STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY

PETE WILSON, Governor

DEPARTMENT OF HEALTH SERVICES
OFFICE OF DRINKING WATER
601 NORTH 7TH STREET
P.O. BOX 942732
SACRAMENTO, CA 94234-7320
(916) 323-6111
(916) 327-6092

March 7, 1995

Mr. Steve Macaulay
General Manager
State Water Contractors
555 Capitol Mall, Suite 725
Sacramento, CA 95814

Dear Mr. Macaulay:

The State Water Contractors (SWC) completed the Sanitary Survey of the State Water Project, October 1990 and submitted it to the Department of Health Services (DHS) on October 26, 1990. The California Surface Water Treatment Regulation requires sanitary surveys be updated every five years. The update of the State Water Project (SWP) Sanitary Survey is required by January 1, 1996.

The focus of the five year update should address the implementation of recommendations included in the original survey, and any major changes in the watershed or water quality data during the preceding five years. Changes in the watershed should address land uses, hydrology, water supply systems, potential contaminate sources, and watershed control and management practices. Also, since the SWP Sanitary Survey was completed prior to the development of the Watershed Sanitary Survey Guidance Manual, December 1993, the SWC should complete, and review with DHS, the checklist included in the manual.

After reviewing the 1990 Sanitary Survey and the follow-up Sanitary Survey Action Plan transmitted to DHS on April 8, 1994, the DHS also requests that the update include a more detailed investigation of the Lake Del Valle, Castaic Lake, Pyramid Lake, Silverwood Lake, Lake Perris, and Barker Slough watersheds.

If you have any questions on this matter please contact Robert Hultquist at (510) 540-2149.

David P. Spath, Ph.D., P.E., Assistant Chief
Division of Drinking Water and
Environmental Management

cc: Regional Engineers
District Engineers
DWFOB
Rick Woodard
Department of Water Resources

PROJECT TEAM

STATE WATER CONTRACTORS

John Coburn, Project Manager

STATE WATER CONTRACTORS, STATE WATER PROJECT
WATER QUALITY TECHNICAL COMMITTEE

Dr. Michael McGuire, Chairman**
The Metropolitan Water District of Southern California

Dick Barnett
Casitas Municipal Water District

Jim Beck**
Kern County Water Agency

Andrew Florendo
City of Vallejo

Russell Fuller**
Antelope Valley - East Kern Water Agency

Ex Ganding
City of Vallejo

Roger James**
Santa Clara Valley Water District

Mike Lanier
Alameda County Water District

Stanley Narwold
Palmdale Water District

Richard Woodard**
Department of Water Resources

<u>Committee Advisors</u>:

John Fields**
U.S. Bureau of Reclamation

PROJECT TEAM

STATE WATER CONTRACTORS, STATE WATER PROJECT
WATER QUALITY TECHNICAL COMMITTEE

Committee Advisors (continued):

Richard Haberman**
California Department of Health Services

Timothy Gannon
California Department of Health Services

Laurence Hancock
U.S. Bureau of Reclamation

BROWN AND CALDWELL

Sciences and Engineering

Elaine Archibald, Project Manager
Jeanne Wallberg, Project Scientist
Craig Goehring
Tami Mihm
Jim Yost
Joe Yun

Report Preparation

Peggie Purdy
Janet Rogers
Greg Sturges
Mindy Wright

BOYLE ENGINEERING CORPORATION

Fritz Redlin
Ben Everett
Rocky Holt

EOA, INC.

Adam Olivieri
Fred Jarvis

PROJECT TEAM

LAVERTY ASSOCIATES

Gordon Laverty

** Member of Sanitary Survey Advisory Committee.

CONTENTS

LIST OF TABLES vii

LIST OF FIGURES ix

EXECUTIVE SUMMARY ES-1
The Water Supply System ES-1
Regulations for the Protection of Drinking Water ES-4
Contaminant Sources in the Watersheds ES-5
Direct Sources of Contamination to the State Water Project ES-8
Water Quality of the State Water Project System ES-9
Effectiveness of Existing Regulations ES-11
Recommendations ES-13

CHAPTER 1. THE STUDY
Background 1-1
Conduct of the Study 1-2
Report Organization 1-2

CHAPTER 2. THE WATER SUPPLY SYSTEM 2-1
State Water Project and Central Valley Project Systems 2-1
Coordinated Operation Agreement 2-2
State Water Project Contractors 2-2
Watersheds Tributary to the Export Pumps 2-7
Sacramento River System 2-7
San Joaquin River System 2-8
East Side Streams 2-12
The Delta 2-13
State Water Project Export Components 2-15
North Bay Aqueduct 2-15
Clifton Court Forebay to Bethany Reservoir 2-15
South Bay Aqueduct 2-16
Bethany Reservoir to O'Neill Forebay 2-25
O'Neill Forebay and San Luis Reservoir 2-25
O'Neill Forebay to End of San Luis Canal 2-25
End of San Luis Canal to the Kern River Intertie 2-26
The Kern River Intertie to the East-West Branch Bifurcation 2-26
West Branch 2-27
East Branch 2-27

CONTENTS (continued)

Relationship Between CVP and SWP Components 2-28
The DMC North of O'Neill Forebay 2-28
The DMC Input to O'Neill Forebay 2-28
The DMC South of O'Neill Forebay 2-30
Proposed Facilities 2-33
Delta Channel Improvements 2-33
Proposed California Aqueduct-DMC Intertie 2-33
Los Banos Grandes Reservoir 2-33
Kern Water Bank 2-33

CHAPTER 3. REGULATIONS FOR THE PROTECTION OF DRINKING WATER 3-1
Drinking Water Standards 3-1
Federal Regulations 3-1
State Regulations 3-8
Overview of Other Pertinent Regulations 3-11

CHAPTER 4. CONTAMINANT SOURCES IN THE WATERSHEDS 4-1
Description of the Watersheds 4-1
Sacramento Basin 4-2
San Joaquin Basin 4-2
Tulare Basin 4-2
The Delta 4-3
Municipal and Industrial Discharges 4-3
Characteristics of Municipal and Industrial Discharges 4-3
Effluent Requirements 4-5
Discharge Quality 4-21
Loads of Contaminants 4-29
Urban Runoff Discharges 4-30
Key Urban Area Discharges 4-30
Urban Runoff Quality 4-37
Loads of Contaminants 4-40
Agricultural Drainage 4-40
Sacramento Basin 4-53
San Joaquin Basin 4-59
The Delta 4-68
Cattle Grazing, Feedlots, and Dairies 4-71
Mine Discharges 4-72
Key Mine Discharges 4-72
Mine Drainage Quality 4-73
Loads of Contaminants 4-73
Sea Water Intrusion 4-82

CONTENTS (continued)

Summary of Contaminants in the Watersheds 4-83
Mitigating Factors 4-87
Municipal and Industrial Discharges 4-87
Urban Runoff Discharges 4-88
Agricultural Drainage 4-89
Cattle Grazing, Feedlots, and Dairies 4-89
Mine Discharges 4-89
Sea Water Intrusion 4-90
Water Quality Monitoring 4-90

CHAPTER 5. DIRECT SOURCES OF CONTAMINATION TO THE STATE WATER PROJECT 5-1
Contaminant Sources 5-2
Siphons 5-2
Drain Inlets 5-2
Bridges 5-3
Overcrossings 5-3
Undercrossings 5-4
Water-Service Turnouts 5-4
Fishing Areas 5-4
Miscellaneous Sanitary Conditions 5-4
Pumping Plant and Power-Generating Plants 5-4
Steel Tanks 5-4
Reservoirs 5-5
North Bay Aqueduct 5-5
Physical Facilities 5-5
Historic Information and Past Concerns 5-6
Field Survey Results 5-6
Summary of Contaminant Sources 5-7
South Bay Aqueduct 5-7
Physical Facilities 5-7
Historic Information and Past Concerns 5-8
Field Survey Results 5-8
Summary of Contaminant Sources 5-12
Clifton Court Forebay to O'Neill Forebay 5-12
Physical Facilities 5-12
Historic Information and Past Concerns 5-13
Field Survey Results 5-13
Summary of Contaminant Sources 5-16
O'Neill Forebay and San Luis Reservoir 5-17
Physical Facilities 5-17
Historic Information 5-18
Field Survey Results 5-18
Summary of Contaminant Sources 5-19

CONTENTS (continued)

O'Neill Forebay to End of San Luis Field Division 5-20
Physical Facilities 5-20
Historic Information and Past Concerns 5-20
Field Survey Results 5-20
Summary of Contaminant Sources 5-24
End of San Luis Field Division to the
Kern River Intertie 5-25
Physical Facilities 5-25
Historic Information and Past Concerns 5-25
Field Survey Results 5-25
Summary of Contaminant Sources 5-28
Coastal Branch 5-28
Physical Facilities 5-28
Historic Information and Past Concerns 5-28
Field Survey Results 5-29
Summary of Contaminant Sources 5-31
Kern River Intertie to the East-West Branch Bifurcation 5-31
Physical Facilities 5-31
Historic Information and Past Concerns 5-32
Field Survey Results 5-32
Summary of Contaminant Sources 5-35
West Branch 5-36
Physical Facilities 5-36
Historic Information and Past Concerns 5-37
Field Survey Results 5-37
Summary of Contaminant Sources 5-43
East Branch 5-44
Physical Facilities 5-44
Historic Information and Past Concerns 5-45
Field Survey Results 5-46
Summary of Contaminant Sources 5-54
Delta Mendota Canal 5-54
Physical Facilities 5-54
Historic Information and Past Concerns 5-55
Field Survey Results 5-55
Summary of Contaminant Sources 5-58
Summary of Direct Sources of Contamination to
SWP Facilities 5-58
Open Canal Segments 5-58
Reservoirs 5-64
Protection of Water Quality During Emergencies 5-64

CONTENTS (continued)

CHAPTER 6. WATER QUALITY OF THE STATE WATER PROJECT SYSTEM 6-1
Water Quality Database 6-1
Data Sources 6-1
Monitoring Locations 6-3
Constituents of Concern 6-7
Disinfection By-Products 6-7
Minerals 6-17
Algae and Nutrients 6-26
Taste and Odor 6-28
Pathogens 6-28
Asbestos and Metals 6-31
Pesticides and Herbicides 6-35
Volatile and Synthetic Organics 6-36
Radiological Constituents 6-37
Summary of SWP of Source Water Quality 6-37
Evaluation of Direct Sources of Contamination 6-38

CHAPTER 7. EFFECTIVENESS OF EXISTING REGULATIONS 7-1
Regulating and Monitoring Sources of Contamination 7-1
Program to Operate the SWP to Protect Water Quality 7-5
Protection of Water Quality During Emergencies 7-6
Attainment Standards 7-7
Summary 7-8

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS 8-1
Source Waters 8-2
Sacramento Basin Upstream of Greene's Landing 8-2
San Joaquin Basin Upstream of Vernalis 8-4
The Tulare Basin 8-6
The Delta 8-6
Operation of the State Water Project Facilities 8-7
Clifton Court Forebay 8-7
O'Neill Forebay 8-8
Kern River Intertie 8-8
Field Survey of the State water Project Facilities 8-8
Coast Range Drainage 8-9
Agricultural Drainage 8-10
Urban Runoff 8-10
Highway Drainage 8-10
Other Potential Sources of Contamination to Open Canal Segments 8-11
Body Contact Recreation in the SWP Reservoirs 8-11
Wastewater Handling Facilities 8-11

CONTENTS (continued)

Water Quality 8-12
Water Quality Degradation 8-12
Drinking Water Standards 8-12
Water Quality Monitoring Programs 8-13
Effectiveness of Regulations 8-13
Water Quality Standards 8-14
Control of Contaminant Sources 8-14

APPENDIX A. REFERENCES A-1

APPENDIX B. WATER QUALITY SUMMARY TABLES B-1

APPENDIX C. ANNOTATED BIBLIOGRAPHY C-1

APPENDIX D. REVIEW OF STATUTES AND REGULATIONS D-1

APPENDIX E. ANALYSIS OF EMERGENCY PLANS OF AGENCIES OPERATING STATE WATER PROJECT FACILITIES E-1

APPENDIX F. FIELD SURVEY FORMS, MAPS, AND SUMMARY TABLES .. F-1

LIST OF TABLES

Number		Page
ES-1	Major Wastewater Treatment Plants	ES-6
2-1	State Water Project Contractor's Entitlements	2-5
3-1	Federal and State Primary Standards	3-3
3-2	Federal and State Secondary Standards	3-9
4-1	Summary of Municipal and Industrial Discharges	4-4
4-2	Major Wastewater Treatment Plants	4-7
4-3	Major Industrial Plants	4-8
4-4	Summary of Effluent Limitations: Wastewater Treatment Plants	4-22
4-5	Summary of Effluent Limitations: Industrial Plants	4-23
4-6	Annual Average Wastewater Treatment Plant Effluent Quality	4-24
4-7	Annual Average Industrial Treatment Plant Effluent Quality	4-25
4-8	Sacramento Regional Plant Effluent Quality	4-27
4-9	Dilution Ratios of Sacramento Regional Plant Effluent in the Sacramento River for Calendar Year 1989	4-28
4-10	Concentrations of Typical Urban Runoff Constituents	4-38
4-11	Metals Concentrations in Sacramento Valley Agricultural Drains	4-59
4-12	Total Dissolved Solids and Trace Elements in Agricultural Drainage	4-67
4-13	Major Inactive Mines in the Watersheds Rated as High or Medium Threat to Water Quality	4-74
4-14	Metals Concentrations in Mine Drainage From Four Major Inactive Mines	4-81
4-15	Summary of Contaminants in the Watersheds	4-84
5-1	Potential Sources of Contamination to SWP Open Canal Sections, South Bay Aqueduct	5-9
5-2	Potential Sources of Contamination to SWP Open Canal Sections, Clifton Court Forebay to O'Neill Forebay	5-15
5-3	Potential Sources of Contamination to SWP Open Canal Sections, O'Neill Forebay to End of San Luis Field Division	5-21
5-4	Potential Sources of Contamination to SWP Open Canal Sections, End of San Luis Field Division to the Kern River Intertie	5-26
5-5	Potential Sources of Contamination to SWP Open Canal Sections, Coastal Branch	5-30
5-6	Potential Sources of Contamination to SWP Open Canal Sections, Kern River Intertie to the East-West Branch Bifurcation	5-34

LIST OF TABLES (continued)

Number		Page
5-7	Potential Sources of Contamination to SWP Open Canal Sections, West Branch	5-39
5-8	Potential Sources of Contamination to SWP Open Canal Sections, East Branch	5-47
5-9	Drainages Into Lake Silverwood	5-51
5-10	Potential Sources of Contamination to SWP Open Canal Sections, Delta Mendota Canal	5-56
5-11	Summary of Contaminant Sources to the Open Canal Sections of the SWP	5-59
5-12	Summary of Contaminant Sources to the SWP Reservoirs	5-65
6-1	Formation Potential Disinfection By-Products in SWP Waters	6-16
6-2	Asbestos Concentrations in SWP Facilities and Source Waters	6-32
7-1	Summary of Effectiveness of Current Regulatory Programs	7-9

LIST OF FIGURES

Number		Page
ES-1	Major Features of the State Water Project and Central Valley Project	ES-3
ES-2	THMFP in the State Water Project and Tributaries	ES-10
2-1	Major Features of the State Water Project and Central Valley Project	2-3
2-2	The State Water Project Tributary System	2-9
2-3	Export Induced Flow to the South Delta	2-14
2-4	State Water Project: Feather River to Below San Luis Reservoir	2-17
2-5	State Water Project: Below San Luis Reservoir to Tehachapi Afterbay	2-19
2-6	State Water Project: Tehachapi Afterbay to Lake Perris	2-21
2-7	1979-1988 Average Annual Pumping at Banks Pumping Plant and Tracy Pumping Plant	2-23
2-8	1979-1988 Average Monthly Pumping at Banks Pumping Plant and Tracy Pumping Plant	2-24
2-9	1976-1988 Average Monthly Flow into O'Neill Forebay and San Luis Reservoir	2-29
2-10	Average January Releases (1,000 Acre-Feet) into O'Neill Forebay, 1976 through 1988	2-31
2-11	Average June Releases (1,000 Acre-Feet) into O'Neill Forebay, 1976 through 1988	2-32
4-1	Average Flows of NPDES Municipal and Industrial Dischargers	4-6
4-2	Wastewater Treatment Plant Effluent Discharge Locations: Sacramento Basin	4-9
4-3	Wastewater Treatment Plant Effluent Discharge Locations: San Joaquin Basin	4-11
4-4	Wastewater Treatment Plant Effluent Discharge Locations: Tulare Basin	4-13
4-5	Industrial Plant Effluent Discharge Locations: Sacramento Basin	4-15
4-6	Industrial Plant Effluent Discharge Locations: San Joaquin Basin	4-17
4-7	Industrial Plant Effluent Discharge Locations: Tulare Basin	4-19
4-8	Major Urban Areas which Discharge Urban Runoff to Surface Water Bodies: Sacramento Basin	4-31
4-9	Major Urban Areas which Discharge Urban Runoff to Surface Water Bodies: San Joaquin Basin	4-33

LIST OF FIGURES (continued)

Number		Page
4-10	Major Urban Areas which Discharge Urban Runoff to Surface Water Bodies: Tulare Basin	4-35
4-11	Agricultural Area by County, Sacramento Basin	4-41
4-12	Agricultural Area by County, San Joaquin Basin	4-43
4-13	Fertilizer Use in Sacramento Basin	4-45
4-14	Fertilizer Use in San Joaquin Basin	4-47
4-15	Pesticide Use in Sacramento Basin	4-49
4-16	Pesticide Use in San Joaquin Basin	4-51
4-17	Location of Major Agricultural Drains in the Sacramento Basin	4-55
4-18	Concentrations of Molinate and Thiobencarb at the City of Sacramento Water Treatment Plant Sacramento River Intake	4-57
4-19	Peak Concentrations of Molinate and Thiobencarb at the City of Sacramento Water Treatment Plant Sacramento River Intake, 1982-1988	4-58
4-20	Location of Agricultural Drains in the San Joaquin Basin	4-61
4-21	Mean Total Dissolved Solids Concentrations in the San Joaquin River, January 1984 to December 1988	4-64
4-22	Mean Selenium Concentrations in the San Joaquin River, January 1984 to December 1988	4-65
4-23	Mean Dissolved Nitrate Concentrations in the San Joaquin River, January 1984 to December 1988	4-66
4-24	Locations of Agricultural Drains in the Delta	4-69
4-25	Major Inactive Mines in the Sacramento Basin	4-75
4-26	Major Inactive Mines in the San Joaquin Basin	4-77
4-27	Major Inactive Mines in the Tulare Basin	4-79
6-1	Monitoring Locations	6-4
6-2	THMFP in the SWP and Tributaries	6-10
6-3	Total Organic Carbon in the SWP and Tributaries	6-11
6-4	Dissolved Organic Carbon in the SWP and Tributaries	6-12
6-5	Predicted Bromide in the SWP and Tributaries	6-14
6-6	Brominated THMFP in Delta Source Waters	6-15
6-7	Total Dissolved Solids in the SWP and Tributaries	6-18
6-8	Chloride in the SWP and Tributaries	6-20
6-9	Sodium in the SWP and Tributaries	6-22
6-10	Turbidity in the SWP and Tributaries	6-24
6-11	Color in the SWP and Tributaries	6-25
6-12	Nitrate as N in the SWP and Tributaries	6-27
6-13	Total Phosphorus as P in the SWP and Tributaries	6-29

EXECUTIVE SUMMARY

The California State Water Project (SWP) provides drinking water to over 20 million people in northern and southern California. At the request of the California Department of Health Services (DHS), the State Water Contractors (SWC) conducted a sanitary survey of the SWP.

Sanitary surveys, which were first mandated by the 1962 U.S. Public Health Service Drinking Water Standards, emphasize the characterization of actual and potential contaminant sources, rather than merely the monitoring and analysis of the finished drinking water. In February 1988, DHS requested that a sanitary survey of the SWP be conducted to enable SWP contractors treating SWP water and the DHS to appraise the effectiveness of the operation of existing water treatment plants and to adequately evaluate new treatment plant design requirements. The SWC decided to conduct one sanitary survey of the SWP system rather than having individual contractors conducting independent surveys when they applied for a new water supply permit or amended their existing permits. Brown and Caldwell Consultants was hired in February 1989, to conduct the Sanitary Survey of the SWP.

The Sanitary Survey of the SWP covered almost two thirds of the State of California, starting with the upper reaches of the Sacramento and San Joaquin River watersheds and extending to the terminal reservoirs of the SWP in southern California. It was not possible or practical with a study area of this size to conduct a classical sanitary survey in which the entire watershed is surveyed in great detail. The actual and potential contaminant sources in the watersheds were identified from literature searches and regulatory agency file searches. The study included a detailed field survey of the SWP aqueducts, reservoirs, and pumping stations. In addition, water quality data from several ongoing monitoring studies, as well as from water agencies treating SWP water, were analyzed to determine if the contaminant sources identified in the watersheds and direct sources of contaminants to the SWP facilities were having any identifiable impact on drinking water quality.

The Water Supply System

The SWP was constructed primarily by, and is operated by, the California Department of Water Resources (DWR). The Sacramento and San Joaquin Rivers are the two major rivers providing water to the Sacramento-San Joaquin Delta (Delta), the source of SWP exports; however, there are numerous smaller rivers that feed into the system. The SWP has 27 lakes and reservoirs which impound 6.8 million acre feet (AF) of water, and some 700 miles of canals and pipelines. Its purposes include municipal and industrial (M&I) and agricultural water supply, flood control, hydroelectric power generation, recreation, fish and wildlife preservation and enhancement, and water quality control in the Delta. There are 242 user turnouts on the SWP system, some of which are for M&I purposes and some of which are for agricultural purposes. The Central Valley Project (CVP) was built, and is operated by, the U.S. Bureau of Reclamation.

Like the SWP, the CVP is a large multipurpose water project. The CVP supplies water to several large M&I users. Its primary purpose, however, is to provide water for agricultural purposes in the Central Valley. Figure ES-1 shows the major features of the SWP and the CVP. There is one principal interconnection between the two projects at O'Neill Forebay.

Water from the north Delta is pumped into the North Bay Aqueduct at the Barker Slough Pumping Plant. This water is mostly Sacramento River water. The North Bay Aqueduct is a continuous pipeline and is thus protected from direct sources of contamination. There are no storage reservoirs along the North Bay Aqueduct. Storage reservoirs eliminate extremely high or low concentrations of water quality constituents in source waters by blending with water in the reservoir.

Water is pumped from the south Delta into the California Aqueduct at the Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant) near Tracy. Likewise, water is pumped from the south Delta into the Delta Mendota Canal (DMC) of the CVP at the Tracy Pumping Plant. The exact proportion of Sacramento and San Joaquin River water flowing into the south Delta pumping plants under different hydrologic regimes is not precisely known. DWR estimates that the Banks Pumping Plant receives 70 percent Sacramento River water and 30 percent San Joaquin River water under normal hydrologic conditions. During wet years, a greater proportion of the water comes from the San Joaquin River, but during these years the San Joaquin River water quality is greatly improved over normal conditions. During critically dry years when pumping at the Tracy Pumping Plant exceeds the flow in the San Joaquin River, virtually all of the San Joaquin River water is diverted into the Tracy Pumping Plant and the Banks Pumping Plant receives only Sacramento River water. Overall, the Tracy Pumping Plant receives a greater proportion of the poorer quality San Joaquin River water and the Banks Pumping Plant receives a greater proportion of the higher quality Sacramento River water.

Water flows from the Banks Pumping Plant to the South Bay Aqueduct and to O'Neill Forebay via the California Aqueduct. South Bay Aqueduct water is carried in both open canal and sections pipelines. Like the North Bay Aqueduct, there are no storage reservoirs. Water flowing south in the California Aqueduct enters the O'Neill Forebay. Water is pumped from O'Neill Forebay into San Luis Reservoir, a 2-million AF off-stream storage reservoir. San Luis Reservoir is primarily filled during winter months. Water from the DMC is also pumped into O'Neill Forebay by the O'Neill Pumping/Generating Plant and is commingled with SWP water from the California Aqueduct. This connection is important to the quality of SWP and CVP water delivered south of O'Neill Forebay and to the CVP water delivered through the Pacheco Pumping Plant located on the west side of San Luis Reservoir. DWR operating records show that DMC water accounts for 13 to 51 percent of the total canal input (DMC plus California Aqueduct) to O'Neill Forebay on a monthly basis. The annual average DMC contribution was 35 percent between 1976 and 1988. DMC water enters O'Neill Forebay primarily between September and April. Although it has not been confirmed by water quality data, there have been visual observations of highly turbid DMC water entering O'Neill Forebay and traveling south down the east side of the forebay where it is released into the San Luis Canal section of the

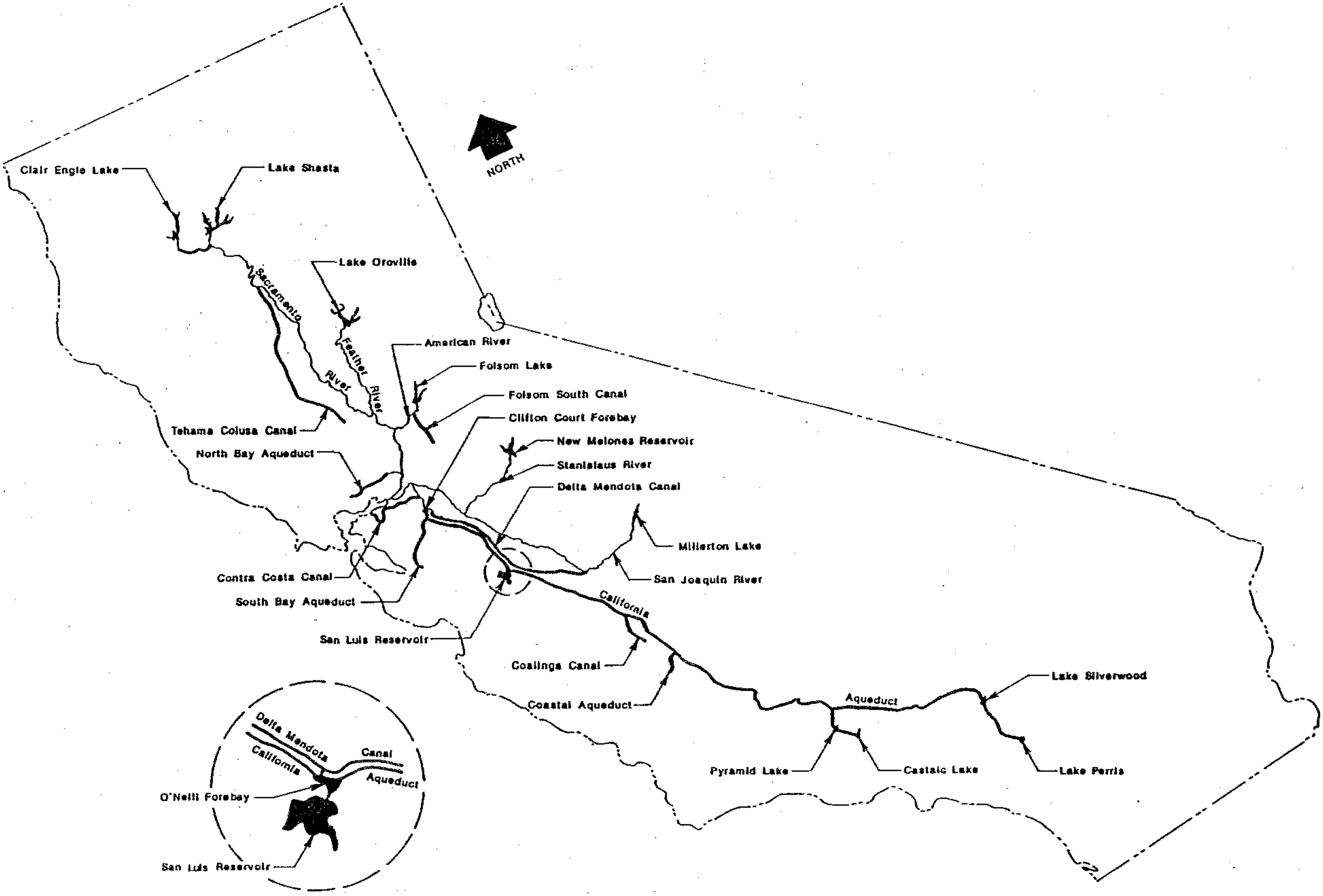


Figure ES-1. Major Features of the State Water Project and Central Valley Project

California Aqueduct without complete blending with the California Aqueduct water entering the forebay. The actual percent of DMC water traveling south in the aqueduct may be as high as 90 percent in winter months though the quality of DMC water during the winter months is generally good.

South of O'Neill Forebay, the water travels down the California Aqueduct through the south San Joaquin valley. The Kern River Intertie contributes water to the California Aqueduct in this reach. Historically, the Kern River flowed into Tulare and Buena Vista Lakes. The Kern River Intertie was built to relieve flooding in the Tulare Lake area by removing excess water from the Kern River during times of high flow. This water is diverted through the Kern River Intertie into the California Aqueduct below Bakersfield. Between 1979 and 1988, the Kern River Intertie contributed water to the California Aqueduct during the five wet years. Most of the transfer has occurred in the winter or spring when the Kern River water, though silt-laden, is of quite good mineral quality.

In the Tehachapi Mountains, south of Bakersfield, the California Aqueduct bifurcates into the west and east branches. South of the bifurcation, water is stored in terminal reservoirs for delivery to southern California water supply agencies. Water from the west branch is stored in Pyramid and Castaic Lakes and water from the east branch is stored in Silverwood Lake and Lake Perris.

Regulations for the Protection of Drinking Water

Contaminants of concern in a domestic water supply are those that either pose a health threat or in some way alter the aesthetic acceptability of the water. These types of contaminants are currently regulated by the U.S. Environmental Protection Agency (EPA) as primary and secondary maximum contaminant levels (MCLs). As directed by the Safe Drinking Water Act amendments of 1986, EPA is expanding its list of primary MCLs at a rapid rate. In response to the federal changes and specific concerns within the state, the State of California is also revising its drinking water regulations extensively. The DHS Office of Drinking Water is the state agency responsible for regulating California drinking water quality under a primacy agreement with the EPA. Chapter 3 of the report contains a discussion of the existing and proposed drinking water regulations that contractors taking water from the SWP must meet now or in the near future.

The standards that will be most difficult for SWP contractors to meet are those imposed by the Surface Water Treatment Rule and the likely standards that will be imposed by the Disinfectants and Disinfection By-Products Rule when it is promulgated in 1993-94. The state's Surface Water Filtration and Disinfection Regulation, which implements the EPA Surface Water Treatment Rule, will be in effect in early 1991. The contractors will have to achieve 99.9 percent reduction by removal and inactivation of Giardia cysts and 99.99 percent reduction by removal and inactivation of viruses while meeting a trihalomethane (THM) standard of probably either 50 or 25 micrograms per liter (µg/l).

Contaminant Sources in the Watersheds

Fresh surface water from the Sacramento River and the San Joaquin River drainage basins and sea water intrusion from San Francisco Bay combine in the Delta. Water from the Tulare Lake drainage basin can also flow into the Delta via the San Joaquin River during periods of very high flow in the Tulare Basin.

The quality of water entering the North Bay Aqueduct and south Delta SWP export pumps is affected by waste discharges in the watersheds of the Sacramento and San Joaquin Rivers and sea water intrusion from San Francisco Bay. A large number and great variety of sources of contamination to the SWP watershed are described in Chapter 4 of the report. Although there are numerous sources of contaminants in the Sacramento River watershed, there appears to be sufficient dilution capacity available in the river, based on current data, so that the water quality at Greene's Landing where the river enters the Delta is quite good. The water at Vernalis where the San Joaquin River enters the Delta is generally of poor quality. There is insufficient flow in the San Joaquin River to dilute the most significant source of contaminants in the San Joaquin Basin, subsurface agricultural drainage. The Tulare Basin contribution to the San Joaquin River flow is generally insignificant. When water from the Tulare Basin enters the San Joaquin River during wet years, it generally improves the water quality of the river.

Municipal and Industrial Discharges. There are 149 M&I discharges in the Sacramento, San Joaquin, and Tulare Basins with a total average continuous flow of 1,400 million gallons per day (mgd) or 1.5 million AF. Fifty-eight of these discharges are municipal wastewater treatment plants with a combined average flow of about 270 mgd (300,000 AF). Table ES-1 shows the major wastewater treatment plants that discharge into the Sacramento, San Joaquin, and Tulare basins. The Sacramento Regional Wastewater Treatment Plant, which discharges to the Sacramento River just upstream of the Delta, is the single largest municipal discharger in the Central Valley, accounting for 56 percent of the total municipal wastewater treatment plant discharges. With the exception of occasionally high residual chlorine levels in Vacaville Easterly Sewage Treatment Plant effluent, all of the major M&I dischargers are meeting their current National Pollutant Discharge Elimination System (NPDES) permit requirements.

The key contaminants discharged from treatment plants are pathogens, nutrients, organics, and metals. Although conventional wastewater treatment reduces the density of most pathogenic bacterial organisms, protozoan cysts, helminth ova, and certain enteric viruses may not be effectively inactivated. Bacteria die off rapidly in receiving waters relative to viruses and cysts which survive longer. Dilution is the only factor that mitigates the discharge of nutrients into receiving waters. Nutrients can stimulate biological productivity downstream of the discharge leading to high concentrations of organic carbon at downstream water intakes. Organic carbon combined with disinfectants used at the water treatment plants can produce THMs and other disinfection by-products. Organics and metals discharged from treatment plants are diluted in the receiving waters and tend to be reduced by adsorption to particulate matter and sedimentation.

Table ES-1. Major Wastewater Treatment Plants

Facility	Average flow, mgd	Basin location
Sacramento Regional	150	Sacramento
Stockton Main	29	San Joaquin
Roseville	11.8	Sacramento
Visalia	8.6	Tulare
Turlock	8	San Joaquin
Vacaville Easterly	6	Sacramento
Merced	5.5	San Joaquin
West Sacramento	4.5	Sacramento
Tracy	4	San Joaquin
Davis	3.6	Sacramento
Redding, Clear Creek	3.5	Sacramento
Oroville	3.5	Sacramento
Chico Main	3	Sacramento
Atwater	2.9	San Joaquin
University of California	1.8	Sacramento
Grass Valley	1.6	Sacramento
EID Deer Creek	1.5	San Joaquin
Red Bluff	1.2	Sacramento
Anderson	1.2	Sacramento
Placerville, Hangtown Creek	1.2	Sacramento
Beale AFB	1.1	Sacramento
Olivehurst PUD	1	Sacramento
Other	13.8	All
Total	268.3	

Urban Runoff Discharges. There are fourteen urban areas with populations greater than 30,000 in the Sacramento, San Joaquin, and Tulare Basins that discharge urban runoff to surface water bodies. Nine of these urban areas are near the Delta. Sacramento is the single largest urban area discharging urban runoff to the Central Valley watersheds. With increasing urbanization of the Central Valley, especially in those areas near the Delta, the contaminants in and the volume of urban runoff discharged into the watersheds of the SWP will increase. The greatest pollutant loads occur during the first few storms of the fall when river flows are typically lowest. The key contaminants in urban runoff are sediment, heavy metals and petroleum hydrocarbons. Metals and petroleum hydrocarbon concentrations in receiving waters are reduced by adsorption to particulate matter and sedimentation.

Agricultural Drainage. Agricultural drainage contributes sediment, pesticides, organics, and nutrients to the SWP system. Agricultural discharges occur primarily below the major reservoirs in the Sacramento and San Joaquin Valleys and in the Delta. Most agricultural discharges are seasonal and/or episodic and are related to specific crop practices. In the Sacramento Valley, the major agricultural drains discharge into the Sacramento River between the Colusa Basin Drain outfall and Suisun Bay. Between mid-May to mid-June, a slug of rice herbicides, which have potential to cause taste and odor problems, passes through the lower Sacramento River. Subsurface agricultural drainage is the primary concern in the San Joaquin Valley. Subsurface drainage discharges continuously to the San Joaquin River system, primarily through Mud and Salt Sloughs. These sloughs contribute high levels of trace metals (especially selenium) and salts. Downstream of the Mendota Pool, before the east side tributaries contribute fresher water, the San Joaquin River receives much of its flow from west side subsurface agricultural discharge. The water quality of the San Joaquin River at Vernalis, therefore, is greatly influenced by the amount of flow in the east side tributaries. Agricultural drainage in the Delta presents special problems due to the proximity to the Delta pumps and the presence of peat soils on Delta islands that contribute organic precursors which contribute to THM formation.

Mine Discharges. There are probably thousands of inactive mines in the Sacramento, San Joaquin, and Tulare Basins. The majority of these mines are upstream of reservoirs in the higher reaches of the Central Valley watersheds. Many of these mines discharge acid mine drainage with low pH and high concentrations of heavy metals, asbestos, mercury and cyanide. Most mine discharges occur from October to April during the wet season. The volume of flow is both seasonal and variable from year to year. The primary effect of these mine discharges is toxicity to aquatic life in the vicinity of the discharges. The mines may contribute a significant load of metals to the Sacramento and San Joaquin River systems, particularly the sediments in the upper reaches of the watersheds. There are data documenting low metals concentrations in Delta drinking water supplies.

Sea Water Intrusion. During periods of reduced freshwater outflow, the operation of water project pumps in the southern Delta can cause the flow of the San Joaquin River and other channels to reverse their normal direction. When this occurs, sea water containing sodium, chloride, bromide and other salts more easily enters the Delta from the estuary and mixes with Delta waters. The primary impacts of sea water intrusion on drinking water supplies derived from the

Delta is an increased salt (sodium, chloride, bromide) content of the water and significant increased production of THMs and other disinfection by-products. The extent to which bromides present in sea water increase the production of THMs and other disinfection by-products in drinking water taken from the Delta has not been precisely determined, but the input is known to be large.

Direct Sources of Contamination to the State Water Project

A field survey of the aqueducts, reservoirs, and pumping plants was conducted to identify actual and potential sources of direct contamination to the SWP facilities. The DMC was included in the field survey because of the interconnection with the SWP at O'Neill Forebay. Although, some of the types of discharges (such as agricultural drainage and urban runoff) are the same as discharges in the watersheds, the scale is much less. For example, the volume of urban runoff discharged to the watersheds is considerably greater than the volume of direct urban runoff discharges into the SWP. However, the California Aqueduct does not have the dilution capacity of the Sacramento and San Joaquin River systems. In addition, the direct discharges are located much closer to water service turnouts. The results of the field survey are described in Chapter 5 of the report.

A large number and great variety of potential direct sources of contamination to SWP facilities were identified in the sanitary survey. The impact of these sources on water quality has not been determined due to a lack of data on the volumes and frequencies of discharges and whether key contaminants exist and at what concentrations. The potentially most significant sources are the input of DMC water at O'Neill Forebay which was described previously, the inflow from the Coast Range creeks, the agricultural discharges particularly to the San Luis Reach, and the urban runoff discharged directly to the East Branch of the California Aqueduct.

Coast Range Drainage. Between O'Neill Forebay and the end of the San Luis Field Division during periods of heavy, continuous rain, the California Aqueduct receives drainage from the Arroyo Pasajero, Little Panoche Creek, Cantua Creek, and Salt Creek. These creeks drain undeveloped land and intensively farmed areas. The Arroyo Pasajero drains a watershed containing several asbestos mines and the cities of Huron and Coalinga. These creeks may contribute many different types of contaminants including sediment, asbestos fibers, agricultural chemicals, pathogens, organics, and nutrients to the water during the rain season.

Agricultural Drainage. One hundred ninety-one agricultural drains discharge into the DMC above the O'Neill Forebay interconnection. Agricultural drainage is discharged to the California Aqueduct between O'Neill Forebay and the end of the San Luis Canal reach near Kettleman City at 87 locations. Most of the agricultural drains in the San Luis Canal discharge about 100 gallons per minute or less when operating (Personal Communication, Dan Peterson, DWR). Agricultural drainage related to crop production occurs primarily during the April through October irrigation season. Rainfall-induced runoff from agricultural fields is generated primarily between October and April. Drainage from dry rangeland likely contains pathogens (especially protozoan cysts) from livestock. Grazing of dry rangeland can result in erosion during storms and increases in turbidity in the receiving waters. Drainage from intensively farmed areas likely contains dissolved solids, metals including selenium, pesticides, herbicides, and fertilizers.

Urban Runoff. Urban drainage from residential/commercial developments in the Hesperia area is discharged to the East Branch. The 44 large-diameter urban runoff drains in this area likely convey sediments, metals, nutrients, and organics to the water. The greatest pollutant loads from urban runoff occur during the first few storms of the fall.

Other Potential Sources of Contamination. A number of other potential sources of contaminants was discovered during the field survey. These sources include highway and canal roadside drainage; overcrossings of pipelines containing a variety of materials including petroleum products; underchutes carrying drainage beneath the Aqueduct; bridges that offer easy access for illegal dumping, vandalism, and accidental spills; locations where shallow groundwater is pumped into the Aqueduct; pumped water-service turnouts where chemicals mixed with irrigation water can backflow into the Aqueduct; and fishing areas not equipped with sanitary facilities. Body contact recreation in reservoirs and sewage handling facilities in the watersheds of some reservoirs may contribute contaminants to the reservoirs.

Water Quality of the State Water Project System

The water quality of the SWP system is described in Chapter 6 of the report. The description of water quality begins in the Sacramento, San Joaquin, and Kern River watersheds tributary to the SWP. The quality of water delivered to contractors at various locations along the California Aqueduct, the North Bay Aqueduct, and the South Bay Aqueduct is described. Water quality data were obtained from a number of monitoring programs. When available, the data analyzed in this study extended from 1975 through 1988.

The data show that the quality of source water degrades for some constituents as it flows into and through the Delta. This is shown for trihalomethane formation potential (THMFP) on Figure ES-2. The quality of the Sierra tributaries, such as the American River, is good with low concentrations of minerals, nutrients, metals, and organics. The THMFP of this water is so low that additional treatment for THM or precursor removal is not needed beyond the reduction afforded by conventional treatment to meet the current MCL of 100 µg/l, or a proposed revised MCL of 50 µg/l. With the exception of turbidity and coliform bacteria, drinking water quality standards for the constituents examined in this study are consistently met in the American River prior to treatment.

The Sacramento River water quality is good, although the constituent concentrations are higher than in the Sierra streams. Except for turbidity and coliforms, most drinking water standards for the constituents examined in this study are consistently met in the raw water. Additional treatment for THM removal is not needed for the Sacramento River water withdrawn from the river at Sacramento unless the finished water THM standard is reduced below 50 µg/l.

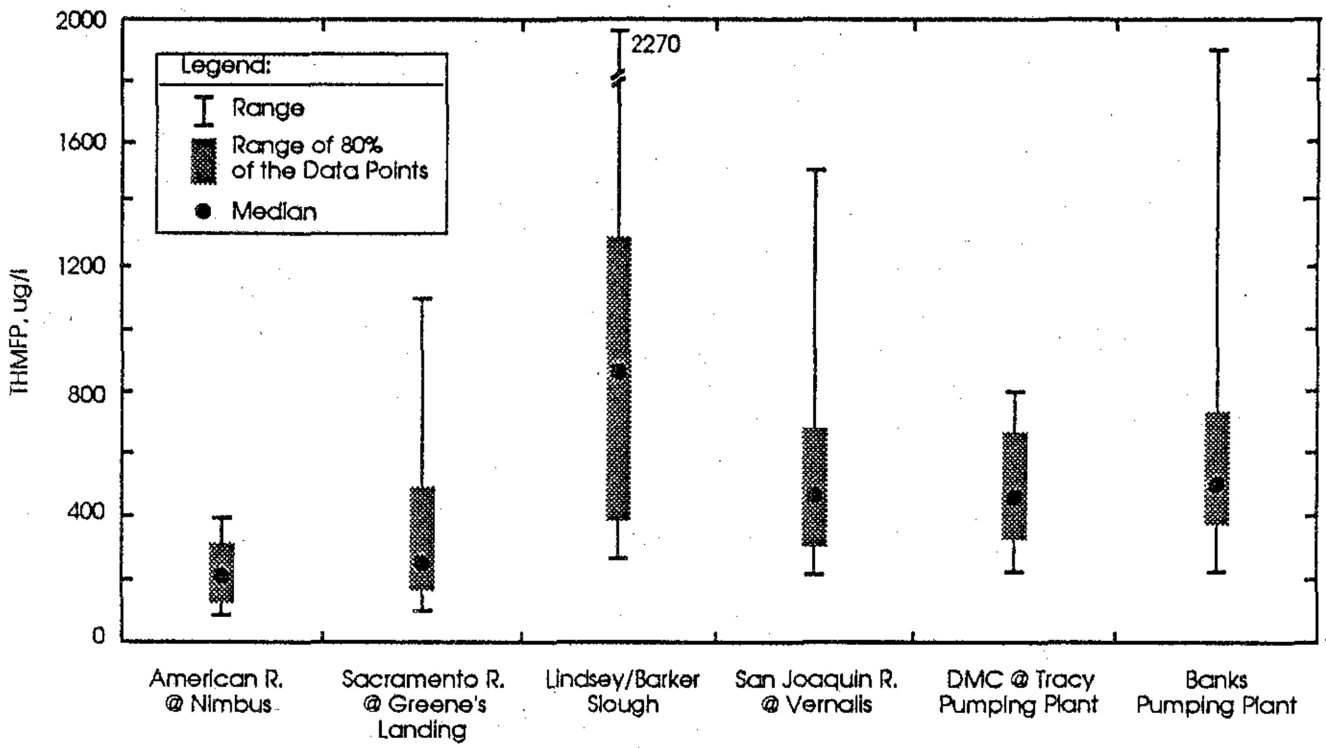


Figure ES-2. THMFP in the State Water Project and Tributaries

While water from the San Joaquin River, the Banks Pumping Plant, and the Barker Slough Pumping Plant can be treated to meet existing drinking water standards, it is of significantly poorer quality than the Sacramento River for some constituents. Delta water quality varies greatly in response to river flows, sea water intrusion, and agricultural drainage. Water diverted from the Delta is significantly degraded below the Sacramento River quality and requires additional treatment to reduce THMs in finished water to acceptable levels. The drinking water standards for turbidity and coliforms are frequently exceeded in untreated Delta waters, although conventional treatment controls these constituents.

Based on the available water quality data, there does not appear to be significant further degradation between the Delta and the SWP terminal reservoirs. This may be due to monitoring programs which are not adequate in frequency and scope to detect the types of contaminants entering the system. The routine monthly monitoring programs may not detect seasonal or short term discharges such as the Coast Range drainage or Hesperia urban runoff. In other cases, monitoring of key constituents has not been conducted. For example, DWR has conducted extensive monitoring of THMFP in the Delta to assess the impacts of agricultural drainage discharges but has only recently initiated THMFP monitoring in SWP facilities south of the Delta.

The data show that, with a few exceptions, the contractors taking water from the SWP are currently able to meet existing drinking water standards with their existing facilities. Several small water systems take CVP water from the San Luis Canal. Drinking water standards are not always met by these smaller systems. Currently, due to the size of the system, they do not have to meet the existing THM standard. However, THM concentrations often exceed the 100 μg/l level applicable to larger water supply agencies. Small water systems often have difficulty meeting drinking water standards with source water that does not pose any difficulties for larger water districts. These difficulties are due to a number of factors including the inability to finance improvements to water treatment facilities and the actual operation of the plants.

Effectiveness of Existing Regulations

The effectiveness of current regulatory programs to assure that high quality water is provided to the SWP export pumps and that the SWP facilities are operated to protect that water quality is assessed in Chapter 7 of the report. Drinking water standards established by EPA and DHS are extremely protective of public health, and drinking water regulations are rigorously enforced by DHS. In addition, the State Board's Inland Surface Waters Plan proposes water quality objectives that protect both human health and aquatic life. The aquatic life objectives are in many cases more stringent than the drinking water standards. Point sources of contamination are effectively regulated and monitored under existing regulations and programs. Nonpoint sources such as agricultural drainage and urban runoff are coming under regulation.

Point sources of contamination have been regulated for a number of years through the California Porter-Cologne Act and the predecessor of the Clean Water Act, the Federal Water Pollution Control Act of 1976. The California Regional Water Quality Control Board, Central Valley

Region (Regional Board) has developed an effective program for regulating the discharge of treated wastewater from M&I facilities through the issuance of NPDES permits and the collection of effluent monitoring data by the permittees pursuant to the Clean Water Act. Although, coliform monitoring of M&I discharges is required, NPDES permittees are not yet required to monitor their effluents for pathogenic microorganisms.

Nonpoint sources of pollution are beginning to be regulated. EPA is expected to issue draft regulations in October, 1990, that will require many industries and all municipalities with populations greater than 100,000 to apply for and obtain NPDES permits for urban runoff discharges. The City and County of Sacramento obtained an NPDES permit for their urban runoff discharges in June, 1990. Because control measures have not yet been identified or implemented, the effectiveness of the regulatory program to control the water quality of urban runoff cannot yet be assessed.

Agricultural drainage is not regulated under an effluent limitation system such as the NPDES permits. Best management practices (BMPs) to control the loads of contaminants are more suited to agricultural drainage because of the extensive use and reuse of the rivers for agricultural irrigation, the number of agricultural drains and responsible parties, and the variability of agricultural drainage quality with crop specific practices. The Regional Board and the Department of Food and Agriculture are in the process of implementing BMPs to control seasonal drainage from rice fields in the Sacramento Valley. This program has resulted in declines in the concentrations of rice herbicides since about 1986. The Regional Board is currently investigating and developing BMPs for agricultural surface runoff and subsurface discharges to the San Joaquin River system. The diversity of agricultural uses and practices in the San Joaquin Basin makes control of agricultural contaminants in that basin especially complex.

Controlling mine drainage can be technically complex and extremely costly. Often, locating responsible parties financially able to pay cleanup costs is not possible. Consequently, the regulatory program to control drainage from inactive mines has not been very effective. Many reaches of streams tributary to the Sacramento and San Joaquin Rivers have been listed by the Regional Board and the State Water Resources Control Board (State Board) as impaired water bodies because of the presence of metals from mine drainage at levels toxic to aquatic life. As mentioned earlier, metals concentrations from mine drainage are diluted when they reach the main river system and the Delta.

Sea water intrusion is currently regulated by the Delta Plan and Water Rights Decision 1485 (D-1485). D-1485 and the Delta Plan establish water quality objectives for various beneficial uses of Delta water. The Delta water quality objectives vary according to year type. For example, the number of days the chloride objective can be exceeded is greater in dry years. The water quality objectives were established at levels considered representative of natural Delta water quality prior to SWP and CVP projects. The State Board is currently considering a Water Quality Control Plan for Salinity which reconsiders the issues addressed in the Delta Plan and D-1485.

Recommendations

The Sanitary Survey of the SWP was a reconnaissance-level study of the sources of contamination and their impact on SWP drinking water supplies. Many sources of contamination were documented. The ability of SWP water to meet current and future drinking water standards is of major importance to over 20 million people in northern and southern California. A State Water Project Sanitary Action Committee (SWPSAC) concerned with protecting the drinking water quality of SWP water, should be formed by the SWC. This committee should consist of SWP water contractors and representatives of DWR, DHS Office of Drinking Water, Central Valley Regional Board, State Board, U.S. Bureau of Reclamation (USBR), and EPA. This committee should review the Sanitary Survey report and develop a priority list for appropriate actions and future studies.

The most significant degradation in the SWP system based on current water quality data occurs between the Sacramento River at Greene's Landing and the north and south Delta export pumps. The major sources of this degradation are agricultural drainage from Delta islands, sea water intrusion, inflow from the San Joaquin River, and possibly local discharges in the Stockton area and into Cache Slough. The SWPSAC should (1) support and accelerate the Delta Islands Drainage Investigation, (2) support efforts to improve salinity standards in the Delta, (3) support efforts to reduce the seismic vulnerability of the Delta levees, (4) support the Regional Board's and the USBR's efforts to find solutions for agricultural subsurface discharges into the San Joaquin River, (5) support the Regional Board's efforts to control urban runoff discharges, and (6) support the Regional Board's efforts to develop mass loading estimates of key contaminants into Delta source waters.

The significance of the direct sources of contamination to the SWP export facilities to drinking water quality could not be determined from the existing water quality data. Although it is good sanitary engineering practice to minimize these direct discharges, the costs of removing direct discharges must be balanced with the expected improvement in drinking water quality. It would be inappropriate to recommend specific corrective actions before problems resulting from direct discharges are documented. Key areas for the SWPSAC to consider for further investigation are (1) the effect of the introduction of DMC water into the SWP at O'Neill Forebay, (2) the impact of the Coast Range drainage, (3) the impact of agricultural discharges, particularly in the San Luis Reach, and (4) the impact of urban runoff discharges, particularly in southern California.

Historically, the DWR monitoring programs have concentrated on ecological monitoring of the Delta and SWP supplies. The historic monitoring programs were not designed to evaluate the impacts of the potential sources of contamination identified in this sanitary survey. DWR should consider elevating, centralizing, and coordinating the ecological, operational, and drinking water monitoring programs. DWR has begun and should continue to improve the drinking water monitoring of the SWP system.

As drinking water standards become more stringent, it will be necessary to more fully characterize discharges and receiving waters with respect to the constituents being regulated. The Regional Board may need to revise discharge limitations for both point and nonpoint discharges to protect source water quality. This increased protection of source water quality may be necessary for water supply agencies to meet future drinking water standards.

CHAPTER 1

THE STUDY

The California State Water Project (SWP) provides drinking water to over 20 million people in northern and southern California. At the request of the California Department of Health Services (DHS), the State Water Contractors (SWC) decided to conduct a sanitary survey of the SWP.

BACKGROUND

Sanitary surveys, which were first mandated by the 1962 U.S. Public Health Service Drinking Water Standards, emphasize the characterization of actual and potential contaminant sources, rather than merely the monitoring and analysis of the finished drinking water. The SWC received a letter from the DHS in February 1988, requesting that a sanitary survey of the SWP be conducted. DHS felt that a sanitary survey was necessary to enable SWP contractors treating SWP water and the DHS to appraise the effectiveness of the operation of existing water treatment plants and to adequately evaluate new treatment plant design requirements. The SWC decided to conduct a sanitary survey of the entire SWP system rather than having individual water agencies conducting independent surveys every time they applied for a new water supply permit or amended their existing permits. Brown and Caldwell Consultants was hired in February 1989, to conduct the Sanitary Survey of the SWP.

Most of the SWP facilities were designed and constructed in the 1960s and early 1970s. Although there has long been a concern for protection of drinking water supplies, many of the constituents that are currently most worrisome in drinking water were not identified at that time. For example, the U.S. Environmental Protection Agency first regulated trihalomethanes (THMs) in 1978, long after many of the SWP facilities were constructed. Studies are still being conducted on the factors that contribute to THM formation in SWP drinking water. As knowledge of contaminants and contaminant sources grows, the importance of identifying the key sources of contamination and where possible, removing those sources from the drinking water supply, will grow. Alternative points of diversion, less affected by the contaminant sources, will also become increasingly sought after.

CONDUCT OF THE STUDY

The Sanitary Survey of the SWP was conducted by Brown and Caldwell with assistance from Boyle Engineering Corporation, EOA, Inc., and Laverty Associates. The study was sponsored by the SWC and directed by John Coburn, staff engineer. The SWC Water Quality Technical Committee helped develop the study work plan and reviewed the draft report. A project Advisory Committee, composed of senior staff members representing four of the water contractors and staff from the California Department of Water Resources (DWR), the DHS, and the U.S. Bureau of Reclamation (USBR), directed the progress of the study. In a series of meetings during the conduct of the study, the Advisory Committee reviewed and commented on work products and provided guidance to the project team. The Advisory Committee also helped develop the conclusions and recommendations.

Brown and Caldwell staff met with many of the water contractors to gather documents and data on water quality and discuss water quality problems experienced by the agencies. In addition, Brown and Caldwell staff met with DWR staff on several occasions to gather data and discuss the operation of the SWP and with California Regional Water Quality Control Board, Central Valley Region staff to obtain information on contaminants in the watersheds. Brown and Caldwell and Boyle staff met with the regional and district engineers from the DHS Public Water Supply Branch to determine their concerns with the SWP. Brown and Caldwell staff and several members of the Advisory Committee also met with the USBR to explain the study.

This study included a detailed field survey of the SWP aqueducts, reservoirs, and pumping stations. Boyle staff met with USBR and DWR field division staff during the conduct of the field survey. This study also included a review of pertinent literature particularly regarding the total hydrologic system, contaminant sources in the watershed, and past sanitary concerns with SWP water. Water quality data from several ongoing monitoring studies, as well as from water agencies treating SWP water, were incorporated into a computerized database and analyzed.

REPORT ORGANIZATION

This report contains 8 chapters. The content of the chapters is as follows:

Chapter 1	Introduction to the study.
Chapter 2	Discussion of the physical and operational characteristics of the SWP and the interrelationship with the Central Valley Project.

Chapter 3	Discussions of current and anticipated drinking water regulations. Summary of other regulations affecting water quality of the SWP.
Chapter 4	Description of contaminant sources in the Sacramento, San Joaquin, and Tulare watersheds.
Chapter 5	Results of the field survey on direct sources of contamination to the SWP.
Chapter 6	Discussion of the water quality of the major rivers entering the SWP facilities and the water quality of the SWP at various locations from the Sacramento-San Joaquin Delta to the terminal reservoirs.
Chapter 7	Discussion of the effectiveness of existing regulations in controlling contaminants and protecting drinking water quality.
Chapter 8	Presentation of conclusions and recommendations.

Detailed technical appendices containing the field survey forms and photographs of contaminant sources are available in the office of the SWC.

CHAPTER 2

THE WATER SUPPLY SYSTEM

The State Water Project (SWP) and its interconnections with the Central Valley Project (CVP) are described in this chapter. It is necessary to describe the physical facilities and operation of the SWP so that the later discussions of contaminant sources and water quality impacts will be understood. A discussion of the major rivers that contribute water to the Sacramento-San Joaquin Delta (Delta) is provided to give an indication of the relative contribution of each watershed to the total water exported by the SWP. The SWP export facilities, including municipal turnouts, are described. Major inputs to the export facilities south of the Delta (the contribution of CVP water to O'Neill Forebay, and the contribution of Kern River water at the Kern River Intertie) are also discussed. Also, briefly described are proposed SWP facilities that would alter, to varying degrees, the composition of SWP export water downstream of these facilities. The CVP is discussed in this chapter because operation of CVP reservoirs has a significant influence on flow in the major rivers tributary to the Delta, and because of the CVP connection at O'Neill Forebay.

STATE WATER PROJECT AND CENTRAL VALLEY PROJECT SYSTEMS

The SWP was constructed by, and is operated by, the California Department of Water Resources (DWR). Figure 2-1 shows the major features of the SWP and CVP. The SWP has 27 lakes and reservoirs which impound approximately 6.8 million acre feet (AF) of water, and some 700 miles of canals and pipelines. The total area of the Sacramento and San Joaquin watersheds, which provide water to the SWP diversion points in the Delta, is about 42,000 square miles. SWP purposes include municipal and industrial (M&I) and agricultural water supply, flood control, hydroelectric power generation, recreation, fish and wildlife protection and enhancement, and water quality control in the Delta. There are 242 user turnouts on the SWP system, some of which are for M&I purposes and some of which are for agricultural irrigation. The system was designed to eventually supply water to 30 agencies from the upper Feather River area in Plumas County to the San Francisco Bay Area, Central Coastal area, San Joaquin Valley, and Southern California. Currently, 60 percent of SWP water is used for M&I purposes.

