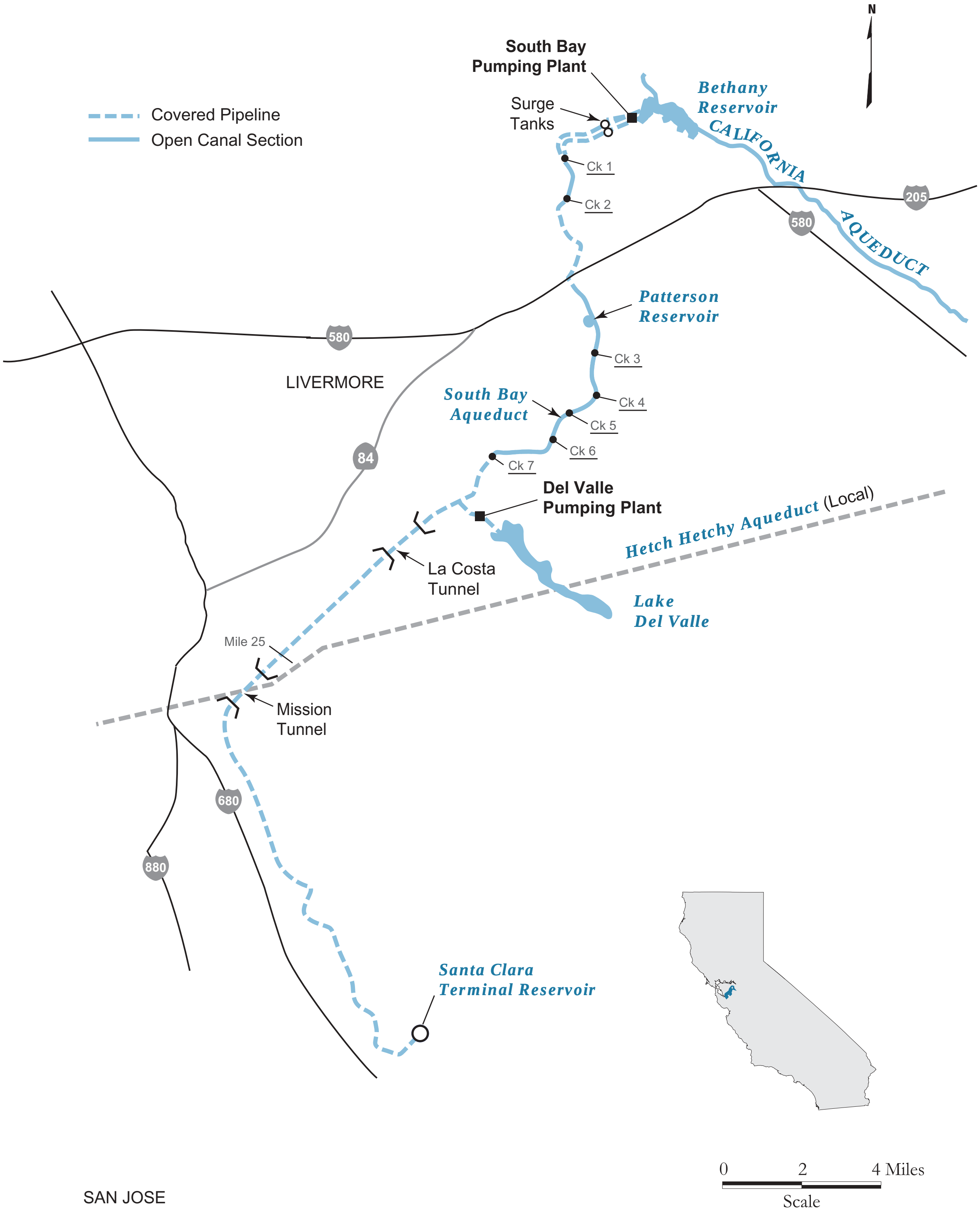
Lake Del Valle is near the southern margin of the Amador groundwater subbasin and within the alluvial basin of Arroyo Valle. In 1995, groundwater elevations in the alluvial basin area ranged from 20 to 30 feet (Livermore 1997).

5.2 WATER SUPPLY SYSTEM

5.2.1 DESCRIPTION OF AQUEDUCT/SWP FACILITIES

Open canals and underground pipelines alternate along the 43-mile long SBA (Figure 5-2). At the upper end of Bethany Reservoir, South Bay Pumping Plant, with a pump capacity of 330 cfs, lifts SWP water 566 feet into the 1st reach of the aqueduct (Brown and Caldwell 1990). For about the first 3 miles, the SBA is a pipeline. From mile 3.26 to 5.21, it is an open canal that begins with a surge pool and has a copper sulfate ($CuSO_4$) feeding facility for algae control. From mile 7.42 to 16.38, the SBA is open canal with a turnout at mile 9.49 for Patterson Reservoir, a raw water storage facility with a capacity of 100 acre-feet. Along the remainder of this open section there are 2 more copper sulfate feeding facilities. The SBA continues as a pipeline from mile 16.38 through the La Costa and Mission tunnels to mile 42.26 and its terminus at the Santa Clara Terminal Reservoir, an uncovered 2.5-million gallon steel tank.

Figure 5-2 South Bay Aqueduct



Aside from its main canal and control gates and pumps, the SBA contains a number of structures that are PCSs as shown in Table 5-2 and discussed in Section 5.3, Potential Contaminant Sources.

Table 5-2 Description of Structures in Open Canal Sections of the SBA

Structure description	Total
Drain Inlets	27
Canal roadside drainage	16
Agriculture drainage	11
Groundwater	0
Other	0
Bridges	11
State	0
County	2
Farm or Private	9
Overcrossings	14
Pipelines	12
Overchutes	2
Undercrossings	26
Drainage	26
Irrigation or domestic	0
Water-Service Turnouts	20
Irrigation pumped upslope	3
Other	17
Fishing Areas	0

At mile 18.63, a 60-inch turnout serves as a common inlet/outlet for Lake Del Valle. Del Valle Pumping Plant with its 4 pumps and 120 cfs capacity supplies Lake Del Valle with SWP water. Lake Del Valle is formed by the 235-foot high Del Valle Dam, which was constructed in 1968. The multipurpose reservoir has a storage capacity of 77,100 acre-feet and a potential surface area of 1,060 acres. It provides water supply, flood control, and year-round recreational activities. As stated in Section 5.1, Watershed Description, the reservoir has an extensive watershed that contributes annual runoff, helping to replace losses from natural evaporation, percolation, and some of the domestic uses for recreation amenities.

Reservoir water can be released into the SBA to supply SWP contractor needs, to meet streamflow requirements for water rights in Arroyo Valle, or to recharge groundwater in Livermore Valley and along Alameda Creek (DWR 1974). At the end of summer, the lake level is lowered to create capacity for flood control. During the wet season, natural watershed inflows in excess of downstream water rights are impounded. Additional water is pumped from the SBA as necessary to maintain the reservoir at 40,000 acre-feet from April to October. Flood control storage is used only during times of high runoff in Arroyo Valle, and the stored water is released in a relatively short period of time. During summer recreation season, the lake is usually maintained at an elevation of 703 feet, which gives it 40,000 acre-feet of storage volume, 715 acres of water surface area, and 5 miles of length with 16 miles of shoreline (DWR 1974).

Inflow and outflow for the SBA and Lake Del Valle from 1996 through 1999 are presented in Table 5-3. Inflows for the SBA are from South Bay Pumping Plant; outflows are measured as the total volume of deliveries. Inflows for Lake Del Valle include both natural watershed source, which is primarily Arroyo Valle, and pump-ins from the SBA; outflows include total releases into the SBA and Arroyo Valle and deliveries to East Bay Regional Park District (EBRPD).

Table 5-3 SWP Inflow/Outflow for the SBA and Lake Del Valle (acre-feet)

SWP Location	1996	1997	1998	1999
SBA:				
South Bay PP (Inflow)	77,023	109,610	78,136	117,115
Outflow (Deliveries)	106,282	126,006	103,234	125,513
Lake Del Valle:				
Inflow: From SBA	0	3,434	0	4,062
From Natural	60,806	47,276	87,265	15,375
Outflow (Total releases)[a]	55,835	51,924	86,886	12,771

Source: DWR, Division of Operations and Maintenance, SWP Operations Data 1996 to 1999

[a] To SBA, Arroyo Valle, EBRPD

Although from 1996 through 1999, SBA outflows always exceeded inflows, the volumes were generally similar and averaged 115,259 and 95,471 acre-feet, respectively. Total deliveries during this period were substantially less than the maximum potential annual entitlement of 188,000 acre-feet for the 3 SWP contractors.

At Lake Del Valle, nearly all of the total inflow in all years was from natural sources, and the volume of inflows exceeded outflows in 3 of the 4 years evaluated. These inflows were also a large percentage of the reservoir volume of 77,100 acre-feet, comprising 79%, 61%, and 113% of this volume in 1996, 1997, and 1998, respectively. SWP inflows to Lake Del Valle ranged from 0% of total reservoir inflow in 1996 to 21% of total reservoir inflow in 1999. These data suggest that water quality in the SBA during reservoir-release periods in 1996 through 1999, and in 1998 in particular, was highly influenced by the natural inflows from the watershed.

5.2.2 DESCRIPTION OF AGENCIES USING SWP WATER

SWP water is withdrawn along the SBA at several locations and distributed to 3 agencies (in order of SBA intake): the Alameda County Flood Control and Water Conservation District-Zone 7 (Zone 7), the Alameda County Water District (ACWD), and the Santa Clara Valley Water District (SCVWD). The current SWP entitlements for each agency are Zone 7, 42,000 acre-feet; ACWD, 46,000 acre-feet; and SCVWD, 100,000 acre-feet (DWR 2000b).

5.2.2.1 Zone 7

Zone 7 is 1 of 10 active zones of the Alameda County Flood Control and Water Conservation District, a public agency established by voters in 1949 to solve the county's problems of flooding, drainage, channel erosion, and water supply. Zone 7 includes all of eastern Alameda County, consisting of about 425 square miles and occupying a major portion of the Alameda Creek watershed. The area has a population of about 172,000 and includes the cities of Dublin, Livermore, and Pleasanton and the communities of Sunol, Altamont, and Mountain House. Much of Zone 7 activity is in the Livermore and Amador valleys and includes small areas of the cities of Fremont, Union City, and Hayward (Zone 7 1999).

Zone 7 has 2 water treatment plants (WTPs): the Patterson Pass WTP, which receives 100% Delta water, and the Del Valle WTP, which receives both Delta water and water released from Lake Del Valle. Each receives most or all of its supply from the SBA. The turnout for Patterson Pass WTP is at mile 9.49, prior to the connection with Del Valle Reservoir at mile 18.63. Del Valle WTP turnout is at mile 19.20 (Deol pers. comm.).

The Patterson Pass WTP, constructed in 1962, has a capacity of 12-million gallons per day (mgd); the Del Valle WTP, constructed in 1975, has a capacity of 36 mgd. Both are in Livermore. Raw SBA water entering the Del Valle and Patterson Pass WTPs goes through a number of treatment processes. Mixing/coagulation begins the process of turbidity removal. Coagulants such as alum (aluminum sulfate) or ferric chloride and special polymers are rapidly mixed with the water during the flocculation/sedimentation process, causing them to form larger particles, or "floc." The water moves slowly through a large basin so flocs can sink to the bottom for removal of 70% to 90% of suspended matter by sedimentation. At the Del Valle WTP, flocs are removed midway through the basin by a special "superpulsation" process (Deol pers. comm. 2000).

The filtration process further removes particles as well as pathogens. The water passes through a dual-media filter made of sand and anthracite coal. After the filtration process, protozoan pathogens such as *Giardia* and *Cryptosporidium* and nearly 100% of suspended matter are removed. In 1997, Zone 7 installed particle counters at both of its treatment plants to monitor filtration effectiveness.

Chlorine is the primary disinfectant, and chloramines (chlorine/ammonia combination) are added to maintain disinfection after the water leaves the treatment plant and enters the distribution system. Chloramines also help prevent the additional formation of disinfection byproducts (DBPs).

5.2.2.2 ACWD

The ACWD has supplied water to residents and businesses in southern Alameda County for more than 85 years. The service area has changed from being an important agricultural center to supporting a growing suburban population. ACWD supplies drinking water to more than 318,000 people living in the cities of Fremont, Newark, and Union City. The SBA provides about 55% of the total ACWD water supply.

ACWD operates 2 WTPs, which use 100% SBA water and are in the City of Fremont. The Mission San Jose WTP, also known as WTP1, is off Vargas Road above Mission San Jose and began operating in 1975. Water Treatment Plant Number 2 (WTP2), a state-of-the-art facility on Mission Boulevard near Interstate 680, was put into operation in 1993. WTP1 has a capacity of 8.5 mgd and is a conventional surface water treatment plant using coagulation and sedimentation, dual-media filtration, and chlorine for disinfection. WTP2 has a capacity of 21 mgd in winter and 28 mgd in summer, when water quality improves, and is the district's newest and most advanced treatment plant. The intake turnouts on the SBA for these WTPs are very close, WTP1 at mile 28.96 and WTP2 at mile 28.97, so source water quality for both plants is considered the same (Marchand pers. comm.).

Water is delivered to WTP2 via a 3-foot diameter pipeline. Because of the elevation difference between the aqueduct and the treatment plant, ACWD installed turbines to generate electricity. This hydroelectric facility produces enough electricity to run all the treatment processes, including ozone generation. Ozone is the primary disinfectant and is applied to the plant influent. In addition to being a highly effective disinfectant, the ozonation process destroys compounds that can cause unpleasant taste and odor in finished water. After ozonation, coagulants are added, and the water goes to flocculation basins for mixing and settling of particles prior to sedimentation. Following sedimentation, the clarified water is filtered via dual-media anthracite coal and sand. A vacuum system removes the settled solids to a solids holding basin. The finished water receives a small dose of chlorine prior to entering the distribution system. The pH is also adjusted for corrosion control, and fluoride is added (Bradanini pers. comm. 2000).

ACWD is in the process of making significant upgrades at both plants to reduce DBPs. WTP2 is going to acid addition to reduce high bromate levels associated with ozonation. ACWD has engaged a consultant to provide the design. Based on handling safety, the district will probably use carbonic acid, not sulfuric acid. ACWD expects this system to be implemented this year. WTP1 still chlorinates, but plans are to go to ultrafiltration to reduce TOC levels and, therefore, DBPs. ACWD is currently receiving bids for construction and estimates upgrades to take about 18 months to complete (ACWD 2000a).

5.2.2.3 SCVWD

The SCVWD is a special district created by public vote, governed by a 7-member board of directors, and responsible for water supply, flood protection, and watershed management in Santa Clara County. The SCVWD encompasses all of the county's 1,300 square miles and serves the area's 15 cities, 1.7 million residents, and more than 200,000 commuters. The district has 2 missions: to provide high quality water and to manage flood and storm water along the county's 700 miles of creeks and rivers.

Imported water makes up more than half of Santa Clara County's supply. Both imported water and groundwater are sold to the 13 water retail agencies that supply most of the communities in Santa Clara County. The SCVWD receives water from the SWP and federal Central Valley Project (CVP) and supplies water to local water retail agencies, such as San Jose Water Company and the City of Milpitas.

The SCVWD operates 3 WTPs in its service area. The Penitencia WTP, which went online in July 1974, was selected for this report because it receives 100% SWP water and predominantly SBA water. It also receives SWP/CVP water from San Luis Reservoir. The Penitencia WTP is in the east San Jose foothills and has a capacity of 40 mgd. It receives SBA water from the Santa Clara Terminal Reservoir Tank at mile 42.26. The WTP uses conventional treatment processes including coagulation/flocculation, flow-through sedimentation, and multimedia filtration. Disinfection is accomplished using chlorination (SCVWD 2000a).

SCVWD initiated a major project to upgrade all of its WTPs. The project will be completed in 2 phases and is intended to help the WTPs comply with Stage 1 Disinfectant/Disinfection Byproducts (D/DBPs) Rule and Interim Enhanced Surface Water Treatment Rule (IESWTR), while maintaining a safe and reliable system and aesthetically pleasing water. Phase 1 improvements include adding new potassium permanganate chemical facilities, replacing the storage and feed system for the existing powdered activated carbon systems with new storage and feed systems, and reviewing and upgrading an existing alum primary coagulant chemical system to enable use of either alum or another primary coagulant, ferric chloride. Phase 2 improvements are longer term and include conversion of the disinfection process from chlorination to ozone and changing filter media to improve the ability to remove biological organisms (SCVWD 1999).

5.3 POTENTIAL CONTAMINANT SOURCES

5.3.1 SOUTH BAY AQUEDUCT

This section focuses on major known or suspected PCSs along the open portions of SBA from approximately mile 3.27 to 16.28 (Figure 5-2).

5.3.1.1 Recreation

There is no authorized recreation along the open portions of the SBA (Gage pers. comm. 2001a). This is not considered a significant contaminant source.

5.3.1.2 Wastewater Treatment/Facilities

There are no known or reported wastewater treatment plants or effluent discharges in this section of the SBA.

Septic Systems

There is an old septic tank and leach field at South Bay Pumping Plant that has been pumped periodically to avoid overflowing into nearby intake. The system only requires occasional pumping—it has not been pumped since 1993—and no sewage overflows have occurred (Scheele pers. comm. 2000). This system is not considered a significant potential source of pathogens.

5.3.1.3 Urban Runoff

Land around the open SBA sections is mostly agricultural, used as grazing for cattle. There is little urban development. Runoff from surrounding hillsides can enter the open portions of the SBA primarily through drain inlets, overcrossings, and bridges (Brown and Caldwell 1990). As in the Lake Del Valle area, soils in this area are generally erodible to highly erodible. The various inlets collect runoff, which can be a source of turbidity, pathogens, and nutrients. The most significant source of runoff is from cattle-grazing areas adjacent to the SBA and from the bridges used to cross the aqueduct, as discussed in Section 5.3.1.4, Animal Populations.

Of the 27 drain inlets identified in Table 5-2, 16 convey drainage from the canal right of way. The remaining 11 drain inlets bring runoff from livestock grazing areas in addition to canal bank drainage. Overcrossings convey runoff from one side of the aqueduct to the other and are potential sources of contaminants associated with adjacent land use activities. Most of the overcrossings are associated with oil industry pipelines varying from 12 to 30 inches in diameter; there were no reports of problems with any of these pipelines on the SBA. *Sanitary Survey 1990* reported that there was a large drain inlet at South Bay Pumping Plant receiving runoff from several hundred acres of land (Brown and Caldwell 1990). See discussion in the following section.

5.3.1.4 Animal Populations

Livestock Grazing

Depending on rainfall, the grazing season usually occurs from November through June to take advantage of new forage growth. Cattle graze along the open portions of the SBA, and during rainfall, the runoff from these areas can enter the aqueduct via drain inlets. There is also substantial grazing on the western shore of Bethany Reservoir (Gage pers. comm. 2000). Grazing is considered a significant potential source of pathogens and nutrients in the SBA. The inlet area around South Bay Pumping Plant also receives runoff from land used extensively for cattle-grazing.

Wooden bridges used by cattle to cross the aqueduct were routes for contamination. Large gaps in the wooden planks allowed cattle droppings to directly enter the aqueduct. These planks have been replaced with sealed flooring to reduce threats to water quality.

5.3.1.5 Algal Blooms

All SBA contractors consistently cite taste and odor problems produced by 2-methylisoborneol (MIB) and geosmin as a significant water quality concern. Certain algal species produce high concentrations of these malodorant compounds. The canal has green algae problems in summer associated with Delta water from the Harvey O. Banks Pumping Plant, along with films of blue-green algae that grow on the side of the canal, resulting in complaints from the SBA contractors (Janik pers. comm.). Additional taste and odor problems occur following the application of copper sulfate, which results in cell death and the eventual release of MIB and geosmin (Deol pers. comm. 2001).

Taste and odor problems generally occur in summer months when conditions are suitable for algal blooms. SWP Delta water supplied by Banks Pumping Plant is enriched with nutrients, and algal growth occurs in Clifton Court Forebay. The algae continue to grow in the SBA open canal especially under the right water temperature and light conditions (Gage pers. comm. 2000). Discussions with staff at DWR's Delta Field Division indicate that most of the algae responsible for taste and odor problems is thought to originate in the Delta and not the SBA (Gage pers. comm. 2001a). Because algae are present in source waters, algal growth in treatment plant basins further contributes to taste and odor problems (SCVWD 2000).

Algal growth is also known to occur in the SBA through data that at times show geosmin levels in the canal exceed those found at Banks Pumping Plant (Janik pers. comm. 2001). Geosmin is produced in the SBA in higher concentrations than MIB, although it not known why. Blue-green algae species found in the SBA include *Oscillatoria* sp., a known geosmin producer, and *Synecchococcus* sp.

Algal blooms have created operational problems for SBA contractors as well. Following some DWR applications of copper sulfate, SBA contractors have reported filter clogging from the large masses of decaying algae (Deol pers. comm. 2001; Brewster pers. comm. 2001; ACWD 2000). Prior to the year 2000, DWR staff added copper sulfate to control algae in the SBA on an as-needed basis, although this was done largely to control the green alga, *Cladophora* sp., which reportedly does not produce taste and odor (Janik pers. comm). This meant that copper sulfate was often added after an algal bloom had occurred and algal populations had reached high levels.

In 2000, SBA contractors and DWR's Division of Operations and Maintenance (O&M) agreed on an improved approach to better control taste and odor problems. The approach is the direct measurement of taste and odor compounds using Closed Loop Stripping Analysis (CLSA) at key sample locations with a fast turn-around time for results. Data are distributed to SBA contractors by e-mail, usually within 1 to 3 days of collection. DWR and SBA contractors use these data to modify water delivery and WTP operations when taste and odor compounds exceed threshold values. In May 2000, O&M began adding a lower concentration of copper sulfate (1.25 mg/L, down from 2.5 mg/L in 1999) every other week until October when copper sulfate additions were stopped (Janik 2000). Beginning and ending dates were based on water temperature (Gage pers. comm. 2001). Although the copper sulfate additions were primarily for control of *Cladophora*, a non-taste and odor producer, all SBA plants evaluated for this report noted an improvement with taste and odor problems in summer 2000. More data are needed, however, to appraise the success of this procedure (Brewster pers. comm. 2001a; Deol pers. comm. 2001; and Hidas pers. comms. 2001).

Aquatic weed growth in the canal is removed mechanically. In Bethany Reservoir, aquatic weed growth is treated with Komeen, an aquatic herbicide, and some weeds are removed mechanically.

Sanitary Survey 1990 also reported that persistent Asiatic clams were a problem in the SBA (Brown and Caldwell 1990).

5.3.1.6 Agricultural Activities

Agriculture is a substantial land use in the area of the SBA. Grapes are a major crop, especially in the area northeast and northwest of Del Valle Dam. Orchards and grazing are the other significant activities in this area (Livermore 1997).

Vineyards were reported as agricultural land use of potential concern along the SBA, and the number of vineyards is increasing (Zone 7 2000). The majority of vineyards appear to be out of the immediate drainage area of the SBA, farther west and north in the valley. Vineyards in the drainage area of the SBA drain into culverts that go underneath the SBA and would not affect water quality (Gage pers. comm. 2001a).

5.3.1.7 Traffic Accidents/Spills

Transportation Corridors

There are 2 major corridors in the Livermore Valley area that cross the SBA and have the potential for runoff and spills to enter the aqueduct (Figure 5-2). There is also some potential runoff from nearby Interstate 580 where it crosses the SBA above Patterson Reservoir near the beginning of the open aqueduct section (Zone 7 2000).

History of Accidents/Spills

DWR field personnel reported that there were no known accidents or spills that could affect drinking water supplies during this period (Gage pers. comm. 2000).

5.3.1.8 Geologic Hazards

There are several major active faults in the immediate area (within 10 miles), including the Livermore, Williams, Valle, Greenville, and Calaveras faults. Farther away are very significant faults including the Hayward fault and the San Andreas Fault (DWR 1996a). Five earthquakes of a 4.0 or larger magnitude have occurred in the area since the turn of the century; the strongest had a magnitude 5.5 (DWR 1979).

If the SBA sustained earthquake damage, deliveries would likely halt. This would create a serious water supply problem for SBA contractors. Many overcrossings convey runoff from one side of the aqueduct to the other. Most are associated with oil industry pipelines varying from 12 to 30 inches in diameter, and during a significant seismic event petroleum-related contaminants—or those associated with adjacent land use activities such as nutrients, pathogens, and turbidity—could be introduced into the SBA.

5.3.2 LAKE DEL VALLE

5.3.2.1 Recreation

The Davis-Dolwig Act of 1961 and State Water Code § 11900 require that the purposes of SWP facilities shall include recreation and the enhancement of fish and wildlife habitat as well as water storage. In keeping with this mandate, recreation activities at Lake Del Valle include many reservoir body-contact and nonbody-contact activities.

Lake Del Valle has a surface area of about 1,060 acres, and its shoreline is developed for numerous types of recreation. The Del Valle Regional Park area includes about 4,000 acres. Developed recreation areas are reachable by automobile, boating, and hiking. Body-contact recreation at the lake includes swimming, wind surfing, and boating. Nonbody-contact recreation includes camping, picnicking, horseback riding, hiking, and fishing (DWR 1996). Recreational areas also have parking, potable water and sanitary facilities, and food, gas, and oil retail. Fishing, swimming, and boating are the major water recreation uses. Water skiing is not allowed. Park services are open all year with both group and family campgrounds available, as well as day use and hiking areas.

The recreational activities are potential sources of contaminants for several reasons:
Contribution of feces from body contact recreation such as swimming,

- Introduction of pathogens by horses,
- Fuel spills or leakage from motorized watercraft,
- Spills or leakage from restrooms and wastewater management facilities, and
- Erosion and higher turbidity associated with hiking, horseback riding, or camping, particularly if activities are conducted off established trails and areas.

The major water quality problems associated with recreational activities at Lake Del Valle are the contribution of microbial pathogens *Giardia* and *Cryptosporidium*, the release of MTBE from motorized watercraft, and turbidity caused by soil erosion.

Recreational use at Lake Del Valle follows a seasonal pattern, with most visitation between April and September and peak attendance on summer weekends. Recreational use for the 1996 to 1999 period is presented in Table 5-4 as recreation days. A recreation day is defined as 1 user visiting the recreation area during part of a 1-day period.

Table 5-4 Recreational Use at Lake Del Valle

Period	1996	1997	1998	1999
Recreation days	353,700	332,200	283,000	318,900

Source Thrapp pers. comm.

Annual recreation days varied from about 280,000 to 350,000 during this period. Estimates of Lake Del Valle recreation use in 1969 to 1970 were from 260,000 to 570,000 recreation days (DWR 1966), which is similar to use levels in recent years. Original estimates of future use in the millions annually have fallen short. Peak usage occurred in 1988 with 504,595 recreation days. It is not known why usage is much lower than originally estimated, but it could be because some of the planned structures have not been built or are smaller in scale. Data indicates usage has declined. There were about 60,000 fewer recreation days in 1996 than in 1995. The decline was attributed to flooding during the 1995/1996 rainy season and a fire later in the season (DWR 1998).

The EBRPD, which covers all of Alameda and Contra Costa counties, operates recreational services at Lake Del Valle. In July 1970, the year the park opened, the EBRPD assumed operation of Lake Del Valle under a 50-year agreement with the California State Parks and DWR (DWR 1991).

The park was developed in 4 phases, beginning with day use areas and boat launches. Group picnic and camping sites and additional restrooms were added over the next 3 phases. Camping is limited to group campsites and the 1 family campground at the southern end of the lake. The family area has 150 units and 6 restrooms with flush toilets. There are 6 group camping areas at Lake Del Valle. Venados, Hetch Hetchy, and Cedar group campsites are on the eastern side of the lake. Ardilla is on the western side of the lake, and Wild Turkey and Punta Vaca are just south of the lake (Figure 5-3). Venados is one of the largest of the group campsites and occupies a total of 353 acres, all above the minimum lake storage elevation. The Venados area includes parking, beaches, concessions, sanitary facilities, and a 6-lane boat launch, which is a mile south of the campsite.

The 2 main swimming beaches at the lake, East Beach and West Beach (Figure 5-3), are regularly monitored for bacterial contamination. Both beaches are monitored 5 times per week during the peak season from about March to September according to California Department of Health Services (DHS) standards for freshwater beaches. The standards specify acceptable levels of total and fecal coliforms, and *enterococcus* or *E. coli.*, for both single samples and a 5-day geometric mean. The 5-day standard was never exceeded during the report period. The single-day standard was exceeded but only rarely (Burger pers. comm. 2000). The EBRPD posts monitoring results regularly at both beaches.

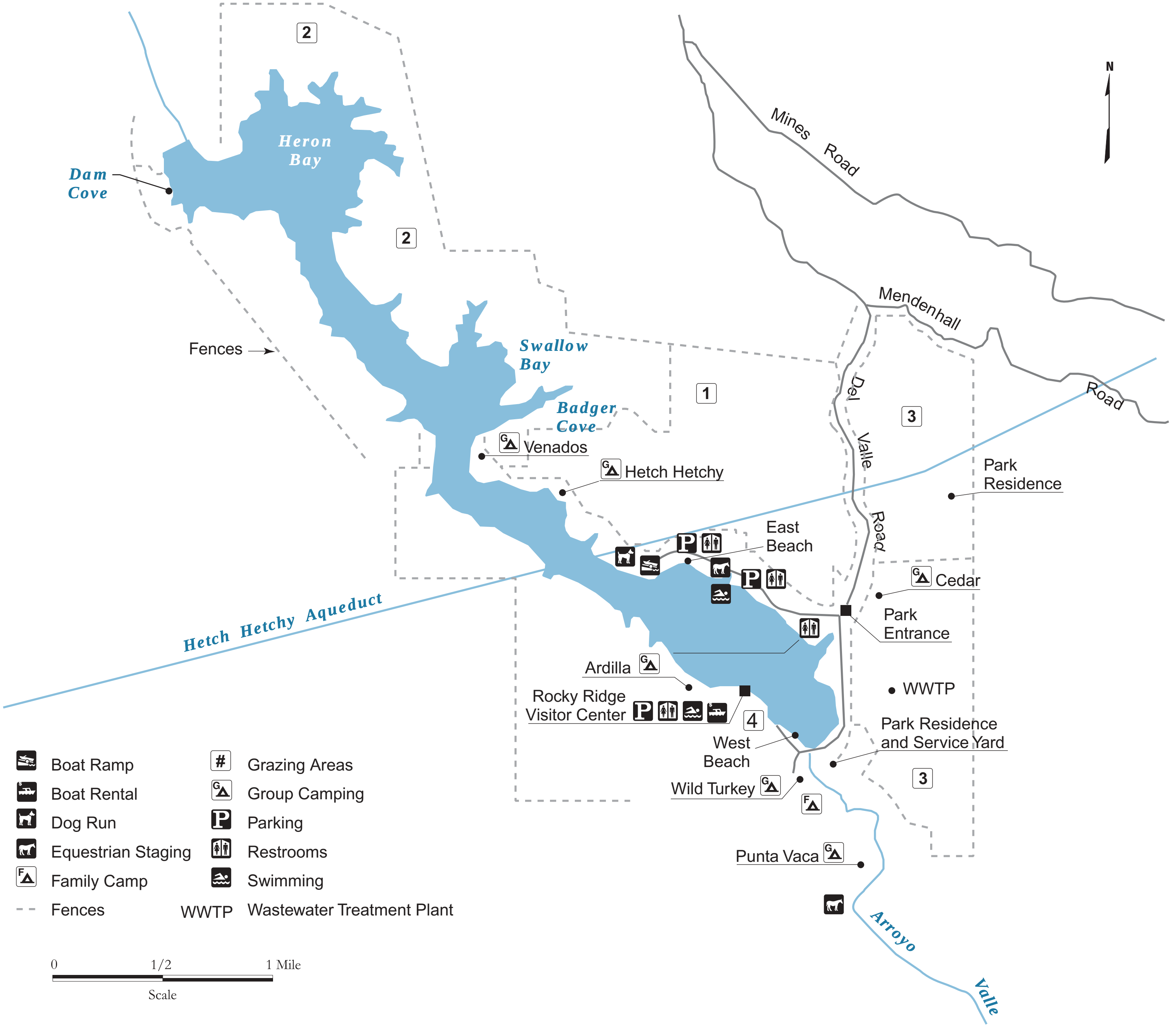


Figure 5-3 Lake Del Valle

One of the main recreation activities at Lake Del Valle is fishing (Gage pers. comm.). The lake is stocked regularly with trout and catfish. There is an extensive trail system around the lake and immediate watershed area. The EBRPD completed the Del Valle East Shore Trail, including a bridge across Arroyo Valle in 1997. This trail connects with several other trails near camping and day use areas. Most of the trail system is concentrated on the eastern side of the lake. Two trails on the southwestern side connect with the Ohlone Trail, which enters the Ohlone Regional Wilderness.

Boating also is a major recreational activity at Lake Del Valle. The primary water quality concern associated with boating is MTBE contamination. Most boating activity occurs from May to October. In 1997, a majority of the boats were powered by 2-stroke outboard engines in the 10 to 75 horsepower range (DWR 1999). The number of private boats launched increased from 1,157 in April to 1,268 in May. The total number of boats remained high at 927 in August and declined to 496 in September. The number of boats using the lake declines by about 50% after Labor Day weekend. As is common in SWP reservoirs, high MTBE concentrations followed heavy boat usage (DWR 1999). A large percentage of the boat usage is resident rental boats. Because rental boats are regularly tuned-up and serviced and their gas tanks removed during filling, which minimizes spills, their higher usage may translate to lower concentrations of MTBE than in lakes with more nonresident boats (DWR 1999).

Swimming is also a significant activity, although it can be dangerous. An EBRPD supervisor at Lake Del Valle reported a drowning that occurred on 3 July 1998 near East Beach. The victim was a nonswimmer who fell from a boat between the boat ramp and the beach.

The availability and quality of recreational activities and services is highly influenced by the lake water levels. The most favorable condition is a lake level at 703 feet. Above the 703-foot level, many areas are inundated and sewage pumping capabilities are lost. Below this level, many services and concessions would close and some parts of the park would need to be closed (DWR 1991). The lake level does fluctuate because of the need to provide flood storage capacity and water supply.

Recreational facilities were continually upgraded during the 1996 to 1999 period, such as renovation of boat launches, new showers, tree plantings, and restroom repair and cleanup. Family campsites and day use facilities were installed in 1998, and renovation of the boat launches was completed in 1999 (DWR 2000a).

5.3.2.2 Wastewater Treatment/Facilities

The major water quality problem associated with wastewater treatment/facilities at Lake Del Valle is the potential contribution of microbial pathogens *Giardia* and *Cryptosporidium* from spills or overflows of raw sewage.

Lake Del Valle park has flush toilets in 21 buildings associated with all major camping areas. Most of the restrooms and related services are in camping areas in the eastern and southwestern areas of the lake. There are also 15 chemical toilets, which EBRPD staff pumped 3 times per week during the summer and once during winter. There were no spills or problems with these toilets from 1996 through 1999.

Treatment Plant Effluent Discharges

There are no known treatment plant effluent discharges at Lake Del Valle or in the watershed area, and no effluents are known to be transported out of the watershed.

Storage, Transport, Treatment, Disposal to Land

There are 6 sewage collection and pumping stations—5 stations out in the park areas and 1 main station. The main station collects all park sewage and pumps it to about 2.5 acres of hypalon-lined wastewater lagoons approximately 8 feet deep on the southeastern side of the lake (Figure 5-3). There is no formal treatment process; treatment of the sewage occurs by natural settling and decomposition. The hypalon lining prevents percolation of the wastewater to soil and groundwater below. Evaporation is used to maintain the water level at acceptable levels. The lagoons occasionally have odors in summer and are drained and inspected as needed (Gigliati pers. comm. 2000).

Some wastewater collection facilities are close to Arroyo Valle, but there was only 1 spill from 1996 through 1999. In 1997, 300 feet of hypalon berm were added around the lagoons, and the graveled road was extended (DWR 1999a). Also, 600 feet of sewer lines and sealed manholes were replaced. Some sewage lines broke during the El Niño storm in 1998, but no sewage was spilled because there was no activity in the park. The El Niño storm raised lagoon water levels, but the berms had been raised 18 inches.

An unknown amount of sewage was released into the Lang Canyon inlet on 24 May 1998. There was a sewage spill from a septic line lift station into the Lang Canyon stream inlet to Lake Del Valle. EBRPD staff reported that the spill had been stopped and booms installed around the area of the spill. The west branch of the reservoir was closed until tests determined the level of contamination. There were no other spills or other problems with any part of the system (Gigliati pers. comm. 2000).

The park is converting to low-flush toilets, upgrading sewer lines, and moving some sewage pumping stations away from Arroyo Valle.

Septic Systems

There were approximately 160 private residences and hunting cabins in the upper portion of the watershed, all served by private septic systems (Brown and Caldwell 1990). Their status is unknown but is thought to be largely unchanged (Gage pers. comm.). There is also a septic tank/leach field system associated with Del Valle Pumping Plant. *Sanitary Survey 1990* reported that this system had no impact on the water quality of Lake Del Valle.

5.3.2.3 Urban Runoff

Because the watershed has little development, urban runoff to the lake is minimal. Urban runoff is primarily from parking lots and roads in the recreation areas. Drainage from the main boat ramp parking area, and probably from the other boat ramps, flows to Lake Del Valle. On the western side of the lake, a 30-acre lawn area is irrigated with water from the park's domestic water system. Runoff from this area into the lake could at times contain fertilizers (Brown and Caldwell 1990). These various sources of runoff can be a minor source of turbidity, pathogens, and nutrients.

The watershed areas are highly erodible during rains (Gage pers. comm. 2000). About 80% of the land in the Lake Del Valle drainage basin is classified as a severe erosion hazard because of its shallow soils and steep slopes. The remaining flat areas around the lake and the San Antonio Valley are less prone to erosion; however, erosion still presents a threat to the development in the area and the use of the recreational amenities. Runoff from surrounding slopes has caused problems adjacent to some existing roads and paved areas. Arroyo Valle has deposited some 20,000 cubic yards of silt in the reservoir since the dam was built (DWR 1996). The sediment load from the creek can cause elevated turbidities in the lake.

Because of these soil and runoff conditions, the Lake Del Valle watershed is extremely sensitive to increased erosion and landslide potential from land use changes such as urbanization and development (DWR 1974). This is addressed in Section 5.3.2.12, Land Use Changes.

5.3.2.4 Animal Populations

Livestock Grazing

Historically, there has been extensive grazing of cattle and sheep in the Lake Del Valle watershed (DWR 1996). The grazing season is dependent on rainfall but usually occurs from late fall through spring. Livestock-grazing on public land is used as a resource management tool to maintain and enhance plant and animal diversity and achieve wildland fire prevention objectives. Although DWR owns the Lake Del Valle SRA land, EBRPD manages it and allows grazing. Revenues from grazing operations are divided between the 2 agencies. (Budzinski pers. comm.).

Two of the largest landowners in the Lake Del Valle watershed, the Naftzger N3 Cattle Company and Patterson Trust, have the largest cattle ranching operations in the watershed. These ranches graze cattle both around the lake and in the upper watershed. The N3 Cattle Company grazes cattle on the southern edge of Lake Del Valle. The Patterson Trust cattle operation is adjacent to the northern edge of the lake, with large holdings around the dam area (Gage pers. comm. 2000). The western side of the lake is not grazed because it is very steep and has poor vegetation. The highest grazing use is typically from November to June, depending on rainfall and grass growth. Historically, cattle have had access to the lake, but not typically from about June through October, when grass is scarce. Some fencing is present, mostly around recreation areas, but much of the grazed land is unfenced to the lake (Chun pers. comm. 2000). Some of the area near lakeshore is fenced, in particular the lower half of the southeastern side of the lake. Much of the northern portion of the lake is unfenced, as is the area around the dam. The approximate locations of fencing around Lake Del Valle are presented in Figure 5-3.

Table 5-5 Total Cattle Grazing Use at Lake Del Valle, 1996 to 1999 (all areas)

	Number of animals								
Grazing Season	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
1995/1996	209	209	209	226	251	251	251	25	1,631
1996/1997	46	226	210	246	212	69	13	0	1,022
1997/1998	187	261	261	290	290	290	290	290	2,159
1998/1999	28	268	200	214	228	228	228	108	1,502
Total	470	964	880	976	981	838	782	423	6,314

Source: Budzinski pers. comm. 2000a.

The density of grazing livestock fluctuates from year to year depending on forage conditions. The livestock may be moved from pasture to pasture over the course of the grazing season. Estimates of the number of cattle grazing in the upper watershed were not available because of the large area and amount of private land involved. Grazing in the recreation area around Lake Del Valle is fairly controlled, and information on grazing allotments was available. Grazing tenants are required to submit stocking plans describing where and how many head of cattle they will graze. Grazing use data from 1996 to 1999 were available for various pasture units around Lake Del Valle from the EBRPD. Grazing activity occurred in 4 areas around the lake primarily from November to June. These areas are numbered 1 through 4 and shown in Figure 5-3. Total grazing use for all 4 areas combined (in numbers of animals) is presented in Table 5-5.

Peak grazing in all areas occurred in the 1997/1998 season with 2,159 animals, followed by 1995/1996 with 1,631 animals. The maximum number of cattle in any one month in any area was 290 in the months February through June 1998. Peak monthly grazing occurred in December, February, and March, with sharp declines noted in November and June. Area 1, which is known as Boat Ramp/Monday, is north of East Beach and east of Hetch Hetchy campsite. This area had the highest overall grazing with a peak annual use of 1,638 animals during 1997/1998, or about 75% of the total grazing at Lake Del Valle that year. Area 1 had an annual average of 1,086 animals. The next highest grazing use was in area 3, which is known as the George/Kennedy Service Yard, with a peak annual use of 560 animals and an annual average of about 283 animals. Approximately 25 to 30 animals grazed in areas 2 and 3 from July to October.

Grazing as a land use practice is being evaluated for all parklands. Additional fencing is being installed to keep cattle from reaching the lake, but only in some areas because of its high cost. When cattle are kept from the lake, it is necessary to create small reservoirs within the fenced areas for water supply. Bullfrogs, then, are able to propagate in these waters and, in turn, prey upon red-legged frogs, an endangered species in the area (Gigliati pers. comm. 2000).

Wild Animal Populations

Because of the watershed's extensive, undeveloped, and rugged nature, its actual number of animals and their condition are unknown. There are reported to be large populations of black-tailed deer, feral goats, wild pig, rabbits, hares, ground squirrels, and other small mammals such as, skunks, gray fox, and coyotes. Their droppings are potential sources of pathogens in the watershed, especially in or near streambeds during rainfall. Contractors have reported concerns about the droppings and their potential effect on water quality (ACWD 2000).

5.3.2.5 Algal Blooms

The occurrence and amount of nuisance algae are controlled by a complex interplay of nutrient loading, species interactions (that is, competition and predation by zooplankton) and physical conditions in the lake, namely, water temperature and light levels. Nutrient availability is controlled by input from source water and by biological regeneration of nitrogen and phosphorus within the lake and from bottom sediments. Assuming there are adequate nutrient levels, temperature and light are commonly the primary determinants for algal blooms observed in spring and fall. A detailed discussion of algae blooms, nutrients, and related reservoir dynamics is presented under Water Quality Summary in Chapter 7, Southern California Reservoirs.

Both historical and recent data collected at Lake Del Valle indicate that MIB and geosmin are being produced and are of concern. MIB is found in the reservoir at higher levels than geosmin, which is opposite the compound levels found in the SBA. Blue-green algae species found include *Synechococcus* sp., which primarily produces MIB but also produces geosmin. Therefore, the source of MIB in Lake Del Valle is uncertain at this point (Janik pers. comm. 2000a). As is common in other

SWP reservoirs, conditions of light, temperature, and nutrients in Lake Del Valle are conducive to algal growth. It is not clear what the relative contribution of the SBA/Delta source waters or the Del Valle watershed is to reservoir algal blooms. Copper sulfate or other chemical controls are not used in Lake Del Valle (Burger pers. comm. 2000). Algal blooms and taste and odor problems are further discussed under Water Quality Summary in Section 5.4.1.7, Taste and Odor.

5.3.2.6 Agricultural Activities

The primary agricultural activity in the watershed is livestock production. Because of the location and type of terrain prevalent in the watershed, other types of agricultural development are extremely limited. In 1974, about 68,400 acres of the watershed were under Williamson Act contracts, which restrict the land to agricultural use for 10-year periods. This has helped to preserve the land in its natural state (DWR 1974).

No pesticides are used in the lake. Roundup is used on terrestrial weeds, and Surflan is used as a pre-emergent herbicide for weeds (Gigliati pers. comm. 2000). There is occasional baiting for ground squirrel control using environmentally benign compounds. An integrated pest management specialist coordinates this and all other applications (Burger pers. comm. 2000). Therefore, this potential contaminant source presents a minimal threat to water quality.

5.3.2.7 Mines

The watershed reportedly had about 35 active and inactive mines, including asbestos and magnesium mines (Figure 5-1). The main road into the park area is named for mines in the vicinity. Past mining activity was for magnesium carbonate deposits in the southeastern part of the watershed near Sweetwater Creek, which receives drainage from the mining area (DWR 1974). Both high magnesium and hardness levels can be associated with this historical mining. In their responses to the sanitary survey questionnaire, SBA contractors did not report any problems or water quality concerns associated with historical mining activities. For further information, refer to discussion of total dissolved solids (TDS) in Section 5.4.1.1.

5.3.2.8 Unauthorized Activity

Underground Storage Tank Leaks

Sanitary Survey Update 1996 reported 1 leaking underground storage tank in Del Valle Park that was removed in 1992. No contamination had reached the lake, and no further action was required. No other problems or incidents were identified or reported during this survey period.

5.3.2.9 Traffic Accidents/Spills

Transportation Corridors

There are several access and feeder roads from the major highways mentioned under Section 5.3.1, South Bay Aqueduct. The main ones are Mines Road, Mt. Hamilton Road, and Patterson Road. The potential appears limited that serious spills of hazardous materials or other contaminants along these roads would reach Lake Del Valle.

History of Accidents/Spills

None of the SBA contractors, DWR field staff, or other agency staff contacted about Lake Del Valle reported any accidents or spills that could affect drinking water supplies during this period.

5.3.2.10 Geologic Hazards

There are several major active faults in the area, as described in Section 5.3.1.8, Geologic Hazards. Five earthquakes of a 4.0 or greater magnitude have occurred in the area since the turn of the century. The strongest was a magnitude 5.5 (DWR 1979).

During a significant seismic event, the SBA would most likely be damaged and water deliveries to and from Lake Valle would cease. There could be catastrophic flooding and damage to area structures if the Del Valle Dam fails. If landslides or earthquakes resulted in significant movement of soil, vegetation, and/or debris into the lake, then water quality in the lake could be seriously affected by turbidity, nutrients, and pathogens or other contaminants associated with land uses that could be flushed into the lake. However, water quality downstream in the SBA would probably not be significantly affected because it is a closed pipeline and utilities would not be taking deliveries.

5.3.2.11 Fires

California Department of Forestry and Fire Protection has primary jurisdiction over wildland fires in the Arroyo Valle area (EBRPD 1998). The EBRPD maintains its own fire department to provide fire and rescue services for regional parklands.

A 1996 fire burned 750 acres and required evacuation of stranded campers from one of the newer campgrounds (DWR 1998). There were no reports of water quality problems associated with the incident.

5.3.2.12 Land Use Changes

The extensive private land ownerships prevalent in the watershed were described under Section 5.1.1, Land Use. There is potential that some of these lands may in the future be subject to development pressures from the growing East Bay region. About 4,000 acres surrounding Lake Del Valle is within the SRA and, because it is held as public land, is less likely to be developed for urban or commercial purposes.

Because of its soil and runoff conditions and high erosion potential, the Lake Del Valle watershed is extremely sensitive to land use changes such as urbanization and development. Even limited land use changes, such as constructing access roads or grading for construction, if not carefully planned, could accelerate soil erosion or landslide problems. Because of this, the watershed is very vulnerable and there is a substantial potential threat to water quality if significant land use changes occur in the basin (DWR 1974).

5.4 WATER QUALITY SUMMARY

In this and the other reservoir water quality sections, comparisons are made between contaminant concentrations in SWP source water and maximum contaminant levels (MCLs) for finished drinking water. Although MCLs are usually applied to finished water, they are useful as conservative indicators of contaminants that are of concern to utilities and that would require removal during the treatment process to meet finished water standards. It follows that if source water concentrations are below MCLs then these contaminants are less likely to be of concern for the finished water supply.

The comparison also serves to focus on 1 or more PCSs associated with the contaminant of concern and allows the development of appropriate recommendations for actions. Although all data examined were below MCLs, land use information suggested the possibility of several water quality concerns, namely, high TDS levels in natural inflows, turbidity, algal blooms, MTBE contamination from recreational watercraft in the reservoir, and pathogen contamination through either recreation or livestock grazing.

5.4.1 WATERSHED

Water quality assessment of Lake Del Valle and its watershed is complicated by reservoir operation practices. SWP water is pumped into the reservoir to maintain a recreational pool during the summer season. Water is released in the fall to reserve flood control capacity. Natural inflow from the watershed is impounded in Lake Del Valle during winter months. From 1996 through 1999, natural inflow constituted the majority of inflows into the reservoir (Table 5-3). Therefore**,** in many cases**,** water quality samples collected at Lake Del Valle may be more representative of natural inflow than of SWP inflow. To examine water quality between Lake Del Valle and the SBA, water quality data from Lake Del Valle was compared to water quality data from Banks Pumping Plant, considered to be representative of SBA's water quality above Lake Del Valle.

Water quality data from Lake Del Valle from 1996 through 1999 are presented in Table 5-6. All parameters were below applicable drinking water levels. Minor elements that were detected at low concentrations in 1 or more samples included arsenic, barium, boron, chromium, copper, iron, manganese, and zinc. Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the detection limit; however, statistics were not calculated for elements with 2 or fewer detections. Results for minor elements in Table 5-6 represent dissolved concentrations. Because MCLs are based on total metal concentrations, direct comparisons between drinking water MCLs were not made.

Table 5-6 Lake Del Valle, Sep 1996 to Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	32	32	27.0	39	28-38	1	17/17
Chloride	10	10	6	16	6-11	1	18/18
Total Dissolved Solids	218	215	169	275	171-270	1	17/17
Hardness (as $CaCO_3$)	160	157	124	204	125-204	1	18/18
Alkalinity (as $CaCO_3$)	148	152	113	182	117-154	1	17/17
Conductivity (uS/cm)	374	379	285	456	294-453	1	18/18
Magnesium	20	20	14	27	14-26	1	17/17
Sulfate	35	35	19	50	25-38	1	18/18
Turbidity (NTU)	17	3	<1	65	1-31	1	17/18
Minor Elements							
Arsenic	0.002	0.002	<0.001	0.003	<0.001-0.002	0.001	14/18
Barium	0.1	0.073	0.05	0.085	0.05-0.08	0.05	18/18
Boron	0.1	0.1	<0.1	0.2	0.1-0.2	0.1	16/17
Chromium	0.006	0.005	<0.005	0.013	<0.005-0.01	0.005	8/18
Copper	0.003	0.002	<0.001	0.005	<0.001-0.005	0.005	11/18
Iron	0.005	0.005	<0.005	0.009	<0.005-0.006	0.005	3/17
Manganese	NC	NC	<0.005	0.028	NC	0.005	2/17
Zinc	0.119	0.076	0.024	0.437	0.03-0.25	0.05	17/18
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.4	0.4	0.2	0.6	0.3-0.5	0.1	25/25
Nitrate (as NO3)	0.8	0.3	<0.1	2.2	0.1-1.4	0.1	13/17
Nitrate+Nitrite (as N)	0.08	0.01	<0.01	0.47	0.01-0.33	0.01	27/50
Total Phosphorus	0.02	0.02	<0.01	0.08	0.01-0.05	0.01	40/50
OrthoPhosphate	0.01	0.01	<0.01	0.03	0.01-0.01	0.01	7/50
Misc.							
Bromide	0.03	0.02	0.01	0.05	0.02-0.04	0.01	12/12
Total Organic Carbon	NC	NC	3.3	3.4	NC	0.1	2/2
pH (pH unit)	8.1	8.1	7.8	8.5	7.9-8.3	0.1	18/18

Barium and zinc were the only minor elements that were detected at higher concentrations in Lake Del Valle than at Banks Pumping Plant (Table 5-7). Samples collected at the Del Valle outlet have historically had the highest zinc concentrations of all samples collected in the SWP (DWR 2000). Zinc ranged from 0.024 to 0.437 mg/L and averaged 0.119 mg/L. Even though these were dissolved values, the highest zinc concentration detected was still an order of magnitude lower than secondary MCLs. Because of the lack of data, organic compounds in Lake Del Valle were not examined.

Table 5-7 Banks Pumping Plant, Jan 1996 to Dec 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	Number of Detects/ Samples
Minerals							
Calcium	17	16	9.0	25	13-22	1	51/51
Chloride	48	40	12	151	19-94	1	52/52
Total Dissolved Solids	204	182	85	399	123-303	1	51/51
Hardness (as $CaCO^3$)	82	82	38	121	60-113	1	52/52
Alkalinity	63	62	33	95	48-76	1	51/51
Conductivity (µmohs/cm)	365	344	148	725	215-535	1	52/52
Magnesium	10	9	4	16	7-14	1	51/51
Sulfate	34	30	12	77	16-55	1	52/52
Turbidity (NTU)	11	8	<1	68	<1-26	1	46/52
Minor Elements							
Arsenic	0.002	0.002	0.001	0.003	0.001-0.002	0.001	47/47
Boron	0.2	0.1	<0.1	1.2	0.1-0.3	0.1	42/51
Barium	NC	NC	<0.05	<0.05	NC	0.05	0/47
Chromium	0.005	0.005	<0.005	0.006	0.005-0.005	0.005	4/47
Copper	0.007	0.004	<0.001	0.095	0.002-0.009	0.005	30/47
Iron	0.016	0.01	<0.005	0.083	0.005-0.03	0.005	39/47
Manganese	0.016	0.015	<0.005	0.034	0.005-0.03	0.005	40/47
Selenium	0.001	0.001	<0.05	0.002	0.001-0.001	0.05	3/47
Zinc	NC	NC	<0.01	0.02	NC	0.01	2/47
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.5	0.4	0.2	0.9	0.3-0.7	0.1	26/26
Nitrate (as NO3)	3.1	2.8	0.4	8	1.2-5.5	0.1	51/51
Nitrate+Nitrite (as N)	0.71	0.67	0.09	1.8	0.28-1.3	0.01	51/51
OrthoPhosphate	0.08	0.07	0.02	0.13	0.05-0.13	0.01	51/51
Total Phosphorus	0.13	0.12	0.07	0.22	0.08-0.18	0.01	51/51
Misc.							
Total Organic Carbon	3.7	3.4	2.3	6.7	2.7-5.1	0.1	44/44
Bromide	0.15	0.13	0.04	0.52	0.06-.29	0.01	51/51
pH (pH unit)	7.4	7.3	6.6	8.1	7-8	0.1	52/52

Source: DWR O&M Division database

Notes: Totel Kjeldahl Nitrogen data from Oct 96 to Mar 98 only
Statistics include values less than detection limit, if applicable
NC= not calculated, statistical values were not calculated for parameters with 2 or less detections

5.4.1.1 Total Dissolved Solids

Highly erodible soils in the Del Valle watershed contribute dissolved solids to the natural runoff entering the reservoir. TDS and conductivity were similar in the Del Valle and Banks samples (Tables 5-6 and 5-7). Because more samples were collected at Banks than at Lake Del Valle, it is unknown whether the greater TDS variation observed at Banks is due to sampling frequency or greater variation in Delta waters. From 1996 through 1999, samples collected from Lake Del Valle had higher concentrations of calcium and magnesium than did the samples collected at Banks. Calcium in Lake Del Valle ranged from 27 to 39 mg/L and averaged 32 mg/L. While these values are far below the secondary MCL of 250 mg/L, they were elevated in comparison to samples collected at Banks Pumping Plant, which had a mean of 17 and ranged from 9 to 25 mg/L. Magnesium followed a similar pattern, ranging from 14 to 27 mg/L in Lake Del Valle and only 4 to 16 mg/L at Banks Pumping Plant.

With respect to hardness, runoff into Lake Del Valle from 1996 through 1999 had a large impact on water quality. Hardness measurements at Lake Del Valle reflected the lake's higher concentrations of calcium and magnesium. The maximum hardness detected at Lake Del Valle was 204 mg/L as $CaCO_3$ compared to 121 mg/L as $CaCO_3$ at Banks Pumping Plant. As discussed in Section 5.1.4, Hydrology, there are magnesium mines in the watershed that, in conjunction with the large natural inflows into the lake, could be related to the high hardness and alkalinity levels.

Lake Del Valle had much lower chloride concentrations than did Banks Pumping Plant samples. Chloride ranged from 6 to 16 mg/L at Lake Del Valle and from 12 to 151 mg/L at Banks. Natural runoff from the Lake Del Valle watershed appears to have a substantial diluting effect on chloride concentrations in the SBA.

5.4.1.2 Turbidity

Erodible soils in the watershed increase turbidity. Recreational activities at the reservoir, algal blooms, and grazing activities in the watershed contribute to erosion and increased turbidity. Turbidity in Lake Del Valle ranged from nondetect to 65 NTUs with a mean of 17 NTUs (Table 5-6). These values were similar to values observed at Banks Pumping Plant (Table 5-7). Turbidity at Banks Pumping Plant ranged from nondetect to 68 NTU and averaged 11 NTUs. At both locations, 90% of the samples collected were below 35 NTUs. The maximum value of 65 NTUs at Lake Del Valle was observed in February 1998 when Arroyo Valle flows were unusually high because of El Niño storms.

5.4.1.3 Total Organic Carbon (DBP Precursors) and Alkalinity

Organic carbon and bromide in source water react with disinfectants in the treatment process to produce trihalomethanes, haloacetic acids, and bromate. Very little total organic carbon (TOC) data were collected at Lake Del Valle from 1996 through 1999 (Table 5-6). Although 2 samples collected in October and November 1999 indicated that TOC levels in Lake Del Valle were similar to levels observed at Banks Pumping Plant, there were not enough data to draw any conclusions on which water source had the most influence on TOC.

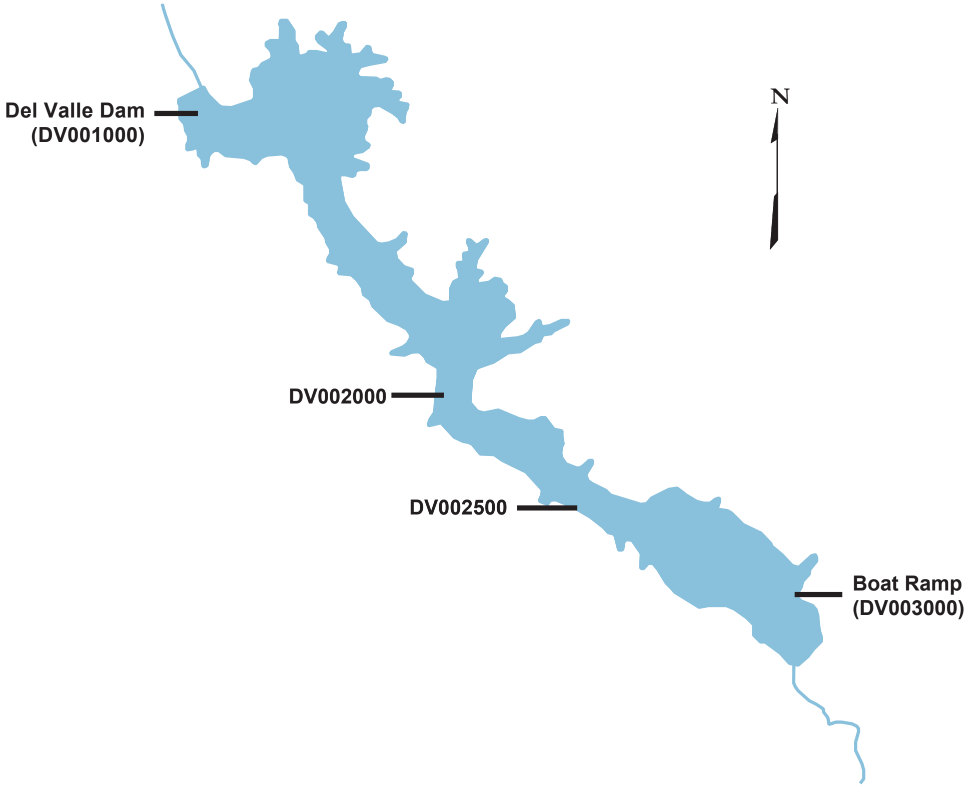
Alkalinity was higher in Lake Del Valle than at Banks Pumping Plant. Alkalinity in Lake Del Valle ranged from 113 to 182 mg/L as $CaCO_3$. SBA water ranged from 48 to 76 mg/L. The D/DBP Rule mandates higher TOC removal for source waters with low alkalinity. Thus, the high alkalinity water entering the SWP from Lake Del Valle probably reduces treatment costs.

Bromide levels observed in Lake Del Valle were much lower than those observed at Banks Pumping Plant (Tables 5-6 and 5-7). Twelve bromide samples were collected at Lake Del Valle from 1996 through 1999. Bromide ranged from 0.01 to 0.05 mg/L and averaged 0.03 mg/L. In contrast, bromide concentrations at Banks Pumping Plant ranged from 0.014 to 0.52 mg/L and averaged 0.15 mg/L, 5 times higher than the average bromide concentration in Lake Del Valle. Although fewer samples were collected at Lake Del Valle, it is reasonable to assume that bromide water quality in the SBA reflects the seawater contributions of Delta water at Banks. Lake Del Valle dilutes the impact of SBA's Delta water. A detailed discussion of bromide levels in SBA source water is provided under Section 5.4.2.2, Total Organic Carbon (DBP Precursors) and Alkalinity, and in the Banks Pumping Plant section of Chapter 4.

5.4.1.4 MTBE

MTBE was sampled at 4 locations in Lake Del Valle in 1997 and 1998 (Figure 5-4). Surface samples were collected at all 4 locations. In 1997, additional depths were sampled near the dam at DV001000. Sampling depth was dependent on the temperature regime in the lake. The mid-depth samples were collected between 4 meters and 12 meters deep; and the lower depth samples between 8 meters and 14 meters. During most of 1997, mid-depth samples were near the bottom of the epilimnion

Figure 5-4 MTBE Sampling Sites on Lake Del Valle, 1997 to 1998



and deep-water samples were below the thermocline.

Data on the temperature regime of Lake Del Valle were available for 1997. The depth to the thermocline was 5 meters at the beginning of the sampling period in April. The thermocline deepened to 10 meters by mid-June. The thermocline began to weaken in late September 1997, and the lake was isothermal by early December 1997.

MTBE concentrations in Lake Del Valle were lower than MTBE concentrations in the 4 Southern California SWP reservoirs. For example, at Lake Perris, DWR detected surface concentrations of MTBE as high as 32 µg/L, while at Castaic, Pyramid, and Silverwood lakes, DWR measured surface MTBE concentrations as high as 24, 27, and 13µg/L, respectively. At Lake Del Valle, surface MTBE concentrations ranged from 1.4 to 10.2 µg/L (Figure 5-5 and Table 5-8). All samples were below the 13 µg/L primary MCL. However, many surface samples exceeded the secondary MCL of 5µg/L. MCLs are only valid for finished drinking water, and some of the MTBE is removed during the treatment process.

Figure 5-5 Surface MTBE Concentrations at Lake Del Valle, 1997 to 1998

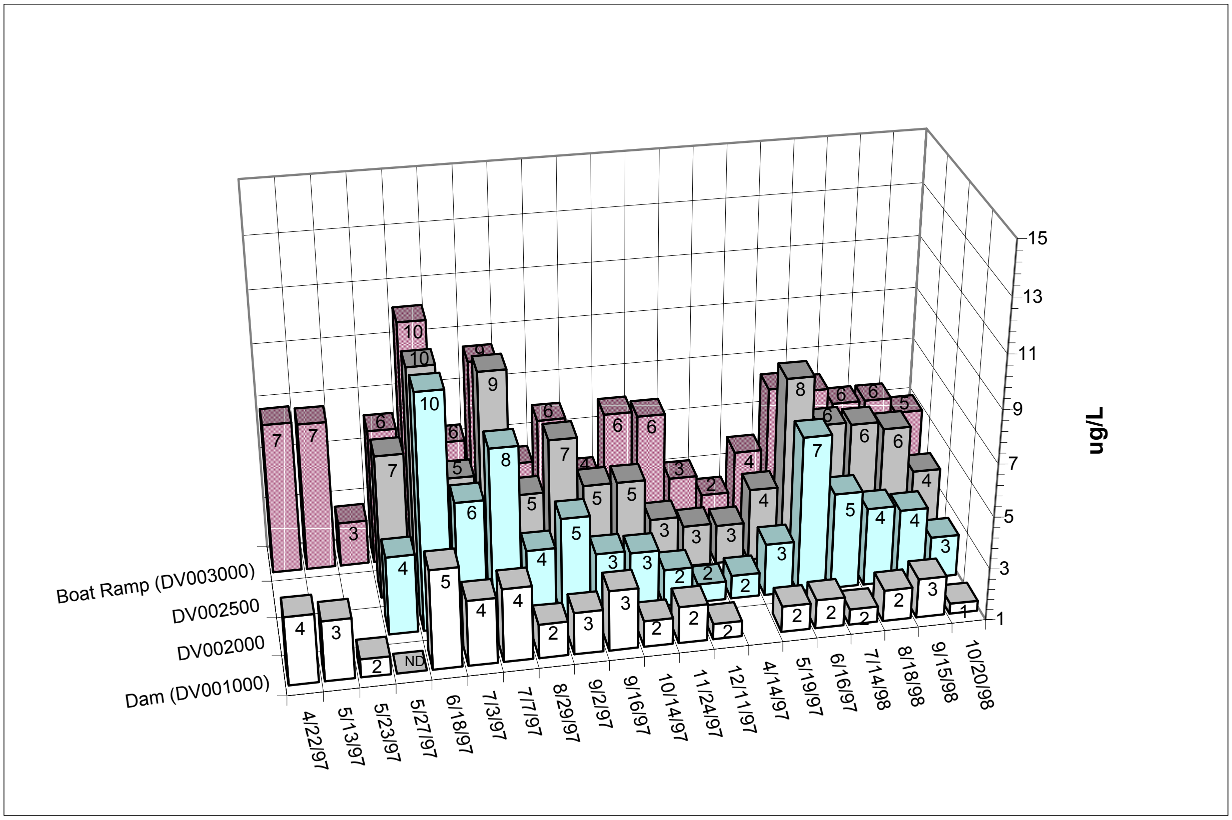


Table 5-8 Surface MTBE Concentrations (µg/L) in Lake Del Valle, 1997 to 1998

Station	Min	Max	Mean
Boat Ramp (DV003000)	2.4	10.2	5.7
DV002500	2.5	9.7	5.3
DV002000	1.7	10.0	4.2
Dam (DV001000)	1.4	4.8	2.6

Note: Statistics do not include values less than the reporting limit.

MTBE concentrations in Lake Del Valle varied both spatially and seasonally. MTBE levels were higher near the boat ramp than at the dam. Samples collected at DV003000, near the boat ramp, had an average MTBE concentration of 5.7 µg/L. This value decreased to 5.3 µg/L at DV002500, 4.2 µg/L at DV002000, and 2.6 µg/L at DV001000 (Table 5-8).

MTBE concentrations were highest in spring and summer when most watercraft recreation occurs. MTBE levels were highest from May through July in 1997 and from May through September in 1998 (Figure 5-5). Surface concentrations at the dam were less variable, ranging between nondetect and 4.8 µg/L.

In 1997, to examine the impacts of peak motorized watercraft activity, MTBE concentrations were examined before and after major holidays. Samples were collected before and after Memorial Day, 4th of July, and Labor Day holiday weekends. As shown in Table 5-9, the increase of MTBE levels over holiday weekends was greatest at the boat ramp and decreased with distance. These findings are

.

Table 5-9 Increase in MTBE Concentrations at Lake Del Valle Over Major Holiday Weekends (µg/L)

Sampling stations	Weekends					
	Memorial Day		4th of July		Labor Day	
	23 May 1997	27 May 1997	13 Jul 1997	7 Jul 1997	29 Aug 1997	2 Sep 1997
Boat Ramp (DV003000)	2.7	6.2	5.5	8.5	4.4	6
DV002500	NS	NS	5.4	9.3	4.5	6.5
DV002000	NS	NS	6	8	4	5
Dam (DV001000)	1.7	<1	3.5	3.8	2.3	2.6

Data provided by DWR O&M, 13 Dec 2000

consistent with Southern California reservoir results discussed in Chapter 7. At the boat ramp, MTBE concentrations increased by almost 4 µg/L over the Memorial Day weekend, 3 µg/L over the 4th of July weekend, and nearly 2 µg/L over the Labor Day weekend. At station DV002500, MTBE increased by 4 µg/L over the 4th of July weekend, and 2 µg/L over the Labor Day weekend. At station DV002000, approximately 1.7 miles from the boat ramp, the increases were less dramatic. MTBE at station DV002000 increased by 2 µg/L over the July 4th weekend and 1 µg/L over the Labor Day weekend. At the dam (DV001000), no appreciable change in MTBE concentration was observed over the holiday weekends.

5.4.1.5 Pathogens

See Chapter 12 for a discussion of pathogen issues.

5.4.1.6. Nutrients

Nutrients such as nitrogen and phosphorus are important water quality parameters because of both their direct effects on water potability and their influence on algal populations in lakes. Because of high nitrogen and phosphorus loading from the SWP, direct runoff and precipitation, most SWP reservoirs are nutrient-rich and would be classified as eutrophic with respect to algal productivity. Nutrient levels indirectly affect water quality in these lakes by stimulating growth of nuisance algae, which are associated with release of taste and odor compounds such as geosmin and MIB. High concentrations of certain diatom species can also affect treatment plant operations by clogging filters and interfering with coagulation and flocculation treatments. Eutrophic lakes often experience periods of anoxia in bottom waters because of microbial respiration fueled by periodic die-off of algae.

The occurrence and amount of nuisance algae are controlled by a complex interplay of nutrient loading, species interactions (competition and predation by zooplankton) and physical conditions in the lake, namely temperature and light levels. Nutrient availability is controlled by inputs from source waters and by biological regeneration of nitrogen and phosphorus within the lake and from bottom sediments.

During spring, reservoirs typically have low turbidity, good light penetration and no temperature stratification (Coburn pers. comm. 2001). As spring progresses, water temperatures rise and stimulate algal growth resulting in a bloom. Decreasing water clarity because of the algal bloom coupled with increasing solar inputs (that is, longer days, higher sun angle) results in thermal stratification of the lake. The warmer (that is, less dense) upper portion of the water column is separated by a thermocline (region of maximum temperature change with depth) from the colder (that is, more dense) lower portion of the water column. The upper portion of the lake is referred to as the epilimnion and is typically well mixed, and light levels are sufficient for algae to grow, thus oxygen levels are high. The portion of the lake below the thermocline is referred to as the hypolimnion and is usually too dark for algal growth. Microbial respiration (that is, consumption of oxygen) fueled by organic materials that sink from the epilimnion (dead algae) and by algal respiration (sinking live algae) can lead to low oxygen levels (hypoxia) or a total depletion of dissolved oxygen (anoxia) in the hypolimnion.

By mid to late summer, nutrients have been depleted by algal growth in the epilimnion, and algal biomass declines. Nutrients released by microbial decomposition in the hypolimnion cannot be resupplied to the epilimnion while a strong thermocline persists. Thermal stratification typically persists into fall when surface waters cool and become more dense (they sink) resulting in a lake mixing or turnover event. Wind can also contribute to lake mixing. When the lakes mix, turbidity decreases and nutrients that have accumulated in hypolimnetic waters reach shallower depths in the lakes with sufficient light for algal growth, leading to a fall bloom. Spring and fall algal blooms are commonly observed in SWP reservoirs and in temperate lakes throughout the world; however, the specific timing and magnitude of algal blooms vary from year to year and from lake to lake and are difficult to predict.

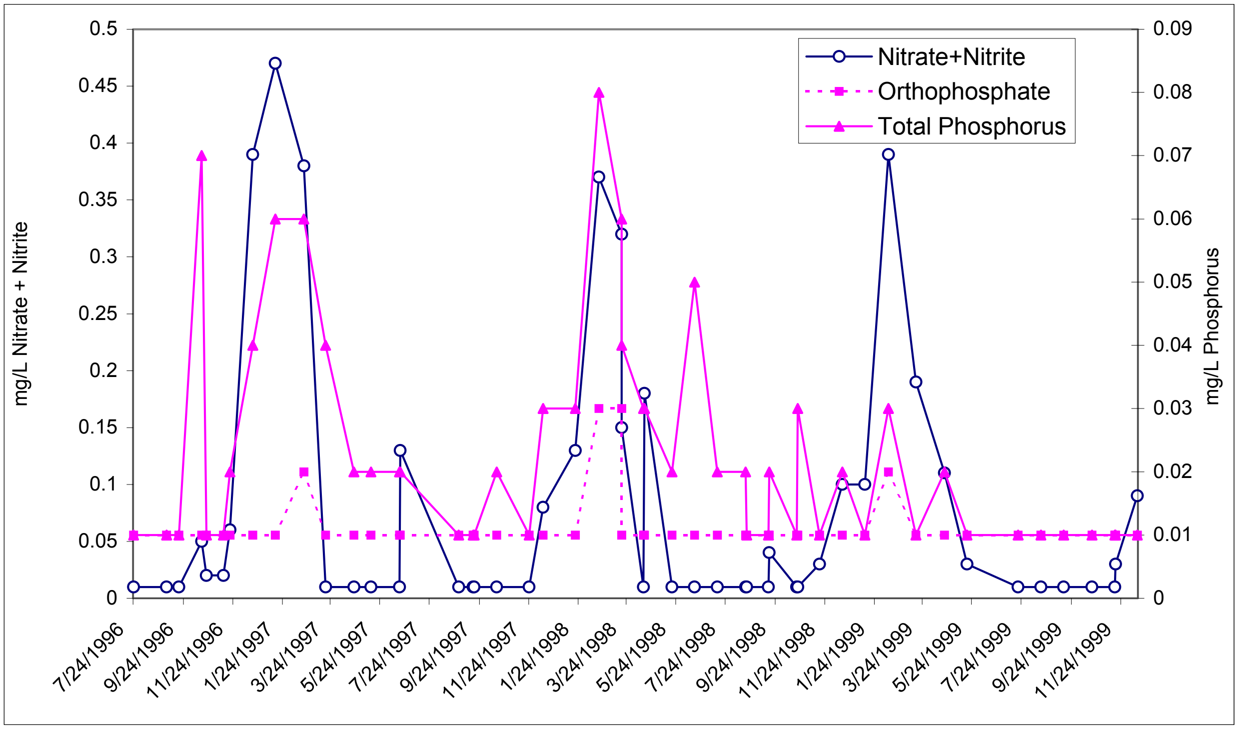
A more detailed analysis of algal/nutrient dynamics and factors controlling the abundance of nuisance algae in each of the individual SWP reservoirs is beyond the scope of this report. Therefore, this *Sanitary Survey Update* will describe nutrient conditions and noteworthy instances of algal blooms or nuisance algae in each of the SWP reservoirs. This report does not attempt to determine the causes of algal population dynamics or establish a connection between specific algal blooms and nutrient, light or temperature conditions in the lakes.

Nutrient levels were generally lower at Lake Del Valle than at Banks Pumping Plant. At Lake Del Valle, total phosphorus ranged from 0.01 to 0.08 mg/L and averaged 0.02 mg/L (Table 5-6). At Banks Pumping Plant, total phosphorus ranged from 0.07 to 0.22 mg/L (Table 5-7). With an average concentration of 0.13 mg/L, the total phosphorous concentrations at Banks Pumping Plant were an order of magnitude higher than those for Lake Del Valle. Orthophosphate showed similar differences, with values ranging from 0.01 to 0.03 mg/L at Del Valle and 0.02 to 0.13 mg/L at Banks Pumping Plant.

Total Kjeldahl Nitrogen averaged 0.5 mg/L at Banks and 0.4 mg/L at Lake Del Valle. Differences between the 2 sites were greater for nitrate. Nitrite concentration in surface waters is generally low; therefore, nitrate+nitrite values were treated as nitrate. Nitrate (as N) averaged 0.71 mg/L at Banks and 0.08 mg/L at Lake Del Valle. Nitrate (as NO_3) averaged 3.1 mg/L at Banks and only 0.8 mg/L at Lake Del Valle. All nitrate samples were well below their respective finished water MCLs.

Nitrogen and phosphorus levels in Lake Del Valle exhibited seasonal variation (Figure 5-6). Levels typically reached a maximum in the winter months and declined sharply in the spring when nutrients were depleted because of algal productivity. Lower nutrient levels in the spring/summer suggest high nutrient utilization and likely serves to limit algal growth. Surface nitrogen and phosphorus concentrations increase in the fall when lake mixing resuspends nutrients sequestered in the hypolimnion and algal growth is limited because of low temperatures and sunlight. It is important to note that nutrient samples were collected at the reservoir's outlet and may not provide an accurate representation of deeper layers of the lake.

Figure 5-6 Seasonal Variation in Nutrient Concentrations in Lake Del Valle, 1996 to 1999



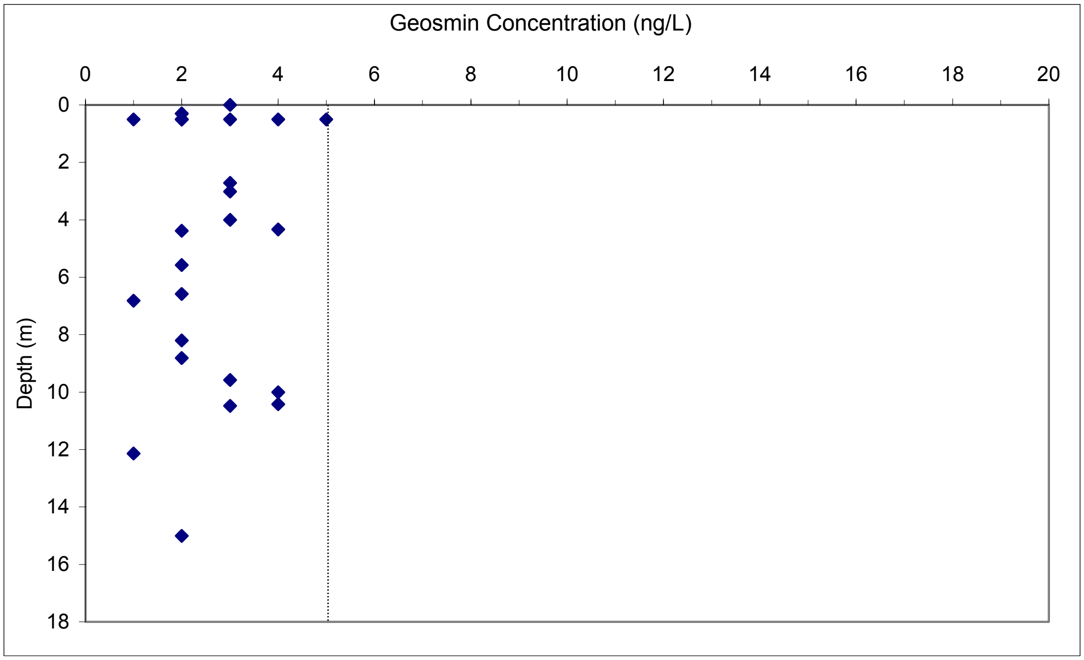
5.4.1.7 Taste and Odor

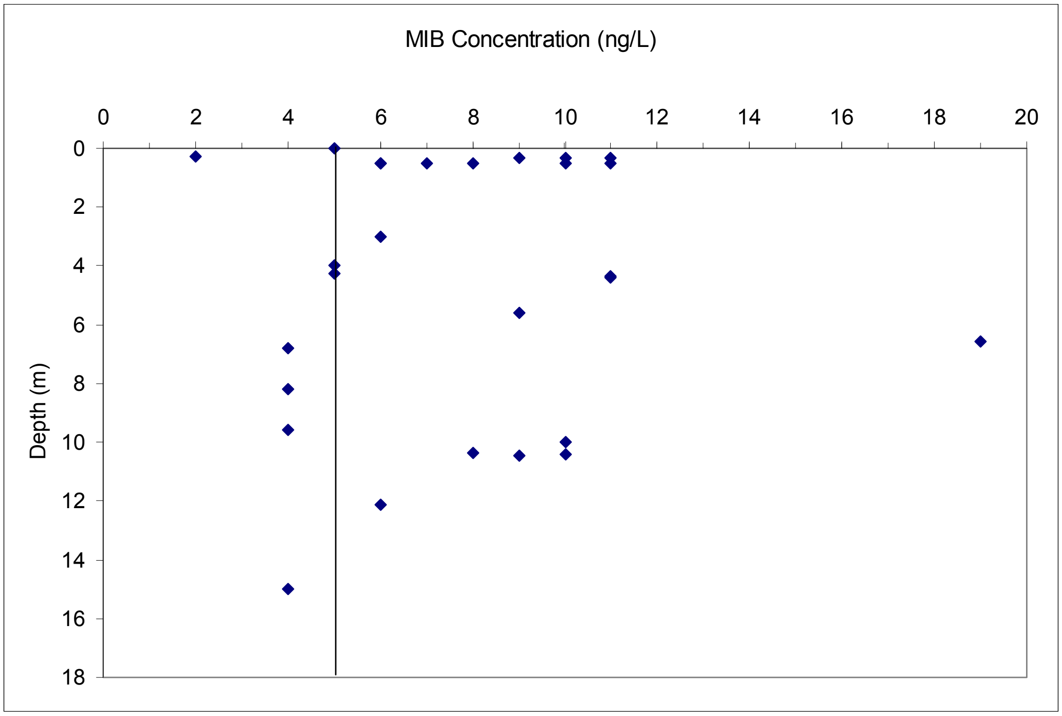
There are several factors that influence the production of malodorant compounds in surface waters. Ambient light conditions, available nutrients, and water temperature are among the most important factors affecting algal production in surface waters. Certain algal species produce high concentrations of malodorant compounds such as MIB and geosmin. MIB and geosmin have extremely low odor detection thresholds; many people can detect concentrations as low as 5-10 ng/L.

Contractors that treat SBA water reported that taste and odor problems in source water occur mainly in spring, summer, and fall. Contractors also noted higher concentrations of taste and odor contaminants in source water following treatment of the SBA with copper sulfate ($CuSO_4$). Copper sulfate treatment kills much of the algae in the aqueduct, which can lead to algal cells lysing and releasing taste and odor contaminants.

Both MIB and geosmin were detected at all depths sampled in Lake Del Valle (Figure 5-7), and there was no apparent pattern associated with depth. The majority of geosmin detections occurred below the 5 to 10 ng/L taste and odor threshold, while the majority of MIB detections occurred above this range. Geosmin concentrations ranged from 1 to 5 ng/L with a mean of 2 ng/L while MIB concentrations ranged from 2 to 19 ng/L and averaged 8 ng/L. The highest MIB values were recorded in October 1998 and October 1999.

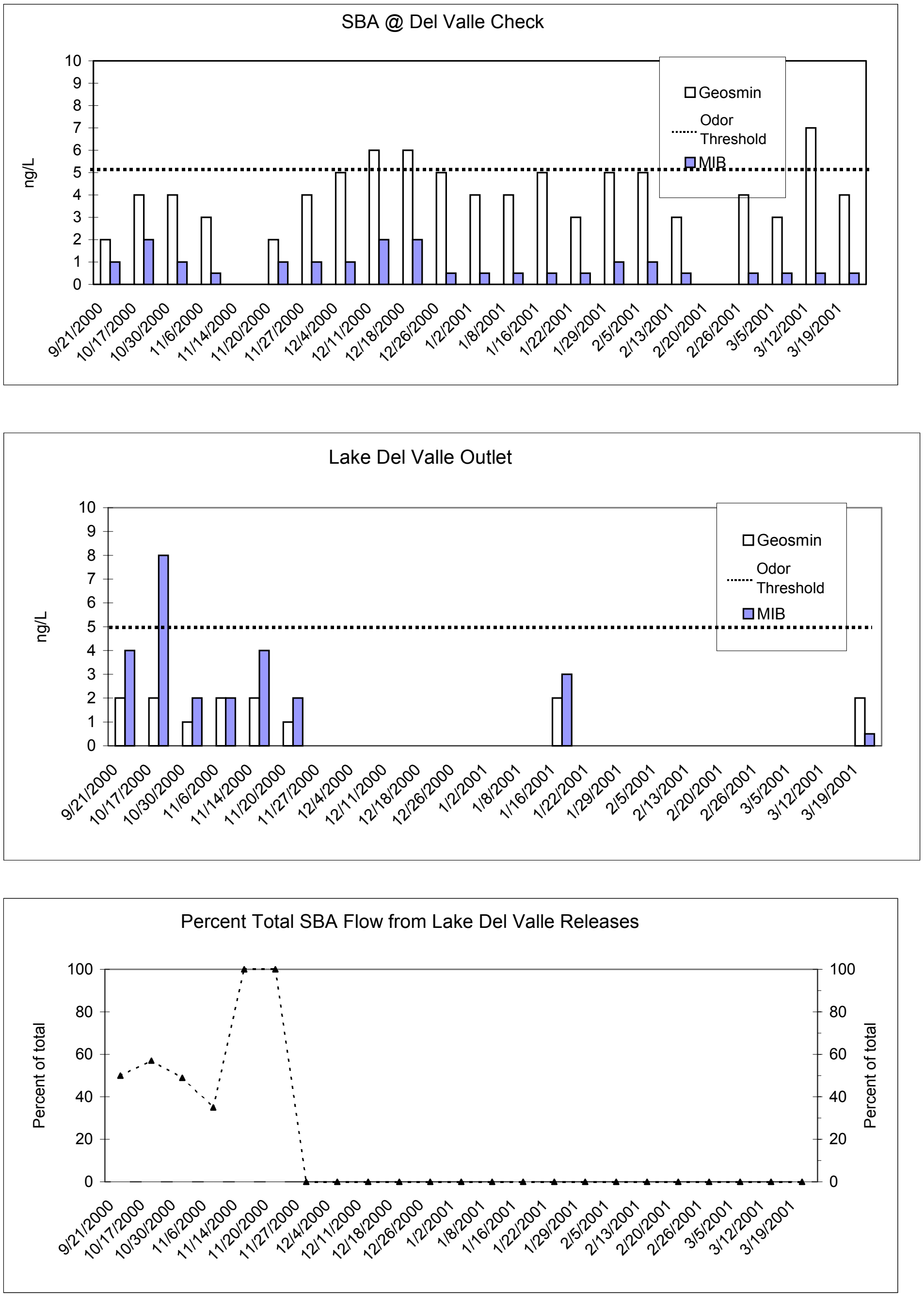
Figure 5-7 Geosmin and MIB Concentrations at Lake Del Valle Dam by Depth





It is difficult to determine the source of MIB and geosmin in Lake Del Valle. The compounds could have been present in SBA inflows, or they could have formed within the reservoir. However, recent DWR data suggest that geosmin may have a larger influence on taste and odor problems when the origin of the source water is the SBA/Delta. MIB may affect taste and odor when the origin of the source water is Lake Del Valle (Figure 5-7). Figure 5-8 shows the relative concentrations of geosmin and MIB in the SBA at the Del Valle check (Check 7 at mile 16.31, above Lake Del Valle) and the Lake Del Valle outlet from weekly samples collected September 2000 through March 2001. Also shown is Lake Del Valle's percent contribution by volume to the total SBA flow. On 1 occasion during Lake Del Valle releases, MIB concentrations were above the taste and odor threshold. Following the cessation of Lake Del Valle releases, measured concentrations of geosmin in Delta water were often at or above the taste and odor threshold. Although this suggests that geosmin problems primarily originate from Delta water and MIB problems from Lake Del Valle water, no samples were collected from Lake Del Valle when water was not released. Therefore, it is unknown whether the relative dominance of MIB and geosmin in Lake Del Valle water would have changed as the season progressed. Several more seasons of data would be required to confirm these observations.

Figure 5-8 MIB and Geosmin Concentrations at the Lake Del Valle Check and the Lake Del Valle Outlet and Percent Contributions of Lake Del Valle Outflow to Total South Bay Aqueduct Volume, Sep 2000 to Mar 2001



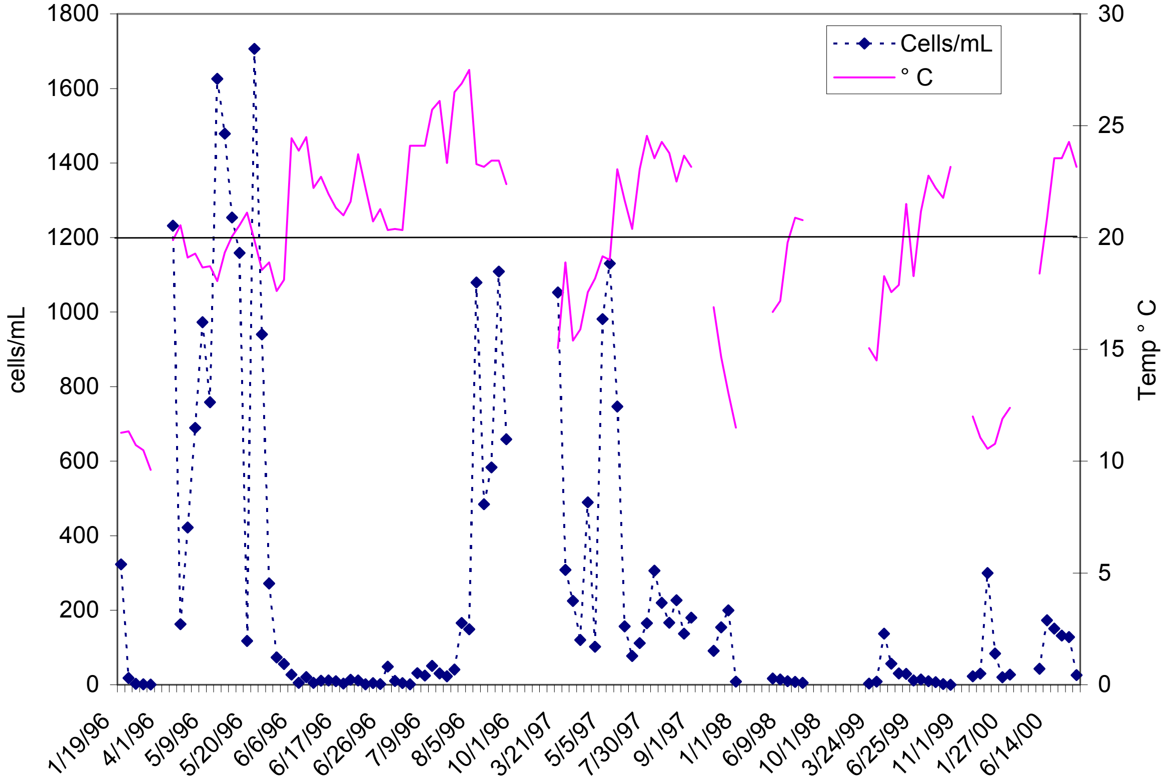
5.4.2 WATER SUPPLY SYSTEM

The 3 SBA contractors evaluated included ACWD, Zone 7 Water Agency, and SCVWD. These agencies reported no Title 22 MCL violations (Brewster pers. comm. 2001, Chun pers. comm. 2001, Marchand pers. comm. 2001, and O'Brien pers. comm. 2001). Title 22 parameter categories for primary MCLs include inorganic chemicals (trace metals, nitrate/nitrite, asbestos), radioactivity, total trihalomethanes (TTHMs), and organic chemicals. Secondary MCLs include—but are not limited to—iron, manganese, odor, turbidity, TDS, conductivity, chloride, and sulfate. Because contractors had no MCL violations, water quality issues within the water supply system focused on what the SBA contractors cited as water quality challenges: taste and odor, DBPs, and DBP precursors TOC and bromide.

5.4.2.1 Taste and Odor

The background and current status of taste and odor problems in the SBA and Lake Del Valle are discussed in sections 5.3.1.5 and 5.3.2.5, respectively. Of the SBA contractors, ACWD conducted the most complete algal studies at its WTP2. In months when algal samples were collected, they were generally collected weekly or biweekly. In both 1996 and 1997, increased algal numbers were observed in the month of May (1996 and 1997) or March through May (1997) (Figure 5-9). Similar peaks were not observed in 1998 or 1999. No samples were collected in March or April 1996, so it is not known whether the increase in algal numbers observed in May 1996 actually began earlier as was observed in 1997 data. Algal blooms were observed in August 1996; a similar bloom was not observed 1997 through 1999 (no data available for 2000).

Figure 5-9 Algal Count (cells/mL) and Temperature of ACWD WTP2 Influent



Algal growth and succession are based on a number of factors. As shown in Figure 5-9, temperature alone could not explain the presence or absence of algal blooms. An examination of algal species by month shows that with the exception of February, *Melosira* spp. was the dominant algal species in influent water (Figure 5-10). However, from 1996 through 2000, extensive algal sampling was only conducted May through August (Table 5-10); therefore, species composition in other months may be inaccurate. Interestingly, geosmin- and MIB-producing algae detected by DWR in either the SBA or Lake Del Valle (for example, *Oscillatoria* sp. or *Synechococcus* sp.) were not detected in ACWD algal samples.

Figure 5-10 Proportion of Algal Species Found in ACWD WTP2 Influent (Averaged by Month from Jan 1996 to Jul 2000)

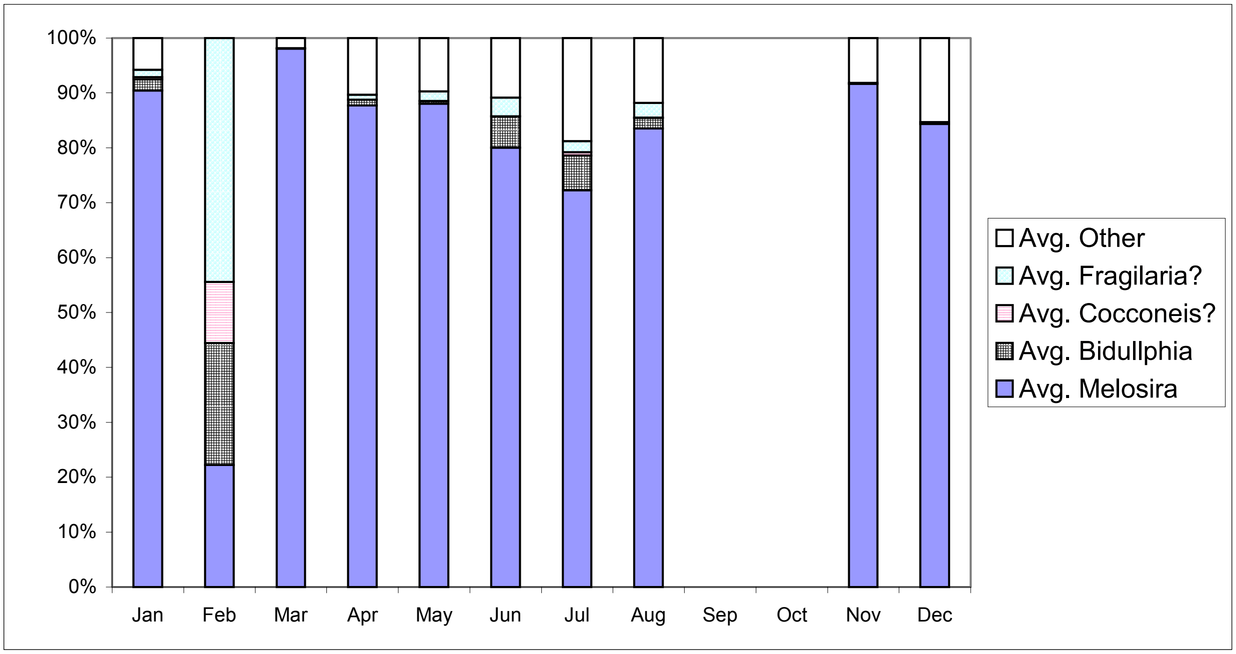


Table 5-10 Number of ACWD WTP2 Influent Samples Counted for Algae by Month, Jan 1996 to Jul 2000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Algal Counts	6	3	4	7	24	25	14	12	0	0	2	4

With respect to actual taste and odor constituents, most geosmin and MIB analyses have been conducted by DWR's O&M (see Section 5.4.1.7). In May 2000, O&M and the SBA contractors agreed to increase MIB and geosmin monitoring in the SBA and Lake Del Valle in fall when blue-green algae become abundant (Janik pers. comm. 2000). The SCVWD also began analyzing for both of these constituents in 2001 (Brewster pers. comm. 2001a).

In summer 2000, following implementation of the new copper sulfate treatment procedure described in Section 5.3.1.5, Algal Blooms, all SBA treatment plants evaluated in this report noted improvement of taste and odor problems (Brewster pers. comm. 2001; Deol pers. comm. 2001; Hidas pers. comm. 2001). Comparisons between algal numbers or taste and odor constituents at Banks Pumping Plant relative to the SBA will have to be examined over several summer bloom seasons to determine the efficacy of this treatment strategy.

5.4.2.2 Total Organic Carbon (DBP Precursors) and Alkalinity

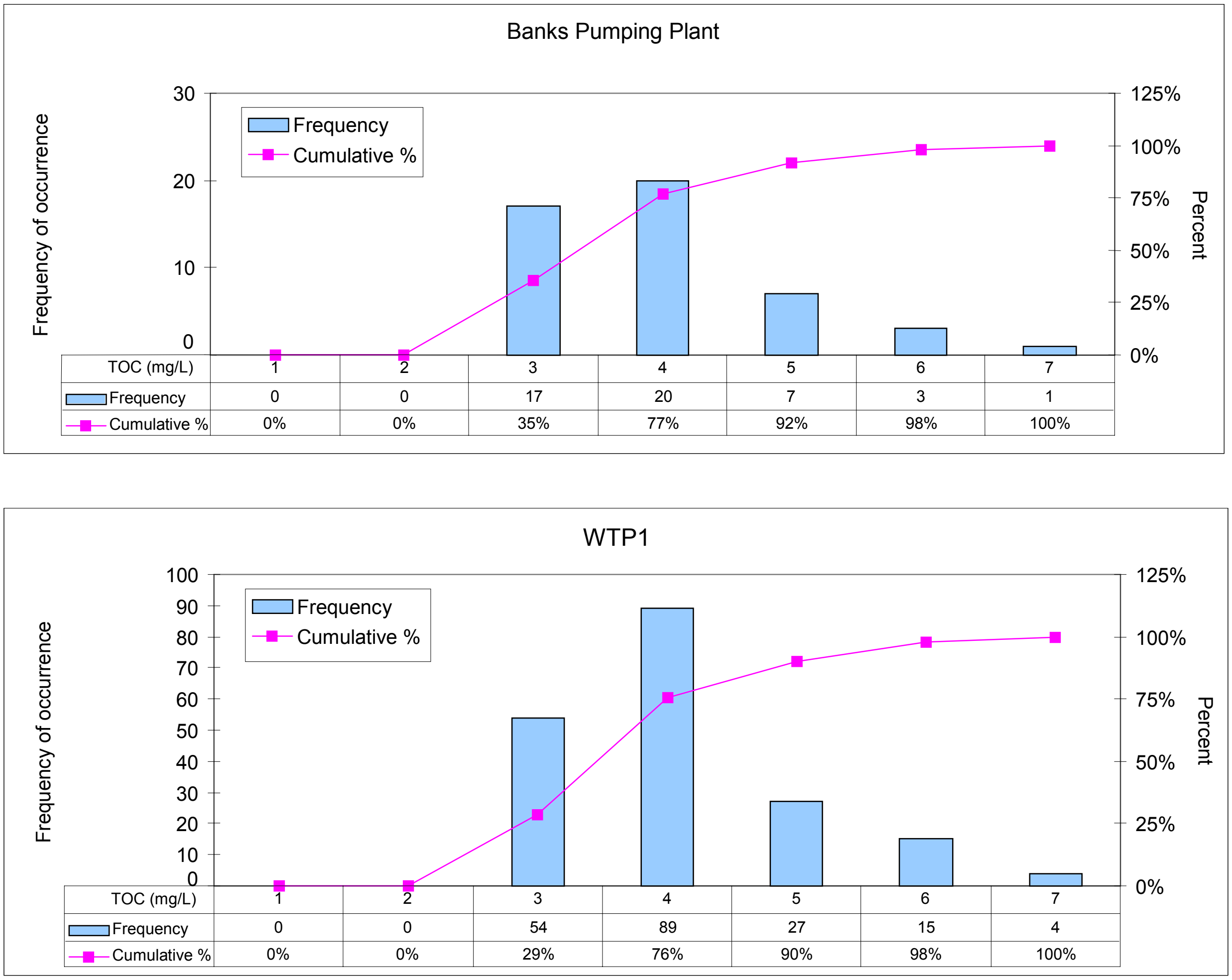
TOC concentrations at Banks Pumping Plant are similar to SBA influent at the WTPs (Table 5-11, Figure 5-11). Since TOC is analyzed weekly at ACWD's WTP1 and monthly at Banks Pumping Plant, the TOC distribution at WTP1 provides a more complete view of carbon levels originating from Banks. WTP1 was included because ACWD uses chlorination for disinfection there. Cumulative probability distributions at WTP1 illustrate that from 1996 through 1999, approximately 30% of all TOC detections met the proposed CALFED TOC target level at the pumps of 3 mg/L (Figure 5-11). The majority of TOC detections occurred between 3 and 4 mg/L with approximately 25% of all carbon concentrations detected above 4 mg/L. In TOC and alkalinity ranges, Table 5-12 shows the required percent removal of TOC under the Stage 1 D/DBP Rule.

Table 5-11 Bromide, TOC, and Alkalinity Concentrations (mg/L) at the Banks Pumping Plant and Selected South Bay Aqueduct Water Treatment Plants, 1996 to 1999

Analyte	Location	Mean	Median	Min	Max	Percentile Range (10-90%)	# Detects/ Total Sampled
Bromide (mg/L)	Banks Pumping Plant[a]	0.15	0.12	0.04	0.52	0.06 - 0.29	48/49
	Penitencia WTP[b]	0.14	0.11	< 0.05	0.47	0.05 - 0.24	46/56
	Del Valle WTP[a]	0.17	0.1	< 0.05	0.6	0.06 - 0.35	36/49
	Patterson Pass WTP[a]	0.21	0.1	< 0.05	0.9	0.06 - 0.42	45/48
	WTP2[c]	0.11	0.09	< 0.003	0.51	0.03 - 0.24	200/206
TOC (mg/L)	Banks Pumping Plant[a]	3.5	3.2	2.3	6.7	2.7 - 4.9	47/48
	Penitencia WTP[b]	2.8	2.6	1.8	4.9	2.2 - 3.3	45/45
	Del Valle WTP[a]	3.0	2.9	1.9	4.3	2.3 - 3.9	44/44
	Patterson Pass WTP[a]	2.9	2.7	1.9	4.8	2.1 - 4.2	43/43
	WTP1[c]	3.6	3.4	2.3	6.4	2.8 - 5.0	189/189
	WTP2[c]	3.6	3.4	2.3	6.4	2.7 - 5.1	205/205
Alkalinity (mg/L)	Banks Pumping Plant[a]	61.9	62	33	95	48 - 74	69/69
	Penitencia WTP[d]	77	67	13	148	48 - 120	880/880
	Del Valle WTP[a]	82	73	41	137	55 - 121	49/49
	Patterson Pass WTP[a]	66	65	38	111	50 - 82	48/48
	WTP1[a]	88	84	42	152	55 - 132	20/20
	WTP 2[a]	92	84	40	152	60 - 134	21/21

[a] Averages based on monthly data Jan 1996 to Dec 1999.
[b] Averages based on monthly data Jan 1996 to Dec 1999. Data not used if source water not identified or from San Luis Reservoir.
[c] Averages based on weekly data Jan 1996 to Dec 1999.
[d] Averages based on daily data.
WTP = water treatment plant
Summary Statistics calculated by substituting detection limit for all values less than the detection limit.

Figure 5-11 Cumulative Probability Distribution of TOC at Banks Pumping Plant and the ACWD WTP1, Jan 1996 to Dec 1999



Banks Pumping Plant

TOC (mg/L)	1	2	3	4	5	6	7
Frequency	0	0	17	20	7	3	1
Cumulative %	0%	0%	35%	77%	92%	98%	100%

WTP1

TOC (mg/L)	1	2	3	4	5	6	7
Frequency	0	0	54	89	27	15	4
Cumulative %	0%	0%	29%	76%	90%	98%	100%

Table 5-12 Percent Removal of TOC by Enhanced Coagulation and Enhanced Softening for Systems Using Conventional Treatment

Source Water TOC (mg/L)	Source Water Alkalinity as $CaCO_3$ (mg/L)		
	0–60	>60-120	>120
> 2.0-4.0	35%	25%	15%
>4.0–8.0	45%	35%	25%
>8.0	50%	40%	30%

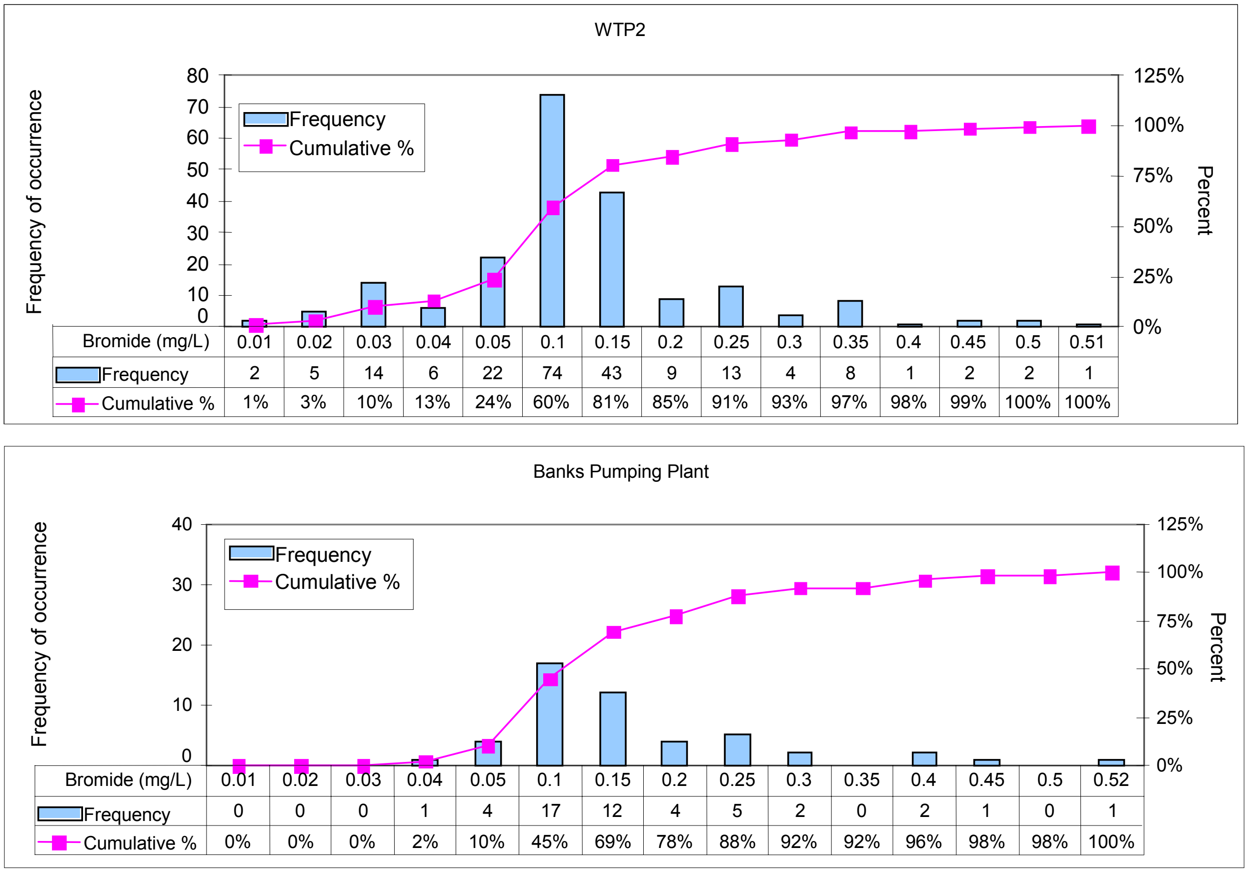
Based on 4-year averages of TOC and alkalinity, all SBA plants would require a minimum of 25% removal of TOC. Both the minimum and maximum values for TOC and alkalinity suggest that depending on the paired combination of these 2 variables, SBA plants may need to remove as much as 45%, or as little as 15% of their incoming TOC. SBA contractors have expressed concerns about meeting the Stage 1 TOC removal requirements (Zone 7 2000; SCVWD 2000). One treatment strategy employed by Zone 7 uses $FeCl_3$ instead of $AlSO_4$ as a coagulant when needed. The use of $FeCl_3$ is much more expensive than $AlSO_4$, but it provides better TOC and particulate removal.

Bromide

Recipients of SBA water are some of the 1st contractors to receive water from Banks Pumping Plant via the California and South Bay aqueducts. Because it is unlikely there are additional sources of bromide within the SBA watershed, it is reasonable to assume that bromide concentrations experienced by SBA plants are a reflection of those exported from Banks Pumping Plant. To prevent problems associated with bromate formation from ozonation, CALFED has suggested target levels of 50 µg/L for bromide concentrations at the export pumps (DWR 2000c).

Like TOC, bromide concentrations at Banks Pumping Plant are similar to those in SBA influent at the WTPs (Table 5-11). An analysis of water quality data using frequency distributions supports the idea that bromide concentrations at Banks Pumping Plant and in SBA plant influent are similar. Bromide concentrations are analyzed weekly at ACWD's WTP2 while bromide samples are collected monthly at Banks Pumping Plant. Based on the different sampling frequencies, actual cumulative percentages between the 2 sites varied; however, the shapes of the bromide distributions were nearly identical (Figure 5-12). At both locations, bromide was detected the most frequently between 0.05 and 0.1 mg/L, followed by detections between 0.1 and 0.15 mg/L. Bromide summary statistics for all SBA WTPs evaluated are shown in Table 5-11. Although sampling dates and frequencies differ between the plants—and in some cases values were not used when a different source water was online, for instance, Penitencia WTP—bromide concentrations recorded at the treatment plants and at Banks Pumping Plant were extremely consistent.

Figure 5-12 Cumulative Probability Distribution of Bromide (mg/L) in Source Water at ACWD WTP2 and Banks Pumping Plant, Jan 1996 to Dec 1999



WTP2

Bromide (mg/L)	0.01	0.02	0.03	0.04	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.51
Frequency	2	5	14	6	22	74	43	9	13	4	8	1	2	2	1
Cumulative %	1%	3%	10%	13%	24%	60%	81%	85%	91%	93%	97%	98%	99%	100%	100%

Banks Pumping Plant

Bromide (mg/L)	0.01	0.02	0.03	0.04	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.52
Frequency	0	0	0	1	4	17	12	4	5	2	0	2	1	0	1
Cumulative %	0%	0%	0%	2%	10%	45%	69%	78%	88%	92%	92%	96%	98%	98%	100%

5.4.2.3 Disinfection Byproducts (Total Trihalomethanes, Haloacetic Acids, and Bromate)

Depending on the treatment process and the plant, SBA contractors cite DBPs formed from both TOC and bromide in SBA source water as their major water quality concerns. From 1996 to 1999, the ACWD WTP2 was the only SBA plant using ozone; therefore, bromate formation was only examined at this SBA plant. The SCVWD is in the process of upgrading plants to use ozone, so they also are concerned with meeting bromate regulations.

Based on survey information and discussion with laboratory and operations staff, Zone 7 has no problems meeting Stage 1 TTHM or haloacetic acids (HAA5) D/DBP MCLs (Zone 7 2000; Deol, pers. comm. 2001; Baker pers. comm. 2001). HAA5 is a group of regulated haloacetic acids: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid and dibromoacetic acid. Depending on the operations of Zone 7's retail water systems, the continued formation of THMs may be an issue. All SBA users reported concern with TOC and/or the production of THMs or HAAs and are in the process of either optimizing or upgrading their treatment processes (ACWD 2000; SCVWD 2000).

Average quarterly and annual TTHM concentrations for the SBA WTPs are shown in Table 5-13. From 1996 through 1999, the annual averages of all WTPs were below the 80 µg/L MCL of the Stage 1 D/DBP Rule. No appreciable pattern appeared between the season and THM formation. However, in 1997 the annual average of WTP1 came close to exceeding the MCL, and the plant exceeded the MCL in 2 of the 4 quarters of that year (April to June at 83 µg/L and October to December at 87 µg/L). None of the other WTPs showed similar increases. Because of the frequency of analyses, it is not known whether higher TTHMs occurred at

WTP1. WTP1 analyzes for TTHMs weekly, while Penitencia analyzes monthly and Zone 7 analyzes quarterly. In both 1996 and 1997, WTP1 generally had higher values than other SBA plants, but in 1998 and 1999 this was not the case. This may indicate that the nature of the carbon was less variable in 1998 and 1999. However, if this were the case, then values would be similar between plants, regardless of the sampling frequency. WTP2 uses ozonation for disinfection. Therefore, its corresponding TTHM production was relatively low with respect to other SBA plants.

Table 5-13 Average Quarterly and Annual TTHM Concentrations (µg/L) by Year for Selected SBA Water Treatment Plants

		Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual Avg
1996	Penitencia WTP	67	63	33	52	54
	Del Valle WTP[a]	71	56	45	66	60
	Patterson Pass WTP[a]	83	59	48	59	62
	WTP1	76	69	70	55	67
	WTP2	9	3	3	15	8
1997	Penitencia WTP	53	50	57	56	54
	Del Valle WTP[a]	71	39	45	50	51
	Patterson Pass WTP[a]	52	61	47	61	55
	WTP1	70	83	73	87	78
	WTP2	4	7	8	23	11
1998	Penitencia WTP	67	56	52	53	57
	Del Valle WTP[a]	39	55	37	44	44
	Patterson Pass WTP[a]	52	84	42	36	54
	WTP1	63	52	55	45	54
	WTP2	8	12	12	17	12
1999	Penitencia WTP	OL	OL	52	68	60
	Del Valle WTP[a]	38	36	45	47	42
	Patterson Pass WTP[a]	43	56	48	60	52
	WTP1	46	53	55	60	54
	WTP2	7	5	4	11	7

[a] Quarterly values represent samples collected once/quarter, not an average of samples collected monthly.

OL = off-line

WTP = water treatment plant

Although Penitencia WTP's annual averages have always been below the Stage 1 MCL, it had several quarters in which TTHMs approached 70 µg/L. This creates a potential THM problem for the district's client agencies. Depending on a client's water delivery infrastructure, there is the potential for continued formation of THMs. Water quality data from client agencies to the SCVWD were not reviewed in this update, so it is unknown whether the infrastructure of the district's client agencies could potentially allow concentrations to exceed Stage 1 regulations. Zone 7's TTHM water quality is similar to other SBA WTPs. Within the distribution system of Zone 7's client agencies, TTHM concentrations average about 50 µg/L (O'Brien pers. comm.2001a), which are similar to Zone 7's and below the MCL.

Average quarterly and annual HAA5 concentrations for selected SBA WTPs are shown in Table 5-14. From 1996 through 1999, all running annual averages were below the 60 µg/L MCL of the Stage 1 D/DBP Rule. At WTP1, quarterly HAA5 concentrations reached the MCL in the January to March quarter of 1997. Throughout 1997, WTP1 experienced high TTHM levels in all quarterly TTHM averages (Table 5-13), although that was not the case for the plant's HAAs levels in 1997. Zone 7 began testing for HAAs in April 1998. As noted earlier, the utility does not consider HAA5 to be a treatment problem for its plants. As with other plants during the same time period, its Del Valle and Patterson Pass WTPs were well below the 60 µg/L MCL. Concentrations of HAA5 in the distribution system of Zone 7's client agencies average around 20 µg/L (O'Brien pers. comm. 2001a). These values are similar to Zone 7's averages and are below the MCL. Available data suggest that SCVWD's Penitencia WTP also experienced low HAA5 concentrations when using only SBA water.

Table 5-14 Average Quarterly and Annual HAA5 Concentrations (µg/L) by Year for Selected SBA Water Treatment Plants

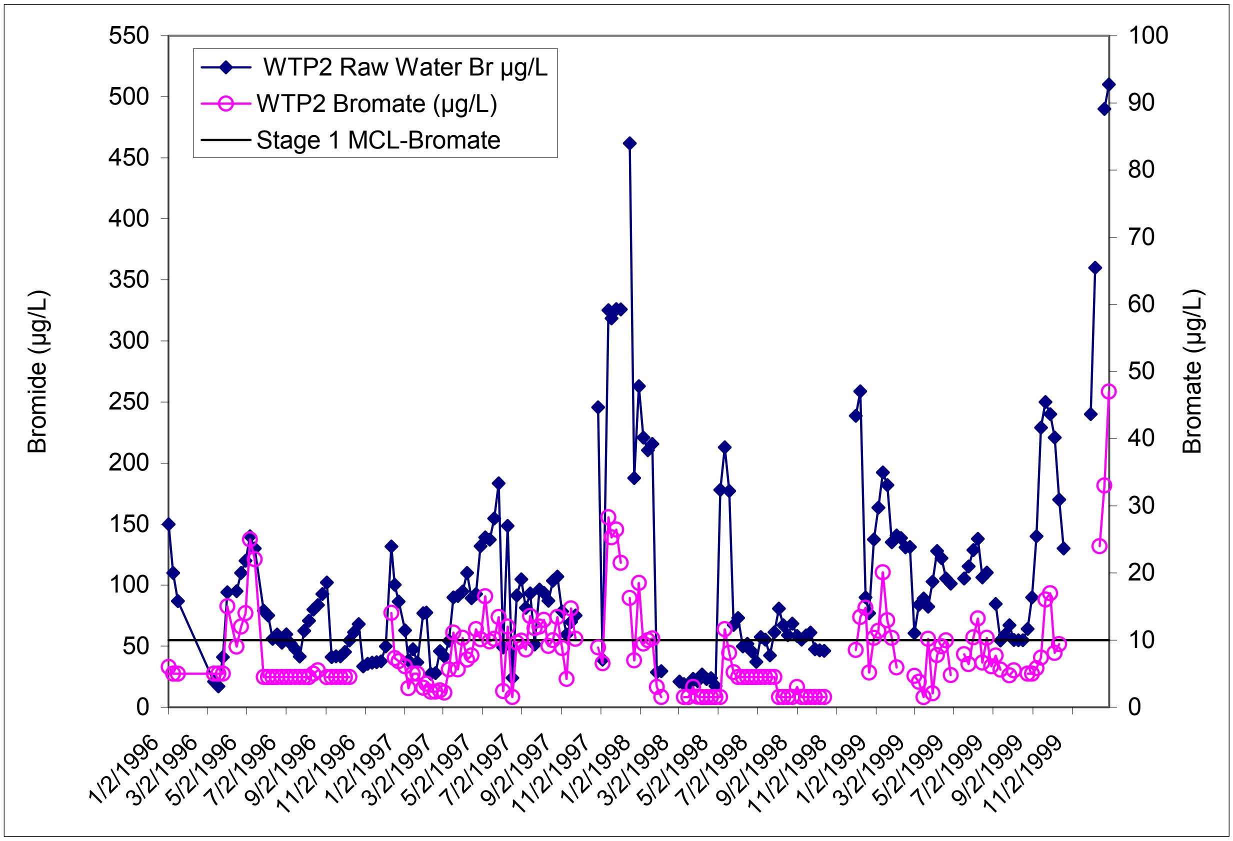
		Jan -Mar	Apr -Jun	Jul -Sep	Oct -Dec	Annual Avg.
1996	Penitencia WTP[a]	UA	UA	10	UA	-
	Del Valle WTP[b]	-	-	-	-	-
	Patterson Pass WTP[b]	-	-	-	-	-
	WTP1	52	39	34	36	40
	WTP2	8	2	2	9	5
1997	Penitencia WTP[a]	UA	UA	UA	UA	UA
	Del Valle WTP[b]	-	-	-	-	-
	Patterson Pass WTP[b]	-	-	-	-	-
	WTP1	60	33	34	34	40
	WTP2	8	5	5	7	6
1998	Penitencia WTP[a]	UA	UA	31	22	27
	Del Valle WTP[b]	-	37	NS	21	29
	Patterson Pass WTP[b]	-	37	NS	18	28
	WTP1	42	30	32	24	32
	WTP2	9	5	5	4	6
1999	Penitencia WTP[a]	NS	NS	32	26	29
	Del Valle WTP[b]	14	20	25	8	18
	Patterson Pass WTP[b]	21	27	22	10	20
	WTP1	19	35	23	22	25
	WTP2	8	4	4	8	6

[a] Calculations made only when source water was identified as SBA or DV

[b] Quarterly values represent samples collected once/quarter, not an average of samples collected monthly. Sample collection started in Apr 1998.

UA = source water not specified, or data not collected. NS = not sampled DL substituted for values <DL

Figure 5-13 Influent Bromide and Treated Water Bromate Concentrations at ACWD WTP2, Jan 1996 to Dec 1999



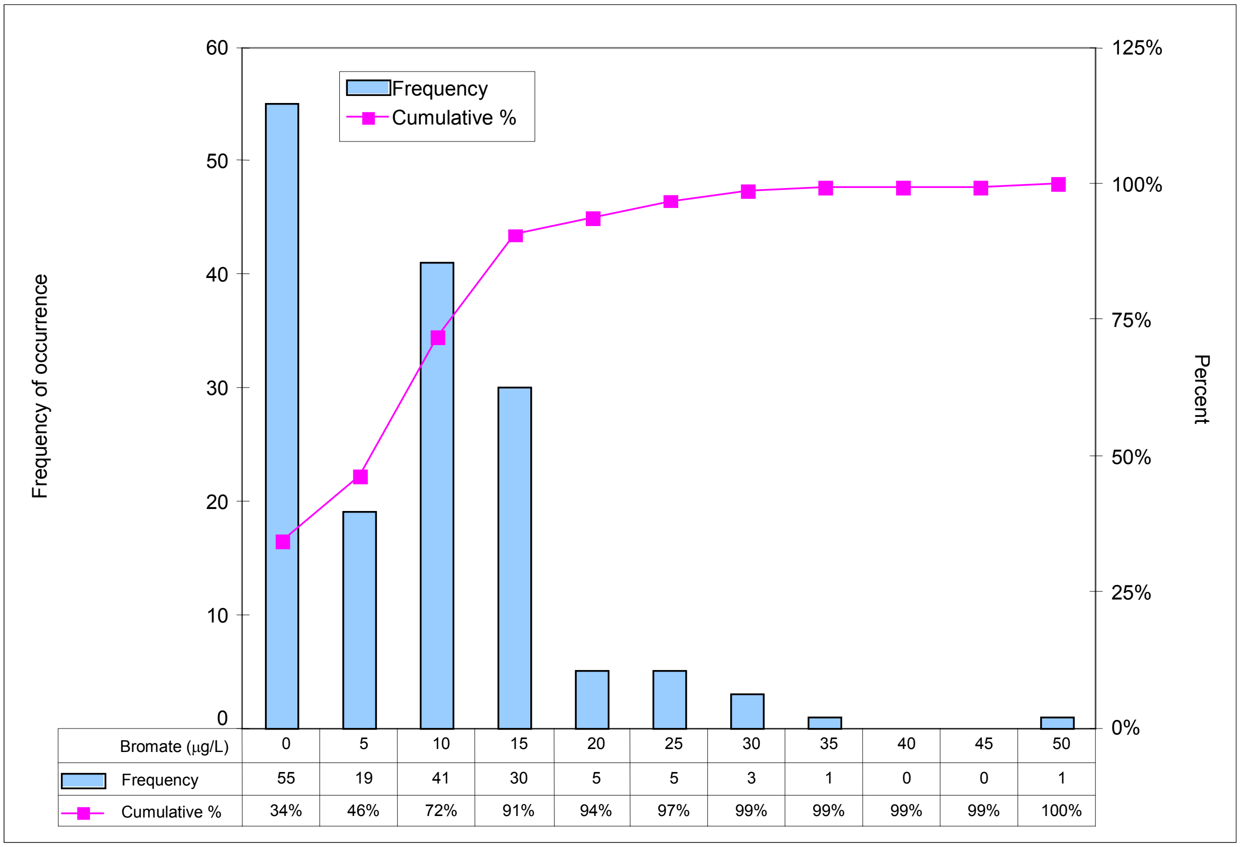
Values < DL changed to DL.
Spaces represent the plant off-line or use of non-SBA water.

Of all bromide samples of SBA source water analyzed at WTP2, approximately 75% were above CALFED's proposed target level of 50 µg/L (Figure 5-12). Ozonation of these bromide concentrations frequently (but not always) produced bromate concentrations above the Stage 1 D/DBP bromate MCL of 10 µg/L (Figure 5-13). Cumulative probability calculations illustrate that while a third of all weekly samples collected at WTP2 were below the detection limit, approximately a quarter of all samples collected were above the bromate MCL (Figure 5-14). Actual bromate compliance is based on the running annual average, computed quarterly, of monthly samples (or average of all samples taken during the month if more than 1 sample was collected). If the average of samples covering any consecutive 4-quarter period exceeds the MCL, the system is in violation (EPA 2001). From 1996 through 1999, bromate quarterly averages at WTP2 have exceeded the MCL at least once between April and December (Table 5-15, Figure 5-15). Of the 4 years evaluated, the running annual average for WTP2 exceeded the bromate MCL in 2 of the 4 years evaluated (1997 and 1999). Overall, the highest bromate concentrations have tended to occur in the winter with the highest recorded value (47 µg/L) occurring in December 1999 (Figure 5-13). High bromate concentrations were unexpectedly observed in winter months. Bromate and bromide concentrations would be expected to increase during drought or below-normal rainfall periods.

Table 5-15 Average Quarterly and Annual Bromate Concentrations (µg/L) by Year at the ACWD WTP2

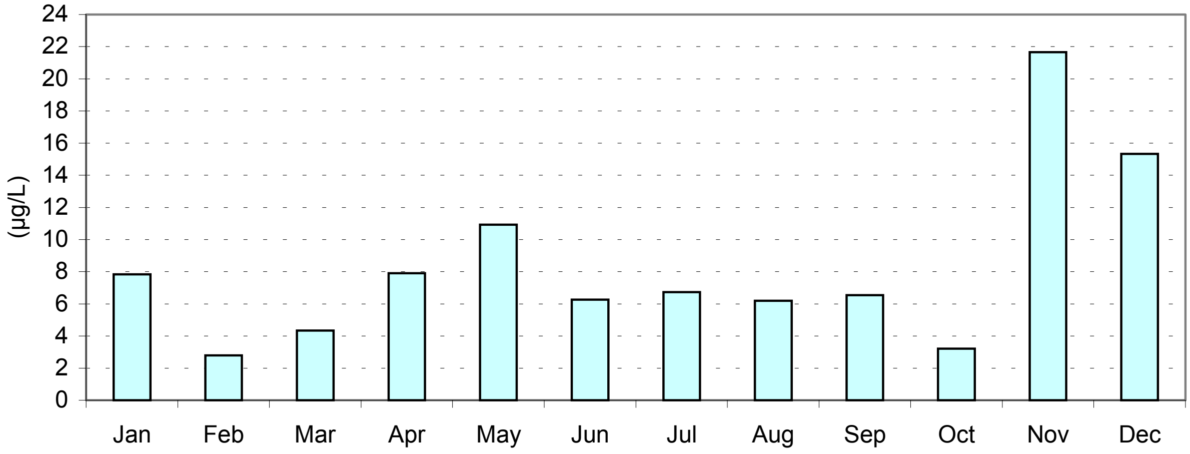
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Annual Avg.
1996	5.2	10.9	4.6	7.4	7.0
1997	4.4	9.4	10.7	17.2	10.4
1998	4.3	4.2	2.6	7.9	4.8
1999	8.3	8.4	8.0	22.1	11.7

Figure 5-14 Cumulative Probability Distribution of Bromate at ACWD WTP2, Jan 1996 to Dec 1999



Bromate (µg/L)	0	5	10	15	20	25	30	35	40	45	50
Frequency	55	19	41	30	5	5	3	1	0	0	1
Cumulative %	34%	46%	72%	91%	94%	97%	99%	99%	99%	99%	100%

Figure 5-15 Monthly Average Bromate Concentrations Between 1996 and 1999 at the ACWD WTP2



In 2001, the ACWD will be upgrading its WTP2 plant to allow acid addition to lower pH and bromate formation. The cost for this improvement is estimated at $1 million (Chun pers. comm. 2001). Although none of the other SBA plants evaluated is using ozone, the SCVWD is upgrading its plants to include ozonation (SCVWD 2000). The district's summary statistics suggest that the upgraded plants as well as any other plant using ozone and SBA water will encounter the same challenges with bromate formation as observed at WTP2. Like the ACWD, the SCVWD plans to use acid addition to control bromate formation (Matthews pers. comm. 2001).

In conclusion, at the 3 plants that have indicated bromate treatment problems (Penitencia and WTPs 1 and 2), the respective agencies are in the process of upgrading their plants to limit the formation of DBPs. The ACWD is in the process of a $1 million upgrade of its WTP2 plant that will allow the addition of acid to limit the formation of bromate. At the SCVWD, all plants are being converted to ozone and will use acid addition to control bromate formation.

5.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The DBP precursors TOC and bromide are 2 major water quality concerns for all SBA contractors because of their presence in SBA source water. These 2 constituents present significant water treatment challenges in meeting future drinking water regulations. Taste and odor issues because of algae in SBA source water have also been a recurring problem for SBA contractors.

Although Zone 7 and its retail water system should be able to meet both Stage 1 and proposed Stage 2 TTTM and HAA5 MCLs, Zone 7 plans to optimize its disinfection and TOC removal processes to further lower the level of DBPs. Also, by the end of 2002, all Zone 7's retail water systems will be using chloramines as the disinfectant residual in their distribution systems, which will limit the formation of DBPs. At the 3 plants that have indicated treatment problems (Penitencia, WTP1 and WTP2), the respective agencies are in the process of upgrading to limit the formation of DBPs.

5.5.1 SOUTH BAY AQUEDUCT

Cattle grazing and algal blooms were the most significant PCSs for the SBA. Grazing could be a significant potential source of pathogens and nutrients. Algal blooms can cause treatment problems, such as filter clogging, and chemical taste and odor problems. Recreation, wastewater treatment/facilities, and urban runoff posed a minimal threat to water quality and were not found to be significant PCSs. There is a substantial amount of agriculture around the SBA, including vineyards, but the majority appears to be out of the immediate drainage area of the SBA, most agricultural activities are farther west and north. Based on their locations, these agricultural activities are considered a minor threat to water quality.

Cattle are grazed along the open portions of the SBA. One route of contamination is runoff from surrounding hillsides, which can enter the open portions of the SBA through drain inlets, overcrossings, and bridges. A 2nd route of grazing contamination was wooden bridges used by cattle to cross the aqueduct. Large gaps between the wooden planks on these bridges allowed cattle droppings to directly enter the aqueduct. These planks have been replaced with sealed flooring to reduce the threat to water quality.

A significant water quality concern consistently cited by all SBA contractors is the taste and odor problem resulting from algal production of the offensive taste and odor compounds MIB and geosmin. Although algal growth was observed in the aqueduct, algae thought to be responsible for most of the taste and odor problems originate in the Delta and not in the SBA. These algae continue to grow in the SBA open canal especially under the right water temperature and light conditions, generally during summer months.

Following implementation of the new copper sulfate treatment procedure described in Section 5.3.1.5, Algal Blooms, all SBA plants evaluated in this report noted an improvement with taste and odor in summer 2000. While encouraging, more data are required before determining the success of this procedure. It is possible that algal numbers in summer 2000 were naturally low; therefore, taste and odor issues would not have been a concern, regardless of copper sulfate applications. Comparisons between algal numbers or taste and odor constituents at Banks Pumping Plant relative to the SBA will have to be examined over several summer bloom seasons to determine the efficacy of this treatment strategy. The new DWR copper sulfate-dosing regime appears promising, but further study is required before its success can be fully determined.

5.5.2 LAKE DEL VALLE

Recreation, grazing, and algal blooms are the most significant PCSs in the Lake Del Valle watershed. Wastewater treatment facilities and erosion related to land use changes could pose threats to water quality, but they were not found to be problems during this survey period.

Recreation activities at Lake Del Valle present a moderate threat to water quality. Body contact recreation and boating are potential sources of *Giardia* and *Cryptosporidium* in the lake. Pathogen issues for SBA contractors who use a combination of Lake Del Valle and SBA source water are discussed in Chapter 12. Boating is a major recreational activity at Lake Del Valle. Most boating activity occurs from May to October. The primary water quality concern associated with boating is MTBE contamination from motorized watercraft. MTBE contamination appears greatest near the boat ramp area and decreases with distance. Activities in and around campground areas, especially those near the water line, along trails, and parking areas can contribute to soil erosion and can cause increased turbidity in the lake.

The Del Valle watershed has a long history of extensive cattle-grazing operations around the edge of the lake, the dam area, and in the upper watershed. Cattle have historically had access to the lake but typically not from June through October when grass is scarce. There is some fencing, mostly around recreation areas, but much of the grazed lands are unfenced to the lake. Installation of fencing to keep cattle from reaching the lake is limited because of the high cost. Although grazing occurs in the SBA/Lake Del Valle watershed, water is normally not drawn from the reservoir until late summer/fall. Flushing of contaminants from the watershed into the lake occurs in the winter when Lake Del Valle water is generally not released to contractors. This may explain the relatively low fecal and *E. coli* bacteria counts observed at water treatment plants when Lake Del Valle water was utilized (see Chapter 12 for pathogen issues). There is a substantial wild animal population present, but because of the extensive undeveloped and rugged nature of the watershed, little is known of actual numbers of animals and their condition. Droppings from wild animals are a potential source of pathogens in the watershed during rainfall and have been reported by contractors as a water quality concern.

Nuisance algal growth has been a historical occurrence at Lake Del Valle and presents a moderate threat to water quality. The primary water quality problems associated with algal blooms are increased turbidity, which affects plant operations, and taste and odor resulting from production of MIB and geosmin. A primary cause of algal blooms in Lake Del Valle and the SBA is the high nutrient load in source water from the Sacramento/San Joaquin Delta. Local potential nutrient sources within the lake watershed (grazing and wild animals, sewage spills, internal lake recycling) may also be significant contributors to algal blooms. However, the relative contribution of SBA/Delta source water and watershed sources to the reservoir's algal blooms is not known.

An unknown amount of sewage was released into the Lang Canyon inlet on 24 May 1998. There was a sewage spill from a septic line lift station into the Lang Canyon stream inlet to Lake Del Valle. EBRPD staff reported that the spill was stopped and booms were installed around the area of the spill. Except for this 1 spill, the wastewater lagoons and all associated systems within the area operated properly within the report period. However, since the potential exists for spills or system failures to contribute pathogens, organic carbon, and nutrients to the lake, these activities may pose a moderate threat to water quality.

The Lake Del Valle watershed is highly susceptible to erosion. About 80% of the land in the drainage basin is classified as a severe erosion hazard because of its shallow soils and steep slopes. Because of these conditions, the Lake Del Valle watershed is extremely sensitive to land use changes such as urbanization and development. Arroyo Valle has deposited some 20,000 cubic yards of silt in the reservoir since the dam was built. The sediment load from the creek can cause elevated turbidities in the lake. Even limited land use changes such as construction of access roads or grading for construction, if not carefully planned, could accelerate soil erosion and/or landslide problems. Because of this, the watershed is very vulnerable, and there is a substantial potential threat to water quality if significant land use changes were to occur in the basin.

The primary agricultural activity in the watershed is livestock production. Because of the location and type of terrain prevalent in the watershed, other types of agricultural development are extremely limited. There are no herbicides or pesticides used in the lake. The herbicide Roundup is used, and Surflan is also used as a pre-emergent herbicide for terrestrial weeds. This potential contaminant source presents minimal threat to water quality.

5.6 WATERSHED MANAGEMENT PRACTICES

With 1 exception, there are no known watershed management programs in the Lake Del Valle watershed. This may be because much of the watershed area is private property. In contrast, the EBRPD actively manages the Lake Del Valle SRA. Much of its activity is focused on grazing management. In 1992, the EBRPD adopted Wildland Management Policies and Guidelines that further refined the program, establishing the current process of using grazing as a tool to maintain and enhance plant and animal resources and minimize fire hazards. The guidelines state:

> "The District will conserve, enhance, and restore biological resources to promote naturally functioning ecosystems. Conservation efforts may involve using controlled grazing, in accordance with Wildland Management Policies and Guidelines, prescribed burning, mechanical treatments, integrated pest management, and/or habitat protection and restoration. Restoration activities may involve the removal of invasive plants and animals or the reintroduction of native or naturalized species adapted to or representative of a given site."

The 1997 EBRPD Master Plan continued this process, providing that the district manages grazing in accordance with the Wildland Management Policies and Guidelines. The district also evaluates other vegetation management alternatives for their costs, benefits, and applicability to specific site conditions. The district policies and guidelines further proposes modifications to program practices, guidelines and/or management activities to achieve resource management and recreational use objectives.

A watershed management program (WMP) should be initiated at Lake Del Valle to coordinate existing and future watershed management activities and studies. Several contaminant sources and related water quality issues—for example, recreation/grazing and pathogens, boating and MTBE, algae and taste and odor—are of concern in the SBA and Lake Del Valle. Evaluation of these issues would greatly benefit from such an integrated WMP approach. As part of the implementation of the WMP, a watershed coordinator position should also be established to monitor land use changes and to work with landowners and agencies to encourage planning and land use practices that protect water quality. Any personnel working for the WMP should act as contacts for information on all watershed management practices and provide a clearinghouse of watershed information (recreational use, cattle-grazing, wastewater facilities operation, etc.).

A comprehensive study should be made of the major sources of nutrients to Lake Del Valle and the SBA. The study should address algal dynamics and nutrient cycling within the major reservoirs to better understand the processes controlling algal populations. This study should also coordinate with and include, if applicable, other studies undertaken for pathogens, MTBE, or other contaminants. Other studies should include but not be limited to:

- An evaluation of grazing practices along the SBA and in the Lake Del Valle watershed to involve private landowners who graze cattle in these areas, and
- An evaluation of the relationship between grazing and pathogen loading and its effects on water quality.

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Chapter 6 - San Luis Reservoir

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters								
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O
Recreation	6.3.1		○				◒		◒	
Wastewater Treatment/Facilities	6.3.2					○	○			
Animal Populations	6.3.3		○			◒	◒		◒	
Algal Blooms	6.3.4								○	◒
Agricultural Activities	6.3.5	○			○	○				
Traffic Accidents/Spills	6.3.6							○	○	
Geologic Hazards	6.3.7		○						◒	
Fires	6.3.8		○						◒	

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

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San Luis Reservoir

6.1 WATERSHED DESCRIPTION

The San Luis Reservoir is 12 miles west of the city of Los Banos on San Luis Creek between the eastern foothills of the Diablo Range and the west foothills of the San Joaquin Valley in Merced County. This major offstream reservoir of the joint-use San Luis Complex stores excess winter and spring flows from the Sacramento-San Joaquin Delta and supplies water to service areas for both the State Water Project (SWP) and the US Bureau of Reclamation's Central Valley Project (CVP). The San Luis Reservoir and its watershed encompass 85 square miles (Figure 6-1). Water is used for agricultural, industrial, municipal, and recreational uses as well as for fish and wildlife enhancement.

6.1.1 LAND USE

The California Department of Water Resources (DWR) and US Bureau of Reclamation (USBR) own most of the San Luis Reservoir watershed. A small fraction of the watershed mostly on the south side of the reservoir outside the recreational boundaries is private agricultural land (Montoya pers. comm.). California State Parks manages recreational use of the land adjacent to the shoreline. The US Bureau of Land Management (BLM) manages the remainder of the watershed.

The San Luis watershed is mostly undeveloped except for recreational improvements. The BLM allows some seasonal livestock grazing on its land near the reservoir, but no farming or land development has been permitted. The semi-arid climate in combination with generally poor to moderate grass cover and steep slopes limit livestock grazing activities around the reservoir watershed. Intermittently, cattle and sheep graze on non-native grassland in the watershed.

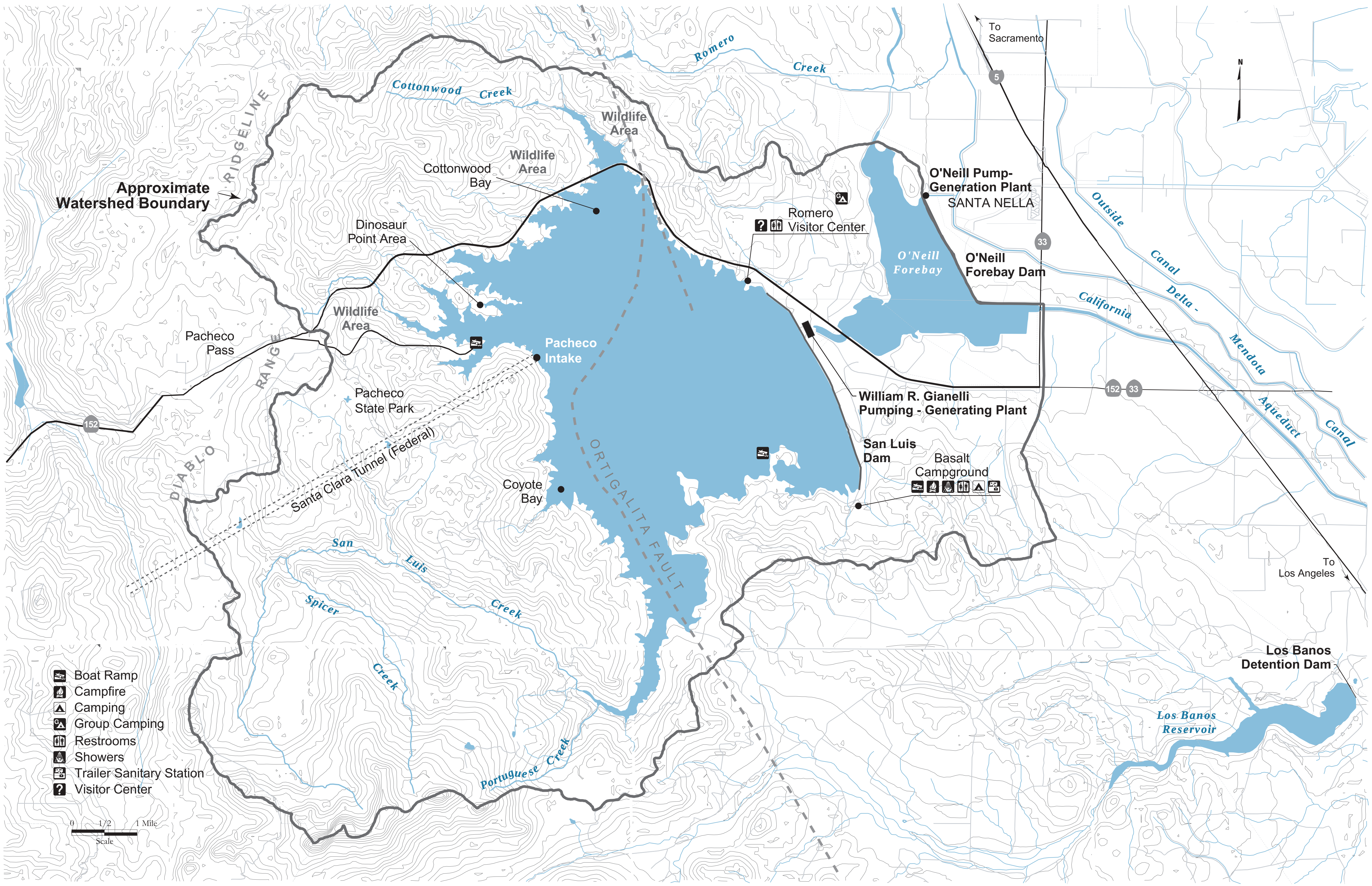
California State Parks operates the San Luis Reservoir State Recreation Area (SRA). Extensive recreational development and 3 wildlife areas are around the reservoir.

