CALFED

TECHNICAL REPORT
AFFECTED ENVIRONMENT

WATER QUALITY

DRAFT

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CALFED
BAY-DELTA
PROGRAM

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BOD	biological oxygen demand
Br^-	bromide
CALFED	CALFED Bay-Delta Program
CDC	Centers for Disease Control
CFU	Colony Forming Unit
CMP	Sacramento River Coordinated Monitoring Program
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
Cl^-	chloride
CWA	Clean Water Act
DBP	disinfection byproduct
DOC	dissolved organic carbon
DO	dissolved oxygen
DWR	California Department of Water Resources
EC	electrical conductivity
EPA	U.S. Environmental Protection Agency
L	liter
µg/L	microgram per liter
µmho/cm	micromho per centimeter
µS/cm	microsiemen per centimeter
mg/L	milligram per liter
M&I	municipal and industrial
mL	milliliter
mS/cm	millisiemen per centimeter
M&I	municipal and industrial
MPN	most probable number
MWD	Metropolitan Water District of Southern California
MWQI	Municipal Water Quality Investigation
NPDES	National Pollutant Discharge Elimination System
o/oo	used to portray salinity in parts per thousand
pg/L	picogram per liter
ppt	parts per thousand
SAR	sodium adsorption ratio
SFEI	San Francisco Estuary Institute
SWP	State Water Project
TDS	total dissolved solids
TIE	Toxicity Identification Studies
TFPC	trihalomethane formation potential carbon
THM	trihalomethane
TOC	total organic content
TSS	total suspended solids
TTHM	total THM
WDR	Waste Discharge Requirement
WQCP	Water Quality Control Plan

WATER QUALITY

INTRODUCTION

This technical report describes the affected environment for resources associated with water quality that could be affected by implementation of the CALFED Bay-Delta Program (CALFED).

The parameters of concern to the beneficial uses of water are listed in Table 1. This list of parameters may change over time in response to new information.

Water quality concerns related to beneficial uses can be summarized as follows.

Environmental Beneficial Uses

Metals, pesticides, salts, and ammonia in certain concentrations can be toxic to early life stages of fish and invertebrate species. Mercury can bioaccumulate in the upper levels of the food chain, affecting larger fish, birds, and mammals. Pathogens can adversely affect fish either acutely (lethality) or chronically (histopathological effects, impaired reproduction). Solids can increase turbidity in waterbodies, reducing photosynthesis and available food for fish. Solids also can cause siltation of waterbodies, burying and ruining

Environment	Urban	Agriculture	Recreation	Industrial
Metals & Toxic Elements	**Disinfection By-product Precursors**	**Other**	**Metals**	**Other**
Cadmium	Bromide	Boron	Mercury	Salinity
Copper	TOC	Chloride	**Organics/Pesticides**	pH
Mercury	**Other**	Nutrients (Nitrate)	PCBs	Alkalinity
Selenium	Pathogens	pH (Alkalinity)	DDT	Phosphates
Zinc	Turbidity	Salinity (TDS, EC)	**Other**	Ammonia
Organics/Pesticides	Salinity (TDS)	SAR	Pathogens	
Carbofuran	Nutrients (Nitrate)	Turbidity	Nutrients	
Chlordane	pH	Temperature		
Chlorpyrifos	Chloride			
DDT				
Diazinon				
PCBs				
Toxaphene				
Other				
Ammonia				
Dissolved Oxygen				
Salinity (TDS, EC)				
Temperature				
Turbidity				
Unknown Toxicity[a]				

NOTE:

[a] Unknown toxicity refers to observed aquatic toxicity, the source of which is unknown.

Table 1. Water Quality Parameters of Concern to Beneficial Uses

spawning gravels that are essential fish reproduction habitat. Nutrient loading can lead to direct or indirect depletion of dissolved oxygen (DO) in waterbodies (through promotion of abnormal algae blooms), which can suffocate aquatic organisms, and lead to observable fish kills. Nutrient limitations may at times limit food availability to aquatic species.

Municipal Drinking Water (Urban) Beneficial Uses

Pathogens, such as *Cryptosporidium parvum*, in source waters can adversely affect public health due to the difficulty in treatment. Nutrient loading, and subsequent algae blooms, can impair the taste and odor of municipal water supplies and increase the expense of treating the water. Elevated turbidity due to suspended solids can be responsible for increased treatment costs. Salts are a major concern because of the presence in seawater of bromide (Br^-), which, when combined with water treatment disinfectants, contributes to unwanted disinfection byproducts (DBPs). Organic carbon in source waters also can adversely affect municipal drinking water supplies by producing DBPs.

Delta diversions for municipal supply water purposes occur through the State Water Project (SWP) H.O. Banks and North Bay Pumping Plants, the Central Valley Project (CVP) Tracy Pumping Plant, and the Contra Costa Water District (CCWD) Pumping Plant at Rock Slough. Figure 1 depicts the interaction between sources of bromides, organic carbon and salinity, and municipal water intakes.

Agricultural Beneficial Uses

Excess salts can result in plant toxicity and negative effects on plant growth and crop yield. Salts affect the ability of a plant to absorb water. Salts coupled with a disproportionate amount of sodium in the water can cause the soil surface to seal, limiting water infiltration. Excessive nutrients can result in excessive vegetative growth or delayed crop maturity. High pH irrigation water can result in deposits on fruit or leaves. Turbidity and nutrients can foul irrigation systems.

More than 1,800 agricultural diversions are located in the Delta. These diversions are shown in Figure 2. Irrigation water destined for use on millions of acres in the San Joaquin Valley and Southern California is exported through the Harvey O. Banks and Tracy pumping plants.

Recreational Beneficial Uses

Pathogens can adversely affect the health of those who are participating in body contact recreation. Pathogen contamination of fish or shellfish can adversely affect consumers. Certain metals and pesticides, such as mercury and DDT, bioaccumulate in the food chain and also can adversely affect consumers of the contaminated fish and shellfish. Solids loadings can increase the turbidity of waters, interfering with the aesthetic enjoyment of these natural resources and constituting a hazard to swimmers. Solids loading is also a mechanism by which pathogens, metals, pesticides, and nutrients are transported into waters that support recreational beneficial uses. Nutrient loading can promote algal blooms that reduce water clarity and sometimes cause unsightly, odorous floating mats and fouling of boat hulls. Locations of public and private Delta recreational facilities are shown in Figure 3.

Industrial Beneficial Uses

Salinity can adversely affect industrial processes such as paper manufacturing through corrosion

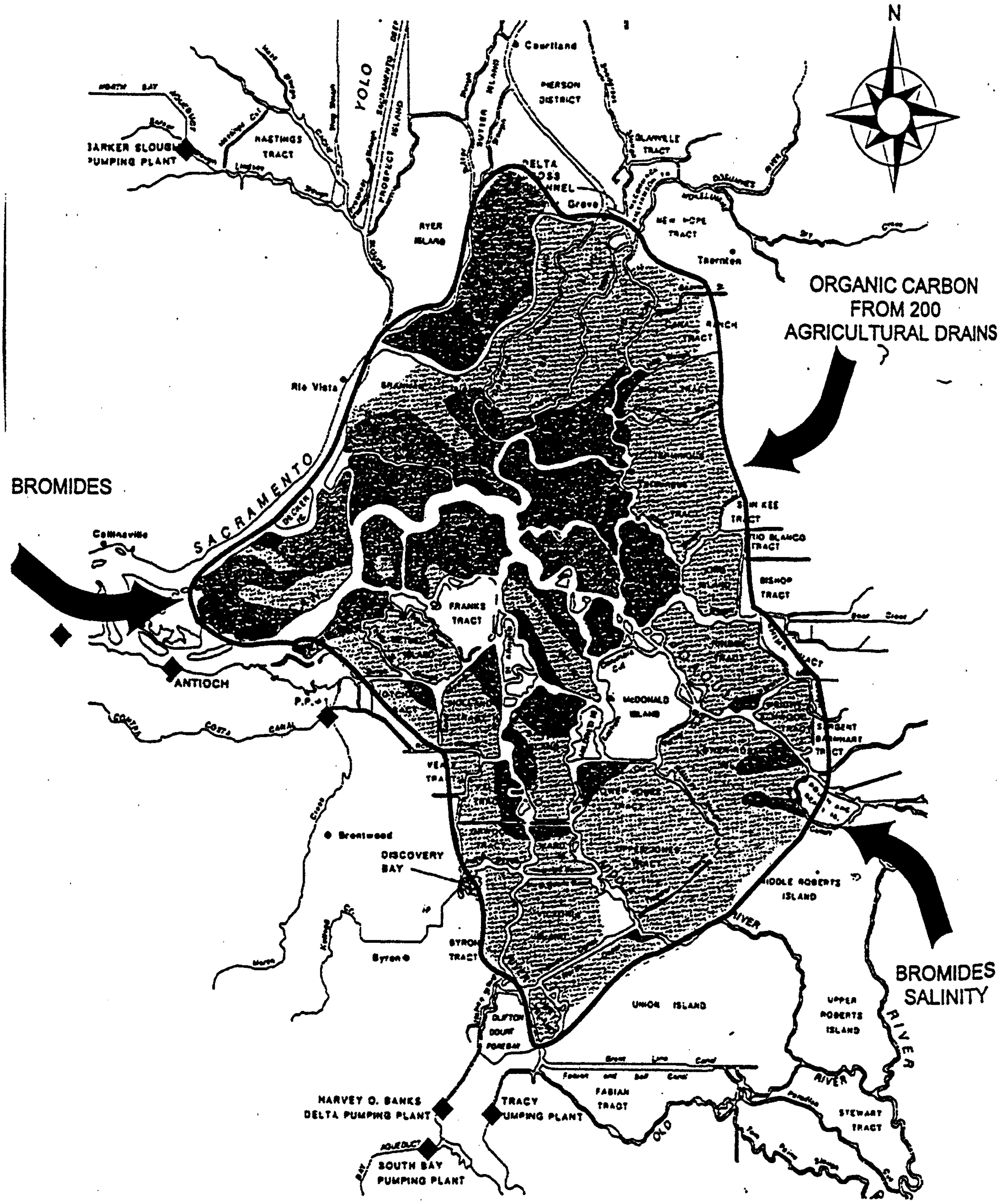


Figure 1. Location of Municipal Water Intakes in Relation to Sources of Bromides, Salinity, and Total Organic Carbon

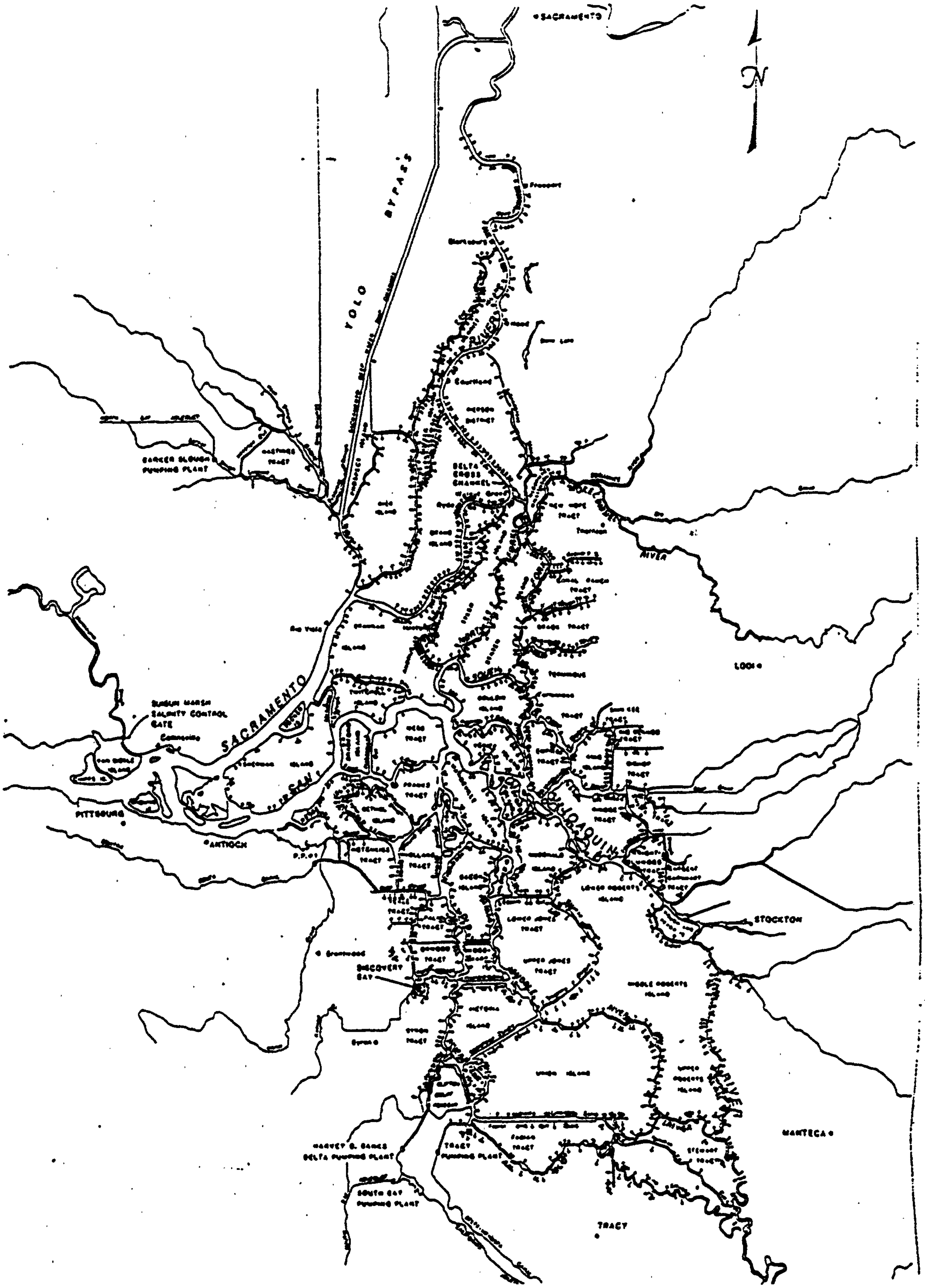


Figure 2. Agriculture Diversions

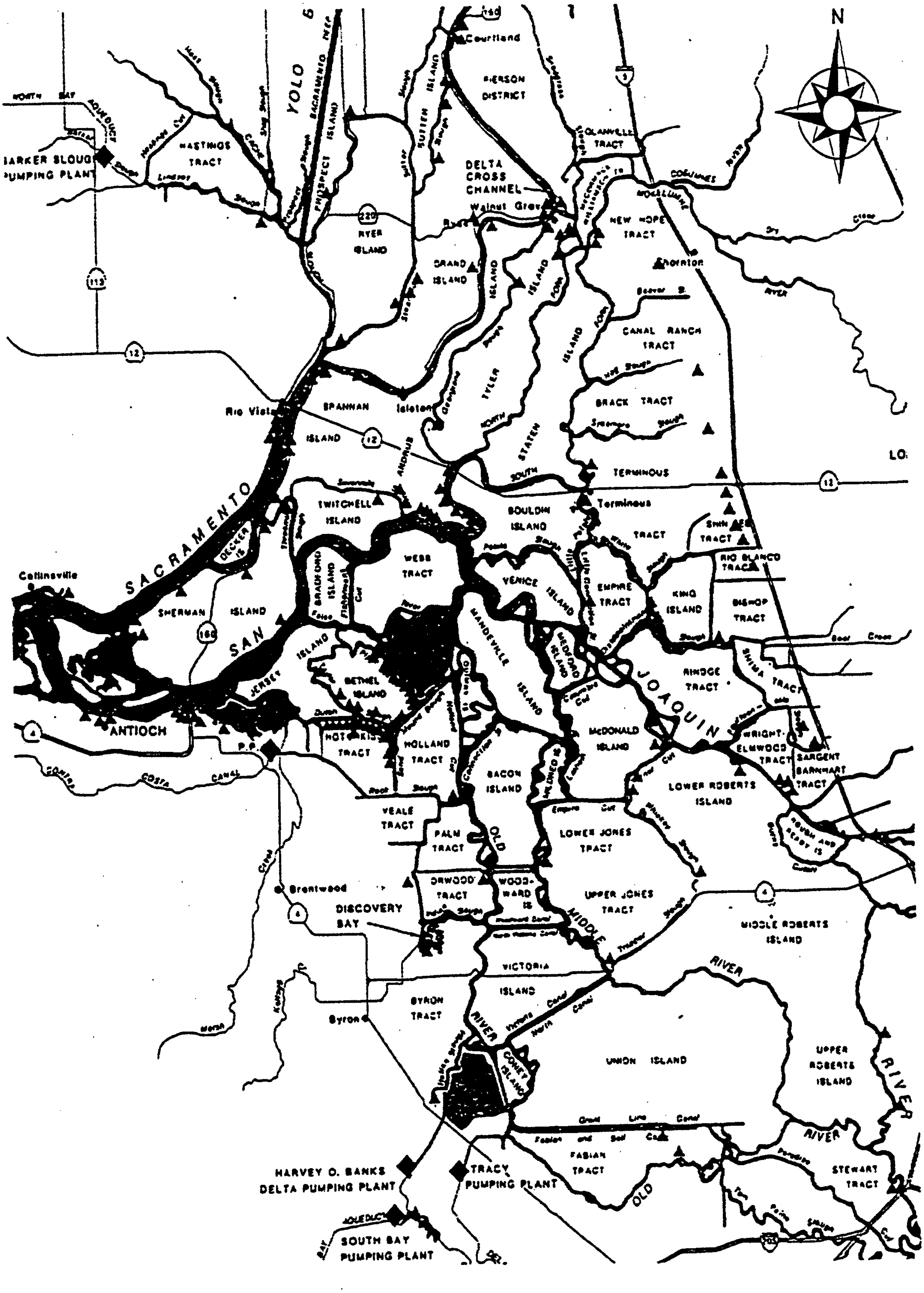


Figure 3. Marinas Located in the Delta

and mineral scaling of industrial equipment. For oil refineries, a major user of industrial water, high concentrations of phosphates can aggravate scaling concerns in cooling water systems, and high levels of ammonia can cause cracking in brass cooling heat exchangers.

Sources of Information

Many federal, state, and local agencies conduct water quality monitoring programs in the Delta. Previous and ongoing studies that provided primary data on key water quality parameters were reviewed and utilized for this assessment. These sources of data provided the results of extensive water quality, sediment, and biological tissue monitoring programs.

Additional details on water quality, sediment, and biological tissue monitoring programs can be found in the Supplement to this report.

ENVIRONMENTAL SETTING

Regulatory Context

In addition to water rights, source water and drinking water quality rules, regulations, and requirements greatly influence the quality of water available for the beneficial uses of Delta water. The following major federal and state rules, regulations, and requirements affect water quality of the Delta supply.

- Source water quality rules, regulations, and requirements
  - Delta Protection Act of 1959
  - Porter-Cologne Act
  - Decision 1485 and the 1978 Water Quality Control Plan
  - Clean Water Act - Section 303(d)
  - Federal Guidance on Water Quality
- Criteria for toxic pollutants
  - Endangered Species Act
  - Central Valley Project Improvement Act of 1992
  - Suisun Marsh Preservation Agreement
  - Bay-Delta Framework Agreement and Bay-Delta Accord
  - 1995 Water Quality Control Plan
  - California-Federal Operations Group
  - Source Water Assessment Requirements
  - National Toxics Rule
  - California Toxics Rule
- Drinking water quality rules, regulations, and requirements
  - Safe Drinking Water Act
  - National Primary Drinking Water Standards
  - National Secondary Drinking Water Regulations
  - Trihalomethane Regulations
  - Federal Lead and Copper Rule
  - Federal Surface Water Treatment Rule
  - California Surface Water Treatment Regulations
  - Disinfectant/Disinfection Byproducts Rule
  - Federal Total Coliform Rule
  - California Total Coliform Regulations

Descriptions of these source water and drinking water quality rules, regulations, and requirements are found in the Supplement to this report.