The CVP was built, and is operated by, the United States Bureau of Reclamation (USBR). Like the SWP, the CVP is a large multi-purpose water project. Its primary purpose, however, is to provide water for agricultural irrigation in the Central Valley.

Coordinated Operation Agreement

The Coordinated Operation Agreement (COA) between DWR and USBR governs the coordination of SWP and CVP releases and diversions to meet various objectives, including (1) in-basin uses, (2) Delta water standards, and (3) Delta diversions. Under the COA, SWP and CVP reservoir releases in the Sacramento Valley and on the Stanislaus River, as well as Delta diversions, are coordinated on a day-to-day basis.

The SWP and CVP make releases for such in-basin uses as water supply, flood control, navigation control, and fish and wildlife protection and enhancement. The SWP and CVP are also operated to protect beneficial uses of water within the Delta according to the standards contained in Water Rights Decision 1485 (D-1485) of the California State Water Resources Control Board. The D-1485 standards (Delta standards), which include M&I water quality standards at the intakes to all Delta SWP and CVP export facilities, are contained in the COA. The sum of SWP, CVP, and other Delta inflow is compared with the quantities of water in the Delta required to meet these standards, and additional SWP and CVP reservoir releases are made as necessary.

Under the COA, the SWP and CVP determine and divide permissible SWP and CVP diversions from the Delta. Additional releases needed for in-basin purposes are shared by the SWP and CVP according to the COA. Excess water conditions apply when it is agreed that releases from upstream reservoirs plus unregulated flows exceed in-basin uses plus diversions. During such periods, the SWP and CVP may divert and store as much Delta water as possible within their physical limits. Excess water conditions typically occur during winter and spring months.

State Water Project Contractors

The State has contracts to supply over 4.2 million AF of water annually from the SWP to 30 public water agencies. These public water agencies, known as the State Water Project Contractors, are listed by geographical area in Table 2-1 along with their maximum annual SWP entitlements. Many of the SWP contractors subcontract and/or exchange SWP water with other water supply agencies. Presently, the SWP can provide, on a dependable basis, 2.3 million AF of water annually. The majority of SWP agricultural contractors have relatively stabilized water needs and are already using their full allocated shares of SWP supplies. Virtually all of the anticipated increase in the need for water within the SWP service area is expected to occur in urbanized areas of the north San Francisco Bay area, the central coastal area, southern California, and, to a lesser extent, the south San Francisco Bay area. Ultimately, 30 percent of SWP water will be used to irrigate farmland and 70 percent will be used to meet the needs of the State's growing population.

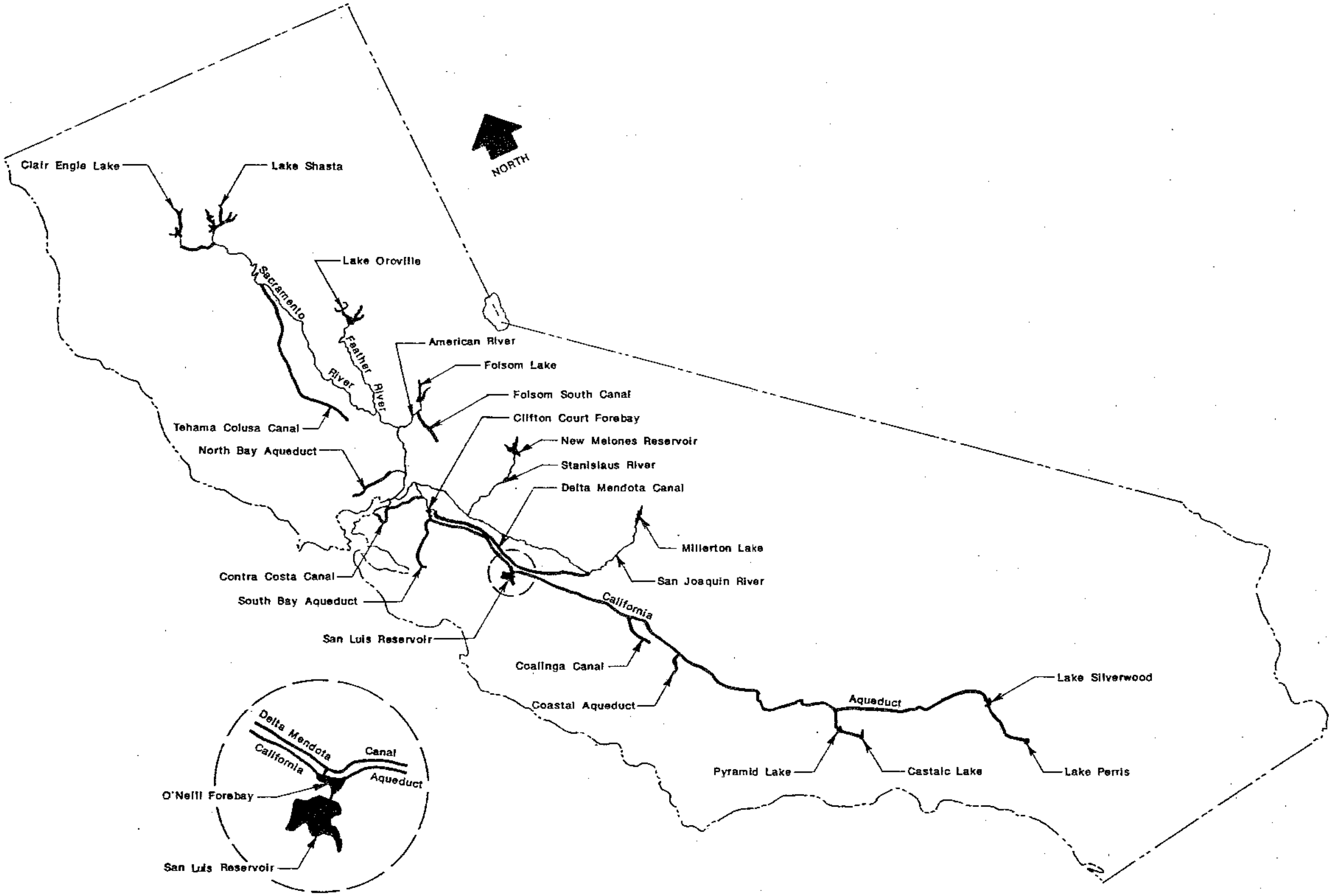


Figure 2-1. Major Features of the State Water Project and Central Valley Project

Watersheds Tributary to the Export Pumps

This section describes the operation of the Sacramento and San Joaquin River systems. Figure 2-2 is a schematic which illustrates the major hydraulic connections discussed in this section. Water from reservoir releases, unregulated tributaries, and irrigation returns flow down the Sacramento and San Joaquin Rivers into and through the Delta. Overall, the Sacramento River contributes 80 percent of the total inflow to the Delta and the San Joaquin River contributes 15 percent, with the east side streams accounting for the remaining 5 percent (DWR, 1974). Seawater intrudes into the Delta through Suisun Bay and, dependent on tides and river flows, mixes to varying degrees with freshwater from the Sacramento and San Joaquin River systems.

Sacramento River System

The Sacramento River system is described below from Lake Shasta to the Delta.

Lake Shasta. The 4.5-million-AF multipurpose Lake Shasta, impounded by Shasta Dam, is the largest of the CVP reservoirs in California. Flow from the upper Sacramento, McCloud, and Pit Rivers from the Cascade Range and Modoc Plateau converge in Lake Shasta. Releases from Lake Shasta enter Keswick Reservoir and then the Sacramento River as it begins its traverse through the Sacramento Valley.

Clair Engle Lake. The 2.5-million-AF Clair Engle Lake, impounded by Trinity Dam, is part of the CVP. The dam impounds Trinity River water from the North Coast Drainage Basin. This water is conveyed into the Sacramento Valley via Clear Creek Tunnel, Whiskeytown Lake, and Spring Creek Tunnel. It enters the Sacramento River below Lake Shasta at the 0.02 million AF Keswick Reservoir, the Lake Shasta Afterbay that is impounded by Keswick Dam. Clair Engle Lake and Lake Shasta share in providing mandatory releases to the Sacramento River.

Colusa Basin Drain and Sacramento Slough. From Keswick Dam to the confluence of the Feather River, a portion of Sacramento River flow is diverted by irrigation canals. A large share of the return flows from Sacramento River diversions west of the Sacramento River in this region are conveyed parallel to the river in Colusa Basin Drain (CBD). They re-enter the Sacramento River through outfall gates above the Feather River confluence. Return flows east of the Sacramento River are conveyed in the borrow pits for Sutter Bypass levees and reenter the Sacramento River through Sacramento Slough downstream of the CBD outfall and just upstream of the Feather River. Colusa Basin Drain and Sacramento Slough are discussed further in Chapter 4 in the section on agricultural drainage.

Sutter and Yolo Bypasses. To control flooding, Sacramento River water is diverted over a system of weirs into the Sutter Bypass during times of high flow. Sutter Bypass flows reenter the Sacramento River above the Feather River. At this point, flood flows may be diverted over Fremont Weir into the Yolo Bypass. Yolo Bypass flows reenter the system in the north Delta. The capacity of Sutter Bypass increases from 60,000 cubic feet per second (cfs) at its northern end to 380,000 cfs where it re-enters the Sacramento River. The capacity of Yolo Bypass increases from 343,000 cfs at Fremont Weir to 579,000 cfs where it re-enters the Sacramento River in the Delta.

Lake Oroville and the Feather River. SWP storage is contained in the 3.5-million-AF Lake Oroville, impounded by Oroville Dam. Oroville Dam impounds water from the upper Feather River from the Cascade Range and the Sierra Nevada. Releases from Lake Oroville enter the lower Feather River. Large west side irrigation diversions from the Feather River flow to Butte Creek. Return flows enter Sutter Bypass channels and then the Sacramento River through Sacramento Slough. West side and east side irrigation diversions also reenter the lower Feather River directly. Agricultural drainage canals are discussed further in Chapter 4. The Feather River flows into the Sacramento River at Verona.

Folsom Lake and the American River. CVP storage is contained in the 1.1-million-AF Folsom Lake, impounded by Folsom Dam. Folsom Lake impounds upper American River water from the Sierra Nevada. Releases from Folsom Lake flow into Lake Natoma, the Folsom Lake Afterbay, formed by Nimbus Dam. At this point, some water is diverted south through the Folsom South Canal and the remainder flows down the lower American River through the City of Sacramento and enters the Sacramento River.

The American River to Suisun Bay. Below the American River, the Sacramento River enters the north Delta. The Delta Cross Channel directs some Sacramento River water into the Mokelumne River. Below the Delta Cross Channel, Sacramento River water is conveyed via Cache Slough and Lindsey Slough into Barker Slough, the headworks of the North Bay Aqueduct. The mouth of the Sacramento River is at Antioch where the river enters Suisun Bay. The transport of Sacramento River water south through the Delta to the Delta export pumps is described later in the section on the Delta.

San Joaquin River System

The San Joaquin River is described below from Millerton Lake to the confluence with the Stanislaus River, its most downstream major tributary before it enters the Delta.

Millerton Lake. The CVP operates the 0.52-million-AF Millerton Lake formed by Friant Dam. Friant Dam impounds upper San Joaquin River water from the Sierra Nevada. Millerton Lake primarily supplies water to the CVP's Madera and Friant-Kern Canals, which carry Millerton Lake water along the east side of the San Joaquin Valley to the north and south, respectively. Releases to the San Joaquin River from Friant Dam are normally only about 50 cfs and are made to maintain fisheries and satisfy irrigation demands along the San Joaquin River upstream of Mendota Pool. The CVP must maintain a flow of 5 cfs to Gravelly Ford, the control point on the San Joaquin River upstream of the San Joaquin River Bypass (about 15 miles upstream from Mendota Pool). Between this control point and Mendota Pool, the San Joaquin River is normally dry. In wet years, additional flow from Millerton Lake is released into the San Joaquin River.

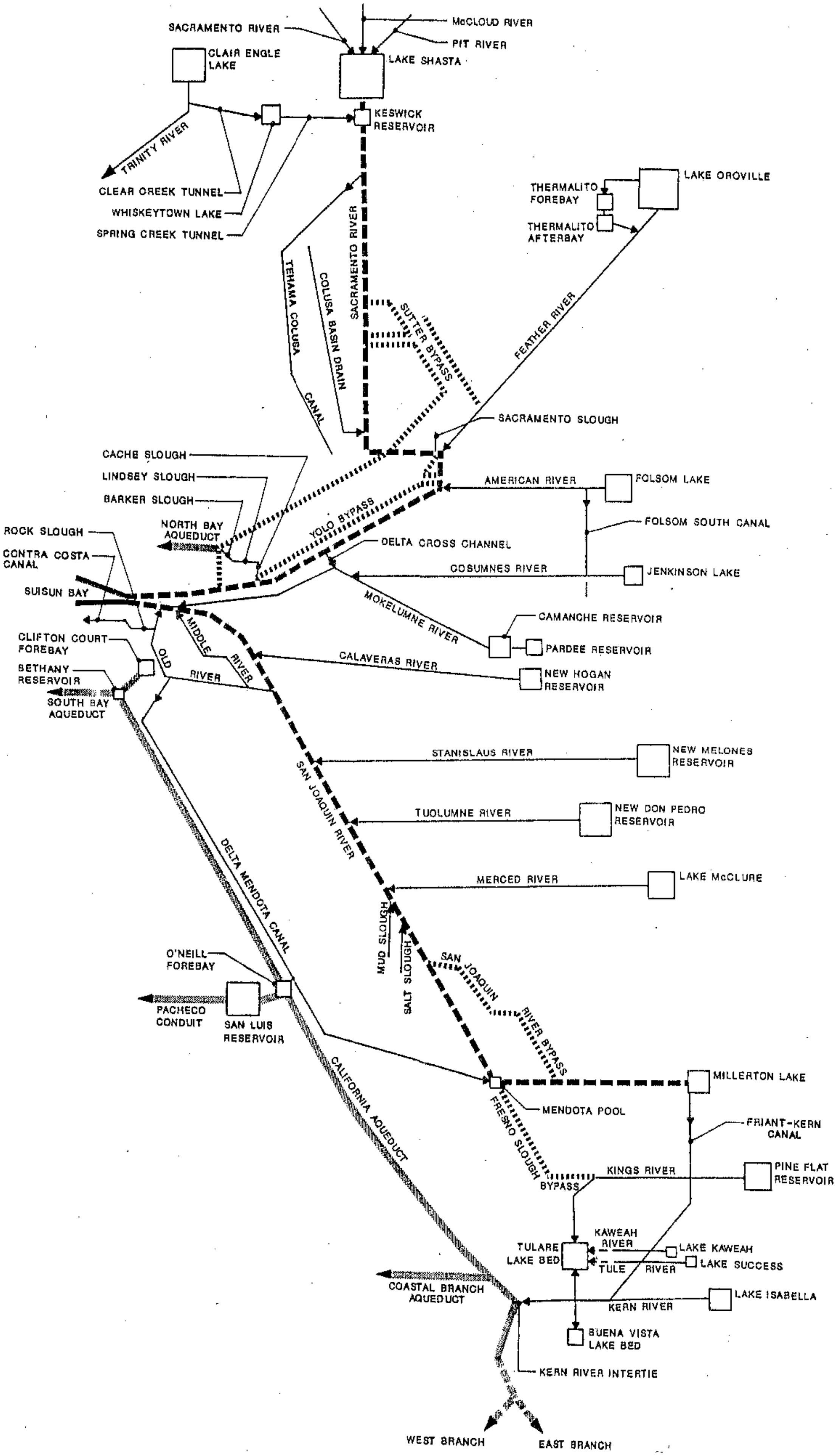


Figure 2–2. The State Water Project Tributary System

San Joaquin River (Chowchilla/Eastside) Bypass. During wet years, most of the flow in the San Joaquin River below Millerton Lake that is not used for irrigation purposes is diverted into the San Joaquin River Bypass. The San Joaquin River Bypass reenters the San Joaquin River downstream of Mendota Pool and upstream of the confluence with the Merced River. This water is diverted to minimize San Joaquin River flow into Mendota Pool. During wet years, when the San Joaquin River Bypass cannot accommodate all of the San Joaquin River flow, excess San Joaquin River water flows to Mendota Pool. For the 13-year period, between 1976 and 1988, San Joaquin River water has entered Mendota Pool during seven of these years, primarily from February through July. The annual amount of San Joaquin River water flowing into Mendota Pool during these 7 years has ranged from 46,000 to 328,000 AF [United States Geological Survey (USGS)].

Mendota Pool. Mendota Pool is formed by Mendota Dam on the San Joaquin River. It is the terminus of the Delta Mendota Canal (DMC). Mendota Pool provides storage and regulation of DMC water prior to release to the Mendota Pool Exchange Contractors who divert water directly from Mendota Pool for irrigation purposes.

Also, during wet years, Kings River water can flow into Mendota Pool. Pine Flat Reservoir formed by Pine Flat Dam, on the Kings River normally releases water to meet downstream irrigation requirements. When water in excess of the amount needed for irrigation demands is released from Pine Flat Reservoir into the Kings River, the first 4,000 cfs is diverted through Fresno Slough (James) Bypass to the Mendota Pool. This water is diverted to minimize flooding in the Tulare Lake area, the terminus of the Kings River. Historically, Kings River water has been diverted into Mendota Pool about once every 4 or 5 years. For the 13 year period 1976 through 1988, Kings River water has entered Mendota Pool during 7 of these years, primarily from March to June. The amount of Kings River water diverted annually through the Fresno Slough Bypass during these 7 years has ranged from 1 thousand to over 2 million AF (USGS). Fresno Slough is the only outlet from the Tulare Basin north into the San Joaquin River drainage basin.

Occasionally, water is released from Mendota Pool into the San Joaquin River for irrigation water deliveries to the San Luis Canal Company. The intake for these deliveries is about 20 miles downstream of Mendota Pool. At this point, any flow in the San Joaquin River is normally diverted. During wet years when Millerton Lake water and Kings River water enter Mendota Pool, this water is released into the San Joaquin River so that there is flow in the San Joaquin River downstream of the San Luis Canal Company diversion.

Mud and Salt Slough. Flow in the San Joaquin River downstream of Mendota Pool and upstream of the confluence with the Merced River is mostly irrigation return flows from west of the San Joaquin River and occasional flow from the San Joaquin River Bypass. Mud Slough and Salt Slough carry most of the irrigation returns in this area and enter the San Joaquin River downstream of the San Joaquin River Bypass. Mud and Salt Slough are discussed further in Chapter 4 in the section on agricultural drainage.

Lake McClure and the Merced River. The 1-million-AF Lake McClure, formed by New Exchequer Dam, is operated by the Merced Irrigation District. Lake McClure impounds upper Merced River flows from the Sierra Nevada. Water released from Lake McClure flows into the Merced Irrigation District canal and into the lower Merced River which flows to the San Joaquin River.

New Don Pedro Reservoir and the Tuolumne River. The 2-million-AF New Don Pedro Reservoir, formed by New Don Pedro Dam, is operated by the Turlock and Modesto Irrigation Districts. New Don Pedro Reservoir impounds upper Tuolumne River flows from the Sierra Nevada. Water released from New Don Pedro Reservoir flows into Turlock and Modesto Irrigation Districts' canals and into the lower Tuolumne River which flows to the San Joaquin River.

New Melones Reservoir and the Stanislaus River. The CVP operates the multipurpose 2.4-million-AF New Melones Reservoir, formed by New Melones Dam. New Melones Reservoir impounds upper Stanislaus River flows from the Sierra Nevada. Releases from New Melones Reservoir flow into Oakdale and South San Joaquin Irrigation Districts' canals and into the lower Stanislaus River which flows to the San Joaquin River.

East Side Streams

The Calaveras, Mokelumne, and Cosumnes Rivers, which contribute flow to the San Joaquin River after the San Joaquin River enters the Delta, are described in this section.

New Hogan Reservoir and the Calaveras River. The 0.32-million-AF New Hogan Reservoir, formed by New Hogan Dam, is operated by the U.S. Army Corps of Engineers. New Hogan Reservoir impounds Upper Calaveras River flows from the Sierra Nevada. Releases from New Hogan Reservoir flow into the lower Calaveras River to its confluence with the San Joaquin River in the Delta.

Mokelumne and Cosumnes Rivers. The 0.21-million-AF Pardee Reservoir, formed by Pardee Dam, and operated by the East Bay Municipal Utility District for municipal water supply deliveries to the East Bay area, impounds upper Mokelumne River flows from the Sierra Nevada. Releases from Pardee Reservoir flow into the 0.43-million-AF Camanche Reservoir. Camanche Reservoir, formed by Camanche Dam, is operated by the East Bay Municipal Utility District to provide downstream flows in the lower Mokelumne River.

The lower Cosumnes River flows into the Mokelumne River in the Delta. Just downstream of the confluence of the Mokelumne and Cosumnes Rivers, flow from the Sacramento River is directed into the Mokelumne River through the CVP's Delta Cross Channel. The Mokelumne River joins the San Joaquin River in the Delta near the southeast corner of Andrus Island.

The Delta

Water in the north Delta is almost entirely Sacramento River flow. Sacramento River water is also transferred via the Delta Cross Channel and Georgiana Slough in the north Delta into the Mokelumne River system, through the central Delta, to the south Delta export pumps. Due to limited capacity in these channels, Sacramento River water also flows around Sherman Island in the west Delta and then back upstream in the San Joaquin River where it blends with Mokelumne River flows in the central Delta on the way to the south Delta export pumps. San Joaquin River water primarily flows to the south Delta pumps via Old River and Grant Line Canal. Export-induced flow to the south Delta is shown schematically on Figure 2-3. The natural flow direction in the Delta is downstream towards Suisun Bay. Seawater intrudes into the Delta through Suisun Bay and, dependent on tides and river flows, mixes to varying degrees with freshwater from the Sacramento and San Joaquin River systems. Tidal action, as well as the south Delta pumps, influences flow direction in the Delta. High tide can cause the San Joaquin River near Stockton to become essentially stagnant for periods of time.

A basic physical property of the Delta is that water in the north Delta is of better quality than that in the south Delta. This is due to the better quality of the Sacramento River and the limited hydraulic capacity of Delta channels (the Delta Cross Channel, Georgiana Slough, and Three Mile Slough) to transport that water southward. To meet Delta standards and provide sufficient flow for Delta exports during the spring, summer, and early fall months, Sacramento River system releases must be made to flow in the Sacramento River to the mouth of the Delta near Antioch and then upstream in the San Joaquin River in reverse of the normal flow direction. The SWP and CVP system operators must anticipate the channel depletion and outflow and vary the Sacramento River system releases and/or Delta exports to account for the cyclical variations of the ocean's salinity intrusion rates which are determined by tidal fluctuations.

The DWR has studied the movement of Sacramento River and San Joaquin River flow towards the south Delta export pumps by monitoring various water quality constituents in the rivers and in major Delta channels (DWR, 1990). Due to differences in the water quality of the Sacramento and San Joaquin Rivers, several constituents (selenium, specific conductance, total dissolved solids, alkalinity, sodium, and sulfate) serve as tracers of the rivers' flows. This monitoring has indicated that San Joaquin River water flows through Old River and Grant Line Canal to the Tracy Pumping Plant intake canal. Sacramento River water backflows down Old River, Middle River, and Victoria Canal to the Clifton Court Forebay intake gate. The actual contributions at any given time of Sacramento River to San Joaquin River flow at the south Delta export pumps is affected by dam releases and also the degree to which wet, dry, or normal conditions affect different parts of the watersheds. According to DWR estimates, the average contributions of the Sacramento River and San Joaquin River at the Clifton Court Forebay intake is 70 percent Sacramento River water and 30 percent San Joaquin River water. During wet years, when the San Joaquin River floods the south Delta, DWR estimates the ratio is more nearly 10 percent Sacramento River water and 90 percent San Joaquin River water. At these times of high flow in the San Joaquin River, the quality of San Joaquin River water is greatly improved due to the effects of dilution. In dry years, when San Joaquin River flow is greatly reduced

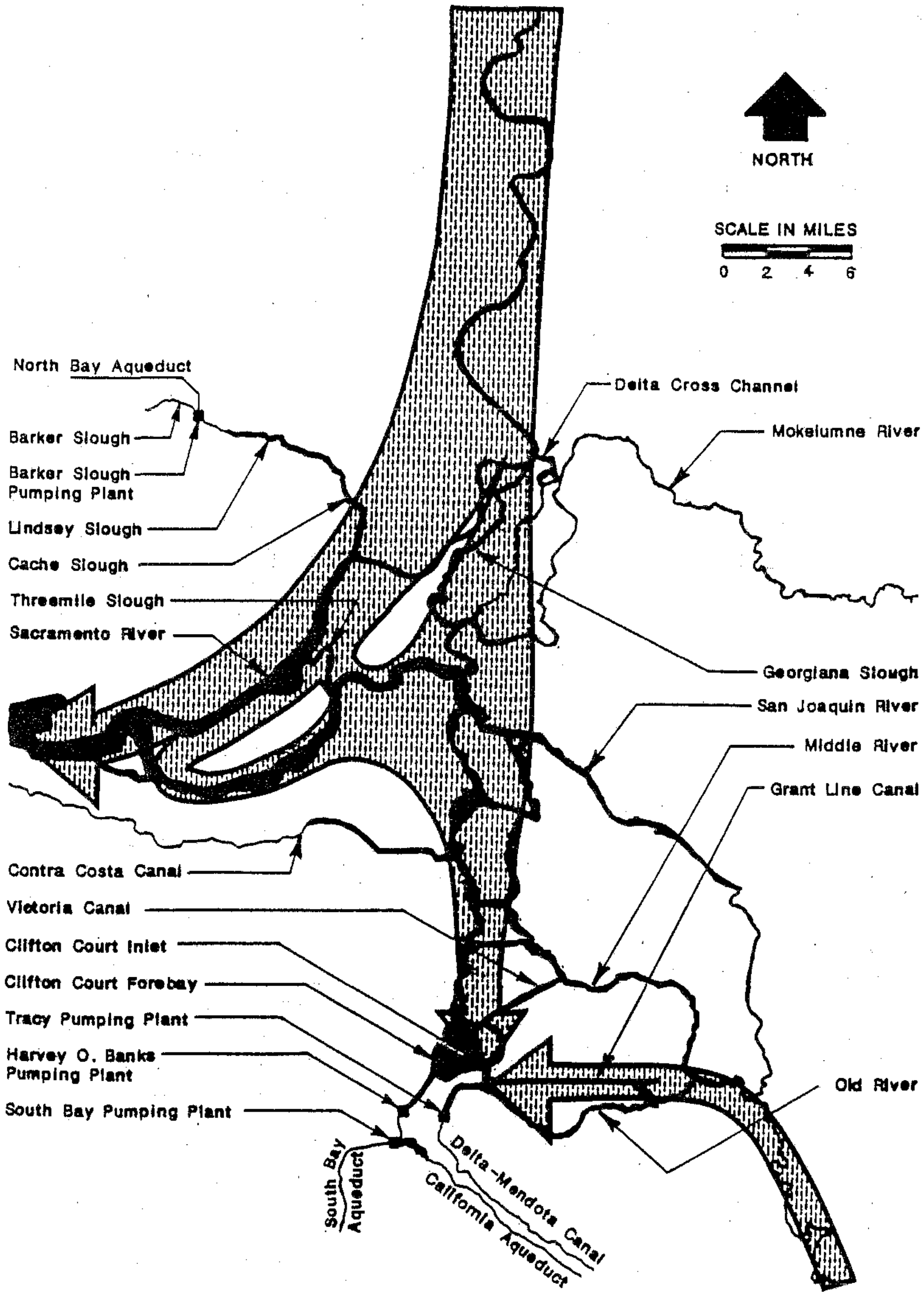


Figure 2-3. Export Induced Flow to the South Delta

compared to Sacramento River flow, DWR estimates the ratio at approximately 90 percent Sacramento River water and 10 percent San Joaquin River water. During critically dry years, when pumping at the Tracy Pumping Plant exceeds San Joaquin River flow by 2 to 3 times, virtually all flow into Clifton Court Forebay is Sacramento River water. It is generally thought that the Tracy Pumping Plant receives a greater portion of San Joaquin River water than the Banks Pumping Plant.

STATE WATER PROJECT EXPORT COMPONENTS

This section discusses the SWP export facilities from the Delta to northern and southern California. These facilities are shown on Figures 2-4, 2-5, and 2-6, along with the location of water-service turnouts used partly or wholly for M&I purposes. Water monitoring stations along the SWP export system discussed in Chapter 6 are also shown on these figures. Water contractor entitlements are shown in Table 2-1. Reservoir, canal, pipeline, and pumping plant capacities are included to indicate the amount of flow in various sections of the SWP. Power plants, which also influence the operation of the SWP are not discussed. The County of Butte and Plumas County Flood Control and Water Conservation District take water out of the system in the upper Feather River and Lake Oroville area. The location of their turnouts are indicated but not shown on Figure 2-4. The SWP export facilities are discussed in greater detail in Chapter 5.

North Bay Aqueduct

The intake for the North Bay Aqueduct is located near the western edge of the north Delta in Barker Slough. The 224-cfs Barker Slough Pumping Plant lifts water into the North Bay Aqueduct for delivery to the Solano County Water Agency and the Napa County Flood Control and Water Conservation District. The North Bay Aqueduct will eventually deliver 67,000 AF of water per year (Figure 2-4). The North Bay Aqueduct is a 27-mile-long underground pipeline with its terminus at the 22-AF Napa Turnout Reservoir. Initial capacity is 175 cfs and capacity at the Napa Turnout Reservoir is 46 cfs. Other facilities along the North Bay Aqueduct include the Travis Surge Tank, and the 145-cfs Cordelia Pumping Plant.

Clifton Court Forebay to Bethany Reservoir

The 31,260-AF Clifton Court Forebay regulates the intake of south Delta water for export via the Banks Pumping Plant to the south Bay Area, the San Joaquin Valley, and southern California. Clifton Court Forebay is located at the western edge of the south Delta by Old River. The Forebay intake gates are opened at the receding low high tide when tidal influences minimize the effects of scour and lowered water levels in Delta channels resulting from the Forebay's intake. Intaking water at receding high tide also maximizes Sacramento River backflow and minimizes San Joaquin River inflow into Clifton Court Forebay. Water flows in a 3-mile-long intake channel from Clifton Court Forebay to the 6,400-cfs Banks Pumping Plant. Water is lifted into the headworks of the California Aqueduct which has an initial capacity of

10,300 cfs. The capacity of the Banks Pumping Plant is currently being increased to 10,300 cfs. Just downstream of the Banks Pumping Plant, California Aqueduct water enters the 5,070-AF Bethany Reservoir.

Figure 2-7 shows the annual volumes of water pumped at Banks and the USBR's Tracy Pumping Plants for the period 1979 through 1988. Over this period of time, the amount of water pumped at Banks Pumping Plant has ranged from 1.3 million AF to 2.8 million AF with an average value of 2.3 million AF. The amount of water pumped at Tracy Pumping Plant has ranged from 2.0 million AF to 2.9 million AF with an average value of 2.5 million AF. The reduced pumping at Banks Pumping Plant in 1983 reflects the large volume of Kern River water transferred into the California Aqueduct at the Kern River Intertie in 1983, which reduced the need for Delta water in the system. The Tracy Pumping Plant has exported water at its maximum capacity for the last 10 years.

Figure 2-8 shows monthly pumping volumes at Banks and Tracy Pumping Plants, averaged over the period 1979 through 1988. Banks Pumping Plant exports are limited by D-1485 in May, June, and July because of fishery requirements for water in the Delta during those months. DWR increases exports from Banks Pumping Plant in summer and early fall. During these months, water is also released from San Luis Reservoir and the southern terminal reservoirs. Increased pumping at Banks Pumping Plant in winter months goes primarily to fill the State share of San Luis Reservoir and the southern terminal reservoirs. Tracy Pumping Plant exports are also limited by D-1485 in May and June. The USBR increases exports from Tracy Pumping Plant in the summer, primarily to meet agricultural demand. Since the agricultural demand is much less in the winter, Tracy Pumping Plant is used in winter months to fill the federal share of San Luis Reservoir.

South Bay Aqueduct

The 330-cfs South Bay Pumping Plant lifts water out of the north end of Bethany Reservoir into the headworks of the 300 cfs South Bay Aqueduct. The South Bay Aqueduct contractors are Alameda County Flood Control and Water Conservation District, Zone 7, Alameda County Water District, and the Santa Clara Valley Water District.

The South Bay Aqueduct is alternately pipeline, open canal and pipeline from Bethany Reservoir to the 120-cfs Del Valle Pumping Plant. Patterson Reservoir is a 100-AF storage facility between Bethany Reservoir and Del Valle Pumping Plant. Del Valle Pumping Plant lifts South Bay Aqueduct water into the 77,110-AF Lake Del Valle, which stores water for recreation and water supply. Lake Del Valle is also operated for flood control and impounds the natural flow of Arroyo Del Valle. This local stored water which belongs to Alameda County Water District (ACWD) is released into the SWP on about a monthly basis for delivery to ACWD. From Del Valle Pumping Plant to the terminus of the South Bay Aqueduct at the Santa Clara Terminal Tank, the South Bay Aqueduct water flows entirely through one continuous pipeline. Capacity in the South Bay Aqueduct at the Santa Clara Terminal Tank is 184 cfs.

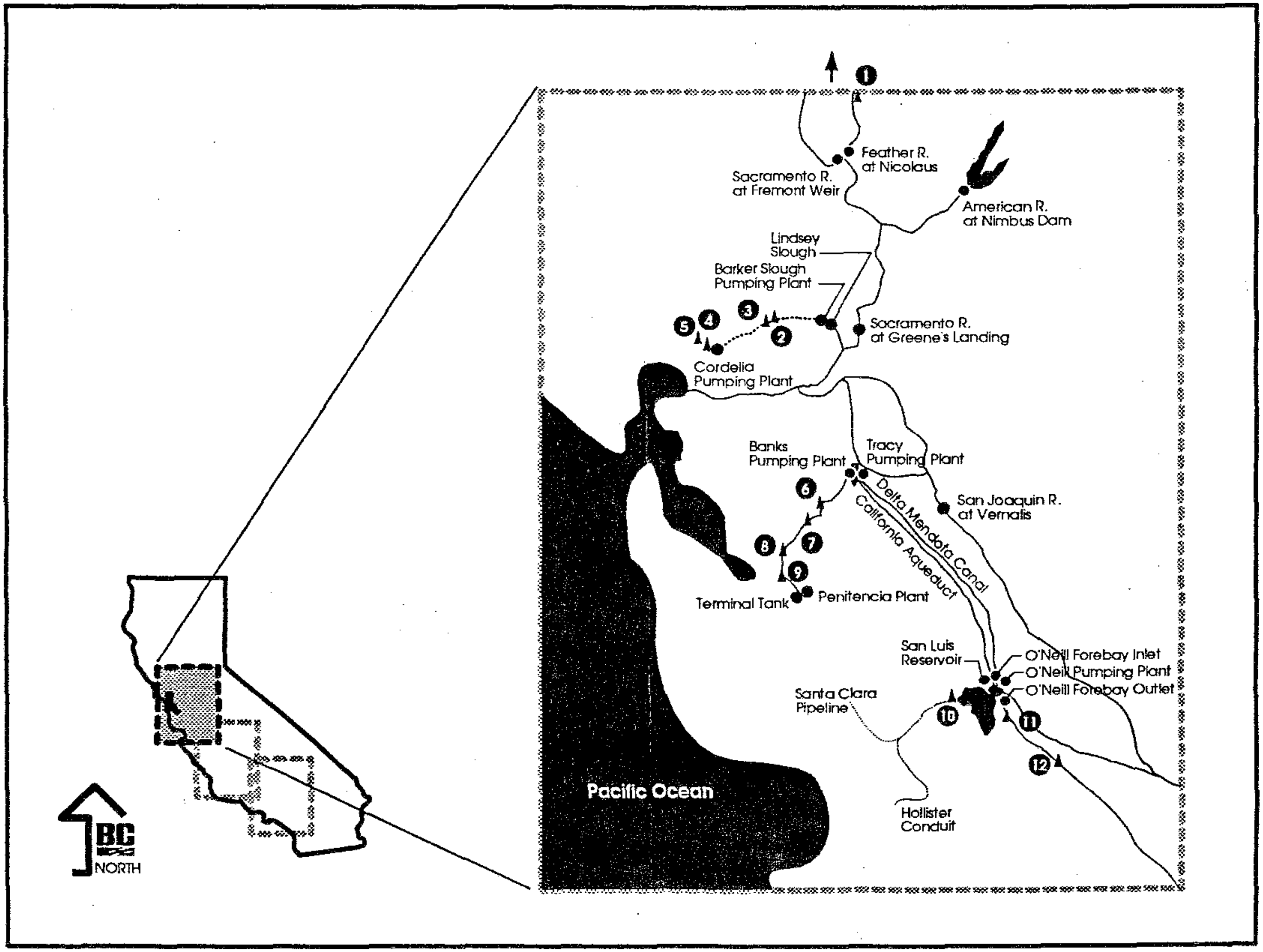
Table 2-1. State Water Project Contractors' Entitlements

Contractor	Maximum annual entitlement[a], acre-feet
Upper Feather Area	
1. City of Yuba City	9,600
2. County of Butte	27,500
3. Plumas County Flood Control & Water Conservation District	2,700
Subtotal	**39,800**
North Bay Area	
4. Napa County Flood Control & Water Conservation District	25,000
5. Solano County Water Agency	42,000
Subtotal	**67,000**
South Bay Area	
6. Alameda County Flood Control & Water Conservation District, Zone 7	46,000
7. Alameda County Water District	42,000
8. Santa Clara Valley Water District	100,000
Subtotal	**188,000**
San Joaquin Valley Area	
9. County of Kings	4,000
10. Devil's Den Water District	12,700
11. Dudley Ridge Water District	57,700
12. Empire West Side Irrigation District	3,000
13. Kern County Water Agency	1,153,400
14. Oak Flat Water District	5,700
15. Tulare Lake Basin Water Storage District	118,500
Subtotal	**1,355,000**
Central Coastal Area	
16. San Luis Obispo County Flood Control & Water Conservation District	25,000
17. Santa Barbara County Water Agency	45,486
Subtotal	**70,486**

Table 2-1. State Water Project Contractors' Entitlements (continued)

Contractor	Maximum annual entitlement[a], acre-feet
Southern California Area	
18. Antelope Valley-East Kern Water Agency	138,400
19. Castaic Lake Water Agency	41,500
20. Coachella Valley Water District	23,100
21. Crestline-Lake Arrowhead Water Agency	5,800
22. Desert Water Agency	38,100
23. Littlerock Creek Irrigation District	2,300
24. Mojave Water Agency	50,800
25. Palmdale Water District	17,300
26. San Bernardino Valley Municipal Water District	102,600
27. San Gabriel Valley Municipal Water District	28,800
28. San Gorgonio Pass Water Agency	17,300
29. The Metropolitan Water District of Southern California	2,011,500
30. Ventura County Flood Control District	20,000
Subtotal	**2,497,500**
TOTAL STATE WATER PROJECT	**4,217,786**

[a]Includes water entitlements for M&I and agricultural uses.



Legend:

Terminal Tank ● Sampling location and name

❼ ▲ Drinking water turnout location and key number

Municipal and Industrial Turnouts

Oroville Field Division

❶ County of Butte
Plumas County Flood Control and Water Conservation District

Delta Field Division

North Bay Aqueduct

❷ Solano County Water Agency (SCWA), Travis AFB

❸ SCWA: Fairfield, Vacaville, Suisun City

❹ SCWA: Benicia, Vallejo

❺ Napa County Flood Control and Water Conservation District: Napa, American Canyon

South Bay Aqueduct

❻ Alameda County Flood Control and Water Conservation District (ACFCWCD), Patterson

❼ ACFCWCD, South Livermore

❽ Alameda County Water Distict, Alameda Bayside

❾ Santa Clara Valley Water District (SCVWD), Santa Clara meter

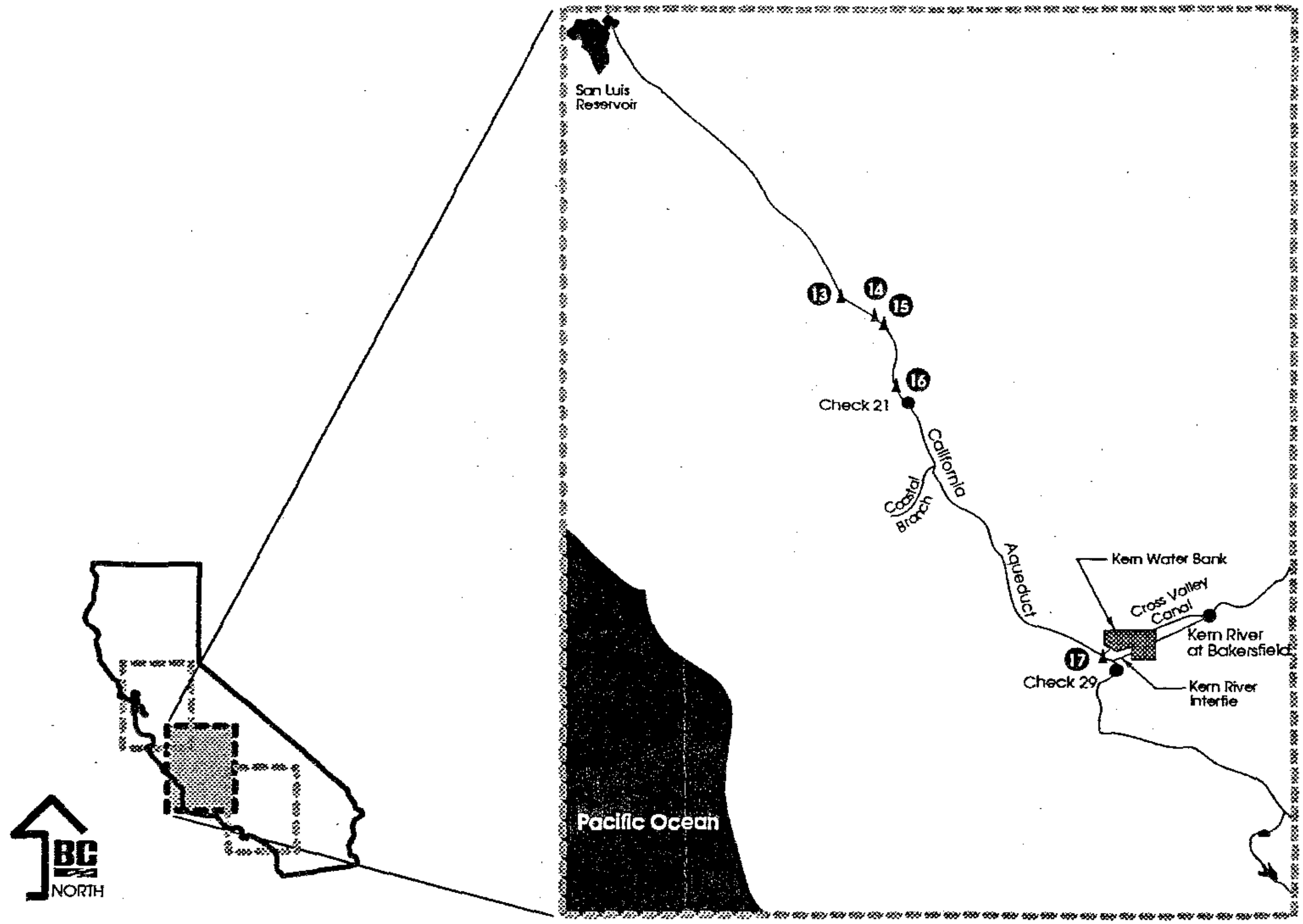
San Luis Field Division, CVP Turnouts

❿ SCVWD, San Luis Reservoir

⓫ San Luis Water District (SLWD), Santa Nella

⓬ SLWD, State of California rest stop

Figure 2-4. State Water Project: Feather River to Below San Luis Reservoir



Legend:

Check 29 ● Sampling location and name

13 ▲ Drinking water turnout location and key number

Municipal and Industrial Turnouts

San Luis Field Division, CVP Turnouts

13 City of Coalinga

14 Lemore Naval Air Station

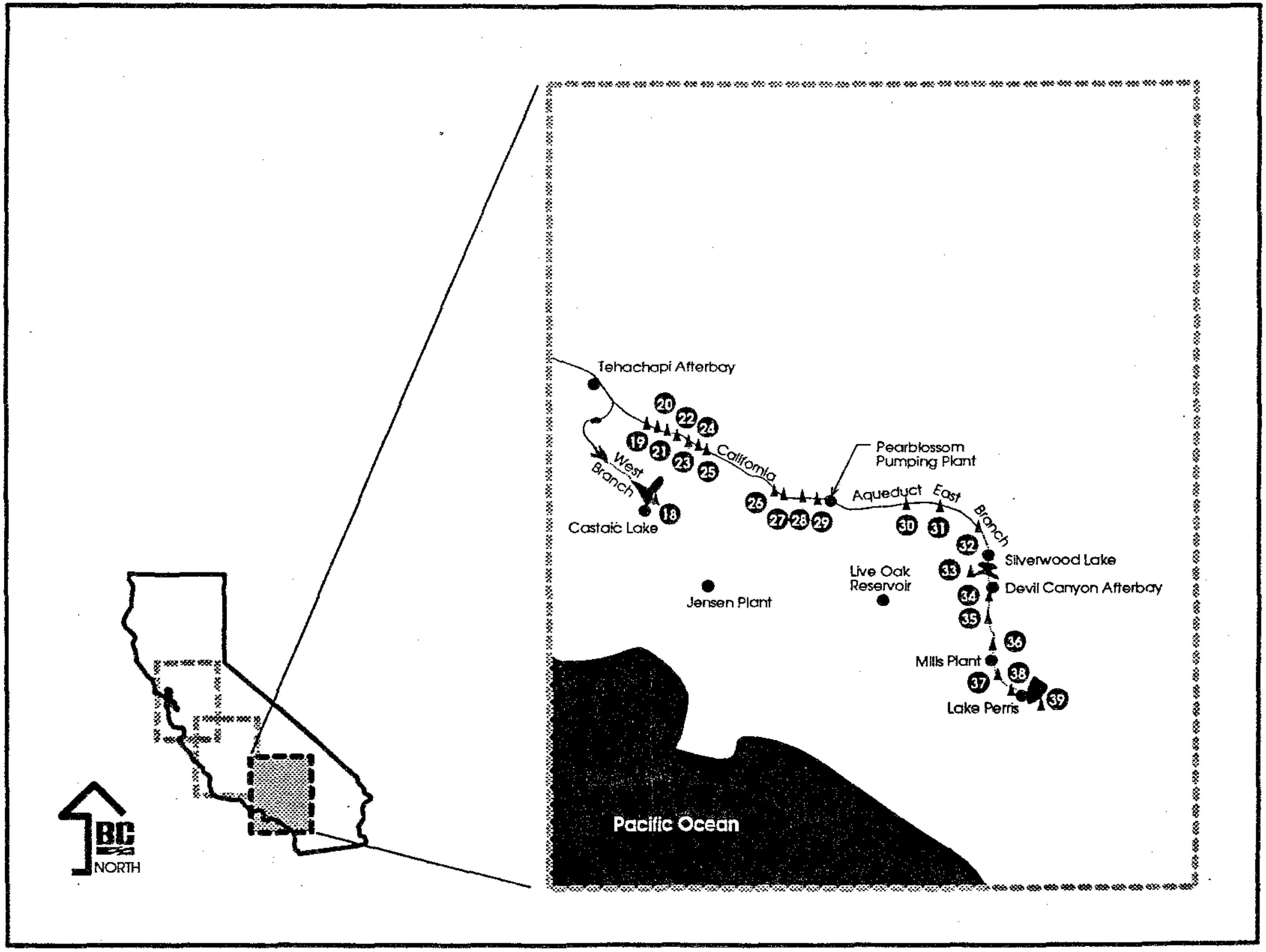
15 City of Huron

16 City of Avenal

17 Kern County Water Agency, Cross Valley Canal/Henry Miller

Note: The San Luis Canal extends from the San Luis Reservoir to Check 21.

Figure 2-5. State Water Project: Below San Luis Reservoir to Tehachapi Afterbay



Legend:

Mills Plant ● Sampling location and name

18 ▲ Drinking water turnout location and key number

Municipal and Industrial Turnouts

Southern Field Division

West Branch

18 Metropolitan Water District of Southern California (MWDSC), Castaic Dam

East Branch

19 Antelope Valley East Kern Water Agency (AVEKWA), 265th Street West

20 AVEKWA, Three Points

21 AVEKWA, 245th Street West

22 AVEKWA, 225th Street West

23 AVEKWA, 180th Street West

24 AVEKWA, 170th Street West

25 AVEKWA, Fairmont

26 Palmdale Water District

27 AVEKWA, Sierra Highway

28 AVEKWA, Littlerock Siphon

29 AVEKWA, 118th Street East

30 Mojave Water Agency (MWA), Sheep Creek

31 MWA, Highway 395

32 MWA, Hesperia

33 Crestline-Lake Arrowhead Water Agency, Silverwood Lake

34 San Bernardino Valley Municipal Water District (SBVMWD), Devil Canyon
San Gabriel Valley Municipal Water District, Devil Canyon
MWDSC, Devil Canyon

35 SBVMWD, Rialto Avenue

36 SBVMWD, Barton Road

37 MWDSC, Box Springs

38 MWDSC, Perris Bypass Pipeline

39 MWDSC, Perris Dam

Figure 2-6. State Water Project: Tehachapi Afterbay to Lake Perris

Bethany Reservoir to O'Neill Forebay

Delta water is exported south out of Bethany Reservoir through the California Aqueduct which has a capacity of 10,000 cfs in this reach. This water is conveyed primarily to contractors in the southern San Joaquin Valley and southern California and to San Luis Reservoir. There are no M&I turnouts in this reach.

O'Neill Forebay and San Luis Reservoir

At O'Neill Forebay, CVP water from the DMC enters the SWP system. O'Neill Forebay and the adjacent San Luis Reservoir are joint-use facilities operated by DWR for regulation and storage of both SWP and CVP water. The role of the 56,430-AF O'Neill Forebay is to receive and regulate inflows from the California Aqueduct, the DMC, and San Luis Reservoir. Outflows from O'Neill Forebay are released to the California Aqueduct to the south, pumped to San Luis Reservoir, and at times released to the DMC. The 4,200-cfs O'Neill Pumping/Generating Plant is the interconnection between the DMC and O'Neill Forebay. The 11,000-cfs San Luis Pumping/Generating Plant is the interconnection between O'Neill Forebay and San Luis Reservoir. Flow into and out of O'Neill Forebay and the degree of blending of SWP and CVP water in O'Neill Forebay are discussed in more detail in the section on the relationship between SWP and CVP components.

The 2.0-million-AF San Luis Reservoir is used primarily for storage; the use of which is divided roughly half and half between the SWP and CVP. San Luis Reservoir is also used as a pump/generation facility to produce power through the San Luis Pumping/Generating Plant. Up to 196,300 AF/year of CVP water is conveyed from San Luis Reservoir through the 480-cfs Pacheco Pumping Plant westward to the Santa Clara Valley and San Benito County.

San Luis Reservoir receives water during winter and spring months when water is available in the Delta under high flow conditions and the SWP and CVP divert at maximum permissible rates to fill the reservoir as quickly as possible. San Luis Reservoir also receives water during balanced conditions when water is transferred from upstream storage reservoirs. Releases from San Luis Reservoir to O'Neill Forebay for transport south in the California Aqueduct are made primarily in the late spring and summer months.

O'Neill Forebay to End of San Luis Canal

From O'Neill Forebay to Kettleman City in Kings County, the California Aqueduct, known in this section as the San Luis Canal (Figure 2-5), conveys both SWP and CVP water. In this joint-use area, there are no SWP deliveries intended for M&I purposes. The SWP conveys water through this section for delivery to the south San Joaquin Valley and southern California. Diversions are made for CVP M&I deliveries directly out of the San Luis Canal and through the Coalinga Canal. The initial capacity of the San Luis Canal is 13,100 cfs, of which the SWP has the right to use 7,100 cfs, and the CVP, 6,000 cfs. The CVP's share decreases progressively to the terminus of the San Luis Canal, where the total capacity is 8,100 cfs. The 13,450-cfs Dos Amigos Pumping Plant is also in this section.

End of San Luis Canal to the Kern River Intertie

The capacity for the SWP of 7,100 cfs through the San Luis Canal is 1,000 cfs less than that in the California Aqueduct beyond. The lower reach was sized to meet SWP contract demands to the south. SWP deliveries in this section are made through the Coastal Aqueduct and from the California Aqueduct itself. The Kern County Water Agency receives M&I water from this section of the California Aqueduct through the Cross Valley Canal (Figure 2-5).

Coastal Branch. The 460-cfs Las Perillas Pumping Plant lifts water out of the California Aqueduct into the Coastal Aqueduct. The 454-cfs Badger Hill Pumping Plant assists in lifting water as the Coastal Branch climbs westward into the Coast Ranges. The existing Coastal Branch serves the Kern County Water Agency in northwestern Kern County. The current terminus of the Coastal Branch, which is entirely open canal, is an irrigation turnout. Studies are now in progress to determine the feasibility of extending the Coastal Branch from its present terminus to fulfill its original intent of serving urban needs in San Luis Obispo and Santa Barbara Counties. The initial capacity of this extended Coastal Branch would be 450 cfs delivered via a subsurface pipeline.

The Kern River Intertie to the East-West Branch Bifurcation

The major features of this section of the California Aqueduct are the Kern River Intertie and the pumping plants which lift water up to and then over the Tehachapi Mountains to Southern California. There are no turnouts intended for M&I use in this section of the California Aqueduct.

The Kern River Intertie. Historically, the Kern River flowed into Tulare and Buena Vista Lakes (Figure 2-2). The Kern River Intertie was built to relieve flooding in the Tulare Lake area by removing excess water from the Kern River during times of high flow. This excess water is a combination of Kern River water and San Joaquin, Kaweah, and Tule River water from the Friant-Kern Canal which is released into the Kern River. The water is collected in a sedimentation basin and then diverted through the Kern River Intertie into the California Aqueduct below Bakersfield. The Kern County Water Agency provides advance notice to the SWP so the SWP can reduce pumping at the Banks Pumping Plant or put additional water into storage at San Luis Reservoir to allow for sufficient capacity in the California Aqueduct for the Kern River Intertie water. The water transferred into the California Aqueduct must meet water quality requirements for suspended solids and contain no deleterious substances such as oil or floating debris.

Between 1979 and 1988, the Kern River Intertie contributed water to the California Aqueduct during the five wet years. The amounts of water transferred through the Intertie during the wet years are shown below:

Year	Amount pumped, AF
1980	139,000
1982	21,000
1983	760,000
1984	27,000
1986	18,000

Most of the transfer (except for 1983) has occurred in the winter or spring. Water was transferred into the California Aqueduct through the Kern River Intertie during every month of 1983 because it was such a wet year. From about February through July of 1983, the Kern River Intertie contributed nearly 100 percent of the flow in the California Aqueduct below the Intertie.

Pumping Plants. The 5,405-cfs Buena Vista, 5,445-cfs Wheeler Ridge, and 4,995-cfs Wind Gap Pumping Plants lift water to the 4,800-cfs A.D. Edmonston Pumping Plant which provides the lift for pumping California Aqueduct water out of the San Joaquin Valley over the Tehachapi Mountains and into southern California. The A.D. Edmonston Pumping Plant lifts water through tunnels and siphons with a capacity of 5,360 cfs into the 550-AF Tehachapi Afterbay where the California Aqueduct splits into the East and West Branches.

West Branch

The 3,252-cfs Oso Pumping Plant lifts water out of the Tehachapi Afterbay into the West Branch of the California Aqueduct. From Oso Pumping Plant to the 7,580-AF Quail Lake, the West Branch is an open canal with a capacity of 3,100 cfs. From Quail Lake to the 171,200-AF Pyramid Lake, the West Branch has a capacity of 1,500 cfs in both open canal and pipeline sections. Flow from Pyramid Lake to the 323,700-AF Castaic Lake, the terminus of the West Branch, is through the 18,000-cfs Angeles Tunnel. West Branch water is pumped back between Pyramid and Castaic Lakes for power generation. Castaic Lake supplies M&I water to the Metropolitan Water District of Southern California (MWD) and the Castaic Lake Water Agency.

East Branch

The capacity of the East Branch as it flows out of the Tehachapi Afterbay is 3,150 cfs. East Branch water flows mostly in open canals through northern Los Angeles County and San Bernardino County. M&I deliveries are made in this area to the Antelope Valley-East Kern Water Agency, to Palmdale Water District, and to the Mojave Water Agency (Figure 2-6). The 1,450-cfs Pearblossom Pumping Plant is located along this open canal section. At the Mojave Siphon water is conveyed under the Mojave River channel from this open canal section into the 74,970-AF Silverwood Lake. Capacity through the Mojave Siphon into Lake Silverwood, which supplies the Crestline Lake Arrowhead Water Agency is 2,876 cfs. From Silverwood Lake to the 131,450-AF Perris Reservoir, East Branch water is conveyed through the 3,230-cfs San Bernardino Tunnel, the Devil Canyon Power Plant and the Santa Ana Valley Pipeline. San

Bernardino Valley and San Gabriel Valley Municipal Water Districts and MWD each have an M&I turnout in the Devil Canyon area. Between Devil Canyon and Lake Perris, MWD and the San Bernardino Valley Municipal Water District divert East Branch water through a total of four turnouts. East Branch capacity is 585 cfs as it enters Lake Perris. At Lake Perris, MWD diverts water directly from the lake and using the Lake Perris Bypass for M&I use.

RELATIONSHIP BETWEEN CVP AND SWP COMPONENTS

Water from the CVP is pumped from the DMC into O'Neill Forebay by the O'Neill Pumping/Generating Plant and is commingled with SWP water. This connection may be important to the quality of SWP water delivered south of O'Neill Forebay and to the CVP water delivered through the Pacheco Pumping Plant west of San Luis Reservoir.

The DMC North of O'Neill Forebay

The 4,600-cfs Tracy Pumping Plant sends Delta water south in the DMC to meet demand along the DMC, the CVP service area along the San Luis Canal, the San Felipe Conduit west of San Luis Reservoir, and the Mendota Pool. The Tracy Pumping Plant does not have a forebay similar to Clifton Court Forebay and therefore pumps Delta water from Old River continuously. Recent operation of the DMC (1979 through 1988) has consisted of average Delta diversions of 2.5 million AF/yr, of which 1.2 million AF/yr were pumped into O'Neill Forebay, and the remaining water comprised deliveries along the canal, to Mendota Pool, and losses. Like the SWP, CVP pumping at Tracy Pumping Plant is restricted during May and June because of D-1485 requirements.

The DMC Input to O'Neill Forebay

Approximately 1.2 million AF of DMC water is lifted annually into O'Neill Forebay. About 60 percent of the CVP contribution to O'Neill Forebay is regulated in the federal share of San Luis Reservoir and provided later on demand pattern. The remaining 40 percent is provided directly to CVP contractors by release south through O'Neill Forebay to the San Luis Canal, or, by diversion through the Pacheco Pumping Plant on San Luis Reservoir.