6.1.2 GEOLOGY

The San Luis Reservoir watershed is on the eastern portion of the Diablo Range, along the western edge of the San Joaquin Valley near Santa Nella (Figure 6-1). Surface geology is predominated by the Tulare Formation developed during the Plio-Pliestocene Age, which generally consists of San Joaquin Valley floor sediments exposed along the eastern edge of the Coast Range. The Tulare Formation was uplifted, broadly folded, locally faulted, and dissected by stream incision in late-Quaternary time (DWR 2000a). Late Pleistocene to recent fluvial deposits rest on the Tulare Formation, often as terrace deposits along modern stream channels. The underlying Great Valley Sequence bedrock consists mainly of conglomerate with interbedded shale and sandstone, and minor sandstone of the Panoche Formation (DWR 2000a).

The watershed has several rock types. The northwestern portion of the reservoir mainly is composed of a melange of sheared fragmented Franciscan Complex rocks (California 1977). The area near B.F. Sisk San Luis Dam and the O'Neill Forebay area east of the reservoir are primarily nonmarine sedimentary rock, and include loosely consolidated sandstone, shales, and gravels. A small portion of the northern shore of the O'Neill Forebay contains terrace deposits from various sources from the Great Valley Syncline. These deposits are both consolidated and semiconsolidated and may be categorized as mostly nonmarine sedimentary rock, possibly including some marine deposits. The surface geology of the watershed for the remainder of the reservoir complex is very similar to that of Lake Del Valle, with the exception of a small area of igneous rock along the Ortigalita fault north of the lake. The igneous rock is mostly serpentinite but may include peridotite, gabbro, and diabase.

Figure 6-1 San Luis Reservoir



6.1.3 SOILS

Soils in the reservoir watershed are mostly coarse-textured mineral soils with low organic carbon content and low water-holding capacity. Some relatively finer textured soils develop on lower elevations near O'Neill Forebay. Dominant soils in the watershed include the Millsholm series, Oneil series, Fifield series, and the Honker series (USDA 1990). Other important soils include the Akad, Appollo, Conosta, Franciscan, Gonzaga, Quinto, Damluis, Bapos, and the Los Banos series (USDA 1990). These soils often occur in combinations, associations, or complexes with one another or with rocks, particularly in steep slopes of the watershed. On low terraces of the watershed (slopes from 0% to 15%), soils are deep, well-drained clay loams. On the foothills (15% to 30% slopes), soils are moderately deep silt and clay loams. On sloping to steep slopes (30% to 75% slopes), soils are mostly well drained sandy, gravelly, cobbly, or bouldery loams. Most soils in the watershed are susceptible to water and wind erosion, and soil loss may occur during heavy surface runoff.

6.1.4 VEGETATION

Vegetation of the mostly uncultivated San Luis watershed is composed of Valley Grasslands with Valley Oak Woodlands near drainage areas (Schoenherr 1992). Primary plant species include filaree (*Erodium botrys*), soft chess (*Bromus hordeaceus*), foxtail fescue (*Vulpia myuros (L.) C. Gmelin var. hirsuta (Hackel) Asch. & Graebner (Poaceae)*), blue oak (*Quercus douglasii*), interior live oaks (*Quercus wislizenii*), valley oak (*Quercus lobata*), ripgut brome, Californian buckwheat (*Eriogonum fasciculatum var. polifolium*), and red brome (*Bromus madritensis ssp. Rubens*). Tree canopies vary from 15% to 50% (USDA 1990). Oak woodlands dominate the foothills with blue oaks, interior live oaks (*Quercus wislizenii*), and valley oak (Schoenherr 1992). In areas of the watershed that have been grazed, native species mostly have been eliminated. Needle grass (*Stipa/Nasella sp.*) and sparegrass (*Stipa/Nasella sp.*) are the dominant native grasses (Schoenherr 1992).

6.1.5 HYDROLOGY

The surface water hydrology is typical of the semi-arid watersheds in the southwest part of the San Joaquin Basin. There are 6 major creeks in the watershed. Five creeks—Hidden Creek, Portuguese Creek, Salt Creek, San Luis Creek, and Spicer Creek—are in the southwest sector; Cottonwood Creek is in the northwest (Figure 6-1). The watershed area is 85 square miles with the reservoir comprising nearly 25% of the total. The daily maximum temperature in this part of the San Joaquin Valley ranges from 80 to 100 degrees Fahrenheit in summer and from 45 to 65 degrees Fahrenheit in winter. Records from the nearby Los Banos Dam precipitation station (operated by DWR) show an average annual rainfall of 9.7 inches between 1961 and 2000. A maximum annual rainfall of 24.1 inches occurred in 1998, and a minimum of 3.5 inches occurred in 1989 at the same station (DWR 2001).

During the 1950 to 1962 water years, the US Geological Survey maintained a streamflow monitoring station on San Luis Creek at the current Sisk Dam site. The average annual streamflow for that period was 4,260 acre-feet (af) (USGS 1963). According to the San Joaquin Valley Water Year Hydrologic Classification Index, a comparative index maintained by the Division of Flood Management of DWR, the index average for the period from 1950 to 1962 was about 90% of normal (DWR 2001a). Based on this index, the average annual streamflow for the San Luis Creek station would be about 4,700 af. Table 6-1 shows the estimated total annual natural inflow for 1996 to 1999. The data indicate that during this period the natural inflow from the watershed was insignificant relative to the reservoir's total capacity.

Table 6-1 Estimated Annual Natural Inflow to the San Luis Reservoir (acre-feet)

1996	1997	1998	1999
5,700	7,600	8,300	4,700

6.2 WATER SUPPLY SYSTEM

The B.F. Sisk San Luis Dam forms the San Luis Reservoir. The dam is 18,600 feet long and 305 feet high. Water enters and exits through a common inlet/outlet tower. The USBR also pumps water out of San Luis Reservoir in a westerly direction to San Felipe Division Water contractors through the Pacheco Pumping Plant and the Santa Clara Tunnel (Figure 6-1).

The reservoir was completed in 1967 and first filled in 1969. It has a capacity of 2,027,840 af, a surface area of about 12,700 acres, and a shoreline of about 65 miles (DWR 1997). Maximum water depth of the reservoir is 295 feet; average water depth, 160 feet. About 67,000 af of water is lost annually to evaporation, considering the gain by annual rainfall. Most of the reservoir's water is pumped from the California Aqueduct and the Delta-Mendota Canal (DMC) via the O'Neill Forebay through the Gianelli Pumping-Generating Plant during winter and spring. The San Luis Reservoir water is delivered to San Joaquin Valley, Santa Clara Valley, and Southern

California when water supply in the California Aqueduct and the DMC is insufficient.

The section of SWP near San Luis Reservoir is operated and maintained by DWR's San Luis Field Division. Major facilities that make up this part of the system include the Gianelli Pumping-Generating Plant and O'Neill Forebay (Figure 6-1). Water diverted from the Delta by the Banks Pumping Plant enters the northern end of O'Neill Forebay. The water either flows through the forebay into the California Aqueduct on the southern side of the forebay or is lifted by the Gianelli Pumping-Generating Plant into San Luis Reservoir. The forebay also receives water from the DMC via the USBR's O'Neill Pump Generation Plant. The Santa Clara Valley Water District (SCVWD), a CVP contractor, has been receiving water from San Luis Reservoir through the Pacheco Intake (Figure 6-1) since 1965. The total annual maximum entitlement for SCVWD is 152,000 af, which is pumped through the Pacheco Pumping Plant on the western side of the reservoir near the Dinosaur Point area (Matthews pers. comm. 2001)The Gianelli Pumping-Generating Plant has 8 pumps with a total capacity of 11,000 cfs. Power is generated by reversing the water flow (17,600 cfs) from San Luis Reservoir to O'Neill Forebay.

6.3 POTENTIAL CONTAMINANT SOURCES

6.3.1 RECREATION

The San Luis Reservoir SRA is one of the most popular recreational facilities in the SWP. Activities in San Luis Reservoir include boating, camping and picnicking, fishing, swimming and water skiing, seasonal hunting, and sightseeing. Among the major potential contaminant sources (PCSs), recreation presents the greatest potential threat to water quality in the reservoir.

6.3.1.1 Body Contact Activities

Potential contamination of water in the reservoir through body contact recreational activities appears to be limited. Swimming, waterskiing, and windsurfing in the San Luis Reservoir are not restricted, but the area around San Luis Reservoir is often very windy. Gusty winds come up suddenly, and strong winds often cause boats to capsize. Occasionally, boaters, surfers, and swimmers drown. Use of the reservoir for swimming is light. Most swimming activities occur at the San Luis Creek area on the west side of O'Neill Forebay where a swimming area is roped off (Hardcastle pers. comm.).

6.3.1.2 Nonbody Contact Activities

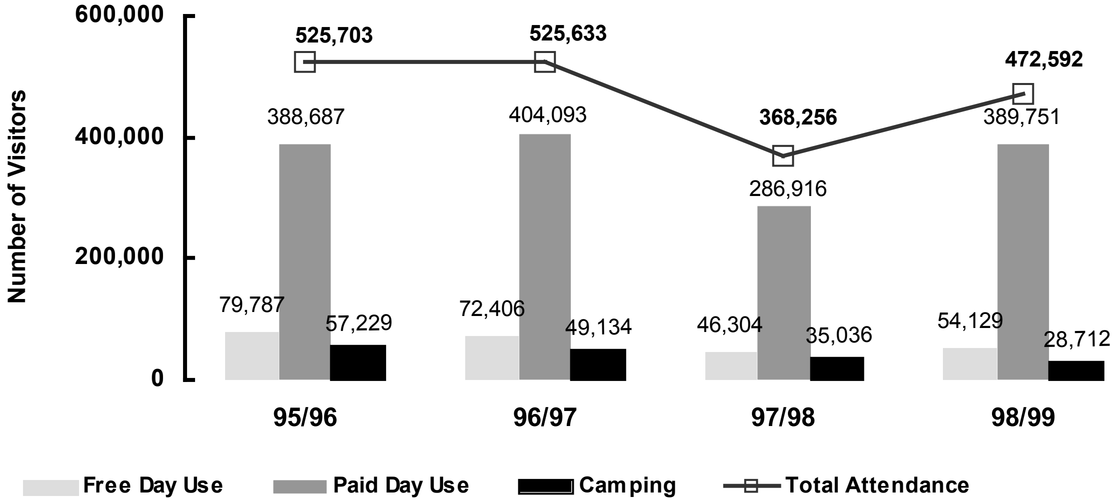
Many people visit the reservoir. Two major recreational areas, the Dinosaur Point Area on the west and the Basalt Area to the south, are close to the reservoir. The Romero Overlook Visitors Center on the east rim of the reservoir is 1 of the 3 visitor centers of the SWP.

Figures 6-2 and 6-3 summarize recreational use statistics in the San Luis Reservoir SRA (San Luis Reservoir, O'Neill Forebay, and Los Banos Reservoir) for the past 5 years. An average 473,000 persons visited the San Luis Reservoir SRA annually from 1995 to 1999 (Figure 6-2). The majority were paid day-users, and more than 10% of the visitors were campers (Figure 6-2). These numbers reflect visitors to all 3 reservoirs in the SRA. A DWR study suggests that approximately 42% of the SRA visitors went to San Luis Reservoir (Thrapp 1989). Therefore, an average of about 200,000 persons visited the San Luis Reservoir annually from 1995 to 1999.

Recreational area attendance is expected to rise because California State Parks lowered all use fees in the San Luis Reservoir SRA in 2000. During the 1999/2000 fiscal year, visitors to the Romero Overlook Visitors Center alone reached 207,380 (Biez pers. comm.).

The large number of visitors requires waste collection and disposal facilities, which include showers, toilets, wastewater treatment, septic systems, fish-cleaning amenities, and garbage collection sites. The Basalt Area is equipped with domestic water and a community wastewater collection, pumping, and disposal system. See Section 6.3.2, Wastewater Treatment/Facilities.

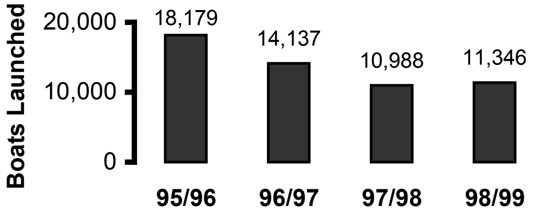
Figure 6-2 Visitors to the San Luis Reservoir Watershed, 1996 to 1999



Source: California State Parks Database, provided by Barry Montoya, DWR O&M, Feb 2001

There are no floating toilets on the reservoir. A portion of the shoreline is fenced and relatively clean. There are 2 major boat launch ramps in the San Luis Reservoir, 1 at the Basalt Area and the other at the Dinosaur Point Area (Figure 6-1). A variety of boats, including power and sail boats, rubber rafts, sailboards, canoes, and kayaks, are allowed to operate on the reservoir. An average of 13,700 boats was launched each year in the San Luis Reservoir SRA from 1995 to 1999 (Figure 6-3). The number of boats launched only in the San Luis Reservoir was not available.

Figure 6-3 Boating in the San Luis Reservoir



Source: California State Parks Database, provided by Barry Montoya, DWR O&M, Feb 2001

Boating activities in the reservoir directly contribute a variety of potential contaminants to the reservoir. These contaminants include diesel fuels, gasoline and their breakdown hydrocarbons, and gasoline additives such as MTBE. Turbidity and pathogens may also increase because of littering and wave actions. Wave actions from boating activities can cause erosion and landslides. However, the largest wave actions are caused by wind fetch across the reservoir. High winds can occur suddenly and pose a threat to boaters. In March 1997, 2 major landslides occurred because of boat wave-wash (DWR 2000b).

Runoff from campgrounds, roads, parking lots, and other recreational facilities in the SRA are potential sources of turbidity and pathogens in the reservoir. Bodies of humans and animals occasionally were found in the reservoir. Three drowning victims were discovered between 1996 and 2000 (DWR 2000c). Detailed records of dead animals are not available, but they were likely to be present in the reservoir because hunting of migratory waterfowl, pheasants, quail, rabbits, deer, and feral pigs is allowed in the reservoir area.

6.3.2 WASTEWATER TREATMENT/FACILITIES

Wastewater facilities include toilets, a recreational vehicle dumping and disposal system, and pumping stations. Treatment is provided by 2 oxidation/evaporation ponds at the northeast slope of the watershed. The ponds are constructed at deep slopes and are quite distant from the reservoir. Although seepage and overflow to the reservoir is unlikely, the potential for contamination to water in the reservoir is unknown. The Dinosaur Point Area and the remaining recreational development around the reservoir use portable chemical toilets, which have been well maintained. The Romero Overlook Visitors Center has wastewater service with disposal in nearby evaporation/percolation ponds.

6.3.3 ANIMAL POPULATIONS

6.3.3.1 Livestock Grazing

Grazing is allowed on certain public lands of the watershed between October and April, which coincides with the rainy season. For example, at the Pacheco State Park (Figure 6-1), about 2,000 acres of the 7,000 acres are contracted for cattle grazing, and up to 640 cattle are allowed from October to March of each year (Hardcastle pers. comm. 2001). The total number of animals and grazing days during the survey period is not known. Most of the area outside the recreational boundaries on the south side of the reservoir is privately owned and fenced for cattle grazing (Montoya pers. comm. 2001). Grazing on private lands is generally more intense than on public lands in the watershed. Grazing activities may cause runoff and erosion and is a potential source of nutrients, turbidity, and pathogens. DWR staff report that cattle have been seen in the water near Cottonwood Bay.

6.3.3.2 Wild Animal Populations

Figure 6-1 shows the approximate location of 3 wildlife areas near the reservoir. California State Parks manages the areas. Major species in the general watershed include cattle, feral pigs, elk, black bear, and black-tail deer (Gerstenberg pers. comm. 2001). Wildlife may be a PCS, but the impact is unknown. Most wildlife is on nongrazed land designated wildlife refuges, parks, or other recreational area. These nongrazed areas are usually covered with grass that may be 3 feet tall. The filtering action of such grass prevents animal wastes from entering the reservoir by surface runoff (Gerstenberg pers. comm. 2001). A tule elk herd resides nearby and has free run of the reservoir area (Montoya pers. comm.). Droppings from large populations of migrating waterfowl such as ducks and coots may be a water quality concern during winter months. The number of waterfowl landing in the reservoir depends on the growth of Swamp Timothy (*Heleochloa schoenoides*), a warm-season grass grown on moist soil and the most favored food of waterfowl in the grasslands. Along the reservoir banks and in dried areas, this grass germinates between February and September with optimal germination and growth occurring from mid-March to early May. When water in the reservoir recedes during this period, Swamp Timothy flourishes and attracts large populations of waterfowl to feed in the reservoir. As many 1 million birds landed in the reservoir during the last decade, and an average of 20,000 to 150,000 birds fed in the reservoir each year in recent years (Gerstenberg pers. comm. 2001).

6.3.4 ALGAL BLOOMS

Algal blooms are likely if other enrichment conditions are met. Nutrients in the reservoir were high during 1996 to 1999 and are discussed in Section 6.4.1.7, Nutrients. Taste and odor in the reservoir is a more serious water quality concern during drought years. In the fall, especially during drought years, a greater demand by SWP contractors creates a much lower water level in the reservoir. Because of the improved light penetration and greater likelihood of a thermocline in the reservoir, algal blooms mainly of blue-green *Aphanizomenon flos-aquae* are more likely to occur. During fall months, winds blow accumulated blue-green algae toward the intake, and taste and odor can be a concern.

The SCVWD is the only SWP contractor that withdraws water directly from the reservoir through the Pacheco Intake (see Figure 6-1). This intake is about 150 feet deep during normal reservoir operating conditions. Historical data suggest that algal blooms caused taste and odor problems for SCVWD during the drought years from 1992 to1993 (SCVWD 2001). During the survey period, however, SCVWD did not report any serious algal blooms, and taste and odor was not a serious water quality concern from 1996 to 1999, according to the flavor profile analysis records of SCVWD (SCVWD 2001). There were no drought years during this period, and precipitation records show that rainfall was heavy in 1995 and 1996 and reached a record high of 24.1 inches in the reservoir watershed during 1998. Because of less demand for water during the survey period, reservoir levels were relatively high. Strong winds mix surface water with water at greater depths, making it less likely that a thermocline will establish in the reservoir. Wind disturbances and the lack of a thermocline limited growth of blue-green algae (Janik pers. comm. 2001).

6.3.5 AGRICULTURAL ACTIVITIES

6.3.5.1 Pesticides

The herbicide Roundup is used around the reservoir for weed control. Roundup contains the active ingredient glyphosate, which is not mobile in soils. Use of Roundup in the watershed is not likely to affect water quality in the reservoir.

6.3.5.2 Agricultural Drainage

The major watershed drainage to the reservoir is from Cottonwood and San Luis creeks. Wheat and barley farms and some orchards are scattered in the reservoir watershed, but they are not close to the reservoir (Gerstenberg pers. comm. 2001). Because many farmers practice conservation measure, drainage is likely to be minimal (Gerstenberg pers. comm. 2001). Although agricultural drainage to the reservoir has not been estimated, it is generally believed that the limited number of barley and wheat farms in the watershed are away from the reservoir; therefore, runoff and drainage are considered a minor threat to water quality in the reservoir.

As discussed before, there is animal grazing on some private lands.

6.3.6 TRAFFIC ACCIDENTS/SPILLS

The reservoir is flanked by Highway 152 on the east and north sides. One section of highway crosses above an arm of the reservoir. Runoff from approximately 10 miles of this highway drains to the reservoir. Oil, grease, and other hydrocarbons from the road may enter the reservoir through runoff or wind. Highway 152 is a major transportation corridor in the area and a major route for trucks hauling hazardous wastes from coastal industries to the Kettleman Hills hazardous waste disposal facility in Kings County. Spills could result from trucking accidents. No documented spills or accidents occurred in the watershed from 1996 to 2000 (Montoya pers. comm. 2001).

6.3.7 GEOLOGIC HAZARDS

San Luis Reservoir is in a seismically active area and is close to 3 geologic faults. The Ortigalita fault passes under the reservoir, and the Calaveras and the San Andreas faults are 23 and 28 miles away, respectively. These faults and their segments can cause earthquakes at or near the reservoir.

From May 1984 to December 1999, 3 earthquakes with magnitudes of 3 to 4 occurred within 10 miles of the reservoir. One was in the reservoir itself, and another in the O'Neill Forebay. Within 46 miles of the reservoir, 86 earthquakes with magnitudes of 4 to 5 occurred. Within 82 miles of the reservoir, 12 earthquakes ranging from 5 to 6 magnitude occurred. Within 154 miles, 1 earthquake had a magnitude of between 7 and 8 in Santa Cruz County (DWR 2000b).

The wave actions of seismic and boating activities often cause landslides and erosion in the reservoir rims and embankments. For example, 2 major slide areas were discovered in March 1997. One was a boat wave-wash area at the base of the road embankment next to the entrance road to the Romero Overlook Visitors Center. This wave-wash area was 100 feet long and 8 feet high (DWR 2000b). The 2nd slide area, the largest identified during the 1997 inspection, was on the north shore of the reservoir parallel to Highway 152 in an excavation waste pile. The estimated volume of this slide was between 5,000 and 6,000 cubic yards (DWR 2000b).

The reservoir is also surrounded by hills and mountainous areas on both the south and west sides. The topography of the watershed, which is composed of numerous downstream slopes, is prone to landslides and erosion. Neither the frequency of such slides and erosion nor the potential for increases in turbidity or other water quality parameters of concern in the reservoir has been determined, but landslides and erosion are still considered moderate threats to water quality.

6.3.8 FIRES

The Valley Grassland vegetation in the San Luis Reservoir watershed is prone to natural fires. The area's semi-arid climate and windy conditions increase fire hazards in the area, especially along Highway 152, where fire incidents occur each year. Each fire burns from 10 to 150 acres (Gerstenberg pers. comm. 2001). Burned areas also become more susceptible to wind and soil erosion. The effect of this runoff on the reservoir's water quality has not been determined. However, runoff from the burned areas has the potential to increase nutrients, turbidity, and sediment loads in the reservoir.

6.4 WATER QUALITY SUMMARY

6.4.1 WATERSHED

In this and the other reservoir water quality sections, comparisons are made between contaminant concentrations in SWP source water and maximum contaminant levels (MCLs) for finished drinking water. MCLs are usually applied to finished water, but they are useful as a conservative indicator of source water contaminants that concern utilities and will require removal during the treatment process to meet finished water standards. If source water concentrations are below MCLs, then these contaminants are not as likely to be of concern to finished water supplies.

The comparisons also serve to focus on 1 or more PCSs associated with the contaminant of concern and allow the development of appropriate recommendations for actions. Although all data examined were below MCLs, land use and source water information suggested the possibility of several water quality concerns:

- High turbidity and total dissolved solids (TDS) levels in the reservoir,
- Algal blooms and taste and odor problems,
- High total organic carbon (TOC) and bromide concentration from the source water,
- MTBE from recreational watercraft in the reservoir, and
- Pathogen contamination through recreation and livestock grazing.

DWR's Division of Operations and Maintenance (O&M) routinely monitors water quality in the reservoir at the Pacheco Intake (Station SL005). Table 6-2 summarizes that water quality data for the period 1996 to 1999. Many organic compounds such as pesticides and petroleum byproducts were sampled but were not found above their reporting limits (Janik pers. comm. 2001).

Each statistic presented in Table 6-2 was calculated from only those analyses with data above the method reporting limit. Only constituents with 2 or more positive detects were presented. The number of positive detects and the total number of measurements were also presented in the table.

Table 6-2 San Luis Reservoir Water Quality Summary, Jan 1996 to Dec 1999[a]

Parameter (mg/L)	Mean[b]	Median[b]	Low[b]	High[b]	Percentile 10 to 90%[b]	Reporting Limit	# of Detects/ Samples
Minerals							
Calcium	19.9	19.8	18.0	26.0	19.0-22.0	1.0	48/48
Chloride	65	64	48	78	56-76	1	48/48
Total Dissolved Solids	248	245	194	295	224-277	1	48/48
Hardness (as $CaCO_3$)	100	99	90	123	92-110	1	48/48
Alkalinity (as $CaCO_3$)	78	78	71	89	73-83	1	48/48
Conductivity (umhos/cm)	448	446	363	501	403-488	1	48/48
Magnesium	12.1	12.0	11.0	14.0	11.0-14.0	1.0	48/48
Sulfate	36	35	27	45	31-42	1	48/48
Turbidity (NTU)	3	2	1	12	1-5	1	29/38
Minor Elements							
Aluminum	0.013	0.013	0.011	0.014	-	0.01	2/52
Arsenic	0.002	0.002	0.002	0.004	0.002-0.003	0.001	48/53
Boron	0.2	0.2	0.1	0.2	0.1-0.2	0.1	48/48
Chromium	0.006	0.006	0.005	0.007	0.005-0.007	0.005	5/53
Copper	0.004	0.002	0.002	0.014	0.002-0.009	0.001	30/53
Iron	0.011	0.009	0.006	0.021	0.006-0.106	0.005	5/52
Manganese	0.048	0.012	0.005	0.312	0.006-0.106	0.005	8/47
Selenium	0.001	-	0.001	0.001	-	0.001	2/47
Zinc	0.015	0.012	0.006	0.042	0.006-0.028	0.005	6/52
Nutrients							
Total Nitrogen[c]	1.0	1.1	0.7	1.4	0.8-1.0	0.1	27/27
Nitrate (as N)	0.6	0.6	0.1	0.9	0.3-0.8	0.1	45/47
Ammonia (dissolved)	0.03	0.02	0.01	0.10	0.01-0.06	0.01	22/47
Total Phosphorus	0.11	0.11	0.05	0.18	0.09-0.14	0.01	45/46
Orthophosphate	0.08	0.08	0.02	0.13	0.06-0.11	0.01	45/46
Miscellaneous							
Bromide	0.20	0.20	0.18	0.22	0.18-0.22	0.01	12/12
Total Organic Carbon[d]	2.7	2.7	2.0	4.1	2.2-3.1	0.1	92/92
pH	7.7	7.7	7.2	8.6	7.3-8.2	0.1	22/22

[a] Data were from DWR O&M Database, May 2000.

[b] Nondetects were not used for computation of these statistics.

[c] Total nitrogen was the sum of Kjeldahl nitrogen and nitrate.

[d] TOC data provided by Jeffrey Janik, DWR O&M, Feb 2001.

6.4.1.1 Minor Elements

Minor elements detected at low concentrations in 2 or more samples included aluminum, arsenic, boron, chromium, copper, iron, manganese, selenium, and zinc. In general, these elements are not considered a water quality concern in the reservoir. Minor elements with positive detection included aluminum, arsenic, boron, chromium, copper, iron, manganese, selenium, and zinc. Results for the minor elements in Table 6-2 represent the dissolved fraction. However, MCLs are based on total concentrations; therefore, strict comparisons between found concentrations and drinking water MCLs were not made.

Copper, iron, manganese, and zinc affect aesthetic quality of drinking water. During 1996 to 1999, they were detected at concentrations below their respective MCLs except for manganese (Table 6-2). The MCL for manganese is 0.05 mg/L. Among the 47 monthly samples, 8 samples had manganese above its reporting limit, and concentrations ranged from 0.005 to 0.312 mg/L. The sample that exceeded the MCL of manganese was in August of 1997 with a concentration of 0.312 mg/L. Manganese dropped below its reporting limit of 0.005 mg/L in September of 1997. This single incidence of high manganese was not likely to impact taste and order of water in the reservoir.

Two nonmetallic minor elements, arsenic and selenium, were detected in low concentrations during 1996 to1999. Arsenic was present in 90% of the samples collected at concentrations ranging from 0.002 to 0.004 mg/L (Table 6-2). These concentrations are much lower than 0.01 mg/L, California Department of Health Services (DHS) recently proposed MCL for arsenic. Selenium was detected at 0.001 mg/L in 2 of the 47 monthly samples during the survey period. The DHS MCL for selenium is 0.05 mg/L. Therefore, arsenic and selenium were not considered a threat to water quality in the reservoir.

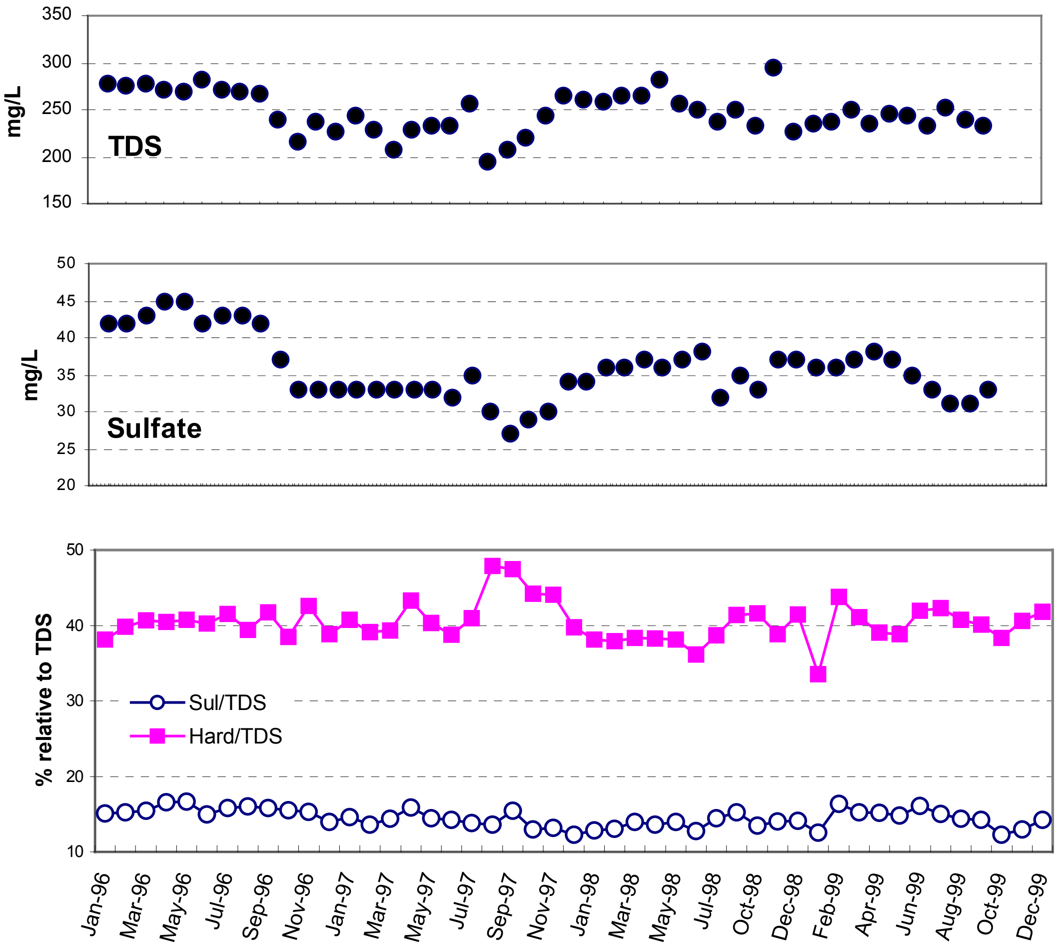
6.4.1.2 Total Dissolved Solids

TDS concentrations ranged from 194 to 295 mg/L and averaged 248 mg/L, significantly lower than the established drinking water MCL of 500 to 1,000 mg/L. TDS did not change significantly within a year nor from year to year (Figure 6-4). Sulfates and carbonates constituted a significant portion of the TDS. Sulfates ranged from 27 to 45 mg/L and averaged 36 mg/L. Concentrations of chlorides were from 48 to 78 mg/L and averaged 65 mg/L. Both the sulfates and chlorides were much lower than their MCL of 250 to 500 mg/L.

Conductivity was not high in the reservoir, and seasonal variations were small. From 1996 to 1999, conductivity ranged from 363 to 501 µmhos/cm and averaged 448 µmhos/cm. The MCL for conductivity is 900 to 1600 µmhos/cm.

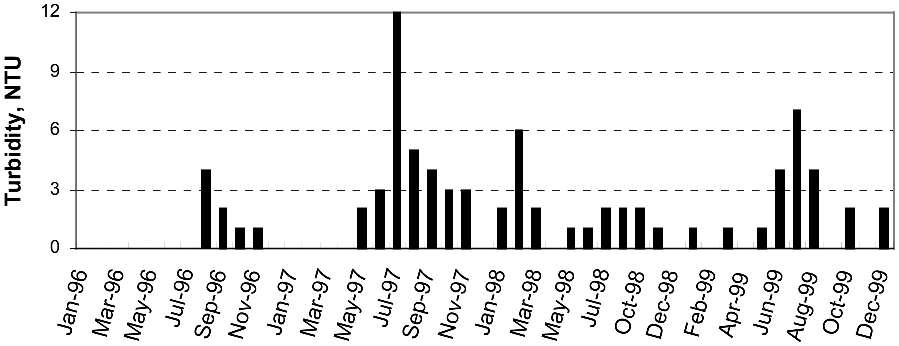
From 1996 to 1999, pH ranged from 7.2 to 8.6 with an average of 7.7. Most pH values were from 7.3 to 8.2, which fell within the drinking water MCL of 6.5 to 8.5. The pH measured at 8.6 in both July and August of 1998. It is unknown what caused the high pH during the 2-month period. As discussed in Chapter 5, this increase in pH and the decrease in nutrients (nitrogen in particular) may have resulted from algal blooms.

Figure 6-4 Total Dissolved Solids and Sulfates in San Luis Reservoir



Source: DWR O&M Database, May 2000

Figure 6-5 Turbidity in the San Luis Reservoir



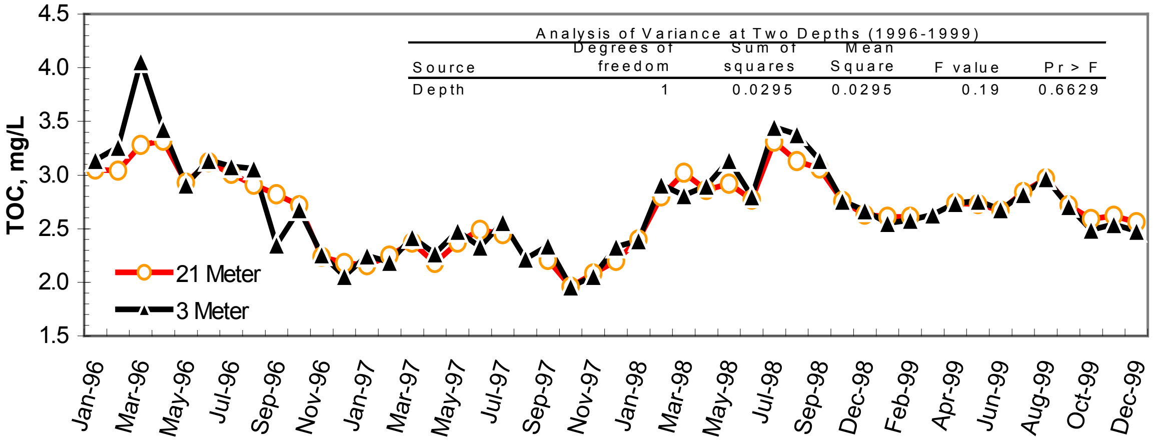
Source: DWR O&M Division Database, May 2000

6.4.1.3 Turbidity

Monthly turbidity data and seasonal variations during 1996 to1999 are summarized in Table 6-2 and Figure 6-5. The turbidity of 25% of the samples was below the reporting limit of 1 NTU. Turbidity for positive samples ranged from 1 to 12 NTUs and averaged 3 NTUs. Although the average was below the MCL of 5 NTUs for finished drinking water, 3 monthly samples were greater than 5 NTUs. The generally low turbidity in the reservoir is associated with the low natural inflows from its natural watershed. Turbidity spikes can occur during heavy rain and perhaps when recreational use of the reservoir is heavy. Turbidity in the reservoir may also come from extensive recreational activities in the watershed and source water from both the California Aqueduct and the DMC. Wave-washes from both wind and boat activities could contribute to turbidity, but supporting data were not available.

Data in Figure 6-5 appear to show that turbidity was highest in summer months, but insufficient data make it difficult to determine if recreational activities contributed to this increase in turbidity.

Figure 6-6 Monthly Total Organic Carbon Measured at 2 Depths



Analysis of Variance at Two Depths (1996-1999)

Source	Degrees of freedom	Sum of squares	Mean Square	F value	Pr > F
Depth	1	0.0295	0.0295	0.19	0.6629

Source: SCVWD Feb 2001

6.4.1.4 Total Organic Carbon (DBP Precursors) and Alkalinity

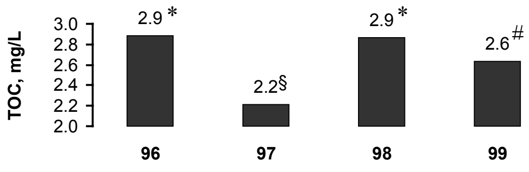
SCVWD monitored TOC monthly (SCVWD 2001). Samples were collected at the Pacheco Intake in the San Luis Reservoir from 2 different depths—3 meters and 21 meters—during each sampling day. Carbon concentrations changed little with depth except in March 1996 (Figure 6-6). An analysis of variance showed no significant difference between carbon concentrations measured at the 2 depths at the same site during the same sampling day TOC ranged from 2.0 to 4.1 mg/L with an average of 2.7 mg/L (Table 6-2). These TOC levels are considered high for source water but were lower than TOC measured at the Banks Pumping Plant (see Chapter 5)

Alkalinity of water in the reservoir ranged from 71 to 89 mg/L and averaged 78 mg/L (Table 6-2). According to the proposed Stage 1 Disinfectants and Disinfection Byproducts Rule (D/DBP Rule) and Interim Enhanced Surface Water Treatment Rule (IESWTR), 25% to 35% TOC removal is required for water in the reservoir.

There was no apparent trend in carbon levels within each year except in 1996 when carbon levels appeared to be higher January to March and started to decline the following months (Figure 6-6). There were significant differences in carbon levels among different years. The average TOC in both 1996 and 1998 was 2.9 mg/L, which was significantly higher than 1997 (Figure 6-7).

High TOC value in 1996 was possibly due to heavy rainfall in the watershed as well as high TOC in the California Aqueduct and the DMC. Rainfall was heavy in 1995 and heavier in 1996 in the San Luis Reservoir watershed. High TOC in 1998 was likely due to DMC water being the only source water from 14 January to 27 February 1998 because of a Banks Pumping Plant shutdown (see Chapter 8). TOC in DMC water was higher than normal from January to March 1998, probably attributable to the El Niño effect that caused heavy rainfall in California, especially in the Central Valley. Heavy runoff often followed heavy rainfall, resulting in increased TOC levels in the DMC.

Figure 6-7 Average Annual Total Organic Carbon Concentrations



Source: SCVWD Feb 2001
Note: Means followed by the same symbol are not significantly different at the 5% significance level by Duncan's Multiple Range Test.

Bromide, measured monthly in 1999, ranged from 0.18 to 0.22 mg/L with a mean of 0.20 mg/L (Table 6-2). These levels appeared to be higher than those in Southern California reservoirs (see Chapter 7) and exceeded a proposed drinking water protection standard of 0.05 mg/L. High bromide comes from source water from both the California Aqueduct and the DMC, which are affected by tidal inflows and seawater intrusion. Bromide in the DMC ranged from 0.04 to 0.42 mg/L from 1996 to 1999 (see Chapter 8).

6.4.1.5 MTBE

As discussed in Section 6.3, there are boating activities in the reservoir that could contribute MTBE. According to a 1997 study by the O&M, MTBE did not appear to be a serious water quality concern in the reservoir (Janik 1999). A total of 34 surface water samples were collected from May to October 1997. Sixteen of these samples were taken at 3 depths—0.5 meters, 8 meters, and 20 meters—at the trash racks where water from O'Neill Forebay enters the reservoir at the Gianelli Pumping-Generating Plant. Six samples each were collected at 0.5 meters at the Pacheco Intake, Dinosaur Point boat ramp, and Basalt Area boat ramp. Of the 34 samples analyzed, only 1 sample at the Dinosaur Point boat ramp measured at 0.002 mg/L.

6.4.1.6 Pathogens

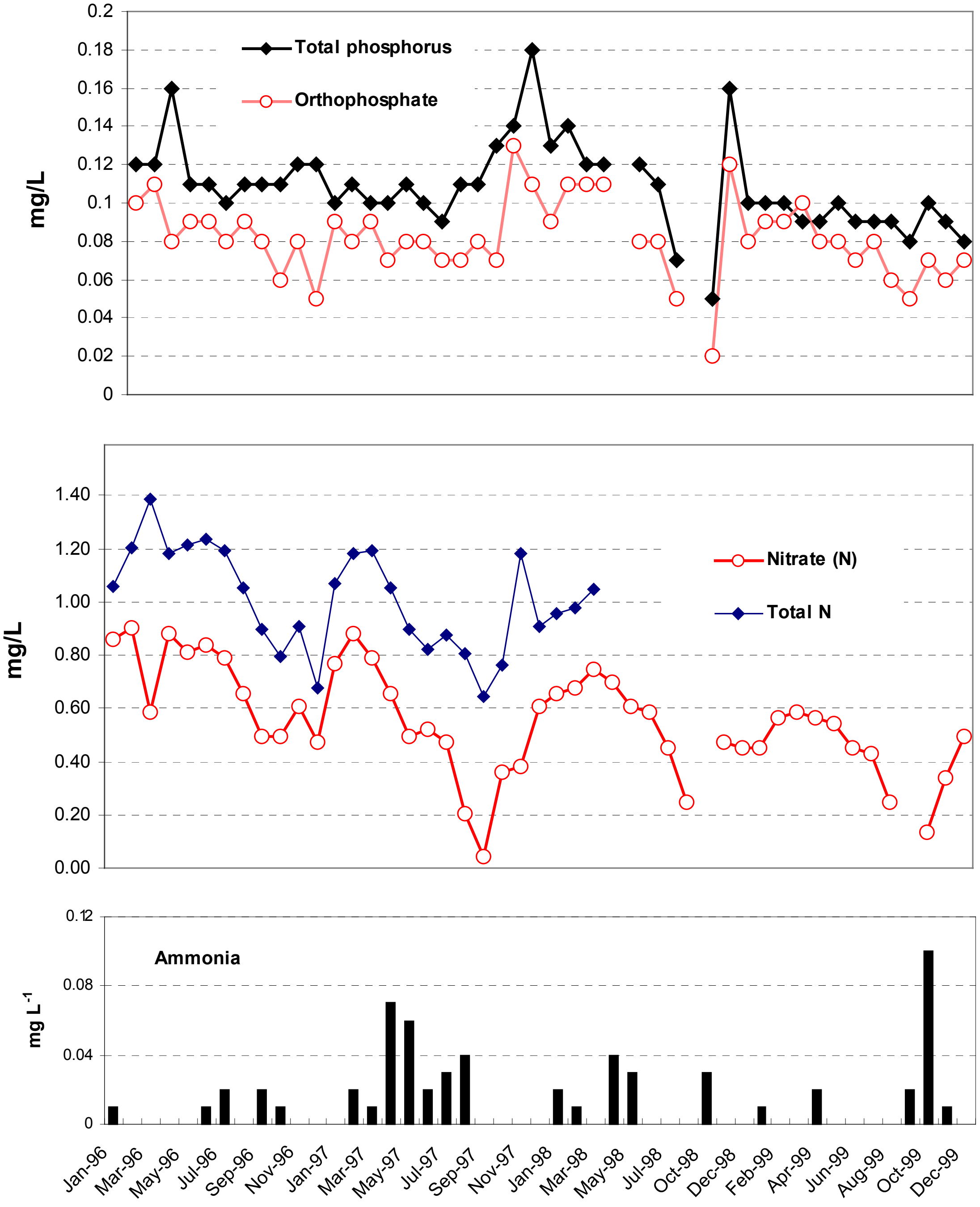
Pathogens are discussed in Section 6.4.1, Water Supply System, and in Chapter 12.

6.4.1.7 Nutrients

Among various nutrients, only nitrate and nitrite are considered mandatory health-related constituents with established drinking water standards. In this section nitrogen and phosphorus will be considered together. Nitrogen and phosphorus act collectively to stimulate growth of algae and, subsequently, may affect water quality by forming taste and odor-producing compounds.

Table 6-2 summarizes nutrient data collected in the reservoir from 1996 to 1999. Figure 6-8 presents seasonal variations of nitrogen and phosphorus. Total nitrogen ranged from 0.7 to 1.4 mg/L with an average concentration of 1.0 mg/L. More than 60% of the total nitrogen was in the nitrate form (Figure 6-8), which averaged 0.6 mg/L and was below the MCL of 10 mg/L. Nitrite was also monitored, but concentration was negligible and was not presented in Table 6-2. Concentrations of both total nitrogen and nitrate appeared to follow the same cyclic pattern in any given year. Nitrogen was generally higher in the earlier months of the year and declined in later months, although some variations occurred. Ammonia was frequently detected in the reservoir with concentrations ranging from 0.01 to 0.10 mg/L (Table 6-2).

Figure 6-8 Nutrient Concentrations in San Luis Reservoir



Source: DWR O&M Database May 2000

Total phosphorus was detected in 45 out of 46 samples and ranged from 0.05 to 0.18 mg/L with an average of 0.11 mg/L. The phosphorus was mostly as orthophosphate (Figure 6-8). Neither total phosphorus nor orthophosphate showed a seasonal variation as nitrogen did. Both forms of phosphorus remained relatively stable with some fluctuations, especially in July and August of 1998.

The changes of nitrogen and phosphorus appeared to coincide with the growth of algae in the reservoir. During July and August of 1998, levels of both nitrogen and phosphorus were significantly lower, and pH was 8.6 for the same 2-month period (see Section 6.4.1.2). It appeared that the decrease in nutrients during summer months was related to algal blooms in the reservoir.

According to a recent EPA nutrient criteria guidance for lakes and reservoirs (EPA 2000), when phosphorus and nitrogen in the reservoir are high, algal growth is likely if other enrichment conditions are met. Algal blooms are triggered by a complex interplay of nutrients, species interactions, and physical conditions such as temperature and light levels in the reservoir. Although nutrients were not limiting for algal blooms in the reservoir, other factors did not appear to favor algal blooms, as mentioned in Section 6.3.4. However, algal growth and taste and odor were not a problem with water from the San Luis Reservoir (Janik pers. comm. 2001).

6.4.2 WATER SUPPLY SYSTEM

As discussed earlier, the San Luis Reservoir is a major offstream storage facility. The SCVWD withdraws water from the reservoir for treatment and distribution through the district's Santa Teresa, Rinconada, and Penitencia water treatment plants. The SCVWD's annual entitlement for federal water, that is, water from San Luis Reservoir, is 152,000 af (Matthews pers comm. 2001). The Santa Teresa and the Rinconada water treatment plants use about two-thirds and one-third of this annual entitlement of federal water, respectively. The Penitencia Water Treatment Plant is not a major treatment plant for water from the reservoir (Matthews pers comm.). At the Santa Teresa Water Treatment Plant (WTP), water quality at the intake is routinely monitored.

Table 6-3 details sampling activities during 1996 to1999. The sampling dates included in Table 6-3 are the dates when the source water for the plant was 100% water from the San Luis Reservoir. Table 6-4 summarizes water quality data. Statistics in Table 6-4 were calculated from only those analyses with data above the method reporting limit as described in Section 6.4.1. Only constituents with 2 or more positive detection are presented.

Table 6-3 Sampling Activities at the Santa Teresa Water Treatment Intake[a]

Sampling Dates	Sampling Frequency	Constituents Analyzed
1 Jan 1996 to 30 Dec 1999	Daily	Alkalinity, conductivity, hardness, pH, and turbidity
12 Nov 1996 to 30 Dec 1999	Daily	Chloride
Jan 1996 to Aug 1999	Monthly	Calcium,TDS, TOC, and UVA
Jan 1996 to Dec 1999	Monthly	Bromide, sulfate, nitrate, and orthophosphate
Jan 1996 to Jul 1999	Monthly	Aluminum, arsenic, barium, chromium, copper, iron, manganese, nickel, and zinc

[a] Source water at the intake was 100% San Luis Reservoir water.

Table 6-4 Water Quality Summary at Santa Teresa Water Treatment Plant, Jan 1996 to Dec 1999[a]

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10 to 90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	22.0	22.0	19.0	28.0	20.1-23.0	1.0	22/22
Chloride	63	60	46	144	56-78	1	389/389
Total Dissolved Solids	239	241	140	315	207-276	1	20/20
Hardness (as $CaCO_3$)	96	96	55	134	87-106	1	564/564
Alkalinity (as $CaCO_3$)	71	72	57	108	64-74	1	560/560
Conductivity (μmhos/cm)	394	393	239	616	343-451	1	564/564
Sulfate	38	38	27	46	32-44	1	33/33
Turbidity (NTU)	2	2	1	19	1-4	1	562/564
Minor Elements							
Aluminum	0.32	0.28	0.04	0.79	0.09-0.55	0.01	17/17
Arsenic	0.003	0.002	0.002	0.005	0.002-0.004	0.002	9/17
Barium	0.04	0.04	0.04	0.05	0.04-0.05	0.05	16/17
Chromium	0.0007	0.0006	0.0005	0.0010	0.0005-0.0010	0.0005	8/17
Copper	0.005	0.004	0.002	0.013	0.003-0.007	0.001	16/18
Iron	0.195	0.158	0.093	0.350	0.106-0.318	0.005	17/17
Manganese	0.031	0.016	0.006	0.120	0.010-0.097	0.005	17/17
Nickel	0.003	0.000	0.002	0.004	0.002-0.004	0.002	6/17
Zinc	0.034	0.038	0.005	0.054	0.011-0.052	0.005	5/17
Nutrients							
Nitrate (as N)	2.6	2.4	0.2	5.1	0.7-4.5	0.1	32/32
Orthophosphate	0.25	0.24	0.09	0.39	0.18-0.36	0.01	33/33
Misc.							
Bromide	0.19	0.21	0.04	0.30	0.10-0.25	0.01	30/32
Total Organic Carbon	2.7	2.7	1.9	3.5	2.1-3.4	0.1	24/24
pH	7.7	7.7	7.1	8.9	7.4-8.1	0.1	566/566
UVA (cm^{-1})	0.096	0.090	0.069	0.143	0.071-0.129	0.001	20/20

[a] Data provided by Matthews pers. comm. Raw water was 100% from the San Luis Reservoir. Nondetects were not used for computation of statistics.

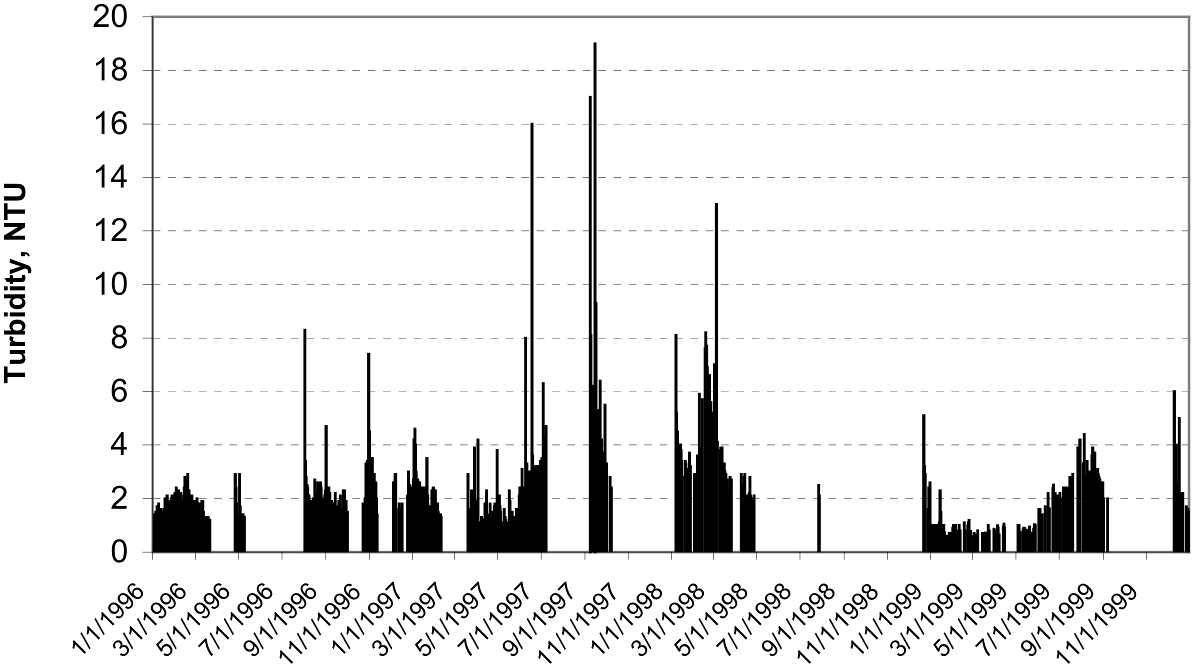
6.4.2.1 Minor elements

Average concentrations of all minor elements were below their respective MCLs (Table 6-4). This is consistent with findings presented in Section 6.4.1.

6.4.2.2 Turbidity

Turbidity of water at the Santa Teresa WTP intake ranged from 1 to 19 NTUs and averaged 2 NTUs (Table 6-4). Figure 6-9 shows the seasonal pattern of turbidity in the reservoir. The turbidity was occasionally high, particularly during winter months from 1996 to 1998 (Figure 6-9), and appeared to coincide with heavy rainfall. High turbidity may also occur in late summer and fall as shown in Figure 6-9 in 1997. Algal blooms caused this high turbidity. From late summer to fall each year, water levels in the reservoir are usually very low. Because water in the reservoir is high in nutrients (see Section 6.4.1.7 and Table 6-4), the nutrient-rich water causes algal blooms. The algae die and decay in the fall, which increases turbidity and produces offensive odors (Matthews pers comm.). When this happens, the Santa Teresa WTP stops taking water from the reservoir. Instead, the SCVWD takes its water mostly from the South Bay Aqueduct (Matthews pers. comm.)

Figure 6-9 Turbidity in Raw Water at the Santa Teresa Water Treatment Plant[a]



[a] Source was 100% from San Luis Reservoir.

6.4.2.3 Total Organic Carbon (DBP Precursors) and Alkalinity

TOC ranged from 1.9 to 3.5 mg/L and averaged 2.7 mg/L (Table 6-4). These TOC concentrations are considered high and were similar to those in the San Luis Reservoir (Table 6-2). Alkalinity ranged from 57 to 108 mg/L and averaged 71 mg/L, which were also similar to those in the San Luis Reservoir. According to the proposed Stage 1 D/DBP Rule and IESWTR, a 25% to 35% TOC removal is required for water in the reservoir.

Bromide was detected in 30 of the 32 monthly samples with an average of 0.19 mg/L (Table 6-4), which exceeded the proposed drinking water protection standard of 0.05 mg/L. These levels are approximately the same as those found in San Luis Reservoir (Section 6.4.1). As discussed earlier, high bromide comes from source water from both the California Aqueduct and the DMC, which are affected by tidal inflows and seawater intrusion.

Table 6-5 Pathogens in Source Water at Santa Teresa Water Treatment Plant, 1996 to 1999[a]

	Mean	Median	Low	High	Percentile Range (10-90%)	# detects/ total sampled
Total Coliform	15	8	2	500	2 - 23	120/160
Fecal Coliform	9	4	2	50	2 - 17	74/161
E. Coli	8	4	2	50	2 - 17	72/161
Cryptosporidium	ND[b]	-	-	-	-	0/11
Giardia	ND[b]	-	-	-	-	0/11

[a] Data were provided by David Matthews, Santa Clara Valley Water District, 23 Jul 2001. Raw water was 100% from the San Luis Reservoir. Nondetects were not used for computation of statistics.

[b] Samples tested by both the ICR Method and Method 1623; results were below their respective detection limits.

6.4.2.4 Pathogens

This section addresses pathogen data collected from the Santa Teresa WTP only when the San Luis Reservoir was the sole source. See Chapter 12 for a more comprehensive discussion on pathogens in the reservoir. The Santa Teresa WTP routinely monitors microbiological constituents in its raw water. During the survey period from 1996 to 1999, microbiological data were available from January 1996 to December 1999. Table 6-5 summarizes monitoring data for raw water that is 100% from the reservoir. The data presented in Table 6-5 were calculated in the same manner as described in Section 6.4.1.

The pathogens *Cryptosporidium* and *Giardia* were monitored, but only 11 measurements were available for each of the 2 organisms during the survey period. Two different methods, the ICR IFA method and EPA Method 1623, with different detection limits were used to test each organism. Results were both negative for both organisms (Table 6-5).

Data on coliform bacteria in raw water from the reservoir at the Santa Teresa WTP are presented in Table 6-5. Among the 160 to 161 samples tested, 120, 74, and 72 tested positive for total coliform, fecal coliform, and *E. coli*, respectively. These bacterial levels were all below the state regulatory numerical values for freshwater beaches (DHS 2000).

6.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Water in the San Luis Reservoir is pumped from both the California Aqueduct and the DMC during fall and winter months. Significant contaminant sources and water quality problems at the reservoir are associated with watershed activities and the source water from the aqueduct and the DMC. Water quality constituents of concern in the reservoir include turbidity, TOC, and bromides. Turbidity can be a serious problem during fall and winter months.

PCSs in the watershed include recreation, animal populations, fires, and highway hazardous chemical spills. Water quality concerns associated with recreation at the watershed include pathogens and turbidity caused by erosion in camping grounds, wildlife areas, and wave-washes of reservoir shorelines. Although not quantified, body contact recreation may also be a major source of pathogens. The contribution from animal populations is unknown, but animal grazing and wildlife also may contribute nutrients, pathogens, and turbidity to the reservoir. Fires in the watershed of the reservoir contribute turbidity and nutrients indirectly. No spills occurred during the survey period, but hazardous chemical spills along Highway 152 may present a potential threat to water quality because of the extent and proximity of the highway to the reservoir, as well as the types of transportation activities that occur along the highway.

The California Aqueduct and the DMC are the major sources of TOC, bromide, and, sometimes, turbidity in the reservoir. Levels of TOC in the reservoir and in raw water at the Santa Teresa WTP often exceeded the target drinking water protection standard of 3 mg/L, and occasionally were above 4 mg/L. Bromide levels also exceeded the target drinking water protection standard of 0.05 mg/L. The high levels of TOC and bromide in water of the California Aqueduct and the DMC present challenges to meeting the regulatory limits set by the Stage 1 D/DBP Rule and IESWTR.

6.6 WATERSHED MANAGEMENT PRACTICES

DWR and the BLM own most of the land in the San Luis watershed, and several agencies manage the watershed area. DWR constructed the reservoir and is primarily responsible for its operation and maintenance. California State Parks manages the recreation activities within the watershed. The California Department of Boating and Waterways regulates recreational boating in the reservoir. The California Department of Fish and Game manages wildlife areas, hunting, and fishing in the watershed and in the reservoir. Most privately owned land is not close to the reservoir.

Recreation represents a challenge in watershed management in the future because recreational use of the reservoir is expected to rise with the lower admission fees. Recreational activities often can be significant sources of contamination. Although most of the reservoir shoreline is fenced, a considerable portion is not fenced. Animals may be in direct contact of the water in the reservoir. At the present time, contamination does not appear to be serious, but interagency coordination and strategies may be needed to address the challenges of increased recreational activities in the watershed.

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Chapter 7.1 - Pyramid Lake

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Recreation	7.1.3.1						◒		◒		◒ 1
Wastewater Treatment/Facilities	7.1.3.2		○			○	○				
Animal Populations	7.1.3.3					◒	◒		◒		
Crude Oil Pipelines	7.1.3.4										◒ 2
Agricultural Activities	7.1.3.5				○	○					
Mines	7.1.3.6							○	○		
Unauthorized Activity	7.1.3.7										⊙ **3**
Traffic Accidents/Spills	7.1.3.8							○	○		○ **3**
Geologic Hazards	7.1.3.9								○		◒ 2
Fires	7.1.3.10										
Land Use Changes	7.1.3.11										

Rating symbols:

- ● PCS is a highly significant threat to drinking water quality
- ◒ PCS is a medium threat to drinking water quality
- ⊙ PCS is a potential threat, but available information is inadequate to rate the threat
- ○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes

1. MTBE
2. Oil
3. MTBE and Petroleum Hydrocarbons

Chapter 7.2 - Castaic Lake

Potential Contaminant Source or Watershed Activity	**Report Section**	**Water Quality Parameters**									
		TDS/ Salts	**Organic Carbon**	**Bromide**	**Pesticides**	**Nutrients**	**Pathogens**	**Trace Elements**	**Turbidity**	**T&O**	**Other**
Recreation	7.2.3.1						◒		◒		●[1]
Wastewater Treatment/Facilities	7.2.3.2		○			⊙	◒				
Urban Runoff	7.2.3.3								○		
Animal Populations	7.2.3.4					◒	●[2]		◒		
Algal Blooms	7.2.3.5								●	●	
Agricultural Activities	7.2.3.6										
Crude Oil Pipelines	7.2.3.7										
Mines	7.2.3.8										
Traffic Accidents/Spills	7.2.3.9										◒[3]
Solid/Hazardous Waste Facilities	7.2.3.10										
Geologic Hazards	7.2.3.11										
Fires	7.2.3.12					◒			◒		
Population/General Urban Area Increase	7.2.3.13										
Land Use Changes	7.2.3.14										

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. MTBE
2. From cattle grazing
3. Pump oil spills

Chapter 7.3 - Silverwood Lake

Potential Contaminant Source or Watershed Activity	**Report Section**	**Water Quality Parameters**									
		TDS/ Salts	**Organic Carbon**	**Bromide**	**Pesticides**	**Nutrients**	**Pathogens**	**Trace Elements**	**Turbidity**	**T&O**	**MTBE**
Recreation	7.3.3.1						◒		◒		◒
Wastewater Treatment/Facilities	7.3.3.2		◒			◒	◒				
Urban Runoff	7.3.3.3								◒		
Animal Populations	7.3.3.4					◒	◒		◒		
Algal Blooms	7.3.3.5								●	●	
Agricultural Activities	7.3.3.6				○						
Unauthorized Activity	7.3.3.7										
Geologic Hazards	7.3.3.8								○		
Land Use Changes	7.3.3.9								◒		

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Chapter 7.4 - Lake Perris

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Recreation	7.4.3.1					◒	●		○		●[1]
Wastewater Treatment/Facilities	7.4.3.2		○			●	●				
Urban runoff	7.4.3.3										
Animal Populations	7.4.3.4					○	○				
Hypolimnetic Anoxia	7.4.4.1								●	●	
Unauthorized Activity	7.4.3.5										●[2]
Land Use Changes	7.4.3.6										

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. MTBE
2. MTBE and petroleum hydrocarbons

Contents

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Southern California Reservoirs

7.1 PYRAMID LAKE

7.1.1 WATERSHED DESCRIPTION

The Pyramid Lake watershed encompasses a drainage area of approximately 372 square miles. It includes the Piru Creek watershed, the largest non-State Water Project (SWP) inflow to the lake (DWR 1999), and is in both the Angeles and Los Padres national forests (Figure 7-1). The US Department of Agriculture (USDA) Forest Service manages the area and is the key land use decision maker.

Primary land use is recreation, which is associated with both the lake and the Hungry Valley State Vehicular Recreation Area. Land use also includes grazing, mining, and other activities described under Section 7.1.3, Potential Contaminant Sources. The watershed's perimeter is bounded by 3 major geologic faults: the Pine Mountain fault on the south, the Big Pine fault on the northwest, and the San Andreas Fault on the north. Several smaller faults occur locally where rock-type boundaries occur. Soils consist primarily of sediments from the parent rock of the surrounding area. In general, vegetation in the area of the lake is chaparral, with riparian areas occurring along larger creeks and some yellow pine forests occurring in higher elevation areas such as Lockwood Valley.

Because of its large watershed, Pyramid Lake receives a substantial amount of natural inflow. These inflows can be important in determining the water quality of the lake because of the large amounts of sediments and natural constituents contained in the runoff (see Section 7.1.4, Water Quality Summary). The amounts of inflow are shown in Table 7-1.

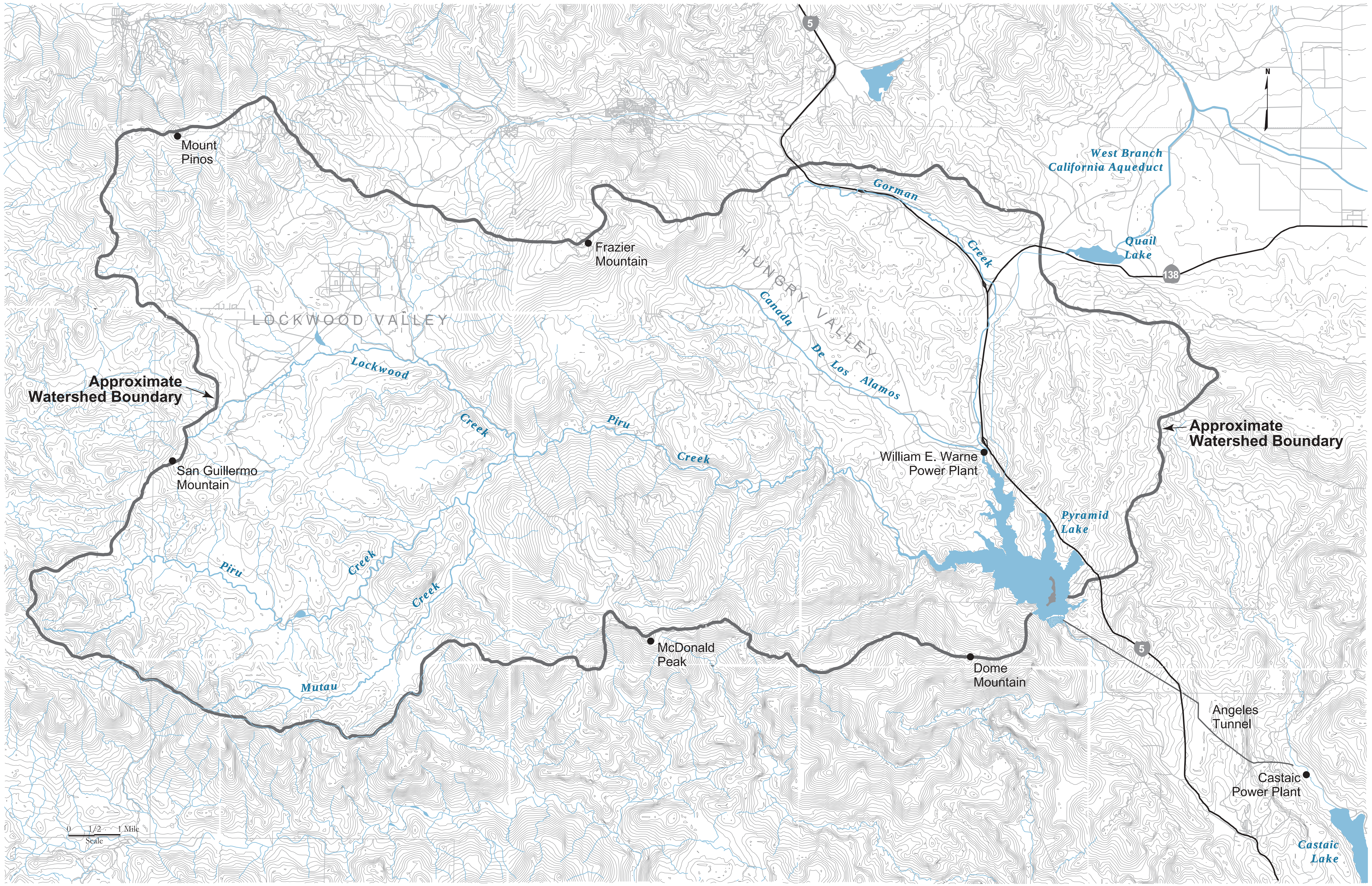
Table 7-1 Total Annual Natural Inflows to Pyramid Lake (acre-feet)

1996	1997	1998	1999
19,352	19,496	133,135	16,493

Source: DWR Division of Operations and Maintenance, SWP Operations Data 1996 to 1999

Piru Creek and its tributaries are the main sources of natural inflow. Piru Creek is the largest creek in the watershed, flowing generally from west to east and entering the lake in the northwest arm. The major tributaries of Piru Creek are Lockwood, Mutau, Frazier, and Snowy creeks. Piru Creek flow is seasonal, depending on the level of rainfall in the wet season. Lockwood Creek receives runoff from seasonal rainfall from the slopes of Mt. Pinos and Mt. San Guillermo. Several ephemeral creeks converge to form Lockwood Creek in Lockwood Valley, including Seymour and Amargosa creeks, Middle Fork, South Fork, and San Guillermo Creek. Hungry Valley is north of the lake and is drained in the lower portion above the lake by the Canada de Los Alamos (a creek), which then flows into Gorman Creek. Gorman Creek flows into Pyramid Lake at the William E. Warne Powerplant. The flow of Gorman Creek is seasonal, mostly underground, and is not noticeable in the dry season.

Figure 7-1 Pyramid Lake Watershed Area



7.1.2 WATER SUPPLY SYSTEM

7.1.2.1 Description of Aqueduct/SWP Facilities

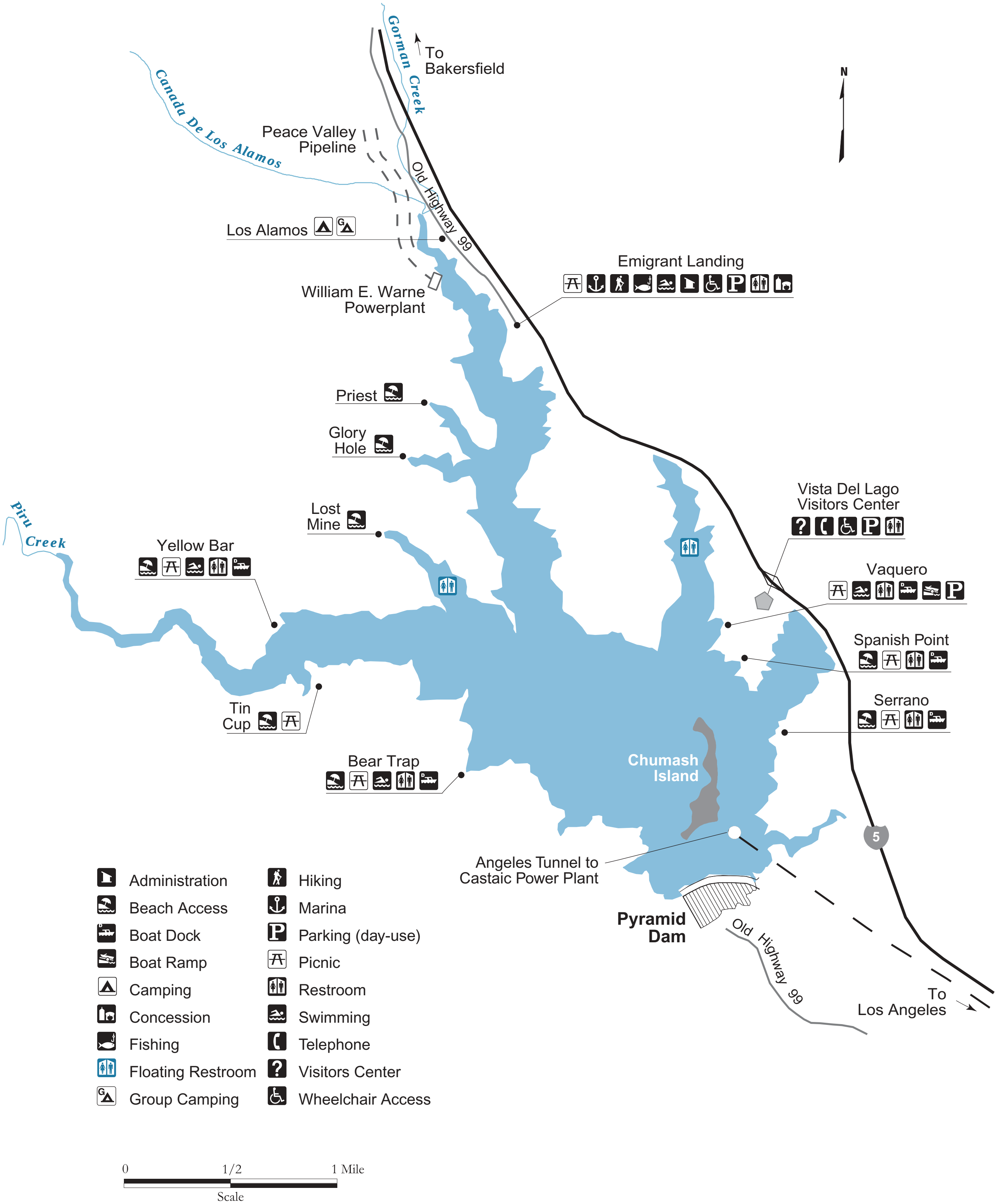
Pyramid Lake forms immediately below the Warne Powerplant at the end of the Peace Valley Pipeline at mile 14.07 of the West Branch of the California Aqueduct (Figure 7-2). The lake has an approximate surface area and storage capacity of 1,300 acres and 171,200 acre-feet, respectively. Pyramid Lake dam and facilities were completed in 1973 and provide the following:

- Regulatory storage for the Castaic Powerplant,

- Normal regulatory storage for water deliveries from the SWP West Branch,
- Emergency storage in the event of a shutdown of the SWP to the north,
- Recreational opportunities, and
- Incidental flood protection.

Pyramid Lake water flows to the Castaic Powerplant via the Angeles Tunnel and into Elderberry Forebay. Water is pumped back into Pyramid Lake during off-peak power usage periods so that power can be generated during peak power usage periods.

Figure 7-2 Pyramid Lake



7.1.2.2 Description of Agencies Using SWP Water

The Castaic Lake Water Agency (CLWA) and the Metropolitan Water District of Southern California (MWDSC) use SWP water from the West Branch of the California Aqueduct. Pyramid Lake water is sent to Castaic Lake via the Angeles Tunnel where MWDSC uses the water at the Joseph Jensen Filtration Plant (FP). Pyramid Lake is also the water source for the recreation area and Vista Del Lago Visitor Center.

7.1.3 POTENTIAL CONTAMINANT SOURCES

7.1.3.1 Recreation

The Davis-Dolwig Act of 1961 and State Water Code § 11900 declare that the purposes of SWP facilities shall include recreation and the enhancement of fish and wildlife habitat as well as water storage. In keeping with this mandate, recreation at Pyramid Lake includes many body-contact and nonbody-contact activities. It is a full-service area with boating, personal watercraft riding, water-skiing, windsurfing, swimming, fishing, picnicking, and camping. Recreational amenities are operated under subcontract to the Forest Service by a concessionaire, Pyramid Enterprises, Inc.

The main improvements at Pyramid Lake include 2 campgrounds at Los Alamos, the Vaquero swim beach and launch area, Emigrant Landing day-use picnic area, Forest Service administrative and residential buildings, and 5 boat-in sites (Emigrant Landing is the main boat launching area). All facilities have toilets and comfort stations nearby (USDA 1999). There are 2 floating restrooms; the newer one was installed in 1997.

During the last 2 years, recreational use has significantly declined. The drop in usage is due to lower household economic conditions in the area and construction that required lowering water levels (DWR 1999a). Recreational use is measured in units of "recreation days," which are defined as 1 user visiting the recreation area during part of a 1-day period (DWR 1999). This information, including the number of boats and cars that entered the recreational area, is presented in Table 7-2.

There have been no new studies or reports on recreation by the Forest Service since 1996 (Wickman 1999).

Several major recreation-related projects have been undertaken at Pyramid Lake since 1996. These include an administrative dock and elevated walkway replacement at Emigrant Landing and a new launch ramp and walkway at Vaquero. The new dock, which accommodates 6 patrol boats and a service barge, has new lights, sewage lines, and water and electric service. There are proposals to upgrade more docks and boat ramps starting in 2000.

Another recreational use is the Hungry Valley State Vehicular Recreation Area, which is operated by California State Parks. The vehicular recreation area is north of Pyramid Lake and occupies about 19,000 acres in the Gorman Creek drainage. About half of this recreation area is drained by the Canada de Los Alamos. Activities in this area can contribute to increased sedimentation and erosion that may contribute sediments flushed into Pyramid Lake via the Canada de Los Alamos and Gorman Creek (Keene pers. comm. 2000). This is a potential concern because there have been ongoing erosion problems in the Gorman Creek channel (Marks pers. comm. 1996). Motor vehicle-related contamination from fuels, oil, and some metals could also occur.

Erosion in campgrounds along creeks, especially along Piru Creek, is another potential source of sediment inflow to the lake.

Personal watercraft is used frequently and is a potential source of petroleum-related contaminants, including MTBE.

7.1.3.2 Wastewater Treatment/Facilities

There are no known wastewater treatment plants or effluent discharges at Pyramid Lake or in the watershed. There is no storage or disposal to land of wastewater effluents. There are pit toilets in the picnic areas and campgrounds.

Table 7-2 Recreational Use at Pyramid Lake

	1996	1997	1998	1999
Recreation days	300,000	315,000	182,200	207,000
Boats	NA	22,333	18,354	17,581
Cars	NA	21,385	24,301	22,979

NA = not available

Storage, Transport, and Disposal

Emigrant Landing has 6 flush toilets. There are restrooms with vault toilets at all boat-in sites. The swim beach area has 2 toilets and shower facilities (USDA 1999). All flush toilets go to concrete holding tanks under each area. As part of the concessionaire operations, all holding tanks, vault toilets, and septic systems are regularly pumped out by truck and disposed of outside the watershed (Roberts pers. comm. 2000). The Los Alamos camping area about 3 miles north of the lake has 5 vault-toilet areas and a septic leach field. There were no reports of accidents or spills (Roberts pers. comm. 2000).

Septic Systems

There are septic systems associated with the administrative/residential area north of the lake off Interstate 5. Septic systems in the recreation areas are pumped out as described above. There is also a septic system and leach field about a quarter mile north of the Warne Powerplant.

7.1.3.3 Animal Populations

Historically, there has been extensive grazing of cattle and sheep in the watershed. Although new information on grazing allotments was not available from the Forest Service, it is known that grazing still occurs and, therefore, has the potential to contribute pathogens and sediment via erosion to creeks and streams entering the lake. There is also a substantial but unknown wild animal population in the watershed that is also a potential source of pathogens in creeks and streams entering the lake.

7.1.3.4 Crude Oil Pipelines

Several crude oil transmission pipelines pass through the Pyramid Lake watershed carrying oil from the Kettleman Hills to refineries in Los Angeles County. There were 3 pipelines in the vicinity of Pyramid Lake, but 1 line (known as Line 1) has been shut down and the oil removed. The other lines are owned and operated by Pacific Pipeline.

One of the lines (known as Line #63) enters the watershed northeast of Pyramid Lake, parallels I-5 near Vista Del Lago, and runs about one-quarter mile above the lake at Gorman Creek, and continues south down to the Emigrant Landing area and on to Castaic Lake. This line, and this area in particular, has the greatest potential to impact water quality in Pyramid Lake (Kellogg pers. comm. 2000). Line #63 also has a pump station in Hungry Valley, north of Pyramid Lake in the Gorman Creek drainage.

This whole area can be prone to pipeline ruptures caused by seismic activity, which can disrupt transmission and damage roads, etc. There have been no releases or breaks in the lines during 1996 through 1999. The last line break occurred during the 1994 Northridge earthquake in Posey Canyon, approximately three-quarters of a mile from the Posey Creek arm of the lake. Reportedly, no oil made it to the lake. (Kellogg pers. comm. 2000).

7.1.3.5 Agricultural Activities

Agricultural Crop Land Use and Pesticide/Herbicide Use

There is some limited agricultural use in the form of pasture crops such as alfalfa to support the grazing activities. No information was available on pesticide use, but commonly used pesticides on alfalfa include chlorpyrifos and other organophosphate pesticides and herbicides.

7.1.3.6 Mines

There are 12 mines in the watershed, many of which are supposedly active gold mines (DWR 1996). These mines are not known to discharge to surface waters, and no evidence or indication of contamination has been reported or found.

7.1.3.7 Unauthorized Activity

Leaking Underground Storage Tanks

There was 1 leaking underground storage tank reported in 1992 that was removed, and remediation was begun (DWR 1996). This site is still being monitored quarterly, but it is not known if there are any effects on lake water quality. No new leaking tanks were reported, and there were no reports of illegal dumping.

7.1.3.8 Traffic Accidents/Spills

The proximity of I-5 and Highway 138 to the watershed and immediate lake area indicates vulnerability from spills along these routes. On 3 March 1998, a tanker truck spilled about 2,500 gallons of diesel fuel on I-5 with much of the spilled fuel draining into Gorman Creek. By chance a hazardous spill crew was nearby and able to contain the spill locally (MWDSC 2000). The Project Operations Center (POC) reported no other incidents, spills, or accidents for Pyramid Lake.

There are 3 airplane landing strips in Lockwood Valley that could be potential sources of petroleum-related contaminants, but there was no information on specific activities.

7.1.3.9 Geologic Hazards

The 3 major faults and several smaller faults in the watershed make the area susceptible to pipeline ruptures (such as crude oil) and other facility damage caused by seismic activity (see Section 7.1.3.4, Crude Oil Pipelines).

7.1.3.10 Fires

There were no fires of significance reported during this survey period.

7.1.3.11 Land Use Changes

The only known land use changes associated with construction were recreation-related improvement projects described in Section 7.1.3.1, Recreation. There are no other known major land use changes in the watershed.

7.1.4 WATER QUALITY SUMMARY

7.1.4.1 Watershed

Water quality data for Pyramid Lake for the 1996 through 1999 period are presented in Table 7-3. Parameters of interest in the Pyramid Lake watershed, including MTBE, are discussed later in this section. All parameters were below drinking water maximum contaminant levels (MCLs) or applicable Article 19 objectives for this period, except for hardness in May 1998 (see discussion under Total Dissolved Solids). Assessing water quality in Pyramid Lake is complicated by the recirculation of water from Elderberry Forebay and because most management agencies focus water quality investigation on Castaic Lake, the point of delivery of SWP water.

Table 7-3 Pyramid Lake at Tunnel Inlet, Feb 1996 through Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	29	26	22	45	23-39	1	16/16
Chloride	44	43	36	58	36-53	1	16/16
Total Dissolved Solids	266	257	228	339	233-311	1	17/17
Hardness (as $CaCO_3$)	128	118	100	183	106-163	1	16/16
Conductivity (µS/cm)	455	435	401	552	414-524	1	16/16
Magnesium	13	12	11	17	12-16	1	16/16
Sulfate	67	66	45	107	47-92	1	16/16
Turbidity (NTU)	4	2	1	21	1-8	1	14/14
Minor Elements							
Aluminum	0.01	0.01	<0.01	0.02	<0.01-0.02	0.01	5/15
Arsenic	0.002	0.002	0.002	0.003	0.002-0.002	0.001	15/15
Boron	0.3	0.3	0.2	0.4	0.2-0.4	0.1	16/16
Chromium	0.005	0.005	<0.005	0.007	<0.005-0.006	0.005	4/15
Copper	0.003	0.003	0.002	0.005	0.002-0.005	0.001	10/15
Iron	0.006	0.005	<0.005	0.018	<0.005-0.008	0.005	3/15
Manganese			<0.005	0.020		0.005	2/15
Zinc			<0.005	0.008		0.005	1/15
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.4	0.3	0.1	2.1	0.2-0.6	0.1	26/26
Nitrate (as NO_3)	1.8	1.8	0.2	2.5	1.3-2.5	0.1	16/16
Nitrate+Nitrite (as N)	0.46	0.45	0.15	0.71	0.31-0.61	0.01	46/46
Total Phosphorus	0.07	0.07	0.01	0.27	0.04-0.08	0.01	46/46
Orthophosphate	0.05	0.05	0.01	0.07	0.03-0.06	0.01	46/46
Misc.							
Bromide	0.12	0.11	0.11	0.13	0.11-0.13	0.01	3/3
pH (pH unit)	7.9	8.0	7.2	9.2	7.4-8.2	0.1	16/16

Source: DWR O&M Division database, May 2000

Notes: Turbidity and bromide data from Aug 1996 to Nov 1999 and Feb 1999 to Nov 1999, respectively

Statistics include values less than detection limit, if applicable

In the reservoir water quality sections, comparisons are made between contaminant concentrations in SWP source water and MCLs for finished drinking water. Although MCL is usually applied to finished water, it is useful as a conservative indicator of contaminants that are of concern to utilities and require removal during the treatment process to meet finished water standards. The comparison also serves to focus on the particular PCS associated with the contaminant of concern and then develop appropriate recommendations for actions. It follows that if source water concentrations were below MCLs, then these contaminants were not likely to be of concern to finished water supplies.

Water quality in Pyramid Lake is strongly affected by runoff from its large watershed, in particular the inflows from Piru Creek. The largest non-SWP inflow source to the lake, Piru Creek is elevated in total dissolved solids (TDS) from marine sediments in the watershed and contributes to the lake's salinity (DWR 1999). Natural inflows were 19,352 acre-feet in 1996 and 19,496 acre-feet in 1997, amounting to about 5% of total annual inflows. However, this inflow comprised from 10% to 14% of total lake inflows during December, January, and February of both years. In 1998, natural inflows totaled 133,135 acre-feet, or about 52% of the total lake inflow from all sources and about 6 times the normal natural inflow to the lake. Piru Creek was the only source of inflow (that is, no SWP inflow) to the lake from March to May 1998 and January to February 1999 (DWR 2000).

Minor elements (for example, trace elements) that were detected in 1 or more samples but at low levels included aluminum, arsenic, boron, chromium, copper, iron, manganese, and zinc (Table 7-3). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the detection limit; however, statistics were not calculated for parameters with 2 or fewer detections.

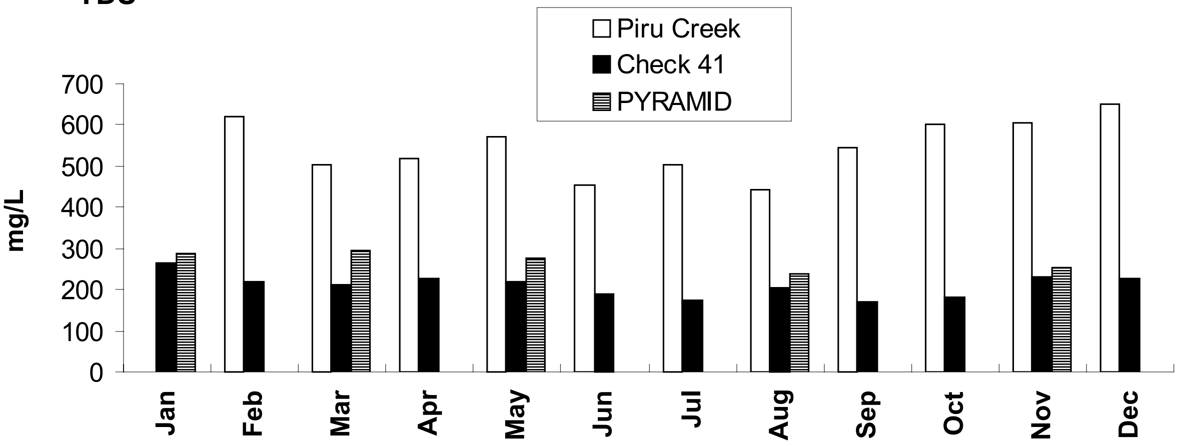
Bromide levels have only been monitored since 1999 and ranged from 0.11 to 0.13 mg/L , which is similar to the other Southern California reservoirs and SWP inflows.

Total Dissolved Solids

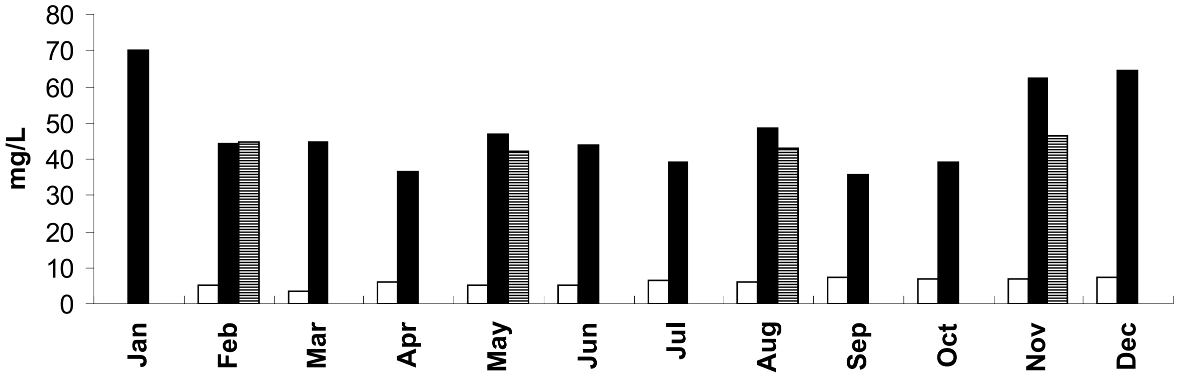
Because of its high TDS levels, Piru Creek has a measurable influence on the salinity of Pyramid Lake, especially during wet years (DWR 1999). Mineralogy analyses have indicated Piru Creek as the clear source of the TDS and sulfate, in addition to SWP inflows. TDS levels in Piru Creek ranged from 423 to 763 mg/L and averaged 554 mg/L (1994 to 1995 data), compared to 266 mg/L in Pyramid Lake. SWP inflows ranged from 114 to 266 mg/L and averaged 198 mg/L (Check 41) during 1996 to 1999. Check 41 is above the bifurcation to the East and West Branches of the California Aqueduct (Figure 7-3).

Figure 7-3 Total Dissolved Solids in Pyramid Lake and Inflows, 1996 to 1999

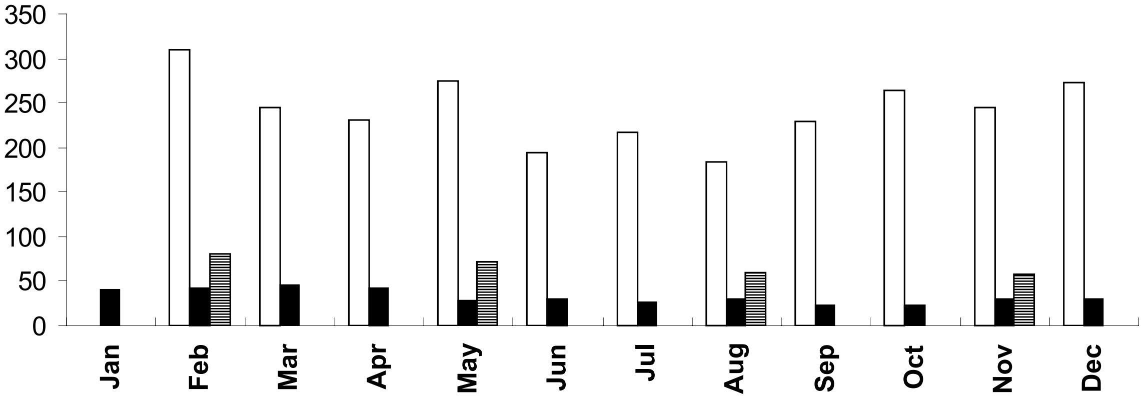
TDS



Chloride



Sulfate



There were high TDS levels during early 1996 caused by unusually high inflows from Piru Creek in 1995. Inflows during 1995 totaled 105,454 acre-feet or 35% of lake inflow from all sources. TDS, sulfate, and hardness declined steadily during 1996 because of large SWP inflows but remained constant during 1997. TDS levels ranged from 228 to 339 mg/L and averaged 266 mg/L. Hardness levels ranged from 100 to 183 mg/L and averaged 127.5 mg/L.

The high TDS levels are due primarily to the high sulfate/bicarbonate composition of the Piru Creek watershed. Average sulfate concentrations in Piru Creek are 8 times higher than SWP water, yet average chloride concentrations are 9 times lower (Figure 7-4). Hardness (as calcium/magnesium) is also high. In May 1998, the hardness was 183 mg/L, which exceeded the Article 19 objective of 180 mg/L. This was due to the high percentage of inflow provided by Piru Creek during the 1998 wet season. In high inflow years such as 1998, sulfate and hardness typically increase by May and decrease in summer, depending on the volume of SWP inflows. Similar effects and trends were observed in Castaic Lake.

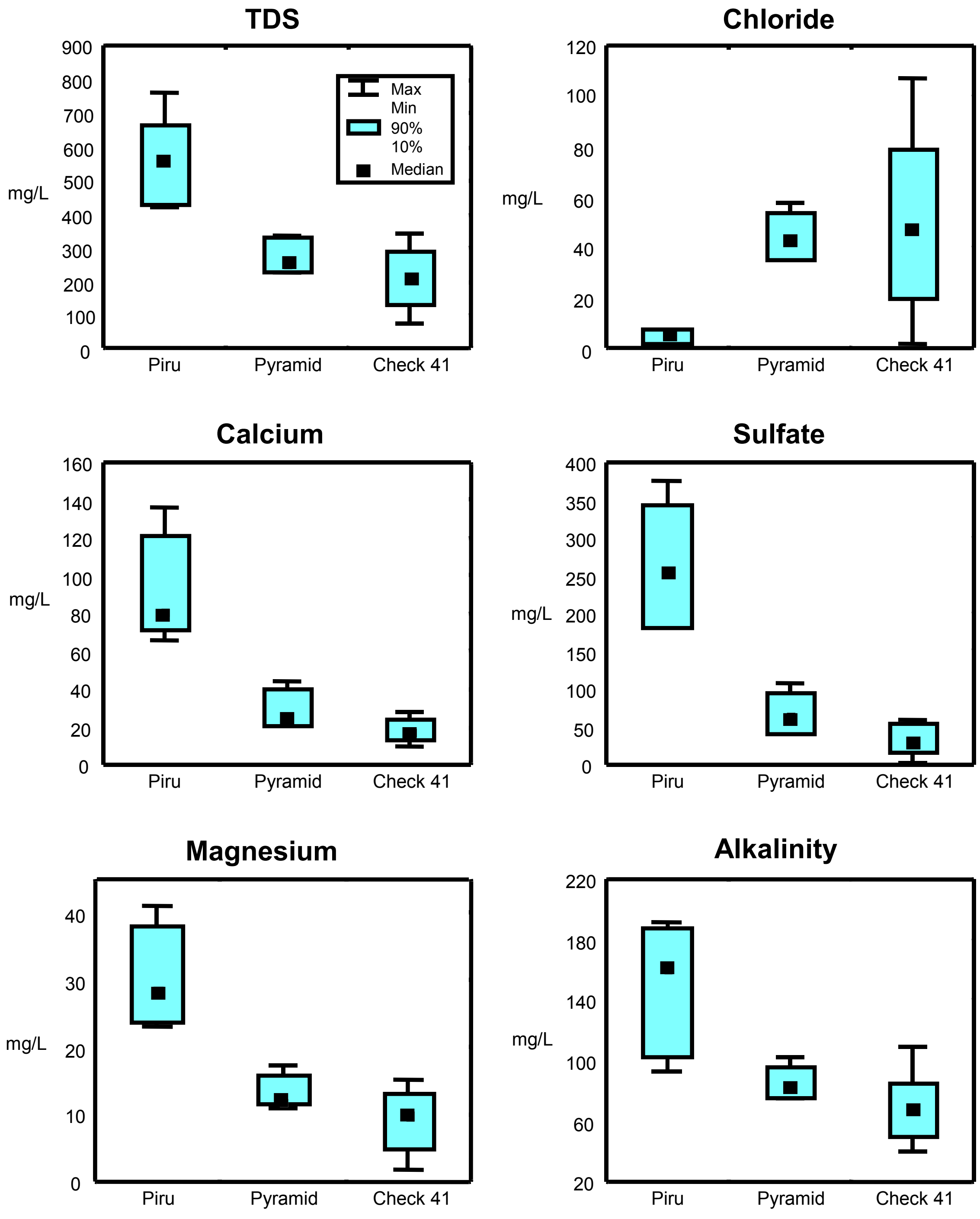
Nutrients

Nutrients such as nitrogen and phosphorus are important water quality parameters because of both their direct effects on water potability and their influence on algal populations in lakes. Because of high nitrogen and phosphorus loading from the SWP, direct runoff and precipitation, all of the Southern California reservoirs are nutrient-rich and would be classified as eutrophic with respect to algal productivity. Nutrient levels indirectly affect water quality in these lakes by stimulating growth of nuisance algae, which are associated with release of taste and odor compounds such as geosmin and 2-methylisoborneol (MIB). High concentrations of certain diatom species can also affect treatment plant operations by clogging filters and interfering with coagulation and flocculation treatments. Eutrophic lakes often experience periods of anoxia in bottom waters because of microbial respiration fueled by periodic die-off of algae. Formation of anoxia is also influenced by lake morphometry, residence time, thermal stratification, and hydrology, particularly the amount and location of water inputs and withdrawals. Anaerobic water contains elevated concentrations of reduced compounds that require higher doses of oxidants during the treatment process. These reduced compounds are also odorous and bad tasting (for example, hydrogen sulfide) and decrease the aesthetic quality of the water. Metals such as iron, manganese, and certain nutrients are more soluble in anoxic waters owing to low pH.

The occurrence and amount of nuisance algae are controlled by a complex interplay of nutrient loading, species interactions (that is, competition and predation by zooplankton) and physical conditions in the lake, namely temperature and light levels. Nutrient availability is controlled by inputs from source waters and by biological regeneration of nitrogen and phosphorus within the lake and from the bottom sediments. Nutrient levels are typically not limiting for algal growth in the Southern California reservoirs except during summer months (Losee pers. comm. 2001), thus temperature and light are the primary determinants for algal blooms observed in spring and fall.

During spring, the reservoirs typically have low turbidity, good light penetration and no temperature stratification (Coburn, and Losee pers. comm. 2001). As spring progresses, water temperatures rise and stimulate algal growth resulting in a bloom. Decreasing water clarity because of the algal bloom coupled with increasing solar inputs (that is, longer days, higher sun angle) results in thermal stratification of the lake. The warmer (that is, less dense) upper portion of the water column is separated by a thermocline (region of maximum temperature change with depth) from the colder (that is, more dense) lower portion of the water column. The upper portion of the lake is referred to as the epilimnion and is typically well mixed, and light levels are sufficient for algae to grow, thus oxygen levels are high. The portion of the lake below the thermocline is referred to as the hypolimnion and is usually too dark for algal growth. Microbial respiration (that is, consumption of oxygen) fueled by organic materials that sink from the epilimnion (dead algae) and by algal respiration (sinking live algae) can lead to low oxygen levels (hypoxia) or a total depletion of dissolved oxygen (anoxia) in the hypolimnion.

Figure 7-4 Water Quality Summary of Pyramid Lake, Piru Creek, and SWP Inflows, 1996 to 1999



Note: Piru Creek data repesents 1994 to 1995 only

By mid to late summer, nutrients have been depleted by algal growth in the epilimnion, and algal biomass declines. Nutrients released by microbial decomposition in the hypolimnion cannot be resupplied to the epilimnion while a strong thermocline persists. Thermal stratification typically persists into fall when surface waters cool and become more dense (they sink) resulting in a lake mixing or turnover event. Wind can also contribute to lake mixing. When the lakes mix, turbidity decreases and nutrients that have accumulated in hypolimnetic waters reach shallower depths in the lakes with sufficient light for algal growth, leading to a fall bloom. Spring and fall algal blooms are commonly observed in all Southern California reservoirs and in temperate lakes throughout the world; however, the specific timing and magnitude of algal blooms vary from year to year and from lake to lake and are difficult to predict.

A more detailed analysis of algal/nutrient dynamics and factors controlling the abundance of nuisance algae in each of the individual SWP reservoirs is beyond the scope of this report. Therefore, this *Sanitary Survey Update* will describe nutrient conditions and noteworthy instances of algal blooms or nuisance algae in each of the Southern California reservoirs. This report does not attempt to determine the causes of algal population dynamics or establish a connection between specific algal blooms and nutrient, light or temperature conditions in the lakes.

The nutrients nitrogen and phosphorus can be high in Pyramid Lake, relative to the other lakes and SWP water. Total nitrogen (defined as Kjeldahl nitrogen plus nitrate+nitrite) peaked at 2.1 mg/L in May of 1996 and averaged 0.4 mg/L (Table 7-3). Nitrate/nitrite values (as N) averaged 0.46 mg/L. The MCL for nitrate in this form is 10 mg/L. Total phosphorus values (as orthophosphate and total phosphorus) were all below 0.1 mg/L (ranging generally from 0.01 to 0.08 mg/L), except for 1 high value of 0.27 mg/L in September 1996. Nutrients are discussed in detail in the Castaic Lake section below because of the recirculation effects described above and because Castaic is the final water supply use point.

Turbidity

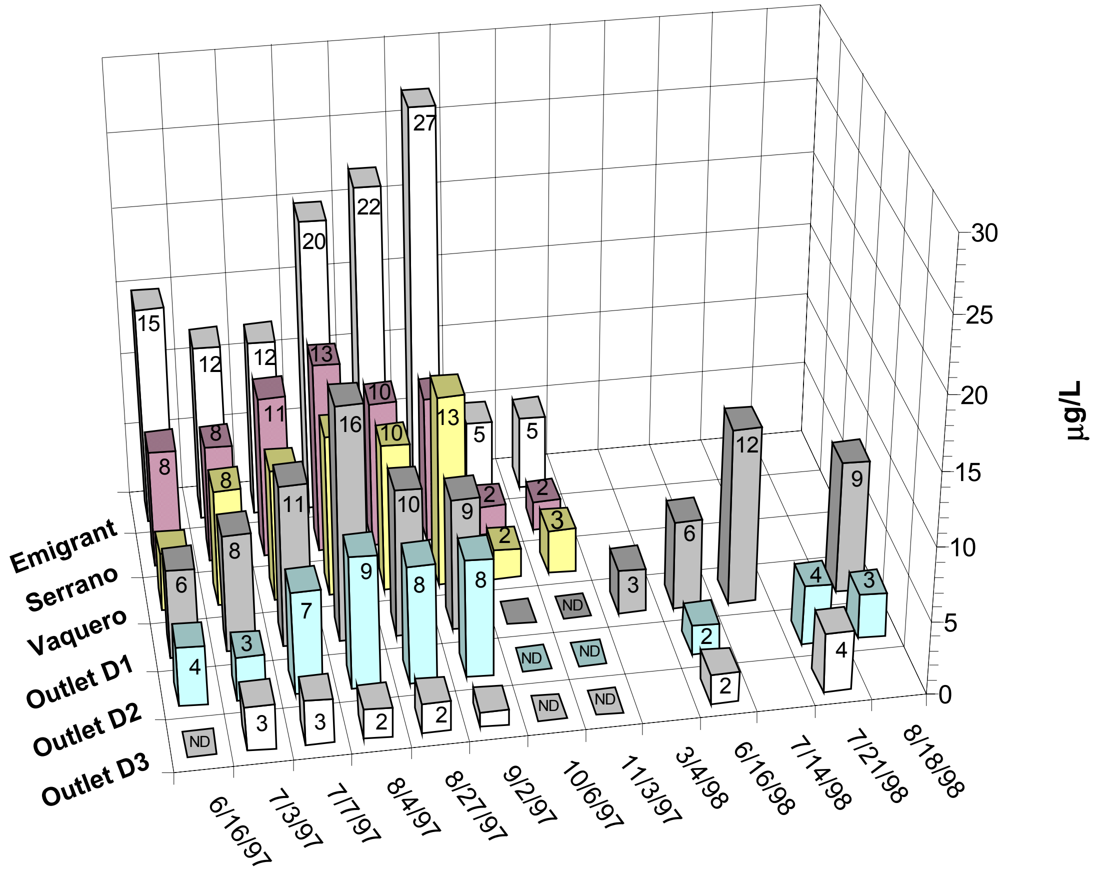
Activities in Hungry Valley recreation area can contribute large sediment loads to Pyramid Lake via Gorman and Piru creeks. Total suspended solids (TSS), soils and particle size analysis, or other erosion indicators currently are not monitored. Turbidity is monitored quarterly, along with other conventional parameters. Turbidities in Pyramid Lake were within the range of SWP inflows and the other lakes, except for 2 high values. High inflows in February 1998 caused the Pyramid Lake turbidity level to reach a high value of 21 NTUs for the period. Another high value of 10 NTUs occurred in August 1996 for unknown reasons. The average turbidity for the period was 3.7 NTUs (Table 7-3).

MTBE

MTBE was sampled at the 3 boat ramps at Pyramid Lake and at the inlet to the Angeles Tunnel (reservoir outlet) (Figure 7-2). The inlet to the Angeles Tunnel was used to represent the open sections of the reservoir. To evaluate the vertical distribution of MTBE, samples at this location were taken at 3 depths: the surface, the lower limit of the epilimnion, and the hypolimnion. During summer months, weak thermal stratification forms in the lake resulting in a shallow thermocline (4 to 12 m). No episodes of hypolimnetic anoxia have been reported for Pyramid Lake.

Results are presented in Figure 7-5. Samples collected at the inlet to the Angeles Tunnel are labeled outlet D1 through D3. Outlet location D1 refers to surface samples collected at depths up to 0.5 meters. Samples collected from the bottom of the epilimnion (4 to 12 meters) are labeled D2. The deep-water samples, collected from the hypolimnion, are labeled D3. In 1997, MTBE was detected in 75% of surface samples taken at the Angeles Tunnel inlet. The range of detected samples was 6 to 16 µg/L, and the mean was 7.4 µg/L. In 1998, surface samples ranged from 3.1 to 12.2 µg/L with a mean of 7.6 µg/L.

Figure 7-5 Summary of MTBE Concentrations in Pyramid Lake



Data sources: DWR 1999, DWR Operations and Maintenance unpublished data 1998
Notes: Outlet D1 = 0-0.5 m, Outlet D2 = 4-12 m, Outlet D3 = >12 m

Samples from the lower limit of the epilimnion ranged from 3 to 9 µg/L with a mean of 4.8 µg/L in 1997. In 1998, values ranged from 2.3 to 4 µg/L, with a mean of 2.9. These values were lower than those detected in the surface samples. Samples from the hypolimnion had the lowest MTBE concentrations. In 1997, MTBE was detected in 5 of 8 samples with a range of 1 to 3 µg/L and a mean of 1.5 µg/L. In 1998, only 2 samples were collected. The MTBE concentrations were 1.7 and 3.5 µg/L.

Surface samples from the Angeles Tunnel exceeded the primary MCL of 13 µg/L only once, on 4 August 1997 (16 µg/L). Surface samples exceeded the secondary MCL of 5 µg/L throughout the summer recreation season in both 1997 and 1998. Samples collected in the hypolimnion were below the secondary MCL throughout the summer recreation season. Samples at all 3 depths followed a similar temporal pattern. MTBE concentrations rose throughout the summer of 1997, reaching a maximum in July or August and then declined to nondetectable levels by early October 1997.

MTBE concentrations were generally higher near the boat ramps than at the tunnel intake. Samples collected at the boat ramps were taken from the surface only. MTBE concentrations at the Emigrant Landing boat ramp ranged from 5 to 27 µg/L in the summer of 1997 with a mean of 14.7 µg/L. Serrano boat ramp samples ranged from 2 to 13 µg/L with a mean of 8 µg/L. Vaquero boat ramp samples ranged from 2 to 13 µg/L with a mean of 7.5 µg/L. The highest values were observed at the Emigrant Landing boat ramp. Emigrant landing is the largest boat ramp, with 8 lanes compared to 2 at Vaquero. Samples taken at Emigrant Landing exceeded the primary MCL in August and September 1997, with the highest values observed after Labor Day weekend. MTBE concentrations at the boat ramps fell to levels at or below the secondary MCL by early October 1997.

7.1.4.2 Water Supply System

All water stored at Pyramid Lake is released to the Elderberry Forebay via the Angeles Tunnel. No water is delivered to contractors from Pyramid Lake. Water from the forebay is periodically recirculated back to Pyramid Lake to support power plant operations at the Castaic Powerplant. Water is then released from Elderberry Forebay to Castaic Lake for delivery to SWP contractors.

Pathogens

Pathogen issues were not addressed directly for Pyramid Lake. See Chapter 12 for this information for Castaic Lake and the Jensen FP.

7.1.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Significant contaminant sources contributing to water quality concerns specific to the Pyramid Lake watershed include recreation, animal populations, crude oil lines, and highway hazardous materials spills. The contribution of TDS and sulfate from Piru Creek is also a watershed issue but is addressed in Section 7.2, Castaic Lake. The water quality problems associated with recreation at Pyramid Lake are the contribution of pathogens, release of MTBE from motorized watercraft, and turbidity caused by erosion in camping areas and Hungry Valley. Pathogens are also potentially contributed by both grazing and wild animals.

Although no ruptures or spills were reported within this period, crude oil lines present a significant potential threat to water quality because of their size and proximity to the lake as well as sensitivity to seismic activity in the area. Pyramid Lake is also vulnerable to highway hazardous materials spills from nearby Interstate 5 and can be affected by return flows from the Elderberry Forebay.

7.1.6 WATERSHED MANAGEMENT PRACTICES

The USDA Forest Service is the primary land manager at Pyramid Lake and its recreation area. California State Parks operates the Hungry Valley Vehicular Recreation Area. The Forest Service has broad authority to manage National Forest lands under the forest planning foundation established in the National Forest Management Act of 1976. Under this Act, the statutory authority to make final decisions for National Forest lands rests with the Forest Service. The Act is being updated by a new Proposed Rule for the National Forest System Land and Resource Management Planning Act. The proposed rule expands the Forest Service's role to focus on sustainability and collaboration to become a facilitator and information provider, collecting and analyzing relevant information and finding solutions to watershed problems.

There are spill and/or rupture contingency plans for the crude oil lines owned by Pacific Pipeline in its Oil Spill Emergency Response Plan. Oil-absorbent boom logs and pads are maintained at the William E. Warne Powerplant. A portable oil-skimmer is stored at Castaic Lake. There do not appear to be any specific hazardous materials response procedures or on-site facilities at Pyramid Lake for highway spills.

7.2 CASTAIC LAKE

7.2.1 WATERSHED DESCRIPTION

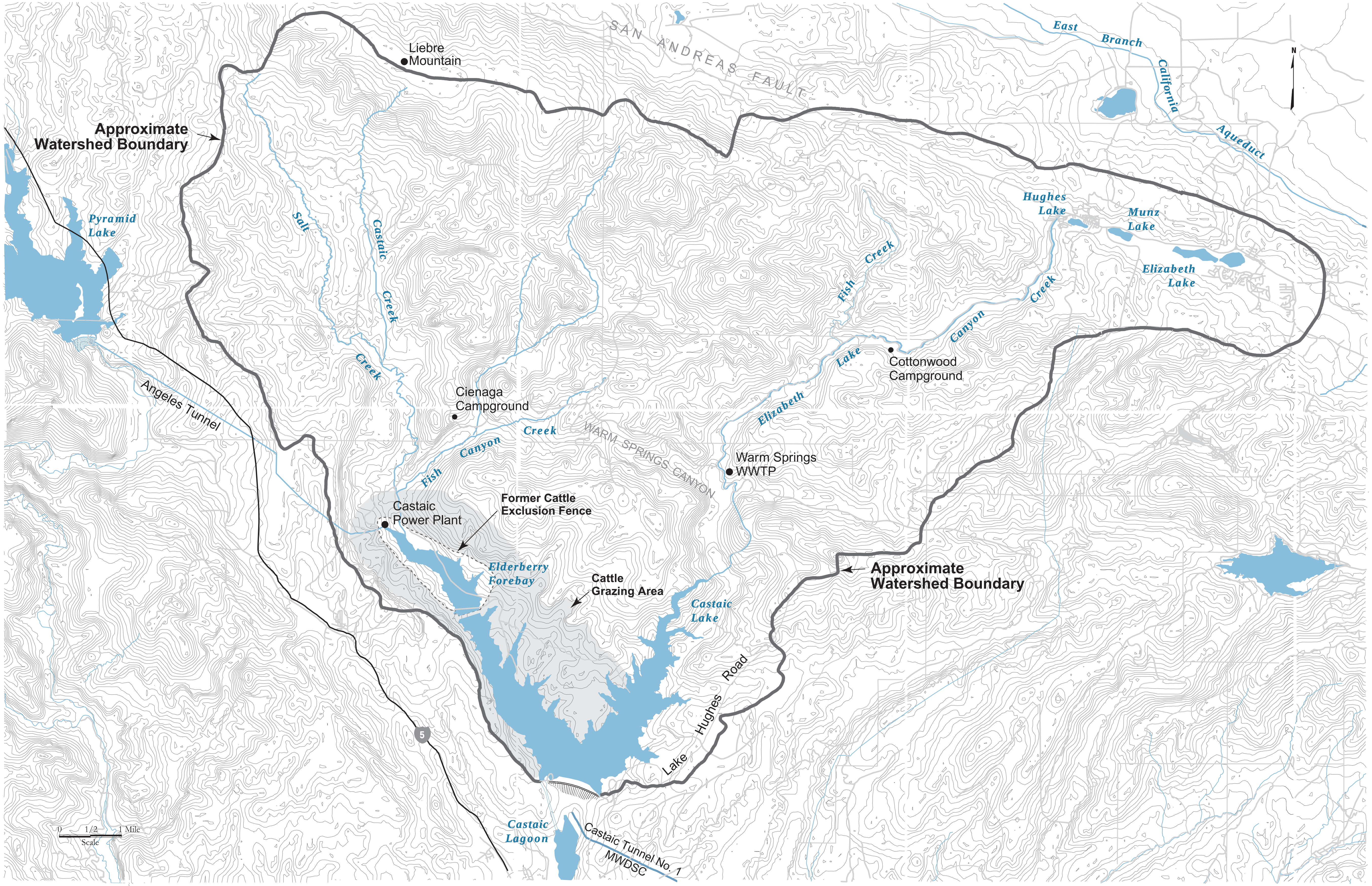
Castaic Lake is in a rugged, mountainous region of Los Angeles County. The lake and its watershed encompass 154 square miles, the 2nd largest of the Southern California SWP reservoirs after Pyramid Lake watershed (Figure 7-6). One of the SWP's largest recreational lakes, Castaic Lake is the terminus of the West Branch of the California Aqueduct. A major feature is the 425-foot tall Castaic Dam. The lake is 2 miles north of the community of Castaic and 45 miles northwest of downtown Los Angeles. Situated in the Liebre Mountains in the southeast part of the Angeles National Forest, Castaic Lake is the former site of a prehistoric Native American Indian settlement.

The Castaic Lake watershed has a Mediterranean climate with hot, dry summers and relatively mild winters. The rainfall period usually begins in November and lasts through April. Historic annual precipitation has been around 16 to 18 inches per year (DWR 1989).

7.2.1.1 Land Use

Information in previous sanitary surveys and from more recent contacts indicates that the watershed is still relatively undeveloped, with the primary land uses being recreation and related activities, cattle and sheep grazing, limited residential development, and some historic mining. Outside the watershed to the south in the upper portion of the Santa Clarita Valley, land has been undergoing significant residential development.

Figure 7-6 Castaic Lake Watershed Area



7.2.1.2 Geology and Soils

The terrain around Castaic Lake is rugged in many areas, with slopes exceeding 25% around most of the upper lake and occasionally exceeding 60%. The watershed is primarily sedimentary rocks of both marine and nonmarine origin of the Castaic Formation in the Ridge Basin region of the San Gabriel Mountains. In the southern portion of the watershed in the vicinity of the lake, rocks consist of sandstone, shale, and conglomerate. Soils in this area in general have a high sand content and are highly erosive, especially along streams. The northern portion of the watershed contains sandstone, shale, and harder rocks such as dolomite limestone, marble, and quartzite. Other than high erosion potential, there are no known natural soil conditions that contribute contaminants of concern in runoff from the watershed.

There are 3 active faults within 3 miles of both the east and west sides of the watershed (DWR 1996). San Andreas Fault lies northeast of the lake just outside the watershed boundary (Figure 7-6). To the west lies the northern portion of the San Gabriel fault. The White Wolf fault in Kern County is about 33 miles north of the dam area. There are also other minor fault traces in the area that mark rock-type boundaries.

7.2.1.3 Vegetation and Wildlife

The environment surrounding the lake consists of riparian vegetation, coastal sage scrub, and chamise chaparral communities mixed with brush and grasses, similar to that found at Pyramid Lake. The upper watershed areas contain native high-desert rangeland and chaparral. The watershed contains numerous wildlife such as mule deer, bobcats, coyotes, and pigs, and smaller mammals such as rabbits and rats typical of brushy, chaparral communities. Parts of the watershed are also within the range of the California Condor.

There are several plant and animal endangered species or species of special concern in the general area, but most findings are not in the Castaic Lake State Recreation Area (SRA). There are findings in San Francisquito Canyon, approximately 4 miles east of the lake and designated an “ecologically sensitive area.” The county of Los Angeles determined that the Castaic Lake SRA and immediately surrounding areas are not ecologically sensitive (DWR 1999a).

7.2.1.4 Hydrology

The watershed drainage into Castaic Lake is relatively large and extensive (154 square miles). There are 2 main sources of natural inflows to Castaic Lake within the watershed boundary, Castaic Creek on the northwest arm and Elizabeth Lake Canyon Creek on the northeast arm (Figure 7-6). Both creeks only flow seasonally. During summer it is common for creek flows to percolate into the ground because of high sand content and relatively low groundwater table (DWR 1985). The sub-watersheds of each of these major creeks are nearly equal, with the Castaic Creek arm being about 47% of the total area and the Elizabeth Lake Canyon arm being about 53% of the area. Historic average annual natural inflows from the watershed have been estimated to be about 23,000 acre-feet (Brown and Caldwell 1990). Depending on the information source, from one-half (DWR 1999) to two-thirds (Brown and Caldwell 1990) of the natural inflow enters into the Elderberry Forebay via Castaic Creek.

Castaic Creek includes 2 tributaries: Salt Creek and Fish Canyon Creek. Fish Canyon Creek is the larger of the 2 tributaries. Salt Creek joins Castaic Creek in the northwest portion of the watershed, while Fish Canyon Creek joins from the east about one-half mile north of the Castaic Powerplant.

The 2 major tributaries combined can contribute substantial inflow to the lake, although SWP inflow is by far the largest contribution. Average annual inflows from the watershed were estimated in 1995 to be 23,000 acre-feet (DWR 1996). Average winter flows reported in previous studies indicated average flows for Castaic and Fish Canyon Creeks of 32 and 39 cubic feet per second (cfs), respectively (DWR 1985). Because of the soil conditions described above, creek banks in the area are unstable and subject to erosion during high velocity floodflows in winter. Natural inflows to Castaic Lake from 1996 to 1999 are presented in Table 7- 4.

Table 7-4 Annual Natural Inflows to Castaic Lake (acre-feet)

1996	1997	1998[a]	1999
8,934	9,475	97,229	6,439

Source: DWR Division of Operations and Maintenance, SWP Operations Data 1996 to1999.

[a] 43,652 acre-feet total in February 1998 during El Niño storms and 18,457 in May.

Elizabeth Lake Canyon Creek drains the Elizabeth Lake area and includes 1 major tributary—Fish Creek (not to be confused with Fish Canyon Creek). The Elizabeth Lakes complex is at the upper end of the creek and includes Elizabeth, Munz, and Hughes lakes. All are within a reach of 5 miles and drain in series to Elizabeth Lake Canyon Creek (Figure 7-6). During very wet periods, the creek may receive overflow from the lakes complex. Streamflow in Elizabeth Lake Canyon Creek is intermittent, with the main contribution in flow coming from Fish Creek and the other tributaries: Ruby Canyon, Hiatt Canyon, and Tule Canyon Creeks. Peak stream flows as high as 3,860 cfs have been observed in Elizabeth Lake Canyon Creek (DWR and USDA 1981). The lakes are mostly privately held and support a variety of recreation, including fishing, camping, and some swimming and boating.

The groundwater basin underlying Castaic Lake comes from deep percolation of winter storm runoff into the alluvial aquifer and the underlying Saugus Formation aquifer. During wet years when large amounts of surface water are available, the alluvial aquifer is recharged, and water levels recover as much as 70 feet (DWR 1999a). Groundwater was the primary local water supply source before the SWP.

7.2.2 WATER SUPPLY SYSTEM

7.2.2.1 Description of Aqueduct/SWP Facilities

The Castaic Project was completed in 1972 and provides regulatory storage for water deliveries, emergency water storage, recreational development, power conversion, and fish and wildlife enhancement. Castaic Dam, which is 425 feet high, forms Castaic Lake. The reservoir is the southern terminus of the West Branch of the California Aqueduct at mile 31.55 and receives SWP water from Pyramid Lake via the Angeles Tunnel. Castaic Lake has 323,700 acre-feet of storage capacity, 2,240 acres of surface area, and about 29 miles of shoreline. Immediately downstream of the dam, Castaic Lagoon provides a recreation pool with a constant water surface elevation and functions as a recharge facility for the downstream groundwater basin.

The lake is shaped like a "V" with the 2 main arms branching to the northwest (Castaic Creek arm) and the northeast (Elizabeth Lake Canyon Creek arm) (Figure 7-6). The upper one-third of the Castaic Creek arm is called the Elderberry Forebay. The Elderberry Forebay Dam cuts across the Castaic Creek arm to form the forebay, which has a water surface elevation about 15 feet higher than the rest of the lake. The forebay has 33,000 acre-feet of storage capacity, 500 acres of surface area, and approximately 7 miles of shoreline.

Elderberry Forebay receives water from the Castaic Powerplant and supplies Castaic Lake through an outlet tower. Water from Elderberry Forebay is pumped back into Pyramid Lake via the Angeles Tunnel during off-peak power usage so that power can be generated during peak usage. Castaic Lake receives all of its non-natural inflow from Elderberry Forebay. Water is withdrawn from the lake through a gated outlet tower near Castaic Dam. The water is conveyed downstream to agencies using SWP water as described in Section 7.2.2.2. Some water is also diverted to the Los Angeles County Department of Parks and Recreation for use around the recreational area.

7.2.2.2 Description of Agencies Using SWP Water

SWP water is withdrawn from Castaic Lake at West Branch mile 31.55 via the Castaic tunnel and distributed to 3 agencies: MWDSC, CLWA, and the Ventura County Flood Control and Water Conservation District (VCFCWCD). The VCFCWCD has an entitlement and an outlet at Castaic Lake but has not built a conveyance system and, therefore, does not take any water.

The West Branch of the California Aqueduct received a smaller amount of SWP water than the East Branch from 1996 to 1999, usually from 37% to 40% of annual deliveries (except 1998) (Table 7-5). East Branch outflow data are also presented for comparison. The total of the 2 branches during the period was typically only 30% to 50% of the total available annual entitlement. Castaic Lake inflows and outflows were generally similar, except for 1998, probably because of the large El Niño storms. Outflows to the contracting agencies, including for Castaic Lagoon and recreational uses, ranged from 269,267 to 367,365 acre-feet.

MWDSC

The MWDSC, whose entitlement of 2,011,500 acre-feet is the largest in the SWP, is a consortium of 27 member agencies and more than 150 subagencies that provide drinking water to nearly 17 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino, and Ventura counties (DWR and SWC 2000). SWP water from Castaic Lake is delivered via the Foothill Feeder to MWDSC's Joseph Jensen FP, where it is treated and distributed to the San Fernando Valley, Ventura County, central Los Angeles, Santa Monica, and the Palos Verdes Peninsula.

The Jensen FP is in Granada Hills and is the only MWDSC plant on the West Branch that normally treats only SWP water. The plant uses conventional treatment processes consisting of coagulation, ferric chloride addition, sedimentation, filtration, and disinfection. Disinfection has been achieved using chlorine, but the plant is being expanded and will be converted to the use of ozone and chloramines for disinfection in order to control disinfection byproduct (DBP) formation and meet Stage 1 and 2 Disinfectants and Disinfection Byproducts (D/DBP) Rule requirements. The Jensen FP has a current capacity of 750 million gallons per day (mgd), but ozone capacity is 600 mgd.

Table 7-5 SWP Inflow/Outflow for East and West Branches and Reservoirs (acre-feet)

SWP Location	1996	1997	1998	1999
West Branch Outflow	346,654	357,141	124,262	393,160
Castaic Lake:				
Inflow	314,233	334,781	214,431	366,538
Outflow	295,282	336,383	269,267	367,365
East Branch Outflow	490,254	603,691	439,565	607,066
Silverwood Lake:				
Inflow	398,250	495,507	352,561	499,644
Outflow	440,661	443,005	356,851	503,735

Source: DWR Division of Operations and Maintenance, SWP Operations Data 1996 to 1999

CLWA

The CLWA service area encompasses approximately 195 square miles in the Santa Clarita Valley, including portions of unincorporated Los Angeles County, the city of Santa Clarita (including previously unincorporated communities of Newhall, Saugus, and Valencia), Castaic, Val Verde, Castaic Junction, and unincorporated portions of eastern Ventura County. CLWA treats and distributes SWP water to 3 retailers in the Santa Clarita Valley, including the Newhall County Water District, Valencia Water Company, and the Los Angeles County Waterworks District N. 36. CLWA also acquired the Santa Clarita Water Company in October 1999 (McLean pers. comm. 2000).

The CLWA maximum annual SWP entitlement is listed as 107,900, but firm entitlement is considered to be 95,200 acre-feet (McLean pers. comm. 2000a). This includes its original annual entitlement of 54,200 acre-feet, plus an additional annual SWP entitlement of 41,000 acre-feet obtained in 1999 through a water transfer with the Kern County Water Agency.

The CLWA operates 2 surface water treatment plants, the Earl Schmidt FP in Castaic and the Rio Vista Treatment Plant in the city of Santa Clarita. The Earl Schmidt FP has a capacity of 28 mgd and receives raw water via a 54-inch pipeline from the outlet structure normally by gravity. The treatment processes include flash mixing and chemical addition, flocculation and sedimentation, dual media filtration, and chlorine disinfection. The Rio Vista plant has a capacity of 30 mgd and receives raw water from the Foothill Feeder, which is owned and operated by MWDSC, via a 102-inch pipeline. Its treatment plant processes include pre-ozonation, rapid mix and chemical addition, contact clarification (a special process replacing conventional flocculation/sedimentation that biologically reduces DBP precursors), filtration, and primary disinfection by ozone with secondary disinfection by chlorine (McLean pers. comm. 2000b).

VCFCWCD

The VCFCWCD is the legal entity for the SWP entitlement that is assigned to the Casitas Water District, which in turn also maintains entitlements to the United Water Conservation District and the city of San Buena Ventura. The district has an annual entitlement of 20,000 acre-feet.

7.2.3 POTENTIAL CONTAMINANT SOURCES

7.2.3.1 Recreation

Recreational improvements at Castaic Lake were created and are maintained to fulfill the mandate of the Davis-Dolwig Act to provide such facilities and enhancement of fish and wildlife habitat. The Castaic Lake SRA encompasses about 11,200 acres of land under State and federal ownership and includes the reservoir, Elderberry Forebay, and Castaic Lagoon. With about 29 miles of shoreline, the SRA is an extensive multipurpose recreational area with many activities including boating, riding personal watercraft, water-skiing, windsurfing, fishing, hiking, bicycling, horseback riding, picnicking, camping, park tours, and model plane flying. Once banned from the lake, swimming is now allowed from Memorial Day weekend through Labor Day. Owing to a lack of swim beaches, little or no swimming occurs in upper Castaic Lake. The recreation area is operated by the Los Angeles County Department of Parks and Recreation.

Recreational activities are potential sources of contaminants for several reasons:

- Contribution of feces from body contact recreation such as swimming,
- Introduction of pathogens by horses,
- Fuel spills or leakage from motorized watercraft,
- Spills or leakage from restrooms and wastewater management facilities, and

- Erosion and higher turbidity associated with hiking, horseback riding, or camping, particularly if activities are conducted off established trails and areas.

The major water quality problems associated with recreation at Castaic Lake are the contribution of microbial pathogens *Giardia* and *Cryptosporidium*, release of MTBE from motorized watercraft, and turbidity caused by soil erosion.

Castaic Lake is stocked with bass, trout, and catfish. There are boat rentals and a tackle bait shop. Other recreational activities include hiking and biking trails, picnicking, and playgrounds. Group picnic areas are available for up to 600 persons. Recreational facilities along with important lake features are shown in Figure 7-7.

Recreational use at Castaic Lake follows a seasonal pattern, with 80% of all visitation between April and September and peak attendance occurring on summer weekends. Recreational use for the 1996 to 1999 period (as recreation days) is presented in Table 7-6.

Annual recreational use varied from about 500,000 to 700,000 recreation days from 1996 to 1999. As with Pyramid Lake, Castaic Lake's recreational use declined in 1999 because of several factors, including household economic conditions, water quality, and construction of facility improvements (DWR 1999a). This decline occurred in the early 1990s after recreational use, which was about 900,000 to 1.4 million in the 1980s, dropped to near current levels.

A Castaic Lake use survey conducted in 1989 reported recreation problems that could have contributed to the decline. Problems included conflicts between personal watercraft riders and anglers, poor water quality (for example, dirty lake, debris in water), too many boats on the lake, too many people, no free parking, poor restroom maintenance, and water level fluctuation throughout the year (DWR 1989).

Boating and related water-oriented activity is the most popular recreation at Castaic Lake. There are 3 boat ramp areas around the lake where much of the recreation activity occurs. The main boat ramp (or east ramp area), the largest of the 3, is just east of the dam (Figure 7-7) and includes an 8-lane launch ramp, 3 parking areas, an entrance kiosk, picnic area and restroom, concessionaire structure, and a 2-lane entrance road (DWR 1999a). The west boat ramp has a 6-lane launch ramp and has similar facilities to the main ramp area, including picnic areas and restrooms. There are also 2 boat-in sites—Sharon's Rest and Laura's Landing—with amenities for boat slips, camping, restrooms, marinas, and picnic areas but no launching facilities.

Campgrounds at Castaic Lake are depicted in Figure 7-7. There are 18 restrooms around the lake and 3 floating restrooms on the lake. Most of the restrooms are within walking distance from the lake, the farthest being about one-eighth of a mile (Yamamoto pers. comm. 2000). Maintenance on the floating restrooms is contracted, and there have been no spills during the period (Coash pers. comm. 1999). Other unnamed recreational areas are equipped with chemical toilets. Sewage handling facilities associated with the campgrounds are discussed under Section 7.2.3.2, Wastewater Treatment/Facilities. Other campgrounds in upper watershed areas are along major creeks. Cienaga and Cottonwood are along Fish Canyon Creek and Elizabeth Lake Canyon Creek above the confluence with Fish Creek, respectively (Figure 7-6).

There have been several completed and in-progress recreation improvements during 1996 to 1999 at Castaic Lake. The largest of these has been at the west ramp boat launching facility and area. The California Department of Boating and Waterways (DBW) designed and funded the improvements. In 1997 DBW funded construction of shoreline erosion control and other general improvements at the west boat launch ramp adjacent to the Castaic Dam right abutment. Construction at the west ramp boating facilities included riprap installation along shoreline for erosion control, lifeguard building additions, and shoreline landscaping between riprap and parking area. Another project in this area was for access road and boat facility improvements and renovations and handicapped access improvements. Additional projects in-progress include a boating instruction and safety center, west ramp parking area improvements, and main ramp area facility renovation/improvements.

Table 7-6 Recreational Use at Castaic Lake

Period	1996	1997	1998	1999
Recreation Days	666,000	684,000	691,000	509,000

Source: Thrapp pers. comm. 2000

Figure 7-7 Castaic Lake

7.2.3.2 Wastewater Treatment/Facilities

Treatment Plant Effluent Discharges

There is a small wastewater treatment plant (WWTP) serving the Warm Springs Rehabilitation Center at 38200 North Lake Hughes Road, which is adjacent to Elizabeth Lake Canyon Creek above the eastern arm of Castaic Lake (Figure 7-6). The WWTP has a design capacity of 30,000 gpd, and all secondary treated wastewater is disposed of by irrigation on 7 acres of land near the WWTP, which is owned by the USDA Forest Service. All sludge and other wastes are hauled off site for disposal. No drainage or disposal is allowed in or near the creek.

The community of Lake Hughes is served by a sewer system and the WWTP. In addition there is another WWTP at the Camp Munz Detention Center, which is operated by Los Angeles County.

The Warm Springs WWTP and disposal facilities are regulated under a National Pollutant Discharge Elimination System (NPDES) permit from the Los Angeles Regional Water Quality Control Board. Both the WWTP and disposal facilities overlie the Santa Clarita Valley Eastern Groundwater Basin and are regulated by the control board to protect the basin's beneficial uses. Regulated parameters include biochemical oxygen demand (BOD), suspended solids, TDS, sulfate, chloride, nitrate, and boron, which are monitored on either a weekly or quarterly basis.

Although the WWTP effluent meets permit requirements for all regulated parameters, several parameters were high or nearly exceeded permit limits during 1997 and 1998. This is probably due to the hardness and mineral content of the groundwater used at the Warm Springs Center. Chloride and sulfate levels were routinely in the 130 and 140 mg/L range, respectively, with the permit limit being 150 mg/L. On most occasions during 1997, sulfate levels were at 150 mg/L. TDS levels were usually about 700 to 720 mg/L, with the limit being 800 mg/L. Also, the total limit of 10 mg/L for various forms of nitrogen was nearly exceeded.

The WWTP is required to submit reports of operations annually to both the control board and the Los Angeles County Health Department. The reports summarize flow, effluent monitoring data, waste volume hauled, and any significant spills, accidents, or operational problems that occurred during the year. Reports were obtained for 1997 and 1998. There were no operational problems or incidents during 1996, 1997, or 1999. During the El Niño floods of 1998, there were operational problems as a result of the storm. Flash floods from the intense storm knocked out power to the sewage lift station and treatment plant. All wastewater and sludge were contained, and no off-site spillage occurred. Corrective or preventive actions were taken to insure proper treatment and disposal of wastewater (Hayman pers. comm. 1999).

Storage, Transport, and Disposal

All wastewater generated at Castaic Lake is collected and transported outside the watershed for treatment. The Los Angeles County Department of Public Works maintains 5 sewage lift stations within the watershed. There have been no significant spills or incidents with this portion of the collection system since 1996 (Cron pers. comm. 2000). Los Angeles County Department of Parks and Recreation maintains another portion of the wastewater collection system. This portion of the collection system has gravity-fed lines that extend throughout the lake area but are mainly on the west side. There are routine minor problems such as roots in lines or low water pressure plugging lines, but no major stoppages or overflows have reached the lake (Heimbach pers. comm. 2000).

Wastewater is collected and pumped to the main sewage pump station (also called the Ridge Route station) at the south end of Castaic Lagoon (Figure 7-7). From the main pump station, wastewater is transported to the Valencia Water Reclamation Plant in Valencia, which is about 10 miles south of Castaic Lake along Interstate 5 (Cron pers. comm. 2000). The Valencia plant is a tertiary treatment facility with a capacity of 12.6 mgd. It discharges treated effluent to the Santa Clara River (Science App 1998).

Septic Systems

At the rustic boat-in sites Sharon's Rest and Laura's Landing, wastewater handling consists of collection, septic tank treatment, and leach field disposal facilities.

A small septic tank/leach field wastewater system is in use at the Castaic Powerplant at Elderberry Forebay. DWR POC incident reports indicate that approximately 50 gallons of raw sewage spilled into the Elderberry Forebay on 5 November 1996. Presumably, it was from this system. An attempt was made to clean up the spill but no further information was available.

Water quality was reportedly poor during the late 1970s in the Elizabeth Lakes complex because of seepage from local septic systems, presumably associated with developments in the area (DWR and USDA. 1981). However, no recent information was found to document current conditions or to indicate that there are a significant number of septic systems in the watershed.

7.2.3.3 Urban Runoff

Urban runoff from the watershed to the lake is minimal because of the low level of development. It results primarily from recreation-related activities. Drainage from the main boat ramp parking area and probably the other boat ramps flows to Castaic Lake.

Erosion presents a threat to development and use of area facilities. Runoff from surrounding slopes has caused problems adjacent to some existing roads (DWR 1985).

7.2.3.4 Animal Populations

Historically, cattle and sheep have grazed extensively in the watershed (DWR 1996). The grazing season is dependent on rainfall and ranges from several weeks to about 6 months. Both cattle and sheep have been observed grazing to the shoreline at Castaic Lake (MWDSC 2000). Under a cooperative agreement, the USDA Forest Service grazes sheep on DWR property during spring and summer. The agreement specifies that those grazing their sheep must supply water in order to keep sheep out of the lake.

According to a USDA Forest Service employee, grazing has either been recently discontinued or greatly decreased in the overall watershed because an endangered toad was found in Castaic Creek and the fire in the area in 1996 left too much soil uncovered (Bautista pers. comm. 1999). The grasses and weeds that have sprouted since the fire are more subject to erosion than are the deep-rooted fire-adapted native plants.

Although new information on grazing allotments was not available from the Forest Service, it is known that grazing still occurs in the vicinity of Elderberry Forebay. Therefore, it has the potential to contribute pathogens and sediment via erosion to creeks and streams entering the lake as well as along the lake shore. Because of poorly maintained fences, cattle frequently have direct access to the water. Additionally, a fire on 26 August 1996 destroyed several cattle fences in the vicinity of the Elderberry Forebay dock, giving cattle direct access to the lake (Wendt pers. comm. 1996, Quintero pers. comm. 2000). The fences have not been repaired, and cattle have recently been seen in the area (Vecchio pers. comm.). Runoff from creeks in surrounding grazing areas also enters the reservoir during rainy periods. Droppings from grazing animals have been observed being flushed into streams during rains (Quintero pers. comm. 2000). Therefore, this is considered a significant threat to water quality.

There is a substantial but unknown wild animal population in the watershed that is also a likely source of pathogens in creeks and streams entering the lake. The general types of wildlife present in the watershed were described in Section 7.2.1, Watershed Description.

7.2.3.5 Algal Blooms

Excessive algal growth (that is, blooms) is caused by a combination of optimum temperature and sunlight conditions and an abundance of the nutrients nitrogen and phosphorus, resulting in a condition in reservoirs known as eutrophication or over-enrichment. Algal blooms can produce water quality conditions that disrupt water treatment processes. The primary adverse effects on water quality associated with algal blooms are increased turbidity, which affects plant operations, and taste and odor resulting from production of 2 organic compounds, MIB and geosmin. These 2 compounds are discussed in detail under Section 7.2.4, Water Quality Summary. A summary of algal growth dynamics and reservoir operations was presented within Section 7.1.4.1 under Nutrients.

Nuisance algal growth has been a historic occurrence at Castaic Lake. Nearby MWDSC treatment plants were shut during the mid-1970s because of algal blooms (Brown and Caldwell 1990). In May 1996, a geosmin-producing blue-green algal bloom reduced the efficiency of plant operations. In October 1997, the Jensen FP experienced a dramatic change in raw water quality from Castaic Lake that disrupted plant operation, resulting in higher than normal effluent turbidities. The alga was a microscopic pennate diatom that because of its large size and pencil-like shape was very difficult to treat (MWDSC 2000). The CLWA also reportedly shut down its treatment plant because of the same problem.

Algal blooms are also frequently associated with a change in pH, which can alter the effectiveness of coagulants and other chemicals added to the treatment process and can result in a treatment plant upset. Algal blooms increase treatment costs by increasing turbidity, which fouls filters more quickly and creates compounds that decrease the aesthetic quality of the water.

Copper sulfate is used on lakes for treatment and control of excessive nuisance-algal growth. In June of 1996, 10 tons of copper sulfate were applied to Castaic Lake. This was 50% of the total amount used that fiscal year on all MWDSC reservoirs (MWDSC 1996). Alternative taste and odor management strategies for controlling nuisance algae are being developed to maintain low levels of copper sulfate use (MWDSC 1998).

7.2.3.6 Agricultural Activities

There are no significant agricultural activities in the watershed (Mann pers. comm. 1996).

7.2.3.7 Crude Oil Pipelines

A crude oil pipeline extends into the Castaic Lake watershed from Pyramid Lake (Line #63) and traverses north to south down the east side of Interstate 5 but west of the lake. Most of the pipeline is underground—except at a control station—and is approximately 1 mile away from the lake area. It presents a low threat to Castaic Lake. There have been no releases or spills since S*anitary Survey Update 1996* (Reese pers. comm. 2000).

7.2.3.8 Mines

The 2 previous sanitary surveys reported the presence of mines in the watershed, but the location, type, and potential for contamination was not known. No new information was found or reported on this activity for this period.

7.2.3.9 Traffic Accidents/Spills

Hydraulic oil leaks from SWP facility operations can be a common occurrence. DWR POC incident reports indicate that on 12 November 1996, 19 gallons of hydraulic oil leaked from the Castaic Intake Tower. Oil booms were placed around the tower to catch the leaked oil. It has been recommended that vegetable oils or water be used as a replacement (MWDSC 2000).

7.2.3.10 Solid or Hazardous Waste Disposal Facilities

There are no known solid or hazardous waste facilities within the Castaic Lake watershed. Private contractors haul solid wastes generated from recreation and other activities at the Castaic Lake SRA and wastes from the CLWA service area to public landfills in Los Angeles County.

7.2.3.11 Geologic Hazards

There are several known faults within 3 miles of both the east and west sides of the watershed. The crude oil pipeline poses a low level threat to water quality but could be susceptible to rupture in the event of an earthquake.

7.2.3.12 Fires

Fires in the watershed, though infrequent, have caused turbidity problems in the lake (Brown and Caldwell 1990). On 26 August 1996, a fire occurred near the Elderberry Forebay boat dock and burned 22,500 acres, along with several fences intended to prevent grazing cattle from having direct access to the lake. The fire also burned structures and feed supplies on the Cordova Ranch, which is adjacent to DWR land around the forebay and to which the cattle belong. The fences were not repaired, and, therefore, cattle had direct access to the shoreline in this area. Increased turbidities were observed at the Jensen FP after the first rains in the fall of 1997. According to USDA Forest Service staff, cattle also had direct access to the water prior to the fire because of poorly maintained fences, and access has only increased since the fire. The cattle had an existing water supply on the ranch and did not need the lake for drinking water (Wendt pers. comm. 1996).