All Regions

SOURCES OF PARAMETERS OF CONCERN

Although variable hydrologic conditions, seasonal demands for water diversion, and agricultural drainage flows result in considerable fluctuations in Delta water supply and water quality conditions, the chemical characteristics of Delta inflows depend largely on land use in the upstream watershed. Sources of the parameters of concern, presented in Table 1, generally include the following:

- Drainage from inactive and abandoned mines that may introduce metals such as cadmium, copper, zinc, and mercury;
- Stormwater inflows and urban runoff that may contribute metals, selenium, turbidity, pathogens, organic carbon, nutrients, pesticides, petroleum, and other chemical residues;
- Municipal and industrial (M&I) discharges that may contribute salts, metals, trace elements, nutrients, pathogens, chemical residues, oil and grease, and turbidity;
- Agricultural tail water, or return flows, that may contribute salts, nutrients, pesticide residues, pathogens, and turbidity;
- Subsurface agricultural drainage that may contribute salts, selenium, and other trace elements; nutrients; and pesticides (some fungicides); and
- Atmospheric deposition that may contribute metals, pesticides, and some organics.

LOADINGS OF PARAMETERS OF CONCERN

As a part of this assessment, estimates of loadings were developed for four of the study area regions: Delta Region, Bay Region, Sacramento River Basin, and San Joaquin River Basin. These estimates were made of the following parameters: cadmium, bromide, copper, mercury, nitrate, selenium, total dissolved solids (TDS), total organic content (TOC), and zinc.

Two approaches were used to estimate loadings in each basin. The first approach was to estimate the load attributable to each major source and then sum the loadings for a total basin load. The second approach was to calculate the load contained in water exiting the basin at its downstream end to estimate the total pollutant emission from a basin. The results were compared. In estimating loads, many assumptions and simplifications were made, the primary ones involving year-to-year precipitation variations (a single load estimate reflecting "typical" conditions was used), the seasonality of loadings (annual basis was used), and background loads (no allowance was made for concentrations of contaminants in waters uninfluenced by human activities). Estimates of loadings will be used to determine the relative importance of different sources of the parameters of concern and the potential effectiveness of CALFED water quality-related actions.

EXISTING OR PLANNED PROGRAMS TO REDUCE LOADINGS

Several programs currently exist or are planned to reduce the loadings of parameters of concern. These programs include:

- Remediation efforts and source controls for reducing mine drainage of cadmium, copper, zinc, and mercury;
- Municipal stormwater management controls for construction site management, planning new development, industrial compliance, illegal discharges and illicit connections, and small cities, as well as the encouragement of public agency activities, public education, and monitoring;
- Permitting of M&I wastewater discharges in the Delta or its tributaries to control loadings;

- Three primary agricultural drainage programs (Drainage Reduction Program, Rice Herbicide Program, and Habitat Enhancement Landowner Program) to improve drainage water quality; and

- Upgrading water treatment facilities and developing source water assessment programs.

Additional information on loadings of parameters is found in the Supplement to this report.

WATER QUALITY CONCERNS

The major water quality issues recognized to be of concern in the Delta can be summarized in terms of parameters of concern, affected beneficial uses, and general sources of the parameter or area affected. Significant water quality issues include the following:

- High-salinity water from Suisun and San Francisco bays intrudes into the Delta during periods of low Delta outflow. Salinity adversely affects agricultural, municipal, recreational, industrial, and environmental uses.

- Delta exports have concentrations of dissolved organic carbon (DOC) that are comparable to average DOC concentrations found in raw water sources in the western United States. When chlorine is used as a disinfectant, DOC is a DBP precursor. As a result of seawater intrusion, the potential for formation of brominated DBPs increases along with increases in concentrations of the precursor, which originates in seawater.

- Synthetic and natural contaminants have accumulated in Delta sediments and can bioaccumulate in fish and other aquatic organisms. Synthetic organic chemicals and heavy metals, such as mercury, are found in Delta fish in quantities that occasionally exceed acceptable standards for food consumption.

- Agricultural drainage in the Delta contains high levels of nutrients, suspended solids, DOC, and salinity, and often contains traces of agricultural chemicals (pesticides). Of particular concern to drinking water is organic carbon generated by decomposition of the peat soils and plant biomass that occur in the Delta. Much of this organic carbon currently is collected and discharged to Delta channels by agricultural drainage, although historically the same land mass drained naturally into the sloughs and channels of the Delta. The San Joaquin River delivers water of relatively poor quality to the Delta; agricultural drainage to the river is a significant source of salts and pollutants, including selenium, boron, and pesticides. The Sacramento River also contributes some pesticide loading.

- Remnants of historical mining activities, such as tailings piles, old mines, and debris, are a source of heavy metals, including cadmium, chromium, copper, mercury, and zinc.

- Populations of striped bass and other species have declined significantly from historical levels. Causes of the declines are uncertain, although water quality conditions in the Bay and Delta, decreases in Delta inflow and outflow rates, habitat loss, agricultural and other instream diversions, and in-Delta exports are thought to be contributing factors.

- The location of the estuarine salinity gradient and its associated "entrapment zone" (where biological productivity is relatively high because of the mixing and accumulation of suspended materials) is controlled by Delta outflow. The location of the entrapment zone affects the quantity and quality of habitat for estuarine species.

- Urban development is causing an increase in pollutants via runoff. The major pollutants found in urban runoff include sediment, nutrients, oxygen-demanding substances, heavy metals, petroleum hydrocarbons, and pathogenic bacteria and viruses.

Historical Perspective

For purposes of this document, current conditions are the conditions in existence in 1995. Where information gaps exist, data from years before and after 1995 also have been used. Water quality conditions as of 1995 are described as much as possible to maintain consistency with other CALFED documents. Historical conditions are defined as those conditions occurring before 1995.

The growth of agriculture, enabled by the diversion of irrigation water from the rivers and Delta during this century has also led to water quality concerns. The application of fertilizers and pesticides on 500,000 acres of farmland within the Delta and another 4.5 million acres in the San Joaquin and Central Valley has resulted in adverse effects on the beneficial uses of water for drinking, fishery resources, recreation, and agricultural uses.

Water quality in the San Joaquin River and the south Delta has been affected by salts, which are concentrated in shallow groundwater on the west side of the San Joaquin Valley, that must be pumped in order to drain agricultural lands. Responses to the problem have included curtailment of discharges of drain water to the river, reduction in applied irrigation, and retirement of some irrigated land.

PARAMETERS OF CONCERN

METALS & TOXIC ELEMENTS

Heavy metals originate primarily from rocks and minerals, mining activities, discharges of M&I wastes, and urban runoff. Residues from heavy metals may produce serious pollution problems in the Delta because of toxic effects on fish and other aquatic organisms and may bioaccumulate in biological tissues. These residues can be measured in water, soils, sediments, and organisms that inhabit Delta channels. The detection of a particular compound depends on its persistence and mobility in the environment, as well as its source characteristics. SWRCB has characterized cadmium, copper, mercury, and zinc as pollutants of concern because their widespread or repeated detection indicates their potential to cause adverse effects on beneficial uses in the estuary (SWRCB 1990).. The bioavailability of metals to aquatic organism varies greatly, depending on the form of the metal and the hardness of the water. For example, methyl mercury is much more bioavailable than elemental mercury. Similarly, cadmium, copper and zinc are more bioavailable in acidic waters.

The majority of mine drainage problems are directly or indirectly associated with mining gold or base metals. The Central Valley Regional Water Quality Control Board (CVRWQCB) currently manages 94 inactive mines under Waste Discharge Requirement (WDR) and National Pollutant Discharge Elimination System (NPDES) permitting programs. Sampling from 1987 through 1992 indicates that 80% of cadmium, 72% of zinc, and 73% of copper in the Sacramento River comes from past mining activities.

The greatest concentration of mines can be found around Shasta Lake, with Iron Mountain Mine complex being considered the largest source in the Central Valley. Other mines can be found in the western slope foothills of the

Sierra Nevada Mountains. The most notable mines are the Penn, Walker, Cherokee, and Newton mines.

CADMIUM, COPPER, & ZINC

The Delta receives the majority of its metals loadings from historical mining activities in upstream watersheds. Mining wastes along Spring Creek in the upper Sacramento River (Shasta Dam to Red Bluff) watershed contribute large loads of chromium, cadmium, copper, nickel, and zinc to the upper Sacramento River (California Department of Water Resources [DWR] 1994a). The Iron Mountain Mine, in particular, contributes most of the cadmium, copper, and zinc transported in the Sacramento River (EPA 1992).

Urban and industrial runoff also can contribute significant loadings of copper and zinc. For example, urban runoff in the Central Valley and the Bay Area has exhibited toxicity to the test algal organism, *Selanastrum*. Toxicity studies with this species identified copper, zinc, and the herbicide diuron as causing toxicity. Cadmium, copper, and zinc have hardness-dependent criteria; these metals increase in toxicity as hardness of the ambient water decreases.

MERCURY

Historically, large amounts of mercury were used in the processing of gold, and river flows originating in historical gold-mining areas continue to contribute mercury to Delta waterways. Mercury deposits that were mined in the Cache Creek Basin are suspected to contribute high loadings of mercury to Delta waters. Natural cinnabar formations (mercury ore) contribute mercury to the Delta from Coast Range areas. Elemental mercury becomes bioavailable when it is converted into methyl mercury by bacteria in the environment. Methyl mercury bioaccumulates in organisms and may pose a human health threat when people consume highly contaminated fish.

Mercury is of concern from an environmental and human health perspective. The U.S. Environmental Protection Agency (EPA) water quality criterion is 12 ppt total mercury. SWRCB biennial water quality assessments lists 48,000 acres of Delta waterways as impaired because of fish consumption advisories for mercury (SWRCB 1992, 1994. A health advisory for the consumption of striped bass from the Delta because of elevated levels of mercury in fish tissues has been in effect since the mid-1970s.

SELENIUM

Selenium is an inorganic constituent of soils found in alluvium derived from rocks that originate on the ocean floor. The chemical forms and characteristics of selenium are in Table S-3 in the Supplement. Different forms of selenium are bioavailable at different rates. It is particularly evident in the soils of the west side of the San Joaquin River Basin. Relative to irrigation water, agricultural drainage concentrates salts containing selenium by two to five times. Selenium is leached out of soils as a result of irrigation, and concentrates further when drainage return flows are stored in surface impoundments for long periods or when irrigated land is inadequately drained.

Selenium is primarily an environmental concern. In 1983, high rates of waterfowl death and deformity were observed at the Kesterson National Wildlife Refuge and were attributed to toxic concentrations of selenium in concentrated agricultural drainage ponds. Concern continues over San Joaquin River selenium transport from irrigated and drained farm lands, industrial discharges of selenium into the Delta, and refinery releases into the Suisun Bay area.

SYNTHETIC ORGANIC CHEMICALS/PESTICIDES

Residues from organic pesticides and herbicides may produce pollution problems in the Delta because of toxic effects on fish and other aquatic organisms, and may bioaccumulate in biological tissues. Similar to heavy metals, organic pesticides are detected in a variety of sample types, depending on the persistence and mobility of the particular compound. Organic compounds such as DDT, PCBs, toxaphene and chlordane persist in the environment for many years and can bioaccumulate while carbofuran, chlorpyrifos and diazinon are relatively short-lived and do not bioaccumulate. DDT, PCBs, and toxaphene are no longer registered for use. They persist in low levels in the environment, posing a long-term chronic negative impact on organisms. In contrast, carbofuran, chlorpyrifos and diazinon are registered for use, persist for short periods (days to weeks) in the environment, and pose a short-term acute negative impact on organisms. SWRCB biennial water quality assessments list Delta waterways as impaired because of elevated synthetic organic chemicals and pesticides.

Urban runoff in the Central Valley and the Bay Area has exhibited acute toxicity to the test organism, *Ceriodaphnia*. Toxicity Identification Evaluation (TIE) studies of urban runoff have linked observed toxicity with the presence of Chlorpyrifos and Diazinon. Both of these pesticides are widely available and have been detected simultaneously in urban creeks throughout the CALFED study area. Although found throughout the year, concentrations peak during the orchard dormant spray season (Foe 1995). Ambient monitoring and composite rainfall samples suggest that the pesticides come from both urban and agricultural sources.

Concentrations of most pollutants in fish do not exceed standards established by the U.S. Food and Drug Administration or the National Academy of Sciences for the human consumption of fish tissues and protection of aquatic life, respectively. The presence of pollutants in fish demonstrates, however, that organic pesticides are bioaccumulating in Delta food webs.

BORON

Boron is essential in small quantities for optimum plant growth; however, slight exceedance of the desirable limit can result in plant toxicity problems, manifested as drying and chlorosis. Climatic and soil conditions also influence boron toxicity, with boron uptake being generally higher at lower soil pH. Sensitive crops have shown toxic effects at and below 1 milligram per liter (mg/L) (Ayers and Westcot 1989). Exceeding this limit can result in significant loss in crop yield. Boron concentrations can be reduced by various management practices similar to those for chloride. Reclaiming boron-affected soils requires leaching the boron from the root zone.

Because boron mobility is reduced by adsorption on soil particles, removing it from the soil profile requires approximately two to three times more leaching water than typically is required for reclaiming saline soils (Hanson 1993). Surface waters do not usually contain boron at toxic levels. Groundwater from wells or springs can contain toxic levels, especially near geothermal areas and earthquake faults. Some areas near the Delta are underlain by groundwater with high levels of boron. Seawater intrusion provides an influx of relatively boron-rich water to the Delta; seawater averages 4.5 mg/L boron as borate (EPA 1976).

CHLORIDE

The most common toxic ion encountered in irrigation water supplies is chloride. Chloride is adsorbed (or retained) only slightly on soil particles. It therefore moves readily with the soil water and is taken up by the crop, accumulating in the leaves during transpiration. At toxic levels, injury symptoms develop such as leaf burning and desiccation. Continued uptake can lead to dead tissue and often is accompanied by early leaf drop or defoliation.

between the ability of the crop to exclude chloride and concentrations in the soil water. Soil-water concentrations are controlled by concentrations in irrigation water and the amount of leaching that occurs. Crop tolerance of chloride is not as well documented as crop tolerance of salinity, and quantitative yield reduction relationships have not been defined. In general, however, woody plants, such as California's fruit and nut crops, tend to be more sensitive to chloride. Crops grown under overhead sprinkler irrigation can take up chloride through foliar adsorption of irrigation water into leaves during and after irrigation events. Management for chloride includes leaching in a manner similar to salinity, more frequent irrigation, selection of more tolerant crops, and blending or switching to alternative water supplies. Where foliar absorption is a problem, certain management practices have been successful in minimizing effects. Some practices require minor changes in management, while others require more elaborate and costly changes. Some of these practices include scheduling irrigation at night, avoiding irrigation during high winds, increasing sprinkler rotation speeds, increasing application rates, and increasing droplet size.

Chloride is used as a surrogate parameter for setting standards for M&I users, and the same concerns for salinity apply to chloride. Under existing standards (the 1995 Water Quality Control Plan [WQCP]) maximum chloride level is 150 mg/L at urban intakes in the Delta for between 155 and 240 days of the year (depending on the water-year type) and 250 mg/L the rest of the year.

Disinfection Byproducts in Treated Drinking Water

Trihalomethane (THM) compounds formed during chlorination of drinking water include chloroform and brominated methanes. Chloroform, when administered at high doses, has been shown to increase the risk of liver and kidney cancer in mice (National Cancer Institute 1976). The suspected carcinogenic risk to humans from THMs has led some communities to study and change their methods of disinfecting drinking water. THM levels in drinking water can be reduced by using alternatives to chlorination to treat water, such as ozonation or chloramination. Other potentially harmful DBP compounds, such as bromate, may be formed during these alternative disinfection processes. Disinfection itself is being more carefully regulated by EPA to avoid problems involving various pathogens (for example, bacteria, viruses, and protozoa). Reducing DOC concentrations in raw water with flocculation or granular-activated carbon adsorption before disinfection, or removal of DBPs after being formed, can reduce DBP levels in finished water but may be quite expensive.

Bromide

Most of the Delta islands are as much as 10 to 15 feet below mean tide level. Tides in the Delta not only threaten the protecting levees but also bring periodic intrusion of seawater, which mixes with the inflowing Delta freshwater. Tidal currents created by the rise and fall of sea levels modify stream flow, particularly when outflows are low or when tides are high (DWR 1989). Intruded seawater is a major source of bromide, particularly in the western Delta. Bromide is a naturally occurring salt ion (halogen) of seawater origin and reacts with disinfectants to form brominated DBPs. Thus, intrusion profoundly affects Delta water withdrawn at the CCWD, SWP, and CVP intakes.

The presence of bromide in a drinking water source complicates the disinfection process. Bromide forms THMs in the chlorination process, and these brominated THMs are also carcinogenic compounds. Bromide is about twice as heavy as chlorine, and the THM standard is based on weight. Hence it takes fewer molecules of brominated THMs to exceed the drinking water standard, as compared to chloroform. Another method of disinfection, ozone treatment, also is complicated by the ozone treatment, also is complicated by the presence of bromide because it forms bromate, another undesirable DBP. Bromide contributes substantially to the formation of DBPs in treated drinking water from the Delta. Sources of bromide in Delta water are seawater intrusion, San Joaquin River inflow containing agricultural drainage and, possibly, connate groundwater, which is water trapped within sedimentary rocks that often is highly mineralized. It is uncertain whether native bromide sources are in the San Joaquin Valley or whether bromide found in the river is a result of concentration of bromides in agricultural irrigation water taken from the Delta and returned to the Delta through the River. Bromide has been measured by the Municipal Water Quality Investigation (MWQI) Program since January 1990.

TOTAL AND DISSOLVED ORGANIC CARBON

Organic materials enter water from the following sources in the Delta:

- natural materials, vegetation, and organics soils;
- agriculture, as vegetative organics in drainage;
- urban runoff;
- M&I wastewater discharges; and
- organic carbon.

Organic carbon is one of the primary variables that influence the potential for DBP formation. Applicable drinking water standards are based on TOC concentrations; however, most of the available data for the Delta have focused on DOC. In general, most TOC in Delta waters is present in the dissolved form. The most common DBP is THM compounds formed during chlorination of DOC in drinking water supplies. These carcinogenic substances include chloroform and bromoform. MWQI studies have documented that Delta exports contain relatively high concentrations of DOC. Of particular concern to drinking water is organic carbon generated by decomposition of the peat soils and plant biomass that occur in the Delta. Much of this organic carbon currently is collected and discharged to Delta channels by agricultural drainage, although historically the same land mass drained naturally into the sloughs and channels of the Delta. Agricultural drainage discharges that contain natural organic matter from decomposing peat soil and crop residues contribute approximately 20% of the DOC exports from the Delta (DWR 1994b). Additionally, DOC is carried into the Delta from upstream inflows. Minimizing DOC concentrations in source waters is a major water quality goal for drinking water uses to meet new EPA regulations for DBPs. Utilities must undertake efforts to control organic carbon in their source water or to modify disinfection methods if TOC exceeds 2 mg/L at the water intake.

DISSOLVED OXYGEN

DO concentrations serve as indicators of the balance between sources of oxygen (aeration and photosynthesis) and oxygen consumption (decay and respiration processes). The capacity of water to hold DO decreases with increasing temperature. DO concentrations often vary with the cycle of daily photosynthetic activity of algae and plants. Historically, significantly reduced DO concentrations in Delta channels have not occurred, except occasionally in the waterways near Stockton and in some dead-end sloughs. Water with high biological oxygen demands (BOD) may have decreased levels of DO when wastes are discharged into them.

NUTRIENTS

Nitrogen and phosphorous are the two nutrients that most often limit algal growth at low concentrations and trigger algal growth at elevated concentrations. Generally, in the presence of sufficient light and elevated temperatures, algal productivity increases as nutrient concentrations increase. This results in a cycle of nutrient enrichment, plant growth, accumulation of decaying plants, oxygen depletion, and nutrient recycling from decomposed material in the sediment. Eventually, the rate of oxygen consumption can exceed production, resulting in odors and in the death of fish and aquatic life. Drinking water taste and odor problems can occur from algae decomposition and the production of blue-green algae.