Figure 2-9 shows monthly flows into O'Neill Forebay from the DMC, the California Aqueduct to the north, and San Luis Reservoir. These data are from DWR operating records for the period between 1976 and 1988. DMC water accounted for 13 to 51 percent of the total canal input (DMC plus California Aqueduct) to O'Neill Forebay on a monthly basis during this period. The annual average DMC contribution during this period was 35 percent. DMC water accounted for 4 to 49 percent of total input (canal input plus input from San Luis Reservoir) to O'Neill Forebay with an annual average of 30 percent. DMC input occurs primarily from September to April. San Luis Reservoir input to O'Neill Forebay accounts for 0.2 to 71 percent of the total input on a monthly basis and occurs primarily between May and August. For the

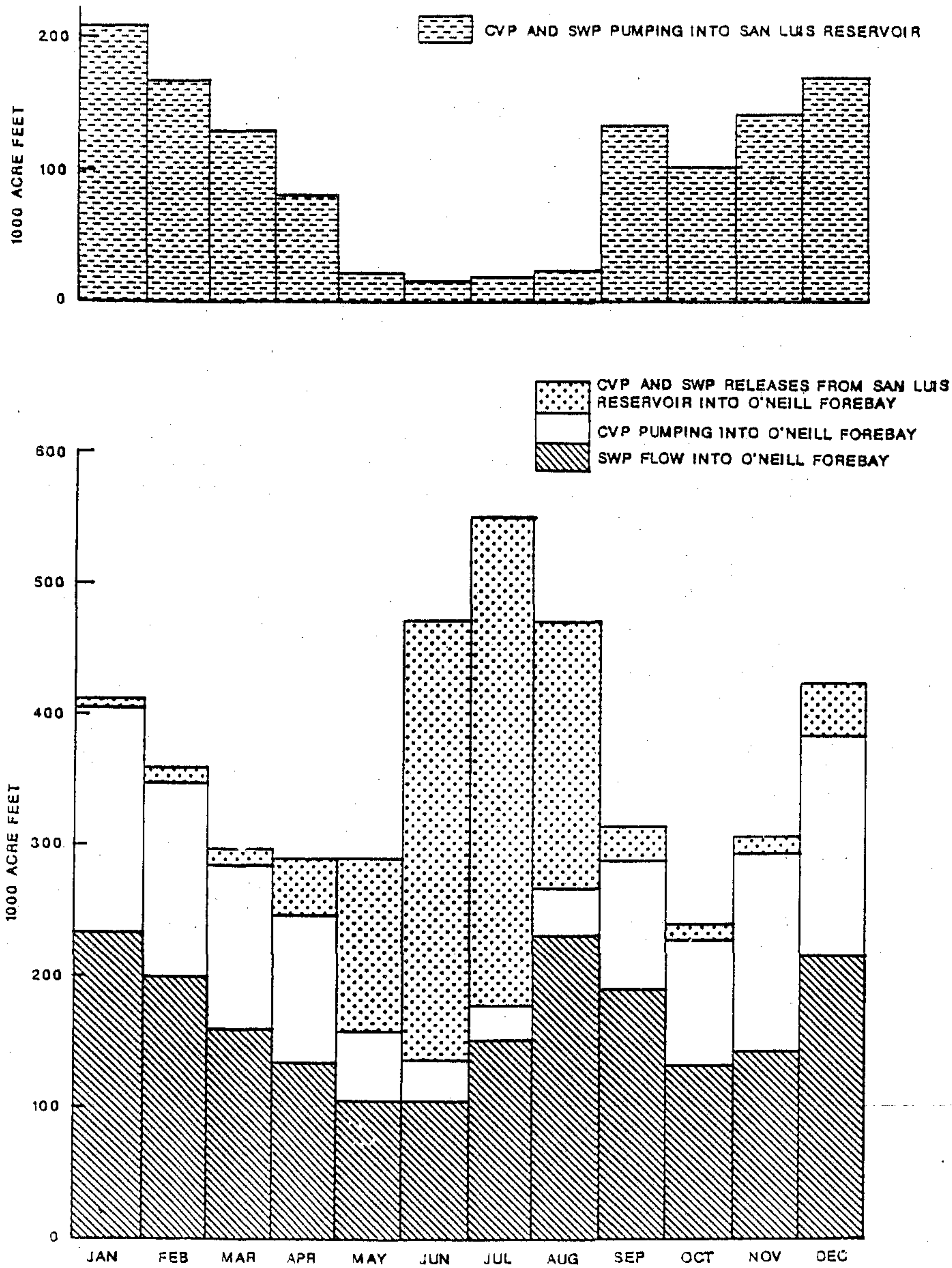


Figure 2–9. 1976-1988 Average Monthly Flow into O'Neill Forebay and San Luis Reservoir

period between 1979 and 1988, the DMC averaged 40 percent of the total canal input to O'Neill Forebay during wet years and 30 percent of the total canal input during dry years. As discussed above in the section on the Delta, DMC water consists of a higher percentage of San Joaquin River water during wet years than dry years. San Joaquin River water, however, is generally of better quality during wet years.

When DMC water enters O'Neill Forebay, it is sometimes visibly distinct from the California Aqueduct water which has entered O'Neill Forebay to the north. The DMC water has been observed to form a distinct plume traveling south down the east side of O'Neill Forebay where it is released into the California Aqueduct and transported south (Personal Communication, Richard Haberman, DHS, 1989). Most of the time, however, the DMC water does not form a distinct plume (Personal Communication, Dan Peterson, DWR). If, at times, California Aqueduct water is lifted into San Luis Reservoir while DMC water flows directly south into the San Luis Canal, then the percent of DMC water in the California Aqueduct south of O'Neill Forebay may be higher than the relative input of DMC and California Aqueduct water from north of O'Neill Forebay would indicate. The difference the degree of blending in O'Neill Forebay may make to the composition of water in the California Aqueduct south of O'Neill Forebay is illustrated on Figures 2-10 and 2-11 for winter and summer months, respectively. These figures are based on the monthly 10-year averages for the period between 1979 and 1988, shown on Figure 2-9. To keep the illustration simple, San Luis Reservoir water is shown as a distinct water source rather than as a blend of DMC and California Aqueduct water on Figures 2-10 and 2-11. Figure 2-10 shows that if DMC water does not blend with California Aqueduct water in O'Neill Forebay, the water in the California Aqueduct south of O'Neill Forebay during winter months may be as high as 90 percent DMC water. As discussed above in the section on the Delta, DMC water may consist of higher percentages of San Joaquin River water in winter months than in summer months. Figure 2-10 also shows that even if DMC and California Aqueduct water mix completely in O'Neill Forebay, the percentage of DMC water in the California Aqueduct south of O'Neill Forebay during winter months is as high as 42 percent averaged over a 10-year period. Figure 2-11 shows that in summer months the volume of DMC water input to O'Neill Forebay is overwhelmed by the volume of releases from San Luis Reservoir and, irrespective of the degree of blending, is about 6 percent of the flow in the California Aqueduct south of O'Neill Forebay. Additionally, in summer months, DMC water consists of a higher percentage of Sacramento River water. Part of Chapter 6, which addresses water quality in the SWP, will focus on the impact of DMC water on the California Aqueduct south of O'Neill Forebay.

The DMC South of O'Neill Forebay

At its Mendota Pool terminus on the San Joaquin River, the DMC discharges up to 840,000 AF/yr of water. When Mendota Pool capacity is exceeded, water can flow upstream (reverse flow) to DMC Check 19, about 15 miles upstream from Mendota Pool. The elevation difference between the Check 19 structure and the O'Neill Pumping Plant ensures that Mendota Pool water cannot backflow to the pumping plant and be pumped into O'Neill Forebay and thus commingle with California Aqueduct water.

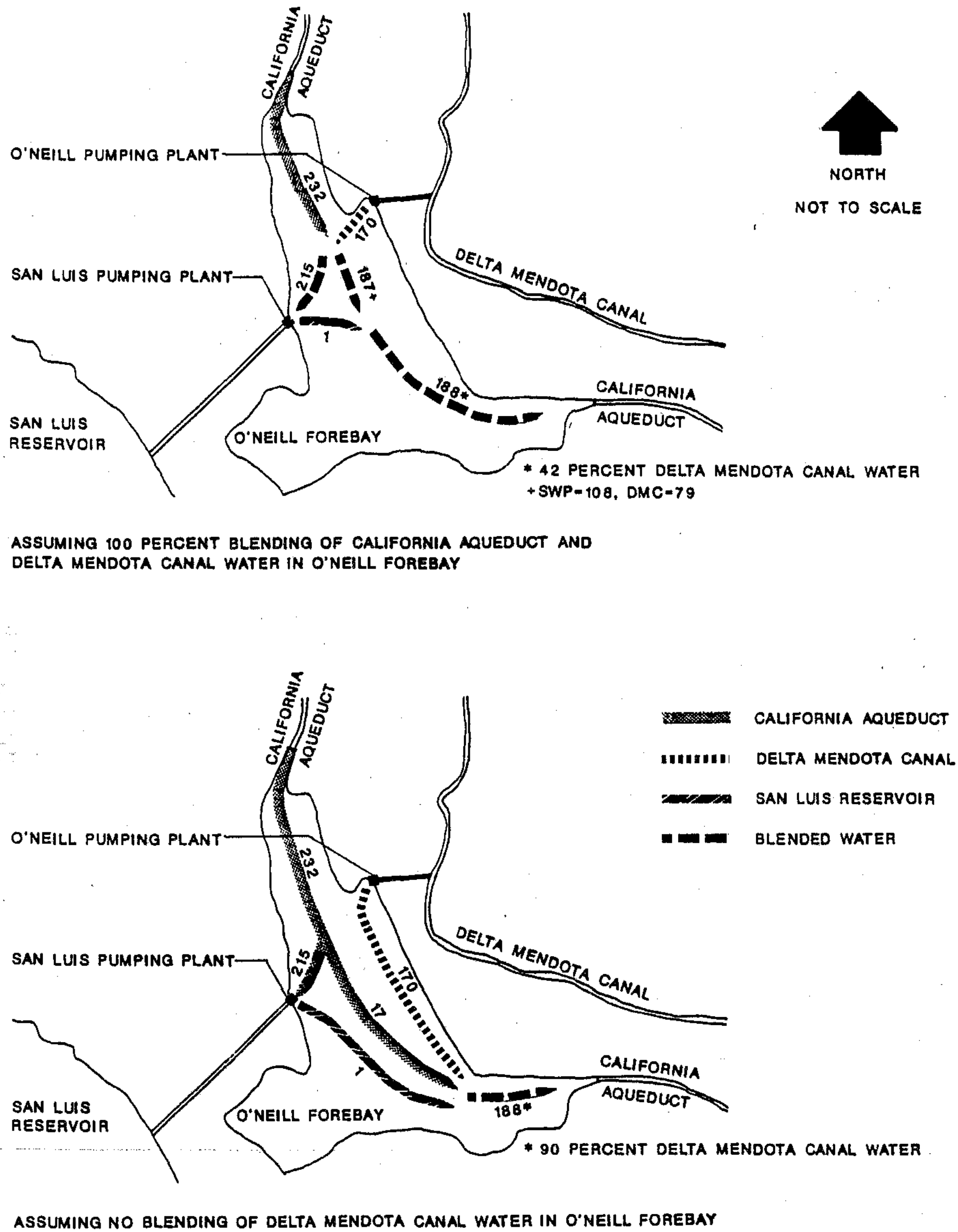
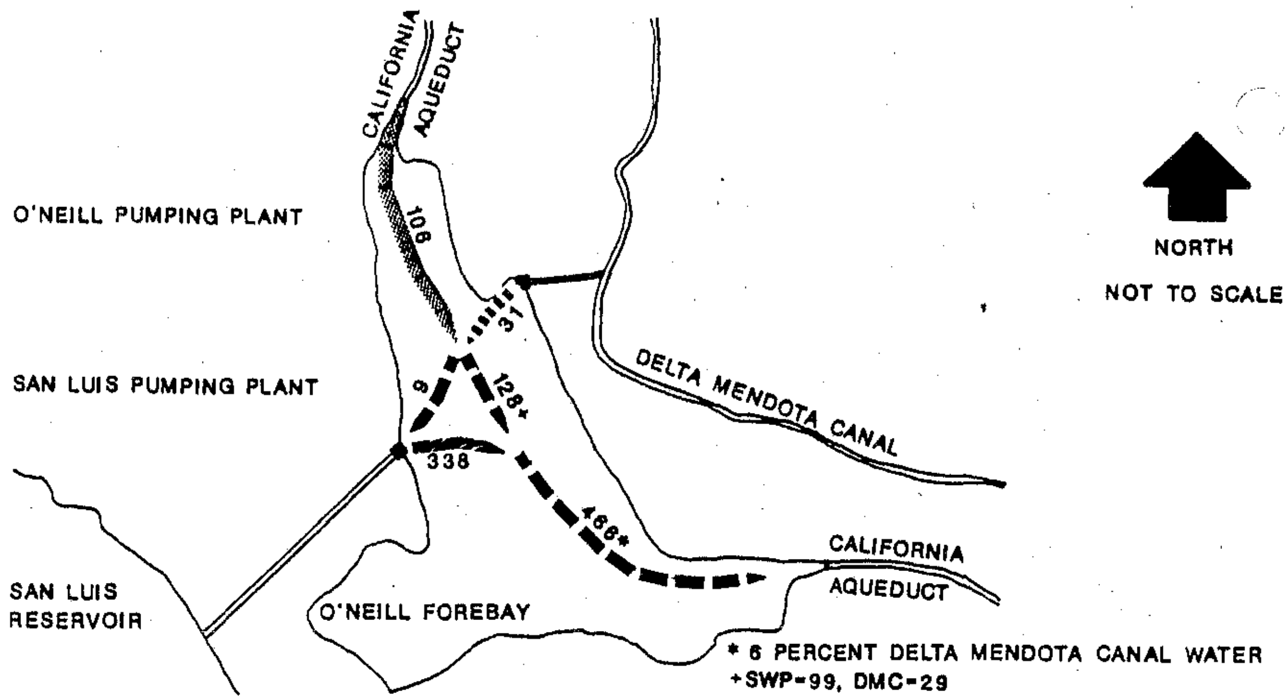
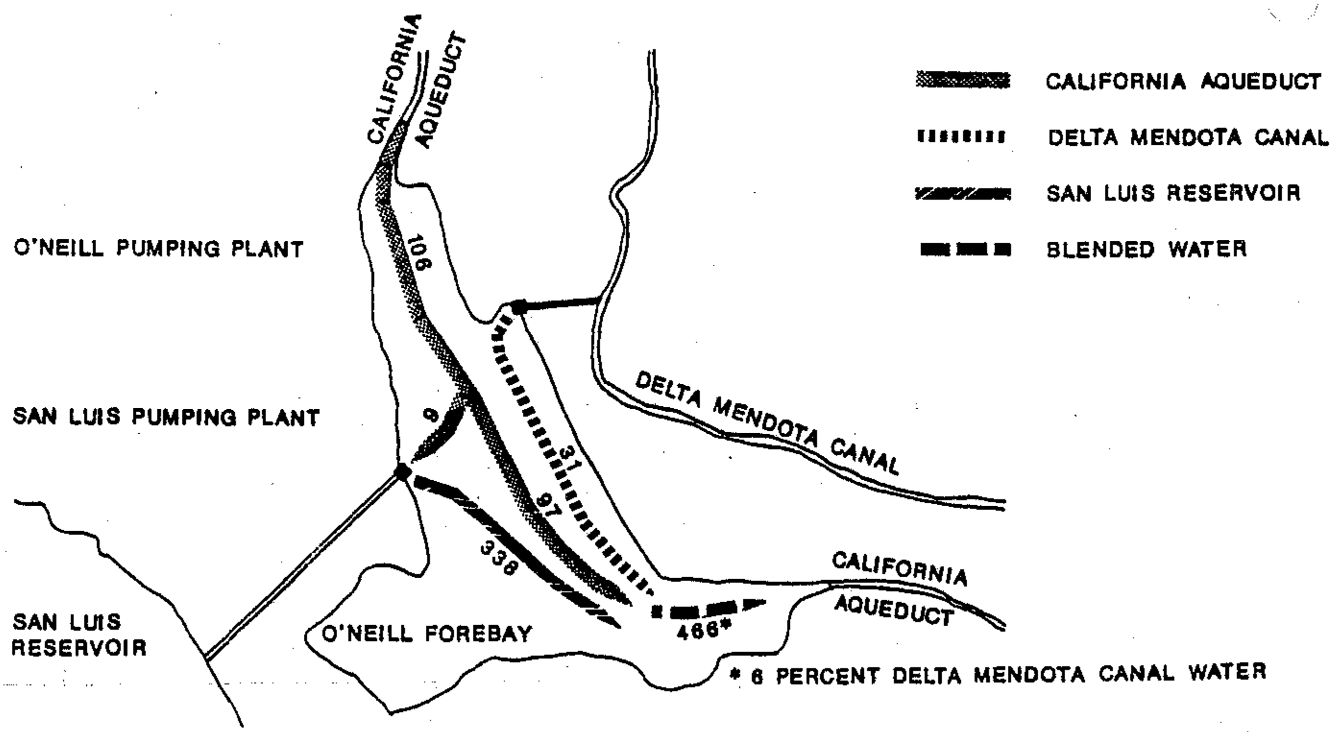


Figure 2–10. Average January Releases (1,000 Acre–Feet) into O'Neill Forebay, 1976 through 1988



ASSUMING 100 PERCENT BLENDING OF CALIFORNIA AQUEDUCT AND
DELTA MENDOTA CANAL WATER IN O'NEILL FOREBAY



ASSUMING NO BLENDING OF DELTA MENDOTA CANAL WATER IN O'NEILL FOREBAY

Figure 2-11. Average June Releases (1,000 Acre-Feet) into O'Neill Forebay, 1976 through 1988

PROPOSED FACILITIES

Proposed facilities which may affect water quality in the SWP are briefly discussed in this section.

Delta Channel Improvements

The capacity of the Banks Pumping Plant is being increased from 6,400 to 10,300 cfs. The SWP currently uses existing channels to move water across the Delta. Lack of sufficient carrying capacity in some channels, however, makes SWP operation inefficient, reduces SWP water supplies, and aggravates local Delta water supply, water quality, and fishery problems. Delta channel improvements designed to overcome these hydraulic deficiencies are being studied by DWR. Use of the increased capacity at the Banks Pumping Plant will require Delta transfer improvements and amendments to the current U.S. Army Corps of Engineers permit. The effect of the Delta transfer improvements would be to increase Sacramento River inflow to the Banks Pumping Plant.

Proposed California Aqueduct-DMC Intertie

The purpose of the proposed intertie is to allow the CVP to use excess capacity in the California Aqueduct during those months when pumping is restricted at the Tracy Pumping Plant because of a conveyance limitation in the DMC near O'Neill Forebay. The proposed intertie would be located about 7 miles downstream of Tracy Pumping Plant. The facility would be capable of lifting 600 cfs from the DMC into the California Aqueduct at a point where the canals are only about 300 feet apart. The facility would be operated when capacity is available in the California Aqueduct during the late winter and early spring months. Up to 125,000 AF/year could be transferred by this intertie between the two water-delivering facilities. The proposed intertie would allow a greater portion of CVP water to be exported south in winter months. The operation of O'Neill Pumping Plant would remain the same. The effect of this intertie would be to increase the amount of DMC water flowing into O'Neill Forebay.

Los Banos Grandes Reservoir

The proposed Los Banos Grandes Reservoir site is on Los Banos Creek six miles west of the California Aqueduct, south of San Luis Reservoir. The proposed reservoir with a capacity of 1.7 million AF would hold water pumped from the Delta during wet months and increase the dependable annual supply of the SWP by about 250,000 AF.

Kern Water Bank

The Kern Water Bank is a planned groundwater storage/extraction program in Kern County. Components of the Kern Water Bank include the Kern Fan Element and the Local Elements. The Kern Fan Element consists of the direct recharge and extraction of California Aqueduct water by DWR on about 20,000 acres of land in the Kern River Fan area (Figure 2-5). Facilities would be constructed to transport SWP water in above-normal and wet years from the California Aqueduct to basins built on the project site where the water would percolate into the groundwater basin. In later below-normal, dry and critically dry years, pumps could extract groundwater from the site for delivery to SWP contractors. The extracted water could either be used locally in exchange for an equal amount otherwise diverted from the California Aqueduct or transported to the California Aqueduct for delivery to other SWP contractors.

The Local Elements involve direct recharge and in-lieu recharge to the Kern Water Bank by local water districts. In-lieu recharge is the delivery of additional surface water to groundwater users in place of pumping. The groundwater that is not pumped is therefore stored.

Overall, the groundwater in the Kern Water Bank area is of good quality and much lower in total dissolved solids than Delta water. However, within the 20,000 acres which comprise the Kern Fan Element, there are isolated areas where the groundwater contains hydrocarbon residues, pesticides, and arsenic. DWR is currently conducting a more detailed characterization of groundwater quality and developing a flexible operating plan in order to avoid use of the lower quality groundwater areas.

CHAPTER 3

REGULATIONS FOR THE PROTECTION OF DRINKING WATER

The challenges created by the federal Safe Drinking Water Act (SDWA) amendments, the California SDWA, and the resulting federal and state drinking water standards underscore the importance of providing urban systems with high quality source water. This chapter presents information regarding current drinking water standards, potential future standards, and an overview of other pertinent regulations.

DRINKING WATER STANDARDS

Contaminants of concern in a domestic water supply are those that either pose a health threat or in some way alter the aesthetic acceptability of the water. These types of contaminants are currently regulated by the U.S. Environmental Protection Agency (EPA) as primary and secondary maximum contaminant levels (MCLs). As directed by the SDWA amendments of 1986, EPA is expanding its list of primary MCLs at a rapid rate. In response to the federal changes and specific concerns within the state, the State of California is also revising its drinking water regulations extensively. This section summarizes the current status of federal and state drinking water regulations.

Federal Regulations

The SDWA (Public Law 93-523) was passed in 1974 giving EPA the authority to protect public health by setting standards, called MCLs, for constituents of concern. The EPA completed the first step in developing the regulations mandated by the SDWA by promulgating the National Interim Primary Drinking Water Regulations (NIPDWR) on December 24, 1975. Subsequent amendments to the SDWA and resultant revisions to the NIPDWR created a total of 22 MCLs, including ten inorganic chemicals, seven organic chemicals, three radionuclides, coliform bacteria, and turbidity.

The regulations were called interim because every 3 years EPA was to review the list of regulated contaminants and revise or add to it based on any new research indicating that adverse health effects were caused by constituents found in drinking water. EPA had begun this process when the SDWA was again amended on June 19, 1986. These amendments called for dramatic changes in the process and rate by which standards are set.

These latest amendments require that maximum contaminant level goals (MCLGs), formerly termed recommended maximum contaminant levels (RMCLs), be set concurrently with MCLs for contaminants which may have an adverse effect on public health and which occur in public water supplies. MCLGs are unenforceable and set at a level at which no known or anticipated adverse health effects will occur, allowing for an adequate margin of safety. For demonstrated carcinogens and reproductive toxins, MCLGs are to be set at zero, because no safe threshold exists for these chemicals. MCLs are enforceable and must be set as close to the MCLGs as feasible. Feasible means accounting for practical limits of treatment technologies, analytical methodology, and costs. Key features of the new SDWA amendments are discussed below.

Standard Setting. The primary requirement of the SDWA amendments is the promulgation of standards. It specified that a total of 83 contaminants be regulated during the initial 3-year period after the date of passage of the amendments. The original 22 MCLs in the NIPDWR except for total trihalomethanes (THMs) are part of the list of 83. Each MCL will be reviewed and re-regulated based on current knowledge of its health significance and its interim status will be removed.

By the end of the first year (June 19, 1987) nine MCLs were to have been set. The promulgation of MCLs for eight volatile organic chemicals (VOCs) on July 8, 1987, together with the standard for fluoride set previously, fulfilled this requirement. Forty additional MCLs were to be set by June 19, 1988. EPA proposed standards for lead and copper on August 18, 1988, and proposed MCLs for eight additional inorganic chemicals and 30 organic chemicals on May 22, 1989. The MCLs for copper and lead are expected to be promulgated in November 1990 and the MCLs for the 38 other chemicals are projected to be promulgated in December 1990. The standards for most of the microbial contaminants are provided by the surface water treatment rule promulgated on June 29, 1989. The standard for total coliform was promulgated as a revised MCL also on June 29, 1989. MCLs for an additional seven inorganic chemicals and sixteen organic chemicals are scheduled for proposal in June 1990 and for promulgation in March 1992. A proposal for five radionuclides is expected in February 1991.

The SDWA amendments require that after the initial 3-year period of standard setting, an additional 25 MCLs be set every 3 years thereafter. A Drinking Water Priority List containing 53 candidate contaminants was published on January 22, 1988. By January 1, 1991, 25 of these contaminants are to be regulated and a new Drinking Water Priority List published. This first Drinking Water Priority List contains contaminants removed by substitution from the original list of 83, as well as disinfectant by-products and other contaminants of concern found in water supplies.

The initial 83 contaminants are listed in Table 3-1. The MCLs for the original 22 contaminants regulated prior to the SDWA amendments and the current MCLs and MCLGs in either proposed or final status are given. Also included are the contaminants for which the California Department of Health Services (DHS) has established or proposed MCLs. Constituents are arranged in the table in chemical groups.

Table 3-1. Federal and State Primary Standards

Contaminants	Standard[a], mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Inorganics				
Aluminum	-	-	-	1
Antimony	-	0.01/0.005[c]	0.003	-
Arsenic	0.05	-	-	0.05
Asbestos, million long fibers/l	-	7[d]	7	-
Barium	1	5[d]	5	1.0
Beryllium	-	0.001[c]	0	-
Cadmium	0.010	0.005[d]	0.005	0.010
Chromium	0.05	0.1[d]	0.1	0.05
Copper	-	1.3[e]	1.3	-
Cyanide	-	0.2[c]	0.2	-
Fluoride	1.4-2.4	4	4	1.4-2.4
Lead	0.05	0.005[e]	0	0.05
Mercury	0.002	0.002[d]	0.002	0.002
Nickel	-	0.1[c]	0.1	-
Nitrate, as N	10	10[d]	10	10.0
Nitrite, as N	-	1[d]	1	-
Selenium	0.01	0.05[d]	0.05	0.01
Silver	0.05	-	-	0.05
Sulfate	-	400/500[c]	400/500	-
Thallium	-	0.002/0.001[c]	0.0005	-
Microbiology and Turbidity				
Giardia lamblia	-	SWTR[f]	0	SWTR[g]
Heterotrophic plate count	-	SWTR[f]	-	SWTR[g]
Legionella	-	SWTR[f]	0	SWTR[g]
Total coliform, coliform/100 ml	1	P/A concept[f]	0	1
Fecal coliform, coliform/100 ml	-	P/A concept[f]	-	-[h]
Turbidity, NTU	1	SWTR[f]	-	SWTR[g]
Viruses	-	SWTR[f]	0	SWTR[g]
Cryptosporidium	-	-	-	-[h]
Radionuclides				
Beta particle and photon radioactivity[i], millirems/yr	4	-	-	-
Gross alpha particle activity[i], pCi/l	15	-	-	15
Gross beta particle activity, pCi/l	-	-	-	50
Radium 226/228[i], pCi/l	5	-	-	5
Radon[i], pCi/l	-	-	-	-
Strontium 90, pCi/l	-	-	-	8
Tritium, pCi/l	-	-	-	20,000
Uranium[i], pCi/i	-	-	-	20

Table 3-1. Federal and State Primary Standards (continued)

Contaminants	Standard[a], mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Volatile Organics				
Benzene	-	0.005	0	0.001
Carbon tetrachloride	-	0.005	0	0.0005
o-Dichlorobenzene	-	0.6[d]	0.6	-
p-Dichlorobenzene	-	0.075	0.075	0.005
1,2-Dichloroethane	-	0.005	0	0.0005
1,1-Dichloroethane	-	-	-	0.005
1,1-Dichloroethylene	-	0.007	0.007	0.006
cis-1,2-Dichloroethylene	-	0.07[d]	0.07	0.006
trans-1,2-Dichloroethylene	-	0.1[d]	0.1	0.1
1,2-Dichloropropane	-	0.005[d]	0	0.005
1,3-Dichloropropene	-	-	-	0.0005
Ethylbenzene	-	0.7[d]	0.7	0.680
Hexachlorobenzene	-	0.001[c]	0	-
Methylene chloride	-	0.005[c]	0	-
Monochlorobenzene	-	0.01[d]	0.1	0.030
Styrene	-	0.005/0.1[d,j]	0/0.1	-
1,1,2,2-Tetrachloroethane	-	-	-	0.001
Tetrachloroethylene (PCE)	-	0.005[d]	0	0.005
Toluene	-	2[d]	2	-
1,2,4-Trichlorobenzene	-	0.009[c]	0.009	-
1,1,1-Trichloroethane (TCA)	-	0.20	0.20	0.20
1,1,2-Trichloroethane	-	0.003[c]	0.003	0.032
Trichloroethylene (TCE)	-	0.005	0	0.005
Trichlorofluoromethane	-	-	-	0.15
1,1,2-Trichloro-1,2,2-trifluoroethane	-	-	-	1.2
Vinyl chloride	-	0.002	0	0.0005
Xylenes (total)	-	10[d]	10	1.75

Table 3-1. Federal and State Primary Standards (continued)

Contaminants	Standard[a], mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Synthetic Organics				
Acrylamide	-	Treatment technique[d]	0	-
Adipates Di(ethylhexyl)adipate	-	0.5[c]	0.5[c]	-
Alachlor	-	0.002[d]	0	-
Aldicarb	-	0.01[d]	0.01	-
Aldicarb sulfone	-	0.04[d]	0.04	-
Aldicarb sulfoxide	-	0.01[d]	0.01	-
Atrazine	-	0.003[d]	0.003	0.003
Bentazon (Basagran)	-	-	-	0.018
Carbofuran	-	0.04[d]	0.04	0.018
Chlordane	-	0.002[d]	0	0.0001
Dalapon	-	0.2[c]	0.2	-
Dibromochloropropane (DBCP)	-	0.0002[d]	0	0.0002
2,4-Dichlorophenoxy acetic acid (2,4-D)	0.1	0.07[d]	0.07	0.1
Dinoseb	-	0.007[c]	0.007	-
Diquat	-	0.02[c]	0.02	-
Endothall	-	0.1[c]	0.1	-
Endrin	0.0002	0.002[c]	0.002	0.0002
Epichlorohydrin	-	Treatment technique[d]	0	-
Ethylene dibromide (EDB)	-	0.00005[d]	0	0.00002
Glyphosate	-	0.7[c]	0.7	0.7
Heptachlor	-	0.0004[d]	0	-
Heptachlor epoxide	-	0.0002[d]	0	0.00001
Hexachlorocyclopentadiene	-	0.05[c]	0.05	-
Lindane	0.004	0.0002[d]	0.0002	0.004
Methoxychlor	0.1	0.4[d]	0.4	0.1
Molinate (Ordram)	-	-	-	0.02
Pentachlorophenol	-	0.2[d]	0.2	-
Phthalates Di(ethylhexyl)phthalate	-	0.004[c]	0	0.004
Picloram	-	0.5[c]	0.5	-
Polychlorinated biphenyls (PCBs)	-	0.0005[d]	0	-
Polynuclear aromatic hydrocarbons [Benzo(a)pyrene]	-	0.0002[c]	0	0.01
Simazine	-	0.001[c]	0.001	0.01

Table 3-1. Federal and State Primary Standards (continued)

Contaminants	Standard[a], mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Synthetic Organics (cont'd)				
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	-	5×10^{-8}	0	-
Thiobencarb (Bolero)	-	-	0	0.07
Toxaphene	0.005	0.005[d]	0	0.005
2,4,5-Trichlorophenoxy propionic acid (Silvex)				
Trihalomethanes, total[k]	0.01	0.05[d]	0.05	0.01
Vydate (Oxamyl)	0.10	-	-	0.10
	-	0.2[c]	0.2	-

[a]All values are in mg/l, except as indicated.
[b]Date and status of MCLG is the same as MCL, since they are required to be proposed and promulgated at the same time.
[c]MCLs and MCLGs were proposed in July 1990 and are scheduled for promulgation in March 1992. Alternative MCLs will be proposed for antimony, sulfate, and thallium.
[d]Proposed MCLs for 38 inorganic and organic chemicals published on May 22, 1989.
[e]A corrosion by-product regulation, including MCLs for lead and copper, was published on August 18, 1988. Final regulations are projected for November 1990.
[f]Coliform bacteria are regulated through a presence/absence compliance calculation and other microbial contaminants are regula[illegible] through a treatment technique outlined in the surface water treatment rule (SWTR) promulgated on June 29, 1989.
[g]California's proposed SWTR. Estimated effective date is early 1991.
[h]Although not currently in California's SWTR, Cryptosporidium may be regulated in the future.
[i]A proposal to regulate radionuclides is scheduled for February 1991.
[j]EPA proposed an MCL of 0.1 mg/l and an MCLG of 0 mg/l based on a group C carcinogen classification and an MCL of 0.005 mg/l and an MCLG of 0.1 mg/l based on a B2 classification.
[k]The current MCL is scheduled to be reviewed, and probably revised by 1991.

A more comprehensive tabulation of all constituents of regulatory concern, including the constituents on the Drinking Water Priority List, is presented in Table 2 of Appendix C. This table also shows concentrations of concern for many currently unregulated pollutants based on a variety of research sources.

Unregulated Contaminant Monitoring. On July 8, 1987, EPA (and in April 1990, California) promulgated a monitoring program for 51 contaminants that had not been previously regulated. The data generated from this effort will assist EPA in determining the necessity of future regulation of certain chemicals. EPA divided this list of unregulated contaminants into three categories. Category 1 contains 34 contaminants which can be readily analyzed. All systems must monitor for these. Category 2 contains two compounds having limited occurrence in drinking water but requiring specialized sampling procedures. Only vulnerable systems need monitor for the two pesticides listed under Category 2. Category 3 contains 15 compounds which only occasionally occur in drinking water but cause difficulties in treatment or analysis. Sampling for Category 3 compounds is at the states' discretion. Monitoring is required once every 5 years beginning on January 1, 1988. If a system serves between 3,300 and 10,000 persons, sampling need not begin until 1 year later. If the system serves less than 3,300 persons, sampling need not begin until 3 years later.

On May 22, 1989, EPA proposed two additional lists of unregulated contaminants for possible monitoring. The first list consists of 23 synthetic organic and 6 inorganic contaminants. The DHS would conduct a vulnerability assessment for each contaminant for each water system to determine which ones from this list must be monitored. The second proposed list contains 84 synthetic organic contaminants that DHS would be able to require system monitoring based on local concerns and discretion.

EPA has drafted a proposal that would standardize the monitoring required for many of the constituents regulated by various rules. The contaminants that would be included are those that are associated with chronic health effects, e.g., VOCs, pesticides, radionuclides, and inorganic chemicals. Such a standardized approach would coordinate and simplify the process of compliance by a utility.

Filtration and Disinfection. The 1986 SDWA specifies that EPA establish criteria under which filtration is required for surface water supplies by December 19, 1987 and disinfection is required for all water supplies by June 19, 1989. The SDWA also provides that when it is not technologically or economically feasible to measure the level of a contaminant, then a treatment technique can be required in lieu of an MCL. This is the case for Giardia, viruses, and Legionellae. It has also been argued that turbidity and heterotrophic plate count are best regulated with a treatment technique. These five contaminants are on the list of 83 requiring standards. On June 29, 1989 EPA promulgated a regulation known as the Surface Water Treatment Rule which addresses these requirements. It sets criteria by which surface waters shall be filtered and disinfected and serves in lieu of an MCL for the microbial contaminants listed above. The Surface Water Treatment Rule requires 99.9 percent removal of Giardia and 99.9 percent removal of viruses. The proposed EPA regulation includes broad exception criteria which, if met, may relieve a water utility from mandatory filtration. Disinfection of groundwater supplies is not addressed in the Surface Water Treatment Rule. It will likely be included in a comprehensive disinfection regulation that will include setting MCLs for disinfectants and their by-products.

Removal of Cryptosporidium oocysts is not currently included in the Surface Water Treatment Rule. Cryptosporidium was responsible for a waterborne disease outbreak of Cryptosporidiosis in communities near Oxford, England. Between 50,000 and 100,000 persons became ill. Boil water notices were issued to 600,000 people. Cryptosporidium may be regulated in the future.

Disinfectants and Disinfection By-Products. The EPA has drafted a conceptual rule known as the Strawman rule to initiate the development of a disinfectant and disinfection by-product regulation. The Strawman rule is a skeletal outline of the regulation, drafted to obtain input from all affected parties early in the proposal development process. The Strawman rule is also intended to help focus research, data gathering and analysis. The major thrust of the rule will be to lower human exposure to disinfectants and their by-products by promulgating MCLs and monitoring requirements. EPA has set a goal of proposing the regulation by the fall of 1991 with a final rule by early 1993. EPA has already indicated that the THM standard of 100 micrograms per liter (µg/l) will be reduced to 50 or 25 µg/l.

Public Notification. The 1986 SDWA mandated revised public notice requirements by September 19, 1987. The purpose was to reflect the severity of a drinking water regulation violation through better public notification. These new rules were published in the Federal Register on October 28, 1987. The final rule creates two classes of violations which require notification, Tier 1 and Tier 2. Tier 1 involves failure to comply with an MCL, a treatment technique, a variance or an exemption schedule. Tier 1 violations can be further subdivided into acute or nonacute health risk. Tier 2 violations include operation under a variance or exemption, or failure to comply with a monitoring requirement or testing procedure.

Secondary Standards. Standards for 13 constituents that affect the aesthetic quality of drinking water currently exist. These are called secondary standards and are not enforceable at the federal level. An additional 9 secondary standards were proposed along with the group of 38 primary MCLs on May 22, 1989. Table 3-2 lists existing and proposed secondary MCLs.

State Regulations

As provided by the SDWA, DHS was delegated primary enforcement responsibility (termed "primacy") for the drinking water program in 1977. Under this agreement, DHS receives an annual grant from EPA and is required to adopt and implement regulations that are at least as stringent as those set by EPA. The original 22 MCLs set by EPA were adopted almost identically by the DHS and incorporated into Title 22 of the California Administrative Code. The California SDWA of 1989 which incorporates all of the requirements of the 1986 federal version maintains the primacy status for California.

Table 3-2. Federal and State Secondary Standards

Contaminant	California and EPA NIPDWR (pre-SDWA) amendments of 1986)	EPA (post-SDWR amendments of 1986)
Chloride	250	-
Color, color units	15	-
Copper	1	-
Corrosivity	Non-corrosive	-
Fluoride	-	2[a]
Foaming agents	0.5	-
Turbidity, units	5[b]	-
Iron	0.3	-
Manganese	0.05	-
Odor, threshold odor number	3	-
pH, standard units	6.5-8.5	-
Sulfate	250	-
TDS	500	-
Specific conductance, umhos/cm	500[b]	-
Zinc	5	-
Aluminum	-	0.05[c]
o-Dichlorobenzene	-	0.01[c]
p-Dichlorobenzene	-	0.005[c]
Ethylbenzene	-	0.03[c]
Pentachlorophenol	-	0.03[c]
Silver	-	0.09[c]
Styrene	-	0.01[c]
Toluene	-	0.04[c]
Xylenes (total)	-	0.02[c]

[a]A secondary standard for fluoride was promulgated on April 2, 1986.
[b]California secondary standard. No EPA standard.
[c]Secondary standards proposed May 22, 1989.

Note: All values are in mg/l except where otherwise noted.

Standard Setting. Prior to the 1986 SDWA, growing concern on the part of the public in California about drinking water quality prompted the State legislature to take aggressive steps to improve controls on contamination. They directed the DHS to begin promulgating MCLs independent of EPA using independent risk assessment analysis and reflecting those contaminants of greatest concern in California. This regulatory development program must also keep abreast of EPA's activity to ensure that any DHS MCL is at least as stringent as its federal counterpart.

In 1988 and 1989, DHS proposed and adopted MCLs for 24 contaminants. These 24 chemicals include the eight VOCs regulated by EPA in July 1987 and required by primacy conditions to be adopted within 18 months. However, as allowed, DHS adopted more stringent MCLs for six of these eight chemicals. Seven additional state MCLs from the group of 24 are for contaminants for which EPA proposed MCLs in May 1989, and four are more stringent than proposed federal standards.

Six other contaminants with state MCLs have been named by EPA for future regulation, including two contaminants that are scheduled for proposal in June 1990. The remaining three state MCLs, for bentazon (Basagran), molinate (Ordram), and thiobencarb (Bolero), are chemicals that EPA does not intend to regulate, at least in the next 5 years.

DHS also publishes action levels for contaminants of concern in California. These are strictly health-based numbers that guide DHS staff in dealing with incidents of contamination prior to the establishment of an MCL. An action level is not an official value so it requires only a scientific risk assessment rather than the comprehensive hearing and review process necessary to promulgate a regulation. DHS staff use action levels to trigger nonenforceable action on the part of a water system. In January 1990, DHS published a list of action levels for 40 contaminants. Action levels are shown in Table 2 in Appendix C.

California applies all of the federal secondary drinking water standards (Table 3-2) but does so more rigidly than EPA. All new drinking water sources must meet the secondary standards for iron and manganese, and existing sources must meet these standards unless the utility makes a showing of public acceptance and cause for exemption. Other secondary standards are not mandatory unless 25 percent of the utility customers so petition and the majority of customers are willing to pay the necessary costs of meeting the secondary standards.

California's draft Surface Water Treatment regulation requires filtration of all surface waters. No exceptions are allowed in the state rule, unlike the EPA draft rule. The state rule is scheduled for adoption by the end of 1990. DHS has included language in the draft guidance manual for implementation of the Surface Water Treatment Rule than can require a water utility to provide higher removal/disinfection of Giardia depending on the source water quality. For example, treatment of waters that contain less than one Giardia cyst per 100 liters must provide 99.9 percent removal. If between 1 and 10 cysts occur, treatment must provide 99.99 percent removal. For waters containing between 10 and 100 cysts, treatment must provide 99.999 percent removal.

The California Safe Drinking Water Act of 1989. Assembly Bill 21 (AB21), which took effect January 1, 1990, effectively amends the California SDWA to conform with the 1986 federal amendments. This bill, sponsored by Assemblyman Sher, includes an aggressive standards setting program. DHS must set primary drinking water standards and recommended public health levels (RPHL). The latter is similar in concept to EPA's MCLGs. However, under AB21, systems which serve greater than 10,000 connections and which exceed any RPHL must prepare a written evaluation annually identifying all reasonable efforts made in reducing the level of the contaminant to as close to the RPHL as feasible. DHS is in the process of writing and implementing regulations for this new law.

The Safe Drinking Water and Toxic Enforcement Act of 1986. The best evidence of the extent of concern for drinking water quality by the California public was the passage of the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) by a two to one margin in November 1986. Proposition 65 requires that the Governor maintain a list of chemicals known to the state to cause cancer or reproductive toxicity. This list must be revised and republished at least once a year. Beginning 12 months from the day a chemical is listed, businesses employing 10 or more employees are required to provide warnings to people if there is any potential exposure to harmful products. Within 20 months of the listing, a business must stop discharging a listed chemical into a source of drinking water. Twenty-nine chemicals were placed on the list on February 27, 1987, and the discharge prohibition on this list took effect on October 27, 1988. Since the original list, the Governor has published six additional lists of Proposition 65 chemicals, bringing the total to 334 chemicals (as of October 1, 1989). Emergency regulations to define "discharge or release to water or to land" of a listed toxicant were issued by the State Health and Welfare Agency and took effect on October 27, 1988.

As originally passed, Proposition 65 does not apply to agencies operating public water systems. Proposition 141 (Toxic Chemical Discharge. Public Agencies. Legislative Statute) placed on the November 1990 ballot by SB 65 (Kopp), requires that public agencies be brought under the provisions of Proposition 65 under certain conditions.

OVERVIEW OF OTHER PERTINENT REGULATIONS

A summary of the primary federal and state statutes and regulations affecting sources of pollutants which could potentially impact the State Water Project (SWP) is provided in Appendix D. The regulatory programs reviewed include the following:

- The permit programs for the discharge of pollutants to surface waters from point sources (federal Clean Water Act and state Porter Cologne Water Quality Control Act, Division 7 of the California Water Code).
- The proposed permit program for the discharge of pollutants to surface waters from urban runoff (federal Clean Water Act).

- The discharge of wastes and wastewaters to land (federal Resource Conservation and Recovery Act and state California Water Code and Health and Safety Code).

- The cleanup of pollution sites (federal Comprehensive Environmental Response, Compensation and Liability Act and state Health and Safety Code and Porter Cologne Water Quality Control Act).

- Establishment of underground injection control (federal Safe Drinking Water Act and state Health and Safety Code).

- The transportation of hazardous materials (federal Hazardous Materials Transportation Act).

- The storage of chemicals and petroleum products in underground tanks (federal RCRA and state Health and Safety Code).

- The regulation of the use and application of pesticides (Federal Insecticide, Fungicide, and Rodenticide Act and state Food and Agricultural Code).

- A number of state plans and policies including Regional Water Quality Control Board Basin Plans, state nondegradation policy State Water Resources Control Board (State Board) Resolution No. 68-16, and State Board's Pollutant Policy Document and proposed Inland Surface Waters Plan for California.

Most of the federal environmental statutes and regulations have counterparts in the state regulatory system, since the State of California has been delegated the authority to administer and enforce many of the federal statutes and regulations. A more detailed description of the relationship between the federal and state programs dealing with particular aspects of environmental regulation is provided in Appendix D.

A summary of the statutes and regulations and their role in regulating pollutant sources and their impact on segments of the SWP is contained in Appendix D, Table 10. Many of the programs which require a permit for the disposal of wastes have monitoring and reporting requirements including special reporting requirements for spills and accidental releases. This is important to the assessment of the potential impact of pollutants on the SWP because not only are the effects of permitted discharges of pollutants of concern, but also the legal and institutional requirements for monitoring and reporting discharges which exceed the permitted levels or which result from spillage or other releases. Spill and release reporting requirements extend beyond the permittee to any responsible party under the reportable quantities concept contained in the Clean Water Act and the State's Water Code.

The statutes and regulations reviewed do not in general affect particular segments of the SWP in unique or notable ways. One of the few exceptions is the requirement of Section 13953 of the California Water Code which mandates that there will be no discharge from a San Joaquin

Valley agricultural drain to the Delta, Suisun Bay, or Carquinez Straits until certain requirements are met including that beneficial uses of the receiving water will be protected by such a discharge and that a substitute water supply will be provided if it is found to be in the public interest to discharge into supply water. Chapter 6 of Title 3 of the California Administrative Code dealing with the use of pesticides has specific restrictions on the use of the herbicide Bentazon (Basagran) in rice fields above the City of Sacramento during certain dates. The Basin Plans adopted by the State Water Resources Control Board and the Regional Water Quality Control Boards identify beneficial uses of particular water bodies, water quality objectives to protect those uses, and an implementation plan to achieve the established water quality objectives. The portions of the Basin Plans which identify beneficial uses and water quality objectives are also approved by EPA. These Basin Plans contain references to specific segments of the SWP as regards beneficial uses and water quality objectives.

The State Water Resources Control Board adopted the "Pollutant Policy Document" on June 21, 1990, and expects to adopt the "Inland Surface Waters Plan for California" in 1990. The "Pollutant Policy Document" is directed exclusively at the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, while the inland surface water plan is applicable state-wide. This policy and plan are likely to lead toward more stringent effluent limits for existing National Pollutant Discharge Elimination System wastewater discharges and to the regulation of additional sources of contaminants, such as boat yards and shipyards and nonpoint sources. The "Pollutant Policy Document" also requires that the San Francisco Bay and Central Valley Regional Water Quality Control Boards implement programs to reduce and eliminate the discharge of pesticides and to expand monitoring substantially. This policy and plan should eventually result in reductions in contaminant concentrations in the Delta.

CHAPTER 4

CONTAMINANT SOURCES IN THE WATERSHEDS

Fresh surface water from two large watersheds, the Sacramento River and the San Joaquin River drainage basins, and sea water from Suisun Bay, combine in the Sacramento-San Joaquin Delta (Delta). Water from the Tulare Lake drainage basin, further south, can also flow into the Delta via the San Joaquin River during periods of very high flow in the Tulare Basin. State Water Project (SWP) water is pumped out of the southern Delta into the California Aqueduct and South Bay Aqueduct and pumped out of the northern Delta into the North Bay Aqueduct. The quality of water entering these components of the SWP is greatly affected by waste discharges in the watersheds and sea water intrusion from Suisun Bay. Municipal and industrial waste discharges, urban runoff, agricultural drainage, and mine drainage entering the Sacramento and San Joaquin Rivers are described in this chapter. Sea water intrusion in the Delta is also discussed. Field surveys to identify all potential sources of contamination were not conducted due to the vast watershed areas and the great distances between many discharge locations and points of use of the water. The information presented in this chapter was obtained from past studies, records searches, and meetings with California Regional Water Quality Control Board, Central Valley Region (Regional Board) staff.

DESCRIPTION OF THE WATERSHEDS

The Sacramento and San Joaquin Rivers, and Tulare Lake receive water drained from the high areas surrounding the great Central Valley of California. The Central Valley is a northwest trending valley bordered by the Coast Ranges on the west, the Sierra Nevada on the east, the Cascade Range and Modoc Plateau on the north, and the Tehachapi Mountains on the south. The Sacramento River Basin extends from a drainage divide within the Cascade Range and Modoc Plateau to a drainage divide between the American and Cosumnes Rivers. The San Joaquin River Basin lies immediately below the Sacramento River Basin and extends south to an indistinct drainage divide between the San Joaquin and the Kings Rivers. The Tulare Lake Basin lies immediately below the San Joaquin River Basin and extends south to the Tehachapi Mountains.

Winter storms, moving onshore from Pacific low pressure systems, drop rain in the Central Valley and snow at higher elevations in the Sierra Nevada. Most precipitation occurs between October and April. The amount of precipitation varies from year to year but ranges from an average 35 inches in the north to about 15 inches in the south. Rain and snowmelt from the Sierra Nevada are the major sources of surface water into the drainage basins. Much of the snowmelt is impounded behind dams on tributary rivers. Flow in the Sacramento and San

Joaquin Rivers is heavily dependent on releases from these dams. Water from the Delta, imported via the California Aqueduct and Delta Mendota Canal, also enters the San Joaquin Basin and Tulare Lake Basin from the west side. Sierra Nevada water from north of the Tulare Lake Basin is imported into the Tulare Basin via the Friant-Kern Canal on the east side.

Climate in the Central Valley is mild, with hot summers and cool winters. Temperatures can top 100 degrees Fahrenheit in the summer. The Valley is mostly frost-free in the winter.

Sacramento Basin

The Sacramento Basin, drained by the Sacramento River, is approximately 26,000 square miles in area. The major east side tributaries to the Sacramento River are the Pit, Feather, Yuba, and American Rivers. The less important west side tributaries are Clear, Putah, and Cache Creeks. The annual average natural runoff in the system is 22 million acre feet (AF).

The population of the Sacramento Basin is about 1.7 million. Approximately 1 million people live in the Sacramento metropolitan area. The other major urban areas (population greater than 30,000) are Redding, Chico, Roseville, Vacaville, Woodland, and Davis. The primary land use is irrigated agriculture. Secondary uses include urban areas, timber harvesting and processing, livestock grazing, and recreation.

San Joaquin Basin

The San Joaquin Basin, drained by the San Joaquin River, is approximately, 16,000 square miles in area. The major east side tributaries to the San Joaquin River before it enters the Delta are the Merced, Tuolumne, and Stanislaus Rivers. Major east side tributaries that flow into the San Joaquin River after the river enters the Delta are the Calaveras, Mokelumne, and Cosumnes Rivers. Some minor creeks flow into the San Joaquin River from the west side. The annual average natural runoff in the system is 8 million AF.

Population in the San Joaquin Basin is about 1.8 million. The major urban areas are Stockton, Antioch, Modesto, Merced, Lodi, and Manteca. The primary land use is irrigated agriculture. Secondary uses include urban areas, timber harvesting and processing, livestock grazing, and recreation.

Tulare Basin

The Tulare Basin, with internal drainage into the Tulare lake bed and Buena Vista lake bed, is approximately 16,000 square miles in area. The major streams, which drain into these lake beds from the east, are the Kings, Kaweah, and Kern Rivers. The annual average natural runoff in the system is 3.5 million AF.

Population in the Tulare Basin is about 1.4 million. The major urban areas are Bakersfield, the Fresno metropolitan area, and Visalia. The primary land use is irrigated agriculture. Secondary uses include urban areas, petroleum production, and recreation.

The Delta

The Delta, the confluence of both the Sacramento and San Joaquin Basins, is approximately 1,000 square miles in area. The Delta, interlaced by a network of about 700 miles of waterways, consists of low, flat islands, bordered by levees. These islands, of mostly organic peat soils, were reclaimed from the Delta and lie at and below sea level. Fresh water, approximately 80 percent from the Sacramento River and 20 percent from the San Joaquin River system, flows through the Delta into Suisun Bay, the eastern arm of San Francisco Bay. Sea water from the Bay mixes with the river water in the west Delta. Varying flows from the Sacramento and San Joaquin Rivers, sea water intrusion (particularly at high tide), and operation of massive pumps at the headworks of the California Aqueduct and Delta Mendota Canal in the south Delta all influence the complex hydrology of the Delta. Delta hydrology is discussed in more detail in Chapter 2.

Population in the Delta is about 14,500. The primary land use is irrigated agriculture. A secondary use is recreation.

MUNICIPAL AND INDUSTRIAL DISCHARGES

Municipal and industrial facilities that discharge waste directly to a surface water body are point source discharges regulated under the National Pollutant Discharge Elimination System (NPDES) administered by the Regional Board. All NPDES dischargers in the Sacramento, San Joaquin, and Tulare Basins are permitted and monitored by the Central Valley Regional Board. The Regional Board places a point source discharger into one of twenty categories based on the type of effluent discharged.

Characteristics of Municipal and Industrial Discharges

Municipal dischargers are wastewater treatment plants that discharge a combination of treated domestic wastewater and industrial wastewater and in some cases, urban runoff. Industrial discharges include power plant cooling water, fish hatchery waste, pulp paper waste, oil production wastewater and/or runoff, food processing waste, ore mining wastewater, runoff from gravel and clay mines, and runoff from cement plants. Other types of effluent, such as lake water treated with algicides and industrial yard storm runoff, are also classed as industrial wastes.

Table 4-1 shows the number and average flows of the major categories of NPDES dischargers in the Sacramento, San Joaquin, and Tulare Basins. Only facilities with continuous flow are included in Table 4-1. Discharges permitted for seasonal rainfall runoff from facility grounds (non-continuous flow) are not included. Total municipal and industrial discharge average

Table 4-1. Summary of Municipal and Industrial Discharges

Discharge type	Sacramento Basin		San Joaquin Basin		Tulare Basin		Total	
	Number	Average flow, mgd[a]	Number	Average flow, mgd	Number	Average flow, mgd	Number	Average flow, mgd
Wastewater treatment plants	38	204	18	55	2	9	58	268
Plant cooling water	9	83	14	609	3	0.2	26	692
Fish hatchery waste	10	222	4	92	1	25	15	339
Treated lagoon water	0	0	1	42	0	0	1	42
Pulp and paper process waste	2	15	2	31	0	0	4	46
Oil production waste	0	0	5	1	14	16	19	17
Other	17	4	2	3	7	4	26	11
Total	76	528	46	833	27	54	149	1,415

[a]Million gallons per day.

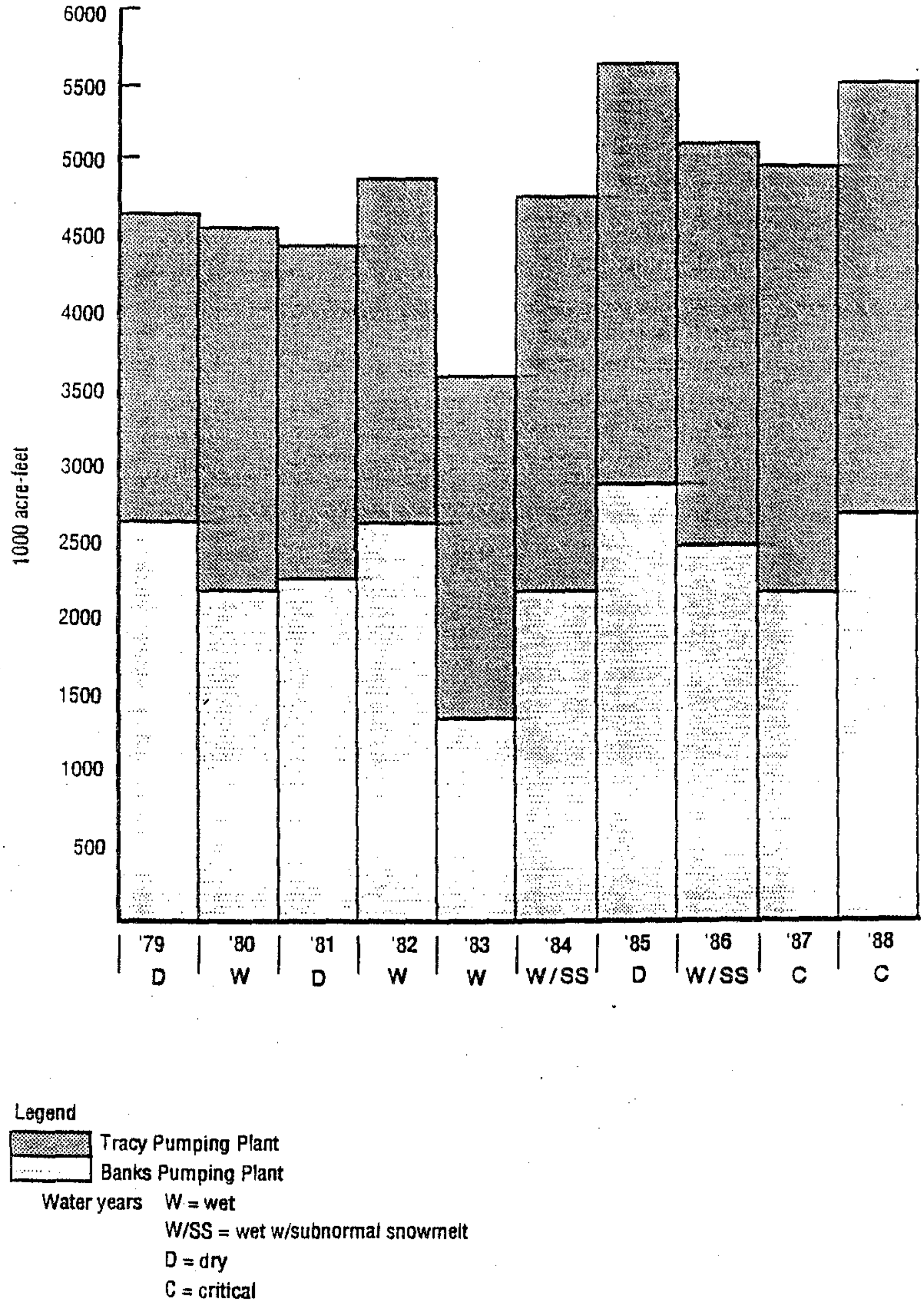


Figure 2-7. 1979 - 1988 Average Annual Pumping at Banks Pumping Plant and Tracy Pumping Plant

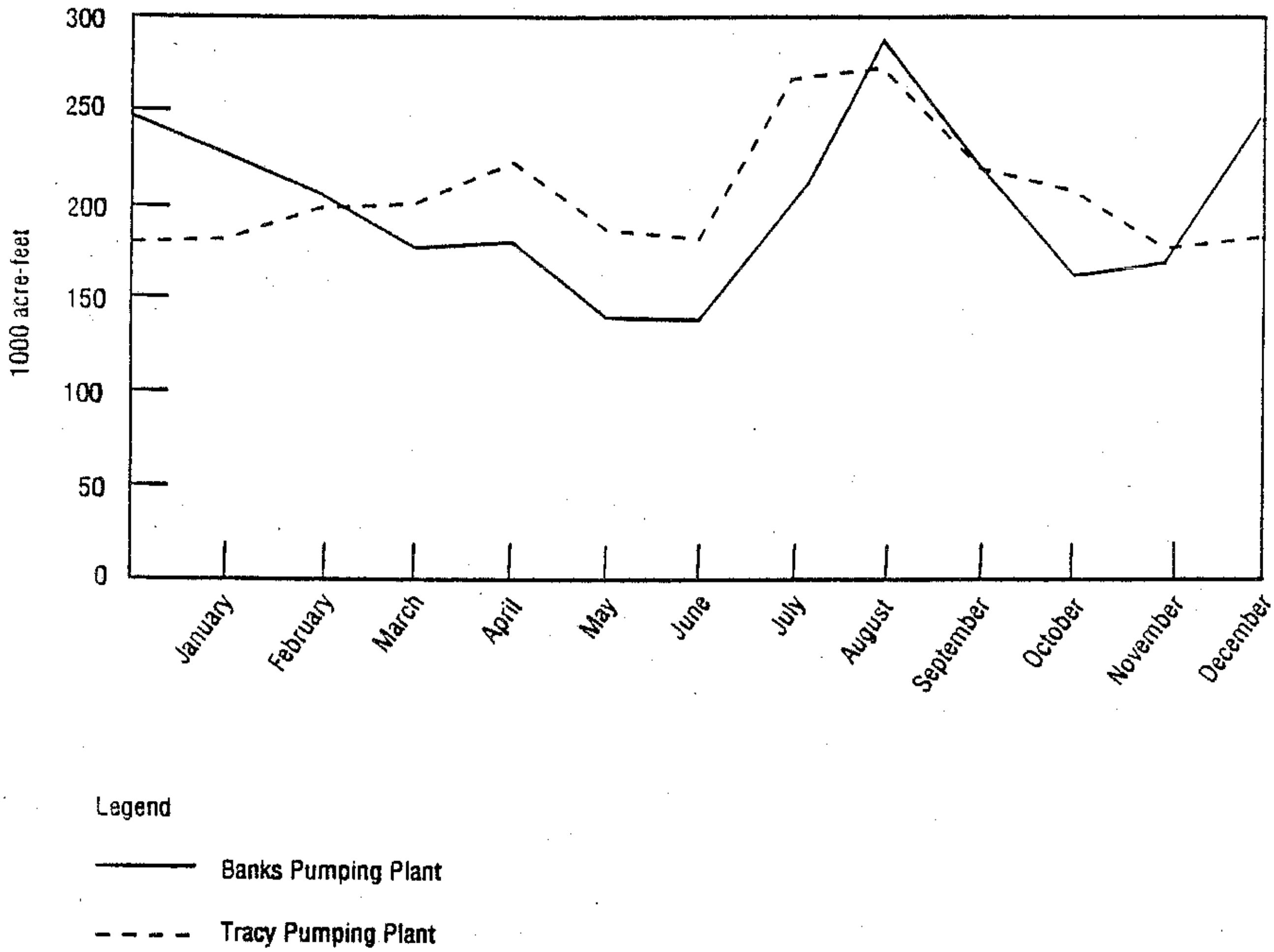


Figure 2-8. 1979 - 1988 Average Monthly Pumping at Banks Pumping Plant and Tracy Pumping Plant

flow in the three basins is about 1,400 million gallons per day (mgd). This information was taken from discharger self-monitoring data collected in 1985 (Montoya, et al., 1988). Effluent type categories not listed in Table 4-1 account for less than 1 percent of the total NPDES flow in the three basins. As shown on Figure 4-1, the three major types of effluent discharges in the Central Valley are plant cooling wastewater (50 percent), fish hatchery waste (24 percent), and wastewater treatment plant effluent (19 percent). Wastewater treatment plant effluent and fish hatchery wastes are the largest volume discharges in the Sacramento Basin. Plant cooling water and fish hatchery waste are the largest volume discharges in the San Joaquin Basin. The largest volume discharges in the Tulare Basin are fish hatchery waste and oil production waste.