There were no specific reports of problems other than the fencing associated with the fire. However, in addition to the substantial increase in erosion potential because of steep terrain and sandy soils at Castaic Lake, grazing cattle also erode the banks of the shoreline and can contribute pathogens directly to the water. No information was available on follow-up actions or mitigation or the current state of fencing and shoreline protection at Castaic Lake.

7.2.3.13 Population/General Urban Area Increase

The Castaic Lake watershed itself appears to remain relatively undeveloped, except for recreation facilities and a small portion of the Elizabeth Lake area. However, there is some residential development occurring around the lake. The North Lake development project is proposed on a bluff overlooking the west lake area and is within the watershed of Castaic Lagoon (Quintero pers. comm. 2000).

Outside the watershed and south of the lake in the Santa Clarita Valley, a proposed Newhall Ranch development would cover 12,000 acres of land, create 24,000 units of housing, and add about 70,000 people to the area. Environmental documents also state that there is no firm water supply for the project. This level of very substantial growth could affect recreation and other infrastructure and have other indirect effects on the SRA.

The Newhall Ranch project would be in the CLWA service area. CLWA prepared an initial study in April 2000 to obtain the transfer of 10,000 acre-feet of SWP water from the Kern County Water Agency, to be held in reserve for use in developments owned by the Newhall Land and Farming Company (land owner for Newhall Ranch). The initial study concluded that the project could significantly affect the environment, and an environmental impact report was required (CLWA 2000). The project, facing opposition from local area residents, is on hold pending further environmental review (McLean pers. comm. 2000b).

7.2.3.14 Land Use Changes

The only known land use changes associated with construction or development were recreation-related improvement projects described in Section 7.2.3.1, Recreation. There were no other known major land use changes in the watershed.

7.2.4 WATER QUALITY SUMMARY

7.2.4.1 Watershed

Water quality data for Castaic Lake for the 1996 to 1999 period are presented in Table 7-7. These data were collected by DWR's Division of Operations and Maintenance (O&M) at the Castaic Lake outlet. All parameters were below drinking water MCLs or applicable Article 19 objectives for this period, except for hardness on 2 occasions in February and August of 1996. Hardness values during these periods were 192 and 189 mg/L , respectively, which exceeded the Article 19 value of 180 mg/L.

Castaic Lake is affected by the water quality of outflow from Pyramid Lake and the Elderberry Forebay (for example, high sulfate and TDS) and from inputs from several small streams within its watershed, particularly Castaic Creek. Data and information collected for this reporting period indicate that there are several water quality concerns, namely, TDS, nutrients, turbidity, DBPs, MTBE, taste and odor, and pathogens.

Minor elements (for example, trace elements) that were detected in at least 1 or more samples but at low levels included arsenic, barium, boron, chromium, copper, and zinc (Table 7-7). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the detection limit. However, statistics were not calculated for parameters with 2 or fewer detections. Arsenic was consistently detected but only at 0.002 mg/L, just above the detection limit of 0.001 mg/L.

Table 7-7 Castaic Lake (Lake Outlet) Feb 1996 through Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection limit	# of Detects/ Samples
Minerals							
Calcium	38	38	30	45	32-43	1	16/16
Chloride	46	45	41	54	42-52	1	16/16
Total Dissolved Solids	319	316	266	406	270-388	1	17/17
Hardness (as $CaCO_3$)	161	162	128	192	140-185	1	16/16
Alkalinity (as $CaCO_3$)	99	99	84	114	88-111	1	16/16
Conductivity (µS/cm)	535	527	479	627	484-604	1	16/16
Magnesium	16	16	13	19	14-19	1	16/16
Sulfate	97	96	70	129	79-126	1	16/16
Turbidity (NTU)	2	1	<1	3	<1-3	1	7/14
Minor Elements							
Arsenic	0.002	0.002	0.002	0.002	0.002-0.002	0.001	17/17
Barium	0.05	0.05	<0.05	0.05	<0.05-0.05	0.05	1/17
Boron	0.3	0.4	0.3	0.4	0.3-0.4	0.1	16/16
Chromium	0.005	0.005	<0.005	0.007	<0.005-0.006	0.005	4/17
Copper	0.005	0.005	0.002	0.014	0.002-0.009	0.001	13/17
Zinc	0.005	0.005	<0.005	0.010	<0.005-0.005	0.005	1/17
Nutrients							
Total Kjeldahl Nitrogen(as N)	0.4	0.4	0.2	0.8	0.2-0.5	0.1	27/27
Nitrate (as NO_3)	0.7	0.8	<0.1	1.8	<0.1-1.6	0.1	9/16
Nitrate+Nitrite (as N)	0.16	0.10	<0.01	0.50	<0.01-0.38	0.01	36/48
Total Phosphorus	0.03	0.03	0.01	0.09	0.02-0.06	0.01	48/48
Orthophosphate	0.02	0.01	<0.01	0.06	<0.01-0.04	0.01	19/48
Misc.							
Bromide	0.13	0.13	0.12	0.15	0.12-0.14	0.01	4/4
Total Organic Carbon	4.0	3.5	2.5	7.7	2.8-5.8	0.1	16/16
pH (pH unit)	8.3	8.2	7.4	9.1	7.7-9.1	0.1	16/16
UVA abs. @ 254 nm (cm^{-1})	0.069	0.069	0.061	0.076	0.062-0.073	0.001	8/8

Source: DWR O&M Division database, May 2000
Notes: Bromide data from Nov 1998 - Aug 1999 only
pH and UVA data from Feb 1998 - Nov 1999 only

Total Dissolved Solids

TDS concentrations in Castaic Lake during 1996 to 1999 were higher than in Pyramid Lake and Check 41, ranging from 266 to 406 mg/L and averaging 319 mg/L (Table 7-7). TDS levels (1971 to 1996 data) in Castaic Lake were also similarly high, ranging from 207 to 471 mg/L and averaging 328 mg/L (DWR 1996a).

In the discussion of Pyramid Lake in Section 7.1, it was noted that in high natural inflow years such as 1996 and 1998, sulfate and hardness typically increase by May and decrease during summer, depending on the volume of SWP inflows, because of the strong influence of Piru Creek. The high TDS levels in Piru Creek are due to the high sulfate/bicarbonate composition of the watershed. Average sulfate concentrations in Piru Creek (554 mg/L) are 8 times higher than SWP water. There were high TDS levels during early 1996 that were due to unusually high inflows from Piru Creek in 1995. TDS, sulfate, and hardness declined steadily during 1996 because of large SWP inflows. Similarly high sulfate (280-425 mg/L) and TDS values were also observed in Castaic Creek.

These effects and trends were also observed in Castaic Lake, suggesting that Piru Creek has an appreciable affect on downstream water quality. TDS levels progressively increased from SWP inflows at Check 41 to Pyramid Lake and on to Castaic Lake, as seen in Figure 7-8 a-c.

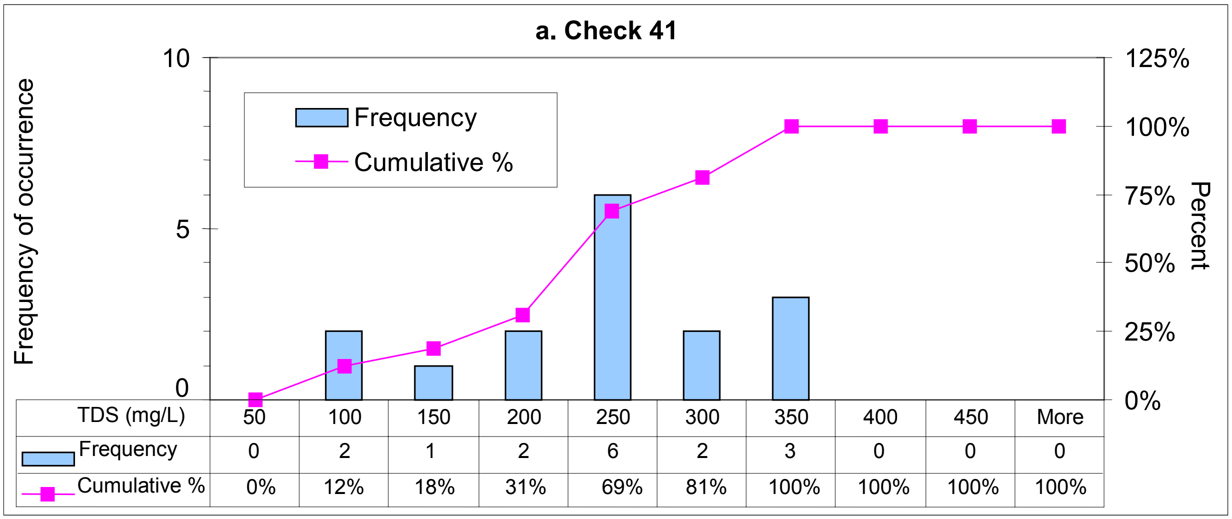
Most of the high TDS and sulfate values in Castaic Lake occurred in 1996 (along with the hardness problems described above) and some values in 1999 (Table 7-8). The 5 highest values out of 17 samples collected for each parameter occurred in 1996 and 1999. This appears to be related to the influence of extremely high TDS/sulfate loads in inflows from Piru Creek inflows to Pyramid Lake in 1995 and again in 1998.

This connection is further suggested by a comparison of regression analyses of TDS and sulfate for both lakes (Figure 7-9). The regressions for Pyramid and Castaic Lake show a similar slope and grouping, while the Check 41 (above Pyramid Lake) regression shows a much different grouping pattern

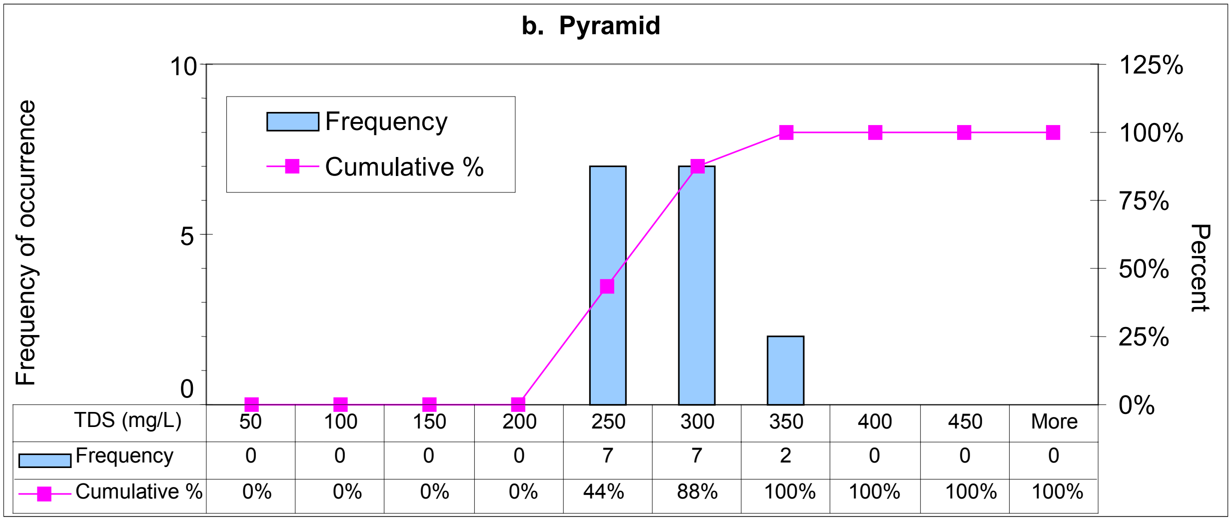
Table 7-8 Highest TDS and Sulfate Values in Castaic Lake (mg/L)

Month/Year	TDS	Month/Year	Sulfate
Feb 1996	406	Feb 1996	129
Aug 1996	390	Aug 1996	128
May 1996	386	May 1996	123
May 1999	347	May 1999	97
Nov 1996	331	Nov 1996	102

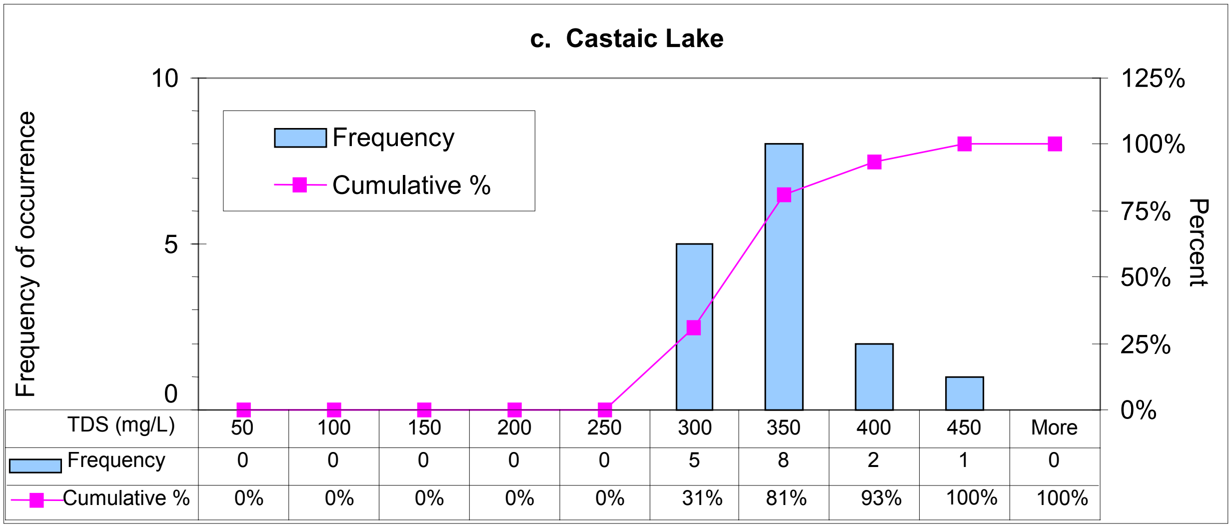
Figure 7-8a-c Cumulative Probability Distribution of TDS at Check 41, Pyramid Lake, and Castaic Lake, 1996 to 1999



TDS (mg/L)	50	100	150	200	250	300	350	400	450	More
Frequency	0	2	1	2	6	2	3	0	0	0
■ Cumulative %	0%	12%	18%	31%	69%	81%	100%	100%	100%	100%

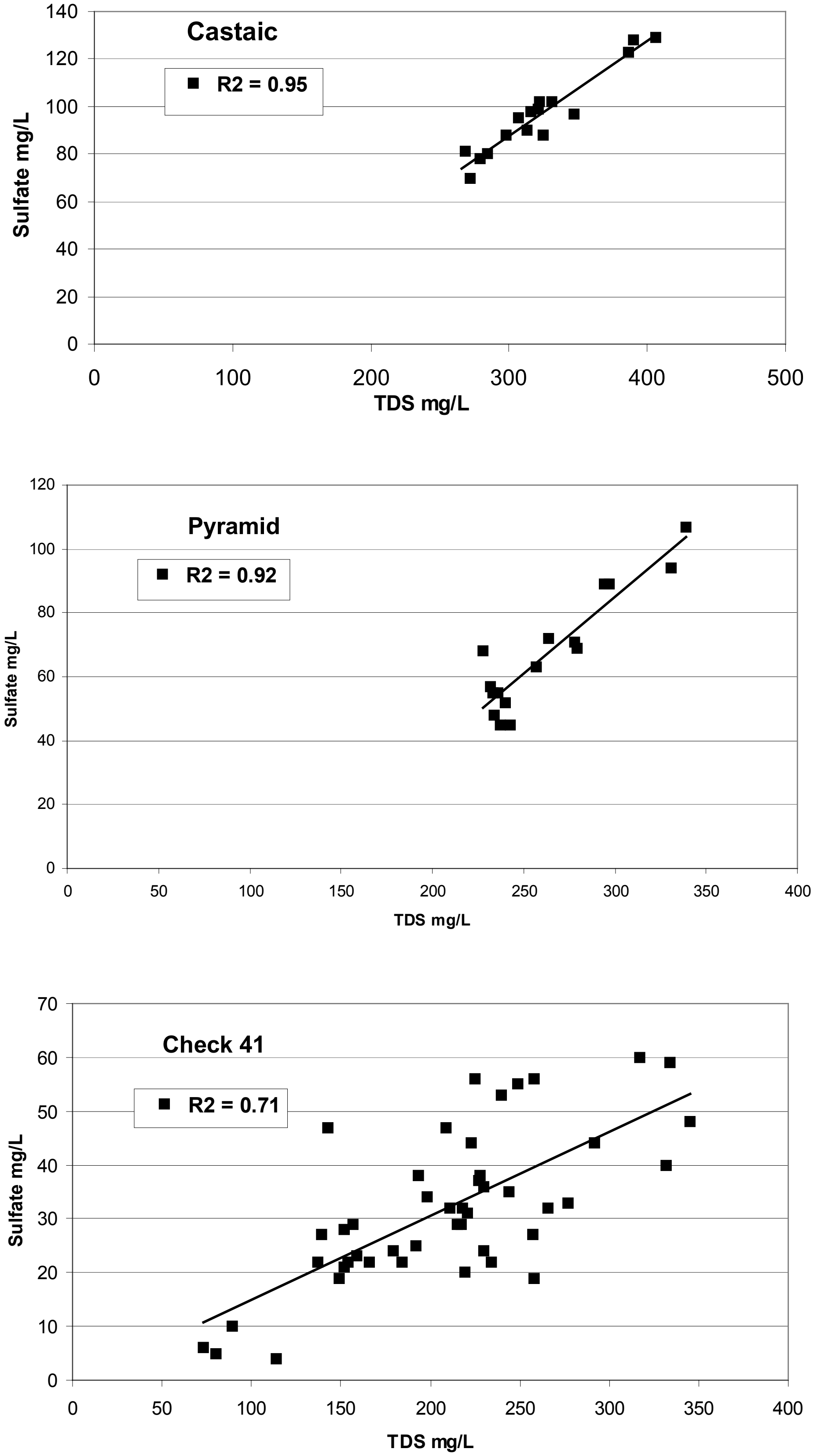


TDS (mg/L)	50	100	150	200	250	300	350	400	450	More
Frequency	0	0	0	0	7	7	2	0	0	0
■ Cumulative %	0%	0%	0%	0%	44%	88%	100%	100%	100%	100%



TDS (mg/L)	50	100	150	200	250	300	350	400	450	More
Frequency	0	0	0	0	0	5	8	2	1	0
■ Cumulative %	0%	0%	0%	0%	0%	31%	81%	93%	100%	100%

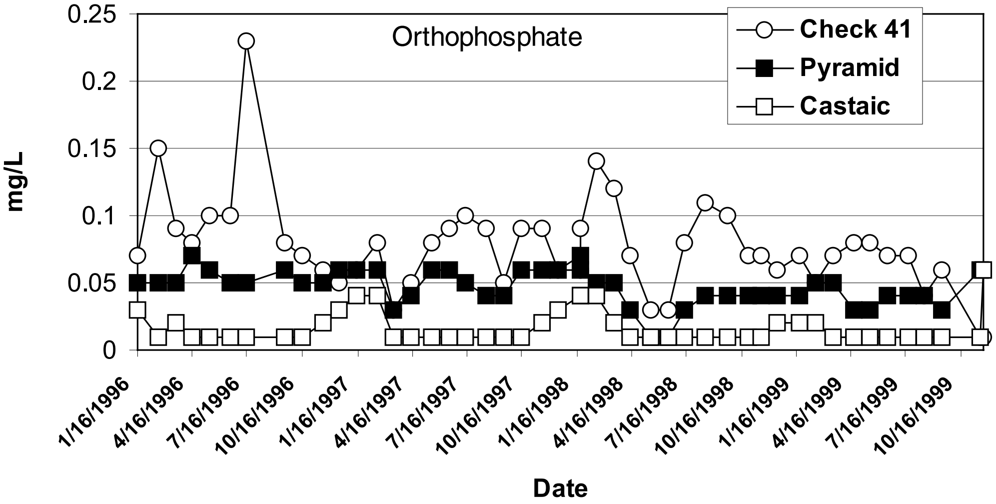
Figure 7-9 TDS vs. Sulfate in Pyramid, Castaic, and Check 41



Nutrients

Nutrient levels in Castaic Lake were lower than both SWP inflows at Check 41 and Pyramid Lake, with a pattern of decreasing concentration evident from one to the next (Figure 7-10). The reason for this observation is unknown, although it could be because of increased algal utilization in Castaic Lake. Total phosphorus levels ranged from 0.01 to 0.09 mg/L , averaging 0.033 mg/L (Table 7-7). Orthophosphate levels ranged from <0.01 to 0.06 mg/L , averaging 0.017 mg/L and detected in only 19 of 48 samples. Kjeldahl nitrogen levels (as N) ranged from 0.2 to 0.8 mg/L , averaging 0.39 mg/L. Nitrate and nitrite levels (as N) ranged from <0.01 to 0.5 mg/L and averaged 0.16 mg/L. Both forms of phosphorus, total and orthophosphate, and nitrate and nitrite followed a seasonal pattern of winter increase and summer decrease (Figure 7-11). The phenomenon is caused by lake turnover and algal uptake rates (see Nutrients under Pyramid Lake Section 7.1.4.1).

Figure 7-10 Nutrient Concentrations at Check 41 and West Branch Lakes



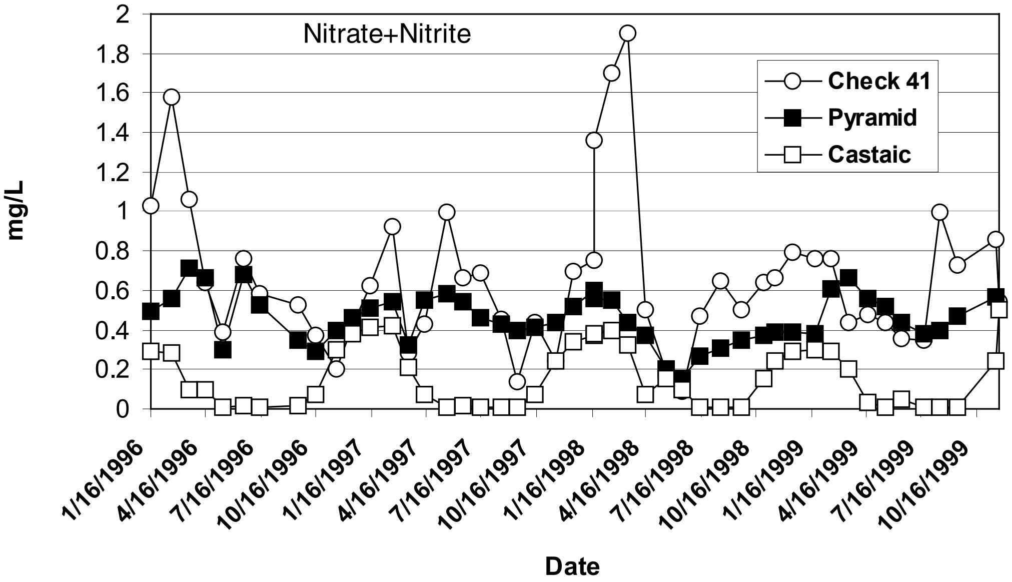
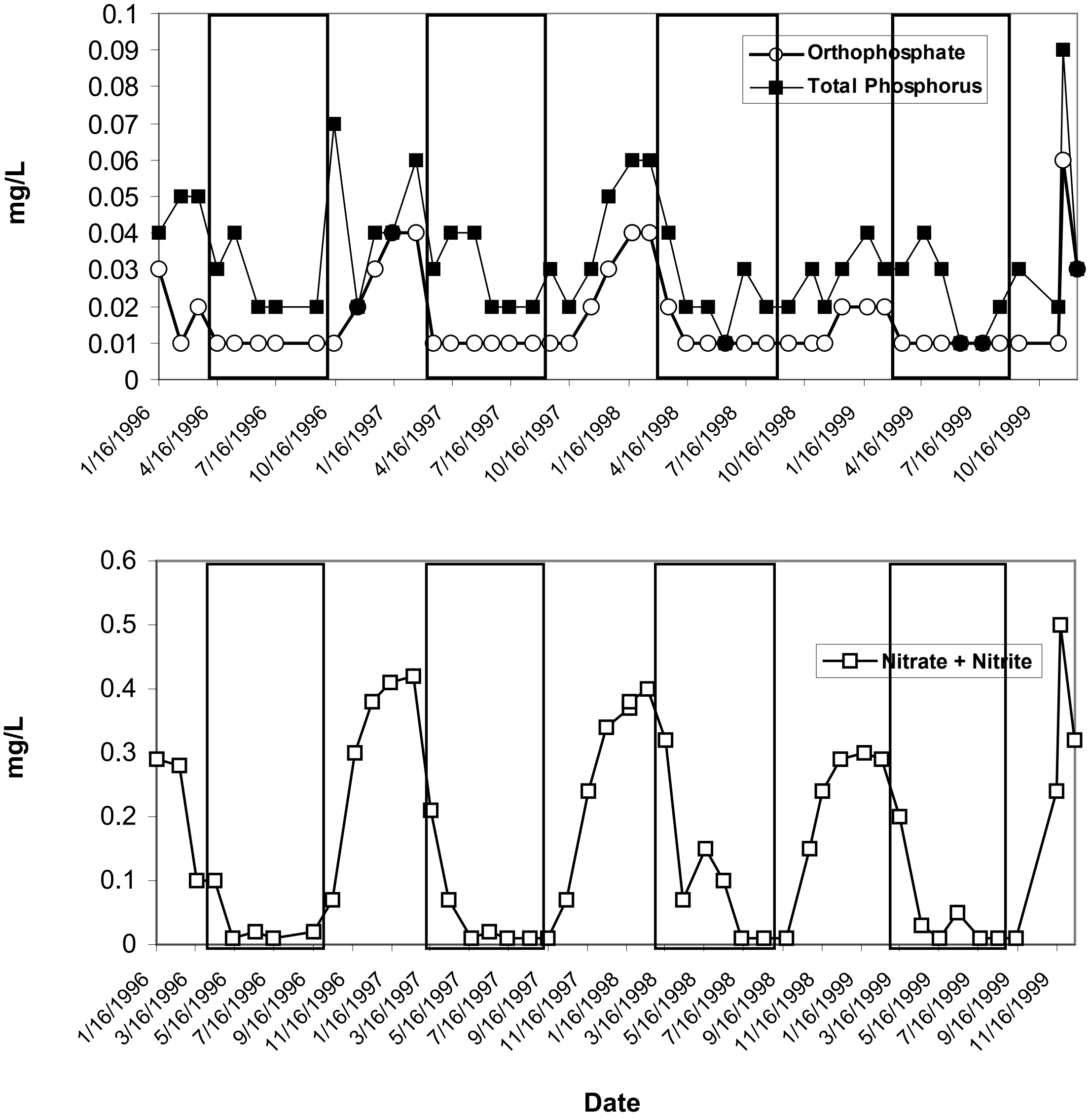


Figure 7-11 Seasonal Variation in Nutrient Concentrations in Castaic Lake, 1996 to 1999



Source: DWR Operations and Maintenance database
Boxed areas represent approximate algal growing season

Turbidity

Activities in the recreation areas can contribute to erosion, given the highly erosive soils around Castaic Lake. Algal blooms can also cause increased turbidity. This is discussed under Section 7.2.2, Water Supply System. Turbidity is also an issue associated with pathogens because of its effect on disinfection efficiency.

Turbidity is monitored quarterly, along with other conventional parameters. Turbidity in Castaic Lake was much lower than SWP inflows and Pyramid Lake, ranging from 1 to 3 NTUs (Table 7-7). Pyramid Lake settles out the majority of the SWP inflow turbidity. However, the effects of these activities could be masked because of the sampling location or settling capacity of the lake or both.

Total Organic Carbon and Alkalinity (DBP precursors)

Total organic carbon (TOC) concentrations at Castaic Lake from 1996 to 1999 ranged from 2.5 to

7.7 mg/L and averaged 3.97 mg/L (Table 7-7). Alkalinity ranged from 84 to 114 mg/L and averaged 98.7 mg/L. These values are based on only 16 samples collected quarterly, as with other conventional parameters.

TOC values appear to be largely affected by SWP inflow quality at Check 41 (Table 7-9). The 5 highest TOC values between 1996 through 1999 at Castaic Lake occurred in 1996, 1997, and 1999. As shown in Table 7-9 and in Figure 7-12, values at Castaic Lake commonly fell 1 month, and no more than 2 months, after the high value at Check 41, and appear to correlate with high levels in SWP inflows.

High TOC levels in 1996 were the result of early and late season runoff in the Central Valley (that is, floodwater inflows in the San Luis Canal) and at Check 41. Total Trihalomethane Formation Potential (TTHMFP) levels were also high during the same periods, and were composed of mostly chloroform and bromodichloromethane (DWR 1999).

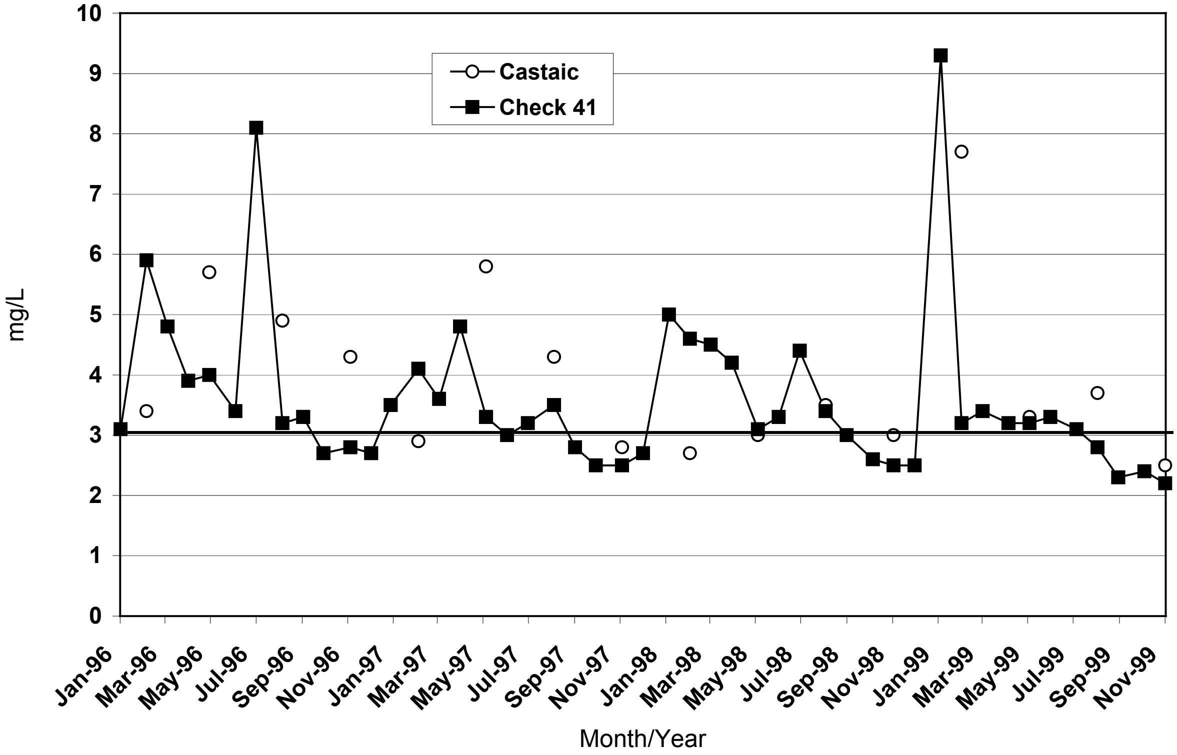
The highest TOC value was found in February 1999, following a very high TOC sample in January 1999 at Check 41. The very high value of 9.3 mg/L at Check 41 in January 1999 was unusual because upstream floodwater and non-SWP inflows were absent that month. It was suspected that a short-duration slug of TOC from the Delta that passed Check 41 at the time of sampling was the cause. Natural inflow to Castaic Lake was probably not the source of the high TOC value of 7.7 mg/L because there was no corresponding increase observed in 1998 when natural inflow accounted for 41% of all inflows (and <1% in 1999) (DWR 2000).

As with Check 41, Castaic Lake TOC levels frequently exceeded the proposed drinking water protection standard of 3 mg/L at the export pumps at Banks Pumping Plant (Figure 7-12). With alkalinity in the 60 to 120 mg/L range, the high TOC levels would still require some removal by water supply agencies, as specified in the proposed TOC removal requirements under the D/DBP Rule. Bromide levels in Castaic Lake ranged from 0.12 to 0.14 mg/L , within the range of values for Check 41, and averaged 0.13 mg/L , also similar to Check 41. Only 4 samples were collected because sampling was only begun in 1998. These values also exceed the proposed drinking water protection standard of 0.05 mg/L for bromide. Both of these parameter levels are a reflection of Delta contaminant sources and water quality conditions.

Table 7-9 Comparison of TOC at Check 41 and Castaic Lake

Check 41		Castaic Lake	
Month/Year	TOC (mg/L)	Month/Year	TOC (mg/L)
Feb 1996	5.9	May 1996	5.7
Mar 1996	4.8	Aug 1996	4.9
Jul 1996	8.1	Nov 1996	4.3
Apr 1997	4.8	May 1997	5.8
Jan 1999	9.3	Feb 1999	7.7

Figure 7-12 TOC Concentrations at Castaic Lake and Check 41



MTBE

The MWDSC performed sampling at Castaic Lake from summer 1996 to summer 1998. MWDSC sampled 3 locations, the lake inlet, the lake outlet, and the main boat ramp. DWR sampled 3 locations during the summer recreation seasons of 1997 and 1998: the lake outlet, the main boat ramp, and the west boat ramp. Surface samples were collected at all locations. Mid-depth and deep water samples were also collected at the lake outlet to evaluate the vertical distribution of MTBE in the water column. The mid-depth samples were collected at the bottom of the epilimnion, just above the thermocline. The deep water samples were collected within the hypolimnion. Results are presented in Table 7-10.

Castaic Lake was thermally stratified during the summer of 1997. The thermocline divided the epilimnion from the hypolimnion from June through September. The depth to the thermocline varied from approximately 8 to 12 meters.

MTBE concentrations in Castaic Lake were higher than other reservoirs with lower recreational use. MTBE concentrations in surface samples began to rise in the early summer as recreation increased. Surface values routinely exceeded the primary MCL of 13 µg/L during the summer months. MTBE concentrations declined in the winter months to levels below the secondary MCL of 5 µg/L. The deep water samples remained below the secondary MCL through the summer recreation season.

The main boat ramp exhibited higher MTBE concentrations than the west boat ramp, probably because the main ramp has 18 boat lanes while the west ramp has only 6 lanes. DWR sampling revealed that MTBE concentrations at the main boat ramp ranged from 9.7 to 22.0 µg/L. The mean was 16.2 µg/L. MTBE concentrations at the west boat ramp ranged from 3.1 to 15 µg/L. The mean was 11.1 µg/L. These data are based on 8 samples collected by DWR between June 1997 and November 1997.

MWDSC and DWR collected 33 surface samples at the outlet tower between October 1996 and

October 1998. MTBE concentrations in MWDSC samples ranged from 1 to 29 µg/L with a mean of 8.9 µg/L (Table 7-10). DWR samples ranged from 1 to 24 µg/L, with a mean of 8.6 µg/L. These and other DWR samples (at the boat ramps) are presented in Figure 7-13. The 2 highest values in both datasets, 24 and 29 µg/L, were detected immediately following the 4th of July weekend in 1997. The 3rd highest value, 20.8 µg/L, was observed after the 4th of July weekend in 1998. Excluding these high values, the overall mean concentration at the outlet was 6.8 µg/L.

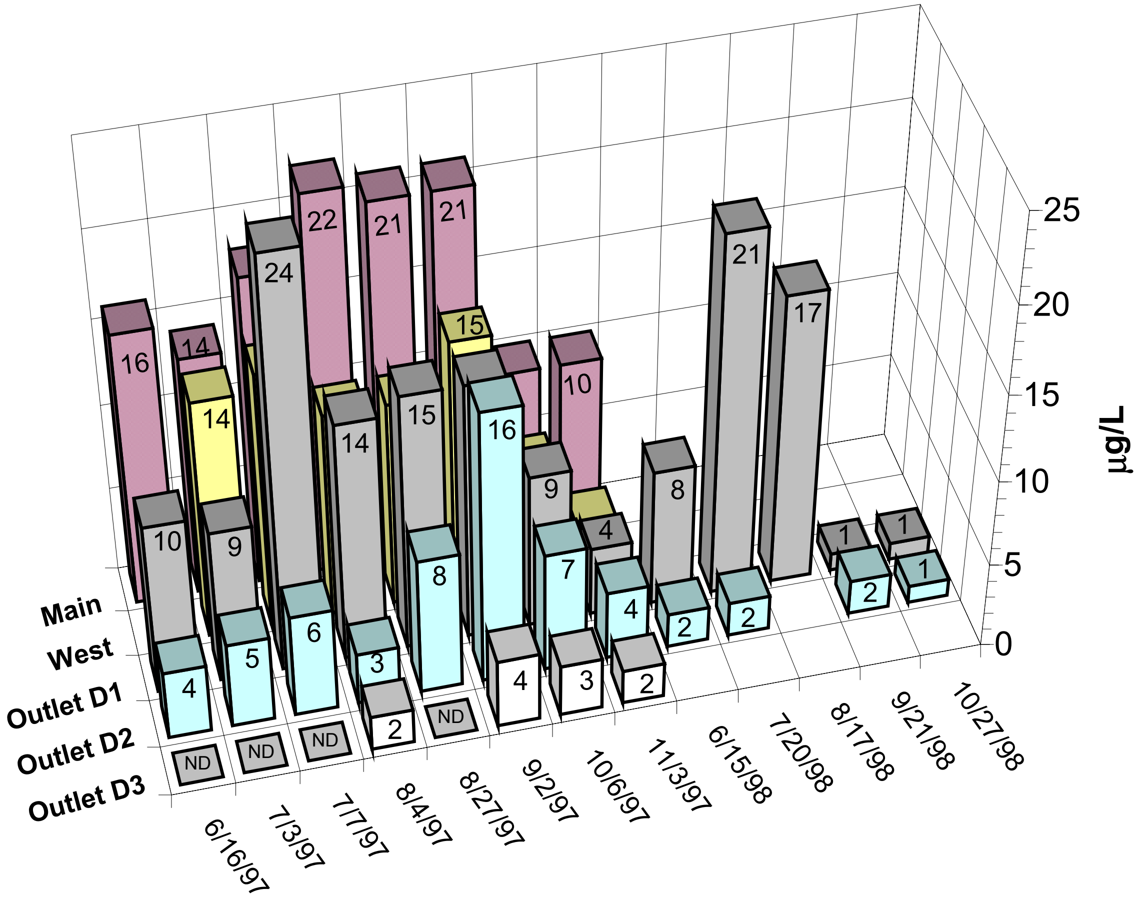
Table 7-10 Summary of MTBE Concentrations in Castaic Lake (µg/L)

MWDSC Sampling	Outlet (1997)		Main Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion)				
Range	2.0 to 29	ND to 2.6	1.0 to 20	ND to 3.8
Mean	8.9	1.0	7.7	1.3
Bottom (Hypolimnion)				
Range	ND to 2.3	N/S	N/S	N/S
Mean	1.0	N/S	N/S	N/S

DWR Sampling	Outlet (1997-98)		Main Boat Ramp (1997)		West Boat Ramp (1997)	
	Summer	Winter	Summer	Winter	Summer	Winter
Surface (Epilimnion D1+D2)						
Range	1.0 to 24	N/S	9.7 to 22	N/S	3.1 to 15	N/S
Mean	8.6	N/S	16.9	N/S	11.1	N/S
Bottom (Hypolimnion)						
Range	ND to 4.0	N/S	N/S	N/S	N/S	N/S
Mean	2.8	N/S	N/S	N/S	N/S	N/S

Notes: Surface samples include samples collected from 0.5 to 15 meters
ND = Not Detected, N/S = Not Sampled

Figure 7-13 Summary of MTBE Concentrations in Castaic Lake



Data source: DWR 1999, DWR Operations and Maintenance unpublished data 1998
Notes: Outlet D1 = 0.5 m, Outlet D2 = 7-10 m, Outlet D3 = >18 m

MTBE concentrations in samples collected from the lower portion of the epilimnion ranged from 3.3 to 16.0 µg/L. The mean was 6.6 µg/L out of 8 samples. MTBE was only detected in 4 of the 8 DWR samples from the hypolimnion in summer. When detected, MTBE ranged from 2 to 4 µg/L and averaged 1.3 µg/L. The high value of 4 µg/L (DWR data) was observed in early September as the thermal stratification was weakening and the epilimnion and hypolimnion began to mix. MWDSC data concur with DWR values.

Surface samples were collected at the outlet tower and boat ramps before and after the 4th of July and Labor Day weekends in 1997 (not shown in table). These 2 weekends represent the periods of highest recreational use at the lake. Over the 4th of July weekend, MTBE concentrations increased from 9 to 24 µg/L at the outlet tower. The outlet tower lies close to the area of the lake reserved for personal watercraft use (Figure 7-7). The boat ramps exhibited less of an increase. The main boat ramp increased from 14 to 15 µg/L and the west boat ramp increased from 12 to 18 µg/L.

A group of compounds commonly associated with fuel contamination, benzene, toluene, ethyl benzene, and xylene (BTEX), and MTBE were detected together in only 14% of the 39 surface samples that DWR collected from the boat ramps and outlet tower in 1997. Because BTEX is not mobile in the water column, its presence indicates local contamination by gasoline. MTBE and BTEX were detected together in 7 out of 8 surface samples taken at the main boat ramp. This number dropped to 2 out of 7 at the west boat ramp and 3 out of 8 at the outlet tower.

Taste and Odor

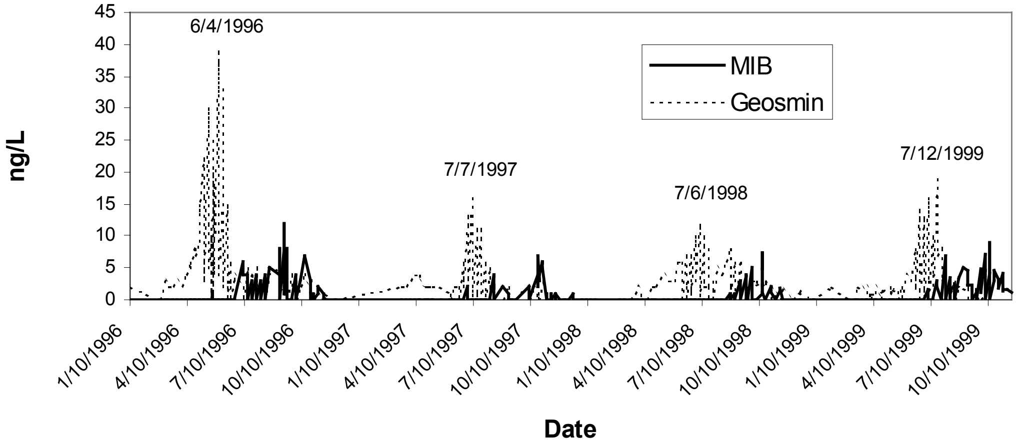
MIB and geosmin are organic compounds resulting from algal growth that impart undesirable taste and odors to drinking water. While periods of excessive MIB and geosmin are associated with algal blooms in spring and fall, detectable levels of taste and odor affectors can occur in the Southern California reservoirs at any time of the year (Losee pers. comm. 2001). The taste and odor threshold for geosmin and MIB ranges from 5 to 10 ng/L.

MIB and geosmin are produced by algae, and in particular blue-green algae, near the surface of Castaic Lake. MIB and geosmin levels decline with increasing depth in Castaic Lake during peak growth season and during the winter. This temporal pattern is illustrated in Figure 7-14. Geosmin was detected in 78% of the surface samples (0 to 3 meters) collected in Castaic Lake. The range was nondetect to 63 ng/L. When detected, the mean was 6.1 ng/L. MIB was detected in only 32% of the surface samples with a range of not detected (ND) to 10 ng/L. When detected, the mean MIB concentration was 1.07 ng/L. The highest values occurred between the months of May and October.

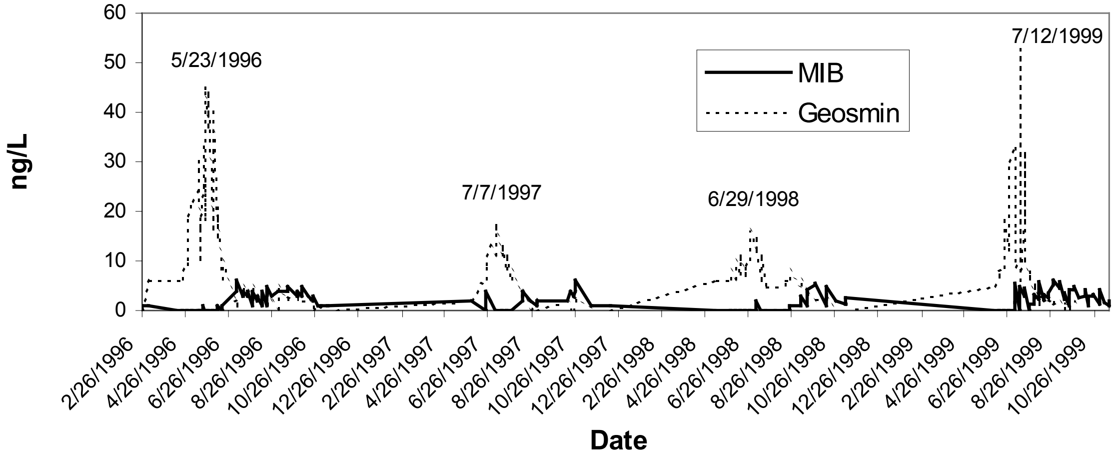
Managers use reservoir management practices such as selective depth withdrawal to minimize the amount of MIB and geosmin in lake outflow sent to the Jensen FP via the Foothill Feeder. The Jensen FP is discussed in detail under Section 7.2.2, Water Supply System.

Figure 7-14 MIB and Geosmin Levels, Castaic Lake Outlet, 1996 to 1999

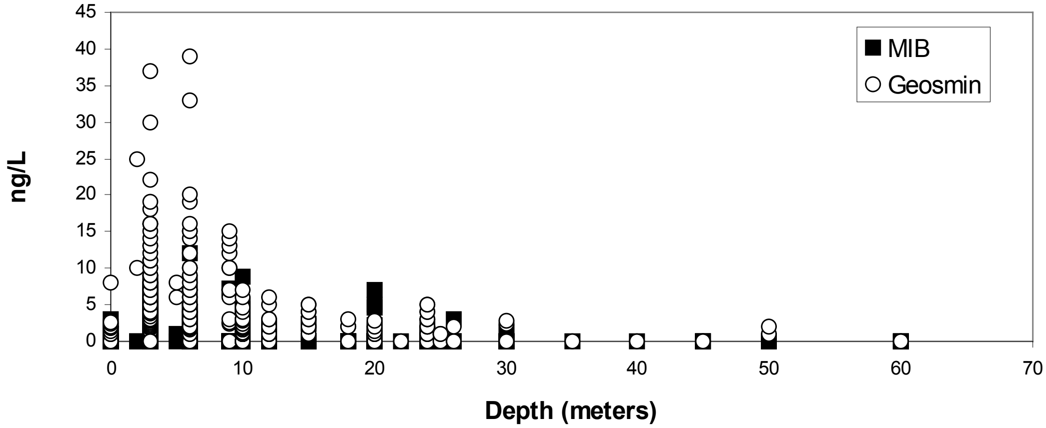
Castaic Lake Outlet



Castaic Lake Project Inlet Arm



Castaic Lake Outlet Tower - by Depth



7.2.4.2 Water Supply System

MWDSC Jensen Filtration Plant

MWDSC routinely monitors source (influent) and treated (finished) water quality to meet primary and secondary MCLs contained in Title 22 California Code of Regulations. Title 22 parameter categories for primary MCLs include inorganic chemicals (trace metals, nitrate/nitrite, asbestos), microbiological radioactivity, TTHMs, and organic chemicals. Secondary MCLs include, but are not limited to, iron, manganese, odor, turbidity, TDS, conductivity, chloride, and sulfate.

The main water quality concerns of MWDSC for treating SWP water are occasional high turbidities, DBP formation from TOC/bromide, and taste and odor problems associated with algal blooms. For the 1996 to 1999 period, finished water quality from the Jensen FP was well below all applicable primary and secondary MCLs for all regulated parameters. Souce water quality was well below primary MCLs for inorganics, organics, and radionuclides. (Torobin pers. comm. 2000). Data were obtained from the MWDSC laboratory database for 1996 to 1999, summaries from annual reports, and their consumer confidence reports for this period.

Trace metals and organic compounds are discussed first because they are either detected at low levels or not routinely detected and are, therefore, not of concern. The main parameters of concern selected for further discussion are presented below after trace metals and organics.

Aluminum, arsenic, barium, and iron were the only trace metals detected in Jensen FP influent (molybdenum and strontium were also detected but have no MCLs). Barium was present below the 0.05 mg/L level reported above in the watershed water quality section, and aluminum averaged 0.035 mg/L , with 1 high value of 0.47 mg/L , which was still below the MCL of 1 mg/L. Iron was not consistently detected and was always below 0.06 mg/L. Arsenic levels ranged from 0.0015 to 0.003 mg/L and averaged 0.002 mg/L, well below the current MCL of 0.05 mg/L. These values are also below the proposed MCL being evaluated for arsenic of 0.01 mg/L. The same trace metals were detected in Jensen FP finished water but at even lower levels.

Organic chemicals have many different analytical classes but in Title 22 are divided into 2 categories: volatile organic chemicals (VOCs) and nonvolatile synthetic organic chemicals (SOCs). VOCs include such compounds as benzene, MTBE, and trichloroethylene (TCE). SOCs include many of the organochlorine and organophosphate pesticides and other pesticides and herbicides. With the exception of MTBE, no VOCs, pesticides, herbicides, or other SOCs were detected at or above both the detection limits for purposes of reporting or laboratory detection limits in either source or finished water (Koch pers. comm. 2000, 20000a; Torobin pers. comm. 2000, 2001). MTBE was never detected in Jensen FP finished water.

The main drinking water parameters of concern in source and finished water as presented in watershed water quality section were selected for further discussion. These include in order: TDS, turbidity, nutrients, TOC (and D/DBPs), MTBE, and taste and odor. As shown in the following discussion of these parameters, the water quality of Jensen FP influent largely reflects that of Castaic Lake.

TOTAL DISSOLVED SOLIDS. Water quality data for TDS and sulfate in Jensen FP influent and finished waters and Castaic Lake are presented in Table 7-11. Sulfate was included with TDS to illustrate the connection with Pyramid Lake and Piru Creek. Chloride levels at these locations are very low and are not an issue.

Table 7-11 Comparison of TDS and Sulfate Concentrations (mg/L)

Parameter/Value	Castaic Lake	Jensen FP	
		Influent	Finished
TDS			
Range	266-406	278-392	302-371[a]
Average	319	323	329[b]
Sulfate			
Range	70-129	70-131	81-120[a]
Average	97	97	98[b]

[a] Range of 1996 to 1999 annual averages only

[b] Average of 1996 to 1999 annual average data

As shown in Table 7-11, both TDS and sulfate values are virtually unchanged in all 3 water sources. The highest TDS and sulfate values at all locations were in 1996, because of high natural inflows; and the lowest values were in 1998, because of the dilution effect of El Niño storms in Castaic Lake runoff, as discussed in the watershed section. The 10-year running average (1988 to 1997) for TDS in Jensen FP influent was 356 mg/L , while finished water was 362 mg/L (MWDSC 1998). All values were less than the secondary MCLs for TDS and sulfate of 500 and 250 mg/L , respectively.

TURBIDITY. High turbidities in the form of short-term spikes in the aqueduct, influent pipelines, and algal growth have caused occasional treatment problems at the Jensen FP. The effects on water treatment plants from high turbidity include increased chemical feed rates, excessive loading on solids handling facilities, lower filter run lengths, and higher than normal plant effluent (finished water) turbidities (MWDSC 2000).

Turbidities in Castaic Lake were low (as discussed in Section 7.2.4.1, Watershed, under Water Quality Summary) and ranged from 1 to 3 NTUs, averaging 1.6 NTU. Jensen FP influent turbidities averaged about the same at 1.4 NTU, but ranged from 0.3 to 9.5 NTUs, a much higher maximum value. The main problem associated with turbidity was high levels of algae in source waters that clog filtration systems. Finished waters were always well below the secondary MCL of 5 NTUs ranging from 0.04 to 0.06 NTU (1998 and 1999 data only - consumer confidence reports) and averaging 0.06 NTU.

NUTRIENTS. Nitrate levels (as NO_3) in Jensen FP influent were consistently higher than those of Castaic Lake. Jensen FP influent ranged from 1.2 to 2.3 mg/L and averaged 1.9 mg/L , while Castaic Lake values were <0.1 to 1.8 mg/L , with an average of 0.7 mg/L. Annual averages for both nitrate and nitrate+nitrite (as N) in finished waters were usually the same and ranged from 0.4 to 0.5 mg/L , well below the MCL of 10 mg/L.

TOTAL ORGANIC CARBON AND ALKALINITY (DBP PRECURSORS). DBP precursors in SWP water such as TOC and bromide react with disinfectants at the Jensen FP to produce TTHMs and haloacetic acids (HAAs), which along with bromate are the primary DBPs of concern. Although MWDSC has not exceeded the current MCL for TTHMs, TOC and bromide levels in SWP water are too high to comply with the Stage 1 D/DBP Rule proposed MCL for TTHMs of 80 µg/L in the absence of additional treatment or other measures. Additionally, member agencies that receive finished water from the Jensen FP experience higher TTHM levels in their distribution systems because of the continued formation of TTHMs in the pipelines (MWDSC 2000).

Water quality data for TOC and alkalinity in Jensen FP influent and finished waters and Castaic Lake are presented in Table 7-12.

Castaic Lake TOC levels frequently exceeded the proposed drinking water protection standard of 3 mg/L at the export pumps at Banks, while Jensen FP influent exceeded it but less frequently. Castaic Lake TOC levels were somewhat higher than Jensen, with a much higher high-range value, while Jensen FP influent and finished water were very similar. It is not known why Castaic Lake TOC levels appear to be higher than Jensen FP influent, given the enclosed nature and relatively short distance of the Foothill Feeder pipeline. Alkalinities were very similar at all locations and were consistently within the 60 to 120 mg/L proposed in the D/DBP Rule for 25% TOC removal at TOC values from >2-4 mg/L. All TOC values in Jensen FP influent were below 4 mg/L.

Bromide levels in Castaic Lake ranged from 0.12 to 0.14 mg/L and averaged 0.13 mg/L. These values also exceed the proposed drinking water protection standard of 0.05 mg/L for bromide.

Table 7-12 Comparison of TOC and Alkalinity at Jensen FP (mg/L)

		Jensen FP	
Parameter/Value	Castaic Lake	Influent	Finished
TOC			
Range	2.5-7.7	2.1-3.3	2.5-2.9[a]
Average	4.0	2.7	2.7[b]
Alkalinity			
Range	84-114	85-106	81-120[a]
Average	99	96	98[b]

[a] Range of 1996 to 1999 annual averages only.
[b] Average of 1996 to 1999 annual average data.

TTHMs are monitored in Jensen FP finished water only. TTHM levels ranged from 39 to 67 µg/L in 1998 to 1999 and averaged 49 µg/L on an annual average basis. During 1997, TTHMs were always below 50 µg/L. In 1996, the annual average was 56 µg/L. Finished water quality always met the current MCL of 100 µg/L, but MWDSC will be challenged with the proposed MCL of 80 µg/L in the Stage 1 D/DBP Rule.

The practice of using chlorine for primary disinfection results in TTHMs in the Jensen FP service areas greater than the proposed MCL of 80 µg/L. In addition, the Stage 1 D/DBP Rule will require enhanced coagulation removal of TOC, unless certain exceptions are met (25% TOC removal from >2-4 mg/L and alkalinity of 60 to 120 mg/L). MWDSC has decided to convert the Jensen FP from chlorination to ozonation for primary disinfection as the most effective solution to comply with Stage 1 and future Stage 2 requirements of the D/DBP Rule. The use of ozone and chloramines will reduce TTHMs to less than 40 µg/L, which will allow MWDSC to qualify for an exception to the enhanced TOC treatment component of the rule. However, the high TOC and bromide levels will still present treatment challenges. High TOC results in a higher ozone demand, which results in a higher level of ozone byproducts, and the conversion of TOC to assimilable organic carbon. The assimilable organic carbon can result in the growth of biofilm in the distribution system. MWDSC plans to employ biological filtration to reduce this carbon type.

Although ozone disinfection will help reduce the levels of TTHMs in finished water, ozone also reacts with bromide in source waters to produce bromate, considered a human carcinogen by the California Office of Environmental Health Hazard Assessment and a DBP regulated in the D/DBP Rule. Because of the relatively high bromide levels in SWP water, bromate levels typically formed during ozonation will exceed the Stage 1 bromate MCL of 10 µg/L. MWDSC plans to control the amount of bromate formed in the ozonation process by lowering the pH to 7.0 or lower using sulfuric acid addition. Higher bromide concentrations will require pH reduction to 6.0. Further, if the future Stage 2 D/DBP Rule lowers the proposed bromate MCL to 5 µg/L, the frequency of pH adjustments would dramatically increase (MWDSC 2000)

MTBE. The MTBE concentrations in surface samples near the outlet tower at Castaic Lake were high and ranged from 1 to 29 µg/L with an overall mean from both MWDSC and DWR samples of 8.7 µg/L. MTBE concentrations in samples collected lower in the reservoir ranged from 3.3 to 16.0 µg/L with a mean of 6.6 µg/L. At the lowest portion of Castaic Lake sampled (the hypolimnion), MTBE was only detected in 4 of the 8 DWR samples and ranged from 2 to 4 µg/L with a mean of 1.3 µg/L.

MTBE levels in Jensen FP influent were generally lower and ranged from not-detected (detection limit 0.5 µg/L) to 1.2 µg/L. This is probably explained by a combination of the lower levels of MTBE in water being withdrawn at the outlet tower from greater depths and loss in the Foothill Feeder. These levels and those in the lowest portion of Castaic Lake were well below the MCL of 13 µg/L. MTBE was never detected in Jensen FP finished water.

TASTE AND ODOR. Jensen FP influent had much lower levels of MIB and geosmin than surface values in Castaic Lake. Geosmin was detected in 8% of 173 samples collected at Jensen FP. The range was ND to 6 ng/L. When detected, the mean geosmin concentration was 2.1 ng/L. MIB was detected in 2.4% of the samples with a range of ND to 2 ng/L. Of the samples where MIB was detected, the mean was 1.2 ng/L.

MIB and geosmin have extremely low taste and odor thresholds. Geosmin has an odor threshold of only 5 to 10 ng/L. Geosmin values were above the threshold level on 1 occasion (that is, 6 ng/L). MWDSC has developed a flavor profile analysis method for taste and odor in finished water that accurately detects odor occurrences.

CLWA Rio Vista Water Treatment Plant

The CLWA treatment plant uses 100% SWP water, and the influent is received at the same location as MWDSC, just with a shorter pipeline. Therefore, CLWA is subject to the same source water quality conditions as MWDSC. The CLWA water quality concerns are the same as those described above for MWDSC. The major concern is high levels of DBP precursors TOC and bromide (CLWA 2000a). They are also concerned about high turbidities associated with local watershed erosion conditions. CLWA did not report a major concern with taste and odor issues for this period. All Title 22 parameters were below applicable MCLs (McClean pers comm. 2000a, 2000b).

Similar to MWDSC, CLWA has chosen to adopt ozonation as the best solution to meet the D/DBP Rule requirements. The CLWA treatment plant processes include preozonation, contact clarification (a special process replacing conventional flocculation/sedimentation that biologically reduces DBP precursors), filtration, and primary disinfection by ozone.

Pathogens

Pathogen issues related to Castaic Lake are discussed in Chapter 12 for the Jensen FP.

7.2.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The significant contaminant sources and major water quality concerns at Castaic Lake are related to both SWP source water and watershed activities. The main concerns associated with source water quality are DBP precursors (for example, TOC and bromide), taste and odor associated with algal growth in the reservoir, and turbidity caused by SWP inflow spikes and algal growth. The main water quality concerns associated with watershed activities include pathogens and MTBE from recreation, pathogens and erosion from animal populations, and TDS in natural inflows.

TOC and bromide do not appear to be significantly changed by watershed activities at Castaic Lake. The major contributor of these parameters is the Delta via the California Aqueduct at Check 41, which can also be a source of turbidity spikes. Castaic Lake and Jensen FP influent TOC levels exceeded the target drinking water protection standard of 3 mg/L , although Jensen FP was never above 4 mg/L. Bromide levels also exceeded the target drinking water protection standard of 0.05 mg/L. The MCLs for these parameters are currently being met, but high levels of DBPs in Delta and aqueduct water present challenges meeting Stage 1 D/DBP Rule limits for TTHMs and bromate.

Eutrophication of the lake caused by nutrient-loading from source waters, results in increased lake turbidity and production of MIB and geosmin, 2 compounds causing taste and odor problems in water supplies. Turbidity in delivery pipelines from Castaic Lake is also affected by sediment resuspension when contractors significantly and abruptly increase their flows. Nutrient levels in Castaic Lake were lower than Pyramid Lake and SWP inflows, and there was no evidence that watershed activities significantly contributed to existing nutrient loads. Use of copper sulfate for algae control can also be a source of copper but is not a concern for drinking water supplies at this time.

Recreation is an important contaminant source and water quality concern within the Castaic Lake watershed. The water quality problems associated with recreational activities at Castaic Lake are the contribution of pathogens, release of MTBE from motorized watercraft, and turbidity because of erosion in camping and shoreline areas, hiking, biking, etc. MTBE, although higher in the lake, was always below the MCL in Jensen FP influent but still poses a potential threat to drinking water quality. Body-contact recreation is considered a significant, although as yet unquantified, potential pathogen source. Also of concern for release of pathogens are the 3 floating toilets (potential spills, leaks) and incidental waste releases from boats. In addition to the potential to cause disease in water recreationists, large enough concentrations of pathogens might also overwhelm the Jensen FP, especially under higher turbidities, and inhibit the required removal levels for pathogens under the Interim Enhanced Surface Water Treatment Rule (IESWTR).

Both grazing and wild animals in the watershed represent a potential pathogen source. However, the contributions from animal populations are impossible to assess with existing data. Erosion caused by grazing animals, especially in shoreline areas, results in increased turbidity in the lake. Grazing has been a problem in the watershed and is exacerbated by poor maintenance of fencing, which results in shoreline erosion and erosion in other areas as well. Fire is not a direct contaminant source but can result in increased erosion and turbidity, especially in grazing areas.

TDS and sulfate concentrations in Castaic Lake and Jensen FP influent are below the secondary MCL of 500 mg/L. However, it appears that the levels of these parameters are elevated relative to SWP source water because of inflows from Piru Creek in the Pyramid Lake watershed.

Wastewater treatment plant effluent is considered a low threat because there are only 2 small WWTPs in the watershed and they do not discharge effluent to a receiving stream. There were no spills or problems with the extensive sewage collection system and 5 pump stations, but the potential exists and could be significant if spills occurred. The contaminants of concern are pathogens, DBPs, and nutrients. Septic systems also present an unknown but significant potential source of pathogens and nitrate in the Elizabeth Lake area, Castaic Powerplant, and the rustic boat-in sites.

Leaks and spills of hydraulic oil used at SWP facilities such as power plants can be a source of organic contaminants such as petroleum hydrocarbons.

7.2.6 WATERSHED MANAGEMENT PRACTICES

There are several agencies with management authority in the Castaic Lake watershed. However, an overall watershed assessment/management program is not present, and no specific best management practices (BMPs) are in place or proposed for implementation. DWR constructed the reservoir and is primarily responsible for its operation. The Los Angeles County Department of Parks and Recreation manages the Castaic Lake SRA and controls recreation activities within the watershed. Recreational boating is also regulated through the DBW. Recreation presents the largest watershed management issue at Castaic Lake, and activities often can be significant potential sources of contamination. Strategies to address and mitigate impacts on drinking water quality are being discussed in a water quality and recreation focus group—DWR, both California and county departments of parks and recreation, and other involved agency staff.

The regional water quality control board regulates through NPDES permits, and unauthorized discharges such as spills or overflows are prohibited. The Los Angeles County Department of Public Works is regulated to prevent spills to surface waters from the sewage collection system. The Los Angeles County Health Department oversees this area, as well as septic system issues.

The USDA Forest Service manages much of the land used for grazing in the watershed, has guidelines in grazing leases, and surveys areas to maintain residual mulch on grazing land to protect the soil base. Its role and powers are described in Section 7.1, Pyramid Lake. The State Water Resources Control Board (SWRCB) Non-point Source program has guidelines for water quality management in rangeland areas. Livestock grazing management practices to protect water quality include exclusion by fencing or other barriers, attraction, culling, and changing herd structure or distribution and grazing systems or both (George 1996). Implementation of these practices around shoreline areas would reduce water quality impacts associated with grazing by protecting bank structure, soils, and vegetation in these areas.

The high TDS and sulfate from natural sources in Piru Creek should be evaluated to verify previous findings, identify the sources and mechanisms involved, and determine if it could have a significant effect on water quality.

DWR is responsible for managing the physical facilities for the SWP such as power plants, etc. Because leaks and spills from equipment are a potential contaminant source, vegetable oils or water have been recommended as possible replacements.

7.3 SILVERWOOD LAKE

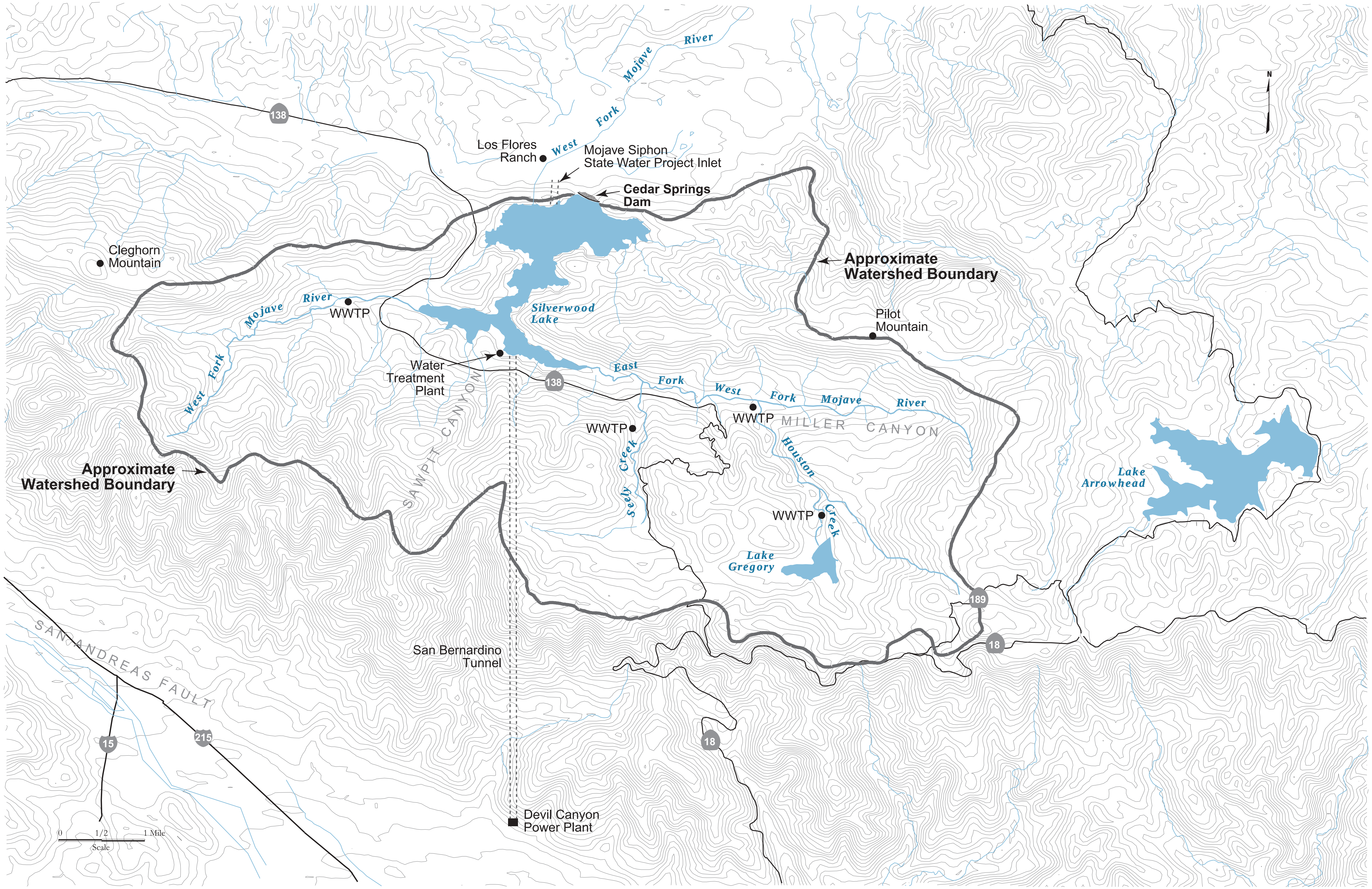
7.3.1 WATERSHED DESCRIPTION

Silverwood Lake is formed by Cedar Springs Dam on the west fork of the Mojave River. It is in the San Bernardino National Forest and approximately 30 highway miles north of the city of San Bernardino. At 3,355 feet, Silverwood is the highest of the 4 Southern California SWP reservoirs but has one of the smallest watershed at 29 square miles. Silverwood Lake is a multipurpose facility, providing emergency and regulatory storage as well as domestic water for the surrounding mountain and desert communities. Silverwood Lake also provides recreational opportunities and fish and wildlife habitat. It is the 1st reservoir on the East Branch of the California Aqueduct. SWP water flows into the lake through the Mojave Siphon Powerplant and flows out of the lake into the San Bernardino Tunnel, which leads to the Devil Canyon Powerplant (Figure 7-15). These facilities are discussed under Section 7.3.2.1, Description of Aqueduct/SWP Facilities.

7.3.1.1 Land Use

The 29 square mile watershed is composed mainly of San Bernardino National Forest land. The Silverwood Lake SRA occupies the area immediately surrounding the lake. California State Parks operates the SRA, which offers a variety of body contact and nonbody-contact recreational activities. Most of the recreational amenities are along the south shore of the lake. There is some residential development along Cleghorn (also known as the West Fork Mojave River) and Sawpit creeks in the southern portion of the watershed. There is a substantial amount of development surrounding Lake Gregory, a lake to the south that drains into Silverwood Lake.

Figure 7-15 Silverwood Lake Watershed Area



7.3.1.2 Geology and Soils

Soils primarily consist of sediments from the parent rock of the surrounding area. The USDA has not conducted a detailed soil survey in this region of the county. Soils north of Cedar Springs Dam are described as loamy and sandy sediments (USDA 1971).

The central portion of the watershed contains granite, quartz monzonite, granodiorite, and quartz diorite. The southern portion of the watershed contains a complex of igneous and metamorphic rocks, consisting mostly of gneisses and schists. In the northern portion of the watershed, Highway 138 bisects a region of alluvium, lake, playa, and terrace deposits, and a region of loosely consolidated sandstone, shale, and gravel deposits. The watershed contains well-located fault traces that occur in the batholithic rocks as well as in the granites.

Cedar Springs Dam lies in a seismically active region, approximately 10 miles north of the San Andreas Fault (Figure 7-15).

7.3.1.3 Vegetation and Wildlife

Climate and weather pattern, along with the watershed's proximity to the ocean, play a role in determining its vegetation types. The lower elevations surrounding the northern portion of the lake are predominately covered by desert chaparral, which is dominated by scrub oak and manzanita. The southern portion of the lake is also surrounded by desert chaparral except along the 2 branches of the Mojave River, which flow seasonally and support oaks and sycamores (DWR 1996). The higher elevations are populated with Ponderosa pines, incense cedar, Douglas fir, and black oaks (DWR 1991).

There is a substantial but unknown wildlife population in the largely undeveloped watershed. Avian species observed in the watershed include mountain chickadees, acorn woodpeckers, Stellar's jays, thrashers, wrentits, and quail. Mammalian species include Mule Deer, mountain lions, bobcats, gray fox, and coyotes as well as squirrels and white-footed mice. Bald eagles have been observed nesting around the lake (DWR 1991).

7.3.1.4 Hydrology

Silverwood Lake is in the rain shadow of the San Bernardino Mountains, which have a varying effect on the climate and weather of the watershed (Schoenherr 1992). The lake has 3 main sources of inflow in the 29 square-mile watershed. They are SWP inflows and natural inflows from the West Fork Mojave River (or Cleghorn Creek) and from the East Fork West Fork Mojave River (or Miller Canyon Creek) (Figure 7-15). Cleghorn Creek drains a relatively undeveloped portion of the watershed descending from Cleghorn Mountain. Miller Canyon Creek collects water from the southeastern portion of the watershed, as well as Seely and Houston creeks. Houston Creek originates at Lake Gregory, approximately 5 miles upstream of Silverwood Lake. Lake Gregory is a small lake in the southern portion of the watershed. Its high elevation means that Lake Gregory collects snow runoff in the spring. Water is kept in the lake through the summer months and released to Houston Creek in September. Houston Creek is tributary to Miller Canyon Creek and Silverwood Lake.

In 1996 and 1997, natural inflows totaled 11,714 and 8,890 acre-feet, or about 2% of the total inflow (Table 7-13). The El Niño storms of 1998 led to higher-than-average natural runoff. In 1998, the natural inflow made up 10% of the total lake inflow.

Table 7-13 Annual Natural Inflows to Silverwood Lake (acre-feet)

1996	1997	1998	1999
11,714	8,890	41,685[a]	2,291

Source: DWR Division of O&M, SWP Operations Data, 1996 to1999

[a] 13,948 acre-feet total in Feb 1998 during El Niño storms; 9,177 in May.

However, SWP inflows are substantially greater than the natural runoff (Table 7-14).

Table 7-14 SWP Inflow/Outflow for East Branch and Silverwood Lake (acre-feet)

	1996	1997	1998	1999
East Branch Outflow	490,254	603,691	439,565	607,066
Silverwood Lake:				
Inflow	398,250	495,507	352,561	499,644
Outflow	440,661	443,005	356,851	503,735

Source: DWR Division of O&M, SWP Operations Data 1996 to 1999

Outflow from the lake includes releases to the Mojave River below Cedar Springs Dam and releases to the San Bernardino Tunnel, which supplies the Devil Canyon Powerplant and the rest of the East Branch of the California Aqueduct. The SWP inflow comes from the north side of the lake, and the major outflow is at the southern side of the lake. This creates a north-to-south flow regime. SWP water has an estimated residence time of only 20 to 30 days in the lake; therefore, thermal stratification does not always occur in the lake (DWR 1996a).

7.3.2 WATER SUPPLY SYSTEM

7.3.2.1 Description of Aqueduct/SWP Facilities

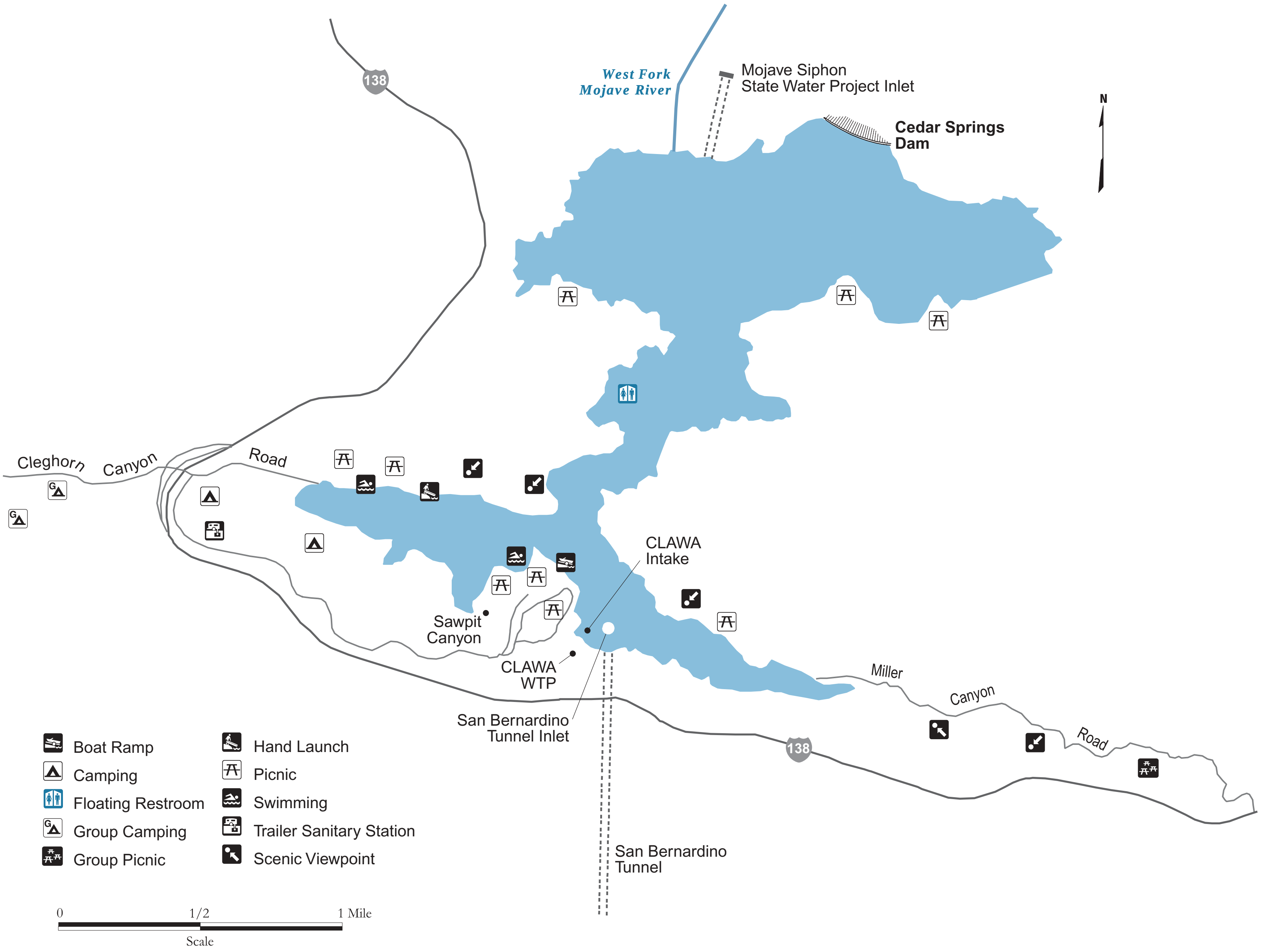
Cedar Springs Dam, constructed on the West Fork Mojave River and completed in 1971, created Silverwood Lake at mile 405.6 of the East Branch of the California Aqueduct. Silverwood Lake provides regulatory and emergency storage, recreation, wildlife habitat, and insures a continuous flow through the Devil Canyon Powerplant. The reservoir has a storage capacity of about 74,970 acre-feet, a surface area of about 980 acres, and a shoreline of approximately 13 miles (Brown and Caldwell 1990). Silverwood Lake has a maximum depth of 166 feet and an average depth of 77 feet. SWP water flows into the lake via the Mojave Siphon Powerplant from the East Branch of the California Aqueduct. A bypass tunnel can carry the water around the power plant, if necessary. The lake inlet is on the northern edge of the lake, west of Cedar Springs Dam.

The stream release point is on the north side of the lake, near and downstream of the dam. SWP water is also discharged from Silverwood Lake through the San Bernardino Tunnel. The tunnel inlet is along the southern shore of Silverwood Lake near the Sawpit Canyon area (Figure 7-16). The San Bernardino Tunnel flows 3.8 miles to the Devil Canyon Powerplant. From Devil Canyon, SWP water enters the Santa Ana Pipeline, which conveys water with several delivery turnouts along the way to Lake Perris, the terminus of the East Branch of the California Aqueduct.

Silverwood Lake is an important link in the East Branch of the California Aqueduct because SWP water flows out from the lake through the San Bernardino Tunnel and, therefore, contamination from the watershed could affect water quality down the East Branch.

The only change in SWP facilities at Silverwood Lake from1996 to 1999 was the construction of a new intake tower to the San Bernardino Tunnel. The intake tower was reconstructed for seismic stability. This construction project is discussed under Section 7.3.3.9, Land Use Changes.

Figure 7-16 Silverwood Lake



7.3.2.2 Description of Agencies Using SWP Water

There are 5 agencies contracting for deliveries from Silverwood Lake between miles 407.7, 412.88, and 425.46. They are MWDSC, San Gabriel Valley Municipal Water District (SGVMWD), San Bernardino Valley Municipal Water District (SBVMWD), San Gorgonio Pass Water Agency (SGPWA), and the Crestline-Lake Arrowhead Water Agency (CLAWA).

MWDSC, the single largest entitlement holder of the SWP, is a consortium of 27 member agencies and more than 150 subagencies that provide drinking water to nearly 17 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino, and Ventura counties. MWDSC has an annual SWP entitlement of 2,011,500 acre-feet, 556,500 of that from the East Branch (Lischeske pers. comm. 2000). MWDSC receives its East Branch deliveries from a turnout at the Devil Canyon afterbay at mile 412.88 of the East Branch of the California Aqueduct. Water stored in Silverwood Lake is delivered to MWDSC's Henry J. Mills FP via Devil Canyon.

The Mills FP is in Riverside at an elevation of 1,650 feet. Treated water flows by gravity to the service areas of Eastern Municipal Water District and Western Municipal Water District of western Riverside County and the Moreno Valley. Specific communities served include Bedford Heights, El Sobrante, Rancho Cucamonga, Sun City, and Upland. The Mills FP has a maximum treatment capacity of 326 mgd. MWDSC is in the process of retrofitting the plant to use ozonation for disinfection instead of the current chlorination process (MWDSC 1998).

CLAWA delivers treated water to wholesale and residential customers in the San Bernardino Mountains from Crestline to Green Valley Lake as well as the Silverwood Lake SRA. CLAWA has an annual entitlement of 5,800 acre-feet and takes its deliveries directly from Silverwood Lake from its own outlet tower near aqueduct mile 407.7, which was constructed along the south shore of the lake near the outlet tower for the San Bernardino Tunnel inlet. CLAWA's treatment plant is on the south shore of the lake adjacent to its outlet tower (Figure 7-16). The CLAWA treatment plant operates at a capacity of 3 mgd. In 1999, CLAWA constructed additional holding tanks to upgrade the treatment process. This construction project is discussed in Section 7.3.3.9, Land Use Changes.

SBVMWD is the largest East Branch contractor of SWP water after MWDSC and has a maximum annual SWP entitlement of 102,600 acre-feet. SBVMWD takes deliveries from the Devil Canyon afterbay as well as from 2 turnouts along the Santa Ana Pipeline.

SGVMWD has a maximum annual SWP entitlement of 28,800 acre-feet and receives its deliveries from a turnout at the Devil Canyon afterbay. The SGVMWD conveys SWP water through its distribution system downstream to 6 or 7 groundwater recharge facilities. The recharge facilities are managed by the Los Angeles County Department of Public Works, which owns and operates the spreading grounds. Individual cities and municipalities such as Azusa, Irwindale, Covina, and Glendora pump and treat groundwater for their service areas (Kasamoto pers. comm. 2000).

SGPWA has a maximum annual SWP entitlement of 17,300 acre-feet and receives deliveries from a turnout at the end of the San Bernardino Tunnel at aqueduct mile 411.46, before the Devil Canyon Powerplant.

7.3.3 POTENTIAL CONTAMINANT SOURCES

7.3.3.1 Recreation

The Silverwood Lake SRA provides a number of body contact and nonbody-contact recreational activities. Body contact activities include boating, water-skiing, and swimming in selected areas. Nonbody-contact activities include fishing, picnicking, camping, hiking, and bicycling. The major water quality problems associated with recreation in the watershed are the following:

- Contribution of feces from body contact recreation such as swimming,
- Fuel spills and exhaust releases from motorized watercraft,
- Spills or leakage from restrooms or wastewater collection systems, and
- Erosion and increased turbidity associated with hiking, horseback riding, or camping, particularly if activities are conducted off established areas and trails.

The Sawpit Canyon area on the south side of the lake includes boat launching ramps and slips, a snack bar, boat rentals, a fishing supply store, a swimming beach, and picnic grounds. The area also includes parking lots and fuel storage facilities. Recreational facilities are illustrated in Figure 7-16.

The Cleghorn Cove area on the southwestern arm of the lake also includes recreational facilities: parking, picnic grounds, 2 campgrounds and a swimming beach. There is a hand launch ramp for nonmotorized boats. The Cleghorn area offers a trailer sanitary station and 2 group camps along Cleghorn Creek; all are less than a mile from the lake.

Table 7-15 Recreational Facilities at Silverwood Lake

	Miller Canyon	Serrano Beach	Sawpit Canyon	Cleghorn
Boat Ramp (Lanes)			6	2
Snack Bar			2	1
Picnic Sites		3	260	88
Group Picnic Sites	3			
Campsites			136	
Group Campsites	3			3
Swimming Beach			1	1
Sanitary Facilities	7	1	16	7
Trailer Sanitation Station			1	
Fish Cleaning Stations			1	1
Parking Spaces	110		878	290

Source: DWR 1991
Notes: Sawpit area includes Mesa Campground.
Cleghorn area includes West Fork campgrounds.
Parking spaces include trailer parking but do not include unmarked spaces around the lake.

Other recreational facilities are around the lake. A summary of the numbers and types of facilities is provided in Table 7-15. The Miller Canyon area includes picnic and group picnic grounds and several scenic viewpoints. Boat-in picnic grounds are around the northern part of the lake. There is also parking at the dam viewpoint on the northern edge of the lake. A 14-mile bicycle trail and a 6-mile hiking trail traverse the southern portion of the lake

Recreational use for the 1996 to 1999 period is presented in Table 7-16. Recreational use has declined since its peak in 1987 of 769,200 recreation days. This decline has been attributed to factors such as poor local economic conditions, increased park fees, changes in fish stocking policies, and restrictions on the types of recreational activities allowed (DWR 1995). Silverwood Lake experienced less recreational use during the 1996 to 1999 period than Castaic Lake or Lake Perris. Recreational use follows a seasonal pattern, with most of the use being between April and September. The lower use figures for 1996 are attributed to the construction of a new inlet tower for the San Bernardino Tunnel that required lowering the reservoir water level.

Table 7-16 Recreational Use at Silverwood Lake (Recreation Days)

1996	1997	1998	1999
237,000	315,400	374,900	330,000

Source: Thrapp pers. comm. 2000a

A total of 26,427 boats were launched at Silverwood Lake during the 1997/98 fiscal year, the last year for which a complete data set was available (Cermak pers. comm. 2000). Eighty-eight percent of those boats were launched between April and September.

Wastewater collection systems for recreation facilities exist at the Cedar Springs Dam, the Sawpit Canyon recreational area, and the Cleghorn Cove area. At Cedar Springs Dam, septic systems and a leach field are used for sanitary waste disposal. The restrooms service site-support buildings. At Sawpit Canyon, wastewater flows by gravity to a lift station where a force main conveys the wastewater to the Crestline Sanitation District's Cleghorn WWTP. The plant is along Cleghorn Creek, upstream of Silverwood Lake (Figure 7-15). There are at least 4 lift stations along this force main. Several of these pump stations have experienced failures and overflowed in the past (Brown and Caldwell 1990). One lift station is within 100 feet of the reservoir. Two are approximately 250 feet from the lake, and the 4th is approximately 1,000 feet from the reservoir. Each lift station is equipped with alarms, spare motors and pumps, and an emergency generator. Wastewater from the Cleghorn Cove area is stored in an underground tank until it is pumped to the force main that connects the Sawpit Canyon area with the Cleghorn WWTP.

Other areas around the lake use chemical toilets for sanitary waste, which are serviced by truck. There is 1 floating toilet on the lake, which is serviced by a septic tank pump truck mounted on a barge. Table 7-15 also lists the number of sanitary facilities by area. In December 1999, the floating toilet capsized releasing a small amount of waste into the reservoir. The incident happened sometime overnight, and the toilet was upright by the following afternoon. The holding tank had recently been emptied, which limited the spill to an estimated 10 gallons. The solids remained in the tank. The incident occurred about 1 mile from the lake outlet. Samples were collected and analyzed for pathogens at the spill site, midway between the spill site and the outlet, at the outlet, and at MWDSC's turnout at the Devil Canyon afterbay. Results showed no detectable levels of contamination (MWDSC 2000).

Much of the watershed area that lies outside of the SRA is national forest land. Allowed recreational activities include hiking, horseback riding, and off-highway vehicle (OHV) riding. These activities may cause erosion and contribute to increased turbidity and TDS levels in creeks tributary to Silverwood Lake. The USDA Forest Service is working with OHV user groups to minimize the erosion caused by OHV use (USDA 2000). A portion of the Pacific Crest Trail runs through the watershed, skirting the west and north sides of the lake.

Additional recreation area changes included minor shoreline improvements such as planting of new turf and trees in April 2000. The DBW provided funding for expansion of the Sawpit Canyon launch ramp from 6 lanes to 7, to overlay it with concrete, and to reconstruct the shoreline. The launch ramp at Cleghorn Canyon was lengthened (DWR 1997a). Additional recreational facilities exist at Lake Gregory, a smaller but fully recreational lake in the upper watershed. Lake Gregory overflows to Houston Creek and eventually reaches Silverwood Lake (Brown and Caldwell 1990).

7.3.3.2 Wastewater Treatment/Facilities

Treatment Plant Effluent Discharges

There are 4 WWTPs within the watershed. The Crestline Sanitation District operates 3 of them: Houston Creek, Seely, and Cleghorn WWTPs. Their service area includes the city of Crestline and neighboring communities around Lake Gregory. Crestline Sanitation District also collects waste from the Silverwood SRA. The 4th WWTP is at the Pilot Rock Camp and is operated by the California Department of Forestry. All 4 WWTPs are within the watershed, above Silverwood Lake (Figure 7-15).

The Houston Creek WWTP is along Houston Creek between Lake Gregory and the confluence of Houston Creek and the East Fork West Fork Mojave River. The Seely WWTP is along Seely Creek, and the Cleghorn WWTP is along the West Fork Mojave River upstream from Silverwood Lake. The 4th WWTP is at the Pilot Rock Conservation Camp, a minimum-security correctional facility that houses firefighting personnel on a seasonal basis. The Pilot Rock WWTP is a small package plant that provides secondary treatment of wastes and has a maximum capacity of 0.01 mgd.

The Houston Creek, Seely, and Cleghorn plants were upgraded during the 1996 to 1999 period. A 2.5 million-gallon emergency storage reservoir was installed at the Houston Creek plant in July 1998. A second emergency storage reservoir is planned for the Seely plant. This reservoir is in the final planning stages with funding scheduled for the 1999/2000 fiscal year. These emergency storage reservoirs will increase the reliability of the treatment plants and allow a temporary interruption in effluent flow for maintenance of the outfall system (Whalen pers. comm. 2000). Improvements to the Cleghorn plant included the coating of all concrete surfaces with a plastic polymer, replacement of bearings in 1 of the motors, and reconstruction of walkways.

All 4 WWTPs provide secondary treatment and disinfection of wastes. Their combined dry weather flow averages 0.8 mgd (DWR 1996). The treated effluent is transported to the Las Flores Ranch just north of the dam and outside the watershed. There it is used for pasture irrigation or distributed to percolation ponds. Waste Discharge Requirements imposed by the Regional Water Quality Control Board regulate treated effluent. Waste discharged to the Las Flores Ranch is regulated for BOD, pH, dissolved oxygen, and other conventional wastewater parameters. There were no reported constituent violations in the district's final effluent from 1996 to 1999 (Whalen pers. comm. 2000).

The volume of wastewater treated annually by the Crestline Sanitation District has increased during the period of this study from 292.35 million gallons in 1996 to 408.26 million gallons in 1998. Crestline Sanitation District did not have any unauthorized wastewater releases caused by high flow conditions posed by El Niño storms of 1998 (Whalen pers. comm. 2000).

The Lake Arrowhead Sanitation District (LASD) operates wastewater collection and treatment facilities in an area adjacent to the Silverwood Lake watershed. The service area and the drainage area of this district lie entirely outside the Silverwood Lake watershed, as opposed to what was reported in the *Sanitary Survey Update 1996*, which included the facilities in the watershed. Drainage from the service area flows north, away from Silverwood Lake (Nelson pers. comm. 1999). Wastewater spills in the LASD service area would not impact the Silverwood Lake watershed.

Storage, Transport, and Disposal

The wastewater collection facilities consist of 4 WWTPs and their associated distribution pipes. Pilot Rock WWTP effluent is discharged to an outfall line owned and maintained by the Crestline Sanitation District. Sludge from the Pilot Rock Plant is transported by truck to the Houston Creek Plant where it is dewatered and disposed of, along with sludge from the Houston Creek Plant, outside of the watershed (Whalen pers. comm. 2000). Wastewater from the Silverwood SRA is transported to the Cleghorn WWTP via a pressurized force main. All 4 WWTPs are connected to a single outfall pipe, which closely parallels Highway 138 as it wraps around the western edge of Silverwood Lake. Treated effluent is transported through this pipe to the Las Flores Ranch, which is outside the watershed.

No incidents that resulted in the release of wastewater to surface waters in the watershed during the period 1996 to 1999 were reported (Whalen pers. comm. 2000). In 1993 a construction accident led to the release of 11 million gallons of treated sewage into the Mojave River, below Cedar Springs Dam. This incident prompted the Crestline Sanitation District to install low flow alarms and a holding vault. Although no wastewater releases were reported during the period of this study, the location of the treatment facilities on creeks tributary to Silverwood Lake presents the potential for contamination.

Septic Systems

Many of the smaller developments and individual residences in the watershed are on septic systems. Very little information is available on the effect septic systems may have on groundwater and surface water quality. The Regional Water Quality Control Board and the San Bernardino County Department of Environmental Health Services have investigated the septic systems of a community called Cedar Pines Park. Cedar Pines Park is in the southern portion of the watershed between Sawpit Creek and Lake Gregory, about a half mile from Sawpit Creek. The control board sampled monitoring wells on the site to determine the effect that the septic systems had on groundwater quality. None of its sampling results showed nitrate levels in excess of applicable drinking water standards. The highest nitrate concentrations (23, 25, and 26 mg/L as NO_3), which were below the MCL of 45 mg/L , were observed in the same well. Environmental health services concluded there were no overall immediate problems with nitrates in Crestline area groundwater (Trujillo pers. comm. 1989).

7.3.3.3 Urban Runoff

Runoff from paved areas is a significant potential contaminant source and may contain metals, organic compounds and petroleum hydrocarbons, pathogens, and suspended solids. The Silverwood SRA has more than 1,000 paved parking spaces as well as paved roads that could contribute runoff. Runoff from Highway 138 and urban development in the southern portion of the watershed may contribute significant amounts of runoff containing the parameters of concern mentioned.

Paved areas of the CLAWA water treatment plant also contribute storm water runoff. The CLAWA plant is adjacent to the lake near the San Bernardino Tunnel intake tower. Personnel working in the Silverwood Lake area have observed muddy water and siltation in Sawpit Creek and drainage near the CLAWA water treatment plant (Rubio pers. comm. 1999). These discharges have been observed over the last 2 years.

The Cedar Pines Park Water Company serves a small community in the southern portion of the watershed near Lake Gregory. In 1997, Cedar Pines Park Water Company drilled additional wells using grant money from the USDA. A USDA inspector noted that the well drilling had caused a significant amount of sedimentation in a downstream pond. The type of sediment found in the pond matched the material present at the drilling site. In addition, the drilling site remained unvegetated and with poor soil conditions. Sediment from the drilling site drains into a small onsite pond and into Sawpit Canyon, which drains to Silverwood Lake (Phillips pers. comm.2000a).

Urban development is around Lake Gregory in the southern part of the watershed, and urban runoff during wet periods could reach Lake Gregory. Lake Gregory drains to Silverwood Lake via Houston Creek.

7.3.3.4 Animal Populations

Grazing has not occurred in the watershed since 1990 (DWR 1996). A total of 1,950 acres on the east side of the lake provided grazing until the permit was rescinded.

There is also a substantial but unquantified wild animal population in the watershed. Wild animals as with grazing animals are a potential source of pathogens. The types of animals present in the watershed were described in Section 7.3.1, Watershed Description.

7.3.3.5 Algal Blooms

Nuisance algal blooms have occurred on occasion in Silverwood Lake and have been controlled through the application of copper sulfate. Algal growth is also a problem in Lake Gregory, which drains into

Silverwood Lake via Houston Creek. Algae are controlled in the creek with application of Cutrine, a proprietary chelated copper compound. Applications are typically made from May through September during most years.

7.3.3.6 Agricultural Activities

There is no known agriculture activity in the watershed. The Silverwood Lake SRA uses mechanical means rather than pesticides to control nuisance weeds around the lake. However, herbicide chemicals may be contained in the natural inflows to the lake because of uses in the forested lands of the watershed (Brown and Caldwell 1990).

7.3.3.7 Unauthorized Activity

Leaking Underground Storage Tanks

Sanitary Survey Update 1996 reported that two 2,000-gallon leaking underground storage tanks at a DWR facility at Cedar Springs Dam were removed in 1994. The leaking tanks were below the elevation of the dam and were not considered to have affected SWP water (DWR 1996).

7.3.3.8 Geologic Hazards

Silverwood Lake lies approximately 10 miles north of the San Andreas Fault zone. This presents the possibility of damage to SWP facilities in the event of seismic activity. If the outlet tower were damaged, deliveries on the East Branch would halt. This would create a water supply problem for much of Southern California. The inlet tower for the San Bernardino Tunnel was replaced in 1996 to meet seismic requirements and greatly reduce this threat (DWR 1994).

7.3.3.9 Land Use Changes

The Silverwood Lake watershed remains a mountainous, relatively undeveloped region. However, urban development has encroached on Lake Gregory in the southern part of the watershed. There were 2 major construction projects in the watershed between 1996 and 1999. A new intake tower for the San Bernardino Tunnel had to be constructed to meet upgraded seismic requirements. Additionally, the CLAWA installed a new clearwell and 2 back flush tanks to expand its capacity and meet increased regulatory demands.

San Bernardino Tunnel Intake Reconstruction Project

The San Bernardino Tunnel Intake is a crucial element of the East Branch, and failure of the structure would result in an interruption in deliveries to contractors serving much of Southern California. Studies by DWR determined that the tunnel intake did not meet seismic standards. The proximity of major geologic faults established the possibility of seismic activity in the area. Replacement of the existing intake tower, which was the preferred design alternative, offered several advantages over strengthening the existing tower. Replacement would provide a superior design, reduce the amount of lake drawdown required during construction, and minimize interruption of downstream deliveries.

Most of the environmental effects associated with the project stemmed from drawing down the lake to facilitate the construction. The lake surface was lowered in 2 phases. In the 1st phase surface elevation was lowered from 3,353 feet to 3,310 feet. The lake surface remained at this elevation for about 11 months, from November 1994 through the end of 1995. In January 1995, the lake was lowered to surface elevation of 3,260 feet, 93 feet below the original lake elevation. The 2nd phase drawdown lasted about 3 months. Reservoir refilling began in March 1996 and lasted through September 1996 (DWR 1994).

The project had significant environmental impacts on air quality, biological resources, aesthetics, recreation, and water quality. The air quality concerns were related to increased particulate matter levels because of construction dust. The biological resources that would be affected by the lake draw down include the fisheries and avian species. The project could have had a significant effect on the endangered bald eagles, which have been observed around the lake. Mitigation measures developed to protect the fisheries concentrated on habitat enhancement (DWR 1997). To combat the loss of habitat caused by lake drawdown, artificial habitat structures and aquatic vegetation were placed along the shore of the lake.

Project construction had negative impacts on recreation. During the 1st phase drawdown, the most affected activities were swimming and nonmotorized boating. During the 2nd phase draw down, boats could not be launched and the marina boat slips were beached. Almost all boating and water-related recreation was suspended (DWR 1995). The loss of recreation activities, along with the aesthetic impacts of the construction, led to decreased numbers of park visitors in 1995 and 1996.

Water quality concerns over the intake tower construction were related to turbidity. The bare soil left by the lake drawdown is prone to erosion and may have caused an increase in lake turbidity levels during storm events. This is discussed in Section 7.3.4, Water Quality Summary.

Crestline-Lake Arrowhead Water Agency Tank Construction Project

In 1999, the CLAWA constructed 3 new tanks at its drinking water treatment plant adjacent to the lake.

The tanks were added to improve the treatment process to comply with increasingly stringent surface water treatment rules (Webb 1998). The current plant capacity is 3 mgd. To treat allocated volumes during peak conditions, CLAWA will need to expand plant capacity to 10 mgd. The project involved the construction of a 2.3-million gallon clearwell and two 0.25-million gallon backwash supply tanks. All tanks required grading and installation of cement pads. An estimated 8,000 cubic yards of material were excavated to grade the platforms. Access roads and additional fencing were added.

Water quality concerns associated with the project were related to soil erosion and increased turbidity. Grading and heavy construction activity was estimated to impact about 0.6 acres of land (Webb 1998). Upon completion of the project, surface runoff will be diverted around the new pads into existing discharge points. The new roads and pads were constructed with drainage swales and berms to reduce erosion potential, and the excavated areas were revegetated.

7.3.4 WATER QUALITY SUMMARY

7.3.4.1 Watershed

Water quality data for the 1996 through 1999 period are presented in Table 7-17. With the exception of 1 manganese sample that exceeded its secondary MCL in February 1997, all parameters were below drinking water MCLs and applicable Article 19 objectives. Water quality at Silverwood Lake is influenced by SWP inflows, natural inflows, and contamination sources such as recreation within the watershed. On a yearly average, natural inflows are minor compared to SWP inflows. However, natural inflows can exert significant influence over reservoir water quality during storm events. Water quality at Silverwood Lake presents several concerns to SWP contractors. The most prevalent are high turbidities, algal blooms, and DBPs.

Minor elements that were detected in 2 or more samples include arsenic, boron, copper, iron, aluminum, manganese, and zinc (Table 7-17). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations as the value of the detection limit; however, statistics were not calculated for parameters with 2 or fewer detections. Elements detected in a high percentage of samples, although at low concentrations include arsenic, boron, and copper. The only minor element that exceeded its respective MCL was manganese. One manganese sample (0.403 mg/L) exceeded the secondary MCL of 0.05 mg/L. All other results were an order of magnitude below the MCL.

Table 7-17 Silverwood Lake at Tunnel Inlet, Feb 1996 to Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	19	18	15	26	17-20	1	16/16
Chloride	42	45	10	62	27-57	1	16/16
Total Dissolved Solids	198	202	148	246	156-231	1	16/16
Hardness (as $CaCO_3$)	85	88	62	94	74-92	1	16/16
Conductivity (µS/cm)	343	353	242	426	270-406	1	16/16
Magnesium	9	10	6	11	6-11	1	16/16
Sulfate	30	28	11	48	24-42	1	16/16
Turbidity (NTU)	4	4	1	10	2-7	1	13/13
Minor Elements							
Arsenic	0.002	0.002	<0.001	0.003	0.002-0.003	0.002	15/16
Boron	0.1	0.1	<0.1	0.2	0.1-0.2	0.1	15/16
Copper	0.004	0.004	0.002	0.006	0.002-0.005	0.002	12/16
Iron	0.009	0.005	<0.005	0.045	0.005-0.016	0.005	3/16
Aluminium	N/A	N/A	<0.01	0.03	N/A	0.01	2/16
Manganese	0.031	0.005	<0.005	0.403	0.005-0.015	0.005	4/16
Zinc	N/A	N/A	<0.005	0.050	N/A	0.005	2/16
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.5	0.4	0.2	0.9	0.3-0.8	0.1	28/28
Nitrate (as NO_3)	1.9	2.0	0.5	3.5	1.0-2.5	0.1	16/16
Nitrate+Nitrite (as N)	0.48	0.48	<0.01	0.77	0.26-0.65	0.01	47/48
Total Phosphorus	0.09	0.09	0.02	0.15	0.06-0.11	0.01	48/48
OrthoPhosphate	0.07	0.08	<0.01	0.11	0.04-0.10	0.01	41/48
Misc.							
Bromide	0.11	0.11	0.09	0.14	0.09-0.13	0.01	3/3
pH (pH unit)	7.7	7.5	6.9	8.9	7.0-8.6	0.1	8/8

Source: DWR O&M Division database, May 2000

Notes: Bromide and pH data from Feb 1999 to Aug 1999 and Feb 1998 to Nov 1999, respectively
Total Kjeldahl Nitrogen data from Jan 1996-March 1998 only
Statistics include values less than detection limit, if applicable

Total Dissolved Solids

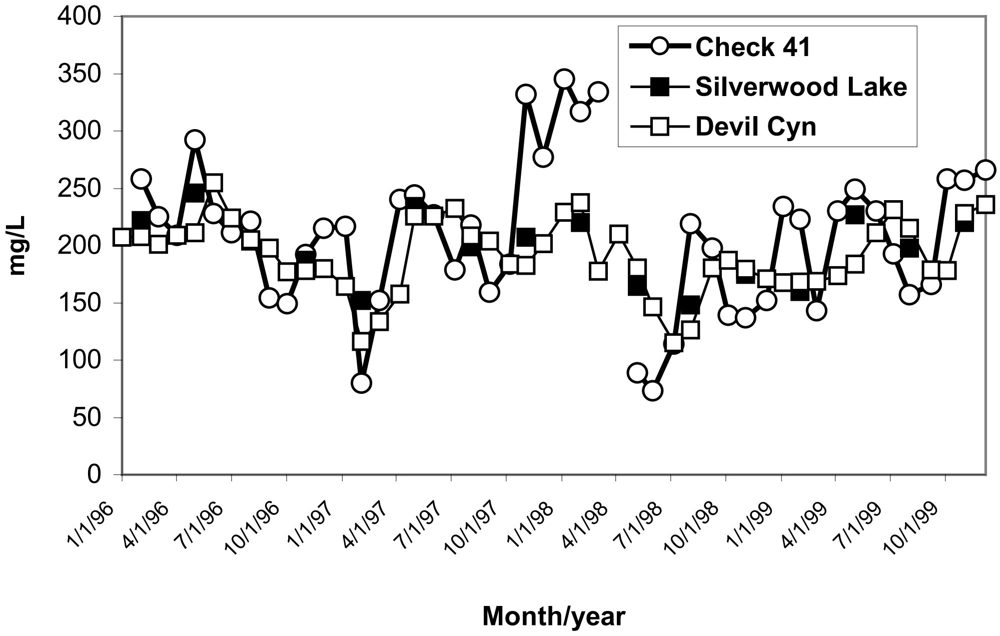
TDS concentrations in Silverwood Lake ranged from 148 to 246 mg/L and averaged 198 mg/L (Table 7-18). All TDS results were well below the recommended secondary MCL of 500 mg/L. TDS concentrations in Silverwood Lake during 1996 to 1999 were similar and slightly lower than SWP inflows at Check 41. TDS levels measured at the Devil Canyon afterbay downstream of Silverwood Lake on the East Branch of the California Aqueduct were also very similar to levels measured in Silverwood Lake.

Figure 7-17 illustrates TDS concentrations at Check 41, Silverwood Lake, and Devil Canyon. With the exception of greater variability at Check 41, TDS concentrations remain very similar from Check 41 to Silverwood and then to Devil Canyon. The peak TDS concentrations in Silverwood Lake were observed in May of most years. High concentrations were also observed in February 1998, during the El Niño storms. High TDS concentrations in Silverwood Lake appear to correlate with high TDS concentrations at Check 41. This observation indicates that TDS concentrations in Silverwood Lake are much more influenced by SWP inflows than natural inflows. It appears that natural inflows and activities in the Silverwood Lake watershed do not have a significant effect on TDS levels.

Table 7-18 Silverwood Lake and Check 41 TDS and Chloride (mg/L)

	Mean	Median	Min	Max
Check 41				
TDS	208	217	73	345
Chloride	48	48	2	107
Silverwood				
TDS	198	202	148	246
Chloride	41.6	45	10	62
Devil Canyon				
TDS	191	185	115	255
Chloride	41	41	5	65

Figure 7-17 TDS at Check 41, Silverwood Lake, and Devil Canyon



Source: DWR O&M Division database, May 2000

Chloride is an important component of TDS that is a good indicator of water quality sources and mixing. Chloride concentrations followed a similar pattern as TDS. Chloride concentrations decreased slightly from Check 41 to Silverwood Lake (Table 7-18). Chloride concentrations in Silverwood Lake and Devil Canyon were very similar. Chloride concentrations in Silverwood Lake ranged from 10 to 62 mg/L and averaged 41.6 mg/L. All chloride concentrations were well below the secondary drinking water MCL of 250 mg/L.

Nutrients

High concentrations of nutrients in source waters contribute to nuisance algal growth and eutrophication of the Silverwood Lake. Phosphorus and nitrogen are the primary nutrients that influence algal growth. Nutrient concentrations in Silverwood Lake are a reflection of SWP inflows at Check 41 with observed values being very similar to those at Check 41 (Table 7-17). This is most likely because of the short residence time in the lake (20 to 30 days), high SWP inflows, and generally low level of natural inflow.

In the 1970s, algal growth in Silverwood Lake was controlled through the application of copper sulfate (last application was in 1976). Algal growth is also a problem in Lake Gregory, which drains into Houston Creek and on to Silverwood Lake. The algal growth is controlled through the application of Cutrine, a proprietary chelated copper compound that is applied May through September of most years (Ryder pers. comm. 1999).

Mean and maximum values at Silverwood Lake were within the range of and commonly below respective values at Check 41 for Kjeldahl nitrogen, nitrate/nitrite, total phosphorous, and orthophosphate. Total phosphorus levels in Silverwood Lake ranged from 0.02 to 0.15 mg/L and averaged 0.09 mg/L. Orthophosphate ranged from 0.01 to 0.11 mg/L and averaged 0.07 mg/L. Kjeldahl nitrogen (as N) ranged from 0.2 to 0.9 mg/L and averaged 0.5 mg/L, almost exactly the same as Check 41. Nitrate and nitrite levels (as N) ranged from 0.04 to 0.77 mg/L and averaged 0.48 mg/L , slightly lower but similar to Check 41. Based on this data, it appears that activities in the Silverwood Lake watershed do not contribute a significant additional nutrient load to the reservoir.

Nutrient concentrations also tend to follow a seasonal trend in reservoirs, as described for Castaic Lake, with concentrations decreasing during the summer growing season because of algal utilization. Figure 7-18 illustrates the seasonal trend of nutrient concentrations in Silverwood Lake. Periods of unexpected higher concentrations during the growing season (1996 and 1997) could be caused by higher levels of SWP inflows at these times.

Turbidity

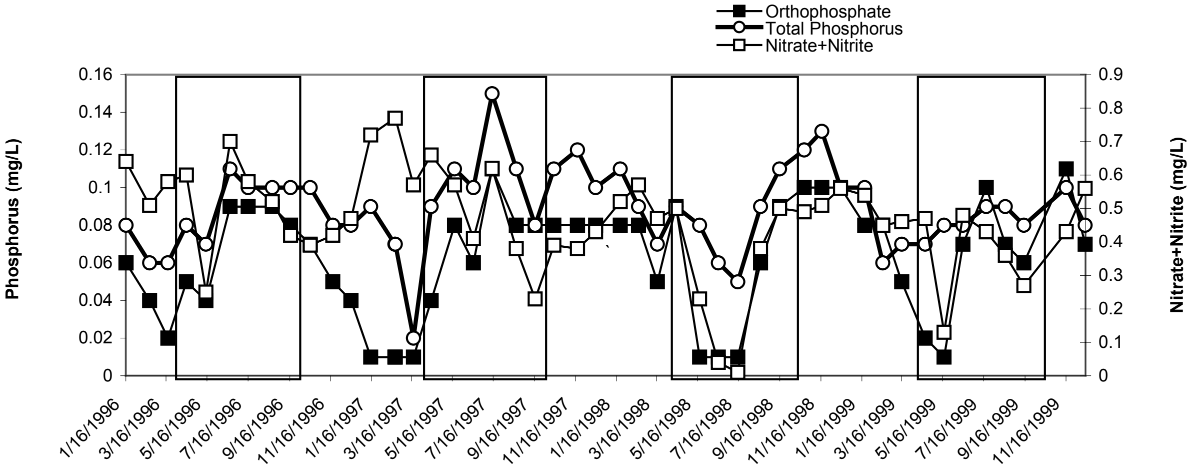
Turbidities ranged from 1 to 10 NTUs, with a mean of 4.2 NTUs (Table 7-17). Turbidity in Silverwood Lake was both lower and much less variable than Check 41 during the 1996 to 1999 period. Turbidities at Check 41 ranged from 2 to 140 and averaged 25 NTUs.

Turbidity is monitored monthly along with other conventional parameters. Inflows from the watershed and SWP significantly affected Silverwood Lake turbidity. Quarterly monitoring failed to reveal a spike in lake turbidity that occurred in late February 1996. Heavy rainfall combined with construction activities related to the reconstruction of the outlet tower led to turbidity readings as high as 154 NTUs at the Devil Canyon afterbay. This turbidity peak lasted approximately 7 days and disrupted treatment plant operations at the Mills FP (MWDSC 1996).

Total Organic Carbon and Alkalinity (DBP precursors)

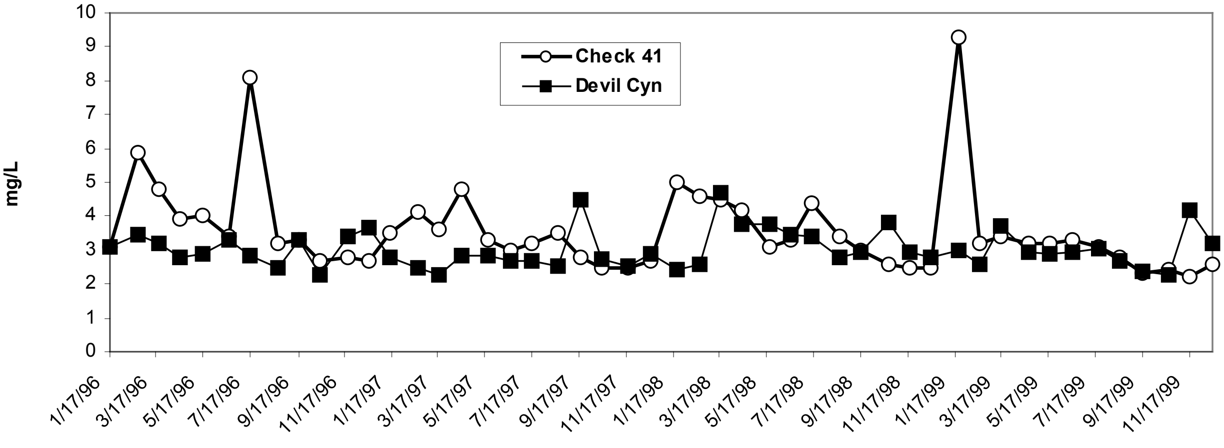
TOC data were not collected at Silverwood Lake during the 1996 to 1999 period. However, TOC data were available for Check 41 and Devil Canyon afterbay. TOC at Check 41 ranged from 2.2 to 9.3 mg/L and averaged 3.6 mg/L. At Devil Canyon, TOC ranged from 2.3 to 4.7 mg/L and averaged 3.03 mg/L. With the exception of the high-range variability, TOC levels at Devil Canyon and Check 41 were very similar (Figure 7-19). TOC spikes in March and September 1996 and February 1999 did not appear to affect Silverwood Lake TOC levels. Alkalinities at Silverwood Lake and Devil Canyon were nearly identical and ranged from 52 to 97 mg/L and averaged 72 and 69 mg/L , respectively. Levels were below 60 mg/L on only 4 occasions from 1996 to 1999.

Figure 7-18 Seasonal Variation in Nutrient Concentrations in Silverwood Lake, 1996 to 1999



Source: DWR O&M Division database, May 2000
Boxed areas represent approximate algal growth season, May through October.

Figure 7-19 TOC Concentrations at Silverwood Lake Outlet and Check 41



Source: DWR O&M Division database, May 2000

As shown in Figure 7-19, TOC concentrations at both Check 41 and Devil Canyon exceeded the proposed drinking water protection standard of 3 mg/L frequently, although there was no apparent connection between the two. TOC did not appear to increase as a result of watershed activities at Silverwood Lake.

Quarterly bromide sampling at Silverwood Lake began in 1998. Only 3 samples were collected during this time. Bromide ranged from 0.09 to 0.14 mg/L. A more extensive data set exists for Check 41. Bromide at Check 41 ranged from 0.01 to 0.38 mg/L between 1996 and 1999. The mean bromide concentration for this period was 0.15 mg/L. These values exceeded the proposed drinking water standard of 0.05 mg/L for bromide. As with TOC, bromide levels did not appear to change significantly or increase as a result of watershed activities in Silverwood Lake. Therefore, there do not appear to be any significant sources of TOC and bromide in the watershed, and their concentrations in Silverwood Lake are a reflection of water quality conditions at Check 41 and Delta source waters.

MTBE

MWDSC and the DWR collected samples at the Sawpit Canyon boat ramp and the Silverwood Lake outlet (inlet to the San Bernardino Tunnel) (Figure 7-16). Only surface samples were collected from the Sawpit Canyon boat ramp. Mid-depth and deep water samples were collected at the lake outlet. In 1997, Silverwood Lake was thermally stratified from May through July. The depth to the thermocline ranged from 20 to 26 meters. Results are presented in Table 7-19.

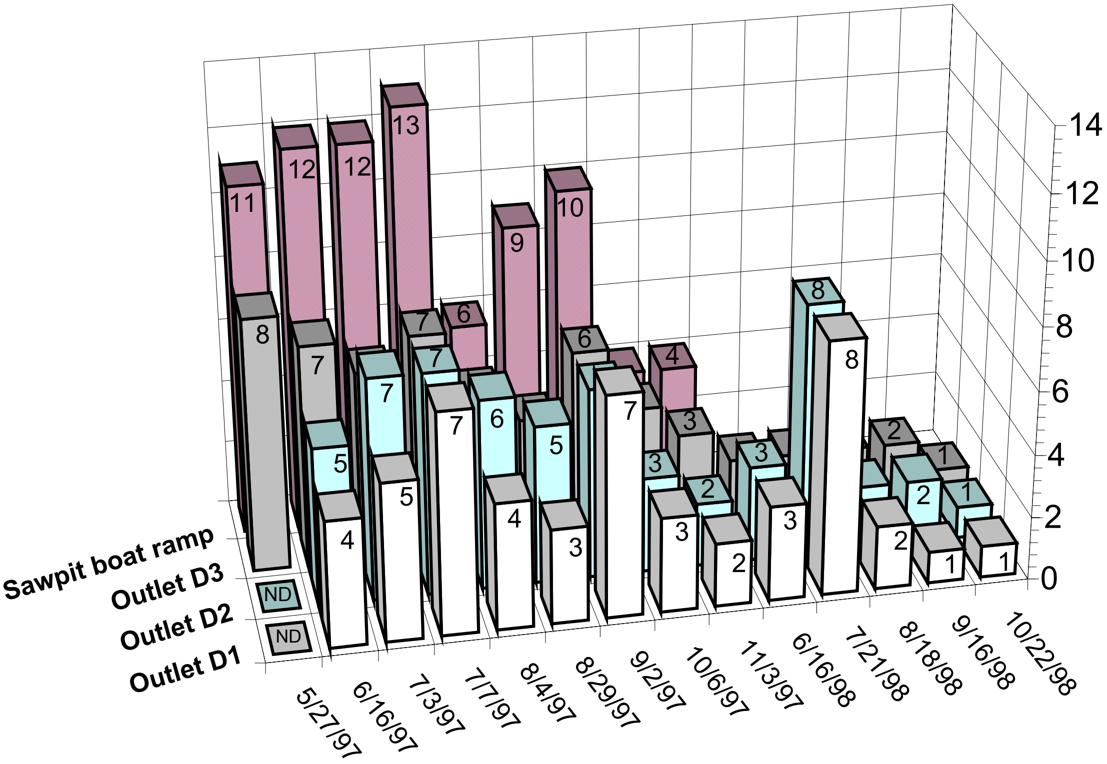
MTBE concentrations in Silverwood Lake rose throughout the summer of 1997 to peak levels in July and August. Concentrations at the boat ramp reached levels near the primary MCL of 13 µg/L (Figure 7-20). Concentrations at the outlet were above the secondary MCL of 5 µg/L for most of the summer season but never exceeded the primary MCL. MTBE concentrations at all locations fell to levels below the secondary MCL in the fall after lake stratification decreased and recreational use declined.

Table 7-19 Summary of MTBE Concentrations in Silverwood Lake (µg/L)

MWDSC Sampling	Outlet (1997)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion)				
Range	2.6 to 6.9	ND to 1.1	2.4 to 6.5	ND to 1.1
Mean	4.1	ND	4.0	ND
Bottom (Hypolimnion)				
Range	2.6 to 4.1	N/S	N/S	N/S
Mean	3.3	N/S	N/S	N/S
DWR Sampling	Outlet (1997/1998)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion D1+D2)				
Range	ND to 8.0	N/S	4.0 to 13	N/S
Mean	4.4	N/S	9	N/S
Bottom (Hypolimnion)				
Range	ND to 7	N/S	N/S	N/S
Mean	3.5	N/S	N/S	N/S

Note: Surface samples include samples collected from 0.5 to 15 meters
ND = Not Detected. N/S = Not Sampled

Figure 7-20 Summary of MTBE Concentrations in Silverwood Lake



Data source: DWR 1999, DWR Operations and Maintenance unpublished data 1998
Notes: Outlet D1 = 0.5 m, Outlet D2 = 6-15 m, Outlet D3 = .>15 m

MTBE concentrations observed at the Sawpit boat ramp were higher than at the outlet (Figure 7-20). MTBE concentrations in surface samples from the boat ramp ranged from 4 to 13 µg/L with a mean of 9 µg/L. Surface samples from the inlet to the outlet ranged from ND to 8 µg/L with a mean of 4.4 µg/L.

MTBE concentrations in the epilimnion were nearly homogenous. Surface values were within a few units of the mid-depth and deep water samples. In 1997, surface samples at the outlet ranged from 1.1 to 7.4 µg/L with a mean of 5.1µg/L. The mean of the mid-depth samples was 5.2 µg/L. The deep water samples were collected at depths ranging from 15 to 20 meters. In 1997, all of the deep water samples collected were sampled from above the thermocline except for 1 sample collected 27 May 1997. The mean of the deep water samples was 3.1 µg/L.

Samples were collected at both the outlet and the boat ramp before and after the 4th of July and Labor Day weekends. These weekends represent the periods of highest recreational use at Silverwood Lake. MTBE concentrations rose only 1 µg/L at both sampling stations after the 4th of July weekend. MTBE concentrations increased by 1 µg/L at the boat ramp over the Labor Day weekend and 2µg/L at the outlet.

Another group of compounds commonly associated with fuel contamination—benzene, toluene, ethyl benzene, and xylene (BTEX) and MTBE—were detected with MTBE in 8 of 9 surface samples collected by DWR at the boat ramp in 1997. BTEX compounds were not detected in any of the samples collected by DWR at the outlet.

Taste and Odor

MIB and geosmin levels were homogenous across the surface of the lake. MIB concentrations at the lake inlet ranged from ND to 8 ng/L and averaged 3.2 ng/L (Table 7-20). MIB was detected in 33% of the surface samples collected at the inlet. Similarly, MIB was detected in 23% of the surface samples collected at the lake outlet. MIB ranged from not detected (ND) to 8 ng/L and averaged 3.3 ng/L. Geosmin concentrations ranged from ND to 5 ng/L at both the inlet and the outlet. The mean geosmin concentration in surface samples collected at the lake inlet was 2.6 ng/L; at the lake outlet, it was 2.4 ng/L (Figure 7-21). Most of the geosmin and MIB found in the lake are believed to have been produced in the East Branch of the California Aqueduct not in the lake (Faulconer pers. comm. 2001).

MIB and geosmin concentrations at Silverwood Lake were detected at uniform concentrations throughout the depth of the water column but were generally below the taste and odor detection limit of 5 to 10 ng/L (Figure 7-21 lower chart). Concentrations remained at a fairly low and constant value throughout the year.

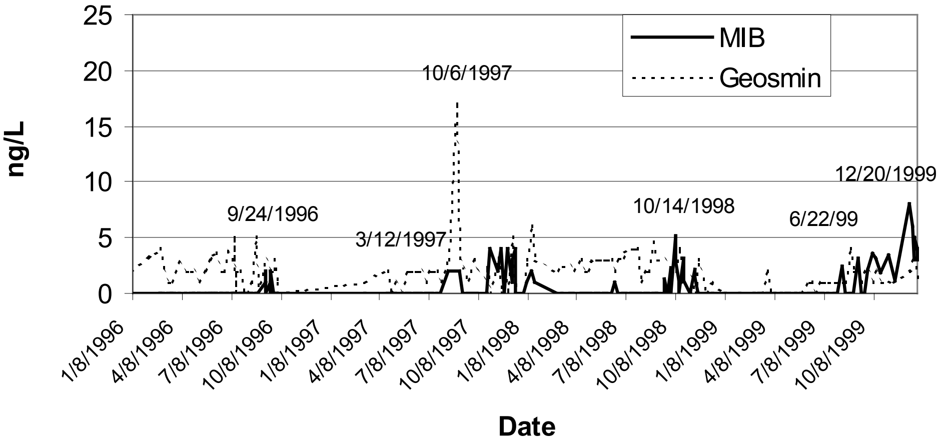
Reservoir management practices such as selective depth withdrawal are used to minimize the amount of MIB and geosmin in lake outflow sent to the Henry J. Mills FP via the Devil Canyon afterbays.

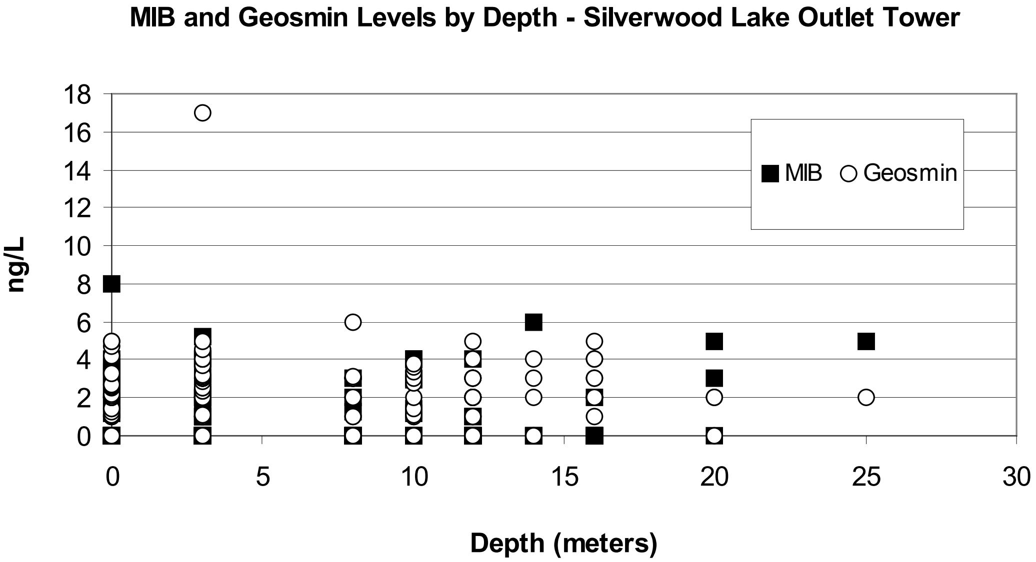
Table 7-20 MIB and Geosmin Concentrations at Silverwood Lake, 1996 to 1999 (ng/L)

	MIB	Geosmin
Silverwood Inlet-Surface (0 m)		
Range	ND to 8.0	ND to 5.0
Mean	3.2	2.6
Percent of samples with detects	33%	51%
Silverwood Inlet-All Depths	MIB	Geosmin
Range	ND to 8	ND to 22
Mean	3.0	2.4
Percent of samples with detects	25%	56%
Silverwood Outlet-Surface (0 m)	MIB	Geosmin
Range	ND to 8.0	ND to 5.0
Mean	3.3	2.4
Percent of samples with detects	23%	64%
Silverwood Outlet- All Depths	MIB	Geosmin
Range	ND to 8.0	ND to 17
Mean	2.7	2.4
Percent of samples with detects	24%	70%
Mills FP Influent	MIB	Geosmin
Range	ND to 6.0	ND to 13
Mean	2.5	2.2
Percent of samples with detects	10%	55%

Note: Mean values do not include samples where the analyte was not detected
ND = Not Detected

Figure 7-21 MIB and Geosmin Levels at the Silverwood Lake Outlet, 1996 to 1999





7.3.4.2 Water Supply System

MWDSC Henry J. Mills Filtration Plant

MWDSC routinely monitors source (influent) and treated (finished) water quality to meet primary and secondary MCLs contained in Title 22 of the California Code of Regulations. The parameter categories in Title 22 for these MCLs were presented in the Castaic Lake water quality section.

MWDSC's major concerns associated with treating SWP water are occasional high turbidities, DBP precursors, and taste and odor compounds produced by algal blooms. Both source and finished waters at the Mills FP were below applicable primary and secondary MCLs during the 1996 through 1999 (Torobin pers. comm. 2000). Data were obtained from the MWDSC laboratory database for 1996 to 1999 and sampling at the Devil Canyon afterbay (for example, source water), summaries from annual reports, and consumer confidence reports for this period.

Trace metals and organic compounds are discussed first because they are either detected at low levels or not routinely detected at all and are, therefore, not of concern. The main parameters of concern selected for further discussion are presented after trace metals and organics.

Aluminum, arsenic, barium, iron, manganese, and strontium were the only trace metals detected in Mills FP influent, but at very low levels. Aluminum averaged 0.3 mg/L over the 1996 to 1999 period, slightly above the secondary MCL (0.2 mg/L). All other trace metals were detected at levels below applicable MCLs except for iron, which exceeded its secondary MCL on 1 occasion (0.4 mg/L). Arsenic levels in Mill FP influent ranged from 0.007 to 0.029 mg/L and averaged 0.02 mg/L, below the MCL of 0.05 mg/L. However, some of these values are greater than the proposed MCL of 0.01 mg/L being evaluated for arsenic. The same trace metals were detected in Mills FP finished water, but at even lower levels.

With the exception of MTBE, no VOCs, SVOCs, or other organic compounds were detected in either Mills FP source or finished waters (Koch pers. comm. 2000; Torobin pers. comm. 2000a).

MTBE levels in Mills FP influent were much lower than ambient lake levels and ranged from nondetect to 5.9 mg/L. The average for the 1996 to 1999 period was 1.6 mg/L. These levels were well below the MCL of 13 µg/L. MTBE was never detected in Mills FP finished water.

TOTAL DISSOLVED SOLIDS. TDS levels in Mills FP source water are a direct reflection of levels found in Silverwood Lake. TDS in Mills FP influent ranged from 115 to 255 mg/L ; the 1996 to 1999 average was 191 mg/L. TDS levels at the Silverwood outlet averaged 198 mg/L. TDS levels in Mills FP finished water were similar to levels observed in plant influent. Annual averages ranged from 180 to 243 mg/L. The annual average influent and finished water TDS levels were very closely matched for each individual year.

Chloride concentrations in Mills FP influent were very similar to chloride concentrations in SWP inflows at Check 41. Chloride concentrations in Mills FP influent ranged from 5 to 65 mg/L and averaged 41 mg/L. The average chloride concentration at the Silverwood Lake outlet was 41.6 mg/L, while the average value at Check 41 was 48 mg/L. Chloride levels in Mills FP finished water were slightly higher than levels in plant influent. Average annual levels in Mills FP finished water ranged from 44 to 61 mg/L.

TURBIDITY. MWDSC experienced significant treatment difficulties at the Mills FP because of high turbidity in source water at Devil Canyon from 1996 to 1999. The difficulties include increased chemical usage, increased solid waste, lower filter run lengths, increased finished water turbidity, and plant flow restrictions.

Sources of turbidity include storm water runoff and high turbidity in SWP inflows from the California Aqueduct at Check 41 and construction activities at Silverwood Lake. Turbidity poses the greatest difficulty during the winter months. A spike in influent turbidity in February 1996 caused the Mills FP to be temporarily shut down. Turbidities as high as 154 NTU were reported (MWDSC 1996). The spike was caused by heavy rainfall in the Silverwood Lake watershed during the time that the lake was drawn down to facilitate the construction of the new outlet tower. However, MWDSC was still able to meet all operation and plant performance criteria required by the California Department of Health Services (DHS) during the 7-day high turbidity event (MWDSC 1996).

Turbidity values in Mills FP influent ranged from 0.5 to 41 NTUs and averaged 6.7 NTUs. These values were above the range of turbidities reported in Silverwood Lake (1 to 10 NTUs). Annual average turbidity in Mills FP finished water ranged from 0.06 to 0.08 NTUs and were well below the secondary turbidity MCL of 5 NTUs.

NUTRIENTS. Nutrients contribute to algal growth and the production of the malodorant compounds MIB and geosmin. Nitrate (as NO_3) is the only nutrient parameter that is regularly monitored in Mills FP influent and finished water. Nitrate values at the Mills FP were well below the primary MCL of 45 mg/L in both plant influent and plant finished water. However, nitrate levels of concern for algal growth are much lower than the MCL.

Nitrate levels in Mills FP influent and finished water were very similar to levels observed in Silverwood Lake. Nitrate levels in Mills FP influent ranged from 0.5 to 3.7 mg/L and averaged 2.1 mg/L. Annual finished water average concentrations ranged from 1.8 to 2.5 mg/L. Nitrate concentrations in Silverwood Lake averaged 1.9 mg/L. Annual averages for both nitrate and nitrate+nitrite (as N) in finished waters were usually the same and ranged from 0.18 to 0.69 mg/L, well below the MCL of 10 mg/L.

TOTAL ORGANIC CARBON AND ALKALINITY (DBP PRECURSORS). TOC and bromide in source water react with disinfectants at the Mills FP to produce DBPs such as TTHMs and HAAs and bromate. TOC and bromide are monitored in Mills FP influent and finished water. TTHMs are monitored in Mills FP finished water only. The current TTHM MCL is 100 µg/L. Although MWDSC did not exceed this MCL at the Mills FP, TOC and bromide levels are too high to comply with the Stage 1 D/DBP Rule-proposed TTHM MCL of 80 µg/L. Additionally, member agencies that receive treated water from Mills FP experience higher TTHM levels because of continued formation of TTHMs in MWDSC's distribution system (MWDSC 2000).

Water quality data for TOC and alkalinity in Mills FP influent and finished waters and Check 41 are presented below in Table 7-21.

Table 7-21 Comparison of TOC and Alkalinity at Mills FP (mg/L)

Parameter/ Value	Check 41	Mills FP Influent	Mills FP Finished
TOC			
Range	2.2-9.3	2.3-4.7	2.0-2.5[a]
Average	3.6	3.1	2.3[b]
Alkalinity			
Range	41-109	52-91	59-74[a]
Average	70	69	68[b]

[a] Range of 1996-99 annual averages only
[b] Average of 1996-99 annual average data

Check 41 TOC levels frequently exceeded the CALFED-target drinking water protection standard of 3 mg/L at the export pumps at Banks, while Mills FP influent exceeded it less frequently but with a high proportion of values in the 2.5 to 2.9 mg/L range. Check 41 TOC levels were similar to Mills FP influent but had a much higher high-range value, while Mills FP influent and finished water were similar. Alkalinities were similar at all locations, and average values were within the 60 to 120 mg/L proposed in the D/DBP Rule for 25% TOC removal at TOC values from >2-4 mg/L. TOC values in Mills FP influent were below 4 mg/L except for 3 samples over the 1996 to 1999 period.

Bromide levels in Silverwood Lake and Mills FP influent were very similar. Mills FP influent values ranged from 0.03 to 0.22 mg/L and averaged 0.13 mg/L. These values also exceeded the CALFED-target drinking water protection standard of 0.05 mg/L for bromide.

TTHM levels in Mills FP finished water ranged from 41 to 67 µg/L and averaged 57 µg/L on an annual average basis (1996 data not available). Finished water quality always met the current MCL of 100 µg/L, but MWDSC will be challenged with the proposed MCL of 80 µg/L in the Stage 1 D/DBP Rule.

The practice of using chlorine for primary disinfection results in TTHMs typically greater than the proposed MCL of 80 µg/L in the Mills FP service areas. In addition, the Stage 1 D/BP Rule will require enhanced coagulation removal of TOC, unless certain exceptions are met (25% removal from >2-4 mg/L and alkalinity of 60 to 120 mg/L). MWDSC has decided to convert the Mills FP from chlorination to ozonation for primary disinfection as the most effective solution to comply with Stage 1 and future Stage 2 requirements of the D/DBP Rule. The use of ozone and chloramines will reduce TTHMs to less than 40 µg/L, which will allow MWDSC to qualify for an exception to the enhanced TOC treatment component of the rule.

Although ozone disinfection will help reduce the levels of TTHMs in finished water, ozone also reacts with bromide in source waters to produce bromate, a powerful carcinogen and DBP regulated under the D/DBP Rule. Because of the relatively high bromide levels in SWP water, bromate levels that will typically be formed during ozonation would, without additional treatment measures, exceed the Stage 1 bromate MCL of 10 µg/L. MWDSC plans to control the amount of bromate formed in the ozonation process by lowering the pH to 7.0 or lower using sulfuric acid addition. Higher bromide concentrations may require pH reduction to 6.0. Further, if the future Stage 2 D/DBP Rule lowers the proposed bromate MCL to 5 µg/L, the frequency of pH adjustments would dramatically increase (MWDSC 2000).

TASTE AND ODOR. Mills FP influent had similar concentrations of MIB and geosmin to those observed at the Silverwood outlet tower. MIB was detected in about 10% of the samples collected at Mills FP between 1996 and 1999. The range was not detected to 6 ng/L, and the mean of all samples where MIB was detected was 2.5 ng/L. These data are similar to those for the Silverwood outlet tower (Table 7-20).

Geosmin was detected in about 55% of the samples collected at Mills FP. The average of detected values was 2.2 ng/L. This is very similar to values observed at the Silverwood outlet tower, which averaged 2.4 ng/L. Geosmin concentrations at Mills FP exceeded the taste and odor threshold of 5 to 10 ng/L on only 1 occasion in May of 1996.

Crestline-Lake Arrowhead Water Treatment Plant

The CLAWA treatment plant is adjacent to Silverwood Lake, near the inlet to the San Bernardino Tunnel (Figure 7-15). CLAWA treats 100% SWP water. CLAWA is subject to the same source water quality concerns as MWDSC: high turbidity, DBP precursors, taste and odor, and algae problems. CLAWA monitors for TTHMs and HAAs in treatment plant finished water. Quarterly averages ranged from 33 to 75 µg/L with the highest concentrations reported in the first 2 quarters.

CLAWA operated in compliance with all applicable primary and secondary MCLs for both influent and finished water. However, CLAWA is often challenged to meet the TTHM MCL (Newell pers. comm. 2000). In order to meet Stage 1 D/DBP requirements, CLAWA will need to practice enhanced coagulation and pH adjustment. CLAWA is working with an independent engineering firm to optimize its treatment process.

In order to meet the 40 µg/L TTHM MCL proposed in the Stage 2 requirements, CLAWA will need to make significant improvements to its treatment process. CLAWA is considering adding ozone disinfection, membrane filtration, or UV treatment techniques (CLAWA 2000). All of these options represent significant expense to CLAWA.

San Gabriel Valley Municipal Water District

The SGVMWD does not treat and, therefore, does not monitor source or finished water. The SGVMWD takes SWP deliveries from a turnout at the Devil Canyon afterbay and conveys this water through its distribution system downstream to groundwater recharge facilities.

Pathogens

Pathogen issues related to Silverwood Lake are discussed in Chapter 12 for the Mills FP.

7.3.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The significant contaminant sources and major water quality concerns at Silverwood Lake are related to both SWP source water and watershed activities. The main concerns associated with source water quality are DBP precursors (for example, TOC and bromide), taste and odor associated with algal growth in the reservoir, and occasional turbidity because of SWP inflow spikes and algal growth. The main water quality concerns associated with watershed activities include pathogens and MTBE from recreation, turbidity caused by construction activities and runoff, and pathogens and erosion from animal populations.

TOC and bromide do not appear to be significantly changed by watershed activities at Silverwood Lake. The major contributor of these parameters is the Delta via the California Aqueduct at Check 41. MCLs for these parameters are being met, but high levels of DBPs in Delta and aqueduct water present challenges meeting Stage 1 D/DBP Rule limits for TTHMs and bromate.

Algal blooms, caused in large part by high nutrient levels in source water, result in increased turbidity and production of MIB and geosmin—2 compounds causing taste and odor problems in water supplies. Nutrient levels were similar in inflows and outflows, and there was no evidence that watershed activities contributed to the existing nutrient load. Spikes from the aqueduct and water delivery pipelines can also be a source of turbidity.

The most significant contaminant source and water quality concern associated with watershed activities is recreation. The water quality problems associated with recreational activities at Silverwood Lake are the contribution of pathogens, release of MTBE from motorized watercraft, and turbidity caused by erosion in camping and shoreline areas. Body-contact recreation is considered the most significant, although as yet unquantified, potential pathogen source. Also of concern for release of pathogens is the floating toilet (potential spills, leaks) and incidental waste releases from boats. In addition to the potential to cause disease in water recreationists, high concentrations of pathogens have the potential to overwhelm the Mills FP, especially under higher turbidities, and inhibit the required removal levels for pathogens under the IESWTR. MTBE, although high in the lake, was always below the MCL in Mills FP influent, but it still poses a potential threat to drinking water quality.

Besides algae and the SWP inflow, watershed activities such as construction and runoff were significant sources of turbidity at Silverwood Lake. Construction activities contributed to a high turbidity spike in February 1996. Storm water runoff combined with low lake levels to drive turbidity readings up to 154 NTUs. High turbidity in source water creates significant treatment difficulties for SWP contractors.

Populations of wild animals in the watershed are also a potentially significant pathogen loading source as would be cattle if grazing were to resume. However, the contributions from this source are not possible to assess with existing data.

The 4 WWTPs within the watershed, their collection systems, and sanitary facilities within the SRA have operated properly during the period of this study. Also, substantial improvements have been made to the treatment plant facilities; however, wastewater treatment and collection facilities continue to have the potential to contribute pathogens, DBPs, and nutrients to the reservoir in the event of a spill or system failure.