For agriculture, excessive nutrients can result in excess vegetative growth, reduced yields, delayed or uneven maturity, or reduced quality. Algal growth stimulated by excess nutrients can increase facilities maintenance costs. In extreme cases, irrigation equipment for sprinkle and drip irrigation can plug, increasing maintenance costs. Sensitive crops may require an alternative or blended water supply, or may not be grown. Alternatively, more tolerant crops can be grown, but other water quality parameters, land suitability, and market conditions dictate crop selection. Sources of nutrients include wastewater treatment plant discharge, urban and industrial runoff, agricultural drainage, and agricultural surface runoff.

PATHOGENS

Microbiological organisms of principal concern as agents of disease or indicators of potential contamination in drinking water include coliform bacteria, viruses, and protozoan and helminth parasites. Total coliform bacteria measurements indicate the general level of urban and animal contamination of a water supply. Microbial agents have been responsible for waterborne outbreaks of infectious disease. Their presence in raw waters has been a principal thrust of water treatment technology. Waterborne diseases still occur in the United States. The Centers for Disease Control (CDC) and EPA have estimated 1 million cases of illness per year and 1,000 deaths per year due to waterborne diseases.

Principal waterborne bacterial agents that cause human intestinal disease are summarized in Table 2. Rather than attempt to analyze each of these pathogenic bacteria, water utilities routinely monitor for total and fecal coliform bacteria, as indicator organisms. With few exceptions, these indicator organisms, which primarily originate in the intestinal tract of warm-blooded animals, are not pathogenic. Because coliforms are usually more abundant by several orders of magnitude than pathogens in human waste, the tests generally provide a margin of safety against pathogens. If coliforms are not detected, it is assumed that bacterial pathogens would be absent below the levels known to be infectious. Although the tests have limitations, they are still the most widely used indicators of bacterial water quality.

VIRUSES

In contrast to bacteria/agents, enteric viruses always are assumed to be pathogenic. The prevailing theory is that only one infective unit (which may be as low as one virus) can cause infection. The extent of waterborne diseases due to viruses is not well quantified for the following reasons: clinical symptoms do not always result from infections; it is difficult to link infections to a waterborne source; there are difficulties in detecting viruses; and people are exposed to viruses from many sources. The CDC estimates that of the 1 million cases per year of illness from waterborne microorganisms, perhaps more than 50% are viral. Viruses of concern in drinking water are listed in Table 3. The enteroviruses (polio, Coxsackie A, Coxsackie B, and echoviruses), adenoviruses, retroviruses, the hepatitis viruses, and rotavirus can be detected by laboratory cell culture techniques.

Bacteria	Disease
Salmonella typhi	Typhoid fever
Salmonella paratyphi-A	Paratyphoid fever
Salmonella (other species)	Salmonellosis, enteric fever
Shigella dysenteriae, S. flexneri, and *S. sonnei*	Bacillary dysentery
Vibrio cholerae	Cholera
Leptospira sp.	Leptospirosis
Yersinia enterocolitica	Gastroenteritis
Francisella tularensis	Tularemia
Escherischia coli (specific enteropathogenic strains)	Gastroenteritis
Pseudomonas aeroginosa	Various infections
Enterobacteriacae (Edwardsiella, Proteus, Serratia, Bacillus)	Gastroenteritis
Campylobacter	Gastroenteritis

Table 2. Principal Waterborne Bacterial Agents and Their Associated Health Effects

Virus Group	Number of Types	Common Disease Syndromes
Enteroviruses		
Polioviruses	3	Poliomyelitis, aseptic meningitis
Coxsackieviruses A	23	Herpangina, asepticmeningitis, exanthem
Coxsackieviruses B	6	Aseptic meningitis, epidemic myalgia, myocarditis, pericarditis
Echoviruses	31	Aseptic meningitis, exanthem, gastroenteritis
Adenoviruses	31	Upper respiratory illness, pharyngitis, conjunctivitis
Retroviruses	3	Upper respiratory illness, diarrhea, exanthem
Hepatitis viruses	1	
Hepatitis A Virus		Viral hepatitis type A or infectious hepatitis
Hepatitis B Virus	4	Viral hepatitis type B or serum hepatitis
Rotavirus	2	Gastroenteritis
Norwalk agent	1	Gastroenteritis

Table 3. Enteric Viruses and Their Associated Diseases

PARASITES

Eggs and cysts of parasitic protozoa and helminths (worms) excreted into the environment may enter water supplies. All can severely disrupt the intestinal tract. Two of these are *Giardia lamblia* and *Cryptosporidium parvum*. Their cysts/oocysts are far more resistant to disinfectants than bacteria or most viruses.

GIARDIA LAMBLIA

This is the intestinal protozoan most frequently found in human populations worldwide and is the most commonly identified agent of water-borne diseases in the United States (Feachem et al. 1983). Waterborne giardiasis may be increasing in the United States, with 95 out-breaks over the last 25 years. However, this increase also may be associated with more accurate diagnosis in recent years. Over 60% of all *Giardia lamblia* infections are believed to be acquired from contaminated water. *Giardia* *lamblia* cysts are found in water contaminated by fecal material from infected humans and animals. *Giardia lamblia* forms an environmentally resistant cyst that allows the parasite to survive in surface water and treated drinking water. Ingestion of as few as 10 cysts can cause infection (as reported in Rose et al 1991a.). In this study, infection was measured by the excretion of cysts, and illness was not determined. The ratio of illness to infection is highly variable. *Giardia lamblia* infections with no symptoms of illness may be as high as 39% for children under 5 years old and 76% for adults in certain populations (Craft 1981, Wolf 1979; as reported in Rose et al. 1991a). At the same time, symptomatic infections have been reported at a rate of 50 to 67% and as high as 91% in others (Veazie et al. 1979, as reported in Rose et al. 1991a). In yet other groups, chronic giardiasis may develop in as many as 58% of an infected population.

CRYPTOSPORIDIUM PARVUM

This intestinal protozoan parasite was first identified in 1907 but was not recognized to cause diarrheal disease in humans until 1980. The first documented waterborne outbreak of cryptosporidiosis in humans occurred in the United States in 1985. In January 1988, EPA added *Cryptosporidium parvum* to the Drinking Water Priority List. The severe gastro-intestinal symptoms of the disease last an average of 12 days and are self-limiting in people with normal immune function. Illness patterns vary with age, immune status, and variations in the virulence of *Cryptosporidium parvum*. Young mammals are more susceptible. In immuno-deficient individuals, cryptosporidiosis can cause mortality. The oocyst (infective stage) dose necessary to cause an infection in humans is unknown but may be low. In a primate study, two individuals became infected after exposure to only 10 oocysts (Miller et al. 1986). No effective treatment for the disease exists.

Cryptosporidium parvum is transmitted between humans and warm-blooded animals, including cats, dogs, cattle, goats, mice, pigs, rats, and sheep (Fayer and Ungar 1986, as reported in Rose et al. 1991a). *Cryptosporidium parvum* from birds will not infect mammals. Common sources of *Cryptosporidium parvum* in water are wildlife in a watershed, sewage discharges, and domestic animals (including runoff from grazing lands and dairies). For example, surface water running through cattle pastures can contain up to 6,000 oocysts per liter (L) (Madore et al., as reported in Peeters et al. 1989).

Cryptosporidium parvum in drinking water strongly resists chlorine disinfection. In addition, *Cryptosporidium parvum* levels do not correlate well with indicator coliform bacteria levels; therefore, meeting standards for coliforms and turbidity (a measure of the reduction of clarity of a water by suspended particles) may not be a sufficient measure of treatment reliability for removal of *Cryptosporidium parvum*. Normal levels of chlorine in drinking water have been shown to be ineffective for inactivating *Cryptosporidium parvum*, even after 18 hours of contact. However, ozone and chlorine dioxide have been found to be more effective disinfectants (Peeters et al. 1989). Sand filtration alone reduces but does not completely eliminate oocyst concentrations. Filtration with coagulation achieves greater removals.

PH

The formation of DBPs in drinking water depends on a variety of parameters, one of which is pH. Source water pH can affect the effectiveness of drinking water treatment technologies. For agriculture, pH problems are related to potential corrosion or plugging of irrigation equipment (such as aluminum pipe and drip emitters) and precipitation of residues on plants (such as cut flowers in greenhouses). Nutritional imbalance can be caused by irrigation water with a pH outside the normal range.

pH also may directly affect the survival and health of aquatic organisms, either as direct effects of excessively high or low pH, or as a determinant of the toxicity of certain contaminants (most commonly ammonia, but also pentachlorophenol).

SODIUM ADSORPTION RATIO

Sodium absorption ratio (SAR) is of concern to agricultural beneficial uses. Sodium in irrigation and soil waters can impair crop production. Excessive sodium can destroy soil structure and reduce the infiltration of water into the soil. Plant growth can be affected by drought stress and lack of aeration. When calcium and magnesium are the predominant cations absorbed onto soil particles, the soil tends to have a granular structure that is easily tilled and readily permeable. Unbalanced by other cations, large amounts of sodium can disperse soil particles, so that soil structure breaks down and hydraulic conductivity decreases. Good soil structure and adequate drainage are essential for sustainable soil and salinity management. Additional agronomic issues arising from excess sodium include soil crusting (especially over seedbeds); temporary saturation of the soil surface layer; and related disease, weed, root-respiratory, and nutritional problems. In extreme cases and for sensitive plants, sodium ions can be phytotoxic, much in the same manner as chloride. Management of sodium by leaching alone can be impractical because of problems with soil aeration and drainage. Sodium generally is managed by replacement with calcium through the addition of gypsum, or sulfuric acid, which reacts with soil calcium carbonate, to liberate calcium. These treatments must be followed by leaching with water of acceptable quality. In general, the benefit of a water-applied amendment is much greater when the irrigation water salinity is relatively low. The primary sources of sodium are seawater and agricultural drainage. SAR can affect crop yields and sensitive crops such as orchards and beans. This is a particular issue in the western and interior Delta.

SALINITY

Salinity is of concern to municipal users because: (1) bromide, a component of saline water, forms DBP precursors (bromide and TOC); (2) low salinity supplies are needed to assure the feasibility of local wastewater reclamation and conjunctive use projects; (3) low salinity supplies are needed to minimize and retard the corrosion of infrastructure and appliances; (4) low salinity supplies are needed to improve the aesthetics of drinking water; and (5) salinity is a health concern for people on low sodium diets. Salinity is of concern to agricultural users because of potential plant toxicity problems (CUWA 1996).

Salinity is of concern to environmental water supplies because the area and amount of low salinity habitat in estuaries is important to the success of many species such as anadromous fish, as well as the success of other estuarine ecosystem components such as tidal marshes.

Sources of salinity include seawater intrusion into the Delta from San Francisco Bay and connate groundwater. The magnitude of saline water intrusion is influenced by Delta outflow, which defines the upstream boundary of the salinity gradient. Seawater is the primary source of salinity. Agricultural drainage from the Delta, upstream agricultural drainage from sources on the Sacramento and San Joaquin rivers, and urban runoff also may affect salinity concentrations. Urban runoff consists of dissolved minerals, whereas agricultural drainage is made up of soluble salts from irrigation water leached from the soils (CUWA 1995). In addition, M&I wastewater is a source of salinity.

Electrical conductivity (EC), more correctly known as specific conductance, is the most common general measure of dissolved minerals in Delta waters, and serves as a common surrogate measure of either TDS or salinity. EC generally is considered a conservative parameter that does not degrade. Therefore, changes in EC values can be used to interpret the movement of water and the mixing of salts in the Delta. EC values increase with concentration and decrease with dilution, and may be elevated in wastewater and agricultural drainage discharges and areas affected by seawater.

For agriculture, irrigation water quality affects the amount and type of salts found in soil. When water is applied as irrigation, crop uptake and evaporation remove pure water with some dissolved salts, particularly nutrient salts. However, most of the water's salt load remains in the crops root zone after uptake of water by roots. When water does not leach from the soil, but is added only to meet crop needs, the soil accumulates residual salt over time. If the frequency of leaching is too low, salt concentrations may reach levels that stress growing plants. In general, salt influences plant growth by depriving the roots of water. Water uptake by plants is driven by differences in water content and salt concentration between the root interior and the soil. When the salt concentration of the soil increases, plants must accumulate salt themselves, or must dehydrate to continue to extract water from the soil.

Plants vary in their ability to adapt to saline conditions by these and other mechanisms, and therefore vary in their ability to tolerate saline conditions. Even tolerant plants, though they survive, may not produce as much when grown under saline conditions. This is because extraction of water from saline soil requires more plant energy, which might otherwise be allocated for plant growth and metabolism. In addition to crop water uptake, salinity can affect agronomic systems in other ways (see "Sodium Adsorption Ratio" above). The major objective in selecting management practices to control salinity is to maintain adequate soil water availability to the crop. Procedures that require relatively minor changes in management are more frequent irrigation events, selection of more salt-tolerant crops, additional leaching, pre-plant irrigation events, and altered seed placement. Alternatives that may require significant changes in management include changing the irrigation method, altering the water supply, land-grading, modifying the soil profile (deep ripping), and installing artificial drainage. Management practices must fit the method of irrigation.

Chloride is used as a surrogate parameter for setting salinity standards for M&I uses. Under existing standards (the 1995 WQCP) maximum chloride level is 150 mg/L at urban intakes in the Delta for between 155 and 240 days of the year (depending on the water year type) and 250 mg/L the rest of the year. For water in the Delta, chloride levels of 150 and 250 mg/L correspond to TDS concentrations of about 390 to 570 mg/L, respectively, and EC of about 700 and 1,050 μS/cm, respectively.

TEMPERATURE

Temperature governs rates of biochemical processes and is a major environmental factor in determining organism habitat preferences behavior, and larval stage and egg survival. Water temperatures in the Delta are generally a function of the weather, runoff conditions, and the amount of vegetation providing shade. Delta water temperatures are influenced only slightly by water management activities. The most common environmental effects associated with water temperatures are localized effects, such as thermal shock, caused by discharges at substantially elevated temperatures. Fish growth, activity, and mortality are related to their temperature tolerances. The Delta supports fish species such as the chinook salmon and striped bass, which require different warmwater and coldwater habitat conditions.

For agriculture, the temperature of irrigation water has direct and indirect effects on plant growth. Physiological functions are impaired by excessively high or excessively low temperatures. The direct effects on plant growth from extreme temperature of the irrigation water occurs when the water is first applied; effects are less pronounced with pressure irrigation systems than with surface irrigation systems. Indirect effects of the temperature of irrigation water on plant growth occur as a result of the water's influence on soil temperature. Most temperature effects primarily are related to rice seedling emergence and crop development. Rice production is concentrated in the northern San Joaquin and southern Sacramento valleys. When water is colder, irrigation facilities that spread water out for solar warming can be used, including shallow reservoirs and flooded fields. Some rice farms designate an upper part of the field for spreading and warming water, or they accept lower productivity in the parts of their farm that receive irrigation water directly from the canal.

TURBIDITY

Turbidity is a nonspecific measure of suspended matter such as clay, silt, organic particulates, plankton, and microorganisms. The presence of total suspended solids (TSS) (often measured as turbidity) is a general indicator of surface erosion and runoff into waterbodies, resuspension of sediment materials, or biological productivity. Following major storms, water quality often is degraded by inorganic and organic solids and associated adsorbed contaminants, such as metals, nutrients, and agricultural chemicals, that are resuspended or introduced in runoff. Because such runoff and resuspension episodes are relatively infrequent and persist for only a limited time, they often are not detected in regular sampling programs. The main causes of high TSS concentrations include large Delta inflows, sediment resuspension during dredging activities, agricultural drainage discharges, and suspended planktonic algae.

The attenuation of light in Delta waters is controlled by TSS concentrations (with some effects from chlorophyll). These concentrations often are elevated in the entrapment zone as a result of increased flocculation, or aggregation of particles, in the estuarine salinity gradient. High winds and tidal currents also contribute to increased TSS concentrations in the estuary. Suspended sediments tend to suppress algae growth in much of the Delta (SWRCB 1995). In addition, recent colonization and growth of introduced bivalves has contributed to seasonal reductions in turbidity in some areas of the Delta (due to enhanced filtration of the water column by the benthic clams).

Elevated concentrations of TSS are of particular concern in upper watershed streams where salmonids spawn in gravel beds. Sediments may smother incubating eggs and kill them by eliminating their exposure to fresh, aerated water.

Turbidity is of concern in drinking water because it can render water aesthetically unacceptable to the consumer; reduce the efficiency of disinfection by shielding microorganisms; and act as a vehicle for the concentration, transport, and release of organic and inorganic toxicants, bacteria, and viruses.

From an agricultural perspective, the effects of turbidity on plants and soils include the formation of crusts at the soil surface (which inhibits water infiltration and aeration, impedes seedling emergence, and hinders leaching of saline soils), and the formation of films on plant leaves (which blocks sunlight and reduces photosynthesis and marketability). High colloidal content in water used for sprinkler irrigation can result in deposition of films on leafy vegetable crops such as lettuce, which affects marketability and management. Settleable matter in the water can prematurely decrease reservoir capacity and increase maintenance requirements on delivery canals due to siltation. Turbidity also increases wear on pumping facilities. As agricultural lands in the Sacramento and San Joaquin valleys continue to be irrigated with low-volume irrigation systems like drip and micro-sprinkle,

Source	Bromide (1,000 lbs/yr)[1,2]	Cadmium (lbs/yr)[3]	Copper (1,000 lbs/yr)	Mercury (lbs/yr)	Nitrate (1,000 lbs/yr)	Selenium (lbs/yr)	TDS (1,000 lbs/yr)	TOC (1,000 lbs/yr)	Zinc (1,000 lbs/yr)
Upper Sacramento River Basin above Dams									
Agriculture	NSL	NSL	NSL	NSL	NSL	NSL	ND	NSL	ND
Mine drainage	NSL	530[b]	220[b]	ND	ND	NSL	NSL	NSL	990[b]
M&I wastewater (POTW)	NSL	2	0.11[c]	0.5[c]	15[c]	4.9[c]	ND	NSL	0.60[c]
Urban runoff	NSL	NSL	NSL	NSL	NSL	NSL	ND	NSL	ND
Flow regulation	NSL	ND	NSL	ND		NSL	NSL	NSL	NSL
Total load									
Basin emission	NSL					ND	ND	ND	ND
Lower Sacramento River Basin below Dams									
Agriculture	380[a]	600[a]	41[a]	NSL	ND	ND	1,600,000[a]	17,000[a]	110[a]
Mine drainage	ND	3,400[b]	330[b]	ND	ND	NSL	ND	ND	4,500[b]
M&I wastewater (POTW)	ND	91[c]	2.8[c]	11[c]	830[c]	260[c]	230,000[c]	9,900[c]	28[c]
Urban runoff	ND	600[d]	21[d]	NSL	1,700[d]	NSL	43,000[d]	ND	161[d]
Flow regulation	NSL	ND	NSL	ND	ND	NSL	NSL	NSL	NSL
Total load									
Basin emission	900[e]	2,200[c]	700[e]	900[e]	ND	ND	8,600,000[e]	230,000[e]	1,300[e]
San Joaquin River Basin									
Agriculture	ND	ND	ND	NSL	ND	7,000[a]	760,000[a]	7,500[a]	ND
Mine drainage	ND	10[b]	0.20[b]	2[b]	ND	NSL	ND	ND	ND
M&I wastewater (POTW)	ND	16[c]	0.80[c]	3.5[c]	120[c]	36[c]	ND	ND	4.5[c]
Urban runoff	ND	200[d]	7[d]	NSL	85[d]	NSL	680[d]	ND	53[d]
Flow regulation	NSL	<160[c]	NSL	ND	ND	NSL	NSL	NSL	NSL
Total load									
Basin emission	1,300[e]	<160[e]	91[e]	ND	N	9,200[e]	1,700,000[e]	35,000[e]	250[e]
Delta Region									
Agriculture	ND	ND	ND	NSL	ND	ND	ND	34,000[a]	ND
Mine drainage	ND	NSL	4[b]	ND	ND	NSL	NSL	ND	ND
M&I wastewater (POTW)	ND	80[c]	1.4[c]	6.0[c]	200[c]	64[c]	ND	ND	7.8[c]
Urban runoff	ND	150[d]	5[d]	NSL	ND	NSL	ND	ND	38[d]
Flow regulation	NSL	ND	NSL	NSL	ND	NSL	NSL	NSL	NSL
Total load									
Basin emission	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bay Region									
Agriculture	ND	NSL	NSL	NSL	NSL	NSL	ND	ND	ND
Mine drainage	ND	NSL	NSL	ND	NSL	NSL	NSL	ND	ND
M&I wastewater (POTW)	260[c]	6,600[c]	13[c]	58[c]	1,900[c]	4,800[c]	ND	ND	74[c]
Urban runoff	3,000[d]	3,000[d]	70[d]	70[d]	ND	NSL	ND	ND	220[d]
Flow regulation	NSL	NSL	NSL	NSL	ND	NSL	NSL	NSL	NSL
Total load									
Basin emission	ND	ND	ND	ND	ND	ND	ND	ND	

NOTES:

NA = Not available.
NSL = Source does not contribute significant load of constituent in this watershed.
POTW = Publically owned treatment works.
ND = Not determined (further literature review is required).