Municipal Discharges. Wastewater treatment plants in the three basins with average flows greater than 1 mgd are listed in Table 4-2. The total municipal discharge flow in the Central Valley is about 270 mgd. The Sacramento Regional County Sanitation District Wastewater Treatment Plant (Sacramento Regional Plant) is the single largest municipal discharger in the Central Valley, accounting for 56 percent of the total municipal discharge flow. The Sacramento Regional Plant is currently being expanded to treat 181 mgd. It is expected that average flow will not reach 181 mgd until some time after 1992. The second largest municipal discharger, Stockton Main Sewage Treatment Plant (Stockton Main Plant), accounts for 11 percent. The locations of all municipal dischargers in the Sacramento, San Joaquin, and Tulare Basins are shown on Figures 4-2 through 4-4. All wastewater discharged in these watersheds receives at least secondary treatment.

Industrial Discharges. Industrial facilities in the three basins with average flows greater than 1 mgd are listed in Table 4-3. The total industrial discharge flow in the Central Valley is about 1,140 mgd. Plant cooling water made up about 50 percent of the total volume of wastewater discharged in the Central Valley under the NPDES program. Plant cooling water is primarily made up of non-contact, once-through water used to cool industrial machinery. The Pacific Gas & Electric Company (PG&E) Contra Costa Power Plant is the single largest industrial effluent discharger in the Central Valley, accounting for 52 percent of the total flow. Fish hatchery wastewater accounted for 24 percent of the total volume of wastewater discharged in the Central Valley under the NPDES program. Fish hatchery wastewater consists of water flowing through rearing ponds and spawning channels. The major hatcheries include the Coleman Fish Hatchery located on a tributary of the upper Sacramento River, the Mokelumne River Fish Installation, and the American River Trout Hatchery. The locations of all industrial dischargers in the Sacramento, San Joaquin, and Tulare Basins are shown on Figures 4-5 through 4-7.

Effluent Requirements

NPDES permit conditions are developed by the Regional Board specifically for each discharger. To obtain a permit, the discharger submits a description of the facility and a thorough chemical characterization of the effluent. In determining permit conditions, the Regional Board must adhere to U.S. Environmental Protection Agency (EPA) minimum effluent quality requirements for some types of industries. Other considerations are specific to the facility

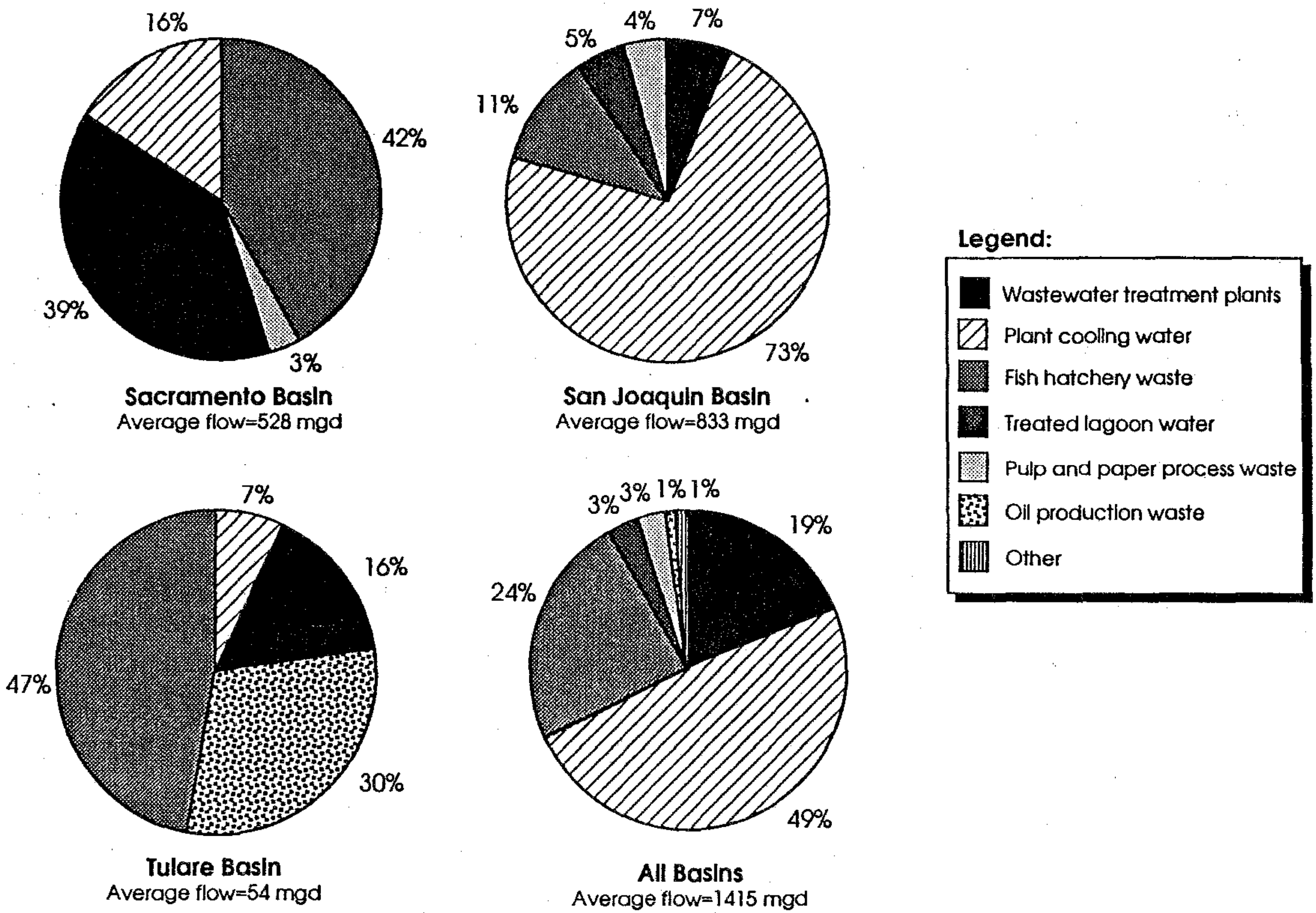


Figure 4-1. Average Flows of NPDES Municipal and Industrial Dischargers

Table 4-2. Major Wastewater Treatment Plants

Facility	Average flow, mgd	Basin location
Sacramento Regional	150	Sacramento
Stockton Main	29	San Joaquin
Roseville	11.8	Sacramento
Visalia	8.6	Tulare
Turlock	8	San Joaquin
Vacaville Easterly	6	Sacramento
Merced	5.5	San Joaquin
West Sacramento	4.5	Sacramento
Tracy	4	San Joaquin
Davis	3.6	Sacramento
Redding, Clear Creek	3.5	Sacramento
Oroville	3.5	Sacramento
Chico Main	3	Sacramento
Atwater	2.9	San Joaquin
University of California	1.8	Sacramento
Grass Valley	1.6	Sacramento
EID Deer Creek	1.5	San Joaquin
Red Bluff	1.2	Sacramento
Anderson	1.2	Sacramento
Placerville, Hangtown Creek	1.2	Sacramento
Beale AFB	1.1	Sacramento
Olivehurst PUD	1	Sacramento
Other	13.8	All
Total	268.3	

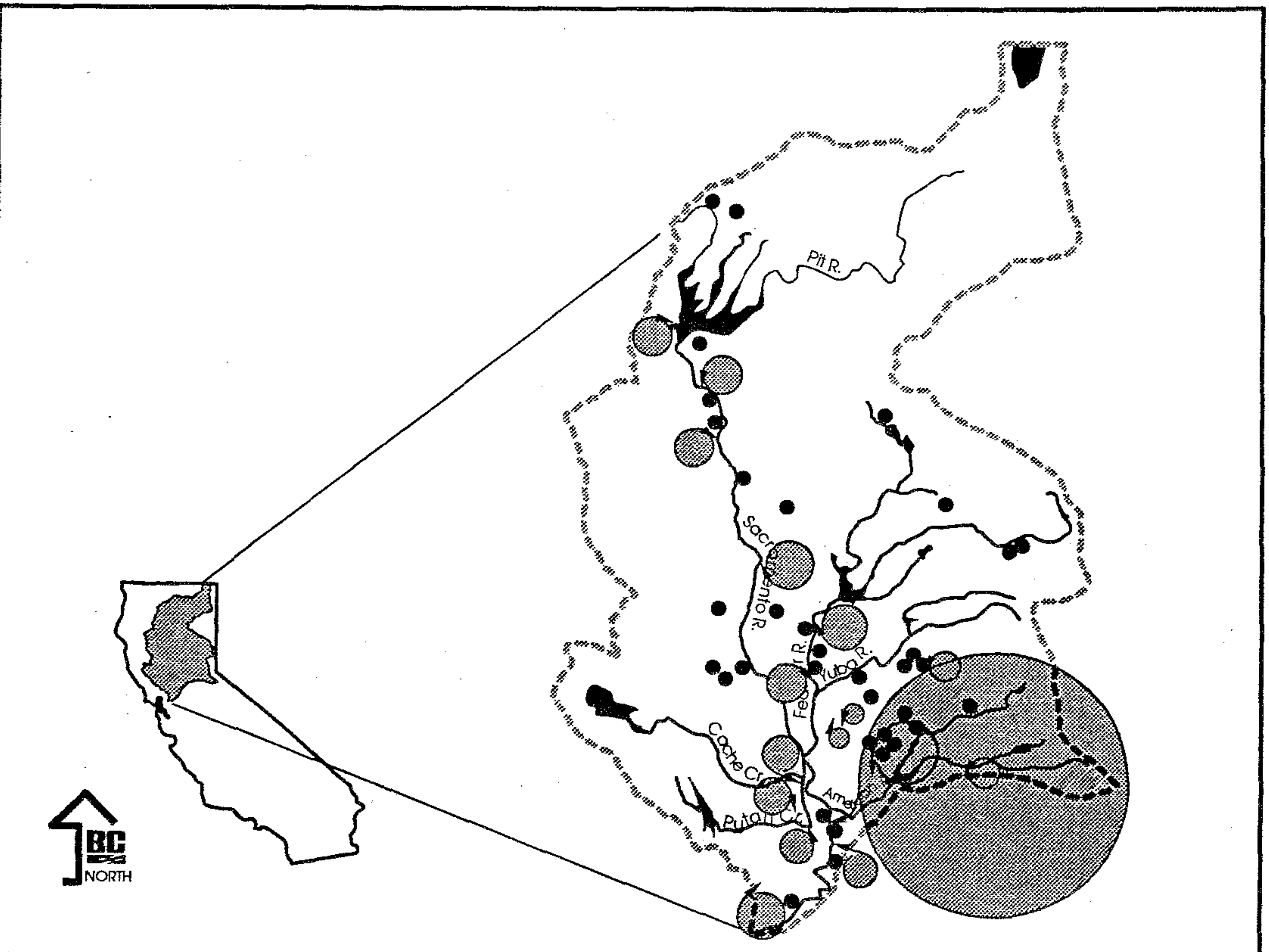
Table 4-3. Major Industrial Plants

Facility	Effluent type	Average flow, mgd	Basin location
PG&E Contra Costa Power Plant	PCW[a]	595	San Joaquin
Chester Sawmill	PCW	71	Sacramento
Coleman Fish Hatchery	FHW	67	Sacramento
Mokelumne River Fish Hatchery	FHW	43	San Joaquin
Discovery Bay Development	TLW	42	San Joaquin
American River Trout Hatchery	FHW	41	Sacramento
Feather River Hatchery	FHW	29	Sacramento
Darrah Springs Fish Hatchery	FHW	27	Sacramento
Pit River Fish Hatchery	FHW	25	Sacramento
Kern River Hatchery	FHW	25	Tulare
San Joaquin Fish Hatchery	FHW	23	San Joaquin
Mocassin Creek Fish Hatchery	FHW	19	San Joaquin
Fibreboard Corporation	PPW	16	San Joaquin
Crystal Lake Fish Hatchery	FHW	16	Sacramento
Crown Zellerbach Antioch Facility	PPW	15	San Joaquin
Simpson Paper/Shasta Mill	PPW	13	Sacramento
Mt. Shasta Fish Hatchery	FHW	10	Sacramento
Merced River Rearing Facility	FHW	7.7	San Joaquin
Texaco	OPW	7.4	Tulare
Chevron	OPW	6.3	Tulare
State Central Heating and Plant Cooling	PCW	5	Sacramento
Proctor & Gamble	PCW	4.5	Sacramento
Mt. Lassen Trout Farms, Dales	FHW	3.6	Sacramento
Atwater Cannery	PCW	2.2	San Joaquin
Mt. Lassen Trout Farm, Meadowbrook	FHW	2.2	Sacramento
Hershey Chocolate Company	PCW	2	San Joaquin
Red Bluff Fiber Plant	PPW	2	Sacramento
Balsam Meadows	CWW	1.9	San Joaquin
Gold Bond Building Products	PCW	1.8	San Joaquin
Escalon Packers	PCW	1.6	San Joaquin
Valley Waste Disposal	OPW	1.3	Tulare
State Printing and Warehouses	PCW	1	Sacramento
Formica Corporation	PCW	1	Sacramento
Other	--[b]	10	All
Total		1,141	

[a]Effluent types are:

PCW = Plant Cooling Water
FHW = Fish Hatchery Waste
TLW = Treated Lake Water
PPW = Pulp Paper Process Waste
OPW = Oil Production Waste
CWW = Construction Waste Water

[b]Includes effluent types listed above; also container sterilizing water, gravel and clay mining and cement plant runoff, geothermal heating water, industrial yard storm runoff, logdeck runoff, livestock runoff, mine processing waste (no acid mine drainage), treated groundwater, treated industrial steam cleaning waste, water treatment waste, and food processing waste.



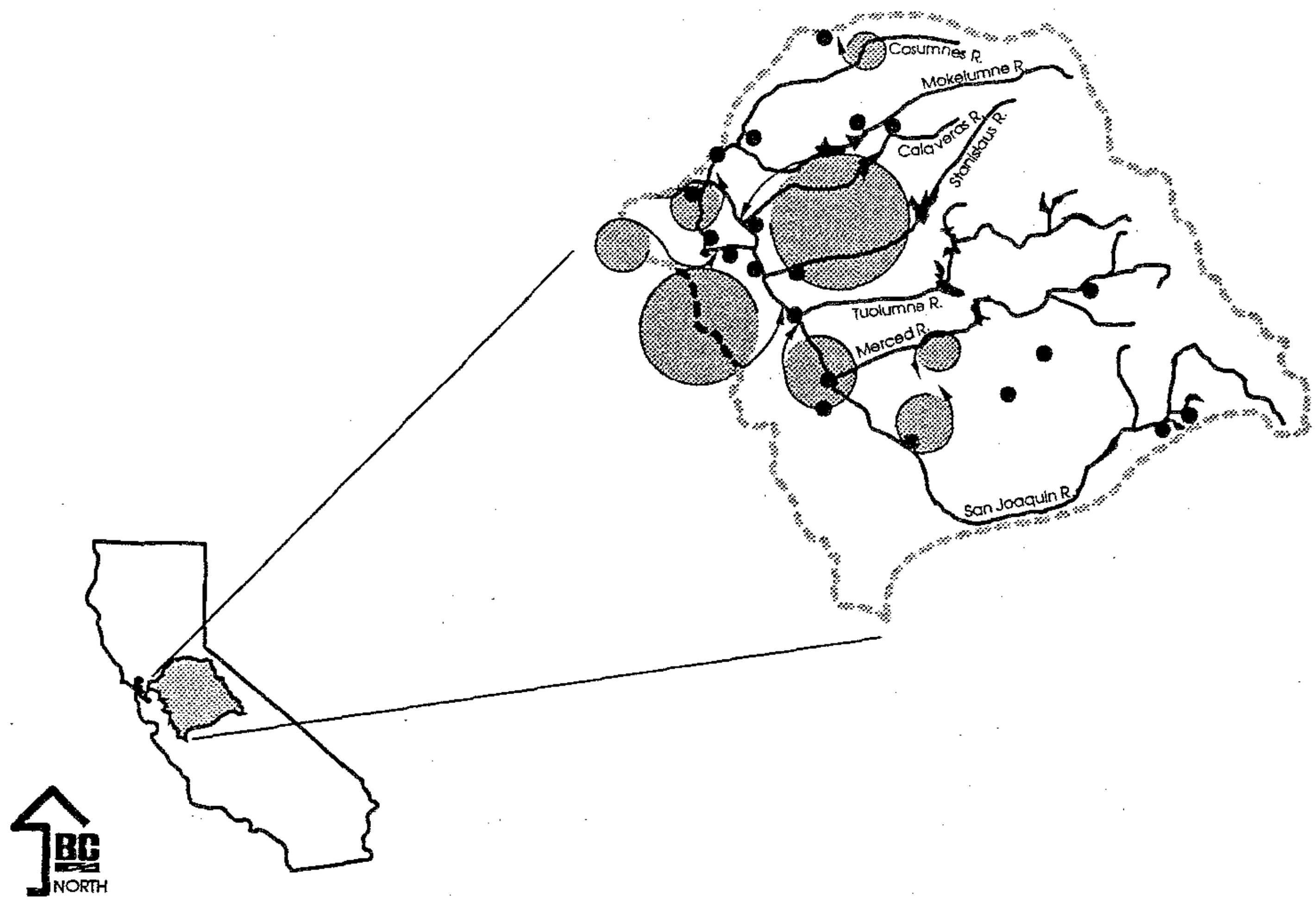
Legend:

Treatment Plant Effluent Discharge Locations: Wastewater plants discharging greater than 1 mgd

(area of circle is proportional to volume of flow)

● Treatment Plant Effluent Discharge Locations: Wastewater plants discharging less than 1 mgd

Figure 4-2. Wastewater Treatment Plant Effluent Discharge Locations: Sacramento Basin



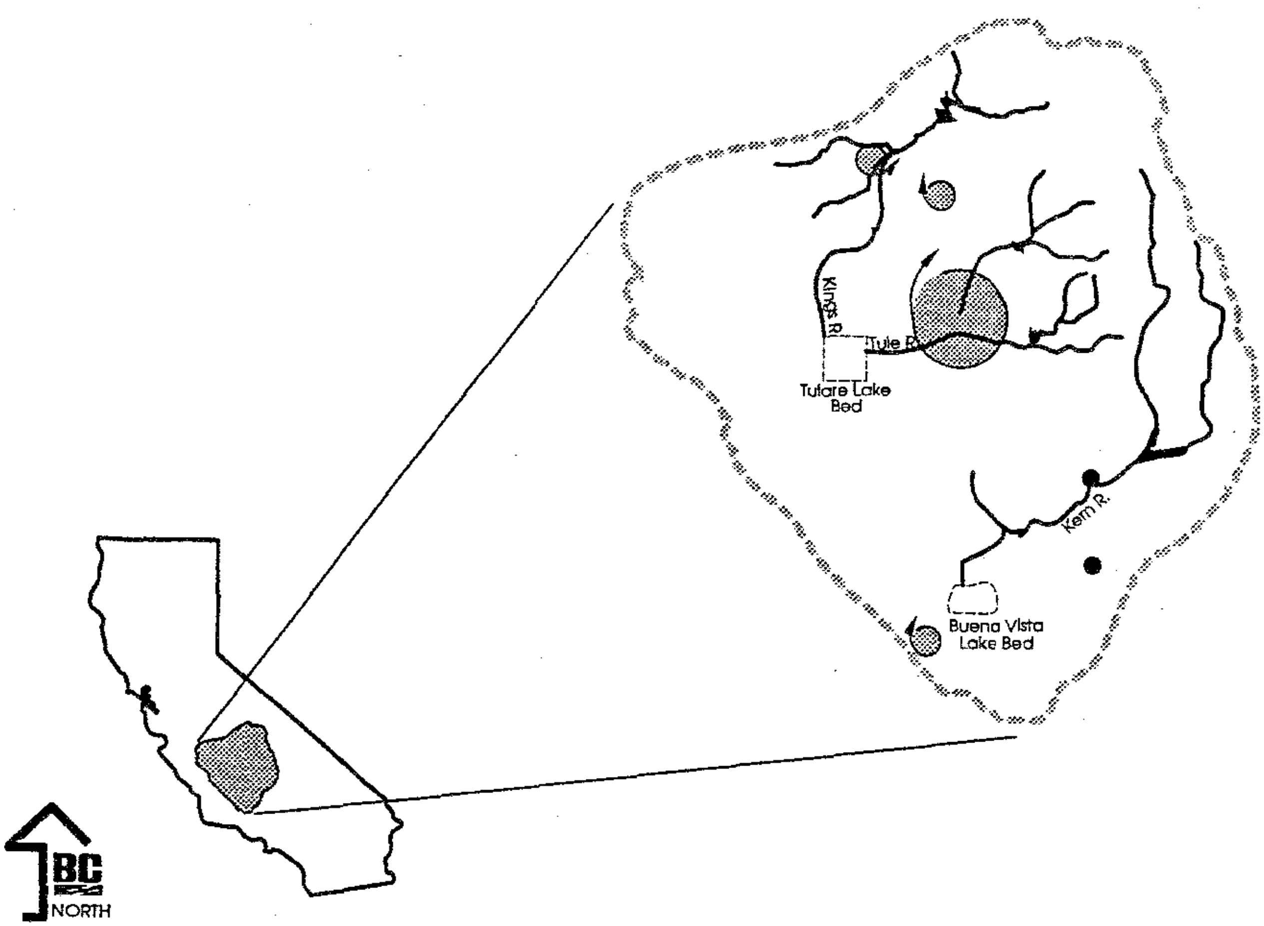
Legend:

Treatment Plant Effluent Discharge Locations: Wastewater plants discharging greater than 1 mgd

(area of circle is proportional to volume of flow)

Treatment Plant Effluent Discharge Locations: Wastewater plants discharging less than 1 mgd

Figure 4-3. Wastewater Treatment Plant Effluent Discharge Locations: San Joaquin Basin



Legend:

Treatment Plant Effluent Discharge Locations: Wastewater plants discharging greater than 1 mgd

(area of circle is proportional to volume of flow)

Treatment Plant Effluent Discharge Locations: Wastewater plants discharging less than 1 mgd

Figure 4-4. Wastewater Treatment Plant Effluent Discharge Locations: Tulare Basin

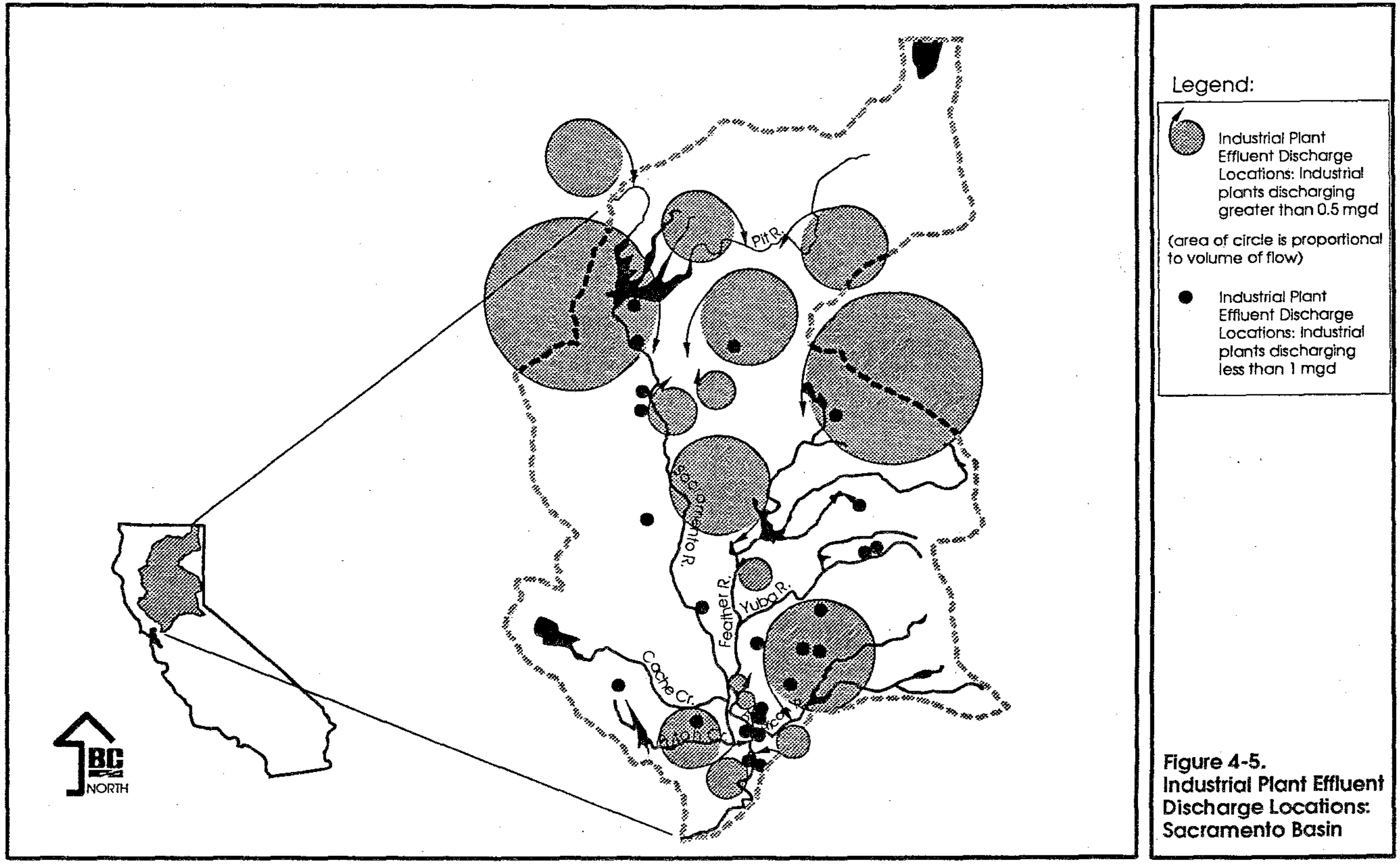
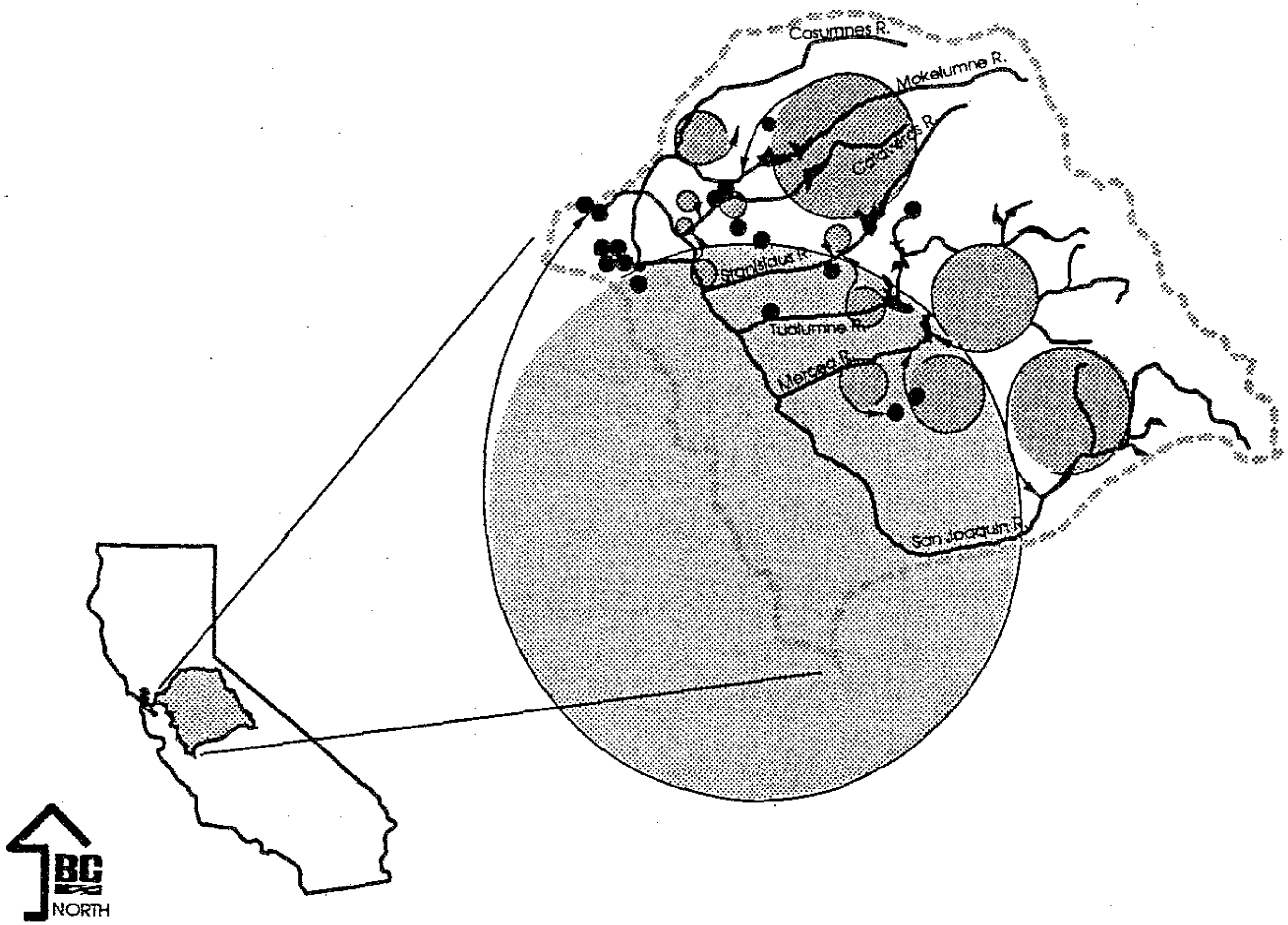


Figure 4-5. Industrial Plant Effluent Discharge Locations: Sacramento Basin



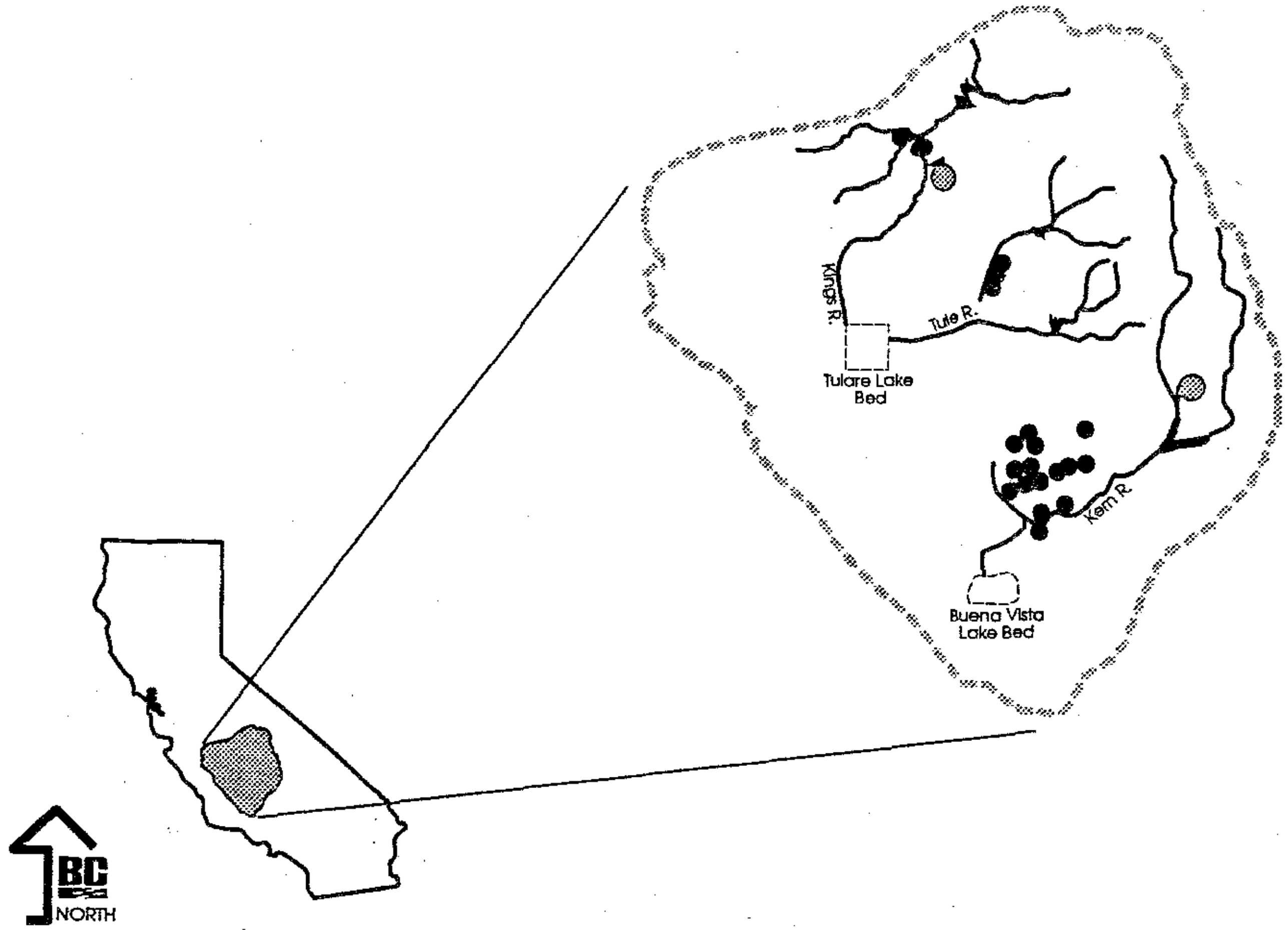
Legend:

Industrial Plant Effluent Discharge Locations: Industrial plants discharging greater than 0.5 mgd

(area of circle is proportional to volume of flow)

Industrial Plant Effluent Discharge Locations: Industrial plants discharging less than 1 mgd

Figure 4-6. Industrial Plant Effluent Discharge Locations: San Joaquin Basin



Legend:

Industrial Plant Effluent Discharge Locations: Industrial plants discharging greater than 0.5 mgd

(area of circle is proportional to volume of flow)

Industrial Plant Effluent Discharge Locations: Industrial plants discharging less than 1 mgd

Figure 4-7. Industrial Plant Effluent Discharge Locations: Tulare Basin

and the receiving waters. The Regional Board considers the proximity of downstream drinking water intakes, the dilution available in the receiving waters, the quality of the receiving waters, downstream aquatic life, treatment technology feasibility, and cost factors. Effluent requirements for industries discharging to wastewater treatment plants are established by the wastewater utility through the industrial pretreatment program. Each facility is responsible for submitting self monitoring effluent quality data to the Regional Board on a monthly basis. Permit conditions are required to be reviewed by the Regional Board at least once every 5 years.

Municipal Discharges. NPDES effluent requirements for key wastewater treatment plants are shown in Table 4-4. The Sacramento Regional Plant and Stockton Main Plant are the two largest municipal dischargers in the Central Valley. Together they account for 67 percent of the municipal flow. Tracy Sewage Treatment Plant is shown because it discharges into Old River in the south Delta. Vacaville Easterly Sewage Treatment Plant is shown because it discharges into Alamo Creek which is tributary to Cache Slough in the north Delta.

The effluent limitations for the four wastewater treatment plants shown in Table 4-4 are quite similar. Where there are differences, they are due to site-specific receiving water characteristics or differences in beneficial uses of the receiving waters. For example, the biochemical oxygen demand (BOD) and total suspended solids effluent requirements for the Stockton Main Plant are based on the ambient dissolved oxygen levels in the San Joaquin River. There is no need for this type of requirement for the Sacramento Regional Plant because the Sacramento River does not have the low dissolved oxygen concentrations that the San Joaquin River has in the summer months.

Industrial Discharges. NPDES effluent requirements for key major industrial facilities are shown in Table 4-5. Dischargers of plant cooling water, fish hatchery waste, and pulp and paper process waste are represented. The PG&E Contra Costa Power Plant accounts for 86 percent of the plant cooling water effluent and discharges into the Delta near the confluence of the Sacramento and San Joaquin Rivers. Fibreboard Corporation's San Joaquin Division Pulp Mill is the largest pulp and paper process waste discharger accounting for 70 percent of all pulp and paper process effluent. Fibreboard discharges into the Delta near the PG&E power plant. The California Department of Fish and Game Mokelumne River Fish Installation accounts for 13 percent of fish hatchery effluent. Although not the largest discharger, it is closer to the Delta than any other major fish hatchery.

Discharge Quality

Actual effluent quality for the municipal plants listed in Table 4-4 and the industrial plants listed in Table 4-5 is shown in Tables 4-6 and 4-7, respectively. These tables were constructed by averaging the last continuous twelve months of self-monitoring data provided by the facility to the Regional Board. With the exception of residual chlorine levels in Vacaville Easterly Sewage Treatment Plant effluent, all of the major municipal and industrial plants discussed are meeting their NPDES permit requirements.

Table 4-4. Summary of Effluent Limitations: Wastewater Treatment Plants

Constituent	Daily maximum				Monthly average			
	Sacramento	Stockton	Tracy	Vacaville	Sacramento	Stockton	Tracy	Vacaville
Flow, mgd	--	--	--	--	150	29	9	8
BOD_5, mg/l	60	50/30[a]	50	50	30	30/10/20[a]	20	30
Total suspended matter, mg/l	60	50/30[a]	50	50	30	30/10[a]	30	30
Settleable matter, ml/l	0.5	0.1	0.2	0.2	0.1	--	0.1	0.1
Residual chlorine, mg/l	0.018[b]	0.05	0.1	0.1	0.011	0.02	--	--
Total coliforms, MPN/100 mls	500	500	500	500	23[c]	23[c]	23[c]	23[c]
Oil and grease, mg/l	15	15	15	--	10	10	10	--
Total chlorinated phenols, ug/l	--	3.2	--	--	--	--	--	--
pH[d]	6.0-8.5	6.0-8.5	6.5-8.5	6.5-8.5	--	--	--	--
Bioassay, percent survival	--[e]	--[f]	--[f]	--	--	--	--	--
Temperature	--[g]	--[g]	--[g]	--	--	--	--	--

[a]Due to low levels of dissolved oxygen (DO) in the San Joaquin River from August through October, the BOD_5 and total suspended matter (TSS) effluent requirements for the Stockton Main plant are as follows:

Period/conditions	BOD_5, mg/l		TSS, mg/l	
	Daily maximum	Monthly average	Daily maximum	Monthly average
8/1 - 10/31 or when DO <5.0 mg/l in San Joaquin River	30	10	30	10
8/1 - 10/31 and when flow in San Joaquin River >3,000 cfs	50	20	50	30
All other periods and conditions	50	30	50	30

[b]Daily average of continuous chlorine residual measurements.
[c]Median values
[d]Allowable pH range of effluent.
[e]Survival of test fishes in weekly continuous flow bioassays of undiluted waste shall be no less than:

Minimum for any one bioassay - 70 percent
Median for any three or more bioassays - 90 percent

[f]Survival of test fishes in 96-hour bioassays of undiluted waste shall be no less than:

Minimum for any one bioassay - 70 percent
Median for any three or more consecutive bioassays - 90 percent

[g]The maximum temperature of the discharge shall not exceed the natural receiving water temperature by more than 20°F.

Table 4-5. Summary of Effluent Limitations: Industrial Plants

Constituent	Daily maximum			Monthly average		
	PG&E	Fibreboard	Mokelumne R. Fish Hatchery	PG&E	Fibreboard	Mokelumne R. Fish Hatchery
Flow, mgd	1,000	21	--	595	19	19
BOD_5, lbs/day	--	13,738	--	--	6,965	--
Total suspended matter, mg/l	100	--	15	30	--	8
Total suspended solids, lbs/day	--	27,600	--	--	14,115	--
Settleable matter, ml/l	--	0.5	0.2	--	0.2	0.1
Residual chlorine, mg/l	0	0.1	--	0	--	--
Total coliforms, MPN/100 ml	--	500	--	--	23[a]	--
Oil and grease, mg/l	20	15	--	10	10	--
pH[b]	6.5-8.5	6.0-8.5	6.5-8.5	--	--	--
Bioassay, percent survival	--	--[c]	--	--	--[c]	--
Temperature	--[d]	--[e]	--	--	--	--
PCBs	0	--	--	0	--	--
Total copper, mg/l	1[f]	--	--	1[f]	--	--
Total iron, mg/l	1[f]	--	--	1[f]	--	--
Total sulfide, mg/l	--	1	--	--	--	--

[a]Median values.
[b]Allowable pH range of effluent.
[c]Survival of test fishes in 96-hour bioassays of undiluted waste shall be no less than:
Minimum for any are bioassay - 70 percent
Median for any three or more consecutive bioassays - 90 percent.
[d]The maximum temperature of the discharge shall not exceed the natural receiving water temperature by more than 37°F for Discharge 001 and 39°F for Discharge 002.
[e]The maximum temperature of the discharge shall not exceed the natural receiving water temperature by more than 60°F nor exceed 105°F.
[f]Limits apply to waste stream D in Discharge 002.

Table 4-6. Annual Average Wastewater Treatment Plant Effluent Quality

Constituent	Average effluent quality			
	Sacramento	Stockton	Tracy	Vacaville
Flow, mgd	143	28.4	4.2	7.4
BOD_5, mg/l	14	20	12	8
Total suspended matter, mg/l	9	19	6	12
Settleable matter, ml/l	<0.1	<0.1	<0.1	0
TDS, mg/l	--	818	1,112	--
Specific conducvitiy, umhos/cm	664	1,113	1,816	--
pH	6.3	6.5	7.5	7.1
Total N, mg/l	--	18.3	--	--
Total P, mg/l	--	2.43	--	--
Residual chlorine, mg/l	0.0002	<0.01	0	0.17
Oil and grease, mg/l	1.5	<1	0.9	--
Total coliforms[a], MPN/100 mls	3	<2	<2	<2
Bioassay[a], percent survival	98	95	100	--

[a]Median values.

Table 4-7. Annual Average Industrial Treatment Plant Effluent Quality

Constituent	Average effluent quality		
	PG&E Contra Costa Power Plant	Fibreboard[a]	Mokelumne River Fish Hatchery
Flow, mgd	440	11.6	10.7
BOD, mg/l	--	81.6	--
Total suspended matter, mg/l	--	96	6.3
Settleable matter, ml/l	--	<0.15	0
TDS, mg/l	--	2,635	29.4
Specific conductivity, μmhos/cm	--	2,523	--
pH	7.6	7.1	--
Residual chlorine, mg/l	NC	0.01	--
Oil and grease, mg/l	--	2.6	--
Total coliforms[b], MPN/100 mls	--	2	--
Bioassay[b], percent survival	--	91	--
PCB, mg/l	0	--	--
Total sulfide, mg/l	--	0.4	--

[a]Now owned by Gaylord Corporation.
[b]Median values.

Constituents of concern to drinking water in municipal effluent can be divided into those that pose an immediate health risk and those that may pose a longer term health risk. Municipal effluent may contain pathogenic microbial organisms such as bacteria, pathogenic cysts, and viruses. Conventional wastewater treatment reduces the density of pathogenic organisms although protozoan cysts, helminth ova, and certain enteric viruses may not be effectively inactivated by current practices which are effective for bacteria (National Research Council, 1982). Raw water containing high levels of microbial pollution increases the potential for incomplete disinfection when there is a breakdown in water treatment facilities.

There are no data available on concentrations of viruses, Giardia, or Cryptosporidium in effluent discharged from wastewater treatment plants in the Sacramento, San Joaquin, and Tulare basins. A study of the occurrence of Cryptosporidium in wastewater, wastewater effluent, and receiving waters conducted by the University of Arizona showed widespread occurrence (Rose, 1988). Of 107 samples, 77 were positive for Cryptosporidium. Mean concentrations ranged from 4.1 to 1,732 oocysts/l in treated wastewater and 0.04 to 18 oocysts/l in receiving waters. Cryptosporidium is particularly insidious because it is extremely resistant to disinfection and has caused major outbreaks of Cryptosporodiosis in Texas, Georgia, and England.

Municipal wastewater treatment plants discharge high concentrations of nutrients and organic carbon. Nutrients can stimulate biological productivity downstream of the discharge leading to high concentrations of organic carbon at downstream water intakes. Organic carbon combined with disinfectants used at water treatment plants produces trihalomethanes (THMs) and other disinfection by-products.

Metals and toxic organic constituents are also discharged from municipal wastewater treatment plants. There are limited data on the concentrations of priority pollutant metals and organics in wastewater effluent. The Sacramento Regional Plant staff collects effluent data on total metals concentrations monthly and volatile and base neutral organics quarterly. The data collected between 1983 and 1989 are presented in Table 4-8. Most of these contaminants in the wastewater effluent are below the analytical detection limits. Many of the detection limits are lower than drinking water standards.

Although the concern is for downstream aquatic life, the Central Valley Regional Board is requiring whole effluent toxicity testing of most municipal effluents that discharge to the Sacramento and San Joaquin Rivers. The Sacramento Regional Plant conducts continuous single species toxicity tests measuring acute toxicity in an effluent flow-through tank. The effluent consistently meets the Regional Board's 70 percent survival requirement. The Regional Board is also requiring the EPA three species (fish, zooplankton, and algae) toxicity tests for all discharges with less than 100:1 dilution in the receiving waters. During 1989 (a dry year), the daily dilution ratios for the Sacramento Regional Plant ranged from a minimum of 31:1 in February to a maximum of 323:1 in March. The average daily dilution ratio during the year was 146:1. These data are shown in Table 4-9. In 1988 and 1989, sixteen 3-species toxicity tests were conducted. Instances of repressed Ceriodaphnia reproduction and stimulated algal growth have been observed.

Table 4-8. Sacramento Regional Plant Effluent Quality

Constituent	Units	Range	Median
Arsenic	μg/l	<4-6	<5
Cadmium	μg/l	0-37	<1
Chromium	μg/l	<1-18	7
Copper	μg/l	2-51	11
Lead	μg/l	<1-14	<5
Mercury, ng/l	ng/l	<200-4,600	<200
Nickel	μg/l	<5-20	5
Selenium	μg/l	<1-<5	<1
Silver	μg/l	<1-<5	<5
	μg/l		
Zinc	μg/l	11-200	69
Aldrin	μg/l	<0.003-<10	<0.02
Benzene	μg/l	<0.1-<11	<1.0
Chlordane	μg/l	<0.04-<100	<0.4
Chloroform	μg/l	<1.0-19	11.7
DDT	μg/l	<0.005-<10	<0.35
1,4-dichlorobenzene	μg/l	<0.5-<11	<4.4
Dichloromethane	μg/l	0.6-40	3
2,4-dichlorophenol	μg/l	<2.0-<20	<2.7
Dieldrin	μg/l	<0.005-<10	<0.02
Endosulfan	μg/l	<0.01-<20	<0.125
Endrin	μg/l	<0.1-<20	<0.04
Fluoranthene	μg/l	<2-<17	<2.2
Halomethanes	μg/l	<0.4-<12	<2.6
Heptachlor	μg/l	<0.002-<10	<0.02
Hexachlorobenzene	μg/l	<1-<11	<1.9
Hexachloro-cyclohexane-alpha	μg/l	<0.002-<5	<0.02
Hexachloro-cyclohexane-beta	μg/l	<0.005-<10	<0.02
Hexachloro-cyclohexane-gamma	μg/l	<0.002-<4.2	<0.04
PAH	μg/l	<1-<70	<3.2
PCB	μg/l	<0.03-<0.5	<0.23
Pentachlorophenol	μg/l	<0.5-<47	<3.6
Phenol	μg/l	<15-<24	<1.8
TCDD equivalents	μg/l	<5-<10	<7.5
Toluene	μg/l	<0.5-<11	<2.2
2,4,6-trichlorophenol	μg/l	<2.0-<18	<2.7
Toxaphene	μg/l	<0.40-<500	<0.78

Table 4-9. Dilution Ratios of Sacramento Regional Plant Effluent in the Sacramento River for Calendar Year 1989

Month	River Dilution	
	Maximum	Minimum
January	99	34
February	95	31
March	323	124
April	162	69
May	124	36
June	114	31
July	182	51
August	138	47
September	130	38
October	117	32
November	130	35
December	137	42
Maximum	323	124
Minimum	95	31
Average	146	48

Discharge requirements based on toxicity testing of municipal effluents provides some protection for downstream drinking water supplies. With many constituents, the concentrations required to protect aquatic life are far lower than drinking water standards.

Constituents of concern in industrial effluent are specific to the type of facility generating the waste. Plant cooling water, mostly "non-contact" water used to cool industrial machinery usually contains oil and grease and some metals. The major constituents in fish hatchery wastewater, which flows through rearing ponds and spawning channels, are suspended solids and settleable matter. Effluent from paper and pulp process facilities contains high BOD levels, suspended solids, and some oil and grease. Dioxin, resulting from bleaching processes, can also be a problem at paper and pulp process facilities. The Regional Board is currently revising the NPDES permit for the Crown Zellerbach Plant in Antioch due to concerns about dioxin in the discharge. The NPDES permit for the Simpson Paper Mill in Anderson may also be revised due to concerns about dioxin in the discharge. Oil production wastewater, generally groundwater that has come into contact with crude oil during the extraction process, contains oil and grease. Oil production wastewater is discharged only in the south Tulare Basin.

Loads of Contaminants

The Central Valley Regional Board compared metals and oil and grease loads to Central Valley surface waters in 1985 (Montoya, et al., 1988). Loads from four sources were estimated. These sources were NPDES dischargers, agricultural drainage, acid mine drainage, and urban runoff. The annual average percent flow contribution of NPDES dischargers to the Sacramento River in 1985 was calculated to be between 3 and 5 percent at Freeport. The flow contribution data for NPDES discharges was taken from NPDES self-monitoring reports.

Metal loads from 13 major municipal and industrial NPDES dischargers were estimated. A major portion of the discharge from the PG&E Contra Costa Power Plant, the single largest volume NPDES discharger, was not included in the estimates. Loads were estimated for eleven metals: arsenic, cadmium, chromium, chromium (VI), copper, lead, mercury, nickel, silver, zinc, and cyanide. High detection limits may have masked the true quantities of metals in some of the estimates. The study concluded that NPDES dischargers contribute between 2 to 3 percent (copper, lead, and zinc) to 8 to 9 percent (chromium and nickel) of metals loads discharged to the Sacramento, San Joaquin, and Tulare Basins. With the exception of chromium (VI), four NPDES dischargers, the Sacramento Regional Plant, the Stockton Main Plant, the Tracy Sewage Treatment Plant, and the Merced Waste Treatment Plant, accounted for 90 percent of the NPDES metals loads. Metals loads varied dramatically from month to month.

Oil and grease loads from 23 major municipal and industrial NPDES dischargers were estimated. High detection limits for some data may have masked the true quantity of oil and grease in some estimates. Over 1 million pounds of oil and grease were discharged by NPDES facilities in 1985, contributing approximately 25 percent of the total oil and grease load discharged to the Sacramento, San Joaquin, and Tulare Basins. Three NPDES dischargers, the Sacramento Regional Plant, the Merced Waste Treatment Plant and the Sacramento Municipal

Utility District Rancho Seco Power Plant, accounted for 95 percent of the NPDES oil and grease loads. The Rancho Seco Power Plant is no longer in operation. The Sacramento Regional Plant was the single largest contributor. Oil production waste facilities were not major contributors due to their relatively low discharge volume. Due to high detection limits at the Sacramento Regional Plant during some months in 1985, it was not possible to identify seasonal trends.

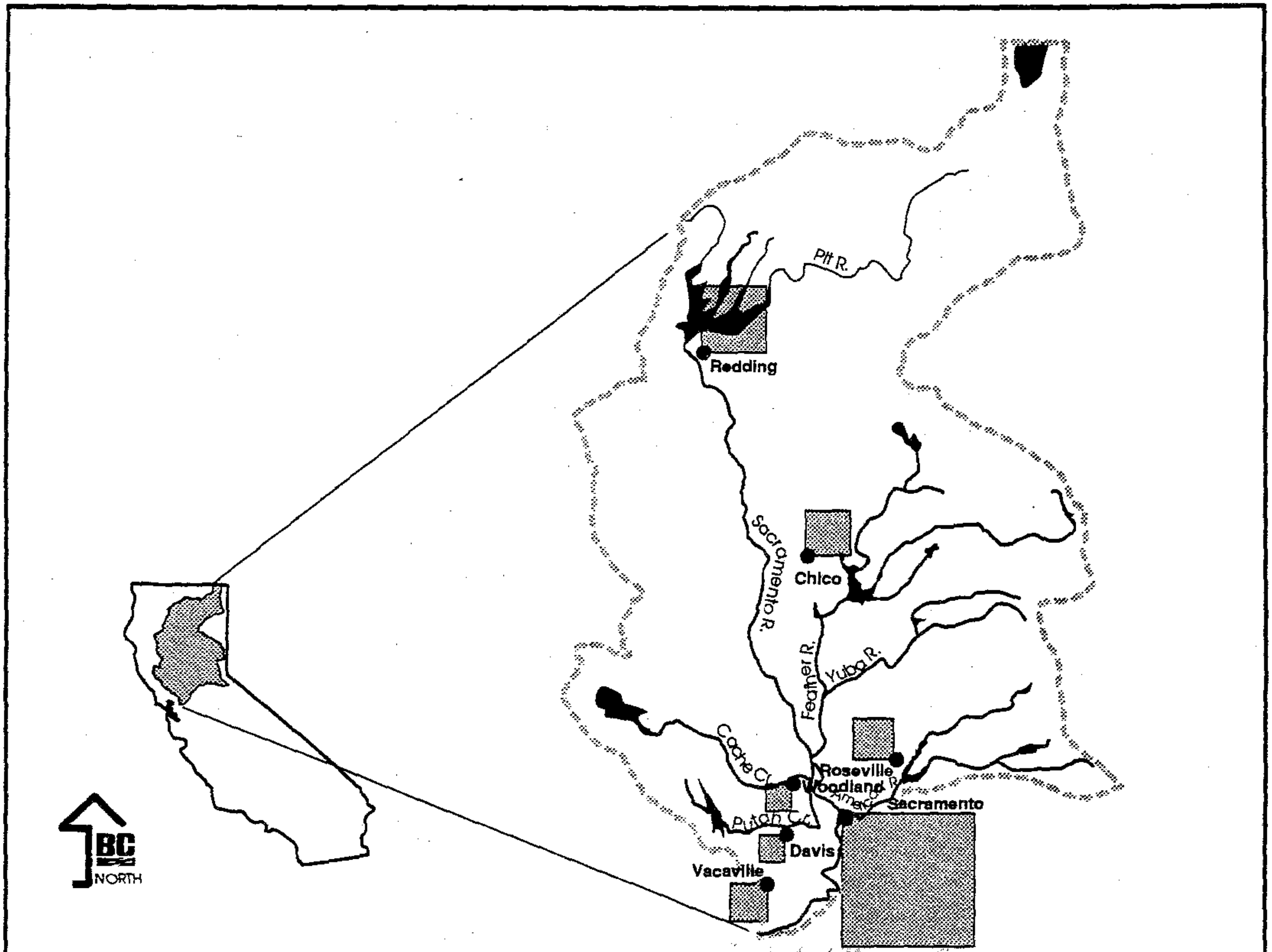
URBAN RUNOFF DISCHARGES

Urban runoff is that portion of rainfall which drains from developed, urban watersheds and flows via natural or man-made drainage systems into receiving waters. Urban runoff continues throughout the dry season as a result of irrigation and washoff practices. As discussed in detail in Appendix C, EPA has issued draft regulations that require NPDES permits for municipal and industrial urban runoff discharges. The final regulations are expected to be promulgated in October 1990. The Regional Boards administer the NPDES program for EPA in California. In June 1990, the NPDES permit for Sacramento's urban runoff was issued.