7.3.6 WATERSHED MANAGEMENT PRACTICES

Several agencies have management authority in the Silverwood Lake watershed. DWR constructed the reservoir and is primarily responsible for its operation. California States Parks is responsible for the management of the Silverwood SRA and has several policies in place to protect water quality, for example, limits on the number of recreationists. The DBW has regulatory authority over boating in the

SRA. Recreation presents the largest watershed management issue at Silverwood Lake, and activities often can be significant sources of contamination. Strategies to address and mitigate impacts on drinking water quality are being discussed in a water quality/recreation focus group in which DWR, state and county recreation departments and other agency staffs participate.

A large portion of the watershed is in the San Bernardino National Forest, which is administered by the USDA Forest Service. The Forest Service's role and powers are described in Section 7.1, Pyramid Lake. The Forest Service is working with private off-highway vehicle (OHV) users groups to develop strategies for minimizing their impact on the environment. The most important issue to water quality concerns would be erosion control practices.

The existing wastewater treatment plants and collection systems in the watershed present a potentially significant but currently low threat to water quality. The Regional Water Quality Control Board regulates wastewater treatment systems through NPDES permits, and unauthorized discharges such as spills or overflows are prohibited. Both the Crestline Sanitation District and the Pilot Rock WWTP are regulated by the NPDES permit system. The Crestline Sanitation District has made several facility improvements to guard against unauthorized wastewater releases, including the construction of 2 emergency storage reservoirs.

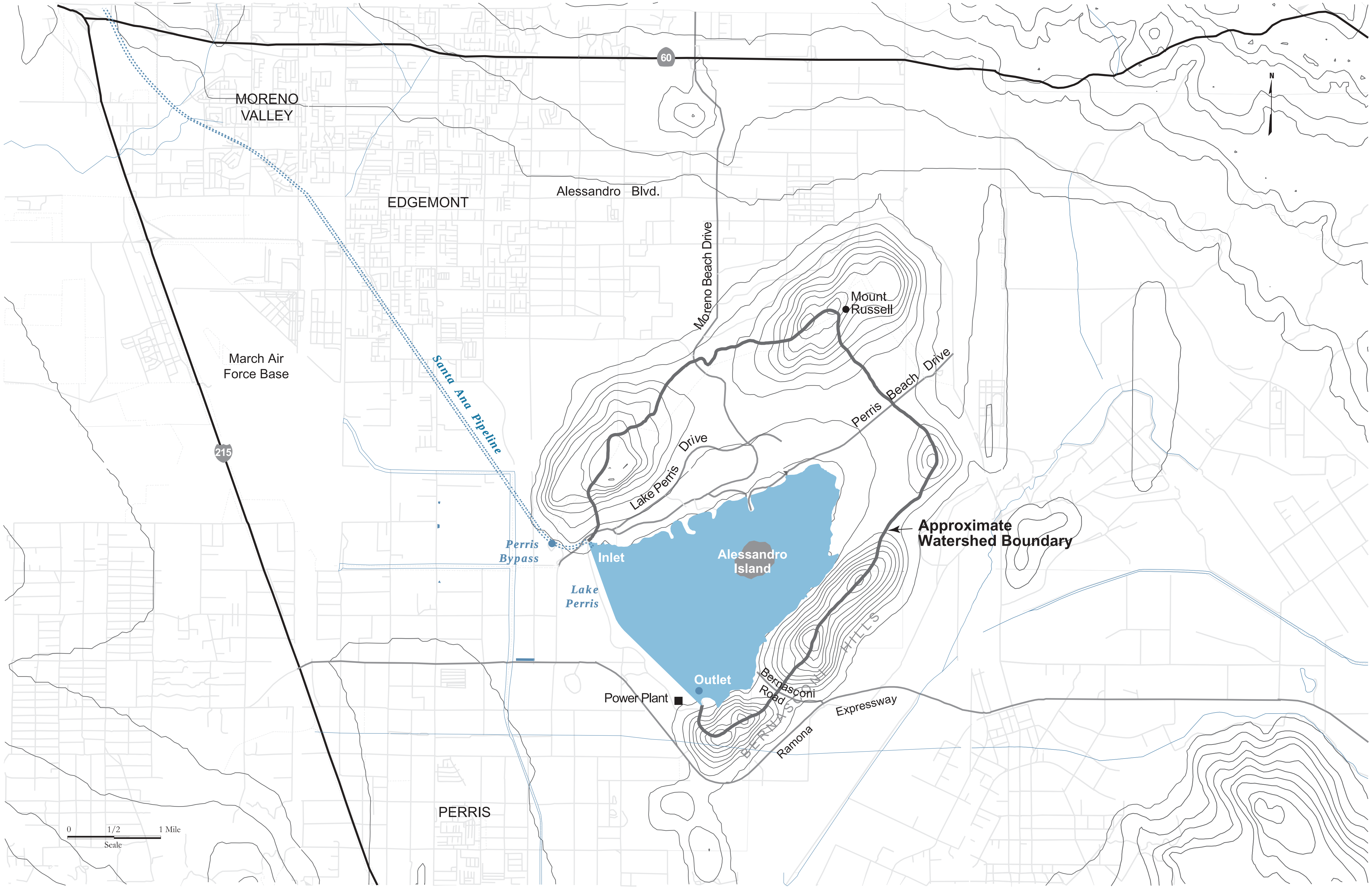
After recreation, the greatest threat to water quality from activity in the watershed is from construction and runoff. Changes in land use or activities such as construction and development during wet periods can be a significant source of turbidity and other contaminants. Silverwood Lake is especially vulnerable to contamination from these activities because of its small watershed size and low hydraulic residence time, which can combine to quickly flush contaminants into the Devil Canyon afterbay and downstream water supply systems. No comprehensive watershed assessment/management program exists, and no BMPs are in place or proposed for implementation. Areas in need of BMPs include control of urban runoff in exposed areas and erosion control. Construction activities greater than 5 acres are required to obtain a general storm water NPDES permit for this purpose. However, it appears that stricter controls on these activities should be implemented.

7.4 LAKE PERRIS

7.4.1 WATERSHED DESCRIPTION

The terminal reservoir of the East Branch of the California Aqueduct is Lake Perris, which was completed in 1974. It lies in Riverside County, about 13 miles southeast of the city of Riverside and approximately 65 miles from downtown Los Angeles. Lake Perris is in the Moreno Valley, an area that has experienced rapid urban growth over the last several years. It is a multiuse facility, providing water storage, recreation, and fish and wildlife habitat (Figure 7-22).

Figure 7-22 Lake Perris Watershed Area



7.4.1.1 Land Use

The Lake Perris SRA, which is operated by California State Parks, occupies the majority of the watershed. The recreation area offers a variety of body-contact and nonbody-contact recreational opportunities. There is almost no other development in the watershed other than the recreational facilities associated with the lake. New residential and commercial development exists outside of the watershed in Moreno Valley. The Lake Perris Fairgrounds also lies immediately outside of the watershed, below the dam. March Field AFB lies approximately 3 miles to the west.

7.4.1.2 Geology and Soils

Rocks in the area consist of granite, quartz monzonite, granodiorite, and quartz diorite. The majority of the watershed is unconsolidated and semi-consolidated alluvium, lake, playa, and terrace deposits. The San Jacinto fault borders the eastern side of the watershed and is the only known major fault in the area.

Upland areas north, south, and east of the lake have well-drained sandy loams and fine sandy loams on granite rock (USDA 1971). The lake bed and shoreline areas consist of well drained sandy to sandy loam soils on alluvial fans. The Russell Mountains on the north and the Bernasconi Hills on the south form the watershed's topography. These rocky hills rise 1,200 feet from the floor of the Moreno and San Jacinto valleys.

7.4.1.3 Vegetation and Wildlife

Three types of vegetation exist within the watershed: coastal sage scrub, chaparral, and riparian. The sage scrub community is composed of various sages, desert encelia, brittlebrush, buckwheat, and cacti (Apante 1999). The chaparral community is made up of chamise, penstemon, and poison oak. The riparian zone lies along springs and around the lakeshore and is composed of willows, cattails, elderberry, and nettles.

There are numerous types of wildlife in the watershed, including quail, dove, ducks, geese, rabbits, and other small mammals include badgers, bobcats, coyotes, weasels, skunks, and snakes. Rodent populations include squirrels, mice, moles, and pocket gophers (Apante 1999). The watershed also contains prime habitat for the Stephen's Kangaroo rat, a federal endangered species. Migratory waterfowl winter at Lake Perris. Some species include pintails, widgeon, geese, whistling swans, egrets, herons, and pelicans. Hunting is allowed in the watershed. Game species include rabbits, ducks, geese, mourning doves, and valley quail. California Department of Fish and Game operates hunting areas for upland game in season at designated areas. The recreation area also serves as a wildlife sanctuary to observe wildlife, with ducks and geese present during winter and shore birds most of the year.

7.4.1.4 Hydrology

The Lake Perris watershed encompasses approximately 16 square miles and is the smallest of the 4 Southern California reservoirs. There is no significant natural inflow to the reservoir, with only 3 small creeks in the north part of the lake. Neither runoff nor natural inflows are measured.

At 2,320 acres, Lake Perris has the largest surface area of the 4 Southern California SWP reservoirs (DWR 1999). However, it is a shallow reservoir. The mean depth is only 57 feet (Anderson 2000). This leads to an intermediate volume of 131,450 acre-feet at full pool. Lake Perris has a slightly larger surface area than Castaic Lake and yet has only half the capacity and a much smaller watershed.

Lake Perris becomes thermally stratified during summer months, confining introduced contaminants to the epilimnion (upper layer). The average volume of the epilimnion in Lake Perris was calculated to be 52,930 acre-feet (Anderson 2000), which represents about 40% of the total lake volume.

7.4.2 WATER SUPPLY SYSTEM

7.4.2.1 Description of Aqueduct/SWP Facilities

SWP water flows into Lake Perris from the Devil Canyon afterbay, through the Santa Ana Pipeline at mile 440.26, the terminus of the East Branch of the California Aqueduct. The covered pipeline presents minimal chance of contamination. In 1983, the Perris bypass and power plant were constructed. The bypass allows water to be delivered to MWDSC directly out of the aqueduct, before it goes into Lake Perris.

The MWDSC is the only agency contracting deliveries from Lake Perris. The agency wholesales this water to 27 member agencies that provide drinking water to about 17 million people. MWDSC reduced its use of Perris water during the period of this study (Table 7-22). Water quality concerns are cited as a primary reason MWDSC does not use its full entitlement of water from Lake Perris, but power generation revenue also plays a significant role in how the lake is operated (Faulconer pers. comm. 2001). The water that is delivered to MWDSC from Lake Perris is treated at the Robert A. Skinner treatment plant and the Mills FP. Water from Lake Perris is mixed with water from MWDSC's Colorado River Aqueduct. SWP water typically makes up less than 25% of the water treated at the Skinner plant

(Torobin pers. comm. 2000). Treated water from the Skinner plant is delivered to some communities in western Riverside County and San Diego County. Annual total deliveries from Lake Perris make up only 2% of MWDSC's maximum annual SWP entitlement.

7.4.3 POTENTIAL CONTAMINANT SOURCES

7.4.3.1 Recreation

Lake Perris SRA, which opened in 1974, fulfills the mandate that all SWP facilities provide recreational amenities and opportunities. Body-contact recreation includes swimming, water skiing, and personal watercraft riding. Nonbody-contact recreation at Lake Perris includes camping, picnicking, horseback riding, sail and power boating, fishing, hiking, bicycling, hunting, and rock climbing (Figure 7-23).

Table 7-22 Water Deliveries from Lake Perris (acre-feet)

	1996	1997	1998	1999	2000
Jan	960	0	0	22	295
Feb	NA	0	0	0	204
Mar	NA	0	4,909	92	1,243
Apr	NA	21,032	18,120	0	5,117
May	2,018	3,714	7,498	13	1,821
Jun	754	357	12,769	<1.0	226
Jul	65	0	5,941	98	65
Aug	4,754	5,538	1,339	0	
Sep	NA	14,184	0	0	
Oct	0	0	1,463	519	
Nov	0	0	0	3,471	
Dec	0	0	0	80	
Total	8,550	44,825	52,039	4,295	8,971[a]

Source: Torobin pers. comm. 2000
[a] Deliveries only through July 2000.
NA – Not available.

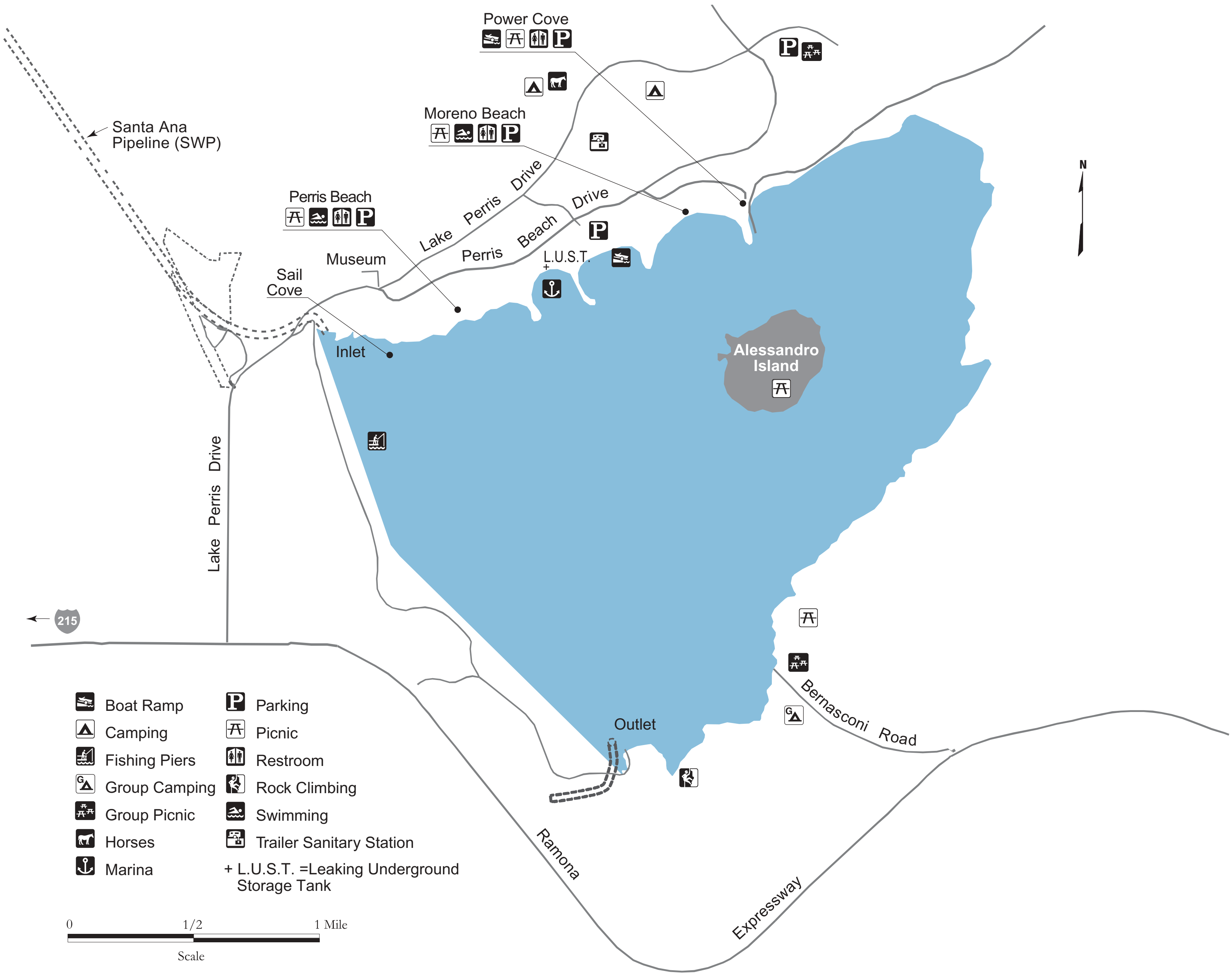


Figure 7-23 Lake Perris

The majority of the recreational improvements are along the north shore of the lake and on Alessandro Island. The island has picnic grounds with water and chemical toilets. Along the lake's southern shore are facilities for rock climbing, picnicking, hunting, and camping. On the north shore are boat rentals, a marina with 300 boat slips, a store, a fuel dock, a boat repair shop, and dry storage. There are three 5-lane boat ramps, 2 swimming beaches, and a waterslide. On the north shore also are Sail Cove, for nonpower boating, and Power Cove, developed for personal watercraft use. The north shore provides day-use picnicking and overnight camping. There are approximately 430 campsites, 6 group campsites, and an equestrian camp that can sleep 56 people. There are about 64 chemical toilets, 33 permanent restrooms, and 3,100 parking spaces in the SRA.

Of the 4 Southern California SWP reservoirs, Lake Perris receives the heaviest recreational use with an average of 1,079,450 recreation days per year over the period 1996 to 1999 (Table 7-23). The number of boats allowed in the water varies with lake surface area. The boating capacity can range from 264 boats to 422 boats at full pool. Boating capacity at Lake Perris is controlled by the number of available parking spaces; however, during a 1998 MTBE study, MWDSC researchers counted 571 boats, either on the water or in the parking lots on Memorial Day (MWDSC 1998). Sixty percent of those boats were personal watercraft, and 17% were 2-stroke boats. A total of 101,810 boats visited Lake Perris during the 1996/1997 fiscal year (Stinson pers. comm. 1999).

Pathogens and MTBE are 2 of the main water quality concerns related to recreation at Lake Perris. Pathogen contamination is due to the high levels of body contact recreation, and MTBE contamination is the result of large numbers of motorized watercraft. The main source of MTBE in Lake Perris is recreational boating. There has been a history of bacteriological and pathogen contamination in the swimming areas on the north shore. Pathogens became an issue in the 1980s when outbreaks of illness were reported among swimmers. The 2 swimming beaches have been closed several times since then because of high levels of total and fecal coliforms. Moreno Beach has been closed since 1997 because of high fecal coliform counts and has been converted to personal watercraft use (MWDSC 1998a).

California State Parks has taken steps to reduce the coliform counts and keep the beaches open. Since the 1980s, the department has implemented a sanitation education program and installed additional toilets on the beaches, approximately 50 feet from the shore. In 1991 it installed 2 circulation pumps at the beaches to increase circulation and move the pathogens away from the beaches. Originally, 1 pump was installed at each beach. The pumps were ineffective at lowering the pathogen concentrations in the swimming areas. In 1998, when Moreno beach was converted to personal watercraft use, both pumps were placed in operation at Perris Beach. Although the pumps may reduce the risk to swimmers, the DWR and the MWDSC are concerned that the pumps may increase the levels of pathogens at the outlet tower. No tracer or dye studies have been conducted to determine the amount of pathogens that will reach the outlet tower with and without the pumps.

Lake Perris has the highest overall MTBE concentrations of the 4 Southern California SWP reservoirs. MWDSC sampling has detected levels as high as 32 µg/L in Lake Perris. MTBE concentrations regularly exceed the MCL for MTBE in drinking water of 13 µg/L. A more detailed discussion is in Section 7.4.4, Water Quality Summary.

There have been several changes in recreational facilities since 1996. In 1999 concrete was replaced on boat ramps 5, 6, and 7. A new 4-lane personal watercraft launch ramp was constructed at Power Cove. Other new facilities include restrooms, a new parking lot for 55 cars and 63 trailers, 30 new picnic tables, and 700 feet of beach grading (DWR 1999). Construction of a new boat ramp to serve waterfowl hunters is planned for the Bernasconi area.

Table 7-23 Recreational Use at Lake Perris

Period	1996	1997	1998	1999
Recreation Days	1,157,300	1,101,000	1,007,400	1,052,100

Source: Thrapp pers. comm.

7.4.3.2 Wastewater Treatment/Facilities

Individual lift stations pump wastewater generated by the lake's recreational facilities to a main sump near the boat ramp area (Figure 7-23). From there, wastewater is lifted to a gravity line that flows to a treatment plant outside the watershed. The wastewater collection line that flows underneath the reservoir to Alessandro Island is no longer in use. The Lake Perris SRA contracts wastewater collection services from the Eastern Municipal Water District (EMWD). Operation and maintenance of the lift stations and lines is contracted to EMWD.

EMWD operates in compliance of the EPA's Capacity, Management, Operations, and Maintenance program. Requirements of this program include routine preventive maintenance and the development of an overflow response plan, which requires that EMWD take all feasible steps to mitigate any sewer system overflows. The overflow response plan also contains procedures for notification of the proper authorities in the event of an overflow, including the county health department and water suppliers.

There have been 2 wastewater overflow events since *Sanitary Survey Update 1996*. On 24 May 1998, the lift station that pumps wastewater from the restroom at Power Cove overtopped its sump, releasing approximately 50 gallons of wastewater that flowed about 50 feet over an area of sand toward the reservoir. The distance and the porous sand minimized the amount of sewage that entered the reservoir. County health officials were called to the scene, and water samples were collected from the reservoir. Approximately 900 feet of shoreline was disinfected using liquid chlorine. MWDSC stopped taking deliveries from Lake Perris pending results of the tests. The overflow occurred shortly after initial operation of the newly constructed lift station. Cause of the malfunction was determined to be a failed electrical switch.

The 2nd wastewater overflow occurred on 18 May 1999 at the Sail Cove lift station. EMWD workers were conducting routine maintenance when they ruptured a water line. An estimated 4,500 gallons of water flooded the adjacent lift station sump, which contained approximately 1,500 gallons of sewage. The mixture of fresh water and wastewater flowed toward the lake. The lift station is fewer than 100 feet from the lake. A storm drain immediately down grade of the lift station allowed the spill to reach the lake within minutes. Although total volume of the spill was relatively large (2,000 to 3,000 gallons), the wastewater was highly diluted by the fresh water. County health officials were called, and all wetted or pooled areas were disinfected. Samples were collected, and the area was closed to the public for several days.

There are 14 restrooms along the Lake Perris shoreline. All except those at Sail Cove and Power Cove are more than 300 feet from the reservoir. A trailer sanitary-station is a half mile north of the lake along Perris Drive. Wastewater spills from these facilities would have to flow a considerable distance over grass and sand to reach the lake. Alarms have been installed at Power Cove and Sail Cove to notify California State Parks and EMWD staff of wastewater overflows.

7.4.3.3 Urban Runoff

Runoff from parking lots associated with recreational facilities, other areas, and roads presumably drains to unpaved areas surrounding them and possibly eventually to the lake. No facilities exist for the collection of runoff from paved areas within the watershed (Agner pers. comm. 2000). However, there are no known water quality problems at Lake Perris caused by urban runoff.

7.4.3.4 Animal Populations

The watershed's animal population consists of wild animals and horses used for equestrian recreation. An equestrian campground north of the lake accommodates 56 people. An equestrian trail, which forms a loop around the lake, is in the upland areas of the watershed to avoid equestrian contact with the reservoir. However, MWDSC staff have observed equestrians riding across the peak of the dam. Apparently, inadequate fencing allows equestrians to access areas where horses are not allowed. This can result in increased soil erosion as well as introduction of pathogens from animal feces.

There is an abundant wild animal population at Lake Perris, including waterfowl. Large numbers of waterfowl using a reservoir can introduce a substantial amount of fecal material that can be a source of nutrients and pathogens. Terrestrial wildlife in the watershed can also be a source of pathogens.

7.4.3.5 Unauthorized Activity

Leaking Underground Storage Tanks

An underground storage tank at the Lake Perris marina failed in July of 1994. Approximately 50 feet from the shoreline and adjacent to the marina store, the underground tank released 5,000 to 6,000 gallons of gasoline with MTBE into the soil. Monitoring wells were installed, and free gasoline was detected floating on top of the groundwater. Gasoline was also observed floating on the surface of the lake, and a boom was installed to contain the contamination. A vapor extraction system was installed to remediate the soil contamination. The leaking underground tank was removed and replaced in February 1995.

Chemical contaminants observed as a result of the tank's failure include total volatile hydrocarbons and the gasoline components BTEX and MTBE. MTBE remains in high concentrations near where the tank leaked. The MTBE concentration in vapor extraction well number 1 was 180,000 µg/L on 22 September 1999. MTBE can be detected in monitoring wells as far as 100 feet north of the failed tank. At present, BTEX compounds can be detected in high concentrations near the area of the former leaking tank but not in monitoring wells farther away. Total petroleum hydrocarbons (TPH) concentration in vapor extraction well 1, which is adjacent to the leaking tank site, was 390,000 µg/L on 22 September 1999 (Boltinghouse pers. comm. 2000).

Because of the contamination site's proximity to the lake, its groundwater levels are directly related to the surface elevation of the lake. The high lake water surface elevation has hindered the vapor extraction remediation process over the last few years. Because the vapor extraction system is only effective at removing contaminants from dry soil, remediation efforts will only be successful when the lake is at low levels.

Approximately 4,686 gallons of gasoline have been recovered by the vapor extraction system as of March 1999. However, because of high groundwater levels in the remediation area, some product remains in the deeper soil (Boltinghouse pers. comm. 2000). Groundwater flow is to the north, away from the lakeshore. The lake was drawn down in the winter of 1997 for construction of a new personal watercraft ramp at Power Cove. The vapor extraction system functioned during the construction but was shut down in April 1998, when the lake was refilled. The vapor extraction system has been unable to function since April 1998 because of high lake levels.

7.4.3.6 Land Use Changes

The only land use changes that have occurred inside the watershed are related to changes in recreation facilities. These changes include the closure of Moreno Beach and construction of Power Cove for personal watercraft. Planned land use changes include the conversion of Moreno beach from a swimming facility to a personal watercraft area or the reopening of Moreno Beach if California State Parks deems that the levels of pathogens at the beach can be controlled.

Land use changes outside of the watershed include substantial growth in residential development in the surrounding communities of western Riverside County. Several years ago, Riverside and San Bernardino counties ranked as the fastest growing counties in Southern California (Apante 1999). Although these developments are outside the watershed, they may have an indirect effect by increasing demand for recreation facilities and other indirect forms of contaminant introduction.

7.4.4 WATER QUALITY SUMMARY

7.4.4.1 Watershed

Water quality in Lake Perris presents a major concern to SWP contractors. There are several major water quality problems at Lake Perris. Each is discussed in this section. High levels of MTBE and concerns about pathogens limit the water utility use of the epilimnion during the summer stratified period. In addition, a condition known as hypolimnetic anoxia, which is a lack of oxygen in the lower reservoir or hypolimnion, further restricts the use of this part of the reservoir during this period. These restrictions on the use of Lake Perris have led to decreased water use, reducing the flow through the lake. This decreased flow has led to an increase in TDS levels, which further reduces the suitability of Lake Perris water for municipal and industrial uses. Water quality data are presented in Table 7-24. All parameters were below drinking water MCLs or applicable Article 19 objectives for this period.

Minor elements that were detected in at least 1 or more samples but at low levels included arsenic, barium, boron, chromium, copper, manganese, and zinc (Table 7-24). Several elements had many samples with values less than the detection limit. Values less than the detection limit were included in statistical calculations by assuming the constituent was present at the detection limit; however, statistics were not calculated for parameters with 2 or fewer detections.

Table 7-24 Lake Perris Outlet, Feb 1996 to Nov 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	Number of Detects/ Samples
Minerals							
Calcium	33	26	23	148	23-29	1	16/16
Chloride	89	89	65	121	67-116	1	16/16
Total Dissolved Solids	324	323	262	405	266-396	1	17/17
Hardness (as $CaCO_3$)	129	132	111	148	113-147	1	16/16
Conductivity (µS/cm)	591	610	483	712	490-699	1	16/16
Magnesium	16	16	13	20	13-19	1	16/16
Sulfate	50	50	40	64	41-62	1	16/16
Turbidity (NTU)	1	1	<1	8	1-2	1	4/13
Minor Elements							
Arsenic	0.002	0.002	0.002	0.002	0.002-0.002	0.001	17/17
Barium	0.05	0.05	<0.05	0.06	<0.05-0.06	0.05	9/16
Boron	0.2	0.2	<0.2	0.3	<0.2-0.3	0.1	16/16
Chromium	0.005	0.005	<0.005	0.007	<0.005-0.006	0.005	3/16
Copper	0.008	0.005	<0.003	0.023	<0.003-0.019	0.002	12/16
Manganese	0.007	0.005	<0.005	0.027	<0.005-0.006	0.005	3/16
Zinc	0.011	<0.005	<0.005	0.009	<0.005-0.030	0.005	1/17
Nutrients							
Total Kjeldahl Nitrogen (as N)	0.5	0.4	0.3	1.2	0.4-0.6	0.1	27/27
Nitrate (as NO_3)	0.2	0.1	<0.1	0.6	<0.1-0.3	0.1	5/16
Nitrate+Nitrite (as N)	0.03	0.01	<0.01	0.20	<0.01-0.08	0.01	23/47
Total Phosphorus	0.04	0.03	<0.01	0.15	<0.02-0.07	0.01	44/47
Orthophosphate	0.02	0.01	<0.01	0.05	<0.01-0.04	0.01	19/47
Misc.							
Bromide	0.21	0.21	0.20	0.22	0.20-0.22	0.01	3/3
pH (pH unit)	8.2	8.3	7.4	8.9	7.8-8.7	0.1	16/16

Source: DWR O&M Division database, May 2000

Notes: Bromide data from Feb 1999-Aug 1999 only

Statistics include values less than detection limit, if applicable

Hypolimnetic Anoxia

Because of high nitrogen and phosphorus loading from the SWP, direct runoff and precipitation, Lake Perris is nutrient-rich and would be classified as eutrophic with respect to algal productivity. Nutrient levels indirectly affect water quality in these lakes by stimulating growth of nuisance algae that are associated with release of taste and odor compounds such as geosmin and MIB. High concentrations of certain diatom species can also affect treatment plant operations by clogging filters and interfering with coagulation and flocculation. Eutrophic lakes often experience periods of anoxia in bottom waters because of microbial respiration fueled by periodic die-off of algae. Anaerobic water contains elevated concentrations of reduced compounds that require higher doses of oxidants during the treatment process. These reduced compounds are also odorous and bad tasting (for example, hydrogen sulfide), and decrease the aesthetic quality of the water. Metals such as iron, manganese, and certain nutrients are more soluble in anoxic waters owing to low pH.

During spring, Lake Perris typically has low turbidity, good light penetration and no temperature stratification (Coburn pers. comm. 2001; Losee pers. comm. 2001). As spring progresses, water temperatures rise and stimulate algal growth resulting in an algal bloom. Decreasing water clarity caused by the bloom coupled with increasing solar inputs (longer days, higher sun angle) results in thermal stratification of the lake. The warmer (less dense) upper portion of the water column is separated by a thermocline (region of maximum temperature change with depth) from the colder (more dense) lower portion of the water column. The upper portion of the lake is referred to as the epilimnion and is typically well mixed, and light levels are sufficient for algae to grow, thus oxygen levels are high. The portion of the lake below the thermocline is referred to as the hypolimnion and is usually too dark for algal growth. Microbial respiration (consumption of oxygen) fueled by organic materials (dead algae) that sink from the epilimnion and by algal respiration (sinking live-algae) can lead to low oxygen levels (hypoxia) or a total depletion of dissolved oxygen (anoxia) in the hypolimnion.

By mid to late summer, nutrients have been depleted by algal growth in the epilimnion, and algal biomass declines (nutrients released by microbial decomposition in the hypolimnion cannot be resupplied to the epilimnion while a strong thermocline persists). Thermal stratification typically persists into the fall when surface water cools and becomes more dense (it sinks) resulting in a lake mixing or turnover event. Wind can also contribute to lake mixing. When the lake mixes, turbidity decreases and nutrients that have accumulated in hypolimnetic waters reach depths in the lakes with sufficient light for algal growth, leading to a fall bloom.

Anoxic conditions in Lake Perris lead to approximately 30% to 40% of the lake's total volume being unusable for drinking water during the summer stratified period (MWDSC 1998a). This period also represents the period of highest water demand. Since operation of the MWDSC hydro-generation plant, algal productivity has decreased because of lower SWP inputs (there is less nutrient loading to the lake). This decrease in nutrient load has shifted the onset of hypolimnetic anoxia from late May to late August or early September.

MTBE

In 1997 DWR staff collected samples for MTBE analysis at 3 depths at the outlet tower. Depth 1 (D1, etc.) was the surface. Depth 2 was the lower limit of the epilimnion, which varied in depth throughout the season. The deep water samples, depth 3, were collected below the thermocline in the hypolimnion. Results are presented in Table 7-25 and Figure 7-24. MTBE levels in Lake Perris were higher than other reservoirs with less recreation. Summer MTBE concentrations reached levels as high as 32 µg/L near the boat ramp and 11 µg/L at the outlet tower, both exceeding the primary MCL of 13 µg/L (DWR 1999a).

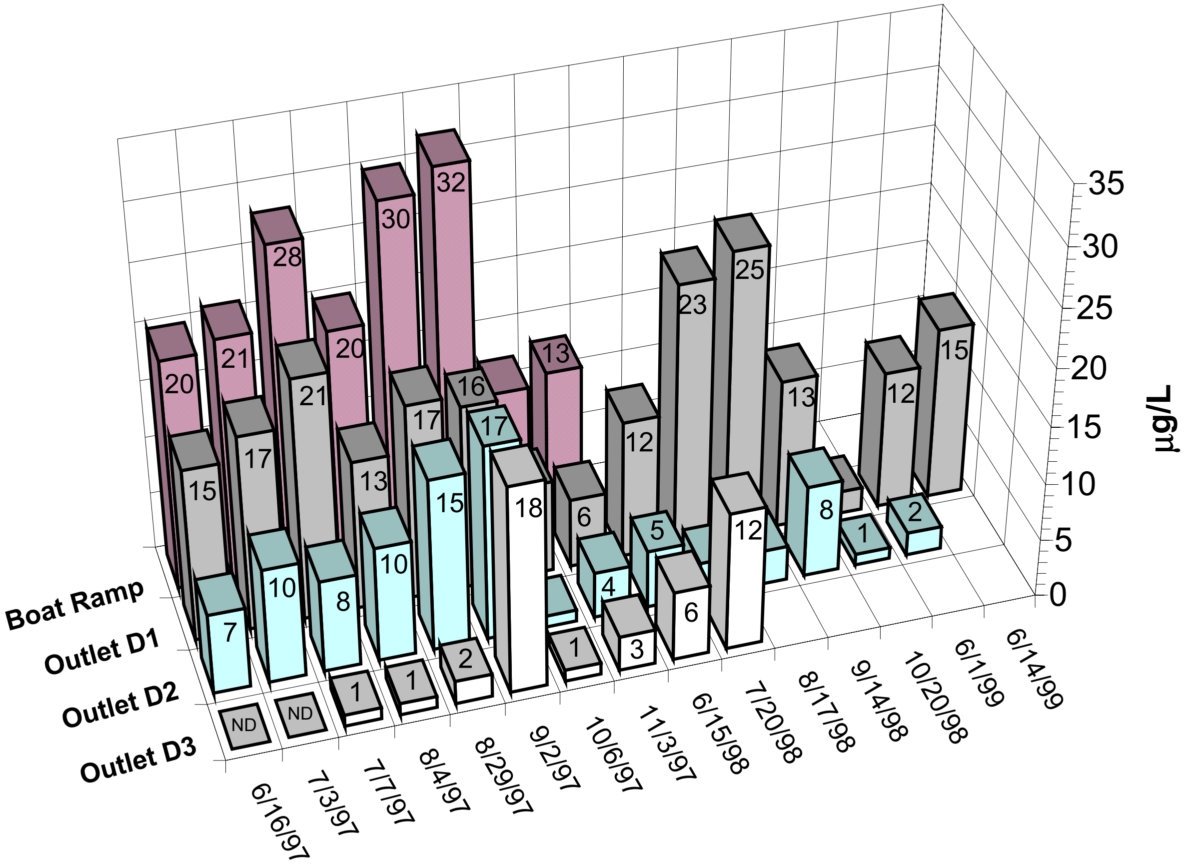
Table 7-25 Summary of MTBE Concentrations in Lake Perris (μg/L)

MWDSC Sampling	Outlet (1997)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion)				
Range	3.9 - 25	ND - 5.0	16 - 45	1.6 - 7.7
Mean	14	2.0	25	5.2
Bottom (Hypolimnion)				
Range	ND – 8.0	N/S	N/S	N/S
Mean	3.7	N/S	N/S	N/S
DWR Sampling	Outlet (1997/1998)		Boat Ramp (1997)	
	Summer	Winter	Summer	Winter
Surface (Epilimnion D1 +D2)				
Range	1.0- 25	N/S	12 - 32	N/S
Mean	11	N/S	22	N/S
Bottom (Hypolimnion)				
Range	ND - 18	N/S	N/S	N/S
Mean	5.5	N/S	N/S	N/S

Note: Surface samples include samples collected from 0.5 to 10 meters
ND = Not Detected.
N/S = Not Sampled

Thermal stratification during summer recreation season leads to a build-up of MTBE in the upper layers of the lake. Surface samples at the outlet tower ranged from 1 to 25 μg/L with a mean of 11 μg/L. MTBE concentrations at depth 2 ranged from 1 to 17 μg/L, with a mean of 8.9 μg/L. The high value was observed in late August, and the low value was observed in October. MTBE in the hypolimnion (D3) ranged from 1 to 3 μg/L, except on September 2, when a concentration of 18 μg/L was observed.

Figure 7-24 Summary of MTBE Concentrations in Lake Perris



Data sources: DWR 1999, DWR Division of Operations and Maintenance unpublished data 1998

MWDSC also collected samples in Lake Perris during the 1997 recreation season (Table 7-25). MTBE concentrations in surface samples collected during the summer at the outlet tower ranged from 3.9 to 25 µg/L with a mean of 13.5µg/L. Samples collected in the hypolimnion during the summer months ranged from nondetect to 8 µg/L, with a mean of 3.7 µg/L.

When thermal stratification breaks down in fall, the lake mixes and MTBE spreads throughout the water column. Along with volatilization, this leads to decreasing MTBE concentrations. Lake Perris was thermally stratified from late June until early October in 1997. During winter 1997/1998, MTBE concentrations declined to ambient levels throughout the water column. Surface samples collected at the outlet tower had a mean of 2.0 µg/L, while samples collected at the boat ramp had a mean of 5.2 µg/L. Three factors had a role in this decline. Decreased recreational boating led to lower MTBE loading, and the thermocline began to weaken in October. This caused the lake to mix, and MTBE was dispersed throughout the water column. Volatilization also eliminated some MTBE from the reservoir.

MTBE concentrations were higher near the boat ramp than at the outlet tower. DWR sampling in 1997 showed MTBE concentrations ranging from 12 to 32 µg/L in surface samples collected at the boat ramp, with a mean of 22 µg/L (Table 7-25). MWDSC sampling showed values at the boat ramp ranging from 16 to 45 µg/L in the summer. The mean was 24.6 µg/L. During winter months, the range was 1.6 to 7.7 µg/L with a mean of 5.2 µg/L.

MTBE concentrations increased over holiday weekends. Samples were collected before and after 4th of July and Labor Day weekends 1997. These weekends represent the periods of highest recreational use in the lake. Over the 4th of July weekend, MTBE concentrations increased by 4 µg/L at the outlet tower and 7 µg/L at the boat ramp. The changes were not as dramatic over Labor Day weekend. Concentrations rose 2 µg/L at the boat ramp but declined by 1 µg/L at the outlet tower.

Lake Perris has the highest recreational use of the 4 SWP Southern California reservoirs and thus has much higher MTBE concentrations. MTBE concentrates in the upper layer of the lake during the summer months. Samples taken in 1997 showed values exceeding the DHS primary MCL of 13 µg/L. Samples collected near the boat ramp had MTBE concentrations nearly twice the primary MCL. Samples collected during winter were generally at or below the secondary MCL of 5 µg/L.

Total Dissolved Solids

Because of water quality problems associated with anoxia in the hypolimnion, MTBE, and pathogens, much of Lake Perris is unusable for water utilities much of the year. The period when the water quality is at its worst is in summer and early fall, which are periods of highest water demand. This situation has led contractors to decrease their use of Perris water. With reduced or no deliveries from Lake Perris, the flow through the lake has decreased. Evaporation causes loss of water from the lake without the loss of the accompanying dissolved solids, and with low inflow to the lake, TDS concentrations have increased.

TDS levels from 1996 to 1999 ranged from 262 to 405 mg/L with a mean of 324 mg/L (Table 7-24). These concentrations were below the secondary MCL of 500 mg/L but routinely exceeded the 10-year average Article 19 objective of 220 mg/L. Water flows into Lake Perris from Silverwood Lake through the Santa Ana Pipeline. TDS levels in Lake Perris are significantly higher than those observed in Silverwood Lake. Silverwood TDS readings ranged from 148 to 246 mg/L with a mean of 198 mg/L. This increase illustrates the effect of evaporation on TDS levels in Lake Perris.

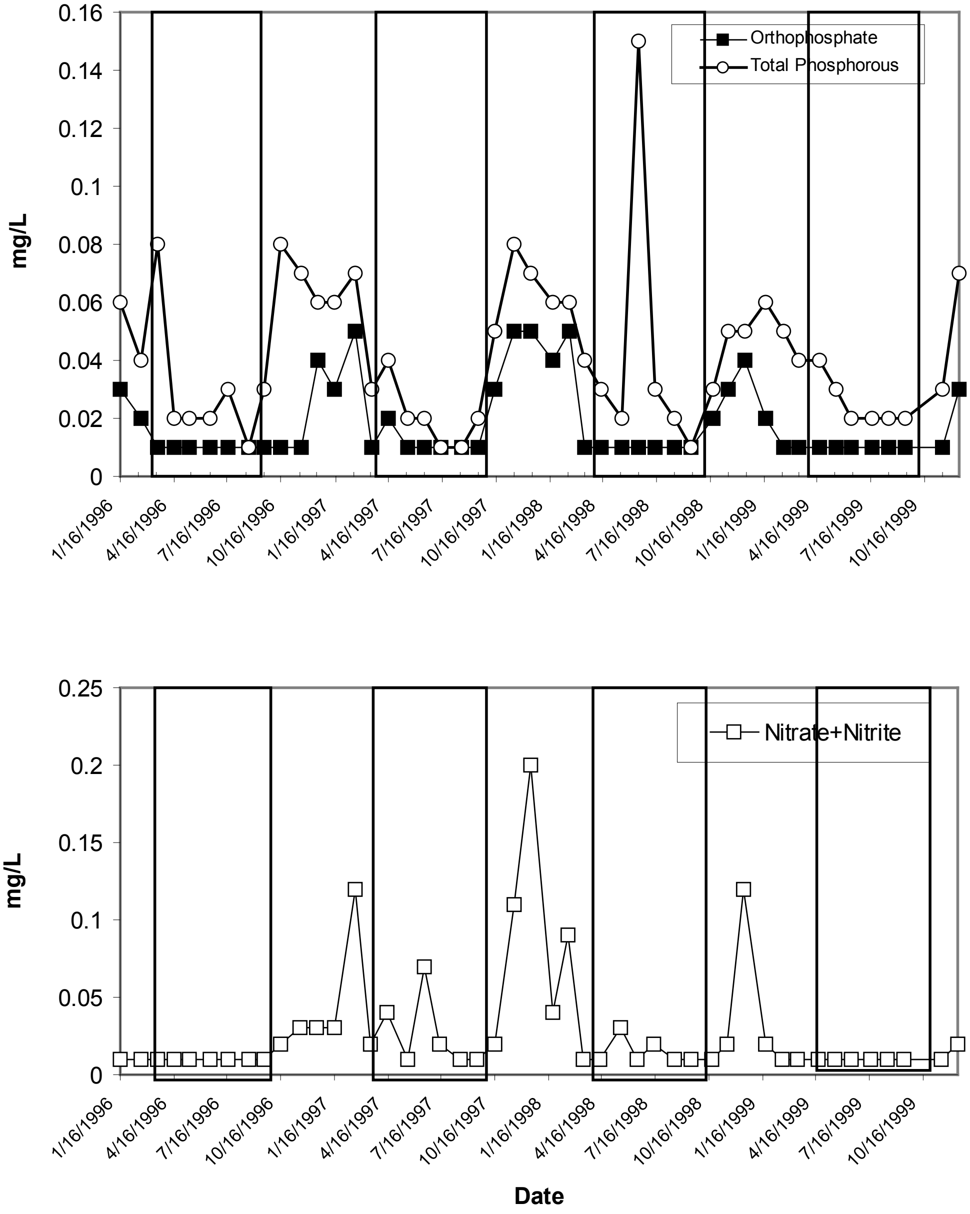
The effects of evapoconcentration is also observed for several other water quality parameters. Sulfate, chloride, bromide and hardness were all observed at higher levels in Lake Perris than in Silverwood Lake (see Tables 7-24 and 7-17). Sulfate concentrations were roughly twice as high in Lake Perris as they were in Silverwood Lake. However, all sulfate values were below the secondary MCL of 250 mg/L. Chloride concentrations also doubled in Lake Perris compared to Silverwood Lake. Chloride concentrations were well below the secondary MCL of 250 mg/L. Hardness and bromide followed similar patterns. Quarterly sampling for bromide began in 1999. Bromide was detected in all samples collected that year with a mean of 0.21 mg/L. Bromide is oxidized to bromate during the treatment process. Bromate is considered a human carcinogen by the California Office of Environmental Health Hazard Assessment and has an MCL of 0.01 mg/L. In order to meet this standard for bromate in finished water, the SWP contractors have identified a goal of 0.05 mg/L for bromide in raw water. Bromide levels in Lake Perris were approximately 4 times higher than this objective.

Nutrients

Nitrogen levels in Lake Perris were generally lower than Castaic or Silverwood lakes, while phosphorus was about the same as Castaic and somewhat lower than Silverwood. However, the same seasonal pattern of summer increase and winter decrease was observed (Figure 7-25). Total phosphorus levels in Lake Perris ranged from <0.01 mg/L to 0.15 mg/L, averaging 0.04 mg/L. Orthophosphate levels ranged from <0.01 mg/L to 0.05 mg/L, averaging 0.02 mg/L (Table 7-24). The high value of 0.15 mg/L total phosphorus occurred in July 1998 and could be an outlier because the sample for orthophosphate on the same date was <0.01 mg/L, although laboratory quality controls were all within acceptable ranges (Fong pers. comm. 2000).

Nitrogen followed the same seasonal pattern as phosphorus (Figure 7-25). Kjeldahl nitrogen (as N) in Lake Perris ranged from 0.3 to 1.2 mg/L, averaging 0.5 mg/L. Nitrate and nitrite (as N) ranged from <0.01 mg/L to 0.2 mg/L and averaged 0.03 mg/L. The high nitrate value was in February 1998 during the El Niño storm period and remained below this level throughout the year.

Figure 7-25 Nutrient Concentrations in Lake Perris, 1996 to 1999



Data source: DWR O&M Division database, May 2000
Boxed areas represent approximate algal growing season, May through October.

Taste and Odor

Algal blooms lead to increased levels of the compounds 2-methylisoborneol (MIB) and geosmin, which cause taste and odor and contribute to negative aesthetic qualities. These 2 compounds are not readily removed by the treatment process and present additional problems for utilities treating raw water. They are also commonly associated with blooms of blue-green algae in reservoirs.

MIB and geosmin levels were higher at Lake Perris than at other SWP reservoirs (Table 7-26). The highest values were observed at the lake inlet and at the lake center. Geosmin at the inlet ranged from ND to 179 ng/L with a mean of 9.2 ng/L. The inlet is on the north side of the lake, near Sail Cove. On the other side of the reservoir, at the outlet structure, geosmin ranged from ND to 87 ng/L with a mean of 7.1 ng/L.

MIB and geosmin levels were higher in summer and fall months (Figure 7-26). However, this pattern was not as strong at Perris as it was at other SWP reservoirs. Levels at or near the taste and odor detection threshold (5 to 10 ng/L) were observed between April and November of most years. The lowest values were also observed between January and March of most years. There were several peaks in MIB and geosmin concentrations observed in January, May and October 1997 and early June 1999 that greatly exceeded the taste and odor detection threshold. In summer 1997, a blue-green algal bloom required application of 10 tons of copper sulfate by DWR (MWDSC 1997).

MIB and geosmin concentrations were higher at the surface and declined with increasing depth (Fig. 7-26 bottom). MIB in the upper portion of the epilimnion (0 to 5 meters) ranged from ND to 81 ng/L at the outlet tower. When detected the mean was 8.4 ng/L. MIB at the bottom of the outlet tower (> 20 meters) ranged from ND to 26 ng/L with a mean of 4.8 ng/L. Surface concentrations of geosmin at the outlet tower ranged from ND to 87 ng/L. When detected, the mean was 7.6 ng/L. Geosmin concentrations at the bottom of the outlet tower ranged from ND to 48 ng/L. The mean of all samples with detectable concentrations was 6.5 ng/L.

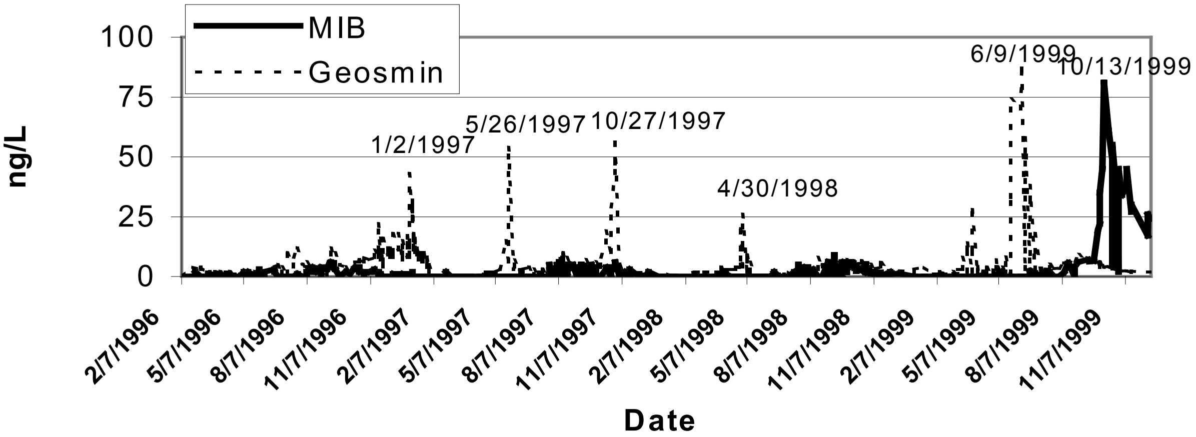
The lowest MIB and geosmin concentrations were observed in the lake outflow. Geosmin concentrations in the outflow ranged from below the detection limit to 5 ng/L. When detected, the mean was 2.8 ng/L (Table 7-26). Only 1 sample collected from the lake outflow contained MIB at levels above the taste and odor threshold. Lower concentrations observed in lake outflow may be a result of reservoir management practices such as selective depth and/or timed withdrawal.

Table 7-26 MIB and Geosmin Concentrations in Lake Perris, 1996 to 1999 (ng/L)

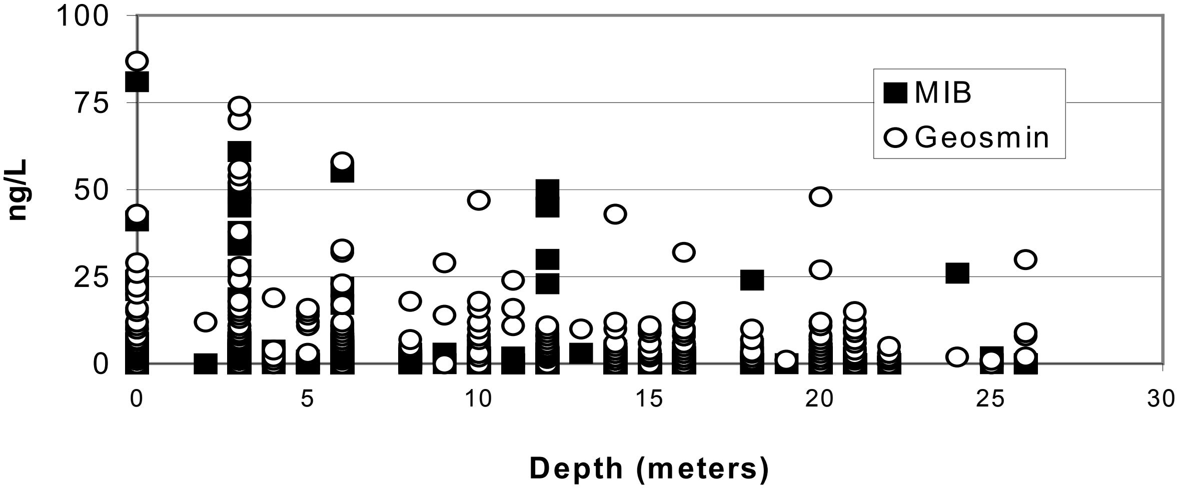
	MIB	Geosmin
Lake Inlet		
Range	ND to 59	ND to 160
Mean	7.8	8.0
Percent of Samples with Detectable levels	52%	84%
Lake Center		
Range	ND to 51	ND to 179
Mean	8.0	9.2
Percent of Samples with Detectable levels	38%	86%
Lake Outlet		
Range	ND to 81	ND to 87
Mean	7.0	7.1
Percent of Samples with Detectable levels	37%	82%
Lake Effluent		
Range	ND to 37	ND to 5.0
Mean	8.0	2.8
Percent of Samples with Detectable levels	38%	75%

Note: Mean values do not include samples where no analyte was detected
ND = Not Detected

Figure 7-26 MIB and Geosmin Levels at the Lake Perris Outlet, 1996 to 1999



MIB and Geosmin Levels by Depth - Lake Perris Outlet



7.4.4.2 Water Supply System

Water quality of utilities using Lake Perris water was not investigated because of the limited use as SWP supply. Additionally, water from Lake Perris used by MWDSC is mixed with Colorado River water, typically at less than 25%. Therefore, treatment plant data would not accurately reflect Lake Perris effluent water quality.

7.4.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

High levels of recreation have a significant effect on water quality at Lake Perris. High concentrations of MTBE from motorized boating and concerns about pathogen loading from body-contact recreation combine to restrict the use of upper layer water during the period of highest water demand. Water utilities have expressed concern that bathers in the swimming area during periods of high recreation could contribute to high pathogen levels that in turn could potentially overwhelm the treatment process. Additionally, pathogen concentrations present a significant risk to the recreationists themselves, as evidenced by frequent beach closures.

Anoxic conditions in the lower lake layer also limit the use of this water during the period of highest water demand. Anoxia is a naturally occurring condition that leads to high concentrations of reduced compounds and odorous chemicals. These reduced compounds require extra doses of oxidants, increasing treatment costs.

The water quality concerns in Lake Perris have led to decreased use of water from the lake. This leads to decreased flow through the lake. Decreasing flow through the lake increases the concentration of dissolved solids. High dissolved solids concentrations further contribute to the unsuitability of Lake Perris water for the contractor's use.

The leaking underground storage tank that was removed from the marina in 1994 continues to contaminate groundwater adjacent to the lake. High water levels in the lake have hampered the remediation process.

7.4.6 WATERSHED MANAGEMENT PRACTICES

There are several agencies with management authority in the Lake Perris watershed. DWR constructed the reservoir and is primarily responsible for its operation. California State Parks manages the Lake Perris SRA, controlling the types of recreation within the watershed. DBW regulates recreational boating. The MWDSC is the only contractor in this reach of the SWP and is involved with DWR in reservoir management decisions such as controlling lake outflow.

As with the other reservoirs, recreation presents the largest watershed management issue at Lake Perris. Recreational activities often present significant sources of contamination, and these activities often can be significant sources of contamination. Strategies to address and mitigate this impact are being discussed in a water quality/recreation focus group of staff representing: DWR, California State Parks, and other involved agencies. Among specific actions taken at Lake Perris is the installation of pumps near the beach areas to increase circulation away from the beaches. These pumps are designed to move the pathogens farther from the recreationists to reduce their risk; however, the practice has the potential to spread the pathogen contamination throughout the lake, possibly increasing the pathogen concentration at the lake outlet. Limits on the numbers of watercraft allowed on the lake may help control MTBE contamination, but these limits appear to be dictated more by safety for the boaters and less by water quality concerns.

The EMWD is responsible for the maintenance and operation of the wastewater collection activities in the watershed and upgraded wastewater collection facilities to reduce the risk of future sewage leaks. These upgrades include 24-hour monitoring at several lift stations. The California Department of Fish and Game is responsible for managing the wildlife habitat in the watershed. All of these entities work toward the common goal of providing recreation and wildlife habitat as well as maintaining drinking water quality.

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Chapter 8 - California Aqueduct
Section 1: Clifton Court to O'Neill Forebay

Potential Contaminant Source or Watershed Activity	**Report Section**	**Water Quality Parameters**									
		TDS/ Salts	**Organic Carbon**	**Bromide**	**Pesticides**	**Nutrients**	**Pathogens**	**Trace Elements**	**Turbidity**	**T&O**	**Hydro-carbons**
Recreation	8.1.3.1					○	○				
Wastewater Treatment/Facilities	8.1.3.2										
Urban Runoff	8.1.3.3	○	○		○	○	○	○	○	○	
Animal Populations	8.1.3.4	○	○			○	○		○	○	
Algal Blooms	8.1.3.5								○	◒	
Agricultural Activity	8.1.3.6	○	○		○	○		○		○	
Wind Erosion	8.1.3.7	○	○			○		○	◒		
Accidents/Spills	8.1.3.8							○		○	●
Groundwater Discharges	8.1.3.9										
Geologic Hazards	8.1.3.10	○		○							

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Chapter 8 - California Aqueduct
Section 2: The O’Neill Forebay

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters								
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O
The Delta-Mendota Canal	8.2.3.1	◒	◒	◒	○	◒	⊙	○	◒	⊙
Recreation	8.2.3.2					○	◒			
Urban Runoff	8.2.3.3									
Agricultural Activities	8.2.3.4									
Animal Populations	8.2.3.5					◒	◒			
Accidents/Spills	8.2.3.6									
Fires	8.2.3.7	○							○	

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Chapter 8 - California Aqueduct
Section 3: Outlet of O'Neill Forebay to Check 21 (Kettleman City): San Luis Canal

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Floodwater Inflows	8.3.3.1	●	⊙	⊙	○	◒	⊙	●	●	○	● ^
Recreation	8.3.3.2						○				
Wastewater Treatment/Facilities	8.3.3.3	○	○			○	○		○	○	
Industrial Discharge to Land	8.3.3.4	○	○					○			
Industrial-site Stormwater Runoff	8.3.3.5	○	○		○	○		○			
Animal Populations	8.3.3.6	○	○			◒	◒				
Agricultural Activities	8.3.3.7				○						
Mines	8.3.3.8	○						○			◒[1]
Solid/Hazardous Waste Facilities	8.3.3.9	○			○	○		○			
Unauthorized Activity	8.3.3.10										
Transportation Corridors	8.3.3.11										○ 2
Accidents/Spills	8.3.3.12	○			○	○	○				○ 2
Groundwater Discharges	8.3.3.13	◒				○		◒			
Geologic Hazards	8.3.3.14	○	○	○	○	○	○	○	○	○	◒[1]
Population and General Urban Area Increase	8.3.3.15										

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Notes:

1. Asbestos and mercury
2. Hydrocarbons

Chapter 8 - California Aqueduct
Section 4: Kettleman City to Kern River Intertie

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Hydro- carbons
Recreation	8.4.3.1						◒				
Wastewater Treatment/Facilities	8.4.3.2										
Floodwater Inflows	8.4.3.3										
Accidents/Spills	8.4.3.4										◒
Water-service Turnouts	8.4.3.5				○	○		○			

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Chapter 8 - California Aqueduct
Section 5: Kern River Intertie to East/West Branch Bifurcation

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Other
Kern River Intertie	8.5.3.1				○	○	○	○	◒		
Groundwater Discharges	8.5.3.2	◒	○	○	○	○		◒ 1			
Recreation	8.5.3.3						○				
Accidents/Spills	8.5.3.4										◒ 2

Rating symbols:

● PCS is a highly significant threat to drinking water quality
◒ PCS is a medium threat to drinking water quality
⊙ PCS is a potential threat, but available information is inadequate to rate the threat
○ PCS is a minor threat to drinking water quality
Blank cells indicate PCS not a source of contaminant

Notes:

1. Arsenic
2. Hydrocarbons

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California Aqueduct

The Edmund G. Brown California Aqueduct is the State's largest and longest water conveyance system, stretching 440 miles from the Sacramento-San Joaquin Delta in the north to Lake Perris in Southern California. The aqueduct and its branches supply water for two-thirds of California's population and to irrigate about 1 million acres of farmland. Water is pumped from the Delta into the California Aqueduct at the Harvey O. Banks Delta Pumping Plant near Tracy. Because of its location in the southern Delta, the pumping plant receives water from both the Sacramento and San Joaquin rivers. Under normal hydrologic conditions the proportion of Sacramento and San Joaquin River water flowing in the aqueduct is approximately 70% and 30%, respectively. During wet years, the proportion of the San Joaquin water increases.

From the Banks Pumping Plant, water is transported via the California Aqueduct to the South Bay Aqueduct (see Chapter 5) and O'Neill Forebay. During winter months, water is pumped from O'Neill Forebay into San Luis Reservoir, a 2 million acre-feet (af) offstream storage reservoir (see Chapter 6). Water from the US Bureau of Reclamation's Delta-Mendota Canal (DMC) is also pumped into O'Neill Forebay for transfer into the reservoir. Commingling of the State Water Project (SWP) and DMC has important water quality impacts that are discussed later. From O'Neill Forebay, Delta water and San Luis Reservoir releases flow into and through a section of the California Aqueduct known as the San Luis Canal (SLC). Farther south the aqueduct intersects the Kern River Intertie (KRI) in Kern County near Bakersfield. Originally, the Kern River flowed into Tulare and Buena Vista lakes. The intertie was built to reclaim farmland, prevent flooding, and provide additional water to the SWP. Below the KRI, water is pumped over the Tehachapi Mountains. The California Aqueduct bifurcates at Gorman into the East Branch and the West Branch (see Chapter 10).

This chapter describes the water supply systems and facilities, potential contaminant sources (PCSs), and water quality of the main sections of the California Aqueduct from the Banks Pumping Plant to the bifurcation. For the purposes of this report, the California Aqueduct has been divided into 5 sections:

- Section 1: Clifton Court Forebay to O'Neill Forebay
- Section 2: The O'Neill Forebay
- Section 3: Outlet of O'Neill Forebay to Check 21 (the SLC)
- Section 4: Check 21 (Kettleman City) to KRI
- Section 5: KRI to East/West Branch Bifurcation

Section 3 is emphasized because the vast majority of PCSs to the aqueduct are found along this reach. Additional focus is also placed on section 5 because of the potential influence of the KRI. Greater detail is provided for these 2 sections because of their higher potential to affect SWP water quality.

8.1 CLIFTON COURT FOREBAY TO O'NEILL FOREBAY

8.1.1 WATER SUPPLY SYSTEM

8.1.1.1 Description of Aqueduct and SWP Facilities

This section of the California Aqueduct includes the reach from the intake into Clifton Court Forebay to the Harvey O. Banks Delta Pumping Plant at mile 3.04, to just before O'Neill Forebay at mile 66.8. The major facilities that make up this portion of the aqueduct include Clifton Court Forebay, the Banks Pumping Plant, Bethany Reservoir, and 2 concrete-lined canals. Key features of this aqueduct reach are presented in Figure 8-1.

Clifton Court Forebay is in the southwestern part of the Delta between Tracy and Byron and is bounded by Byron Tract on the northwest, Victoria Island on the north, Coney Island on the northeast, and the Byron-Bethany Highway on the south. The forebay stabilizes the water surface for the intake of the Banks Pumping Plant at a slightly higher level to reduce pumping costs and improve water quality in the aqueduct and through the southern portion of the Delta. Timed operation of the forebay intake gates bring Sacramento River water upstream through the San Joaquin River channel.

Figure 8-1 California Aqueduct: Clifton Court to O'Neill Forebay

Clifton Court Forebay has a surface area of 2,180 acres and a nominal storage capacity of 31,260 af, assuming a 14-foot average depth. Over the years, silt has settled in the forebay, reducing storage capacity. Present depths are estimated at 0.2 foot to 9 feet, except for a deep scour hole just inside the inlet structure. Water flows into Clifton Court from the northern and eastern portions of the Delta by way of Old River and the Victoria Canal into the intake structure at the southeast corner of the forebay. When flows in the San Joaquin River are low, water intake is timed for an outgoing high tide, so that water continues to flow upstream in the portion of Old River between Clifton Court and the central portion of the Delta. Water flows out of Clifton Court through the John E. Skinner Delta Fish Protective Facility to the Banks Pumping Plant via a 3-mile long intake channel.

The Banks Pumping Plant is the 1st of several on the aqueduct that transport water south along the western side of the San Joaquin Valley, parallel to the Coast Ranges. At the Banks Pumping Plant, water is lifted 244 feet into the California Aqueduct. From the Banks outlet, water travels 1.5 miles in a concrete-lined canal to Bethany Reservoir, which is a flow-through reservoir with a storage capacity of 5,070 af; a 6-mile long shoreline; and a surface area of about 180 acres. Bethany Reservoir's water surface elevation is controlled by radial gates at Check 1. The maximum water surface elevation is 245 feet above sea level. Beyond Check 1, water flows 61 miles through the concrete-lined canal, controlled by check structures every few miles until at Check 12 it flows into O'Neill Forebay.

Table 8-1 Description of Structures from Banks Pumping Plant to O'Neill Forebay

Type	Number
Drain inlets for canal operating road and/or canal right of way	485
Drain inlets for canal right of way and upslope range and cropland	23
Drain inlets for canal right of way and public roads or highways	3
Pump pads for portable storm water runoff pumps	1
Overchutes	26
Evacuation culverts	16
Submersible pumps for relieving canal seepage and/or groundwater pressure against the canal liner	9

Source: DWR memo from Dick Buchan to Don Kurosaka, 4 May 1992; Brown and Caldwell 1990

Aside from the main canal and its control gates and pumps, this section of the aqueduct contains a number of structures built to handle surface water runoff and groundwater inflows (Table 8-1).

Some local runoff from cropland or rangeland is conveyed into the aqueduct via the 23 drain inlets. However, most runoff is conveyed around the aqueduct in overchutes and evacuation culverts that intercept upslope runoff and convey it to the downslope, or eastern side of the aqueduct. There are 42 of these structures and 1 pump pad in this section of the aqueduct (Table 8-1). Groundwater can be pumped into the aqueduct via Department of Water Resources (DWR) sump pumps. These are automated groundwater pumps that relieve groundwater pressure on the upslope, or western side of the canal liner. Groundwater can also be pumped in at water service turnouts to supplement downstream supplies.

There are also numerous structures on the aqueduct unrelated to drainage. These include bridges, pipeline crossings, and fishing areas (Table 8-2).

Table 8-2 Nondrainage Structures from Banks Pumping Plant to O'Neill Forebay

Type	Number
Bridges	45
State	2
County	35
Farm or private	8
Pipeline overcrossings	76
Fishing areas	3

8.1.1.2 Description of Agencies Using SWP Water

There are 6 water service turnouts in the aqueduct from Clifton Court to O'Neill Forebay. These are predominately for agriculture services with possibly some domestic use. Five are pumped, and 1 flows naturally by gravity. Oak Flat Water District, the only SWP contractor in this section, draws the water for agricultural use with 4 turnouts from mile 42.46 to mile 46.18.

8.1.2 WATERSHED DESCRIPTION

No watershed runoff enters the 1st section of the California Aqueduct. The western side of the San Joaquin Valley through which this section flows is primarily composed of cropland and rangeland.

8.1.3 POTENTIAL CONTAMINANT SOURCES

8.1.3.1 Recreation

Recreational use of Clifton Court Forebay is limited to fishing and duck hunting. Fishing is done from the 8-mile shoreline, and duck hunting is done from the shoreline and from small nonmotorized skiffs. There is no boat ramp, and no restrooms are provided. Access to the levees around the forebay is limited to walk-in and boat-in, so the full length of the shoreline is not well used. Boats are not allowed to pass through the gates. With no power boats, gasoline spills and MTBE contamination do not originate in the forebay but can be imported from the Delta through the intake gates. With no restrooms, there is potential for fecal contamination of the forebay waters.

Recreational use is measured in units of "recreation days," which are defined as 1 user visiting the area during part of a 1-day period. No count has been made of recreation days at Clifton Court Forebay. A rough estimate would be fewer than the 1998 count of about 32,000 recreation days for nearby Bethany Reservoir, where boating is allowed. Therefore, a reasonable estimate would be about 20,000 to 30,000 recreation days per year at Clifton Court.

Body and nonbody contact recreation occur in Bethany Reservoir, which is operated by the California State Parks. Recreational activities include boating (power and sail), swimming, fishing, and picnicking. No camping is allowed. There are 4 chemical toilets provided for the general public. All of these activities can contribute pathogens and hydrocarbons. Visitor attendance is shown in Table 8-3.

Table 8-3 Visitor Attendance at Bethany Reservoir

Fiscal Year	Total Attendance	Boat Launching
1995/96	14,496	194
1996/97	11,007	259
1997/98	14,181	295
1998/99	13,950	292
1999/00	26,175	497

Source: California State Parks

The aqueduct is also accessible to the public for fishing through gated structures at 3 locations. These gates allow people to enter but exclude the entry of motor vehicles. Two of these locations are equipped with portable chemical toilets.

8.1.3.2 Wastewater Treatment/Facilities

Domestic wastewater collection, treatment, and effluent storage facilities serve the employees at the Banks Pumping Plant. These facilities were reported to be in good condition and should not pose any significant hazard to the water conveyance facilities (Brown and Caldwell 1990).

8.1.3.3 Urban Runoff

There are 485 toe drains that convey runoff into the aqueduct from canal operating roads, but they are not considered a major source of inflow. Most of the runoff from the drain inlets is conveyed around the aqueduct in overchutes or evacuation culverts. During wet periods, several hundred drain inlets convey canal shoulder runoff directly into the aqueduct. Most of these drains range in size from 4 to 12 inches in diameter. Three drains also allow storm water from nearby Interstate Highway 5 and State Highway 205 to enter the aqueduct. This inflow can contribute solids, metals, oils, and grease as well as any spilled materials.

8.1.3.4 Animal Populations

Livestock Grazing

There is no grazing on land south of Clifton Court, which drains into the forebay. Typically, crops such as alfalfa and corn are grown in this area. There is a possibility of cattle grazing after harvest to clean up the silage. Several drain inlets along the aqueduct accept rainfall runoff from adjacent rangeland. *Sanitary Survey 1990* estimated the size of watersheds contributing inputs to the aqueduct ranges from 100 to 200 acres. Floodwater from these lands as well as from cropland are conveyed into the aqueduct at 22 locations.

The Bethany Reservoir watershed is surrounded by about 500 to 600 acres of undeveloped land used primarily for cattle grazing. California Department of Health Services (DHS) has been concerned about cattle having direct access to the shoreline of Bethany Reservoir (Brown and Caldwell 1990). Cattle grazing in the watershed may contribute pathogens, organics, and nutrients into the water.

During a routine canal patrol in 1998, DWR field staff observed a corral next to the aqueduct near mile 52 that had been set up to hold cattle grazing on adjacent land. Although the corral was on the eastern side, it was on land that was higher than the aqueduct. A toe drain on the aqueduct was less than 10 feet from the corral and conveyed runoff from this land and the levee road. Field staff located the rancher and asked him to move the corral. The rancher complied, and the corral now poses little threat to water quality.

Waterfowl

Large numbers of ducks and geese use Clifton Court Forebay during migration season. Seagulls and cranes are present at all times in the forebay, feeding on shallow-water fish. Although counts are not available, there is potential for fecal contamination from waterfowl.

8.1.3.5 Algal Blooms

The warm, shallow, nutrient-rich water in the forebay provides optimal conditions for algae growth. High nutrient loads are caused by incoming Delta water and resident and transient waterfowl. The primary adverse effects on water quality associated with algal blooms are increased turbidity and taste and odor resulting from the production of 2 organic compounds, MIB and geosmin.

8.1.3.6 Agricultural Activities

Pumped agricultural drains on the south side of Clifton Court serve about 1,000 acres, making contamination by fertilizers and pesticides possible. However, no information is available on fertilizer or pesticide use. The herbicide Komeen is sprayed during the months of May and June in Clifton Court to control aquatic weeds.

Rainfall runoff from agricultural land is possible at 1 inlet draining the intensively farmed 100- to 200-acre parcel upstream of the aqueduct that was reported in *Sanitary Survey 1990*. There are 16 undercrossings of relatively large pipelines ranging from 36 to 93 inches in diameter. Fourteen of the pipelines convey storm drainage from undeveloped lands, lands grazed by cattle, and lands that are intensively farmed. Agriculture drainage in the watersheds of Bethany Reservoir may contribute pesticide residues from agricultural chemical or fertilizer or both.

Below mile 32.60, seasonal aerial spraying is more pronounced because of the intensive farming practices. The major threat to water quality is from overspray of the aqueduct. This has been observed by field staff on numerous occasions. At times, crop dusters have left a visible layer of a powdered substance, believed to be sulphur dust, on the surface of the aqueduct. Overall, agricultural activity is considered a minor threat to water quality.

8.1.3.7 Wind Erosion

With high winds common in the Clifton Court area, wind friction on the water surface of the 2-mile reach across the forebay can create high waves. These waves can range from 1 to 2 feet. Riprap protection on the surrounding levees minimizes wave erosion and the resulting turbidity, but shallow water areas are susceptible to wave action and can generate sediments that are pumped into the aqueduct. This is considered a moderate potential threat to water quality.

8.1.3.8 Accidents and Spills

There are 76 pipeline crossings in this section of the aqueduct (Brown and Caldwell 1990). The largest pipeline noted was 60 inches in diameter. Oil, storm drainage, irrigation water, and natural gas flow through these pipelines. Hazardous spills on Highway 152 would drain directly into O'Neill Forebay. Roadside drainage from Interstate Highway 5 and State Highway 205 could also allow hazardous material to drain into the aqueduct. *Sanitary Survey 1990* reported a few leaks in petroleum pipelines adjacent to the aqueduct. Since then, only 1 major incident has been documented regarding leakage from these pipelines.

On 9 August 1997, a small portion of aqueduct liner slumped into the water at mile 62.23 when the aqueduct was shut down for repairs upstream. On startup, oil was observed, and absorbent booms were deployed downstream. Monitoring for hydrocarbons began on a daily basis. Some remediation was attempted by excavating soil and treating groundwater. The oil leakage was attributed to residual oil from a 1984 pipeline break, which was discovered when hydrocarbons were detected in a sump pump at mile 62.39 (DWR 1999d). The residual oil found in 1984 was from a release of crude oil that was reportedly up to 1,000 barrels (50,000 gallons) and had migrated east and northwest.

Contamination associated with these incidents has continued to be a problem in this reach of the aqueduct. The Tosco/Pacific Environmental Group has been remediating and monitoring groundwater at this site. In September and October 1999, DWR Project Geology staff reviewed operation status reports. The review indicated that groundwater contamination on the west side of the aqueduct has continued to migrate eastward toward the SWP and that contamination is also now present on the east side of the aqueduct. Staff's conclusion was that the contamination posed a threat to water quality in the SWP (Glick pers. comm. 1999).

To date Tosco/Pacific Environmental has not fully characterized the extent of soil and groundwater contamination. Remediation activities include a groundwater monitoring, interception and extraction, and treatment system. DWR believes that these systems are insufficient to prevent the flow of contaminated water into the aqueduct and recommends that the full extent of the contamination be determined and a thorough site characterization be completed in order to conduct a public health risk assessment.

This is considered a significant threat to water quality.

8.1.3.9 Groundwater Discharges

Groundwater is pumped into the aqueduct at many locations to reduce the pressure of shallow groundwater on the aqueduct. The aquifer moving east from the Diablo Range must be kept below a certain level to prevent canal liners from being displaced. Groundwater pump-ins in this section have historically, been small relative to the other sections of the California aqueduct. However, pumping groundwater into the aqueduct may contribute sodium, chloride, sulfate, trace elements, and total dissolved solids (TDS).

Pumped-groundwater drains on the western side of Clifton Court discharge into Italian Slough and do not directly affect the forebay. Along the northern and eastern sides is a double levee system where pumps between the levees hold the groundwater level below the surface, protecting the back side of the levees from wave wash. Groundwater in this area tends to be high in salinity (Byron Hot Springs is only 2 miles to the west), but the total pumped flow is insignificant compared to the volume of Clifton Court.

Groundwater can also enter the aqueduct at water service turnouts. From 1990 to 1996, pump-ins from water service turnouts occurred throughout the entire length of the California Aqueduct. These pump-ins were done to assist State and federal water contractors during periods of entitlement deficiency caused by the 1987 to 1992 drought. Only 1 of these pumps is in the 1st section of the aqueduct and was only briefly active during the reporting period. The Oak Flat Water District had pump-ins in 1992 that exceeded DWR water quality limits for nitrate and selenium (DWR 1994). The small amount of pump-in from the Oak Flat Water District was immediately stopped when high constituent levels were identified. Overall, the pump-ins are considered a minor PCS for the aqueduct.

Gas, Oil, Geothermal Wells

Groundwater contamination was found in 1997 at mile 62.23 from an oil leakage attributed to the 1984 pipeline breaks. Contamination associated with these incidents has continued to be a problem in this part of the aqueduct and is discussed in Section 8.1.3.8.

8.1.3.10 Geologic Hazards

The south levee of Clifton Court Forebay lies parallel to the Vernalis geologic fault. The Vernalis fault runs northwest, southeast under or close to the forebay, following the Coast Ranges. Byron Hot Springs is 2 miles west of Clifton Court, and the local groundwater is relatively saline, similar to water in some of the nearby springs. There is no indication of increased salinity in Clifton Court because of these groundwater inputs.

8.1.4 WATER QUALITY SUMMARY

8.1.4.1 Watershed

There were no major water quality problems noted for section 1 of the California Aqueduct other than the oil spill downstream of mile 62. Drain inlets and overcrossings probably contribute some pollutants from urban runoff, but there were no data or reports on this. It is most likely a minor source.

The August 1997 spill at mile 62.23 resulted in an oil sheen downstream in the aqueduct observed for about a week following the incident. The oil leakage was attributed to residual from a pipeline break in 1984. DWR's Operations and Maintenance Division (O&M) staff began monitoring for hydrocarbons on a daily basis. Samples were collected immediately downstream at mile 62.26 and 62.44, and approximately 4 to 4.5 miles farther downstream just above O'Neill Forebay. A sheen, and thus the likelihood of hydrocarbons, was also observed in O'Neill Forebay during the incident and in the aqueduct several times since the incident.

Parameters analyzed included total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene, and xylene. All but TPH were detected for 6 days at various locations. With the exception of a benzene detection of 2.2 µg/L, all other samples were less than the maximum contaminant levels (MCLs) for these compounds. The MCL for benzene is 1 µg/L.

The Tosco/Pacific Environmental Group has been monitoring groundwater in the site area since 1996. Its monitoring reports from 1998 and 1999 indicate significant groundwater contamination remaining in several wells adjacent to the aqueduct.

Table 8-4 includes a summary of data from 4 aqueduct sites downstream of the spill and from area wells monitored by Tosco/Pacific Environmental Group.

Table 8-4 Summary of Hydrocarbon Contamination Data Mile 62.23 Oil Spill

				Range of Hydrocarbon Concentrations (µg/L)				
Site	Dates	# of Samples	# of Detects	TPH	Benzene	Toluene	Ebenzene	Xylenes
Aqueduct (mile)	11 Aug 1997- 2 Oct 1997							
62.26[a]	-	21	5[b]	<50-220	<0.5-2.2	<0.5-0.59	<0.5-0.64	<0.5-5.7
62.44	-	22	2[b]	<50-5,400	<0.5	<0.5-1.3	<0.5-0.5	<0.5-2.2
66.32	-	23	3[b]	<50-110	<0.5-0.76	<0.5-0.89	<0.5-0.61	<0.5-2.1
66.77[c]	-	6	0					
Area Wells[d]	1998-1999	N/A	N/A	450-2,200	4-5.4	0.7	N/A	2.3-25

Sources: Aqueduct data, DWR O&M 1997a; well data, Glick pers. comm. 1999

[a] No hydrocarbons detected at upstream sample location mile 61.36

[b] Almost all detects occurred within 1 week after incident

[c] Includes 3 samples immediately above O'Neill Forebay

[d] Includes data in Tosco reports from 1-3 wells with detected contamination. Several well samples had floating product as much as 0.4 feet.

Ebenzene - Ethyl Benzene; N/A - not available

8.1.4.2 Water Supply System

The Banks Pumping Plant is the major water supply feature and primary monitoring point associated with section 1 of the California Aqueduct. Water quality data for Banks Pumping Plant are presented in Chapter 4, Sacramento/San Joaquin Delta, and Chapter 5, South Bay Aqueduct/Lake Del Valle.

8.1.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The largest known source of contaminants in the 1st section of the California Aqueduct is oil contaminated soil near mile 62.23 that entered the SWP as the result of a canal liner slump in 1997. After the oil sheen was detected, groundwater interceptor pumps were installed around the area to prevent further seepage. An absorbent oil boom was placed in the aqueduct and continues to be maintained at the time of this report. These actions, along with the fact that hydrocarbons are very volatile and there is a lengthy travel time to most downstream users, indicate that this contamination source is of low to moderate significance.

The only other major source of potential contamination in section 1 of the aqueduct is from rainfall runoff. *Sanitary Survey 1990* identified several watershed areas that drain to the aqueduct as either cropland or rangeland. The watershed for this section of the aqueduct covers from 100 to 200 acres, relatively small when compared to similar land that drains into the SLC (Section 8.3, Outlet of O'Neill Forebay to Check 21) and can exceed 500 square miles. Although runoff to section 1 of the aqueduct probably contains pathogens, pesticides, nutrients, and organic carbon, the relative size reduces its significance to a minor PCS to the SWP.

8.1.6 WATERSHED MANAGEMENT PRACTICES

There are no known watershed management activities in section 1 of the California Aqueduct that impact water quality. However, because of routine canal patrols and emergency plans in place as discussed in Chapter 11, State Water Project Emergency Action Plan, the potential discharge of pathogens and other contaminants was reduced because of action taken by DWR staff.

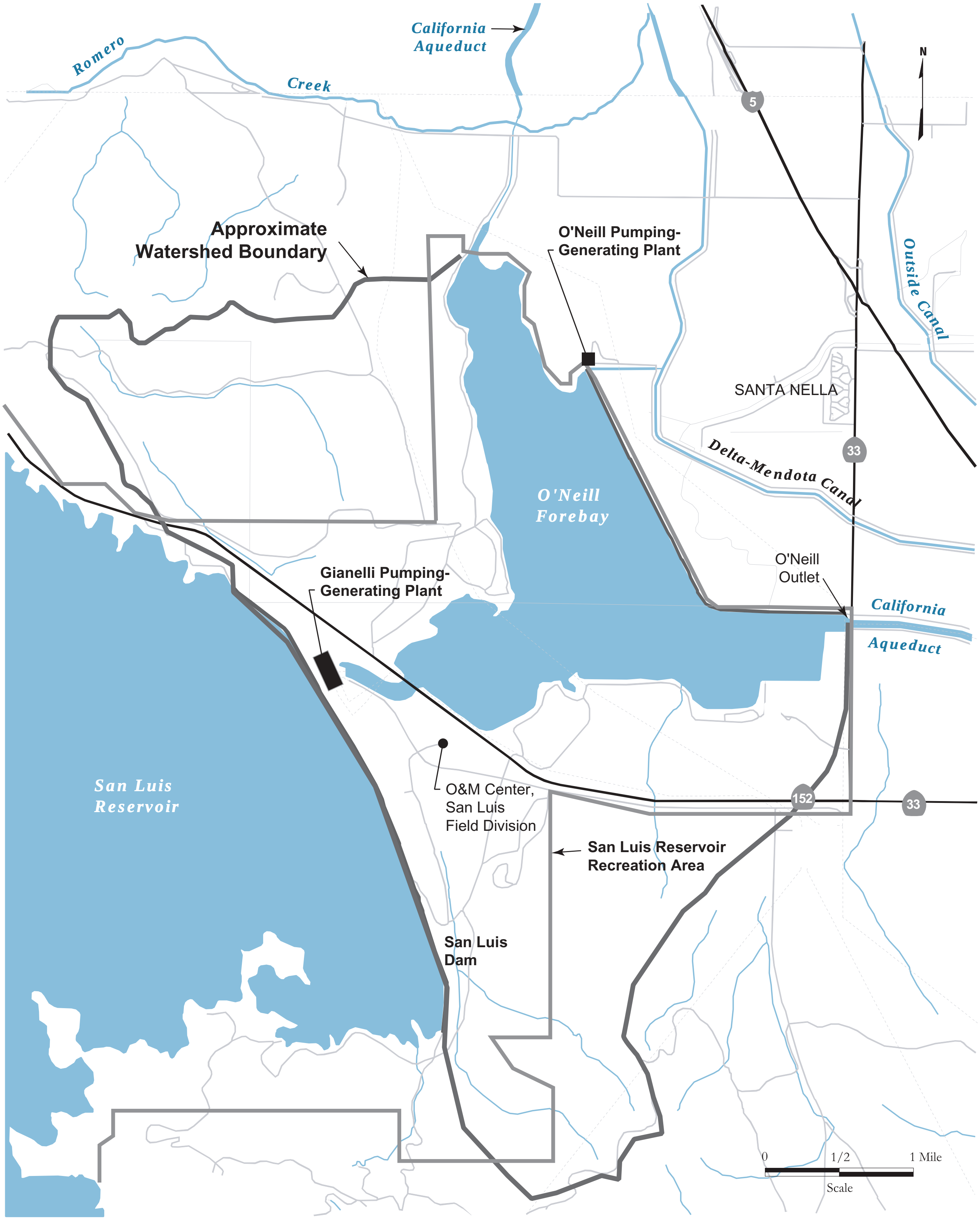
8.2 THE O'NEILL FOREBAY

8.2.1 WATER SUPPLY SYSTEM

8.2.1.1 Description of Aqueduct and SWP Facilities

O'Neill Forebay, part of the San Luis Field Division's Joint-Use Facilities, is operated to deliver water to State and federal water contractors (see detailed description of joint-use operations for the SLC in Section 8.3) and to San Luis Reservoir. O'Neill Forebay has a gross storage capacity of 56,436 af, a maximum depth of 40 feet, a surface area of 2,700 acres, and 12 miles of shoreline (Figure 8-2). The forebay has a glory hole spillway that leads to a cut-and-cover conduit. Spillway water is routed under the dam to a stilling basin and then to the approach channel to O'Neill Pumping-Generating Plant. The spillway was designed in case an outage prevented floodwater releases via the pumping-generating plant.

Figure 8-2 Watershed of O'Neill Forebay



Because the drawdown of San Luis Reservoir sometimes affects its recreation potential, a proportionately greater investment was made in recreation amenities at O'Neill Forebay. Operated by the California State Parks, the forebay offers camping, picnicking, sailing and power-boating, water-skiing, windsurfing, fishing, swimming, and bicycling. There are 2 boat launches, 45 pit toilets, and 7 Comfort Stations (equipped with toilets and sinks) around the shoreline.

Delta exports enter the forebay from the aqueduct via Check 12 and from the DMC via O'Neill Pumping-Generating Plant (Figure 8-2). From the forebay, water either flows down the aqueduct though O'Neill Outlet or is pumped into the San Luis Reservoir for release later in the year when demand is greater than Delta diversions. Releases can supply water to both the California Aqueduct and the DMC. From 1996 to 1999, 2.5 million to 4 million af were sent down the aqueduct while 1 million to 2 million af were pumped into San Luis Reservoir (Figure 8-3). A small amount (0.03 million to 0.14 million af) was released back into the DMC, mostly during the summer. Joint-use facilities minimize energy costs for pumping and delivering water on demand (DWR 1974).

Increased outflow from O'Neill Forebay to the California Aqueduct generally coincides with San Luis Reservoir releases during spring and summer. Water from the forebay is pumped into San Luis Reservoir largely during fall and winter when SWP demands are low and excess water can be stored. The combined operation of these facilities determines the quality of water in the forebay and what is ultimately sent down the aqueduct.

8.2.1.2 Description of Agencies Using SWP Water

There are no water service turnouts in O'Neill Forebay.

8.2.2 WATERSHED DESCRIPTION

Most of the watershed draining to O'Neill Forebay is native grassland (Figure 8-2). The watershed south of the forebay is gradually sloping rangeland with no discernable drainage channel. It is well vegetated and accepts runoff from a wide area beginning near Basalt Campground next to B.F. Sisk San Luis Dam. Most of the land north of the forebay is open grassland, designated as a wildlife area. The DFG owns and maintains the land outside the park boundary. Although no runoff data exist for this area, small eroded gullies were observed in the larger drainage pathways leading to the forebay. Because there is no distinct channel and no signs of erosion, flows of significance are unlikely. Regardless, any runoff draining this area would sheet flow across well-vegetated swales and natural depressions as it approaches the forebay.

Figure 8-3 O'Neill Forebay Inflow and Outflow, 1996 to 1999

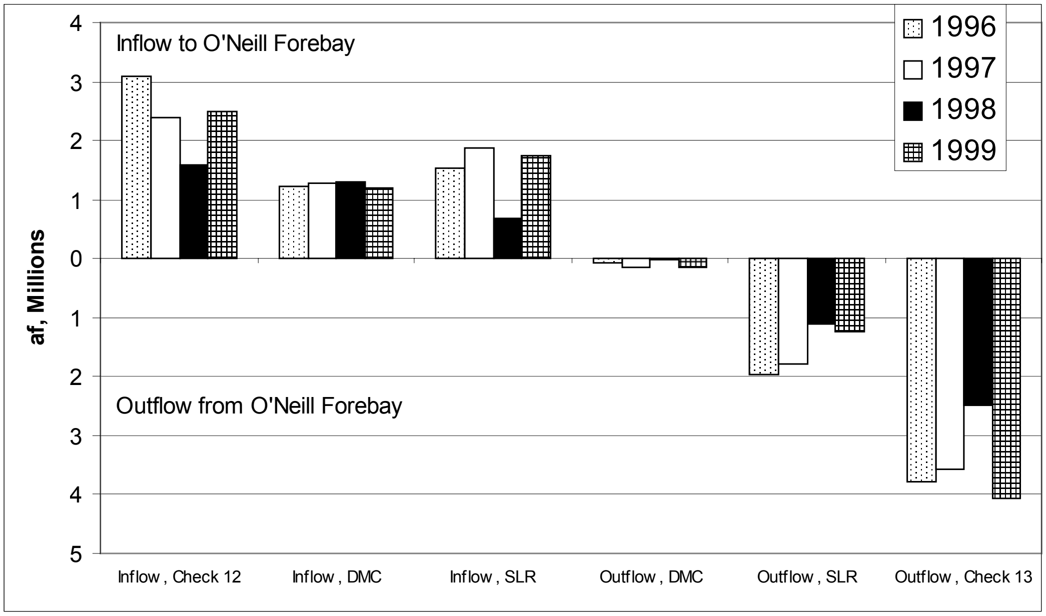
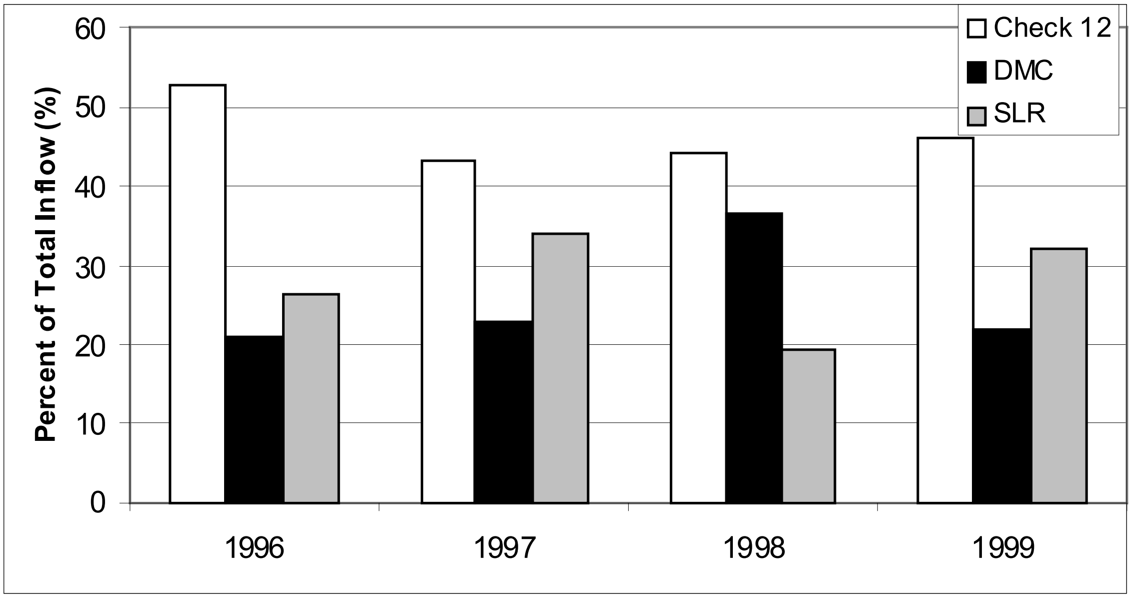


Figure 8-4 Percent of Total O'Neill Forebay Inflow from the California Aqueduct at Check 12, Delta Mendota Canal, and San Luis Reservoir, 1996 to 1999



Impervious land in the watershed is limited to roads, a few buildings, and DWR's San Luis Field Division operational facilities. Highway 33 runs along the east side of the forebay and crosses it just below the San Luis Reservoir (Figure 8-2).

8.2.3 POTENTIAL CONTAMINANT SOURCES

There are a number of PCSs to O'Neill Forebay including swimming, cattle grazing, and boating. However, inflows from the California Aqueduct, San Luis Reservoir, and DMC are arguably the largest influence on water quality in the forebay. The first 2 sources are discussed elsewhere in this report (Section 8.1, Clifton Court Forebay to O'Neill Forebay, and Chapter 6, respectively). Although not considered a PCS, the DMC is discussed here because it is a major source of inflow to the SWP, there are a number of PCSs on the DMC, and its inflows are not discussed anywhere else in this report. A discussion of the DMC is followed by individual PCSs in the forebay's watershed.

8.2.3.1 The Delta-Mendota Canal

Completed in 1951, the DMC carries water from the southern Delta along the western side of the San Joaquin Valley for irrigation supply, for use in the San Luis Complex, and to replace San Joaquin River water stored at Friant Dam and used in the Friant-Kern and Madera systems. The canal is about 117 miles long and terminates at Mendota Pool. O'Neill Pumping-Generating Plant can pump DMC water into O'Neill Forebay at mile 69.25 on the DMC.

From 1996 to 1999 the DMC accounted for 21% to 37% of the inflow to O'Neill Forebay or a little more than one-fourth of the total inflow during the 4-year period (Figure 8-4).

The aqueduct at Check 12 accounted for the majority of inflow to O'Neill Forebay with 43% to 53% followed by San Luis Reservoir releases with 19% to 34%.

A number of studies have concluded that DMC water has a different composition than State exports largely because of San Joaquin River influence. *Sanitary Survey 1990* stated that SWP diversions are composed of 70% Sacramento River water and 30% San Joaquin River water (Brown and Caldwell 1990). During wet years, a greater proportion comes from the San Joaquin. During critically dry years, the DMC diverts San Joaquin water almost exclusively while the aqueduct receives only Sacramento water. These descriptions had been obtained from discussions with DWR modeling staff. Various models can provide flow, stage height, and salinity estimates for a variety of stations around the Delta. Models have been used extensively to predict the effects of proposed Delta modifications on export salinity.

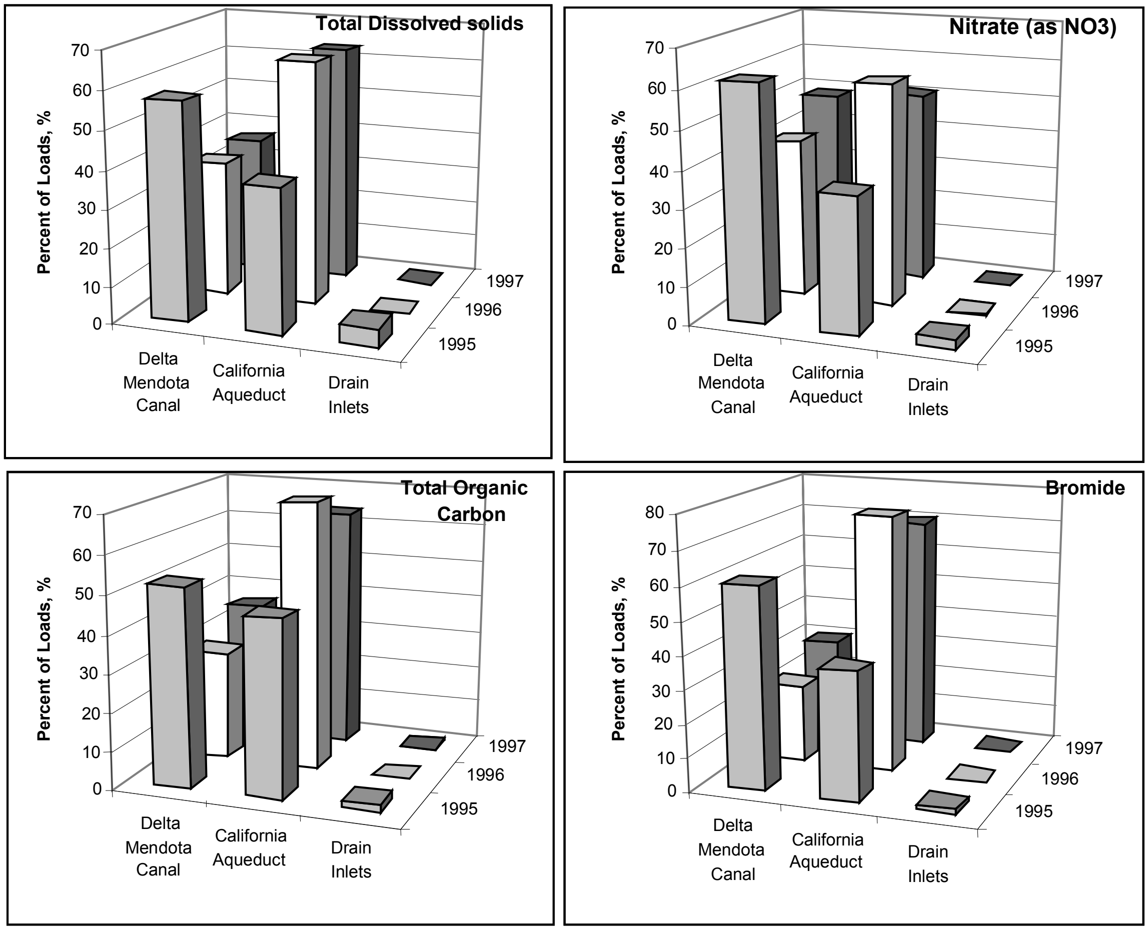
One particular modeling run estimated export composition for a critical water year (Orlob 1991). Salt contributions from the Sacramento and San

Joaquin rivers, tidal boundary (seawater intrusion), and in-Delta agriculture were estimated without south Delta barriers. The composition of federal exports in July of a critical year was 12% San Joaquin and 60% Sacramento. The rest was made up by seawater intrusion (17%) and in-Delta agriculture (11%). For State exports during the same month and water year type, the composition was 1% San Joaquin and 68% Sacramento followed by seawater intrusion and in-Delta Agriculture. Export composition was also estimated for May and Sepember of a critical year. For May, federal and State exports were 34/2% San Joaquin and 52/73% Sacramento. For September, federal and State exports were 30/1% San Joaquin and 52/73% Sacramento. Seawater intrusion and in-Delta agriculture made up the rest. These modeling runs confirm the preceding general description that State exports contain very little San Joaquin water (1% to 2%) in a critical water year.

The difference in river proportion between State and federal exports should also result in differences in their water quality. Based on this information, DMC inflow to O'Neill Forebay is not expected to have the same water quality as that from the aqueduct. No study has definitively quantified the difference in water quality between these 2 sources. Regardless of any possible concentration differences, the relative influence of these sources on the overall contribution of constituents to O'Neill Forebay can be assessed by loads, that is, the combination of concentration and inflow volume.

An unpublished loading study by O&M shows that salt and carbon loads from the DMC to O'Neill Forebay can surpass those from the California Aqueduct. Annual loads to O'Neill Forebay were calculated for TDS, nitrate, total organic carbon (TOC), and bromide for the years 1995 through 1997. Floodwater inflows were included for comparison. In all 3 years, floodwater inflows were minor in proportion to loads from the DMC and California Aqueduct (Figure 8-5).

Figure 8-5 Relative Loads of TDS, Nitrate, Bromide, and TOC to O'Neill Forebay and the San Luis Canal, 1995 to 1997



The DMC contributed 23% to 36% of the TDS, TOC, and bromide loads during 1996 and 1997 and from 52% to 60% of these loads during 1995 (Figure 8-5). The California Aqueduct accounted for 63% to 77% of the TDS, TOC, and bromide loads during 1996 to 1997 and from 38% to 46% of the 1995 loads. Therefore, DMC loads to O'Neill Forebay were higher than that from the aqueduct during 1995. That year the DMC contributed 47% of the total forebay inflow followed by the aqueduct with 33%. Therefore, the DMC is a significant source of a variety of water quality constituents, and in 1995, it was the largest source.

Similar to the aqueduct, there are several structures that cross over the DMC such as gas and power lines, bridges, turnouts, and safety float lines (Table 8-5). It should be noted that these structures are between the start of the intake canal, north of Tracy Pumping Plant, to mile 69.25 where the DMC reaches O'Neill Forebay. There are 76 bridges in this section of DMC including county roads, 2 Interstate 5 crossings, and timber structures used by farmers. Numerous pipelines were identified as petroleum or irrigation; there were also a number of unidentified pipelines. The significance of these as PCSs is similar to those on the aqueduct as discussed in *Sanitary Survey 1990*. However, unlike most of the aqueduct, the DMC was built with numerous drain inlets that accept drainage from adjacent upstream land.

Table 8-5 Structures that Cross Over the DMC, Mile Zero to 69.25

Structure	Number
Road Bridges	76
Railroad Bridges	2
Oil Pipelines	11
Irrigation Pipelines	12
Gasoline Pipelines	2
Small Drain inlets (6 to 30 inch)	187
Large Drain Inlets (>30 inch to 5.0 x 2.6 ft)	77
"Weed Oil Tank"	1

Source: USBR 1996; DMC Structures List.

There are 187 small drain inlets within the first 69 miles of the DMC. Some of these were identified as "shoulder drain inlets" and are probably similar to toe drains on the aqueduct handling runoff from adjacent operating roads. The larger drain inlets handle an unknown amount of runoff from the west side of the DMC. The land upstream from the DMC is mostly farmland, similar to what is present west of the SLC—row crops and orchards. Drainage from these lands is expected to be greatest during rainfall runoff events. Runoff from over-irrigation of adjacent lands is also possible during the summer. Large inflows from major watersheds are routed either over or under the DMC in structures similar to those on the aqueduct. Based on this information, the DMC is considered a moderate threat to water quality.

8.2.3.2 Recreation

Because the drawdown of San Luis Reservoir sometimes affects its recreation potential, a proportionately greater investment was made toward recreation amenities at O'Neill Forebay. Operated by the California State Parks, they include camping, picnicking, sailing and power-boating, water-skiing, windsurfing, fishing, swimming, and bicycling. Coliform bacteria data are collected at the swimming beaches and discussed under 8.2.4, Water Quality Summary.

The north side of the forebay is equipped with 2 designated swimming beaches (Figure 8-6). The northern and southern swimming beaches have 6 Comfort Stations with flush toilets and sinks, 2 shower facilities, and a fish-cleaning trough. All are equipped with running water. Wastewater flows to an underground holding vault, then it is pumped into 2 ponds, each 60 feet by 80 feet, for percolation and evaporation. The ponds are less than a mile from the shoreline. The wastewater vault has an alarm system for overflow prevention. The vault can be manually evacuated if the primary pump system goes down. There have been no reports of wastewater spills or leaks.

Figure 8-6 Recreation and Sanitary Facilities in the O'Neill Forebay Watershed

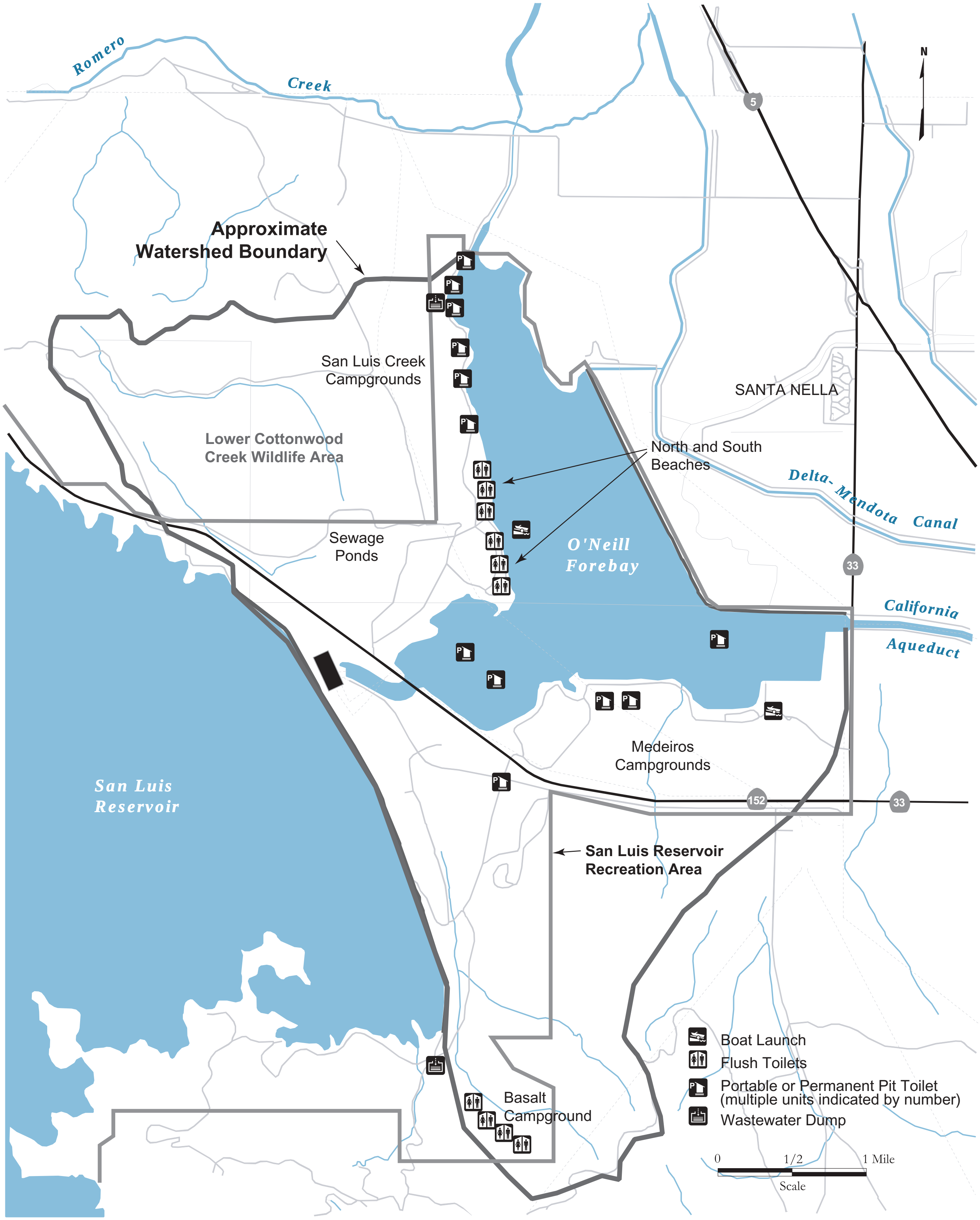


Table 8-6 Visitor Attendance and Use of the San Luis Reservoir Recreation Area, 1995 to 1999

Fiscal Year	Free Day Use	Paid Day Use	Camping Attendance	Total Attendance	Boat Launching
1995/96	80,000	389,000	57,000	526,000	18,000
1996/97	72,000	404,000	49,000	525,000	14,000
1997/98	46,000	289,000	35,000	370,000	11,000
1998/99	54,000	390,000	29,000	473,000	11,000

Source: California State Parks

The north shore campgrounds are equipped with running water and electricity. Nearby is a motor home dump station. Waste from this dump station is dissipated via underground leach lines. Concentrated near the north shore swimming beaches are more than 100 picnic tables (some with barbecue pits). There are also permanent and portable pit toilets that are pumped out when needed.

The forebay's southern shoreline is available for day use or camping. There are about 30 pit toilets (most of them portable) and a limited number of picnic tables on the south shore. Camping is allowed anywhere between the road and shoreline.

Within the forebay's watershed is the Basalt Campground. There are a number of Comfort Stations with flush toilets, sinks, and 1 dump station. Wastewater is conveyed to an underground vault and pumped south, over a hill, and into another watershed to evaporation/percolation ponds. The system is similar to that described above for the swimming beaches.

Visitor attendance records are not kept for O'Neill Forebay alone, but for the entire San Luis Reservoir Recreation Area (San Luis Reservoir, O'Neill Forebay, and Los Banos Reservoir). These are shown in Table 8-6.

Although these numbers are combined from all 3 reservoirs, a study published in 1989 provided use numbers for each water body (DWR 1989). From 1973 to 1987, O'Neill Forebay made up 38% to 66% of all visitors attending the entire recreation area with an average of 50%. Therefore, to get a rough estimate of the forebay's specific use numbers, halve the attendance numbers in Table 8-6. San Luis Reservoir provided about 29% to 48% of the total visitor use (average = 42%).

In 2000, the California State Parks lowered all use fees, possibly affecting future attendance numbers. North shore campground fees were reduced from $15/vehicle/night to $12; south shore camping fees, from $10/vehicle/night to $7; day use fees, from $5/vehicle to $2; and boat launching fees, from $5 to free. The lower costs may result in higher use numbers in the future.

8.2.3.3 Urban Runoff

There are no urban areas in the upstream watershed. Impervious land in the watershed is limited to roads, a few buildings, and the operational facilities of DWR, California State Parks, and California Department of Forestry and Fire Protection.

8.2.3.4 Agricultural Activities

There are no agricultural activities within the watershed of O'Neill Forebay.

8.2.3.5 Animal Populations

Livestock Grazing

Cattle grazing is the primary use of the forebay's southern watershed (within the park boundaries north of Highway 152). The California State Parks leases the land to a rancher for grazing between November and May. The entire grazing area is sectioned off into individual paddocks. Cattle are moved between these pens on a weekly basis to prevent overgrazing. An electric fence separates cattle from the forebay's shoreline. *Sanitary Survey 1990* stated that about 1,000 head of sheep also use the forebay's watershed for grazing about 6 months of the year (Brown and Caldwell 1990).

Wildlife

On the north shore of the forebay, the watershed outside of the park boundary is a wildlife area owned by the DFG. Mostly devoid of trees and brush, the most numerous mammals would be limited to rabbits and rodents. Trees and brush are abundant along the forebay's shoreline, providing cover for a small herd of deer. Other mammals include raccoons, opossums, skunks, foxes, coyotes, and feral cats.

8.2.3.6 Accidents/Spills

Transportation Corridors

State Highways 33 and 152 cross portions of O'Neill Forebay. Highway 133 is on the east side of the forebay and crosses it just below the San Luis Reservoir. There were no reported vehicle incidents during 1996 to 1999. The significance of transportation corridors as a PCS was addressed in *Sanitary Survey 1990*.

8.2.3.7 Fires

In 2000 a fire swept through the wildlife area on the north end of the forebay. Although there was no sign of heavy erosion, some of the larger drainage channels showed signs of a small amount of erosion. This is considered a minor threat to water quality.

8.2.4 WATER QUALITY SUMMARY

Water quality in the DMC at its connection with O'Neill Forebay is discussed below. Routine water quality samples are not collected in O'Neill Forebay. The closest water quality station is the forebay's outlet, and its data are discussed in the SLC section, Section 8.3. Routine coliform sampling in O'Neill Forebay was initiated in 1996 and is presented below after the DMC water quality analysis.

8.2.4.1 The Delta-Mendota Canal

DWR collects water quality samples in the DMC on a monthly basis just upstream the connection with O'Neill Forebay. All data were below primary and secondary MCLs.

TOC ranged from 2.3 to 6.5 mg/L (Table 8-7). The high concentration was detected in January 1998 when the DMC dominated inflows to O'Neill Forebay (Figure 8-7). Inflows from the aqueduct were limited from 14 January to 27 February of that year because of a shutdown at Banks Pumping Plant. Inflow down the aqueduct was mostly from the DMC and San Luis Reservoir releases. This was reflected in the water quality at O'Neill Outlet higher than normal TOC during January and February 1998 (DWR 2000).

Table 8-7 Delta Mendota Canal, Jan 1996 to Dec 1999[a]

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10 – 90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	18.9	18.0	8.5	34.0	11.8 – 26.4	1.0	45/45
Chloride	47	39	13	122	19 – 77	1	49/49
Suspended Solids	60	61	22	98	–[b]	1	3/3
Total Dissolved Solids	216	189	77	435	119 – 322	1	49/49
Hardness (as $CaCO_3$)	89	85	36	175	54 – 121	1	49/49
Alkalinity (as $CaCO_3$)	66	66	32	111	46 – 85	1	49/49
Conductivity	381	358	145	761	206 – 564	1	49/49
Magnesium	10.0	10.0	3.5	20.0	5.8 – 14.2	1.0	49/49
Sulfate	40	38	14	94	18 – 66	1	49/49
Turbidity (NTU)	20	16	3	68	16 – 24	1	40/40
Minor Elements							
Aluminum	0.02	0.01	<0.01	0.04	0.01 – 0.03	0.01	4/48
Arsenic	0.002	0.002	<0.001	0.003	0.001 – 0.002	0.001	45/48
Barium	0.05	0.05	<0.05	0.06	0.05 – 0.06	0.05	4/48
Boron	0.2	0.2	<0.1	0.4	0.1 – 0.3	0.1	43/49
Chromium	0.006	0.006	<0.005	0.006	–	0.005	3/48
Copper	0.002	0.002	<0.001	0.003	0.002 – 0.003	0.001	27/48
Iron	0.021	0.016	<0.005	0.076	0.006 – 0.039	0.005	28/48
Manganese	0.022	0.012	<0.005	0.081	0.007 – 0.052	0.005	15/48
Selenium	0.001	0.001	<0.001	0.001	0.001 – 0.001	0.001	10/47
Zinc	0.016	–	<0.016	0.016	–	0.005	1/48
Nutrients							
Total Kjeldahl Nitrogen(as N)	N/A[c]	N/A	N/A	N/A	N/A	0.1	N/A
Nitrate (as NO_3^-)	3.9	3.5	1.7	8.3	2.1 – 6.0	0.1	48/48
Ammonia (dissolved)	N/A	N/A	N/A	N/A	N/A	0.01	N/A
Nitrate+Nitrite (as N)	N/A	N/A	N/A	N/A	N/A	0.01	N/A
Total Phosphorus	N/A	N/A	N/A	N/A	N/A	0.01	N/A
Orthophosphate	N/A	N/A	N/A	N/A	N/A	0.01	N/A
Misc.							
Total carbon	3.52	3.20	2.3	6.5	2.58 – 4.88	0.1	45/45
Bromide	0.15	0.12	0.04	0.42	0.05 – 0.25	0.01	49/49
pH	7.5	7.4	6.9	8.8	7.0 – 8.0	0.1	49/49
UVA (cm^{-1})	0.077	–	0.072	0.081	–	0.001	2/2

[a] Data retrieved from DWR Division of Opersations and Maintenance's database, and were from 16 Jan 1996 to 15 Dec 1999.
[b] Computation of this statistic not needed due to a small sample size.
[c] Data not available.

Figure 8-7 Water Quality Summary for DMC, 1996 to 1999

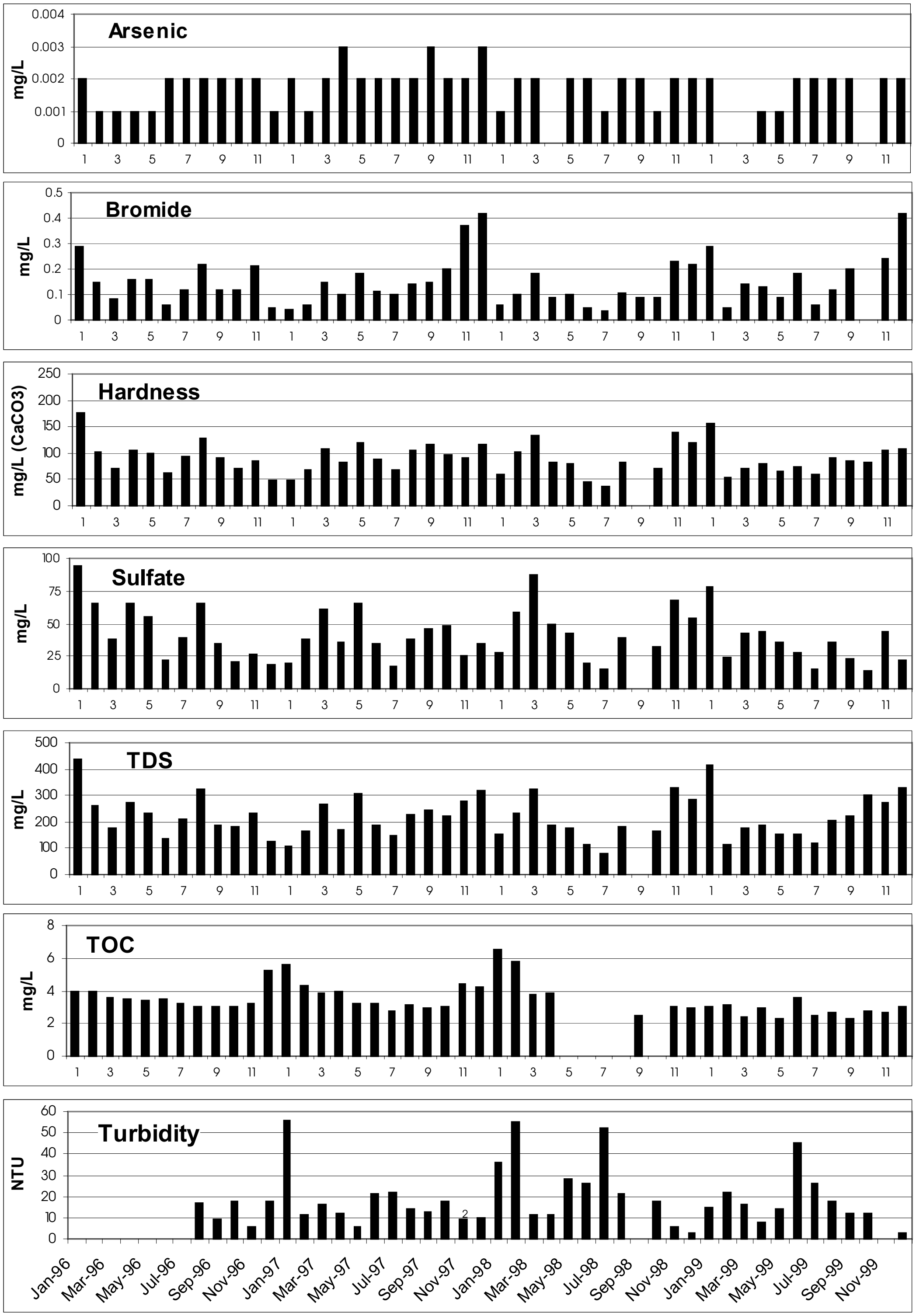
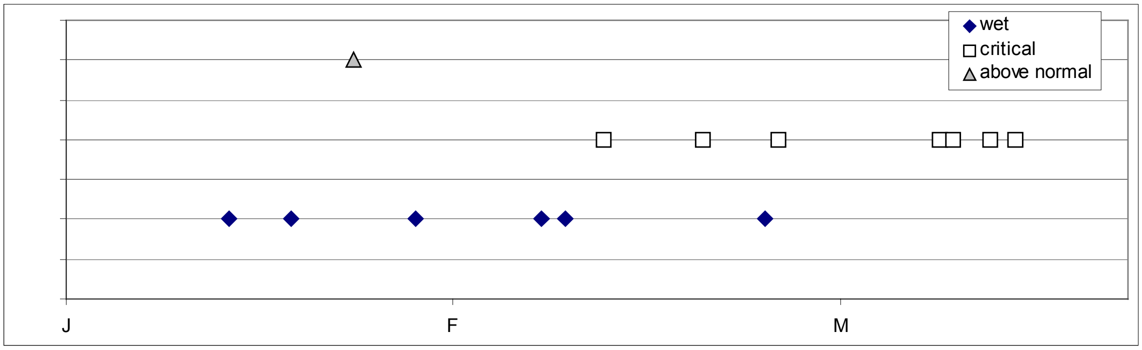


Figure 8-8 Onset of the 1st Peak Outflow from Mud and Salt Sloughs from Jan to Mar, 1985 to 1999 J=January, F=February, M=March



Bromide in the DMC ranged from 0.04 to 0.42 mg/L during 1996 to 1999 and was highest during the last few months of 1997 and 1999 (Figure 8-7). These trends were not unlike those in the aqueduct at Banks Pumping Plant. On the other hand, TDS in the DMC ranged from 77 to 435 mg/L and was sometimes more than 100 mg/L higher than levels measured at Banks Pumping Plant during the same month.

TDS exceeded 400 mg/L in January of 1996 and 1999 (Figure 8-7). These levels were much higher than those in the aqueduct at Banks Pumping Plant during the same months (160 and 270 mg/L, respectively). The higher TDS levels in DMC exports may relate to the effect of the San Joaquin River. As previously discussed, DMC exports may contain a greater proportion of San Joaquin River water than SWP exports. Although winter flows would typically have lower TDS because of rainfall runoff, winter in the San Joaquin Valley also coincides with the pre-irrigation season.

Each winter, pre-irrigation of west-side San Joaquin Valley farmland may be necessary, in part, to remove salts and prepare for spring planting (DWR 1974a). Water is applied to farmland prior to planting to remove salts accumulated in the soil during the previous growing season. The salt-laden water is conveyed to Salt and Mud sloughs and, eventually, the San Joaquin River via underground tile drains. Pre-irrigation occurs during winter so that the salty discharges can be diluted by the higher San Joaquin River flows (DWR 1960). This method of dilution remains 1 of the recommended strategies for meeting downstream water quality objectives year-round (SWRCB 1995). The onset of winter drainage varies with water year. During wet years, peak outflow from pre-irrigation occurs earlier in the season. Figure 8-8 shows the 1st peak outflow from Mud and Salt sloughs occurred largely during January or February of a wet year. During critical water years, peak outflow occurred later in the season, during February and March. There was 1 above-normal year during the period of record (1985 to 1999), and its 1st peak outflow occurred in late January. Exports could be influenced by this drainage earlier in the season during wet years than drier years. Arsenic in the DMC rarely exceeded 0.002 mg/L, and no seasonal trends were apparent.

Table 8-8 Total and Fecal Coliforms in O'Neill Forebay, 1996-1998

Year	Date	Station	Total Coliform[a]	Escherichia Coliform[b]
1996	2 Apr	North Beach	Positive	Positive
		South Beach	Positive	Positive
	16 Apr	North Beach	Positive	Positive
		South Beach	Positive	Positive
	22 May	North Beach	Positive	Positive
		South Beach	Positive	Negative
	4 Jun	North Beach	Positive	Positive
		South Beach	Positive	Positive
	18 Jun	North Beach	Positive	Positive
		South Beach	Positive	Negative
	9 Jul	North Beach	Positive	Positive
		South Beach	Positive	Negative
	23 Jul	North Beach	Positive	Positive
		South Beach	Positive	Negative
	14 Aug	North Beach	Positive	Positive
		South Beach	Positive	Negative
	27 Aug	North Beach	Positive	Positive
		South Beach	Positive	Negative
	10 Sep	North Beach	Positive	Negative
		South Beach	Positive	Positive
	24 Sep	North Beach	Positive	Negative
		South Beach	Positive	Negative
1997	24 Apr	North Beach	Positive	Positive
		South Beach	Positive	Positive
	28 May	North Beach	Positive	Positive
		South Beach	Positive	Negative
	11 Jun	North Beach	Positive	Positive
		South Beach	Positive	Positive
	1 Jul	North Beach	Positive	Negative
		South Beach	Positive	Negative
	22 Jul	North Beach	Positive	Negative
		South Beach	Positive	Negative
	19 Aug	North Beach	Positive	Negative
		South Beach	Positive	Negative
1998	27 Apr	North Beach	Positive	Positive

[a] Colilert® [b] Ultraviolet Light

8.2.4.2 O'Neill Forebay

From 1996 to 1998, coliform samples were routinely collected from the north and south swimming beaches in O'Neill Forebay. Coliform and *E. coli* were only recorded as present or absent; no quantifications were made. Field staff initiated the study to obtain background data on the effects of swimming.

Total coliforms were present in all samples (Table 8-8). Fecal coliform (or *E. coli*) was present in 13 of 17 samples collected from the north beach and in 6 of 17 samples from the south beach. The samples were collected during the workweek whenever it was convenient for field staff. High-use periods during the weekend and holidays were not monitored. Field staff recalled that most samples were collected when there was little or no swimming activity. This data would then represent coliform levels outside the periods of high use

8.2.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Of all the PCSs listed in Section 8.2.3, none would likely be large enough to overshadow the effects of State and federal inflows. Inflows from the DMC, California Aqueduct, and San Luis Reservoir largely control water quality in O'Neill Forebay.

One of the primary sources of potential contamination is boating. Boating is 1 of the main forms of recreation on the forebay and is a source of hydrocarbons and MTBE. However, samples collected at the outlet from 1996 to 1999 contained no volatile organics and, on 1 occasion, only 0.5 mg/L of MTBE. Organic samples were collected at the forebay's outlet in March, June, and September of each year from 1996 to 1999. It is possible that the large inflow volumes to the forebay quickly dilute any MTBE released by boating activity.

Animal populations may also contribute nutrients and pathogens and are considered a moderate threat to water quality. Although runoff from adjacent rangeland could enter the forebay during rainfall events, the amount is minimal because of the lack of any major drainage channel. Further, the rangeland is nearly flat, and runoff would sheet flow across well-vegetated land that has many depressions and swales. These features would provide a filtering effect that would tend to reduce the off-site movement of particulates and pathogens.

The park's wastewater facilities have adequate capacity to treat the waste load from visitors. They are also equipped with alarms and backup pumps in case the primary pumps break down. The sewage treatment ponds are distant from the forebay and do not pose a threat.

The 45 portable and permanent pit toilets surrounding the forebay pose a potential source of fecal contamination, although if any toilet is tipped over, the waste material would be contained on land. They are placed along the shoreline at close intervals, making them easily accessible. A contract firm routinely checks and empties them as needed. The toilets may be preventing contamination from human activities.

8.2.6 WATERSHED MANAGEMENT PRACTICES

Commingling of DMC and SWP waters in O'Neill Forebay has a large effect on water quality in the California Aqueduct. Joint-use facilities are operated to minimize energy costs for pumping and to deliver water on demand (DWR 1974), although Metropolitan Water District of Southern California (MWDSC) has recently requested that O&M use San Luis Reservoir releases to dilute high levels of Delta-imported TOC in the aqueduct.

8.3 OUTLET OF O'NEILL FOREBAY TO CHECK 21 (KETTLEMAN CITY): SAN LUIS CANAL

8.3.1 WATER SUPPLY SYSTEM

The San Luis Canal (SLC) is the part of the California Aqueduct that extends from O'Neill Forebay outlet at mile 70.89 (Check 13) to the end of San Luis Field Division at mile 172.40 (Check 21), a distance of about 101 miles (Figure 8-9). The SLC delivers water to both municipal and agricultural contractors. The United States Bureau of Reclamation (USBR) designed, funded, and constructed the SLC to provide water for agriculture, not to protect drinking water. This is significant because the agency did not extensively incorporate drainage conveyances across the aqueduct such as overchutes or culverts that intersect runoff, channeling it across the SLC. Instead, the SLC was built with drain inlets to convey floodwater directly into the aqueduct. The cost of adding drainage conveyances was considered too expensive and any runoff was additional supply. Although there was a good deal of debate between the State and USBR at the time, the federal bureau prevailed. The debate took place in the 1960s, well before drinking water issues were at the forefront.

Figure 8-9 California Aqueduct: The San Luis Canal

Table 8-9 Inflow Structures on the SLC (Drain inlets or other)[a]

Structure	Number
Toe drains for canal operating road and/or canal right of way	352
Drain inlets (DIs) for canal right of way and upslope rangeland	17
DIs for canal right of way and upslope cropland[b]	37
DIs for canal right of way and public roads or highways	1
DIs for off-site facilities such as water district pump stations	2
Little Panoche Creek	1
Cantua Creek	2
Salt Creek	1
Arroyo Pasajero	4
Pump pads for portable storm water runoff pumping	35

[a] From a DWR memorandum from D. Buchan to D. Kurosaka, "Drainage into the California Aqueduct." 1992.

[b] Eighteen of these inlets are gated; 1 can receive stop-logs. The inlets are closed during the irrigation season and opened during the rainy season. Those inlets without controls are said to be elevated above grade so that a certain amount of ponding is required before runoff is taken into the canal.

The San Luis Field Division's Joint-Use Facilities, which includes the SLC, are the integrated works of the USBR's Central Valley Project (CVP) and the SWP. The CVP provides water to an agricultural service area of more than 500,000 acres along the west side of the San Joaquin Valley. The service was intended to reduce the need to pump from deep aquifers, which was causing groundwater overdraft and regional land subsidence. The State's portion of conveyed water continues south past Check 21 in the California Aqueduct. Maintenance and operation of the SLC is the responsibility of the State with a cost sharing percentage of approximately 55% State and 45% federal.

8.3.1.1 Description of Aqueduct and SWP Facilities

The major facilities that make up the SLC include Dos Amigos Pumping Plant (mile 86.73) and 2 sections of canal. The 2 sections include a 16-mile section from O'Neill Forebay to the Dos Amigos Pumping Plant and an 85-mile section from Dos Amigos to the southern end of the canal at Check 21.

There are more than 60 drain inlets in the SLC that accept floodwater from the Diablo Range (Table 8-9).

The largest of these are Arroyo Pasajero and Little Panoche, Salt, and Cantua creeks. Runoff from adjacent operating roads and canal right of way is also conveyed into the SLC by 352 toe drains. There are 35 pump pads on the SLC. Pump pads are parkways designed to allow portable pumps to pump floodwater into the SLC without impeding traffic on the canal's operating road. The physical and water quality characteristics of drain inlets are discussed later in this chapter.

Numerous structures on the SLC are not related to conveying floodwater into the aqueduct, including bridges, pipeline crossings, and water service turnouts (Table 8-10).

Table 8-10 Nondrain Inlet Structures on the San Luis Canal [a]

Structure	Number
Bridges	47
State	5
County	39
Farm or private	3
Overcrossings	53
Pipelines	53
Overchutes	0
Undercrossings	73
Evacuation culverts	3
Irrigation or domestic water	70
Siphon (Panoche Creek)	1
Water service turnouts	128
Irrigation pumped upslope[b]	106
Other	22
Fishing areas[c]	14
Submersible pumps for relieving canal seepage and/or groundwater pressure against the lining.	45
Submersible pumps for intercepting seepage downslope from the canal	1
Vertical pumps for intercepting seepage from a slope stability trench	2

[a] From Brown and Caldwell 1990

[b] From DWR 1994, *Analysis of water quality impacts from ground water pump-in on the State Water Project, 1990-92.* Feb.

[c] Ten of these sites have toilets, generally portable chemical type. The rest have no sanitary facilities.

Four structures on the SLC were built to keep Diablo Range floodwater out of the aqueduct. These include 3 drainage undercrossings, or evacuation culverts, and a siphon at Panoche Creek (their exact locations are discussed later). The siphon is a large 4-barreled conveyance structure that allows Panoche Creek to flow naturally over the SLC, preventing any commingling of water. The original design to exclude Panoche Creek was due, in part, to a number of hard rock and mercury mines in the upstream watershed. There are no overchutes on the SLC.

Groundwater can be pumped into the SLC from 106 agricultural water service turnouts (Table 8-10). Pump-ins from these sources have been allowed in the past because of drought conditions. Pump-ins occurred from 1990 to 1996, assisting State and federal water contractors during periods of entitlement deficiency caused, in part, by the 1987 to 1992 drought. Groundwater can also be pumped into the SLC via DWR sump pumps, automated groundwater pumps that relieve pressure on the upslope, or western side, of the canal liner (Table 8-10). These waters are discussed further in Section 8.3.3, Potential Contaminant Sources.

8.3.1.2 Description of Agencies Using SWP Water

There are no SWP contractors taking water from the SLC; only federal CVP contractors. Most of the water diverted out of the SLC is used for agricultural purposes. The 2 largest diverters are the water districts of San Luis and Westlands. A small amount of domestic water is taken by the cities of Coalinga, Huron, and Avenal. Their turnouts are located at miles 143.16, 156.34, and 164.79, respectively.

Previous sanitary surveys identified many PCSs to the SLC. These included bridges, overcrossings, water service turnouts, fishing, and accidental spills. However, the largest PCS to the SLC is floodwater inflows. Following is a general description of all floodwater inflows. Specific PCSs within each watershed are listed after this description.

8.3.2 WATERSHED DESCRIPTION

Floodwater inflows to the SLC originate as rainfall runoff from the eastern flank of the Diablo Range. The Diablo Range extends from San Francisco Bay to Polomo Creek, south of Kettleman City (Davis 1961). The topography varies from mildly sloped foothills to rugged and steeply sloped mountains making up the headwaters. The geology of the Diablo Range is dominated by marine sandstone containing continental and ancient ocean deposits (Davis and others 1959). The SLC is situated on mildly sloped foothills and, to some extent, alluvial deposits originating from historical erosion and mass wasting. A more detailed description of Diablo Range geology as it pertains to water quality is presented in the Section 8.3.3.14, Geologic Hazards.

Twenty-three semidistinct watersheds drain toward the SLC and range in size from 7 square miles to more than 500 square miles, the largest being the Arroyo Pasajero at 539 square miles and Panoche Creek at 302 square miles (Figure 8-10 and Table 8-11). They are semidistinct because many of the streambeds intersect as they approach the aqueduct. Streams can often commingle on the flatter portions of land before ponding against the aqueduct. One example of this is Salt Creek and the Jordan Group. The 2 drain inlets are about 2 miles apart on the aqueduct, but their mineralogical makeup is oftentimes identical, indicating commingling (DWR 2000).

Figure 8-10 General Schematic of the San Luis Canal with Drain Inlet Numbers

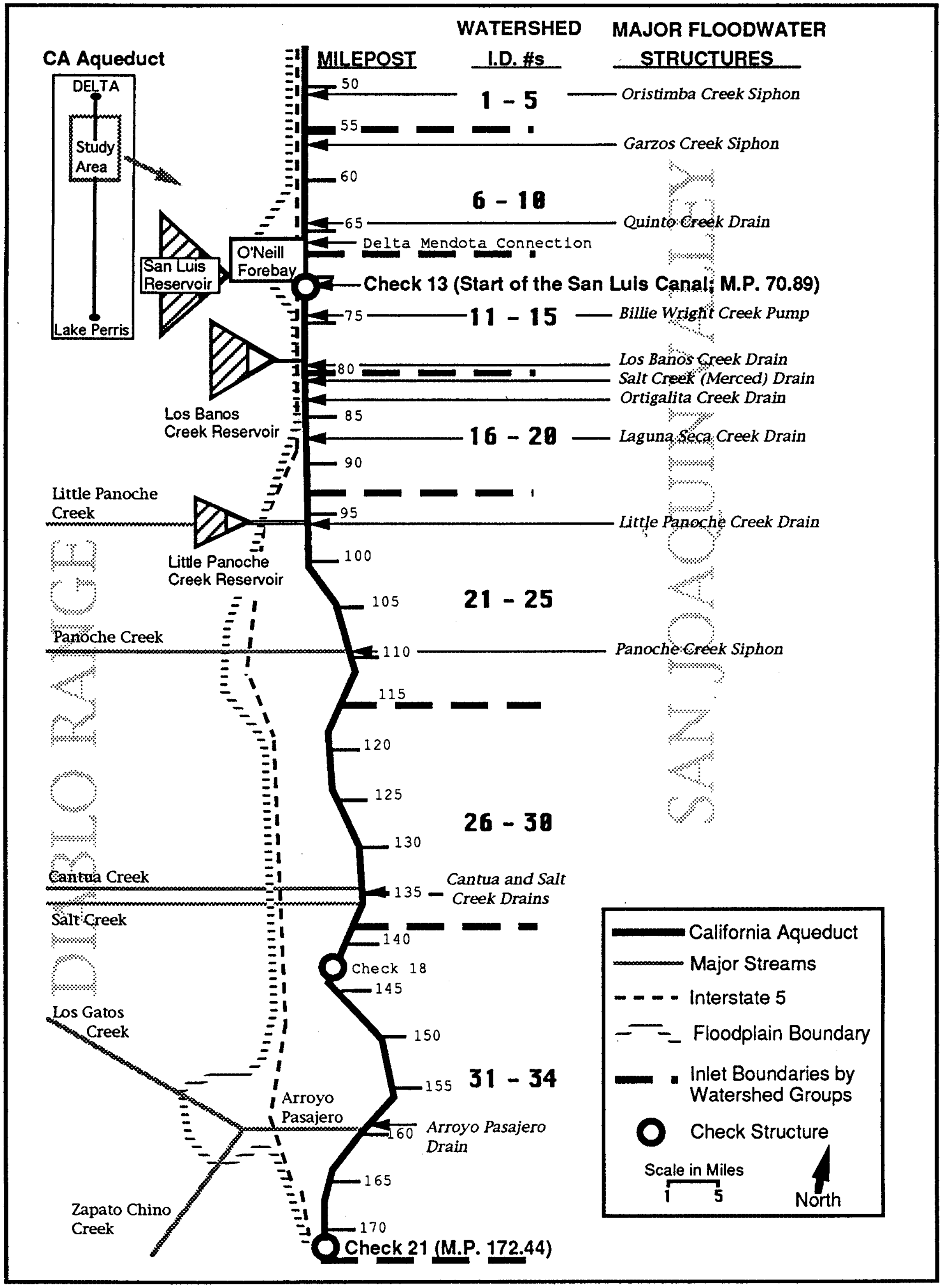


Table 8-11 Watersheds West of the San Luis Canal

	Watershed[a]			
ID # [b]	Milepost Range	Name	Square Miles	Major Drainages and Their Tributaries
11	70.60 – 74.10	O'Neill Forebay drng, S.		
12	74.10 – 74.80	Billie Wright drainage	25c	Billie Wright Creek
13	74.80 – 78.36	Volta Group		
14	78.36 – 79.50	Los Banos Creek	157	Los Banos Creek: Los Banos Reservoir: N. & S. Forks Los Banos Crk., Wildcat Crk.
15	79.50 – 82.00	Salt Creek Grp (Merced Co.)	22	Salt Creek
16	82.00 – 84.40	Ortigalita Creek Group	57	Ortigalita Creek: Piedra Azul Creek
17	84.40 – 87.78	Dos Amigos	14	
18	87.78 – 89.55	Laguna Seca Creek	11	
19	89.55 – 93.70	Etoheverry Group	7	Laguna Seca Creek
20	93.70 – 95.40	Wildcat Canyon	20	Wildcat Canyon
21	95.40 – 96.78	Little Panoche Creek	101	Little Panoche Creek: Little Panoche Reservoir: Vasquez Crk., Mercey Crk., Mine Crk.
22	96.78 – 108.50	Panoche Hills Group	75	Capita Canyon. Moreno Gulch
23	108.50 – 110.85	Panoche Creek	302	Panoche Creek (Siphon): Las Aquilas Crk., Bitterwater Canyon, Clough Canyon,
24	110.85 – 113.82	Tumey Hills Group	29	Tumey Gulch
25	113.82 – 119.50	Monocline Ridge Group	50	
26	119.50 – 127.90	Arroyo Ciervo Group	8	Arroyo Ciervo
27	127.90 – 131.55	Arroyo Hondo Group	26	Arroyo Hondo
28	131.55 – 134.88	Cantua Creek Group	48	Cantua Creek: Arroyo Leona
29	134.88 – 138.24	Salt Creek Grp (Fresno Co.)	25	Salt Creek: Martinez Creek
30	138.24 – 141.90	Jordan Group	11	Domengine Creek
31	141.90 – 144.70	Ford Group	20	
32	144.70 – 154.11	Skunk Hollow	12	
33	154.11 – 163.95	Arroyo Pasajero	539	Arroyo Pasajero: Los Gatos Creek: Bear Canyon, White Crk., Mud Run, Nunez Canyon, Salt Canyon, Warthen Crk., Jacolitos Crk. Zapato Chino Creek: Cedar Canyon, Garcia Canyon, Canoas Crk.
34	163.95 – 172.44	Kettleman Hills Group		Arroyo Largo: Arroyo Torcido

[a] Refer to Figure 8-10 for areal location.
[b] ID # = Identification number assigned to the watershed.
[c] Combined area from O'Neill Forebay drainage (South), Billie Wright drainage, and the Volta Group.

Most streams draining toward the SLC can be classified as either ephemeral streams in interfan areas or larger intermittent streams that have created the major alluvial fans (Bull 1964). Intermittent streams such as Panoche and Los Gatos creeks receive groundwater flow along their entire length for weeks or months after the rainy season. Ephemeral streams drain the smaller gullies and usually flow only as a result of high precipitation.

Land use in the hilly or mountainous portions of the Diablo Range is predominantly unconfined animal rangeland and wilderness. Agriculture dominates land use on the floodplain or less hilly portions. Cotton made up the single largest land use in this area with 30%, followed by tomatoes (15%), fallow and idle (14%), and other truck crops such as lettuce and melons (14%). Most orchards were either almond or pistachio and accounted for almost 7% of all agriculture. Note that these numbers are for land use within the boundaries of the agricultural use area, and do not include the hilly or mountainous areas. More information on crop designations is presented in section 8.3.3.7, Agricultural Activities, under Potential Contaminant Sources.

Less than 3% of the land within the agricultural use area is classified as urban. The largest cities west of the SLC are Coalinga and Huron; both are in the Arroyo Pasajero watershed.

8.3.3 POTENTIAL CONTAMINANT SOURCES

8.3.3.1 Floodwater Inflows

The SLC was built with drain inlets to convey west-side floodwater into the aqueduct. There are more than 60 of these drains ranging in size from 6-inch pipes to a new 550-foot concrete flume near Salt Creek. The majority are 24-inch to 48-inch pipes (Table 8-12). Smaller pipes draining adjacent service roads (called toe drains) were not included in this estimate.There are also 34 established pump pads to handle floodwater that ponds against the aqueduct levee. Pump pads are used in conjunction with portable pumps between Little Panoche Creek and Arroyo Pasajero, where ponding against the levee is common. With the exception of Salt and Cantua creeks, this section is not extensively equipped with drain inlets. Farmers pump water that ponds against the levee in preparation for planting. Water is also pumped to protect the levee from erosion-causing wind fetch. Portable pumps can, in fact, be used anywhere along the aqueduct. Pumps on wheels are equipped with long hoses to access the ponded water. Both DWR and private landowners own and use portable pumps, although landowners do most of the pumping.