Loads include background and/or upland sources.
Loads may vary significantly from mean annual values, depending on water-year type.
See Supplement for further notes and an explanation of how the loading estimates were derived.

1 Seawater intrusion from San Francisco Bay is a source of bromide to the Delta; however, no quantitative estimate of this source is available.
2 San Joaquin loads reflect bromide that originates from the Bay and is recirculated (see Supplement).
3 *Basin emissions for cadmium are unreliable as most data are below detection levels.*

a-e Lettered footnotes provide the background and references associated with the accompanying load (see Supplement).

Table 4. Estimated Mean Annual Loadings for Parameters of Concern

clogging, maintenance, and on-farm water management (filtration) requirements will need to be considered when selecting a new system or evaluating water supply. Filtration and maintenance requirements for turbid water for low-volume irrigation can be costly and may make the water unusable.

LOADINGS OF PARAMETERS OF CONCERN

Where information was available, estimated loadings for parameters of concern were developed. These estimates are shown in Table 4. Source loadings originate primarily from agricultural drainage or mine drainage, wastewater discharges, and urban runoff. They may be modified by flow regulation. These tables provide the quantitative results of the analysis of the relative loadings of parameters from all CALFED study regions except for the SWP and CWP Service Areas Outside the Central Valley. Additional information used in compiling these tables can be found in the Supplement.

The Sacramento River Basin estimates were subdivided into loads generated above and below the three major dams: Shasta, Oroville, and Folsom.

Load estimates were used to help evaluate the relative importance of different sources and the potential effectiveness of CALFED water quality actions. For example, it may be determined that M&I wastewater treatment plants contribute less than 5% of the copper discharges to the Delta. It is apparent from the copper loading estimates that additional measures to reduce copper from this source are unlikely to significantly affect copper concentrations in the Delta.

ANALYTICAL APPROACH AND ORGANIZATION OF INFORMATION

Considerable information on pollutants discharged to the Sacramento River Basin, the San Joaquin River Basin, the Delta, and the Bay Region, as well as pollutant concentrations found in various waterbodies, is available, but it is not found in a single repository. Developing estimates of pollutant loadings involves compilation of potentially relevant data from published and unpublished sources, review of the data by the CALFED water quality team, and, in many cases, further adjustment of the data to provide the most realistic load estimates possible.

Pollutant load estimates are difficult to make for large geographical areas because data are always limited and many assumptions must be made. The approach used here was to try to make fairly complete load estimates for the various constituents, even if fairly gross assumptions are required.

The results of the analysis are summarized in nine separate sections which address each key constituent of concern. Each section contains a tabular summary of loading data and a series of notes. Additional notes in the Supplement describe the data sources and any analyses undertaken to produce the load estimates.

Two approaches to load estimation were used, and where possible, their results were compared in the tabular summaries. The first approach was to estimate the loads attributable to each of the major sources and then to sum the loads to provide a total basin load. Major contaminant source categories include agricultural tailwater (surface) runoff and subsurface drainage, mine drainage, M&I wastewater discharges, and urban stormwater runoff. Loadings from these sources are typically associated with discharges from outfalls and/or agricultural drains.

The second approach was to estimate the total pollutant emission from each basin based on in-stream flows and water quality data. The loads calculated using the two approaches are not directly comparable because some of the pollutants discharged to waterways in a basin may be stored in sediments, reservoirs and biota, or transformed into other substances as a consequence of chemical reactions and biological activity. However, they do provide a means to check for order-of-magnitude reasonableness.

LIMITATIONS

Because of the many assumptions and simplifications involved in the load estimates, the results are only order-of-magnitude estimates and they should be used with caution. Moreover, informational gaps precluded making estimates for all sources, including many that are considered to be major. The more important assumptions and simplifications are noted below.

Year-to-Year Variations

Most contaminant sources are affected by meteorological conditions. For example, the total annual contaminant loads from agricultural and urban runoff depend on the volume of runoff, which can vary widely from year-to-year. Similarly, annual mine drainage loads are weather-dependent. Waste loads associated with M&I wastewater discharges are less affected by weather. The same may be true for waste loads in agricultural subsurface drainage, which probably depend more on irrigation rates than precipitation.

Because the data available to characterize contaminant loads are limited, they were not separately compiled for different meteorological conditions. Ideally, loads should be separately estimated for wet, normal, dry, and very dry years. Instead, data from different years, representing different meteorological conditions, were compiled to produce a single annual load estimate. Thus, they are not truly representative of actual conditions.

Seasonality of Loadings

Most contaminant emissions vary seasonally. The initial load estimates contained in this report were made on an annual basis. In cases where pollutant effects are seasonal, seasonal loads may be a more appropriate indicator than annual loads.

Background Loads

The load estimates do not attempt to account for background loads. Many substances regarded as contaminants occur at low concentrations in waters not influenced by human activities. This is the case for metals and trace elements, salts, naturally-occurring organic substances, and nutrients. It does not apply to synthetic organics, including pesticides.

This lack of allowance for background loads probably does not greatly affect load estimates for relatively concentrated waste streams. If, for example, a city draws water from a river, uses it for municipal supply, and discharges it back to the river following wastewater treatment, then the phosphorus load attributable to the municipal wastewater discharge is the load contained in the effluent less the background load contained in the source water. In this case, the background phosphorus concentration might be 0.05 mg/L while the concentration of phosphorus in the wastewater effluent would range from 5 to 10 mg/L. Thus the phosphorus load attributable to the municipal source would be similar, whether or not the background concentration was considered.

However, the lack of adjustment for background loads can have greater effects on loads attributable to dilute, but high-volume, waste streams. For example, copper concentrations in agricultural runoff may be estimated at 0.01 mg/L, while copper concentrations in runoff from non-agricultural lands with similar soil chemistry characteristics may be 0.005 mg/L. Accounting for the background concentration in the load calculations would result in an overestimation of loads attributable to agricultural runoff by a factor of 2.

Current Resource Conditions

PARAMETERS OF CONCERN

TEMPERATURE

Temperature data were obtained from 41 stations monitored by DWR, the Sacramento River Coordinated Monitoring Program (CMP), USGS, and the San Francisco Estuary Institute (SFEI). The minimum temperature was measured at the Little Connection Slough at Empire Tract, with a value of 1.5°C. The maximum temperature was measured at the Woodward/North Victoria Canal near Old River, with a value of 31.9°C. For additional information on ongoing and previous water quality monitoring programs, refer to the Supplement.

TURBIDITY

Turbidity data were obtained from 34 stations monitored by DWR, CMP, USGS, and SFEI. The minimum turbidity was measured at the Contra Costa Pumping Plant No. 1, Woodward/ North Victoria Canal near Old River, and Sacramento River at Rio Vista Bridge, with a value of 0 mg/L. The maximum turbidity was measured at the Delta-Mendota Canal. Intake at Lindmann Road, with a value of 305 mg/L. For additional information, refer to the Supplement.

DISSOLVED OXYGEN

DO data were obtained from 41 stations. These stations monitored by DWR, CMP, USGS, and SFEI. The minimum DO was measured at Honker Bay, with a value of 3 mg/L. Maximum DO values are expected to average near 12 to 15 mg/L at full saturation in these waters at normal ambient temperatures, as was represented by the high value of 13.1 mg/L recorded for Little Connection Slough at Empire Tract. Several aberrant, higher values occur in the record, possibly due to supersaturation. For additional information, refer to the Supplement.

DO concentrations in Delta channels generally are not considered to be a problem, except near Stockton and in some dead-end sloughs. DO concentrations in MWQI agricultural drainage samples were sometimes slightly below normal (less than 5 mg/L), indicating the presence of large quantities of decomposing organic material (measured by DOC).

Considerable research has been conducted on the historical DO problems in the lower San Joaquin River near Stockton. Water temperatures in late summer and fall often exceed 75 to 80°F, temperatures at which full DO saturation at that altitude is approximately 8.0 mg/L. The available oxygen then is used by oxygen-demanding processes that lead to significant reductions in the DO levels. Channel sediments are believed to exert the greatest oxygen demand, followed by point sources, such as domestic and cannery wastewater discharges, and nonpoint sources of pollution (City of Stockton 1996). Reverse flows and stagnant conditions in this reach of the river exacerbate the problems. Installation of a temporary flow barrier at the head of Old River has helped to alleviate DO problems near Stockton by increasing the amount of water moving in the San Joaquin River past Stockton. In 1995, the U.S. Army Corps of Engineers began operating an aeration device in the Stockton ship-turning basin to improve DO conditions. The RWQCB is working with the City of Stockton to address DO effects from wastewater treatment plant effluent.

NUTRIENTS

Ammonia

Total and dissolved ammonia data were obtained from seven stations monitored by DWR, USGS, and SFEI. The minimum ammonia concentration was measured at Sacramento River at Freeport Marina, with a value of 0.01 mg/L. The maximum ammonia concentration was measured at Sacramento River at Collinsville, with a value of 0.73 mg/L.

For additional information, refer to the Supplement (note unit changes in database).

Nitrate

Nitrate data were obtained from 26 stations monitored by DWR, USGS, and SFEI. The minimum nitrate concentration was measured at the Sacramento River at Freeport Marina, with a value of 0.04 mg/L (dissolved nitrate plus nitrite as total nitrogen). The maximum nitrate concentration was measured at the San Joaquin River at Antioch, with a value of 40.60 mg/L. For additional information, refer to the Supplement (note unit changes in database).

Phosphate

Total phosphate data (measured as total phosphorus) were obtained from six stations monitored by USGS and SFEI. The minimum and maximum phosphate concentrations were measured at Sacramento River at Freeport Marina, with values of 0.01 and 0.54 mg/L, respectively. For additional information, refer to the Supplement (note unit changes in database).

PH

pH data were obtained from 41 stations monitored by DWR, USGS, CMP, and SFEI. The minimum pH was measured at the Sacramento River at Freeport Marina, with a value of 5.6. The maximum pH was measured at the Middle River at Mowry Bridge, with a value of 9.5. For additional information, refer to the Supplement.

ALKALINITY

Alkalinity data (measured as total alkalinity as $CaCO_3$) were obtained from 34 stations monitored by DWR, USGS, and SFEI. The minimum alkalinity concentration was measured at the Delta Pumping Plant Headworks, with a value of 8.2 mg/L. The maximum alkalinity concentration was measured at the Sacramento River at Rio Vista Bridge, with a value of 250 mg/L. For additional information, refer to the Supplement.

HARDNESS

Hardness data (measured as total hardness as $CaCO_3$) were obtained from 38 stations monitored by DWR, USGS, CMP, and SFEI. The minimum hardness concentration was measured at the Sacramento River at Freeport Marina, with a value of 27 mg/L. The maximum hardness concentration was measured at Old River 6/10 mile below DMC Intake and Old River upstream from DMC Intake, with a value of 72 mg/L. For additional information, refer to the Supplement.

SALINITY (ELECTRICAL CONDUCTIVITY AND TOTAL DISSOLVED SOLIDS)

Conductivity

Conductivity data were obtained from 40 stations monitored by DWR, USGS, CMP, and SFEI. Values are recorded in the database both as conductivity and as specific conductance. The minimum conductivity was measured at the Middle River near Latham Slough, with a value of 5 micromhos per cm (μmho/cm). The maximum specific conductance was measured at Sacramento River at Mallard Island, with a value of 18,500 μmho/cm. For additional information, refer to the Supplement (note unit changes in database).

TDS

TDS data were obtained from 33 stations monitored by DWR, USGS, and SFEI. The minimum TDS concentration was measured at the Little Connection Slough at Empire Tract and the Sacramento River at Greenes Landing, with a value of 49 mg/L. The maximum TDS concentration was measured at the Sacramento River at Mallard Island, with a value of

11,000 mg/L. For additional information, refer to the Supplement.

Salinity

Salinity data were obtained from five Delta stations monitored by SFEI. The minimum salinity concentrations were measured at all the stations monitored as below detection limits. The maximum salinity concentration was measured at Pacheco Creek, with a value of 12.6 o/oo (ppt). For additional information, refer to the Supplement.

Sodium

Dissolved sodium data were obtained from 34 stations monitored by DWR, USGS, CMP, and SFEI. The minimum sodium concentration was measured at the Sacramento River at Freeport Marina, with a value of 2.9 mg/L. The maximum sodium concentration was measured at the Sacramento River at Mallard Island, with a value of 3,430 mg/L. For additional information, refer to the Supplement.

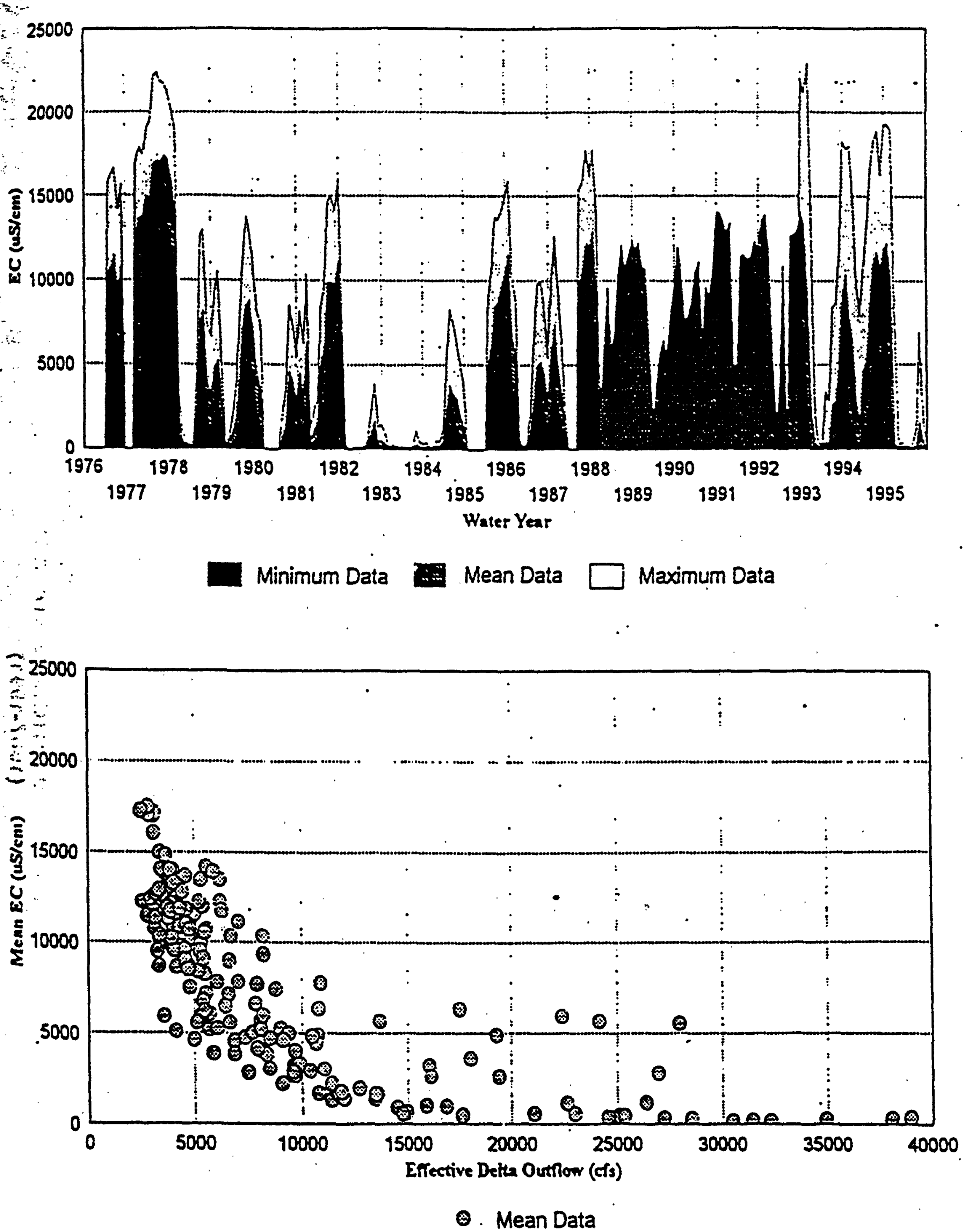
A recent study of *Drinking Water Quality in Delta Tributaries* (CUWA 1995) evaluated benchmark concentrations and contaminant source concentrations in the lower Sacramento River (Red Bluff to Delta), lower San Joaquin River, and the Delta. Benchmark TDS concentrations are presented in Table 5. In general, the review concluded that there were no apparent significant seasonal trends. Instream flow does not significantly alter TDS concentrations in the Sacramento River at Greenes Landing, although an inverse relationship exists in the San Joaquin River near Vernalis with higher instream flows having lower TDS concentrations. The primary contributors of TDS in the San Joaquin River Basin are agricultural drainage from Mud and Salt sloughs. Peak TDS occurs during the peak irrigation month of July, followed by TDS increases in late fall and early winter caused by agricultural drainage leachate.

Joaquin River near Chipps Island. The figure shows that periods of low Delta outflow correspond with major salinity intrusion episodes at Pittsburg, and periods of high Delta outflow correspond with salinity being flushed from the Delta.

Extensive historical data exist on EC from about 20 Delta locations. Average EC is generally 100 to 200 microsiemens per centimeter (μS/cm).

Location	Concentration (mg/L)	Percent Contribution to the Delta (River)
Sacramento River at Greene's Landing	39 to 132	65 to 78
Natomas East Main Drain	225 to 674	(2)
Sacramento Slough and Colusa Basin Drain	70 to 314	(26 to 33)
Sacramento urban runoff	22 to 440	(2)
Sacramento combined sewer overflow	50 to 300	(2)
Sacramento Regional Wastewater Treatment Plant	422 to 666	(2)
San Joaquin River at Vernalis	143 to 768	22 to 35
Mud and Salt sloughs	483 to 5180	(50)
Delta at Banks Pumping Plant	44 to 417	NA

Table 5. Benchmark TDS Concentrations in the Lower Sacramento (Red Bluff to the Delta) and San Joaquin Rivers and the Delta



Source: California Department of Water Resources D-1485 Continuous Water Quality Monitoring Program database.

Figure 4. Monthly Minimum, Mean, and Maximum EC at Chipps Island and Relationship of EC to Effective Delta Outflow for Water Years 1976 to 1995

Sacramento River EC measurements decrease with higher flows, exhibiting a typical flow-dilution relationship. Monthly average EC values for the San Joaquin River are usually higher than those for the Sacramento River, with typical values varying between 200 and 1,000 μS/cm. Data indicate that EC measurements from the San Joaquin River near Vernalis also generally decrease with increases in flow.

Figure 4 shows historical monthly EC patterns in the Delta and their relationship to effective outflows for 1976 to 1995 measured at Chipps Island. Pittsburg is downstream of the confluence of the Sacramento and San Joaquin rivers.