Key Urban Area Discharges

Figures 4-8 through 4-10 show the major urban areas (population greater than 30,000) in the Sacramento, San Joaquin, and Tulare Basins which discharge their urban runoff to surface waters. The urbanization of the Central Valley is a growth trend which is expected to continue. The Sacramento metropolitan area is the single largest urban area. The Central Valley Regional Board estimates that the Sacramento metropolitan area urban runoff contributed 1 to 3 percent of Sacramento River flow in water year 1985, at Sacramento (Montoya, 1987). Runoff volumes were determined for those Sacramento urban area watersheds with good pump records for 1984-85. Extrapolations for all Sacramento urban area discharges were based on the monthly average discharge per acre values thus determined. Other important urban areas are Vacaville, which discharges urban runoff into creeks that flow into the north Delta near the North Bay Aqueduct intake, and Stockton and Manteca, the closest major urban areas to Clifton Court Forebay. Most urban runoff discharges untreated directly to streams.

The downtown Sacramento area (approximately 7,000 acres) is served by a combined sewer system, i.e., a sewer system which conveys both sanitary sewage and urban stormwater. During dry weather periods, the combined wastewater is pumped to the Sacramento Regional Plant where it receives secondary treatment prior to discharge to the Sacramento River at Freeport. During wet weather, up to 60 mgd may be pumped to the Sacramento Regional Plant. Flows in excess of 60 mgd are pumped to the Sacramento Combined Wastewater Treatment Plant (CWTP). The CWTP provides primary treatment for up to 130 mgd and discharges the effluent to the Sacramento River a few miles south of downtown Sacramento. Since the CWTP began operating in January 1986, there have been 41 days when primary treated combined wastewater has been discharged from the CWTP.



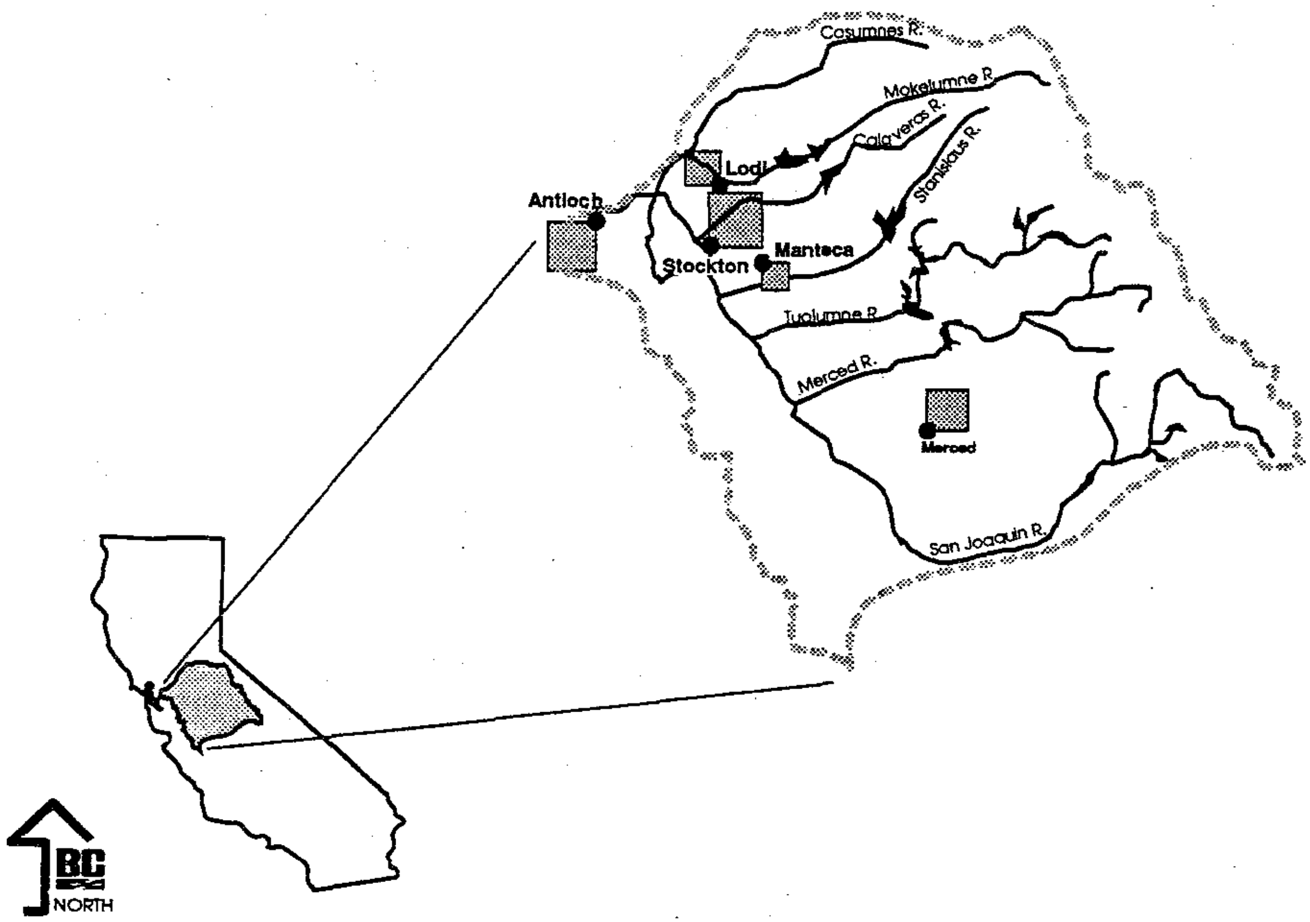
Legend:

Redding

Location and name of urban area (population greater than 30,000). Area of shaded square is proportional to urban acreage.

(1 square inch=3,000 acres)

Figure 4-8. Major Urban Areas which Discharge Urban Runoff to Surface Water Bodies: Sacramento Basin



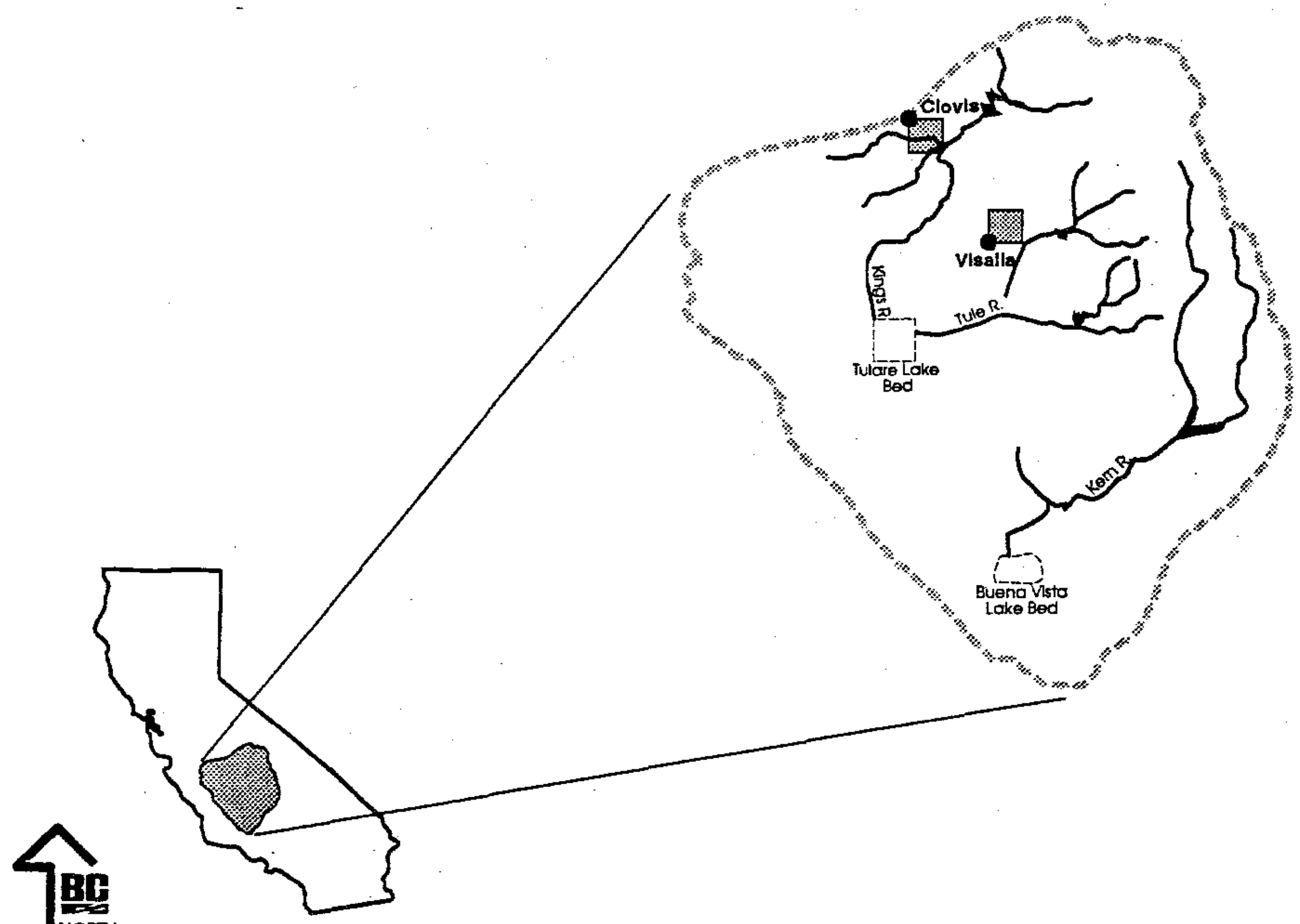
Legend:

Manteca

Location and name of urban area (population greater than 30,000). Area of shaded square is proportional to urban acreage.

(1 square inch=3,000 acres)

Figure 4-9. Major Urban Areas which Discharge Urban Runoff to Surface Water Bodies: San Joaquin Basin



Legend:

Clovis Location and name of urban area (population greater than 30,000). Area of shaded square is proportional to urban acreage.

(1 square inch=3,000 acres)

Figure 4-10. Major Urban Areas which Discharge Urban Runoff to Surface Water Bodies: Tulare Basin

When combined wastewater flows exceed the capacity of the Sacramento Regional Plant and the CWTP, the excess flow is pumped to Pioneer Reservoir for interim storage until the stored flow can be returned to the Sacramento Regional Plant for treatment. During large storms, Pioneer Reservoir becomes full and it is necessary to discharge from the reservoir to the river near downtown Sacramento. The combined wastewater receives partial treatment consisting of solids and floatables removal before discharge. Combined sewer discharges from Pioneer Reservoir have occurred on 23 days or an average of 5 days per year since January 1986. During very large storms, when both treatment plants and the reservoir are operating at capacity, it is necessary to discharge untreated combined wastewater directly to the river. Since the system was placed in operation in 1986, direct discharge of untreated combined sewage has occurred only once during the large storm of February 1986. During the period of discharge, flow in the Sacramento River near Sacramento ranged from 103,000 to 115,000 cubic feet per second (cfs), compared to the average flow of 24,600 cfs. Discharges from the combined wastewater control system are regulated by an NPDES permit issued by the Central Valley Regional Board.

It has recently been recognized that urban runoff generated during dry periods may be significant. The Regional Board has estimated that about 50 percent of the urban runoff from the Sacramento metropolitan area is discharged to the American and Sacramento Rivers and combined sewer system during dry periods (Montoya, 1987). Dry weather flows are known to occur in Fresno, although the volume of Fresno dry weather flow has not been determined (Brown and Caldwell, 1984). As in Sacramento, the Fresno dry weather flows are due primarily to lawn irrigation and washoff practices. It is expected that dry weather flows are significant in the other urban areas of the Central Valley since it is common practice to water lawns several times per week during the hot, dry summer months.

Urban Runoff Quality

Urban runoff quality studies in 28 cities were funded by EPA under the Nationwide Urban Runoff Program (NURP) between 1978 and 1983. The final report on the NURP (EPA, 1983) concluded that heavy metals, especially copper, lead, and zinc are the most prevalent priority pollutants discharged in urban runoff. Arsenic, cadmium, chromium, and nickel are also common constituents. For metals concentrations, the particulate fraction is generally higher than the dissolved fraction. Synthetic organic chemicals (including some pesticides) are periodically detected in urban runoff at much lower concentrations than metals. Oil and grease and polycyclic aromatic hydrocarbons, primarily from vehicle and road use, are common constituents of urban runoff. Urban runoff also typically carries fecal coliform bacteria.

A detailed study was conducted in Fresno as part of the NURP (Brown and Caldwell, 1984). Data were gathered on runoff quality from residential, commercial, and industrial watersheds during 27 storm events between October 1981 and April 1983. Although urban runoff in Fresno is primarily discharged to retention basins rather than to surface water streams, the Fresno urban runoff quality is used in this study to characterize urban runoff quality in the Central Valley. Typical pollutant concentrations in urban runoff from the Fresno NURP study are shown in Table 4-10.

Table 4-10. Concentrations of Typical Urban Runoff Constituents

Constituent	Median concentration	Number of samples
Arsenic, µg/l	1.7	246
Cadmium, µg/l	1.0	133
Chromium, µg/l	11.8	186
Copper, µg/l	18.5	185
Lead, µg/l	143.3	249
Mercury, µg/l	0.14	247
Nickel, µg/l	13.6	247
Zinc, µg/l	142.3	185
Suspended solids, mg/l	389	244
BOD 5, mg/l	12.0	111
Dissolved nitrate as N, mg/l	0.82	109
Total phosphorous, mg/l	0.69	241
Oil and grease, mg/l	2.9	46
Chlordane, µg/l	0.10	65
Diazinon, µg/l	0.29	67
Lindane, µg/l	0.014	67
Malathion, µg/l	0.52	67
Parathion, µg/l	0.09	67
2,4-D, µg/l	0.05	65

Source: Brown and Caldwell. 1984. Fresno Nationwide Urban Runoff Program.

The median values shown in Table 4-10 are for the single-family residential, multiple-family residential, and commercial watersheds sampled. Residential and commercial runoff were found to be similar and thought to be most representative of urban runoff in general. Industrial runoff differs from residential/commercial runoff (dependent on the types of industry involved) and is generally higher in most constituents. Exceptions are pesticides and lead which are generally higher in residential watershed runoff.

A limited amount of data have been collected on the quality of urban runoff discharged to the American and Sacramento rivers from the Sacramento metropolitan area (Montoya, 1987; Sacramento Area Consultants, 1975). The City and County of Sacramento are currently conducting an urban runoff study to characterize industrial and commercial/residential urban runoff and to assess the impacts of runoff on the American River. The past studies and the current study are confirming the findings of the Fresno NURP study and the EPA NURP study.

Urban runoff flows and concentrations of contaminants are variable. Some factors affecting this variability are duration and intensity of a storm event, existing saturation in the watershed, watershed land use, and degree of watershed land development. The "first flush" pattern is one of the few consistent elements in urban runoff. That is, the highest concentration of most constituents occurs during the initial runoff in any one storm event, then decreases. Also, the event mean concentrations (the total constituent mass discharge divided by the total runoff volume) for most constituents is highest for the first few storms of the year, then declines at a fairly uniform rate. Urban runoff discharges are thus, intermittent. The receiving water is subject to a sequence of discrete pulses contaminated by pollutants to varying degrees.

The principal short-term impacts of urban runoff are temporary elevated levels of turbidity and pathogens in receiving waters during and immediately after a storm. This could result in temporary increases in the amount of chlorine used and a reduction in filter run times for water utilities immediately downstream of urban runoff outfalls.

Urban runoff also contributes nutrients to waterways. Nutrients stimulate algal growth which results in greater amounts of organic THM precursors in the water. Although there are limited data available on dry weather runoff, nutrient concentrations are likely to be quite high due to the application of lawn and garden fertilizers.

A potentially more serious long-term impact of urban runoff is the concentration of metals and organics in sediments and aquatic organisms. Sediment containing metals can be resuspended into the water column during dredging operations or during high river flows. Although not of concern to drinking water supplies, there is a public health risk associated with consumption of aquatic organisms that have accumulated metals and organics in their tissues. The lower American River and lower Sacramento River have been classified as impaired waterways in the Proposed 1990 Water Quality Assessment (State Board, 1990) and the Beneficial Use Assessment Report (Central Valley Regional Board, 1988/1989) due to the accumulation of organics in fish tissue. Urban runoff is listed as the likely source of the organics.

Loads of Contaminants

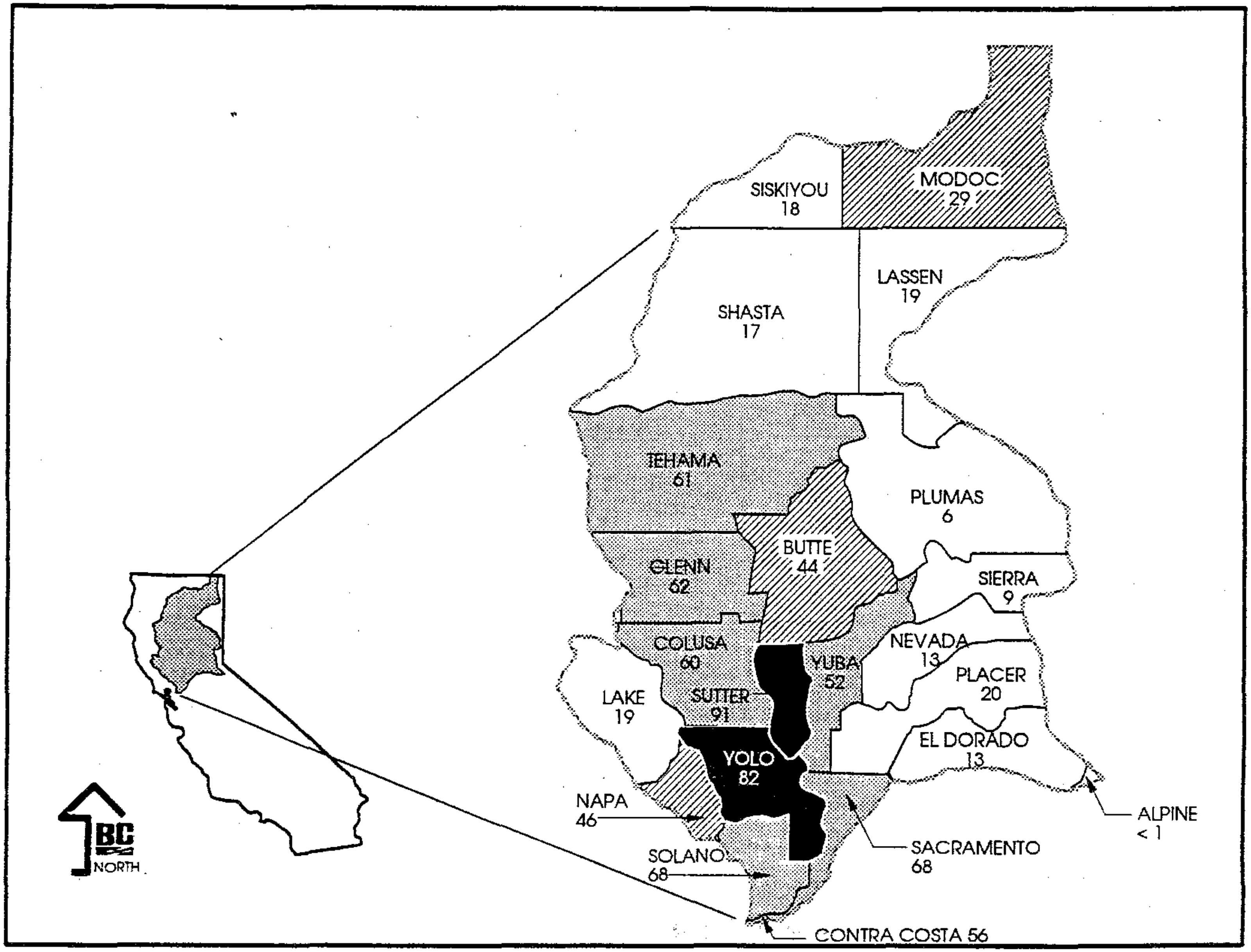
The Central Valley Regional Board mass-loading study found that urban runoff is the major contributor of lead (94 percent) and oil and grease (77 percent) to the Sacramento River (Montoya, 1987). Other metal loads to the Sacramento River from urban runoff were estimated at 8 to 9 percent for copper, cadmium, and zinc, and from 14 to 16 percent for nickel and chromium. These loads are rough estimates based on extrapolating data collected during one wet season (1986-1987) from one storm drain in Sacramento. Similar loading analyses have not been completed for the San Joaquin and Tulare Basins. The urban runoff studies conducted in Fresno and Sacramento and the EPA NURP studies show that the greatest pollutant loads occur during the first few storms in the fall. River flows are typically lowest during these months resulting in the greatest potential for water quality degradation.

AGRICULTURAL DRAINAGE

Irrigated agriculture, the primary land use in the Sacramento, San Joaquin, and Tulare Basins, is centered primarily in the Central Valley portion of each basin along the lower stretches of rivers. Most agricultural drains in the Tulare Basin discharge to evaporation ponds around Tulare Lake which are not hydrologically connected to any SWP water source. The Tulare Basin, therefore, is not discussed further in this section. As irrigated agriculture is also the primary land use in the Delta, agricultural drainage in the Delta is discussed in this section. Figures 4-11 and 4-12 show the percent agricultural area in Sacramento and San Joaquin Basin counties.

Figures 4-13 and 4-14 show the average annual tonnage of commercial fertilizer per acre sold in Sacramento and San Joaquin Basin counties. The tonnage figures are reported sales figures and are probably low. The constituents of concern in fertilizer are primarily nitrogen (as nitrate) and phosphate. The percent of applied fertilizer lost to excess irrigation water discharged to streams is not known. It is estimated, however, that 35 percent of the applied nitrogen either runs off to surface water or is leached to groundwater (Hanson, et al., 1989).

Figures 4-15 and 4-16 show the annual average poundage per acre of applied restricted pesticides in Sacramento and San Joaquin Basin counties. The poundage figures include only a portion of nonrestricted pesticide application and are, therefore, low in terms of total pesticides applied. The reported application of restricted pesticides includes usage by structural pest control operators. The percent of restricted pesticides used in agriculture, although unknown, could be high. It is estimated that total use of pesticides (both agricultural and urban use) may be three times the reported use (Hanson, et al., 1989). The percent discharged to streams in excess irrigation water is also unknown. Agricultural pesticides, such as organophosphates have a short half life and may have degraded or been carried in dissolved form. Pesticides, such as chlorinated hydrocarbons, may adsorb onto particulate matter in agricultural drainage and settle in the river bottom with much of the sediment load.



Legend:

- < 25 %
- 25-50 %
- 50-75 %
- >75 %

Figure 4-11.
Agricultural Area by County, Sacramento Basin

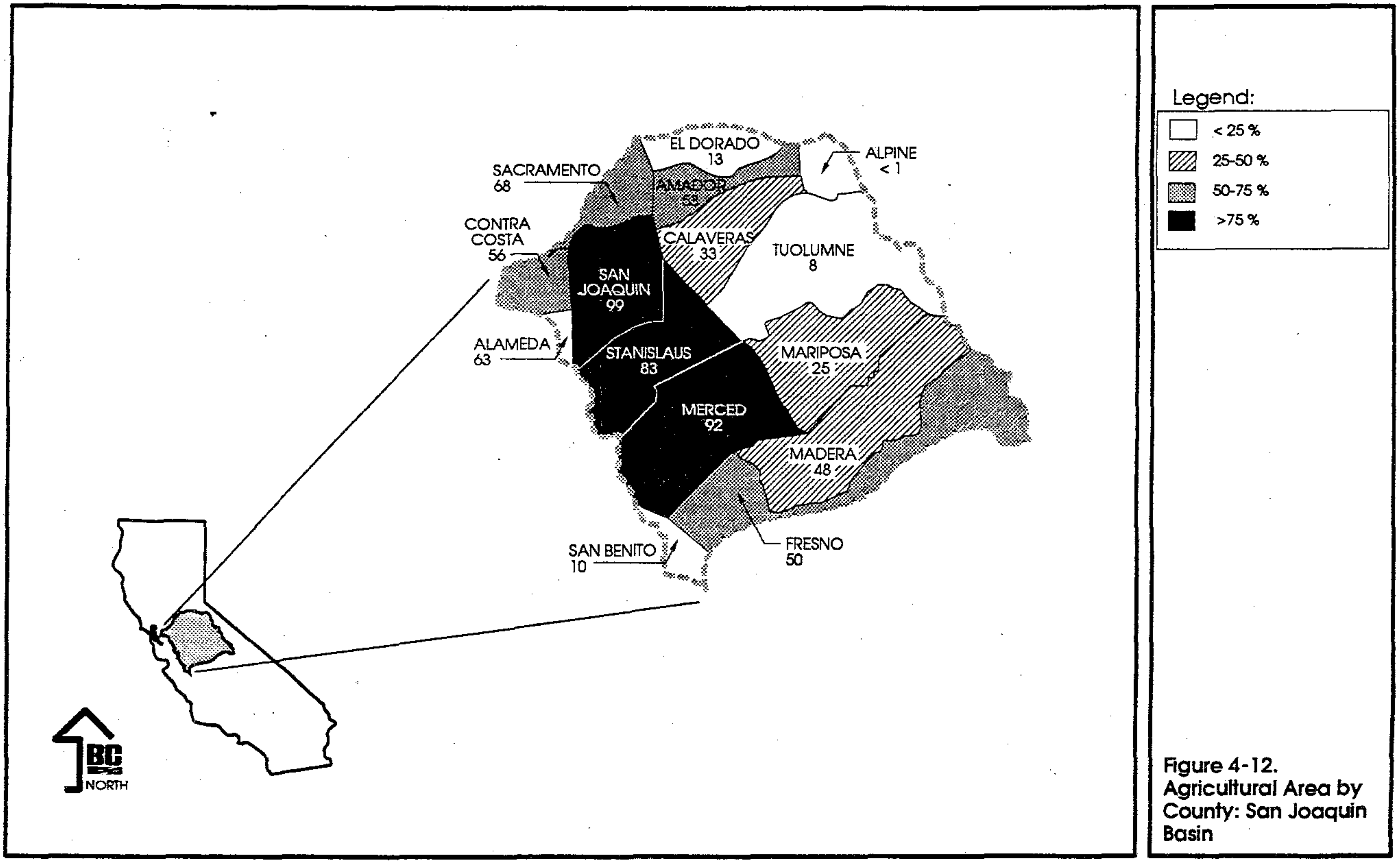
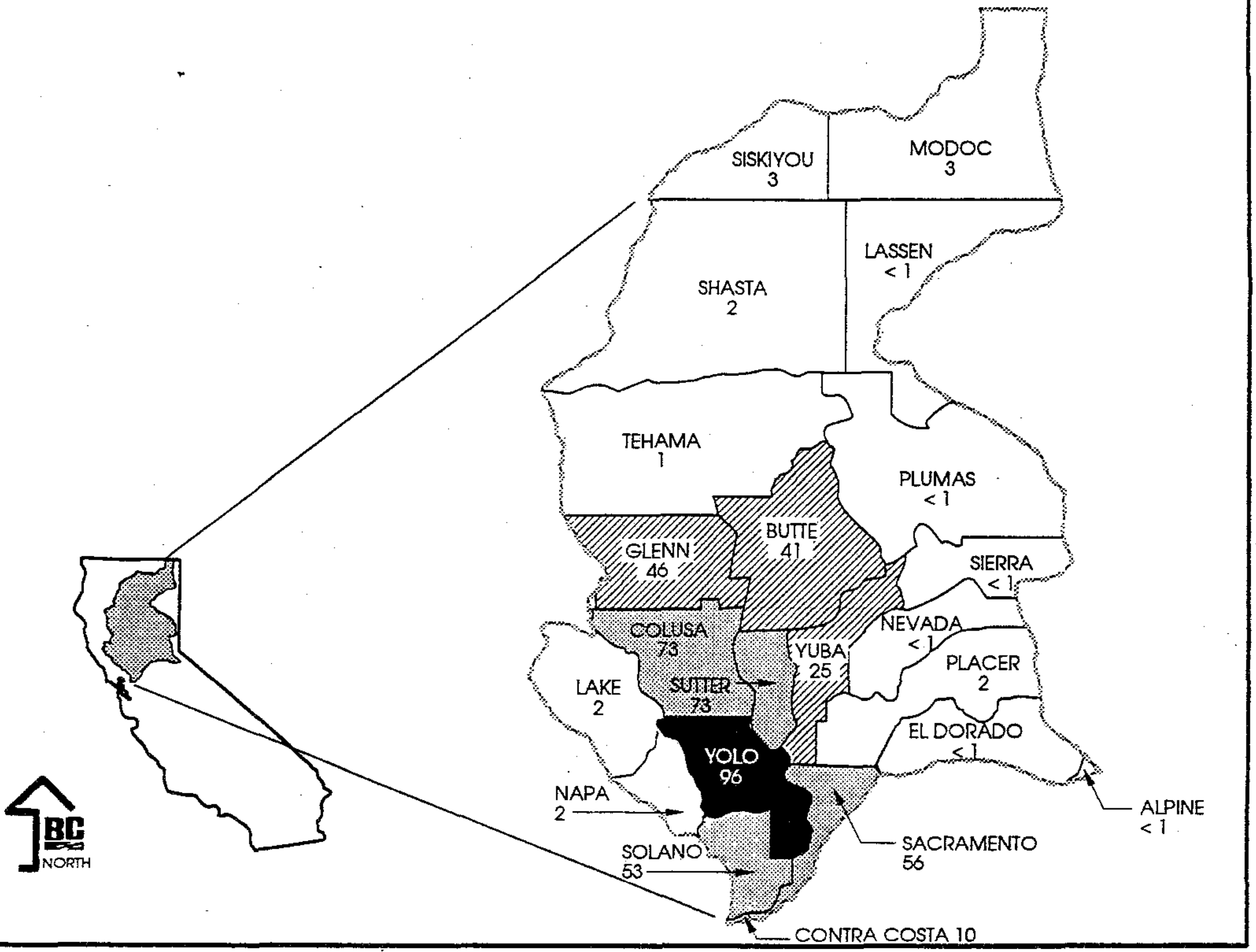


Figure 4-12. Agricultural Area by County: San Joaquin Basin

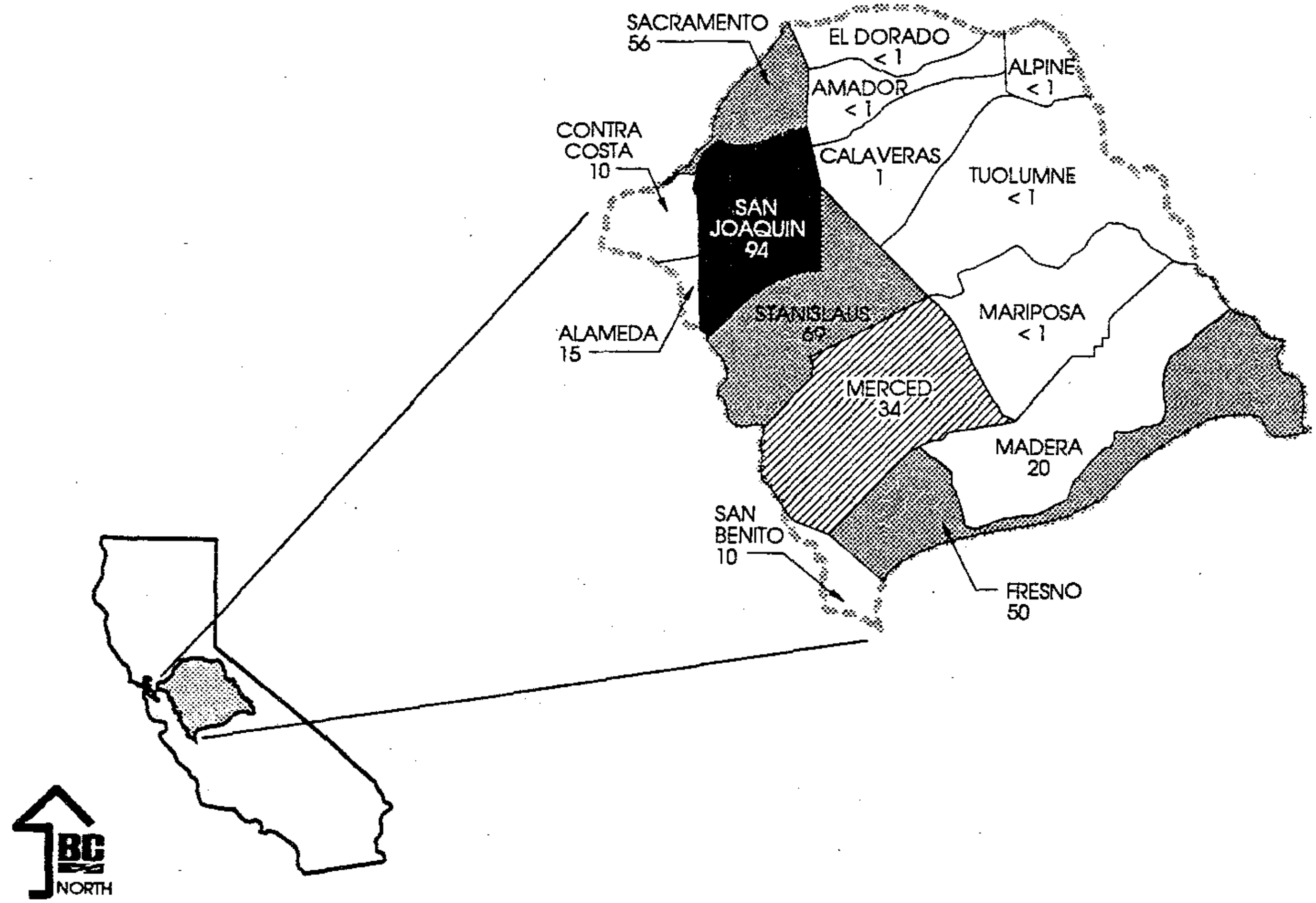


Legend:

- < 25 tons/sq mi
- 25-50 tons/sq mi
- 50-75 tons/sq mi
- >75 tons/sq mi

Note: Average annual sales for 1984 through 1988

Figure 4-13. Fertilizer Use in Sacramento Basin



Legend:

☐	< 25 tons/sq mi
▨	25-50 tons/sq mi
▒	50-75 tons/sq mi
■	>75 tons/sq mi

Note: Average annual sales for 1984 through 1988

Figure 4-14. Fertilizer Use in San Joaquin Basin

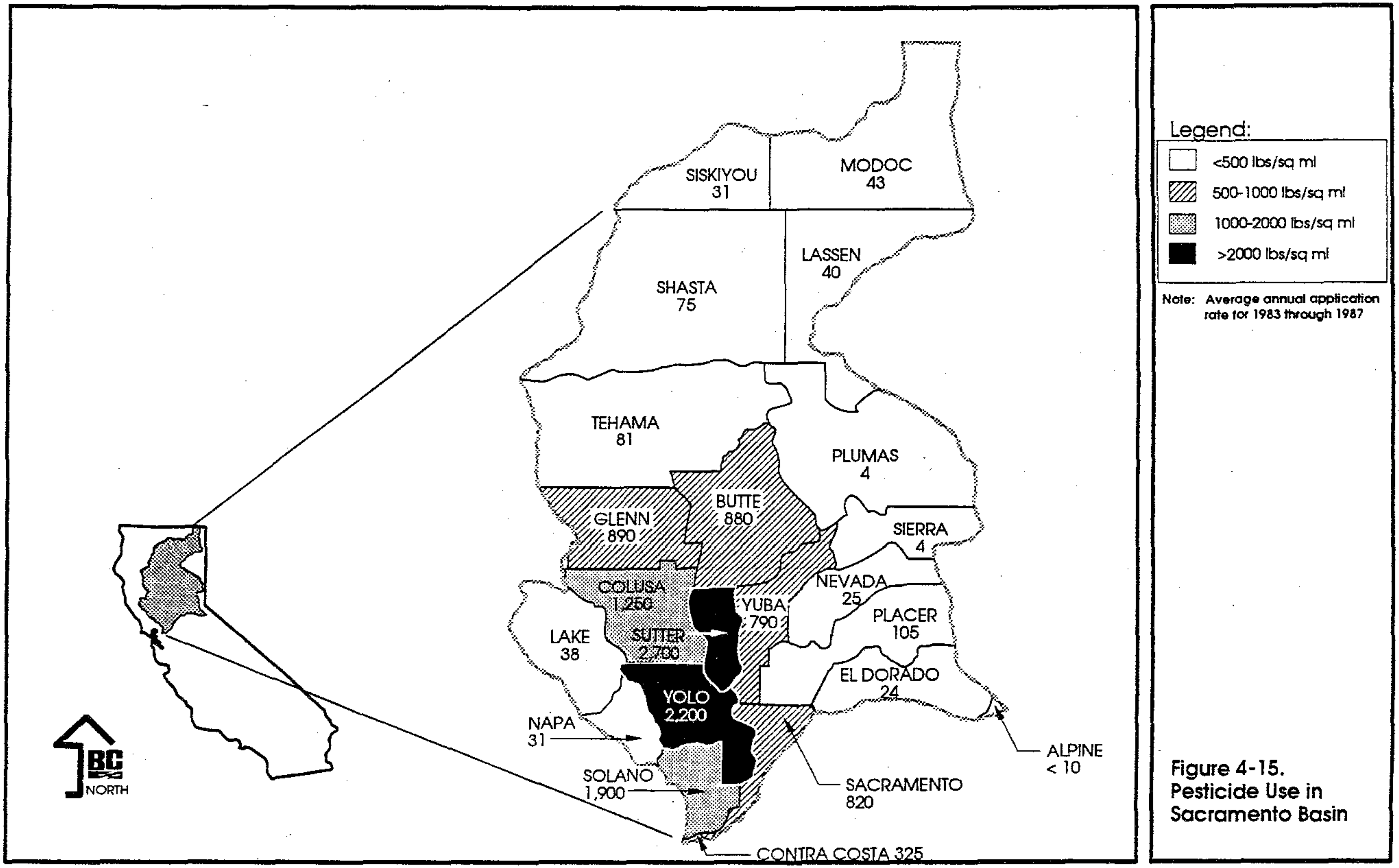


Figure 4-15. Pesticide Use in Sacramento Basin

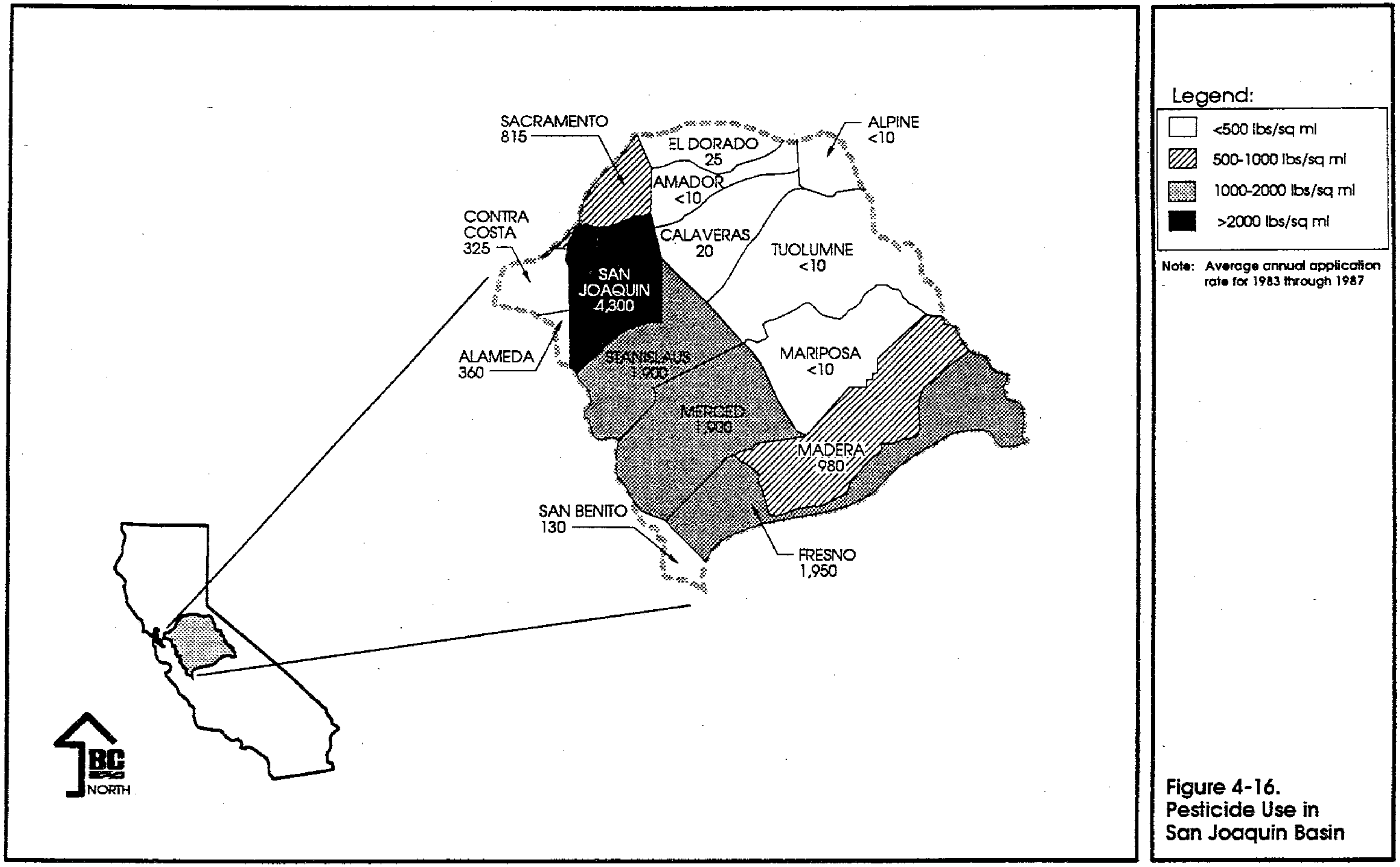


Figure 4-16. Pesticide Use in San Joaquin Basin

The volume and quality of agricultural drainage are largely dependent on the season and on crop-specific practices for application of fertilizer, pesticides, and irrigation water. Such crop-specific practices are responsible for seasonal episodic occurrences of agricultural chemicals in agricultural drains. Rainfall-related agricultural area runoff occurs from about October to April.

Sacramento Basin

Rice is the largest single crop grown, accounting for almost 40 percent of Sacramento Valley agricultural acreage. Orchards, field crops, and some truck crops and grapes are also grown. Because rice cultivation dominates Sacramento Valley agriculture and requires large quantities of water, rice irrigation water contributes most of the surface runoff in Sacramento Valley agricultural drains. The major rice cultivation area extends from about Chico, south, to below Sacramento. When rice fields are flooded in early spring in preparation for planting, pesticides are applied to control algae and tadpole shrimp. After the rice is seeded, herbicides containing molinate (ordram) and thiobencarb (bolero) are applied for weed control. In late summer and early fall the fields are drained in preparation for harvest.

Drainage System. Most irrigation water in the Sacramento Valley is either pumped directly onto fields from adjacent streams or is imported via canals. Groundwater is also a source of irrigation water in the Sacramento Valley. Excess irrigation water, as surface runoff, is discharged from the fields either directly to streams, or to major agricultural drains and sloughs which eventually discharge to streams.

There are 17 major agricultural drain discharge locations in the Sacramento Valley, as shown on Figure 4-17. These drains discharge to the Feather River (which flows into the Sacramento River at Knight's Landing) to Cache Slough (which flows into the Sacramento River in the North Delta) or directly to the Sacramento River. About 80 percent of the surface runoff volume is contributed by five of these drains: Colusa Basin Drain, Sacramento Slough, Reclamation District (RD) 1000, RD 108, and Toe Drain (Montoya, et al., 1988). Colusa Basin Drain and Sacramento Slough contribute about 70 percent of surface runoff in the May-June rice season. Colusa Basin Drain carries most of the surface runoff from agricultural acreage above Knight's Landing, west of the Sacramento River, and Sacramento Slough carries a good portion of the surface runoff from agricultural acreage above Knight's Landing, east of the Sacramento River. Colusa Basin Drain flows normally discharge to the Sacramento River but during periods of extremely high river flow may be diverted into Cache Slough via the Yolo Bypass. A few of the major agricultural drains (Natomas East Main Drain, RD 1000, and Sacramento Sump 90) carry a mixture of agricultural surface runoff, urban runoff, and NPDES discharges.

River Dilution. The total average annual outflow from five major drains (Colusa Basin Drain, Sacramento Slough, RD 108, RD1000, and Toe Drain) in 1985 ranged from 46,000 AF to 270,000 AF (Montoya, et al., 1988). Flow data for these drains were taken from the California Department of Water Resources (DWR) and Reclamation District gaging stations. Agricultural drainage ranged from 4 to 28 percent of the Sacramento River flow at Freeport in 1985 (Montoya, et al., 1988). The percent of agricultural drainage in the Sacramento River is typically lowest from January to April and then increases continuously until dewatering of the rice fields is complete in about September. The continuous use and reuse of the rivers to irrigate and drain agricultural fields makes it difficult to estimate the volume contribution of agricultural drainage to Sacramento River, San Joaquin River, or to Delta channel flow.

Drainage Quality. Surface runoff is usually high in dissolved and suspended solids and organic matter, and may carry from the surface of the field, pesticides (herbicides and insecticides), and fertilizer constituents (such as nitrate and phosphate) either in dissolved form or adsorbed onto sediments. Figure 4-18 shows the concentrations of molinate and thiobencarb in the Sacramento River at Sacramento during the 1987 and 1988 rice seasons. The seasonal slug of rice herbicides passes through the river system in about a month between mid-May and mid-June. Figure 4-19 shows molinate and thiobencarb concentrations in the Sacramento River at the City of Sacramento's water intake over a 7-year period from 1982 to 1988. The concentrations shown on these figures do not exceed the California maximum contaminant levels of 20 µg/l for molinate and 5 µg/l for thiobencarb. The Department of Food and Agriculture began molinate control programs in 1984 and thiobencarb control programs in 1985. Thiobencarb concentrations in the Sacramento River have been declining since 1985. Molinate concentrations have been declining since 1986. The highest concentrations of molinate occur in Colusa Basin Drain (67 µg/l) and Sacramento Slough (30 µg/l). In 1988, over 5,500 pounds of molinate and 104 pounds of thiobencarb were transported in the Sacramento River past Sacramento.

In 1985 the Regional Board sampled six major Sacramento Valley agricultural drains for metals and oil and grease. Oil and grease were rarely detected in agricultural drainage. The five metals listed in Table 4-11 were commonly detected in agricultural surface runoff in samples collected from 1985 to 1987. The Regional Board loading estimates did not take into account the metals load in the applied irrigation water, which may be considerable. An estimated 74 percent of the chromium load, 75 percent of the nickel load, and 5 to 17 percent of the zinc, cadmium, and copper loads in the Sacramento River were contributed by agricultural drains in 1985. Colusa Basin Drain and Sacramento Slough accounted for over 90 percent of the metals loads of the five major drains included in the study. Copper concentrations were found to be higher in the rice season than at any other time of year. This may be due to the use of copper based algicides in the rice fields before planting.

The Department of Food and Agriculture tested for pesticides other than molinate and thiobencarb in Colusa Basin Drain and Sacramento Slough during the rice season. Bentazon was detected in both drains, with a peak concentration of 5.5 µg/l in Colusa Basin Drain. Carbofuran was detected in both drains, with a peak concentration of 4.4 µg/l in Colusa Basin Drain. Propanil and carbaryl were not detected in either drain (Department of Food and Agriculture, 1989).

The Regional Board has established that Colusa Basin Drain can be acutely toxic to aquatic organisms during the rice season. Little toxicity has been observed at other times of the year (Foe, 1988). Pesticides applied before the major application of herbicides are thought to be responsible for the rice season toxicity. In 1987 toxic levels of methyl parathion and carbofuran

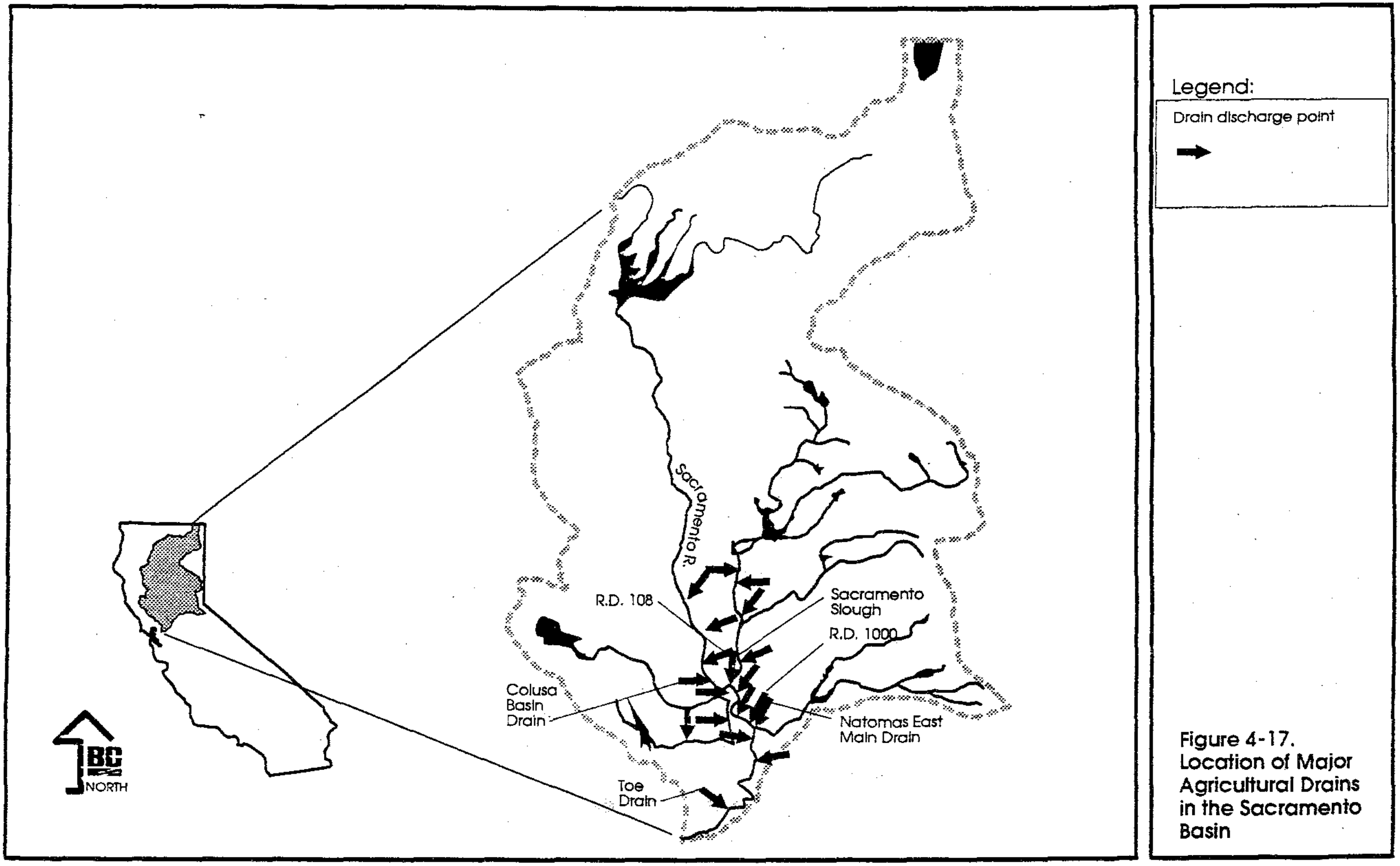
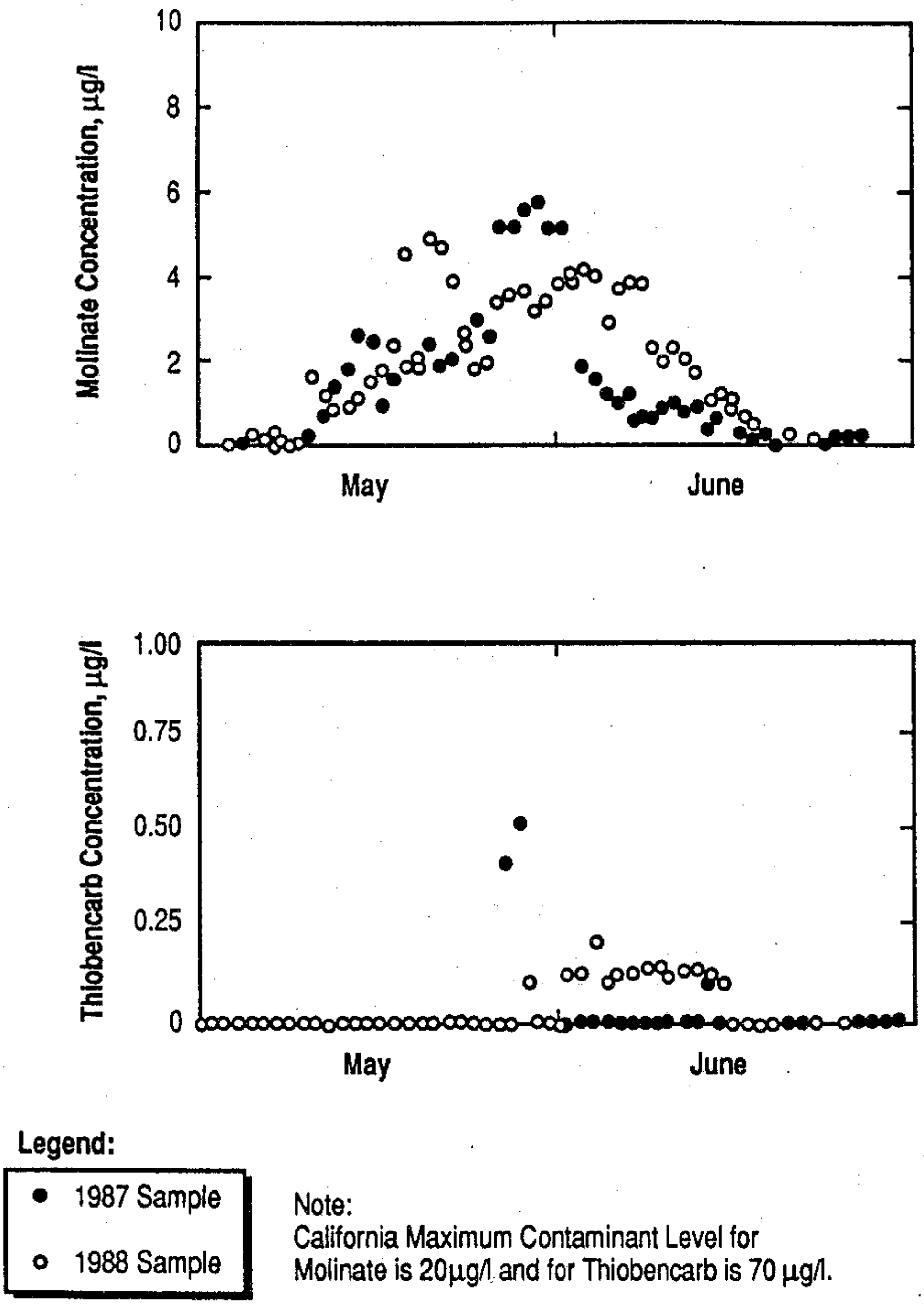


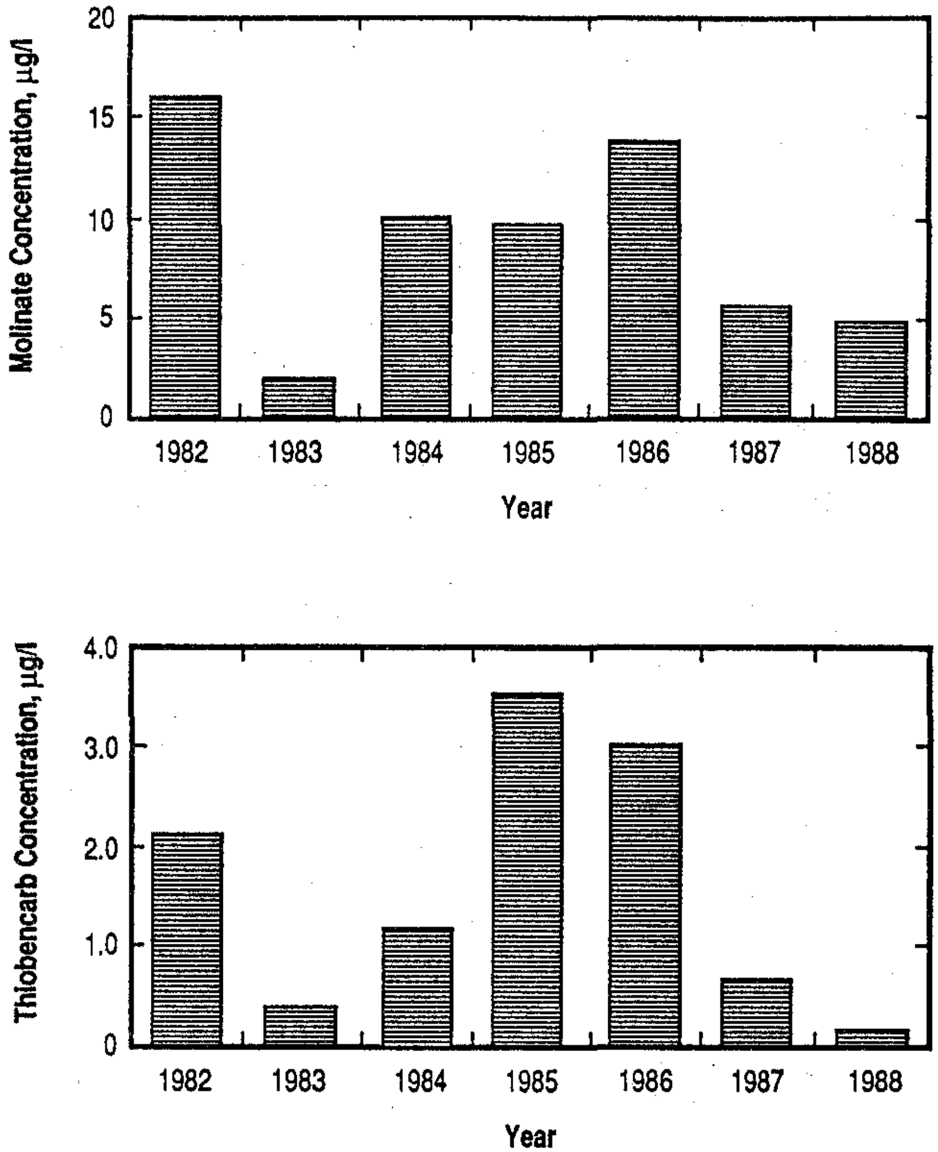
**Figure 4-17.
Location of Major Agricultural Drains in the Sacramento Basin**



Note:
California Maximum Contaminant Level for Molinate is 20µg/l and for Thiobencarb is 70 µg/l.

Figure 4-18. Concentrations of Molinate and Thiobencarb at the City of Sacramento Water Treatment Plant Sacramento River Intake

Source: State of California, Department of Food and Agriculture, 1989 Program to Prevent Off-Site Movement of Pesticides from California Rice Fields.



Note:
California Maximum Contaminant Level for
Molinate is 20µg/l and for Thiobencarb is 70 µg/l.

Figure 4-19. Peak Concentrations of Molinate and Thiobencarb at the City of Sacramento Water Treatment Plant Sacramento River Intake, 1982-1988

Source: State of California Department of Food and Agriculture 1989 Program to Prevent Off-Site Movement of Pesticides from California Rice Fields.

were identified in Colusa Basin Drain rice season drainage. In 1988, carbofuran, methyl parathion, and malathion were identified at toxic levels. Department of Food and Agriculture fish tissue studies show that molinate and thiobencarb accumulate in fish tissue during exposure in the rice season but are purged once the exposure subsides.