Table 8-12 Floodwater Structures on the San Luis Canal[a]

Watershed			Drain Inlets			Bypasses		Pumps [e]		
ID # [b]	Milepost Range	Name	No. [c]	Opening size (ft^2)	% of total. [d]	No. [c]	Size (ft^2)	Sump	Pad	Perm
11	70.60 - 74.10	O'Neill Forebay drng, S.	6	32	(10)	1	30	0	0	4
12	74.10 - 74.80	Billie Wright drainage	0	0	(10)	1	30	0	0	1
13	74.80 - 78.36	Volta Group	8	57	(16)	0	0	8	0	0
14	78.36 - 79.50	Los Banos Creek	0	0	(16)	1	180	0	0	0
15	79.50 - 82.00	Salt Creek Grp (Merced Co.)	4	68	(23)	0	0	0	0	0
16	82.00 - 84.40	Ortigalita Creek Group	4	67	(29)	0	0	0	0	0
17	84.40 - 87.78	Dos Amigos	6	64	(35)	0	0	0	0	1
18	87.78 - 89.55	Laguna Seca Creek	3	94	(45)	0	0	0	0	0
19	89.55 - 93.70	Etoheverry Group	3	92	(54)	0	0	0	0	0
20	93.70 - 95.40	Wildcat Canyon	0	0	(54)	0	0	0	0	0
21	95.40 - 96.78	Little Panoche Creek	2	140	(68)	1	90	0	0	0
22	96.78 - 108.50	Panoche Hills Group	2	13	(69)	0	0	0	2	0
23	108.50 - 110.85	Panoche Creek	0	0	(69)	1	siphon	0	0	0
24	110.85 - 113.82	Tumey Hills Group	0	0	(69)	0	0	0	2	0
25	113.82 - 119.50	Monocline Ridge Group	0	0	(69)	0	0	0	4	0
26	119.50 - 127.90	Arroyo Ciervo Group	0	0	(69)	0	0	0	9	0
27	127.90 - 131.55	Arroyo Hondo Group	0	0	(69)	0	0	0	2	0
28	131.55 - 134.88	Cantua Creek Group	3	162	(85)	0	0	0	0	0
29	134.88 - 138.24	Salt Creek Grp (Fresno Co.)	3	23	(87)	0	0	0	1	0
30	138.24 - 141.90	Jordan Group	0	0	(87)	0	0	0	3	0
31	141.90 - 144.70	Ford Group	0	0	(87)	0	0	0	3	0
32	144.70 - 154.11	Skunk Hollow	0	0	(87)	0	0	0	4	0
33	154.11 - 163.95	Arroyo Pasajero	4	80	(95)	1	60	0	3	0
34	163.95 - 172.58	Kettleman Hills Group	12	49	(100)	0	0	0	1	0
		Total	60	941		6		8	34	6

[a] Adapted from San Luis Field Division Water Operations Manual OP-350R, Jun 1989.
[b] Refer to Figure 8-10 for areal location.
[c] Number of drain inlets or bypasses within each milepost range.
[d] Cumulative percent-of-total of the drain inlet opening size.
[e] Sump pumps, pump pads, and permanent pumps.

Figure 8-11 Annual Floodwater Inflow Volumes, 1973-1999

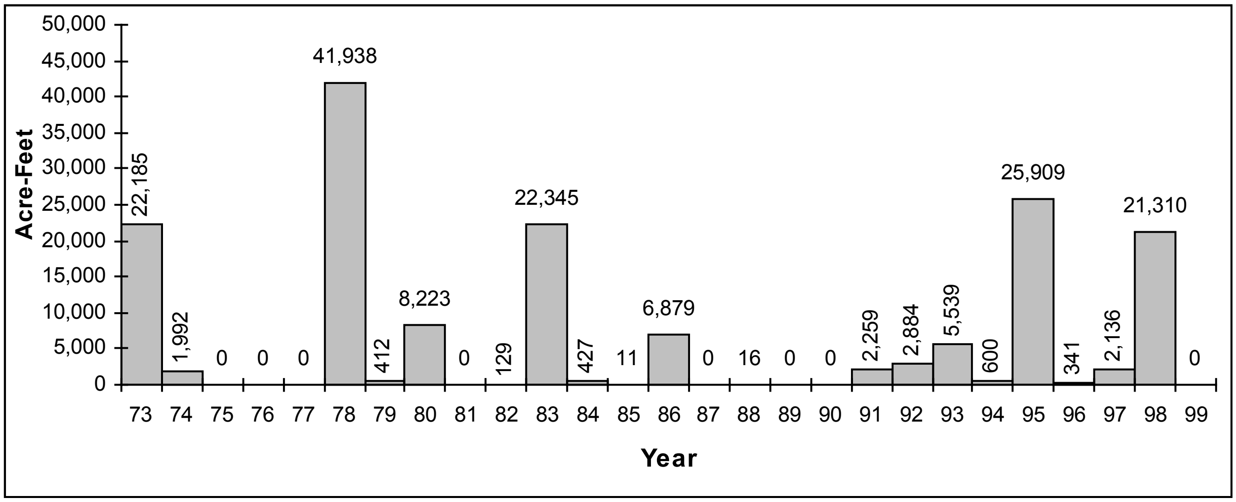
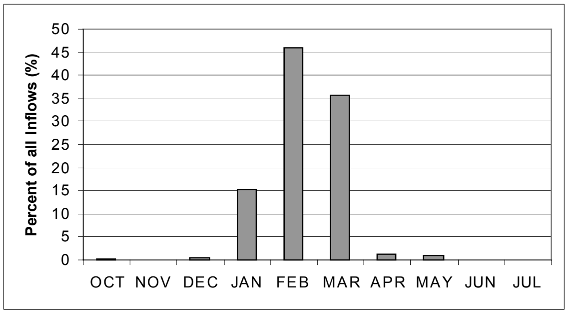


Figure 8-12 Relative Monthly Floodwater Inflows in Percent, 1973-1999



Floodwater has been admitted to the SLC in 19 out of 27 years with the largest inflows occurring in 1973 (22,186 af), 1978 (41,938 af), 1983 (22,345 af), 1995 (25,909 af), and 1998 (21,310 af) (Figure 8-11). Although inflows were admitted to the SLC prior to 1973 (1968 was a very large inflow year), accurate records were not kept.

Most inflows occur from January through March (Figure 8-12). A little less than half of all inflows have occurred in February. Inflows during January and March accounted for 15% and 36%, respectively. In 1998, inflows occurred during June and July for the 1st time ever. Inflows are rare during October and May and nonexistent in November.

Following is a brief description of the major drain inlets and any important features. An extensive amount of information exists for Arroyo Pasajero. It is summarized here because it is relevant to DWR's history of addressing impacts from floodwater inflows. Individual PCSs associated with the watersheds follow along with floodwater quality.

Little Panoche Creek

Little Panoche Creek intersects the SLC at mile 97 (Figure 8-10). There is a 5-by-6-foot box culvert to route flows under the canal to a ponding basin on the east, or downslope, side of the aqueduct. The ponding basin was built to prevent water from entering agricultural property. Farmers on the eastern side of the aqueduct consider the creek's mineralogy to be undesirable for growing crops and do not use the water even when flow continues into summer. During heavy runoff events, the basin fills up, and flows are diverted to another basin on the western side of the aqueduct, in front of the drain inlet structure. When this basin fills, water is admitted to the aqueduct via a 4-by-5-foot inlet structure. The structure is equipped with slide gates to control inflow volumes and limit the amount of sediment discharged. When a sufficient amount of sediment has settled out in the ponding basin, the slide gates are lowered to decant floodwater into the aqueduct.

In the upstream watershed, Little Panoche Creek Detention Dam was constructed to detain watershed runoff. Discharge from the outlet works is uncontrolled and begins when the surface elevation reaches a certain level. Discharge over the spillway is also uncontrolled and begins when the reservoir level exceeds 641 feet.

Inflow to the SLC from Little Panoche Creek has occurred in 7 of 27 years between 1973 and 1999 (Table 8-13). In 1998, rainfall in the Little Panoche Creek watershed was unusually high, and the capacities of both the upstream dam and ponding basins were exceeded, resulting in discharge of 6,092 af to the SLC, the highest annual volume on record from this source (Table 8-13).

Table 8-13 Floodwater Inflow by Drain Inlet, 1973-1999 (acre-feet)[a]

Year	Little Panoche Creek	Cantua Creek	Salt Creek[b]	Arroyo Pasajero	Other Drain Inlet[c]	Floodwater Pump-ins[d]	Breach	Total
1973	1,144			8,417	12,624			22,185
1974				1,992				1,992
1975								0
1976								0
1977								0
1978	3,034	1,985	197	35,035		1,687		41,938
1979				412				412
1980	633	489	256	6,259		586		8,223
1981								0
1982		124	5					129
1983	5,029	4,923	598	9,951	121	1,723		22,345
1984			114			313		427
1985						11		11
1986		4,268	333	2,278				6,879
1987								0
1988			15		1			16
1989								0
1990								0
1991		1,890	296			73		2,259
1992		1,531	518		287	548		2,884
1993		4,520	676		125	218		5,539
1994		62	118		70	350		600
1995	1,184	9,689	1,704	4,144	103	2,182	5,010	25,909
1996		288	51		2			341
1997	203	1,369	305		60	199		2,136
1998	6,092	6,506	1,162	2,278	3,694	1,446	132	21,310
1999								0
TOTAL	17,319	37,644	6,348	70,766	17,087	9,336	5,142	163,642
Percent (all)	11	23	4	43	10	6	3	
% (1973 to 1985)	10	8	1	64	13	4	0	
% (1986 to 1999)	11	46	8	13	7	8	8	

[a] Inflow data was taken from monthly tables or annual reports provided by San Luis Field Division. Although floodwaters were admitted prior to 1973, accurate records were not kept.

[b] Fresno County.

[c] Includes all other passive inflows from smaller drain inlets (DIs).

[d] Includes water pumped in from portable floodwater pumps.

Cantua Creek

Inflow from this watershed is admitted through a 10-by-6-foot concrete flume at mile 134.81 (Figure 8-10). A secondary inflow structure is upstream at mile 133.67 (6-by-4-foot concrete flume). This portion of aqueduct was damaged in 1995 when floodwater exceeded the capacity of both inlets, overtopping the canal levee. The aqueduct's concrete liner was either cracked or displaced for a section of almost 300 feet. Along with repairing the liner in 1996 and 1999, workers dug a small ponding basin against the levee. Further, a larger drain inlet was built south of the main inlet (mile 135) to handle excess floodwater from both Cantua and Salt creeks.

Inflow from Cantua Creek has occurred in 13 of 27 years between 1973 and 1999. Cantua Creek has been the single largest floodwater source in recent years. Table 8-13 shows that between 1986 and 1999, 44% of all floodwater originated from this watershed. Arroyo Pasajero has historically been the largest single source, but operational modifications have reduced its contributions (see Arroyo Pasajero below).

Salt Creek

Salt Creek intersects the SLC near mile 136 (Figure 8-10). The main inlet structure had been a 48-inch opening in the liner, with 1 or 2 smaller drains nearby. Similar to Cantua Creek, floodwater in 1995 caused major damage to the aqueduct at the Salt Creek drain inlet. A 550-foot concrete flume was installed in late 1999 to prevent this from occurring again. The new inlet at mile 135 is capable of handling floodwater from both Salt and Cantua creeks.

Inflow from Salt Creek has occurred during 15 of 27 years between 1973 and 1999 (Table 8-13). These inflows have accounted for 8% of the total during 1986 to 1999. Although Salt Creek inflows are secondary in volume to the other major drains, they have some of the highest levels of suspended solids measured in floodwater (see Section 8.3.4, Water Quality Summary).

Arroyo Pasajero

Arroyo Pasajero is the most studied of all SLC watersheds. It has a 540 square mile watershed with 4 main tributaries: Los Gatos, Jacolitos, Warthan, and Zapato Chino creeks (Figure 8-13).

The drain inlet at mile 158 is composed of 4 gated structures capable of admitting up to 3,500 cubic feet per second (cfs) into the SLC. During construction of the aqueduct, a 16,500 af ponding basin was incorporated into the design to capture runoff for evaporation and percolation. Because of sedimentation, the current capacity of the ponding basin is less than one-fourth the original capacity. An evacuation culvert at mile 155.73 was also included in the original design to pass a maximum of 1,100 cfs beneath the canal, mostly to farmland on the eastern side. Use of this structure had been limited in the past because of downstream flooding at Lemoore Naval Air Station. All of these features were designed in the mid-1960s prior to the construction of the SLC. Floodwaters that occurred over the next 30-plus years showed the original design to be seriously inadequate. Floodwater and sediment volumes proved to be 4-to-6 times those estimated in design.

Prior to 1986, Arroyo Pasajero had been the single largest floodwater source to the SLC. From 1973 to 1985, Arroyo Pasajero contributed 64% of all SLC floodwater, largely due to unusually high inflows in 1978. Inflows in 1980 and 1983, and the corresponding detection of asbestos in the aqueduct below Arroyo Pasajero, resulted in a change in operating procedures. In 1985, Standing Order No. SLFD-OP-85-8B was approved to coordinate the operation of the drain inlet gates to optimize ponding capacity.

In short, inflows were to be admitted to the SLC only when ponding areas north and south of Gale Avenue had been filled (Figure 8-13). This differed from previous operations where only DWR-owned land north of Gale Avenue was used. The new ponding area increased storage capacity by 42,650 af but flooded privately owned cropland. Periodic flooding of this land in the following years led to lawsuits and subsequent monetary restitution. A decantation weir was built around the drain inlet to further reduce sediment loads. The weir is a gabion-mesh structure that acts as a porous dam to slow the flow of water before it is released to the SLC. After 1985, only 13% of all floodwater originated from this watershed (Table 8-13).

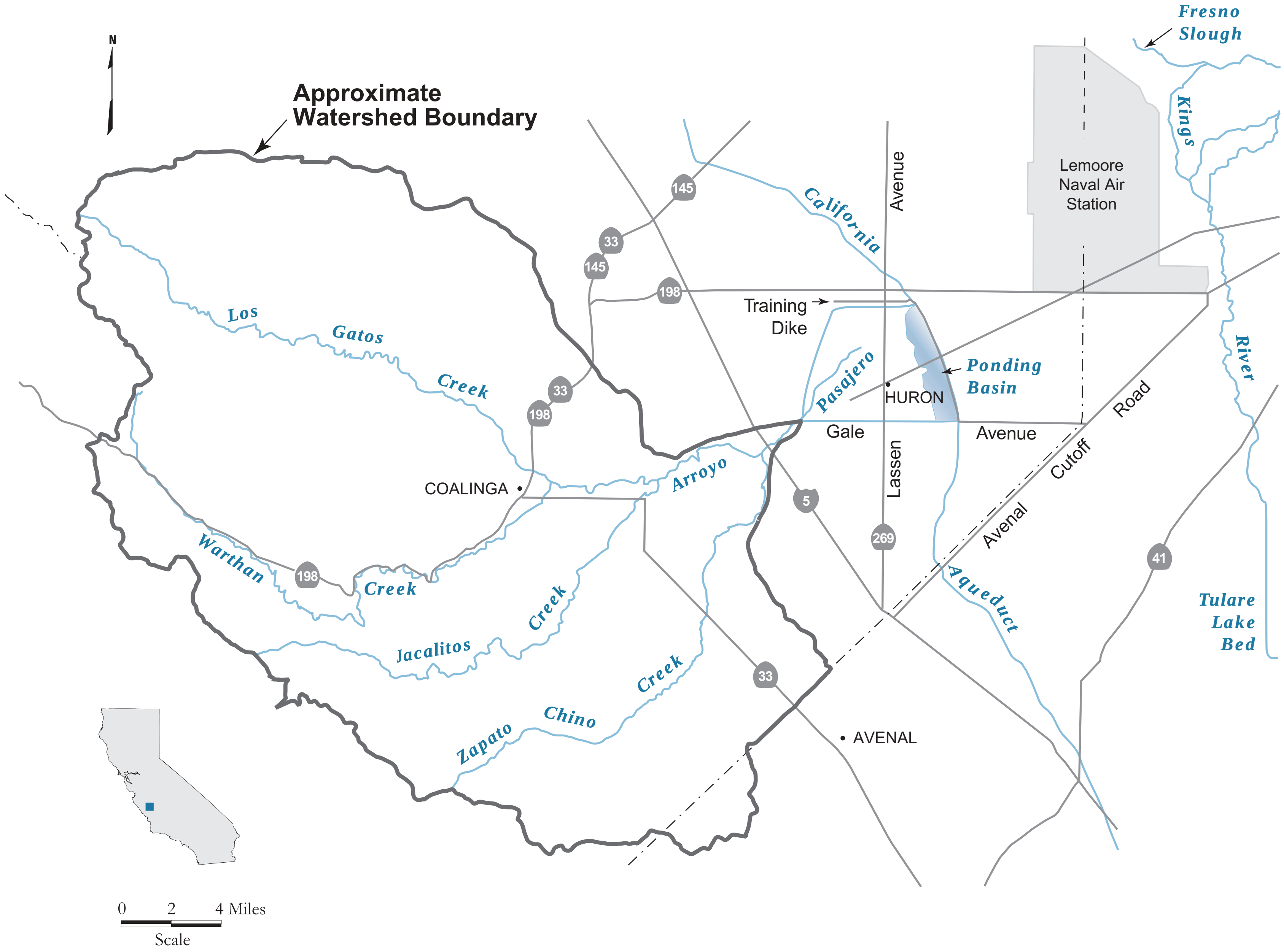


Figure 8-13 Arroyo Pasajero Watershed

In the early 1980s, MWDSC expressed concern about asbestos detected in the aqueduct downstream from Arroyo Pasajero and in the watershed's ponding basin. MWDSC was concerned about potential human health threat of asbestos-laden sediment entering a major drinking water source. Initially, the asbestos was thought to originate from 2 abandoned asbestos mines in the upstream watershed. The Coalinga (Johns-Manville) and Atlas mines are both in the Los Gatos Creek watershed, a tributary of Arroyo Pasajero. Commercial production ceased in the mid to late 1970s followed by hazardous waste listings in 1984. The US Environmental Protection Agency (EPA) listed both mines as Superfund sites because of their potential release of asbestos into both the air and water. An asbestos-processing site near the city of Coalinga was also listed.

Both the Coalinga Mine and the city of Coalinga Unit were remediated in 1993 and deleted from the National Priorities List in 1998. Any site deleted from this list remains eligible for further cleanup if necessary. Both sites will be monitored every 5 years to ensure cleanup measures remain in place. The Atlas Mine remains on EPA's priority list because of stunted revegetation efforts. These efforts are described in Section 8.3.6.1, Abandoned Mine Remediation. Regardless of the remediation efforts, natural sources of asbestos can still be flushed downstream.

Naturally occurring serpentinite in the Los Gatos Creek watershed still remains a major source of asbestos. The asbestos-containing outcrops extend well beyond the boundaries of the abandoned asbestos mines and are part of the New Idria Formation (USACE 1999). The uplift and erosion of the New Idria Formation has been ongoing for more than 15 million years and has resulted in the prevalence of naturally occurring asbestos in sediments of Arroyo Pasajero's alluvial fan. There are more than 65 square miles of naturally occurring soils and outcrops that contain 30% by volume, or more, asbestos. The entire area is within US Bureau of Land Management's (BLM) Clear Creek Management Area, but not all of it is within the Los Gatos Creek watershed (DWR 1997). BLM has designated most of this land as an asbestos hazard, and posted signs warn people of the health threat. The exposed serpentine is so prolific that 1 of the creeks draining the area was named White Creek because during significant storms the creek flowed milky white with asbestos and left a white coating on streambanks (DWR 1990).

These natural sources have been determined to contribute the bulk of asbestos carried down into Arroyo Pasajero. Prior to remediation efforts at the mines, EPA concluded that most asbestos in Arroyo Pasajero was from naturally occurring sources (Levine-Friecke 1989). Only 0.3% to 1.6% was estimated to originate from the upstream abandoned mines. Although natural sources of asbestos are elevated in this watershed (and other watersheds with serpentinite outcrops), the human health implications for SWP water containing Arroyo Pasajero inflows may not be as critical as earlier thought. The relative threat of asbestos from Arroyo Pasajero is discussed in section 8.3.5.2 under Significance of Potential Contaminant Sources.

During the 1990s DWR continued to address impacts from Arroyo Pasajero. In 1991, at the request of the State Water Contractors, DWR enlisted the US Army Corp of Engineers (USACE) and USBR to conduct a basinwide study of Arroyo Pasajero. The goal was to find a solution to the problem using the environmental impact report/environmental impact statement (EIR/EIS) process (feasibility report). Standing Order SLFD-OP-93-8D was approved in 1993 as an interim measure pending completion of this report. Briefly, the order states that both the ponding basin and evacuation culvert, are to be used before any runoff is admitted to the aqueduct. If after opening the culvert, levels in the basin continue to rise and threaten to breach the levee, floodwater would be admitted to the aqueduct. Prior to this, the culvert had not been routinely used due, in part, to the threat of lawsuits from downstream landowners. In 1995, the culvert was opened and downstream agricultural property was flooded. Afterwards, a lawsuit was filed against the State for financial losses. However, the suit was dropped when the Attorney General's Office argued that the SLC provided a net benefit to agribusiness, offsetting any negative impacts.

In March 1995 floodwater also ruptured a live oil pipeline, and 4,400 barrels of oil were released 4 miles upstream from the aqueduct (Figure 8-14). Although the ponding basin held much of the oil-water mixture, a breach in the aqueduct levee occurred on the same day, releasing about 5,000 af of this water to the SLC. Because of rising levels in the ponding basin along with a power outage that prevented opening of the evacuation culvert, the drain inlets were open at the time of the spill and also draining floodwater to the SLC. An attempt was made to close the inlet gates when the oil release was discovered. However, 1 gate could not be closed because of an 18-inch log. Attempts were made to stop the inflow by progressively dumping a combination of stop-logs, rocks, and gravel in front of the inlet gates. Flow was stopped 3 days later. Water quality monitoring showed that some oil entered the aqueduct (DWR 1996). Other problems caused by the March 1995 floods included destruction of a bridge on Interstate Highway 5 (resulting in 7 deaths), dislocation of railroad tracks, and closure for 2-½ months of Lassen Avenue because of heavy sedimentation. Soon after, the State Water Commission requested DWR to form a multi-agency forum to solicit input from lawmakers, local government, citizens and others in determining a solution. As a result, DWR had to modify its *Arroyo Pasajero Feasibility Report* (started in 1991) to address the input. The report also had to account for record-breaking runoff in 1995 that changed the magnitude of future predicted storms.

In March 1999 DWR, in conjunction with the USACE and USBR, released the draft *Arroyo Pasajero Feasibility Investigation*, a detailed description of the problems and possible ways to address them (USACE 1999). Essentially, it was a full EIR/EIS that proposed 2 possible solutions: 1) a detention dam upstream or 2) greater ponding capacity against the aqueduct with overchutes.

The various interested parties rejected both proposals, prompting the development of a new solution. A new work plan was proposed in May 2000 that addressed all floodwater, not just that from Arroyo Pasajero. The SLC would be used as a conveyance to transport floodwater to a newly proposed waste way turnout. The turnout would divert floodwater to land purchased exclusively for ponding. More details are discussed in Section 8.3.6, Watershed Management Practices.

Los Banos Creek

As the 1995 rainy season progressed, continued rainfall was expected to produce uncontrolled releases from the Los Banos Creek Dam. Similar to Little Panoche Creek Dam, Los Banos Creek Dam was built to moderate floodwater so that the capacity of the evacuation culvert at mile 79 would not be exceeded (there are no drain inlets for this watershed). Uncontrolled releases from the upstream dam were forecast during the 1995 rainy season, posing a potential threat to the aqueduct. Under emergency conditions a temporary overflow weir was constructed to allow excess floodwater to sheet flow into the SLC. Essentially, a 500-foot section of canal levee was lowered by several feet and lined with Gunite to prevent erosion. Without this, overtopping of the unprotected levee could result in a major breach of the western and possibly eastern side of the aqueduct levee (as well as higher inflow volumes). Fortunately, levee overflows were averted by a change in the weather. However, the overflow weir remains a permanent feature of the SLC.

Toe Drains, Bridges, and Pipeline Overcrossings

These are smaller pipes that drain adjacent service roads. Many convey canal roadside drainage into the open canal sections when it rains. These drains could contribute sediment, and possibly herbicides used for weed control in the canal right of way, to the canal water. Several of the drains discharge runoff from major highways and could contribute metals, oil, and grease, as well as materials spilled from trucking accidents. There are an estimated 353 toe drains in the SLC. This estimate includes those that drain roads and highways (see Section 8.3.3.11, Transportation Corridors).

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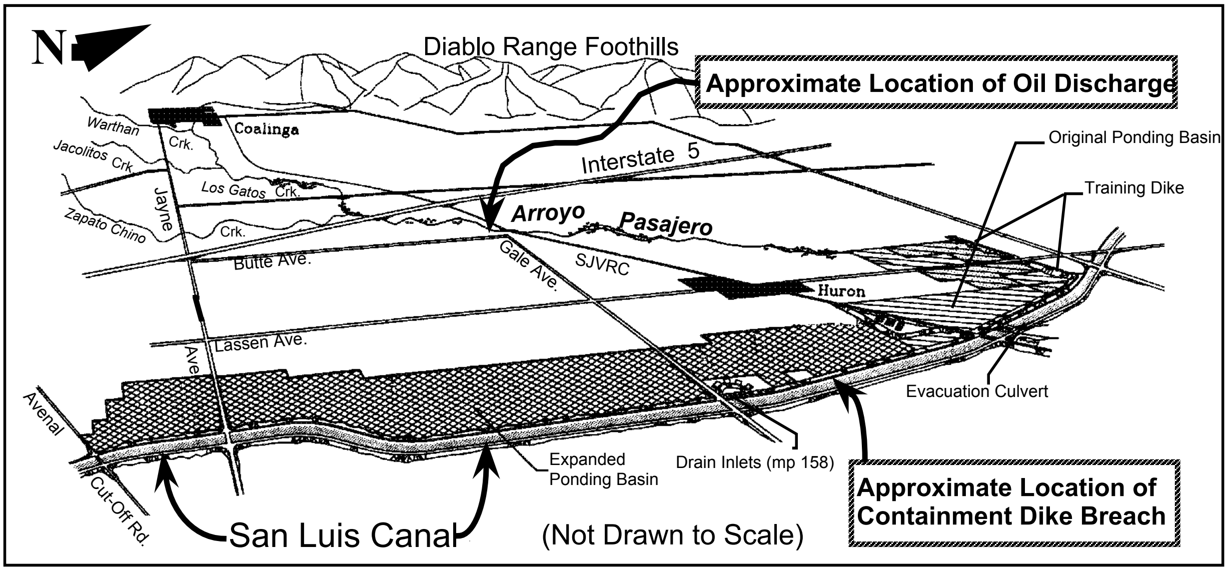
Figure 8-14 Location of the Containment Dike Breach and Oil Discharge in the Arroyo Pasajero Watershed



There are 47 bridges crossing the SLC. These consist of interstate and state highways, county roads, and farm bridges. Bridges offer easy access for illegal dumping and vandalism. Motor vehicle accidents can result in spills into the canal of petroleum products and potentially hazardous substances as well as the vehicle itself. Herbicides, pesticides, and fertilizers are frequently transported across the canal on farm bridges. Animal waste products can enter the water from cattle driven over the bridges. Drainage from the bridges flows into the canals in several locations. Bridges are also used to support pipeline crossings over the canals in many locations.

Pipeline overcrossings exist in numerous locations. Materials conveyed in the pipelines can include petroleum products, domestic water, and natural gas. Their relative threat to water quality was addressed in *Sanitary Survey 1990.*

These structures appear to pose only a minor threat to water quality.

8.3.3.2 Recreation

There are no recreation amenities on the SLC, although several locations are popular for fishing. A 1992 DWR survey identified 14 fishing sites, 10 with portable chemical toilets. The SLC can be fished anywhere public access is available. There is no contact recreation on the SLC, and numerous posted signs discourage swimming in the canal because of the inherent danger.

Noncontact recreation such as hunting and fishing is allowed at the reservoir of Little Panoche Creek Dam. The lake is administered by California State Parks. There are picnic areas and a boat launch but no camping. No signs are posted to discourage contact recreation. California State Parks does not keep visitor attendance records for this water body. The water quality threat from any recreational activities is expected to be minimal to nonexistent because summer flow from this reservoir is routed under the aqueduct.

8.3.3.3 Wastewater Treatment Facilities

There are 3 wastewater treatment plants west of the SLC. They were evaluated by reviewing the files and talking with staff at Central Valley Regional Water Quality Control Board, Fresno Office (CVRWQCB).

City of Huron Wastewater Treatment Facility

This wastewater treatment plant (Waste Discharge Identification number (WDID #) 5D100107001) is about 1.5 miles from the aqueduct in the Arroyo Pasajero watershed. From 0.3 million to 0.6 million gallons per day (mgd) of treated domestic sewage is discharged to nearby ponds. The plant is near Arroyo Pasajero's ponding basin, but the sewage ponds are surrounded with a protective dike designed to prevent inundation. In 1997, the CVRWQCB identified permit violations for not maintaining a flowmeter, bar screens, and disposal ponds. The city responded that the flow recording equipment would be fixed, the screens were to be cleaned and would be operating, and weeds would be removed from the pond.

Harris Ranch

Harris Ranch Inc. operates a permitted packaged wastewater treatment plant. The plant treats domestic sewage from the Harris Ranch restaurant and hotel complex using activated sludge technology. The 30-day average design capacity of the plant is 65,000 gallons a day. The treated sewage is discharged to 4 evaporation/percolation ponds in the Skunk Hollow watershed. The plant is approximately 5 miles west of the aqueduct between miles 144 and 153. There are no drain inlets or sump pumps in this portion of aqueduct, although there are a number of pump pads. Ponded floodwater cannot migrate south past mile 153 because of Arroyo Pasajero's training dike that contains floodwater within a ponding basin. Land between the Harris plant and the SLC is primarily cropland.

The Harris Ranch complex is planned for expansion: a new car wash, recreational vehicle park, expansion of the hotel, a drive-up restaurant, a new 150-room economy motel, commercial service center, and increased parking for trucks, buses, and recreation vehicles. Expansion of the wastewater treatment plant is also proposed. The current mechanical plant would be replaced with an aerated lagoon system with more evaporation/percolation ponds. This system would be able to handle the expected increase in wastewater. The design flow during dry weather would be 100,000 gallons a day with a peak capacity of 300,000 gallons a day, typically needed on weekends during the tourist season.

A water balance was performed to design the size of the ponds. Ponding requirements were based on a 100-year return frequency rainfall interval and a wet year evaporation rate. The raw sewage would 1st flow through a series of screens to remove solids prior to ponding. The solids would be compacted, de-watered, and deposited in a bin for later transport to a landfill. The wastewater would continue to a series of ponds for treatment, percolation, and evaporation. The 1st pond is to be equipped with floating aerators to facilitate biological treatment and waste reduction. The stabilized wastewater will then flow to a polishing pond for further treatment and settling of suspended solids. The polishing pond will also serve as a standby if the aeration pond needs to be de-watered or cleaned. The polished water will then be sent to a series of 5 ponds with a combined capacity of nearly 8 million gallons. These shallow ponds will be used to percolate and evaporate the treated wastewater. They do not have to be lined because there is no shallow groundwater and no nearby domestic wells. The portion of aqueduct downstream from this plant is not equipped with sump pumps.

This expansion was proposed in early 1999, and the CVRWQCB approved it in June 2000. After the order is revised and approved by the State Water Resources Control Board (SWRCB), completion of the expanded facility is expected to take about 9 months.

Coalinga Wastewater Treatment Facility

This conventional wastewater plant (WDID # 5F10S011605) produces about 1.3 mgd of treated domestic sewage from the city of Coalinga. The discharge irrigates nearby farmland. Coalinga is in the Warthan Creek tributary of Arroyo Pasajero and is approximately 18 miles from the SLC.

These facilities appear to pose only a minor threat to water quality in the SLC.

8.3.3.4 Industrial Discharge to Land

PG&E Kettleman Compressor Station Class II Surface Impoundments

This facility (Order No. 99-145) maintains pressure in a natural gas pipeline. The compressors are cooled by water that is circulated through a cooling tower. From 1929 to 1989, the discharger operated 5 unlined surface impoundments for disposal of cooling tower blowdown and other minor facility wastewater streams. Maintenance activities included draining an on-site swimming pool, descaling copper-alloy cooling systems, and degreasing equipment. In 1989, the facility was permitted for the 1st time with a discharge to land permit (Waste Discharge Requirement or WDR). In 1994, the unlined impoundments were closed. The facility currently discharges an average of 38,000 gallons a day of nonhazardous wastewater to newly permitted class II surface impoundments constructed in accordance with Title 27 regulations. An inspection in 1999 reported no permit violations.

The facility is in the Kettleman Hills watershed, a little more than 2 miles from the aqueduct between miles 163 and 170. There are a number of drain inlets in this section of canal. Water quality samples collected from some of these inlets have exhibited elevated levels of metals and organic carbon (DWR 1995). It is unclear whether there is any relationship between these data and the permitted facility.

8.3.3.5 Industrial Site Stormwater Runoff

Several industries within the Arroyo Pasajero watershed are permitted for storm water runoff. They were evaluated by talking with CVRWQCB staff and reviewing their files.

Chemical Waste Management, Coalinga Transportation Facility

This is a truck maintenance yard (WDID # 5F10S005416) with diesel fuel tanks, motor and hydraulic oil containers, propane tanks, and waste oil tanks. The yard is within the city of Coalinga approximately 18 miles from the SLC. Although there were no data from past monitoring, the company applied for and received a Notice of Termination (NOT) for its storm water permit in 1999. The basis of the termination was that all storm water is retained on site. The CVRWQCB approved the termination and sent it to the SWRCB for final approval.

Chemical Waste Management, Coalinga Facility

This is an inactive class II waste disposal site (WDID # 5D100305001) just north of Coalinga. It was in operation between 1973 and 1984 and accepted primarily oil field-related wastes. These wastes consisted of drilling mud, scrubber waste, tank bottoms, waste brine from water softening units, oily wastes, and produced water. About 2.7 million barrels of this waste was accepted. The previous owner buried some restricted waste, but that was removed in 1984 with oversight from the CVRWQCB and DHS. In October 1997, the CVRWQCB determined that this facility presented no water quality threat to the beneficial uses of surface waters. It also presented a comparatively small threat to the underlying aquifer because naturally occurring salts render the groundwater unusable.

Artesia Ready Mix

This facility (WDID # 5F54S006290) is about 5 miles south of Coalinga within the Zapato Chino Creek watershed of Arroyo Pasajero. The facility makes ready-mixed concrete. No monitoring data were available.

Waste Management, Inc., Coalinga Treatment Facility

This is a “refuse systems waste treatment facility” (WDID # 5C10S011518) and is within the city of

Coalinga. A single water quality sample had been collected from the site during a rainfall event. The sample had relatively high levels of total suspended solids (4,240 mg/L) and conductivity (20,100 µS/cm). No other monitoring data or information was available.

Pool California Energy Services, Inc.

This company stores and maintains equipment used to service oil wells throughout Fresno County and surrounding areas (no WDID available). The operation is termed an "oil and gas field services facility" and is in Coalinga. In 1997, the company submitted its annual storm water report and stated that there had been no storm water discharges from the site. A 1-foot berm surrounds the property. Runoff is conveyed into a recessed area that is about 100 feet by 80 feet by 1 foot in size. No other information was available.

Coalinga-Huron Unified School District, Transportation Department

This is a school bus yard in Coalinga (WDID # 5F10S003915) where buses are parked, fueled, washed, and serviced. The yard contains diesel fuel tanks and new and used oil containers. Two runoff samples collected in 1999 contained oil and grease at <10 and 49 mg/L. Conductivity was below 100 µS/cm and total suspended solids (TSS) ranged from 11 to 18 mg/L.

City of Coalinga Wastewater Treatment Facility

This is a conventional wastewater plant in Coalinga (WDID # 5F10S011605). The facility requested and received, a Notice of Termination in August 1998. All runoff is now ponded on site.

It appears that none of the industrial sites poses a significant threat to water quality at this time.

8.3.3.6 Animal Populations

Livestock Grazing

Although no surveys have been performed, livestock grazing has been observed in most of the hilly areas west of the SLC. Grazing is not considered a significant threat to water quality at this time.

Confined Animal Facilities

Two confined animal facilities are west of the SLC. A review of CVRWQCB files located 1, and DWR staff identified the other.

Harris Feedlot

The Harris Feedlot is a sophisticated cattle-feeding operation that covers more than a square mile of land upstream from the SLC. In 1989, the number of cattle was estimated at 100,000 head. In the last few years, several corrals have been added, so the current population is probably higher. Runoff from the feedlot drains to a large catch basin that overflows into a series of evaporation ponds. The basins are a little more than a mile from the SLC, near mile 142 and 143. This section of aqueduct is not equipped with either drain inlets or sump pumps, although a pump pad is at mile 142.5. Ponded water cannot extend south of mile 143 because of Coalinga Canal.

In the past, dry manure was scraped from the corrals and transported to a processing area where it was stored before being sold. In the late 1980s, this process occurred on the property where the ponds are located. Berms had been constructed around the processing area to protect against flooding and overflow. No available information indicates whether manure is still processed on-site, and if so, where it occurs.

Rainfall runoff from the facility was thought to flow unimpeded toward the aqueduct. DWR's unofficial policy was to disallow any pumping of this water into the aqueduct for obvious reasons. Water ponded against the aqueduct could cause levee erosion from wind fetch. Because of DWR complaints, the CVRWQCB in 1988 requested Harris Ranch to rectify the problem. The ranch responded by enlarging the ponding basins and installing headgates on the collector dams for better control. The new capacity was 224 af, twice the amount of runoff expected for a 100-year, 24-hour storm. Although considered adequate at the time, weather changes since then have probably lessened the design capacity. Capacity may have also declined from sedimentation.

In addition to enlarging the ponds, Harris Ranch also cross-levied and bermed land below the primary and secondary catch basins to accommodate any emergency runoff. Theoretically, if the ponds overflowed, water would be diverted north to some temporary holding basins near mile 141.5. This water would be used to irrigate adjacent agricultural land or be pumped back to the western side of the aforementioned berm. It is unknown whether this emergency measure was ever used or if the diversion berm still exists.

More recently in 1995 USBR complained to the CVRWQCB about ponded water downstream of Harris Ranch. A subsequent inspection and discussions with a Harris Ranch representative indicated that the water originated from runoff north of the corrals. According to the inspection report, "Runoff simply flows around the north end of the corrals and down a field road to the aqueduct." It was implied that no runoff from the facility makes it to the aqueduct. The ponding basins were also inspected. The smaller of the 2 ponds—5 acres in size—was one-third to one-half full. Wastewater was trickling through the head gate of this pond into a 25-acre pond that was nearly empty. Apparently, the ponds were able to handle a high runoff year.

The Harris Ranch Feedlot is not permitted by the CVRWQCB because there are no permit requirements for operations that do not discharge storm water to surface waters or storm sewers. According to regulations, "To avoid liability, the discharger should be certain that a discharge of industrial storm water to surface waters will not occur under any circumstances."

Thommen Dairy

This dairy is approximately a quarter mile from the SLC in the Etoheverry Group watershed. There are a host of drain inlets along this section of canal, the nearest at miles 92.72 and 93.41. The 1st is a 4-by-4-foot concrete structure, and the 2nd is a 48-inch concrete pipe. Any potential runoff from the site would end up closer to the 92.72 inlet. There are no water quality data for either of these drain inlets.

CVRWQCB staff did not have any record or knowledge of this dairy. DWR staff confirmed its existence from a nearby road. DWR staff noted a pond on the downstream side of the property. Apparently, Fresno County does not require any permits for dairies on agricultural land, so they are not reported to the CVRWQCB unless there is a problem. Further, the CVRWQCB has been historically underfunded, and money specifically earmarked for dairy regulation has been virtually nonexistent (there was also a 20% vacancy rate at the CVRWQCB's Fresno Office at the time of this writing).

Wild Animal Populations

Land west of the SLC is prime habitat for wildlife, especially in the upper reaches of the watershed. A wildlife survey was performed in Arroyo Pasajero and probably reflects that of the other watersheds (USACE 1999). It identified several species of mammals, birds, and reptiles inhabiting the area around the confluence of Los Gatos and Warthan creeks and the ponding basin against the aqueduct. The most common mammals included jack rabbits, cottontails, kangaroo rats, skunks, and coyotes. Wildlife such as feral pigs, black tailed deer, and black bear probably inhabit the upper reaches of the watershed. Relative to confined animal facilities, this PCS is considered minor.

8.3.3.7 Agricultural Activities

Agricultural land uses such as field and truck crops, dominate the flatter portions of land west of the SLC (Table 8-14 and Figure 8-15). Cotton made up the single largest land use in this area with 30%, followed by tomatoes (15), fallow and idle (14), and other truck crops such as lettuce and melons (14). Most orchards were either almond or pistachio and accounted for almost 7% of the total agricultural land uses.Based on water quality analyses in floodwater inflows, pesticides and herbicides are applied to land west of the SLC. The most frequently detected compounds during 1996 to 1999 were cyanazine, dacthal, simazine, diazinon, methadathion, trifluralin, oxyfluorfen, and diuron. They are carried into the SLC during winter when pesticide applications are followed by rainfall runoff events (see Section 8.3.4, Water Quality Summary).

Although floodwater inflows contribute pesticides to the aqueduct, present-day pesticides are made to decay quickly in the environment. Further, most of the pesticides detected in the SLC originate from Delta exports (DWR 1995), so floodwater would only be contributing to levels already present in the aqueduct. In light of the fact that no pesticide MCLs were violated during 1996 to 1999, pesticides from floodwater are not considered a major concern in the SLC.

Table 8-14 Irrigated Land Uses West of the San Luis Canal, 1994-1995

Land Use [a]	Acres	Percent of Total
Subtropical	564	0.2
Pasture	608	0.2
Alfalfa	661	0.3
Corn	734	0.3
Nonirrigated Agricultural Land	2,089	0.8
Sugar Beets	2,391	0.9
Other Deciduous (apple, cherries, etc.)	2,553	1.0
Grapes	4,868	1.9
Other Field (flax, corn, etc.)	5,433	2.1
Urban	6,931	2.7
Almond and Pistachio	17,760	6.8
Grain	27,710	11.0
Other Truck (lettuce, melons, etc.)	35,310	14.0
Fallow and Idle	35,575	14.0
Tomatoes	38,021	15.0
Cotton	78,212	30.0
Total	259,420	100

[a] Covers only land that uses SWP water. Land use farther up the watershed is not included here.

8.3.3.8 Mines

One survey has collected data on potential mining activities west of the SLC, and it was done for Arroyo Pasajero (USACE 1999). County surveys identified many mineral resources in Arroyo Pasajero, but only sand and gravel was considered economically viable. Several inactive or abandoned asbestos mines are in the same watershed and could contribute asbestos and mercury in drainage entering the SLC.

The only other mine upstream of the SLC with a known water quality threat is New Idria Mine. The abandoned mine is in the upper reaches of Panoche Creek, which passes over the aqueduct via siphon, thereby preventing mine drainage from entering the aqueduct.

8.3.3.9 Solid or Hazardous Waste Disposal Facilities

Two waste disposal facilities operate within the SLC watershed. They were located by reviewing CVRWQCB files and talking with CVRWQCB staff.

Billie Wright

The Billie Wright solid waste municipal landfill (class III) is approximately 1.5 miles upstream from the SLC near mile 75. The landfill consists of 1 inactive and 1 active, unlined, waste management unit covering 3 and 30 acres, respectively. An additional 88 acres is to be added in a permit revision in latter part of 2001. A nearby ephemeral stream drains toward the aqueduct and is called Billie Wright Creek. The SLC is equipped with both a box culvert and a sump pump to pass this drainage under the canal or accept it into the aqueduct. Before 1992, the sump pump operated by float valve, periodically discharging drainage into the aqueduct. Groundwater accretion from this watershed has naturally elevated mineral levels such as TDS (average 6,500 mg/L), hardness (1,600 mg/L as $CaCO3$), and selenium (0.182 mg/L). Because of this, the sump pump was disconnected in 1992. Since then, all flows pass under the SLC to the DMC where it also passes underneath to an almond orchard.

Blue Hills

The Blue Hills landfill was constructed in 1973 and accepted class I hazardous waste until it was closed in 1990. It is in the foothills of Skunk Hollow, about 10 miles from the SLC. An unnamed intermittent drainage traverses the landfill, but diversion structures have been built to convey flows around it. Any runoff from this area large enough to make it to the aqueduct would pond against the levee between miles 144 and 153. There are pump pads in this section of canal but no sump pumps or drain inlets.

Operated by Fresno County, the landfill had previously accepted pesticides, empty pesticide containers, and other agricultural industry-related hazardous and nonhazardous wastes. After closure, the facility was classified as a class III landfill containing hazardous waste in accordance with Title 23 of the California Code of Regulations. It is currently under a 1999 Post-Closure order that requires periodic inspections of the flood protection structures following all storm events as well as periodic groundwater monitoring. The last inspection in 1998 noted no problems, although low concentrations of herbicides were detected in the underlying groundwater. Fresno County is implementing a corrective action plan. The underlying groundwater is isolated and not connected to San Joaquin Valley aquifers to the east.

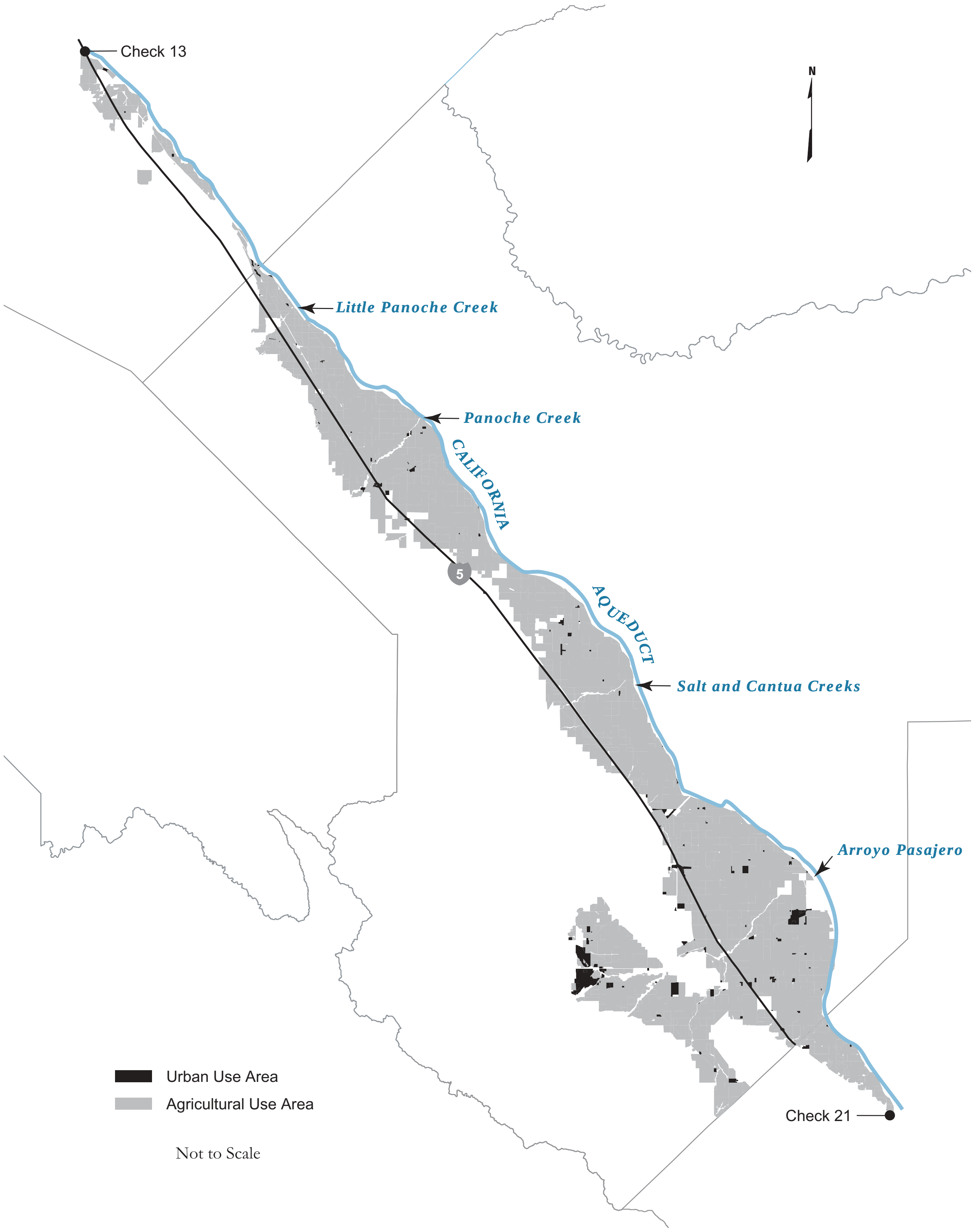
8.3.3.10 Unauthorized Activity

Only 1 survey has been done to detect unauthorized activity or illegal dumping. In Arroyo Pasajero, a ground survey was done to identify any potential hazardous, toxic, or radiological materials within the study area (DWR 1999). The study area included the proposed ponding basin against the aqueduct and, upstream, where the Gap Dam was proposed at the confluence of Los Gatos and Warthan creeks. These 2 areas represent a very small fraction of the entire watershed. The survey identified numerous tanks and drums, either in use or discarded. Some of the discarded drums were empty, and some exhibited visible leakage, usually petroleum products. A number of trash pits were also observed to contain a variety of nonhazardous items such as construction debris (concrete and wood), tires, and scrap metal. However, these appear to pose only a minor threat to water quality.

8.3.3.11 Transportation Corridors

During 1996 to 1999, a total of 29 vehicles were recovered from the SLC. Among these were 2 tractor-trailer rigs that released several gallons of oil to the SLC. On both occasions, absorbent booms were placed downstream to remove insoluble oil products. The more soluble products like benzene and toluene could get past the booms but would quickly volatilize downstream. Other potential threats from transportation corridors were addressed in *Sanitary Survey 1990* and appear to pose a minor threat to water quality.

Figure 8-15 Agricultural and Urban Use Areas West of the San Luis Canal



8.3.3.12 Accidents and Spills

There have been several incidents where contaminants were released into the aqueduct. The 1st was a small amount of hydraulic oil that leaked from a blown hydraulic line at Dos Amigos Pumping Plant. The 2nd incident involved a substance that was found floating on the surface of the aqueduct. The substance was identified as sulfur dust; probably overspray from aerial applications made to adjacent orchards. The 3rd incident was a sewage spill at the Kettleman City Water Treatment Plant. The sewage spill was contained by an earthen berm constructed next to the aqueduct. This potential source is considered a minor threat to water quality.

8.3.3.13 Groundwater Discharges

Groundwater discharges to the SLC can come from water service turnouts. There are 106 of these turnouts that can pump in groundwater from east-side agricultural lands (see Table 8-10). Pump-ins assisted State and federal water contractors during periods of entitlement deficiency caused, in part, by the 1987 to 1992 drought. Groundwater is pumped into the aqueduct in return for an equal amount of SWP water returned at another time and a place other than the original pump-in. Pump-ins mitigate for supply deficiencies imposed on federal water contractors. The pump-in program ended in 1996, when a very small amount of water (121 af) was admitted to the SLC. A new agreement is being developed to allow pump-ins in the event of future drought conditions.

A water quality study suggested that pump-ins can increase SLC salinity (DWR 1994). SLC pump-ins are typically elevated in TDS with levels ranging largely between 500 mg/L and 1,500 mg/L. At times, pump-ins comprise as much as 46% of Check 21 outflow. During these periods, TDS in the aqueduct increased. Pump-ins can also increase arsenic levels in the aqueduct.

Arsenic in SLC pump-ins ranges from <0.002 to 0.032 mg/L. Approximately two-thirds of the samples collected had arsenic levels below 0.005 mg/L. Regardless, the study indicated that high pump-in volumes had resulted in a net increase in aqueduct arsenic of about 0.001 mg/L. Levels in the aqueduct typically range between 0.001 and 0.003 mg/L. With the current MCL of 0.05 mg/L, this increase would not be significant.

Groundwater can also be pumped into the SLC via DWR sump pumps. These are automated groundwater pumps that relieve groundwater pressure on the upslope, or west side, of the canal liner. In some areas of the SLC, perched groundwater, if allowed to build up, can cave-in cement liners. These are typically where the canal right of way extends off the valley floor and up into the foothill zone. No information was available regarding the volume or quality of these inflows.

Gas, Oil, Geothermal Wells

There are several PCSs in this category that can affect ground water quality.

There are several thousand petroleum extraction wells in the San Joaquin Valley; an unknown number are west of the SLC. A land-use survey done in the mid-1990s counted 6 oil wells in 2 small areas within the Arroyo Pasajero watershed (USACE 1999). The survey was for the proposed Gap Dam site and not the entire watershed. The largest water quality threat from well activities is the marine-like water that is brought up along with the oil.

Nonhazardous brine water with salinity as high as 10,000 mg/L TDS can be co-extracted with crude oil. Oil companies deal with this water in several ways. Some send the mixture to tanks to separate out the oil. Brine water can also be sent to unlined excavations, or sumps, for evaporation and/or infiltration. Sumps vary in size, but most are about 50 by 20 feet. Brine water can also be reinjected into marine formations or recycled. There are other nonhazardous wastes generated from oil extraction, and they are handled using a variety of techniques:

- Mud pits are used to dispose of drill mud and cuttings in accordance with regulations contained in Title 27.
- Operational sumps are used in conjunction with drilling rigs when wells are newly drilled or reworked.
- Emergency overflow containment basins or catch basins are used where there is a potential for unplanned overflow of either brine water or oil. They also serve to prevent channel washouts during storms. Although these basins can be lined, oil companies can use them for emergencies only and must immediately remove any discharged oil by following a Spill Prevention, Control, and Countermeasure Plan.
- Pigging sumps consist of small trenches or poorly defined topographic low areas that receive waste fluid generated from internal cleaning of wastewater pipes. The pigging process can be performed, on average, every 3 years using fresh water.

Permitting of the brine water ponds began in the 1950s. In the 1970s, additional permits were issued for the ponds but tapered off because of changing priorities and limited staff. CVRWQCB considers oil field activities west of the SLC less of a priority because there are few nearby water bodies (ground or surface) with any beneficial uses. The Fresno office has recently received new positions dedicated to addressing oil well issues. Staff is needed because most oil field disposal methods do not meet current regulatory standards.

California is 1 of a few states where brine disposal sumps still exist. The California Water Code stipulates that any discharge to land has to meet certain conditions. Compliance may include liner construction coupled with groundwater monitoring. The CVRWQCB's current effort focuses on bringing brine dischargers into compliance with regulations by eliminating sumps and requiring other methods of disposal such as groundwater reinjection or recycling.

Although oil extraction wells exist in Arroyo Pasajero, no permits for brine water sumps were found in the CVRWQCB's files. Several larger, permitted sumps are farther south, beyond the SLC. Therefore, brine sumps do pose a water quality threat, but whether they exist west of the SLC remains unclear.

Oil Pipeline Break

In March 1995, floodwater in Arroyo Pasajero ruptured a live oil pipeline, releasing 4,400 barrels of oil 4 miles upstream from the aqueduct. Although the ponding basin held much of the oil-water mixture, a breach in the aqueduct levee occurred on the same day, releasing about 5,000 af of this water into the SLC. Water quality monitoring showed that some oil entered the aqueduct (DWR 1996).

Above-ground Petroleum Tanks

In Arroyo Pasajero, a ground survey was undertaken to identify any potential hazardous, toxic, and radiological materials within the study area. The study area included the proposed ponding basin against the SLC and upstream, where the Gap Dam was proposed at the confluence of Los Gatos and Warthan creeks. These 2 areas represent a very small fraction of the total watershed. Several above-ground storage tanks were identified in this survey. Sizes ranged from 500 to 10,000 gallons and usually contained gas or diesel.

On the SLC there are several turnouts with lubricated oil pumps sitting on top of the aqueduct levee. Some of these pumps are equipped with oil containers used to automatically lubricate the pumps. There are 5 such oil containers between mile 72 and 82, and 12 oil containers between mile 102 and 128. They range in size from 1 gallon to 55 gallons. In 1998, the USBR required Westlands Water District to install secondary containment structures for the tanks to capture any leakage, but only 2 of the containers are equipped with these containment devices. There is still a potential threat that leaks could enter the aqueduct, but these tanks and the previous PCSs appear to pose only a minor threat to water quality.

8.3.3.14 Geologic Hazards

Geology of the Diablo Range is dominated by marine sandstone such as continental and ancient ocean deposits, up to 1,000 feet thick in some places (Davis and others 1959). These deposits can contain concentrated salts such as sulfate, chloride, and magnesium. Sulfate originates from both marine and continental deposits. High chloride can also originate from the Panoche Formation that dominates the Salt (Merced County) and Little Panoche Creek watersheds. Serpentinite outcrops produce magnesium bicarbonate water that is unique to Arroyo Pasajero and Cantua Creek.

Highly saline springs exist in some of the SLC watersheds. The high salinity can originate from contact with ancient ocean deposits. As groundwater moves through these deposits, it dissolves the salts and transports them downstream. Other springs originate as ancient seawater trapped between sedimentary deposits (Davis 1961). These waters are called connate and are characterized as dilute seawater. Springs of this nature are known or suspected within the watersheds of both Salt creeks (Fresno and Merced counties), Panoche, Billie Wright, and Little Panoche creeks, Arroyo Ciervo, and Etoheverry (DWR 1995).

Serpentinite outcroppings are a source of asbestos in runoff and have been identified specifically in the headwaters of Arroyo Pasajero. The New Idria serpentinite body covers 48 square miles along the central part of the Diablo Range in Fresno County and eastern San Benito County. Serpentinite or other ultramafic intrusives comprise 13% of the Los Gatos Creek watershed, a tributary of Arroyo Pasajero (Davis 1961). Cantua Creek is also a source of asbestos, with 6% of the watershed containing exposed serpentine outcroppings. Asbestos-containing outcrops probably exist in other Diablo Range watersheds based on waterborne asbestos samples.

Diablo Range is the largest source of selenium in the San Joaquin Valley (Tidbal and others 1986). Selenium originates from marine sedimentary deposits defined as the Moreno and Kreyenhagen formations. These formations are intermixed with others of low selenium content in most of the Diablo Range watersheds but dominate the Monocline Ridge area (Gillium and others 1989). Runoff from this watershed contains elevated selenium relative to the other SLC watersheds (discussed in Section 8.3.4, Water Quality Summary). Most of the other watersheds west of the SLC contain a diverse mixture of sediment types with lower selenium levels.

Since these contaminants would only reach the SLC via floodwater inflows, they are included with the assessment of that PCS in Section 8.3.3.1.

8.3.3.15 Population and General Urban Area Increase

Approximately 3% of the farmable land is urbanized, not counting roads (see breakdown in Section 8.3.3.7, Agricultural Activities, under Potential Contaminant Sources). However, this represents only a small fraction of the total acreage west of the SLC. Therefore, urban areas make up a very small portion of the total watershed.

8.3.4 WATER QUALITY SUMMARY

8.3.4.1 Diablo Range Watersheds

From 1996 to 1999, floodwater inflows to the SLC totaled 23,787 af, with the majority occurring in 1998 (Table 8-15). During that year, 86% of all inflows occurred in February. The major contributors were Cantua Creek with 31% of the February total followed by Little Panoche Creek (25%) and Arroyo Pasajero (12%) (Figure 8-16). In addition to inflows from the Diablo Range, water from the Kings River (7,236 af) was admitted to the aqueduct via Lateral 7 (mile 115.40) April through June 1998 (Figure 8-16). The water originated from the Mendota Pool and was composed largely of releases for flood control from Sierra Nevada reservoirs (DWR 2000). There were no inflows, floodwater or otherwise in 1999.

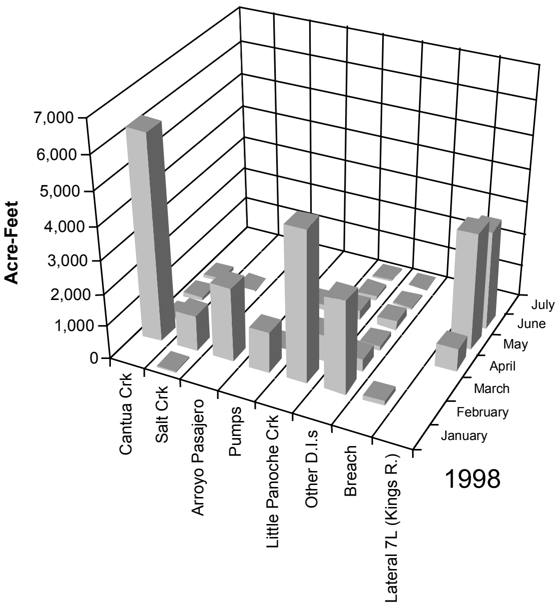
Federal contractors usually take water from the SLC during the winter for preirrigation. This sometimes has the unintentional benefit of diverting floodwater out of the aqueduct. For instance, during February 1998, about half of all SWP/non-SWP inflow to the canal was diverted for preirrigation. This means that some of the February floodwater inflow, mixed with SWP water from the Delta, was diverted from turnouts located throughout the SLC. Although these diversions would tend to minimize water quality impacts in the aqueduct, downstream conductivity increased by 50 µS/cm to 400 µS/cm (approximately equal to 30-230 mg/l calculated TDS) for more than a month.

TDS in floodwater during 1996 to 1999 ranged from a low of 89 mg/L in Skunk Hollow to a high value of 2,890 mg/L in Salt Creek (Table 8-16). Historically, median TDS has ranged between 705 mg/L and 897 mg/L (Figure 8-17). TDS levels as high as 4,310 mg/L have been measured in the past, but most extreme values were from smaller drains grouped in the “All others” category in Figure 8-17. Individually, these sources comprise a small portion of the total volume. Some of the highest TDS levels were from watersheds like Monocline Ridge where no drain inlet structures exist and floodwater is pumped into the SLC by portable pumps (DWR 1995). Regardless, TDS levels in floodwater are higher than those in the aqueduct and have been shown to affect in-stream concentrations (DWR 2000).

Table 8-15 Sources of Annual SLC Floodwater Inflows, 1996 to 1999

Source	1996	1997	1998	1999
Cantua Creek	288	1,369	6,506	0
Salt Creek	51	305	1,162	0
Arroyo Pasajero	0	0	2,278	0
Little Panoche Cr.	0	203	6,092	0
Pumps	0	199	1,446	0
Other DIs	2	60	3,694	0
Breaches	0	0	132	0
Total Inflows	341	2,136	21,310	0

Figure 8-16 Monthly Floodwater Inflows, 1998



From 1996 to 1999, TSS in floodwater inflows ranged from 14 to 12,500 mg/L (Table 8-16). The high value from Little Panoche Creek approached the historical maximum of 13,000 mg/L in Salt Creek (Figure 8-17). This is consistent with field staff observations that sometimes have compared floodwater to “chocolate milk.” Suspended solids were lowest in Arroyo Pasajero with a 1998 concentration of 14 mg/L and a historical range of between 14 and 77 mg/L. The low levels there are attributable to ponding against the aqueduct and a decantation weir. The weir, installed in 1985, was designed to reduce sediment inputs into the aqueduct.

Inflow from the Jordan Group and Salt Creek exhibited nearly identical mineralogy in January 1998. Although a distance of 2 miles separates these drain inlets, runoff from both watersheds can apparently commingle prior to reaching the aqueduct, and historical data supports this. Conversely, mixing of Cantua and Salt creeks appears to be uncommon. Samples collected on the same day at Salt and Cantua creeks rarely exhibited similar mineralogy. A little more than 1 mile separates these 2 inlets. In late 1999, a new drain inlet was installed that combines floodwater from both watersheds.

Little Panoche Creek had higher chloride and sulfate concentrations than other floodwater sources to the aqueduct. This is an indication of upstream springs composed of connate water. Connate water is ancient seawater trapped between sedimentary deposits. Although most floodwater is high in salts, it does not usually exhibit these characteristics. Water reflecting the mineralogy of seawater would also contain other ocean-related parameters such as bromide. This was supported with a limited bromide database.

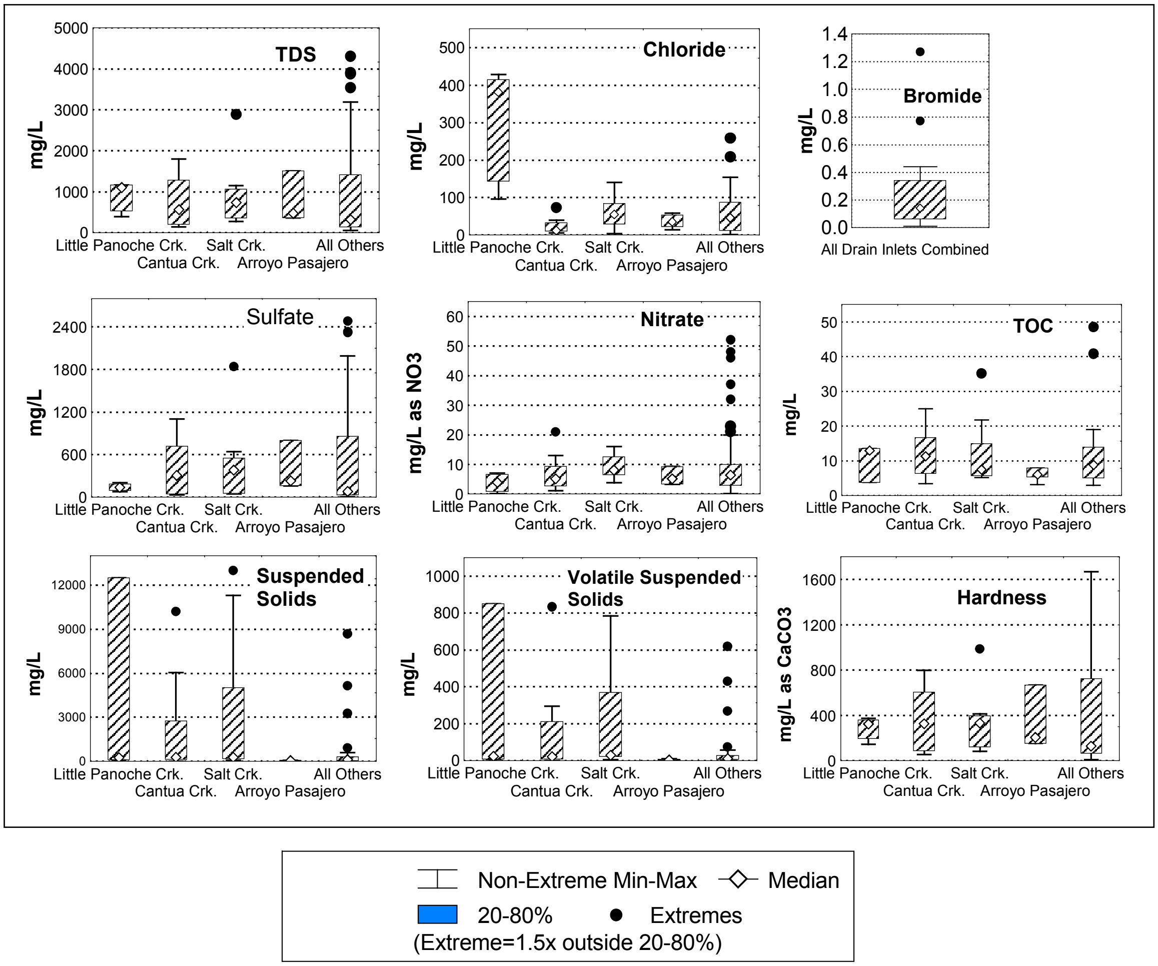
Bromide is not monitored routinely in floodwater, so no data exist for 1996 to 1999. Bromide in 15 historical floodwater samples ranged from 0.01 to 1.27 mg/L (Figure 8-17). The high value of 1.27 mg/L was measured in Little Panoche Creek. Another high value of 0.77 mg/L was measured in floodwater from Monocline Ridge (mile 113 to 119). Water from this area must be pumped in, and as a result, inflow volumes from this area tend to be relatively minor. One sample each from Arroyo Pasajero and Cantua and Salt creeks had relatively low concentrations of 0.03, 0.16, and 0.06 mg/L, respectively. Therefore, bromide was not consistently elevated in the few samples collected. However, the paucity of data precludes any final determination of whether floodwater is a major source of bromide to the aqueduct.

Table 8-16 General Water Quality Parameters in San Luis Canal Floodwater Inflows[a]

			Conventional Parameters									Cations				Anions			Other	
Watershed	Milepost	Sample Date	pH	Organic Carbon (Tot.)	Turbidity, NTU	Susp. Solids (Tot.)	Susp. Solids (Vol.)	TDS	Conductivity, µS/cm	Hardness (CaCO3)	Bicarbonate (CaCO3)	Calcium	Magnesium	Sodium	Potassium	Sulfate	Chloride	Nitrate (NO3)	Fluoride	Boron
Ortigalita Creek	82.67	1/27/1997	8.3	14	480	596	56	606	1000	209	194	41	26	126	NA	155	96	3.7	0.3	1.3
	82.67	2/3/1998	8.1	48.6	6,120	8,680	620	313	523	115	97	23.0	14.0	62.0	NA	95	38	5.2	0.3	0.50
Little Panoche Crk.	96.56	1/25/1997	8.3	NA	50	NA	NA	1100	1920	349	246	74	40	260	NA	132	381	1.6	0.5	7.1
	96.59	2/3/1998	8.1	13.0	9,920	12,500	850	391	681	144	100	38.8	11.4	79.8	NA	76	96	3.9	0.3	1.99
Monocline Ridge	115.43	3/3/1996	7.1	5	NA	31	4	232	394	95	55	20	11	39	NA	52	44	5.0	<0.1	0.3
Lateral 7L (Kings R.)	115.43	4/27/1998	7.4	NA	32	NA	NA	106	169	43	40	10.5	4.1	13.8	NA	19	13	1.0	<0.1	<0.10
	115.43	5/19/1998	7.9	NA	16	NA	NA	146	266	64	58	13.7	7.2	28.4	NA	25	32	0.5	<0.1	0.12
Cantua Creek	134.81	2/5/1996	8.7	7	NA	593	55	509	792	341	246	31	64	49	4.3	170	10	1.1	0.1	0.3
	134.81	1/3/1997	8.5	5	NA	106	7	372	629	263	207	26	48	31	3.3	109	6	1.2	0.1	0.3
Salt Creek	135.96	4/7/1998	NA	5.3	152	NA	NA	391	NA	130	NA	27.3	14.9	54.6	NA	83	57	5.6	0.1	0.37
	136.00	2/1/1996	7.9	14	NA	121	11	2890	3560	985	98	236	96	520	9.8	1840	140	12	0.5	2.1
	136.00	1/3/1997	7.8	22	NA	472	35	1150	1600	393	88	90	41	198	4.9	638	44	3.8	0.5	0.9
	136.00	1/13/1998	8.0	5.7	NA	169	24	310	539	116	80	27.5	11.6	62.4	NA	46	84	8.0	<0.1	0.18
Jordan Group	138.14	1/20/1998	8.0	7.5	101	132	10	323	576	128	81	26.7	15.0	62.0	NA	56	84	6.7	<0.1	0.22
	138.96	1/16/1997	7.0	4	42	15	1	242	412	100	32	30	6	38	NA	118	17	5.0	0.2	0.4
Skunk Hollow	146.44	2/17/1998	7.6	4.3	267	163	14	89	161	45	35	11.8	3.7	10.1	NA	9	5	22.7	0.2	<0.10
Arroyo Pasajero	158.38	2/8/1998	8.0	5.8	12	14	2	585	886	244	122	49.2	29.3	94.3	NA	283	22	3.7	0.3	0.51

[a] Units are mg/L unless otherwise noted.

Figure 8-17 Historical Water Quality of SLC Floodwater Inflows



Similar to bromide, TOC data for floodwater are not extensive. Median TOC levels in floodwater ranged between 7 and 12 mg/L (Figure 8-17). A very high value of 49 mg/L was reported for Ortigalita Creek in 1998 (Table 8-16), the highest ever recorded in floodwater. This sample was collected on the 1st day of inflow and likely captured the peak of a 1st flush effect. Concentrations can peak in the early stages of a runoff event and then taper off as less TOC is available to be flushed from a watershed (this can also occur with a number of other parameters). Inflows from Ortigalita Creek have historically been minor, but almost 2,000 af flowed into the SLC during 1998 when the high level was measured. TOC was lowest in Arroyo Pasajero and ranged from 3 to 8 mg/L in 7 historical samples. TOC ranged from 3.5 to 25 mg/L in Cantua Creek and from 5.2 to 35 mg/L in Salt Creek. Little Panoche Creek exhibited TOC levels of 13 and 13.9 mg/L in 2 samples.

Unlike the major minerals and other parameters of concern, minor elements are not typically elevated in floodwater inflows. From 1996 to 1999, arsenic levels ranged from 0.001 mg/L to 0.003 mg/L (Table 8-17). The highest arsenic level ever recorded in floodwater was 14 µg/L (DWR 1995). The database on arsenic is limited because the reporting limit was 10 µg/L up until 1986. Selenium in floodwater ranged from below detection to 16 µg/L (Salt Creek) from 1996 to 1999. For most drain inlets, selenium was below detection.

The common earth metals iron and manganese were detected at relatively low levels from 1996 to 1999 and never exceeded 0.051 mg/L (Table 8-17). Historically, higher levels have been detected in some of the smaller watersheds, but the cause of the high levels was never determined (DWR 1995). Aluminum was never detected above the reporting limit from 1996 to 1999.

Table 8-17 Water Quality of Minor Elements in San Luis Canal Floodwater Inflow (Concentration in mg/L)

	Watershed															
	Ortigalita Creek		Little Panoche Creek		Lateral 7L (Kings R.)		Monocline Ridge Grp.	Cantua Creek		Salt Creek			Jordan Group		Skunk Hollow	Arroyo Pasajero
Milepost	82.67	82.67	95.56	96.59	115.43	115.43	115.81	134.81	134.81	136.00	136.00	136.00	138.14	138.96	146.44	158.38
Sample Date	27 Jan 1997	3 Feb 1998	25 Jan 1997	3 Feb 1998	27 Apr 1998	19 May 1998	3 Mar 1996	5 Feb 1996	3 Jan 1997	1 Feb 1996	3 Jan 1997	13 Jan 1998	20 Jan 1998	16 Jan 1997	17 Feb 1998	8 Feb 1998
Aluminum	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Arsenic	0.003	0.002	0.002	0.003	0.001	0.001	0.001	0.003	0.002	0.002	0.001	0.002	0.002	0.003	0.004	0.001
Barium	0.056	<0.050	0.116	0.070	<0.050	<0.050	<0.050	<0.050	<0.050	0.128	0.101	0.093	0.052	0.055	<0.050	<0.050
Cadmium	<0.005	<0.001	<0.005	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.001	<0.001
Chromium	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	<0.005	0.003	<0.005	0.003	0.002	0.002	<0.005	0.005	<0.005	<0.005	<0.005	0.005	0.003	<0.005	0.002	0.004
Iron	0.034	0.009	<0.005	0.012	<0.005	0.009	0.041	<0.005	<0.005	0.007	0.006	0.020	0.030	0.006	<0.005	<0.005
Lead	<0.005	<0.001	<0.005	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.001	<0.001
Manganese	0.034	0.024	0.009	0.008	<0.005	<0.005	0.008	0.008	<0.005	0.010	0.007	0.010	0.051	<0.005	0.018	0.007
Mercury	<0.001	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.0002	<0.001	<0.0002	<0.0002
Selenium	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.003	0.016	0.007	<0.001	<0.001	0.002	<0.001	0.003
Silver	<0.005	<0.001	<0.005	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.001	<0.001
Zinc	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.050	<0.005	<0.005	<0.005

Organic chemicals, more specifically insecticides and herbicides, are routinely detected in floodwater inflows. The most frequently detected compounds from 1996 to 1999 were cyanazine, dacthal, simazine, diazinon, methadathion, trifluralin, oxyfluorfen, and diuron (Table 8-18). Cyanazine, diuron, and dacthal are preemergence and early postemergence herbicides (WSSA 1983). During the winter, applications are likely made to land west of the SLC in preparation for planting or general weed control. They are carried into the SLC when applications are followed by rainfall events.

The insecticide diazinon, and possibly simazine, is applied to stone fruit and nut orchards (almond, apricot, peach) to prevent flower bud predation by insects. Not as extensive as ground crops, orchards make up about 7% of the irrigated land west of the SLC. Applications are made in winter before trees blossom, the same period when floodwater inflows are highest. The window of application is between December and April. The offside migration of these pesticides from stone fruit orchards occurs around the Central Valley.

Most pesticides in floodwater are at or below 1 µg/L, and therefore, would have probably been diluted to below detection in the SLC. Two exceptions to these low levels occurred in 1998: Both cyanazine and dacthal were detected in a drain inlet from the Jordan Group at around 40 µg/L. These detections were made when inflow measured 7 af, thus, the pesticides would have been heavily diluted in the SLC. Another high detection occurred the same year in Salt Creek–cyanazine at 22 µg/L. Studies have shown that most pesticides are conveyed into the aqueduct via south Delta exports (DWR 1995).

Table 8-18 Water Quality of Organic Chemicals in San Luis Canal Floodwater Inflows (Concentration in µg/L)

	Watershed												
	Ortigalita Creek		Little Panoche Creek	Monocline Ridge Group	Cantua Creek			Salt Creek			Jordan Group	Skunk Hollow	Jordan Group
Milepost	82.67	82.67	96.59	115.43	134.81	134.81	136.00	136.00	136.00	138.96	138.96	146.44	158.38
Sample Date	1/27/1997	2/3/1998	2/3/1998	3/3/1996	2/5/1996	1/3/1997	2/1/1996	1/3/1997	1/13/1998	1/16/1997	1/20/1998	2/17/1998	2/8/1998
Chlorinated Pesticides	ND	ND	ND					ND				ND	ND
Simazine				0.40	<0.02	<0.02	0.03		0.14	0.60	0.11		
Diuron				3.47	<0.05	0.40	0.16			0.24			
Dacthal (DCPA)				0.08	0.03	<0.01	1.27			41			
Oxyfluorfen				<0.02	<0.02	0.07	<0.02			1.16			
Nitrogen/ Phosphorus Pesticides	ND	ND	ND								ND		ND
Cyanazine				0.16	0.15	0.47	0.92	1.02	22.10	40		0.39	
Diazinon				0.04	0.03	<0.01	0.09	<0.01					
Methidathion				<0.02	<0.02	<0.02	0.03	<0.02					
Trifluralin				<0.05	<0.05	<0.05	<0.05	0.12					
Chlorinated Phenoxy Acid Herbicides	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorinated Pesticides	ND	ND	ND						ND	ND	ND	ND	ND
2,4,-D				0.06	<0.10	<0.10	<0.10	<0.10					
Purgeable Aromatics	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbomate Pesticides	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Volatile Organics	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = None Detected

Data on asbestos in floodwater are limited because of cutbacks in asbestos monitoring during the 1990s. Existing data show asbestos is not consistently detected in floodwater, although high turbidities are partially responsible for many of the below-detection values. Asbestos ranged from <5.3 million fibers per liter or MFL (only fibers greater than 10 microns) to a high of 1,900 MFL in Salt Creek (Table 8-19). Asbestos analysis is hindered by high TSS levels typically present in floodwater inflows. Suspended solids are trapped along with asbestos during filtration and physically occlude individual fibers from being counted resulting in below detection results accompanied by unusually high detection limits.

8.3.4.2 Water Supply System

A complete 1996 to 1999 water quality assessment has already been performed for Check 13 and Check 21 (DWR 1999b and 2000). Below is a review of selected drinking water parameters for these stations along with any violations of the primary or secondary MCLs. Check 13 is technically identified as Dos Amigos Pumping Plant because flow is controlled there and not at the outlet of O'Neill Forebay. For the purposes of this discussion, Check 13 will refer to the forebay's outlet.

Check 13 (O'Neill Outlet)

Check 13 reflects the water quality of all inputs from O'Neill Forebay including inflows from the San Luis Reservoir, California Aqueduct at Check 12, and DMC.

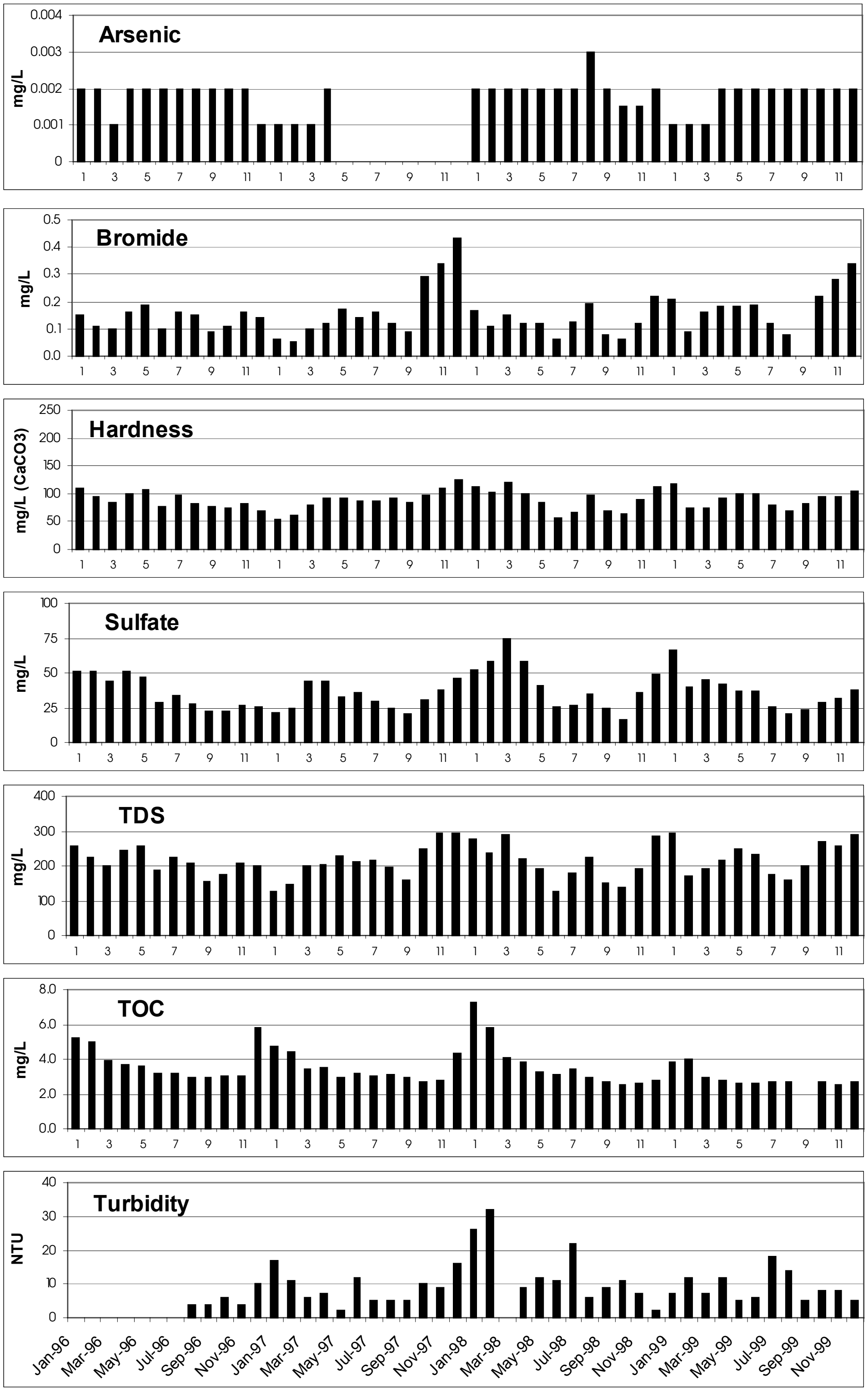
Arsenic ranged largely between 0.001 and 0.002 mg/L during the 1996 to 1999 period with 1 value reaching 0.003 mg/L (Figure 8-18). Bromide ranged largely below 0.2 mg/L with peaks of 0.43 mg/L and 0.34 mg/L during December of both 1997 and 1999, respectively. Hardness at Check 13 ranged from 54 to 125 mg/L and sulfate ranged from 16 to 74 mg/L. Peaks of these 2 compounds were much higher at Check 21 due to floodwater inflows. TOC exceeded 4 mg/L on several occasions, largely around January of 1996, 1997, and 1998. The TOC peak of 7.3 mg/L was detected in January 1998 when inflows to O'Neill Forebay were largely from San Luis Reservoir releases and the DMC. All organic chemicals (such as pesticides), metals, and nutrients were below any respective primary or secondary MCLs.

Table 8-19 Asbestos in San Luis Canal Floodwater Inflows

Watershed				
ID #	Name	Sample Date	Concentration MFL[a]	Detection Limit
28	Cantua Creek Group	4 Mar 1991	ND	11
		4 Mar 1991[b]	ND	5.3
		16 Jan 1993	950	320
		19 Feb 1993	380	380
29	Salt Creek Group	4 Mar 1991	ND	110
		16 Jan 1993	ND	1,300
		19 Feb 1993	1,900	480
	Milepost 137.80[b]	20 Mar 1991	ND	210
		20 Mar 1991[c]	ND	210
33	Arroyo Pasajero[d]	20 Mar 1991	ND	210
		20 Mar 1991[c]	ND	210
		17 Mar 1993	ND	64
		10 Mar 1995	83	23
		10 Mar 1995	166	45
		10 Mar 1995	416	113
		23 Mar 1995	17	5
		23 Mar 1995	42	11

[a] Million fibers per liter of fibers >10 microns in length. ND = Not Detected
[b] Replicate
[c] Pump-in from portable pump at milepost 137.80
[d] Water sampled from the ponding area weir although none was admitted to the aqueduct.

Figure 8-18 Water Quality on the California Aqueduct, Check Check 13



Check 21 is at the end of the SLC and represents aqueduct water affected by Diablo Range floodwater inflows directly upstream. Arsenic at Check 21 remained at or below 0.002 mg/L during 1996 to 1999 (Figure 8-19). Bromide trends were similar to those at Check 13, with a peak of 0.39 mg/L in November 1997. In February 1998, TDS was 593 mg/L, above the recommended secondary MCL for finished drinking water of 500 mg/L. In the same sample, sulfate was above the secondary MCL of 250 mg/L. These high levels were caused by floodwater inflows from the Diablo Range. Although not as extensive as Check 13 data, quarterly TOC sampling detected peaks of 6.2 mg/L during February 1996 and up to 5 mg/L in February and March 1998. Turbidity reached 69 nephelometric turbidity units (NTUs) in July 1998 and probably reflects the resuspension of floodwater sediments deposited several months earlier. Sediments deposited during winter when aqueduct flow is low can be resuspended during the summer when higher flows from increased demand cause increased scour. All organic chemicals (such as pesticides), metals, and nutrients were below any respective primary or secondary MCLs.

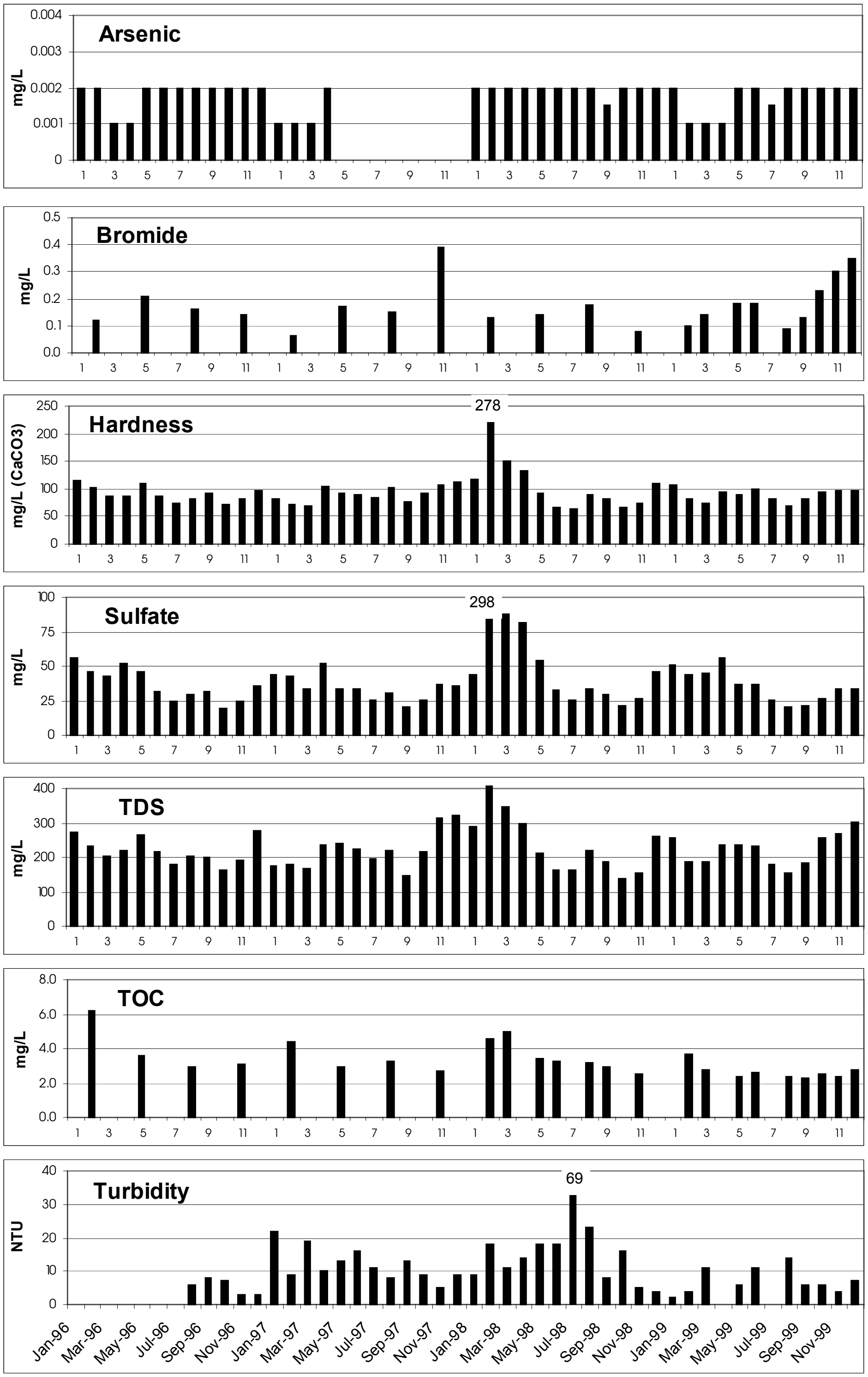


Figure 8-19 Water Quality on the California Aqueduct, Check 21

8.3.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The significance of floodwater inflows in general is discussed followed by the significance of individual sources and specific watersheds or both.

8.3.5.1 Floodwater Inflows

The single most significant PCS along the SLC, floodwater inflows are significant contributors of salt and sediment. Insufficient data were available to determine the significance of other important drinking water parameters such as bromide and organic carbon. Although available data show these compounds can be elevated in some drain inlets, not enough data exist to determine whether floodwater overall is the major source to the SLC. Pathogen data are also limited, but suspended solids can sometimes be an indicator of pathogens.

Suspended solids in floodwater can be up to 4 orders of magnitude higher than aqueduct levels. Up to 80% of the monthly sediment load to the aqueduct can come from floodwater inflows (DWR 1995). Unlike salts, sediment can settle out in the aqueduct, only to be resuspended when flows increase as deliveries are made the following summer. Suspended sediments cause problems for drinking water contractors and are potential indicators of other constituents such as pathogens and asbestos.

High turbidities (a measure of suspended solids) in raw water require greater coagulant dosages to settle the particles. The resulting floc quickly clogs filters, necessitating more frequent backwashing to keep the filters in operation. More floc means more sludge production, increasing management costs. High turbidities also interfere with the disinfection process. Particulates adhering to the surface of a bacterium's cell can shield it from the oxidizing action of disinfecting agents, thereby reducing treatment efficiency and increasing dosages needed to assure complete sterilization. Other effects include the formation of chlorinated organic compounds. Problems caused by floodwater sediment were particularly evident in 1995.

In March 1995, floodwater inflow discharged tons of sediment to the SLC. Because the sediment was composed largely of clay and silt, it was easily suspended in the aqueduct. The Avenal Water Treatment Plant was forced to shut down and issue an immediate boil order. Because of severe sediment loading and filter clogging, the plant was producing potable water with turbidities ranging between 1 and 6 NTUs, well above the 0.5 standard. A stoppage occurred on March 10 because of a break in the main line and elevated turbidities. Raw water turbidities peaked at 2,900 NTUs on March 11, decreased to 500 NTUs on March 12 and to 45 NTUs on March 13. Until the time of the break, the plant was producing potable water, although with difficulty. The difficulty was attributed to filter clogging which, in turn, forced more frequent and lengthy backwashing. Six days after the stoppage, the treatment plant was brought back into service. The boil advisory lasted for a total of 15 days.

Sediment from the March 1995 floodwater migrated downstream and affected Southern California water treatment plants several months later. High turbidities were initially detected on the East Branch of the California Aqueduct in June. All 5 MWDSC treatment plants taking water from Silverwood Lake experienced high influent turbidities that lasted almost 3 months. One plant measured turbidities of around 28 NTUs for a short period of time and elevated levels above 10 NTUs for about 2 months. During this period, treatment plants experienced various operational difficulties. Chemical dosages of alum, ferric chloride, and polymer coagulation enhancers were increased to handle the higher particulate loads. The turbidity goal of 0.10 NTU in finished water was exceeded several times at 1 plant. This goal is more conservative than the State's enforced maximum of 0.5 NTU and was adopted by MWDSC as recommended by the American Water Works Association (AWWA), EPA, and DHS. Increased sludge production resulted in handling difficulties and excessive equipment wear. Potable water production was slowed to facilitate particulate removal. Influent turbidities began returning to normal in early September. The added operational costs from this event approached $500,000.

Water drawn from the West Branch of the California Aqueduct was not affected because sediment had an opportunity to settle out in Castaic and Pyramid lakes. The settling capacity of Silverwood Lake on the East Branch is not as great because of a shorter retention time.

The 1995 flood also affected groundwater recharge operations in Kern County. SWP water was rejected during the spring/summer because the small grain size of the suspended sediment could effectively seal off pore spaces in the basin soils, potentially lowering infiltration rates. Once pore spaces have been plugged, restoration of a basin can be a time-consuming and expensive process. When heavy machinery is used to scrape the surface, soils can become compacted, further reducing infiltration rates. Another restoration technique involves planting crops to "reopen" the soil matrix. However, this effectively removes the basin from service for an extended period of time.

Kern County Water Agency (KCWA) staff estimated that their plan to recharge 150,000 af to 200,000 af during the summer months of 1995 would have brought 80,500 cubic yards of sediment into the participating basins. Delivery of SWP water to Kern Water Bank, Pioneer, and the city of Bakersfield recharge properties was delayed until turbidities dropped to acceptable levels.

Therefore, suspended sediment in the form of turbidity from floodwater inflows is considered to be significant, not only from a human health standpoint, but also from a water treatment plant management standpoint. As such, several recommendations were made to address these inputs. Sediment from floodwater has caused more problems than from TDS, the other general constituent that is elevated in floodwater inflows.

Similar to TSS, TDS is also relatively high in floodwater. Monthly salt loads to the SLC were estimated to be as high as 6% (DWR 1995). Salinity in the aqueduct has become a major concern to SWP contractors in Southern California. Salinity problems were documented in a recent study (Bookman 1999):

- Calcium and magnesium (components of salinity) leave deposits in plumbing systems and reduce the effectiveness of laundry detergents.
- Plumbing and home appliances wear out faster.
- At sufficiently high levels, salt can impart an undesirable taste in potable water.
- Salinity levels increase with each cycle of urban use for residential, commercial, or industrial purposes. When levels become too high, recycled water cannot be used for groundwater recharge or crop irrigation.

The MWDSC initiated a blending program to manage these issues. SWP water from the East Branch is blended with higher salinity water from the Colorado River to achieve a TDS goal of 500 mg/L, the secondary State and federal drinking water standard. As a result, salinity in the aqueduct has become an important issue. The secondary blending option occurs from April through September when floodwater inflows are unlikely. However, unlike pathogens, salt standards in drinking water were developed to reduce taste and odor problems, not to protect human health. Therefore, salt in floodwater would not be considered as significant as other more problematic constituents like suspended solids.

8.3.5.2 Asbestos from Arroyo Pasajero

Studies have documented elevated levels of asbestos in Arroyo Pasajero (DWR 1990). Recent data show the threat to drinking water from this source may not be as great as originally thought, although it is still a concern.

Airborne asbestos is a known human health threat. If inhaled, it can cause lung tissue scars, hindering oxygen exchange with blood capillaries. Asbestos has also been associated with the incidence of certain types of lung cancer. Alternately, the health implications linking human-related ailments to waterborne asbestos are not as clearly understood. Regardless, concerns over any potential health risks led the EPA in 1992 to adopt a standard of 7.1 MFL (longer than 10 microns) as the MCL for asbestos in treated drinking water.

Long-fiber asbestos concentrations ranged from below detection to 416 MFL in samples collected from inside Arroyo Pasajero's decantation weir where discharges to the aqueduct are made (see Section 8.3.4, Water Quality Summary). Most of these samples were collected when there was no flow, that is, inflow gates were closed at the time of sampling. This would allow some of the asbestos to settle out and result in an underestimate. On the other hand, Arroyo Pasajero has the lowest turbidities of any other floodwater source and, presumably, lower asbestos levels. The supposition that low suspended solids equals low asbestos is due to asbestos being a component of suspended solids. Therefore, the decantation weir and ponding basin strategy have been successful at reducing suspended solids and, presumably, asbestos. Regardless of the relative concentrations, most asbestos in Arroyo Pasajero is of the short-fiber type (fibers less than 5 microns in length on average), and these are considered less of a human health threat than the longer type (USACE 1999). Further, asbestos levels in the decantation weir were not that much higher than those in the aqueduct.

At Banks Pumping Plant, asbestos fibers greater than 10 microns ranged from 0.7 to 83 MFL (median 14 MFL) with detection limits of 0.19 to 22 MFL. The presence of asbestos in the aqueduct indicates that Arroyo Pasajero, as well as all drain inlets, are contributing to levels already present and routinely above the MCL of 7.1 MFL for treated drinking water. This would tend to diminish the significance of Arroyo Pasajero with respect to asbestos. Regardless of whether or not Arroyo Pasajero is a major source of asbestos to the aqueduct, studies show that the conventional water treatment process removes most asbestos present in aqueduct water.

In 1986 a study was undertaken to determine how much asbestos is removed through the conventional water treatment process. Three MWDSC plants in Southern California averaged 99% removal of total asbestos with raw water levels as high as 500 MFL. One plant operated by KCWA removed 99.9% of the raw water asbestos at levels ranging from 1.2 to 1,400 MFL total asbestos. This study would indicate asbestos inputs from Arroyo Pasajero, or possibly all floodwater sources, would not be as big a water quality threat as once thought. However, it is still considered a significant potential threat.

8.3.5.3 Other Sources

Most of the specific PCSs listed above were not considered significant. This includes, but is not limited to, most of the permitted facilities, urban runoff, toe drains, and unauthorized activity. The overwhelmingly large floodwater volumes generated west of the SLC would likely dilute any single source releasing a particular contaminant. Further, natural sources of potential contaminants such as TOC and pathogens can be inherently elevated in floodwater and would probably overshadow any input from 1 or several sources. In other words, it would be difficult to document whether a facility or activity in the watershed resulted in an increase in potential contaminants in floodwater admitted to the aqueduct. The exceptions, of course, are activities like pesticide applications or vehicles in the aqueduct. However, their significance was identified as minor. The other exceptions are confined animal facilities and pump-ins.

Both Harris Ranch (cattle) and Thommen Dairy are particularly significant PCSs. If the holding ponds that collect yard runoff failed, wastewater with very high pathogen levels could be released off-site. This water could pond against the aqueduct in the case of Harris Ranch or flow into the aqueduct in the case of Thommen Dairy. According to the CVRWQCB, breaches or releases from confined animal facility holding ponds are not uncommon. Further, neither site is permitted, so there is no oversight with respect to pond integrity or manure management. Therefore, a recommendation was made to specifically address these sources.

Pump-ins can increase salinity and, possibly, arsenic in the aqueduct. Although salinity is a concern to MWDSC because of its blending program, the associated MCLs were adopted to address problems of taste and odor, not human health. Arsenic is another constituent in pump-ins that DHS has identified as a potential threat to human health.

Approximately one-third of the SLC pump-in samples contained arsenic above 0.005 mg/L with a maximum of 0.032 mg/L. With the current MCL of 0.05 mg/L, these waters do not pose a threat to aqueduct water quality. However, anticipated changes in the law may lower this number to 0.01 or 0.03 mg/L. If this occurs, SLC pump-ins will become a significant source of arsenic.

8.3.6 WATERSHED MANAGEMENT PRACTICES

The only known watershed management activity west of the SLC is related to abandoned asbestos mines in Arroyo Pasajero. This activity, conducted by the EPA, is briefly described. Following is a review of DWR actions and procedures that are intended to reduce the input of floodwater to the aqueduct. Finally, the canal waste way proposal is described along with an existing structure that may be useful at lowering sediment loads.

8.3.6.1 Abandoned Mine Remediation

The abandoned asbestos mines in the Arroyo Pasajero watershed underwent remediation following a plan that contained 5 main elements (EPA 1994):

1) Run-on/Runoff Control—construction of diversion channels and sediment retention dams to minimize off-site release during storms.
2) Access Restriction—gates and signs to restrict access.
3) Re-vegetation—revegetation of disturbed areas to increase stability of the tailing piles and decrease erosion.
4) Road Maintenance—paving of roads through the area to reduce emissions and protect public health.
5) Mill Demolition—demolition of the mill and debris removal.

The Coalinga Mine and the city of Coalinga Unit were remediated, but the Atlas Mine was not. In 1999, revegetation progress at the Atlas Mine was studied (EPA 1999). From 1996 to 1998, a total of 28 acres were treated, planted, and seeded with more than 10,000 individual plants. The goal was to reduce the off-site movement of airborne and waterborne asbestos. Each phase of planting was increasingly successful. After each planting sequence, the right combination of plant species and soil amendments were identified and applied to the next planting phase. After the 3rd phase, about 75% of all plantings were living and potentially viable. Another 2 to 5 years of unaided growth will be needed before the Atlas Mine could be considered remediated. Regardless of the remediation, the Los Gatos Creek watershed remains a major potential source of asbestos to Arroyo Pasajero.

8.3.6.2 DWR Actions

Project Operating Procedures

A number of SWP operating procedures have been written and amended to address floodwater inflows. These are instructions that codify the operation of specific structures or incidents.

OP-13. The 1st is Project Operations and Maintenance Instruction No. OP-13. This order, last amended in 1993, addresses how all floodwater are to be handled. It has 4 major sections.

1) Make every reasonable effort to prevent or minimize the inflow of floodwater. The actions taken are usually further identified in SWP orders specific to particular floodwater structures (presented next).
2) Measure inflow volumes and provide information to Project Operations Control office, which is responsible for revising pump schedules and gate settings that may be affected by these inflows.
3) Monitor the water quality of floodwater inflows. Grab samples will be collected at drain inlets and ponded water pumped into the aqueduct. Flow measurements will be collected from pump run-time, visual estimates, or stage-discharge curves where available.
4) Coordinate the disposal of floodwater to confine sediment in the SLC to as small an area as possible. Some of the actions include the following: Reduce Dos Amigos pumping to meet San Joaquin Valley demands only; use floodwater to fill Southern California reservoirs; remove floodwater from the SLC via the KRI or other waste ways. These actions are to be coordinated with Project Operations Control.

SLFD-OP-95-8F AND SLFD-0P-97-8G. This standing order outlines the operating procedures of the Arroyo Pasajero floodwater gate structures. It essentially provides a sequence of measures to be taken in order to reduce inflows and protect noneasement property.

1) Use the retention basin north of Gale Avenue to store initial inputs.
2) If water in the 1st basin reaches elevation 328 at Gale Avenue, it will flow south onto private (noneasement) property all the way to Avenal Cutoff Road.
3) If water exceeds elevation 328 after both basins are filled, the evacuation culvert will be opened and water allowed to flow onto private property to the east.
4) If floodwater is predicted to exceed elevation 328 even after the culvert gates have been opened, floodwater will be admitted to the SLC via the inlet gates.

SLFD-OP-91-20E. This standing order dictates the operation of the inlet structure for Little Panoche Creek. The slide gates in front of the inlet are to be manipulated to limit sediment inputs. During initial flows, the slide gates will be closed and water passed under the aqueduct to the east ponding basin. When its capacity is reached, water will be redirected into the west ponding basin in front of the closed inlet gates. When a sufficient amount of sediment has settled in the ponding basin, the slide gates will be lowered to decant floodwater into the aqueduct. Slide gates will be lowered as needed to keep the water in the west ponding basin at a safe level.

LOS BANOS CREEK RETENTION DAM: This dam will provide 14,000 af of space for flood control between September and March. Dam releases are determined by the USACE, and downstream flows are not to exceed 1,000 cfs. The creek's rate of change is not to change by 100 cfs in any 4-hour period, in part because of the capacity of the evacuation culvert under the aqueduct. During spring and summer, reservoir levels are raised for recreation. Although there is an evacuation culvert to pass releases under the aqueduct, a weir was built in 1995 to accept floodwater into the SLC if flow gets high enough.

LITTLE PANOCHE CREEK DETENTION DAM: This dam modulates floodwater from the upstream watershed. It was designed to prevent peak flows from exceeding the capacity of the evacuation culvert on the SLC. Discharge from the outlet works is uncontrolled and will begin when the reservoir surface exceeds 603 feet. Discharges from the spillway are also uncontrolled and will occur when the reservoir levels exceed 642 feet.

Miscellaneous

In March 1992, the pump at mile 74.57 was disconnected. This was a permanent structure installed to pump water from the Billie Wright watershed into the SLC. Water from this watershed is highly saline and contains elevated selenium levels. Now the water flows under the aqueduct through an evacuation culvert. The water eventually passes through orchards to a bypass on the DMC.

During summer 1998, DWR field staff noticed agricultural drainage being pumped into a channel that led to Little Panoche Creek. Staff pointed out to the farm operator that the tail water, mostly from truck crops like strawberries, could flow into the aqueduct and may contain pesticides. The farm operator cooperated by stopping all discharges, and none have been reported since.

Waste way Proposal

A new DWR work plan was proposed in May 2000 to address all floodwater inflow (USACE and DWR 2000). The SLC would be used as a conveyance to transport floodwater to a newly proposed waste way turnout. The proposed turnout, just north of Check 21, could be operated to divert low quality floodwater out of the aqueduct and onto land to the east. The identified land would have to be purchased by DWR for the sole purpose of ponding floodwater. With modifications such as an 11-mile earthen dam, a bridge, and a siphon for an existing water conveyance, the land would serve as a retention basin with a capacity of about 70,000 af.

As opposed to earlier plans that focused on Arroyo Pasajero, this one has the added benefit of addressing (essentially removing) floodwater from all drain inlets including the largest—Cantua Creek. Modifications were also proposed specifically for Arroyo Pasajero; increasing the capacity of the ponding basin and installing a larger drain inlet. This was needed to handle a probable maximum flood scenario. Efforts are under way to investigate this plan in detail; a final feasibility report/EIS/EIR is tentatively scheduled for 2002.

Interceptor Drain Near Dos Amigos Pumping Plant

Starting at mile 83.7 and extending to Dos Amigos Pumping Plant at mile 86.7, an interceptor drain exists on DWR easement property. It intercepts drainage from agricultural fields that flow toward for the aqueduct. Once the drain fills, water can either overflow into the aqueduct or be pumped into another drain. Because of the drain's settling capacity, it provides an efficient means of reducing sediment loads to the aqueduct.

Runoff enters the interceptor drain at the north end (mile 83.7) and flows south. The drain gets progressively larger as it approaches South Mercy Springs Road at mile 85.07. At this point, the drain is about 20 feet wide and 15 feet deep. There are 2 pumps at this location—1 that pumps water to other side of the road and into another easement drain and 1 that pumps water into the aqueduct. The former is used by the landowner for irrigation recirculation purposes, and the latter is owned by DWR. DWR's pump is addressed in OP-350R and called "Open Drain Sump Pump (No 15.1)." The procedures state that this pump is to be used only when the landowner's pump is inoperative.

There is also a 6-by-4-foot drain inlet on the lip of the interceptor drain at mile 85.05. The intake is about 9 feet from the bottom of the drain. Therefore, any runoff large enough to fill the drain to this level would essentially be "decanted" into the aqueduct with presumably lower suspended sediments. Although 13 af was admitted to the aqueduct from this drain in 1998, no accompanying water quality samples were collected. Sediment is periodically removed from the drain to keep it operational, further evidence of its sediment removal capability. The sediment is removed by DWR staff and transported off-site. The existing information indicates that this drain provides a cost-effective means of keeping sediment out of the aqueduct. A recommendation was made to incorporate more of these interceptor drains along the SLC if they are feasible.

8.4 KETTLEMAN CITY TO KERN RIVER INTERTIE

8.4.1 WATER SUPPLY SYSTEM

8.4.1.1 Description of Aqueduct and SWP Facilities

Major facilities that make up section 4 of the California Aqueduct include a 69-mile long canal that extends from the end of the SLC (mile 172.4, below Check 21) to the KRI below Check 28 (mile 241) (Figure 8-20). Water flows by gravity and is not pumped into this section. The Coastal Branch Aqueduct begins at mile 184.63 just below Check 22 (see Chapter 9).

Figure 8-20 California Aqueduct: Kettleman City to Check 41 (Sections 4 and 5)

There is 1 continuous, cement-lined canal section within section 4 of the California Aqueduct, and flow is controlled along the reach with 7 check structures composed of 4 radial gates. The canal is constructed as a siphon under Avenal Gap at mile 184.27 and at Temblor Creek, mile 220.27. The siphons allow floodwater to flow over the aqueduct. As with other sections of the aqueduct, section 4 contains a number of structures built to handle surface water runoff and groundwater inflows that are potential sources of contamination (Table 8-20).

Table 8-20 Description of Structures from South of Avenal to the Kern River Intertie

Type	Number
Drain Inlets	
Canal Roadside Drainage	429
Agricultural Drainage	0
Groundwater	1
Other	5
Bridges	22
State	4
County	11
Farm or private	7
Overcrossings	111
Pipelines	59
Overchutes	52
Undercrossings	12
Drainage	10
Irrigation or domestic water	2
Water service turnouts	39
Irrigation pumped upslope	3
Other	27
Fishing Areas	9

8.4.1.2 Description of Agencies Using SWP Water

There are 6 agencies that receive SWP water in this section. Five of the 6 agencies use the water exclusively for agricultural purposes. The KCWA uses about 11% of its supply for municipal and industrial uses and another 1% for groundwater recharge. The agencies are presented in Table 8-21.

Table 8-21 Agencies Supplied by Section 4 of the California Aqueduct

Agency	Service Area (sq. miles)	Entitlement (acre-feet)
Oak Flat Water District	4,000	5,700
County of Kings	1,081	4,000
Empire West Side Irrigation District	12	3,000
Dudley Ridge Water District	60	53,370
Tulare Lake Basin Water Storage District	296	118,500
Kern County Water Agency	2,152	1,046,730

8.4.2 WATERSHED DESCRIPTION

The region traversed by section 4 of the California Aqueduct is sparsely populated, consisting mainly of crops and rangeland and does not contain watershed such as the SLC nor does it have substantial floodwater inflows.

8.4.3 POTENTIAL CONTAMINANT SOURCES

8.4.3.1 Recreation

The Kettleman City fishing access site is at the Milham Road crossing, just west of Kettleman City, and is very popular with the local people. Eight other fishing areas were identified in *Sanitary Survey 1990* (Brown and Caldwell 1990), but no estimate of user days is available. It is also unknown whether there are trash receptacles accessible to the public at these sites. Lack of such facilities could lead to contamination of the aqueduct with garbage. *Sanitary Survey 1990* reported that only 1 of the fishing sites had portable toilets, which increases the risk that the aqueduct can be contaminated with human waste.

8.4.3.2 Wastewater Treatment Facilities

There are no known wastewater treatment facilities discharging into section 4 of the California Aqueduct.

8.4.3.3 Floodwater Inflows

Water from the Kings River (7,236 af) was admitted to the aqueduct via Westlands Water District pumping facilities to Lateral 7 (mile 115.40) April to June 1998. It originated from the Westlands Water District inlet canal on the Mendota Pool and was composed largely of releases from Sierra Nevada dams for flood control. In typical years, no watershed runoff reaches the aqueduct in this section.

Sanitary Survey 1990 (Brown and Caldwell 1990) reports that there have been instances of overchute culverts overflowing into the aqueduct during periods of high runoff. Additionally, the report mentioned that erosion had occurred in the canal from unlined side slopes. It is unknown whether these deficiencies have been corrected.

8.4.3.4 Accidents and Spills

Interstate Highway 5 and State Highway 41 cross the aqueduct just south of Kettleman City. State highways 46, 58 and 119 cross near Wasco, Buttonwillow, and Bakersfield. There are no reports of accidents or spills flowing into the aqueduct, but storm water drainage from the bridges could contribute accumulated urban pollutants. Two bodies were recovered from this section of the aqueduct between June 1998 and August 1999. Two automobiles were also discovered in this reach of the aqueduct during the same time frame.

In December 1998, the Lost Hills oil fire deposited a light film of oil over a section of the aqueduct at mile 201.5 and extending downstream as far as Check 24. Cleanup efforts included oil booms in the water, which was periodically skimmed by a vacuum truck to remove the oil. The deposition of oil in the aqueduct lasted approximately 3 days. The oil well discharge was diverted after several days so that the plume would not be carried by the wind over the aqueduct. Cleanup efforts on the area continued, and it was reported that the discharge was sufficiently controlled to prevent further impacts on SWP water quality. However, this is still considered a moderate potential contaminate source.

8.4.3.5 Water Service Turnouts

There are 30 water service turnouts to various water districts in section 4 of the California Aqueduct (Brown and Caldwell 1990). Three of the turnouts are pumped, while the other 27 turnouts flow by gravity. No information was available on whether the pump turnouts had backflow prevention devices. Lack of such devices creates the potential for pesticides and nutrients in contaminated surface water to enter the aqueduct, which can pose a moderate threat to water quality.

8.4.4 WATER QUALITY SUMMARY

8.4.4.1 Watershed

There were no water quality data available for this aqueduct section, other than the Lost Hills fire incident, and none of the regularly monitored check stations are in this section. Check 21 is discussed in Section 8.2, The O'Neill Forebay; and Check 29 is discussed in Section 8.5.4.3.

The Lost Hills oil fire at mile 201.5 was the only major water quality problem noted for this section of the aqueduct. Drain inlets and overcrossings probably contribute some pollutants associated with urban runoff, but there were no data or reports on this and it is likely a very minor source.

The oil deposition in the Lost Hills oil fire was sampled to determine the status and extent of contamination. Samples were collected upstream, at the site of the film, and downstream of Check 24. The results showed relatively low TPH levels, ranging from 190 µg/L at the site to 630 µg/L at Check 24 (Joyce pers. comm. 1998). Several samples had levels below detectable limits. No follow-up information on the status of the oil deposition was available.

8.4.4.2 Water Supply System

The KCWA is the only agency in this section of the aqueduct that uses SWP water for municipal, industrial, and domestic use. Whenever possible, Irrigation District 4 trades SWP water for higher quality Kern River water, and uses SWP water solely for irrigation. On the occasions that Kern River water is not available, SWP water is conveyed from the aqueduct through the Cross Valley Canal, and pumped at the treatment plant into a temperature equalizing pond, and then treated by their normal process. No water quality data were available for this water treatment facility, but the KCWA has reported no problems with SWP deliveries.

8.4.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

There was only 1 significant floodwater inflow to this section of the aqueduct during 1998. Accidents or spills are the only other significant sources of contamination to the aqueduct, although recreational activity could be a potential source of pathogens. The December 1998 Lost Hills oil fire deposited a light film of oil over a section of the aqueduct, which reportedly was cleaned up by oil booms in approximately 3 days.

There is also potential for contamination from highway crossings. Rainfall in this section is sparse. Local runoff from the infrequent rain carries the accumulation of brake dust, tire rubber, and spills from vehicles into the aqueduct, but this is likely a minor threat to water quality.

Overcrossings exist in numerous locations in the form of pipelines and overchutes used to convey runoff across the canals. Materials conveyed in the pipelines include petroleum products, storm drainage, irrigation water, domestic water, and natural gas. If overchutes are designed with insufficient capacity or if sediment accumulation reduce pipeline capacity, floodwater inflows can enter the canal. Depending on the source of the runoff (roadside drainage, agricultural drainage), a number of different contaminants can enter the canal. Relative to the contamination risk to upstream sections of the California Aqueduct such as the SLC, the overall risk of contamination in section 4 is minor.

8.4.6 WATERSHED MANAGEMENT PRACTICES

The aqueduct was dredged in 1996 to remove sediment deposited by floodwater inflows the previous season. Dredging was done with a low-profile cutter head that suctioned material onto land west of the levee. Several locations were dredged between mileposts 157 and 163. Extensive monitoring determined that no substantial changes in aqueduct water quality occurred during the operation. There are no known watershed management activities west of this section of aqueduct. However, routine canal patrols and emergency plans such as discussed in Chapter 11 reduce the potential for discharge of contaminants into the aqueduct.

8.5 KERN RIVER INTERTIE TO EAST/WEST BRANCH BIFURCATION

8.5.1 WATER SUPPLY SYSTEM

8.5.1.1 Description of Aqueduct and SWP Facilities

This 63-mile section of aqueduct starts at mile 241 where the KRI is and ends where the East and West Branches of the California Aqueduct bifurcate at mile 304 below Check 41 (Figure 8-20).

Throughout this section are 4 pumping plants: Buena Vista, John R. Teerink, Ira J. Chrisman Wind Gap, and A. D. Edmonston. The Edmonston Pumping Plant is the largest of these and pumps water almost 2,000 feet over the Tehachapi Mountains into Tehachapi Afterbay at Check 41. From the Tehachapi Afterbay at milepost 303.45, the aqueduct continues another half-mile to the East/West branch bifurcation at milepost 304.

There are a number of over- and undercrossings to pass floodwater to the downslope, or eastern side of the aqueduct, including 23 overchutes and 18 evacuation culverts (Table 8-22). Although there are 10 designated fishing areas, fishing has been observed at numerous undesignated locations. Toe drains convey runoff from adjacent operating roads or road crossings.

Several toe drains convey natural runoff from a small area of adjacent hillside into the Tehachapi Afterbay. Sanitary Survey 1990 (Brown and Caldwell 1990) addressed the significance of most of these features as contaminant sources. The most notable feature in Table 8-22 from a water quality standpoint is the KRI. The KRI is a gated channel designed to convey water into or out of the aqueduct. Inflow from the KRI can occur during the winter when Sierra Nevada runoff threatens to flood agricultural land in the dry lakebeds of Tulare and Buena Vista. This occurred in 2 out of 4 years from 1996 to 1999.

Table 8-22 Major Structures on the Aqueduct, Milepost 241 to 304

Structure	Number
Toe drains for canal operating road and/or canal right of way	327
Bridges	17
Overcrossings	76
Pipelines	53
Overchutes	23
Undercrossings	18
Evacuation culverts	18
Waste way or drain	2
Kern River Intertie	1
Pastoria Creek Drain	1
Siphons	9
Water service turnouts	24
Fishing areas	10
Submersible pumps for relieving canal seepage and/or groundwater pressure against the lining	36

Sources: Brown and Caldwell 1990, DWR 1999a.

Similar inflows (Sierra Nevada runoff) were admitted to the aqueduct from the Cross Valley Canal in 1998. The Cross Valley Canal is a turnout used to make deliveries to KCWA. However, flow is sometimes reversed to alleviate flooding of agricultural land in the Tulare Lakebed. Although this source is upstream of the KRI at milepost 238, it is discussed here because its inflows coincide with KRI inflows.

8.5.1.2 Description of Agencies Using SWP Water

The KCWA uses all 24 turnouts throughout this section of aqueduct. The diverted water is used for a variety of purposes, including agriculture, groundwater recharge, and municipal/industrial. Most of the water taken for municipal/industrial use during 1998 was diverted between mileposts 241 and 243 and 282 and 293 (DWR 1999d).

8.5.2 WATERSHED DESCRIPTION

Section 5 of the aqueduct traverses the southern San Joaquin Valley and Tehachapi Mountains of Southern California. The dominant land use in this region of the San Joaquin Valley is cropland and rangeland. The Tehachapi Mountains are generally aligned near east-west and form the southern end of the Sierra Nevada. The range is composed of granitic rocks with limited areas of pre-batholith metamorphic outcrops. Elevation ranges from about 3,500 feet up to 7,981 feet. The predominant natural plant communities are Blue oak, singleleaf pinyon, and canyon live oak; mixed chaparral shrublands are common on shallow soils. There are some Ponderosa pine, Jeffrey pine and White fir in the higher elevations. Black oak and Valley oak are common on mountain footslopes and in valleys of the Tehachapi Mountains.

8.5.3 POTENTIAL CONTAMINANT SOURCES

Sanitary Survey 1990 addressed several PCSs to this section of aqueduct, including bridges, overcrossings, water service turnouts, fishing, and accidental spills. However, the largest PCSs are inflows from the KRI, Cross Valley Canal, and groundwater pump-ins. Following is a general description of these 3 as well as miscellaneous PCSs.

8.5.3.1 Kern River Intertie

The KRI is a gated channel designed to convey water into, or out of, the aqueduct. It is used mostly to convey water into the aqueduct to relieve flooding east of the aqueduct. Inflow from the KRI can occur during the winter when Sierra Nevada runoff threatens to flood agricultural land in the dry lakebeds of Tulare and Buena Vista. Flood-flows from the Kern River pass through a siltation basin and then into the aqueduct at milepost 241, approximately 3 miles above Check 29. A more detailed description of the Kern River watershed and PCSs can be found in previous sanitary surveys. The KRI is a significant potential source of turbidity and is considered a moderate threat to water quality.

Between 1996 and 1999, water from the KRI was admitted to the aqueduct on 2 occasions (Table 8-23). In 1997 inflows totaled 52,858 af and occurred between 9 January and 26 February. The following year, 188,048 af of KRI water entered the aqueduct. During both inflow events, most of the water sent down the aqueduct was from this source (DWR 1999b and 2000).

During 1998, 10,398 af of water was also admitted to the aqueduct via the Cross Valley Canal (milepost 238.04, just prior to Check 28), which is a turnout used to make deliveries to KCWA. In 1998 water was pumped from the canal into the aqueduct to alleviate flooding of agricultural land in the Tulare Lakebed. Cross Valley Canal inflows originated from the Tule and Kaweah rivers and were sent to the aqueduct via the Friant-Kern Canal. Water quality of inflows from the Cross Valley Canal and KRI is described in Section 8.5.4, Water Quality Summary.

Table 8-23 Inflow to the Aqueduct from the Kern River Intertie, 1996 to 1999

Year	Period	Avg Flow	Total Volume
1997	9 Jan – 26 Feb	550 cfs	52,858 af
1998	3 Apr – 8 Jul	977 cfs	188,048 af

8.5.3.2 Groundwater Discharges

Groundwater can be pumped into the aqueduct from DWR sump pumps that protect the canal liner. There are 36 of these in this section of aqueduct (Table 8-22). As with sump pumps located in the SLC, no quantity or quality information was available.

Groundwater can also originate from any of the 24 water service turnouts (DWR 1994). Groundwater underlying land east of the aqueduct can be conveyed into the aqueduct via these turnouts in return for an equal amount of SWP water returned at another time and place than the original pump-in. Pump-ins mitigate for supply deficiencies imposed on federal water contractors, usually during drought periods. Although there were no pump-ins from 1996 to 1999, they remain a potential source of salinity and arsenic.

Pump-ins within this section of the aqueduct have higher levels of TDS and arsenic than aqueduct water. More than half of the pump-in samples collected between mileposts 241 and 304 contained arsenic higher than 0.005 mg/L (the mean) with a range of <0.001 to 0.010 mg/L (DWR 1994). TDS ranged from 549 to 1140 mg/L with an average of 763 mg/L. Therefore, pump-ins are a source of TDS and arsenic to the aqueduct. A new policy regarding future pump-ins has been negotiated.

8.5.3.3 Recreation

There are 10 designated fishing areas, but fishing activity has been observed at numerous undesignated locations. There is no contact recreation allowed in the aqueduct. However, human waste and trash associated with these activities are considered a moderate potential source of pathogens.

8.5.3.4 Accidents/Spills

In June 1999, two oil releases were reported at Chrisman Pumping Plant. On the 1st occasion, approximately 280 gallons of hydraulic oil were released into the number 1 discharge line. The line was drained back, and the oil removed. A similar release occurred later that month involving 15 to 20 gallons. On this occasion, booms were placed in the aqueduct to contain and recover the oil.

Several other potentially contaminating accidents/spills took place from 1996 to 1999. The 1st occurred when a blacktop roller tipped over in the aqueduct. The 2nd occurred in 1999 when a fuel tank went into the aqueduct after a truck accident on the Interstate 5 crossing about 8 miles upstream from the Edmonston Pumping Plant. An oil sheen was observed in the pumping plant's forebay and determined to have come from the accident. Information from the truck owner indicated the tank contained 15 to 20 gallons of diesel fuel. DFG divers were unable to locate the tank. Oil booms were used to remove the fuel in the forebay. A 3rd incident involved a truck that was observed dumping mulch and paper debris into the aqueduct near the Sunset Railroad siphon (approximately milepost 260). This is considered a moderate potential source of hydrocarbons in the aqueduct.

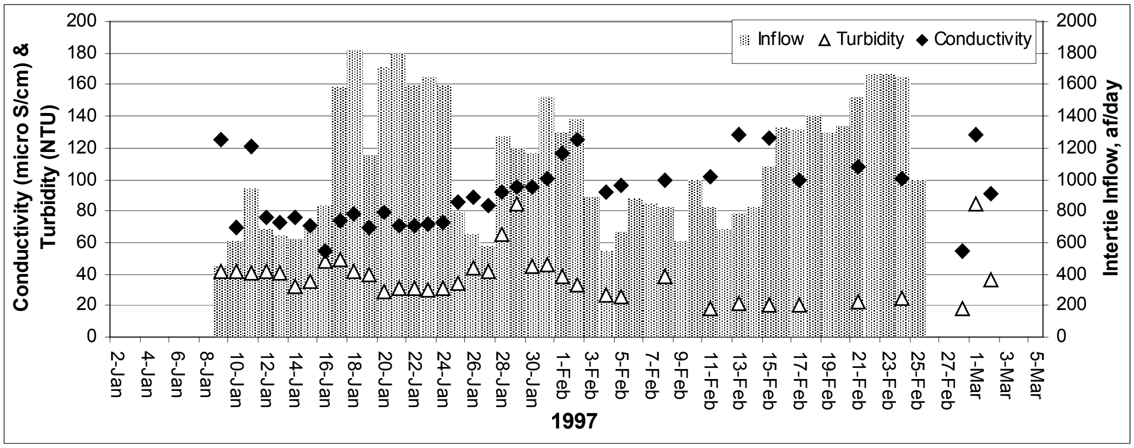
8.5.4 WATER QUALITY SUMMARY

A water quality assessment of the KRI and Cross Valley Canal is followed by a review of water quality in the aqueduct at Check 29 and Check 41.

8.5.4.1 Kern River Intertie

Low salinity and relatively moderate turbidity characterizes the water quality of inflows from the KRI. During the 1997 inflow event, daily conductivity ranged from 55 to 128 µS/cm with an average of 91 µS/cm (Figure 8-21). Similar levels were measured downstream in the aqueduct at Check 29 and Check 41 soon after the KRI gates were opened (DWR 1999b). Turbidity in the KRI ranged from 18 to 85 NTUs with an average of 37 NTUs. Downstream turbidity in the aqueduct generally following KRI trends but at lower levels.

Figure 8-21 Conductivity, Turbidity, and Volume of Kern River Intertie Inflows, 1997



Laboratory analyses of the 1997 KRI inflows showed low mineral levels, TOC levels of 4.0 and 4.9 mg/L in 2 samples, and arsenic levels between 0.002 and 0.003 mg/L (Tables 8-24 and 8-25). A complete metals scan detected low levels of iron. All other metals were below the reporting limit. A single sample collected for organic chemicals contained diuron at 0.39 ppb and simazine at 1.41 ppb (Table 8-26). Although bromide was not analyzed in KRI inflows, downstream levels in the aqueduct dropped to <0.01 mg/L at Devil Canyon Afterbay in February 1997, coinciding with the period of inflow (DWR 1999b).

Table 8-24 Major Minerals and Conventional Parameters in the Kern River Intertie and Cross Valley Canal, 1997 to 1998 (mg/L unless otherwise stated)

	Kern River Intertie						Cross Valley Canal	
	9 Jan 1997	13 Jan 1997	28 Jan 1997	11 Feb 1997	6 Apr 1998	14 Apr 1998	6 Apr 1998	14 Apr 1998
Bicarbonate ($CaCO_3$)	33	32	40	44	63	64	57	66
pH	6.8	6.7	7.0	7.0	7.9	7.9	7.6	7.9
Sulfate	4	4	4	6	9	9	9	9
Chloride	2	3	3	3	4	4	4	6
Nitrate (as NO_3)	1.3	1.1	1.7	1.2	2.2	1.8	3.7	2.5
Fluoride	<0.1	<0.1	<0.1	0.1	0.1	0.2	<0.1	0.1
Boron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Organic Carbon	4.9	4.0				4.5		4.1
Suspended Solids (Tot.)	29	28	47	17	29	56	88	28
Suspended Solids (Vol.)	2	6	6	6	6	6	11	4
Turbidity (NTU)		23	31	12	58	38	85	24
TDS	66	61	72	80	110	102	102	124
Conductivity (micro S/cm)	89	80	103	115	161	166	155	176
Hardness (as $CaCO_3$)	28	28	33	36	57	59	54	59
Calcium	8	8	10	11	16	17	15	17
Magnesium	2	2	2	2	4	4	4	4

Table 8-25 Minor Elements in the Kern River Intertie and Cross Valley Canal, 1997 and 1998 (mg/L)

	Sample Dates							
	Kern River Intertie						Cross Valley Canal	
	9 Jan 1997	13 Jan 1997	28 Jan 1997	11 Feb 1997	6 Apr 1998	14 Apr 1998	6 Apr 1998	14 Apr 1998
Arsenic	0.003	0.002	0.002	0.003	0.004	0.004	0.002	0.002
Barium	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Aluminum	<0.010	0.010	<0.010	0.010	<0.010	<0.010	<0.010	<0.010
Zinc	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury	<0.0010	<0.0010	<0.0010	<0.0010	<0.0002	<0.0002	<0.0002	<0.0002
Manganese	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001
Iron	0.020	0.021	0.017	0.023	0.018	0.016	0.010	0.008
Copper	<0.005	<0.005	<0.005	<0.005	0.003	0.002	0.006	0.002
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.001	<0.001

Table 8-26 Organic Chemicals Detected in the Kern River Intertie[a]

	Sample Date	
	16 Jan 1997	6 Apr 1998
EPA 608 Scan (Chlorinated Organics)		ND
Diruon	0.39	
Simazine	1.41	
EPA 614 Scan (Organo-Phosphorus Pesticides)	ND	ND
EPA 615 Scan (Chlorinated Phenoxy Acid Herbicides)	ND	ND
EPA 602 Scan (Purgeable Organics)	ND	ND
EPA 547 Scan (Glyphosate, Propargite)	ND	ND
EPA 531.1 Scan (Carbamates)	ND	ND

[a] µg/L, ND = None Detected

Table 8-27 Pathogens in Kern River Intertie Inflows, 19 Jan 1997

Pathogen	Units	Concentration
Fecal Coliforms	MPN/ 100 mL	220
Total Coliforms	MPN/ 100 mL	1,600
Giardia	# Cysts/ 100 L	73
Cryptosporidium	# Oocysts/ 100 L	10.4

One pathogen sample was collected for coliforms, *Giardia cysts*, and *Cryptosporidium oocysts* (Table 8-27). Pathogen data are discussed in Chapter 12.

During 1998, water from both the Cross Valley Canal and KRI was admitted to the aqueduct. Conductivity in the KRI ranged from 63 to 170 µS/cm with an average of 104 µS/cm. Conductivity was higher in the Cross Valley Canal with 2 of the 8 values increasing to 525 µS/cm (Figure 8-22). However, the high level measurements were on days with no inflow. On 20 April and 30 April, conductivity was 521 and 525 µS/cm, respectively. These levels were unusual because conductivity was rarely above 200 µS/cm in either the Cross Valley Canal or KRI. Although there was no inflow on those days, there were several days surrounding those dates where inflows occurred with no conductivity measurements. The automated monitoring station at Check 29 indicated a multiday rise in conductivity corresponding with the 20 April and 30 April dates (DWR 1998). Therefore, Cross Valley Canal inflows with elevated conductivity appear to have affected aqueduct water quality.

The cause of the high Cross Valley Canal conductivity remains unknown. Staff from the KCWA was contacted but provided no explanation. Possible explanations include side drains on the Friant-Kern Canal that take in runoff from adjacent farmland. Groundwater pump-ins could have been made to the Cross Valley Canal. Regardless, the higher salinity indicates that water other than Sierra Nevada runoff such as with the KRI had entered the Cross Valley Canal.

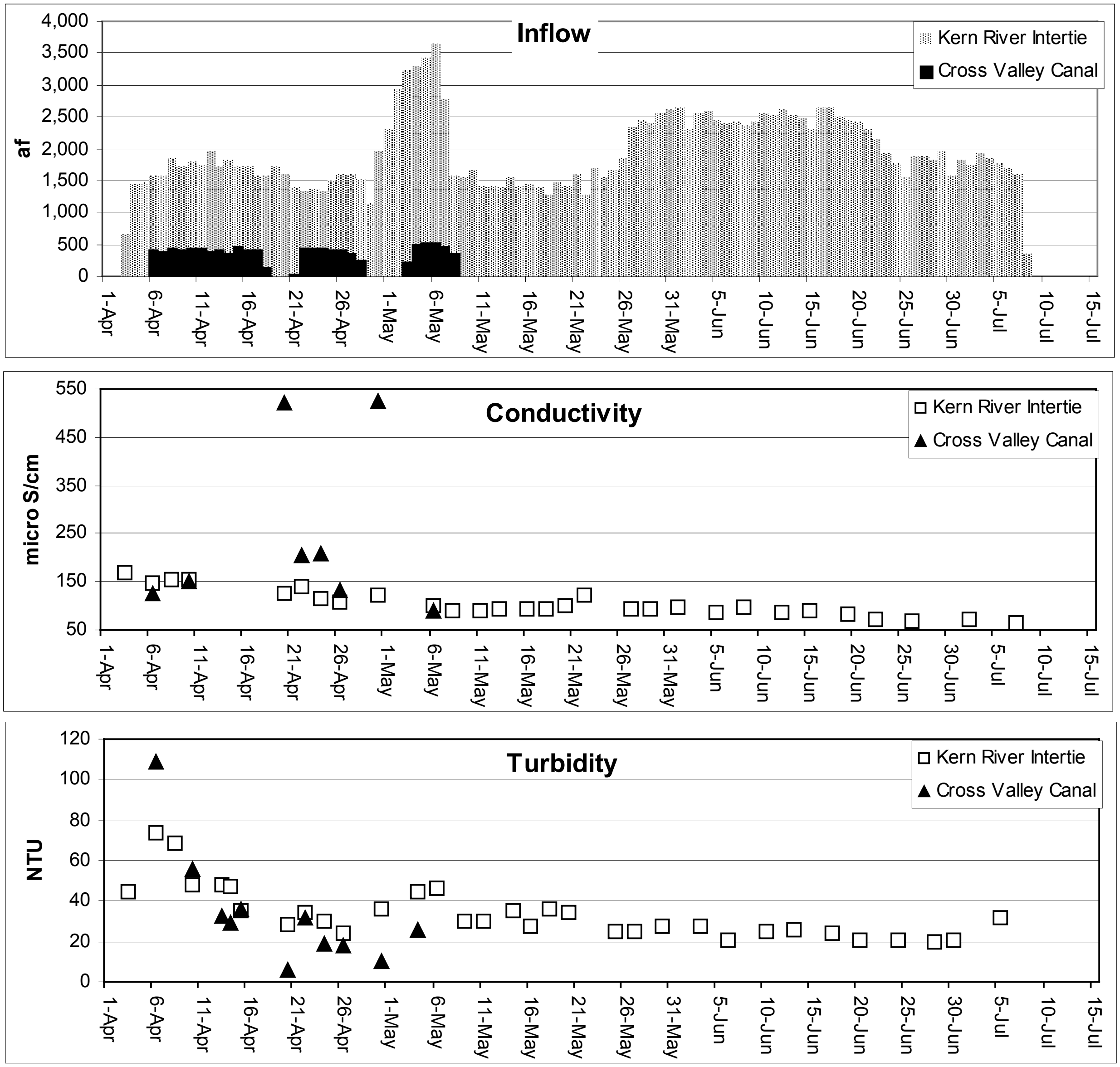
Turbidity in both sources was highest during the 1st week of inflow. For the KRI, turbidity during the 1st week ranged from 45 to 74 NTUs and then tapered off to between 20 and 45 NTUs for the rest of the inflow period (Figure 8-22). A similar trend was observed for the Cross Valley Canal. Note that the lowest levels in the Cross Valley Canal were measured when conductivity was highest. However, as explained, there had been no inflow on those days, and the low turbidities may be due to particulates settling out in calm water.

Laboratory analyses of both inflows during 1998 showed low mineral levels, organic carbon concentrations of 4.1 and 4.5 mg/L in 2 samples, and arsenic ranging between 0.002 and 0.004 mg/L (Tables 8-24 and 8-25). With the exception of low levels of copper and iron, no other metals were detected in the 1998 inflows. No organic chemicals were detected (Table 8-26). Bromide was not analyzed in the inflows; however, downstream levels in the aqueduct at Check 41 ranged from 0.010 to 0.012 mg/L between April and June, corresponding with the period of inflow (discussed next).

8.5.4.2 California Aqueduct

This section of the aqueduct has 2 routine monitoring stations, Check 29 and Check 41. A complete water quality assessment has already been performed on these stations for 1996 through 1999 (DWR 1999b and 2000). A review of select drinking water parameters appears below along with any important observations.

Figure 8-22 Conductivity, Turbidity, and Volume of the Kern River Intertie and Cross Valley Canal Inflow

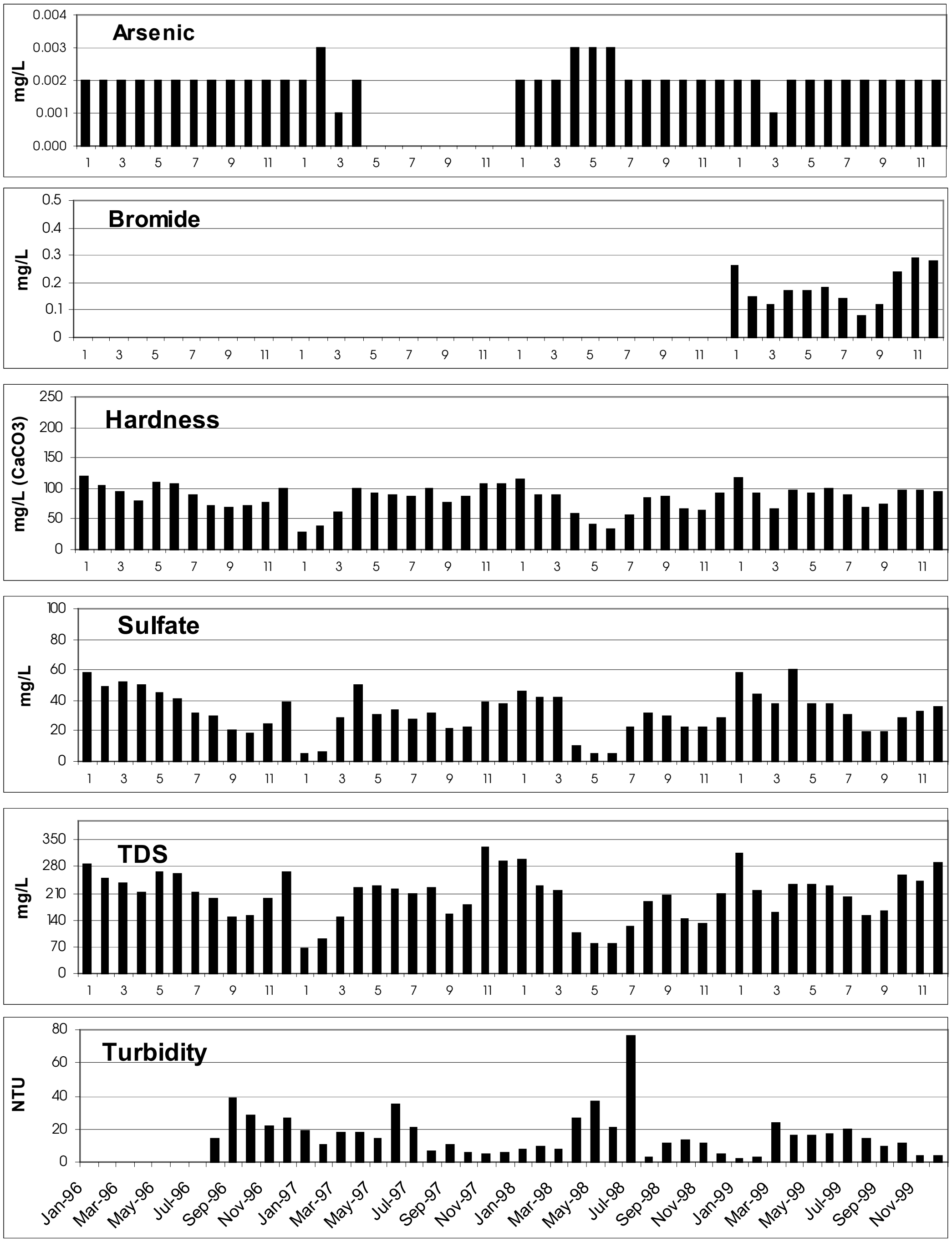


8.5.4.3 Check 29

Check 29 is downstream from the Cross Valley Canal and KRI at mile 244.54. None of the water quality data collected from 1996 to 1999 exceeded any primary or secondary MCLs (DWR 1999b and 2000). Organic chemical analyses during 1996 showed low levels (at or below 1 ppb) of 2,4-D, cyanazine diazinon, dacthal, diuron, and simazine. During 1997 only 2,4-D, cyanazine, and simazine were detected. No organic chemicals were detected at this station in either 1998 or 1999.