The Delta is subject to tidal action and saltwater intrusion. Saltwater intrusion is governed by the flushing action of Delta outflow and the transport of salt upstream through tidal mixing exchange. Seawater intrusion has the greatest effect in the western portion of the Delta, although increased EC has been measured as far upstream as Courtland on the Sacramento River and Stockton on the San Joaquin River during critically dry years before CVP and SWP pumps were constructed (Smith 1987). The western Delta and Bay Region, where saltwater intrusion is greatest, historically has a high EC range.

Figure 5 shows the historical pattern of monthly average EC at Benicia for 1967 to 1991. At Benicia, monthly average EC values range from less than 1,000 μS/cm during high Delta outflows to 30,000 μS/cm during low Delta outflows. Comparison with Figure 4 demonstrates the relationship between monthly average effective Delta outflow and monthly average EC at Benicia. Considerable scatter in the pattern is the result of using monthly average EC values; the effects of daily changes in effective Delta outflow on EC are not always accurately described with monthly average values. The X2 location (EC of about 3 millisiemens per centimeter [mS/cm]) will be downstream of Benicia only at an effective Delta outflow greater than 50,000 cfs.

Figure 6 shows the historical pattern of monthly average EC at Port Chicago (opposite Roe Island) for 1967 to 1991. Comparison with Figure 4 shows the relationship between monthly average effective Delta outflow and monthly average EC at Port Chicago. The X2 location will be in the vicinity of Port Chicago during months with an effective outflow of 25,000 to 30,000 cfs.

Figure 7 shows the historical pattern of monthly average EC at Pittsburg (near Chipps Island) for 1967 to 1991. The relationship between monthly average EC and monthly average effective Delta outflow is similar to that of Port Chicago. At Pittsburg, historical EC values have been approximately 3 mS/cm during months with an effective Delta outflow of approximately 8,000 to 10,000 cfs.

Figure 8 shows the historical pattern of monthly average EC at Collinsville (near the confluence of the Sacramento and San Joaquin rivers) for 1967 to 1991. At Collinsville, historical EC values have been approximately 3 mS/cm during months with an effective Delta outflow of approximately 7,000 to 8,000 cfs.

Figure 9 shows the historical pattern of monthly average EC at Emmaton for 1967 to 1991. The Emmaton monitoring station is located farther up the Sacramento River, where the extent of saltwater intrusion is reduced. Only during a few periods of low effective Delta outflow (approximately 3,000 cfs) did saltwater intrusion of 3 mS/cm extend up the Sacramento River as far as Emmaton.

The Contra Costa Canal Pumping Plant is located at the end of Rock Slough. Figure 10 shows the monthly range of EC at the pumping plant for 1967 to 1991, along with the corresponding monthly average chloride concentrations at the Contra Costa Canal Pumping Plant.

The 1995 WQCP includes an export EC objective of less than 1 mS/cm and a chloride objective of less than 250 mg/L, with a specified

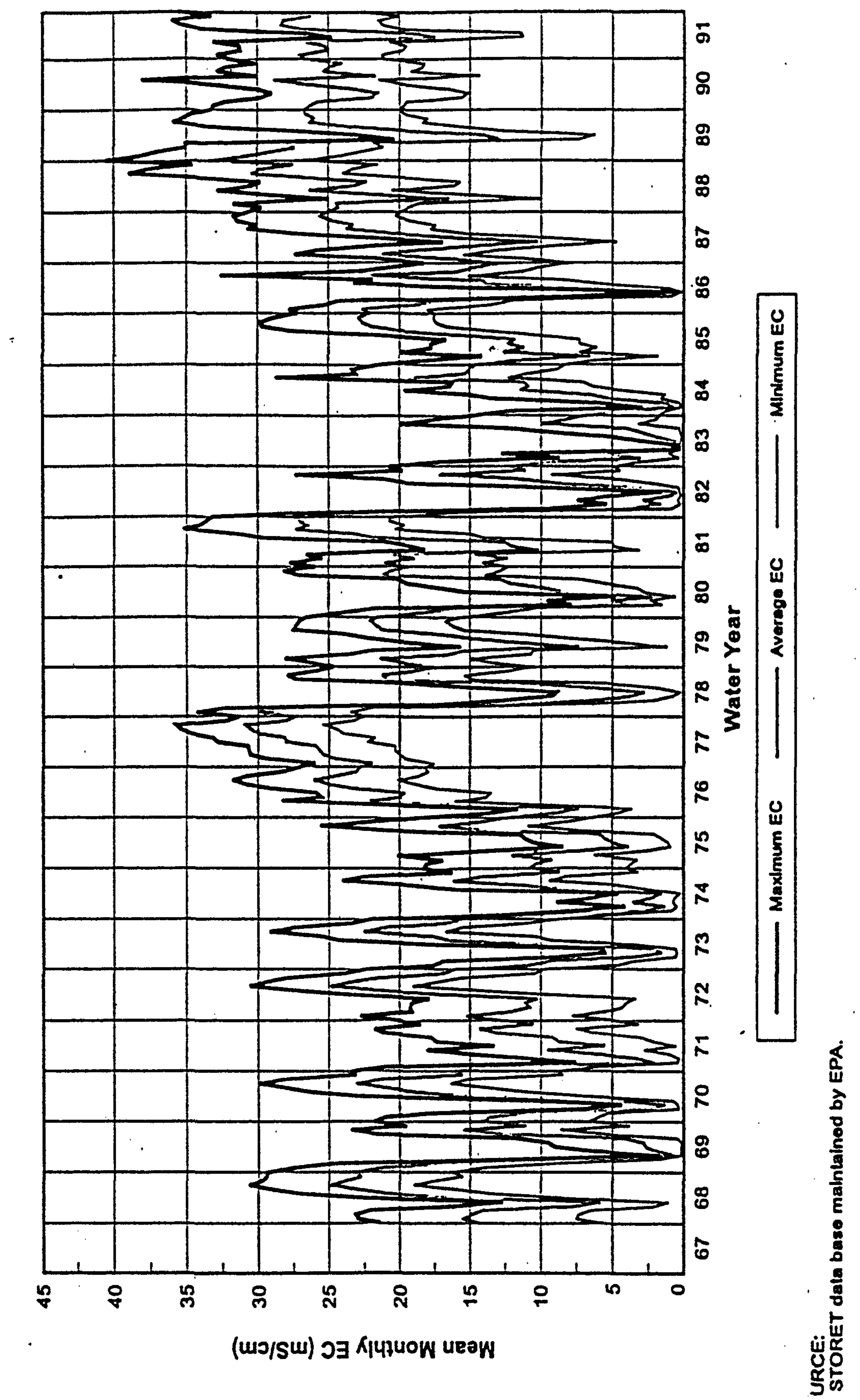


Figure 5. Mean Monthly EC Values for the Benecia Monitoring Station (1967 to 1991)

C — 0 0 9 3 1 6

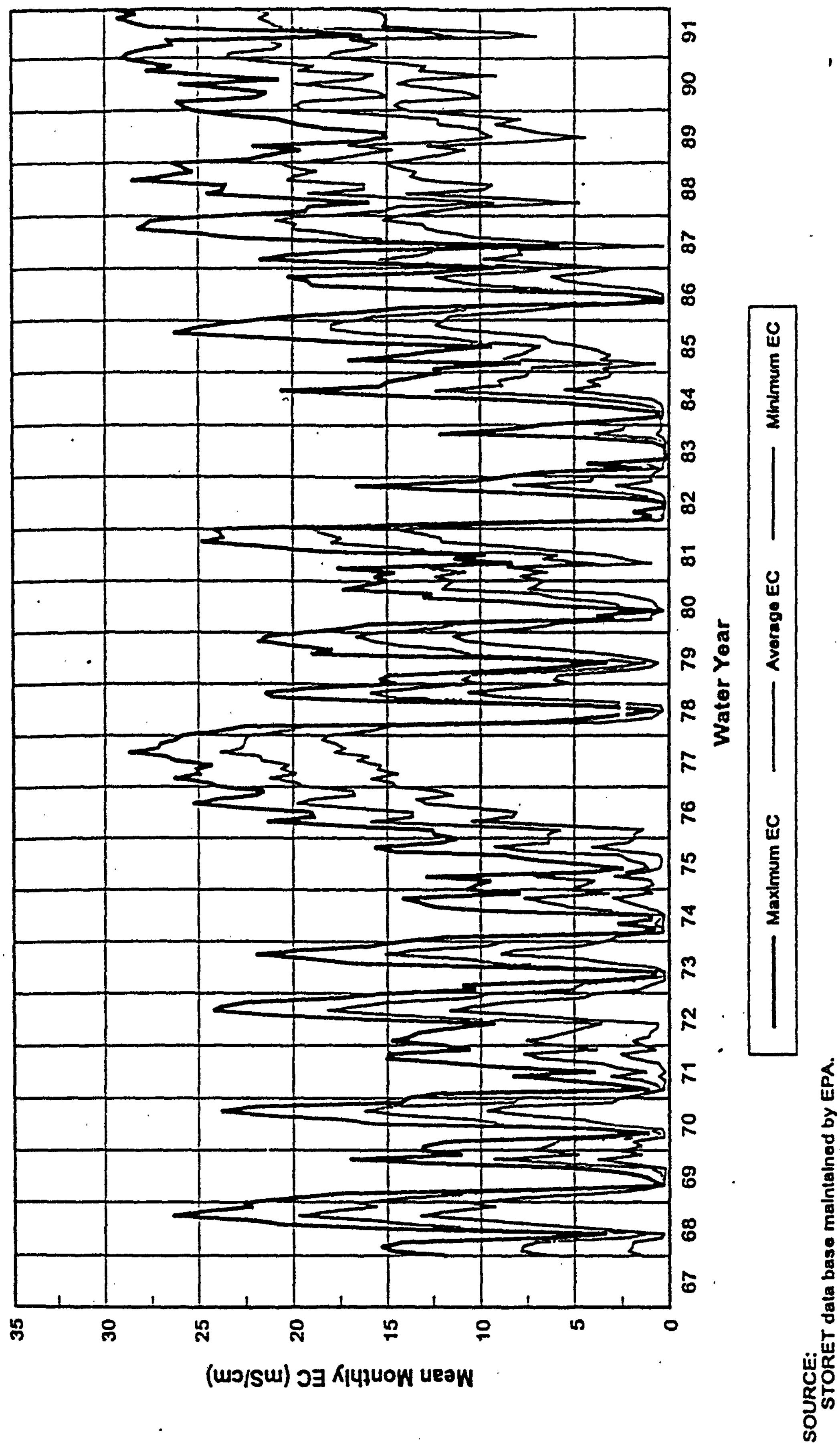
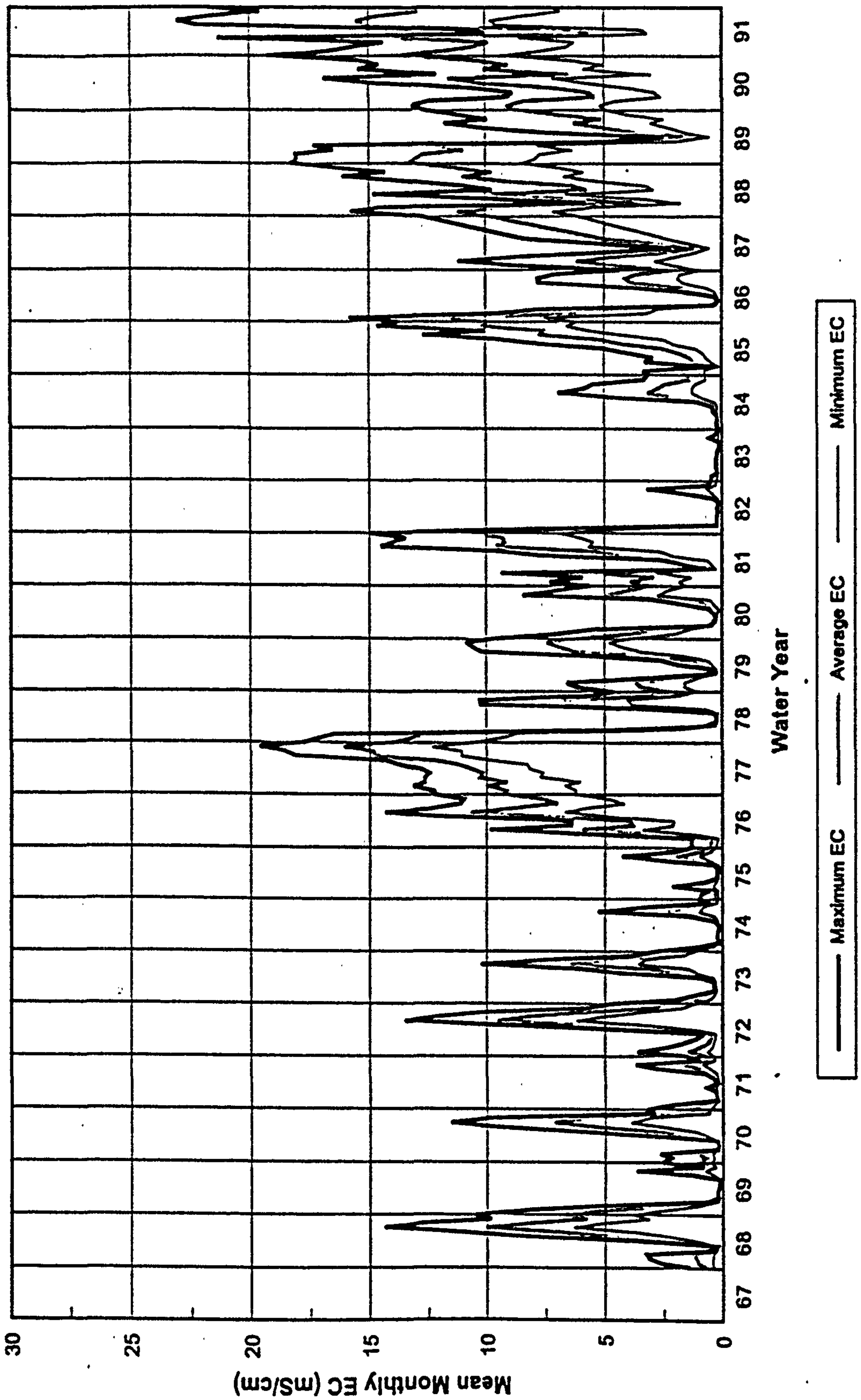


Figure 6. Mean Monthly EC Values for the Port Chicago Monitoring Station (1967 to 1991)



SOURCE:
STORET database maintained by EPA.

Figure 7. Mean Monthly EC Values for the Pittsburg Monitoring Station (1967 to 1991)

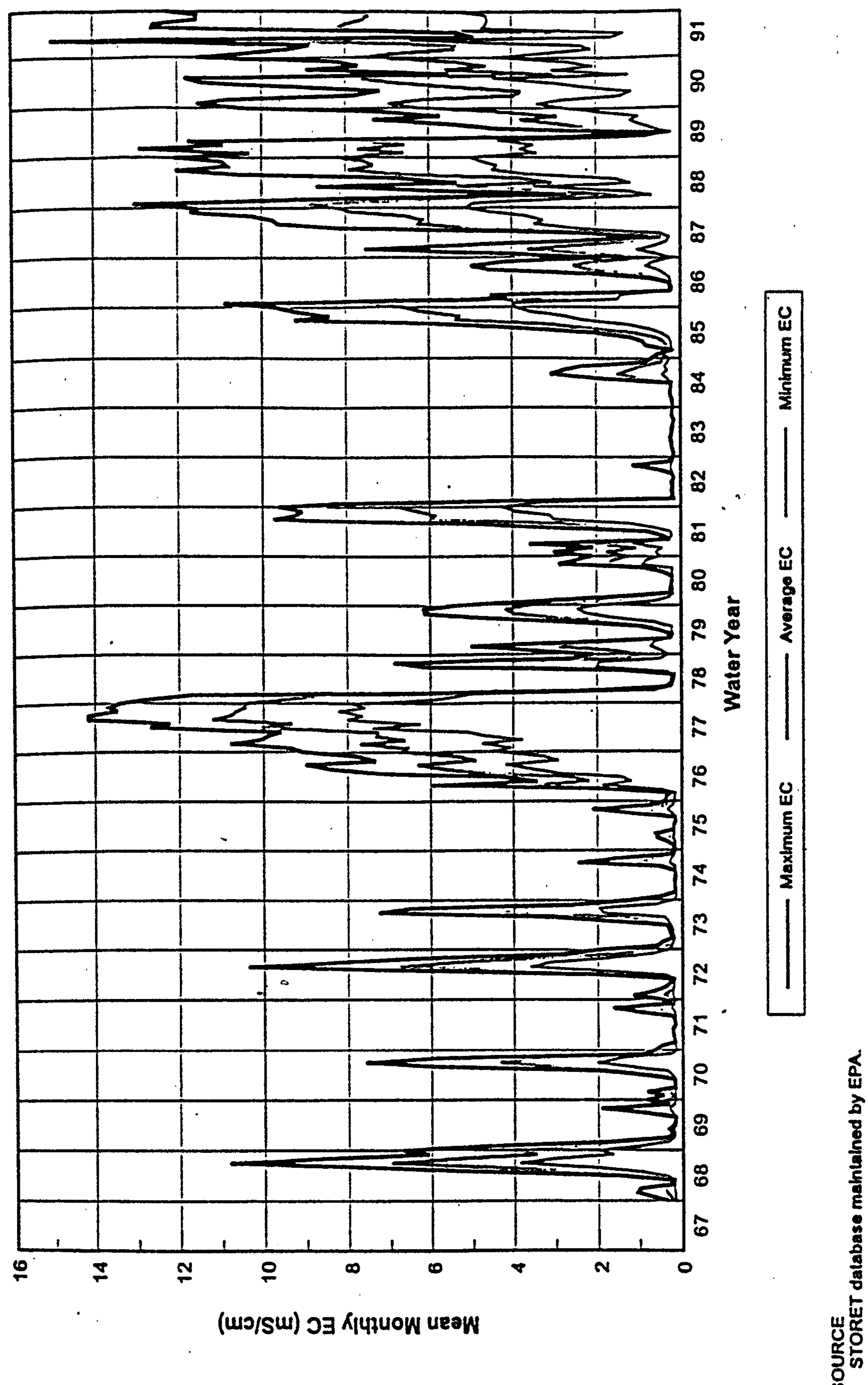


Figure 8. Mean Monthly EC Values for the Collinsville Monitoring Station (1967 to 1991)