Table 4-11. Metals Concentrations in Sacramento Valley Agricultural Drains

Drain	Concentration, µg/l				
	Cadmium	Chromium	Copper	Nickel	Zinc
RD108	0.2 (200)[a]	4.7 (51)	7.6 (32)	8.7 (47)	14 (48)
Colusa Basin Drain	0.1 (300)	12 (64)	9.6 (36)	8.6 (62)	25 (112)
Sacramento Slough	0.1 (100)	8.6 (45)	8.6 (59)	7.9 (72)	21 (86)
RD1000	0.1 (100)	3.1 (58)	8.7 (126)	3.1 (100)	26 (158)
Natomas East Main Drain	0.2 (100)	6.5 (37)	7.6 (33)	4.5 (100)	34 (76)
Toe Drain	0.1 (100)	12 (34)	11 (20)	22 (30)	21 (19)

[a]Number of samples in parentheses.

Source: Montoya et. al., 1988, A Mass Loading Assessment of Major Plant and Nonpoint Sources Discharging to Surface Waters in the Central Valley, California, 1985

Management practices being investigated and implemented by the Regional Board and the Department of Food and Agriculture to control rice season agricultural drainage include reduced use of chemicals, regrading rice fields to more efficiently use less water, increased holding time of treated irrigation water before discharging to allow some chemicals to dissipate, and conservation through recycling of irrigation water. Management practices that have already been implemented, combined with the implementation of those currently being investigated, will result in further reductions in rice herbicides in the Sacramento River.

San Joaquin Basin

The San Joaquin Basin supports a wide variety of crops: vineyards, orchards, field crops, truck crops, and some rice cultivation. Unlike the Sacramento Valley, no single crop dominates agricultural use in the San Joaquin Basin.

Drainage System. Groundwater and surface water from east side streams are the sources of most irrigation water on the east side of the San Joaquin River. The west side is primarily irrigated by surface water imported via the California Aqueduct and the Delta Mendota Canal. Agricultural drainage in the San Joaquin Basin consists of both surface runoff and subsurface discharges. Surface runoff is discharged directly to the San Joaquin River or its tributary streams and sloughs. Surface runoff occurs throughout the San Joaquin Basin irrigation season (about April to October), and carries with it dissolved and suspended solids and organic matter, pesticides, and fertilizer constituents.

Subsurface discharges consist of irrigation water (and rain water) collected by a network of shallow drains designed to intercept and transport near surface percolating water. This type of agricultural drainage system is common in the San Joaquin Basin west of the San Joaquin River where near surface clays have restricted groundwater percolation and caused high water table conditions. The availability of imported surface water in the west side of the San Joaquin Basin has enabled agricultural development of an arid area where groundwater quality is unsuitable for agricultural use. Crop irrigation in the west San Joaquin Basin contributes water to the subsurface that must be drained to prevent the water table from rising into a crop's root zone. The principal constituents of concern in subsurface discharges are dissolved solids, selenium, boron, and molybdenum. The irrigation water picks up these constituents as it percolates through the west San Joaquin Basin soils, which are naturally high in salts and trace elements. The most sensitive beneficial uses to these constituents are aquatic life and wildlife. Trace elements, especially selenium, in subsurface discharges, were responsible for the waterfowl deaths and deformities at Kesterson Reservoir. Prior to 1984, a portion of the west side subsurface discharge water (from Westlands Water District) was drained to the Kesterson wetlands. The remainder of the west side drainage water, which includes both surface runoff and subsurface discharge water, has historically discharged to the Grasslands Water District and the San Joaquin River. Since recognition of the threat to wildlife from water high in selenium, minimal west side agricultural drainage has been used in Grasslands Water District and other wetlands. Now that Kesterson is closed as a subsurface discharge destination and the use of west side agricultural drainage in other wetlands is greatly reduced, virtually all agricultural subsurface discharge water is drained from the San Joaquin Basin by the San Joaquin River.

Mud and Salt Slough drain the southwest San Joaquin Basin of its subsurface discharge and surface runoff. West side agricultural drainage north of Mud Slough is carried to the San Joaquin River by a network of lesser sloughs and drains. Over 77,000 acres on the west side of the San Joaquin River, of which 48,000 are upstream of Merced, are drained by subsurface discharge. Surface runoff is discharged directly into the lower reaches of east side streams and into the San Joaquin River from both the east and west. The number and general location of agricultural drains along sections of the San Joaquin River and its east side tributaries are shown on Figure 4-20. The locations of these drains were surveyed by the Central Valley Regional Board as part of their continuing investigation of San Joaquin Valley agricultural drainage. The northern most east side tributaries (the Cosumnes, Mokelumne, and Calaveras Rivers) have not yet been surveyed for agricultural drain locations. Agricultural surface runoff makes a contribution to flow in these rivers in their lower reaches.

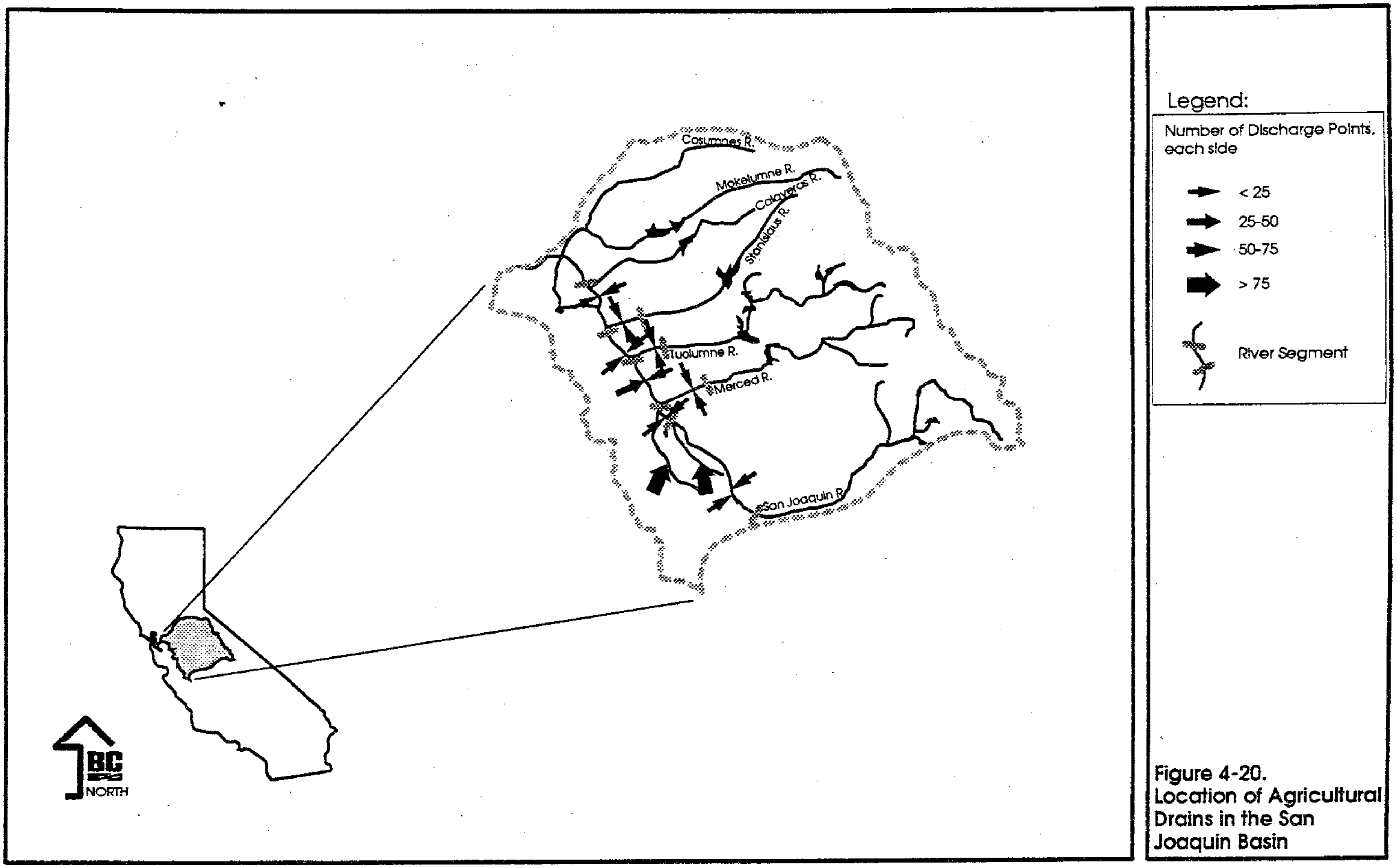


Figure 4-20. Location of Agricultural Drains in the San Joaquin Basin

River Dilution. Agricultural surface runoff may make up 90 percent of the San Joaquin River flow at Vernalis during primary irrigation season, about April to October (Crooks and Westcot, 1989). Highest flows in the San Joaquin River occur in May when irrigation is heavy and dam releases are high. San Joaquin River flows are at their lowest in fall and early winter when little irrigation and low dam releases coincide. At this time agricultural drainage from west side drains including Mud and Salt Slough, which contain subsurface discharge all year, may make up 10 to 15 percent of San Joaquin River flow at Vernalis (Crooks and Westcot, 1989).

Drainage Quality. Figures 4-21, 4-22, and 4-23, respectively, show the 5-year (1984-1988) mean concentrations of total dissolved solids (TDS), selenium, and nitrate in the San Joaquin River between Mendota Pool and Vernalis. The concentrations of these constituents in the major San Joaquin River tributaries (Mud and Salt Slough and the Merced, Mokelumne, and Stanislaus Rivers) are also shown. TDS concentrations (Figure 4-21) in Mud and Salt Sloughs are very high (1,768 and 1,247 mg/l). The San Joaquin River has the highest dissolved solids concentrations after receiving Mud and Salt Slough drainage. The dissolved solids concentrations in the east side tributaries are much lower. Flow from these rivers dilutes the salinity of the west side subsurface discharges so that the average dissolved solids concentration in the San Joaquin River at Vernalis is 390 mg/l.

Selenium concentrations (Figure 4-22) are also highest in subsurface discharge and the effect of west side subsurface discharges, including Mud and Salt Slough, can be seen in the high selenium concentrations (about 25 μg/l) in the San Joaquin River from Salt Slough to the Merced River. The Merced river dilutes the selenium concentrations in the San Joaquin River to about 4 μg/l. The San Joaquin River concentration decreases with the inflow from the Tuolumne and Stanislaus Rivers to an average of less than 1 μg/l at Vernalis.

Mud and Salt Slough also contribute a significant amount of nitrate (Figure 4-23) to the San Joaquin River. Phosphate concentrations averaged 0.3 mg/l along the entire reach of the San Joaquin River from Mendota Pool to Vernalis.

The Regional Board collected subsurface discharge samples from over 300 sample sites in the April to June 1986 irrigation season. A summary of TDS and trace element concentrations in subsurface discharge are shown in Table 4-12. The Regional Board also monitored primarily surface runoff drains discharging into the east side of the San Joaquin River from Mendota Pool to the Stanislaus River. Irrigation and nonirrigation season samples were collected from 1986 through 1988. A summary of TDS and trace element concentrations in surface runoff are also shown in Table 4-12.

Flow and salt load inputs to the San Joaquin River at Vernalis were calculated for water years 1981, 1984, and 1985 (State Board, 1987). Mud and Salt Slough accounted for 5 to 12 percent of the flow and 34 to 46 percent of the salt. East side tributaries accounted for 69 to 85 percent of the flow and 14 to 32 percent of the salt. Over 80 percent of the selenium load in the San Joaquin River at Vernalis was attributed to Mud and Salt Slough. Agricultural drainage is

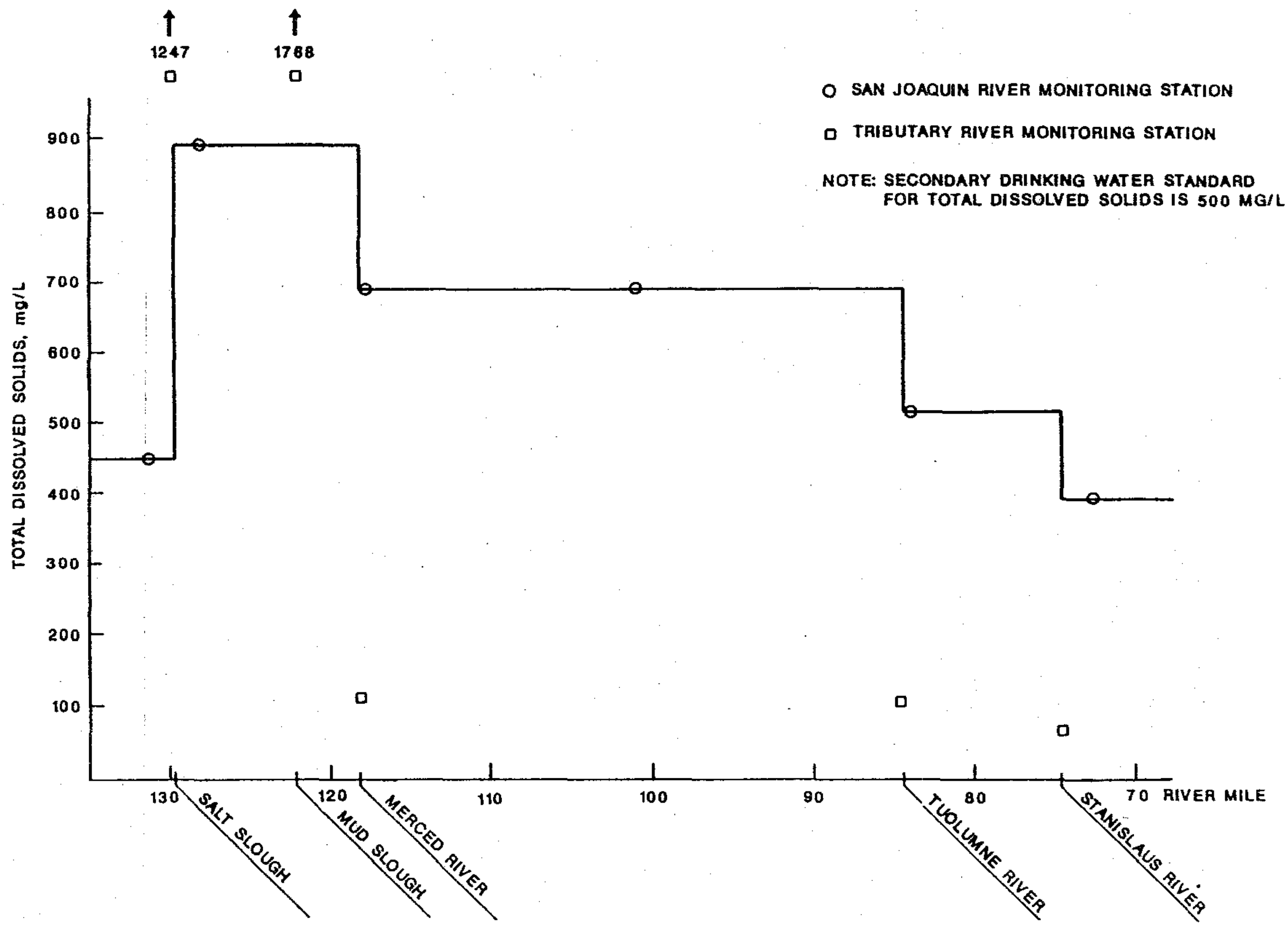


Figure 4–21. Mean Total Dissolved Solids Concentrations in the San Joaquin River, January 1984 to December 1988

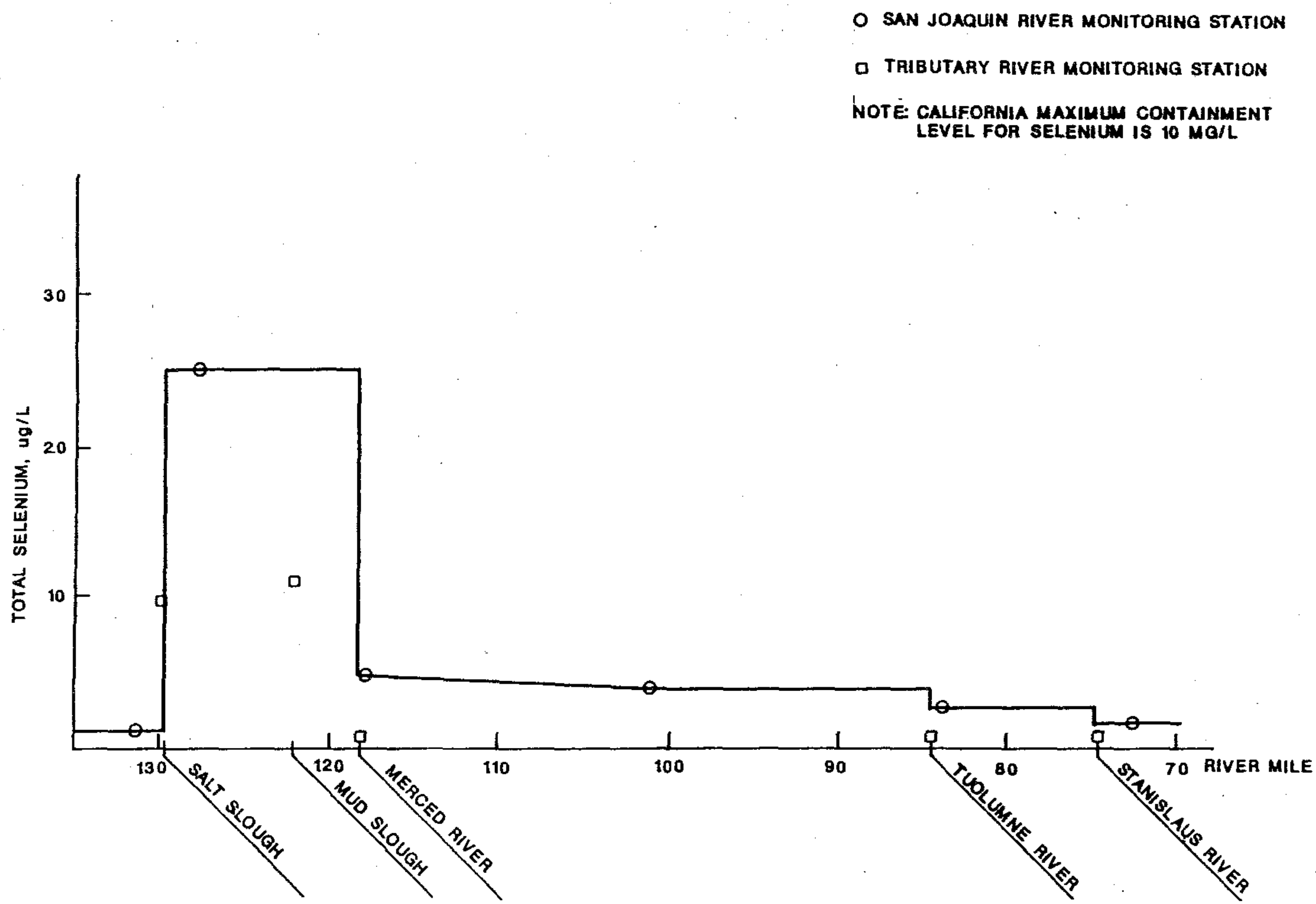


Figure 4–22. Mean Selenium Concentrations in the San Joaquin River, January 1984 to December 1988

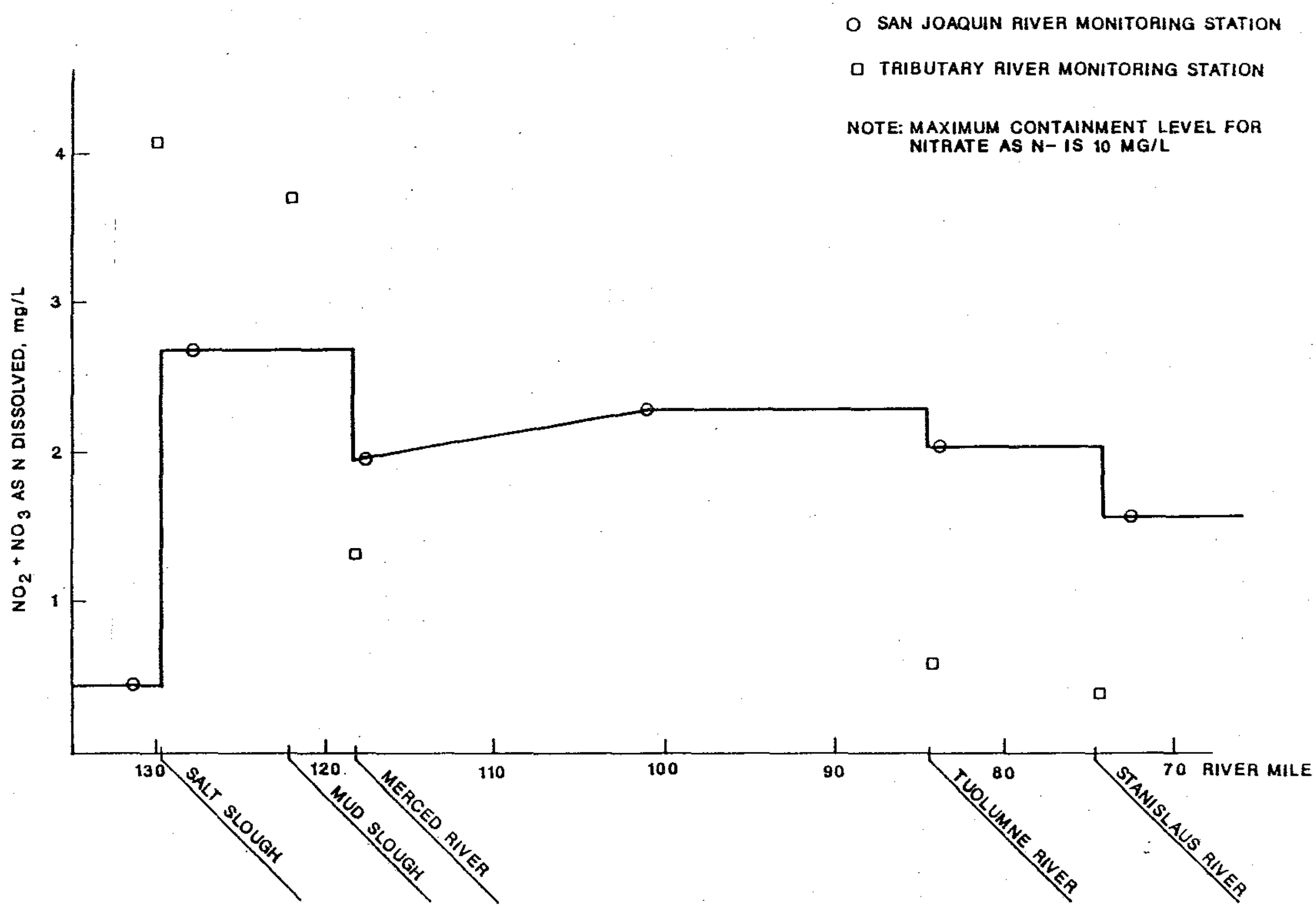


Figure 4–23. Mean Dissolved Nitrate Concentrations in the San Joaquin River, January 1984 to December 1988

Table 4-12. Total Dissolved Solids and Trace Elements in Agricultural Drainage

Constituent	Subsurface drainage[a]		Surface drainage[b]	
	Median	Range	Median	Range
TDS, mg/l	3,400	400 to 22,800	117	32 to 250
Boron, mg/l	5.6	<0.05 to 61		
Arsenic, µg/l	2	<1 to 63		
Cadmium, µg/l	<5	<5 to 57		
Chromium, µg/l	10	<1 to 268	3.7	<1 to 140
Copper, µg/l	<5	<1 to 180	5	2 to 16
Lead, µg/l	<5	<2 to 42	<5	<5 to 6
Manganese, µg/l	10	<5 to 4,660		
Mercury, µg/l	<0.2	<0.2 to 4		
Molybdenum, µg/l	17	<5 to 724		
Nickel, µg/l	<5	<1 to 230	<5	<5 to 51
Selenium, µg/l	47	<1 to 2,812	0.6	<0.2 to 2.7
Silver, µg/l	<5	<5 to 4		
Zinc, µg/l	1	<1 to 1,280	<0.5	<0.5 to 3.2

[a]Source: Central Valley Regional Board. 1988. Water Quality Survey of Tile Drainage Discharges in the San Joaquin River Basin.

[b]Source: Central Valley Regional Board. 1988. Quality of Agricultural Drainage Discharges to the San Joaquin River from Area East of the River in Stanislaus, Merced and Madera Counties, California, January 1986 to September 1988.

considered responsible for 84 percent of the total salt load to the San Joaquin River. (State Board, 1987).

Although pesticides are not routinely detected in San Joaquin River water samples, toxicity events are common in the San Joaquin River. The toxicity events in the San Joaquin River may be attributable to a variety or combination of causes other than pesticides, such as dissolved oxygen content, temperature, and turbidity. Toxicity testing by the Regional Board has also shown acute aquatic toxicity events in San Joaquin Basin agricultural drains and sloughs. Pesticides detected in the drainage were eptam, carbaryl, and diazinon (Foe, 1989). The Regional Board has found the occurrence of pesticides in agricultural drains is erratic and has indicated that slugs of pesticides from recently treated fields and illegal dumping (New Jerusalem Drain) move through the river system.

The State Board Toxic Substances Monitoring Program has documented the accumulation of dichlorophenyl trichloroethane, toxaphene, dieldrin and other pesticides in fish tissue samples from the San Joaquin River. The major source of the organochlorines is thought to be eroded agricultural sediment. Regional Board sampling has shown suspended sediment concentrations exceeding 5,000 mg/l in drains west of the San Joaquin River.

Agricultural management practices to control agricultural drainage in the San Joaquin Basin are being investigated by the Regional Board. They include water conservation methods such as less, more efficient use and recycling of water, sediment control, taking some land out of production, and changing crops grown in some areas. The implementation of agricultural drainage management in the San Joaquin Basin is complicated by the agricultural diversity of the basin.

The Delta

The Delta islands support a variety of crops, primarily truck and field crops in addition to some orchards and livestock production.

Drainage System. Irrigation water is siphoned from the Delta channels over levees into ditches. The subsurface drainage collects in open ditches and is pumped back into the Delta channels. There are approximately 260 individual drains in the Delta, as shown on Figure 4-24. The locations of these drains were surveyed as part of the Interagency Delta Health Aspects Monitoring Program (IDHAMP).

Drainage Volume. The DWR conservatively estimates that annual Delta agricultural drainage is over 400,000 AF. Although drainage patterns and volumes differ from island to island in the Delta, overall there are two peak drainage periods; June to July when fields are being irrigated and November to January when fields are being flooded and then drained to leach salts from the soil.

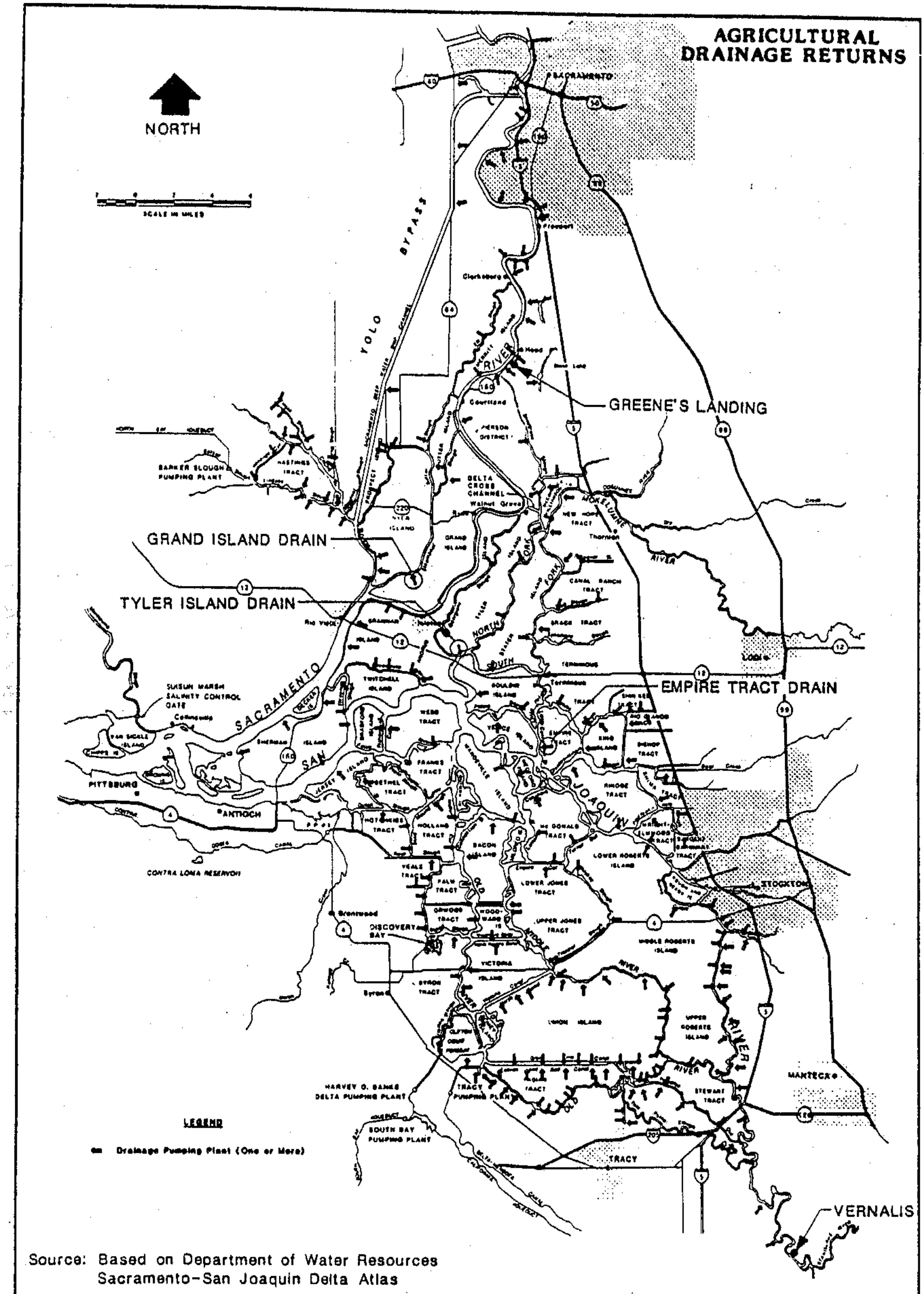


Figure 4-24. Locations of Agricultural Drains in the Delta

During summers of critical water years, the volume of Delta drainage is significant (7 to 10 percent) when compared to total river inflow from the Sacramento and San Joaquin Rivers. During the summer of a critical water year under certain tidal and flow conditions, the volume of Delta agricultural drainage may be up to 20 percent of the water exported at the south Delta pumps for short periods of time.

Drainage Quality. DWR initiated the IDHAMP in 1983 to monitor the quality of Delta water supplies. Water quality information is collected at about 15 Delta channel locations and three agricultural drains on Empire Tract, Tyler Island, and Grand Island. The IDHAMP data demonstrate that water pumped out of the Delta at the export pumps has higher trihalomethane formation potential (THMFP) concentrations than water flowing into the Delta from the Sacramento River. Agricultural drainage was shown to be a significant source of the organic matter contributing to the higher THMFP concentrations at the export pumps. DWR is conducting the Delta Islands Drainage Investigation (DIDI) to determine the effects of agricultural drainage on Delta water quality. The data presented in this section were obtained from these two DWR monitoring programs.

Data collected by DWR indicate that agricultural drains discharging into Delta waters are the major source of the organic precursors that contribute to THM formation upon chlorination of Delta water supplies. DWR estimated that in 1988, agricultural drainage discharged to Delta channels increased the amount of carbon available for THM production by an average of 67 percent. THMFP data in agricultural drainage from Empire Tract, Tyler Island, and Grand Island are available from 1985 through 1988. The median THMFP concentrations in these Delta drains are 1,200 µg/l (Grand Island), 2,100 µg/l (Tyler Island), and 3,100 µg/l (Empire Tract). In contrast, the median THMFP concentrations in the Delta waterways range from 250 µg/l in the Sacramento River at Greene's Landing to 500 µg/l at the Banks Pumping Plant and 870 µg/l at the headworks of the North Bay Aqueduct. The THMs formed in the THMFP tests of the drainage consists of both chlorinated and brominated methanes. The principle source of bromide is sea water intrusion which occurs during periods of low freshwater outflow. Sea water intrusion is discussed in detail later in this chapter.

The DIDI study has shown that drainage from the central Delta islands that contain rich organic peat soils has higher THMFP concentrations (greater than 2,000 µg/l) than drainage from the peripheral mineral soil islands (less than 1,000 µg/l). THMFP concentrations are highest in winter months when Delta islands are flooded to remove salts that have accumulated during the irrigation season. Flows in Delta channels are typically higher at this time of year.

The median TDS concentrations in agricultural drainage are 232 mg/l on Grand Island, 339 mg/l on Tyler Island, and 779 mg/l on Empire Tract. The TDS contribution from Delta agriculture is difficult to assess as TDS concentrations in Delta irrigation water are already high before its application. As with THMFP, TDS concentrations in Delta island drainage are highest in winter months during island flooding.

In July 1988, 30 Delta agricultural drain samples were analyzed for 26 target pesticides. Target pesticides were water soluble pesticides in use in the Delta at the time of sampling. Six of the 26 pesticides were found above the analytical detection limit in one or more of the drain water samples. These were atrazine, bentazon, carbaryl, nudrin, ordram, and simazine. Pesticides in drainage water during the peak summer irrigation season were well below drinking water standards or action levels established by DHS.

The identification of agricultural management practices to control THMFP in Delta agricultural drains will be dependent on a more thorough characterization being conducted as part of the DIDI study.

CATTLE GRAZING, FEEDLOTS, AND DAIRIES

Much of the area between the floor of the Central Valley and the mountains of the Coast Range and Sierra Nevada is devoted to cattle grazing. Grazing removes the vegetative cover and increases soil compaction which reduces infiltration and increases runoff. This results in greater erosion of the soil. Domestic stock have a tendency to congregate near waterbodies and rivers due to the amount of forage, presence of shade, and access to water. Consumption of riparian vegetation and trampling of stream banks results in more sediment entering the waterbodies. Water quality concerns related to grazing are predominantly due to sediment input and resultant turbidity as a result of erosion from overgrazed lands. There have been no studies on the water quality effects of grazing in the Sacramento, San Joaquin, and Tulare basins.

Discussions were held with the Central Valley Regional Board staff on the impacts of dairies and feedlots on water quality. The discharge of dairy or feedlot wastes to surface waters is prohibited by the Regional Board. Because it is illegal, the Regional Board only responds to reported violations. Cease and Desist Orders are issued in extreme cases. The Regional Board staff believe that there are illegal discharges of animal wastes but do not have any data to determine the resultant water quality impacts. Constituents of concern in animal wastes include pathogenic organisms and nitrogen. It would be necessary to collect water quality samples downstream of an illegal discharge as it was occurring or soon after it occurred. If this could be done, the ratio of fecal coliforms to fecal streptococci (FC/FS) could be used to determine that a discharge of animal wastes had occurred. FC/FS ratios of 0.1 to 0.4 are generally thought to indicate livestock and poultry sources (Burge and Parr, 1981). Samples must be collected in the vicinity of the discharge as it is occurring because growth and differential die-off make the ratios meaningless with time and distance from the source.

<u>Cryptosporidium</u> has been found in domestic and wild animals (Rose, 1988). It seems particularly prevalent in cattle (Silverman, 1988). There are no data available on the relative contribution of <u>Cryptosporidium</u> to the Sacramento and San Joaquin Rivers from municipal wastewater treatment plants and from agricultural drainage from livestock impoundments and cattle grazing areas.

MINE DISCHARGES

Past mining operations in California have been primarily for the recovery of copper, zinc, and other nonferrous metals from sulfide ore bodies, for gold recovery, and for mercury. Mining of sulfide ore bodies has occurred primarily in the Lake Shasta area and also in the foothills of the Sierra Nevada. Mining for gold has centered in the Sierra Nevada foothills. Mercury mining has been primarily in the Coast Ranges. The majority of mines are north of Sacramento. Some asbestos mining has occurred in the Coast Ranges within the San Joaquin Basin. Asbestos mine discharges are a direct source of contamination to the California Aqueduct and are discussed in Chapter 5.

Several thousands of mines have been worked and later abandoned. Discharges from inactive mines constitute a significantly greater threat to water quality than discharges from active mining operations. The Central Valley Regional Board currently manages active and inactive mines in the Sacramento, San Joaquin, and Tulare Basins under the Waste Discharge Requirement program, the NPDES permitting program, and on a case-by-case basis. Permit conditions for active mines usually allow only inert or non-hazardous waste releases. Active mining operations meet these conditions by controlling the acidity of their discharges and by other management practices.

Acid mine drainage is formed primarily from the oxidation of pyrite sulfide ores within mine tunnels and at the surface of used waste rock piles. This reaction produces sulfuric acid with a pH of about 3. The low pH dissolves metals in the surrounding rock generating a discharge containing high dissolved metals concentrations. Acid mine drainage can contain elevated levels of copper, cadmium, and zinc and, usually, lower concentrations of other metals such as nickel, lead, and chromium. The products of acid mine drainage, formed in the mine, are carried out of the mine when infiltrating water floods the interior to the level of the lowest adit. Acid mine drainage is also discharged from waste rock piles when rainfall or stream flow contact the pile. As the dissolved metals are transported away from the mine, the pH increases as the mine drainage is diluted from contact with other water. Some percent of the metals then precipitate out and metal concentrations in the receiving stream decrease. Much of the concern with acid mine drainage, therefore, is with the threat to aquatic life immediately downstream of the discharge. Acid mine drainage may also carry radionuclides. Radionuclide levels in Central Valley acid mine drainage have not been studied.

Runoff from gold mine waste piles can contain elevated levels of arsenic, once used in the gold amalgamation process. Runoff from mercury mine waste piles can contain elevated levels of mercury. Inactive gold and mercury mines can also produce acid mine drainage.

Key Mine Discharges

The Central Valley Regional Board ranked the largest inactive mines according to their threat to downstream water quality (Buer, et al., 1978). Inactive mines with high and medium rankings are listed in descending order in Table 4-13. The locations of these mines are shown on Figures 4-25 through 4-27. Also shown on these figures are the type(s) of discharge from each mine site. The majority of these mines are clustered around Redding in the northern Sacramento Valley. Eleven of the inactive mines listed in Table 4-11 are located upstream of reservoirs. Some unknown percent of the constituents in the mine drainage from these mines will be entrained within the sediments of the downstream reservoir. The Iron Mountain Mine, located just downstream of Lake Shasta, is considered the largest acid mine drainage pollutant source in the Central Valley (Montoya, et al., 1989). It is a federal and state Superfund site. Other major mines in the Central Valley include the Balaklala, Keystone, Mammoth, Walker, and Sulfer Bank mines which are on the state Superfund list.

The mines closest to SWP facilities include the Penn Mine, which is an inactive copper mine adjacent to the Mokelumne River just upstream of Camanche Reservoir. Drainage from the Mount Diablo mercury mine enters the San Joaquin River near Oakley. The New Idria mercury mine drains to the San Joaquin River near Mendota via Panoche Creek and Fresno Slough. The Atlas and Coalinga asbestos mines are on the federal and state Superfund lists. They drain into Cantua Creek and into the Arroya Pasajero which discharges into the California Aqueduct during wet years, as discussed in Chapter 5.

Mine Drainage Quality

Most inactive mines do not have extensive drainage quality monitoring systems. Therefore, limited drainage quality data are available. Table 4-14 shows average mine drainage quality from four inactive mines. Iron Mountain Mine has been studied more extensively than most other mines. The most complete drainage quality data are, therefore, from Iron Mountain Mine. Of the average concentrations shown in Table 4-14, mercury concentrations in drainage from New Idria Mine exceed the primary drinking water standard. Zinc concentrations in drainage from Iron Mountain Mine and Afterthought Mine exceed the secondary drinking water standard.

Although mercury, asbestos, cyanide, and heavy metals mobilized by acid mine drainage represent potential threats to public health, there is no evidence that mining wastes have ever resulted in illness or death of an individual (University of California, Berkeley, 1988). The greatest problem caused by acid mine drainage is the toxicity to aquatic life caused by the high metals concentrations and low pH of the drainage. As discussed in the section on urban runoff, the accumulation of metals in sediment and aquatic organisms does not pose an immediate threat to drinking water supplies but there is a public health risk associated with consumption of metals-tainted aquatic organisms. Many of the tributaries to the Sacramento River and the upper Sacramento River have been classified as impaired waterways by the State Board (1990) and the Central Valley Regional Board (1989/1990) due to mine drainage.

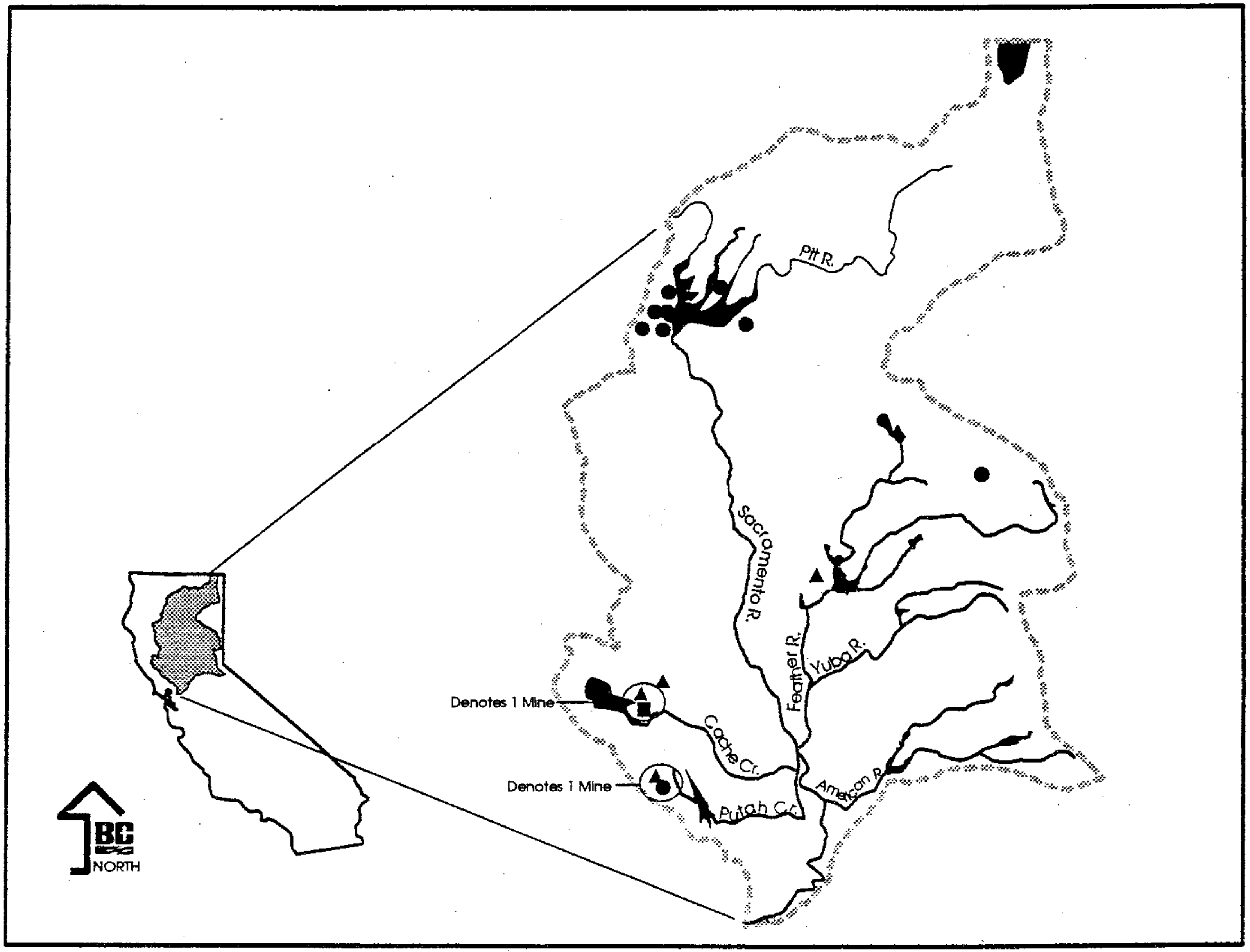
Loads of Contaminants

The Regional Board estimated the 1985 loads from Iron Mountain Mine and Afterthought Mine (Montoya, et al., 1988). Iron Mountain Mine is the single largest mine discharger in the

Table 4-13. Major Inactive Mines in the Watersheds Rated as High or Medium Threat to Water Quality

Mine	Basin location
Iron Mountain	Sacramento
Mammoth	Sacramento
Penn	San Joaquin
Balaklala	Sacramento
Keystone	Sacramento
Afterthought	Sacramento
Mt. Diablo	San Joaquin
Bully Hill, Rising Star	Sacramento
Walker	Sacramento
Sulfer Bank	Sacramento
Newton	San Joaquin
Greenhorn	Sacramento
New Idria	San Joaquin
Corona	Sacramento
Manzanita	Sacramento
Cherokee	Sacramento

Source of information: Central Valley Regional Water Quality Control Board. 1985. Mass Loading Assessment of Major Point and Nonpoint Sources Discharging to Surface Waters in the Central Valley.



Legend:

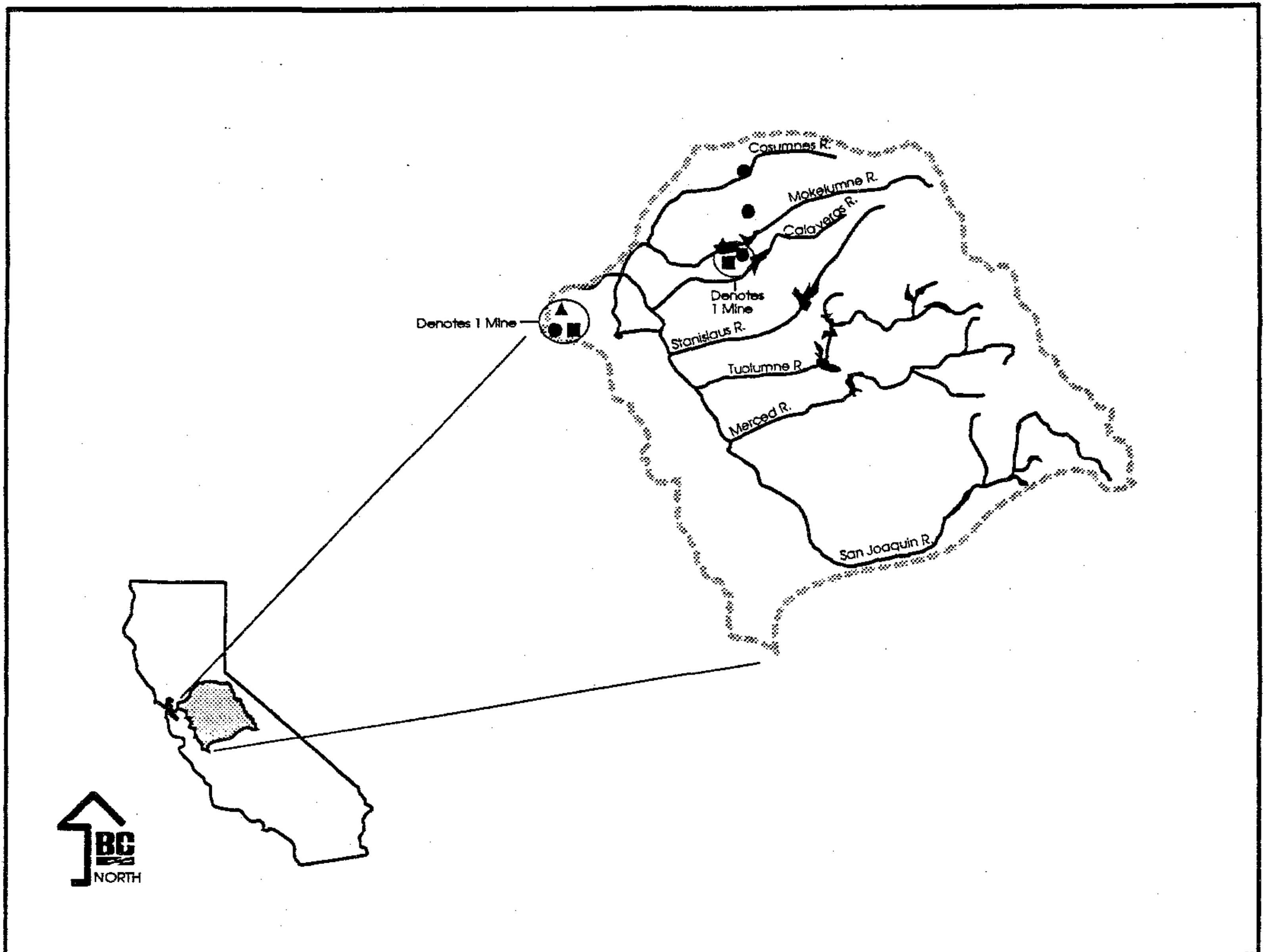
Pollutant in Mine Discharge

■ Acid Mine Drainage

● Mercury

▲ Arsenic

Figure 4-25. Major Inactive Mines in the Sacramento Basin

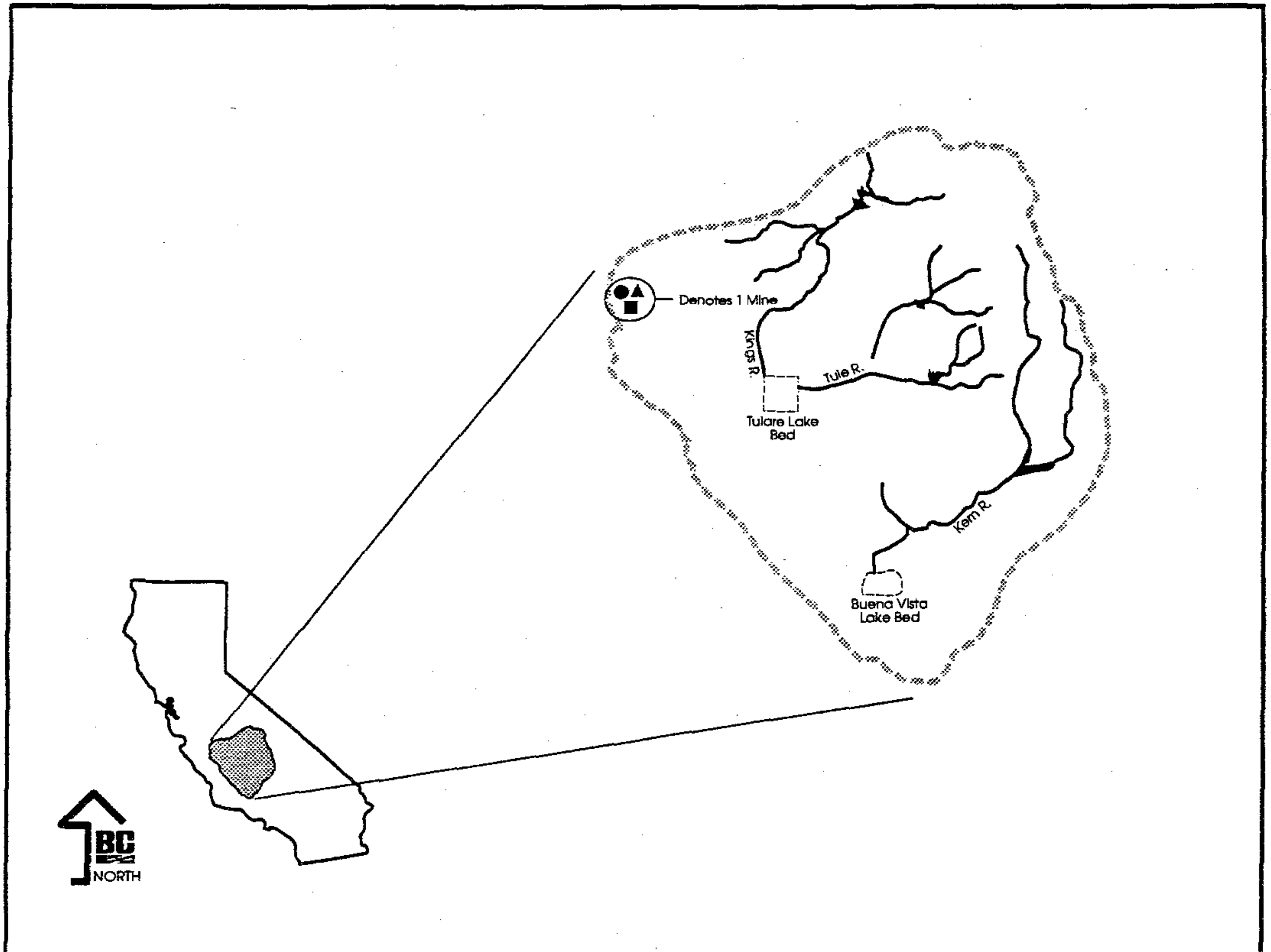


Legend:

Pollutant in Mine Discharge

- ■ Acid Mine Drainage
- ● Mercury
- ▲ Arsenic

Figure 4-26.
Major Inactive Mines in the San Joaquin Basin



Legend:

Pollutant in Mine Discharge

- ■ Acid Mine Drainage
- ● Mercury
- ▲ Arsenic

Figure 4-27. Major Inactive Mines in the Tulare Basin

Table 4-14. Metals Concentrations in Mine Drainage From Four Major Inactive Mines

Constituent (μg/l)	Iron Mountain Mine	Afterthought Mine	Newton Mine	New Idria Mine
Arsenic	--[a]	--	--	25 (3)
Cadmium	88 (13)	303 (18)	--	17 (3)
Chromium	10 (1)	--	--	125 (2)
Copper	2,700 (36)	12,083 (16)	11,700 (2)	370 (3)
Lead	13 (2)	--	--	57 (3)
Mercury	--	--	0.2 (1)	4 (5)
Nickel	12 (2)	--	--	--
Zinc	24,300 (36)	70,982 (18)	--	--

[a]-- Not analyzed.
[b]Number of samples are in parentheses.

Source of information: Central Valley Regional Board. 1985. Mass Loading Assessment of Major Point and Nonpoint Sources Discharging to Surface Waters in the Central Valley.

Delta watersheds in terms of volume. Although it is estimated that acid mine discharge from these two mines made up less than 1 percent of the flow in the Sacramento River below Keswick Reservoir, it was estimated that they contributed 81 percent of the cadmium, 84 percent of the zinc, and 71 percent of the copper. Load percentages for chromium, lead, and nickel were estimated between 1 and 3 percent. Iron Mountain Mine contributed 95 percent of the loads from these two mines. A study for the State Board estimated the average daily discharge from Iron Mountain Mine at 4,800 pounds of iron, 1,466 pounds of zinc, 423 pounds of copper, and 10 pounds of cadmium (University of California, Berkeley, 1988).

The greatest loads of metals from inactive mines are typically discharged between October and April when rainfall causes runoff from waste piles and tunnel complexes where water has risen and overflown. The seasonal loading pattern is different at Iron Mountain Mine due to the Spring Creek Diversion Dam release schedule stipulated in a 1980 Memorandum of Understanding with the Regional Board and several other agencies. Spring Creek Diversion Dam was constructed to control releases from the mine to prevent salmon kills in the Sacramento River. Releases from Spring Creek Reservoir are timed to coincide with higher summer releases from Keswick Dam on the Sacramento River to provide maximum dilution of the mine drainage. During periods of heavy rainfall, releases from Spring Creek Reservoir may be increased to lower the Spring Creek Reservoir level and prevent an uncontrolled spill. Total monthly loads from Iron Mountain Mine are, therefore, greatest during the summer months and at times during periods of heavy rainfall (Montaya, 1989).

SEA WATER INTRUSION

During periods of reduced freshwater outflow, the operation of water project pumps in the southern Delta causes the flow of the San Joaquin River and other channels to reverse their normal direction. When this occurs, sea water containing sodium, chloride, bromide and other salts more easily enters the Delta from the estuary and mixes with Delta waters. The primary impacts of sea water intrusion on drinking water supplies derived from the Delta is an increased salt content of the water and increased production of THMs in the finished water. Dissolved solids, sodium, and chloride concentrations in the water exported from the Delta approach drinking water standards at times, as discussed in detail in Chapter 6.

Recent studies have shown that the presence of bromide results in the formation of brominated THM species and also increases the total amount of THM formation potential (THMFP) (Luong, et al., 1982; Amy, et. al., 1985). Very recent work by Metropolitan Water District has shown that the presence of bromide also results in the formation of many different brominated disinfection by-products when ozone is used for disinfection (McGuire, 1990). Since the atomic weight of bromine is approximately twice that of chlorine, the substitution of bromine for chlorine in a molecule increases the molecular weight. Drinking water standards are set on a weight basis. Thus, a 100 µg/l THM standard that is met when no bromide is present may not be met during periods of sea water intrusion when the heavier brominated THMs are formed.

For example, THM levels in treated SWP water have been higher during the current drought because of elevated brominated THMs formed with bromides coming from the Delta as a result of sea water intrusion (McGuire, et. al., 1990).

A study prepared for the California Urban Water Agencies showed that the THMFP increases by about 130 µg/l as the Sacramento and San Joaquin River water flows through the Delta to the export pumps (Brown and Caldwell, 1989). A semiquantitative approach using a mass balance of average THMFP concentrations and DWR estimates on flow contributions from the Sacramento and San Joaquin Rivers to the export pumps was used to estimate the increase in THMFP in the Delta. Using a number of assumptions, the mass balance showed that sea water intrusion contributes about 20 µg/l of THMFP (15 percent of the increase) and agricultural drainage contributes 90 µg/l of THMFP (70 percent of the increase) to Delta export waters. The remaining 15 percent of the increase was attributed to increases due to organic matter in the Delta channels.

DWR has recently attempted to determine the effect of agricultural drainage on Delta export water THMFP, as discussed previously in this chapter. The DWR study examined the impact of agricultural drainage on organic carbon precursors that form THMs. They found that in 1988, agricultural drainage was responsible for an average increase in THM carbon of 67 percent. DWR has not yet examined the impacts of sea water intrusion on THMFP production in the Delta. DWR has found, however, that the production of brominated THMs is not solely related to the concentration of bromide in the water. The types of dissolved organic carbon compounds (humic vs. nonhumic) can have a significant impact on the formation of brominated THMs. DWR will be further examining the impact of sea water intrusion in the ongoing DIDI study.

The Delta peat soils are particularly susceptible to liquefaction during earthquakes. A number of active faults are close enough to the Delta to cause liquefaction of Delta soils and collapse of Delta levees. If Delta levees collapse, sea water from San Francisco Bay would surge into the Delta and render the Delta unusable as a source of drinking water. An earthquake of sufficient magnitude to liquefy Delta levees is likely to occur within the next 30 years (Miller, 1990).

SUMMARY OF CONTAMINANTS IN THE WATERSHEDS

A large number and great variety of potential sources of contamination to the SWP have been identified in this chapter. Table 4-15 contains a summary of the contaminant sources, the period of discharge, key contaminants, and some factors that mitigate the potential of some key contaminants for harming drinking water supplies. Although many actual and potential sources of contaminants to the SWP have been identified in this chapter, there are many mitigating factors which prevent them from adversely affecting the drinking water quality of SWP users.