Arsenic levels were usually between 0.001 and 0.002 mg/L during the 4-year period and increased to 0.003 mg/L only from April to June 1998 when KRI water dominated aqueduct flow (Figure 8-23). Bromide data were limited because monitoring only began in 1999. TOC is not monitored at Check 29.

Figure 8-23 Water Quality on the California Aqueduct, Check 29



TDS, hardness, and sulfate declined to unusually low levels at Check 29 when water from the KRI was admitted to the aqueduct in both 1997 and 1998. Sulfate went from 39 mg/L in December 1996 to 5 mg/L the following month in 1997. TDS and hardness also declined in January 1997. The same trend occurred the following year from April to June. The declines were largely the result of Sierra Nevada inflows from the KRI, as discussed above.

Turbidity at Check 29 ranged between 2 and 76 NTUs from 1996 to 1999 (Figure 8-23). The high value of 76 NTUs was measured in July 1998, well after KRI inflows had ceased, and was likely due to the resumption of summer flow through the SLC and the corresponding resuspension of sediment discharged by Diablo Range floodwater 5 months earlier. Sediments deposited during low aqueduct flow in winter can be resuspended during summer when demand increases along with the scouring effects of increased flow. An even higher turbidity value was measured that same month farther downstream at Check 41.

8.5.4.4 Check 41

Check 41 is at mile 303.41, just above the bifurcation of the East and West Branches of the California Aqueduct. None of the water quality data collected from 1996 to 1999 exceeded any primary or secondary MCLs (DWR 1999c and 2000). Similar to Check 29, low levels (at or below 1 ppb) of 2,4-D, cyanazine diazinon, dacthal, diuron, and simazine were detected at this station during 1996. The following year, only cyanazine was detected (at the reporting limit of <0.01 ppb in March 1999). No organic chemicals were detected at this station in either 1998 or 1999.

Arsenic at this station was 0.002 mg/L for most of the 4-year period (Figure 8-24). TOC ranged from 2.2 to 9.3 mg/L. Two values of more than 8 mg/L were detected during 1996 to 1999. The 1st occurred when a concentration of 8.1 mg/L was measured in July 1996. No non-SWP inflows occurred that month. Unusually, trihalomethane formation potential (THMFP) was not correspondingly high in the same sample (DWR 1999b). A similar event occurred in January 1999 when TOC was detected at 9.3 mg/L and THMFP was not correspondingly elevated. No explanation could be provided (DWR 2000).

Similar to Check 29, Check 41 was positively affected by the KRI inflows during 1997 and 1998. In February 1997 hardness, sulfate, and TDS declined to some of the lowest levels measured during the 4-year period and coincided with the period of KRI inflow (Figure 8-24). The following year, these inflows occurred again for a 3-month period from April to July, and minerals at Check 41 declined correspondingly. Bromide decreased to 0.010 to 0.012 mg/L, representing some of the lowest salinity ever measured in the aqueduct (mineral data for 2 of the 3 months were missing).

8.5.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

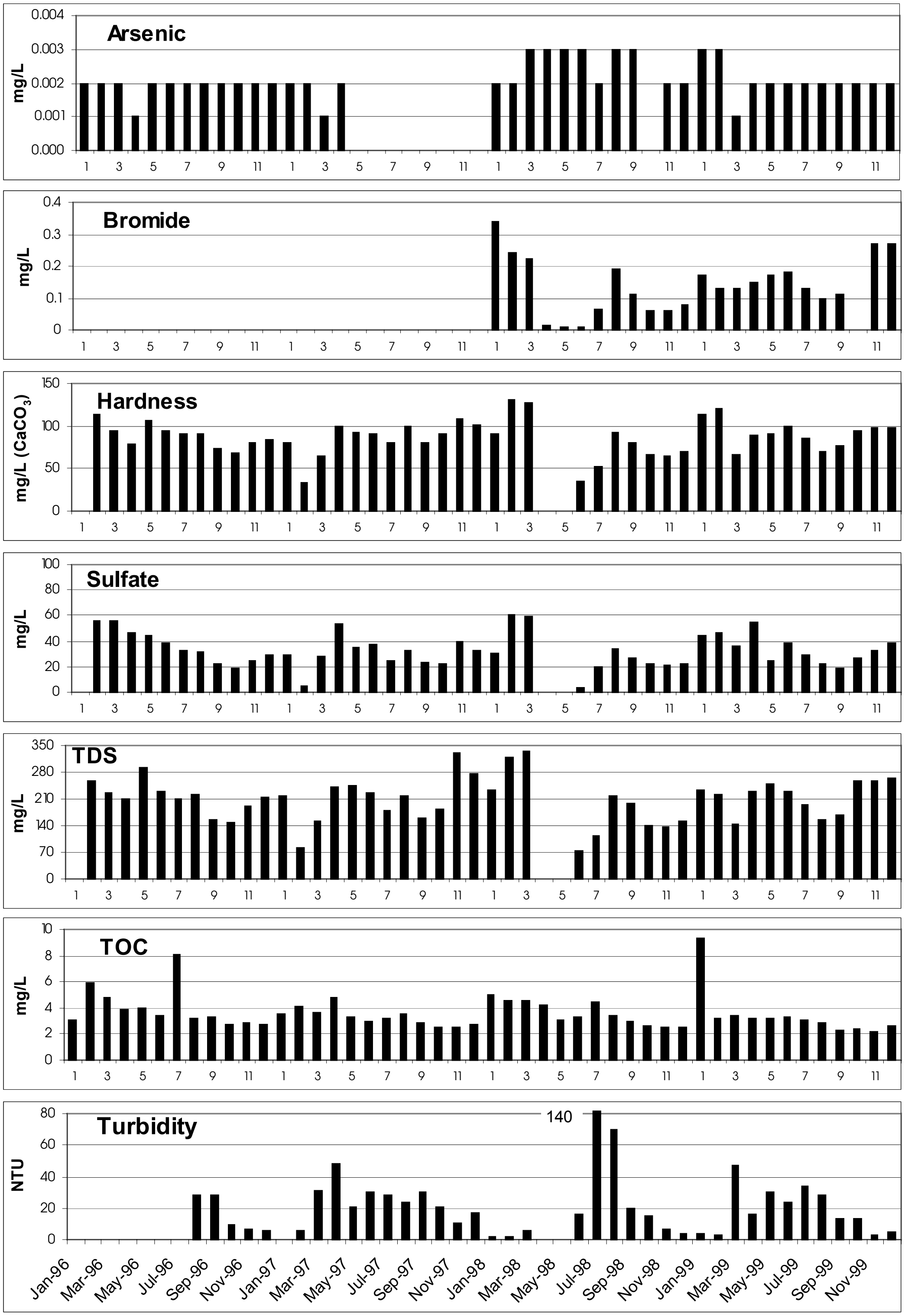
Sanitary Survey 1990 addressed the significance of several features in this section of aqueduct, including bridges, overcrossings, water service turnouts, fishing, and accidental spills. However, the largest source of non-SWP inflow to this section is from the KRI, Cross Valley Canal (just upstream of KRI), and groundwater pump-ins. Their significance with respect to potential contaminants in inflows is discussed here.

8.5.5.1 Kern River Intertie

During 1997 and 1998 the KRI contributed a substantial amount of water to the aqueduct. In 1998 for instance, KRI inflow totaled 188,000 af while floodwater from the Diablo Range totaled 21,000 af. KRI inflow made up most of the water sent down the aqueduct for more than a month during 1997, and almost 3 months during 1998 (DWR 1999b and 2000). Therefore, the KRI was a significant source of water to the aqueduct during those years. With regards to water quality, the KRI appears to provide a net benefit to the aqueduct, specifically with respect to salt and salt-related potential contaminants. The only exception to this is for turbidity, which is considered a moderate threat to water quality.

KRI inflows are of high quality with respect to most drinking water parameters. The inflows resulted in some of the lowest salinity and bromide levels ever measured in the aqueduct. A limited number of TOC samples collected from the KRI were consistently between 4 and 5 mg/L. Although levels in the aqueduct have been lower than this, KRI inflows occur during—or and in the case of 1998 right after—winter when TOC in Delta exports can be as high or higher. Therefore, KRI inflows would contribute to levels already in the same range and may actually provide some dilution when TOC in Delta exports is higher. KRI arsenic levels were sometimes higher than those commonly detected in the aqueduct, but were well below the MCL of 0.05 mg/L.

Figure 8-24 Water Quality on the California Aqueduct, Check 41



Sanitary Survey 1990 identified oil fields and urban runoff from Bakersfield as pollutant sources to the Kern River and, hence, the aqueduct from KRI inflows. Two extensive pollutant scans did not indicate any signs of pollution related to these 2 potential sources: elevated metals and hydrocarbons. Although urban runoff may have commingled with Kern River water, the higher river volumes would have provided heavy dilution. Further, most pollutants associated with urban runoff and oil fields (metals, general hydrocarbons such as polycyclic aromatic hydrocarbons, and organo-chlorine pesticides) are tightly associated with sediment and would move through the system as bedload or suspended sediment. Therefore, the significance of this PCS, in relation to others, would be considered minor. With the exception of turbidity, the net benefit to water quality in the aqueduct would appear to offset any potential problems.

Cross Valley Canal inflows would also appear to provide a net benefit to aqueduct water quality. Although data on its water quality are limited, inflow volumes were relatively minor compared to those from the KRI.

Pump-ins can increase salinity and, possibly, arsenic in the aqueduct. Although salinity is a concern to MWDSC because of its blending program, the MCLs associated with salinity were adopted to address problems with taste and odor, not human health. Arsenic in pump-ins is identified as a potential human health threat.

More than half of the pump-in samples collected between mileposts 241 and 304 contained arsenic above 0.005 mg/L with a maximum of 0.010 mg/L. With the MCL at 0.05 mg/L, these waters do not pose a threat to aqueduct water quality. However, anticipated changes in the law may lower the MCL to 0.01 or 0.03 mg/L. If this occurs, SLC pump-ins may be a significant source of arsenic.

8.5.6 WATERSHED MANAGEMENT ACTIVITIES

Other than floodwater from the KRI and Cross Valley Canal, there are no watersheds draining directly to this section of aqueduct. There are, however, several structures on the aqueduct designed to capture bedload sediment. The aqueduct was designed with sediment traps in the forebays of both Buena Vista and Teerink pumping plants. Their design is described in DWR Bulletin 200 (DWR 1974):

> "Sediment traps upstream of the pumping plant forebays are comprised of 3 cells on each side of the centerline beneath the aqueduct invert. The traps are rectangular in shape, 6 feet deep, 48 feet long, and 11 feet 3 inches wide. Lengthwise, the trap is partially open to the flow and is divided into 3 sections. The 1st quarter is open without any restrictions, the 2nd quarter is covered with a grizzly of 3-inch channels of 8-inch centers perpendicular to the flow and the final half of the trap is covered with 6-inch concrete slabs. Since the need for sediment removal was expected to occur infrequently, no provision was made in the design for hydraulic or mechanical removal of sediments contained by the traps. Sediment removal will be done by maintenance forces using portable equipment."

A sediment trap was also installed between Teerink and Edmonston pumping plants at about mile 292. DWR has historically removed sediment from other locations in the aqueduct using hydraulic dredging techniques (DWR 1997).

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Chapter 9 - Coastal Branch Aqueduct

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters							
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	T&O
Recreation	9.3.1								
Wastewater Treatment/Facilities	9.3.2								
Urban Runoff	9.3.3								
Animal Populations	9.3.4					◒	◒		
Oil Wells and Pipelines	9.3.5								
Agricultural Activities	9.3.6				◒	◒			
Algal Blooms	9.3.7								◒
Unauthorized Activity	9.3.8				◒	◒			
Traffic Accidents/Spills	9.3.9								
Geologic Hazards	9.3.10				○	○	○		
Fires	9.3.11								
Land Use Changes	9.3.12								

<u>Rating symbols:</u>

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

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Coastal Branch Aqueduct

9.1 INTRODUCTION

Water demand during the 1980s exceeded dependable water supplies by an average 60,000 acre-feet per year in Santa Barbara County and 61,000 acre-feet per year in San Luis Obispo County (CCWA 2000). In both counties, the lowering of groundwater levels has resulted in overdraft conditions and deteriorating water quality for consumers. During the 1987-1992 drought, a number of Central Coast communities had severe water shortages. As a result, voters in both counties approved a referendum in 1991 requiring the San Luis Obispo and Santa Barbara County flood control and water conservation districts to request the California Department of Water Resources (DWR) to complete construction of the Coastal Branch Aqueduct, which was originally begun in 1963. The aqueduct was completed in 1997 and consists of 15 miles of canal and 100 miles of pipeline. The aqueduct supplies communities throughout San Luis Obispo and Santa Barbara counties and supports agriculture in western Kern County.

This chapter describes the State Water Project (SWP) facilities and the major participants in the Coastal Branch Aqueduct (Figure 9-1). Water quality data from the California Aqueduct are compared to data from open-canal sections of the Coastal Branch Aqueduct and the raw and treated water at the Polonio Pass Water Treatment Plant (WTP). Identification of potential contaminant sources was restricted to the initial 15-mile stretch of the Coastal Branch Aqueduct, which is a concrete-lined, trapezoidal canal. All other sections of this aqueduct are pipeline and, therefore, not subject to contamination from activities in the adjacent watershed.

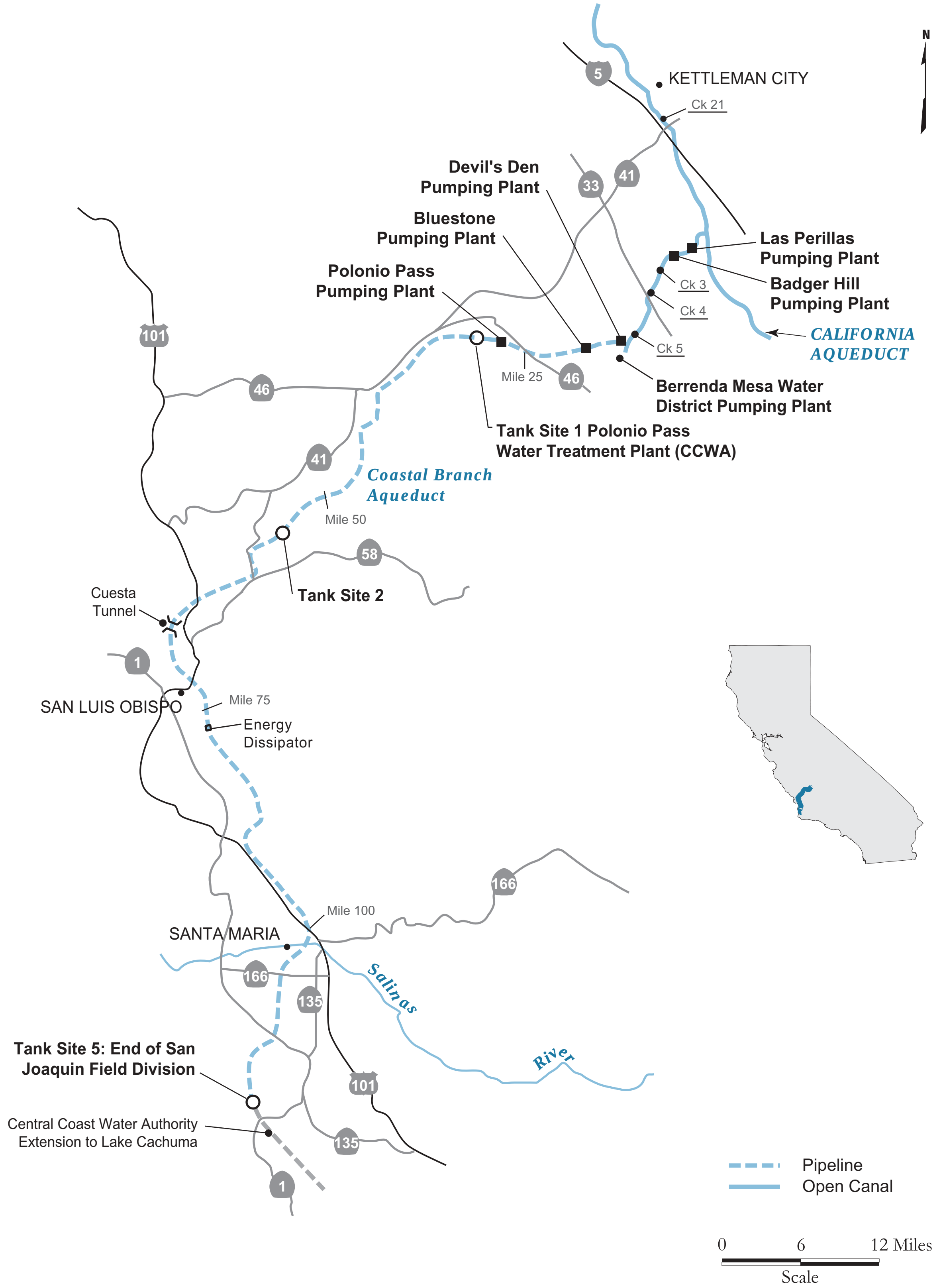
9.2 WATER SUPPLY SYSTEM

9.2.1 DESCRIPTION OF AQUEDUCT AND SWP FACILITIES

The Coastal Branch Aqueduct begins southward from the Kettleman Hills of western Kings County and stretches about 115 miles into southern Santa Barbara County. Figure 9-1 shows the major features of the Coastal Branch Aqueduct.

The branch was constructed in 2 phases. Phase 1, completed in 1968, consists of about 15 miles of canal and 2 pumping plants, Las Perillas and Badger Hill. Phase 2 was constructed between 1993 and 1998 and includes 3 pumping plants—Devil's Den, Bluestone and Polonio Pass—that lift water 1,500 feet through buried pipeline to the Polonio Pass WTP (capacity 43 mgd). Treating water to potable levels at this site near the upstream end of the Coastal Branch offered economies of scale to Central Coast contractors as compared to building a series of smaller WTPs serving individual users. From the Polonio Pass WTP, water is delivered via pipeline to SWP participants in San Luis Obispo and Santa Barbara counties, terminating at a tank site at Vandenberg Air Force Base in western Santa Barbara County. A 42-mile pipeline owned and operated by the Central Coast Water Authority (CCWA) carries water from the tank site to Lake Cachuma; CCWA also owns and operates the regional WTP at Polonio Pass.

Figure 9-1 Coastal Branch Aqueduct



A cooperative group of local water agencies and cities, CCWA formed to construct, manage, and operate local plants for distribution and treatment of State water. CCWA holds water supply agreements with its contractors throughout Santa Barbara County, and as a result the agency is obligated to pay all costs charged for SWP deliveries to the county. On 1 October 1996, the State entered into an agreement with CCWA to have the agency operate and maintain all of the Coastal Branch facilities downstream of the Polonio Pass WTP. Initial deliveries to turnouts along the pipeline commenced on 11 August 1997, and to Lake Cachuma on 20 November 1997. Following are the primary uses of SWP entitlements on the Central Coast:

- To offset groundwater overdrafts,
- To improve water quality for consumers, and
- To provide for future growth consonant with community general plans.

9.2.2 DESCRIPTION OF AGENCIES USING SWP WATER

The Coastal Branch Aqueduct is designed to deliver 4,830 acre-feet per year of SWP water to San Luis Obispo County and 42,986 acre-feet per year to Santa Barbara County (including a 3,908 acre-feet drought buffer). The Berrenda Mesa Water District (western Kern County) operates a takeout near the Devil's Den Pumping Plant. Its entitlement is 11,000 acre-feet, although data on how much water the district withdraws from the Coastal Branch Aqueduct were not available. Tables 9-1 and 9-2 list the major SWP participants in Santa Barbara and San Luis Obispo counties and their SWP allocations.

Table 9-1 Major SWP Participants in Santa Barbara County and their Allocations

Coastal Aqueduct Participant	SWP Allocation (af/yr)
Santa Barbara County (CCWA)	
City of Santa Maria	16,200
Vandenberg Airforce Base	5,500
Goleta Water Dist.	4,500
City of Santa Barbara	3,000
Montecito Water Dist.	3,000
Carpenteria Valley Water Dist.	2,000
Santa Ynez River Water Dist.	2,000
La Cumbre Mutual Water Co.	1,000
City of Buellton	578
City of Guadalupe	550
California Cities Water Co.	500
Morehart Land Co.	200
Santa Barbara Research	50

Table 9-2 Major SWP Participants in San Luis Obispo County and their Allocations

Coastal Aqueduct Participant	SWP Allocation (af/yr)
San Luis Obispo County (CCWA)	
City of Morro Bay	1,313
City of Pismo Beach	1,240
Oceano Community Service Dist.	750
County of San Luis Obispo[a]	725
California Men's Colony (State)	400
San Miguelito Mutual Water Dist.	275
Avila Beach Service Dist.	100
Avila Valley Mutual Water Co.	20
San Luis Coastal School Dist.	7

[a] Includes CSA No. 16-1, Operations Center and Regional Park, and Community College District (Cuesta College).

9.3 POTENTIAL CONTAMINANT SOURCES

9.3.1 RECREATION

There are no recreational activities in the vicinity of the 15-mile open-canal section of the Coastal Branch Aqueduct.

9.3.2 WASTEWATER TREATMENT/FACILITIES

Septic systems are used to collect and treat wastewater from operations at all of the SWP pumping stations along the Coastal Branch Aqueduct and at Polonio Pass WTP. These systems do not pose a significant water quality hazard to the water conveyance system because they are outside drainage areas to the aqueduct. During the reporting period, no problems were reported for the septic systems.

9.3.3 URBAN RUNOFF

Storm runoff is conveyed over the Coastal Branch Aqueduct in 29 pipes and 4 overchutes (Brown and Caldwell 1990). An additional 8 undercrossings provide drainage from surrounding terrain and cattle-grazing zones. There are also 32 drain inlets that convey canal-shoulder runoff into the aqueduct. No spills were reported at any of these locations.

9.3.4 ANIMAL POPULATIONS

Cattle-grazing occurs year round on open-range, nonirrigated pasture in the watershed adjacent to the open canal. In the past, sheep have been reported to also graze in this area. On a field survey conducted 11 July 2000 (Brennan, pers. comm. 2000), it was noted that the potential existed for runoff from grazing areas to enter the canal at mile 7.13 to 7.25; this problem was also noted in *Sanitary Survey Update 1996*.

In addition, fencing in the area of mile 13.1 was missing, creating the potential for livestock to reach the canal.

9.3.5 OIL WELLS AND PIPELINES

Open sections of Coastal Branch Aqueduct pass through portions of the Devil's Den oil field. Wells can be found along the western side of the canal beginning at the Badger Hill Pumping Plant. Seven petroleum pipelines and 2 natural gas pipelines cross the Coastal Branch Aqueduct (Brown and Caldwell 1990). No spills occurred during the reporting period. Additional information on hydrocarbon and hazardous material sources within areas adjacent to the aqueduct can be found in Appendix G of *Sanitary Survey Update 1996* (DWR 1996).

9.3.6 AGRICULTURAL ACTIVITIES

While most of the area surrounding the canal is used for grazing, various agricultural crops are grown on both sides of the aqueduct. During a July 2000 inspection, agricultural turnouts at mile 9.34 and 4.22 (Green Valley Turnout) apparently lacked backflow prevention devices or air gaps to prevent reverse-flow into the canal. Turnout operators have been observed adding aqueous ammonia to the water at the turnout at mile 9.34. Operating the turnout without reverse-flow protection creates the possibility of ammonia entering the canal.

9.3.7 ALGAL BLOOMS

Instances of taste and odor problems have been reported by CCWA and may be associated with algal blooms in open-canal and forebay sections of the Coastal Branch Aqueduct. The combination of high nutrient levels in SWP water, warm temperatures and long days can produce problem-levels of algal growth under low-flow conditions in the Coastal Branch Aqueduct.

9.3.8 UNAUTHORIZED ACTIVITY

During an inspection conducted 11 July 2000, 2 large tanks (2,000 to 3,000 gallons) were observed at mile 10.4, just outside the aqueduct right of way. The tanks were full of water, which was likely removed from the aqueduct using portable pumps. It was unknown whether these pumps had adequate backflow prevention devices. Lack of such devices can lead to contamination of the aqueduct via cross-contamination or backflow, although no reports of such contamination have been reported.

9.3.9 TRAFFIC ACCIDENTS / SPILLS

Four roadways cross the open section of the Coastal Branch Aqueduct, including 25th Avenue, Barker Road, and Highway 33. There were no reported incidences of hazardous waste spills along these roads.

9.3.10 GEOLOGIC HAZARDS

Both the open canal and pipeline sections of the Coastal Branch Aqueduct pass near the San Andreas Fault. The Kettleman Hills and coastal transverse mountains of central California are among the most earthquake-prone areas of California (Drager and Savage 1999). Very strong earthquakes have occurred in this area including the magnitude 8.0 Fort Tejon event in 1857 and the magnitude 7.5 Kern County event of 1952. Therefore, the potential exists for damage to the Coastal Branch Aqueduct from earth movements.

9.3.11 FIRES

There were no fires of significance during the period of interest.

9.3.12 LAND USE CHANGES

There were no major land use changes during the reporting period other than the completion of the Coastal Branch Aqueduct.

9.4 WATER QUALITY SUMMARY

9.4.1 COASTAL BRANCH AQUEDUCT

During the period of 1996 through 1999, water quality in the Coastal Branch Aqueduct was monitored by DWR at 1 site along the open canal section of the aqueduct, Check 4, and by CCWA at the Polonio Pass WTP. Grab sample data were collected by DWR at Check 4 on a monthly basis from 1996 through 1999 to monitor SWP source waters to the plant. Real-time data for conductivity, turbidity, temperature, and flow were also collected at Check 4 for calendar year 1999. With the exception of color, iron, odor and turbidity, SWP deliveries from the Coastal Branch Aqueduct met all maximum contaminant levels (MCLs) for drinking water (Table 9-3).

Table 9-3 Summary of Selected Constituents in Raw Water at Checks 4 and 21 and Raw and Treated Water at Polonio Pass WTP, 1996 to 1999

Parameter	Units		Treated CCWA PPWTP	Raw SWP @ PPWTP	Raw SWP @ Check 4	Raw SWP @ Check 21
Minerals						
Calcium	mg/L	Range	14 – 27	16 – 28	13 – 42	14 – 70
		Average	19	21	19	20
Chloride	mg/L	Range	23 – 98	30 – 70	21 – 116	20 – 117
		Average	61	52	52	52
TDS	mg/L	Range	157 – 510	187 – 296	137 – 496	137 – 593
		Average	262	243	224	228
Hardness (as CaCo$_3$)	mg/L	Range	60 – 127	86 – 106	61 – 204	65 – 278
		Average	93	96	93	95
Alkalinity (as CaCo$_3$)	mg/L	Range	51 – 95	67 – 83	50 – 108	48 – 100
		Average	75	74	74	70
Specific Conductance	µS/cm	Range	256 – 564	308 – 518	236 – 779	234 – 883
		Average	445	420	408	408
Magnesium	mg/L	Range	6 – 16	8 – 15	7 – 24	7 – 25
		Average	11	12	11	11
Sulfate	mg/L	Range	28 – 112	25 – 65	19 – 233	19 – 298
		Average	45	42	42	43
Turbidity (monthly)	NTU	Range	0.04 – 0.10	3.6 – 9.8	0.0 – 77	2 – 69
		Average	0.06	5.6	12	12
Minor Elements						
Aluminum	mg/L	Range	ND – 0.25	ND – 0.74	NC	0.01 – 0.08
		Average	0.05	0.31	NC	0.02
Arsenic	ppb	Range	ND – 2.1	ND – 3.0	NC	1.0 – 3.0
		Average	0.1	1.1	NC	2.0
Copper	mg/L	Range	ND – 0.03	ND – 0.04	NC	0.00 – 0.01
		Average	0.01	0.00	NC	0.00
Fluoride	mg/L	Range	0.06 – 0.18	0.08 – 0.09	0.0 – 0.2	0.1 – 0.2
		Average	0.08	0.06	0.1	0.1
Iron	ppb	Range	ND	64 – 868	NC	5 – 179
		Average	ND	371	NC	18
Nutrients						
Nitrate (as N)	mg/L	Range	1.8 – 6.5	NC	0.1 – 7.3	0.0 – 5.9
		Average	1.6	1.2	2.4	3.0
Misc.						
Color	color	Range	2 – 6	2 – 22	NC	NC
		Average	2.6	13	NC	NC
pH	pH	Range	7.9 – 8.3	8.2 – 8.9	7.1 – 9.3	6.9 – 8.4
		Average	8.1	8.5	8.1	7.6
Total Organic Carbon	mg/L	Range	NC	NC	NC	2.3 – 6.2
		Average	NC	NC	NC	3.2
Total Trihalomethane	ppb	Range	18 – 38	NC	NC	NC
		Average	27	NC	NC	NC
Bromide	mg/L	Range	NC	NC	NC	0.06 – 0.39
		Average	NC	NC	NC	0.17

Sources: DWR O&M database, Feb 2001; Central Coast Water Authority

Averages for treated CCWA water are the mean of the annual averages from 1996 through 1999

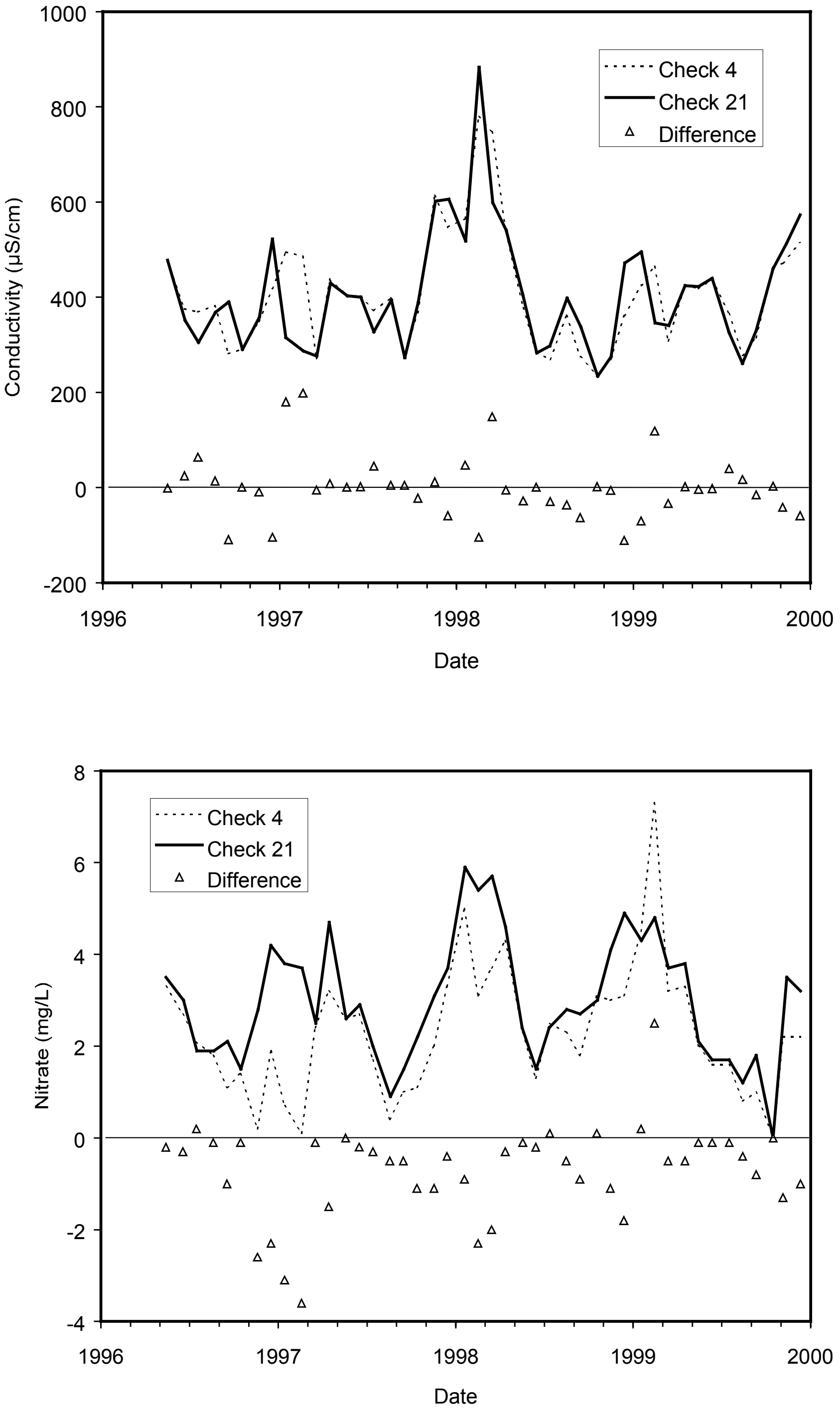
PPWTP = Polonio Pass Water Treatment Plant NC = Not Collected ND = None Detected

Real-time data collection was halted at Check 4 in early 2000, at the request of CCWA, which felt that the data did not provide sufficient early warning for the Polonio Pass WTP. Plant operators now rely on real-time data from Check 21 on the California Aqueduct near Kettleman City, which is 12.3 miles upstream from the origin of the Coastal Branch.

About 27 miles of open canal separate Check 21 from the pipeline intake of the Coastal Branch Aqueduct located at Devil's Den Pumping Plant. Thus, water quality at Check 21 should provide an accurate depiction of SWP inputs to the Polonio Pass WTP. Water quality data for Check 21 are discussed in detail in Chapter 8. To evaluate the assumption that water quality in the Coastal Branch is similar to that at Check 21, a comparison was made between DWR samples collected within approximately 1 day at both sites.

For all major constituents, for example, TDS, hardness, major cations, there were no significant differences in levels measured at the 2 sampling stations. Data for electrical conductivity (EC) at both Check 4 and Check 21 are presented in Figure 9-2; interstation differences in EC are representative of those for most water quality parameters measured. Differences in EC between Check 21 and Check 4 were slightly greater during low flow periods in fall and winter than in spring and summer when water deliveries in the Coastal Branch were highest. During the early part of 1997 and 1999, time lags on the order of 20 to 45 days were observed in EC levels as water slowly moved from Check 21 to Check 4. These lags suggest that during fall and winter months water is stored for appreciable periods in the Coastal Branch canal and pumping plant forebays before reaching the Polonio Pass WTP.

Figure 9-2 Comparison of Conductivity and Nitrate Values at Checks 4 and 21



During low flow periods, nitrate concentrations in Coastal Branch water declined markedly from levels present in the California Aqueduct (Figure 9-2); these declines are most likely due to nitrate assimilation by attached algae in the canals and forebays. Instances of taste and odor problems in the autumn of 2000 were reported by CCWA and may be associated with algal blooms in open sections of the Coastal Branch Aqueduct. The combination of high nutrient levels in SWP water, warm temperatures, and long days can produce problem-levels of algal growth under low flow conditions in the Coastal Branch Aqueduct. There was 1 instance where Check 4 nitrate exceeded the Check 21 level, 16 February 1999. It is unknown whether the high Check 4 nitrate value was the result of contamination in the canal section of the Coastal Aqueduct or a sampling artifact.

9.4.2 WATER SUPPLY SYSTEMS: POLONIO PASS WTP

Water quality information for finished water at the Polonio Pass WTP was obtained from CCWA and is presented in Table 9-3. The ranges and averages were computed for the period of 1996 through 1999; data for raw SWP water at the plant and at Check 21 and Check 4 are presented for comparison.

For all constituents, CCWA-treated water met MCL values. For comparison, source water from the SWP typically exceeded MCL values for color, iron, odor, and turbidity and approached the MCL for aluminum. Values for all other constituents were below their MCL values in raw SWP deliveries. It is notable that average values for both iron and aluminum at Check 21 are less than 10% of the concentrations measured in SWP deliveries at Polonio Pass WTP. These differences suggest that there may be a source of metals somewhere along the Coastal Branch Aqueduct. Alternately, the concentration differences could result from analytical error at the CCWA laboratory. Average nitrate concentration at the WTP plant was less than half that measured at Check 21 and is indicative of algal growth in open canal and forebay sections of the Coastal Branch Aqueduct.

Total organic carbon (TOC) levels at Check 21 frequently exceeded the proposed drinking water protection standard of 3 mg/L at the export pumps at Banks Pumping Plant. However, total trihalomethane (TTHM) levels in treated water at Polonio Pass WTP ranged from 18 to 38 parts per billion (ppb) (average 27 ppb) for the 3-year period and are within both the current and proposed MCLs of 100 ppb and 80 ppb, respectively. Thus, it appears that current treatment practices at the plant are adequate to address future D/DBP Rules for TOC and TTHM in water with alkalinity in the 60 to 120 mg/L range.

Bromide levels at Check 21 ranged from 0.06 to 0.39 mg/L and exceed the proposed drinking water protection standard of 0.05 mg/L. These constituent levels are likely a reflection of Delta contaminant sources and water quality conditions. Since chlorination is the primary disinfection method used at the Polonio Pass WTP, bromate formation is not a water quality issue at this time and would be a potential problem only if ozonation treatment were employed to meet lower TTHM standards in the future.

9.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

The only part of the Coastal Branch Aqueduct with significant risk of contamination is the initial 15-mile section of open canal. All other portions of the aqueduct are piped and, therefore, have low risk of contamination.

Currently, the major risk for contamination in the open canal section of the aqueduct comes from agricultural turnouts that do not employ backflow protection. In particular, withdrawals of water between miles 9.34 and 10.5 (between Check 4 and Check 5) are potential sources of contaminants such as agricultural chemicals and vehicle oil and gasoline. This section of the canal was identified as a potential contaminant source in the *Sanitary Survey Update 1996* as well. Based on the comparison between water quality at Check 21 and Check 4, activities at the turnouts do not appear to result in gross contamination of the canal. However, smaller transient events may still occur. There were no reported incidences of contamination from aqueduct under- and overcrossings, and the potential risks appear small.

9.6 WATERSHED MANAGEMENT PRACTICES AND RECOMMENDATIONS

Other than copper treatments in open canal sections and forebays along the Coastal Branch Aqueduct, there are no current management practices that are likely to impact water quality. CCWA requests that DWR ensures that all turnouts, whether at permanent or temporary stations, have adequate backflow prevention devices.

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Chapter 10 - East and West Branches of the California Aqueduct

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters									
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity	T&O	Hydro- carbons
WEST BRANCH											
Animal Populations	10.1.3.1					○	○		○		
Recreation	10.1.3.2						○		○		
Urban Runoff	10.1.3.3				○						
EAST BRANCH											
Recreation	10.2.3.1						⊙	○	○	○	
Traffic Accidents/Spills	10.2.3.2										⊙
Unauthorized Activity	10.2.3.3										
Urban Runoff	10.2.3.4	⊙	⊙		⊙	⊙	⊙		⊙		
Algal Blooms	10.2.3.5								⊙	●	
Groundwater Discharges	10.2.3.6										
Other Potential Sources	10.2.3.7										⊙

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

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East and West Branches of the California Aqueduct

Just after the Tehachapi Afterbay, the California Aqueduct bifurcates into the East and West Branches. The bifurcation occurs after Check 41 at about mile 303.92 (DWR 1999). This chapter of *Sanitary Survey Update 2001* covers the canal, tunnel, and pipeline sections of the West and East Branches. Chapter 7, Southern California Reservoirs, describes reservoirs in these 2 branch aqueducts.

10.1 WEST BRANCH

10.1.1 WATER SUPPLY SYSTEM

10.1.1.1 Description of Aqueduct and SWP Facilities

The West Branch (Figure 10-1) starts at mile 0 immediately after the bifurcation and flows through the Oso siphon to the Oso Pumping Plant at mile 1.49. The plant lifts the water 231 feet into Quail Canal, which flows through Check 1 at mile 4.64 into Quail Lake. Quail Lake discharges into Lower Quail Canal at mile 6.07, which enters the Peace Valley Pipeline at mile 8.25. The 5.8-mile pipeline drops the water into the William E. Warne Powerplant at mile 14.07. The water is discharged into Pyramid Lake, then travels through the 7.2-mile Angeles Tunnel into the Castaic Powerplant. From the power plant, the water is discharged into Elderberry Forebay, which acts as an afterbay to the power plant, providing a pool of water that can be pumped back into Pyramid Lake during off-peak hours. The forebay also serves to maintain a relatively constant surface elevation in Castaic Lake. The Los Angeles Department of Water and Power constructed Elderberry Forebay and is responsible for its operation. Water is discharged from Elderberry Forebay into Castaic Lake, which is the southern terminus of West Branch.

Of its total length of approximately 25 miles, West Branch has 8.4 miles of open canal. There are 3 pools in the branch. A pool is the reach between check structures. The open canal is located in the upper reach, which is sparsely populated. The rest is pipeline and tunnel (Table 10-1).

Table 10-1 Sectional Lengths (miles) of the West Branch

Type	Length in Miles
Canals	8.4[a]
Tunnel	7.2
Pipeline	5.5
Reservoirs	10.8
Total	31.9

Source: DWR 1999

[a] Including Quail Lake.

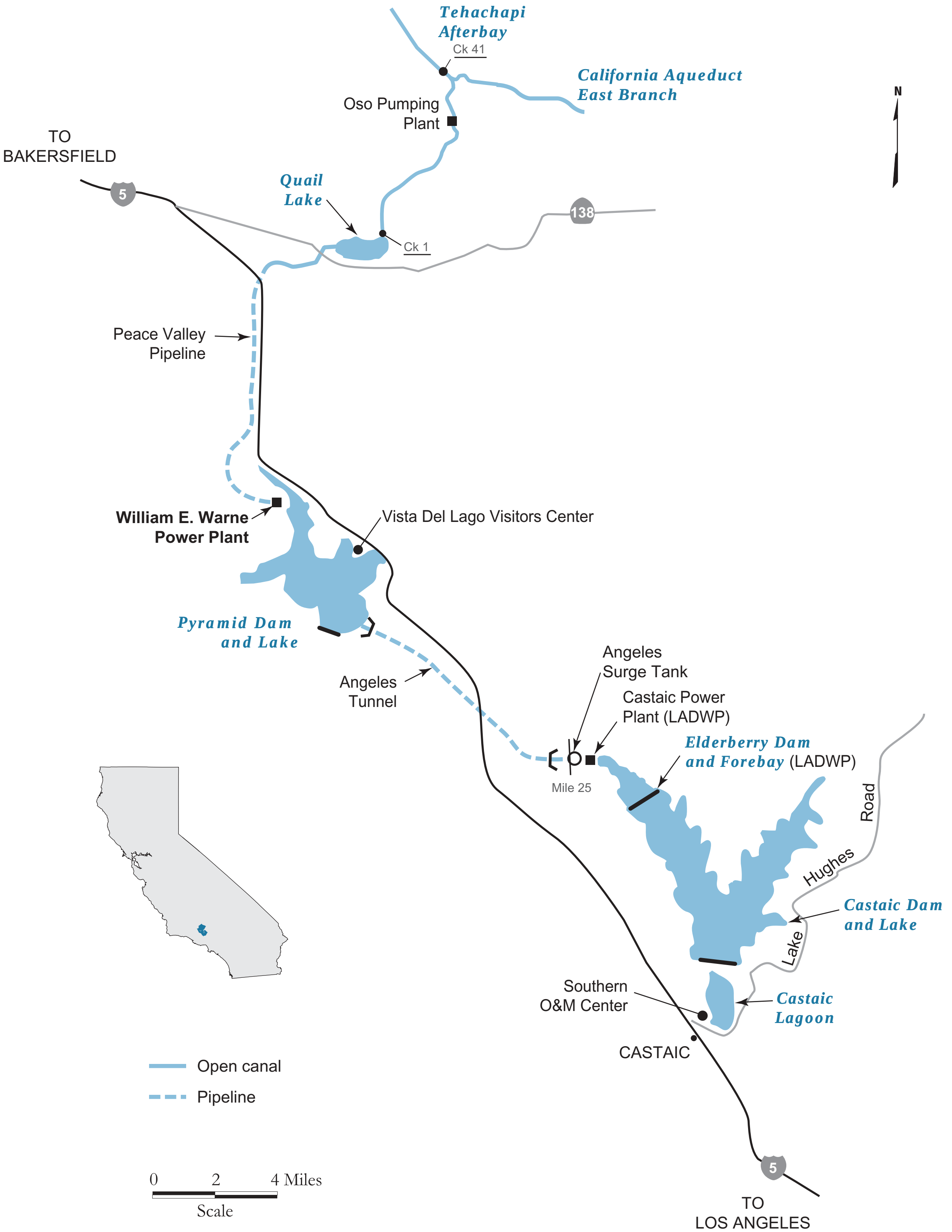
10.1.1.2 Description of Agencies Using SWP Water

The West Branch terminates into Castaic Lake. For a listing of agencies using Pyramid Lake water, see Chapter 7, Section 7.1.2.2. For a listing of agencies using Castaic Lake water and their entitlements, see Chapter 7, Section 7.2.2.2.

10.1.2 WATERSHED DESCRIPTION

The section of the West Branch below Quail Lake is within Angeles National Forest. Most of this aqueduct section consists of pipeline or tunnel. Angeles National Forest topography ranges from 280 feet to 8,000 feet above sea level (USDA 1998). The area is in earthquake zones, including those of San Andreas and Big Pine faults (USDA 1998). Rainfall ranges from 6 to 40 inches. Pines and firs cover the higher elevations while chaparral covers the lower elevations. Land use activities include many types of recreation, telecommunication sites, utility corridors, filmmaking, and mining (USDA 1998).

Figure 10-1 California Aqueduct: West Branch



The 8.4-mile open section of the aqueduct includes Quail Lake and is in western Antelope Valley. Quail Lake is a sag pond on the San Andreas Fault that was enlarged to its current 7,580 acre-feet during construction of the State Water Project (SWP) (DWR 1999). The lake provides water storage for Warne Powerplant and has a watershed of about 4 square miles and vertical relief from 3,300 to 4,400 feet. Wildlife is found in the watershed, and livestock graze around the lake. Fishing amenities are accessible from Highway 138.

10.1.3 POTENTIAL CONTAMINANT SOURCES

There are no industrial or wastewater treatment plants along or near the West Branch Aqueduct. There are relatively few infrastructure sources of contamination (Table 10-2).

Table 10-2 Potential Sources of Contamination on the West Branch

Description	Type	Number
Bridges	State	1
	County	0
	Private	1
Turnouts		2
Culverts		10
Overchutes		0
Pipelines	Gas	6
	Oil	4
	Water	0

There are only 2 bridges over West Branch Aqueduct. The 4 oil pipelines may pose a potential hazard. The major potential contaminant sources involve activities in the Quail Lake watershed.

10.1.3.1 Animal Populations

There are cattle-grazing operations and wild animal populations within the 4 square-mile Quail Lake watershed. Watershed runoff is conveyed to the lake via natural drainage and piped conduits. The amount of drainage is unknown.

10.1.3.2 Recreation

About 10,000 people fish Quail Lake annually, but swimming and boating are not allowed. Fishing sites are accessible from a parking lot off Highway 138. There are picnic tables and restrooms at the parking lot (DWR 1997).

10.1.3.3 Urban Runoff

According to *Sanitary Survey 1990*, there is a glider airport and 3 residences with septic systems near the lake. No new information was available.

10.1.4 WATER QUALITY SUMMARY

No water quality data are collected along the open canal sections of the West Branch. No accidents or illegal dumping incidences were reported by the Joint Operations Center (JOC).

10.1.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Quail Lake and the adjoining open canal sections are the only areas exposed to potential contaminant sources along the West Branch Aqueduct. Quail Lake is a flow-through system and is flushed rapidly. The Quail Lake watershed is only 4 square miles and probably does not contribute significant contaminants to West Branch. Livestock graze in the watershed, but the extent is unknown.

10.1.6 WATERSHED MANAGEMENT PRACTICES

No management activities are likely to impact water quality in the West Branch Aqueduct.

10.2 EAST BRANCH

10.2.1 WATER SUPPLY SYSTEM

10.2.1.1 Description of Aqueduct and SWP Facilities

The 148.5-mile East Branch traverses Antelope Valley and the San Bernardino Mountains and terminates at Perris Lake near the city of Riverside (Figure 10-2). The East Branch Aqueduct has about 93 miles of open canals and 32 miles of enclosed pipeline and tunnels (Table 10-3). The canals have 24 pools and a capacity of 2,630 to 2,880 cfs (DWR 1999). There are no river or stream inflows from surrounding watershed.

Table 10-3 Sectional Lengths (miles) of the East Branch

	East Branch	East Branch Extension
Canals	93.4	
Tunnel	3.8	
Pipeline	28.1	13
Reservoirs	23.2	
Total	148.5	13

Source: DWR 1999

After the bifurcation, the East Branch flow passes through the Alamo Powerplant for power generation. It then travels 55 miles in open canal to Pearblossom Pumping Plant at mile 360.59, where water is lifted 540 feet (DWR 1999).

Water then flows downhill in open canal to Check 66 at mile 403.41 where it enters underground pipelines for about 2.2 miles to the Mojave Siphon Powerplant before entering Silverwood Lake. From the lake, water is discharged into the 3.8-mile San Bernardino Tunnel at mile 407.65. The tunnel discharges into the Devil Canyon Powerplant (mile 411.34). From the power plant's afterbays at mile 412.88, water is distributed through the 28-mile buried Santa Ana Pipeline to Lake Perris at mile 440.97.

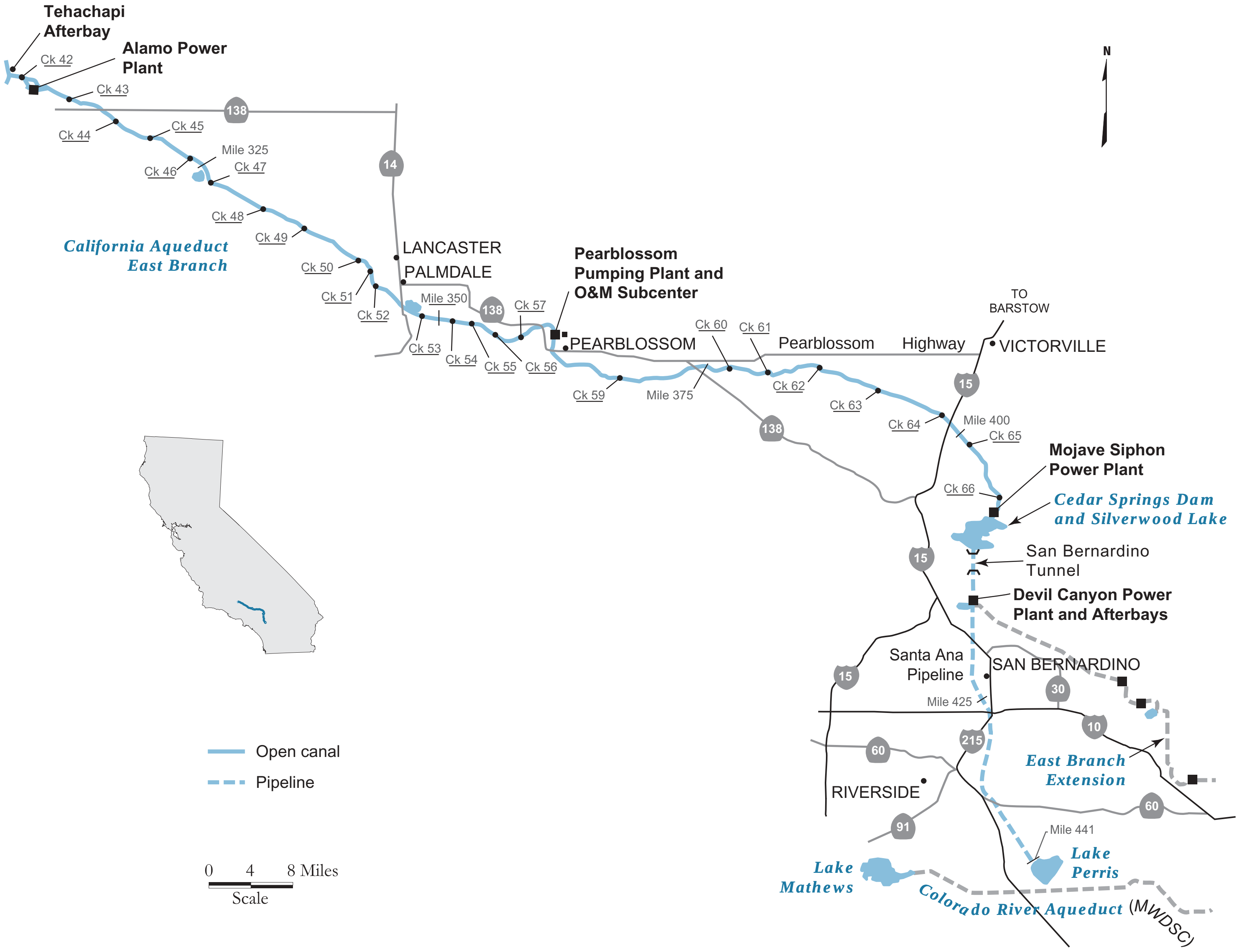


Figure 10-2 California Aqueduct: East Branch

East Branch Extension: Phase 1 and Phase 2

The East Bay Extension (EBX) has been in planning since 1962 when the San Gorgonio Pass Water Agency (SGPWA) contracted with the SWP for water to supplement groundwater supplies in the service area. The area has experienced groundwater overdrafts since the 1980s. Currently, the overdraft is 25% more than the basin's safe yield (DWR 2001). DWR is the lead construction agency for the extension in cooperation with the SGPWA and the San Bernardino Valley Municipal Water District (SBVMWD). When the EBX completed, DWR will turn over its operation to the SGPWA and the SBVMWD. The 2 agencies also will manage retirement of the construction debt.

Phase 1 will include construction of a 13-mile pipeline and use of the SBVMWD's 19-mile Foothill Pipeline. The EBX will serve the communities of Yucaipa, Calimesa, Banning, and Beaumont in San Bernardino and Riverside counties (DWR 2001). The inlet to Foothill Pipeline is at Devil Canyon Powerplant's afterbays. The EBX will terminate at Noble Creek near Beaumont in Riverside County. Phase 1 was expected to be completed in June 2001 and will supply up to 8,650 acre-feet annually at a flow of about 16 cfs. The EBX will have 3 pumping plants and a 5-acre reservoir at Crafton Hills. With an additional capacity of 8,650 acre-feet annually, EBX Phase 2 is proposed for the future when demand increases beyond the 16 cfs of Phase 1. Phase 2 will be a new pipeline that will bypass the SBVMWD's Foothill Pipeline.

10.2.1.2 Description of Agencies Using SWP Water

SWP contractors and entitlements for the East Branch are summarized in Chapter 7. Briefly, Metropolitan Water District of Southern California (MWDSC) and Antelope Valley-East Kern Water Agency (AVEK) are the largest contractors served by this section of the aqueduct. The Littlerock Creek Irrigation District (LCID) does not divert water directly from the aqueduct but is reliant on Palmdale Water District's turnout, which diverts the combined agencies' allotments into Lake Palmdale where it is mixed with discharge from Littlerock Reservoir. LCID then draws its allotment from the Palmdale reservoir. Mojave Water District's turnout is near Hesperia, with water passing through the Morongo Basin Pipeline; the district uses the water for groundwater recharge.

10.2.2 WATERSHED DESCRIPTION

After the bifurcation, the East Branch crosses the San Gabriel and San Bernardino Mountains at the edge of Antelope Valley. The aqueduct passes through Silverwood Lake and on to Lake Perris. The San Andreas Fault runs along the southern slope of Antelope Valley. Despite the fault's proximity, the aqueduct's current location was the preferred alternative that minimized earthquake risk (DWR 1974).

Antelope Valley is in the western part of the Mojave Desert, which is mainly alluvial. The valley is a closed basin, and rainfall percolates into the ground or collects in the lower sections.

10.2.3 POTENTIAL CONTAMINANT SOURCES

Organic carbon and bromide are mainly imported from the Delta. Nutrients and turbidity may originate from the Delta as well as in the watersheds of the reservoirs discussed in chapters 6 and 7. Contaminants imported from outside the East Branch can only be managed at the source and will not be discussed here.

There are about 93 miles of open canal sections traversing large populated areas. There are no stream drainages from the watershed into this section of the aqueduct. Table 10-4 lists other potential sources of contamination. These sources add to the imported contaminant load, but there are no data to estimate their relative contributions.

Table 10-4 Potential Sources of Contamination in the East Branch

Description	Type	Number
Bridges	State	8
	County	40
	Private	18
Turnouts		17
Culverts		106
Overchutes		85
Pipelines	Gas	5
	Oil	1
	Water	40

10.2.3.1 Recreation

Recreation activities such as fishing and picnicking occur at some of the open canal sections, especially bridge overcrossings. These were described in *Sanitary Survey 1990*. No additional information was available.

10.2.3.2 Traffic Accidents/Spills

Many roads cross the East Branch over its 66 bridges, which belong to the State or counties or are privately owned, such as farming roads. Potential for contamination of the aqueduct exists in the event of an automobile or commercial truck accident. However, there were no reported accidents or spills during this reporting period. Caltrans is in the process of enlarging the Highway 14 bridge near Palmdale.

The JOC records daily incidents that occur along the aqueduct. The East Branch had more reported incidents involving vehicles and other objects than any other section of the aqueduct (Table 10-5). However, these incidents are not separated into those originating from vehicle accidents and those originating from illegal dumping of stolen vehicles. The JOC reports incidents as they occur, but in general, police have little information on the incidents unless the vehicle had been reported stolen. Therefore, follow-up information on removal and remediation is not often available.

Table 10-5 Reported Incidents in the East Branch

Date	Vehicle	Motor Cycle	Body	Other	Location	Comments
11 Sep 1996				Truck observed dumping heavy objects into aqueduct	Pool 58	Vehicle impounded
12 Sep 1996	1				Pool 58	
4 Nov 1996	2				Pool 50	
9 Nov 1996				Spill of 220 gallons of hydraulic oil	Pearblossom	
17 Dec 1996	1				Pool 65	
17 Dec 1996	5				Pool 66	
19 Dec 1996	1				Pool 65	
22 Dec 1996	1				Pool 65	
7 Aug 1997				Pipe bomb	Downstream of Check 66	Later found to be fake
22 Mar 1998			1		Pool 53	
22 Mar 1998	1		1		Pool 63	
4 Jul 1998	1		3		Pool 60	
8 Jul 1998	1		1		Pool 53	
23 Oct 1998			1		Pool 64	
2 Feb 1999		1	1		Pool 53	
8 Jul 1999	1		1		Pool 53	
4 Aug 1999	1				Pool 66	
25 Aug 1999	1				Pool 66	
2 Sep 1999	1				Pool 63	
Total	18	1	9			

Other potential sources of spills are aqueduct facilities. The pumps and generators use hydraulic oil, which may leak following accidents or malfunctions. For example, on 9 November 1996, 220 gallons of hydraulic oil leaked at the Pearblossom Pumping Plant, according to JOC reports. The oil was contained with booms.

10.2.3.3 Unauthorized Activity

The East Branch traverses populated areas, and there is potential for illegal dumping from roadsides and the 66 bridges. Between 1996 and 1999, 19 motor vehicles and 9 bodies were found in the East Branch Aqueduct. Most incidents occurred between Pool 53 and Pool 66 (Table 10-5). Many of the vehicles had been reported stolen. Others had entered the aqueduct under unknown circumstances. The vehicles were usually detected during low flows. A complete inspection of this section of the aqueduct's bottom has not been performed, and likely there are more vehicles and other debris in the pools. Vehicles can leak chemicals such as MTBE, oils, coolants and refrigerants, which may affect water quality; the extent and impacts of such leaks are unknown.

10.2.3.4 Urban Runoff

There are 45 drop inlets along a 1.8-mile stretch of the East Branch within Hesperia, an unincorporated community under the jurisdiction of San Bernardino County. The inlets are between 30 and 36 inches in diameter and convey storm water into the aqueduct at about mile 397 (Figure 10-3). The drains likely contribute total dissolved solids (TDS), metals, nutrients, and organics to the East Branch. The inlets were installed during construction of the aqueduct to prevent flood damage to downstream urban properties. Population growth and expansion in Hesperia continue to increase storm water discharge. Quarterly monitoring by DWR Operations and Maintenance Division (O&M) at Check 66 indicates that these storm water inflows have had no significant impact on water quality. However, storms are relatively unpredictable in this area, so no studies have been conducted to evaluate the water quality of aqueduct or floodwater inflow during these events.

To lessen the impact of urban storm water inflows on East Branch water quality, DWR has been coordinating with San Bernardino County and other contractors to study modifications that would minimize or eliminate storm water inflows. In response, the San Bernardino County Flood Control District has proposed a Hesperia Master Plan of Drainage (MPD). The MPD would utilize a canal to intercept storm water and direct flow away from the aqueduct into detention ponds, where the runoff would seep into the ground or evaporate. To implement the MPD, San Bernardino County has requested DWR to pay the $17 million cost of the project (Hunt pers. comm. 2001). As of February 2001, DWR was studying the proposal. It was not known when a decision would be made.

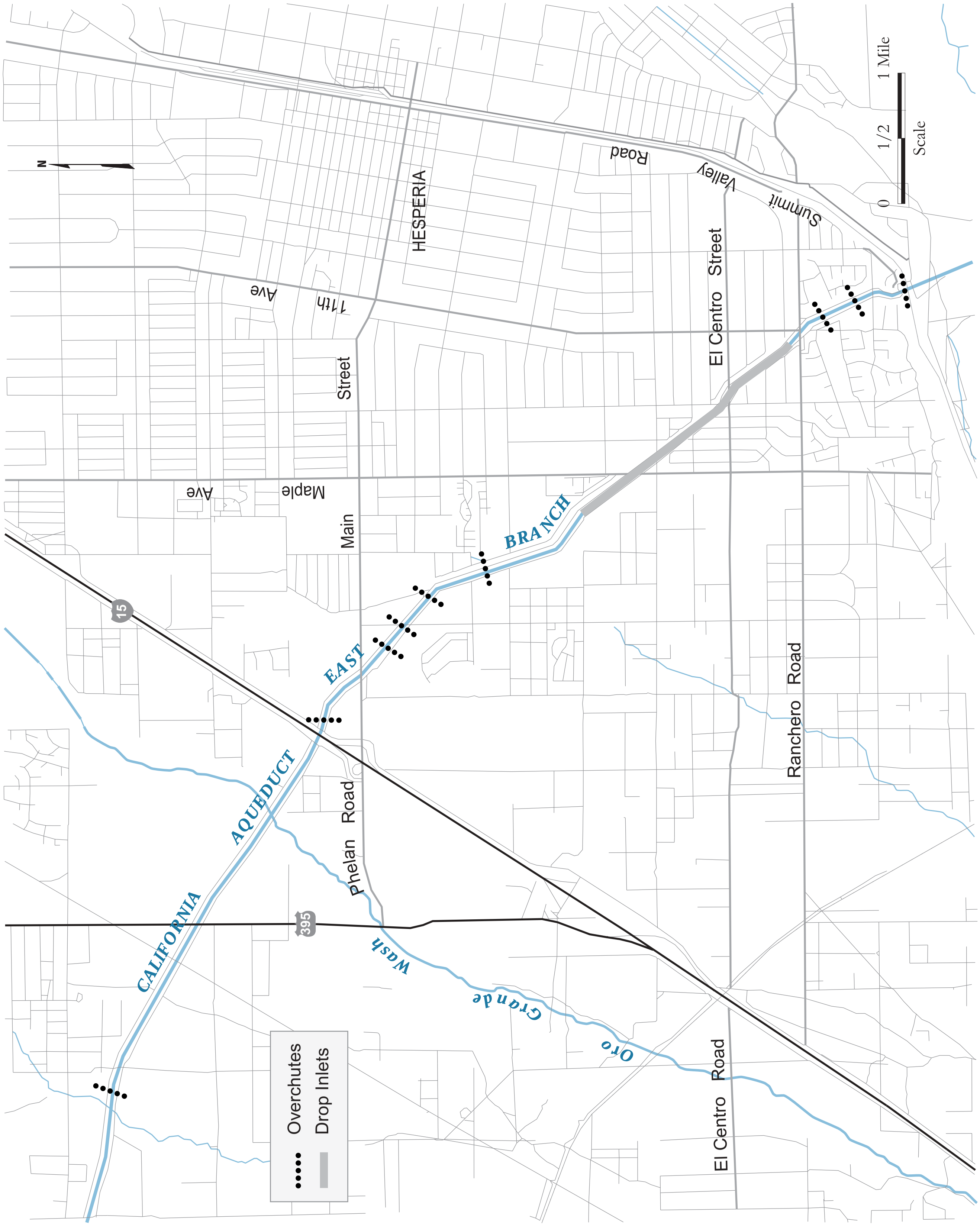
10.2.3.5 Algal Blooms

Abundant nutrients, long days and warm water temperatures create ideal growing conditions for attached algae in the East Branch Aqueduct during the summer. An Algal Growth Potential (AGP) experiment conducted by MWDSC indicated a dry weight biomass production of 40 to 45 mg/L with SWP sample water. For comparison, a similar experiment, using Colorado River water, produced an AGP of 1.5 to 2 mg/L dry weight (MWDSC unpublished AGP experiment, 28 Feb 1996). Algal blooms can lead to increased turbidity, filter clogging, and taste and odor problems at water treatment facilities. Taste and odor have been the most serious problem from algal blooms. Taste and odor problems are primarily caused when some, but not all, genera of algae produce 2 algal exudates: geosmin and 2-methylisoborneol (MIB). DWR and MWDSC conducted investigations to determine the algae involved in the taste and odor episode of 1990-1991 (Faulconer pers. comm 2001). A *Microcoleus*-like organism was isolated but was not positively identified. Subsequent investigations between 1992 and 1994 found additional taste and odor-producing algae namely *Lyngbya* and *Hyella* (Izaguirre and Taylor 1995).

The last serious algal blooms were reported in the dry years of 1990-1991. Since that time there have been no reported blooms, most likely because of increased use of copper compounds to control algal growth. Palmdale Water District, which has a turnout on East Branch at Reach 20B, mile 343.74, continuously treats the SWP water with Cutrine Plus® at its turnout into Lake Palmdale (Dluzak pers. comm 1999). The district also treats the lake biweekly with copper sulfate.

Many methods are used to monitor taste and odor problems (McGuire and others 1981). The oldest method is sensory analysis of water samples using the human nose. The resulting threshold odor number (TON) can indicate when a problem may be developing. A second method is microbiological culturing and identification in the laboratory, but culturing could take 7 to 14 days. Closed-loop stripping analysis (CLSA) is a more advanced and rapid method based on removing semi-volatile organic compounds such as geosmin and MIB from water using a recirculating stream of air.

Figure 10-3 Hesperia Stormwater Drain Inlets, East Branch California Aqueduct



The air sample is later analyzed with gas chromatography-mass spectrometry to quantify the concentrations of geosmin and MIB. MWDSC has been using CLSA since 1979. DWR visually inspects the aqueduct and also uses results of CLSA conducted by MWDSC to monitor algal growth in East Branch. Although this method can be used as a general algal growth indicator, it may not pinpoint the exact source of the nuisance algae in flowing water.

10.2.3.6 Groundwater Discharges

Where the groundwater level is high, it is possible for seepage into the aqueduct to occur at joints. This is probably an insignificant contaminant source. In other sections, sump pumps are used to pump the groundwater into the aqueduct to avoid impacting the canal (DWR 1974). There is a concentration of sump pumps near Leona siphon at mile 342.

10.2.3.7 Other Potential Sources

According to questionnaire responses received from water contractors, there were no indications that the contamination from agricultural activities, overchutes or turnouts had changed significantly since *Sanitary Survey 1996*. There are 46 pipelines, but only 1 oil pipeline, which can be considered a hazard (Table 10-4).

10.2.4 WATER QUALITY SUMMARY

The only water quality data available were from the beginning and end of the East Branch (Checks 41 and 66). Water quality at Check 41 and in reservoirs fed by the East and West Branches is discussed in Chapter 7. Reference to MCLs is made for comparison purposes only with the understanding that the aqueduct represents raw water and all MCL values were met in treated water.

10.2.4.1 Minerals

Only quarterly monitoring water quality data were available along the East Branch. Mineral concentrations at Check 66 were low compared to MCLs (where established). Comparison of water quality data at Check 41 and 66 (Table 10-6 and Table 10-7) does not indicate significant changes in concentration for most analytes between these stations. Turbidity was an exception with no detections in 5 of the 16 samples at Check 66. It is likely that these data are erroneous.

10.2.4.2 Minor Elements

Arsenic was reported above the detection limit once, but it was below the MCL (Table 10-6 and Table 10-7). Chromium, iron, and manganese were detected in 20% or fewer of the samples.

10.2.4.3 Nutrients

Nutrient concentrations in the East Branch were low in comparison to drinking water MCLs (Table 10-6 and Table 10-7). There was a slight decrease in nitrates and nitrate/nitrite from Check 41 to Check 66 indicating algal assimilation in reservoirs or open canal sections of the East Branch. Observed nutrient levels were probably enough to stimulate algal growth if other conditions such as low flows and temperature had occurred (Faulconer pers. comm 2001). Based on these results and findings in Chapter 9, Coastal Branch, it appears that algal uptake removes an appreciable portion of the nitrogen load transported from the Delta.

10.2.4.4 Organic Carbon and Bromide

Total organic carbon (TOC) at Check 66 ranged between 3.4 and 5.1 mg/L, higher than the CALFED target of 3 mg/L at Banks Pumping Plant (Table 10-7). The highest TOC concentrations occurred in February and March, which could be due to storm water flows (see Section 10.2.3.4). The maximum TOC concentration of 5.1 mg/L at Check 66 was significantly lower than the maximum concentration of 9.3 mg/L at Check 41. This may suggest that Lake Silverwood acts as a TOC sink. More frequent sampling will be required to understand TOC source and sinks in the SWP.

The overall mean bromide concentration in the East Branch at Check 66 was 0.04 mg/L, and measurable levels were detected in only 4 out of 15 samples. As with TOC, mean bromide levels at Check 41, 0.15 mg/L, were higher than at Check 66 and may suggest that Lake Silverwood also acts as a sink for bromide.

10.2.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

Watershed runoff in streams or rivers does not enter into the East Branch Aqueduct and is, therefore, not a potential contaminant source. Roadside runoff occurs in some sections, but contaminant loading is likely to be insignificant. In contrast, storm water runoff from the community of Hesperia has been a concern and has a greater potential to affect water quality in the East Branch. More intensive sampling data are needed to assess this potential. Urban runoff may contribute TDS, TOC, nutrients, and hydrocarbons to the aqueduct and is deserving of further study.

Most nutrients are imported from the Delta, although there are probably contributions from reservoir watersheds, recreational use, and possibly atmospheric deposition of nitrogen.

Table 10-6 Water Quality Data at Check 41, Jan 1996 to Dec 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects Samples
Minerals							
Calcium	18	18	10	28.1	14-22.8	1	47/47
Chloride	48	48	2	107	20.6-78.4	1	47/47
Total Dissolved Solids	208.4	217.5	73	345	138-284.5	1	46/46
Hardness	86	90	33	131	61.2-114	1	47/47
Conductivity (µS/cm)	371	392	106	607	237-521.5	1	46/46
Magnesium	9.8	10	2	15.3	6.2-13	1	47/47
Sulfate	32	31	4	60	19-53.8	1	47/47
Turbidity (NTU)	24.8	21	2	140	4.6-47.4	1	47/47
Minor Elements							
Arsenic	0.0022	0.002	<0.001	0.004	0.002-0.003	0.001	48/49
Boron	0.15	0.1	<0.1	0.3	0.1-0.2	0.1	41/47
Chromium	0.0051	0.005	<0.005	0.007	0.005-0.005	0.005	8/49
Copper	0.0032	0.002	<0.001	0.005	0.002-0.005	0.001	31/49
Iron	0.0085	0.005	<0.005	0.05	0.005-0.0196	0.005	15/48
Selenium	0.001	0.001	<0.001	0.001	0.001-0.001	0.001	4/47
Zinc	0.0108	0.005	<0.005	0.05	0.005-0.0297	0.005	9/48
Nutrients							
Total Nitrogen (Org+NH_4)	0.5	0.4	0.2	1.2	0.3-0.74	0.1	27/27
Nitrate (as NO_3)	2.9	2.55	0.3	8	1.35-4.9	0.1	46/46
Nitrate + Nitrite (as N)	0.7	0.6	0.09	1.9	0.27-1.04	0.01	48/48
OrthoPhosphate	0.08	0.07	<0.01	0.23	0.036-0.104	0.01	45/47
Total Phosphorus	0.13	0.13	0.04	0.31	0.07-0.194	0.01	47/47
Misc.							
Bromide	0.15	0.14	<0.01	0.38	0.060-0.254	0.01	46/47
Total Organic Carbon	3.6	3.2	2.2	9.3	2.5-4.8	0.1	48/48
pH (pH unit)	7.6	7.6	7	8.7	7.2-8	0.1	23/23
UVA (Abs @ 254 nm)	0.0836	0.071	0.06	0.149	0.064-0.131	0.001	23/23

Source: DWR O&M database May 2000
Notes: pH data from Jan 1998 to Dec 1999 only.
Total Nitrogen data from Jan 1996 to Mar 1998 only.

Table 10-7 Water Quality Data at Check 66, Jan 1996 to Dec 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	18	19	13	23	15-21	1	15/15
Chloride	50	52	3	99	24-79	1	16/16
Total Dissolved Solids	210	213	83	299	146-280	1	16/16
Hardness (as $CACO_3$)	87	92	42	107	67-106	1	17/17
Conductivity (µS/cm)	371	394	130	570	256-487	1	16/16
Total Alkalinity	73	73	52	97	65-84	1	16/16
Magnesium	10	11	3	13	7-13	1	16/16
Sulfate	29	28	1	46	21-42	1	16/16
Turbidity (NTU)	17	6	<1	68	1-40	1	11/16
Minor Elements							
Arsenic	0.002	0.002	0.002	0.003	0.002-0.003	0.002	11/11
Chromium			<0.005	0.005		0.005	2/11
Copper	0.003	0.003	<0.002	0.005	0.002-0.004	0.001	10/11
Iron			<0.005	0.014		0.005	1/11
Manganese			<0.005	0.026		0.005	2/11
Nutrients							
Total Nitrogen (Org+NH_4)	0.5	0.5	0.3	0.9	0.3-0.7	0.1	26/26
Nitrate (as NO_3)	1.8	1.5	0.3	4.2	0.8-3.5	0.1	16/16
Nitrate + Nitrite (as N)	0.49	0.46	0.07	1.00	0.18-0.89	0.01	47/47
OrthoPhosphate	0.07	0.07	<0.01	0.14	0.03-0.10	0.01	45/47
Total Phosphorus	0.11	0.10	<0.01	0.22	0.06-0.17	0.01	46/47
Misc.							
Bromide	0.04	0.01	<0.01	0.17	0.01-0.13	0.01	4/15
Total Organic Carbon	3.4	3.6	<0.1	5.1	2.7-4.6	0.1	15/16
pH (pH unit)	7.9	8.0	7.0	8.9	7.4-8.5	0.1	16/16
UVA (abs/cm @ 254 nm)	0.021	0.001	<0.001	0.071	0.001-0.070	0.001	5/17

Source: DWR O&M Division database May 2000
Note: Total Nitrogen data from Jan 1996 to Mar 1998 only.

Recreation such as fishing and picnicking occurs at bridges and open sections of the East Branch. However, there are no data to quantify the relative contributions of these different sources. High nutrient levels combined with high light levels and warm temperatures can result in nuisance algal blooms, which can lead to significant taste and odor problems. O&M monitors algal growth and initiates preventive measures, such as copper additions, as needed.

Illegal dumping, especially from bridges, is a potential contaminant source of unknown extent. There have been reports of people dumping from bridges, but most turned out to be false alarms. In 1 instance, a citizen's report of dumping from a bridge turned out to be somebody emptying an ice chest after failing to catch any fish (Faulconer pers. comm 2001). The JOC has documented incidents involving the dumping of stolen vehicles. Fluids from the vehicles can be a source of contamination. No analytical data on petroleum hydrocarbons were available, and relative contaminant contributions from these sources are unknown.

10.2.6 WATERSHED MANAGEMENT PRACTICES

A number of agencies besides DWR have operations that may impact the East Branch. Both private and public roads and 66 bridges crisscross the East Branch. Various agencies manage and maintain these facilities. Through Caltrans, the State manages its bridges and roadside drainage. Caltrans has a statewide Storm Water Management Program to mitigate effects of storm water runoff from highways and streets. The East Branch is in Los Angeles and San Bernardino counties, and maintenance activities on county roads and bridges could potentially affect water quality in the East Branch.

San Bernardino County is involved in managing the urban runoff in Hesperia. Managing the urban runoff will involve the Lahontan Regional Water Quality Control Board, which oversees this region's Basin Plan.

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11

State Water Project Emergency Action Plan

11.1 INTRODUCTION

The Department of Water Resources (DWR) performs numerous water resources planning and management activities throughout California and is responsible for protecting life and property from emergencies caused by catastrophic events such as flood, drought, and dam or levee failure. An extensive and complex emergency planning and management system, which starts at the statewide level and includes individual State agencies and departments, addresses these situations and ensures that appropriate actions are taken.

Emergency Action Plans (EAPs) and their implementation at the DWR field level are the focus of this chapter because of their relevance to State Water Project (SWP) operations and its ability to function during emergency situations. Although too complex to describe fully here, EAPs are actually a part of a much larger overarching structure that includes the DWR Recovery Action Plan (RAP) and the Emergency Response Plan (ERP). These plans and their relationship to the overall emergency management structure are discussed in more detail below.

This chapter presents a brief summary of the structure that includes the major related plans and processes that guide EAPs for the SWP. A regulatory overview and description of authority is presented, and the overall emergency management system structure is briefly described. Related emergency planning documents are presented, and finally, there is a description of a typical EAP.

11.2 REGULATORY OVERVIEW AND AUTHORITY

During a state of emergency of any type (local, state, or war), the Governor has authority over all State government agencies, as provided in the California Emergency Services Act, through the State Emergency Plan (SEP). The SEP and the Governor's Office of Emergency Services (OES) form the overarching authority and foundation for the emergency management system in California and DWR. The SEP and Section 128 of the California Water Code also give DWR certain responsibilities and authorities during State or federal emergency proclamation.

The Emergency Services Act authorizes the Governor to proclaim a state of emergency when conditions of a disaster are of extreme peril to citizens and/or their property. Such disasters include fire, flood, storm, drought, earthquakes, severe energy shortages, or other conditions beyond the resources of local agencies. OES performs executive functions assigned by the Governor, and its Director coordinates the State's disaster preparedness and response activities with representatives of State agencies under the authority of the Emergency Services Act and Executive Order W-9-91 (DWR 2000).

OES maintains the SEP, which outlines the organizational structure for State management of response to natural and man-made disasters. OES assists local governments and other State agencies in developing their own emergency preparedness and response plans, in accordance with the SEP, for earthquakes, floods, fires, hazardous material incidents, nuclear power plant emergencies, and dam breaks (OES 1999). The SEP lists responsibilities and protocols required of State agencies regarding response and provision of resources during an emergency (Fong pers. comm. 2001). OES also performs its functions in accordance with the Standardized Emergency Management System (SEMS), which was established by Senate Bill 1841 in 1992 after the 1991 East Bay Hills Fire in Oakland. The intent of this law was to improve the coordination of State and local emergency response, and it required all State agencies to incorporate this system by 1 December 1996 (DWR 2000).

An integral part of the emergency planning and management system that enables all subsequent plans operating below the SEP are Administrative Orders (AOs). During an emergency, OES is the designated coordinator and assigns functions to State agencies before and during an emergency through AOs. These are agreements between OES and the State agencies that are assigned functions before and during an emergency. The AO for DWR (dated 5 March 2001) describes the general roles of OES and State agencies and specific responsibilities of DWR for emergency procedures, continuity of government and business, and preparedness and response activities. Some of the specific activities include:

- Working closely with the CHP, FBI, and other appropriate entities to protect SWP facilities from harm or destruction;
- Maintaining a comprehensive emergency response plan in conformance with the SEP;
- Mitigating the effects of an incident on the SWP; and
- Continuing to operate the State's flood control works and the SWP.

DWR is the lead agency in providing expertise for flood emergency response through its Division of Flood Management, Flood Operations Center, and for dam safety response through the Division of Safety of Dams, as provided in Section 128 of the California Water Code (DWR 2000). As set forth in the regulations and Water Code provisions, DWR has 6 major responsibilities:

1) Planning and managing statewide water resources;
2) Developing, operating, and maintaining the SWP;
3) Protecting the Sacramento-San Joaquin Delta;
4) Providing dam safety, flood management, and emergency assistance;
5) Educating the public; and
6) Providing local assistance.

11.3 DESCRIPTION OF THE EMERGENCY MANAGEMENT SYSTEM STRUCTURE

As previously stated, the SEP and the OES form the overarching authority and foundation for DWR's emergency management system. Following this authority, the ERP and the Business Resumption Plan (BRP) are the main documents guiding emergency actions most relevant to DWR and the SWP for the purposes of the sanitary survey. These plans and their relationship to the overall emergency management structure are presented in Figure 11-1.

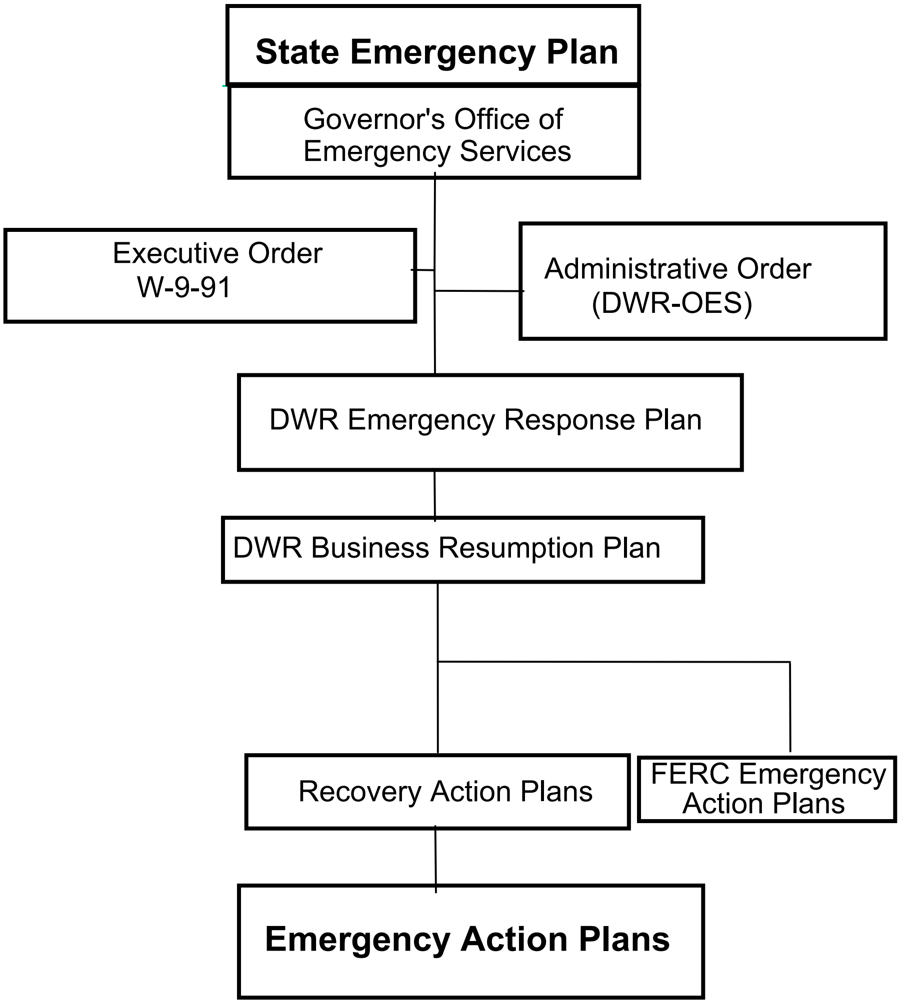
The ERP is the DWR master plan that incorporates the emergency plans of department units and describes the emergency management organization and responsibilities for protecting lives and property. The ERP is mandated by government code and the SEP, which requires each agency to submit an ERP to OES and explain what it will do to provide resources and how critical business will be resumed (Fong pers. comm. 2001). The ERP also describes critical functions of DWR, including the management of essential resources, coordination of emergency response and preparedness, and communication within DWR and with OES (DWR 2000). Along with the BRP, which is discussed below, the ERP is the main document forming the overarching structure for the EAPs. Specifically, the ERP:

- Establishes and maintains guidelines for division and district/field offices for responding to emergencies (that is, preparation and execution of EAPs);
- Outlines how DWR will respond to and manage flood and dam emergencies, incidents on the SWP, acts of terrorism and war, and provide the necessary support to other State agencies during catastrophic events, especially OES;
- Identifies the organization and functions that DWR staff may be assigned to during an emergency using the SEMS concept;
- Outlines the responsibilities of key DWR staff; and
- Integrates essential emergency organizations.

The ERP also incorporates coordination with other federal, State, and local authorities and, at a minimum, is revised annually.

The BRP contains the overall structure and process for addressing business recovery and resumption, including specific plans for critical functions, remote facilities, and major departmental organizations. Its relationship to the other plans and programs is presented in Figure 11-1. The BRP is a confidential document prepared by DWR in July 1999. Because the State would be greatly affected if the DWR were unable to recover and resume business functions following a disaster or during an emergency, the BRP establishes a process that DWR will follow to recover after a catastrophic event.

Figure 11-1 Emergency Planning and Management Structure



Adapted from Fong pers. comm. 2001; DWR 2000

The BRP includes a business analysis listing critical operations and functions, an impact analysis of potential risks and operational impacts, and a detailed recovery strategy. This document is not mandated by law and, like the ERP, is updated annually. The BRP follows SEMS and defines functions, necessary support, decision-making processes, and notification processes. SEMS defines the function of management, operations, planning/intelligence, logistics, and finance/administration during emergency actions. It is used to develop emergency plans and procedures, especially for response to emergencies involving multiple jurisdictions or agencies.

Following the structure presented in Figure 11-1, major components of BRPs are RAPs and field division EAPs, along with the EAPs of the Federal Energy Regulatory Commission (FERC) (DWR 2000). Each division and district office of DWR uses its RAP, along with the EAPs, to provide specific guidance for critical systems and functions of facilities, contacts, actions to take, etc., and interdependency with other agencies.

The EAPs are more specific and contain detailed information on notice procedures within departments, which agencies will do what tasks for different types of emergencies, protocols to handle them, and who will do them. There are 5 DWR field divisions, and the EAP formats are the same and include basic emergency response procedures and concepts for including specific field position assignments, notification flow charts, actions to be taken, and reference information. Specific emergencies addressed in the EAPs include earthquakes, fires, bomb threats, floods, dam or aqueduct failures, hazardous materials spills, civil disturbances, death or injury, and equipment malfunctions affecting delivery of water. More information is provided in Section 11.6, "Description of a Typical DWR Field Division EAP."

11.4 DWR EAP RESPONSIBILITY AND PROCEDURES

The Operations Control Office of DWR's Division of Operations and Maintenance (O&M) has overall responsibility for coordinating SWP operations. The 5 field divisions provide support to the operation and maintenance of SWP facilities. Standard operating orders are an important component of proper operation of the SWP; they provide a consistent procedure for carrying out key tasks and reliable operation of SWP facilities. Orders range from detailed instructions on unit operations to criteria and actions for emergency operation of flood control facilities and notification of affected entities through the EAP. Orders exist for each field division and for the Project Operations Center (POC)/Flood Operations Center at 3310 El Camino Avenue in Sacramento (DWR 2000).

SWP emergencies are declared by staff following directions contained in each field division's EAP. In each field division EAP, a section provides detailed information, criteria, and actions to declare an emergency incident and mobilize a response. The specific incidents covered were described previously. Emergencies can be unique to a particular field division. Once an SWP emergency is declared, a field division coordinates with a designated emergency operations center to assess the situation and form an incident command structure to meet specific response requirements (DWR 2000). An emergency operations center is where centralized emergency management can be carried out, such as the POC.

11.5 RELATED EMERGENCY PLANNING DOCUMENTS

In addition to the ERP and the BRP, there are other important emergency management plans and documents related to the EAP. The DWR Division of Flood Management's *Flood Emergency Manual* describes the coordination of responsibilities between local agencies and OES for responding to flood emergencies under the SEMS. It also describes coordination with the United States Army Corps of Engineers (USACE) under separate memorandum.

Coordination with federal agencies is a major component of DWR's emergency management system. Operation and maintenance of the SWP require coordination with FERC and the United States Bureau of Reclamation (USBR). FERC licenses and regulates power generation facilities and related project features. USBR jointly owns a portion of the SWP known as the San Luis Canal Joint-Use Facilities (aqueduct section 3 in Chapter 8). The SWP joint-use facilities—which include O'Neill Forebay, San Luis Reservoir and Sisk Dam, Los Banos Reservoir, and the San Luis Canal—are part of O&M's San Luis Field Division. Its EAP directs staff to coordinate with USBR field staff when conditions occur that could lead to emergency action (DWR 2000).

Most of the facilities owned by the SWP and their related project features are regulated by FERC. FERC requires that EAPs be prepared to their guidelines and that periodic exercises in emergency response be conducted. FERC would be notified of an emergency and of DWR's response to it. The Oroville complex in the Oroville Field Division and Warne E. William Power Plant and Mojave Power

Plant in Southern Field Division are under the jurisdiction of FERC and have EAPs that cover federal emergency response requirements.

11.6 DESCRIPTION OF A TYPICAL DWR FIELD DIVISION EAP

As previously stated, the purpose of an EAP is to provide comprehensive, easy to follow, and up-to-date information to persons responding to emergencies for a specific field division. The EAP also serves as a reference for emergency training. The EAP is intended to help save lives and reduce property damage in a hydrologic or nonhydrologic event in the SWP. The EAP provides guidance in mobilizing available resources in the most expeditious way in order to manage an emergency.

EAPs for each of the 5 field divisions of the SWP follow essentially the same format. The standardized format serves 2 main purposes.

1) Personnel transferring from one field division to another are able to more readily understand the EAP at their new location; and
2) A consistent format expedites the response of the POC to an emergency in any particular field division because dispatchers know where to look for information within that field division's EAP.

Area Control Centers (ACCs) are linked to the POC and share operational responsibility. The present format was recommended in the initial sanitary survey of the State Water Project conducted in 1990 (Laverty 1990). Copies of field division EAPs are kept at the POC and all ACCs.

The EAP is divided into 5 parts: Basic Information, Emergency Response, Appendices, Enclosures, and Oversized References. Part 1, Basic Information, includes background information and guidance for EAP implementation. Part 2, Emergency Response, contains specific emergency response procedures. These are not expected to change much over time. Part 3, Appendices, contains information that may require updating occasionally. Items such as descriptions of aqueduct check structures, reporting forms, and turnout summaries are contained as appendices. Part 4, Enclosures, includes information that will be frequently updated (names, phone numbers, etc.). Part 5, Oversized References, contains foldout maps and facility lists.

The San Luis Field Division EAP was reviewed and serves to illustrate a typical EAP (DWR 2000a). Information includes details of dams, sections of the aqueduct, generating plants, and other specific structures in the San Luis Field Division. Detection, decision-making, and notification during emergencies are described. Descriptions include routine methods and procedures that will be implemented to detect abnormal structural or hydrologic conditions, notification of appropriate downstream entities, and how to provide information to the public and the media. Detection is the discovery phase that reveals that a hydrologic or nonhydrologic incident has occurred at 1 of the facilities under the jurisdiction of the field division. Decision-making is the analytical process to determine the severity and extent of the incident. Notification is the process of informing downstream public safety officials and other appropriate agencies elsewhere that an event has occurred. Evacuation plans and implementation are the responsibility of downstream local authorities within their respective jurisdictions. The EAP contains inserts that address specific hazards for each facility and outline responsibilities and procedures that downstream local authorities would implement in response to emergency events affecting their jurisdictions.

The emergency response procedure for a particular event consists of a core set of directives, which may reference additional procedures in other parts of the EAP. The EAP should be as self-contained as possible in order to shorten response time.

11.7 EMERGENCY ACTION PLAN MAINTENANCE PROCEDURE

To be effective, the EAP must be current. The format is designed to facilitate updating by placing information that requires frequent changes in a specific section. Section 1 (Basic Information) and Section 2 (Emergency Response) should require little updating. Section 3 (Appendices) may require occasional updating. Section 4 (Enclosures) and Section 5 (Oversized References) contain information that must be updated most frequently.

Each field division is responsible for updating the major sections of its EAP. Section maintenance is the responsibility of the Civil Maintenance Branch of O&M. However, information in certain EAP sections originates from DWR Headquarters, which is better suited to mesh that information with other Departmental and State operations. Copies of the revised plans are sent to all holders of the EAP with instructions to replace outdated pages with the revised pages. A list of the holders of the EAP for each Field Division is provided in each EAP.

11.8 EMERGENCY ACTION PLAN MAINTENANCE RESPONSIBILITY

DWR's O&M Field Division emergency command coordinator and the Civil Maintenance Branch are responsible for updating the EAP by 1

July of each year. The EAP also receives additional review during the annual inspection by the Civil Maintenance Branch.

11.9 EMERGENCY MANAGEMENT AND DUTIES

Unusual events in the SWP are classified into 3 general categories in order to help define the required response:

1) Incident,
2) Emergency, and
3) Disaster.

11.9.1 SWP INCIDENT

An incident is an occurrence that affects the integrity of some portion of the SWP. Although it requires action beyond the routinely prescribed maintenance and repair procedures, an incident is within the capabilities and authority of normally assigned SWP personnel. An SWP incident does not constitute an emergency and will be dealt with by intensified field division effort.

11.9.2 SWP EMERGENCY

An emergency is any occurrence that involves actual or potential damage to SWP facilities, personnel, or to the general public. It cannot be resolved in a timely manner without using procedures beyond those available in the normal operation and maintenance of the division. SWP emergency status exists until remedial actions to resolve the emergency are completed. An SWP emergency status activates procedures contained in the EAP and invokes special emergency fiscal procedures. Emergencies in the SWP are classified into 3 categories, Class 1, Class 2, and Class 3.

11.9.2.1 Class 1 Emergency

A Class 1 emergency is within the capabilities of the specific field division where the event occurred and does not materially affect operations in any other field division. It may require the use of private contractors under field division direction and the use of exempt fiscal authority up to a maximum commitment of $50,000. The field division chief or the designated alternate can declare a Class 1 Emergency.

11.9.2.2 Class 2 Emergency

A Class 2 emergency requires the use of exempt fiscal authority up to a maximum commitment of $500,000. It is declarable by the O&M division chief or the designated alternate. However, it will probably require coordination with OES' State Operations Center and the use of private contractors under field division direction.

11.9.2.3 Class 3 Emergency

A Class 3 emergency requires the use of exempt fiscal authority and financial commitments in excess of $500,000. It is declared only on the authority of DWR's Director. It requires coordination with OES and other involved agencies.

11.9.3 SWP DISASTER

A disaster results in major damage to SWP facilities and is beyond the physical or financial resources of the SWP. A disaster will generally involve a major reevaluation of the impacted site and interrelated SWP facilities. It will also probably require Legislative authorization of special funding.

11.10 EMERGENCY DUTIES OF FIELD DIVISION PERSONNEL

11.10.1 FIELD DIVISION CHIEF

The field division chief is responsible for overall planning of emergency operations and for representing the division on decisions that require O&M Headquarters approval. The field division chief shall determine if an O&M Headquarters investigation is required pursuant to O&M Project Instruction OP-24. If so, the field division chief shall notify the chief of the Water and Plant Engineering Office as soon as practicable, but no later than 24 hours of the occurrence of the incident. Such notification may be channeled through the ACC and POC to expedite contact.

11.10.2 EMERGENCY COMMAND COORDINATOR

The field division chief assigns the emergency command coordinator to a particular individual, usually the hydroelectric plant operations superintendent. The emergency command coordinator is in charge of the Field Division Command Post and coordinates all activities associated with an SWP emergency or disaster. The emergency command coordinator is also responsible for maintenance of the EAP.

11.10.3 HYDROELECTRIC PLANT OPERATIONS SUPERINTENDENT

The hydroelectric plant operations superintendent is responsible for all operations involving plants, aqueducts, and reservoirs. Any work that affects system operation will be coordinated through this position.

11.10.4 CHIEF HYDROELECTRIC PLANT OPERATOR

The chief hydroelectric plant operator is responsible for the operation of plants, control of the remote operation of check structures, and the operation of the ACC.

11.10.5 AREA CONTROL CENTER SENIOR OPERATOR

The ACC senior operator is responsible for notifying the chief hydroelectric plant operator, the POC, and the hydroelectric plant operations superintendent of conditions affecting the system. This information is used to determine if the procedure specified in the EAP is to be put into action. If necessary, the POC informs other field divisions affected by the emergency. All instructions to field division personnel for the operation of plant units or gate operations come through the ACC senior operator.

11.10.6 CIVIL MAINTENANCE SUPERINTENDENT

The civil maintenance superintendent is responsible for determining personnel, supplies, and equipment needed in the impacted area. Decisions are coordinated with the hydroelectric plant operations and hydroelectric plant maintenance superintendents.

11.10.7 HYDROELECTRIC PLANT MAINTENANCE SUPERINTENDENT

The hydroelectric plant maintenance superintendent is responsible for assigning mechanics, electricians, or technicians to the affected plant or aqueduct check. If required, the work is coordinated with the hydroelectric plant operations superintendent or the civil maintenance superintendent.

11.10.8 SUPERVISING POWER O&M ENGINEER

The supervising power O&M engineer is responsible for assigning field division Engineering Branch staff for technical support during an emergency. Staff assignments are coordinated with other superintendents and the emergency command coordinator.

11.10.9 REGIONAL ADMINISTRATIVE OFFICER

The regional administrative officer is responsible for procuring emergency funds, supplies, and services such as aerial flights. The person is also responsible for providing security and for requesting staff from other agencies as needed.

Figure 11-1 illustrates the general emergency management system for SWP. The number of entities that would become involved in the management of an SWP emergency depends on the event's severity. For example, a Class 1 emergency would probably not require establishing a DWR Command Center or coordinating with OES' State Operations Center. However, all of the agencies identified in the diagram would be involved in an SWP disaster.

11.11 AREA CONTROL CENTER AND PROJECT OPERATIONS CENTER NOTIFICATION RESPONSIBILITIES

The ACC is responsible for notifying local agencies and the POC. Local entities include appropriate field division personnel, emergency response staff (such as fire, police and county health departments), local property owners, and SWP water contractors. The ACC will also notify local offices of State agencies such as the Department of Fish and Game and CHP. POC is responsible for notifying the dispatchers of other power agencies—Central Valley Project Dispatch Center, OES, FERC, SWP Headquarters, DWR Division of Safety of Dams, and other SWP ACCs as appropriate. The ACC may request assistance from the POC in making necessary calls. On the other hand, the POC may request assistance from the ACC in making the required notifications.

11.12 COORDINATION WITH THE OFFICE OF EMERGENCY SERVICES

The OES Director is assisted by representatives from other State agencies. This assistance constitutes the State Emergency Management Staff. DWR's Director is the Department's representative to the State Emergency Management Staff. During a "significant emergency," O&M will locate, assess, and report SWP damage to the OES State Operations Center. If appropriate, O&M will also identify damage to field division buildings, request an assessment by the Division of Engineering, and report the results to OES.

11.12.1 MUTUAL AID REGIONS

The mutual aid concept is based on "neighbor helping neighbor" (OES 2001). The mutual aid system provides a mechanism for cities, counties, and the State to assist each other in times of emergencies and disasters. The State is divided into 6 mutual aid regions, and OES maintains an office in each region. The Mutual Aid Regional offices are responsible for carrying out OES programs at the local level and for maintaining working relationships with local emergency management organizations. In addition to emergency managers, staff members from other OES divisions—Law Enforcement, Fire and Rescue, Telecommunications, and Hazardous Material—are assigned to the regions.

During an emergency, the Mutual Aid Region offices are responsible for staffing their emergency operation centers, collecting local damage assessment information, and working with the affected areas in response and recovery efforts.

11.13 PUBLIC INFORMATION AND NEWS MEDIA ASSISTANCE

The DWR Office of Water Education (OWE) is the designated contact for communication with news media and the public during emergencies. The management of OWE recognizes that its staff will not be able to respond quickly enough to help field divisions handle media inquiries during the 1st hours of an emergency. Each field division will designate and train staff to act as crisis information contacts who will provide information to the public and the media during the initial phases of the emergency.

One person is designated as the primary contact, another as the secondary contact. These contacts will be trained to interact with OWE, news media, and the public. The crisis information contacts for field divisions are listed in the appropriate EAP section. Each field division will provide the ACC and the POC with the names of crisis information contacts and the means for contacting them to respond to media inquiries in a timely manner. Inquiries from the public or news media regarding the emergency should be directed to the crisis information contact.

At the onset of an emergency, the crisis information contact should immediately call the OWE chief to determine if the situation warrants sending public information staff to the field division to assist in crisis communication. The OWE chief will also discuss the need to document the situation through videotape or photography. The crisis information contact will be responsible for updating OWE on the status of the emergency. Close communication between the field division and OWE is vital. Information released to the media by OWE and SWP headquarters should be consistent with reports from field divisions.

All OWE information officers maintain a list of all field division crisis information contacts and their office and home phone numbers. OWE staff may call the contacts for firsthand information or, when necessary, to determine the latest state of the emergency conditions. Crisis information contacts also maintain a list of OWE chief and information officers and their office and home phone numbers. OWE information officers and the crisis information contacts are expected to keep a copy of the list at the office and at home. OWE is responsible for annually updating the list of crisis information contacts.

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Pathogens

12.1 INTRODUCTION

This chapter focuses on a number of pathogen issues including bacteria and protozoan occurrences. The topics, scope, and treatment plants selected for review were determined through a joint series of discussions between California Department of Water Resources (DWR) and the California Department of Health Services (DHS). Instead of incorporating a pathogen component into every watershed chapter, selected pathogen topics are highlighted using several water treatment plants (WTPs) from representative sections of the State Water Project (SWP) as examples of pathogen water quality. This chapter focuses solely on pathogen data. Potential contaminating activities that could contribute to pathogen contamination are discussed in individual watershed chapters. Additionally, the reader should refer to Chapter 2 for an in-depth discussion of drinking water regulations.

Representative sections of the SWP chosen for closer examination are presented in Table 12-1. Pumping facilities are discussed in Chapter 7 for the Southern California reservoirs, Chapter 5 for the South Bay Aqueduct (SBA), and Chapter 3 for the North Bay Aqueduct (NBA). Unless otherwise noted, all data in this chapter reflect only SWP raw water influent. In addition to raw water influent at selected WTPs, the majority of pathogen data collected by DWR was also examined in this section.

This chapter is divided into 2 parts. In the 1st part, pathogen water quality data is examined for the WTPs treating water from the selected sections of the SWP. Based on discussions with DHS, the following topics are covered in the 1st part:

- Bacteria Summary Statistics, Section 12.2
- Southern CA Reservoirs-Castaic, Silverwood
- SBA
- NBA
- DWR sample sites
- *Giardia* Cyst Removal, Section 12.3
- Recommended removal based on total coliform numbers
- Recommended removal based on *Giardia* numbers

Table 12-1 Geographical Areas of the SWP Examined for Pathogen Trends

Geographical Area	Agency	Water Treatment Plant
Southern California Reservoirs	MWDSC[a]	Jensen (Castaic Lake) Mills (Silverwood Lake)
South Bay Aqueduct	SCVWD[b] ACFCWCD Zone 7[c] ACWD[d]	Penitencia Del Valle Patterson Pass Water Treatment Plant 2
North Bay Aqueduct	City of Napa City of Benicia North Bay Regional City of Vallejo	Jameson Canyon Benicia NBR[e] Travis

[a] Metropolitan Water District of Southern California
[b] Santa Clara Valley Water District
[c] Alameda County Flood Control and Water Conservation District, Zone 7
[d] Alameda County Water District
[e] North Bay Regional

- *Cryptosporidium* Running Averages, Section 12.4
- Long Term 2 Enhanced Surface Water Treatment Rule (ESWTR) Microbial Index, Section 12.5

The 2nd part of this chapter summarizes work conducted by Dr. Michael Anderson of UC Riverside. In his paper, Dr. Anderson evaluates the impacts of body-contact recreation on water quality at SWP's 4 Southern California reservoirs: Perris, Castaic, Silverwood, and Pyramid. Appendix A contains the full text of Dr. Anderson's report.

Previous chapters suggest pathogen studies for several watersheds. During the years covered by this sanitary survey, the United States Environmental Protection Agency (EPA) promulgated 2 methods to examine *Cryptosporidium* and *Giardia* concentrations. They are the EPA's Information Collection Rule (ICR) and Method 1623. Municipal Water Quality Investigations (MWQI) at DWR has conducted special studies on both of these methods. Section 12.7, Protozoan Sampling Method Concerns, summarizes the issues surrounding the difficulty using these methods for pathogen sampling. The weakness in data quality using these methods and the inherent difficulty interpreting the results, make conducting some of the proposed pathogen studies in previous watershed chapters problematic. Appendices B and C contain details of the sample design and data analyses conducted by DWR using either the ICR method (Appendix B) or Method 1623 (Appendix C).

12.2 BACTERIA SUMMARY

Table 12-2 summarizes total coliform data for all sites routinely sampled by DWR and selected WTPs, which processed only SWP water (or virtually only SWP water as in the case of the Jensen and Mills Filtration Plants (FPs)). In the case of SBA contractors, data from the SBA and Lake Del Valle were combined. Tables 12-3 and 12-4 summarize fecal coliform and *E. coli* data, respectively. Data are not always directly comparable. Different WTPs often sampled on different days or used different sampling regimes. In some cases, data were not available for the entire period of record; in others, sampling frequency varied between those collected weekly and those collected daily. Table 12-2 also illustrates the effect of dilution and test sensitivity on calculated densities. In some cases, the maximum values could only be listed as greater than a calculated value (for example, not enough dilutions were conducted to resolve densities beyond the stated maximum value). In other cases, the sensitivity of the test could not resolve densities below a certain level, for example, less than 2. For statistical calculations, the maximum value was substituted for values greater than the stated maximum level. Zero was substitued for values reported as less than the detection limit. In both cases, this could potentially skew the results; however, it was felt that this approach was preferable to removing the data completely from the analysis. While data may not have been always directly comparable, the size of most datasets provided patterns of occurrence that should be fairly robust.

Currently, DHS only requires presence/absence reporting for *E. coli*; however, all plants profiled enumerated *E. coli*. Of particular importance was the use of Colilert™ data for the measurement of both total and *E. coli*. The majority of utilities profiled used either Multiple Tube Fermentation (MTF) or Membrane Filtration (MF) to enumerate total coliforms in their source water. However, a significant minority used the enzyme-based Colilert™ method. A number of comparative tests have found no significant difference between Colilert™ results and either the MTF or MF methods (Covert and others 1988, Wollin and others 1992). Others have found a slight, nonsignificant bias toward Colilert ™ (Edberg and others 1988, Katamay 1990). However, Smith (1992) found a high rate of false positives for total coliform using California Aqueduct water and the Colilert™ method. Eighty-two percent of tests that were negative for total coliform using the MTF method were recorded as positive for total coliform by the Colilert™ method and were found to be non-coliforms upon subculturing. A more recent study has found a lower rate of false positives for total coliform with Colilert™ (between 13% and 36%), but high rates of false positives for total coliform with other enzyme-based methods, for example, Colilert 18™ or E*Colite™ (Smith 1999). Unfortunately, no replication appeared to have been conducted with the 1999 study, but these results suggest that the most conservative approach to determining source water occurrence of total coliform would be to exclude Colilert™ data. In the case of contractors along the SBA, 3 of the 4 utilities used Colilert™ for at least 3 of the 4 years covered by this sanitary survey update. Because only 1 SBA WTP would have been examined if Colilert™ data had been excluded, DHS and DWR decided to include Colilert™ data for SBA contractors. With respect to *E. coli*, Smith found the methods are comparable (1992, 1999); therefore, all Colilert™ *E. coli* data were included.

Table 12-2 Total Coliform Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water

(Except Where Noted, All Samples Analyzed by Multiple Tube Fermentation) (MPN/100 mL)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	# Detects/ Total Sampled
DWR	Barker Slough Pumping Plant[a]	500	4	50,000	157 – 1,600	34/34
	Banks Pumping Plant[b]	50	7	3,000	15 - 710	24/24
	Delta Mendota Canal @ McCabe Road[b]	75	8	9,000	16 - 780	24/24
	Arroyo Valle Creek Inflow to Lake Del Valle[c]	110	13	3,000	38 - 760	15/15
MWDSC	Jensen Filtration Plant[d]	4	<2	≥1,600	<2 - 50	NA/1,040
	Mills Filtration Plant[d]	4	<2	≥1,600	<2 - 17	NA/1,011
NBA	City of Benicia WTP[e]	105	9	≥1,600	30 - 300	184/184
	Jameson Canyon WTP (Napa)[f]	170	8	>2,400	19 – 1,600	54/54
	North Bay Regional WTP (Fairfield, Vacaville)[g]	100 CFU/ 100 mLs[l]	<4	5,500	20 - 300	504/517
	Travis Air Force Base WTP (Vallejo)[h]	50 CFU/ 100 mLs[l]	<4	3,300	10 - 200	199/206
SBA	Penitencia WTP[i]	22	< 2	1,600	4-80	242/251
	Del Valle WTP[j**]	201	0	1,652	18 – >1,003	204/206
	Patterson Pass WTP[h**]	59	0	>1,003	6 - 583	200/203
	WTP2[k*]	500	<2	≥1,600	50 –1,600	993/995

[a] Samples collected monthly from Nov 1996 to Dec 1999, monthly sampling to continue indefinitely.

[b] Samples collected monthly from Apr 1996 to May 1998, no samples collected since May 1998.

[c] Sampled monthly from Apr 1996 to May 1998 unless no flow.

[d] Samples collected 4 times a week from Jan 1996 to Jun 2000.

[e] Samples collected Jan 1996 and then weekly from Mar 1996 to Dec 1999.

[f] Samples collected weekly from May 1997 to Dec 1999 when plant receiving NBA water, otherwise off-line.

[g] Samples collected daily from Mar 1996 to Jan 1998 when plant receiving NBA water. Plant switched to Colilert™ method Feb 1998. Colilert™ data not used for calculations.

[h] Samples collected weekly from Jan 1996 to Dec 1999.

[i] Samples collected daily from Jan 1996 to Apr 1997. Samples collected weekly May 1997 to Dec 1999.

[j] Samples generally collected weekly from Jan 1996 to Dec 1999. No data provided from 16 Jan to 13 Feb 1996.

[k] Sample collected Jan 1996 and then generally daily from Oct 1996 to Dec 1999. No data provided from 23 Oct 1996 to 26 Jan 1998, 2 Nov to 17 Nov 1998, 25 Oct to 26 Nov 1999.

[l] Samples analyzed by Membrane Filtration.

*Samples analyzed by Colilert™.

**Beginning Feb 1997, samples analyzed by Colilert™.

Summary Statistics calculated by substituting 0 for all values less than the detection limit.

Recorded value substituted for values recorded as > than the recorded value.

NA-- unable to analyze from data received

Table 12-3 Fecal Coliform Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water
(Except Where Noted, All Samples Analyzed by Multiple Tube Fermentation) (MPN/100 mL)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	Number Detects/ Total Sampled
DWR	Barker Slough Pumping Plant[a]	220	2	3,000	75 - 500	36/36
	Banks Pumping Plant[b]	14	4	300	7 - 290	26/26
	Delta Mendota Canal @ McCabe Road[b]	29	<2	240	6 - 105	24/26
	Arroyo Valle Creek Inflow to Lake Del Valle[c]	70	2	800	23 - 200	15/15
MWDSC	Jensen Filtration Plant[d]	2	<2	≥1600	<2 - 30	NA/1,040
	Mills Filtration Plant[d]	<2	<2	900	< 2 - 4	NA/1,016
NBA	City of Benicia WTP	not analyzed				
	Jameson Canyon WTP (Napa)	not analyzed				
	North Bay Regional WTP (Fairfield, Vacaville)	not analyzed				
	Travis Air Force Base WTP (Vallejo)[e]	20 CFU/ 100 mL[h]	<2	3,300	< 2 - 132	168/203
SBA	Penitencia WTP[f]	7	<2	240	< 2 - 30	211/251
	Del Valle WTP[g]	-	-	-	-	-
	Patterson Pass WTP[g]	-	-	-	-	-
	WTP2	NA				

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[a] Samples collected monthly from Nov 1996 to Dec 1999, monthly sampling to continue indefinitely.
[b] Samples collected monthly from Apr 1996 to May 1998, no samples collected since May 1998.
[c] Samples collected monthly from Apr 1996 to May 1998 unless no flow.
[d] Samples collected 4 times a week from Jan 1996 to Jun 2000.
[e] Samples collected weekly from Jan 1996 to Dec 1999.
[f] Samples collected daily from Jan 1996 to Apr 1997. Samples collected weekly from May 1997 to Dec 1999.
[g] Fecal coliform samples only collected Jan 1997.
[h] Samples analyzed by Membrane Filtration.
NA—not analyzed.
Summary Statistics calculated by substituting 0 for all values less than the detection limit.
Recorded value substituted for values recorded as > than the recorded value.

Table 12-4 *E. coli* Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water (Except Where Noted, All Samples Analyzed by Multiple Tube Fermentation) (MPN/100 mL)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	Number Detects/ Total Sampled
DWR	Barker Slough Pumping Plant[a]	195	<2	3,000	60 - 500	35/36
	Banks Pumping Plant	NA				
	Delta Mendota Canal @ McCabe Road	NA				
	Arroyo Valle Creek Inflow to Lake Del Valle	NA				
MWDSC	Jensen Filtration Plant[b]	2	<2	≥1,600	<2 - 30	NA/1,040
	Mills Filtration Plant[b]	<2	<2	900	<2 - 4	NA/1,016
NBA	City of Benicia WTP[c]	26	<2	>1,600	6 - 94	181/183
	Jameson Canyon WTP (Napa)[d]	17	<2	>2,400	4 - 687	26/27
	North Bay Regional WTP (Fairfield, Vacaville)	not reported				
	Travis Air Force Base WTP (Vallejo)	NA				
SBA	Penitencia WTP[e]	4	<2	240	< 2 - 23	207/251
	Del Valle WTP[f*]	5	0	109	0 – 29	86/102
	Patterson Pass WTP[f*]	1	0	101	0 – 26	72/100
	WTP2[g*]	7	<2	>1,600	<2 - 33	871/995

[a] Samples collected monthly Nov 1996 to Dec 1999, monthly sampling to continue indefinitely

[b] Samples collected 4 times a week from Jan 1996 to Jun 2000.

[c] Sample collected Jan 1996 and then weekly from Mar 1996 to Dec 1999.

[d] Samples collected weekly Nov 1998 to Dec 1999 when plant receiving NBA water, otherwise off-line.

[e] Samples collected daily, Jan 1996 to Apr 1997. Samples collected weekly in May 1997 to Dec 1999.

[f] Samples collected from Feb 1997 to Dec 1998. Sampling discontinued per ELAP approval.

[g] Sample collected Jan 1996 and then generally daily from Oct 1996 to Dec 1999. No data provided from 23 Oct 1996 to 26 Nov 1998, 2 Nov 1998 to 17 Nov 1998, 25 Oct 1999 to 26 Nov 1999.

[*] Samples analyzed by Colilert™

NA—not analyzed

Summary Statistics calculated by substituting 0 for all values less than the detection limit

Recorded value substituted for values recorded as > than the recorded value.

12.2.1 BACTERIA SUMMARY STATISTICS – SOUTHERN CALIFORNIA RESERVOIRS

At 4 most probable number (MPN)/100 mL, the median total coliform densities were identical for the Jensen and Mills FPs of Metropolitan Water District of Southern California (MWDSC) (Table 12-2). Total coliform are measured 4 days a week at each of these plants, so these results are highly robust. Furthermore, although samples greater than or equal to 1600 MPN/100 mL were detected at both sites, 90% of all total coliform densities fell below 50 and 17 MPN/100 mL for Jensen and Mills, respectively.

Like total coliforms, fecal coliform detected at MWDSC's Jensen and Mills FPs were also very low and were nearly identical (2 and <2 MPN/100 mL for Jensen and Mills, respectively) (Table 12-3). At both plants, values near or above 1,000 MPN/100 mL have been detected; however, 90% of all detections fell below 30 or 4 MPN/100 mL for Jensen and Mills, respectively.

Median , minimum, maximum, and percentile ranges for *E. coli* at the Jensen and Mills FPs were identical to their respective fecal coliform values (Table 12-4).

12.2.2 BACTERIA SUMMARY STATISTICS – SOUTH BAY AQUEDUCT

The highest total coliform densities of any of the WTPs examined were calculated from Water Treatment Plant 2 (WTP2) of the Alameda County Water District (ACWD). WTP2 only receives water from the SBA and, like Jensen and Mills, analyzes total coliform daily. The plant's 4-year median of 500 MPN/100 mL was 2 orders of magnitude higher than the 4 MPN/100 mL total coliform median calculated for the MWDSC plants (Table 12-2). However, WTP2 also uses Colilert™ to analyze total coliform; therefore, the inflation of total coliform numbers cannot be ruled out. Comparison of Jensen and Mills with the only SBA plant to use the MTF method (Penitencia WTP) showed similar percentile ranges and minimum and maximum values; however, median densities were higher at Penitencia than at the Southern California WTPs.

Of the 4 plants receiving SBA water, WTP2 had the highest median total coliform densities while Penitencia had the lowest. Although Penitencia's total coliform densities could reach as high as 1,600 MPN/100 mL or greater, its median and percentile ranges were the lowest of any of the SBA plants profiled. With respect to the 2 remaining SBA WTPs—Patterson Pass and Del Valle—the Patterson Pass WTP appeared to have better total coliform water quality. Like the Del Valle WTP, Patterson Pass WTP has detections of total coliform above 1,000 MPN/100 mL. However, Patterson Pass's percentile ranges and its 4-year median of 59 MPN/100 mL indicate that high total coliform densities have not occurred as frequently or in as high of numbers as at the Del Valle WTP.

With the exception of the Patterson Pass WTP, all the SBA treatment plants examined received their water from the enclosed sections of the SBA. It is not known why such a large difference in total coliform numbers should be observed between the Penitencia WTP and the Del Valle WTP and WTP2. One explanation may be the method used to analyze for total coliform. Both WTP2 and the Del Valle WTP use Colilert™ to analyze their source waters. The Penitencia WTP uses the MTF method. The higher bacterial concentrations at WTP2 and the Del Valle WTP could be explained if Colilert™ detects bacteria other than coliforms. The Patterson Pass WTP also analyzes total coliform using the Colilert™ method. This is the only WTP examined that received water from the Delta. Furthermore, the 30 million gallons per day (mgd) raw water reservoir at the plant serves as a presedimentation basin, which appears to improve the water quality for several constituents including bacteria (Deol pers. comm.). Unfortunately, only 1 (Penitencia WTP) out of 4 SBA plants monitors for fecal coliform, thus the data could not be used as an indicator of bacterial water quality among SBA WTPs (Table 12-3). All 4 plants monitor for *E. coli*. The data indicated that although WTP2's total coliform levels were substantially higher than any of the other SBA plants profiled, this was not the case for the plant's *E. coli* measurements (Table 12-4). *E. coli* numbers at WTP2 could reach higher levels than *E. coli* numbers detected at Penitencia, Del Valle, and Patterson Pass WTPs (>1600 MPN/100 mL vs. 240 MPN/100 mL, 109 MPN/100mL, and 101 MPN/100 mL, respectively). However, the percentile ranges and the medians between the 4 plants were similar, suggesting that *E. coli* levels at WTP2 are only slightly higher than at the other SBA plants profiled.

When compared to other daily measurements of *E. coli*, WTP2's appeared similar to daily samples collected from the Jensen FP in Southern California. However, the median suggested that higher *E. coli* densities occurred more frequently at WTP2.

12.2.3 BACTERIA SUMMARY STATISTICS – NORTH BAY AQUEDUCT

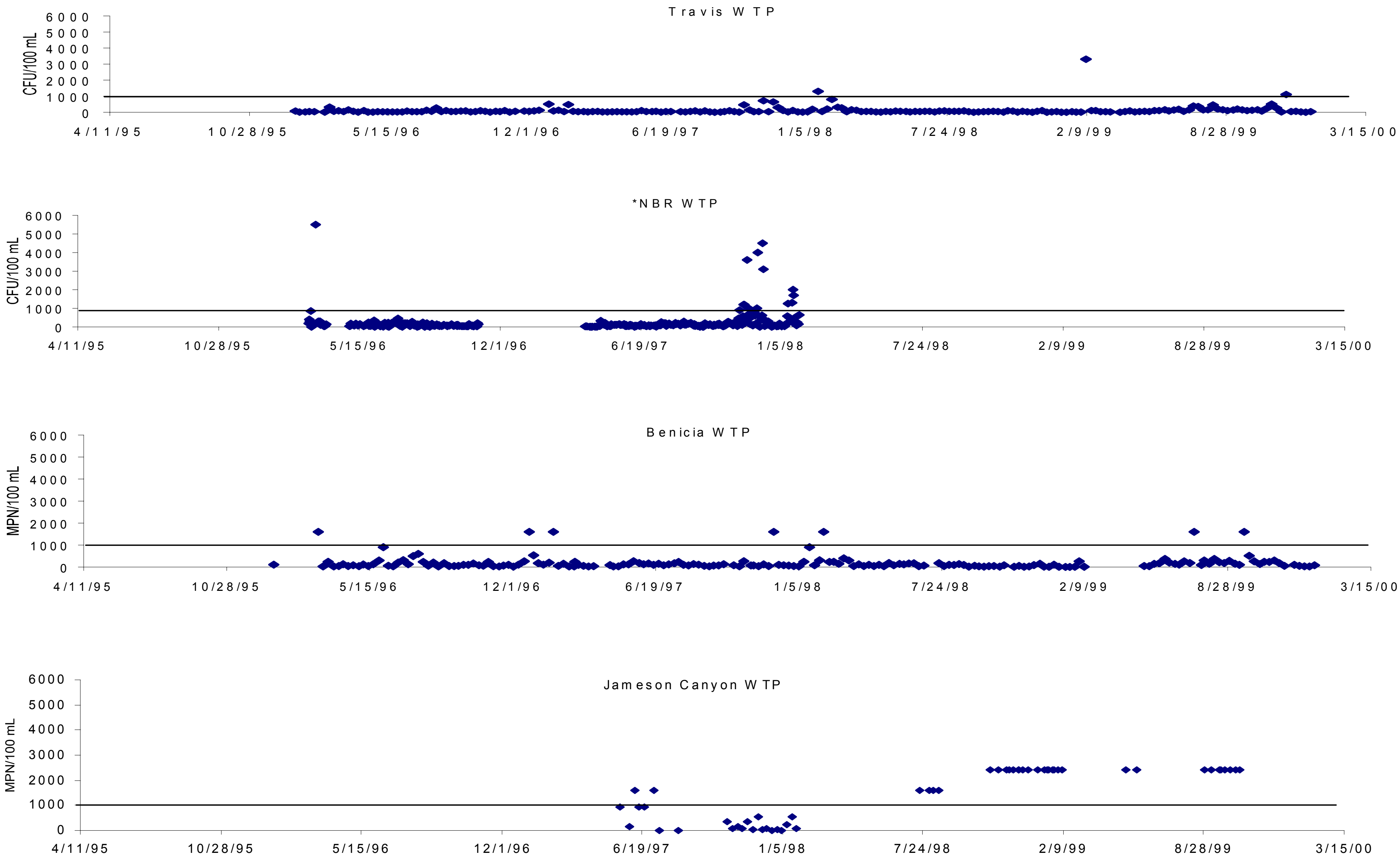
Unlike the SBA WTPs where some plants had relatively low median coliform values and others had relatively high values, the median values for all of the NBA WTPs profiled were relatively high (Table 12-2). In some cases NBA data sets did not cover a full year of sampling or the entire 4-year reporting period (Jameson Canyon and North Bay Regional WTP). With this sort of data, it is important to remember that samples collected for only a part of the year may create summary statistics skewed to the water quality conditions associated with the season of collection. For example, on average plants that primarily operate in the winter would be expected to have higher pathogen densities than plants that operate all year. Of the NBA plants profiled, the City of Napa's Jameson Canyon WTP uses NBA water most often in the winter.

Of the NBA plants, the highest reported total coliform values occurred at the North Bay Regional (NBR) and the Jameson Canyon WTPs. However, 90% of NBR WTP's coliform densities fell at or below 300 Colony Forming Units (CFU)/100 mL, whereas 90% of Jameson Canyon's total colform densities fell at or below 1600 MPN/100 mL. The NBR WTP used MF during this period to enumerate total coliform while the Jameson Canyon WTP used the MTF method. When evaluating raw water using median values, DHS considers the MTF and the MF methods equivalent (Mills pers. comm.), and both labs must show adequate correlation between MTF and MF in order to be certified to use the MF method. However, Standard Methods does note that results from the MTF test would be expected to be higher than MF results because of a built-in positive statistical bias of approximately 23%, but that 80% of MF test results would be expected to fall within the 95% confidence limits of the MTF test results (Anonymous 1995)

The NBR WTP has the option of switching to an alternative water source; however, during the period when this plant was using NBA water, its summary statistics were also similar to the Benicia and Travis WTPs (Table 12-2). The NBR used MF from January 1996 through January 1998. In February 1998, the laboratory began using Colilert™. Total coliform analyzed by Colilert™ were not included in the analysis. The WTPs for the City of Benicia and Travis AFB rely primarily on NBA water all year. Both plants analyze their raw water weekly for total coliform. Although the City of Benicia measures total coliform using MTF and Travis uses MF, the results between the 2 plants were similar.

As noted previously, Jameson Canyon's statistics may be skewed toward higher numbers; however, an analysis of the data suggests that the higher total coliform numbers may reflect more than a seasonal inflation of the numbers or the effects of a small sample size. Both the Jameson Canyon and the City of Benicia's WTPs rely principally on NBA water. Both also use the MTF method to evaluate total coliforms. Upstream to the Cordelia Forebay, the same conveyance structure is used by both utilities. Downstream of the Cordelia Forebay, separate conveyance structures deliver water to the respective plants. An analysis of the 39 total coliform samples collected at the 2 plants within 24 hours of each other found that nearly half (18/39) of Jameson Canyon's total coliform 95% confidence intervals (CI) did not overlap with total coliform 95% CI values from the Benicia WTP (Figure 12-1). Because contamination would have to occur downstream of the Cordelia Forebay, there may be an unknown source of total coliform contamination between the Cordelia Forebay and the inlet to the Jameson Canyon WTP. To corroborate this conclusion, total coliform densities were also examined upstream of the Cordelia Forebay. Because NBR uses Colilert™, total coliform patterns could not be examined at the NBR WTP upstream of the Cordelia Forebay. However, the Travis AFB WTP is also upstream of Jameson Canyon and the Cordelia Forebay. Total coliform at this plant is analyzed by MF. As shown in Figure 12-1, periods of high total coliform values at the Jameson Canyon WTP were not observed at the Travis AFB WTP. With respect to total coliform, a 2nd pattern was observed in winter 1997/1998 at the NBR WTP. When compared to the Travis AFB WTP, total coliform values from November 1997 through January 1998 were higher at the NBR WTP (MF method was used by the NBR plant during this period). However, statistical comparisons of total coliform densities collected on the same day ($n = 12$) found no significant difference ($p = 0.53$), and the patterns between the 2 plants were similar (Spearman $r = 0.72$). One factor in these results may have been the small sample size.

Figure 12-1 Total Coliform Densities (CFU or MPN/100 mL) for Selected NBA Utilities



0 substituted for values < DL. Values > upper DL changed to upper value.

*NBR began use of Colilert 2/98

Fecal coliform values were only available from the Travis WTP (Table 12-3). Samples are collected weekly. Fecal coliform values as high as 3,300 CFU/100 mL were recorded at this plant. Ninety percent of this plant's fecal coliform values fell below 132 CFU/mL, whereas for other plants profiled, 90% of their fecal coliform fell below 40 MPN/100 mL.

E. coli values from NBA contractors were also higher than *E. coli* values recorded from the other plants profiled in this section. For example, both the City of Benicia and the ACWD's WTP2 could experience *E. coli* numbers above 1,600 MPN/100 mL (Table 12-4). However, Benicia's *E. coli* values were higher than WTP2's both statistically (Mann-Whitney, 2-tailed, $p< 0.05$) and visually (median and percentile ranges). Median *E. coli* values at Jameson Canyon were similar to those observed at Benicia; however, as shown by the maximum and percentile range values, *E. coli* contamination at Jameson Canyon could be more severe than at the Benicia WTP.

In summary, bacterial statistics and conclusions in this chapter were derived from very large datasets. Bacteriological sampling at the utilities generally occurred weekly or, in the case of the MWDSC data, 4 times a week. Therefore, this data suggest fairly robust occurrence patterns. However, based on method differences, direct comparisons were not always possible. Given these caveats, bacteriological statistics suggested that MWDSC generally had the best bacteriological water quality of any of the SWP utilities examined. This does not mean that the MWDSC plants could not experience episodic events where bacteria numbers peaked (for example, during rainfall events and as shown by the maximum values recorded). Based on 90th percentile values, 90% of MWDSC's total, fecal, or *E. coli* values fell below 50 MPN/100 mL. This suggests that any proactive measures to minimize livestock and recreation impacts should continue. The same conclusion appeared to be true for fecal and *E. coli* contamination in the SBA. Ninety percent of SBA utilities' fecal and *E. coli* densities also fell below 50 MPN/100 mL. Like the Southern California reservoirs, this suggested that any proactive measures to minimize the impacts of livestock and recreation should be continued. It is difficult to determine the true density of total coliform numbers for most SBA utilities because of the potential confounding factor associated with the Colilert ™ method; however, 90% of the total coliform densities from the 1 utility that did not use Colilert ™ (SCVWD) were below 80 MPN/100 mL. In some cases NBA bacteria data could be more problematic to interpret, but with respect to fecal and *E. coli* values, NBA contractors appeared to experience the worst bacteriological water quality of any of the plants examined. Data suggested *E. coli* contamination occurring between the Cordelia Forebay and the Jameson Canyon WTP. The uncovered Napa Turnout tank is the 1st obvious source to examine for contamination. For all NBA contractors, their higher levels of bacterial contamination probably reflect the influence of easy access to the slough by livestock.

12.2.4 BACTERIA SUMMARY – DWR

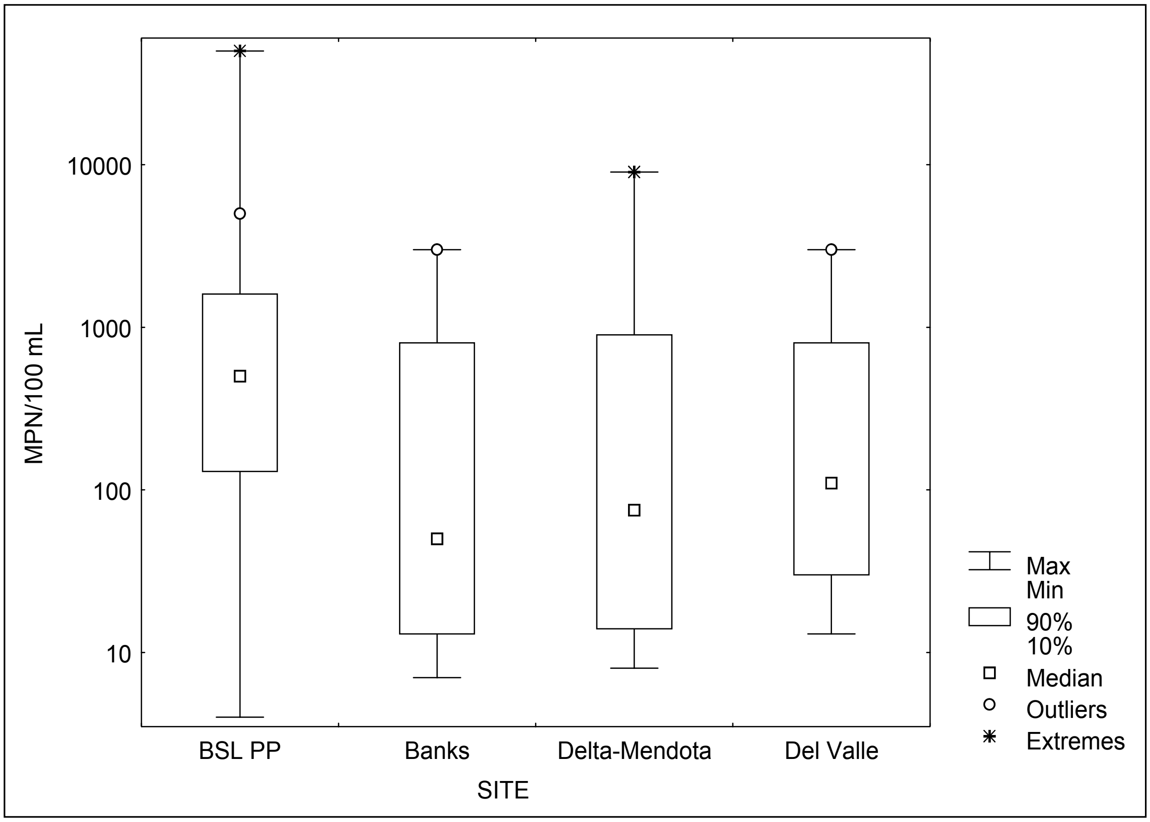
Tables 12-2 through 12-4 summarize all total, fecal coliform and *E. coli* sampling of the SWP between 1996 and 1999 conducted by DWR's Division of Operation and Maintenance (O&M). Bacteria data were also collected in the summers of 1996 and 1997 at the O'Neill Forebay. However, the data were only recorded as presence/absence; therefore, no quantification was possible. See Chapter 8, Section 2.4.2 for this information. Not shown are the few occasional samples that have been collected by O&M on the SWP or the nonelectronic data collected at the 5 small WTPs serving O&M's district offices.

Of the 4 sites sampled, coliform data for the Barker Slough Pumping Plant are the most complete. Total and fecal coliform and *E. coli* data have been collected there monthly since November 1996. Monthly sampling has continued through 2001 and is slated to continue based on contractor input. Of the remaining 3 sites, monthly samples for total and fecal coliform were generally collected between April 1996 and May 1998 as part of the EPA's ICR sampling program at the Banks Pumping Plant, Delta-Mendota Canal at McCabe Road. At the inflow of Arroyo Valle Creek to Lake Del Valle, samples were collected during the rainy season (late October/November to May) or during storm events (October 1996 to May 1998). No *E. coli* data were available at these 3 sites.

Based on input from SBA contractors, O&M resumed bacteria (total, fecal and *E. coli*) sampling in Lake Del Valle beginning September 2000. Samples are collected monthly at the Conservation Outlet Works tunnel during Lake Del Valle releases. Additionally, samples are collected quarterly at the lake's surface and 2 valve locations—the 650-foot and 670-foot valve elevations. Sampling for these and other parameters is expected to continue for at least a year at which time data will be reviewed and determined if continued sampling is necessary (Janik pers. comm.).

Because of the small dataset and the infrequency of sampling (once a month), any comparisons or conclusions between the DWR sites can only be

Figure 12-2 Total Coliforms for Sites Sampled by DWR, 1996 to 1999



considered preliminary. Based on the size of the dataset, data from the Barker Slough Pumping Plant are the most robust. However, to verify the observations between the respective DWR sampling sites, a more rigorous sampling program overall would be required. With these caveats, of the 4 DWR sites sampled, the highest median total and fecal coliform values occurred at the Barker Slough Pumping Plant while the lowest values occurred at the Banks Pumping Plant. Median total and fecal coliform levels at the Barker Slough Pumping Plant (500 and 220 MPN/100 mL, respectively) were approximately an order of magnitude higher than median values at Banks Pumping Plant or the Delta-Mendota Canal (Tables 12-2 and 12-3, respectively). Also, the maximum recorded value at the Barker Slough Pumping Plant was 50,000 MPN/100 mL—the highest total coliform value of any site profiled in this section. Barker Slough Pumping Plant also showed the largest variation in bacterial density (Figure 12-2). Ninety percent of Barker Slough samples were found at 1,600 MPN/100 mL or less. In contrast, 90% of samples collected at the Arroyo Valle Creek site (the site with the next highest total coliform densities) fell at or below 760 MPN/100 mL. As stated earlier, samples were only collected at the Arroyo Valle site during the rainy season. Often the highest coliform densities are observed during the rainy season. This suggests that under conditions conducive to high coliform densities, coliform levels at the Arroyo Valle site were still lower than those observed at Barker Slough; however, the smaller sample size may also be a factor in these results. In general total, fecal, and *E. coli* medians and percentile ranges at the DWR sampling sites were higher than those observed at the WTPs; however, the differences in sampling frequencies or sample sizes precludes robust conclusions.

In addition to O&M, the Department's MWQI unit has collected bacteria data for special studies (Table 12-5). In general, over the 4-year period, less than 15 samples have been collected at any 1 site. The only exceptions are many locations within the Barker Slough sampling area and the Natomas East Main

Table 12-5 Coliform and *E. coli* Values in MPN/ 100 mL for all Samples Collected by MWQI, 1996 to 1999[a]

	Total coliform			*E. coli*					
	Colilert™			Colilert			EC-MUG		
Site	Median	Range	Detects/ total sampled	Median	Range	Detects/ total sampled	Median	Range	Detects/ total sampled
Alamar					22	1/1			
Alomar Marina				<1	<1	0/4			
Alomar Marina								<2	0/1
American				32	3 - 145	10/10			
Banks				30	3 - 238	8/8			
Barker Sl @ Cook Rd				262	18 – 3,240	50/50			
BarkerNoBay				113	11 – 1,013	30/30			
BarkerNoBay	<1	<1	0/11						
BkrSlDalRd					488	1/1			
BkrSlHayRd					1,733	1/1			
Calhoun Cut @ Hwy 1				238	29 – 2,419	51/51			
Camplbell					74	1/1			
ConCosPP1				12	4 - 41	10/10			
Dally				1,468	326 – 7,701	4/4			
DMC				25	9 - 782	11/11			
Fremont					48	1/1			
Greenes				6	< 2 - 50	8/12			
Greenes								<2	0/1
Greenes									
Greenes									
Hay				1,811	192 – 6,131	6/6			
Lindsey Sl. @ Bridge				18	2 - 782	50/50			
MallardIS				12	3 - 78	11/11			
Meridian					1,640	1/1			
MiddleR				13	3 - 364	10/10			
Miller					27	1/1			
Natomas EMDC A EL CA				345	52 – 12,033	25/25			
Natomas EMDC A EL CA	<1	<1	0/19						
OldRivBacISL				6	2 - 344	12/12			
PS-1/ Mokelumne					831	1/1			
SacWSacINT				10	6 - 21	9/9			
Shag				165	101 - 659	3/3			
SJRMossDale				109	7 - 406	10/10			
Station09				12	3 - 531	11/11			
Vernalis				70	< 2 – 3,440	11/15			
Vernalis								<2	0/1

[a] No bacteria samples in database prior to 1996.

Notes: Locations in bold are sites with *E. coli* numbers above 1,000 MPN.
Recorded values substituted for values recorded as > recorded value.
Summary statistics calculated by substituting 0 for values less than detection limit.

Drainage Canal at El Camino. Of the 35 sites sampled by MWQI, 9 had *E. coli* numbers with maximum values $\geq$ 1,000 MPN/100 mL. The majority of these samples were collected from the Barker Slough sampling area; however, the highest value (12,033 MPN/100 mL) was detected at the Natomas East Main Drainage Canal in an urban area

12.3 *GIARDIA*

12.3.1 RECOMMENDED REMOVAL BASED ON TOTAL COLIFORM

The Surface Water Treatment Rule sets minimum treatment requirements for source waters used in the State, which are of reasonably high quality. The EPA based the federal regulations on a health risk of 1 case of microbiologically caused illness per year per 10,000 people and provided guidance on levels of protection for sources with varying concentrations of *Giardia* cysts. However, in some situations source waters may be subjected to significant sewage and recreational hazards where it may be necessary to require higher levels of virus and cyst removal (DHS 1991). Additionally, monitoring for *Giardia* is not always reliable, and for smaller utilities, it may not be economically feasible. To determine the minimum levels of treatment required to remove *Giardia* and viruses and meet EPA health risk recommendations, DHS uses total coliform numbers as a guideline for increased treatment. State guidelines for *Giardia* cyst reduction based on total coliform numbers are shown in Table 12-6. State guidelines for virus reduction are presented in Table 12-7. These guidelines are considered conservative and provide flexibility for a supplier who may disagree with this approach (DHS 1991).

Figure 12-3 shows the total coliform median values for MWDSC's Jensen and Mills FPs calculated by month over the 4-year period of the report. During this period, monthly medians at MWDSC's Jensen and Mills plants never exceeded 1,000 MPNs/100 mL. (Note that this utility provided monthly averages of its daily values. Four-year monthly medians were calculated based on these values. These 4-year monthly medians are not true medians of the data, but the overall conclusions should remain the same).