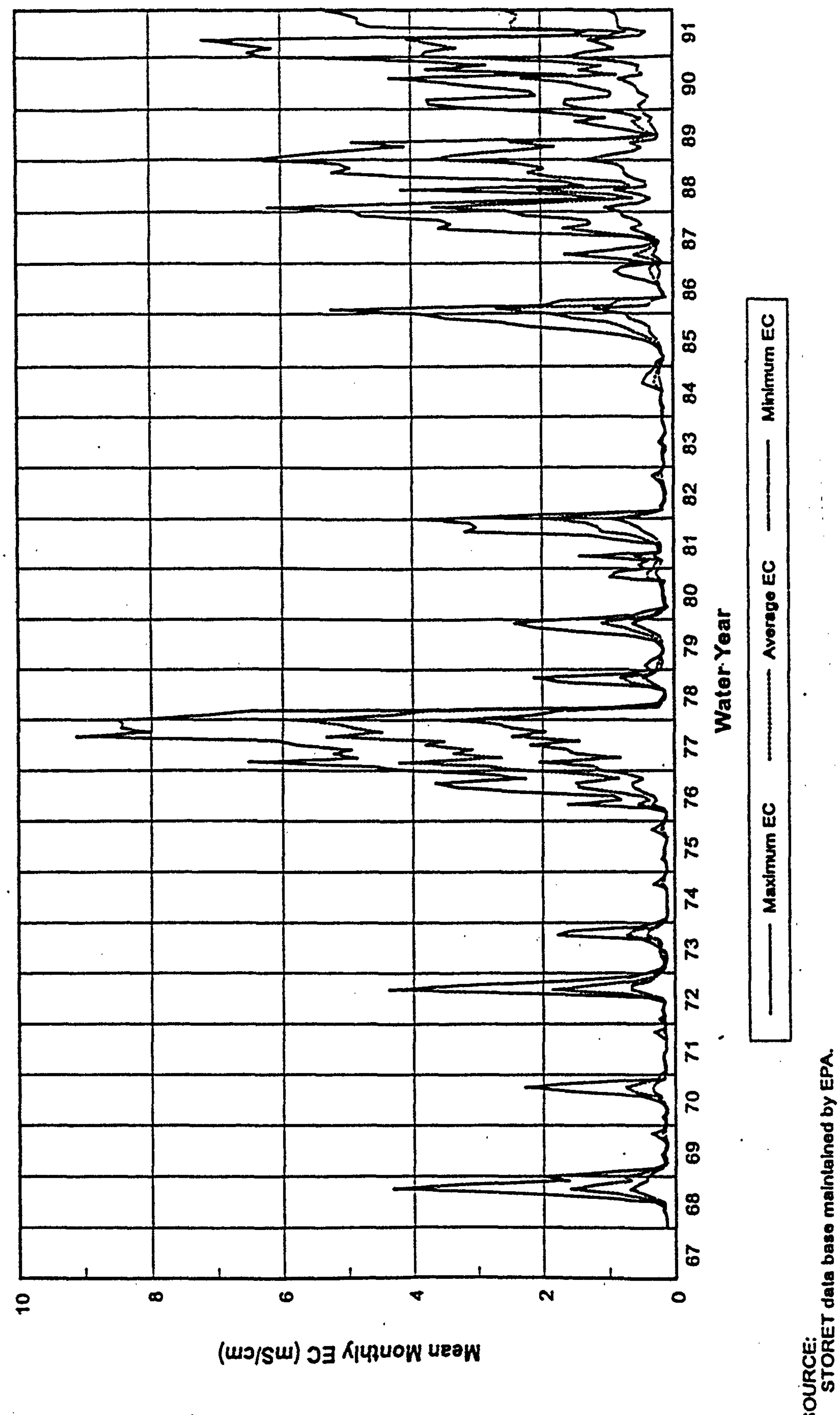


Figure 9. Mean Monthly EC Values for the Emmaton Monitoring Station (1967 to 1991)

C-009320

C — 0 0 9 3 2 0

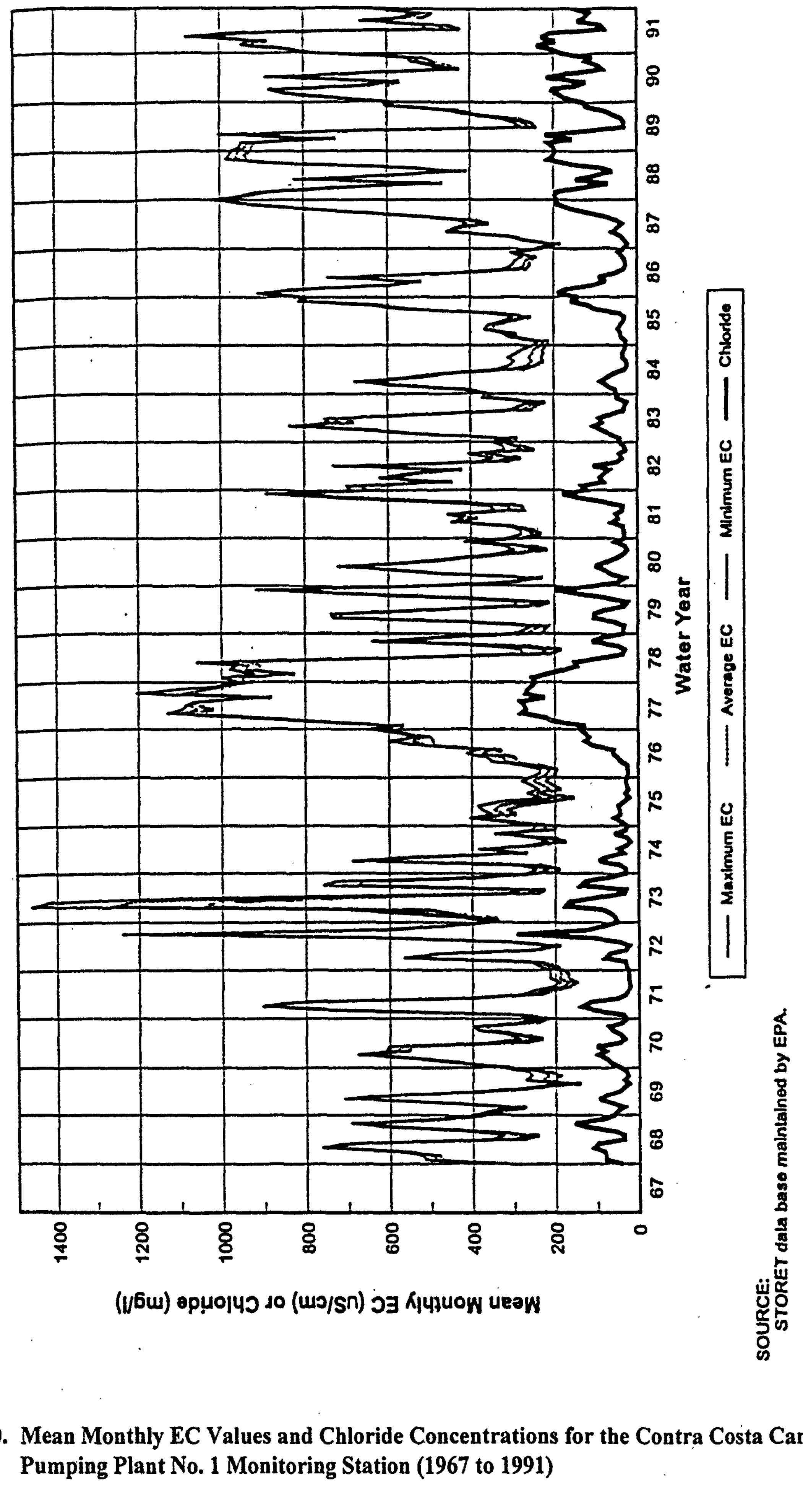


Figure 10. Mean Monthly EC Values and Chloride Concentrations for the Contra Costa Canal Pumping Plant No. 1 Monitoring Station (1967 to 1991)

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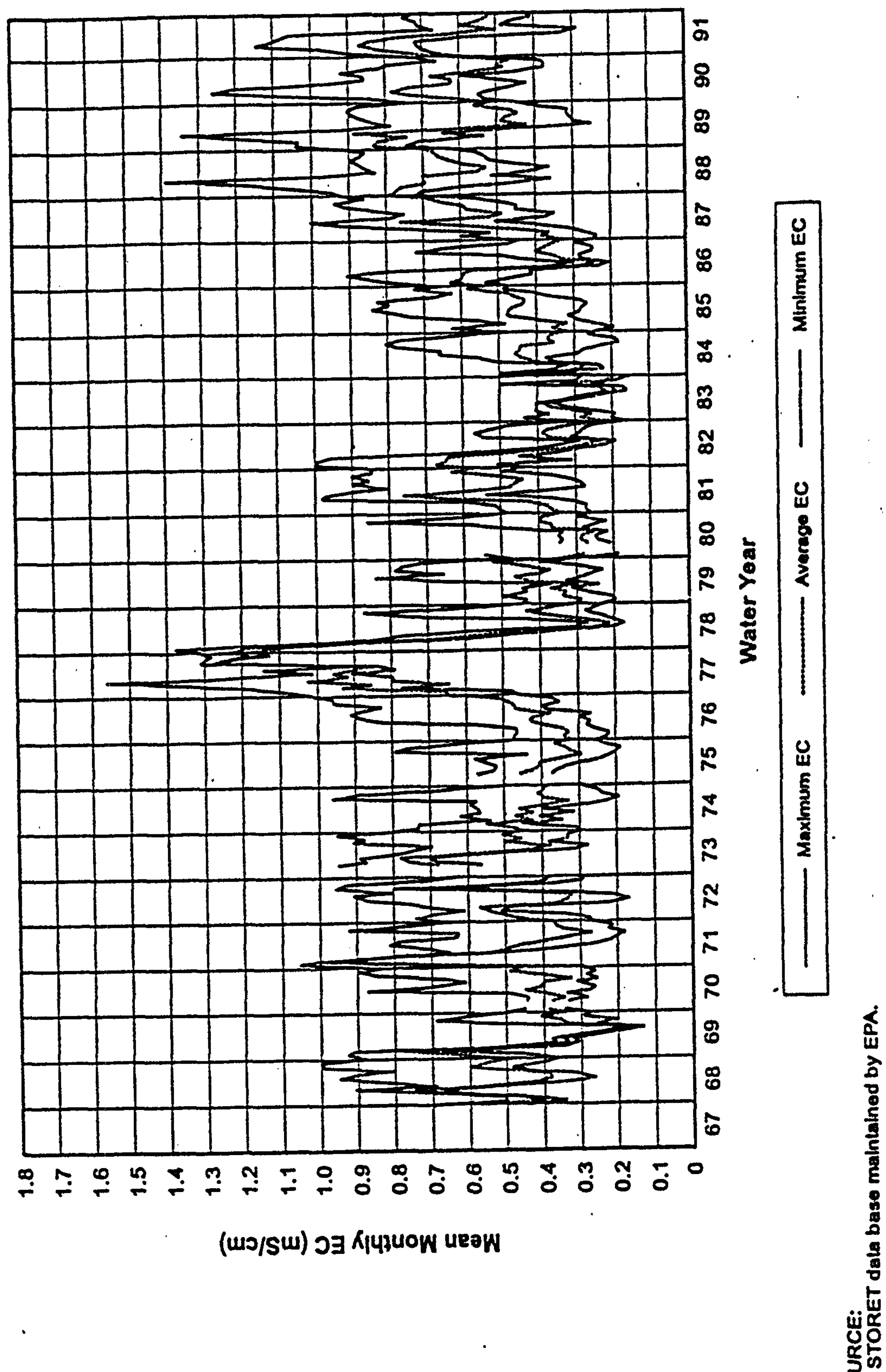
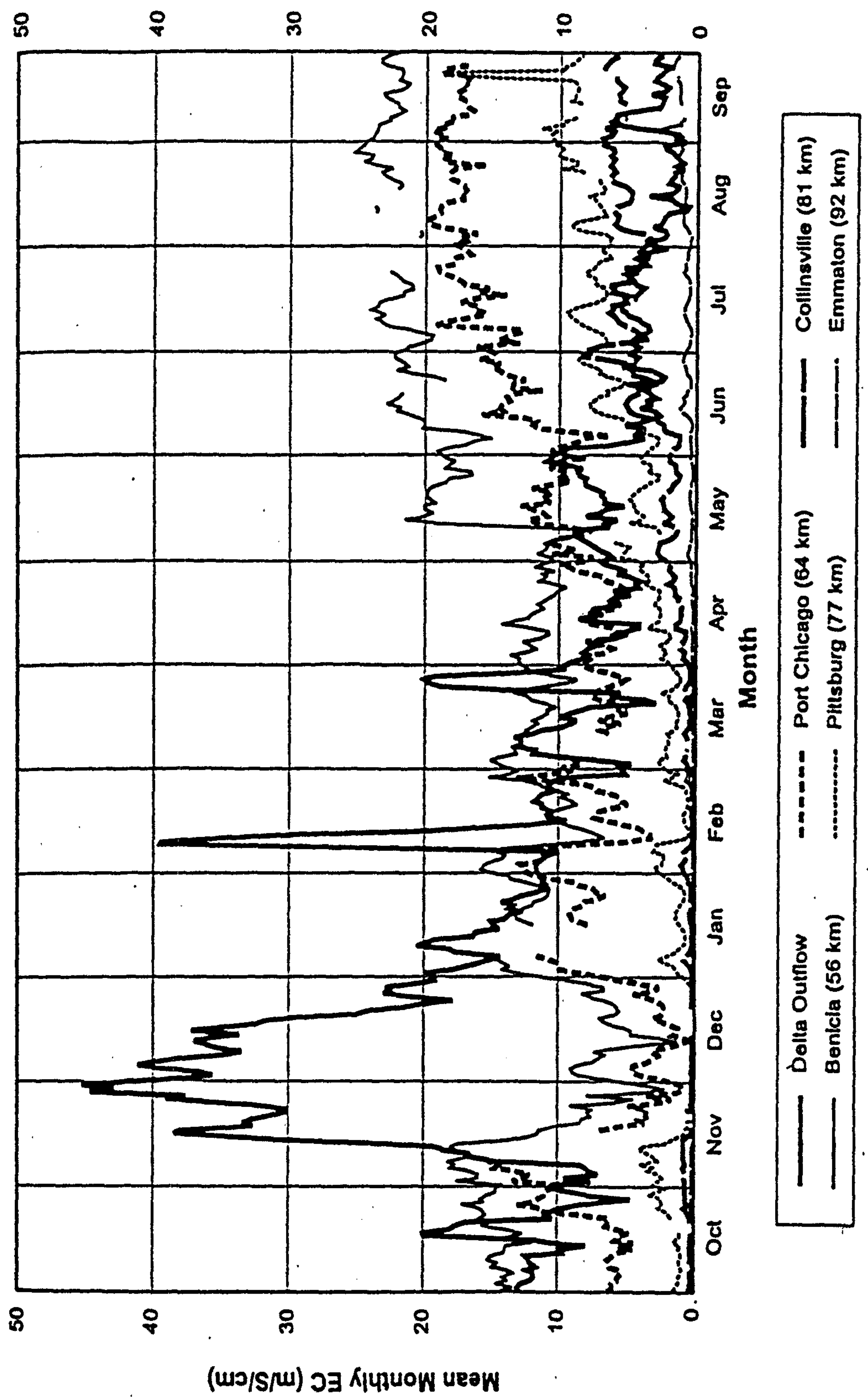


Figure 11. Mean Monthly EC Values for the Delta-Mendota Canal Monitoring Station (1967 to 1991)



SOURCE:
STORET data base maintained by EPA.
DAYFLOW data base maintained by DWR.

Figure 12. Daily Average EC at Selected Stations and Delta Outflow (1985)

number of days per year less than 150 mg/L, depending on the water-year type.

Figure 11 shows the monthly range of EC measurements in the Delta-Mendota Canal near the CVP Tracy Pumping Plant. Fluctuations in EC values are caused by periods of seawater intrusion, changes in San Joaquin River inflow EC, and agricultural drainage in the southern Delta.

Seawater intrusion and the movement of X2 is more dynamic than indicated by these monthly average EC and outflow values. For example, Figure 12 shows daily 1985 Delta outflow in relation to historical daily EC values for several western Delta stations (Benicia, Port Chicago, Pittsburg, Collinsville, and Emmaton). The interpolated daily position of the EC gradient (entrapment zone) and the estimated X2 position are shown in Figure 13 for 1985.

METALS AND TOXIC TRACE ELEMENTS

Cadmium

Total cadmium data were obtained from eight stations monitored by USGS, CMP, and SFEI. The minimum cadmium concentration was measured at the Sacramento River at Collinsville, with a value of 0.02 μg/L. The maximum cadmium concentration was measured at Sacramento River at Freeport Marina, with a value of 160 μg/L. For additional information, refer to the Supplement.

Copper

Dissolved and total copper data were obtained from 14 stations monitored by DWR, USGS, CMP, and SFEI. The minimum copper concentration was measured at below detection limits at seven stations. The maximum copper concentration was measured at the Sacramento River at Freeport Marina, with a value of 20 μg/L. For additional information, refer to the Supplement.

Mercury

Total mercury data were obtained from 10 stations monitored by DWR, USGS, CMP, and SFEI. The minimum mercury concentration was measured at below detection limits at three stations. The maximum mercury concentration was measured at the Sacramento River at Freeport Marina, with a value of 15 μg/L. For additional information, refer to the Supplement (note unit changes in database).

Selenium

Total and dissolved selenium data were obtained from 23 stations monitored by DWR, USGS, CMP, and SFEI. The minimum selenium concentration was measured at below detection limits at 19 stations. The maximum selenium concentration was measured at the Sacramento River at Freeport Marina, with a value of 290 μg/L. For additional information, refer to the Supplement (note unit changes in database).

Zinc

Dissolved zinc data were obtained from 10 stations monitored by DWR, USGS, CMP, and SFEI. The minimum zinc concentration was measured at below detection limits at five stations. The maximum zinc concentration was measured at the Delta Pumping Plant Headworks, with a value of 4.3 mg/L. For additional information, refer to the Supplement (note unit changes in database).

SYNTHETIC ORGANIC CHEMICALS/PESTICIDES

Chlordane

Total chlordane data were obtained from three stations monitored by SFEI. The minimum value was 59 pg/L at Grizzly Bay. The maximum value was measured at the San Joaquin River at Antioch, with a value of 254 pg/L. For additional information, refer to the Supplement.

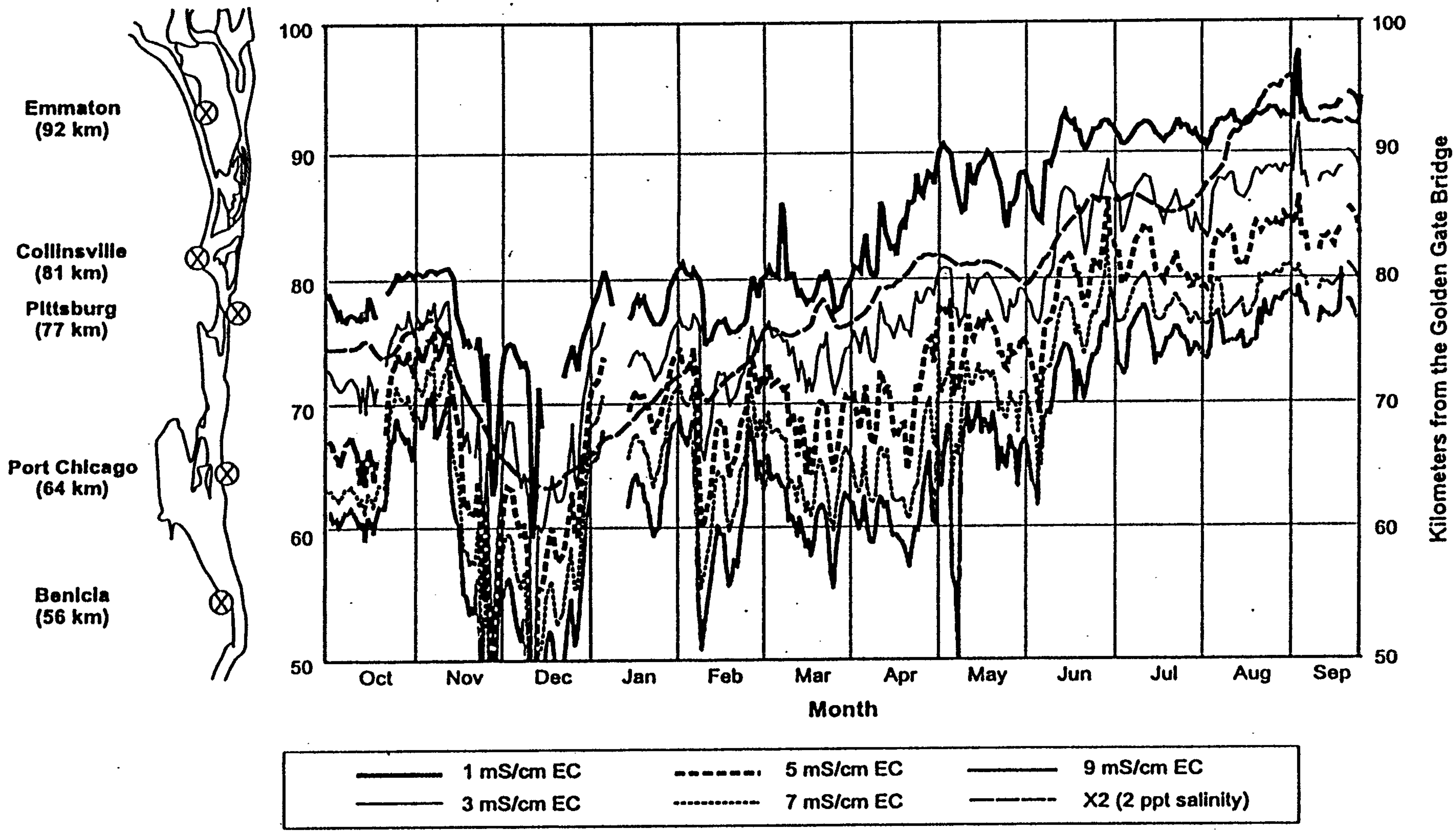


Figure 13. Location of Salinity Gradient Interpolated from Daily Average EC Measurements and Estimated X2 Position

Chlorpyrifos

Total chlorpyrifos data were obtained from five stations monitored by CMP, USGS, and SFEI. The minimum value was measured at below detection limits at two stations. The maximum value was measured at the Sacramento River at Collinsville, with a value of 46,629 pg/L. For additional information, refer to the Supplement (note unit changes in database).