Table 4-15. Summary of Contaminants in the Watersheds

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	Comments
Municipal and industrial discharges	Continuous	Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	Recent policy requiring effluent toxicity testing provides limited protection of drinking water supplies.
		Nutrients	None identified	
		Organics	Sediment adsorption	
		Metals	Sediment adsorption	
Urban runoff	Discrete pulses of stormwater occur October through April. Continuous dry weather flows.	Suspended solids	Sedimentation	NPDES permits for urban runoff will be required in the next few years.
		Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	
		Nutrients	None identified	
		Metals	Sediment adsorption	
		Organics	Sediment adsorption	
Agricultural drainage				
Sacramento Basin	Irrigation-related discharges occur primarily in May and June. Rainfall induced runoff occurs October through April.	Rice herbicides	None identified	On-farm best management practices are being implemented to reduce concentrations of rice herbicides in discharge water.
		Nutrients	None identified	
		Suspended solids	Sedimentation	
		Organic carbon	None identified	
		Metals	Sediment adsorption	
		Pesticides	Sediment adsorption, biological uptake and degradation	

Table 4-15. Summary of Contaminants in the Watersheds (continued)

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	Comments
Agricultural drainage (continued)				
San Joaquin Basin	Irrigation-related surface runoff occurs during the April to October irrigation season. Rainfall-induced runoff occurs October through April. Subsurface drainage occurs all year.	Dissolved solids	None identified	
		Selenium	None identified	
		Nutrients	None identified	
		Metals	Sediment adsorption	
		Pesticides	Sediment adsorption, biological uptake and degradation	
Delta	Discharge occurs year-round with peaks in June to July and November to January.	Dissolved solids	None identified	
		Nutrients	None identified	
		Organic carbon	None identified	
Cattle Grazing, Feedlots, and Drains	Primarily rainfall induced runoff from October through April	Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	
Mine discharges	Rainfall-induced discharges occur October through April. Discharges from Iron Mountain Mine are controlled by Spring Creek Diversion Dam. They occur during summer months and periods of heavy rainfall.	Low pH	Dilution	
		Metals	Precipitation as pH increases	

Table 4-15. Summary of Contaminants in the Watersheds (continued)

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	Comments
Sea water intrusion	Occurs during periods of low river flows.	Dissolved solids	None identified	Risk of severe sea water intrusion in the event of seismic failure of Delta levees.
		Bromide	None identified	
		Chloride	None identified	
		Sodium	None identified	

Mitigating Factors

Dilution of contaminants by inflows of higher quality waters reduces the impacts on drinking water quality. The San Joaquin River consists mostly of agricultural drainage downstream of Mendota Pool and does not have any dilution capacity. The high quality east side tributaries dilute the contaminants in the San Joaquin River. This is clearly demonstrated by the decreasing concentrations of dissolved solids, selenium, and nitrate in the San Joaquin River, shown on Figures 4-21 through 4-23. The Sacramento River has a much greater capacity for diluting contaminants. For example, the large discharge from the Sacramento Regional Plant had an average daily dilution ratio of 146:1 in 1989, which was a dry year.

Sedimentation of particulate matter and adsorbed metals and organics occurs in storage reservoirs and in slow moving streams. Although sedimentation has been shown to adversely affect salmon and trout spawning in the Sacramento and San Joaquin Rivers and their tributaries, it has a beneficial impact on drinking water by removing contaminants from the water.

Bacteria die off rapidly in receiving waters, however, pathogenic cysts are quite resistant and persist in receiving waters. Pesticides can be degraded by biological activity in receiving waters.

Storage of water in reservoirs can lead to changes, some minimal, some significant, in the quality of the stored water. The quality of water stored in reservoirs is less variable than water taken directly from the source of water to the reservoir. An important function of reservoir storage is to eliminate extremely high or low concentrations of water quality constituents in source waters by blending with water in the reservoir. The primary water quality benefit of storage of water in large reservoirs in the Sacramento and San Joaquin Basins is sedimentation of particulate matter and its associated metals and organics. Many of the mines discussed in this chapter are located upstream of major reservoirs in these watersheds so the impact of the high metals concentrations discharged from these mines is greatly reduced.

In addition to storage in the large Sacramento River reservoirs, SWP water is also stored in San Luis Reservoir and in the terminal reservoirs in southern California. West Branch users get the benefit of storage in the large terminal reservoirs, Pyramid Lake and Lake Del Valle. The North Bay Aqueduct users have no storage reservoirs and South Bay Aqueduct users have minimal storage in Lake Del Valle.

Municipal and Industrial Discharges

There are 149 municipal and industrial discharges in the Sacramento, San Joaquin, and Tulare Basins with an average continuous flow of 1,400 mgd. Wastewater treatment plants, which discharge continuously, have the greatest potential for degrading drinking water quality. There are 58 municipal wastewater treatment plants with an average total flow of about 270 mgd. Many of these treatment plants are located in the upper reaches of the watersheds, although most are located downstream of major reservoirs. The four municipal wastewater treatment plants located nearest to the SWP export facilities were examined in detail. The Sacramento Regional Plant, which discharges to the Sacramento River just upstream of the Delta, is the single largest municipal discharger in the Central Valley, accounting for 56 percent of the total municipal wastewater treatment plant flow into the river systems. The second largest municipal discharger, Stockton Main Plant, accounts for 11 percent of the total flow and discharges to the San Joaquin River within the Delta. The Tracy Sewage Treatment Plant (4 mgd) discharges into the Delta close to the headworks of the California Aqueduct and Delta Mendota Canal. Vacaville Easterly Sewage Treatment Plant (6 mgd) discharges into the Delta close to the headworks of the North Bay Aqueduct. With the exception of residual chlorine levels in Vacaville Easterly Sewage Treatment Plant effluent, all of the major municipal and industrial plants discussed are meeting their NPDES permit requirements.

The key contaminants discharged from treatment plants are pathogens, nutrients, organics, and metals. Although conventional treatment reduces the density of pathogenic organisms, protozoan cysts, helminth ova, and certain enteric viruses may not be effectively inactivated. Bacteria die-off rapidly in receiving waters. Dilution is the only factor that mitigates the discharge of nutrients into receiving waters. Although ammonia is converted to nitrate in receiving waters, it is still available for biological uptake. Nutrients can stimulate biological productivity downstream of the discharge leading to high concentrations of organic carbon at downstream water intakes. Organic carbon combined with disinfectants used at the water treatment plants produces THMs and other disinfection by-products. Organics and metals discharged from treatment plants may be reduced in receiving waters by adsorption to particulate matter and sedimentation.

Urban Runoff Discharges

There are fourteen urban areas with populations greater than 30,000 in the Sacramento, San Joaquin, and Tulare Basins that discharge urban runoff to surface water bodies. Nine of these urban areas (Sacramento, Stockton, Antioch, Roseville, Vacaville, Lodi, Woodland, Manteca, and Davis) are near the Delta. Sacramento is the single largest urban area discharging urban runoff to the Central Valley watersheds. With increasing urbanization of the Central Valley, especially in those areas near the Delta and the Bay Area, the contaminants in and the volume of urban runoff will increase.

The effect of Regional Board regulation under the NPDES program in controlling urban runoff discharges is not yet known. The regulation of urban runoff will provide a more complete water quality and loads characterization of urban discharges.

The key contaminants in urban runoff are heavy metals, particularly lead, and oil and grease. The greatest pollutant loads occur during the first few storms of the fall when river flows are typically lowest. Metals concentrations in receiving waters are reduced by adsorption to particulate matter and sedimentation.

Agricultural Drainage

Agricultural drainage contributes sediment, pesticides, and nutrients to the Sacramento-San Joaquin River and Delta system. Agricultural discharges occur primarily below the major reservoirs in the downstream reaches closest to and in the Delta. Most agricultural discharges are seasonal and/or episodic and are related to specific crop practices.

In the Sacramento Valley, the major agricultural drains are Colusa Basin Drain, Sacramento Slough, RD1000, RD108, and Toe Drain. These drains which are estimated to contribute 80 percent of the agricultural drainage in the Sacramento Valley, discharge into the Sacramento River system between the vicinity of the Feather River and Suisun Bay. Between mid-May to mid-June, a slug of rice herbicides passes through the system.

Subsurface agricultural drainage is the primary concern in the San Joaquin Valley. Subsurface drainage discharges continuously to the San Joaquin River system, primarily through Mud and Salt Slough. These sloughs contribute high levels of trace metals (especially selenium) and salts. Downstream of Mendota Pool, before the east side tributaries contribute fresher water the San Joaquin River is mostly a drain for west side subsurface agricultural discharge. The water quality of the San Joaquin River at Vernalis, therefore, is greatly influenced by the amount of flow in the east side tributaries.

Agricultural drainage in the Delta presents special problems due to the proximity to the Delta pumps and the presence of peat soils on Delta islands that contribute organic precursors which contribute to THM formation.

Cattle Grazing, Feedlots, and Dairies

Water quality concerns related to grazing are predominantly due to sediment input and resultant turbidity as a result of erosion from overgrazed lands. The discharge of dairy or feedlot wastes to surface waters is prohibited by the Regional Board, but Regional board staff believe that illegal discharges occur. Constituents of concern in animal wastes include nitrogen and pathogenic organisms, including Cryptosporidium and Giardia.

Mine Discharges

There are thousands of inactive mines in the Sacramento, San Joaquin, and Tulare Basins discharging acid mine drainage high in heavy metals, asbestos, mercury, and/or cyanide. The majority of these mines are upstream of reservoirs in the higher reaches of the Central Valley watershed. Sixteen inactive mines have been ranked by the Regional Board as presenting a high or medium threat to downstream water quality. Of these 16 mines, the Mt. Diablo Mercury Mine, is closest to the Delta. Most mine discharges occur from October to April during the wet season. The volume of flow is both seasonal and variable from year to year.

Sea Water Intrusion

During periods of reduced freshwater outflow, the operation of water project pumps in the southern Delta causes the flow of the San Joaquin River and other channels to reverse their normal direction. When this occurs, sea water containing sodium, chloride, bromide and other salts more easily enters the Delta from the estuary and mixes with Delta waters. The primary impacts of sea water intrusion on drinking water supplies derived from the Delta is an increased salt (sodium, chloride, bromide) content of the water and increased production of THMs and other disinfection by-products. The extent to which bromides present in sea water increase the production of THMs and other disinfection by-products has not been precisely determined, but the input is known to be large. The State Water Contractors have asked the State Board to set a Delta standard of 50 mg/l chloride, when feasible, to control the bromide impact on SWP water. If an earthquake of sufficient magnitude to cause liquefaction of Delta levees occurs, sea water would surge into the Delta and make it unusable as a source of drinking water.

Water Quality Monitoring

The effects of contaminants discharged to the Sacramento, San Joaquin, and Tulare Basins is best evaluated by monitoring key water quality constituents in the Sacramento and San Joaquin Rivers near the points where they enter the Delta and the Kern River near the Kern River Intertie with the California Aqueduct. The water quality of these rivers is discussed in Chapter 6.

CHAPTER 5

DIRECT SOURCES OF CONTAMINATION TO THE STATE WATER PROJECT

A field survey was conducted to identify actual and potential sources of direct contamination to the State Water Project (SWP) facilities. The methods used to conduct the field survey and the findings are described in this chapter. A brief discussion of emergency response plans is also included.

The SWP facilities were divided into the following segments:

North Bay Aqueduct
South Bay Aqueduct
Clifton Court Forebay to O'Neill Forebay
O'Neill Forebay and San Luis Reservoir
O'Neill Forebay to End of San Luis Field Division
End of San Luis Field Division to Kern River Intertie
Coastal Aqueduct
Kern River Intertie to Bifurcation of East Branch/West Branch
West Branch
East Branch
Delta Mendota Canal

The Delta Mendota Canal (DMC), from the Tracy Pumping Plant to the O'Neill Pumping Plant, was included in the field survey because water pumped from the DMC commingles with SWP water in O'Neill Forebay. The operation of the DMC, as it relates to the SWP, is described in Chapter 2.

Prior to conducting the field survey, U.S. Geological Survey (USGS) maps were obtained for the areas traversed by the Governor Edmund G. Brown California Aqueduct (California Aqueduct) and the DMC and the watersheds of the reservoirs. Information was obtained from the U.S. Bureau of Reclamation (USBR) and from the various field divisions of the California Department of Water Resources (DWR) regarding known features along the canals, such as siphons, canal control structures, water-service turnouts, pipe discharges, overchutes, undercrossings, and bridges.

A meeting was held with the California Department of Health Services (DHS) district and regional engineers, prior to conducting the field survey, to discuss the scope of the sanitary survey and to obtain information from them on known or suspected sources of contamination to the SWP facilities. This meeting was followed up by a request that the DHS engineers provide

Undercrossings

There are a number of canal undercrossings of relatively large diameter pipelines. The pipelines convey storm drainage from adjacent lands, farm irrigation water, and petroleum products from one side of the canal to the other. If undercrossings are undersized and therefore not capable of conveying all of the drainage under the canal, drainage can overflow on the upstream side of the canal and enter the canal as overland flow.

Water-Service Turnouts

A large number of municipal and agricultural turnouts are located along the SWP and the DMC. A potential source of contamination exists with the agricultural turnouts that are pumped upslope from the canals. Many farmers mix agricultural chemicals into the irrigation systems. This practice is known as chemigation. Since most irrigation districts do not require backflow prevention devices, the potential exists for chemicals to be mixed in irrigation water that can then flow by gravity back into the canal.

Fishing Areas

There are a number of locations along the California Aqueduct that are designated fishing areas. There are also locations that are heavily used for fishing but were not planned as fishing areas. If fishing areas are not equipped with sanitary facilities, there is the potential for human wastes to enter the Aqueduct. However, when the fishing areas are equipped with chemical toilets, they are frequently vandalized and often thrown into the California Aqueduct (Personal Communication, Dan Petersen, DWR).

Miscellaneous Sanitary Conditions

A variety of miscellaneous conditions were noted during the field survey. These observations include residential, commercial, and industrial buildings; chemical storage tanks; defective canal lining; livestock confinements; poultry farms and dairies; and wastewater ponds. The canal system is also exposed to agricultural chemicals from both aerial spraying and ground rigs.

Pumping Plant and Power-Generating Plants

Each pumping station and power-generating plant has sewage handling facilities for operators and visitors. If these facilities are not properly sited or operated, there is a potential for sewage contaminants to enter the water.

Steel Tanks

Each steel tank was inspected to determine if it was covered and reasonably protected against vandalism.

Reservoirs

For each large water storage reservoir, the field survey objectives were to determine the land uses and waste discharge potential of each reservoir's watershed, the recreational uses on each reservoir and surrounding shorelines, the manner of sewage collection, conveyance, pumping, treatment and disposal, the adequacy of trash management and algae growth control measures currently being practiced.

NORTH BAY AQUEDUCT

The North Bay Aqueduct is a 27-mile-long, underground pipeline that serves water consumers in Napa and Solano Counties. The North Bay Aqueduct will ultimately deliver 67,000 acre-feet (AF) of water each year to the Solano and Napa County Flood Control and Water Conservation Districts.

Physical Facilities

This section of the SWP was built in two phases. The first phase, built in 1967-1968, consisted of the Cordelia Surge Tank, the Napa Turnout Reservoir, and a 4-mile-long pipeline connecting these two storage units. The second phase of construction began in 1986 and consisted of 23 miles of pipeline from the Cordelia Surge Tank eastward to Barker Slough, where an intake pumping station diverts water from the western edge of the Delta into the North Bay Aqueduct. The Barker Slough water diversion location was selected to ensure as much as possible that water of good quality would be obtained. The North Bay Aqueduct system, using water from Barker Slough, was activated during 1988.

The Barker Slough Pumping Plant, located a few miles north of Rio Vista, has nine pumps with a capacity of 178 cubic feet per second (cfs). The water is pumped into a 6-foot-diameter pipeline that conveys the water to the 2-million-gallon (MG) Travis Surge Tank. The Travis Surge Tank is an uncovered steel tank. Before reaching the Cordelia Forebay, water is delivered through two turnouts to Travis Air Force Base and to the Solano County communities of Fairfield, Suisun City, and Vacaville. Cordelia Forebay is an asphalt-lined forebay for the Cordelia Pumping Plant. The forebay stores 11 AF of water, has a surface area of 2 acres, and a maximum water depth of 30 feet.

There are 11 pumps at the Cordelia Pumping Plant and three separate discharge pipelines. The Benicia area (32 cfs) and the Vallejo area (42 cfs) are each served by a separate pipeline. The third pipeline (46 cfs) carries water to the Cordelia Surge Tank, which is an uncovered 44.5-foot-high, 25-foot-diameter steel tank. From this small tank, the water continues through a 4-mile pipeline to the Napa Turnout Reservoir, a 22-acre-foot (7-MG) steel storage tank which is the western terminus of the North Bay Aqueduct. The uncovered tank is 200 feet in diameter. Two turnouts at the reservoir deliver water to the American Canyon Water District and to the

City of Napa, which in turn uses its piping system to deliver water to the communities of Yountville and Calistoga in Napa County.

Historic Information and Past Concerns

During 1985, Camp, Dresser, and McKee (1986) conducted a water quality study of Lindsey Slough. They found that Lindsey Slough receives agricultural drainage from Hastings Island. During 1989, the DHS district engineer for the North Bay Aqueduct expressed concern that Barker Slough receives wastewater from Vacaville and agricultural drainage when Cache Slough is drawn into Barker Slough by the pumps at the Barker Slough pumping station (Personal Communication, Robert Hultquist, 1989).

Field Survey Results

Since the North Bay Aqueduct is actually a pipeline system and not an open canal system, the route of the pipeline was not inspected. The major facilities along the water delivery system, such as pumping stations and storage/surge tanks, however, were inspected.

Barker Slough Intake and Pumping Station. A dead cow was found floating in the water near the intake area during the field survey. The pumping station is equipped with sanitary toilet facilities. The toilets drain into a holding tank, which is periodically pumped out. These sewage facilities do not pose a hazard to the water supply conveyance system.

Travis Surge Tank. This large steel tank is open on top. The lack of cover does not pose a significant water quality hazard. A ladder leading up to the tank is vandal proof. The storage tank site is also fenced to exclude unauthorized persons. No significant sanitary hazards were found at this facility.

Cordelia Holding Reservoir. This 11-acre-foot forebay is asphalt lined but uncovered. The site is surrounded by a drainage system that diverts most of the runoff from tributary, undeveloped lands. The only nearby area used for cattle grazing is located downhill from the reservoir. The toilet facility and sewage holding tank serving the nearby Cordelia Pumping Station is located over 100 feet away from the reservoir and does not pose a sanitary hazard to the water stored in the reservoir. Weeds on the Cordelia site are controlled with Round-Up and Paraquat. The site is fenced to exclude unauthorized persons. No significant sanitary hazards were found at this facility.

Cordelia Surge Tank. This tank is similar in construction to the Travis Surge Tank but smaller in size. No significant sanitary hazards were found at this facility.

Napa Turnout Reservoir. This tank is also similar to the Travis Surge Tank but much larger in capacity. No significant sanitary hazards were found at this facility.

Summary of Contaminant Sources

There are no major direct sources of contaminants to the North Bay Aqueduct. As discussed in Chapter 4, there are sources of contaminants to Lindsey and Barker Sloughs.

SOUTH BAY AQUEDUCT

The South Bay Aqueduct is operated and maintained by DWR's Delta Field Division. The South Bay Aqueduct serves water to Alameda County Water District, Santa Clara Valley Water District, and Alameda County Flood Control and Water Conservation District, Zone 7 (Zone 7).

Physical Facilities

The South Bay Aqueduct system is supplied by the South Bay Pumping Plant, which has nine pumps with a capacity of 330 cfs. The water is pumped 565 feet out of an arm of the 5,070-acre-foot capacity Bethany Reservoir into the first reach of the aqueduct.

The South Bay Aqueduct is a pipeline from the South Bay Pumping Plant to mileage point 3.26. Along this stretch there are no turnout deliveries. The pipeline system is equipped with numerous blow-off and air valves and a surge tank. From mileage point 3.26 to 5.21, the South Bay Aqueduct is an open canal. The canal starts in a fenced back-surge pool. Adjacent to this pool is a copper sulfate feeding facility capable of dosing the flow at a rate of 2 mg/l for algal control. From mileage point 5.21 to 7.42, the South Bay Aqueduct is again an underground piping system. From mile point 7.42 to 16.38, the South Bay Aqueduct is again an open canal. At mileage point 9.49, there is a turnout for Patterson Reservoir. This reservoir stores raw water for the Zone 7 Patterson Pass Filtration Plant. This reservoir has a storage capacity of 100 acre-feet. At mileage points 10.68 and 14.65 there are copper sulfate feeding facilities for algal control. From mileage point 16.38, the aqueduct continues as a pipeline through the Mission Tunnel south of Sunol to curve through the hills until it terminates at mileage point 42.26 and empties into the Santa Clara Terminal Tank, an uncovered 9-AF (2.5-MG) steel tank that is 160 feet in diameter.

At mileage point 18.63, there is a 60-inch turnout that serves as a common inlet/outlet to Lake Del Valle. Lake Del Valle, formed by 235-foot-high Del Valle Dam, is a multipurpose reservoir, having a storage capacity of 77,110 AF. Lake Del Valle provides water supply, flood control, and year-round recreational activities. The recreational facilities are operated by the East Bay Regional Parks District and include picnicking, swimming, boating, fishing, and camping. Lake Del Valle is supplied with SWP water by four pumps housed in the Del Valle Pumping Station, which is located below the dam. These pumps have a capacity of 120 cfs. The 1,060-surface acre reservoir has an extensive watershed that contributes local runoff to the reservoir each year, making up both evaporation and some of the percolation losses, together with domestic uses for the recreational facilities.

Historic Information and Past Concerns

The Santa Clara Valley Water District (1988) has documented water quality problems with high turbidity, high trihalomethane formation potential, high bacteriological levels, and taste and odor. Persistent algae and Asiatic clam problems occur in the South Bay Aqueduct. Lake Del Valle is a potential source of human pathogens due to body contact sports by a significant number of daily visitors. Cattle grazing operations in the watershed may contribute to water quality problems. On other occasions, the DHS has stated concerns over land use practices in the Lake Del Valle watershed and has identified faulty sewage handling facility design, siting, and lack of adequate maintenance of some of these facilities. DHS suspects that high winds in the Bethany Reservoir area may be partially responsible for high turbidity problems in South Bay Aqueduct water (Personal Communication, Dave Clark, DHS, 1989). Clifton Court Forebay may also be partially responsible.

Field Survey Results

The South Bay Aqueduct is partially a canal system and partially an underground piping system. The open canal system and the major facilities along the canal/piping system were inspected and appraised.

South Bay Pumping Plant. The inlet area to the pumping station receives surface runoff from several hundred acres of land that is used extensively for cattle grazing. The drain inlet from this land is 10 feet wide and 4 feet high. The sanitary facilities at the pumping station consist of a septic tank and a leach field. The survey revealed that this leach field is plugged, causing the septic tank to overflow. The septic tank, therefore is now periodically pumped. These wastewater facilities could overflow into the intake facilities, being higher in elevation and located nearby.

Pipeline Segments. There are numerous air valves and blow-off valves along these pipeline stretches.

Open Canal Sections. Table 5-1 shows the types and numbers of potential sources of contamination found during the survey of the open canal sections.

Canal Control Structures, Siphons, and Wasteways--The South Bay Aqueduct is conveyed as a siphon under three public roads, a drainage canal, and Seco Creek.

Drain Inlets--During the field survey of the open canal, sections of the South Bay Aqueduct, 27 drain inlets were found. Sixteen of these drains convey drainage from the canal right-of-way. There are 11 other drain inlets that bring in stormwater runoff from livestock grazing areas along with canal bank drainage.

Bridges--This canal segment is crossed by two county bridges and nine private bridges. Most of the private bridges are constructed using spaced timbers and are used as cattle crossings.

Table 5-1. Potential Sources of Contamination to SWP Open Canal Sections, South Bay Aqueduct

Drain Inlets	27
Canal roadside drainage	16
Agricultural drainage	11
Groundwater	0
Other	0
Bridges	11
State	0
County	2
Farm or private	9
Overcrossings	14
Pipelines	12
Overchutes	2
Undercrossings	26
Drainage	26
Irrigation or domestic water	0
Water-Service Turnouts	20
Irrigation pumped upslope	3
Other	17
Fishing Areas	0

Overchutes and Overcrossings--During the field survey, 14 overchute and pipeline overcrossing locations were found. There are five oil industry pipelines varying from 12 to 30 inches in diameter crossing over the canal. There are nine other canal overcrossings, one of which is a 5-foot by 6-foot box culvert. Most of them convey storm runoff from grazed rangeland from one side of the canal to the other.

Undercrossings--There are four major underchute box culvert crossings carrying storm runoff water from one side of the canal to the other. There are 22 other smaller pipeline undercrossings.

Water-Service Turnouts--Twenty water-service turnouts were found. Three of the irrigation water turnouts are pumped.

Patterson Reservoir. This is a raw water, domestic water supply reservoir located near mileage point 9.49, which was found to be free of significant sanitary hazards. Recreation is not permitted, and the reservoir area is fenced to exclude cattle and people. There are no discharges of any kind into the reservoir. It is curbed to exclude all surface drainage. The reservoir is asphalt lined. Most of the surrounding reservoir shore embankments are also asphalt lined or covered with gravel. This reservoir and the open canal sections of the South Bay Aqueduct are treated with copper sulfate weekly from March through October to control algal growth. The surrounding land uses are not of the type that would indicate that aerial spraying is taking place.

Lake Del Valle. Lake Del Valle has a surface area of about 1,060 acres. Its shoreline is developed for numerous types of recreation. The areas developed for recreation can be reached by automobile, hiking, and boating. The lake recreational facilities include:

- Boating/marinas
- Boat launching facilities
- Gas/oil sales for boats and cooking
- Shops/food establishments
- Sanitary wastewater facilities/holding tank dump station
- Potable water facilities
- Parking areas
- Camping
- Fishing
- Picnicking
- Swimming/beaches

Water skiing is not allowed. Fishing, swimming, and boating are the major water uses. There are no washdown facilities for the public to use for boat maintenance and cleaning. The facility is open all year from 6 a.m. to 9 p.m. with one overnight campground. This campground is on the Arroyo Del Valle Creek, which is the major stream that flows into the upper end of Lake Del Valle.

Domestic water is supplied to the public from a package filtration plant with an intake to the lake. The filter backwash water is discharged back into the lake via a local creek. The water system includes two treated water storage tanks.

The wastewater collection and treatment system consists of at least seven lift stations and wastewater oxidation ponds. The lift stations are inspected weekly. Preventive maintenance is performed on them once every three months. None of the facilities was inspected in detail in this field survey.

The wastewater facilities serving the visiting public include nine rest rooms, four on each of the two long sides of the lake, and one at the boat marina. All rest rooms were found to be clean and well maintained. There are a number of wastewater hazards around the lakeshore areas, such as wastewater lift stations that may malfunction, resulting in wet well overflows, sewer manholes that can overflow, and overflows at the wastewater treatment/disposal ponds. Some of these wastewater facilities cross and lie in close proximity to Arroyo Del Valle Creek, which drains a large watershed and then discharges into the upper end of Lake Del Valle. Trash was found to be carefully managed all around the reservoir. On the west side of the lake, there is a 30-acre lawn area irrigated with water from the domestic water system. Runoff from this area into the lake containing fertilizers may occur at times. Weed growth around the developed lake areas is mostly controlled manually. Simazine was used in the past. Round-Up is currently the predominantly used chemical.

The reservoir is periodically sampled for bacteria, turbidity, plankton, electrical conductivity, dissolved oxygen, pH, and temperature from top to bottom at three locations (dam area, middle, and upper end).

It was not possible to conduct a detailed survey of the watershed of Lake Del Valle. The following information was gathered.

- There is a sizable cattle ranch (N-3 Cattle Ranch) located near the upstream end of the reservoir. The cattle population of this ranch could be as large as 500 animals. Runoff from the confined cattle pens flows into the lake.

- There are about 155 to 160 dwellings within the watershed, which are all on private wastewater disposal systems. The failure rates of these wastewater systems are unknown. Many of these dwellings are located in eight or nine camping areas.

- The watershed has about 35 active/inactive mining operations, including some asbestos mines.

In normal years, Arroyo Del Valley Creek is usually flowing from October through July. It is estimated that the creek has deposited some 20,000 cubic yards of silt in the lake since the dam was built. This sediment load in the creek creates elevated turbidities in the lake. There are several minor creeks draining small, almost totally undeveloped, watersheds that drain into

Lake Del Valle. These creek entrances are all around the reservoir.Water is normally released into the South Bay Aqueduct from September through November to prepare for the winter runoff.

Del Valle Pumping Plant. The septic tank/leach field facilities are adequately located and have no impact on the water quality of Lake Del Valle.

Santa Clara Terminal Tank. This tank does not have a roof. The sanitary significance of this atmospheric exposure is negligible. The tank is also reasonably well protected against vandalism.

Summary of Contaminant Sources

The major potential sources of contaminants to the South Bay Aqueduct are:

1. Agricultural drains and cattle grazing in the Lake Del Valle watershed may contribute agricultural chemicals, pathogens, organics, and nutrients to the South Bay Aqueduct.

2. Body contact recreation in Lake Del Valle and wastewater handling facilities in the watershed may contribute pathogens and nutrients to the water.

CLIFTON COURT FOREBAY TO O'NEILL FOREBAY

This section of the SWP is operated by DWR's Delta and San Luis Field Divisions. There are no domestic water-service turnouts in this section of the California Aqueduct.

Physical Facilities

The major facilities that make up this stretch of the system include Clifton Court Forebay, Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant), Bethany Reservoir, and three cement-lined canal sections.

Clifton Court Forebay is a 31,260-acre-foot storage facility in the Delta. The reservoir has a shoreline of about 8 miles and a surface area of about 2,180 acres. The Banks Pumping Plant started operating in 1969 and consists of seven pumps having a combined capacity of 6,400 cfs. Expansion of pumping facilities to 11 pumps with a combined capacity of 10,300 cfs is currently under way. The water is lifted 244 feet above the water level in the intake channel from Clifton Court to the California Aqueduct. Bethany Reservoir is a flow-through reservoir with a storage capacity of 5,070 AF, a 6-mile-long shoreline, and a surface area of about 180 acres. The dam that forms the reservoir has a spillway elevation of 245 feet.

There are three cement-lined canal sections within this segment of the California Aqueduct:

- The intake channel from Clifton Court Forebay to the Banks Pumping Plant (3 miles).
- Banks Pumping Plant to Bethany Reservoir (1.5 miles).
- Bethany Reservoir to O'Neill Forebay (61 miles).

Historic Information and Past Concerns

The DHS has expressed concern about the discharges of wastewater and agricultural drainage into the San Joaquin River (Personal Communication, Carl Lischeske, DHS, 1989). They are particularly concerned about discharges near the Banks and Tracy Pumping Plants, such as those from Tracy and Stockton. The district engineers are concerned that water from the San Joaquin River is drawn directly into the pumps with little blending with Sacramento River water. The mixing of waters in the Delta is described in Chapter 2. The DHS has also expressed concern about cattle having direct access to the shoreline of Bethany Reservoir.

Field Survey Results

Clifton Court Forebay, the Harvey O. Banks Pumping Plant, Bethany Reservoir, and the open canal sections of the California Aqueduct were inspected.

Clifton Court Forebay. The recreational activities currently allowed are fishing and hunting. No sanitary toilet facilities were observed around the reservoir shoreline for the fishermen.

Banks Pumping Plant. The wastewater collection, treatment, and effluent storage facilities that serve the plant are in good condition and do not pose any significant hazard to the water conveyance facilities. Site runoff from around the pumping plant facilities is conveyed into the pumping plant inlet channel.

Bethany Reservoir. Recreational uses of Bethany Reservoir are boating (power and sail) and fishing. The public visits the reservoir area daily; however, the number of visitor days per year could not be determined. Four chemical toilets have been provided for use by the general public. Their level of maintenance was found to be generally good. These toilets are located at the reservoir inlet area. There is currently no algae growth control program being maintained at this water storage site.

The watershed area is about 500 to 600 acres and is undeveloped. The watershed is used for cattle grazing. The immediate reservoir area is not fenced to preclude cattle access to the reservoir. Drainage from an extensive cattle grazing area is discharged into the reservoir near the South Bay Aqueduct Pumping Plant.

The reservoir area is affected by frequent strong winds. The reservoir itself is surrounded by wind-powered generators. These strong winds may have disturbed the water in the relatively shallow reservoir and created high turbidity levels.

Open Canal Sections. Table 5-2 shows the types and numbers of potential sources of contamination found during the survey of the three open canal sections.

Canal Control Structures, Siphons, and Wasteways--There are 12 check structures, each made up of four radial gates. There are two sections of the canal constructed as siphons, one under Orestimba Creek and the other under Garzas Creek. There are also two wasteways that permit the Aqueduct to be drained in case of an emergency. These wasteways are located between Check 2 and Check 3 and between Check 6 and Check 7. The check structures, siphons, and wasteways do not pose any risk to water quality.

Drain Inlets--A large number of drain inlets were found during the field survey of this section of the Aqueduct. About 570 of the noted drain inlets convey canal shoulder runoff into the Aqueduct when it rains. These drains range from 4 to 12 inches in diameter. Three drains that bring in canal shoulder drainage also drain stormwater from nearby highways such as Interstate 5 and State Highway 205. Drainages from adjacent undeveloped dry range lands are conveyed to the California Aqueduct at 17 locations. Four inlets drain intensively-farmed acreages as large as 100 to 200 acres into the canal. Most of these drains flow into the canal by gravity; however, some drainage is collected in natural or man-made sump (settling) areas and is then periodically pumped into the canal. At 46 locations, groundwater is pumped into the canal to reduce the pressure of shallow groundwater on the lining of the canal.

Bridges--There are 46 bridges spanning the three separate canal sections. Three are state bridges, 35 are county bridges, and eight are private and farm bridges.

Overchutes and Overcrossings--During the field survey, 93 overchute and pipeline overcrossing locations were found. There are multiple pipelines at some of these locations, so there is a total of 104 culvert overchutes and pipelines crossing the California Aqueduct. Most of the observed overcrossings are pipelines. The largest pipeline noted was 60 inches in diameter. The largest overchute found was 50 feet wide and 8 feet high. No sanitary sewer crossings were found, but the contents of some pipelines could not be identified. The overchutes and pipelines convey the following materials:

- 36 petroleum product lines
- 32 storm drainage lines
- 28 irrigation water lines (no hazard)
- 2 natural gas lines (no hazard)
- 6 pipes with unknown contents

There have been leaks in petroleum pipelines adjacent to the California Aqueduct that have resulted in minor amounts of petroleum products entering the water.

In 1988, a leak in a petroleum-products pipeline adjacent to the California Aqueduct inlet to Bethany Reservoir was discovered and repaired. A site investigation and characterization of the effects of the petroleum-contaminated soil is currently being conducted.

In 1984, during dewatering and repairs to the California Aqueduct, an oil sheen was noticed on bank storage water discharging to the Aqueduct through an expansion joint at about milepost 9.7. The source of the petroleum is thought to be a prior leak in a petroleum-products pipeline adjacent to the Aqueduct at this location. A site investigation and characterization of the effects of the petroleum-contaminated soil is currently being conducted. There is a potential for petroleum-contaminated water to enter the Aqueduct if this section of the Aqueduct is again dewatered.

In 1984, an oil sheen was noticed on sump water being discharged into the Aqueduct at milepost 62.39. The source of the water is shallow groundwater which is pumped to relieve pressure on the canal lining. The source of the petroleum was a former leak in a petroleum-products pipeline adjacent to the Aqueduct at this location. The sump water is no longer being conveyed into the canal but is pumped into a holding tank for off-site disposal. Remediation of the petroleum contamination at this location is being initiated.

Undercrossings--There are 16 undercrossings of relatively large diameter pipelines. These pipelines range from 36 to 93 inches in diameter. Fourteen of these pipelines convey storm drainage water from undeveloped lands, lands that are grazed by cattle, and lands that are intensively farmed. Two pipelines convey irrigation water.

Water-Service Turnouts--Six water-service turnouts were found. All are for predominantly agricultural service with possibly some domestic water use. Five of these turnouts are pumped, and one is by gravity.

Fishing Areas--In this reach, the California Aqueduct is accessible to the public through gated structures at key locations. These gates allow people to enter but exclude the entry of four-wheel vehicles. There are three locations where the public fishes in the Aqueduct. Two of the locations are equipped with two portable chemical toilets. The third does not have toilet facilities.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include the presence of nearby livestock holding pens, poultry farms, residential dwellings, defective canal lining areas, a large gravel pit operation, and industrial activities. Below mileage point 32.60, more intensive farming practices begin. Therefore, the impacts from seasonal aerial spraying may become more pronounced on the canal water downstream of this point 32.60.

Summary of Contaminant Sources

The major potential sources of contaminants to this segment of the SWP are:

1. Agricultural drainage and cattle grazing in the Bethany Reservoir watershed may contribute agricultural chemicals, pathogens, organics, and nutrients to the water.

Table 5-2. Potential Sources of Contamination to SWP Open Canal Sections, Clifton Court Forebay to O'Neill Forebay

Drain Inlets	640
Canal roadside drainage	570
Agricultural drainage	21
Groundwater	46
Other	3
Bridges	46
State	3
County	35
Farm or private	8
Overcrossings	104
Pipelines	78
Overchutes	26
Undercrossings	16
Drainage	14
Irrigation or domestic water	2
Water-Service Turnouts	6
Irrigation pumped upslope	5
Other	1
Fishing Areas	3

2. Roadside drainage, particularly drainage from Interstate 5 and Highway 205 contribute solids, metals, oil, and grease. Hazardous materials spilled on the Interstate 5 or Highway 205 bridges would drain directly to the Aqueduct.

3. Shallow groundwater pumped into the Aqueduct at 46 locations may contribute sodium, chloride, sulfate, trace elements, and total dissolved solids to the water.

O'NEILL FOREBAY AND SAN LUIS RESERVOIR

This section of the SWP is operated and maintained by DWR's San Luis Field Division. The Santa Clara Valley Water District, a Central Valley Project (CVP) contractor, receives water from San Luis Reservoir through the Pacheco Pumping Plant.

Physical Facilities

The major facilities that make up this part of the system include O'Neill Forebay, San Luis Pumping/Generating Plant, and San Luis Reservoir. Water from the Banks Pumping Plant enters the northern end of O'Neill Forebay. The water either flows by gravity through the forebay into the California Aqueduct on the southeastern side of the forebay or is lifted by the San Luis Pumping Plant up to San Luis Reservoir. The forebay also receives water from the Delta Mendota Canal via USBR's O'Neill Pumping Plant.

O'Neill Forebay has a storage capacity of 56,430 AF, a surface area of 2,700 acres, and about 12 miles of shoreline. This water impoundment is formed by a dam that is 14,350 feet long and 88 feet high. The maximum water depth is 40 feet, and the average water depth is about 21 feet.

Water is pumped into San Luis Reservoir by the San Luis Pumping/Generating Plant, which has eight pumps with a capacity of 11,000 cfs. Power is generated by reversing the water flow (17,600 cfs) from San Luis Reservoir back to O'Neill Forebay.

San Luis Reservoir has a storage capacity of 2,027,840 AF, a surface area of about 12,700 acres, and approximately 65 miles of shoreline. San Luis Reservoir has a maximum water depth of 274 feet and an average water depth of 160 feet. San Luis Reservoir is formed by a dam that is 18,600 feet long and 385 feet high. The water enters and exits through a common inlet/outlet tower. The USBR also feeds water out of San Luis Reservoir in a westerly direction to San Felipe Division water consumers with the Pacheco Pumping Plant.

San Luis Reservoir was completed in 1967 and filled in 1969. Approximately 67,000 AF of water is lost annually to evaporation, considering the gain by annual rainfall. The mean annual inflow by runoff from the watershed into San Luis Reservoir/O'Neill Forebay has not been calculated to date.

Historic Information and Past Concerns

The DHS has expressed minor concerns over the wastewater handling facilities around the recreational facilities at both San Luis Reservoir and O'Neill Forebay (Personal Communication, Cindy Forbes, DHS, 1989). The DHS has also expressed concern over the quality of DMC water entering O'Neill Forebay and mixing with SWP water. The general perception is that DMC water quality is poorer than SWP water quality. It is thought that at times, DMC water flows along the eastern side of O'Neill Forebay and directly into the Aqueduct with little mixing with SWP water.

Field Survey Results

The shoreline areas of O'Neill Forebay and San Luis Reservoir and the two pumping plants were inspected during the field survey.

O'Neill Forebay. O'Neill Forebay recreational facilities include boating with two boat launching facilities, community water and wastewater systems, parking areas, camping and picnicking, fishing, swimming, water skiing, and seasonal hunting.

The San Luis Creek Recreation Area is a day-use area, served by a community wastewater system with eight toilet facilities. The wastewater is pumped via a 6-inch force main to aerated evaporation/percolation ponds. The other major recreational facility is the Maderios Recreational Area, where overnight camping is permitted. This area has five portable chemical toilets that are in good condition. There is a large park area on the west shore of the lake with about 100 acres of irrigated lawn. Runoff from this lawn may reach the lake. There are no pleasure boat washdown facilities around the forebay. The recreational areas around the shoreline were found to be clean and well maintained. Weeds are controlled mostly by the use of Round-Up.

The watershed of O'Neill Forebay is undeveloped except for the recreational facilities. About 1,000 head of sheep use the watershed of O'Neill Forebay for grazing about 6 months of the year. There are a few underground fuel tanks around the forebay. They are all located at least 200 feet away from the shoreline. DWR conducts an algae monitoring program in which samples are collected monthly from four locations. Chemicals are not used for algae control in O'Neill Forebay.

San Luis Pumping and Generating Plant. A stabilization pond is used for the treatment and disposal of the wastewater generated by the 40-person operating staff. The wastewater handling facilities do not pose any significant water quality hazard to the water conveyance facilities.

Pacheco Pumping Plant. There are no wastewater handling facilities at this plant.

San Luis Reservoir. San Luis Reservoir recreational facilities include boating with two boat launching facilities, community water and wastewater systems, parking areas, camping and picnicking, fishing, swimming, water skiing, seasonal hunting, and the visitor center (at Romero Overlook).

There are two major recreational areas around the lake. The Basalt Area is equipped with domestic water facilities and a community wastewater collection, pumping, and disposal system. These wastewater facilities serve toilets and a recreational vehicle dumping station. Treatment and disposal is in two oxidation/evaporation ponds. This wastewater system includes pumping stations. The other major recreational area is Dinosaur Point. This area and the remaining minor recreational facilities around the reservoir are served by portable chemical toilets. In general, these toilets appear to be well maintained. The Romero Overlook facility has wastewater service with disposal in nearby evaporation/percolation ponds. There are no floating toilets on the lake at this time. The lake shoreline was found to be relatively clean. Solid wastes are handled very adequately around the shoreline facilities of the lake.

The reservoir is flanked by Highway 152 on the east and north sides. Runoff from this highway is tributary to the lake. This would include spills resulting from trucking accidents. Highway 152 is a major route for trucks hauling hazardous wastes from coastal industries to the Kettleman Hills hazardous waste disposal facility in Kings County.

Much of the watershed of San Luis Reservoir was purchased by the USBR and DWR. The California Department of Parks and Recreation (DPR) manages the land adjacent to the shoreline and strictly controls its use for public recreation. The remainder of the watershed is managed by the Bureau of Land Management. This department has allowed some grazing of livestock around the reservoir, but no farming or land development has been allowed. The management of this watershed will not be changed from what exists now.

The major drainages entering the reservoir from the watershed are Cottonwood Creek and San Luis Creek. There are no mining activities in the watershed other than a rock quarry. There are no underground fuel tanks buried near the reservoir. Fencing restricts access to the reservoir from higher elevation areas. The west end of the reservoir area is bordered by the San Luis Reservoir Wildlife Area and the Cottonwood Creek Wildlife Area.

DWR is monitoring the reservoir for algae growth. Samples are collected monthly at four different reservoir locations. There is no chemical algae treatment control program in the reservoir.

Summary of Contaminant Sources

The major potential source of contaminants to O'Neill Forebay and San Luis Reservoir is:

1. Roadside drainage from Highway 152 may contribute solids, metals, oil, and grease to the water of San Luis Reservoir. A hazardous materials spill on Highway 152 would drain into O'Neill Forebay and San Luis Reservoir.

O'NEILL FOREBAY TO END OF SAN LUIS FIELD DIVISION

This section of the California Aqueduct system is operated by DWR's San Luis Field Division. Domestic water is supplied to CVP contractors including the San Luis Water District, the Cities of Coalinga, Huron, and Avenal, and the Lemore Naval Air Station from this section of the Aqueduct. Agricultural water is supplied to Westlands Water District at numerous locations.

Physical Facilities

The major facilities that make up this stretch of the system include the Dos Amigos Pumping Plant (located at mileage point 86.73) and two sections of canal. The pumping plant consists of six pumps having a combined capacity of 13,450 cfs. There are two cement-lined canal sections within this segment of the California Aqueduct. One 16-mile-long section extends from O'Neill Forebay to the Dos Amigos Pumping Plant. The other 85-mile-long section extends from the Dos Amigos Pumping Plant to the southern end of the San Luis Field Division at mileage point 172.40.

Historic Information and Past Concerns

The DHS is particularly concerned about the San Luis portion of the SWP, which extends from O'Neill Forebay to the Kettleman City area. The DHS is specifically concerned about the quantity and quality of drainage that is conveyed into the Aqueduct from the Coast Range and farm land adjacent to the Aqueduct. The Arroyo Pasajero watershed contains numerous asbestos mines. Some of the drainage from this watershed enters the Aqueduct and results in high levels of sediment and asbestos in the water. Drainage from thousands of acres of land that is intensively farmed is also discharged into the Aqueduct (DHS, 1982).

Field Survey Results

The Dos Amigos Pumping Plant and the open canal sections of the Aqueduct were inspected.

Dos Amigos Pumping Plant. The wastewater collection, pumping, treatment, and leach field disposal facilities are potential sources of contaminants at this pumping plant. According to plant personnel, the wastewater lift station has malfunctioned on occasions. Also, the septic tank has overflowed at times. Surface runoff from the pumping plant site drains into the Aqueduct.

Open Canal Sections. Table 5-3 shows the types and numbers of potential sources of contamination found during the survey of the open canal sections.

Table 5-3. Potential Sources of Contamination to SWP Open Canal Sections, O'Neill Forebay to End of San Luis Field Division

Drain Inlets[a]	332
Canal roadside drainage	227
Agricultural drainage	87
Groundwater	13
Other	5
Bridges	47
State	5
County	39
Farm or private	3
Overcrossings	53
Pipelines	53
Overchutes	0
Undercrossings	73
Drainage	3
Irrigation or domestic water	70
Water-Service Turnouts	121
Irrigation pumped upslope	99
Other	22
Fishing Areas	10

[a]Salt Creek, Little Panoche Creek, Cantua Creek, and Arroyo Pasajero are discharged into the Aqueduct in addition to the drain inlets listed in this table.

Canal Control Structures and Siphons--There are nine check structures, each made up of four radial gates. The Aqueduct is constructed as a siphon under Panoche Creek at mileage point 108.71. Neither the check structures nor the siphon pose any significant risk to Aqueduct water quality.

Drain Inlets--During the field survey of this section of the Aqueduct, a large number of drain inlets were found. About 227 of the drains convey canal shoulder runoff into the Aqueduct when it rains. These drains range from 4 to 12 inches in diameter. There are 54 permanent drain structures that convey stormwater runoff and agricultural tailwater into the Aqueduct from large acreages of cattle grazing lands, row crops, vineyards, and orchards. These drains range from pipes to large culvert inlet structures. The 46 drainpipe inlets found vary from 24 to 48 inches in diameter. The eight culvert structures found vary from 3 feet by 3 feet to 4 feet by 6.5 feet in cross-section. Not all of these drains flow into the Aqueduct by gravity. Some of these drainages are first collected in natural or man-made sump (settling) areas and are then periodically pumped into the Aqueduct. There are another 33 temporary drain inlets that convey drainages from cattle grazing lands and from farmed areas into the Aqueduct. These temporary installations consist of permanently constructed pump pads where portable pumping equipment is set up and operated on a demand basis. The lands drained by these facilities varied in land use and acreage. The volume of water entering the Aqueduct from these 87 drainages was not quantified during this study.

Shallow groundwater is pumped into the Aqueduct to reduce the pressure of groundwater on the canal lining at 13 locations. These drain discharge pipes vary in size from 4 inches to 10 inches in diameter. There are five drains that convey runoff from canal right-of-ways, nearby public and private roads, and developed land areas near the canal. These drainpipe discharges range from 24 to 48 inches in diameter.

There are several major drainage structures that periodically bring in major creeks and drainages from relatively large watersheds in the Coast Range. The watersheds were not inspected during the field survey, but a literature review was conducted and maps were inspected.

Little Panoche Creek drains Little Panoche Canyon. From the examination of maps, it can be seen that unsewered residential dwellings, mining, cattle ranches, farming, and Interstate 5 traffic can all have an impact on the water quality of the runoff that may enter the Aqueduct. Where Little Panoche Creek intersects with the Aqueduct near mileage point 97, there is a 5-foot by 6-foot culvert underchute route below the Aqueduct and a 4-foot by 5-foot drain culvert that discharges into the Aqueduct. The drain inlet permits underchute overflows to enter the Aqueduct.

Cantua Creek drains an extensive farming area. From the examination of maps, it can be seen that unsewered residential dwellings, cattle ranching, farming, and Interstate 5 traffic can all have an impact on the water quality of the runoff. Where Cantua Creek intersects with the Aqueduct near mileage point 134, there is a 4-foot by 6-foot drain culvert that discharges into the Aqueduct.

Salt Creek drains an extensive agricultural area. From the examination of maps, it can be seen that unsewered residential dwellings, cattle ranching, farming, and Interstate 5 traffic can all have an impact on the water quality of the runoff. Where Salt Creek intersects with the Aqueduct at mileage point 135, there is a 48-inch drain inlet that discharges into the Aqueduct.

Several creeks from a very extensive watershed join and drain into the Arroyo Pasajero. These creeks drain extensive mountain areas that contain various mines, including several asbestos mines. The Arroyo Pasajero watershed contains the cities of Huron and Coalinga. Overflows from the wastewater treatment/disposal ponds and stormwater runoff from Huron and Coalinga enters the Arroyo Pasajero. The Arroyo Pasajero also receives runoff from oil drilling and storage facilities, cattle grazing areas, unsewered residential homes, and farming areas.

The Arroyo Pasajero dead-ends at the California Aqueduct near mileage point 158 in an area west of the canal between Lassen Avenue and Gale Avenue. In this 2,000 plus acre area, the runoff ponds and is currently held in specially designed ponding basins prior to entering the California Aqueduct through four 4-foot by 5-foot culverts. There is one underchute facility nearby to permit the drainage of the Arroyo Pasajero to cross under the Aqueduct.

Avenal takes water out of the California Aqueduct downstream of the Arroyo Pasajero. The city has persistently complained about sand, silt, and other debris introduced to the Aqueduct by the Arroyo Pasajero. In the early 1980s, high levels of asbestos in the water were traced to the Arroyo Pasajero. Irrigation water consumers and DWR have also expressed concerns about excessive sediments entering the Aqueduct and reducing the water conveyance capacity of the canal. Runoff through the still-existing asbestos mine tailings, together with asbestos fall-out over a wide area because of historic dry-milling operations, are now known to be the cause of high levels of asbestos fibers [up to 15 billion fibers/liter, as determined by Metropolitan Water District of Southern California (MWD), DWR, and DHS] in some of the creeks feeding into the Arroyo Pasajero. Also, in association with inflow events from the Arroyo Pasajero, high numbers of fibers have been found in the California Aqueduct downstream of Gale Avenue, the Arroyo Pasajero drain inlet.

DWR attempted to mitigate the asbestos problem by dredging the Aqueduct both upstream and downstream of the inlet. This was done with mixed results since the asbestos fibers are so small. The USBR and DWR have conducted feasibility studies to reduce and eliminate the discharge of the Arroyo Pasajero into the Aqueduct. The discharge has been reduced to some extent by increasing the storage/ponding capacity in the Arroyo Pasajero floodplain adjacent to the Aqueduct. This was done by excavating areas filled in by stream sediment. Studies have recently been completed to determine the feasibility of constructing upstream dams on the various creeks that contribute asbestos, other sediments, and significant runoff. Watershed control and watershed management practices have been identified to reduce erosion and asbestos-laden sediments. DWR will soon publish a report identifying alternatives, incorporating various combinations of possible actions, designed to protect the California Aqueduct from a 100-year flood event at the Arroyo Pasajero inlet. EPA has been working on remedial action plans at several abandoned asbestos mines. Enforcement and cleanup efforts are planned. It is not known if these cleanup efforts will soon result in significant improvements in runoff water quality.

Bridges--There are 47 bridges that span the two separate canal sections. There are five state bridges, 39 county bridges, and three farm bridges.

Overchutes and Overcrossings--During the field survey, 39 pipeline overcrossing locations were found. There are multiple pipelines at some of these locations so there is a total of 53 pipelines crossing the Aqueduct. All of the overcrossings are pipelines that range from 2 inches to 63 inches in diameter. The pipelines contain the following materials:

- 22 petroleum product lines
- 22 irrigation water lines (no hazard)
- 6 natural gas lines (no hazard)
- 3 pipes with unknown contents

No storm drains, farm tailwater, or sanitary sewer lines were found.

Undercrossings--During the field survey, 71 undercrossing locations were found. There are multiple pipelines at some of these locations, so there is a total of 73 culverts and pipelines crossing under the Aqueduct. There are three rectangular concrete culverts and 70 pipelines. The pipelines ranged from 3 to 30 inches in diameter. The three culverts convey storm drainage water from lands that are undeveloped, grazed by cattle, and lands that are intensively farmed. The pipelines convey irrigation and domestic water.

Water-Service Turnouts--There are 121 water-service turnouts to mostly agricultural water users and a few domestic water users. Twenty-two of the water outlet structures flow by gravity, and 99 are pumped.

Fishing Areas--The canal portions of the Aqueduct are accessible to the general public through gated structures at key locations. These gates permit people to enter but exclude the entry of four-wheel vehicles. Ten areas were identified as locations where the public fishes in the Aqueduct. Four of these locations are equipped with portable chemical toilets, but six fishing areas do not have toilet facilities.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include the presence of livestock holding pens, developed properties (residential, commercial, and industrial) near the canal, defective canal lining, mercury-containing pump controls located adjacent to the canal, and trash collection bins. DWR is replacing the mercury-containing pump controls.

Summary of Contaminant Sources

The major sources of contaminants to this segment of the SWP are:

1. Drainage from the Arroyo Pasajero, Little Panoche Creek, Cantua Creek, and Salt Creek may contribute many different types of contaminants including sediment, asbestos fibers, agricultural chemicals, pathogens, organics, and nutrients to the water.

2. Agricultural drainage from intensively-farmed areas and cattle grazing areas may contribute agricultural chemicals, pathogens, organics, and nutrients to the water.

3. Shallow groundwater pumped into the Aqueduct at 13 locations may contribute minerals and salts to the water.

END OF SAN LUIS FIELD DIVISION TO THE KERN RIVER INTERTIE

This section of the SWP is operated and maintained by DWR's San Joaquin Field Division. The Kern County Water Agency receives domestic water from this segment of the California Aqueduct, through the Cross Valley Canal.

Physical Facilities

The major facilities that make up this segment of the SWP include a 69-mile-long canal segment that extends from the end of the San Luis Field Division (mileage point 172.40) to the Kern River Intertie (mileage point 241.02) and the diversion structure to the Coastal Branch at mileage point 184.63.

Historic Information and Past Concerns

The DHS has expressed concerns about the possibility of Tulare Lake flood water being pumped into the California Aqueduct (DHS, 1982).

Field Survey Results

The open canal section of this segment of the Aqueduct was inspected.

Open Canal Section. There is one continuous cement-lined canal section within this segment of the California Aqueduct. Table 5-4 shows the types and number of potential sources of contamination found during the survey of the open canal section.

Canal Control Structures and Siphons--There are seven canal check structures, each made up of four radial gates. Also, the canal is constructed as a siphon under Avenal Gap at mileage point 184.27 and under Temblor Creek at mileage point 220.27. The check structures and siphons do not pose any significant risk to canal water quality.

Table 5-4. Potential Sources of Contamination to SWP Open Canal Sections, End of San Luis Field Division to the Kern River Intertie

Drain Inlets	435
Canal roadside drainage	429
Agricultural drainage	0
Groundwater	1
Other	5
Bridges	22
State	4
County	11
Farm or private	7
Overcrossings	111
Pipelines	59
Overchutes	52
Undercrossings	12
Drainage	10
Irrigation or domestic water	2
Water-Service Turnouts	30
Irrigation pumped upslope	3
Other	27
Fishing Areas	9

Drain Inlets--During the field survey of this section of the Aqueduct, 435 drain inlet locations were found. About 429 out of the 435 noted drains convey canal shoulder runoff into the Aqueduct when it rains. They range from 6 to 12 inches in diameter. There are five additional drains that convey runoff from canal right-of-ways, nearby public and private roads, and developed land areas near the Aqueduct. These drainpipes are 6 inches in diameter. There are no direct discharges into the Aqueduct from farmed areas, cattle grazing lands, or urbanized areas. At one location, shallow groundwater is pumped into the Aqueduct to reduce the pressure of shallow groundwater on the canal lining.

Bridges--There are 22 bridges that span this canal section. There are four state bridges, 11 county bridges, and seven private/farm bridges.

Overchutes and Overcrossings--During the field survey, 79 overchute and pipeline overcrossing locations were found. There are multiple pipelines at some of these locations, so there is a total of 11 culvert overchutes and pipelines crossing the Aqueduct. There are 52 uncovered rectangular concrete overchutes ranging from 2.5 feet by 2.5 feet to 6 feet by 32 feet in cross section. The overchutes convey runoff from grazing lands, agricultural fields, and livestock impoundment areas. There are 59 pipelines ranging from 2 to 34 inches in diameter. The pipelines convey the following materials across the Aqueduct:

- 9 storm runoff from grazing lands, agricultural fields, and oil field areas
- 28 petroleum product lines
- 8 irrigation and domestic water lines (no hazard)
- 3 natural gas lines (no hazard)
- 11 pipes with unknown contents

No sanitary sewer lines were found, but the contents of some pipelines could not be identified.

Undercrossings--There are 11 undercrossings involving 12 pipelines. The pipelines range from 1 to 60 inches in diameter. Ten pipelines convey storm drainage from lands that are undeveloped, grazed by cattle, lands that are farmed, and lands that are used for crude oil production. Two pipelines convey irrigation water and domestic water.

Water-Service Turnouts--There are 30 water-service turnouts to various irrigation water districts, one of which supplies domestic water to the Kern County Water Agency. Three of the turnouts are pumped, while the other 27 turnouts flow by gravity.

Fishing Areas--This portion of the Aqueduct is accessible to the general public through gated structures at key locations. These gates permit people to enter but exclude the entry of four-wheel vehicles. There are nine locations where the public fishes in the Aqueduct. Only one of the locations is equipped with portable chemical toilets.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include the presence of nearby livestock holding pens, developed properties (residential, commercial, and industrial) near the canal, defective canal lining, oil industry structures located near the canal, and numerous trash collection and burning bins. Other items noted along this stretch of the Aqueduct are:

- There are signs of significant erosion into the canal from the unlined side slopes; sand bagging has been implemented to mitigate the problem.

- Several overchute culverts are known to periodically overflow into the canal.