Table 12-6 Treatment Requirements for *Giardia* Cyst Reduction

Level of Microbiological Contamination[a]	Giardia cyst Treatment Requirements (Log Removals)	Monitoring Frequency
< 1,000	3	2/month
> 1,000 - 10,000	4	Weekly
>10,000 - 100,000	5	Daily

Adapted from DHS 1991

[a] Median monthly total coliform concentrations [MPN or CFU]/100 mL raw water. Levels developed with MTF method (Haberman pers. comm 2001)

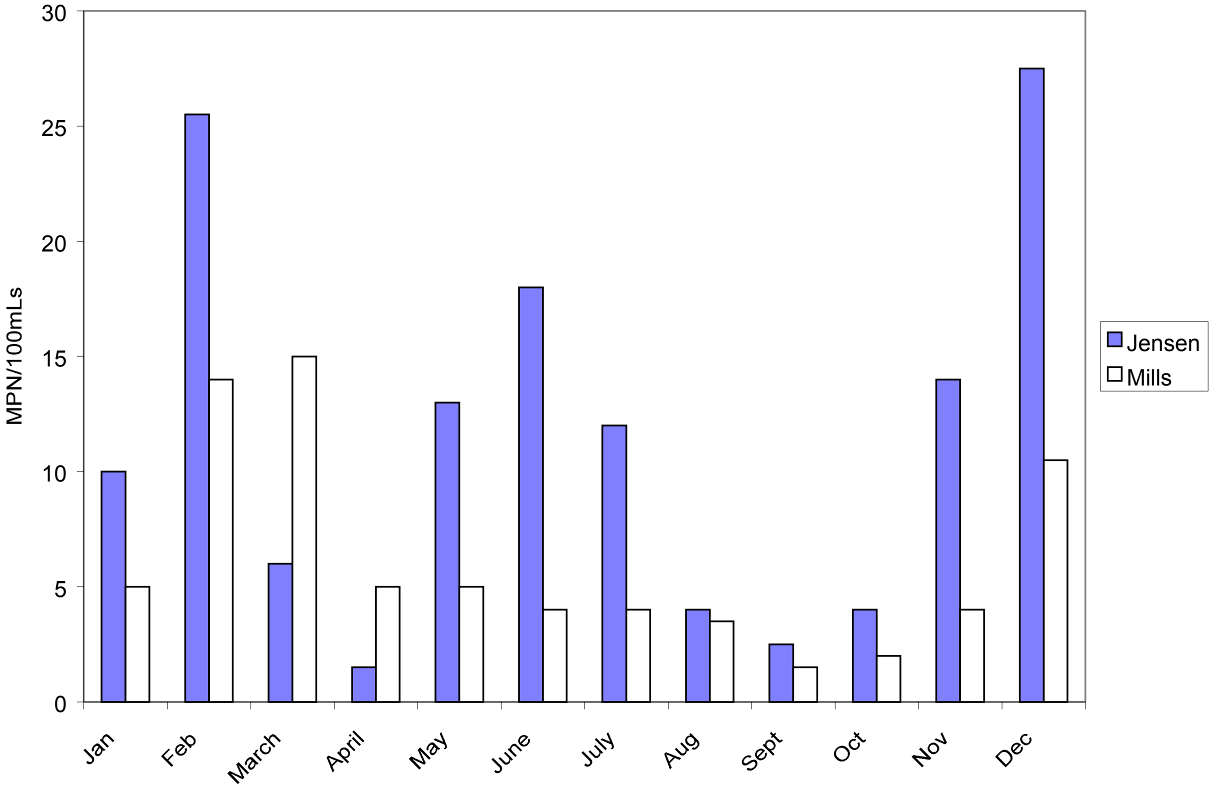
Table 12-7 Treatment Requirements for Virus Reduction

Level of Microbiological Contamination[a]	Virus Treatment Requirements (Log Removals)
< 1,000	4
> 1,000 - 10,000	5
>10,000 - 100,000	6

Adapted from DHS 1991

[a] Median monthly total coliform concentrations [MPN or CFU]/100 mL raw water

Figure 12-3 Median Total Coliform Values By Month – Jensen vs. Mills Filtration Plants, 1996 to 1999



With respect to the SBA plants, monthly medians above 1,000 MPNs/100 mL occurred the most frequently at WTP2 and least frequently at the Penitencia WTP (Figure 12-4). At least once in the years analyzed, the WTP2 monthly medians exceeded 1,000 MPN/100 mL in 9 out of 12 months. For example, in September total coliform exceeded this value for every year examined, while in October, 2 of the 3 years examined exceeded this value. In all, approximately 30% of all samples analyzed at WTP2 were ≥ 1,000 MPN/100 mL (Figure 12-5). At the Penitencia WTP, total coliform monthly medians never exceeded 1,000 MPN/100 mL. At this plant, all samples analyzed had total coliform densities of 300 MPN/100 mL or less (Figure 12-6). At Del Valle and Patterson Pass, total coliform monthly medians were above 1,000 MPN/100 mL generally between July through December. Based on the cumulative probability graphs, these occasions occurred in approximately 15% and 10% of the samples collected (Figures 12-7 and 12-8, respectively). Overall, Patterson Pass experienced lower total coliform densities than at Del Valle. At Patterson Pass, approximately 50% of all samples analyzed fell between 50 and 100 MPN/100 mL while at Del Valle, this same point was reached at approximately 200 MPN/100 mL.

Figure 12-4 Number of Monthly Total Coliform Medians Above or Below 1,000 MPN/100 mL for Plants Receiving SBA Water

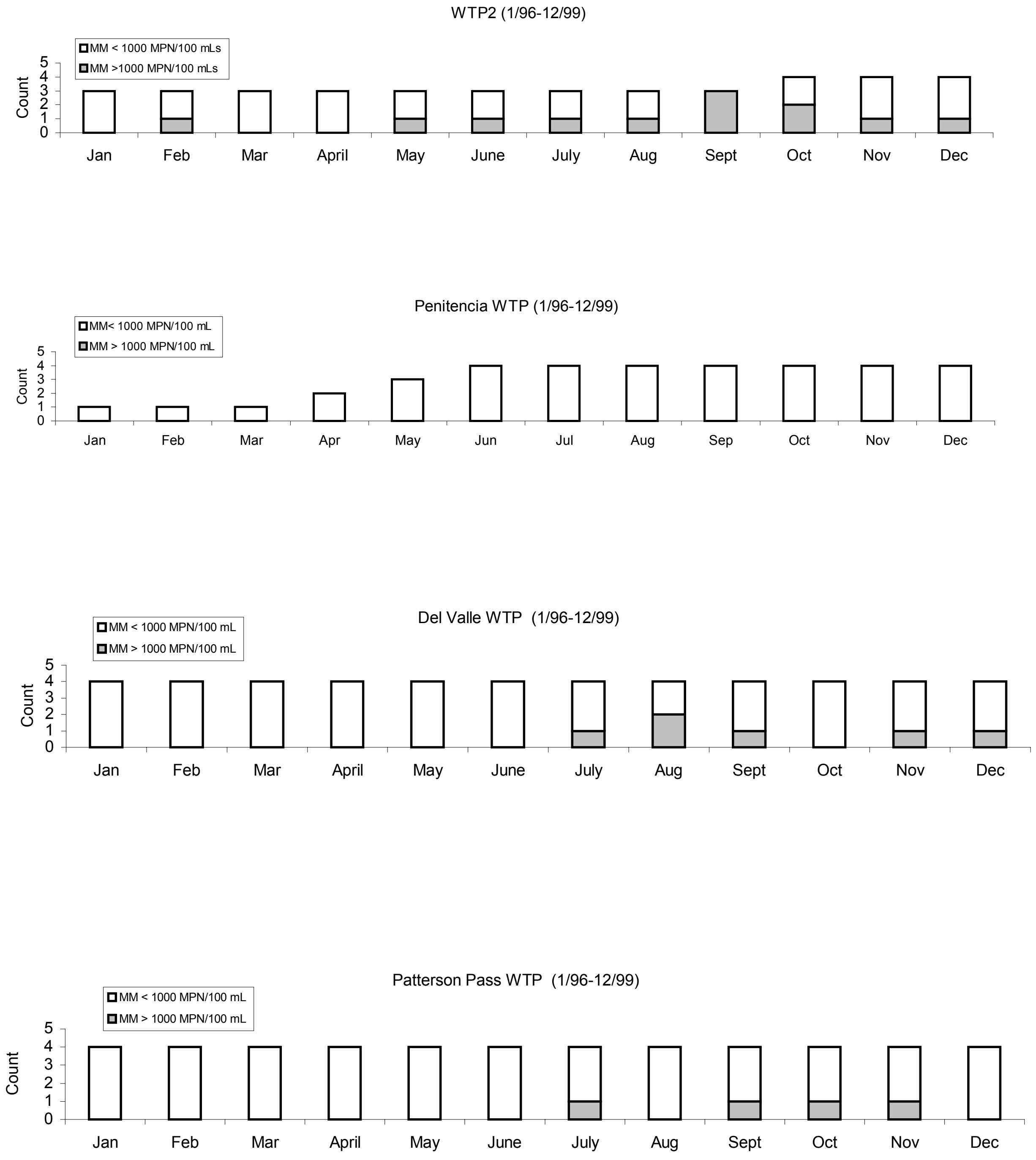
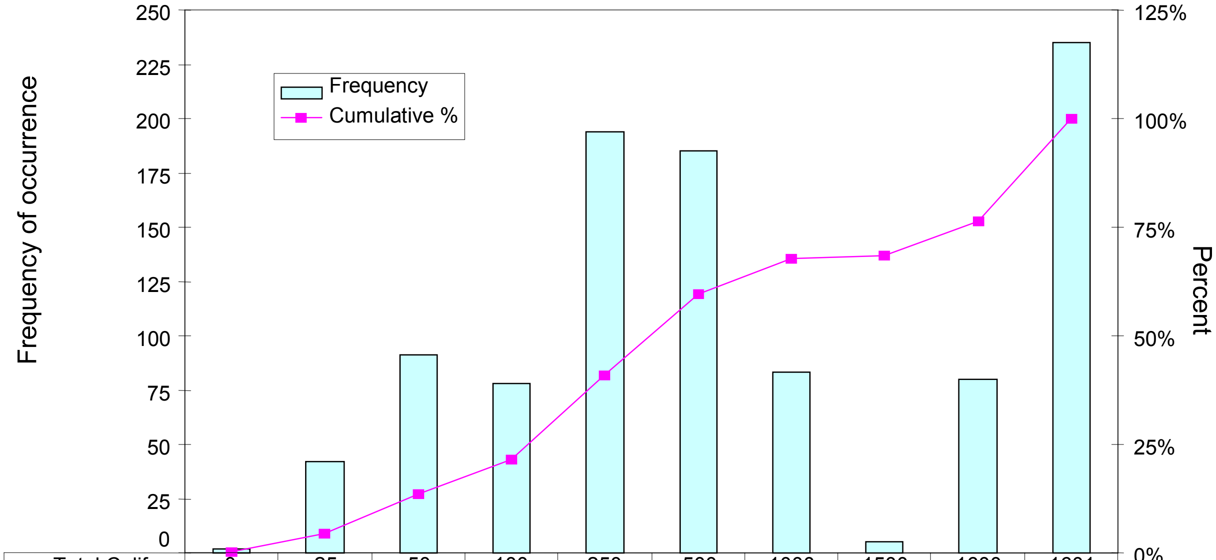
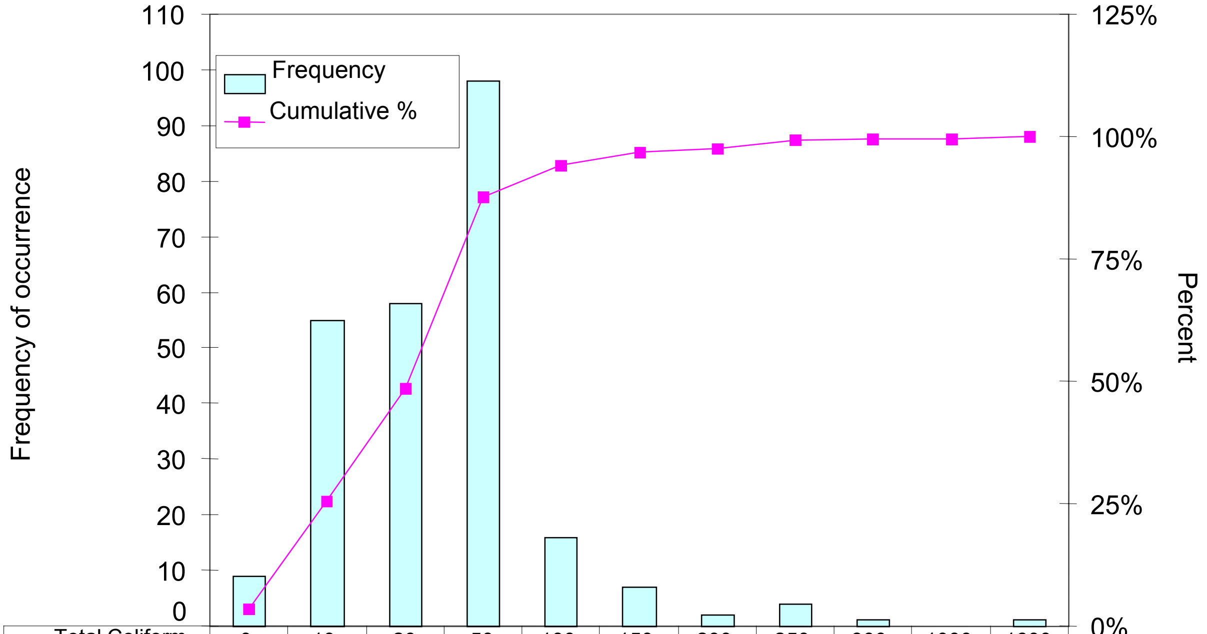


Figure 12-5 Cumulative Probability Distribution of Total Coliform Counts (MPN/100 mLs) at WTP2, Oct 1996 to Dec 1999



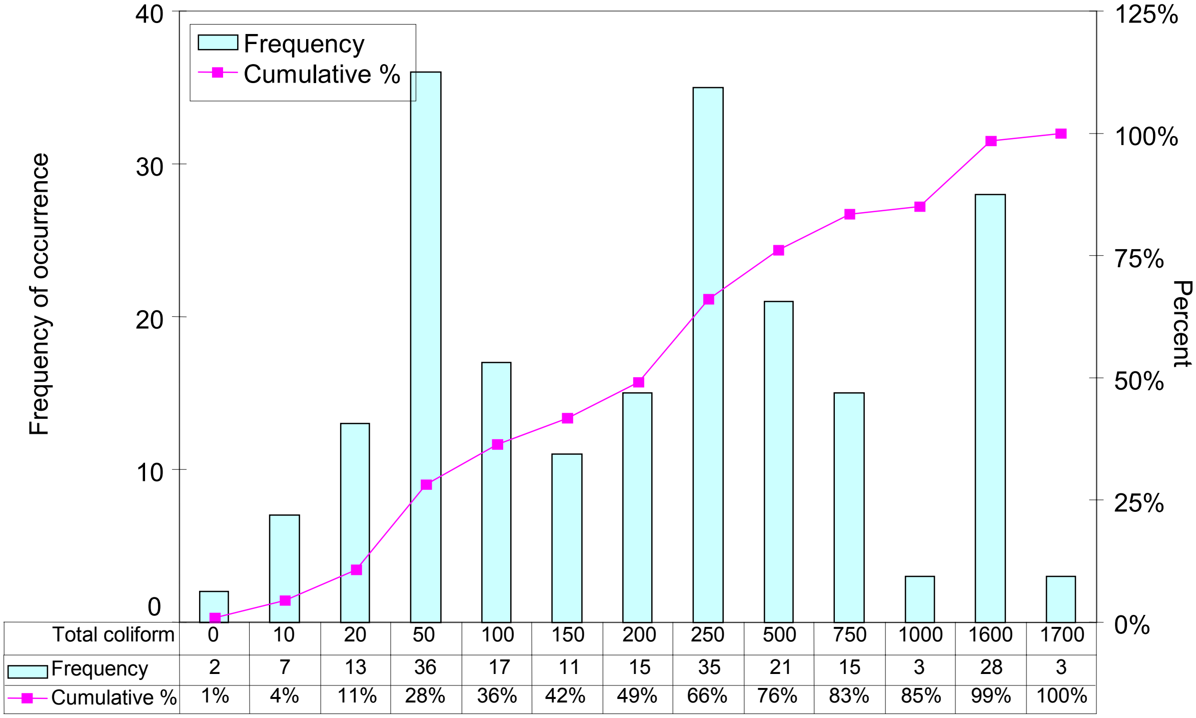
Total Coliform	0	25	50	100	250	500	1000	1500	1600	1601
Frequency	2	42	91	78	194	185	83	5	80	235
Cumulative %	0%	4%	14%	21%	41%	59%	68%	68%	76%	100%

Figure 12-6 Cumulative Probability Distribution of Total Coliform (MPN/100 mL) at the Penitencia WTP, Jan 1996 to Dec 1999



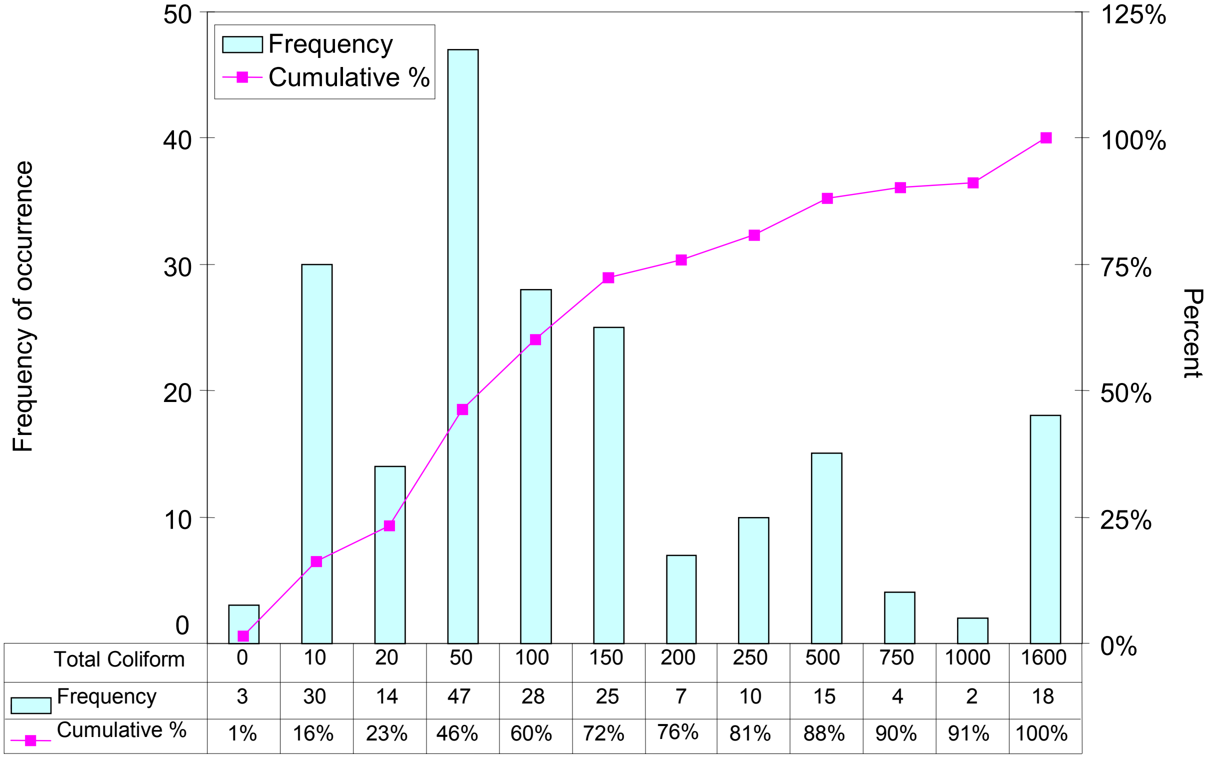
Total Coliform	0	10	20	50	100	150	200	250	300	1000	1600
Frequency	9	55	58	98	16	7	2	4	1	0	1
Cumulative %	4%	25%	49%	88%	94%	97%	98%	99%	100%	100%	100%

Figure 12-7 Cumulative Probability Distribution of Total Coliform (MPN/100 mL) at the Del Valle WTP, Jan 1996 to Dec 1999



Total coliform	0	10	20	50	100	150	200	250	500	750	1000	1600	1700
Frequency	2	7	13	36	17	11	15	35	21	15	3	28	3
Cumulative %	1%	4%	11%	28%	36%	42%	49%	66%	76%	83%	85%	99%	100%

Figure 12-8 Cumulative Probability Distribution of Total Coliform (MPN/100 mL) at the Patterson Pass WTP, Jan 1996 to Dec 1999



Total Coliform	0	10	20	50	100	150	200	250	500	750	1000	1600
Frequency	3	30	14	47	28	25	7	10	15	4	2	18
Cumulative %	1%	16%	23%	46%	60%	72%	76%	81%	88%	90%	91%	100%

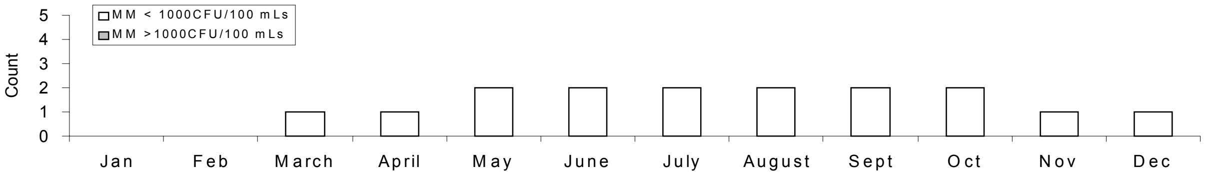
One problem with applying total coliform guidelines to SBA results is that with the exception of the Penitencia WTP, the SBA contractor's total coliform values are based on samples analyzed by Colilert™. The guidelines, however, were developed using the MTF method (Haberman pers. comm.). Since higher total coliform densities can be an artifact of the Colilert™ method, the use of the guidelines summarized in Tables 12-6 and 12-7 could precipitate increased log reductions where none are required. The difference between the MTF and Colilert™ methods also explains why the lowest total coliform values were observed at the 1 SBA plant that did not use the Colilert™ method—the Penitencia WTP.

In contrast to the high total coliform values, *E. coli* densities of the SBA plants suggested a low level of fecal contamination (Table 12-4). Since Colilert™ and MTF are equivelent with respect to *E. coli*, the relatively low levels of *E. coli* are potentially a more fitting assessment of the level of contamination. Therefore, in the case where total coliforms were measured by Colilert™, but *E. coli* values were low, the baseline level of suggested *Giardia* removal may be more appropriate (Haberman, pers. comm.). These results also suggest that further investigations are required of the Colilert™ method to determine if its use is appropriate with these guidelines.

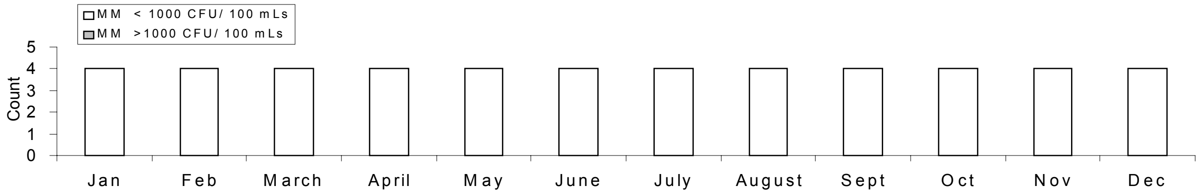
Of the plants using NBA waters, the Jameson Canyon WTP was the only one experiencing monthly total coliform medians above 1,000 MPN/100 mL (Figure 12-9). Monthly medians exceeded 1,000 MPN/100 mL in 7 of the 9 months samples were collected. However, in many cases, only 1 year of data was available. For all other NBA WTPs, individual samples could exceed 1,000 MPN (CFU)/100 mL; however, the monthly medians were always below this threshold. As discussed in Section 12.2.3, there is potentially a contamination problem between the Cordelia Forebay and the Jameson Canyon WTP. One simple place to test for contamination is to analyze the uncovered Napa Turnout reservoir. Additionally, investigations of American Canyon total coliform densities and further side by side comparisons with the Benicia WTP would help determine if this conclusion is correct.

Figure 12-9 Number of Monthly Total Coliform Medians Above or Below 1,000 MPN (CFU)/100 mL for Plants Receiving NBA Water

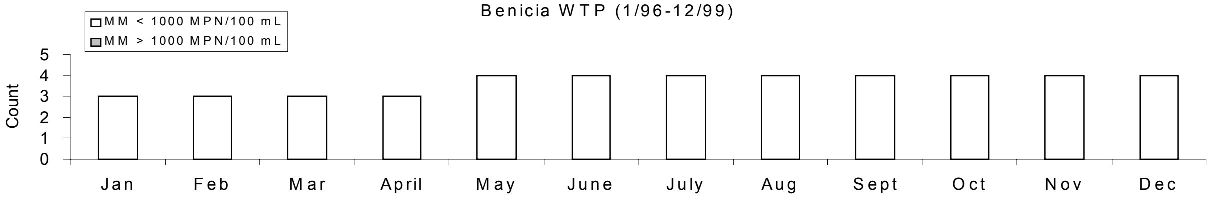
NBR WTP (1/96-1/98)



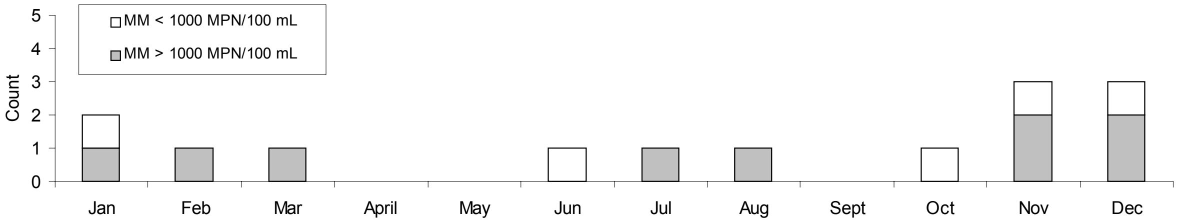
Travis AFB WTP (1/96-12/99)



Benicia WTP (1/96-12/99)



Jameson Canyon WTP (1997-1999)



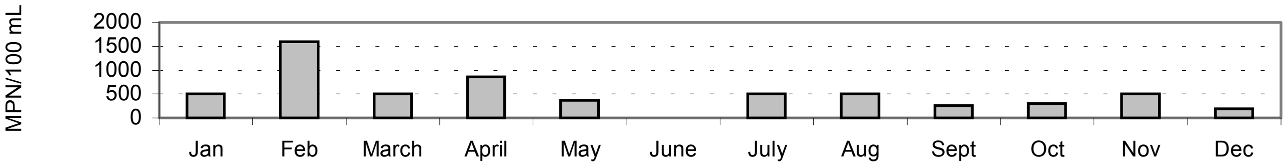
<DL changed to 0; values > DL for assay changed to upper value

With respect to samples collected by DWR, samples were collected once a month; therefore, a monthly median could not be calculated. Instead, median bacteria densities were calculated by month for the years sampled (Figure 12-10). If samples had been collected for 4 years, then a total of 4 monthly values would have been available for calculations; however, in some cases, only 2 data points were available. Barker Slough had the most data of any of the 4 DWR sample sites. With the exception of the Arroyo Valle Creek site, all sites in February experienced median total coliform values above 1,000 MPN/100 mL. Monthly medians did not exceed 1,000 MPN/100 mL for any other month of the year.

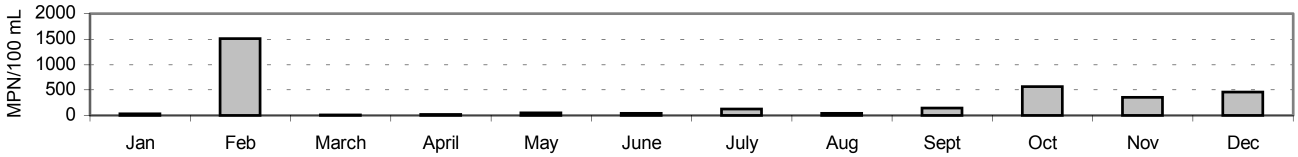
One problem associated with using total coliforms densities to suggest levels of removal of *Giardia* is that no correlation has been found between total coliform and *Giardia* densities (Pope and others 2001). The lack of correlation may be due to the relatively poor recovery and high variability associated with *Giardia* detection methods. The use of Colilert™ vs. the MTF method for total coliform analysis further clouds the issue. Therefore, until these issues are resolved, the use of this guideline may be problematic.

Figure 12-10 Monthly Median Total Coliform Values for Barker Slough PP, Banks Pumping Plant, Delta-Mendota Canal, and Arroyo Creek Inflow Into Lake Del Valle

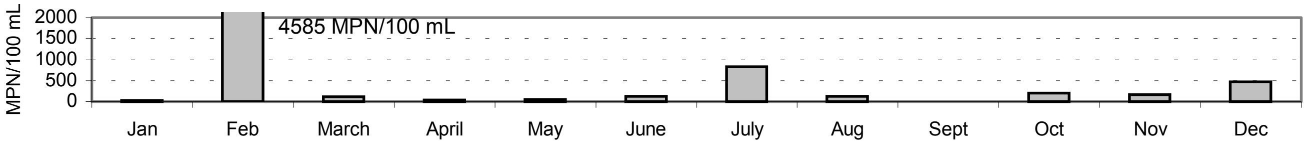
Barker Slough Pumping Plant (11/96-12/99)



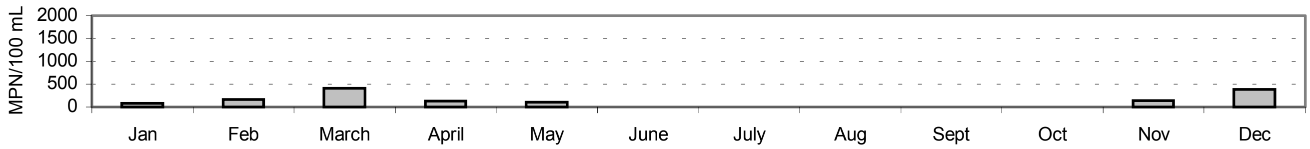
Banks Pumping Plant (4/96-5/98)



Delta-Mendota Canal at McCabe Road (4/96-5/98)



Arroyo Valle Creek to Lake Del Valle (4/96-5/98, when flowing)



12.3.2 RECOMMENDED REMOVAL BASED ON GIARDIA

In addition to using total coliform as a surrogate indicator for the level of *Giardia* removal, EPA published guidance on *Giardia* cyst removal based on the degree of *Giardia* contamination in the source water. These levels are shown in Table 12-8.

Table 12-8 *Giardia* Cyst Reduction Based on Source Water Concentrations

Giardia Cyst Treatment Requirements (Log Reduction)	3-log	4-log	5-log
Daily Average Cyst Concentration (Geometric Mean Cysts/100 L)	<1	>1 - 10	>10 - 100

Source: EPA 1989

None of the profile plants collected daily samples for *Giardia* analysis. In most cases monthly samples were collected. Additionally, samples were not necessarily collected over the entire period of record.

The cyst reduction based on suggested EPA guidelines in Table 12-8 were compared to the cyst reductions suggested by total coliform concentrations in Table 12-6. Based on the data available, summary statistics of *Giardia* cyst concentrations are shown in Table 12-9. Medians were calculated instead of geometric means due to values less than the detection limit. The majority of *Giardia* results were determined using the ICR method. The ICR method has been criticized for its high rates of false positives and negatives as well as its lack of sensitivity. Because of the method's limitations, it is unknown whether the data presented in Table 12-9 presents a true picture of the *Giardia* environment. For example, for every plant profiled, the median *Giardia* concentration was below the detection limit, while the percentage of nondetects at all locations ranged from 84% to 100%.

Table 12-9 ***Giardia*** **Cyst Concentrations (cysts/100L) for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water** (Except Where Noted, All Samples Analyzed by ICR IFA)

Agency	Location	Median	Min	Max	Percentile Range (10-90%)	Number Detects/ Total Sampled	Percent nondetect
DWR	Barker Slough Pumping Plant[a]	<DL	< DL	75	< DL - 40	14/42	67
	Banks Pumping Plant[b]	<DL	< DL	34	<DL - <DL	1/23	96
	Delta-Mendota Canal @ McCabe Road[b]	<DL	<DL	<DL	<DL - <DL	0/21	100
	Arroyo Valle Creek Inflow to Lake Del Valle[d]	<DL	<DL	2	<DL - <DL	1/12	92
MWDSC	Jensen Filtration Plant[e]	<DL	< DL	4.11	<DL - <DL	2/48	96
	Mills Filtration Plant[e]	<DL	< DL	346.5	0 - 4.18	6/48	88
NBA	City of Benicia WTP	-					
	Jameson Canyon WTP (Napa)	-					
	North Bay Regional WTP (Fairfield, Vacaville)[e]	<DL	<DL	123	< DL - 42	1/7	86
	Travis Air Force Base WTP (Vallejo)	-					
SBA	Penitencia WTP[f]	<DL	< DL	< DL	<DL - <DL	0/17	100
	Del Valle WTP[f]	<DL	< DL	< DL	<DL - <DL	0/16	100
	Patterson Pass WTP[f]	<DL	< DL	<DL	<DL - <DL	0/31	100
	WTP2[f]	<DL	<DL	25	<DL - <DL	1/17	84

[a] Samples generally collected monthly from Oct 1996 to Dec 1999, no samples collected Jun 1998. Monthly sampling to continue indefinitely.
[b] Samples collected monthly from Jul 1996 to May 1998, no samples collected since May 1998.
[c] Samples collected monthly from Jul 1996 to May 1998 unless no flow.
[d] Samples collected monthly from Jan 1996 to Dec 1999. Samples analyzed by Method 1623 beginning 1999.
[e] Samples collected monthly from Jul 1997 to Dec 1998 when plant receiving NBA water.
[f] Samples collected monthly from Jul 1997 to Dec 1998.
Summary Statistics calculated by substituting 0 for all values less than the detection limit
<DL = less than the detection limit

Method 1623 was introduced in 1999 to provide a more robust method to analyze for pathogens. The method is generally not as susceptible to false positives as the ICR methodology and its recovery rates, based on spiked samples, are also substantially higher. MWDSC began using Method 1623 in 1999. However, even with 1623 analysis, no *Giardia* was detected at MWDSC's Jensen and Mills FPs. Method 1623 data were not available from the other WTPs. For samples collected from Barker Slough by DWR, Method 1623 data were only available for the last 5 months of 1999. With so few data points, these data were not used for calculations. For comparative purposes, the results of the 2 methods are shown below (Table 12-10).

Table 12-10 *Giardia* Concentrations at the Barker Slough Pumping Plant Using ICR IFA and Method 1623[a]

Date Sampled	ICR IFA (cysts/100 L)[b]	Method 1623 (cysts/L)
31 Aug 1999	0	0
21 Sep 1999	0	0
25 Oct 1999	44	0
29 Nov 1999	0	0
28 Dec 1999	0	0.05 [c]

[a] All values less than the detection limit changed to 0.
[b] Information Collection Rule Immonufluorescent Assay (ICR IFA).
[c] Average of duplicate analysis.

The original purpose of this section was to compare log reductions suggested by total coliform numbers against log reductions suggested by actual *Giardia* concentrations. Due to the limited data set (that is, lack of daily geometric means) and the uncertainty of the reliability of the data, this comparison was not realistic.

Although false positives and recovery are a problem with the ICR method, the method may be useful as a frequency of occurrence indicator rather than as an absolute number. To determine if there were any seasonal patterns of *Giardia* occurrence, WTPs and DWR facilities with 2 or more *Giardia* detections were graphed (Figures 12-11 and 12-12). With respect to the Jensen FP, *Giardia* was detected once in September and November (although not necessarily in the same year). With respect to the Mills FP, 4 of the 6 detections occurred between December and March (although again, not necessarily in the same year).

The relationship between *Giardia* detections and season were stronger for samples collected from the Barker Slough Pumping Plant. With the exception of 2 samples, 10 of the 14 detections at the Barker Slough Pumping Plant occurred between December and March. Unlike the Jensen and Mills FPs these results were consistent from year to year. This lends credibility to the hypothesis that the most frequent *Giardia* occurrences at the Barker Slough Pumping Plant occur in the winter; however, the increase in false positives from storm water debris must be considered.

Figure 12-11 *Giardia* Concentration (cysts/100 L) at Jensen and Mills Filtration Plants, Jan 1996 to Dec 1999

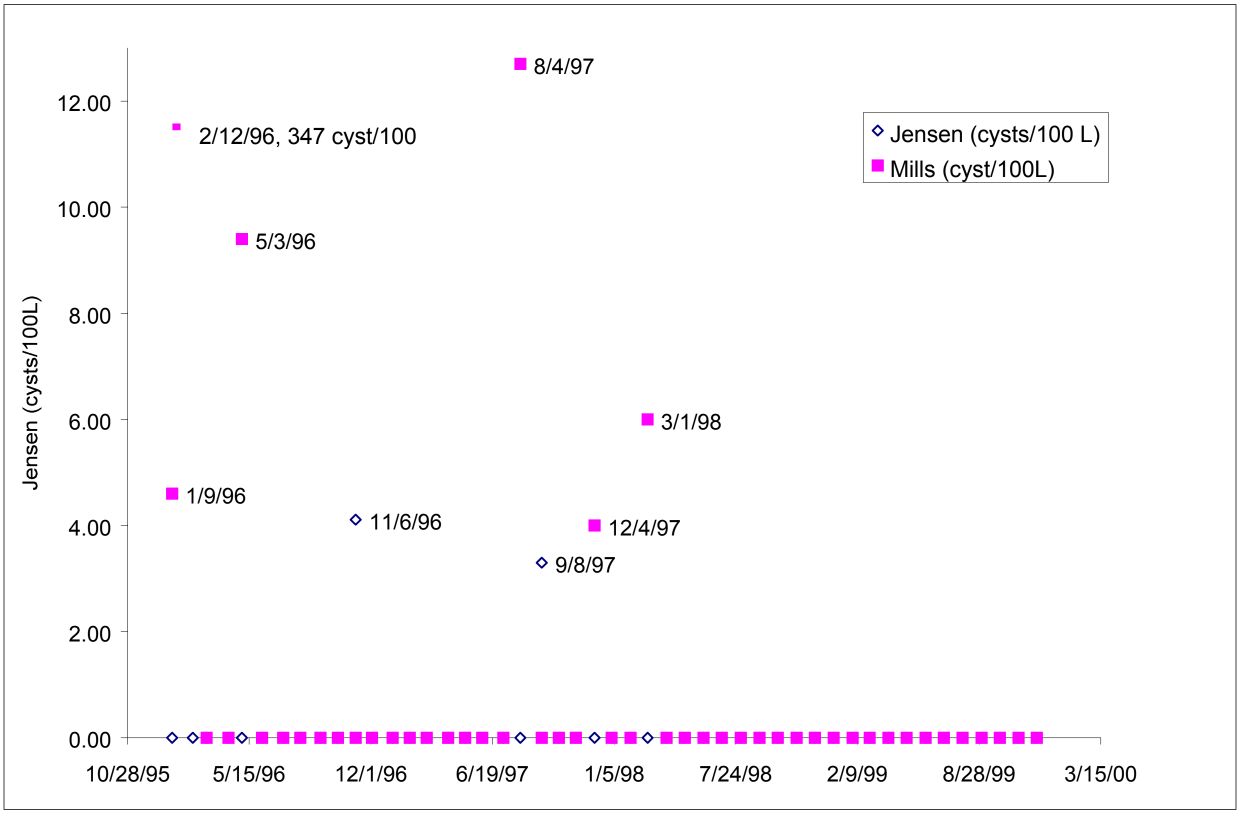
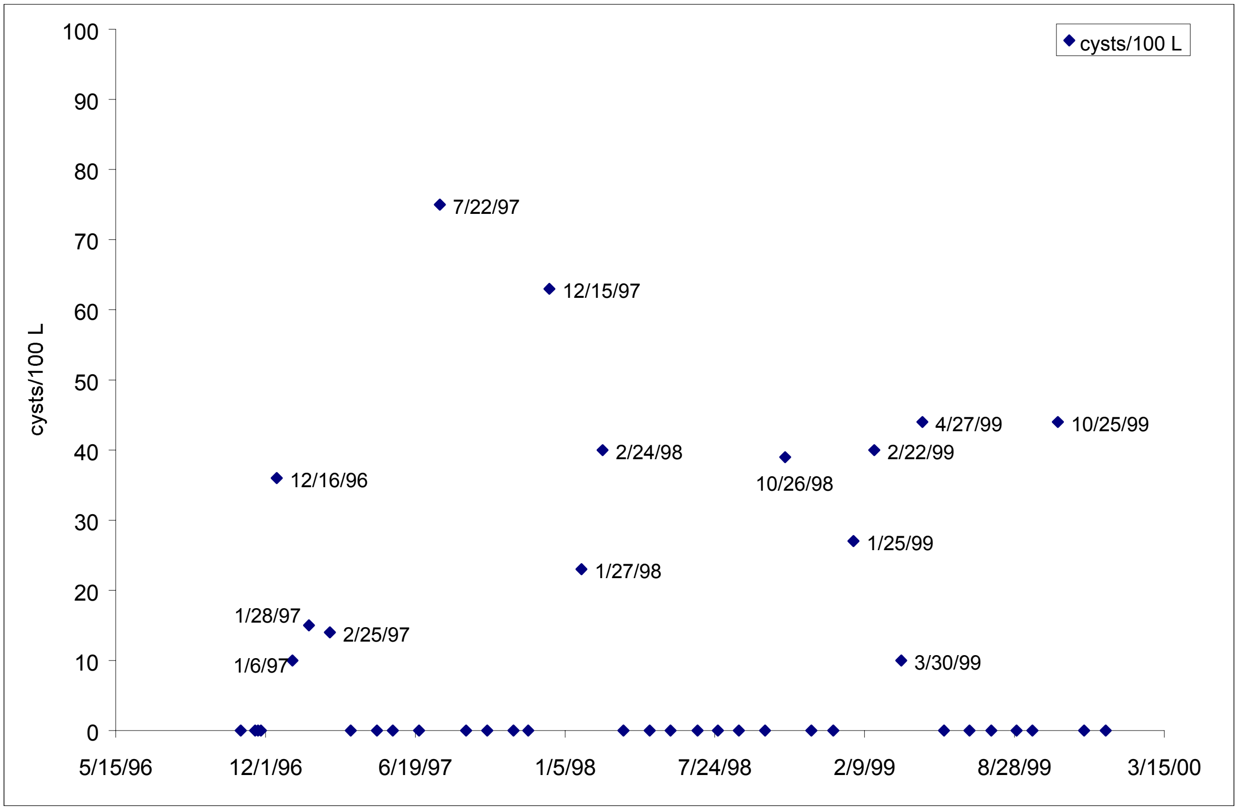


Figure 12-12 *Giardia* Concentration (cysts/100 L) at the Barker Slough Pumping Plant, Oct 1996 to Dec 1999



12.4 *CRYPTOSPORIDIUM*

In this section, the highest 12-month running average for *Cryptosporidium* monthly samples for the profiled WTPs, was compared to the "bin" log removals proposed in the Stage 2 Microbial Disinfection Byproducts Agreement in Principle (AIP) (Tables 12-11 and 12-12). In the future, this approach will be used to determine the level of log removals of *Cryptosporidium* oocysts (if any) at a WTP (EPA 2000). A 2nd approach also endorsed by the Stage 2 AIP is the calculation of a monthly average from 2 samples collected monthly over a 1-year period. This approach was not used as *Cryptosporidium* numbers had not been analyzed twice a month by any utility.

Table 12-11 Treatment Requirements for *Cryptosporidium* Removal Under the Stage 2 Microbial Disinfection Byproducts Agreement in Principle

Bin #	Avg. Cryptosporidium Concentration (oocyst/L)	Additional Treatment Requirements[a]	Final Log Removal Achieved by Meeting IESWTR & Stage 2 Additional Requirements
1	Cryptosporidium < 0.075/L	None	3
2	0.075/L > Cryptosporidium <1.0/L	1-Log	4
3	1.0/L > Cryptosporidium <3.0/L	2-Log	5
4	Cryptosporidium > 3.0/L	2.5-Log	5.5

Adapted from EPA 2000

[a] Additional treatment requirements are for systems with conventional treatment that are in full compliance with the Interim Enhanced Surface Water Treatment Rule (IESWTR).

Table 12-12 Highest 12-Month Running Average Value for *Cryptosporidium* Concentrations (oocysts/L) for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water

(Except where noted, all data analyzed by ICR IFA)

Agency	Location	1996-97	1997-98	1998-99
DWR	Barker Slough Pumping Plant[a]	-	0.091	0.1
	Banks Pumping Plant[b]	0.14	-	-
	Delta Mendota Canal @ McCabe Road[b]	0	-	-
	Arroyo Valle Creek Inflow to Lake Del Valle	-	-	-
MWDSC	Jensen Filtration Plant[c]	0.01	0	0
	Mills Filtration Plant[c]	0.22	0.01	0.01
NBA	City of Benicia WTP	-	-	-
	Jameson Canyon WTP (Napa)	-	-	-
	North Bay Regional WTP (Fairfield, Vacaville) [d]	-	-	-
	Travis Air Force Base WTP (Vallejo)	-	-	-
SBA	Penitencia WTP			
	Del Valle WTP[e]	-	0	-
	Patterson Pass WTP[e]	-	0	-
	WTP2[f]	-	0	-

[a] Samples collected monthly. Used data from Jan 1997 to Nov 1998 and Jan 1998 to Nov 1999.

[b] Samples collected monthly. Used data from Jul 1996 to May 1998.

[c] Samples collected monthly. Used data from Jan 1996 to Nov 1997, Jan 1997 to Nov 1998, and from Jan 1998 to Nov 1999. Method 1623 used starting Jan 1999.

[d] Insufficient number of samples to calculate running average.

[e] Samples collected monthly. Used data from Jan 1997 to Nov 1998.

[f] Samples collected monthly. Used data from Jul 1997 to Dec 1998.

Notes: Summary Statistics calculated by substituting 0 for all values less than the detection limit.
- = data not available or incomplete.

Based on data available, not all Stage 2 AIP specifications for calculating running averages could be met. For example, ICR data were primary sources for most *Cryptosporidium* calculations. The Stage 2 agreement recommends calculating the 12-month running average using 2 full years of data; however, with ICR data, 2 years of data were not available (ICR data were collected from July to December 1998). In some cases, plants had been collecting monthly *Cryptosporidium* data prior to the ICR survey. These data were used whenever possible. In addition, under the Stage 2 agreement, *Cryptosporidium* concentrations were to be calculated using Method 1623. With the exception of MWDSC's Jensen and Mills FPs, Method 1623 data were not available for the WTPs. MWDSC began analyzing *Cryptosporidium* concentrations by Method 1623 in January 1999. These data were used for calculating Jensen and Mills running averages for the 1998 to 1999 two-year period. Running annual averages could not be computed for NBA contractors because only 7 samples were analyzed for *Cryptosporidium* using SWP water.

With 1 exception, *Cryptosporidium* concentrations at the WTPs fell within the 1st bin range of < 0.075 oocysts/L (Table 12-12). Using ICR data and Stage 2 AIP specifications, these results indicate no further treatment would be required beyond a plant meeting the Interim Enhanced Surface Water Treatment Rule (IESWTR) regulations. The 1 exception was the Mills FP. The highest 12-month running average at Mills FP in 1996/1997 was 22 times higher than averages calculated for the 1997/1998 and 1998/1999 seasons. The subsequent years, when running averages were lower, suggest that basing decisions on a single 2-year sampling period may be inadequate.

Tracking 12-month running averages over a 4- or 6-year period may prove more useful in determining whether higher averages are a 1-time occurrence or a long-term trend. However, because samples collected in 1996/1997 were analyzed by the ICR method, another possibility is that false positives may have incorrectly inflated oocyst concentrations and created a false difference between years. Because actual comparisons will be made using Method 1623 data, this may not be an issue. Additionally, using a single 2-year average to determine oocyst watershed concentrations potentially represents oocyst mobilization only under particular conditions. For example, water years from 1996 to 1999 were wet or above normal. Data generated from above-average water years may provide the most conservative estimate of the level of protection a treatment plant should achieve. However, if oocyst concentrations are generated during a drought period with little runoff, a false sense of confidence could be achieved. In these cases, it would be advisable for a plant to continue sampling for *Cryptosporidium* so that running averages incorporating above-normal rainfall years can also be determined.

Running averages were also calculated for the 4 sites analyzed by DWR. Oocyst concentrations at the Barker Slough Pumping Plant were above 0.075 oocysts/L, but below 1 oocyst/L (bin 2).

Cryptosporidium oocysts were detected above 0.075 oocysts/L at the Banks Pumping Plant. How this concentration relates to WTPs that receive SWP water is unknown. No oocysts were detected in the Arroyo Valle Creek inflow to Lake Del Valle.

12.5 LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE MICROBIAL INDEX

Using data collected from the ICR and the Supplemental Survey, the EPA developed a microbial index for reservoir/lake and running stream water sources (Pope and others 2001). For small systems, the expense and difficulty of analyzing samples for *Cryptosporidium* can be prohibitive; therefore, 1 of the issues examined by the EPA was the possibility of using a microbial index to assess a source water's vulnerability to high *Cryptosporidium* concentrations.

The goal of the LT2 ESWTR Microbial Index is to identify watersheds with potentially high concentrations of *Cryptosporidium* using fecal contamination as an indicator of risk. One misconception is that the presence of the indicator organism is statistically correlated with *Cryptosporidium* occurrences. This is not correct. Based on ICR and Supplemental Survey data, there is not a good correlation between coliform and *Cryptosporidium* concentrations (Pope pers. comm.). Instead, the indicator organism is used to identify a level of fecal contamination that signals a warning to the analyst that enough fecal contamination may be present in the watershed to warrant *Cryptosporidium* monitoring. At a certain level, watersheds that have fecal contamination may or may not have *Cryptosporidium* contamination. However, watersheds without fecal contamination should not have *Cryptosporidium* contamination. For several reasons, *E. coli* was initially chosen as the microbial indicator organism because of its use as an indicator of fecal contamination.

Analyses of ICR and Supplemental Survey data suggest that concentrations of 5 to 10 *E. coli*/100 mL from WTPs receiving water from a reservoir/lake may indicate a water source is vulnerable to *Cryptosporidium* contamination. For WTPs receiving water from a flowing stream, *E. coli* levels of 50 organisms/100 mL may indicate vulnerability to *Cryptosporidium* contamination. These initial values are based on ICR and Supplemental Survey datasets, which have a number of weaknesses that compromise their results and, in turn, affect the conclusions reached by the microbial index. One reason for the *Cryptosporidium* and *E. coli* monitoring with the promulgation of Stage 2 is to develop a more robust dataset. Therefore, *E. coli* and *Cryptosporidium* trigger and bin values could change as data from Stage 2 pathogen monitoring are analyzed. However, until the Stage 2 monitoring is complete, these index values are the only analyses available to assess watershed vulnerability to *Cryptosporidium* contamination.

For this report, 6 of the 7 WTPs with *Cryptosporidium* data were classified into WTPs receiving their water from either a reservoir/lake or a flowing stream. (NBR data were not used because of the lack of oocyst data from SWP water). Technically, 1 of the original water sources for all WTPs profiled is either the Delta or a watershed tributary to the Delta. For this report, Delta water stored or passed through a reservoir or lake was classified under the reservoir/lake category. Water that passed through surge tanks was not classified under the reservoir/lake category because surge tanks are not designed for storage but to dampen sudden changes in water pressure through a pipeline. Also, all the systems listed in this report are medium to large systems; therefore, all would be required to monitor for *Cryptosporidium* regardless of their *E. coli* levels. These data were used in this report simply to examine the bin and microbial index approaches.

In calculating its microbial index, the EPA used mean *E. coli* concentrations; therefore, in general, average *E. coli* values were calculated over the same period as a plant's *Cryptosporidium* 12-month running average. Like running average data, *E. coli* data that corresponded to *Cryptosporidium* sampling were mostly available from ICR data. Therefore, in most cases, a full 2 years of data were not available for analysis. The 1 exception was *E. coli* data from Zone 7's Del Valle and Patterson Pass WTPs. For these plants, *E. coli* data were available for samples collected from the ICR survey beginning in July 1997. A full year of *Cryptosporidium* monitoring was available beginning in January 1997. Because *Cryptosporidium* was not detected at the plants in 1997 or 1998, the absence of 6 months of *E. coli* data may not be critical. With these caveats, 12-month running averages and average *E. coli* concentrations are shown in Table 12-13.

E. coli density data presented in Table 12-13 were compared to the *E. coli* microbial index criteria of 50 organisms/100 mL for plants receiving water from flowing streams and a range of 5 to 10 organisms per 100 mL for plants receiving water from a reservior or lake. These comparisons were used to determine whether fecal contamination was high enough to warrant further monitoring for *Cryptosporidium*. This conclusion was then compared to the plant's theoretical bin assignment determined from the *Cryptosporidium* highest 12-month running average in Table 12-13. Table 12-14 shows the comparison between a plant's bin assignment based on *Cryptosporidium* concentrations from source water monitoring and whether further *Cryptosporidium* monitoring would be required based on the microbial index.

Table 12-13 Highest *Cryptosporidium* Annual Running Average Values and Corresponding Average *E. coli* Values for Sites Sampled by DWR and Selected Water Treatment Plants Receiving Only SWP Water

			1996-97		1997-98		1998-99	
Agency	Location	Waterbody Type	Highest *Cryptosporidium* 12 Month Running Avg (oocysts/L)	Avg *E. Coli* Concentration (MPN/ 100 mL)	Highest *Cryptosporidium* 12 Month Running Avg (oocysts/L)	Avg. *E. Coli* Concentration (MPN/100 mL)	Highest *Cryptosporidium* 12 Month Running Avg (oocysts/L)	Avg. *E. Coli* Concentration (MPN/100 mL)
DWR	Barker Slough PP[a]	Flowing Stream	-	-		360	0.1	306
	Banks PP[b]	Flowing Stream	0.14	Not analyzed	-	-	-	-
	DMC @ McCabe Road[b]	Flowing Stream	0	Not analyzed	-	-	-	-
	Arroyo Valle Creek Inflow to Lake Del Valle	Flowing Stream	-	Not analyzed	-	-	-	-
MWDSC	Jensen Filtration Plant[c]	Reservoir/ Lake	0.01	0	0	4	0	23
	Mills Filtration Plant[c]	Reservoir/ Lake	0.22	8	0.01	2	0.01	1
NBA	City of Benicia WTP	-	-	-	-	-	-	-
	Jameson Canyon WTP (Napa)	-	-	-	-	-	-	-
	North Bay Regional WTP (Fairfield, Vacaville)	Flowing Stream	-	-	-	-	-	-
	Travis AFB WTP (Vallejo)	-	-	-	-	-	-	-
SBA	Penitencia WTP[d*]	Flowing Stream and reservoir/lake	-	-	0.01	7	-	-
	Del Valle WTP[e]	Flowing Stream	-	-	0	12	-	-
	Patterson Pass WTP[e]	Flowing Stream	-	-	0	12	-	-
	WTP2[d]	Flowing Stream	-	-	0	14	-	-

Cryptosporidium Vulnerability Suggested by average *E. coli* concentrations of: Flowing stream = 50 org/100 mLs; Reservoir/Lake = 5-10 org/100 mLs; - = data not available or incomplete.
Summary Statistics calculated by substituting 0 for all values less than the detection limit.

[a] Samples collected monthly. Used data from Jan 1997 to Nov 1998 and Jan 1998 to Nov 1999.

[b] Samples collected monthly Used data from Jul 1996 to May 1998.

[c] Samples collected monthly. Used data Jan 1996 to Nov 1997, Jan 1997 to Nov 1998, and Jan 1998 to Nov 1999.

[d] Samples collected monthly. Used data from Jul 1997 to Dec 1998

[e] Samples collected monthly. Used data from Jan 1997 to Nov 1998.

* Water body varied by sample date.

Table 12-14 Comparison Between Stage 2 Bin Ranges and *E. coli* Microbial Index

Agency	Location	Waterbody Type	Additional Treatment Based on Bin Range?	Additional Cryptosporidium Monitoring Based on Index?
DWR	Barker Slough Pumping Plant	Flowing Stream	Not applicable	Yes
	Bank's Pumping Plant	Flowing Stream		
	Delta Mendota Canal @ McCabe Road	Flowing Stream		
	Arroyo Valle Creek Inflow to Lake Del Valle	Flowing Stream		
MWDSC	Jensen Filtration Plant	Reservoir/Lake	No	Maybe (depending on sample year)
	Mills Filtration Plant	Reservoir/Lake	Maybe	Maybe (depending on sample year)
NBA	City of Benicia WTP	-		
	Jameson Canyon WTP (Napa)	-		
	North Bay Regional WTP (Fairfield, Vacaville)	Flowing Stream	-	-
	Travis Air Force Base WTP (Vallejo)	-		
SBA	Penitencia WTP[a]	Flowing Stream and Reservoir/Lake	No	-
	Del Valle WTP	Flowing Stream	No	No
	Patterson Pass WTP	Flowing Stream	No	No
	WTP2	Flowing Stream	No	No

[a] Waterbody type varied by sample date. Unable to determine appropriate Index value for comparisons.

The microbial index and *Cryptosporidium* log-removal based on the WTP's bin were generally in agreement. In the case where the bin suggested greater treatment (Mills FP, 1996 to 1997), the microbial index also indicated that fecal contamination was high enough to warrant further monitoring. The 1 exception between the 2 techniques occurred with samples collected at Jensen FP between 1998 and 1999. In this period, no *Cryptosporidium* were detected at the treatment plant; however, the microbial index indicated the potential for *Cryptosporidium* contamination. These results do not mean that *Cryptosporidium* contamination was present, but that there was that possibility. If these had been the *E. coli* results from a small system, subsequent *Cryptosporidium* monitoring would be required. However, under this system, the microbial index numbers are simply indicators. Actual *Cryptosporidium* values are the final arbiter as to whether there is a *Cryptosporidium* problem.

12.6 STUDIES OF HEALTH RISKS RESULTING FROM BODY-CONTACT RECREATION IN SOUTHERN CALIFORNIA SWP RESERVOIRS

The California Water Code allows body-contact recreation on reservoirs constructed and operated as part of the SWP to the extent that it is compatible with public health and safety requirements (California Water Code, Section 12944(a)). In the 1980s and 1990s, both *Cryptosporidium* and *Giardia* were identified as important causitive agents in waterborne disease. Unfortunately, because of the difficulties and costs associated with *Cryptosporidium* and *Giardia* sampling and detection, little information is available on the importance of this source of pathogens to surface waters. One of the problems with using coliform as surrogates for *Cryptosporidium* and *Giardia*, is that both protozoa are more resistant to environmental conditions. Coliforms tend to die off quickly outside a host's body, while protozoan can remain viable for several weeks. Since fecal shedding and accidental fecal releases by infected individuals can result in high numbers of pathogens shed into a water body, it is important to understand the potential health implications resulting from body-contact recreation on reservoirs used as a source drinking water. Recently, model simulations have been used to estimate pathogen concentrations in source drinking water reservoirs impacted by recreation.

In 1995, the MWDSC commissioned a microbiological risk assessment study for its new Eastside Reservoir in Riverside County to examine the health risk impacts and appropriate levels of recreation from the impacts of various recreation use scenarios (Yates and others 1997). The study incorporated published data on the infection rate of individuals as a function of age, pathogen inactivation rates, and other data to produce probabilistic descriptions of predicted pathogen concentrations in the reservoir. Data from these analyses produced predicted pathogen concentrations, which were then used with dose response models to predict probability of risk of infection to consumers (Yates and others 1997).

The DHS requested that a similar analysis be conducted on 4 Southern California SWP Reservoirs—Castaic Lake, Lake Perris, Pyramid Lake, and Silverwood Lake. Through the State Water Contractors, Dr. Michael Anderson of UC Riverside was contracted to predict, based on the MWDSC study, the impact of body-contract recreation on water quality in the reservoirs. The full report is included as Appendix A. What follows is a summary of Dr. Anderson's findings.

Based on Anderson's calculations, recreational use ranking by lake (highest to lowest) were Lake Perris, Castaic Lake, Pyramid Lake, Silverwood Lake. With the exception of predicted rotavirus numbers at Castaic and Pyramid lakes, predicted pathogen levels also reflected higher pathogen numbers with increased recreational use (Table 12-15).

At the median concentration, 50% of the predicted pathogen concentrations would fall above or below this value. At the 95% density, only 5% of the predicted concentrations would lie above this value. The 95% value is more protective of public health.

To determine the probability of exceeding the EPA's target of 1 infection per 10,000 consumers, Anderson used the median and 95% predicted pathogen concentrations listed in Table 12-15 to calculate health risks to consumers from body-contact recreation in the respective SWP reservoirs. With this approach, the probability of contracting an infection or illness is a function of both the exposure and the infectivity of the pathogen. Exposure to consumers is governed by the pathogen concentration in the source water, any inactivation during transit from reservoir to the treatment plant, and the removal efficiency at the treatment plant. As part of his calculations, Anderson used the 2-log *Cryptosporidium* removal efficiency that conventional WTPs were assumed to meet under IESWTR turbidity requirements. For *Giardia* and viruses the removal efficiency is 3- and 4-log removals, respectively. Based on Anderson's calculations, the annual risk of infection per 10,000 consumers at both the 50% (median) and 95% predicted pathogen concentrations are shown in Table 12-16.

Table 12-15 Median and 95% Predicted Annual Average of Pathogen Levels at 4 Southern California SWP Reservoirs (95% given in parentheses)

	Lake Perris	Castaic Lake	Pyramid Lake	Silverwood Lake
Cryptosporidium (oocyst/100L)	0.85 (16.6)	0.43 (8.3)	0.31 (6.08)	0.22 (4.41)
Giardia (cyst/100L)	0.031 (0.8)	0.016 (0.4)	0.01 (0.29)	0.008 (NA)
Poliovirus (pfu/100L)	5.7 (44)	2.9 (22.3)	2.1 (16.3)	1.5 (NA)
Rotavirus (pfu/100L)	267 (3055)	13.4 (1530)	98 (120)	71 (NA)

Adapted from Anderson 2000

NA = Data not sufficient to compute statistic

Table 12-16 Predicted Consumer Risk Assessment (Infections/10,000 consumers/year) at 4 Southern California SWP Reservoirs at 50% and 95% Probabilities (95% given in parentheses)[a]

	Lake Perris	Castaic Lake	Pyramid Lake	Silverwood Lake
Cryptosporidium	2.39 (46.6)	1.20 (23.4)	0.88 (17.1)	0.64 (12.4)
Giardia (cyst/100L)	0.0115 (NG)	0.0058 (NG)	0.0042 (NG)	0.0031 (NG)
Poliovirus (pfu/100L)	NA	NA	NA	NA
Rotavirus (pfu/100L)	NG	NG	NG	NG

Adapted from Anderson 2000

[a] Assuming 2-log Removal Efficiency for *Cryptosporidium*, 3-log Removal Efficiency for *Giardia*, and 4-log Removal Efficiency for Viruses.

NA = not analyzed, NG = analyzed but no numbers given

Under this scenario, the median risk of infection for *Cryptosporidium* exceeds EPA levels of 1 infection/10,000 consumers/year at lakes Perris and Castaic. *Cryptosporidium* standards are not exceeded at Pyramid and Silverwood lakes. At the 95% probability, all lakes exceeded EPA levels. With respect to *Giardia*, all lakes fell below EPA's annual risk of infection. Anderson noted that even using the 99% level of predicted *Giardia* concentrations, the risk of infection from *Giardia* remained below 1 infection/10,000/year.

Anderson gave no numbers of predicted risk of infection values for rotavirus or poliovirus. He noted that with respect to rotavirus, the model predicted median infection rates of up to hundreds of infections per 10,000 per year. Moreover, community health and other data suggested lower rates of infection than predicted. The capacity for virus removal at MWDSC plants above 4-logs led MWDSC to discount rotavirus as a risk to water consumers (Anderson 2000). Nevertheless, even with reduced shedding rates, rotavirus remains a concern (Anderson 2000). With respect to poliovirus, calculations were not possible because of the lack of suitable dose-response models in the literature. It was also suggested that poliovirus may be a minimal health risk to water consumers based on its lower concentrations relative to rotavirus and MWDSC's ability to remove viruses above 4-logs.

Like any model, predicted values are subject to the limitations regarding the assumptions made and quality of the data being used. Anderson (2000) identifies the following limitations:

1) Differences in recreational use patterns and limnological features among the lakes that were not adjusted for (for example, lakes with limited body-contact recreation vs. lakes with greater body-contact recreation),
2) Difference in age distributions of the recreation population (for example, children vs. adults),
3) Differences in treatment efficiencies of the WTPs receiving lake water,
4) The additivity of risks,
5) Seasonal effects on risk values, and
6) Other inputs of pathogens to the lake.

For most of the limitations listed above, the data may be lacking to refine the model. Stage 2 Microbial Disinfection Byproducts AIP notes that conventional WTPs meeting IESWTR turbidity requirements would achieve 3-log removal of *Cryptosporidium*, not the 2-log removal assumed by the IESWTR and used by Anderson for calculations of risk assessment. If the remaining variables in the model remain the same, then the annual level of risk of *Cryptosporidium* infection per 10,000 consumers falls by a factor of 10. If this is the case, then the risk of infection at the 50% probability level from *Cryptosporidium* at all SWP Southern California reservoirs falls below the EPA's 1 in 10,000/year (Table 12-17).

Table 12-17 Predicted Consumer Risk Assessment (Infections/10,000 consumers/year) at 4 Southern California SWP Reservoirs at 50% and 95% Probabilities (95% given in parentheses) Under 2-log and 3-log Removal Efficiency for *Cryptosporidium*

	2-log removal	3-log removal
Lake Perris	2.39 (46.6)	0.239 (4.66)
Castaic Lake	1.20 (23.4)	0.120 (2.34)
Pyramid Lake	0.88 (17.1)	0.088 (1.71)
Silverwood Lake	0.64 (12.4)	0.064 (1.24)

Although at the 50% median concentration *Cryptosporidium* levels fall below EPA's infective levels, at the 95% concentration all sites are still above 1 infection/10,000 consumers/year. However, both Pyramid and Silverwood lakes are only slightly above the EPA limit. As noted previously, calculated *Cryptosporidium* annual running averages at both Jensen and Mills indicate that oocyst concentrations may generally be below levels requiring additional treatment (Table 12-13). Samples collected under the LT2 ESWTR will help confirm this hypothesis.

Unfortunately, the remaining limitations listed by Anderson could also have a significant impact on the calculated risk assessment. Improved predictions of risk could be achieved through application of risk assessment models specifically developed for each of the reservoirs, rather than extrapolation of results from the Eastside Reservoir study for MWDSC. Therefore, consumer risk assessments at both the 2-log and 3-log removal efficiency levels at these 4 reservoirs should be viewed with caution.

As part of the study by Anderson (2000), daily levels of fecal coliform at Perris Beach and Moreno Beach at Lake Perris were also used in a finite element model developed for Lake Perris. Predicted fecal coliform concentrations were compared with monitoring data collected by the Riverside County Health Department. Anderson found good agreement between the predicted and actual fecal coliform values; however, it would be premature to judge the accuracy of the model based on multiple samples collected at only 1 time of the day. Although encouraging, until samples are collected over the course of the day, the goodness of fit of the model should only be considered preliminary. The model suggested that coliform levels would rise until about 3 PM and then fall throughout the afternoon and evening. At 2 popular swimming beaches on the lake, additional calculations suggested that predicted fecal coliform concentrations might exceed DHS single-sample bathing beaches coliform value of 400 cfu/100 mL a minimum of 2.5% and 5.5% of the time. Fecal coliform levels were not modeled at the remaining 3 reservoirs. Therefore, it is unknown whether the hierarchy of pathogen contamination as recreation use increases would have been similar for bacteria.

Anderson concluded that body-contact recreational activity is predicted to have significant effects on the pathogen concentrations in all of the SWP reservoirs with Lake Perris predicted to experience the most substantial impacts because of its high level of recreational use relative to the volume of its epilimnion. However, Anderson based these conclusions on 2-log removal of *Cryptosporidium*, not the 3-log removal currently assumed for plants meeting IESWTR requirements. If this is the case, then risks fall by a factor of 10. Depending on the levels chosen by the EPA, all lakes might meet the EPA's levels of risk.

Anderson's transport simulations conducted for Lake Perris predicted a complex circulation pattern within the reservoir. Samples collected at Perris Beach at about noon during the summer weekends of 1999 were in good agreement with predicted concentrations using the model. Predicted and observed concentrations near the buoy line were also in good agreement. Using his model, cumulative probability distribution functions developed from coliform monitoring data indicated that fecal coliform concentrations at mid-day would exceed the DHS simple sample limit of 400 cfu/100 mL at a probability of about 2.5% for Perris Beach and 5.5% for Moreno Beach. Because Dr. Anderson's model shows a peak in coliform numbers around 3 PM, this finding suggests that the probabilities for exceeding the recommended DHS single sample limit will be higher later in the afternoon. Additional field samples will be required to verify the model's prediction.

Finally, although *Cryptosporidium* risk may be lower than what is indicated in Dr. Anderson's report, virus removal remains unaffected by new calculations in the LT2 ESWTR. The levels of rotavirus predicted by Dr. Anderson based on the Eastside Reservoir results are high. More detailed modeling using improved rotavirus data would be informative. Nevertheless, if rotavirus or other viruses are perceived as a threat, field monitoring to determine actual concentrations would be advisable.

12.7 PROTOZOAN SAMPLING METHOD CONCERNS

Sampling methodology for *Cryptosporidium* and *Giardia* is still in its infancy. While improvements have been made, problems with the methods often make the interpretation of protozoan results problematic and open to debate. Recommendations made in Chapter 13 for several watersheds have called for more focused studies on pathogen occurrence. Unfortunately, the weaknesses and/or expense associated with the protozoan methods, may compromise the ability to design studies that adequately address the questions requiring study.

The EPA has promulgated 2 methods to determine *Cryptosporidium* and *Giardia* concentrations in source and treated waters. The first, the ICR immunofluorescent assay (IFA) method for pathogens, was proposed in February 1994 but not promulgated until May 1996. One of the reasons for delay involved the scientific issues surrounding the

IFA method used to quantify oocysts (Pontius 1999). In 1998 and 1999, the EPA introduced Method 1622 (for *Cryptosporidium*) and Method 1623 (for *Cryptosporidium* and *Giardia*). DWR's MWQI conducted several studies with either the ICR method or Method 1623.

DWR studies led to the conclusion that the ICR method exhibited poor recovery, accuracy, and precision and that because of these failings, it was impossible to know whether the results accurately reflected pathogen distribution and concentration in source, Delta, SWP aqueduct, and reservoir waters (see Appendix B). These results are not dissimilar from nationwide ICR results. With 18 months of national ICR data analyzed, the majority of samples have found no detection of either *Cryptosporidium* or *Giardia*. Of the 5,829 samples analyzed, 93% have been nondetect for *Cryptosporidium* and 81% have been negative for *Giardia* (Allen and others 2000). Problems with the ICR protozoan method include poor reproducibility, poor sensitivity, high detection limit, high false-positive rate, and high false-negative rate. Allen and others (2000) concluded that since no estimate of the true concentration of pathogens in a sample can be made with confidence, the ICR method should be considered at best a screening test when cysts or oocysts are found, while the lack of organisms does not necessarily mean that the pathogens are not present (Allen and others 2000). Although the EPA has maintained that the collected data from the ICR were adequate for estimating the national occurrence of protozoa, the agency and the water supply profession were concerned that ICR data may not accurately describe protozoa occurrence in drinking water plant source water (Connell and others 2000). This concern led to the Information Collection Rule Supplemental Surveys and the use of Method 1622 and 1623.

While Method 1623 is the best method available to analyze for *Cryptosporidium*, it still has significant problems that compromise the ability to perform studies suggested in this document. Recovery and variability of the method may be influenced by the background matrix of the sample (see also Appendix C). Overlying the issue of method strengths and weaknesses are the inherent problems associated with sampling an organism that is not homogeneously distributed throughout the water column. Regardless of the method, if sampling designs do not account for the spatial variability of organisms, this could lead to false conclusions on concentrations or occurrence. Problems with using Method 1623 for environmental and treated water monitoring have led several researchers to recommend a different approach to assessing pathogen contamination. For water treatment plants, Allen and others (2000) have suggested using source-water protection, treatment optimization, and maintenance of water quality through storage and distribution instead of using monitoring results from Method 1623.

The 3 parameters necessary to ensure statistically valid microbial data are sensitivity, specificity, and reproducibility (coefficient of variation) (Ferraro and Kunz 1982). With respect to these constituents, Method 1623 is an improvement over the ICR method; however, based on these criteria, it still is inadequate to accurately summarize pathogen occurrences. Generally, methods that demonstrate sensitivities and specificities of < 90% and coefficient of variation (CV) of > 15% are too inaccurate and variable to make sound public health decisions (Allen and others 2000). Table 12-18 shows the mean percent recovery and relative standard deviation for *Cryptosporidium* from the EPA's method validation study for Method 1623 in both reagent water and matrix spikes (EPA 1999).

Table 12-18 Final Method 1623 Quality Control Acceptance Criteria

	Mean Percent Recovery	Percent Relative Standard Deviation
Reagent Water Matrix	21% to 100%	40%
Spike/matrix spike duplicate	13% to 111%	61%

Adapted from EPA 1999

Table 12-19 shows the mean percent recovery and relative standard deviation for *Cryptosporidium* for the data collected by the EPA for its supplemental survey sampling program (Connell and others 2000). As shown in Tables 12-18 and 12-19, Method 1623 does not generally meet the accuracy criteria and shows much higher precision than 15%. At this time the true sensitivity of the method is unknown.

Table 12-19 Supplemental Survey Mean Recovery and Relative Standard Deviation

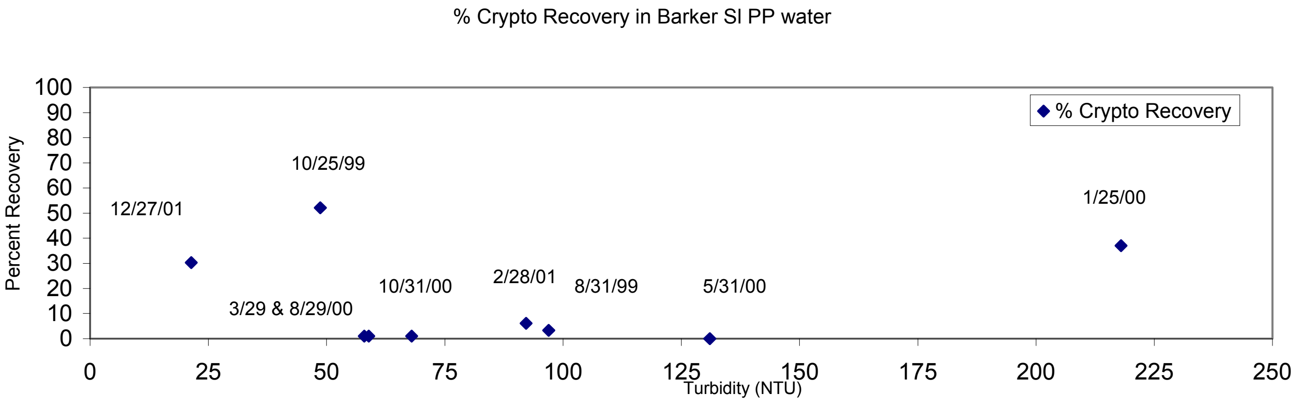
	Mean Recovery	Relative Standard Deviation
Spiked source water	43%	47%

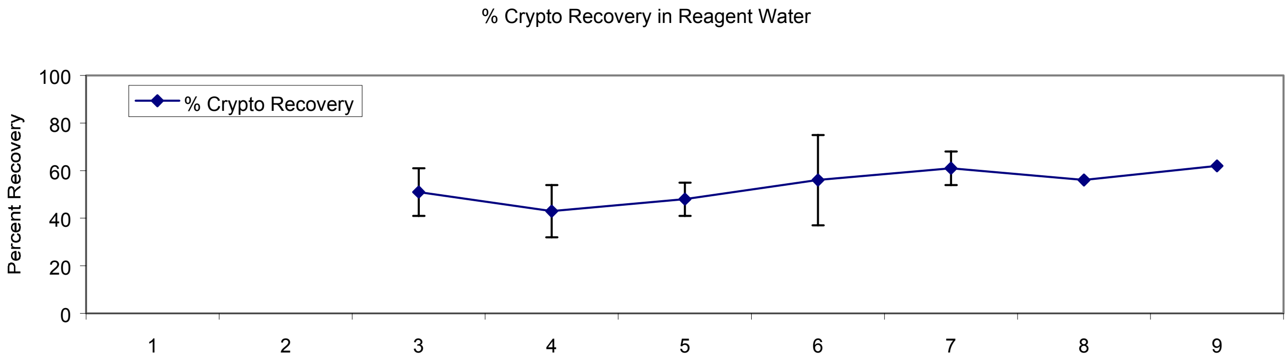
Adapted from Connell and others 2000

Based on the 1623 sampling completed by DWR to date, some of the most acute problems with the method can be observed in the Barker Slough watershed. Increased pathogen monitoring is warranted because of the known presence of livestock in the slough that drains the watershed.

Figure 12-13 shows the results of approximately a year and a half of Method 1623, matrix spike recovery experiments in Barker Slough waters as well as the laboratories' ongoing precision and recovery of spiked samples in reagent water. Average recovery of matrix spikes in Barker Slough water was 15%. The coefficient of variation was 135%. In contrast, the laboratories' average recovery in reagent water was within EPA's criteria for the method with an average recovery of 54% and a coefficient of variation of 13%. In Barker Slough waters, most recoveries ranged between zero and 3%; however, high and low recoveries could be found at high and low turbidities. This suggested that either turbidity was not the variable affecting recovery or that the level of variability with a single sample was so great an extremely large number of replicates would be required to accurately describe the spiking concentration. In either case, the level of accuracy and variability are so poor that accurate counts of *Cryptosporidium* in this water are extremely problematic. As a caveat (shown in Appendix C), the greatest variability associated with MWQI recovery experiments also occurred in Barker Slough water (coefficient of variation of 38%); however, in these experiments, the average percent recovery was 55%. While recoveries were higher, the large variability associated with this recovery result also suggests that a large number of samples would be required to accurately determine oocyst concentrations.

Figure 12-13 Matrix Spike Percent *Cryptosporidium* Recovery in Barker Slough Waters and Ongoing Precision Percent Recovery in Reagent Water





Unlike Barker Slough, coefficients of variation were less than 15% at other sites studied by MWQI (Appendix C). However, while the level of variability was low, recovery may have been influenced by matrix water quality, not turbidity. *Cryptosporidium* recoveries for samples at high and low turbidities were statistically similar; however, recoveries of both high and low turbidity samples differed statistically between the turbidity sample collected between the 2 extremes. This result would not have been expected if turbidity was responsible for method performance.

Before further environmental sampling, 2 experiments should be conducted. The 1st would be to repeat the experiment of Appendix C with more replicates. The 2nd would be to determine if matrix effects are influencing recovery results of the method.

Overlying the issue of method strengths and weaknesses are the inherent problems associated with sampling an organism that is not homogeneously distributed throughout the water column. Based on the total monthly volume of finished water produced and the volume of monthly pathogen samples collected, Allen and others (2000) calculated that of the major utilities they examined, the greatest percentage of total produced water analyzed for protozoans was 0.00039%. In many ways the percentage of source water examined under field conditions is analogous. Unless it is a small stream, the volume of water processed from larger rivers or reservoirs is a small fraction of the total volume of the water body sampled. Since protozoa are not homogeneously distributed in the water body, sampling frequency, location, and volume become critical when trying to characterize organism concentration or origin. Given the method and environmental limitations, the highest chances of success would potentially occur in small, highly polluted streams with data becoming more difficult to interpret with the size and complexity of the water body or watershed.

Given the issues above, environmental sampling of pathogens suggested in this document will be costly to perform, and the data quality may still be questionable even with stringent QA/QC in place. Allen and others (2000) have suggested that pathogen monitoring should be considered only in rare and special instances (for example, research studies, point source evaluations in a watershed, or with an infective outbreak). However, even under these circumstances, the limits of the method must be fully realized. So that the reader can judge the quality of the data for themselves, any results should reflect the specificity, sensitivity, and reproducibility of the method used (Allen and others 2000)

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Contents

13

Conclusions and Recommendations

The purpose of this chapter is to present specific conclusions and recommendations developed by the individual authors of *Sanitary Survey Update 2001*. As part of the process, the conclusions and recommendations were reviewed for consistency and relevance in a workshop with other report authors. Members of the Sanitary Survey Action Committee (SSAC) then reviewed the draft chapter, and their comments were integrated into the final document.

Conclusions are grouped by chapter and by potential contaminant source (PCS). Report section numbers are provided for each PCS for the reader to reference the section from which the conclusion was drawn. Each section's conclusions are presented consecutively and identified with a lowercase letter, that is, Conclusion a, Conclusion b, etc. Each recommendation appears below the conclusion to which it pertains. Recommendations are not numbered or lettered.

The following chapters do not have conclusions or recommendations: Chapter 1, Introduction and background; Chapter 2, Water Quality Overview; Chapter 11, State Water Project (SWP) Emergency Action Plan.

This chapter does not state a conclusion for every PCS or drinking water parameter, and not every conclusion has a recommendation. On the other hand, some conclusions have multiple recommendations. The goal was to provide a focused set of conclusions and recommendations for priority PCSs that could act as a guide to readers of *Sanitary Survey Update 2001*. Generally, PCSs that were a minor threat to drinking water do not have conclusions and recommendations except in cases where past information had suggested a significant threat to drinking water quality. After the publication of this document, the SSAC will meet to review and prioritize the recommendations for further action. These actions may include increased monitoring or study as well as actions to protect and improve the source waters of the SWP.

CHAPTER 3 BARKER SLOUGH/NORTH BAY AQUEDUCT

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: Studies conducted jointly by the California Department of Water Resources (DWR) and the North Bay Aqueduct (NBA) contractors as well as a recent study conducted by an independent consultant have not identified any single source responsible for the high levels of organic carbon, turbidity, and coliforms. These contaminants continue to create treatment challenges for the contractors treating NBA water. Potential sources of these contaminants include cattle grazing, urban runoff, recreation, and natural processes in the watershed.

Conclusion b: With respect to potential sources of contaminants, the geologic makeup of the watershed may be one of the most important influences on water quality. HydroScience suggested that high sodium content of exposed channels may be the single most important factor in creating the observed turbidity and that the soils and vegetation may naturally lead to higher dissolved organic carbon (DOC) concentrations. Natural background levels of some metals at the Barker Slough Pumping Plant (for example, aluminum or iron) can exceed primary or secondary maximum contaminant levels (MCLs).

Conclusion c: The interactions in hydrology between the Barker Slough watershed, the adjacent Calhoun Cut watershed, the Yolo Bypass, and tidal influences are poorly understood. It has been hypothesized that in the winter, water flowing down Barker Slough as well as Calhoun Cut are trapped in the lower portion of Barker Slough near the pumping plant. Decreased pumping rates combined with poor flushing may then contribute to high concentrations of contaminants remaining in the vicinity of the pumping plant for long periods of time. This results in a continous source of poor quality water to the NBA contractors. In addition, during high flow years a hydrologic plug may be formed by the Yolo Bypass, which exacerbates these dynamics.

> **Recommendation:** The natural processes of the watershed need to be studied. These include the dispersive and settling properties of the soil and its liberation of organic carbon as well as the role that aluminum and iron may play in enhancing the mobility of organic carbon.
>
> **Recommendation:** Hydrology's role on water quality at the pumping plant needs further study. Soil maps of downstream watersheds need to be examined to determine whether the same general soils found in the Barker Slough watershed are present in nearby downstream watersheds.
>
> **Recommendation:** If natural process in the watershed(s) is primarily responsible for the high total organic carbon (TOC) and turbidity levels, then studies examining the feasibility of pretreatment of NBA source water should be explored as well as other Best Management Practice (BMP) recommendations made by HydroScience, such as the feasibility of source water quality improvements through alternative intake locations, blending, and exchanges.

3.3.1 RECREATION

Conclusion a: The recreational activities at the Cypress Lakes Golf Course and the Jepson Prairie Reserve do not have a significant impact on water quality in Barker Slough. Most recreation in the watershed occurs at the Cypress Lakes Golf Course and the Argyll Park motocross facility. Based on its proximity to the pumping plant and the erosive activities that occur at the motocross park, recreation activities at Argyll Park have the greatest potential impact on water quality.

> **Recommendation**: The transport and fate of contaminants from Argyll Park recreation should be determined.

Conclusion b: In addition to motocross recreation, Campbell Lake at Argyll Park is used by hobbyists and serves as an irrigation pond for the property.

> **Recommendation:** Studies that examine the role played by Campbell Lake in influencing the watershed's water quality should continue. If loading from Campbell Lake or the nearby pond are found to have a significant impact on water quality, then BMPs should be evaluated.
>
> **Recommendation:** Flow measurements should be refined so that loading contributions from the lake during peak storm events can be determined.

3.3.2 WASTEWATER TREATMENT/FACILITIES

Conclusion a: Because of the rural nature of the watershed, the small number of septic tanks, and the low density of septic tanks in the watershed, wastewater is not considered to be a significant source of contaminants to Barker Slough.

3.3.3 URBAN RUNOFF

Conclusion a: A small portion of the upper northwest corner of the watershed is urbanized. Storm drains from approximately 256 acres of the city of Vacaville empty into a drain that leads to the Noonan Main Drain and Barker Slough. The results of special studies suggest that urban runoff is not a major contributor to TOC and turbidity problems.

> **Recommendation:** Flow measurements should be refined so that urban loading contributions during peak storm events can be determined.

3.3.4 ANIMAL POPULATIONS

Conclusion a: A large portion of the Barker Slough watershed is devoted to cattle and sheep grazing. It has been estimated that there are 2,600 to 3,000 cattle and 1,500 sheep in the watershed. Cows are present in the watershed for longer periods of time, and there is substantial evidence of stream bank trampling and animals defecating in the slough. The cattle may be a substantial source of organic carbon, turbidity, and pathogens; however, the relative load of contaminants from cattle and other sources in the watershed is not understood.

Conclusion b: With the exception of the pumping plant itself, fencing along Barker Slough is inadequate to keep livestock out of the slough. Cows have often been observed in the slough, and the banks and wallows used by cows are highly disturbed. Animals may use the slough because water is unavailable elsewhere.

Conclusion c: High coliform densities are routinely measured at the Barker Slough Pumping Plant. The fecal coliform and *E. coli* densities at the pumping plant are routinely higher than the levels measured at other locations in the SWP (see Chapter 12). The cattle in the watershed are suspected of being a source of the coliforms, and *E. coli* and may be a source of pathogenic microorganisms.

> **Recommendation:** Focused studies on contaminant contributions from livestock need to be conducted.
>
> **Recommendation:** If cattle are found to be a major source of contaminants, specific BMPs such as the installation and maintenance of fencing along the length of Barker Slough and the installation and maintenance of water sources away from the waterway should be evaluated.
>
> **Recommendation:** HydroScience recommends that the implementation of other BMPs to reduce bank erosion and livestock control be examined and supported.

Conclusion d: Of the areas grazed in the watershed, only the Jepson Prairie Preserve has a range management plan.

> **Recommendation:** Coordination between water utilities, UC Extension, the Natural Resources Conservation Service, and livestock owners should be supported/pursued to create range management plans for all livestock owners.
>
> **Recommendation:** A watershed coordinator position should be created to facilitate watershed studies, serve as a contact for information on all watershed management practices, work with the livestock owners and UC Extension on range management plans, insure implementation of BMPs, and serve as a clearinghouse of watershed information.

3.3.5 AGRICULTURAL ACTIVITIES

Conclusion a: Based on contractor Title 22 sample analyses and samples analyzed by DWR, pesticides do not appear to reach levels that are of concern to drinking water. However, sampling frequencies are not correlated to agricultural applications of pesticides. Because row cropping makes up a small percentage of the watershed, the conclusion is that the overall effects of pesticides on NBA drinking water quality are probably minimal.

> **Recommendation:** Any future pesticide monitoring program should consider a pesticide sampling program that realistically mirrors the application of pesticides on row crops.
>
> **Recommendation:** Where feasible, improve agricultural tailwater conveyance into the drains. This would reduce vulnerability of this drinking water source to pesticide pollution while also reducing off-site transport of sediment and organic carbon.

Conclusion b: Solano Irrigation District (SID) follows strict guidelines to minimize off-site movement of pesticides. To control unwanted vegetation, SID is in the process of allowing revegetation of grass along the banks of some drains.

> **Recommendation**: SID's bank stabilization through revegetation should be supported. The sediment contribution from unpaved SID-maintained roads to access the Noonan Main Drain for weed control should be examined.

CHAPTER 4 THE DELTA

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: Monitoring at Banks Pumping Plant detected herbicides, arsenic, copper, zinc, and manganese. All were at concentrations significantly below regulatory levels for treated drinking water.

> **Recommendation:** Periodic monitoring of selective pesticides and other regulated and unregulated chemicals based on use, environmental fate, solubility, and other properties should be conducted with review by the Department of Health Services (DHS) and SWP contractors.

Conclusion b: Taste and odor problems in the South Bay Aqueduct (SBA) result from a combination of algal production in Delta source waters entering at Banks and in the open portions of the SBA. Algae continue to grow in the SBA open canal during favorable growth conditions that generally occur during the warmer months.

> **Recommendation:** See recommendations under Chapter 5 review, Section 5.3.1.5.

4.2.1 RECREATION

4.2.1.1 Recreational Use Surveys

Conclusion a: No current study exists that documents the number of recreational users, length of visits, number of dollars spent per visitor day, age, sex, etc., on recreation use visits, or types of facilities needed to meet present or future visitor needs for the entire Delta. The most recent study, commissioned in 1995 by the Delta Protection Commission, focused on boating and fishing because these are the most popular uses of the Delta.

> **Recommendation:** A central information agency/repository is needed to collect, collate, and analyze visitor days, number of visitors, number and type of restrooms, types of facilities, etc. on all public and private recreational facilities throughout the State.

Conclusion b: A recreation survey conducted by DWR in 1980 is considered one of the best recreational use surveys of the Sacramento River. No recreation use surveys were found for the San Joaquin River.

> **Recommendation:** Recreational use surveys for the Delta and the Sacramento River need to be updated. The San Joaquin River Management Plan recommended a recreational use survey of the San Joaquin River in 1995; however, no action has been taken. Performance of this survey should be encouraged.

Conclusion b: Based on a 1995 survey, the west Delta (including the lower Sacramento and San Joaquin rivers, and the Brannan Island State Reserve) is the most popular area in the Delta for boating and fishing as well as nonboating activities like swimming.

> **Recommendation:** If funding is limited, priority should be given to upgrades of restroom facilities in recreation areas and educational programs in the west Delta.

> **Recommendation:** Funding needs to be provided to carry out the aforementioned recreation-use recommendations.

4.2.1.2 Boating and Pathogen Contamination

Conclusion a: Congress found that "sewage discharged from recreational vessels because of an inadequate number of pump-out stations is a substantial contributor to localized degradation of water quality in the U.S." The Water Quality Control Plan for the Central Valley region also prohibits the discharge of toilet wastes from the vessels of all rental houseboats in the Delta. Chapter 6 of the Harbors and Navigation code mandates that all marinas must have pump-out facilities.

Conclusion b: In practice, many marinas have no pump-out facility. In the Delta area, as many as 70% of all marinas may not have a pump-out facility.

> **Recommendation:** Education efforts for marina users and the general public conducted by the California Department of Boating and Waterways (DBW) and other agencies need to be continued and expanded to inform the public on the need for using pump-out facilities and the problems with inappropriate disposal.

> **Recommendation:** Support a strong education program on the Pumpout Grant Program, which will reimburse recipients for up to 75% of the installed cost of pump-out and dump stations.

Conclusion c: Because of staffing limitations at the Central Valley Regional Water Quality Control Board (CVRWQCB), the pump-out requirement is minimally enforced.

> **Recommendation:** Additional staff needs to be added to the CVRWQCB to allow better enforcement of pump-out regulations.

Conclusion d: The most popular boats used in the Delta (powerboats) generally do not have Marine Sanitation Devices (MSDs).

> **Recommendation:** The feasibility of installation of type III MSD devices on all powerboats above a certain size class should be investigated.

Conclusion e: Although small in volume, boat sewage is highly concentrated. The DBW estimates that a single weekend boater flushing untreated sewage into the water produces the same amount of bacterial pollution as 10,000 people whose sewage passes through a treatment plant.

Conclusion f: In addition to fecal contamination, some of the chemicals used for MSD disinfectants include chlorine, ammonia, and formaldehyde. These constituents are also discharged when boaters empty an MSD directly into the water.

> **Recommendation:** Education efforts for marina users and the general public conducted by the DBW and other agencies need to be continued and expanded to educate the public on the problems associated with inappropriate disposal of boating sewage.

Conclusion g: Boat MSDs frequently have a Y valve that allows boaters to direct wastes either to a holding tank or overboard. Boats operating in the Delta or other inland waters must secure the Y valve handle in the closed position with a wire tie or padlock. Overboard discharges frequently are caused by intentional or unintentional misuse of the Y valve.

> **Recommendation:** Existing regulations and legislation regarding the modification of the Y valve on MSDs to minimize accidental release of waste material need to be evaluated.

4.2.1.3 Body-Contact Recreation and Pathogens

Conclusion a: In the Delta, most body-contact recreation is centered on waterskiing and windsurfing. Because of the lack of public beaches, swimming from shore is limited; therefore, swimming from a boat is more popular.

Conclusion b: Results from the most recent survey of existing on-shore restroom facilities in the Delta suggest that the number of facilities are inadequate.

Conclusion c: No data are available that correlate pathogen numbers with recreation use in the Delta. Even if sewage originates from a human source, it is difficult to know whether it comes from a boat, swimming from shore, a malfunctioning septic system, or a wastewater treatment plant. Under these circumstances, the best strategy may be prevention through installation of MSDs, pump-out facilities, and restrooms.

> **Recommendation:** More restroom facilities are needed on shore and on the water. More pump-out facilities and MSDs are also needed for swimmers who choose to swim from boats.

> **Recommendation:** Education programs at public beaches need to be expanded. Public outreach at schools might also be helpful.

Conclusion d: Bacteria sampling of freshwater public beaches is generally sporadic or nonexistent.

Conclusion e: Without accurate use numbers and with sporadic coliform sampling by local agencies at Delta recreation areas, it is not possible to draw conclusions on body-water contact and pathogens.

> **Recommendation:** Local health authorities should be contacted to discuss options for increasing bacteriological monitoring of Delta waters used for recreation.

4.2.1.4 Delta Recreation and MTBE

Conclusion a: MTBE is a fuel additive to boost octane and make gasoline burn more efficiently.

Conclusion b: Carbureted 2-stroke outboard engines can discharge up to 25% of their unburned fuel/oil mixture (including MTBE and hydrocarbons) through their exhaust into the surface water.

Conclusion c: Outboard 2-stroke direct fuel injection engines and 4-stroke inboard and inboard-outboard engines burn fuel more efficiently and do not discharge large amounts of unburned fuel into the water through their exhaust. Four-stroke engines burn fuel more efficiently than 2-stroke direct injection engines.

Conclusion d: Starting in 2001, the California Air Resources Board (CARB) has enacted regulations reducing allowable emissions from outboard motors and personal watercraft (PWC). These regulations will also serve to reduce the discharge of unburned fuel into surface waters.

Conclusion e: Beginning in 2001, 2-stroke direct fuel injection engines will be sold. Carbureted 2-stroke engines will not be sold.

Conclusion f: The CARB regulations do not require retrofitting or replacement of pre-2001 model year engines.

> **Recommendation:** Encourage CARB to create a buy-back program to remove pre-2001 model year carbureted 2-stroke engines from use. Coordinate and cooperate with the CARB and marine engine manufacturers on this issue.

Conclusion g: MTBE as a gasoline additive is being phased out by 2002; however, the phaseout is complicated by the federal ruling that mandates oxygenates in fuel.

Conclusion h: A recent evaluation of MTBE in Delta surface waters determined that, based on its low concentrations, MTBE in Delta waters was of limited significance to drinking water.

> **Recommendation:** To minimize contamination, all MTBE sampling should be conducted from a boat with a 2-stroke direct injection engine, 4-stroke engine, or an engine filled with non-MTBE gasoline.

> **Recommendation:** MTBE results need to be reported to DHS. DHS and the CVRWQCB should work together to devise MTBE basin plan limits.

4.2.2 WASTEWATER TREATMENT FACILITIES

Conclusion a: Data collected by wastewater treatment plants (WWTPs) are generally insufficient for evaluating impacts on drinking water quality. Data are collected to comply with the National Pollutant Discharge Elimination System (NPDES) permits, which do not always include drinking water parameters of concern.

> **Recommendation:** WWTP sampling should include analyses of components important to drinking water such as TOC/DOC, nutrients, pathogens, chromium 6, and mercury.

> **Recommendation:** Encourage development of nutrient export coefficients and nutrient loading data from WWTPs.

> **Recommendation:** Continue to review and comment on CEQA documents for expansion of existing WWTPs and construction of new plants.

> **Recommendation:** Analyses should be conducted on the cumulative impact on Delta water quality of contaminant loading from WWTPs.

4.2.3 URBAN RUNOFF

Conclusion a: Urban runoff is increasing in the Delta watersheds, including at sources close to drinking water diversions. Current monitoring is conducted to comply with a NPDES general storm water permit. Data are not required to be collected to assess the impacts to drinking water quality. Existing information shows extreme peaks that are episodic in nature for bacteria, carbon, and other drinking water parameters of concern.

> **Recommendation:** As part of their storm water permit monitoring program, agencies should be required to collect data for drinking water parameters of concern.

> **Recommendation:** Even if drinking water parameters are added to storm water permits, the frequency of permit sampling may not adequately assess drinking water impacts. Therefore, specific studies should be developed to examine the impacts of storm water runoff on drinking water, including sampling major pumping stations during storm events to monitor contaminants flushed to the Delta.

> **Recommendation:** Assessments of impacts from urban loading should be used to determine whether controls should be pursued. Size of discharge, proximity to drinking water intakes, and runoff sources should be evaluated.

4.2.4 LIVESTOCK GRAZING

Conclusion a: As urbanization is increasing, grazing as a land use is stable or decreasing. San Joaquin County shows the highest density of animals per acre.

> **Recommendation:** Support the California Cattlemen's Association, UC Cooperative Extension, and other range management efforts to reduce impacts to the watershed through BMPs. Support CALFED's efforts to potentially assess the findings of these individual programs.

4.2.5 CONFINED ANIMAL FEEDING OPERATIONS

Conclusion a: There was a lack of reliable data on locations of confined animal feeding operations (CAFOs), which constrained production of accurate distribution maps for *Sanitary Survey Update 2001*. In the CAFO database available from the California Department of Food and Agriculture (CDFA), some facilities data included street addresses. Others only had owner address, which could be in a different county from the CAFO location. Therefore, the distribution maps in this report should only be considered to represent approximate CAFO locations. (EPA Region 9 has Geographic Information System (GIS) data for large dairies with 1,000+ animals, but these are only a subset of the total CAFOs in the watersheds.)

> **Recommendation:** Initiate acquisition of geo-referenced spatial data (latitudes and longitudes) to create more accurate CAFO distribution maps.
>
> **Recommendation:** Explore potential for CVRWQCB and DWR cooperating to acquire necessary spatial data. Informally, CVRWQCB had indicated that it would start collecting GPS data when its funding allows.
>
> **Recommendation:** Ensure that GIS data has appropriate metadata. CVRWQCB would likely collect facility location at lagoons, which are the potential points of discharge, whereas EPA collects GPS data at the milk house. On a large dairy, the milk house and lagoon may be widely separated, and the facility spatial depiction derived from the 2 methods may appear significantly different when plotted (depending on the map scale).

Conclusion b: There is a lack of water quality data from CAFO discharges. CVRWQCB mostly collects ammonia and electrical conductivity (EC) data at accidental/illegal discharge locations. There are no regularly scheduled programs to monitor water quality in areas with heavy CAFO concentrations. The impacts of land applications of wastewater and biosolids, which may contribute nutrients, pathogens, TOC, etc. into storm water runoff that drain into Delta tributaries, is unknown.

> **Recommendation:** Initiate coordination with other agencies that have an interest in CAFO operations such as CVRWQCB, DHS, EPA Region 9, California Department of Pesticide Regulations, county agencies and UC Extension (which manages agricultural and range water quality). Coordination could reduce duplication of efforts and better implement control measures.
>
> **Recommendation:** Establish cooperation with CVRWQCB to collect geo-referenced samples that can be analyzed for TOC/DOC, nutrients, total dissolved solids (TDS), minerals, emerging contaminants, and pathogens. The data will provide a preliminary evaluation of the CAFO waste discharge problem in the watersheds and also help in designing subsequent detailed studies. Funding for this additional work should be sought through the CALFED Bay-Delta Program.
>
> **Recommendation:** Encourage development of nutrient loading for CAFOs in the watersheds. The Delta watersheds export nutrients that promote algal growth in the SWP. From this data, nutrient export coefficients should be derived and used to model relative contributions of different land use types to water body eutrophication.

Conclusion c: Current staff funding at the CVRWQCB is inadequate to identify all the CAFOs that illegally discharge into Delta tributaries.

> **Recommendation:** To successfully support the quality of SWP supply sources, increased staff levels should be required to identify any illegal discharges.

4.2.6 AGRICULTURAL DRAINAGE

4.2.6.2 Delta Agricultural Drainage

Conclusion a: Delta island drainage is a significant source of organic carbon.

> **Recommendation:** Support CALFED program studies of methods to protect Delta drinking water quality. Some of these actions include re-routing drainage discharge locations, treating drainage to reduce TOC, and timing storage and releases to maximize dilution.

Conclusion b: When Delta water is siphoned onto the islands for irrigation, bromide from seawater intrusion is transported onto the fields and then returned back into the channels in drainwater. Some bromide may be released from decaying peat and plant matter.

Conclusion c: Delta island drainage is high in TDS, EC, and other salts because of evaporation of applied irrigation water and, for some islands, connate water.

Conclusion d: Pesticides from applications to Delta island crops do not appear to be a significant contaminant at the Banks headworks. When found, they are well below MCLs for drinking water.

Conclusion e: The contribution of nutrients from Delta island drainage is poorly understood because of lack of data. Applied nutrients and those from decaying peat and crop mass may be a significant source of nutrients that can stimulate algal growth at SWP reservoirs.

> **Recommendation:** Begin selective monitoring of nutrient loads from Delta island drains.

Conclusion f: Future development in and upstream of the Delta, including new or enlarged diversions and storage projects may impair Delta flows and reduce drinking water quality.

> **Recommendation:** Ensure proposals for future developments in and upstream of the Delta—such as new diversions and storage projects—are thoroughly evaluated to assure they do not impair flows and reduce water quality.

4.2.6.3 Sacramento River Basin

Conclusion a: Significant amounts of pesticides are used on 2 million acres of crops in the Sacramento River Region. Colusa Basin Drain (CBD1) and Sacramento Slough capture 80% of the agricultural drainage. Monthly sampling over an 18-month period detected a number of pesticides, with the majority being herbicides. None were detected above the MCL set for treated drinking water. Pesticides at measured levels are not a significant threat to drinking water quality.

Conclusion b: Nitrogen and phosphorus are found at higher concentrations in the drains than in the Sacramento River. Sacramento agricultural drainage provides a significant amount of nutrients. Nutrient loading from agricultural drains affects the Sacramento River concentrations from winter through early summer, but the impact to the water quality at Delta drinking water intakes is unknown.

> **Recommendation:** Nutrient loading to the Sacramento River from various sources should be monitored. New or expanding nutrient sources should be identified, and control measures encouraged.

> **Recommendation:** An analysis of the seasonal impact of nutrients should determine whether effects at Banks are great enough to warrant pursuing source evaluation and possible control.

Conclusion c: EC values are 4 times higher in CBD1 than in the Sacramento River. EC readings show an inverse relationship to flow. During periods of low flow such as in the late summer through early winter, concentrations of salt in the river are measurably increased by agricultural drainage.

Conclusion d: Organic carbon concentrations in the agricultural drains discharging to the Sacramento River ranged from 2 to 10 mg/L, while the receiving water averaged below 2 mg/L. As river flows decrease in the summer, fall, and early winter, agricultural drainage provides an increased portion of the TOC load, as high as 30%. Concentrations in the river are increased during this time by the agricultural drainage.

> **Recommendation:** An analysis of the seasonal impact of carbon loading should determine whether effects at Banks are great enough to warrant pursuing source evaluation and possible control.

Conclusion e: A shift from burning of rice stubble to decomposition by flooding may increase carbon loading.

> **Recommendation:** Track rice acreage subjected to flooding and correlate with measured organic carbon concentrations at key locations to determine whether a trend exists. If this analysis indicates a possible trend, further investigation leading to improved control should be implemented.

4.2.6.4 San Joaquin River Basin

Conclusion a: Significant amounts of pesticides are used on 2 million acres of crops in the San Joaquin River Region. Monthly sampling over an 18-month period detected a number of pesticides, the majority being herbicides. None were detected above the MCL for treated drinking water; consequently, this water when treated would not have higher concentrations. Pesticides at measured levels are not a significant threat to drinking water quality.

Conclusion b: Nitrogen and phosphorus are found at higher concentrations (roughly 3 times greater) in the San Joaquin River than in the Sacramento River. Less dilution flows, wastewater treatment plant and confined animal facility discharges, and recirculated nutrients from the west side of the San Joaquin Valley contribute to the San Joaquin River's higher concentrations.

> **Recommendation:** Nutrient loading from various sources should be monitored in the San Joaquin River. Existing, new, and expanding nutrient sources should be identified and control measures encouraged.
>
> **Recommendation:** Coordination with the San Joaquin River Dissolved Oxygen TMDL (total maximum daily loading) Development Group Deep Water Ship Channel project should include addressing drinking water concerns through sharing of related nutrient data.

Conclusion c: Though Mud and Salt sloughs account for less than 10% of the mean annual discharge to the San Joaquin River, they account for over 40% of the TDS load. Salt is recirculated through the Delta-Mendota Canal (DMC) and then reapplied to the west side of the region. CAFOs and publicly owned treatment works (POTWs) in the region are also sources of salts. Control of agricultural drainage from Mud and Salt sloughs would result in lower TDS concentrations in the lower San Joaquin River. Salt control measures implemented in the San Joaquin River Basin would probably improve water quality at the Tracy Pumping Plant and, to a lesser extent, at Banks Pumping Plant.

> **Recommendation:** The San Joaquin Valley Drainage Implementation Program and CALFED need to address the impacts to Delta export drinking water quality when exploring drainage control measures to meet existing standards for ecosystem water quality. CALFED recommends the following control measures for salts in the San Joaquin Basin: treat drainage, relocate discharge points, release drainage during ebb tidal flows, manage frequency of leaching, implement BMPs, or modify land management practices to reduce loadings of TDS. Support land retirement programs for drainage-impaired lands with local sponsorship.
>
> **Recommendation:** Additional data should be collected on contaminants and contaminant loads from Mud and Salt sloughs. These findings should be confirmed by concurrent monitoring of flow and TDS in the San Joaquin River and Mud and Salt sloughs. It is unlikely that the Mud and Salt Slough drainage will be removed from the river, but the additional data may be useful in recommending BMPs to improve the quality of the drainage water.
>
> **Recommendation:** The potential of more efficient irrigation practices and drainage programs to reduce bromide and salt loads should be evaluated. Use of incentives such as grants and low-interest loans for drainage reuse, drainage reduction, and improved irrigation efficiency should be considered.

Conclusion d: Organic carbon concentrations are significantly higher in the San Joaquin River than in the Sacramento River. Very little source water quality data for organic carbon are available for the San Joaquin River, except at Vernalis. The river contributes to elevated carbon concentrations in the SWP.

> **Recommendation:** Source water quality data should be collected to determine the relative organic carbon sources in the watershed. The San Joaquin Valley Drainage Implementation Program and CALFED need to examine the potential benefits of pulse discharges and other agricultural drain management programs designed for salt control on carbon concentrations and Delta exports.

4.2.7 GEOLOGIC HAZARDS

Conclusion a: Earthquakes pose a catastrophic threat to Delta levees. A levee failure in the central or western Delta could disrupt or interrupt water supply deliveries, transportation, and the regional flow of goods and services. The effects of salinity intrusion from levee failure would be intensified if the seismic event occurred during a period of low river flows and/or during a high tide.

> **Recommendation**: Support the CALFED Levee System Integrity Program Plan to protect levees from failure.

4.2.8 SEAWATER INTRUSION

Conclusion a: Seawater intrusion is the most significant source of EC, TDS, and bromide to Delta waters. Its contribution to organic carbon and nutrient loads at the intake pumps is unknown.

Conclusion b: Based on available data, neither connate (trapped seawater groundwater of ancient origins) nor methyl bromide used in Delta watersheds plays a significant role in Delta bromide levels.

Conclusion c: Next to seawater, the San Joaquin River may be the most important contributor of salts and bromide to the Delta, but both constituents reflect the recirculation of salts and bromide originally introduced to the San Joaquin Valley from Delta waters. Additionally, salt loading may reflect salt leaching of naturally saline subsurface soils.

Conclusion d: Since bromide and TDS are largely a function of seawater intrusion, diverting or repelling seawater would require substantial reconfiguration of general Delta flows. Substituting cleaner source water is another option being considered by CALFED as improving treatment capabilities for Delta water users. Anthropogenic sources of salt are also subject to some degree of control.

> **Recommendation:** Programs encouraging voluntary exchanges or purchases of high-quality source waters should continue to be supported.
>
> **Recommendation:** Support CALFED's efforts to improve source water quality and provide assistance to water treatment plants (WTPs) to improve their existing plants or to construct new facilities to meet new disinfection byproduct (DBP) and pathogen regulations. Additional recommendations made by CALFED to evaluate and improve Delta drinking water quality should be supported as appropriate.

Conclusion e: Of the TDS loading occurring in the Sacramento River, it has been estimated that depending on the year approximately 26% to 33% comes from agricultural drainage while approximately 6% comes from urban runoff. The majority of TDS sources are unknown. Depending on the year, between 79% and 100% of all of the TDS in the San Joaquin River can be traced to Mud and Salt sloughs with only 21% coming from unknown sources.

CHAPTER 5 SOUTH BAY AQUEDUCT AND LAKE DEL VALLE

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: Organic carbon and bromide are 2 major water quality concerns for all SBA contractors. Concentrations of these constituents are largely out of contractors' control because of their presence in Delta source waters.

> **Recommendation:** CALFED's efforts to improve source water quality and provide assistance to water utilities to improve their existing treatment plants or construct new facilities to meet new DBP and pathogen regulations should be supported.

Conclusion b: There are several contaminant sources and related water quality problems (for example, recreation/grazing and pathogens, boating and MTBE, algae and taste and odor) that are of concern in Lake Del Valle, the analysis of which would greatly benefit from an integrated watershed management program approach.

> **Recommendation:** A watershed management program (WMP) should be initiated at Lake Del Valle to coordinate existing and future watershed management activities and studies. Funding and support for a watershed coordinator position should be investigated and obtained if possible. The WMP staff should act as contacts for information on all watershed management practices and provide a clearinghouse of watershed information (recreational use, cattle grazing, sewage system operation, etc.).
>
> **Recommendation:** A comprehensive study should be made of the major sources of nutrients to Lake Del Valle and the SBA. The study should address algal dynamics and nutrient cycling in Lake Del Valle and the open sections of the aqueduct to better understand the processes controlling algal blooms. The study should include correlation of algal growth and taste and odor data with SBA delivery times and natural lake inflows. If the study finds significant local inputs of nutrients, a local source reduction program should be implemented. This study should also be coordinated with and include, if applicable, other studies undertaken for pathogens, MTBE, or other contaminants.

5.3.1 SOUTH BAY AQUEDUCT

5.3.1.1 Recreation

Conclusion a: There is no authorized recreation activity along the open sections of the SBA; therefore, it constitutes a minimal threat to water quality.

5.3.1.2 Wastewater Treatment/Facilities

Conclusion a: There are no known or reported wastewater treatment facilities or effluent discharges to the open sections of the SBA. There is one septic tank and leach field at the South Bay Pumping Plant. This is not considered a significant potential source of pathogens.

5.3.1.3 Urban Runoff

Conclusion a: There is very little urbanization in this section; therefore, urban runoff into the open section of the aqueduct is not significant.

5.3.1.4 Animal Populations

Conclusion a: Cattle graze along the open portions of the SBA. Runoff from surrounding hillsides can enter the open portions of the SBA through drain inlets, overcrossings, and bridges. The open portions of the SBA are fenced so this is not a direct source of contamination. Grazing is considered a significant potential source of pathogens and nutrients in the SBA.

A major route of contamination was via wooden bridges used by cattle to cross the aqueduct, and large gaps on these bridges allowed cattle wastes to directly enter the aqueduct. The wooden planks were replaced with sealed flooring to reduce impacts to water quality and are routinely inspected and repaired as necessary. Although bridge repair greatly reduced the overall impact of grazing by eliminating wastes from this source, cattle wastes from hillside grazing can still enter the SBA via runoff into drain inlets.

> **Recommendation:** DWR should conduct a feasibility study to redirect inlet drainage away from the SBA. Every effort should be made to direct hillside drainage in grazing areas away from the open portions of the SBA.

5.3.1.5 Algal Blooms

Conclusion a: A significant water quality concern consistently cited by all SBA contractors is the taste and odor problem and the production by algae of the offensive taste and odor compounds, MIB and geosmin. Taste and odor problems in the SBA result from a combination of algal production in Delta source waters and in the open portions of the SBA. Algae continue to grow in the SBA open canal during favorable growth conditions that generally occur during the warmer months.

Algal blooms in the SBA have historically been treated with copper sulfate. Beginning in 2000, DWR began adding a lower concentration of copper sulfate earlier in the season to better control algal blooms. SBA water treatment plants reported an improvement in taste and odor problems.

> **Recommendation:** DWR should continue the current copper sulfate regime for several years and the high-frequency closed loop stripping analysis (CLSA) with rapid feedback to SBA contractors to determine appropriate water delivery and WTP operations when taste and odor values exceed thresholds.

> **Recommendation:** DWR should continue to evaluate algal presence and species to determine relative contributions to taste and odor problems and if there also are ancillary benefits from copper sulfate treatments. DWR should also continue to evaluate the results of CLSA studies and coordinate this and recommended studies with related activities at Lake Del Valle.

5.3.1.6 Agricultural Activities

Conclusion a: There is a substantial amount of agriculture in the vicinity of the SBA, including vineyards, but the majority is out of the immediate drainage area of the SBA, farther west and north. Although contractors reported vineyards as an agricultural land use of potential concern along the SBA and the number of vineyards were reported to be increasing, the vineyards appear to be a minor threat to water quality at this time.

5.3.2 LAKE DEL VALLE

5.3.2.1 Recreation

Conclusion a: Recreation usage figures from 1996 to 1999 indicate a general decline from 1995 and previous years. The availability and quality of recreation activities and services at Lake Del Valle are highly affected by lake water levels, with the most favorable lake level at about 703 feet.

Conclusion b: Recreation activities at Lake Del Valle present a moderate threat to water quality. Body contact recreation and boating are potential sources of the microbial pathogens *Giardia* and *Cryptosporidium* in the lake. Pathogen issues at Lake Del Valle and the SBA are addressed in Chapter 12.

Conclusion c: Boating is a major recreational activity at Lake Del Valle. The primary water quality concern associated with boating is MTBE contamination from motorized watercraft. Most boating activity occurs from May to October.

> **Recommendation:** Support implementation and enforcement of new regulations for changed engine design. Evaluate and support use of alternative fuels without MTBE (for example, as with some Santa Clara Valley Water District reservoirs), especially in rental boats at the concessionaire. Encourage owners of older boats using Lake Del Valle to replace 2-stroke engines with direct injection engines or 4-stroke engines.
>
> **Recommendation:** DWR should continue and/or increase regular MTBE monitoring and event sampling around peak holidays. Conduct monitoring from a boat using non-MTBE gasoline or a direct injection engine, or an electric motor. The data should be made available to all interested parties.

Conclusion d: Activities in and around campground areas, especially those near the water line, along trails, and parking areas can contribute to soil erosion and can cause increased turbidity in the lake.

> **Recommendation:** DWR and the East Bay Regional Park District (EBRPD) should evaluate conditions and implement erosion control BMPs if necessary in coordination with other responsible agencies in areas close to Arroyo Valle Creek and the lake.

5.3.2.2 Wastewater Treatment/Facilities

Conclusion a: The major water quality problem associated with wastewater facilities at Lake Del Valle is the potential contribution of microbial pathogens *Giardia* and *Cryptosporidium* from spills or overflows of raw sewage.

Conclusion b: The wastewater facilities serving the Lake Del Valle park area include full service restrooms with flush toilets located in camping areas, associated collection and pumping facilities, wastewater evaporation ponds, and 15 chemical toilets. There were no spills or problems with the chemical toilets during 1996 to 1999.

Conclusion c: On 24 May 1998 there was a sewage spill of an unknown amount from a septic line lift station into the Lang Canyon stream inlet to Lake Del Valle. EBRPD staff reported that the spill was stopped and booms were installed around the area of the spill. The west branch of the reservoir was closed until tests determined there was no contamination.

Conclusion d: Except for the spill described in Conclusion c, all systems within the area were reported to have operated properly within the report period. However, the potential for spills or system failures to contribute pathogens, organic carbon, and nutrients to the lake poses a moderate threat to water quality.

> **Recommendation:** DWR should coordinate with the EBRPD to evaluate the need for upgraded and/or expanded prevention and back-up systems for wastewater facilities determined to have the highest potential risk because of their proximity to the lake or streams.
>
> **Recommendation:** DWR, EBRPD, and other applicable public health agencies should review emergency response procedures for septic and sewage system spills and upgrade as necessary.

5.3.2.3 Urban Runoff

Conclusion a: Runoff from urban areas in the watershed to the lake is minimal because of the low level of development and results primarily from parking lots and roads in the recreation areas. While these various sources of runoff can be a source of turbidity, pathogens, and nutrients, the threat to water quality is considered minimal.

5.3.2.4 Animal Populations

Conclusion a: The Del Valle watershed has a long history of extensive cattle grazing operations both around the edge of the lake and the dam area and in the upper watershed. Cattle have historically had access to the lake, but not typically from June through October when grass is scarce. There is some fencing present, mostly around recreation areas, but much of the grazed lands are unfenced to the lake.

Conclusion b: Grazing as a land use practice is being evaluated by EBRPD on all park lands. Installation of fencing to keep cattle from reaching the lake is limited because of the high cost.

> **Recommendation:** DWR should coordinate with EBRPD to obtain funding sources for additional fencing in critical areas.

Conclusion c: Although grazing occurs in the SBA/Lake Del Valle watershed, water is not normally drawn from the reservoir until late summer/fall. Flushing of contaminants from the watershed into the lake occurs in the winter. This may explain the relatively low fecal and *E. coli* bacteria counts observed at water treatment plants when Lake Del Valle water was utilized (see Chapter 12 for pathogens issues).

Conclusion d: A substantial wild animal population is present, but because of the extensive undeveloped and rugged nature of the watershed, little is known of actual numbers of animals and their condition. Droppings from these animals are a potential source of pathogens in the watershed and have been identified by contractors as a water quality concern.

> **Recommendation:** If future operational scenarios envision use of Del Valle water earlier in the year, a watershed assessment study should be conducted to characterize seasonal pathogen contamination. See "General Conclusions and Recommendations" at the start of this section on Chapter 5.

5.3.2.5 Algal Blooms

Conclusion a: Nuisance algal growth has been a historical occurrence at Lake Del Valle and presents a moderate threat to water quality. The primary adverse effects on water quality associated with algal blooms are increased turbidity, which affects plant operations, and taste and odor resulting from production of 2 organic compounds, MIB and geosmin.

Conclusion b: Algal blooms at Lake Del Valle and other SWP reservoirs result from a complex interaction of nutrient loading (nitrogen and phosphorus), mixing processes, and species interactions and are hard to predict. However, the level of algal growth in Lake Del Valle is lower than in Southern California SWP reservoirs.

Conclusion c: A primary cause of algal blooms at Lake Del Valle is the nutrient loads from the Sacramento-San Joaquin Delta. Local nutrient sources within the lake watershed (animal populations, sewage spills, internal lake recycling) may also be causes of algal blooms. However, the relative contribution of SBA/Delta source waters and watershed sources to the observed reservoir algal blooms is not known.

Conclusion d: Chemical controls for algal growths have never been used in Lake Del Valle.

> **Recommendation:** DWR should support taste and odor monitoring efforts to evaluate algal presence and species to determine relative contributions to taste and odor problems, including times when SBA water is delivered to Lake Del Valle. Taste and odor monitoring efforts should be coordinated with the general watershed assessment study recommended in this section.

5.3.2.6 Agricultural Activities

Conclusion a: The primary agricultural activity in the watershed is livestock production. Because of the location and type of terrain prevalent in the watershed, other types of agricultural development are extremely limited. There are no herbicides or pesticides used in the lake. The herbicide Roundup® is used. Surflan® is also used in the watershed for control of terrestrial weeds on roads and camping areas away from the lake shore. This potential contaminant source presents minimal threat to water quality.

5.3.2.12 Land Use Changes

Conclusion a: The lake and watershed area is highly erosive during rains. About 80% of the land in the Lake Del Valle drainage basin is classified as a severe erosion hazard because of its shallow soils and steep slopes. Because of these conditions, the Lake

Del Valle watershed is extremely sensitive to land use changes such as urbanization and development.

Conclusion b: Arroyo Valle Creek has deposited some 20,000 cubic yards of silt in the reservoir since the dam was built. The sediment load from the creek can cause elevated turbidities in the lake.

Conclusion c: Even limited land use changes such as construction of access roads or grading for construction, if not carefully planned, could accelerate soil erosion and/or landslide problems. Because of this the watershed is very vulnerable, and there is a substantial potential threat to water quality if significant land use changes were to occur in the basin.

> **Recommendation:** Establish a watershed coordinator position to monitor land use changes and to work with landowners and agencies to encourage planning and land use practices that protect water quality. See "General Conclusions and Recommendations" at the start of this section on Chapter 5.

CHAPTER 6 SAN LUIS RESERVOIR

6.3.1 RECREATION

Conclusion a: Body contact recreation and boating in the reservoir are potential sources of microbial pathogens and bacteria. In addition to wind, motorized boats increase wave action on the shoreline and increase turbidity. Motorized boats did not appear to contribute significant MTBE. The highest turbidity occurred in the summer months during the survey period. Ammonia, low levels of total and fecal Coliform, and *E. Coli* were detected frequently at the Pacheco Intake that supplies source water to the Santa Clara Valley Water District (SCVWD) for treatment.

> **Recommendation**: DWR in collaboration with the California State Parks should seek to improve public awareness of water quality and provide more restrooms around the reservoir. If future recreational use increases, DWR should investigate the need to restrict swimming and reduce the number and speed of boats.

Conclusion b: Use of the watershed by visitors was moderate during the survey period compared with visitation at the Southern California reservoirs. Runoff from campgrounds, parking grounds, the Pacheco State Park, and boat ramps contributes contaminants such as turbidity and TOC to the reservoir, particularly during the winter and spring months.

> **Recommendation:** The number of visitors to the watershed will likely increase because of lowered use fees that were recently enacted. DWR should consider conduct studies to estimate total runoff in the watershed and quantify contaminants that enter the reservoir.

6.3.2 WASTEWATER TREATMENT/FACILITIES

Conclusion a: There are no wastewater treatment plants or effluent discharges to the reservoir. Existing wastewater evaporation ponds and toilets are designed to prevent discharges to the lake and have evidently been successful.

6.3.3 ANIMAL POPULATIONS

Conclusion a: No dairy farms are close to the reservoir. Seasonal animal grazing, wild animals, and large numbers of migrating waterfowl are considered significant contributors of turbidity, nutrients, TOC, and pathogens. Animals were found in direct contact with water in the reservoir. The number of seasonal grazing animals and the species and number of wild animals are not known. Pathogens and ammonia were detected frequently in water at the SCVWD Pacheco Intake.

> **Recommendation:** DWR should build fences in areas as needed on the periphery of the reservoir to confine grazing animals and wildlife to eliminate pathogen exposure from this source. Alternative water supplies for animals should also be considered.
>
> **Recommendation:** DWR should study the effects of animal populations on water contamination in the reservoir, particularly contributions of TOC, nutrients, turbidity, and pathogens by grazing, wild animals, and waterfowl.
>
> **Recommendation:** DWR needs to review existing grazing leases to ensure the watershed is protected.
>
> **Recommendation:** DWR should investigate possible ways to divert runoff immediately downstream from the 2 wildlife areas away from the reservoir.

6.3.4 ALGAL BLOOMS

Conclusion a: The SWP source water for San Luis Reservoir contains high concentrations of nutrients (nitrogen and phosphorus) that can support significant algal growth (see discussion on SWP nutrients in Chapter 7). Other factors in San Luis Reservoir such as temperature, disturbance, and light penetration often limit algal formation. Algal growth was a problem during the drought years from 1992 to 1993, but algal blooms did not produce taste and odor problems during 1996 to 1999.

> **Recommendation:** DWR needs to review existing flavor profile data of the SCVWD and investigate the need to control algae during drought years or other times when blooms occur.

6.3.5 AGRICULTURAL ACTIVITIES

Conclusion a: Very little irrigated crop production occurs in the watershed. Pesticides are used for weed control, but no off-site movement of pesticides was observed. No significant agricultural runoff drained to the reservoir.

6.3.6 TRAFFIC ACCIDENTS/SPILLS

Conclusion a: Highway 152 is a major transportation corridor in the area. A section of Highway 152 (approximately 10 miles) runs adjacent to and across the reservoir and watershed. A Caltrans fence is on either side of the highway. Spills of hazardous chemicals are possible, but no serious accidents or spills occurred during the survey period.

> **Recommendation:** DWR, in collaboration with other agencies, should identify and assess emergency action plans and procedures for possible hazardous spills along Highway 152. Responsible agencies should also evaluate training and education needs to ensure a coordinated and prompt response to an emergency.

6.3.8 FIRES

Conclusion a: Fires occurred in the reservoir watershed during the survey period and likely contributed turbidity, TOC, and TDS to the reservoir.

> **Recommendation:** Evaluate the existence and appropriate level of public education on fire dangers, including warning signs and billboards.

DELTA SOURCE WATER QUALITY

Conclusion a: Seawater intrusion influenced to the reservoir through the source water from both the State and federal water projects. Bromide concentrations in the reservoir were comparable to those at the Banks Pumping Plant and DMC during the survey period. Source water from DMC and the California Aqueduct can be a contributor of TOC, turbidity, and TDS in the reservoir because these constituents are generally higher during the winter and spring months when water is pumped into the reservoir.

> **Recommendation:** DWR should determine the relative contributions of TOC, turbidity, and bromide from the California Aqueduct, the DMC, and the reservoir's natural watershed and investigate operational scenarios to minimize concentrations of these constituents in the reservoir consistent with maintaining reliable water supply.

> **Recommendation:** DWR should study the effects of algal blooms on TOC in the reservoir.

CHAPTER 7 SOUTHERN CALIFORNIA RESERVOIRS

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: Although water quality at all 4 reservoirs is an important concern, the water quality at Castaic and Silverwood lakes is of particular concern because these lakes are the supply points for the majority of the SWP Southern California supply via Jensen and Mills filtration plants (FPs) and the Castaic Lake Water Agency.

Conclusion b: Recreational boating is a known source of MTBE and hydrocarbons in all SWP reservoirs where motorized watercraft are allowed. The following recommendations apply to the 4 reservoirs addressed in this chapter.

> **Recommendation:** Support implementation and enforcement of new regulations for changed engine design. Evaluate the feasibility of requiring boaters using the reservoirs to use alternative fuels without MTBE. Encourage

owners of older boats using the reservoirs to replace 2-stroke engines with direct injection engines or 4-stroke engines.

Recommendation: Support CARB efforts to create a buy-back program to remove pre-2001 model year marine engines from use. Coordinate and cooperate with the CARB and marine engine manufacturers on this issue.

Recommendation: DWR and the Metropolitan Water District of Southern California (MWDSC) should continue and/or increase regular hydrocarbon and MTBE monitoring and event sampling around peak holidays. Monitoring should be conducted from a boat using non-MTBE gasoline, a direct injection engine, or an electric motor. The data should be made available to all interested parties.

Conclusion c: There are several contaminant sources and related water quality problems (for example, grazing, recreation, pathogens, MTBE, algae, taste and odor) that are common to the 4 reservoirs. Their analysis would greatly benefit from an integrated watershed management program approach. Relative to the other Southern California reservoirs, water quality problems in Pyramid Lake are minor in terms of potential impacts associated with common major contaminant sources such as recreation, wastewater facilities, and grazing.

Recommendation: A WMP should be initiated at Castaic and Silverwood lakes and Lake Perris to coordinate existing and future watershed management activities and studies. DWR should support this effort by creating a watershed coordinator position. Personnel heading the WMP should act as contacts for information on all watershed management practices and provide a clearinghouse of watershed information (recreational use, cattle grazing, sewage system operation, etc.).

Recommendation: A comprehensive study in coordination with MWDSC should be made of the major sources of nutrients to Castaic Lake and the other Southern California reservoirs. This study should be coordinated with other recommendations made in the individual reservoir sections and be integrated with the current reservoir water quality management program by DWR's Southern Field Division and MWDSC. The study should address algal dynamics and nutrient cycling within the major reservoirs to better understand the processes controlling algal populations. Study findings should provide information for early warning of algal blooms and offer recommendations on more effective and lower cost control measures, including pre-emptive treatment or reduction in local nutrient sources. These activities should be coordinated with and adapted to construction projects or other activities potentially causing erosion and increased turbidity.

Recommendation: Because of the complex and dynamic nature of potential contaminant sources in the Southern California SWP reservoirs, consideration should be given to constructing a Geographic Information System (GIS) as part of the WMP to provide state and local agencies with information required for effective management of the lake and watershed.

7.1 PYRAMID LAKE

General Conclusions and recommendations

Conclusion a: Natural sources in Piru Creek contribute high loadings of TDS and sulfate, which are then transferred to Castaic Lake. However, the impact of these constituents on drinking water supplies taken from the West Branch of the California Aqueduct appears to be modest.

Recommendation: Monitor loads of these constituents in Piru Creek and Pyramid Lake, including measuring Piru Creek flows.

7.1.3.1 Recreation

Conclusion a: Recreation activities at Pyramid Lake can contribute pathogens from boating, floating and chemical toilets, and body contact activity. No data were available to determine the level of contamination from any of these sources.

Recommendation: Review programs of responsible agencies such as the US Forest Service, DWR, or their contracted concessionaires to evaluate both floating and land chemical toilet use, location, and management. Evaluate stability and design for better control of tipping and spillage. Review the adequacy of contingency plans for spill prevention and abatement.

> **Recommendation:** Review the programs of responsible agencies such as the US Forest Service, DWR, or their contracted concessionaires to evaluate boating pump-out facilities and install or upgrade if necessary. Educate boaters about the problem and encourage use of pump-out facilities or on-shore and off-shore restrooms.

Conclusion b: Activities in and around campground areas, especially those near the water line, and Hungry Valley State Recreation Area (SRA) off-highway vehicle (OHV) use contribute to erosion and can cause increased turbidity in the lake.

> **Recommendation:** Implement erosion control BMPs, in coordination with the US Forest Service and other responsible agencies in areas close to the creek or lake. Evaluate activities and recreation use in the Hungry Valley SRA and implement specific BMPs in that area if warranted.

7.1.3.3 Animal Populations

Conclusion a: Cattle grazing has occurred historically in the watershed and also during the report period; however, the current status is unknown. Data on the numbers and specific grazing areas were not available. The large watershed also contains a significant wild animal population. Wastes from these animal populations can be flushed into the lake and are a potentially significant source of pathogens.

> **Recommendation:** DWR and the US Forest Service should evaluate grazing allotments, locations, proximity to water, and identify areas near water or where high erosion potential exists that are sensitive to grazing activities. Grazing allotments should be modified accordingly. Evaluate adequacy of fencing in grazing areas. Detailed data should be collected on past and future grazing activities in order to assess the need for additional fencing around Pyramid Lake. Better coordination among governing agencies is needed.

> **Recommendation:** Re-evaluate the range management policies of DWR and US Forest Service using updated grazing data and water quality information to determine the carrying capacity of the watershed with respect to water quality protection.

7.1.3.4 Crude Oil Pipelines and 7.1.3.8 Traffic Accidents/Spills

Conclusion a: A fuel spill incident from a truck occurred on I-5 and drained into Gorman Creek. The spill was contained and cleaned up by a nearby HAZMAT crew. No incidents were reported for crude oil pipelines. There is potential for ruptures of crude oil pipelines in the vicinity of the lake and hazardous materials spills from I-5 to reach the lake. Overall accidents and spills pose a moderate threat to water quality in Pyramid Lake.

> **Recommendation:** Identify and assess emergency action plans and procedures relating to these potential sources of contamination. Review training and education and coordination with responsible and interested agencies to ensure effective emergency response.

> **Recommendation:** DWR should review emergency spill procedures to determine if they are adequate for future population and traffic growth in the area and update these procedures as needed.

7.1.3.7 Unauthorized Activity

Conclusion a: One leaking underground storage tank was reported in 1992. It was removed, and remediation was begun. This site is reportedly still being monitored quarterly, but it is not known if there are any effects on lake water quality.

> **Recommendation:** DWR should determine the status of the remediation with the Regional Water Quality Control Board and county health department to ensure that there is no threat to water quality.

7.1.3.9 Geologic Hazards

Conclusion a: Three major faults and several smaller faults in the watershed make the area susceptible to pipeline ruptures (such as crude oil) because of seismic activity. This is considered a moderate potential threat to water quality.

7.2 CASTAIC LAKE

7.2.3.1 Recreation

Conclusion a: Recreation activities in Castaic Lake present a moderate threat to water quality. Body contact recreation and use of PWC and boats are sources of pathogens and MTBE in the lake. Pathogen issues at Castaic Lake are addressed in Chapter 12. Erosion associated with hiking, horseback riding, or camping, particularly if activities are conducted off established trails and areas, can be a source of turbidity.

Conclusion b: Surface MTBE values in Castaic Lake routinely exceed the primary MCL of 13 µg/L during the summer months when recreational use is highest. Highest concentrations were found near the boat ramps and outlet to the lake; PWC users are confined to an area near the outlet of the lake. Deep waters in the lake appear to have low or undetectable levels of MTBE even during summer months.

In addition to the previous general recommendations for MTBE contamination, the following are specific recommendations for Castaic Lake:

> **Recommendation:** No fueling of PWC or boat engines using portable gas cans should be allowed on the lake or in the vicinity of the boat ramps.
>
> **Recommendation:** Because MTBE levels are directly related to recreational activities, PWC areas should be moved away from the outlet of the lake, thereby providing for more dilution of the contaminant before it reaches the outlet.

7.2.3.2 Wastewater Treatment/Facilities

Conclusion a: There are a number of sewage lift stations and small septic systems in the Castaic Lake watershed operated by DWR, the Los Angeles Department of Water and Power (LADWP), and private parties. These systems can contribute to pathogen contamination in the lake and represent a moderate threat to water quality. Limited data were available on the number, location, and condition of septic systems in the Castaic Lake watershed.

Conclusion b: A sewage spill occurred at the Elderberry Forebay (Castaic Powerplant) from a septic system in 1996. Problems with septic systems in the Elizabeth Lakes complex were reported in the 1970s, which is in the northeastern-most portion of the watershed and drains to Elizabeth Lake Canyon Creek.

> **Recommendation:** Emergency response procedures for septic and sewage system spills should be reviewed by DWR, LADWP, and applicable public health agencies and upgraded as necessary.
>
> **Recommendation:** Secondary containment and spill alarms should be installed at all sewage lift stations operated by LADWP.
>
> **Recommendation:** An evaluation of existing septic systems and sewage lines and their potential risk to water quality should be conducted in coordination with the aforementioned WMP under General Conclusions and Recommendations for Southern California Reservoirs. These data should be made readily available to State and local agencies.

7.2.3.4 Animal Populations

Conclusion a: Grazing of livestock (cattle and sheep) occurs in the Castaic Lake watershed and presents a significant threat to water quality because of the potential contribution of pathogens. Both cattle and sheep have been observed grazing to the edge of Castaic Lake, and cattle have been observed grazing in the Elderberry Forebay since a 1996 fire destroyed the fencing.

Conclusion b: There is concern that grazing management practices in the Castaic watershed may contribute to nutrient and pathogen contamination in the reservoir.

Conclusion c: Grazing is under the management of multiple agencies, including DWR and the US Forest Service.

> **Recommendation:** DWR and property owners should hold discussions to ensure that preventive measures are in place to reduce the risk of contamination, including possibly replacing the fence around Elderberry Forebay. See also General Conclusions and Recommendations for Southern California Reservoirs regarding watershed assessment studies and coordination.
>
> **Recommendation:** Pathogens issues at Castaic Lake are discussed in Chapter 12. See General Conclusions and Recommendations

for Southern California Reservoirs regarding watershed assessment studies and coordination. Consider studies to identify potential contribution from wild animal populations versus grazing animals.

Recommendation: DWR and the US Forest Service should evaluate grazing allotments, locations and proximity to water and identify sensitive areas to avoid grazing such as the Elderberry Forebay, around the lake, or where high erosion potential exists. Grazing allotments should be modified accordingly. Evaluate the adequacy of fencing in sensitive grazing areas. Detailed data should be collected on past and future grazing activities in order to assess the need for additional fencing around Castaic Lake. No comprehensive database exists on numbers and types of animals grazed and areas where grazing is allowed. Better coordination between governing agencies is needed.

Recommendation: Re-evaluate the range management policies of DWR and US Forest Service using updated grazing data and water quality information to determine the optimal carrying capacity of the watershed.

7.2.3.5 Algal Blooms

Conclusion a: Nuisance algal growth has been a historical occurrence at Castaic Lake and presents a moderate threat to water quality. Algal blooms can produce water quality conditions that disrupt water treatment plants. The primary adverse effects on water quality associated with algal blooms are increased turbidity, which clogs treatment plant filters, disruption of filters causing turbidity breakthrough, and taste and odor resulting from production of the taste and odor causing compounds, MIB and geosmin.

Conclusion b: The Jensen FP experienced a dramatic change in raw water quality from Castaic Lake that disrupted plant operation, resulting in higher than normal effluent turbidities. The Castaic Lake Water Agency elected to shut down its treatment plant because of treatment difficulties caused by algal blooms. Treatment of Castaic Lake has been necessary to control algal populations, increasing costs to the SWP.

Conclusion c: Algal blooms at Castaic and other SWP facilities result from a complex interaction of nutrient loading (nitrogen and phosphorus), mixing processes and species interactions that are hard to predict.

Conclusion d: A primary cause of algal blooms at Castaic and in the SWP is high nutrient loads from the Sacramento-San Joaquin Delta. Local nutrient sources within the Castaic Lake watershed (animal populations, sewage spills, internal lake recycling) may also be significant causes of algal blooms, but data are lacking to judge their significance.

Recommendation: Refer to the Southern California Reservoirs General Conclusions and Recommendations for a discussion of the comprehensive watershed study for early warning and control of algal blooms and other contaminant sources.

7.2.3.9 Traffic Accidents/Spills

Conclusion a: Hydraulic pump oil leaks from SWP facility operations can be a common occurrence. On 12 November 1996, 19 gallons of hydraulic oil leaked from the Castaic Intake Tower. This is considered a moderate potential threat to water quality.

7.2.3.12 Fires

Conclusion a: Large wildfires have occurred in the Castaic Lake watershed and have resulted in sediment loading to the lake. Sediment loading can increase the TDS and turbidity of the lake resulting in the need for additional treatment. Ash may also represent a large nutrient input and could stimulate algal blooms. Overall, wildfires represent a moderate threat to water quality in Castaic Lake.

7.3 SILVERWOOD LAKE

7.3.3.1 Recreation

Conclusion a: The most significant potential contaminant source at Silverwood Lake associated with watershed activities is recreation.

Conclusion b: Recreation activities such as body contact sports, boating, and restroom facilities may contribute pathogens. Body contact recreation is probably the most significant, although unquantified, potential pathogen source, followed by spills from restroom facilities. One incident occurred where a floating toilet capsized about a mile from the lake outlet. Pathogen issues at Castaic Lake are addressed in Chapter 12.

> **Recommendation:** The stability of the floating restroom should be evaluated and measures should be taken to prevent capsizing and spills, if possible. Rapid clean-up response procedures should also be evaluated and implemented, if necessary.

Conclusion c: MTBE is released from motorized watercraft and is routinely detected throughout the reservoir. MTBE levels in Silverwood Lake did not exceed the primary MCL of 13 µg/L but routinely exceeds the secondary MCL of 5 µg/L even deep in the reservoir. This is of concern because sensitive members of the population could taste MTBE at the levels that occur in the reservoir. Deep water in the lake appears to have low or undetectable levels of MTBE even during summer months.

In addition to the recommendations for MTBE contamination presented under General Conclusions and Recommendations for Southern California Reservoirs, the following are specific recommendations for Silverwood Lake:

> **Recommendation:** No fueling of PWC or boat engines using portable gas cans should be allowed on the lake or in the vicinity of the boat ramps.

> **Recommendation:** Because MTBE levels are directly related to recreational activities, the feasibility of moving PWC areas away from the outlet of the lake should be evaluated. This would provide more dilution of the contaminant before it reaches the outlet.

Conclusion d: Recreation activities such as hiking, horseback riding, and off-highway vehicle use may cause erosion and contribute to increased turbidity in the lake.

> **Recommendation:** Implement education and coordination outreach program to educate all users. Evaluate implementation of BMPs and other erosion control measures. For example, the US Forest Service is working with OHV user groups to minimize erosion caused by OHV use.

7.3.3.2 Wastewater Treatment/Facilities

Conclusion a: There are 4 wastewater treatment plants and their associated collection and pumping facilities in the Silverwood Lake watershed. Some of these facilities are close to the lake and/or tributary streams. All systems within the area were reported to have operated properly within the report period; however, the potential for spills or system failures to contribute pathogens, organic carbon, and nutrients to the lake is significant.

> **Recommendation:** Evaluate the need to upgrade and/or expand prevention and back-up systems for wastewater treatment plants determined to have the highest potential risk because of their proximity to the lake or streams. For example, the Crestline Sanitation District improved its emergency overflow storage facilities. Also evaluate facilities in the Lake Gregory area.

7.3.3.4 Animal Populations

Conclusion a: Grazing has occurred but did not appear to be a significant activity during the report period; however, there is a substantial but unquantified wild animal population in the watershed. Animal populations are considered a moderate potential source of nutrients and pathogens.

> **Recommendation:** Pathogens issues at Silverwood Lake are discussed in Chapter 12. See General Conclusions and Recommendations for Southern California Reservoirs regarding related watershed assessment studies and the watershed coordinator position. Consider studies to identify potential contribution from wild animal populations versus grazing animals.

7.3.3.5 Algal Blooms

Conclusion a: Excessive algal blooms result in increased turbidity and increased production of MIB and geosmin in Silverwood Lake. However, residence time is generally too short for algal biomass to increase to problematic levels. Treatment of algal blooms with copper sulfate has only been necessary on rare occasions when the East Branch of the California Aqueduct was shutdown for an extended period. Algal growth is also a problem in Lake Gregory, which drains to Silverwood Lake at certain times of the year. Algal blooms can produce water quality conditions that disrupt water treatment processes. The primary adverse effects on water quality associated with algal blooms are increased turbidity, which affects plant operations, and taste and odor resulting from production of MIB and geosmin.

Conclusion b: Algal blooms at Silverwood Lake and other SWP facilities result from a complex interaction of nutrient loading (nitrogen and phosphorus), mixing processes, and species interactions that are hard to predict.

Conclusion c: A primary cause of algal blooms at Silverwood and in the SWP is the high nutrient loads from the Sacramento/San Joaquin Delta. As a result of the short residence time of water in Silverwood Lake, nutrients from the local watershed (for example, animal populations, sewage spills) will only become important if the nutrient loading from the Sacramento/San Joaquin Delta is greatly reduced.