Diazinon

Total diazinon data were obtained from five stations monitored by CMP, USGS, and SFEI. The minimum value was measured at below detection limits at two stations. The maximum value was measured at Sacramento River Mile 44, with a value of 0.70 μg/L. For additional information, refer to the Supplement (note unit changes in database).

DDT

Total DDT data were obtained from three stations monitored by SFEI. The minimum value was measured at the Sacramento River at Collinsville, with a value of 52 pg/L. The maximum value was measured at the same location, with a value of 728 pg/L. For additional information, refer to the Supplement.

PCB

Total PCB data were obtained from three stations monitored by SFEI. The minimum value was measured at the San Joaquin River at Antioch, with a value below detection limits. The maximum value was measured at the Sacramento River at Collinsville, with a value of 850 pg/L. For additional information, refer to the Supplement.

DISINFECTION BYPRODUCTS IN TREATED DRINKING WATER

There are four types of THM compounds. A total THM concentration (by weight) of 100 μg/L is the basis for current EPA drinking water standards; however, the greater weight of Br^- causes the three brominated THMs to be heavier and complicates the comparison of THM precursors from water samples with different Br^- concentrations. To normalize the total THM (TTHM) concentrations, MWQI studies include computed values of the total carbon weight of the four THMs. The carbon-fraction concentrations of the four THM molecules are added together to calculate the carbon equivalent of the THM concentration, known as the trihalomethane formation potential carbon (TFPC) in the MWQI program. The DWR assay compares the maximum capacity of source waters to produce DBPs, and produces values that are considerably higher than are actually experienced in water treatment facilities.

Bromide and Chloride

Salinity in the Delta derives from four major sources: seawater, San Joaquin River inflows, Sacramento River inflows, and local and upstream agricultural drainage. Concentrations of chloride (Cl^-) and Br^- increase in proportion to EC values, and each Delta inflow can be characterized by a specific chemical composition. Available data indicate that the ratio of Cl^- to EC in each of the different Delta sourcewaters (Sacramento River, San Joaquin River, and seawater) is nearly constant, and therefore can be used to distinguish the source of water sampled at different Delta locations. The Cl^-/EC ratio of agricultural drainage return flows depends on the source of the water used to irrigate the fields. Although evaporation and consumptive use increase the concentration of salts in drainage return flows, the overall Cl^-/EC ratio remains relatively constant. Where Br^- measurements are available, data indicate that all three sources of Delta water have a nearly identical and constant Br^-/Cl^- ratio of 0.0035. Variability in the Br^-/Cl^- ratio is greatest for the Sacramento River because of the low concentrations of Cl^- and Br^-.

Bromide

Dissolved bromide data were obtained from 30 stations monitored by DWR and USGS. The minimum value was measured at seven stations, with a value below detection limits. The maximum value was measured at the Sacramento River at Mallard Island, with a value of 22.6 mg/L. For additional information, refer to the Supplement.

Chloride

Dissolved and total chloride data were obtained from 32 stations monitored by DWR and USGS. The minimum value was measured at two stations, with a value of 1 mg/L. The maximum value was measured at the Sacramento River at Mallard Island, with a value of 6,060 mg/L. For additional information, refer to the Supplement.

The chloride concentrations and Cl^-/EC ratio in Delta inflows at Chipps Island and at the export locations for 1982 to 1995 are shown in Figure 14. In Sacramento River inflows, EC values are generally 100 to 200 μS/cm, and Cl^- concentrations are usually 5 to 10 mg/L. The Cl^-/EC ratio averages 0.04 in the Sacramento River, and the average Br^- concentration is low (0.05 mg/L). In San Joaquin River inflows, EC values are much higher (150 to 1,300 μS/cm), and Cl^- concentrations fluctuate between about 20 and 150 mg/L. The Cl^-/EC ratio in the San Joaquin River increases from about 0.08 at low EC values to about 0.15 at high EC values. The change in the Cl^-/EC ratio may be explained by the fact that San Joaquin River inflow is a mixture of San Joaquin River water, which contains significant amounts of agricultural drainage, and Stanislaus River water, which has a low average Cl^-/EC ratio and may therefore decrease the ratio in the San Joaquin River during seasonal periods of high runoff. The Cl^-/EC ratio has averaged about 0.30 for MWQI samples from Mallard Island near the confluence of the Sacramento and San Joaquin rivers, because a mixture of Sacramento River water and ocean water presumably was collected in the samples. Br^- concentrations would be about 17.5 mg/L at Mallard Island when Cl^- concentrations are 5 mg/L, resulting in a Br^-/Cl^- ratio of 0.0035. The Cl^-/EC ratio for seawater is approximately 0.35.

The export Cl^- concentrations during the period ranged from 15 to 300 mg/L. The highest concentrations of export Cl^- generally coincided with elevated Cl^-/EC ratios. The only sourcewater with a Cl^-/EC ratio greater than 0.15 is seawater. Consequently, the data suggest that the dominant source of Cl^- during these periods is seawater. CCWD water diverted from Rock Slough generally has a higher Cl^-/EC ratio than that found at other export locations.

TOTAL AND DISSOLVED ORGANIC CARBON

DOC values are lowest in the Sacramento River, averaging about 2 mg/L but occasionally exceeding 3 mg/L. The San Joaquin River and Delta export DOC range between 3 and 6 mg/L. The MWQI study concluded that Delta island drainage is a major source of DOC, based on the high concentrations measured and the mass load estimated from historical drainage volumes. Some contributions of DOC from crop residue and wetland plants have been postulated but have not been measured.

Dissolved Organic Carbon

DOC data were obtained from 32 stations monitored by DWR, CMP, USGS, and SFEI. The minimum DOC was measured at the Sacramento River at Mallard Island, with a value of 0.8 mg/L. The maximum DOC was measured at the Santa Fe-Bacon Island Cut near Old River, with a value of 30 mg/L. For additional information, refer to the Supplement.

Total Organic Carbon

Total organic carbon data were obtained from three stations monitored by CMP and USGS. The minimum value was measured at two stations, with a value of below detection limits.

The maximum value was measured at the Sacramento River at Freeport Marina, with a value of 7.90 mg/L. For additional information, refer to the Supplement.

PATHOGENS

Biological indicators (bacteria) and bacterial counts (as fecal coliform and fecal streptococci) were obtained from the Sacramento River at Freeport Marina as monitored by USGS. Fecal coliform counts range from 3 to 1,200 colonies/ 100 milliliters (mL). Fecal streptococci counts range from 2 to 2,000 colonies/100 ml. For additional information, refer to the Supplement.

The Metropolitan Water District of Southern California (MWD) conducted a pathogen monitoring survey of selected upstream and downstream sites in the SWP/Delta system from April 1992 through April 1993. The study evaluated the following sites that potentially affected pathogen loading in the water system, including:

- Greene's Landing, which represents water prior to entering the Delta, located 10 miles downstream from City of Sacramento wastewater discharges;
- H. O. Banks Pumping Plant headworks (Milepost 3.3), which reflects SWP water quality entering the California Aqueduct;
- Delta-Mendota Canal (Milepost 67), which reflects the quality of water being introduced from the San Luis Canal at O'Neill Forebay; and
- Aqueduct Checkpoint 29, which represents a site immediately above the southern California area.

A total of 48 samples were collected and analyzed for *Giardia lamblia* cysts, *Cryptosporidium parvum* oocysts, enteric viruses, and coliform bacteria. The percent positive and mean concentrations (cysts[ondocysts]/100 L) at each of the four stations for protozoans are shown in Table 6.

Means and ranges for total and fecal coliform bacteria concentrations at the four sites are shown in Table 7.

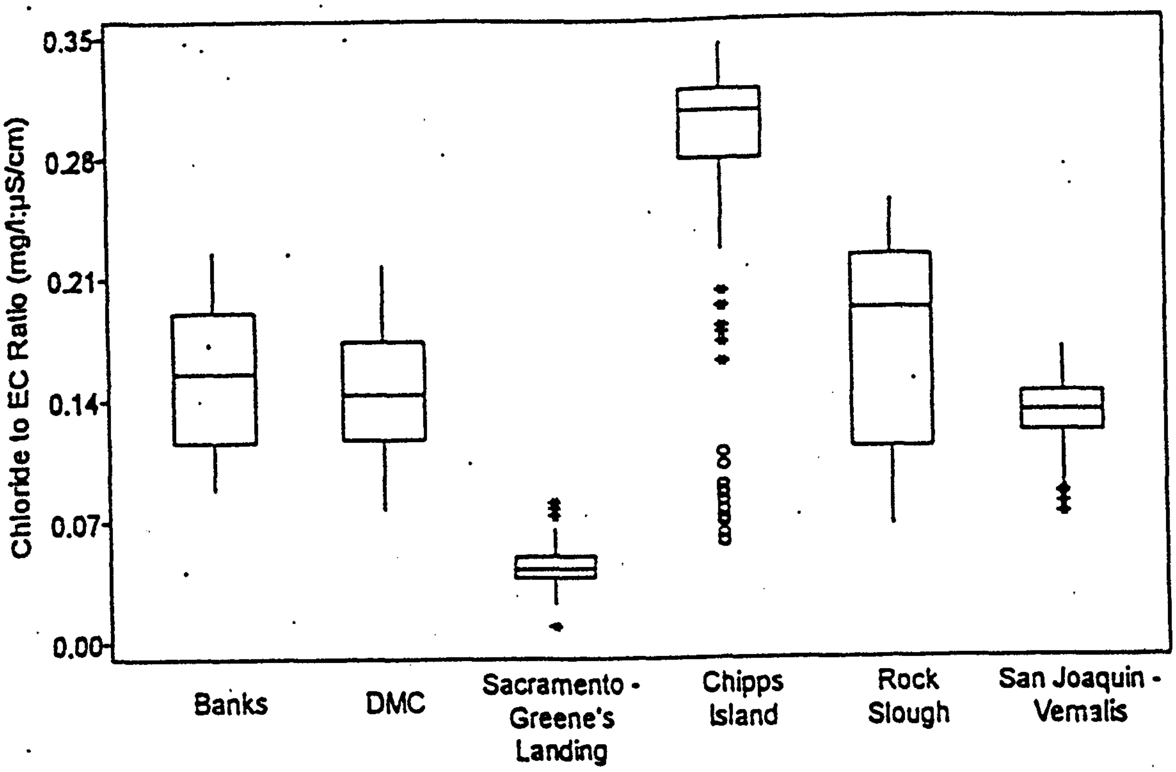
In general, these results suggest that the highest coliform activity occurred at Greene's Landing, and the lowest at Aqueduct Checkpoint 29. This relationship also was evidenced for *Giardia lamblia* and *Cryptosporidium*. Moreover, two of the three positive enteric virus samples were recovered at Greene's Landing. The source of pathogens at Greene's Landing is not known but may include effluent from upstream sewage treatment plants, release of sewage from boats, upstream recreational activity, and nonpoint fecal discharge.

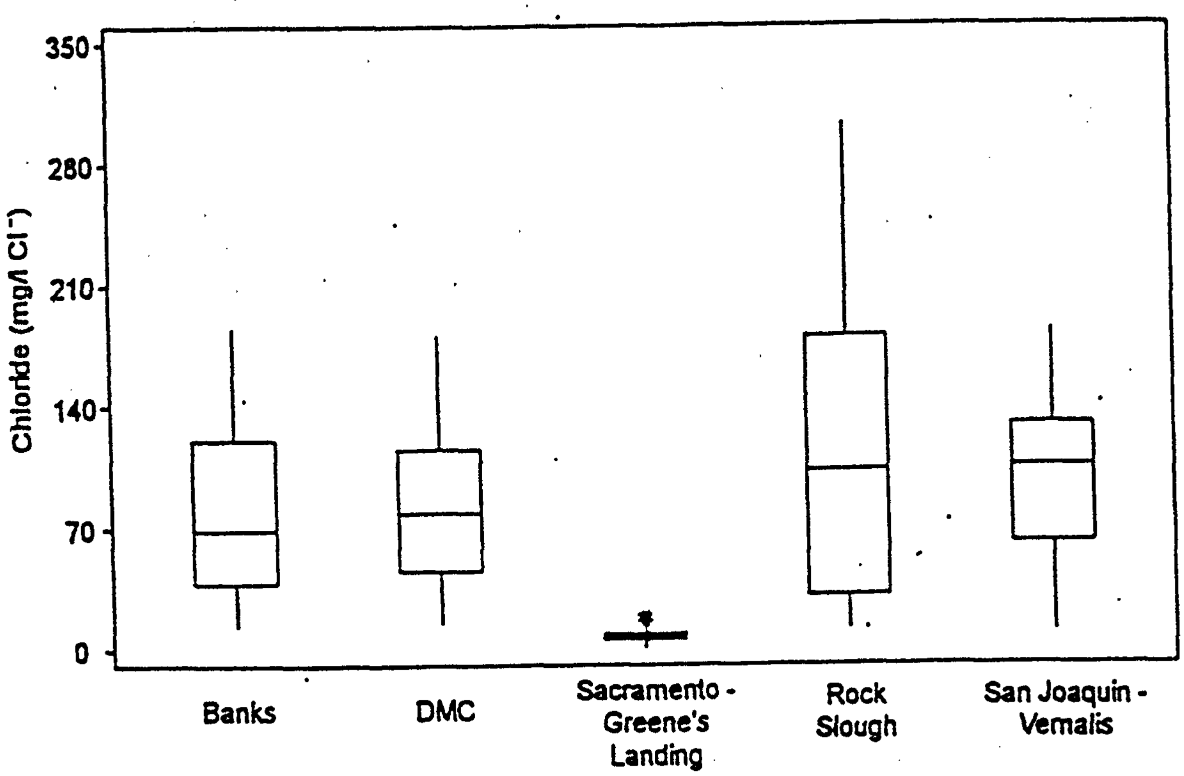
The protozoan appears everywhere in the water environment. In a survey of waters in the western United States, 91% of sewage samples, as well as 77% of rivers and 75% of lakes receiving wastewater discharges or agricultural pollution, were found to contain oocysts at varying levels (Rose 1988). Even 83% of pristine water supplies with no human activity in the watershed contained *Cryptosporidium* oocysts. Limited samples of treated drinking water reported 28% of the samples contained oocysts. The levels of oocysts in these waters are shown in Table 8.

MWD also conducted a pathogen monitoring survey of reservoirs in southern California receiving SWP water and Colorado River water. The results indicated that in both source waters, as measured downstream of Banks Pumping Plant, the levels of *Giardia lamblia* cysts ranged from 0 to 1.5 cysts/100 L, with a mean of 0.05 cysts/100 L.

Cryptosporidium oocysts ranged from 0 to 1.8 oocysts/100 L, with a mean of 0.18 oocysts/ 100 L.

Giardia lamblia and *Cryptosporidium parvum* concentrations in SWP/Delta water were





Source: California Department of Water Resources D-1485 Continuous Water Quality Monitoring Program database.

Figure 14. Chloride-to-EC Ratios and Chloride Concentrations for 1982 to 1995 MWQI Monthly Samples from the Sacramento River, San Joaquin River and Delta Export Locations

Site	*Giardia lamblia* Percent Positive	*Giardia lamblia* Mean (Range) Conc.	*Cryptosporidium* Percent Positive	*Cryptosporidium* Mean (Range) Conc.
Greene's Landing	42	37 (8-82)	50	50 (5-132)
Banks Pumping Plant	0	0 (NA)	25	54 (32-70)
Delta-Mendota Canal	8	6 (6)	58	40 (9-92)
Aqueduct Checkpoint 29	0	0 (NA)	8	17 (17)

Table 6. Percent Positive and Mean Concentration Range of *Giardia lamblia* Cysts and *Cryptosporidium parvum* Oocysts at Four Sites

Site	Coliform Concentration Mean (Range) Total Coliforms (MPN/100 mL)[a]	Coliform Concentration Mean (Range) Fecal Coliform (CFU/100 mL)[b]
Greene's Landing	666 (140-1,600)	24 (1-120)
Banks Pumping Plant	112 (11-500)	76 (0-310)
Delta-Mendota Canal	268 (13-1,600)	16 (0-100)
Aqueduct Checkpoint 29	20 (2-50)	11 (0-99)

NOTE:

[a] Most Probable Number/100 milliliters. [b] Colony Forming Units/100 milliliters

Table 7. Mean Concentration and Range for Total Coliforms and Fecal Coliforms at Four Sites

Water Source	Percent of Samples Positive for Oocysts	Average Oocysts per Liter[a]
Sewage, raw	91	4 - 5,180
Sewage, treated	91	4 - 1,297
Streams/rivers	77	0.94, 1.09, 1.3
Lakes/reservoirs	75	0.58, 0.91
Pristine rivers	83	0.02, 0.08
Treated drinking water	28	0.002, 0.009

NOTE:
[a] Geometric means of samples.

SOURCE:
Rose 1988.

Table 8. *Cryptosporidium* Oocysts in Typical U.S. Waters

approximately six times lower than in surface water compared in nationwide surveys (LeChevallier et al. 1991).

IMPAIRED WATERBODIES

Waterbodies impaired by parameters of concern, according to the 303(d) list, are shown in Table 9. The 303(d) list is the most comprehensive listing of waterbody impairments in the state. Although some data are relatively old, they represent the best data to date on the current status of watersheds throughout the state.

DELTA REGION

Runoff from the first major storm of the year in Stockton appears to annually produce an oxygen deficit, causing fish kills in adjacent Delta sloughs. The cause of the deficit is not yet known (Foe 1995). The Delta contains elevated mercury, diazinon, and chlorpyrifos. These constituents impair environmental and recreational beneficial uses. Urban runoff from cities in the Central Valley contribute mass loading of these parameters of concern.

BAY REGION

The Bay Region includes Suisun Bay and Marsh, San Pablo Bay, and the Bay watershed. In addition, a zone of approximately 25 miles offshore from Point Conception to the Oregon border has been included to cover potential ocean harvest management of anadromous fish along the California coast.

Numerous waterbodies drain to the San Francisco Bay Delta Estuary, many of which are listed as impaired waterbodies under Clean Water Act (CWA) Section 303(d). For example, the Napa and Petaluma rivers are conveyances for a combination of urban and agricultural runoff, and may contribute pathogens, nutrients, and turbidity. Urban runoff from cities around San Francisco Bay and San Pablo Bay is a significant source of metals to the estuary.

SACRAMENTO RIVER REGION

Several drainages in the Sacramento Basin contain metals in concentrations that may impair environmental beneficial uses. The upper Sacramento River (Shasta Dam to Red Bluff) contains elevated copper, cadmium, and zinc. Loadings to the river in this region are predominantly from mine drainage, although urban runoff does contribute metals to the upper Sacramento River drainage.