> **Recommendation:** Refer to General Conclusions and Recommendations for Southern California Reservoirs for a discussion of the comprehensive watershed study for early warning and control of algal blooms and other contaminant sources.

7.3.3.9 Land Use Changes

Conclusion a: Both the San Bernardino Tunnel Reconstruction Project and the Crestline/Lake Arrowhead Water Agency Tank Reconstruction Project contributed to soil erosion and increased turbidity in Silverwood Lake and diversions from Devil Canyon.

> **Recommendation:** Regulatory agencies, for example, the Regional Water Quality Control Board, responsible for storm water runoff from construction or other activities with potential to increase erosion should review construction mitigation measures and ensure they are properly implemented.

7.4 LAKE PERRIS

General Conclusions and Recommendations

Conclusion a: Lake Perris has unique problems caused by a combination of several factors. The reservoir strongly stratifies with a shallow epilimnion. The hypolimnion has a very high oxygen demand caused by decomposition of settling algae in the sediments. This results in 30% to 40% of the water column becoming unusable because of hypolimnetic anoxia during the summer months when water demands are the highest. There have been long periods when withdrawals from Lake Perris were minimized. During these periods, evaporation has concentrated dissolved solids, increasing TDS.

7.4.3.1 Recreation

Conclusion a: Lake Perris has the highest numbers of recreational visitors of all the SWP reservoirs addressed in this sanitary survey. The heavy recreational use, especially body contact recreation, leads to high levels of pathogens. This has resulted in several beach closures during the past 2 decades.

> **Recommendation:** DWR, the California State Parks, local governments, and representatives of water utilities formed an SWP Recreation and Water Quality focus group that meets regularly to discuss recreation in conjunction with water quality improvement. This group should review the recommendations of *Sanitary Survey Update 2001* and implement them at Lake Perris as appropriate.

> **Recommendation:** Re-evaluate and aggressively implement sanitation education programs and increase the availability of restroom facilities near swimming beaches.

> **Recommendation:** Install baby changing stations in restrooms near the swimming beaches to encourage hygienic disposal of infant waste.

Conclusion b: Large circulation pumps were installed at the 2 swimming beaches in an attempt to reduce pathogen levels at the beaches. These pumps may have the effect of moving the pathogens toward the lake outlet, which could have a negative effect on the drinking water supply to MWDSC.

> **Recommendation:** A tracer study should be conducted to determine the effectiveness of the pumps and to insure that they will not circulate pathogens toward the lake outlet.

Conclusion c: Because of high levels of recreational boating, Lake Perris has the highest MTBE levels of any SWP reservoir.

In addition to the General Conclusions and Recommendations for Southern California Reservoirs regarding MTBE contamination, specific recommendations for Lake Perris follow:

> **Recommendation:** Re-evaluate limits on the number of motorized watercraft allowed at Lake Perris to avoid excessive concentrations of MTBE. One objective should be to avoid exceeding the secondary MCL for MTBE.
>
> **Recommendation:** Discourage PWC use at Lake Perris to reduce levels of MTBE and hydrocarbons.

7.4.3.2 Wastewater Treatment/Facilities

Conclusion a: Wastewater collection and conveyance facilities present a considerable potential to fail and contaminate the lake. Sewage lift stations at Lake Perris overflowed on 2 occasions during the period of this study. Both lift stations were near the lakeshore and contaminated the reservoir with untreated sewage.

> **Recommendation:** Conduct a thorough evaluation of the condition of sewage collection facilities at Lake Perris. Install secondary containment and warning alarms wherever applicable.

7.4.3.5 Unauthorized Activity

Conclusion a: An underground storage tank near the marina failed in 1994, contaminating groundwater adjacent to the lake. Remediation has been hampered by high groundwater elevation in the area, which is directly related to the lake surface elevation.

> **Recommendation:** Draw down the reservoir for a sufficient period to remediate contaminated groundwater in the area that could affect the water quality of Lake Perris.

CHAPTER 8 CALIFORNIA AQUEDUCT

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: Water quality in the California Aqueduct is largely determined by conditions in the Sacramento/San Joaquin Delta Estuary. Floodwater inflows from the Diablo Range are a significant PCS in the San Luis Canal. Inflows from the Kern River Intertie (KRI) and Cross Valley Canal (CVC) generally improved the mineral quality of aqueduct water with low salinity runoff from the Sierra Nevada but can contribute significant sediment loads to the California Aqueduct.

8.1 CLIFTON COURT FOREBAY TO O'NEILL FOREBAY

8.1.3.1 Recreation

Conclusion a: Recreational use of Clifton Court Forebay is light relative to other SWP reservoirs and is confined to shore fishing and duck hunting. Since motorized watercraft and swimming are prohibited, recreation poses minimal threat to water quality in the California Aqueduct.

8.1.3.4 Animal Populations

Conclusion a: No livestock grazing takes place in the watershed to Clifton Court, and wildlife populations within the basin pose little threat to water quality in the California Aqueduct.

8.1.3.8 Traffic Accidents and Spills

Conclusion a: In 1997, a small portion of liner slumped into the aqueduct at milepost 62. Oil was released from soil under the liner that contained residual from a pipeline break in 1984. Aromatic hydrocarbons (such as benzene and toluene) were detected in the aqueduct for several days thereafter. The exposed soil was covered to prevent further oil seepage, and absorbent booms were placed in the aqueduct to ensure containment.

Conclusion b: Liner repair at this site has been delayed because any activity could release oil to the aqueduct. DWR has requested that the CVRWQCB have the site remediated by the pipeline owner so that repairs can be made.

8.1.3.9 Groundwater Discharges

Conclusion a: Groundwater is pumped into the aqueduct along the west bank to reduce the pressure of shallow groundwater on the aqueduct. Some of these groundwaters have high salinity. Groundwater pump-ins in this section have historically been small relative to the other sections of the California Aqueduct and pose a minor threat to water quality.

8.1.3.11 Geologic Hazards

Conclusion a: The south levee of Clifton Court Forebay lies parallel to the Vernalis geologic fault, and the local groundwater is relatively saline. There is no indication of increased salinity in Clifton Court because of these groundwater inputs, and this source appears to pose a minor risk to water quality in the California Aqueduct.

> **Recommendation:** Because geologic faults are dynamic, groundwater conditions could change in the future, thus water quality data should continue to be collected and evaluated.

8.2 THE O'NEILL FOREBAY

8.2.3.1 The Delta Mendota Canal

Conclusion a: DMC water can be pumped into O'Neill Forebay by the O'Neill Pumping-Generating plant at mile 69.25 on the DMC. DMC inputs can significantly influence water quality in the SWP. During 1995 to 1997, the DMC accounted for 21% to 37% of the inflow to O'Neill Forebay but contributed 33% to 55% of the TDS load and 37% to 59% of the nitrate load. In 1995, DMC inflows made up 49% and 56% of the load of TOC and bromide, respectively, to the O'Neill Forebay.

Conclusion b: A number of studies have concluded that DMC water has a different composition than California Aqueduct diversions, largely due to greater influence from the San Joaquin River. The DMC generally has higher salinity than the California Aqueduct upstream of O'Neill Forebay.

Conclusion c: Salinity has become an important issue for SWP contractors in Southern California who blend higher-salinity Colorado River water with aqueduct water to improve drinking water quality. Blending is also done to reduce the salinity of water used to replenish regional groundwater aquifers. SWP salinity is variable, partly because of fluctuating DMC inputs, which complicate blending practices. In the future, more operational flexibility may be required at O'Neill Forebay to respond to variable water quality conditions.

> **Recommendation:** The capability to forecast salinity and identify joint-use operations (such as DMC pumping) that could reduce the salinity of SWP water without increasing other constituents of concern should be developed.

8.2.3.2 Recreation

Conclusion a: Contact and noncontact recreation in O'Neill Forebay includes camping, picnicking, sailboating and powerboating, waterskiing, windsurfing, fishing, swimming, and bicycling.

Conclusion b: Routine monitoring at the forebay's outlet shows that MTBE is infrequently detected. Fecal coliform bacteria are routinely detected in the north and south swim beaches during low-use periods. No data exist for high-use periods. Entrance and boat launching fees were recently reduced and may result in increased recreational use.

> **Recommendation:** MTBE and pathogen monitoring data should continue to be collected in the O'Neill Forebay.

8.2.3.5 Animal Populations

Conclusion a: The southern portion of the O'Neill watershed is used for cattle grazing between November and May. An electric fence separates the animals from the forebay's shoreline. Overall, animal populations in the basin pose only a minor threat to water quality in the forebay because catchment runoff is low due to sparse rainfall.

8.3 OUTLET OF O'NEILL FOREBAY TO CHECK 21 (KETTLEMAN CITY): SAN LUIS CANAL

Conclusion a: The San Luis Canal was built with drain inlets that convey rainfall runoff from the Diablo Range into the aqueduct. This segment of the California Aqueduct begins on the southeast edge of O'Neill Forebay and extends about 101.5 miles southeasterly to a point near Kettleman City. These floodwater inflows are the largest local contaminant source to the San Luis Canal.

8.3.3.1 Floodwater Inflows

Conclusion a: Floodwater inflows are usually high in suspended and dissolved solids. The dissolved solids, or salts, come from naturally occurring marine sediments in the Diablo Range. Suspended solids come from streambed erosion during runoff events. Floodwater inflows are significant contributors of these 2 constituents to the San Luis Canal and pose a moderate to severe threat to water quality in the California Aqueduct.

Conclusion b: Floodwater inflows can disrupt aqueduct operations and result in additional maintenance costs. Sediment inputs to the San Luis Canal can complicate drinking water treatment plant operations and increase treatment cost. Furthermore, downstream users have declined to use SWP water to recharge aquifers during periods with high floodwater inputs because high sediment loads can clog recharge ponds and injection wells. In 1998, about 21,000 acre-feet of water entered the San Luis Canal, but this gain was offset by 150,000 to 200,000 acre-feet of lost groundwater storage in Kern County.

> **Recommendation:** CALFED should support DWR and other watershed protection activities related to reducing floodwater inflows to San Luis Canal. This support could be in the form of funding and/or official endorsement of the proposed wasteway investigation. The proposal has the potential to substantially lower the potential contamination threat from floodwater inputs.

Conclusion c: Operations of drain inlet structures have been modified over the years to reduce inflow volumes and sediment loads. Studies have been ongoing since the early 1990s to address floodwater inflows from Arroyo Pasajero. The latest proposal is to convey all floodwater down the San Luis Canal to a wasteway turnout for ponding and evaporation on adjacent land. An existing interceptor drain near Dos Amigos Pumping Plant appears to act as a settling basin, removing sediments from floodwater before it enters the aqueduct.

> **Recommendation:** DWR should investigate the feasibility of incorporating interceptor drains in front of more drain inlets. The drains may provide a cost-effective means of reducing sediment discharges to the aqueduct, which constitute a significant problem for downstream SWP contractors.

Conclusion d: More data are needed to assess whether floodwater is a significant source of DBP precursors to the SWP.

> **Recommendation:** DWR should analyze organic carbon and bromide in all future floodwater inflows to the aqueduct.

8.3.3.2 Recreation

Conclusion a: There are no recreation facilities on the San Luis Canal, although several locations are popular for fishing. Noncontact recreation such as hunting and fishing is allowed in the reservoir of Little Panoche Creek Dam. Adequate toilet facilities exist at these sites, so recreational activities in the San Luis Canal reach of the aqueduct pose a minor threat to water quality.

8.3.3.5 Industrial Site Storm Water Runoff

Conclusion a: Several industries within the Arroyo Pasajero area are permitted for storm water runoff. These entities include waste management, landfills, cement production, and energy generators. Existing information suggests there is little chance of contamination of the California Aqueduct from these facilities.

8.3.3.6 Animal Populations

Conclusion a: Both range grazing and stockyards are found along the San Luis Canal section of the California Aqueduct, but in relation to the stockyards, cattle grazing is a minor PCS. Storm water runoff from the 2 confined animal operations, Harris (cattle) Ranch and Thommand Dairy, pose a significant threat of contaminating the SWP with nutrients and pathogens in the event of containment failure.

Conclusion b: At the request of DWR, Harris Ranch enlarged its ponding basins and installed headgates on the collector dams for better control of on-site runoff. The new capacity was 224 acre-feet, twice the amount of runoff expected for a 100-year, 24-hour storm. The ranch also cross-leveed and bermed land below the primary and secondary catch basins to accommodate any emergency runoff, thus providing additional protection.

> **Recommendation:** The Regional Water Quality Control Board should permit and routinely inspect 2 confined animal operations west of the San Luis Canal—Harris (cattle) Ranch and Thommand Dairy. Discharges from their holding ponds could potentially enter the aqueduct. The board should issue standing orders that codify the exclusion of this runoff.

> **Recommendation:** DWR should investigate possible ways to prevent runoff from entering the aqueduct immediately downstream of the 2 confined animal facilities. Prevention might include interceptor drains or overchutes.

8.3.3.7 Agricultural Activities

Conclusion a: Agricultural uses such as field and truck crops dominate the flatter portions of land west of the San Luis Canal. Currently used pesticides are frequently detected in low concentrations in the California Aqueduct, although it is uncertain whether these compounds are from local sources or imported from the Sacramento/San Joaquin Delta. Overspray from aerial pesticide applications made to adjacent orchards has been reported. Although agricultural activities have resulted in the introduction of pesticides to the aqueduct, pesticide MCLs were not exceeded in the SWP. Because MCLs apply to treated drinking water, concentrations measured in the source water would likely be reduced as a result of treatment.

> **Recommendation:** DWR should determine whether local or Delta sources are the dominant source of pesticides in the San Luis Canal. If canal sources are identified, control measures should be studied and implemented where feasible.

8.3.3.8 Mines

Conclusion a: There are several inactive or abandoned asbestos mines in the Arroyo Pasajero watershed along with a few active sand and gravel operations. The only other mine upstream of the San Luis Canal with a known water quality threat is the New Idria mine, an abandoned mercury mine in the upper reaches of Panoche Creek. However, runoff from the creek passes over the aqueduct via siphon, thereby preventing mine drainage from entering the aqueduct.

8.3.3.14 Geologic Hazards

Conclusion a: The geology of the Diablo Range watersheds west of the California Aqueduct contains several problematic rock types and minerals. Marine deposits contain concentrated salts such as sulfate, chloride, and magnesium. Serpentinite outcrops produce magnesium bicarbonate waters and are a source of asbestos. Highly saline springs exist in some of the watersheds that drain into the San Luis Canal during storms. The Diablo Range is the largest source of selenium in the San Joaquin Valley.

> **Recommendation:** Where feasible, runoff from Diablo Range watersheds should be prevented from entering the California Aqueduct because of water quality concerns and high sediment loads. See recommendations in Section 8.3.3.1, Floodwater Inflows.

8.4 KETTLEMAN CITY TO KERN RIVER INTERTIE

8.4.3.1 Recreation

Conclusion a: The 9 fishing sites on this section of the California Aqueduct pose a mild threat of pathogen contamination. Some of these sites lack adequate trash and toilet facilities, thus increasing the potential for contamination of the SWP with garbage and human waste.

> **Recommendation:** DWR should re-evaluate these fishing sites and ascertain whether portable toilets and garbage collection are needed to prevent contamination of drinking water supplies conveyed through the SWP.

8.4.3.3 Floodwater Inflows

Conclusion a: Water from the Kings River can be admitted to the aqueduct during storm events via Westlands Water District pumping facilities. Most of this runoff originates from the Westlands Water District inlet canal on the Mendota Pool and is composed largely of releases from Sierra Nevada dams for flood control. In typical years, no watershed runoff reaches the aqueduct in this section. There are reports of overchutes overflowing into the aqueduct during periods of high runoff. Overall, these inputs pose a minor threat to water quality in the aqueduct compared to floodwater entering the San Luis Canal.

8.4.3.4 Accidents and Spills

Conclusion a: Interstate 5 and State Highway 41 cross over the aqueduct just south of Kettleman City. State Highways 46, 58 and 119 cross over near Wasco, Buttonwillow, and Bakersfield. Two bodies and 2 automobiles were recovered from this section of the aqueduct between June 1998 and August 1999.

Conclusion b: In December 1998 the Lost Hills oil fire deposited a light film of oil over a section of the aqueduct at mile 201.5, extending downstream as far as Check 24. Clean-up efforts included oil booms in the water, which were periodically skimmed by a vacuum truck to remove the oil. The deposition of oil in the aqueduct lasted approximately 3 days. Emergency response and clean-up efforts were sufficient to prevent major impacts on SWP water quality.

> **Recommendation:** DWR should review emergency spill procedures to determine if they are adequate to address future population, traffic, and oil-industry growth along this section of the California Aqueduct.

8.5 KERN RIVER INTERTIE TO EAST/WEST BRANCH BIFURCATION

8.5.3.1 Kern River Intertie

Conclusion a: During 1997 and 1998, the Kern River Intertie (KRI) and Cross Valley Canal (CVC) contributed a substantial amount of water to the aqueduct. KRI inflow made up most of the water delivered to Southern California during 1 month in 1997 and in almost 3 months during 1998. These floodwaters originated as Sierra Nevada runoff and were accepted into the aqueduct to protect agricultural land in the dry lakebeds of Tulare and Buena Vista.

Conclusion b: KRI and CVC inflows are of high quality with low salinity, moderate turbidity, and no significant contaminant levels. These inflows provided a net benefit to aqueduct water quality when they occurred.

8.5.3.2 Groundwater Discharges

Conclusion a: Groundwater of unknown quality is pumped from the west side of the aqueduct to protect liner integrity. Groundwater pump-ins from the east did not occur during 1996 to 1999.

Conclusion b: Groundwater has also been pumped into the aqueduct to better manage local water supplies during drought emergencies. Although there were no pump-ins during 1996 to 1999, they remain a significant potential source of salinity and arsenic to the California Aqueduct.

> **Recommendation:** In establishing its policies directing groundwater pump-ins to the SWP, the effects of such operations on the quality of drinking water supplies should be fully addressed and this quality adequately protected.

8.5.3.3 Recreation

Conclusion a: There are 10 designated fishing areas; however, fishing activity has been observed at numerous undesignated locations. There is no contact recreation allowed in the aqueduct. These sites pose a moderate risk of pathogen contamination to the aqueduct.

8.5.3.4 Accidents/Spills

Conclusion a: In June of 1999, two oil releases were reported at Chrisman Pumping Plant. On the 1st occasion, approximately 280 gallons of hydraulic oil were released into the No. 1 discharge line. Several other potentially contaminating accidents/spills took place during 1996 to 1999, including a blacktop roller that tipped over in the aqueduct, a truck accident on an I-5 overcrossing and an incident of deliberate dumping of mulch and paper into the aqueduct. In all cases, proper measures were taken to control the spills and remove the substances from the water. Overall, accidents and spills have posed a minor to moderate threat to water quality in the aqueduct.

> **Recommendation:** DWR should review emergency spill procedures to determine if they are adequate to address future population and traffic growth along this section of the California Aqueduct.

CHAPTER 9 COASTAL BRANCH AQUEDUCT

9.3.4 ANIMAL POPULATIONS

Conclusion a: Field surveys have noted areas where aqueduct fencing is missing which could allow cattle access to the aqueduct. Cattle are a potential source of pathogen and nutrient contamination.

> **Recommendation:** Fencing in the area near mile 13.1 should be repaired.

9.3.6 AGRICULTURAL ACTIVITIES

Conclusion a: Field inspections have identified agricultural turnouts lacking backflow prevention devices and areas where runoff from cattle grazing areas is entering the aqueduct. Agrichemicals are commonly added at turnouts, creating the potential for aqueduct contamination. Cattle grazing is common in the area surrounding the Coastal Branch and can be a significant source of contamination.

Recommendation: DWR should investigate the adequacy of backflow prevention devices at established turnouts along the 15-mile canal section of the Coastal Branch Aqueduct.

Recommendation: A topographical review of the area near mile 7.13 to 7.25 should be conducted to determine if runoff from cattle grazing areas can reach the canal and whether drainage should be corrected.

9.3.7 ALGAL BLOOMS

Conclusion a: Algal blooms have caused taste and odor problems at the Polonio Pass Water Treatment Plant. To control these problems, aqueduct treatment and additional water treatment have been required.

Recommendation: DWR should implement a seasonal sampling program to monitor algal growth in canal and forebays along the Coastal Branch Aqueduct. Seasonal occurrences of nuisance algal growth should be studied in order to design more effective treatment regimes.

9.3.8 UNAUTHORIZED ACTIVITIES

Conclusion a: Field inspections have revealed instances of portable pumps removing water from the aqueduct, and some of these pumps lacked backflow prevention devices. Injection of agrichemicals at these pumps is a potential source of nutrient and pesticide contamination.

Recommendation: DWR should investigate the adequacy of backflow prevention devices at portable pump sites used to remove water from the 15-mile canal section of the Coastal Branch Aqueduct.

OTHER: DEFERRED MAINTENANCE

Conclusion a: Deteriorating sandbags along the west side of the aqueduct at mile 5.65 have been identified, and cracked and buckled canal panels were at mile 1.5 to 2.2.

Recommendation: The sandbags should be removed, and the damaged sections of the canal repaired. These conditions were noted in *Sanitary Survey Update 1996*, but as of March 2001 the work had not been completed.

OTHER: HIGH IRON AND ALUMINUM VALUES AT POLONIO PASS WTP

Conclusion a: Iron and aluminum values for SWP water at Polonio Pass WTP are much higher than at Check 21 of the California Aqueduct. Differences in concentrations for these stations could indicate a source of trace metals along the Coastal Branch Aqueduct or result from analytical errors.

Recommendation: QA/QC procedures for trace metals analysis by participating laboratories should be reviewed. Interlaboratory comparisons using standard references materials should be conducted between Central Coast Water Authority (CCWA) and DWR laboratories.

Recommendation: If the apparent differences in iron and aluminum concentrations are verified, DWR should make the effort to locate possible sources of iron and aluminum along the Coastal Branch Aqueduct.

CHAPTER 10 EAST-AND WEST BRANCHES OF THE CALIFORNIA AQUEDUCT

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: There were limited data to evaluate water quality conditions in the open canal sections of the East and West Branches of the California Aqueduct. Monitoring data for the East Branch of the aqueduct are collected quarterly. There are no routine monitoring data for the West Branch of the aqueduct. Available information indicates that taste and odor problems caused by algal growth are a problem in the East Branch during periods of low aqueduct flow and warm weather.

Recommendation: DWR should prepare a proactive plan for increased algal growth monitoring and treatment as required to reduce the taste and odor problem when low flows are predicted during the warm season.

Recommendation: DWR should improve access to existing water quality data. Water quality data from the existing continuous recording stations at East Branch (Check 41, 66, and Devil Canyon) should be made available on a real-time as well as historical basis to promote better evaluations of the SWP water quality conditions. Presently only current and prior month data are available online. Use of the existing California Data Exchange Center to receive telemetered data of a longer period of record should be explored.

> **Recommendation:** The Devil Canyon Monitoring Station should be repaired. This station was offline for an extended period.

Conclusion b: Information on recreation and illegal dumping of vehicles is very limited. Their potential impacts on water quality are unknown. Recreation could be a source of pathogens, and vehicles can contribute hydrocarbons.

> **Recommendation:** DWR should review security procedures for sections of the aqueduct that are susceptible to recreational activities and dumping. Perform a limited screening for MTBE and polynuclear aromatic hydrocarbons (PAHs) to determine if they are significant between Pool 53 and 66.

Conclusion c: SWP facilities can discharge hydraulic oils into the aqueduct from accidents or malfunctioning equipment. A few incidents were reported on the East Branch.

> **Recommendation:** Investigate the conversion from petroleum to vegetable oils for use in hydraulic systems. Review facilities and procedures to eliminate discharges to SWP water from DWR installations.

Conclusion d: Urban runoff into the aqueduct continues from the city of Hesperia as reported in *Sanitary Survey Update 1996*. Proposals to mitigate the problem by the San Bernardino County Flood Control District are under review. Possible contaminants in urban runoff include TDS, organic carbon, pesticides, nutrients, pathogens and turbidity.

> **Recommendation:** DWR should maintain awareness of the proposed actions as they are implemented and monitor to verify their effectiveness.

Conclusion e: There were no water quality data for the aqueduct section of the West Branch. However, there is probably little contamination because most of the branch is either pipeline or tunnel. The only potential source is from the 4 square-mile watershed around Quail Lake.

CHAPTER 12 PATHOGENS

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Conclusion a: The use of different approved methods for analyzing coliform densities made comparisons between water treatment plants difficult. In many cases, only qualitative comparisons could be made.

> **Recommendation:** Prior to the next sanitary survey, DHS should recommend the use of coliform methods that allow the direct comparison of coliform data between utilities. Studies should be conducted that examine the potential for inflation of total coliform counts with Colilert™, and also include side-by-side comparisons of the multiple tube fermentation (MTF), Colilert™, and membrane filtration (MF)/subculturing methods under a variety of water quality conditions. Without this, pattern of occurrence data may be the only tool available to compare densities between sites. This approach compromises the ability of all users to quantitatively compare coliform densities spatially and temporally.

Conclusion b: By necessity, much of the protozoan pathogen data used in this update drew upon data analyzed by Information Collection Rule (ICR) methodology. Because of the limitations of the ICR method, robust conclusions cannot be drawn for protozoan pathogen data analyzed in this update.

Conclusion c: With respect to the use of data from the national ICR monitoring program, sample collection did not necessarily correspond to flood or storm events (a period when protozoan mobilization into surface water may be at its highest). This also potentially compromises sanitary survey conclusions drawn from nationwide ICR survey data.

12.2 BACTERIA SUMMARY

Conclusion a: With respect to the agencies profiled, some of the highest total coliform densities occurred at plants receiving South Bay Aqueduct water; however, it is unknown whether this is an artifact of the Colilert™ method. Potential uncertainties associated with the Colilert™ method complicate direct comparisons of total coliform densities.

> **Recommendation:** To determine whether bacteria other than coliforms are counted in the

total coliform assay, Colilert™ needs to be examined further through discussions with the company that markets Colilert™ and investigations of the Colilert™ method in different source water

Recommendation: DHS and utilities should work together to resolve the appropriate methodology for determining total coliforms in source water. Potential over-counts of total coliforms in source water by the Colilert™ method should be resolved prior to the next sanitary survey so that data analyzed for the sanitary survey is comparable across utilities. In the interim, for purposes of the next sanitary survey, utilities should agree on 1 method for total and fecal coliform analysis.

Conclusion b: Total, fecal, and *E. coli* bacteria densities were consistently the lowest for the Southern California treatment plants profiled. Fecal coliform and *E. coli* numbers were also low at the SBA treatment plants. NBA contractors had the highest fecal and *E. coli* numbers.

Conclusion c: Total coliform, fecal coliform, and *E. coli* densities were routinely elevated at the Barker Slough Pumping Plant as well as in the untreated water at a number of NBA water treatment plants. However, direct comparisons between all NBA contractors was hampered by the lack of a consistent method across utilities. This could hamper investigative studies.

Conclusion d: Cattle, which make extensive use of the slough, are the most likely source of fecal contamination for Barker Slough and the NBA. There is a lack of any known septic tank leaks or wastewater treatment plant effluent into the slough (see Chapter 3 for grazing impacts).

Recommendation: Bacterial sources and loads in the watershed should be evaluated. Preventive measures should be taken to keep all livestock out of Barker Slough source water. BMPs should be evaluated to determine if there are cost-effective methods for reducing the load of pathogens to Barker Slough.

Conclusion e: Preliminary analyses suggested that there may be a bacterial contamination problem between the Cordelia Forebay and the City of Napa's Jameson Canyon Water Treatment Plant.

Recommendation: To determine if the preliminary conclusion of contamination between the Cordelia Forebay and the Jameson Canyon WTP is correct, the Benicia, American Canyon and the Jameson Canyon WTPs should, where possible, create sampling schedules that allow direct comparison of coliform data. If analysis of a larger dataset confirms a contamination problem between the Cordelia Forebay and the Jameson Canyon WTP, then, as directed by the data, possible sources of contamination should be investigated. In the interim, potential contamination at the Napa Turnout reservoir should be investigated and all NBA utilities may wish to use the same total and fecal coliform methods to facilitate this and future contamination studies.

Conclusion f: Although fecal and *E. coli* values were low for the SBA contractors, grazing occurs in the Lake Del Valle watershed. Water is not drawn from the reservoir until late summer/fall. Based on climate patterns, contaminant flushing into the lake from the watershed potentially occurs primarily in the winter. This may explain the relatively low densities at the treatment plants when Del Valle water is used in the fall (see Chapter 5, SBA/Lake Del Valle, for hydrology).

Recommendation: To better understand the bacteriological dynamics of Lake Del Valle, a watershed/lake study should be conducted to characterize seasonal pathogen contamination in Lake Del Valle. (See General Recommendations in Chapter 5.)

Conclusion g: There is concern that grazing management practices in the Castaic watershed may contribute to contamination of the reservoir (see Chapter 7, Section 7.2, for livestock impacts).

Recommendation: Discussions should be held with the property owners to ensure preventive measures are in place to reduce the risk of contamination.

Conclusion h: With respect to DWR bacteriological sampling, the highest levels of total coliform, fecal coliform and *E. coli* were observed at the Barker Slough Pumping Plant, while the lowest was observed at the Banks Pumping Plant. Between 1996 and 1999, four sites were sampled for bacteria. The sampling frequency was inadequate to draw conclusions on bacterial levels in the SWP or for comparative purposes with State Water Contractors.

Recommendation: Bacteria numbers can change rapidly. Samples collected once a month are unable to capture actual patterns of bacteria numbers in the SWP. To understand spatial and seasonal patterns, bacteria samples need to be collected more frequently and expanded to key locations along the SWP. This recommendation parallels DHS recommendations regarding the need for more bacteriological sampling within the SWP.

Recommendation: Support DWR Division of Operations and Maintenance evaluation of bacteriological data from the water treatment plants of its 5 field divisions.

12.3 *GIARDIA*

Conclusion a: If Colilert™ overcounts total coliform densities, then the guideline linking total coliform densities to suggested *Giardia* log removals may be inappropriate.

Recommendation: To determine whether bacteria other than coliforms are counted in the total coliform assay, Colilert™ needs to be examined further through discussions with the company that markets Colilert™ and investigations of the Colilert™ method in different source water.

Recommendation: Based on the outcome of the preceding recommendation, DHS should determine if Colilert™ is an appropriate method for use with DHS guidelines of total coliform densities and *Giardia* removal. In lieu of this, for the next sanitary survey utilities should agree on 1 method for total coliform analysis.

Recommendation: If Colilert™ is used to measure total coliform, the use of fecal or *E. coli* data may be a more useful indicator of whether the *Giardia* log removal guideline is appropriate.

Conclusion b: No correlation has been found between total coliform and *Giardia* densities.

Recommendation: DHS should re-examine the validity of using total coliform as a surrogate organism for suggesting additional *Giardia* log removals. Source water protection may be a more valuable tool than quantitative guidelines based on questionable relationships.

Conclusion c: Based on *Giardia* data collected from EPA's nationwide ICR, median *Giardia* concentrations were all below the detection limit.

Conclusion d: Ambient *Giardia* concentrations are still open to question. Future analysis using Method 1623 may reach different conclusions then those generated from ICR data.

Conclusion e: Frequency of occurrence data suggest that *Giardia* concentrations may be higher in Barker Slough in the winter.

Recommendation: Cattle are present in the watershed during the winter rainy season and have been observed defecating in the slough. Proactive steps should be taken to keep livestock out of the slough. Since *Giardia* analysis is still questionable, the effect of restricting livestock access to the slough should be monitored in the winter before and after exclusion through daily *E. coli* sampling.

12.4 *CRYPTOSPORIDIUM*

Conclusion a: ICR data suggest that all WTPs profiled would fall into the first bin of *Cryptosporidium* log removals. If Interim Enhanced Surface Water Treatment Rule (IESWTR) and Stage 2 requirements were met, this could mean that no additional log removals would be required of the plants profiled. However, results were generated using questionable ICR data.

Recommendation: Based on the weaknesses of the ICR method, it would be premature to draw any final conclusions on utilities' *Cryptosporidium* concentrations and levels of log removals. Future sanitary surveys using Method 1623 may identify different bin classifications.

12.6 STUDIES OF HEALTH RISKS FROM BODY CONTACT RECREATION IN SOUTHERN CALIFORNIA SWP RESERVOIRS

Conclusion a: Depending on the cumulative probability used and the 3-log removal requirement of the LT2 ESWTR, infections from *Cryptosporidium* at DWR's 4 Southern California reservoirs could be below EPA target level of risk. In the original report, only a 2-log removal was assumed, and Perris and Castaic lakes were above EPA target risk levels (see Appendix A).

> **Recommendation:** Similar risk assessments should be conducted at other SWP source reservoirs, including San Luis Reservoir and Lake Del Valle using the 3-log removal assumption.

Conclusion b: Michael Anderson's health risk report to the State Water Contractors did not resolve the issue of whether rotavirus is a risk to human health in the reservoirs modeled (see Appendix A). The data for modeling health risks for rotavirus are contradictory and/or limited precluding a robust risk analysis.

> **Recommendation:** If rotavirus is considered a health risk in the reservoirs, then a monitoring program with field studies should be created to investigate rotavirus concentrations.

12.7 PROTOZOAN SAMPLING METHOD CONCERNS

Conclusion a: Sampling of the SWP with the ICR method suggested that *Cryptosporidium* and *Giardia* are more prevalent in the Delta and its tributaries than in the SWP aqueduct and reservoirs, and they occur more frequently and at higher concentrations during flood and storm events. However, the ICR method exhibited poor recovery, accuracy, and precision. Therefore, it is impossible to know whether these results are accurate.

> **Recommendation:** The ICR method should not be used to assess concentrations of *Cryptosporidium* and *Giardia* in Delta source waters.

Conclusion b: Better recoveries for *Giardia* and *Cryptosporidium* were obtained using EPA's Method 1623 over the ICR method. However, experiments using Method 1623 did not examine whether matrix effects caused recovery variability.

Conclusion c: Differences in *Cryptosporidium* recovery, independent of turbidity, suggest other factors may be influencing Method 1623 recoveries. Detection limits also appeared to vary with the water tested.

> **Recommendation:** More studies using Method 1623 should be conducted before this method is used for large-scale source water sampling of the SWP. The studies should be conducted to evaluate whether the method is valid in SWP source waters during suspected periods of high pathogen transport in the watersheds, for example, storm events.

Recommendation: The EPA should be strongly encouraged to further improve the accuracy, sensitivity, and precision of Method 1623 (or develop a new method) that allows for more robust assessments of pathogens for source water monitoring.

APPENDIX A

PREDICTED PATHOGEN CONCENTRATIONS AND CONSUMER HEALTH RISKS RESULTING FROM BODY-CONTACT RECREATION ON THE EAST AND WEST BRANCH STATE WATER PROJECT RESERVOIRS

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FINAL REPORT TO:

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Executive Summary

Swimming and other body-contact recreational activities have been identified by the USEPA, California Department of Health Services, and other public health professionals as a potential source of microbiological contamination of recreational waters. Fecal shedding and accidental fecal release by infected individuals can result in high numbers of pathogenic organisms, including *Cryptosporidium*, *Giardia*, and rotavirus, being input into surface waters. Nevertheless, little information is available on the importance of this source of pathogens to surface waters. Moreover, the potential health implications resulting from body-contact recreation on reservoirs used as source drinking water supplies are not well-understood.

This study was undertaken to quantify, using available theoretical and empirical data, the impacts of body-contact recreation on water quality in the four southern State Water Project (SWP) reservoirs. Mean annual *Cryptosporidium*, *Giardia*, rotavirus and poliovirus concentrations for the SWP reservoirs were predicted using results from a detailed simulation study conducted for MWD's Diamond Valley Lake (formerly known as the Eastside Reservoir) in conjunction with available recreator and reservoir data. Dose-response models were then applied to predicted concentrations following treatment to provide an estimate of health risks resulting from consumption of recreator-impacted SWP water. Hydrodynamic and transport simulations were also conducted to evaluate the short-term temporal and spatial dynamics of coliform and pathogen concentrations in Lake Perris resulting from heavy recreational use of the beaches there. Simulation results are compared with coliform monitoring data collected during the summer of 1999.

Lake Perris was found to have the highest level of recreational use, both in absolute numbers and when normalized to its epilimnetic volume (9.5 recreators/acre-foot/yr). Castaic Lake had a projected use intensity about one-half that of Lake Perris, while Pyramid Lake was somewhat lower than Castaic Lake. Silverwood Lake had the lowest use intensity (2.6 recreators/acre-foot/yr) of the four SWP reservoirs. These differences in use intensity translated to predicted pathogen concentrations that varied rather significantly among the reservoirs. Median predicted annual *Cryptosporidium* concentrations ranged from 0.22 oocysts/100 L in Silverwood Lake to 0.85 oocysts/100 L in Lake Perris. Predicted concentrations of *Giardia* were much lower than those for *Cryptosporidium*, and ranged from 0.008 - 0.031 cysts/100 L. Predicted median annual rotavirus levels were considerably higher than either *Giardia* or *Cryptosporidium* in the

reservoirs (71- 267 pfu/100 L). Poliovirus concentrations ranged from 1.5 - 5.7 pfu/100 L. Results were also presented using cumulative probability distribution functions (cdf) in which concentrations were plotted as a function of cumulative probability. The principal benefit from use of cdfs can be perhaps best demonstrated by considering the statistical implications associated with use of median values. It was stated above that the median predicted annual concentration of *Cryptosporidium* in Lake Perris was 0.85 oocysts/100 L. Since by definition the median value of a population indicates that one-half of a population or set of observations lays below the median value and one-half lays above it, there is a 50% chance that the predicted annual *Cryptosporidium* concentration in Lake Perris will be *above* 0.85 oocysts/100 L. At higher cumulative probability, the likelihood of exceeding the corresponding concentration decreases. For example, at the 95% cumulative probability, there is only a 5% chance that the annual concentration in Lake Perris will exceed 16.6 oocysts/100 L. In the interest of protecting public health, MWD considered cumulative probabilities of 95 and 99%. For the SWP reservoirs, predicted pathogen concentrations at the 95% level were ~10 - 100x higher than the median values.

Application of the appropriate dose-response models also yielded probabilistic descriptions of annual risk of infection to consumers. Such an approach allows one to define the probability of exceeding the EPA’s target of 1 infection per 10,000 consumers per year. For *Cryptosporidium*, the probability of exceeding 1 infection per 10,000 consumers per year is approximately 65% for Lake Perris, 53% for Castaic Lake, 45% for Pyramid Lake and 40% for Silverwood Lake. Prospects for infection due to *Giardia* were much lower (<1% for all reservoirs).

Transport simulations conducted for Lake Perris predicted a rather complex circulation pattern within the reservoir that tended to limit dispersion of fecal coliform from beach areas. Simulations predicted fecal coliform concentrations at Perris Beach that increased substantially through the late morning and early afternoon, peaked at approximately 3 p.m. with concentrations approaching 120 cfu/100 mL, and then fell sharply in the late afternoon and early evening. Wind-induced currents were predicted to move coliform in a northeasterly direction down the beach toward tower 5, where a small clockwise gyre transported coliform along the point and then moved the plume in a southwesterly direction out several hundred meters from the beach area. Dispersion and inactivation lowered the concentrations to ~2 cfu/100 mL or less by midnight. Because of the longer inactivation half-life, *Cryptosporidium* was predicted to be transported further into the reservoir than fecal coliform.

These simulation results were in reasonable accord with available fecal coliform monitoring data; samples collected at Perris Beach at approximately noon during the summer weekends of 1999 yielded a mean from a log-normal distribution of 15.3 ± 5.3 cfu/100 mL, which was in good agreement with a predicted concentration of 24 cfu/100 mL. Predicted and observed concentrations near the buoy line were both below 2 cfu/100 mL. Cumulative probability distribution functions developed from coliform monitoring data indicate that fecal coliform concentrations at noon will exceed the DHS simple sample limit of 400 cfu/100 mL at a probability of about 2.5% for Perris Beach and 5.5% for Moreno Beach. Simulation results do indicate, however, that the probabilities for exceeding the DHS level will be higher later in the afternoon. Given the importance of transport processes in defining exposure, measurements of water currents within the lake, additional monitoring both near the beaches and in the main body of the lake, and more comprehensive modeling are needed to fully define the recreator and consumer health risks resulting from body-contact recreation.

Introduction

Swimming and other recreational activities that involve direct human contact with water have been found to negatively impact water quality in some settings (Rose *et al.*, 1987; Calderon *et al.*, 1991; Kramer *et al.*, 1996). The impacts are generally more pronounced for water bodies that are subject to intense use, *i.e.*, with high numbers of recreators in limited areas or on small water bodies. In such settings, fecal coliform concentrations can exceed 1600 cfu/100 mL (*e.g.*, CCWD, 1999). Because of difficulties and costs associated with sampling and detection, concentrations of pathogens in recreator-impacted waters and the associated health risks to consumers and recreators remain poorly understood.

As a result, numerical simulations have recently been used to estimate pathogen concentrations in source drinking water reservoirs (Yates et al., 1997; Anderson *et al.*, 1998). An extensive simulation study of Diamond Valley Lake (formerly the Eastside Reservoir) was conducted for the Metropolitan Water District of Southern California (MWD). In that study, Monte Carlo (MC) techniques were incorporated into a finite segment-based pathogen transport model to predict pathogen concentrations in the reservoir under different recreational scenarios (Anderson *et al.*, 1998). The model divided Diamond Valley Lake (Eastside Reservoir) into 38 lateral segments, with each lateral segment further divided into an upper, epilimnetic zone and a lower, hypolimnetic zone, for a total of 76 segments. The concentrations of pathogens (*Cryptosporidium*, *Giardia*, rotavirus and poliovirus) within each segment of the reservoir were then predicted based upon inputs associated with body-contact recreational activities, and losses due to inactivation, export and sedimentation. The model considered advective and dispersive flux between segments, age-weighted infection rate of body-contact recreators, mass of fecal material shed by a recreator, pathogen content of the fecal material, frequency of accidental fecal releases (AFRs), mass of AFR, the inactivation rate constant for the pathogen, epilimnetic settling velocity of the pathogen, cross-sectional area for epilimnion-hypolimnion exchange, and the hypolimnetic settling velocity. The inputs from fecal shedding and AFRs were summed over the number of recreators on a given segment per day (Yates *et al.*, 1997; Anderson *et al.*, 1998). Monte Carlo techniques were incorporated into the model to define relevant features about each of the recreators using the reservoir on a given day, *e.g.*, the occurrence of infection and AFRs, mass of feces shed, pathogen content of feces, and so on. MC techniques were also used to conduct an uncertainty analysis in which 5000 simulations were conducted using randomly selected uncorrelated parameter sets based on values derived from the literature (Anderson *et al.*, 1998).

Results from the Monte Carlo analyses were used to develop cumulative distribution and probability density functions for *Cryptosporidium*, *Giardia*, rotavirus, and poliovirus concentrations in the reservoir. This probabilistic approach was deemed necessary given the uncertainty in pathogen shedding rates and other model input parameters (Anderson *et al.*, 1998). *Cryptosporidium* was the pathogen of greatest concern due to its slow rate of inactivation in the environment and its resistance to chlorination. Predicted pathogen concentrations were then used with dose-response models to predict probability of infection.

Results from the MWD study were subsequently used to estimate pathogen concentrations in Contra Costa Water District's Contra Loma Reservoir and the associated risks to consumers and recreators (Anderson, 1999a). Calculations for the Contra Loma Resevoir, which involved scaling recreational use rates, epiliminion volumes, and other factors to Diamond Valley Lake (Eastside Reservoir), yielded results that were consistent with more detailed hydrodynamic simulations for the Contra Loma Reservoir (Anderson, 1999b) and with risk calculations using *E. coli* and enterococcus monitoring data in conjunction with health effects relationships developed by Dufour (1984) (Anderson, 1999c).

Results from an analysis of body-contact recreational impacts on water quality are presented for the four southern State Water Project (SWP) reservoirs (Lakes Castaic, Pyramid, Silverwood and Perris). The analysis includes predictions of pathogen concentrations based upon scaling of results from the Diamond Valley Lake (Eastside Reservoir) study, and application of dose-response models to predict corresponding health risks to consumers. Numerical simulations describing circulation within Lake Perris and the transport of coliform and *Cryptosporidium* away from beach areas were also conducted. Results from the analyses were compared with available monitoring data.

Estimated Pathogen Concentrations in State Water Project Reservoirs

With some assumptions, results from the MWD study can be used to estimate pathogen concentrations in the SWP reservoirs. As was done in the Contra Loma

Reservoir study, it is assumed that parameters describing pathogen loading and loss are valid for application to the SWP reservoirs. Recreational use rates, reservoir volumes, and other site specific parameters will be used to estimate concentrations in the SWP reservoirs based on levels predicted for Diamond Valley Lake (Eastside Reservoir) (Anderson, 1999a; Anderson *et al.*, 1998; Yates *et al.*, 1997).

Recreational Use and Reservoir Data

The SWP reservoirs vary significantly in their size (Table 1). Silverwood Lake is the smallest of the reservoirs, with a surface area of 976 acres and a capacity of 74,970 acre-feet at full pool, while Castaic Lake is the largest (323,700 acre-feet capacity). It is noteworthy that all are well below the 800,000 acre-foot capacity of Diamond Valley Lake (Eastside Reservoir). Lake Perris is the shallowest of the SWP reservoirs at a mean depth at full pool of 57 feet, while the west branch reservoirs of Castaic and Pyramid have mean depths nearly 3x larger (Table 1). In the context of these calculations, the total reservoir volume is less important than the epilimnetic volume, however. Because these reservoirs are generally stratified during the summer when most body-contact recreational activities occur, pathogen inputs will largely be restricted to the warm, well-mixed upper portion of the water column (Anderson *et al.*, 1998). Average epilimnetic volumes were calculated from capacity-elevation data for the reservoirs (DWR, pers. comm.) assuming depths to the thermocline of 7 m for Lakes Castaic and Pyramid, 25 m for Lake Silverwood, and 8 m for Lake Perris (Lund *et al.*, 1993; DWR, pers. comm., MWD, pers. comm.) and average summer surface elevations of 1497, 2570, 3348, and 1585 feet, respectively (DWR, 2000) (Table 2).

Table 1. SWP reservoir data (at full pool)[a].

Reservoir	Surface Area	Capacity	Mean Depth
	-- acres --	-- acre-feet --	-- feet --
Castaic	2235	323,700	145
Perris	2325	131,500	57
Pyramid	1298	171,200	132
Silverwood	976	74,970	77

[a] data from G. Faulconer, DWR

Total annual visitation to the SWP reservoirs ranged from 207,000 – 1,007,460 visitors per year for the 1998-1999 fiscal year (Table 2), with approximately one-half of the total recreators engaging in body-contact recreational activities at the reservoirs (DPR, pers. comm.). Recreational activities at Lakes Perris, Silverwood and Pyramid include swimming, personal watercraft use, and water skiing, although swimming is not allowed at Castaic Lake. These values compare with projected annual total recreator use rates for Diamond Valley Lake (Eastside Reservoir) of approximately 380,000 – 700,000 per year or 50,000 – 290,000 body-contact recreators per year (depending upon the recreational scenario).

Normalization of body-contact recreational use to epilimnetic volume provides a useful measure of overall intensity of use and information about the level of pathogen loading due to recreational activities to each of the reservoirs. Results from such a normalization are provided in Table 2.

Table 2. Recreational data and body-contact recreational use normalized to epilimnion or mixed layer volume.

Reservoir	Annual Visitation[a]	Body-Contact Recreator Use[b]	Epilimnion Volume	Use-Volume Normalization
	-- yr^{-1} --	-- yr^{-1} --	-- acre-feet --	-- recreators/acre-feet/yr --
Castaic	890,573[b]	225,000[c]	45,490	4.95
Perris	1,007,460	504,000	52,930	9.52
Pyramid	207,000	103,000	28,500	3.61
Silverwood	329,357	165,000	63,000	2.62

[a] Annual visitation data (FY 98-99): Castaic: M. White, DPR; Perris: DPR website (parks.ca.gov/districts /loslagos/lpsra.htm); Pyramid: M. Apante, DWR; Silverwood: DPR website (parks.ca.gov/districts/loslagos /slsra.htm).

[b] Calculated from annual visitation data assuming 50% of all visitors will engage in body-contact recreational activities (DPR, pers. comm.)

[c] Calculated assuming one-half of all body-contact recreators will use Castaic Lake for PWC and water-skiing, while one-half will use Castaic Lagoon for swimming and other body-contact activities (DPR, pers. comm..). Thus ~225,000 body-contact recreators were assigned to the main reservoir.

Based on this normalization, one sees that Lake Perris is the most heavily impacted of the SWP reservoirs by body-contact recreation, with 9.5 body-contact recreators/acre-foot/yr in the upper, epilimnetic portion of the water column. The other reservoirs have normalized use rates approximately one-quarter to one-half of that of Lake Perris, broadly comparable to that projected for Diamond Valley Lake (Eastside Reservoir) under the boating+skiing+PWC recreational scenario (3.03 body-contact recreators/acre-feet/year). Nevertheless, the SWP reservoirs have normalized use rates well-below that caculated for the Contra Loma Reservoir near Antioch, CA, (38.1 body-contact recreators/acre-feet/year) (Anderson, 1999).

Subject to a number of assumptions, the comparison of normalized SWP use rates to that predicted for Diamond Valley Lake (Eastside Reservoir) provides a convenient means by which one can extrapolate the results from Monte Carlo simulations conducted for Diamond Valley Lake (Eastside Reservoir) to the SWP reservoirs. The limitations to this approach will be discussed later in this report.

Lake Perris

The predicted median annual average *Cryptosporidium* concentration in the epilimnion of Diamond Valley Lake (Eastside Reservoir) was 0.27 oocysts/100 L under the full basin boating+skiing+PWC recreational scenario (Yates *et al.*, 1997; Anderson *et al.*, 1998). When corrected for recreator and volume differences, one estimates a median *Cryptosporidium* concentration of 0.85 oocysts/100 L for Lake Perris. For comparison, while more than 3x higher than that predicted for Diamond Valley Lake (Eastside Reservoir), it is only approximately one-quarter the median *Cryptosporidium* concentration of 3.38 oocysts/100 L predicted for the Contra Loma Reservoir (Anderson, 1999a). The predicted median concentration of *Giardia* in Lake Perris was lower than that for *Cryptosporidium* (0.031 cysts/100 L), although predicted poliovirus and rotavirus concentrations were higher (5.7 and 267 pfu/100 L, respectively).

The full cumulative probability distribution functions for *Cryptosporidium* and the other pathogens scaled from the Diamond Valley Lake (Eastside Reservoir) simulations are presented in Fig. 1. Fig. 1 shows that, by definition, one-half of the predicted annual average concentrations of *Cryptosporidium* fell below the median value of 0.85 oocysts/100 L, and one-half of the predicted concentrations were greater than the median value. In the interest of public health, MWD considered concentrations at the 95 and 99% levels (wherein only a 5 and 1% probability of underestimating pathogen concentrations exists) (Yates *et al.*, 1997). At the 95% level, this corresponds to an annual average *Cryptosporidium* concentration of 16.6 oocysts/100 L in the upper 8 m of the water column. The predicted concentration of *Giardia* at the 95% level was 0.8

cyst/100 L, while concentrations of poliovirus and rotavirus were about 44 and 3055 pfu/100 L, respectively (Fig. 1).

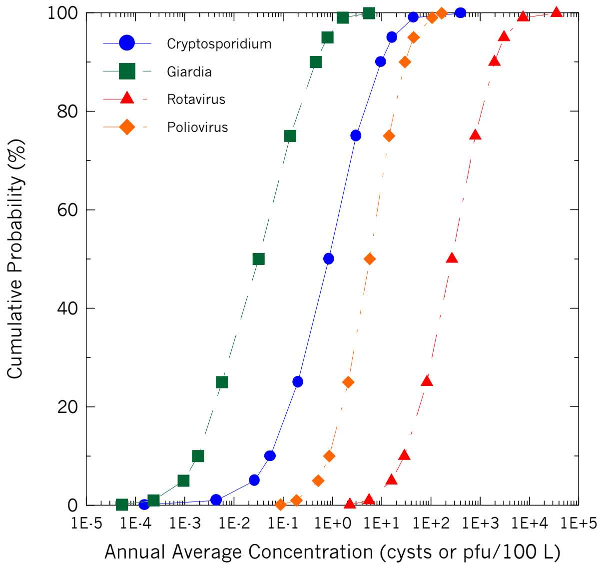


Fig. 1. Predicted annual average epilimnetic pathogen concentrations in Lake Perris.

Silverwood Lake

Estimated annual average epilimnetic pathogen concentrations in Silverwood Lake are shown in Fig. 2. The projected median concentration of *Cryptosporidium* was 0.22 oocysts/100 L, a value only one-fourth as large as that for Lake Perris. At the 95% level, the predicted concentration was 4.41 oocyts/100 L, much lower than that predicted for Lake Perris (16.4 oocysts/100 L). Median concentrations for the other pathogens ranged from 0.008 cysts/100 L for *Giardia*, to 1.5 pfu/100 L for poliovirus and 71 pfu/100 L for rotavirus. The lower predicted concentrations in Lake Silverwood result from both the lower level of body-contact recreational use relative to Lake Perris, and the operations of the reservoir (Table 2). Large flows through the reservoir result in a well-mixed water column with limited thermal stratification and short hydraulic retention times (~1.5 – 2 months) (DWR, pers. comm.). As a result, pathogen inputs from recreators, considered to be effectively confined to the warm, well-mixed epilimnion, are dispersed over a much greater depth in Lake Silverwood when compared with Lake Perris or the other SWP reservoirs.

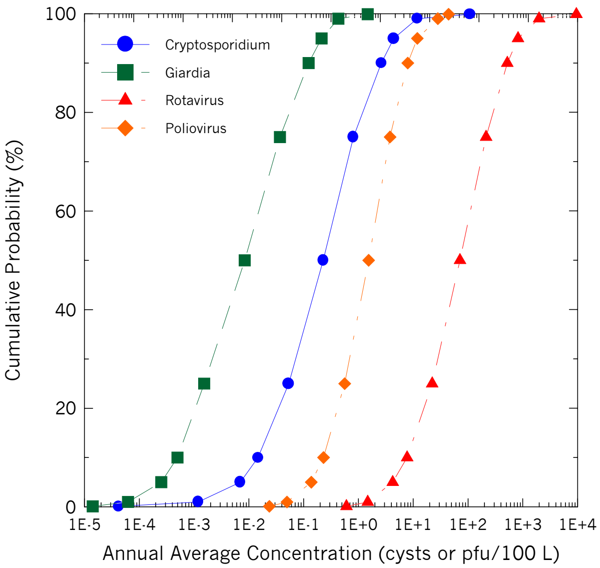


Fig. 2. Predicted annual average epilimnetic pathogen concentrations in Silverwood Lake.

Castaic Lake

Concentrations of pathogens in Castaic Lake were intermediate between those predicted for Lake Perris and Lake Silverwood (Fig. 3). Median *Cryptosporidium*, *Giardia*, poliovirus and rotavirus were 0.43, 0.016, 2.9, and 13.4 per 100 L, while concentrations at the 95% level were 8.3, 0.4, 22.3 and 1530 per 100 L, respectively.

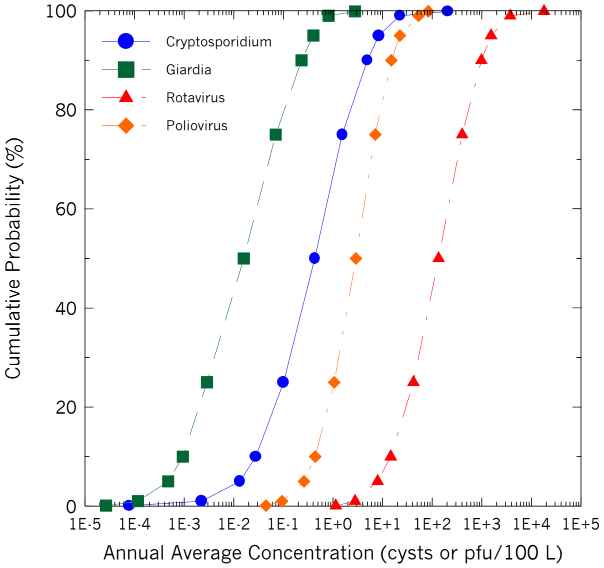


Fig. 3. Predicted annual average epilimnetic pathogen concentrations in Castaic Lake.

Pyramid Lake

Pathogen levels in Pyramid Lake were lower than those predicted for Lake Perris and Castaic Lake, but slightly higher than those for Silverwood Lake. The median *Cryptosporidium* concentration was 0.31 oocysts/100 L, *Giardia* was 0.01 cysts/100 L, poliovirus was 2.1 pfu/100 L and rotavirus was 98 pfu/100 L. Concentrations at the 95% cumulative probability were 6.08,0.29,16.3 and 120 per 100 L, respectively (Fig. 4).

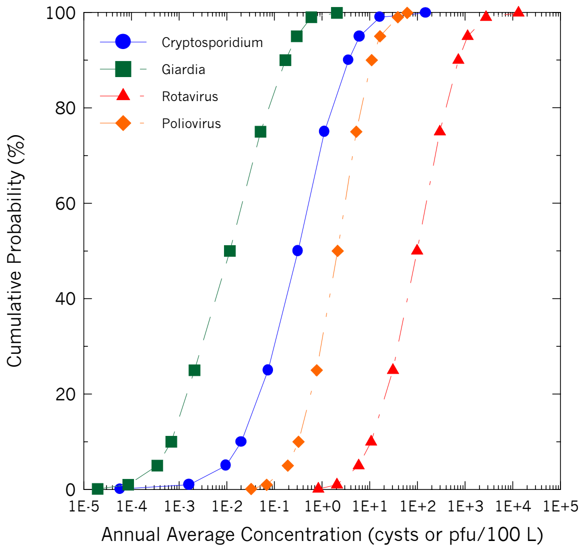


Fig. 4. Predicted annual average epilimnetic pathogen concentrations in Pyramid Lake.

Comparison of Predicted Concentrations with Available Monitoring Data

Limited monitoring data exists for the SWP reservoirs. Of the four southern SWP reservoirs, only Lake Perris is monitored on a regular basis. Samples are collected weekly at the beaches during the summer by DPR staff and the results are reported to the Riverside County Health Department. Samples are analyzed for total and fecal coliform. Since swimming is not allowed on Castaic Lake, the Los Angeles County Health Department does not monitor the lake. (Swimming is restricted to a treated off-line lagoon.) Although Silverwood Lake has two designated swim beaches, water quality at the beaches is not monitored by State Parks, DWR or the San Bernardino County Health Department. Analogously, monitoring is not conducted at Pyramid Lake. There is no regular monitoring for pathogens at any of the reservoirs.

MWD has conducted periodic monitoring of their filtration plant influent for *Cryptosporidium*, however. Monitoring data collected from October 1994 – December 1997 was plotted in the form of a cumulative distribution function and compared with predicted results for the SWP reservoirs (Fig. 5). Plant influent concentrations are broadly comparable to the predicted mean annual concentrations for Castaic Lake, although it should be noted that the monitoring data represent single-sample values that correspond to a point in time rather than an annual average value. Nevertheless, the observed distribution is qualitatively reproduced by the cdfs developed for the SWP reservoirs. Moreover, the average predicted median concentration of 0.45 oocysts/100 L for the four SWP reservoirs is in general agreement with the mean *Cryptosporidium* concentration of 0.36 oocysts/100 L for Diamond Valley Lake (Eastside Reservoir) source waters (Yates *et al.*, 1997), which include both East Branch SWP and Colorado River waters.

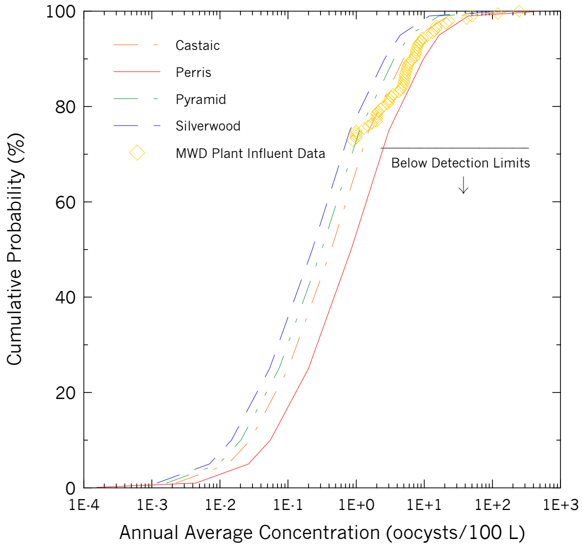


Fig. 5. Predicted SWP and MWD plant influent Cryptosporidium concentrations.

Health Risks Resulting from Body-Contact Recreation

Predicted pathogen concentrations were then used to calculate health risks to consumers resulting from body-contact recreation on the SWP reservoirs. For these calculations, risks resulting from body-contact recreation were quantified following the risk assessment approach used in the Eastside Reservoir study (Yates *et al.*, 1997). In this approach, the probability of contracting an infection or illness is a function of both the exposure and the infectivity of the pathogen. Exposure to consumers is governed by the pathogen concentration in the source water, any inactivation during transit from reservoir to the treatment plant, and the removal efficiency at the treatment plant. In the following calculations, the probabilities of contracting an infection due to *Cryptosporidium* and *Giardia* are considered.

Cryptosporidium

For these calculations, a 1-day transit time from reservoir to the treatment plant was assumed. Based upon an inactivation rate constants of 0.08 d^{-1} for *Cryptosporidium* (Anderson *et al.*, 1998), inactivation of *Cryptosporidium* during transport resulted in an 8% reduction in concentration entering the treatment plant. A 2-log removal for *Cryptosporidium* at the plant was assumed following USEPA guidance. It should be noted that, based on particle removal studies by MWD at their treatment plants, a 2.5 log removal was used in the MWD study.

Daily exposure to the consumer was calculated based on the concentration of pathogens in water delivered to consumers and the volume of water consumed per day, assumed to be 2 L/day (Regli *et al.*, 1991; Haas *et al.*, 1993). Recreator-contracted infection was calculated assuming ingestion of 30 mL of untreated water (Yates *et al.*, 1997). The probability of contracting an infection due to *Cryptosporidium* was then determined using an exponential dose-response model, which assumes that the daily probability of infection, P_i, is given by:

$$P_i = 1 - exp(-rN) \qquad (1)$$

where r is a parameter describing the dose-response curve and N is the exposure (*e.g.*, number of oocysts). A best fit value of r of 0.0042 was used in the Diamond Valley Lake (Eastside Reservoir) study and will also be used here (Yates *et al.*, 1997). The annual risk of infection was calculated from the daily probability using the relationship (Yates *et al.*, 1997):

$$P^d = 1 - (1 - P_i)^d \qquad (2)$$

where d is the number of days of exposure (here assumed to be 365).

Using the projected median *Cryptosporidium* concentrations for the SWP reservoirs, a 1-day transit time from reservoir to treatment plant, and a 2 log removal efficiency at the treatment plants, one estimates a median annual risk of infection of 0.64

to 2.39 infections per 10,000 consumers per year resulting from use of the recreator-impacted SWP reservoir waters (Table 3). These consumer risk levels are up to an order of magnitude higher than the median value of 0.26 infections per 10,000 per year predicted for the Diamond Valley Lake (Eastside Reservoir) under the boating+skiing+ personal watercraft recreational scenario (using a 2.5-log removal efficiency), but lower than the value of 3.1 infections per 10,000 per year predicted for the Contra Loma Reservoir (also calculated assuming 2.5-log removal at the treatment plant).

In addition to the probability of infection, one can predict the prospects of illness and mortality resulting from consumption of the water. Assuming morbidity and mortality ratios of 61 and 0.0001 %, respectively (Bennett *et al.*, 1987; Yates *et al.*, 1997) and using the median *Cryptosporidium* concentrations for the SWP reservoirs, one calculates 0.39 – 1.46 illnesses per 10,000 people per year and $6.4x10^{-7}$ – $2.4x10^{-6}$ deaths per 10,000 people per year resulting from the use of recreationally-impacted SWP reservoirs as a drinking water source (Table 3).

Table 3. Consumer risk assessment results: *Cryptosporidium.*

	--- Median Values ---			Probability of
Reservoir	Infections	Illnesses	Mortality	Exceeding EPA
	--- per 10,000 consumers per year ---			%
Castaic	1.20	0.73	$1.2x10^{-6}$	53
Perris	2.39	1.46	$2.4x10^{-6}$	65
Pyramid	0.88	0.54	$8.8x10^{-7}$	45
Silverwood	0.64	0.39	$6.4x10^{-7}$	40

One notes that the median risk of infection for both Castaic Lake and Lake Perris exceed the EPA level of 1 infection/10,000/year, while Pyramid and Silverwood Lakes remains below this standard. Using the data in Figs. 1-4 and the dose-response model, one can calculate the cumulative distribution function for risk of infection from *Cryptosporidium* (Fig. 6). The figure shows that there exists about a 60% probability that the risk of infection from consumption of treated Lake Silverwood water will be below the EPA's target of 1 infection per 10,000 consumers per year (Fig. 6). The higher pathogen concentrations in Lake Perris result in a correspondingly lower probability of remaining below the EPA's target (35%). Predicted consumer risks for Pyramid and Castaic Lakes were intermediate between these two reservoirs, with the prospects of remaining below the EPA's target of 1 infection per 10,000 per year at about 45% and somewhat more than 50%, respectively (Fig.6). Thus, there is a two-thirds chance that use of Lake Perris water will result in an infection rate exceeding 1 per 10,000 per year, but only a 40% chance for Silverwood Lake (Table 3).

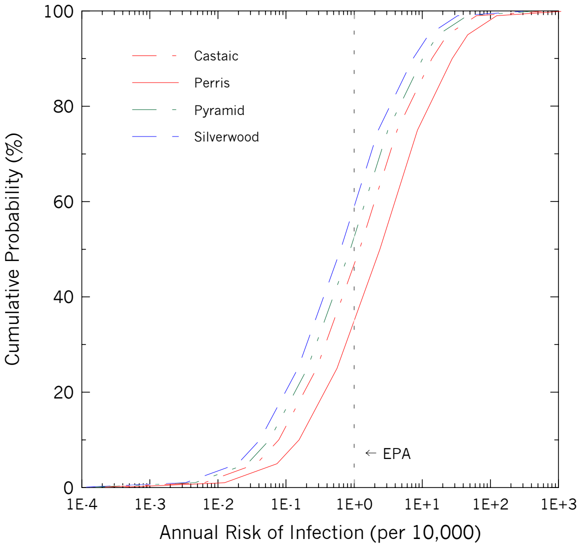


Fig. 6. Predicted annual risk of infection to consumers due to Cryptosporidium.

The annual risk of infection increases with increasing cumulative probability (or decreasing exceedance probability); at the 95% level, the annual risk of infection from *Cryptosporidium* increase to 46.6, 23.4, 17.1, and 12.4 per 10,000 per year for Perris, Castaic, Pyramid and Silverwood Lakes, respectively.

<u>*Giardia*</u>

Risk calculations were also conducted for *Giardia*. Based upon human feeding trials, an exponential dose-response model for *Giardia* has been developed (eq 1), with a best-fit value for *r* of 0.0198 (Yates *et al.*,1997). Using the median *Giardia* concentrations predicted in the reservoirs, a transit time from reservoir to plant of 1 day, an inactivation rate of 1.375 d^{-1} (Anderson *et al.*, 1998), and 3-log removal at the treatment plant, one calculates consumer infection rates about 200 times lower than those calculated for *Cryptosporidium* (Table 4). Prospects for illness and mortality are also correspondingly lower.

Cumulative distribution functions developed for the SWP reservoirs indicate that even at the 99% level (that is, where there exists only a 1% probability of underpredicting infection), risk of infection from *Giardia* remains below the 1 per 10,000 per year level (Fig. 7). Thus, body-contact recreational activities do not appear to have a significant effect on giardiasis consumer risk levels (Table 4).

Table 4. Consumer risk assessment results: *Giardia.*

Reservoir	Infections	--- Median Values --- Illnesses	Mortality	Probability of Exceeding EPA
	--- per 10,000 consumers per year ---			%
Castaic	0.0058	0.0023	5.8×10^{-9}	0.1
Perris	0.0115	0.0046	1.2×10^{-8}	0.2
Pyramid	0.0042	0.0017	4.2×10^{-9}	<0.1
Silverwood	0.0031	0.0012	3.1×10^{-9}	<0.1

[a] Morbidity ratio of 0.4 (Meyer, 1990)
[b] Mortality ratio of 10^{-6} (Meyer, 1990)

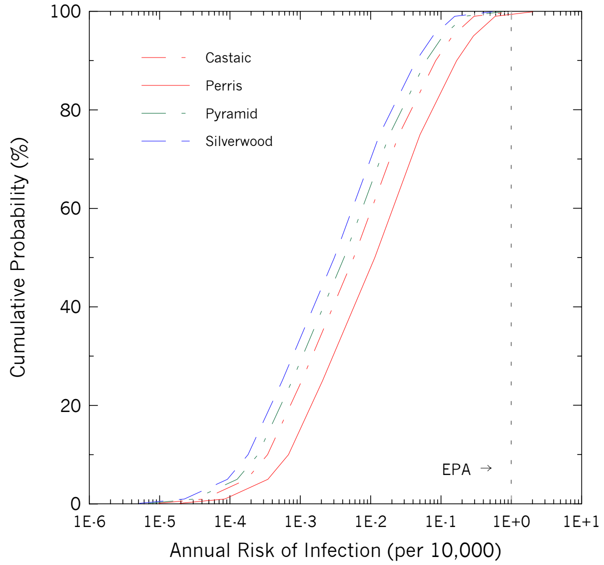


Fig. 7. Predicted annual risk of infection to consumers due to Giardia.

Rotavirus

Infectivity of rotavirus has been described using a beta-Poisson model of the form:

$$P_I = 1-(1+N/\beta)^{-\alpha} \qquad (3)$$

where α and β are fitted dose response parameters of 0.24 and 0.42, respectively.

Application of this dose-response model, in conjunction with predicted rotavirus concentrations for the SWP reservoirs, inactivation during transit, and 4-log removal at the treatment plant, yields predicted median infection rates of up to hundreds of infections per 10,000 per year. Community health data and other evidence point to lower prevalence of illness than predicted in the above calculations, however. Furthermore, recent work suggests lower rates of fecal shedding of rotavirus than assumed in the Diamond Valley Lake (Eastside Reservoir) study. Additionally, the capacity for virus removal beyond 4-logs at the plants led MWD to discount rotavirus risk to water consumers, and identified *Cryptosporidium* as a more probable health concern (Yates *et al.*, 1997). Nevertheless, rotavirus risk to recreators, even in light of decreased fecal shedding, remains a concern (Anderson, 1999c).

Poliovirus

A suitable dose-response model for poliovirus was not identified in the literature. Nevertheless, the lower concentrations in the water column relative to rotavirus, and the efficacy of treatment at removing viruses from the water suggests that poliovirus should represent limited health concerns relative to other pathogens assuming normal plant operation.

Potential Limitations and Additional Considerations

While the scaling of the Diamond Valley Lake (Eastside Reservoir) results to SWP reservoirs based upon recreator use and reservoir volume data is a useful way of estimating local pathogen concentrations, some potential limitations to this approach need to be considered. The potential limitations to this approach include those that arise due to the different hydraulic and limnological characteristics of the reservoirs and from different patterns of recreational use. The model developed for Diamond Valley Lake (Eastside Reservoir) allowed for both lateral and limited vertical gradients in pathogen concentrations within the reservoir which were defined by its morphometric and hydraulic properties. These properties can be expected to differ quite significantly for the SWP reservoirs.

Furthermore, body-contact recreation on Diamond Valley Lake (Eastside Reservoir) resulted from water skiing, personal watercraft use, and/or limited body-contact boating (*e.g.*, kayaking) which was either distributed across the entire reservoir or restricted to the east basin. While this recreational scenario is comparable to that for Castaic Lake, the other SWP reservoirs include swimming at beach site(s). Thus, potentially high levels of pathogen inputs would also be localized; such inputs are different from the distributed inputs considered for Diamond Valley Lake (Eastside Reservoir). Due to the slow rate of inactivation of *Cryptosporidium*, the pathogen of primary concern, however, transport away from the beach and into the open water is expected to be significant.

This can be evaluated for Lake Perris through some simple calculations assuming that swimmers at the beach areas are major sources of bacteria and pathogens to the lake. Since pathogen inactivation follows a first-order process, the concentration reaching the outlet can be estimated from:

$$C = C_0 e^{-kt} \tag{4}$$

where C is the concentration at the dam, C_0 is the concentration at the beach, k is the inactivation rate coefficient and t is the travel time. Assuming a transport velocity of 1 cm/s and a distance from Perris Beach to the outlet tower of ~2500 m, one calculates transport time of 2.9 days. Inactivation rate coefficients and percent of fecal coliform, *Cryptosporidium, Giardia* and rotavirus removed during transport to the outlet tower assuming a 2.9 day transport time are given in Table 5.

Table 5. Inactivation rate coefficients and organism loss during transport from beach to outlet assuming a travel time of 2.9 days.

Organism	k (d^{-1})	% Removed
Fecal coliform	1.0[a]	94
Cryptosporidium	0.08[b]	21
Rotavirus	0.30[b]	58
Poliovirus	0.58[b]	81
Giardia	1.37[b]	98

[a] Thomann and Mueller (1987)
[b] Yates *et al.* (1997)

These calculations show two important features. First of all, based upon available median inactivation coefficients taken from the literature for freshwater samples at 20-25 °C, only ~6 % of the fecal coliforms would be expected to remain after transport from Perris Beach to the reservoir outlet, while almost 80% of the *Cryptosporidium* is expected to persist (Table 5). It seems reasonable then to conclude that, although recreational use patterns and limnological features of the Eastside Reservoir and Lake Perris are quite different, the slow rate of inactivation of *Cryptosporidium* in natural waters allows extension of results from Diamond Valley Lake (Eastside Reservoir) to Lake Perris. Similar conclusions hold for the other SWP reservoirs. In fact, sensitivity analysis conducted as part of the MWD study found that simulation results for *Cryptospordium* were overall relatively insensitive to transport parameters (Yates *et al.*, 1997). Model results were highly sensitive to the loading parameters, however (*i.e.*, the number of body-contact recreators, the infection rate in the recreator population, and the pathogen content of the feces of infected individuals).

It bears noting that, due to the higher rates of inactivation for the other pathogens considered, transport becomes more important in accurately estimating their local concentrations in the reservoir. The high inactivation rate of *Giardia* results in low predicted concentrations at the outlet, with percent removal comparable to that estimated for fecal coliforms. Rotavirus will be removed to a larger extent than *Cryptosporidium* although less than that predicted for *Giardia* or coliform. For these more readily inactivated pathogens, inactivation during transit within the distribution system may also become significant. In the above risk calculations for *Cryptosporidium*, a 1-day transit time was assumed, which resulted in an 8% reduction in concentration during transit from reservoir to treatment plant. A more rigorous analysis of hydrodynamics and transport of pathogens within Lake Perris is given in a subsequent section.

In addition to the issues related to inactivation and transport, it bears noting that additional factors may serve to influence pathogen concentrations and associated risks relative to the levels estimated in the preceding sections. Those factors include (i) a different age distribution for the recreator population for the SWP reservoirs as compared with Diamond Valley Lake (Eastside Reservoir); (ii) treatment efficiencies at some plants receiving SWP water may differ significantly; (iii) the additivity of risks; (iv) the issue of elevated concentrations and risks during the summer; and (v) other inputs of pathogens to the reservoir.

The age distribution of the recreator population is an important factor in defining the overall or age-weighted infection rate and, ultimately, in establishing the pathogen loading to the reservoir. Numerous researchers have reported higher incidence of infection and pathogen excretion from children than from adults (*e.g.*, Melnick and Rennick, 1980; Sealy and Shuman, 1983; Champsaur *et al*, 1984). In the Diamond

Valley Lake (Eastside Reservoir) study, for example, the rate of *Cryptosporidium* infection of children <7 years of age was 3.5x higher than older children and adults (7.7 vs. 2.2%, respectively). Since the body-contact recreational activities on Diamond Valley Lake (Eastside Reservoir) (*i.e.*, boating, skiing and personal watercraft use) are directly comparable to those at Castaic Lake, it seems likely that the age distribution from the Diamond Valley Lake (Eastside Reservoir) study would be appropriate. The SWP reservoirs with swimming beaches, however, would presumably include a significant population of younger recreators. Thus one might anticipate a somewhat higher age-weighted rate of infection and, ultimately, higher pathogen concentrations and risk levels in the other SWP reservoirs (especially Lake Perris). The magnitude of this can be estimated by considering that only 3.6% of the recreator population for Diamond Valley Lake (Eastside Reservoir) is <7 years old and thus yields an age-weighted infection rate of 2.4%. Although an exact age breakdown of recreators for Lake Perris or the other SWP reservoirs with swimming is not available, if one assumes that 25% of the swimmers are <7 years old, one estimates an infection rate weighted over all recreators of about 3.6%. This value is 50% higher than that used in the Eastside Reservoir study and consequently also used to estimate pathogen levels in the SWP reservoirs. Based on this, then, one might anticipate that the actual probability of infection is about 50% higher than the risk levels described in the preceding section.

Assumptions about treatment plant efficiencies also influence the estimated risk levels associated with use of the SWP reservoirs. The risk to consumers was calculated assuming a 2 log removal of *Cryptosporidium* at the treatment plant following EPA guidance. In the Diamond Valley Lake (Eastside Reservoir) study, a 2.5 log removal of *Cryptosporidium* at the filtration plant was assumed based upon particle removal studies conducted by MWD (Yates *et al.*, 1997). Removal efficiencies at the filtration plant will directly affect consumer risk levels; higher removal at the plant would result in lower pathogen concentrations in water delivered to consumers and lower corresponding risk to consumers relative to the levels presented above, while plant failure would substantially increase consumer health risks.

An additional point about consumer risk levels is based on the additivity of risk of infection. The risk calculations in the preceding sections are presented as individual risks due to *Cryptosporidium* and *Giardia*. Due to the additivity of risks, however, it should be recognized that the total risk of infection to consumers is the sum of all individual risks.

Thus the total risk of infection will necessarily be higher than the risk of cryptosporidiosis, for example, in Fig. 6.

Beyond the annual average pathogen concentrations and corresponding risk levels, Yates *et al.* (1997) also considered the short-term or peak risks that are present during the summer during high levels of recreational use. Risks associated with delivery of the water during the summer were generally about 4x higher than the corresponding annual risk levels. Moreover, peak events associated with, *e.g.*, AFRs, can result in concentrations and risk levels an order of magnitude or more higher than the mean annual values. These risks are not quantified in this study.

Finally, a fifth factor which could increase overall risk to consumers and recreators in the reservoir beyond that discussed above is the potential for pathogen inputs from additional sources within the watershed (*i.e.*, non-body-contact inputs). Inputs as a result of stormwater runoff, sewage leaks, agricultural activities and other sources have not been explicitly evaluated in this study.

Hydrodynamic and Transport Simulations of Lake Perris

In addition to the annual average pathogen concentrations predicted for the SWP reservoirs, hydrodynamic and transport simulations were conducted for Lake Perris. Simulations were conducted for Lake Perris because of the high intensity of recreational use relative to other SWP reservoirs (Table 2), frequency of beach closings, and availability of monitoring data.

Simulations were conducted using a 2-dimensional, depth-averaged finite element model applied to the epilimnion. While such an approach will yield a less accurate representation of the velocity field within the lake relative to a full 3-dimensional simulation, near-shore currents are thought to be reasonably represented. Bathymetric data was taken from available topographic and lake maps. A finite-element mesh for the epilimnion was developed with about 250 nodes (Fig. 8).

Simulations for a typical summer weekend day were conducted using available meteorological data and an assumed total daily body-contact recreational use of 3750 swimmers at each of the two beaches. Meteorological data was taken from a nearby CIMIS station; ~7 summer days were randomly selected from the database and averaged to derive a typical hourly windspeed and wind direction (Fig. 9).

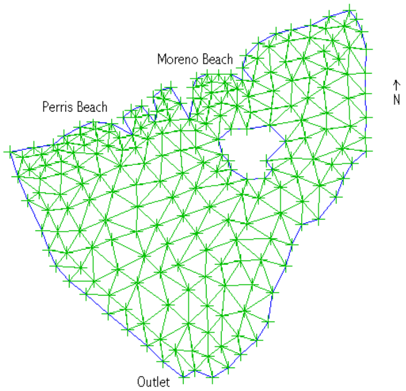


Fig. 8. Finite element mesh for Lake Perris simulations.

Wind speed was found to vary substantially over the day; the wind speed averaged ~0.5 m/s through much of the night and early morning, reached a minimum around 7 a.m., and then increased significantly throughout the remainder of the morning and into the afternoon. Wind speed reached a maximum value of 4.7 m/s at 4 p.m., and then decreased sharply through the rest of the afternoon and early evening (Fig. 9a). Winds were generally out of the southwest (Fig. 9b).

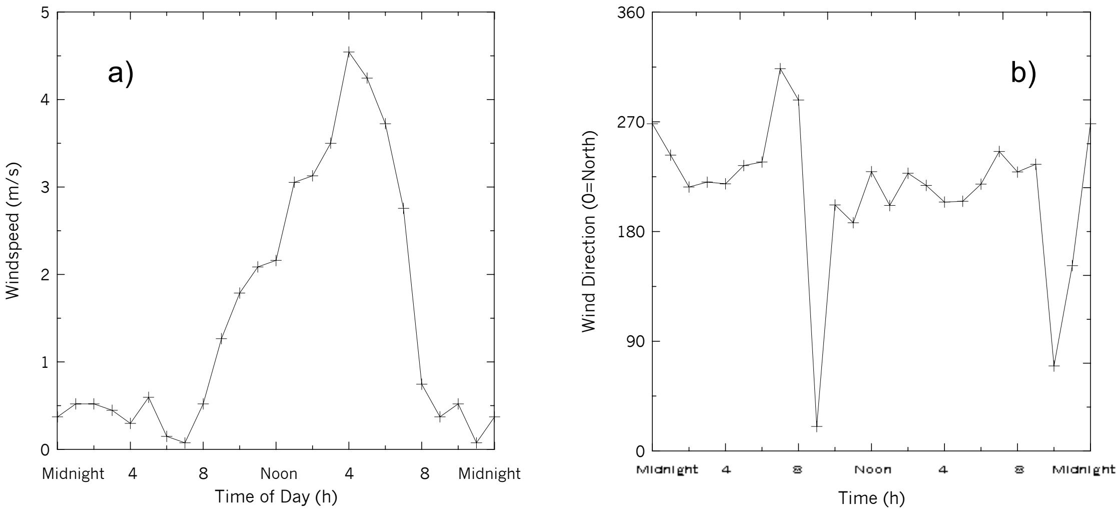


Fig. 9. Meteorological conditions used in simulations: a) wind speed and b) wind direction (N = 0 degrees)

In response to the wind energy acting on the surface of the lake, a rather complex velocity field within the lake was set up (Fig. 10). Mid-lake velocities of 0.1-0.5 cm/s were predicted, while higher velocities (~1-2 cm/s) were predicted near shore. Interestingly, the model predicts small clockwise gyres near Perris and Moreno Beach, with somewhat higher velocities predicted for Perris Beach relative to Moreno Beach. It should be noted that the 1000 gpm pumps, which have been included in these simulations, were not found to have a significant effect on circulation patterns at the beach areas when compared to simulation results in which the pumps were turned off. Such an observation is consistent with empirical data that show that high coliform concentrations and beach closures have continued even after installation of the systems. Thus, it appears that wind energy controls circulation at the beach areas.

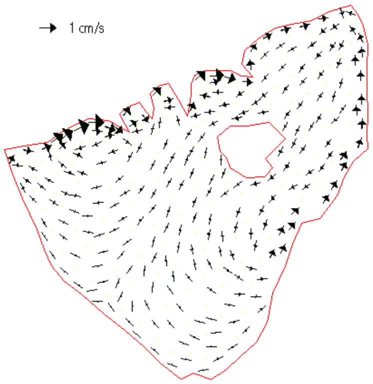


Fig. 10. Predicted typical afternoon circulation pattern in Lake Perris.

Predicted Fecal Coliform Concentrations

Assuming that one-half of the body-contact recreators are swimmers at the two beaches, that each swimmer sheds 3.8×10^7 fecal coliforms (Rose *et al.*, 1991), and an inactivation rate of 1.0 d^{-1} for fecal coliform (Yates *et al.*, 1997), one can calculate the fecal coliform concentrations as a function of time and space within Lake Perris. Concentrations at Perris Beach were predicted to increase steadily through the morning and afternoon, and reach a maximum concentration of almost 120 cfu/100 mL at approximately 3 p.m. (Fig 11). Strong temporal trends in coliform concentrations near swimming areas have been previously confirmed by monitoring (Anderson, 1999b).

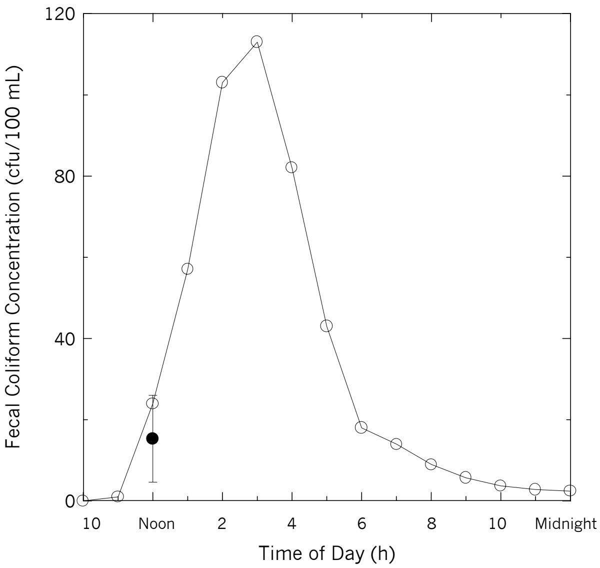


Fig. 11. Predicted fecal coliform concentrations at Perris Beach (open symbols). Mean concentration ± two standard deviations from 1999 summer sampling is also shown.

A plot of the spatial distribution at 3 p.m. of fecal coliform within the reservoir shows that concentrations quickly fall away from the beach areas, although there is some convection down Perris Beach due to wind-driven surface currents (Fig. 12a). At 7 p.m., several hours after peak beach use, the center of the coliform plume has migrated downfield from Perris Beach, with dispersion and inactivation lowering the peak concentration to about 15 cfu/100 mL. Some clockwise transport following the weak gyre has also occurred, resulting in the coliform plume extending out ~400 m from shore with concentrations ~3.5 cfu/100 mL. By comparison, relatively little transport away from Moreno Beach has occurred (Fig. 12b). It appears that the more protected nature of the Moreno Beach embayment limits wind-driven circulation within Moreno Beach and may result in higher and more persistent concentrations of fecal coliform relative to Perris Beach under equivalent use intensity.

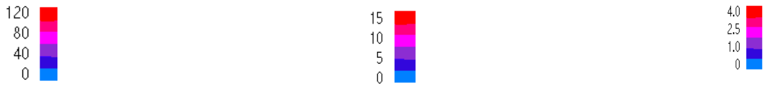


Fig. 12. Predicted summer weekend fecal coliform concentrations in cfu/100 mL in L. Perris.

Nevertheless, the plumes are fairly limited in areal extent, and generally do not extend out more than ~500 m from the beach areas under the meteorological conditions used in the simulations. The rapid rate of inactivation also limits migration of high concentrations of the bacteria away from the beach areas.

Comparison with Available Fecal Coliform Monitoring Data

Monitoring at Lake Perris for the summer of 1999 (Memorial Day - Labor Day) included sampling at lifeguard towers 3 and 5 at Perris Beach and at towers 6, 8 and 10 at Moreno Beach (J. Gillis, 1999). Samples were collected every Sunday between noon and 1 p.m. Fecal coliform concentrations at the two beaches ranged from <2 - 1600 cfu/100 mL, with an arithmetic mean concentration for all sites at each beach of 57±107 cfu/100 mL at Perris Beach and 124±257 cfu/100 mL at Moreno Beach. These values are well above the median concentrations at the beaches (15 and 26.5 cfu/100 mL for Perris and Moreno Beach, respectively). As is generally observed, the monitoring data better conformed to a log-normal distribution; applying such a distribution, one calculates mean values of 15 and 37 cfu/100 mL for the two beach sites. One notes that these values are much closer to the median concentrations, supporting the assumption of a log-normal distribution as the appropriate statistical descriptor for the monitoring data. Concentrations at buoys demarcating the outer edge of the swimming area were 2 cfu/100 mL or less in all instances except the July 11, 1999 sampling (J. Gillis, 1999).

Monitoring data are quite consistent with simulation results which predicted concentrations of 24 cfu/100 mL at Perris Beach at noon (Fig. 11), and concentrations generally ~1 cfu/100 mL offshore at the buoy line. Concentrations were predicted to approach 120 cfu/100 mL at the beach during typical peak weekend use with limited transport away from shore (concentrations generally <2 cfu/100 mL or less).

Following the approach used to present data for pathogen concentrations and consumer risks, cumulative distribution functions were developed from the fecal coliform monitoring data at Perris and Moreno Beaches (Fig. 13). One can see that fecal coliform data follow quite closely the sigmoidal shape predicted for the pathogens (*e.g.*, Figs. 1-4). The figure also shows that, for a given probability, coliform concentrations are consistently higher for Moreno Beach than for Perris Beach. Assuming the sample size is sufficient to characterize the statistical distribution of fecal coliform concentrations at the beaches during the summer weekends, Figure 13 also allows one to estimate the probability of exceeding the DHS single sample limit of 400 cfu/100 mL. The data indicates that the probability of exceeding the DHS value is about 2.5% for Perris Beach and 5.5% for Moreno Beach. Because of the predicted temporal variations (Fig. 11), however, it can be expected that the probabilities of exceeding the DHS guidelines later in the afternoon will be higher than those shown in Fig. 13. Thus, fecal coliform levels during the summer are generally significantly higher at the beaches than further out into the reservoir, with concentrations at the beaches potentially exceeding DHS single-sample and 30-day limits.

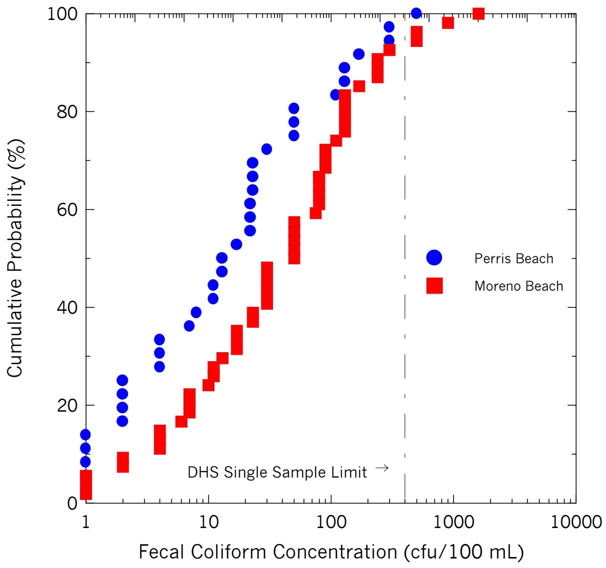
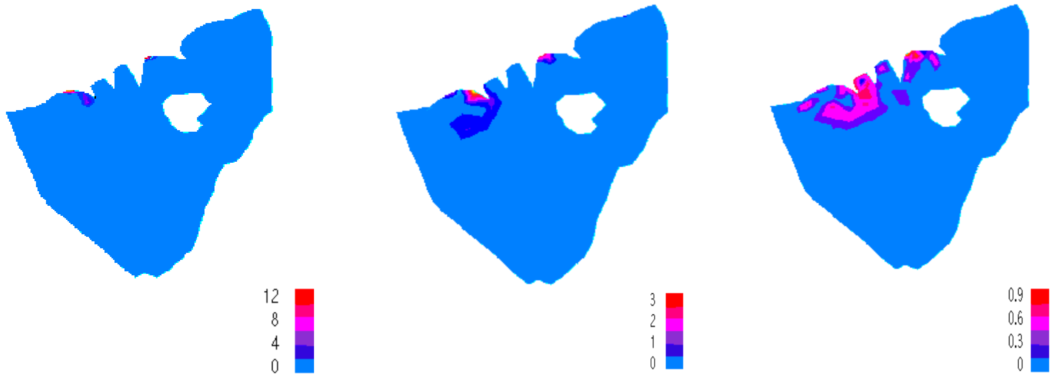


Fig. 13. Cumulative probability distribution functions developed from fecal coliform monitoring data for Perris Beach and Moreno Beach at Lake Perris.

<u>Predicted *Cryptosporidium* Concentrations</u>

Simulations were also conducted to elucidate predicted *Cryptosporidium* concentrations near the beach. For these simulations, concentrations were calculated using the median values from the Diamond Valley Lake (Eastside Reservoir) study and assumed 0.1 g fecal material was shed per swimmer, an infection rate of 2.5%, a pathogen concentration of the feces of 10^6 oocysts/g, and an inactivation rate of 0.08 d^{-1}. Accidental fecal releases (AFRs), previously shown to be potentially very important in defining pathogen loading, are excluded from this deterministic calculation due to the stochastic nature of the loading. Results for *Cryptosporidium* are shown in Fig. 14. The spatial distribution of *Cryptosporidium* is similar to that for fecal coliform (Fig. 12), although the lower loading rate results in much lower maximum concentrations (note units) (Fig. 14). Predicted *Cryptosporidium* concentrations at the beach increased during the late morning, reached a maximum concentration of almost 12 oocysts/100 L at approximately 3-4 p.m. (Fig. 14a), and then subsequently decreased as a result of convective and dispersive processes (Fig. 14b,c). The low rate of inactivation limits the importance of this removal process relative to fecal coliform. Moreover, the long inactivation half-life for *Cryptosporidium* (~8.7 days) relative to fecal coliform (~0.7 days) indicates that transport away from the beach and to the outlet tower can become significant. Thus, *Cryptosporidium* concentrations in the epilimnion will tend to increase over a period of weeks during the summer, while fecal coliform concentrations will tend to be locally and transiently high during periods of high use, and then rapidly decrease during the evening and during periods of limited recreational use (*e.g.*, weekdays).



a) 3 p.m. *b) 7 p.m.* *c) Midnight*

Fig. 14. Predicted summer weekend Cryptosporidium concentrations in oocysts//100 L in L. Perris.

The data depicted in Fig. 14 can also be presented in terms of distance from the beach or outlet tower. Concentrations along a transect from Perris Beach to the outlet tower were determined for 3 p.m., 7 p.m. and midnight (Fig. 15). High concentrations were observed in close proximity to the beach at 3 p.m., while peak concentrations later in the afternoon/evening were displaced ~400 m offshore by clockwise convective-dispersive transport (Fig. 14). Dispersion further lowered somewhat the peak concentration by midnight, but did transport very low concentrations of *Cryptosporidium* out to about 1000 m (Fig. 15). Continued body-contact recreation, coupled with convective-dispersive transport, will result in significant concentrations of *Cryptosporidium* reaching the outlet tower (Fig. 1). Superimposed on this are the inputs distributed across the reservoir from personal watercraft, waterskiiers and other recreators.

While the numerical simulations yielded results that were consistent with available monitoring data, additional studies are needed to adequately quantify the impacts of body contact recreation on water quality in Lake Perris. That is, given the importance of transport processes in defining the exposure and thus the health risks to recreators and consumers, measurements of water currents within the lake, additional monitoring near the beaches and in the main body of the reservoir, and more comprehensive modeling efforts are needed to adequately define the recreator and consumer health risks resulting from body-contact recreation, and to evaluate possible mitigation strategies.

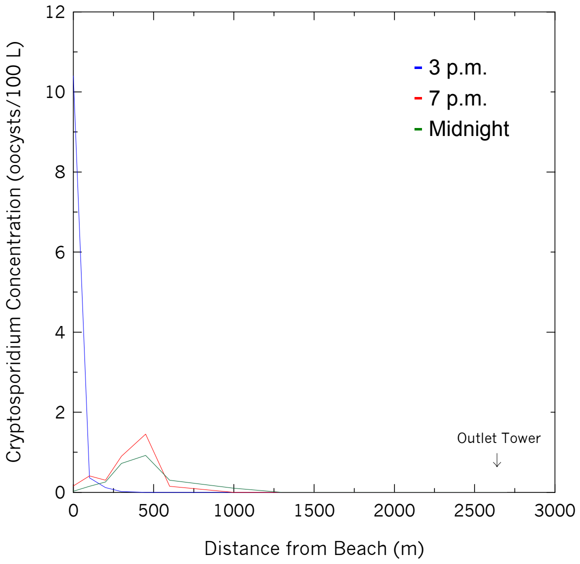


Fig. 15. Cryptosporidium concentrations along transect from Perris Beach to outlet tower.

Conclusions

Body-contact recreational activity is predicted to have significant effects on the pathogen concentrations in all of the SWP reservoirs. Lake Perris is predicted to experience the most substantial impacts due to its high level of recreational use relative to the volume of its epilimnion. Use levels normalized to epilimnetic volume were about 2-4x higher for Lake Perris than the other SWP reservoirs. These high levels of recreational intensity translated to the highest predicted concentrations of pathogens and, correspondingly, the highest consumer risk levels of the SWP reservoirs. The probability of exceeding the EPA target of 1 infections per 10,000 consumers per year was approximately 40% for Silverwood Lake, 45% for Pyramid Lake, 53% for Castaic Lake and 65% for Lake Perris.

Transport simulations conducted for Lake Perris predicted a rather complex circulation pattern within the reservoir that tended to limit offshore dispersion of fecal coliform from beach areas. Simulations predicted fecal coliform concentrations at the Perris Beach that increased substantially through the late morning and early afternoon, peaked near 3 p.m. with concentrations over 100 cfu/100 mL, and then fell sharply in the late afternoon and early evening. Dispersion and inactivation lowered the concentrations to ~2 cfu/100 mL or less by midnight. Because of the longer inactivation half-life, *Cryptosporidium* was predicted to transport further into the reservoir than fecal coliform.

Simulation results were in reasonable accord with available fecal coliform monitoring data. Samples collected at Perris Beach at approximately noon during the summer weekends of 1999 yielded a mean from a log-normal distribution of 15.3 ± 5.3 cfu/100 mL, which was in good agreement with a predicted concentration of 24 cfu/100 mL. Predicted and observed concentrations near the buoy line were also in good agreement, both yielding concentrations below 2 cfu/100 mL. Cumulative probability distribution functions developed from coliform monitoring data indicate that fecal coliform concentrations at approximately noon will exceed the DHS simple sample limit of 400 cfu/100 mL at a probability of about 2.5% for Perris Beach and 5.5% for Moreno Beach. Simulation results do indicate, however, that the probabilities for exceeding the recommended DHS single sample limit will be higher later in the afternoon. Additional studies are needed to better quantify recreator and consumer health risks resulting from body-contact recreation.

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APPENDIX B

Summary of Pathogen Occurrence in the SWP and QA/QC Work Using the EPA's Information Collection Rule Immunofluorescent Assay (ICR IFA)

The US Environmental Protection Agency (EPA) established the Surface Water Treatment Rule (SWTR) of 1989. The rule set the goals of microbial integrity and focused specifically on reducing risks from *Giardia* cysts and viruses in surface water and groundwater under the direct influence of surface water. One shortcoming of the SWTR was that it did not specifically control for *Cryptosporidium*. A 1993 waterborne disease outbreak from this protozoan in Milwaukee caused 400,000 people to experience intestinal illness, hospitalized more than 4,000 people, and caused at least 50 deaths. The incident demonstrated that drinking water supplies can be vulnerable to this waterborne disease (EPA 1999). The Safe Drinking Water Act Amendments (SDWA) of 1996 mandated that the EPA develop interrelated regulations to control microbial pathogens and disinfectant/disinfection byproducts (D/DBP) in drinking water (EPA 1999a).

One regulation stemming from the amendments to the SDWA was the Information Collection Rule (ICR). One purpose of the rule was to collect occurrence and treatment information to help evaluate the need for possible changes to the SWTR and microbial treatment practices. Among other requirements, the ICR compelled EPA to collect research data on disease-causing microbes (including *Cryptosporidium*) in drinking water sources and indicators of fecal contamination.

The ICR method for pathogens was proposed in February 1994 but was not promulgated until May 1996. One reason for the delay was the scientific issues surrounding the immunofluorescent assay (IFA) method used to quantify *Cryptosporidium* and *Giardia* (oo)cysts (Pontius and Clancy 1999). The first collaborative study of the IFA method was conducted in 1993. Results from 16 laboratories found that recoveries were low and false positives and negatives were common (Clancy and others 1994). Following this study and prior to the rules promulgation, modifications were made in an attempt to improve the method's performance. Two studies examining the modifications found that variability remained high, false positives and negatives were still common, and both inter- and intralaboratory variability was high among the laboratories (Pontius and Clancy 1999). By 1996, promulgation of the ICR had been delayed several times, and the EPA faced issuing the ICR without *Cryptosporidium* testing. The EPA determined that meaningful national data on *Cryptosporidium* occurrence and regulatory decisions could be reached if laboratories achieved on average more than 8% recovery for protozoan cysts. Pathogen monitoring under ICR began July 1996 and ended in December 1998.

The California Department of Water Resources (DWR) used the ICR IFA method to conduct a Coordinated Pathogen Monitoring Program (CPMP) to assess the potential human health threat by microbial contaminants, including *Cryptosporidium*, *Giardia*, and *Clostridium perfringens* in State Water Project (SWP) waters. Total and fecal coliform as well as *E. coli* were also analyzed. For the CPMP, Kern County Water Agency, DWR, and Metropolitan Water District of Southern California (MWDSC) collected samples monthly from October 1996 through April 1998. In addition to monthly samples, storm event samples were collected during the 1st major storm of the wet season and during 2 additional major storm events. Storms that were sampled were based on a number of conditions, but a general guideline of 1 inch of rain in a 24-hour period was used as a trigger to assess a storm event for monitoring. Four flood-related locations were added to the 12-storm event monitoring locations as a result of the January 1997 floods.

Pathogen samples were collected from the SWP's source waters (the Sacramento and San Joaquin rivers) as well as the California Aqueduct. Samples were collected at locations spanning a distance of approximately 600 miles from the northernmost sampling site at Alamar on the Sacramento River to Lake Perris, the terminal reservoir on the East Branch of the California Aqueduct. DWR's Division of Planning and Local Assistance (DPLA) collected source water samples, the Department's Division of Operations and Maintenance (O&M) collected samples within the SWP. Additionally, Kern County Water Agency assisted with sampling at the Check 29 sampling site. The MWDSC collected samples from Castaic and Silverwood lakes. All sampling sites are shown in Table B-1. Based on the first 12 months of data, the number of sampling stations for both storm event and monthly sampling were reduced. Samples collected during the final 6 months of the study focused on locations having the greatest detection frequency. These included the Sacramento River, the San Joaquin River, and Delta sampling locations.

DWR also examined the recovery efficiencies of the ICR method in Delta source waters and SWP waters. In 1 set of experiments, sample water was spiked with certified concentrations of *Cryptosporidium* and *Giardia*. *Cryptosporidium* oocysts were spiked at 4,480 oocysts/200 L (2,240 oocysts/100 L). *Giardia* cysts were spiked at 3,656 cysts/200 L (1,828/100 L). The spiked sample water was then simultaneously filtered into 2 split samples. Waters used for these recovery experiments were collected from 4 sample sites in the CPMP as well as the American River. Sampling sites for the matrix study are also shown in Table B-1. Equipment blanks were also analyzed to examine any loss due to the equipment itself. Laboratory performance was evaluated by directly spiking filters with a known amount of *Cryptosporidium* and *Giardia*, placing the spiked filters in containers of known turbidity matrix water, and sending the filters to 2 independent laboratories for analysis. This design bypassed any loss of (oo)cysts because of filtration and allowed the evaluation of the method itself under different turbidity matrix waters.

Table B-1 Monthly, Storm, and Flood Event Sample Sites for the Coordinated Pathogen Monitoring Program Project

Sample Site	Monthly Sample	Storm Sample	Flood Sample	QA/QC Sample	Sampler[a]
American River @ Fairbairn WTP				X	DPLA
Sacramento River @ Bryte Bend (Alamar Marina)	X	X			DPLA
Sacramento River above Sacramento Regional Wastewater Treatment Plant & Below Confluence with American River @ Miller Park Dock (Miller)	X	X			DPLA
Sacramento River Below Sacramento Regional Wastewater Treatment Plant @ Greenes Landing	X				DPLA
San Joaquin River @ Vernalis at Airport Road Bridge	X	X		X	DPLA
San Joaquin River @ Holt[b]	X				DPLA
Clifton Court @ West Canal Intake Near Radial Gates		X			O&M
Delta-Mendota Canal @ McCabe Road	X	X			O&M
Banks Pumping Plant @ Bethany Reservoir[c]	X	X		X	O&M
Arroyo Valle Creek Inflow to Lake Del Valle (when flowing, about 5 months/year) @ Creek Mouth	X	X			O&M
California Aqueduct, Check 29[d]	X	X		X	KCWA/O&M
Pyramid Lake at the Piru Creek Gaging Station		X			O&M
Pyramid Lake at the Tower in Elderberry Forebay, Release from Elderberry Forebay to Castaic	X				O&M
Castaic Lake @ Elderberry Forebay[e]		X			O&M
Castaic Lake Influent to Jensen Filtration Plant (FP)	X				MWDSC
Silverwood Lake, Influent at Mills FP or Devil Canyon	X			X	MWDSC
Silverwood Lake[f]		X			O&M
Lake Perris @ Outlet Tower	X				O&M
Barker Slough Pumping Plant, North Bay Aqueduct Intake	X	X			O&M
Mokelumne River @ New Hope			X		O&M
Shag Slough @ Liberty Island Bridge			X		O&M
Kern River Intertie Immediately Prior to Confluence with CA Aqueduct			X		O&M
CA Aqueduct @ Mile 241.02 Immediately Upstream of the Kern River Intertie			X		O&M

[a] All QA/QC samples sampled by DPLA.

[b] Samples taken downstream of Stockton Publicly Owned Treatment Works outfall at or shortly after the midpoint of an ebb tide at the sampling site to ensure flow toward the Delta.

[c] Sample collected at the inlet to Bethany Reservoir immediately downstream from Banks Pumping Plant.

[d] Inflow to the San Luis Reach of the CA Aqueduct from Cantua and Salt creeks may be used as a storm event-monitoring trigger for this site.

[e]
1. Fish Creek and Castaic Creek confluence at the lowest debris basin above Elderberry Forebay.
2. Fish Creek - if no water in debris basin.
3. Castaic Creek.
4. Elizabeth arm of lake at the gaging station.

[f]
1. Miller Canyon gaging station.
2. Cleghorn drainage.
3. Sawpit.

Table B-2 ICR IFA Split Matrix Spike Results

	Giardia Recovery 1,828 cysts/spike		*Cryptosporidium* Recovery 2,240 oocysts/spike		Turbidity
Matrix Water Source	cysts/100 L	% recovered	oocysts/100 L	% recovered	NTU
American River @ Fairbarn					2.6
Split Sample 1	5.0	0.27	<5	0	
Split Sample 2	6.7	0.37	<6.7	0	
Background	<6.7		<6.7		
San Joaquin River @ Vernalis					21.5
Split Sample 1	<10	0	<10	0	
Split Sample 2	33.7	1.84	<11.1	0	
Background	10		<10		
Banks at Bethany Reservoir					8.6
Split Sample 1	36	1.96	24	1.07	
Split Sample 2	45.5	2.50	22.6	1.01	
Background	<4.5		<4.5		
Devil Canyon					4.8
Split Sample 1	16.7	0.91	<8.3	0	
Split Sample 2	104.2	5.7	8.3	0.37	
Background	<6.3		<6.3		
California Aqueduct at Check 29					10.8
Split Sample 1	158	8.66	8.3	0.37	
Split Sample 2	57.1	3.12	14.3	0.64	
Background	<8.4		<8.4		
All Samples Average Recovery (SD, n-1)[a]	46.3 (50)	2.53 (2.74)	7.75 (9.59)	0.35 (0.43)	

[a] Standard Deviation with n-1 degrees of freedom

Results of the matrix spike study found that average recoveries were very low for both *Cryptosporidium* and *Giardia*. Recoveries were higher for *Giardia* than for *Cryptosporidium*. The average recovery for spiked *Giardia* cysts was 46.3 cysts/100 L (2.53%). The average recovery for spiked *Cryptosporidium* oocysts was 7.75 oocysts/100 L (0.35%). Recoveries were low regardless of the turbidity or sample location (Table B-2). Low recoveries were also not due to retention of the organisms by the equipment. In all cases, equipment blanks were below the detection limits (Table B-3).

Table B-3 Equipment Blank Results

	Giardia	*Cryptosporidium*	Turbidity
Sample Type	cysts/100L	oocysts/100L	NTU
Equipment Blank			<1
Sample 1	<2.7	<2.7	
Sample 2	<2.7	<2.7	

Table B-4 Recovery Comparisons Between 2 Laboratories, Cysts Seeded (2928 ± 447) and Oocysts Seeded (5532 ± 880)

Giardia

Matrix	Laboratory A (8/95 ICR)		Laboratory B (8/95 ICR)	
NTU	cysts/100L	%	cysts/100L	%
60	350	11.9	1,266.7	43.3
10	232	7.92	1,220	41.7
Wastewater	90.4	3.09	1,733.3	59.2
Average Recovery		7.6		48.1

Cryptosporidium

Matrix	Laboratory A (8/95 ICR)		Laboratory B (8/95 ICR)	
NTU	oocysts/100L	%	oocysts/100L	%
60	440	7.97	33.3	0.60
10	200	3.6	<10	0
Wastewater	142.5	2.58	50	0.90
Average Recovery		4.7		0.5

Source: DWR 1996

Recovery results from directly spiked filters sent to 2 different laboratories are shown in Table B-4. With the exception of 1 set of *Giardia* results, recoveries were <10%. For laboratory A, average recovery of both *Cryptosporidium* and *Giardia* were similar (4.7% and 7.6%, for *Cryptosporidium* and *Giardia*, respectively). For laboratory B, recovery between the 2 organisms varied by a factor of 10 (0.5% and 48.1% for *Cryptosporidium* and *Giardia*, respectively). Recovery results were not consistent between laboratories. In the case of *Giardia*, laboratory B recoveries were on average 6 times higher than laboratory A recoveries. However, with respect to *Cryptosporidium*, laboratory A recoveries were nearly 10 times higher than laboratory B recoveries.

Monitoring results of the CPMP potentially reflected the poor recoveries observed in the spiking studies. Of the 195 monthly samples collected, 7 tested positive for *Cryptosporidium* (4%). Mirroring the higher recoveries in the spiking studies, *Giardia* detections were more frequent. *Giardia* was detected in 46 of the 195 samples collected (24%). Since the method's recovery was so low and its variability was so high, it was impossible to know whether these results were a true reflection of pathogen occurrence or an artifact of the method.

Because of the high variability and poor recovery for both *Cryptosporidium* and *Giardia*, it was not possible to compare organism concentrations between sampling sites. Therefore, results from all samples were combined to generate summary statistics (Table B-5). Detections were subdivided into monthly samples collected in the first 12 months of the project (Phase I) and the 6 months of sampling focusing on locations with the greatest number of positive detections (Phase II). Pathogen concentrations from samples collected only during rainfall or flood events are shown separately. Summary statistics combining the results of both monthly sampling and rainfall/flood events are also shown

Regardless of the time period (Phase I or Phase II), the geometric means and the ranges for both *Cryptosporidium* and *Giardia* were higher for samples collected during rainfall/flood events than samples collected monthly. For *Giardia*, geometric means for both Phase I and II event sampling were higher than geometric means calculated for Phase I and II monthly sampling. For *Cryptosporidium*, the geometric mean for Phase I storm event data was twice as high as the geometric mean for Phase I monthly samples. However, like all data from this study, interpretation of these patterns are tenuous. With the exception of storm event sampling, the geometric means between *Cryptosporidium* and *Giardia* were similar. However, no statistical comparisons were conducted, and any statistical conclusions would be suspect.

Table B-5 *Giardia* and *Cryptosporidium* Summary Statistics (Total IFA count)

		Giardia (Cysts/100L)			*Cryptosporidium* (Oocysts/100L)			
Study		Number Positive	Range	Geo. Mean	Number Positive	Range	Geo. Mean	N
CPMP Monthly Sampling	Phase I[a]	22% (35 of 158)	2.4 - 92.3	16.6	4% (6 of 158)	9.0 - 26.7	18.0	158
	Phase II[b]	30% (11 of 37)	2.5 - 62.8	15.6	3% (1 of 37)	13.3	N/A	37
	Combined	24% (46 of 195)	2.4 - 92.3	16.4	4% (7 of 195)	9.0 - 26.7	17.2	195
CPMP Rainfall/ Flood Event Sampling	Phase I[a]	33% (9 of 27)	10.05 - 129.8	58.9	30% (8 of 27)	4.4 - 200	35.0	27
	Phase II[b]	35% (9 of 26)	10 - 140	28.5	19% (5 of 26)	10 - 50	22.6	26
	Combined	34% (18 of 53)	10 - 140	40.9	24% (13 of 53)	4.4 - 200	29.6	53
CPMP Combined (Monthly & Rainfall/ Flood Events)	Phase I[a]	24% (44 of 185)	2.4 - 129.8	21.5	8% (14 of 185)	4.4 - 200	26.3	185
	Phase II[b]	32% (20 of 63)	2.5 - 140	20.4	10% (6 of 63)	10 - 50	20.7	63
	Combined	26% (64 of 248)	2.4 - 140	21.2	8% (20 of 248)	4.4 - 200	24.5	248

[a] Phase I: Oct 1996 through Oct 1997
[b] Phase II: Nov 1997 through Apr 1998

Table B-6 Percent Positive *Giardia* Detections for CPMP

Water Type	Sample Location	% Positive Monthly Samples	% Positive Storm/Flood Event Samples
Source and Delta Waters	Alamar	63	67
	Miller	33	100
	Sac River @ Greenes Landing	65	100
	Barker Slough PP	40	29
	San Joaquin River near Vernalis	59	40
	Holt	17	Not sampled
	Delta-Mendota Canal	0	0
	Banks	0	0
SWP Aqueduct and Reservoir Waters	Arroyo	11	0
	Check 29	5	Not sampled
	Elderberry	0	Not sampled
	Jensen	8	Not sampled
	Devil's Canyon	0	Not sampled
	Perris	0	Not sampled

Positive detections of both *Cryptosporidium* and *Giardia* occurred the most frequently in source waters, not the SWP (Tables B-6 and B-7). *Cryptosporidium* was detected in 11% of the source water samples and 5% of the SWP samples. *Giardia* was detected in 50% of the source water samples and in only 2% of the SWP samples.

For *Giardia*, the majority of samples collected from SWP locations were below the detection limit. *Giardia* recovery and variability values were extremely poor; therefore, these distribution patterns must be viewed cautiously. There is the potential that the patterns of occurrence may be incorrect because of false positives or negatives. The high variability of the method also points to the inadequacy of the ICR's single-grab sample describing *Giardia* occurrence in a water body.

Because of poor *Cryptosporidium* recoveries, it is difficult to determine occurrence patterns. Potentially, *Cryptosporidium* may have occurred more frequently in source waters and during storm events. Although logical, the tendency for the ICR method to create false positives cannot rule out the possibility that the increased pathogen numbers during storm events reflects increased false positives from storm water debris.

Table B-7 Percent Positive *Cryptosporidium* Detections for CPMP

Water Type	Sample Location	% Positive Monthly Samples	% Positive Storm/Flood Event Samples
Source and Delta Waters	Alamar	6	0
	Miller	0	50
	Sac River @ Greenes Landing	1	25
	Barker Slough PP	0	14
	San Joaquin River near Vernalis	12	20
	Holt	17	0
	Delta-Mendota Canal	0	25
	Banks	0	25
SWP Aqueduct and Reservoir Waters	Arroyo	0	29
	Check 29	5	Not Sampled
	Elderberry	0	Not Sampled
	Jensen	0	Not Sampled
	Devil's Canyon	0	Not Sampled
	Perris	0	Not Sampled

Like *Giardia* and *Cryptosporidium*, detection frequencies for *Clostridium perfringens* was higher in storm and flood event samples than in monthly samples. Similarly, positive detections occurred more frequently in river and Delta source waters than in the SWP system. The range of positive *Clostridium perfringens* concentrations in monthly samples was 2 to 800 CFUs/100 mL, with a geometric mean of 46.9 CFUs/100 mL. The highest frequency of detection was at the North Bay Aqueduct intake at Barker Slough, which also had the highest geometric mean of all monthly sampling locations for *C. perfringens*.

Like protozoans and *C. perfringens*, total/fecal coliform and *E. coli* detection frequencies and concentrations were highest in the Sacramento River, San Joaquin River, and Delta when compared with the SWP aqueduct and reservoirs. Storm and flood event sample detections, frequency, and geometric means were also higher than those of the monthly samples.

In order to gain information about pathogen levels in floodwaters, additional samples were collected during the January 1997 floods. The highest geometric means for any of the organisms (protozoans or bacteria) were observed in flood event samples. Flood event geometric means were not only higher than monthly values but were also higher than storm event values. Seventy percent of the flood samples tested positive for *Giardia*, while 40% tested positive for *Cryptosporidium*.

The Department's study also conducted correlation analyses to identify possible surrogate indicators for *Cryptosporidium* and *Giardia*. Unfortunately, the quality of data associated with the ICR IFA method precluded any meaningful conclusions from being drawn. Only the relationship between fecal coliform and *E. coli* exhibited a correlation coefficient greater than 80%. Given that *E. coli* is an indicator of fecal contamination, this result is not surprising. Similarly, it is not surprising that no correlation was found between protozoa and bacteria or turbidity. Even if a correlation actually did exist, a lack of correlation would be expected if a method was highly variable and subject to nondetects, false positives, and false negatives.

DWR concluded that the ICR method exhibited poor recovery, accuracy, and precision. Because of these failings, it is impossible to know whether the results obtained from the study accurately reflected pathogen distribution and concentration in source, Delta, SWP Aqueduct, and reservoir waters. Potentially, *Cryptosporidium* and *Giardia* are more prevalent in source and Delta waters than in SWP aqueduct and reservoir waters and occur more frequently at higher concentrations during storm and flood events. The limitations of the method precluded any correlation being drawn between protozoa and bacteria or turbidity concentrations.

The results observed from DWR's study are similar to nationwide ICR results. With 18 months of national ICR data analyzed, the majority of samples have found no detection of either organism. Of the 5,829 samples analyzed, 93% have been nondetect for *Cryptosporidium,* and 81% have been negative for *Giardia* (Allen and others 2000). Like DWR's studies, these results do not mean that the organisms are not present, only that the limitations of the method failed to discern them. The EPA also has not found a correlation between *Cryptosporidium* and bacteria surrogates (Pope pers. comm.).

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PERSONAL COMMUNICATION FOR APPENDIX B

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APPENDIX C

Summary of Method 1623 Recovery Analysis

As discussed in Appendix B, problems associated with the Information Collection Rule immunofluorescent assay (ICR IFA) methodology were not uncommon and—as shown by California Department of Water Resources (DWR) experiments—limited the usefulness of the method. Prior to the introduction of the ICR methodology, the US Environmental Protection Agency (EPA) began developing an improved method for detecting protozoan for a special study it planned to conduct (Pontius and Clancy 1999). This study, the Supplemental Survey, was designed to collect protozoan occurrence data from some participating ICR utilities as well as medium- and small-size systems that did not participate in the ICR.

In 1998 and 1999, the EPA introduced Method 1622 (for *Cryptosporidium*) and Method 1623 (for *Cryptosporidium* and *Giardia*) (EPA 1999 and 1999a, respectively). The method represented a significant improvement over the ICR IFA methodology. In the QA/QC of Method 1622 performance, mean recovery of *Cryptosporidium* in spiked reagent water was 35% with a relative standard deviation of 30% (Allen and others 2000).

DWR undertook a Coordinated Pathogen Monitoring Program (CPMP) in 1996 to determine the relative sources of pathogens within the State Water Project (SWP). Unfortunately, at the time of the study, only ICR methodology was available. Based on the problems with the ICR IFA method, the results were unable to answer this question (see Appendix B). DWR was asked to use Method 1623 when it was released in April 1999 to determine the relative sources of pathogens within the SWP.

Prior to again evaluating Delta and SWP waters for *Cryptosporidium* and *Giardia*, it was important to understand Method 1623 capabilities under ambient Delta and SWP conditions. Depending on the site and season, turbidities at key locations in the SWP and the Delta can range from 5 to 200 nephelometric turbidity units (NTUs). Highest turbidities are usually associated with winter runoff when the highest levels of pathogens in surface water would be expected. Although the method is used at utilities across the United States, very little published literature exists on the full method's recoveries in ambient waters with turbidities above 20 NTUs. The EPA validation study tested recovery in turbidities as high as 13.8 NTUs (EPA 1999b), while Clancy and others (1999) reported using turbidities as high as 19.5 NTUs.

In addition to recoveries, the level of variability is also important. Low variability among replicates allows detection of significant differences in pathogen concentrations between sites. Another statistical consideration is the method's performance in different matrices. The EPA's wide acceptance criteria for matrix spikes suggest that the method's recoveries may vary with the matrix (Table C-1). If this is the case, then standard hypothesis testing methods (for example, ANOVA or Kruskal-Wallis) cannot be used to compare site differences. Both statistical approaches assume the method will not perform differently under different environmental circumstances.

Table C-1 Method 1623 Acceptance Criteria for Ongoing Precision and Recovery of Matrix Spike

	Cryptoporidium	*Giardia*
Mean Recovery (as percent)	13 - 111	15 - 118
Precision (as max relative percent difference)	61	30

Adapted from EPA 1999b

The objectives of DWR's Method 1623 study were threefold. The 1st objective was to test the relative capacity of the standard and High Volume Gelman Envirochek™ filters. The standard Gelman filter is commonly used in Method 1623 filtrations. Gelman developed the High Volume filter to filter hundreds of liters of finished water without compromising pathogen recovery. If this filter could be used in ambient waters, then the chances would increase that the full 10 liters could be sampled with turbid storm water samples. A 2nd objective was to determine if it was possible to recover *Cryptosporidium* and *Giardia* from waters collected at key points in the system. Although it was recognized that background water matrices might change with the season, samples were collected once at 4 sites to determine if recoveries were possible under a wide range of water matrices and conditions. Sample sites were the canal into Bethany Reservoir, immediately downstream of the Banks Pumping Plant, the Sacramento River at Hood, the Barker Slough Pumping Plant, and the San Joaquin River near Vernalis. Replicate samples of each water were spiked with 100 organisms/10 L, filtered, and then sent to the laboratory for Method 1623 analysis. The final objective was to compare recovery and variability of spiked samples analyzed by 2 different laboratories.

Comparisons of filtration capacity of the 2 filters found that when the turbidities were high, the High Volume filter could filter about twice the volume of the standard filter; however, neither filter could filter the full 10 liters.

There did not appear to be appreciable differences between recovery and variability of the 2 filter types. In 1 trial *Cryptosporidium* recovery efficiencies were higher with the High Volume filter, while there were no significant differences between *Giardia* recoveries. In a 2nd trial, *Cryptosporidium* recoveries between the 2 filters were not significantly different. Unless noted, all remaining experiments were conducted with High Volume filters.

For both organisms, the lowest recoveries were found in the highest turbidity water (Figure C-1). Recoveries for *Cryptosporidium* ranged from 36% to 75%. Between 11 and 47 NTUs, *Cryptosporidium* recoveries were at or above 50%. Above 47 NTUs, recoveries fell below 50%. Recoveries for *Giardia* ranged from 0.47% to 53%. Unlike *Cryptosporidium* there was a sharp drop in recovery at 47 NTUs in Barker Slough waters. For *Cryptosporidium* the highest variability was associated with spiked samples of Barker Slough water. For *Giardia* the highest variability was associated with spiked samples of water collected immediately above Bethany Reservoir.

Figure C-1 *Cryptosporidium* and *Giardia* Percent Recovery (± std. dev.) vs. Turbidity

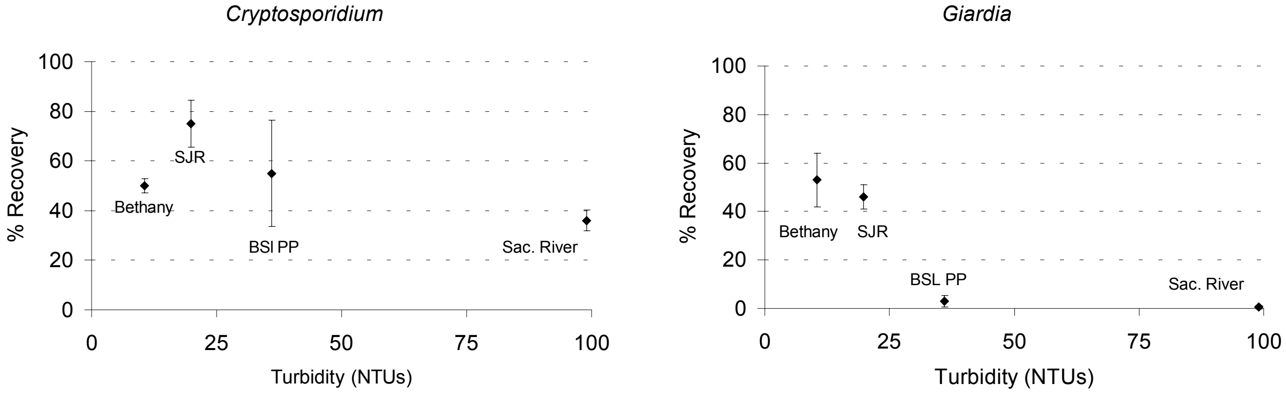

Table C-2 *Cryptosporidium* Average Percent Recovery and Coefficient of Variation by Site

	Turbidity (NTUs)	Average Recovery (%)	Coefficient of Variation (%)
Bethany Reservoir	11	51	6
San Joaquin near Vernalis	20	75	13
Barker Slough Pumping Plant	36	55	38
Sacramento River @ Greenes Landing	99	36	12

Results suggested that changes in *Cryptosporidium* recovery and variability by site were not necessarily influenced by turbidity but from the unique matrix of the water. Table C-2 shows the turbidity, average percent recovery, and coefficient of variation of the sites sampled. Based on coefficient of variations, variation at 99 NTUs was identical to variation at 20 NTUs; however, variation at 36 NTUs was 3 to 6 times higher than at any other turbidity. This suggests a variable other than turbidity is affecting method performance.

Matrix water detection limits were also calculated for each water. Using spiking doses of approximately 100 organisms/10 liters, matrix water detection limits (MWDLs) were calculated at the 99% confidence limit using standard method detection limits (MDLs) equations and an *n* of 3 (40 CFR). Since MDLs are normally calculated in reagent water and do not take into account recoveries, the final MWDL was determined by dividing the MDL value by its percent recovery. Additionally, MDLs are usually calculated with 7 replicates; therefore, a *t* value of 6.965 was used instead of 3.14. Final MWDLs are given in Table C-3. Although an estimate, the process provided a rough idea of the minimum number of organisms under the conditions of this study that a researcher could expect to observe 99% of the time.

One problem with calculating microbial detection limits is that the organisms occur in discrete particles and are not randomly distributed throughout the water column like a chemical contaminant. The EPA has recently begun testing a new method to determine *Cryptosporidium* detection limits in reagent water with Method 1623 (Connell pers. comm.).

Table C-3 Calculated MWDL Based on Initial Spike Dose of Approximately 10 Organisms/L (n = 3)

Cryptosporidium

Site	sd	t value	MDL (org/L)	Recovery	Recovery Adjusted MWDL (org/L)
Bethany	0.30	6.965	2.1	0.50	4.2
Sac. River	0.40		2.8	0.36	7.9
SJR	0.93		6.5	0.75	8.7
BSl PP	2.08		14.5	0.55	26.3

Giardia

Site	sd	t value	MDL (org/L)	Recovery	Recovery Adjusted MWDL (org/L)
Bethany	1.10	6.965	7.7	0.53	14.5
Sac. River	0.08		0.58	0.005	122.3
SJR	0.50		3.5	0.46	7.7
BSl PP	0.23		1.6	0.03	61.8

Table C-4 Average Percent Recovery (org/L) ± 1sd by 2 Independent Laboratories

Sample Water	Organism	Lab A	Lab B
San Joaquin River near Vernalis	*Cryptosporidium*	59 ± 9.8	75 ± 9.6
	Giardia	37 ± 3.5	46 ± 5.0[a]

[a] Significantly different, arc sin transform, p = 0.03.

Recovery results between 2 different laboratories were inconclusive (Table C-4). Significant differences in recovery varied by the organism. No significant differences were found between *Cryptosporidium* recoveries, but significant differences were found between *Giardia* recoveries. The experiment was repeated using Barker Slough waters. Unfortunately, the spiking solutions were unknowingly contaminated by the supplier with *G. muris*; therefore, recovery results were not valid. Because of time and financial constraints, no additional comparisons were made.

In conclusion, DWR's Method 1623 study determined that recoveries in ambient water using the Gelman High Volume filter were similar to those using the Gelman standard filter. While neither could filter the full 10 liters in highly turbid water, the High Volume filter could filter twice as much volume as the standard filter. This suggests that the High Volume filter should be used for field sampling.

As verified by EPA studies, Method 1623 recoveries for both organisms were markedly higher than the ICR IFA method. For *Cryptosporidium*, recoveries fell below 50% at 47 NTUs; however, recoveries were still at 36% at 99 NTUs. At lower turbidities, *Giardia* recoveries were also above 50%; however, unlike *Cryptosporidium*, recoveries fell dramatically at 47 NTUs. Average recoveries and coefficient of variation results also suggested that matrix affects could be occurring in samples collected from the San Joaquin River near Vernalis. The variability associated with samples collected from Barker Slough suggested that a large number of samples would be required to accurately assess *Cryptosporidium* concentrations.

While Method 1623 recoveries were higher than the ICR IFA method, the detection limits of the method may still be above ambient concentrations of organisms. Therefore, like the ICR IFA method, there is still a likelihood of false negatives. Also, if detection limits do vary with the matrix, it may be unwise to use a single detection limit across all matrices. Experiments did not determine whether Method 1623 reacts the same in different turbidities or matrices. In order to examine this question, spiked samples of different waters at identical turbidities would have to have been analyzed; however, the EPA's performance criteria for Method 1623 suggest that the method may be influenced by unknown factors in different ambient waters. If this is the case, then both parametric and nonparametric methods of analyses would not be valid. Both families of statistics assume that Method 1623 functions identically in all types of waters. Similarly, if recoveries vary by the matrix, it might be unwise to use 1 recovery rate for all water types.

The study also concluded that given these potential problems, the method might be useful as an indicator of pathogen contamination based on frequency of occurrence. The problems associated with false negatives were still a weakness of the method and could compromise frequency of occurrence data by suggesting that no organisms were present when this was not the case. Based on the patchy distribution of the organisms, any field study would require careful design and a strong QA/QC component. The highest likelihood of success might come from a focused study on a small watershed that had a direct response to local rainfall and that had the potential for high pathogen runoff.

References

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PERSONAL COMMUNICATIONS FOR APPENDIX C

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Glossary

A

ACC
area control center

ACWA
Association of California Water Agencies

af
acre-foot/acre-feet

Ag
silver

AGP
Algal Growth Potential

Al
aluminum

AL(s)
action level(s)

AO
administrative order

AVEK
Antelope Valley East Kern Water Agency

AWWA
American Water Works Association

B

B
boron

BAT
best available technology

BLM
US Bureau of Land Management

BMP(s)
Best Management Practice(s)

BOD
biochemical oxygen demand

BRP
Business Resumption Plan

BTEX
benzene, toluene, ethyl benzene, xylene

C

Ca
calcium

CalEPA
California Environmental Protection Agency

CALFED
CALFED Bay-Delta Program

CALFED's ERPP
Ecosystem Restoration Program Plan

Caltrans
California Department of Transportation

CCF
Clifton Court Forebay

CCR
Consumer Confidence Report

CCWA
Central Coast Water Authority

CCWD
Contra Costa Water District

Cd
cadmium

CDC
Centers for Disease Control and Prevention

CDEC
California Data Exchange Center

cfs
cubic feet per second

CFU
colony forming units

CI
confidence intervals

Cl
chloride

CLAWA
Crestline-Lake Arrowhead Water Agency

CLSA
closed-loop stripping analysis

CMARP
Comprehensive Monitoring, Assessment, and Research Program

CO_3
carbonate

COE
use USACE for US Army Corps of Engineers

CAFO(s)
confined animal feed operation(s)

CPMP
Coordinated Pathogen Monitoring Program

Cr
chromium

CSO
combined sewer outflows

CSS
combined sewer system

Cu
copper

CUWA
California Urban Water Agencies

CVP
Central Valley Project

CVPIA
Central Valley Project Improvement Act

CVRWQCB
Central Valley Regional Water Quality Control Board

CWRA
California Water Resources Association

CWS(s)
community water system(s)

CWTP
combined wastewater treatment plant

D

DBW
California Department of Boating and Waterways

D/DBP(s)
disinfectant/disinfection byproduct(s)

DCC
Delta Cross Channel

DHS
California Department of Health Services

DLR
detection limit for purposes of reporting

DMC
Delta-Mendota Canal

DO
dissolved oxygen

DOC
dissolved organic carbon

DPR
California Department of Pesticide Regulation

DWCWG
CALFED Drinking Water Constitutents Work Group

DWR
California Department of Water Resources

DWSAP
Drinking Water Source Assessment and Protection

E

EAP
emergency action plan

EBMUD
East Bay Municipal Utility District

EBRPD
East Bay Regional Park District

EBX
East Branch Extension

EC
electrical conductivity

EIS/EIR
CALFED Programmatic Environmental Impact Statement/Environmental Impact Report

ELAP
Environmental Laboratory Accreditation Program

EMWD
Eastern Municipal Water District

EPA
US Environmental Protection Agency

ERP
emergency response plan

F

F
fluoride

Fe
iron

FERC
Federal Energy Regulating Commission

FP
filtration plant

G

GAC
granular activated carbon

GWUDI
groundwater under direct influence

H

HAA(s)
haloacetic acid(s)

HAA5
The regulated haloacetic acids:
monochloroacetic acid
dichloroacetic acid
trichloroacetic acid
monobromoacetic acid
dibromoacetic acid

Hg
mercury

I

ICR
Information Collection Rule

IESWTR
Interim Enhanced Surface Water Treatment Rule

IFA
Immunofluorescent Assay

IOC(s)
inorganic contaminant(s)

Is
island

J

JOC
DWR's Joint Operations Center

K

K
potassium

KCWA
Kern County Water Agency

KRI
Kern River Intertie

L

L
liters

LADWP
Los Angeles Department of Water and Power

LCID
Littlerock Creek Irrigation District

Ldg
landing

LUST
leaking underground storage tank

M

maf
million acre-feet

MCL
maximum contaminant level

MDL
method detection limit

MF
membrane filtration

MFL
million fibers per liter

Mg
magnesium

mg/L
milligrams per liter

mgd
million gallons per day

MMM
multimedia mitigation

Mn
manganese

mp
milepost

MPN
most probable number

MPD
master plan of drainage

MRDL(s)
maximum residual disinfectant level(s)

MRDLG
maximum residual disinfectant level goal

MTBE
methyl tertiary-butyl ether

MTF
multiple tube fermentation

MWDL
matrix water detection limit

MWDSC
Metropolitan Water District of Southern California

MWQI
DWR Municipal Water Quality Investigations

N

n
number

N
nitrogen

Na
sodium

NBA
North Bay Aqueduct

NBR WTP
North Bay Regional Water Treatment Plant

NEMDC
Natomas East Main Drainage Canal

ng/L
nanogram per liter

NH_4
ammonia

NO_2
nitrite

NO_3
nitrate

NPDES
National Pollutant Discharge Elimination System

NPDWR
National Primary Drinking Water Regulation

NPS
nonpoint source

NTNCWS(s)
Nontransient, noncommunity water system(s)

NTU(s)
nephelometric turbidity unit(s)

O

O&M
DWR Division of Operations and Maintenance

OEHHA
Office of Environmental Health Hazard Assessment

OES
California Office of Emergency Services

OWE
DWR Office of Water Education

P

P
phosphorus

PAHs
polynuclear aromatic hydrocarbons

Pb
lead

PCS(s)
potential contaminant source(s)

pH
negative log of the hydrogen ion activity

PHG(s)
public health goal(s)

PO_4
Phosphate

POC
Project Operations Center

POTWs
publicly owned treatment works

PP
pumping plant

ppb
parts per billion

PWC
personal watercraft

Q

QA/QC
quality assurance/quality control

R

RAP
Recovery Action Plan

RPD
relative percent difference

RWCF
regional wastewater control facility

S

SBA
South Bay Aqueduct

SBVMWD
San Bernardino Valley Municipal Water District

SCVWD
Santa Clara Valley Water District

SCWA
Solano County Water Agency

SDWA
Safe Drinking Water Act of 1974

Se
selenium

SEMS
Standardized Emergency Management Systems

SEP
State Emergency Plant

SFRWQCB
San Francisco Regional Water Quality Control Board

SGPWA
San Gorgonio Pass Water Agency

SGVMWD
San Gabriel Valley Municipal Water District

SID
Solano Irrigation District

SJR
San Joaquin River

SJRMP
San Joaquin River Management Program

SLC
San Luis Canal

SMARTS
Special Multipurpose Applied Research Technology Station

SO_4
sulfate

SOC(s)
synthetic organic chemical(s)

SRA
state recreation area

SRCSD
Sacramento Regional County Sanitation District

SRI
Sacramento River Index

SRWTP
Sacramento Regional Wastewater Treatment Plant

SSAC
Sanitary Survey Action Committee

SUVA
specific ultra violet absorbance

SVOC(s)
synthetic volatile organic chemical(s)

SWA
source water assessment

SWC
State Water Contractors

SWP
State Water Project

SWRCB
State Water Resources Control Board

SWTR
Surface Water Treatment Rule

T

TCE
trichloroethylene

TCR
Total Coliform Rule

TDS
total dissolved solids

THM
trihalomethane

TKN
total Kjeldahl nitrogen

TMDL
total maximum daily loading

TOC
total organic carbon

TON
threshold odor number

TPH
total petroleum hydrocarbons

TSS
total suspended solids

TTHMFP
total trihalomethane formation potential

U

UCMR
Unregulated Contaminant Monitoring Rule

USACE
US Army Corps of Engineers

USBR
US Bureau of Reclamation

US EPA
see EPA

USGS
US Geological Survey

UVA
see UVA$_{254}$

UVA$_{254}$
ultraviolet absorbance measured at a wavelength of 254 nanometers

UVM
ultrasound velocity meter

V

VOC(s)
volatile organic chemical(s)

W

WMP
watershed management plan

WQCP
water quality control plan

WQT
water quality threshold

WRF
wastewater reclamation facility

WSS
watershed sanitary survey

WTP
water treatment plant for production of drinking water

WWTP
wastewater treatment plant

Z

Zn
Zinc

Zone 7
Alameda County Flood Control and Water Conservation District – Zone 7

OTHERS

1µm
one micron

µ

µg/L
micrograms per liter

µm
micrometers

µmole/L
micromoles per liter

µS/cm
microseimens per centimeter

CONVERSION FACTORS

Quantity	To convert from customary unit	To metric unit	Multiply customary unit by	To convert to customary unit, multiply metric unit by
Length	inches (in)	millimeters (mm)●	25.4	0.03937
	inches (in)	centimeters (cm)	2.54	0.3937
	feet (ft)	meters (m)	0.3048	3.2808
	miles (mi)	kilometers (km)	1.6093	0.62139
Area	square inches (in^2)	square millimeters (mm^2)	645.16	0.00155
	square feet (ft^2)	square meters (m^2)	0.092903	10.764
	acres (ac)	hectares (ha)	0.40469	2.4710
	square miles (mi^2)	square kilometers (km^2)	2.590	0.3861
Volume	gallons (gal)	liters (L)	3.7854	0.26417
	million gallons (10^6 gal)	megaliters (ML)	3.7854	0.26417
	cubic feet (ft^3)	cubic meters (m^3)	0.028317	35.315
	cubic yards (yd^3)	cubic meters (m^3)	0.76455	1.308
	acre-feet (ac-ft)	thousand cubic meters (m^3 x 10^3)	1.2335	0.8107
	acre-feet (ac-ft)	hectare-meters (ha - m)■	0.1234	8.107
	thousand acre-feet (taf)	million cubic meters (m^3 x 10^6)	1.2335	0.8107
	thousand acre-feet (taf)	hectare-meters (ha - m)■	123.35	0.008107
	million acre-feet (maf)	billion cubic meters (m^3 x 10^9)◆	1.2335	0.8107
	million acre-feet (maf)	cubic kilometers (km^3)	1.2335	0.8107
Flow	cubic feet per second (ft^3/s)	cubic meters per second (m^3/s)	0.028317	35.315
	gallons per minute (gal/min)	liters per minute (L/min)	3.7854	0.26417
	gallons per day (gal/day)	liters per day (L/day)	3.7854	0.26417
	million gallons per day (mgd)	megaliters per day (ML/day)	3.7854	0.26417
	acre-feet per day (ac-ft/day)	thousand cubic meters per day (m^3 x 10^3/day)	1.2335	0.8107
Mass	pounds (lb)	kilograms (kg)	0.45359	2.2046
	tons (short, 2,000 lb)	megagrams (Mg)	0.90718	1.1023
Velocity	feet per second (ft/s)	meters per second (m/s)	0.3048	3.2808
Power	horsepower (hp)	kilowatts (kW)	0.746	1.3405
Pressure	pounds per square inch (psi)	kilopascals (kPa)	6.8948	0.14505
	head of water in feet	kilopascals (kPa)	2.989	0.33456
Specific capacity	gallons per minute per foot of drawdown	liters per minute per meter of drawdown	12.419	0.08052
Concentration	parts per million (ppm)	milligrams per liter (mg/L)	1.0	1.0
Electrical conductivity	micromhos per centimeter	microsiemens per centimeter (mS/cm)	1.0	1.0
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F - 32)/1.8	(1.8 x °C) + 32

● When using “dual units,” inches are normally converted to millimeters (rather than centimeters).

■ Not used often in metric countries, but is offered as a conceptual equivalent of customary western U.S. practice (a standard depth of water over a given area of land).

◆ ASTM Manual E380 discourages the use of billion cubic meters since that magnitude is represented by giga (a thousand million) in other countries. It is shown here for potential use for quantifying large reservoir volumes (similar to million acre-feet).

OTHER COMMON CONVERSION FACTORS

1 cubic foot=7.48 gallons=62.4 pounds of water

1 cubic foot per second (cfs)=450 gallons per minute (gpm)

1 cfs=646,320 gallons a day=1.98 ac-ft a day

1 acre-foot=325,900 gallons=43,560 cubic feet

1 million gallons=3.07 acre-feet

1 million gallons a day (mgd)=1,120 ac-ft a year