Data collected on the lower Sacramento River (Red Bluff to the Delta) indicate that environmental and recreational beneficial uses are impaired due to elevated mercury, diazinon, and chlorpyrifos. Both the lower American River and the lower Feather River are similarly impaired. Elevated mercury in these tributaries may pose a risk to people who catch and consume fish. Elevated levels of diazinon and chlorpyrifos have been documented in the lower Feather River. In these three waterbodies, urban runoff has been identified as a source of mercury, and in the lower Sacramento (Red Bluff to the Delta) and Feather rivers, urban runoff has been identified as a source of diazinon and chlorpyrifos.

Other waterbodies that are influenced by urban and industrial runoff include Natomas East Main Drain and Sacramento Slough. These two waterbodies contain elevated levels of diazinon and chlorpyrifos. Natomas East Main Drain has elevated levels of PCBs, and Sacramento Slough has elevated mercury. PCBs and methyl mercury are bioaccumulative substances that impair recreational beneficial uses such as fishing in these areas.

SAN JOAQUIN RIVER REGION

Urban and industrial runoff contribute to the overall mass loading of parameters of concern in

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Delta Region			
Carquinez Strait	2	Metals	Municipal and Industrial Point Sources, Mining, Urban
Delta Waterways	5	Mercury Diazinon, Chlorpyrifos Group A Pesticides (Chlordane, Toxaphene) Unknown Toxicity DDT Dissolved Oxygen Salt	Mining Agriculture, Urban Agriculture Unknown Agriculture Municipal, Urban Agriculture
Lone Tree Creek	5	Ammonia, Salt, DO	Dairies
Marsh Creek	5	Mercury	Mining
Bay Region			
Napa River	2	Pathogens Nutrients Turbidity	Urban Runoff, Agriculture Agriculture Agriculture, Urban Runoff
Petaluma River	2	Pathogens Nutrients Turbidity	Agriculture, Urban Runoff Agriculture, Urban Runoff Agriculture, Urban Runoff
Richardson Bay	2	Pathogens	Urban Runoff, Marinas
San Francisco Bay, Central	2	Metals	Municipal and Industrial Point Sources, Mining, Urban Runoff
San Francisco Bay, Lower	2	Metals	Municipal Point Sources, Urban Runoff
San Francisco Bay, South	2	Metals	Municipal Point Sources, Urban Runoff, Mining
San Pablo Bay	2	Metals	Municipal and Industrial Point Sources, Mining, Urban Runoff
Sonoma Creek	2	Nutrients, Pathogens, Turbidity	Agriculture, Urban Runoff, Construction

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Suisun Bay	2	Metals	Municipal and Industrial Point Sources, Mining, Urban
Suisun Marsh Wetlands	2	Metals	Agriculture, Urban, Flow Regulation
		Nutrients	Agriculture, Urban, Flow Regulation
		Salinity	Agriculture, Urban, Flow Regulation
		Dissolved Oxygen	Agriculture, Urban, Flow Regulation
Sacramento River Region			
American River, Lower	5	Mercury Group A Pesticides (Chlordane) Unknown Toxicity	Mining Urban Unknown
Beach Lake	5	Copper, Mercury, Zinc Pesticides	Urban Runoff Industrial Point Source, Urban Runoff
Cache Creek	5	Mercury Unknown Toxicity	Mining Unknown
Colusa Drain	5	Pesticides (Carbofuran) Unknown Toxicity	Agriculture Unknown Agriculture
Feather River, Lower	5	Mercury Diazinon, Chlorpyrifos Group A Pesticides (Toxaphene) Unknown Toxicity	Mining Agriculture, Urban Agriculture Unknown
Harley Gulch	5	Mercury	Mining
Humbug Creek	5	Copper, Mercury, Zinc Sedimentation	Mining Mining
James Creek	5	Mercury	Mining
Little Cow Creek	5	Copper, Zinc, Cadmium	Mining
Natomas East Main Drain	5	PCBs Diazinon, Chlorpyrifos	Industrial, Urban Agriculture, Urban

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Sacramento River (Red Bluff to Delta)	5	Mercury Diazinon, Chlorpyrifos Carbofuran Unknown Toxicity	Mining Agriculture Agriculture Unknown
Sacramento Slough	5	Mercury Diazinon, Chlorpyrifos	Unknown Agriculture, Urban
Sulfur Creek	5	Mercury	Mining
Berryessa Lake	5	Mercury	Mining
Clear Lake	5	Mercury Nutrients	Mining Unknown
Horse Creek	5	Copper, Cadmium, Zinc	Mining
Keswick Reservoir	5	Copper, Cadmium, Zinc	Mining
Little Backbone Creek	5	Copper, Cadmium, Zinc pH	Mining Mining
Pit River	5	Low Dissolved Oxygen, Temperature, Nutrients	Hydromodification, Grazing, Agriculture
Shasta Lake	5	Copper, Cadmium, Zinc	Mining
Spring Creek	5	Copper, Cadmium, Zinc pH	Mining Mining
Town Creek	5	Copper, Cadmium, Zinc	Mining
West Squaw Creek	5	Copper, Cadmium, Zinc	Mining
Whiskeytown Reservoir	5	Pathogens	On-site Disposal Systems
Willow Creek	5	Copper, Zinc pH	Mining Mining
San Joaquin River Region			
Grasslands Marshes	5	Selenium TDS	Agriculture Agriculture
Kings River, Lower	5	Copper	Unknown

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Merced River, Lower	5	Group A Pesticides (Toxaphene)	Agriculture
		DDT	Agriculture
Mokelumne River, Lower	5	Copper, Zinc	Mining
		Dissolved Oxygen	Dam
Mud Slough	5	Selenium	Agriculture
		TDS	Agriculture
		Boron	Agriculture
		Pesticides	Agriculture
		Unknown Toxicity	Agriculture
Orestimba Creek	5	Pesticides	Agriculture
		Unknown Toxicity	Unknown
Panoche Creek	5	Mercury	Mining
		TDS	Agriculture
		Selenium	Agriculture
Salt Slough	5	Selenium	Agriculture
		TDS	Agriculture
		Mercury	Mining
		Pesticides	Agriculture
		Boron	Agriculture
San Carlos Creek	5	Mercury	Mining
San Joaquin River	5	Selenium	Agriculture
		Diazinon, Chlorpyrifos	Agriculture
		Unknown Toxicity	Unknown
		Group A Pesticides (?)	Agriculture
		Salt, Boron	Agriculture
Stanislaus River, Lower	5	Group A Pesticides (Endosulfan)	Agriculture
		DDT	Agriculture
		Unknown Toxicity	Unknown
Temple Creek	5	Ammonia	Dairies
Tuolumne River, Lower	5	Group A Pesticides (Chlordane, Toxaphene)	Agriculture
		DDT	Agriculture
		Unknown Toxicity	Unknown

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Turlock Irrigation District Lateral #5	5	Ammonia	Wastewater Discharge, Agriculture
		Pesticides	Agriculture
		Unknown Toxicity	Unknown
SWP and CVP Service Areas Outside the Central Valley			
Carpinteria Marsh	3	Nutrients	Agriculture
		Low Dissolved Oxygen	Construction
		Turbidity	Storm Sewers, Construction
Goleta Slough/Estuary	3	Metals	Industrial Point Sources
		Pathogens	Urban Runoff/Storm Sewers
		Turbidity	Construction
Nacimiento Reservoir	3	Metals	Natural Sources, Mining
Carpinteria Creek	3	Pathogens	Agriculture, Septic Tanks, Land Disposal
Chorro Creek	3	Metals	Mining
		Turbidity	Agriculture
Las Tablas Creek	3	Metals	Surface Mining
Las Tablas Creek, North Fork	3	Metals	Surface Mining
Las Tablas Creek, South Fork	3	Metals	Surface Mining
Llagas Creek	3	Nutrients	Habitat Modification, Agriculture, Urban Runoff/Storm Sewers, Hydromodification, Municipal Point Sources
		Turbidity	Hydromodification, Habitat Modification, Agriculture
Los Osos Creek	3	Turbidity	Agricultural Grazing
Mission Creek	3	Pathogens, Unknown Toxicity	Urban Runoff/Storm Sewers
San Luis Obispo (Below West Marsh Street)	3	Nutrients	Municipal Point Sources, Agriculture
		Pathogens	Urban Runoff/Storm Sewers

Table 9. Clean Water Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Santa Ynez River	3	Nutrients Salinity, Chlorides Turbidity	Nonpoint Source Agriculture Urban Runoff/Storm Sewers
Channel Islands Harbor	4	Zinc	Nonpoint Source
Long Beach Harbor, particularly Main Channel, Southeast Basin, West Basin, Pier J, and Breakwater	4	DDT, PCBs	Nonpoint Source
Los Angeles Harbor: At Main Channel, Fish Harbor, Carbrillo Pier, and Breakwater	4	Copper, Zinc DDT, PCBs	Nonpoint/Point Source Nonpoint/Point Source
Los Angeles Harbor: Consolidated Slip	4	Zinc DDT, PCBs, Chlordane	Nonpoint Source Nonpoint Source
Los Angeles Harbor: Southwest Slip	4	DDT, PCBs	Nonpoint Source
Marina del Rey Harbor	4	Chlordane, Copper, DDT, PCBs, Zinc	Nonpoint Source
Point Hueneme Harbor	4	DDT, PCBs, Zinc	Nonpoint Source
San Pedro Bay nearshore and offshore zone: Cabrillo Pier area	4	Copper, Zinc, DDT, PCBs	Nonpoint/Point Source
Santa Monica Bay nearshore zone and offshore zone	4	Cadmium, Copper, Mercury, Zinc, Chlordane, DDT, PCBs	Nonpoint/Point Source
Ballona Creek Estuary	4	Zinc, Chlordane, DDT, PCBs	Nonpoint/Point Source
Dominguez Channel (includes estuary)	4	Zinc, Chlordane, DDT, PCBs	Nonpoint/Point Source
Malibu Lagoon	4	Selenium	Nonpoint/Point Source
McGrath Lake (Estuary)	4	Chlordane, DDT, Total Pesticides	Nonpoint Source
Mugu Lagoon	4	Cadmium, Copper, Mercury, Zinc, Chlordane, DDT, PCBs, Toxaphene	Nonpoint Source/Point Source

Table 9. Clean Water Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
San Gabriel River Estuary	4	Copper	Nonpoint/Point Source
Ventura River Estuary	4	DDT	Nonpoint/Point Source
Calabasas Lake	4	Cadmium, Copper, Zinc, DDT, Ammonia, Low Dissolved Oxygen, pH	Nonpoint Source
Echo Park Lake	4	Copper, PCBs, Ammonia, pH	Nonpoint Source
El Dorado Lakes	4	Copper, Mercury, Ammonia, pH	Nonpoint Source
Lake Lindero	4	Selenium, Chloride	Nonpoint Source
Lake Sherwood	4	Mercury, Ammonia, Low Dissolved Oxygen	Nonpoint Source
Legg Lake	4	Copper, Ammonia, pH	Nonpoint Source
Lincoln Park Lake	4	Ammonia, Low Dissolved Oxygen	Nonpoint Source
Machado Lake	4	Chlordane, DDT, PCBs, Ammonia	Nonpoint Source
Malibou Lake	4	Cadmium, Copper, Zinc, Chlordane, PCBs, Low Dissolved Oxygen	Nonpoint Source
Peck Road Park Lake	4	Low Dissolved Oxygen, DDT, Chlordane	Nonpoint Source
Santa Fe Dam Park Lake	4	Lead, Copper, pH	Nonpoint Source
Westlake Lake	4	Cadmium, Copper, Zinc, Chlordane, Low Dissolved Oxygen, Ammonia	Nonpoint Source
Aliso Canyon Wash	4	Selenium	Nonpoint Source
Arroyo Las Posas Reach 1 and 2	4	Ammonia, DDT	Nonpoint/Point Source
Arroyo Simi (Moorpark Fwy (23) to Brea Canyon)	4	Selenium, Zinc	Nonpoint/Point Source

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Ashland Avenue Drain	4	Low Dissolved Oxygen	Nonpoint Source
Ballona Creek	4	Cadmium, Copper, Zinc, Chlordane, DDT, PCBs	Nonpoint/Point Source
Burbank Western Channel	4	Cadmium, Ammonia	Nonpoint/Point Source
Calleguas Creek, Reach 1 and 2 (Estuary to Arroyo Las Posas)	4	Ammonia, DDT, Toxaphene, PCBs, Chlordane	Nonpoint/Point Source
Compton Creek	4	Copper, pH	Nonpoint/Point Source
Conejo Creek/Arroyo Conejo (Confluence Calleguas to above Lynne Rd)	4	Low Dissolved Oxygen, Ammonia, Toxaphene, DDT, Cadmium	Nonpoint/Point Source
Conejo Creek/ Arroyo Conejo, North Fork	4	Ammonia, Chlordane, DDT	Nonpoint/Point Source
Coyote Creek	4	Ammonia, Copper, Chloride	Nonpoint/point Source
Duck Pond Oxnard Drain (Tributary from duck ponds to Mugu Lagoon)	4	DDT, Chlordane, Toxaphene	Nonpoint Source
Las Virgenes Creek	4	Selenium, Low Dissolved Oxygen,Nutrients	Nonpoint Source
Lindero Creek	4	Selenium	Nonpoint Source
Los Angeles River Reach 1 (upstream Carson St. to estuary)	4	Ammonia, pH	Nonpoint/Point Source
Los Angeles River Reach 2 (Figueroa St. to upstream Carson St.)	4	Ammonia	Nonpoint/Point Source
Los Angeles River Reach 3 (Riverside Drive to Figueroa St.)	4	Ammonia	Nonpoint/Point Source
Los Angeles River Reach 4 (Sepulveda Dam to Riverside Dr.)	4	Ammonia	Nonpoint/Point Source
Los Angeles River Reach 5	4	Ammonia, Chlorpyrifos	Nonpoint/Point Source
Malibu Creek (Lagoon to Malibou Lake)	4	Cadmium, Copper, Selenium	Nonpoint/Point Source

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Medea Creek Reach 1 (Lake to confluence with Lindero)	4	Selenium	Nonpoint Source
Medea Creek Reach 2 (Above confluence with Lindero)	4	Selenium	Nonpoint Source
Pico Kenter Drain	4	Ammonia, Copper	Nonpoint Source
Revolon Slough and Beardsley Channel/Wash	4	Selenium, Toxaphene, Chlordane, DDT, Chlorpyrifos, PCBs	Nonpoint Source
Rio do Santa Clara (tributary to Mugu Lagoon)	4	Chlordane, Toxaphene, DDT, PCBs	Nonpoint Source
Rio Honda Reach 1 (Santa Ana Freeway to Los Angeles River)	4	Ammonia, Copper, Zinc, pH	Nonpoint/Point Source
Rio Honda Reach 2 (from Whittier Narrows Flood Control Basin to Spreading Grounds)	4	Ammonia	Nonpoint/Point Source
San Gabriel River Reach 1 (Estuary to Firestone)	4	Ammonia	Nonpoint/Point Source
San Gabriel River Reach 2 (Firestone to Whittier Narrows Dam)	4	Ammonia	Nonpoint/Point Source
Sepulveda Channel/ Canyon	4	Ammonia	Nonpoint Source
Torrance Carson Channel	4	Copper	Nonpoint Source
Triunfo Canyon Creek Reaches 1 and 2	4	Mercury	Nonpoint Source
Tujunga Wash (downstream Hansen Dam to Los Angeles River)	4	Ammonia, Copper	Nonpoint Source
Ventura River Reaches 1 and 2 (Estuary to Weldon Canyon)	4	Copper, Selenium, Zinc	Nonpoint/Point Source
Walnut Creek Wash	4	pH	Nonpoint /Point Source
Wilmington Drain	4	Ammonia, Copper	Nonpoint Source

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
Colorado Lagoon	4	Copper, Zinc, Chlordane, DDT, PCBs	Nonpoint Source
Los Cerritos Channel	4	Ammonia, Copper, Zinc	Nonpoint Source
Horsehoe Lake	6	Turbidity	Construction
Little Rock Reservoir	6	Metals	Nonpoint Source, Natural Sources
Searles Lake	6	Salinity, Chlorides	Unknown
Alamo River	7	Selenium, Pesticides	Agricultural Return Flows
Imperial Valley Drains	7	Selenium, Pesticides	Agricultural Return Flows
Anaheim Bay	8	Metals Pesticides	Urban Runoff/Storm Sewers Unknown Nonpoint Source
Huntington Harbour	8	Pathogens Metals Pesticides	Urban Runoff/Storm Sewers Urban Runoff/Storm Sewers Unknown Nonpoint Source
Newport Bay, Lower	8	Metals Nutrients Pathogens Pesticides	Urban Runoff/Storm Sewers, Contaminated Sediments Agriculture Urban Runoff/Storm Sewers Agriculture, Contaminated Sediments
Upper Newport Bay Ecological Reserve	8	Metals Nutrients Pathogens Pesticides	Urban Runoff/Storm Sewers Agriculture Urban Runoff/Storm Sewers Unknown Point Source, Agriculture
Chino Creek	8	Nutrients Pathogens	Daires, Agriculture Dairies, Urban Runoff/Storm Sewers
Mill Creek (Prado Area)	8	Nutrients Pathogens	Agriculture, Dairies Dairies

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

Waterbody	Regional Board	Parameters of Concern	Probable Sources
San Diego Creek, Reach 1	8	Metals	Unknown
		Nutrients	Agriculture, Nurseries, Unknown Nonpoint Source
		Turbidity	Unknown Nonpoint Source
		Pesticides	Unknown Nonpoint Source
San Diego Creek, Reach 2	8	Metals	Urban Runoff/Storm Sewers
		Nutrients	Nurseries, Agriculture, Unknown Nonpoint Source
		Turbidity	Construction
		Unknown Toxicity	Unknown Nonpoint Source
Santa Ana River, Reach 3	8	Nutrients	Municipal Point Source, Dairies
		Pathogens	Municipal Point Source
		Salinity, Chlorides	Municipal Point Source, Dairies
Santa Ana River, Reach 4	8	Pathogens	Municipal Point Source
		Salinity, Chlorides	Municipal Point Source
		Unionized Ammonia	Municipal Point Source
		Unknown Toxicity	Urban Runoff/Storm Sewers
San Diego Bay, North; Shelter Island Yacht Basin	8	Dissolved Copper	Nonpoint/Point Source
Buena Vista Lagoon	8	Nutrients	Nonpoint/Point Source
Tijuana River Estuary	8	Pesticides	Nonpoint/Point Source
Chollas Creek	8	Cadmium, Copper, Zinc, Toxicity	Nonpoint/Point Source
Tecolote Creek	8	Cadmium, Copper, Zinc	Nonpoint/Point Source
Tijuana River	9	Low Dissolved Oxygen, Cadmium, Copper, Zinc	Nonpoint/Point Source

NOTE:

These waterbodies represent Clean Water Act 303(d) impaired waterbodies within the CALFED study area that are impaired due to the presence of one or more CALFED water quality parameters of concern.

SOURCES:
1996 California 303(d) and Total Maximum Daily Load (TMDL) Priority List.

Table 9. Clean Water Act Section 303(d) Listed Impaired Waterbodies in the CALFED Study Area (Continued)

the San Joaquin River Basin. In this basin, however, urban runoff is not considered a major source of diazinon or chlorpyrifos relative to agricultural sources. The principal sources of identified parameters of concern are agriculture and some mines.

SWP AND CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

According to the 303(d) list, the San Gabriel, Santa Clara, and Los Angeles rivers contain ammonia levels that may impair beneficial uses. The possible source of ammonia has been attributed to nonpoint and point sources. Environmental beneficial uses may be impaired in the Ventura River due to elevated levels of copper, selenium, and zinc from nonpoint and point sources.

Data collected from the Santa Ynez River indicate beneficial use impairment due to nutrients, salinity, and turbidity from nonpoint sources, agriculture, urban runoff, and mining. Other waterbodies that are influenced by urban runoff include Goleta Slough/Estuary, Llagas Creek, Mission Creek, Anaheim Bay, Huntington Harbor, Newport Bay, and San Diego Creek.

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