Summary of Contaminant Sources

The potential sources of contaminants to this segment of the SWP are not as significant as the sources to other segments. There are a large number (435) canal roadside drainage inlets. Agricultural drainage is conveyed under or over the canal.

COASTAL BRANCH

The Coastal Branch is operated and maintained by DWR's San Joaquin Field Division. There are no domestic water turnouts along the Coastal Aqueduct.

Physical Facilities

The major facilities that make up this segment of the SWP include the Las Perillas Pumping Plant, the Badger Hill Pumping Plant, and open canal and pipeline conveyance facilities. The Las Perillas Pumping Plant consists of six pumps with a combined capacity of 460 cfs. The static lift is about 55 feet. The Badger Hill Pumping Plant consists of six pumps, which have a combined capacity of 454 cfs. The static lift is about 151 feet. There are three continuous cement-lined canal sections in the Coastal Branch. The first is a 1-mile-long section from the California Aqueduct to the Las Perillas Pumping Plant at mileage point 1.16. The second is a 3-mile-long section from the Las Perillas Pumping Plant to the Badger Hill Pumping Plant at mileage point 4.27. From this pumping plant, the water is conveyed through a pipeline for a distance of about 3,400 feet to mileage point 4.93, beyond which the third open canal section spans a distance of about 10 miles (mileage point 4.93 to 14.83). At the end of the Coastal Branch is the Berenda Mesa Pumping Plant (not part of the State Water Project) that is owned by the Berenda Mesa Water District. This pumping plant conveys water from the Coastal Branch through private pipelines to points of agricultural use.

Historic Information and Past Concerns

DHS has not expressed any concerns about the Coastal Branch since there are currently no domestic water deliveries.

Field Survey Results

The pumping plants and open canal sections of the Coastal Aqueduct were inspected.

Pumping Plants. The method of wastewater collection, treatment, and disposal (septic tank/leach field system) at the Las Perillas and Badger Hill pumping stations does not pose a water quality hazard to this water conveyance system. This conclusion is made due to the location of the disposal facilities and the fact that the existing systems have functioned to date without any significant problems.

Pipeline Segment. The route of the 0.65-mile-long pipeline segment of the Coastal Branch was not surveyed. The pipelines are 6.5 feet in diameter. No significant sanitary hazards associated with these pipeline facilities are readily apparent.

Open Canal Sections. Table 5-5 shows the types and numbers of potential sources of contamination found during the survey of the three open canal sections.

Canal Control Structures and Siphons--There are three canal check structures, each made up of two radial gates. The Coastal Branch is constructed as a siphon under Highway 33 at mileage point 9.34. Neither the check structures nor the siphon appears to pose any risk to water quality.

Drain Inlets--During the field survey of the Coastal Branch, 32 drain inlets were found. All 32 drains convey canal shoulder runoff into the canal when it rains. They are all 8 to 10 inches in diameter.

Bridges--There are four bridges that span the canal section. Two are county bridges and two are private bridges.

Overchutes and Overcrossings--During the field survey, 42 overchute and pipeline overcrossing locations were found. There are multiple pipelines at some of these locations so there is a total of 42 overcrossings. The culverts that convey runoff from cattle grazing land range in cross-section from 4 feet by 4 feet to 4 feet by 6 feet. There are 38 pipelines ranging from 6 to 36 inches in diameter. The pipelines convey the following materials across the Coastal Aqueduct.

- 29 storm runoff from grazing land and agricultural fields
- 7 petroleum product lines
- 2 natural gas lines (no hazard)

There are no sanitary sewer lines crossing the canal.

Undercrossings--During the field survey, eight undercrossing locations were found involving 12 pipelines. The pipelines range from 18 to 30 inches in diameter. The pipelines

Table 5-5. Potential Sources of Contamination to Open Canal Sections, Coastal Branch

Drain Inlets	32
Canal roadside drainage	32
Agricultural drainage	0
Groundwater	0
Other	0
Bridges	4
State	0
County	2
Farm or private	2
Overcrossings	42
Pipelines	38
Overchutes	4
Undercrossings	8
Drainage	12
Irrigation or domestic water	0
Water-Service Turnouts	3
Irrigation pumped upslope	2
Other	1
Fishing Areas	0

convey storm drainage waters from lands that are undeveloped, grazed by cattle, and lands that are farmed.

Water-Service Turnouts--There are three agricultural water-service turnouts. Two of these water outlet structures are operated by means of pumps and one is operated by gravity.

Fishing Areas--The Coastal Branch is not accessible to the general public, so there are no fishing areas.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include developed properties (residential, commercial, and industrial) near the canal, defective canal lining, and oil industry-related structures located near the canal.

Summary of Contaminant Sources

The potential sources of contaminants to this segment of the SWP are not as significant as the sources to other segments. Agricultural runoff waters are either conveyed under or over the canal.

KERN RIVER INTERTIE TO THE EAST-WEST BRANCH BIFURCATION

This section of the SWP is operated and maintained by DWR's San Joaquin Field Division. There are no domestic water-service turnouts in this segment of the SWP.

Physical Facilities

The major facilities that make up this segment of the SWP include the Kern River Intertie inlet structure at mileage point 184.63; the Buena Vista, Wheeler Ridge, Wind Gap, and the A.D. Edmonston pumping plants and penstocks; the Tehachapi Afterbay; and the various open canal sections between these pumping and storage facilities.

Water from the Kern River is diverted into the Kern River Intertie and pumped into the California Aqueduct below Bakersfield. As discussed in Chapter 2, the intertie is used during wet years to relieve flooding in the Tulare and Buena Vista Lake Beds.

The Buena Vista Pumping Plant consists of 10 pumps which have a capacity of 5,405 cfs. The normal static lift of the station is 209 feet. The water is discharged to the higher elevation through 8- to 9-foot-diameter penstocks. The Wheeler Ridge Pumping Plant consists of nine pumps which have a capacity of 5,445 cfs. The normal static lift of the station is 223 feet. The water is discharged to the higher elevation through 7- to 9-foot-diameter penstocks. The Wind Gap Pumping Plant consists of nine pumps having a capacity of 4,995 cfs. The normal static lift of the station is 518 feet. The water is discharged to the higher elevation through one 9.5-foot-diameter penstock and three 12.5-foot-diameter penstocks. The A.D. Edmonston Pumping Plant consists of 14 pumps that have a capacity of 4,480 cfs. The normal static lift of the station is 1,920 feet through penstocks ranging from 12.5 to 14.0 feet in diameter. The Tehachapi Afterbay from South Portal No. 4 (mileage point 303.45) to the bifurcation of the California Aqueduct (mileage point 303.92) is a 0.5-mile-long enlarged canal segment that receives the water pumped over the Tehachapi Mountains by the A.D. Edmonston Pumping Plant. At the end of the Tehachapi Afterbay, the California Aqueduct bifurcates into the East and West Branches.

There are four cement-lined canal sections (totaling 51.7 miles) within this segment of the SWP. The first section is 10 miles long and extends from the Kern River Intertie to the Buena Vista Forebay and Pumping Plant. The second section is 27 miles long and extends from the Buena Vista Pumping Plant penstocks to the Wheeler Ridge Pumping Plant. The third section is 2 miles long and extends from the Wheeler Ridge Pumping Plant penstocks to the Wind Gap Pumping Plant. The fourth section is 13 miles long and extends from the Wind Gap Pumping Plant penstocks to the A.D. Edmonston Forebay and Pumping Plant.

Historic Information and Past Concerns

The DHS believes the water quality of the California Aqueduct can be adversely impacted by discharges of Kern River water at the Kern River Intertie (DHS, 1982). The Kern River receives oil industry waste discharges regulated under the National Pollutant Discharge Elimination System program. Urban runoff from the City of Bakersfield is discharged to the Kern River at only one location. Most Bakersfield urban runoff is discharged to detention basins. In 1982, the Kern River Intertie was used to convey Kaweah River water from Sequoia-Kings Canyon National Park into the California Aqueduct. This was done via the Friant Kern canal and the Kern River. The Friant Kern Canal receives many agricultural discharges. Use of the Kern River Intertie, however, occurs primarily in winter months when agricultural discharges are minimized and dilution capacity is high. Water quality requirements for use of the Intertie are discussed in Chapter 4.

DHS feels that its concerns are warranted because of the near downstream domestic water users that are supplied by the Tehachapi-Cummings County Water District (TCCWD) (Personal Communication, Richard Haberman, 1989). This district retails domestic water to their own domestic water consumers and wholesales domestic water to the Stallion Springs Community Services District, the Golden Hills Community Services District, and to the State Prison at Tehachapi. The TCCWD however does not supply SWP surface water. They use SWP water to recharge their groundwater basin and supply groundwater pumped from well fields.

Field Survey Results

The pumping plants, Tehachapi Afterbay and the open canal sections of the Aqueduct were inspected. The watershed tributary to the Kern River Intertie is discussed in Chapter 4.

Pumping Plants. Wastewater service at the Buena Vista, Wheeler Ridge, Wind Gap, and Edmonston pumping plants is provided by septic tank/leach field disposal systems. The facilities at the four pumping plants appeared very well maintained and do not pose any significant water quality hazards to the water conveyance system. The wastewater facilities were adequately designed and sited. To date, no significant operational/breakdown problems have been noted. Local site drainage and drainage from surrounding range lands are conveyed into the pumping station forebays. The sites are fenced to exclude the public.

Tehachapi Afterbay to Bifurcation. This is a 0.5-mile-long lined canal. The site is fenced. Surface runoff from local cattle-grazed rangelands drain into the afterbay through man-made drainage structures. This drainage is the same as the drainage that is conveyed into the various forebays at each of the upstream pumping plants in the San Joaquin Valley.

Open Canal Sections. Table 5-6 shows the types and numbers of potential sources of contamination found during the survey of the open canal sections.

Canal Control Structures and Siphons--There are nine check structures with radial gates and ten canal siphons. None of these check structures has any sanitary significance. The canal is constructed as underground siphons at the following locations:

	Mileage Point
Sandy Creek	254.08
Sunset Railroad Tracks and Basin Road	259.65
Santiago Creek	261.72
Los Lobos Creek	264.37
San Emidio Creek	267.36
Old River Road	270.16
Pleitito Creek	271.27
Salt Creek	283.95
Grapevine Creek	287.09
Pastoria Creek	292.11

Drain Inlets--During the field survey of this section of the Aqueduct, 327 drain inlet locations were found. All 327 drains convey canal shoulder runoff into the Aqueduct when it rains. They range from 6 to 12 inches in diameter. There are no direct discharges into the canal from farmed areas, cattle grazing lands, or urbanized areas.

Bridges--There are 17 bridges that span the four canal sections. There are three state bridges, six county bridges, and eight private/farm bridges.

Overchutes and Overcrossings--There are 60 canal overchute and pipeline overcrossing locations. There are multiple pipelines at some of these locations, so there is a total of 78 overchutes and pipelines crossing the Aqueduct. There are 24 uncovered rectangular concrete

Table 5-6. Potential Sources of Contamination to SWP Open Canal Sections, Kern River Intertie to the East-West Branch Bifurcation

Drain Inlets	327
Canal roadside drainage	327
Agricultural drainage	0
Groundwater	0
Other	0
Bridges	17
State	3
County	6
Farm or private	8
Overcrossings	78
Pipelines	54
Overchutes	24
Undercrossings	31
Drainage	19
Irrigation or domestic water	6
Other	6
Water-Service Turnouts	23
Irrigation pumped upslope	8
Other	15
Fishing Areas	10

culverts ranging in cross-section from 5 feet by 5 feet to 8 feet by 42 feet. The overchutes carry drainage from grazing lands. There are 54 pipelines ranging from 2.5 to 30 inches in diameter. The pipelines convey the following materials across the Aqueduct:

- One storm runoff from oil reserve lands
- 20 petroleum product lines
- 16 irrigation and domestic water lines (no hazard)
- 8 natural gas lines (no hazard)
- 9 pipes with unknown contents

No sanitary sewer lines were found, but the contents of some pipelines could not be identified.

Undercrossings--There are 29 undercrossings involving 31 pipelines. The pipelines range from 1.5 to 90 inches in diameter. Nineteen pipelines convey storm drainage waters from lands that are undeveloped, grazed by cattle, and lands that are farmed. Four pipes convey petroleum products, and two lines convey natural gas. Six pipelines convey irrigation water and, in some cases, domestic water.

Water-Service Turnouts--There are 23 water-service turnouts to various water districts. Eight of the turnouts are pumped. The other 15 turnouts are operated by gravity.

Fishing Areas--This portion of the Aqueduct is accessible to the general public through gated structures at key locations. These gates permit people to enter but exclude the entry of four-wheel vehicles. Ten areas were identified as locations where the public fishes in the Aqueduct. Only five of the ten locations are equipped with portable chemical toilets.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include the presence of developed properties (residential, commercial, and industrial) near the canal, defective canal lining, oil industry structures located near the canal, trash accumulation along the canal, and numerous trash collection and burning bins.

Summary of Contaminant Sources

The potential sources of contaminants to this segment of the SWP are not as significant as the sources to other segments. When Kern River water is discharged into the Aqueduct during wet years, downstream water districts sometimes have difficulty chemically preconditioning the water prior to filtration. This is discussed in more detail in Chapter 6.

WEST BRANCH

This section of the SWP is operated and maintained by DWR's Southern Field Division. The Metropolitan Water District of Southern California and the Castaic Lake Water Agency take water out of Castaic Lake.

Physical Facilities

The major facilities that make up this segment of the Aqueduct system include:

Oso Pumping Plant. This pumping plant is located at mileage point 1.49. This station consists of eight pumps which have a capacity of 3,252 cfs. The average static lift of this pumping station is about 231 feet. The water is lifted through two 5-foot-diameter penstocks which are 2,036 feet long.

Power Plants. There are two power generating plants along the West Branch. The William E. Warne Power Plant is located at mileage point 14.07, and the Castaic Power Plant is located at mileage point 25.82. The William E. Warne Power Plant consists of two power generation units fed by one 12-foot diameter penstock which is 1,460 feet long and 650 feet in elevation. The Castaic Power Plant consists of seven power generation units, fed by penstock facilities, which are 2,530 feet long and drop 1,050 feet in elevation. After power generation, the water discharges into Elderberry Forebay, which is an arm of Castaic Lake. This power plant is also used to pump water from Elderberry Forebay back to Pyramid Lake during off-peak power periods. The rate of water return can be as high as 17,600 cfs. This plant is owned by the Los Angeles Department of Water and Power.

Underground Portions of West Branch. There are two underground water conveyance structures. The first major underground facility is the Peace Valley Pipeline. This pipeline is 12 feet in diameter and 5.5 miles long. It conveys water from the end of the open canal portion of the West Branch (mileage point 8.33) to the William E. Warne Power Plant penstocks at mileage point 14.07. The second major underground facility is the Angeles Tunnel. This facility is 30 feet in diameter and is 7.1 miles long. It conveys water from Pyramid Lake to the Castaic Power Plant penstocks at mileage point 25.34.

Open Canal Sections. There are three small, open canal sections (totaling 6.5 miles) within this segment of the Aqueduct. The first canal segment is from the bifurcation of the California Aqueduct (mileage point 0.00) to mileage point 1.45, the inlet into the forebay of the Oso Pumping Plant. This section of the West Branch is called the Oso Canal. The second canal segment is from the Oso Pumping Plant penstocks (mileage point 1.90) to the inlet of Quail Lake at mileage point 4.64. This section of the West Branch is called the Upper Quail Canal. The third canal segment is from the outlet of Quail Lake at mileage point 6.07 to the beginning of the Peace Valley Pipeline at mileage point 8.33.

Quail Lake. Quail Lake is formed by a 40-foot-high dam. It has a storage capacity of 7,580 AF, a surface area of 290 acres, and about 3 miles of shoreline.

Pyramid Lake. Pyramid Lake is formed by 400-foot-high Pyramid Dam on Piru Creek and other drainages such as Gorman Creek. The lake and dam were completed during 1973. The reservoir is located about 50 miles northwest of downtown Los Angeles in the Angeles National Forest. The reservoir has a storage capacity of 171,200 AF, a surface area of about 1,300 acres, and about 21 miles of shoreline. The water enters the lake through the William E. Warne Power Plant on its most northern end. The water leaves the reservoir east of the dam through the Angeles Tunnel.

Castaic Lake. Castaic Lake is formed by Castaic Dam, which is 425 feet high. This reservoir is the southern terminus of the West Branch of the California Aqueduct. Castaic Lake has a storage capacity of 323,700 AF, a surface area of 2,240 acres, and about 29 miles of shoreline. Shaped somewhat like a "V", Castaic Lake's two arms branch to the northeast (Elizabeth Lake Canyon arm) and the northwest (Castaic Canyon arm). The upper one-third of the Castaic Canyon arm is called Elderberry Forebay. Elderberry Forebay Dam cuts across the Castaic Canyon arm from Elderberry Forebay, which has a water surface elevation about 15 feet higher than the rest of Castaic Lake. The forebay has a storage capacity of 33,000 AF, a surface area of 500 acres, and approximately 7 miles of shoreline.

Elderberry Forebay receives water from the Castaic Power Plant and supplies Castaic Lake by means of an outlet tower. Water from Elderberry Forebay is pumped back into Pyramid Lake during off-peak power periods so that power can be generated during peak power periods. Castaic Lake receives its water from Elderberry Forebay. Water is withdrawn from Castaic Lake through a gated outlet tower near Castaic Dam. The water is conveyed to MWD's Jensen Filtration Plant and to a filtration plant owned and operated by the Castaic Lake Water Agency. Water is also diverted to the Los Angeles County Department of Parks and Recreation for use around the recreational areas.

Historic Information and Past Concerns

The DHS staff expressed concern that wastewater spills from the two floating toilets or the Warm Springs Rehabilitation Center could adversely affect drinking water quality due to the proximity of the downstream users to the lake (Personal Communication, Gary Yamamoto, 1989). There has been one spill during pump-out operations at the floating toilets (DHS, 1984), but there have been no operational problems at the Warm Springs Rehabilitation Center that have resulted in wastewater spills.

Field Survey Results

The Oso Pumping Plant, power plants, open canal sections, and lakes were inspected.

Oso Pumping Plant. Wastewater service at the Oso Pumping Plant is provided to 2 to 16 plant operators and occasional visitors by a septic tank/leach field disposal system. There have been no recent problems with these facilities. The leach field is located about 500 feet from the Aqueduct. Local site drainage is conveyed into the pumping station forebay. The site is fenced to preclude public access. The wastewater handling facilities do not pose any significant water quality hazards to this water conveyance facility.

Power Plants. Wastewater service at the William E. Warne and Castaic Power Plants is provided by septic tank/leach field disposal systems. The William E. Warne plant has 10 to 12 operators and occasional visitors. The septic tank/leach field facilities malfunctioned 2 to 3 years ago. Repairs have been made, and the system has been functioning properly since. The Castaic plant has about 30 operators and some occasional visitors. The septic tank/leach field is currently said to be free of significant problems. There were some lift station blocking problems some time ago. Overflows from the septic tank and leach field would be tributary to the afterbay. According to plant personnel, the septic tank has never been pumped. Local site drainage is conveyed into Pyramid Lake at the William E. Warne Power Plant and is conveyed into Elderberry Afterbay at the Castaic Power Plant. Both sites are fenced to exclude unauthorized personnel. A 200-gallon hydraulic oil spill occurred at the William E. Warne Power Plant in October 1989 and entered Pyramid Lake. This spill was cleaned up quickly by DWR personnel.

Open Canal Sections. Table 5-7 shows the types and numbers of potential sources of contamination found during the survey of the open canal sections.

Canal Control Structures--There is one check structure with radial gates. This structure does not have any sanitary significance. There are two sections of the canal constructed as siphons under Oso Creek and Highway 138.

Drain Inlets--During the field survey of this section of the Aqueduct, 29 drain inlet locations were found. Sixteen of the 29 noted drains convey canal road and shoulder runoff into the canal when it rains. They range from 6 to 12 inches in diameter, and most are 8 inches in diameter. Some of these drains also convey drainage from adjacent sloping rangelands (grazed and ungrazed), located around and near power generating plant/pumping station forebay/afterbay structures. At 13 locations, shallow groundwater is pumped into the canal to relieve the pressure of groundwater on the canal lining.

Bridges--There is one county bridge that spans this canal section.

Overchutes and Overcrossings--There is one natural gas pipeline that crosses the open canal segments of the Aqueduct.

Undercrossings--There are four pipeline undercrossings. These pipelines range from 48 to 72 inches in diameter. The pipelines convey storm drainage waters from lands that are grazed by cattle.

Table 5-7. Potential Sources of Contamination to SWP Open Canal Sections, West Branch

Drain Inlets	29
Canal roadside drainage	16
Agricultural drainage	0
Groundwater	13
Other	0
Bridges	1
State	0
County	1
Farm or private	0
Overcrossings	1
Pipelines	1
Overchutes	0
Undercrossings	4
Drainage	4
Irrigation or domestic water	0
Other	0
Water-Service Turnouts	1
Irrigation pumped upslope	0
Other	1
Fishing Areas	2

Water-Service Turnouts--There is only one domestic water-turnout structure. It is not operational and has no sanitary significance.

Fishing and Picnic Areas--Two areas were identified as locations where the public fishes in or picnics alongside the Aqueduct. One of the two locations is equipped with portable chemical toilets.

Quail Lake. The drainage area of Quail Lake is about 4 square miles. The amount of annual runoff from the watershed into the reservoir has not been determined. DWR has built an access road that encompasses the entire lake. This road is used for maintenance purposes and for access to the West Branch of the California Aqueduct. Public cars and boats are not allowed to enter the reservoir area. Only walk-in fishermen are admitted. The immediate reservoir area is fenced. Quail Lake is a popular public fishing lake. There is a picnic area without toilets where the West Branch Aqueduct enters Quail Lake. There are two chemical toilets for public use located on the west end of the lake in the public parking area. They are not well maintained. The shoreline around the lake is full of trash. Weeds are occasionally controlled by use of Round-up.

The land surrounding this lake on the northeast, north, and northwest is very heavily grazed by livestock. There are at least five 24- to 30-inch drain pipes that convey runoff from this native rangeland directly into the lake. These pipes are located in natural drainage channels.

The land on the southeast, south, and southwest is separated from the lake's edge/service road by State Highway 138 which, in some areas, is within 40 feet of the water's edge. The land on the south side of Highway 138 (away from the lake) is also heavily grazed by livestock. The areas around the lake are most likely also inhabited by various types of wildlife. On the southeast end of the lake, about 1,000 feet from the water's edge there is a small "glider" landing strip with three residences on site. These residences are served by private wastewater disposal systems. Two of these homes are within 300 feet of the lake. There is also a cement production plant in the watershed. On the east side of the lake, there are two or three additional 24- to 30-inch pipes that allow runoff from the heavily grazed native rangeland to flow directly into the lake. These pipes are also located in natural drainage channels. There is currently no water quality monitoring activities at this lake.

Pyramid Lake. Pyramid Lake's recreational facilities include boating with boat launching facilities, sanitary facilities and potable water, parking areas for cars and boats, camping and picnicking, fishing, swimming, water skiing, gas/oil sales, and shops/refreshments. The recreation program at the lake is administered by a concessionaire operating under an agreement with the U.S. Forest Service.

There are several major recreation areas along the shoreline. The Emigrant Landing area includes an eight-lane boat launching ramp, a marina, and boat rentals. The area is served by three or four comfort stations, each consisting of chemical toilet facilities. These facilities are well maintained and periodically emptied using a pump truck. The Spanish Point, Serrano, Yellow Bar, and Bear Trap areas have beaches, boat landing areas, and picnic sites. These areas can be reached only by boat or hiking. These facilities are equipped with chemical toilets that are well maintained and periodically serviced using a tank truck brought in by means of a barge. Chumash Island has one chemical toilet, which is poorly maintained. Los Alamos Campground in Lower Hungry Valley contains 93 family camping units and three group facilities. On Piru Creek, Hard Luck Campground accommodates 22 family camping units. Both camps are located in the watershed just upstream of the reservoir. Neither camp was inspected to determine the adequacy of wastewater handling and disposal facilities. Weed control around the shoreline is performed mechanically without the use of chemicals. Trash collection and trash control appeared excellent, not only around the shoreline, but also on the water surface of the lake.

There are two floating (anchored) chemical toilets on the lake. These toilets appeared well maintained. They are serviced by a tank truck that is floated out onto the lake with a barge. The wastes from all chemical toilets around the lake (about 12 to 14) are hauled for disposal to the Los Angeles County Sanitation District's Valencia Wastewater Treatment Plant.

The reservoir has an extensive watershed consisting of portions of the Los Padres National Forest. The watershed has an area of approximately 250 square miles, and most of it is located in neighboring Ventura County to the west of the reservoir. The watershed is probably heavily inhabited by wildlife. DWR has estimated this watershed to contribute an annual inflow of 50,000 AF to the lake. The watershed was not inspected.

The major drainages that enter Pyramid Lake are Gorman Creek, Apple Canyon Creek, and Hungry Valley Creek on the north; Piru Creek on the west; Liebre Gulch on the east; and several minor drainages.

The watershed draining into Pyramid Lake includes the following:

- The community of Gorman and the Gorman community wastewater treatment and disposal facilities.
- Several cattle ranches.
- Numerous campgrounds on private wastewater disposal systems.
- Mines (mostly inactive--type unknown).
- Drainage from Interstate 5.
- Rural residential cabins and commercial dwellings on private wastewater disposal systems.
- Three airplane landing strips in Lockwood Valley.

The sides of this lake are steeply sloped, which causes some problems with landslides and turbidity in the water when runoff occurs. DWR monitors dissolved oxygen, electrical conductivity, pH, and temperature throughout the water column. During the summer, bacteriological monitoring is conducted at several locations in the lake. Algal growth is not monitored on this lake.

Castaic Lake. Castaic Lake recreational facilities include boating with boat launching facilities, sanitary facilities and potable water, parking areas for cars and boats, picnicking and hiking, fishing, swimming, shops/refreshments, and a visitor center. There are several major recreation areas along the shoreline of Castaic Lake. The wastewater handling facilities of Laura's Landing Recreational Area on the northwest arm of the lake and Sharon's Rest Recreational Areas on the north side of the lake, between the two arms, consist of collection, septic tank treatment, and leach field disposal facilities. Wastewater from the Ball Point Recreational Area on the northeast arm of the lake, the main boat ramp area located east of Castaic Dam, the Dam Overlook and Visitor Center, and the west boat ramp area located west of Castaic Dam is collected and pumped to the Los Angeles County Sanitation District's Valencia Wastewater Treatment Plant. Other unnamed recreational areas are equipped with chemical toilets. There are two floating, but anchored, toilets on the lake. These toilets appeared well maintained. The toilets are periodically serviced with a pump truck. The floating toilets are pulled to landing docks for purposes of pumping them dry. This maintenance is done by a contractor. There is one documented spill of wastewater into the lake while emptying a floating toilet. Also, one toilet broke loose from its anchorage, overturned partially, and floated to the shoreline, but no wastewater was spilled.

There is restrictive fencing around the reservoir site. State police staff routinely patrol the area. A recent fire in the watershed created some turbidity problems in the lake. Otherwise, the watershed is not normally a cause for significant turbidity increases. Weed control around the shoreline is said not to be a problem, mainly because of fluctuating reservoir water levels. What weed control is needed is done mechanically. Herbicides are not used near the reservoir. Trash seems to be quite well controlled, based on visual inspection of the shoreline and the water surface of the lake.

The watershed drainage into Castaic Lake and Elderberry Forebay is rather extensive. DWR has estimated that the average annual inflow into Castaic Lake from the watershed is about 23,000 AF. The major drainages are Castaic Creek draining into Elderberry Forebay and Elizabeth Canyon Creek draining into Castaic Lake. Fish Creek and Castaic Creek join together about 1/4 mile northeast of the power plant. They then flow directly into Elderberry Forebay. Both of these creeks flow only seasonally. The incoming runoff flow averages about 18,000 AF per year. This flow is monitored by gaging stations located fairly close to the junction of the two creeks.

The watershed was not inspected. From examination of recent USGS maps, it can be seen that the watershed is relatively undeveloped. The developments that can be seen are:

- Warm Springs Rehabilitation Center, which has a community wastewater collection, treatment, and disposal system

- Cienega, Cottonwood, and Bear Gulch campgrounds

- Kelly ranch (possibly other ranches involving cattle and sheep)

- Some mining activities (type of mines not determined)

There is an access road with a bridge overcrossing at Castaic Creek that has several open areas with large trees that is heavily used during the day and by overnight campers. This area has a lot of trash lying around very close to Castaic Creek. One of these areas is located on the east side, downstream from the bridge. The other area is on both sides of the creek upstream of the bridge.

The lake is surrounded by native high desert rangeland that is inhabited by various types of wildlife such as deer and pigs. Some cattle and sheep grazing activities occur in the watershed.

South of Castaic Dam is Castaic Lagoon, a strictly recreational water contact sports facility. Castaic Lagoon receives water through Castaic Dam from Castaic Lake. Castaic Lagoon holds 5,560 AF of water, covers an area of 200 acres, and has a 3-mile shoreline. Castaic Lagoon is formed by a small dam 25 feet high. Water is released through this dam (mileage point 31.87) into the downstream portion of Castaic Creek to satisfy downstream water rights. The recreational uses of Castaic Lagoon include boating, boat launching, fishing, parking areas, potable water, swimming, sanitary wastewater facilities, shops/refreshments, and picnicking. Castaic Lagoon is not part of the drinking water conveyance system of the SWP.

Castaic Lake is currently sampled for algal growth weekly during the summer and bimonthly throughout the rest of the year. This frequent sampling program is a direct result of troublesome algal growths that forced a shutdown of nearby MWD water treatment plant facilities during the middle 1970s. Copper sulfate is used on the lake occasionally for spot treatment purposes to control excessive algal growth. Bacteriological samples are collected at selected areas twice monthly during the summer months and monthly during the rest of the year.

Summary of Contaminant Sources

The major sources of contaminants to the West Branch are:

1. Shallow groundwater pumped into the Aqueduct at 13 locations may contribute minerals and salts to the water.

2. Agricultural drainage from cattle grazing lands is discharged to Quail Lake and may contribute pathogens, organics, and nutrients to the water.

3. Body contact recreation in Pyramid Lake and Castaic Lake, floating toilets on the lakes, and wastewater handling facilities in the watersheds may contribute pathogens, nutrients, and organics to the water.

EAST BRANCH

This section of the SWP is operated and maintained by DWR's Southern Field Division. The Metropolitan Water District of Southern California, Antelope Valley-East Kern Water Agency, Palmdale Water District, Mojave Water Agency, and the San Bernardino Valley Municipal Water District take water out of the East Branch of the SWP.

Physical Facilities

The major facilities that make up this segment of the SWP include the Pearblossom Pumping Plant, the Alamo Power Plant, the Devil Canyon Power Plant, underground pipelines and tunnels, open canal segments, Lake Silverwood, and Lake Perris.

Pearblossom Pumping Plant. This pumping plant is located at mileage point 360.61. This plant consists of six pumps which have a capacity of 1,450 cfs. The average static lift is about 540 feet. The water is lifted through two 9-foot-diameter penstocks that are 6,780 feet long.

Power Plants. There are two power generating plants along the East Branch. The Alamo Power Plant is located at mileage point 305.73 and the Devil Canyon Power Plant is located at mileage point 412.73. The Alamo Power Plant consists of one power generating unit, fed by one 12-foot-diameter penstock which is 4,780 feet long. The Devil Canyon Power Plant consists of two power generating units, fed by one 9.5-foot-diameter penstock, which is 1,357 feet long and drops 1,600 feet in elevation. This plant is currently being expanded.

Underground Portions of East Branch. There are several underground pipelines and tunnel segments making up portions of the East Branch. The first major underground facility is the 2.2-mile-long Mojave Siphon. This facility is an 11-foot-diameter barrel and conveys water from the end of the open canal segment at mileage point 403.41 to the inlet structure of Lake Silverwood at mileage point 405.60. The next major underground facility is the San Bernardino Tunnel, which is a 3.8-mile-long, 12.75-foot-diameter conduit. This facility conveys water from Lake Silverwood to the beginning of the penstocks into the Devil Canyon Power Plant at mileage point 411.46. The next major underground facility is the Santa Ana Valley Pipeline, which is 27.4 miles long and varies from 9 to 10 feet in diameter. This facility conveys water from the Devil Canyon Power Plant Afterbay to Lake Perris. The last underground pipeline sections are Lake Perris inlet/bypass and outlet piping facilities at Lake Perris. This piping consists of 3,750 feet of 8.5-foot-diameter and 2,600 feet of 12.5-foot-diameter conduits. This piping allows the incoming water to bypass the reservoir completely.

Open Canal Section. The open canal segment extends from the bifurcation of the California Aqueduct (mileage pint 303.92) to mileage point 403.41, the beginning of the Mojave Siphon, beyond which all Aqueduct conveyance system components become subsurface in nature, with the exception of Lake Silverwood, the Devil Canyon Power Plant Afterbay, and Lake Perris. This canal portion includes 17 underground, dual-barrel siphon structures.

Lake Silverwood. Lake Silverwood, formed by Cedar Springs Dam on the west fork of the Mojave River, is located in the San Bernardino Forest, about 30 road miles north of the City of San Bernardino. The reservoir has a storage capacity of about 74,970 AF, a surface area of about 980 acres, and approximately 13 miles of shoreline. Cedar Springs Dam is 249 feet high and has a crest length of 2,230 feet. The reservoir has a maximum depth of 166 feet and an average depth of about 77 feet. Water deliveries from the lake began in May 1972. The lake inlet structure is located west of the dam spillway. The water leaves the lake through an outlet tower, which feeds into the 3.8-mile-long San Bernardino Tunnel. This outlet tower is located in the Sawpit Canyon area of the lake. The Crestline-Lake Arrowhead Water Agency also diverts water from the lake using a separate outlet tower.

Lake Perris. Lake Perris is formed by Perris Dam, which is 128 feet high and has a crest length of 11,600 feet. Lake Perris is located about 15 miles southwest of the City of Riverside and is the southern terminus of the SWP. Lake Perris has a storage capacity of 131,450 AF, a surface area of about 2,230 acres, and approximately 10 miles of shoreline. Lake Perris has a maximum water depth of 110 feet and an average water depth of 57 feet. The water enters the reservoir between the northern end of the dam and Perris Beach and leaves the reservoir through an outlet tower located in the lake between the southern end of the dam and Ski Beach. The water usually bypasses Lake Perris via a pipeline from near the inlet structure to the outlet structure, located west of the dam. This water bypassing is done mainly because of inferior water quality conditions in Lake Perris. The specific problem is excessive algae growth and/or anaerobic conditions below the thermocline. The outlet tower is protected against visitor encroachment by floating warning signs and buoys.

Historic Information and Past Concerns

Information obtained from DHS shows that there have been numerous wastewater spills into Lake Silverwood from the Crestline Sanitary District facilities but there have been no documented public health hazards resulting from these spills (DWR, 1975; DHS, 1975, 1976, and 1977; and County of San Bernardino, 1982 and 1983).

Both DHS and the Riverside County Department of Health have documented serious wastewater contamination problems in Lake Perris caused by poor sanitation practices compounded by heavy use at the designated swimming beaches (DHS, et. al., 1987). DHS has requested that more toilets be installed to better accommodate and service the great number of lake visitors. Also, both health agencies have instituted a water quality sampling program with the idea that visitor density may have to be decreased if the bacteriological quality of the water does not improve.

Field Survey Results

The Pearblossom Pumping Plant, power plants, open canal sections, and lakes were inspected.

Pearblossom Pumping Plant. Wastewater service at the Pearblossom Pumping Plant is provided to 19 to 20 operators and occasional visitors by a septic tank/leach field system. These facilities are currently being revamped due to septic tank overflows. Past septic tank overflows have not reached the pumping station forebay. Local site drainage is conveyed into the forebay. The site is fenced to preclude public access.

Power Plants. Wastewater service at the Alamo and Devil Canyon Power Plants is provided by septic tank/leach field disposal systems. The Alamo Power Plant has six or seven part-time operators and occasional visitors. The septic tank/leach field facilities are relatively new and have functioned properly. The Devil Canyon Power Plant has about 14 operators and some occasional visitors. The septic tank/leach field facilities are said to be free of significant operational problems. While inspecting the septic tank area, a very strong wastewater odor was noted. Overflows would be tributary to the afterbay because of the local topography. According to plant personnel, the septic tank has never been pumped. Local site drainage is conveyed into the Alamo Power Plant Afterbay. At the Devil Canyon Power Plant, most of the local site drainage is being diverted, but some drainage is conveyed into the afterbay. Both sites are fenced to exclude unauthorized personnel.

Open Canal Section. Table 5-8 shows the types and numbers of potential sources of contamination found during the survey of the open canal section.

Canal Control Structures and Siphons--There are 23 check structures with radial gates. None of these structures has any sanitary significance. The canal becomes an underground siphon at 16 locations along this segment of the Aqueduct. These siphons range in length from about 200 feet to over 1 mile, as shown on page 5-48.

Drain Inlets--During the field survey of this section of the Aqueduct, 602 drain inlet locations were found. About 556 of the 602 noted drains convey canal road and shoulder runoff into the canal when it rains. They range from 6 to 12 inches in diameter, and most are 8 inches in diameter. Some of these drains also convey drainage from adjacent sloping rangelands (grazed and ungrazed), into forebays and afterbays of power plants and pumping plants. Between mileage points 398.30 and 399.40 in the Hesperia area, there are 44 large-diameter (30 to 36 inches) drain inlets that convey urban drainage from residential/commercial developments into the Aqueduct. A wide variety of pollutants typically found in urban runoff could be carried into the Aqueduct by these inlets. Two drains convey liquid materials into the canal of unknown origin.

Bridges--There are 67 bridges that span this canal section. Six are state bridges, 50 are county bridges, and 11 are private/farm bridges.

Table 5-8. Potential Sources of Contamination to SWP Open Canal Sections, East Branch

Drain Inlets	602
Canal roadside drainage	556
Agricultural drainage	0
Groundwater	0
Other	46
Bridges	67
State	6
County	50
Farm or private	11
Overcrossings	104
Pipelines	19
Overchutes	85
Undercrossings	139
Drainage	132
Irrigation or domestic water	5
Other	2
Water-Service Turnouts	48
Irrigation pumped upslope	11
Other	37
Fishing Areas	23

Location	Mileage point	Length (feet)	Cross section
Cottonwood	305.45	354	2 - 9.5' x 13.5'
Box Siphon #1	308.12	335	2 - 16' x 12.5'
Box Siphon #2	309.94	185	2 - 16' x 12.5'
Box Siphon #3	311.72	215	2 - 16' x 12.5'
Mirick Check (#46)	323.85	1,175	2 - 13'D
Willow Springs Check (#47)	326.77	1,026	2 - 13'D
Johnson Creek Check (#48)	330.82	740	2 - 13'D
Ritter Creek Check (#50)	341.51	1,140	2 - 13'D
Leona Creek Check (#51)	342.07	1,940	2 - 13'D
Soledad Check (#53)	348.17	1,643	2 - 13'D
Cheseboro Check (#55)	352.70	1,020	2 - 13'D
Little Rock Check (#56)	354.76	980	2 - 13'D
Tejon Siphon	363.51	660	2 - 12'D
Big Rock Creek Check (#59)	366.09	7,690	1 - 19.5'D
Check Siphon (#64)	395.10	420	2 - 20' x 18'
Antelope Check (#65)	400.32	3,870	2 - 11'D
Mojave Check (#66)	403.41	11,600	1 - 11'D

Overchutes and Overcrossings--There are 104 overchutes and pipelines crossing the Aqueduct. Eighty-five of the overcrossings are uncovered, rectangular concrete culverts ranging from 5 feet by 5 feet to 7.5 feet by 39 feet in cross-section. These culverts convey storm runoff from rangeland, grazing lands, farmed lands, and residential subdivisions across the Aqueduct. Nineteen overcrossings are pipelines ranging from 4 inches to 121 inches in diameter. The pipelines convey the following materials across the Aqueduct.

- 1 petroleum product pipeline
- 14 irrigation and domestic water lines (no hazard)
- 2 natural gas lines (no hazard)
- 1 pipe with unknown contents
- 1 pipe carrying wastewater

Undercrossings--There are 99 undercrossing locations involving 72 pipelines and 67 concrete culverts. At some undercrossing locations there are multiple conduits. The pipelines range from 6 to 72 inches in diameter. The concrete culverts range from 4 feet by 5 feet to 9 feet by 9 feet in cross-section. There are 93 pipelines and culverts that convey storm drainage waters from lands that are undeveloped and lands that are grazed by cattle. Five underdrains also convey stormwater runoff from residentially developed, subdivided areas. Five pipes convey domestic or irrigation water, and two lines convey natural gas.

Water-Service Turnouts--There are 48 water-service turnouts to various water districts. Thirty-seven of these turnouts are operated by gravity, and 11 of the turnouts are pumped. Some of the turnouts are used for both agricultural and domestic water conveyance. The joint use facilities are owned by the Antelope Valley East Kern Water Agency, which has instituted a cross-connection control program. Backflow prevention devices are installed at the points of agricultural service along the raw water pipelines that connect the Antelope Valley East Kern Water Agency filtration plants to the East Branch.

Fishing and Picnic Areas--Twenty-three areas were identified as locations where the public fishes or picnics alongside the Aqueduct. Only 13 of the 23 locations are equipped with portable chemical toilets.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include the presence of developed properties (residential, commercial, and industrial) near the Aqueduct, agricultural land uses, cattle impoundments, recreational uses along the Aqueduct, structures located near the Aqueduct, and trash accumulation along the Aqueduct.

Lake Silverwood. Lake Silverwood recreational facilities include boating with boat launching facilities, sanitary facilities and potable water, parking areas, camping and picnicking, fishing, swimming (designated areas), water skiing (north area of lake only), gas/oil sales, and shops/refreshments.

The reservoir has three specific areas that are equipped with sanitary wastewater collection and disposal systems. At the Cedar Springs Dam Area, a wastewater system serves several structures consisting mainly of site support facilities. The wastewater system includes collection facilities, two septic tanks, and a leach field disposal area. These facilities are operated properly, and no problems were evident.

Sawpit Canyon Recreational Area, located on the south side of the lake, includes boat launching ramps and boat boarding docks. The area also includes parking areas for cars and boats, a snack bar, rental boats, fishing supply store, and boat touring facilities. There are fuel storage facilities at the marina. This area has 10 to 12 toilets. The wastewater is collected with piping mostly 6 inches in diameter. The wastewater runs by gravity to a lift station where a force main begins that conveys the wastewater to the Crestline Sanitary District's Cleghorn Wastewater Treatment Plant. This plant is located on the southwest corner of the lake in the West Fork area. There are at least four lift stations along this force main. Several of these pump stations have experienced failure and overflow problems in the past. One is located 100 feet away from the reservoir, two are located 250 feet from the reservoir, and the fourth station is located 1,000 feet from the reservoir. Spare motors (one for each pump) are now kept on hand. Each lift station is now equipped with alarms, and with provisions to hook up a portable power generator to operate the pumps during an electrical power outage. Each station has two pumps--one for standby purposes.

The Cleghorn Cove Recreational Area is served by a wastewater collection system that includes an underground holding tank, which is a 48-inch-diameter, 92-foot-long pipe. The wastewater is conveyed by gravity to a lift station, which conveys the wastewater from one of four lift stations described in the previous paragraph, to the Cleghorn Wastewater Treatment Plant of the Crestline Sanitary District. This station also has two pumps, each capable of pumping a flow of 170 gpm. The wet well has a storage capacity of 7,500 gallons and is also equipped with alarm features. The pumps can also be run with a portable generator. This recreational area has three or four toilet facilities. The toilets, sewer lines, and lift station are adequately located away from the water's edge.

The reservoir shorelines have other recreational areas, such as Miller Canyon Camp, Serrano Beach, Sycamore Landing, Live Oak Area, Dam View Point, Chamise Area, West Fork Area, and Lower Mesa Area. These areas are mostly served by portable chemical toilets. All of the toilet facilities inspected appeared clean and well maintained. The toilets are periodically pumped out by a septic tank truck.

The additional recreational uses at the other lakeside areas are as follows:

- There is a group picnic area at Miller Canyon, east of the lake's southeast arm along Highway 130.
- There is an 8-mile hiking and bicycle trail that connects Serrano Beach on the southeast arm of the lake, with the Cleghorn area to the west.
- There are marked (with buoys) swimming areas at the Manzanita and Cleghorn areas.
- There are marked (with buoys) fishing areas at Live Oak, Chamise, and Serrano Beach areas, and in the waters flanking the "waist" of the lake.
- Boat-in picnic areas are located at Live Oak, Chamise, and Sycamore on the northern arms of the lake. At these areas, no drinking water is provided and, because of fire hazards, no open fires or stoves are allowed.
- Family picnic sites are located at the Black Oak, Manzanita, Cleghorn, Chaparral, and Willows areas.
- Picnic tables located at Serrano Beach can be reached by boat, by hiking, or by bicycle.
- Camping sites and a bicycle camping area are at Mesa campground, and group campgrounds are at the West Fork area, just west of the lake's southwest corner.

The lake also has two floating sanitary toilet facilities. These facilities are maintained by a septic tank pump truck that is moved to each site using a barge. There are also two portable chemical toilets on top of the dam. The shoreline around the reservoir was found mostly free of trash. Some trash was found floating on the lake water surface. The watershed of Lake Silverwood was not inspected. An examination of the most recent USGS maps shows that many portions of the watershed are extensively developed with residential and commercial properties.

The three major wastewater treatment plants (Cleghorn, Seeley Creek, and Houston Creek) in the watershed area and the piping that conveys the effluents from all three plants to the Las Flores Ranch for irrigation disposal in the past have caused wastewater spills (raw and treated) into Lake Silverwood. There is another small wastewater collection, treatment, and disposal system at Pilot Rock Camp, operated by the California Department of Forestry. The watershed lands also have ranches with livestock and some inactive mines.

DWR has estimated the average annual inflow to Lake Silverwood from the watershed to be about 30,000 AF/year. Table 5-9 lists the creeks flowing into the lake and some comments on the development in the watersheds of these creeks.

Table 5-9. Drainages Into Lake Silverwood

Creek	Comment
West Fork of Mojave River and Cleghorn Creek	Development in the watershed and Cleghorn Wastewater Treatment Plant
East Fork of Mojave Creek and Houston Creek	Extensive residential development in the watershed, the Houston Creek Wastewater Treatment Plant, and the Pilot Rock Wastewater Treatment Plant and disposal facilities
Sawpit Canyon Creek	Development in the watershed
Burnt Mill Canyon Creek	Extensive residential development in the watershed
Seeley Creek	Extensive residential development in the watershed and Seeley Wastewater Treatment Plant
Other smaller drainages	Some watershed development

Carter Creek, Miller Canyon Creek, and Cleghorn Creek at times create quite significant turbidity problems in the lake. Also, some of the creeks entering the lake at times deliver water with very high coliform bacteria counts. There are no significant agricultural land uses within the watershed other than cattle grazing. Herbicide chemicals may be contained in the runoff because of uses in the forests of the watershed. The watershed also includes Lake Gregory, another fully recreational, but smaller, lake. It overflows into Houston Creek, then to Lake Silverwood.

The impacts of power boats on water quality has been monitored by MWD for some time. Traces of volatile organic compounds are detected at times in the lake but are not detected in the water leaving the lake by the outlet towers. Bacteriological water quality monitoring is frequently being performed around the floating toilets and at the designated swimming beaches. This sampling is done monthly during the winter and every two weeks during the summer.

Algae growth and other water quality testing is performed at six locations in the lake area. Copper sulfate has been used occasionally on the lake for spot treatment purposes. Weed control around the shoreline is manually controlled without the use of chemical herbicides.

Lake Perris. Lake Perris is an important recreational attraction for water-oriented sports enthusiasts. The lake opened for recreation in mid-1974 and offers a full range of traditional water-related recreation. Visitors can sightsee, swim, boat, water ski, study nature, picnic, camp, fish, hike, and ride bicycles or horses. Of special interest are areas and facilities for scuba diving, rock climbing, and hunting. The 8,200-acre Lake Perris Recreation Area is operated by the DPR. In recent years, the total yearly visitors have exceeded 2 million people. Peak month visitors exceed 300,000 people. At times, use is so heavy that people are not allowed to enter the area as early as 8:30 a.m.

On the north side of the lake, there are two boat launching ramps with a total of 10 boat launching lanes. There is ample parking for cars and trailers. A concessionaire runs a marina near the ramps which offers wet and dry storage, boat repairs, boat fuel, bait and tackle, boat rentals, and a coffee shop. There are boat washdown and fish cleaning facilities. Swimming is the most popular activity at Lake Perris. Swimming is allowed only at Moreno and Perris beaches on the north shore of the lake.

Most of the formal picnic sites are located on the north shore and on Alessandro Island. These sites have ramadas, tables, grills, and nearby rest rooms. There is a group picnic area at the east end of Moreno Beach. Informal picnicking is also allowed all around Alessandro Island and in the Bernasconi Pass area. For overnight visitors, there are campgrounds for families and large groups with sites for tents and recreational vehicles. RV sites have hookups for water, electricity, and sink water disposal. Group camp areas have campfire centers.

Fishing and hunting are allowed at designated areas. Upland game and waterfowl may be hunted only in designated areas and only in season. The watershed is open for horseback riding and hiking. A rock climbing area (Big Rock) near Bernasconi Pass provides climbers with a practice area. The other unique area is a special scuba diving area near the west end of Perris Beach, where large-diameter sections of concrete pipe lie in 40 feet of water. A trailer park is currently being constructed on the northeast side of the lake around the entrance to the reservoir park area.

The North Shore Recreation Area is served by six or seven spaced-out comfort stations. The wastewater from these rest rooms flows by gravity to a wastewater lift station that transports it to a sewer trunk line belonging to the Eastern Municipal Water District. This trunk line conveys the wastewater out of the watershed to the Sunnymead Wastewater Treatment Plant. The wastewater collection, pumping, and force main facilities were not reviewed. The comfort stations all appeared well maintained.

Alessandro Island is a day-use facility equipped with five or six chemical toilets. These toilets are emptied periodically by a small septic tank pump truck which is transported to the island by barge. This waste is temporarily stored in a 2,000-gallon tank on the mainland. The location of this mainland tank could not be determined. The condition of the island's toilets was average.

There are other recreational areas around the lake such as the Perris Dam, Bernasconi Pass, and Ski Beach. Each is equipped with one or more chemical toilet facilities. A visual inspection indicated these facilities to be very well maintained.

Trash has not been managed very well in the recent past. A large amount of trash was found floating in the water, pointing to the need for better public education and perhaps more trash receptacles. Weed control around the reservoir shoreline is performed mostly manually.

The watershed around Lake Perris is relatively small. The average annual inflow from the watershed to Lake Perris has not been determined. Three identifiable creeks drain into the north part of the lake. Other than for recreational uses, the watershed around the reservoir is almost totally undeveloped. Water quality monitoring for various constituents is conducted at six reservoir sampling stations. Algae counts are made weekly during summer months and biweekly during the rest of the year. Copper sulfate is used occasionally on the lake for spot treatment purposes.

Since 1985, after several cases of shigellosis were related to swimming, it has been determined by DHS and by the Riverside County Health Department that high fecal organism levels frequently occur in the recreational swim areas, especially around the north shore area of the lake. This problem has been attributed to wastewater contamination of the water in the swimming area caused by poor sanitation practices and too many swimmers and possibly by an inadequate number of rest rooms that also are not conveniently located nor well identified. These problems, including greater control of the number of visitors are currently being solved by providing more toilets and by exercising better control methods. Also, the health agencies, DPR, and DWR are now conducting intensive bacteriological monitoring which has not confirmed high bacteriological levels outside the swimming area.

Summary of Contaminant Sources

The major sources of contaminants to the East Branch are:

1. The 44-large-diameter drains that convey urban drainage from residential/commercial developments in the Hesperia area into the Aqueduct could contribute solids, metals, nutrients, and organics to the water.

2. The runoff from the watershed of Lake Silverwood could potentially contain significant amounts and various types of contaminants because of the extensive development of the watershed and the presence of four wastewater treatment plants and associated piping and pumping facilities. Most of the ultimate disposal of the wastewater effluent occurs outside of the watershed. However, the piping and pumping stations required to convey the raw wastewater to these treatment plants, and the treated effluents from these plants to the ultimate disposal location have failed and resulted in wastewater spills to the lake in the past.

3. Body contact recreation in Lake Silverwood may contribute pathogens and nutrients to the water.

4. Body contact recreation in Lake Perris has resulted in verified cases of Shigellosis and other complaints of human illness after swimming in the lake. These problems have been caused by a combination of overcrowding, inadequate sanitation services at the overcrowded areas, and possibly due to the lack of sufficient public education and enforcement of public behavior.

DELTA MENDOTA CANAL

The DMC is operated by the USBR and the Central California Irrigation District. The DMC was included in the field survey because DMC water is pumped into O'Neill Forebay by the O'Neill Pumping Plant and commingles with California Aqueduct water. Some of this water is then pumped into San Luis Reservoir. As described in Chapter 2, 35 percent of the water entering O'Neill Forebay on an average annual basis comes from the DMC.

Physical Facilities

The DMC system consists of the Tracy Pumping Plant, the O'Neill Pumping Plant, Mendota Pool, and an open canal. The open canal has two segments--the 2.5-mile-long intake canal into the Tracy Pumping Plant and the 114-mile-long canal that extends from the Tracy Pumping Plant to Mendota Pool in Fresno County. The USBR operates and maintains all facilities upstream of and including the O'Neill Pumping Plant. The remainder of the facilities downstream of O'Neill Pumping Plant are operated and maintained by the Central California Irrigation District.

The Tracy Pumping Plant pumps water from Old River and Middle River into the DMC. The water is lifted 197 feet by six pumps which have a capacity of 4,602 cfs. The O'Neill Pumping plant lifts the water an average of 50 feet from the DMC into O'Neill Forebay. O'Neill Pumping Plant has six pumps, having a combined capacity of 4,200 cfs. Approximately 1.2 million AF per year is transferred annually from the DMC to the San Luis Canal through O'Neill Forebay. This amount constitutes 42 percent of the average DMC supply of 2.9 million AF.

The 116-mile-long DMC is concrete-lined to approximately mileage point 98.62. It is unlined from there to Mendota Pool. There are four wasteways along the canal. These wasteways are provided for draining the DMC into the San Joaquin River in case of emergency conditions. Mendota Pool is a terminal reservoir at the end of the DMC. This reservoir is formed by Mendota Dam on the San Joaquin River. There is no direct connection between Mendota Pool and the SWP, as described in Chapter 2.

Historic Information and Past Concerns

DHS has expressed concern over the quality of DMC water in numerous internal memoranda and letters to the City of Tracy. In the water supply permit for Tracy, DHS states, ". . . this water source must be considered one of the poorest sources of domestic water supply currently being used in California." (DHS, 1978). These concerns include the belief that lower San Joaquin River water and Old River water carrying wastewater discharges and agricultural wastewaters, with little dilution, influence the quality of the water pumped by the Tracy Pumping Plant. DHS claims that when DMC water is pumped into O'Neill Forebay, the DMC water is visible from the air as a turbidity plume (Personal Communication, Richard Haberman, 1989).

Field Survey Results

The pumping plants and open canal sections were inspected.

Pumping Plants. The wastewater collection, pumping, treatment, and leach field disposal facilities at the Tracy Pumping Plant and O'Neill Pumping Plant were found to be in good working condition, and no sanitary hazards were found.

Open Canal Sections. Table 5-10 shows the types and numbers of potential sources of contamination found during the survey of the open canal sections. The numbers of potential sources of contamination above the O'Neill Pumping Plant intake channel are shown in addition to the total numbers in Table 5-10. There is a direct connection to the SWP at O'Neill Forebay so contaminants entering the DMC above the O'Neill Pumping Plant are pumped into O'Neill Forebay. There is no direct connection between the DMC and SWP below O'Neill Forebay.

Weep Holes--The bottom of the DMC is equipped with "weep holes" through which shallow groundwater can rise up into the canal. These holes thus protect the structural integrity of the canal. The amount and quality of groundwater rising up into the canal was not

Table 5-10. Potential Sources of Contamination to Open Canal Sections, Delta Mendota Canal

	Above O'Neill Pumping Plant	Total
Drain Inlets	268	359
Canal roadside drainage	62	69
Agricultural drainage	191	266
Groundwater[a]	15	24
Other	0	0
Bridges	63	101
State	4	6
County	30	48
Farm or private	29	47
Overcrossings	58	117
Pipelines	45	102
Overchutes	13	15
Undercrossings	23	41
Drainage	19	26
Irrigation water	4	14
Other	0	1
Water-Service Turnouts	207	291
Irrigation pumped upslope	85	120
Other	122	171
Fishing Areas		2

[a]Shallow groundwater enters the DMC through numerous weep holes in the bottom of the canal lining, rather than being pumped into the canal as it is in the California Aqueduct.

determined. The approximate depth at which this weeping inflow occurs varies from 16 to 20 feet below the ground surface.

Canal Control Structures, Siphons, and Wasteways--There are 21 check structures. At nine locations, the DMC is constructed as a siphon to cross under the Hetch Hetchy Aqueduct (mileage point 23.99), under Puerto Creek and Zacharias Road (mileage point 37.24), under Orestimba Creek (mileage point 51.18), under Garzas Creek (mileage point 58.29), under Los Banos Creek (mileage point 79.64), under railroad tracks (mileage point 111.02), under the San Luis Master Drain (mileage point 111.07), and under unnamed canals (mileage point 111.5 and 115.57). There are four wasteways that permit the canal to be drained in case of an emergency. The check structures, siphons, and wasteways do not pose any risk to water quality.

Drain Inlets--During the field survey of the DMC, 359 drain inlets were found. There are 65 rectangular culverts that vary in cross section from 2.5 feet by 2.5 feet to 4 feet by 4 feet. There are 203 pipe drain inlets that vary from 4 inches to 42 inches in diameter. There are 268 drain inlets above the intake channel to the O'Neill Pumping Plant. Of the 268 drain inlets, 62 convey canal shoulder runoff and 191 convey agricultural drainage into the DMC. Agricultural drainage consists of drainage from row crops, orchards, dry rangelands, and livestock confinement areas. Most of the drains that flow into the DMC flow by gravity. The other drainages are collected in natural or man-made sump (settling) areas and are then periodically pumped into the canal.

Bridges--The DMC is crossed by 101 bridges. Upstream of O'Neill Pumping Plant, it is crossed by four state, 30 county, and 29 private and farm bridges for a total of 63 bridges.

Overchutes and Overcrossings--There are 117 overchutes and pipelines crossing the DMC. There are 58 overcrossings upstream of the O'Neill Pumping Plant, consisting of 13 overchutes and 45 pipelines. The overchutes range in cross section from 4 feet by 3 feet to 15 feet by 6 feet, and convey storm drainage from grazing and farmed lands across the DMC. The 45 pipelines range from 3 inches to 26 inches in diameter and convey the following materials across the DMC.

- 25 petroleum product pipelines
- 13 irrigation lines (no hazard)
- 7 pipes with unknown contents

Undercrossings--There are 41 undercrossings of the DMC. Twenty-three undercrossings are upstream of the O'Neill Pumping Plant. Of the 23, four underdrains convey irrigation water and the remainder convey storm drainage under the DMC.

Water-Service Turnouts--There are 291 water-service turnouts along the DMC. There are 207 upstream of the O'Neill Pumping Plant. Eighty-five of the turnouts located above the O'Neill Pumping Plant are pumped upslope. The City of Tracy has a diversion point at mileage point 15.85. Various irrigation districts supplied with water from the DMC in turn supply small domestic water users with raw surface water from their irrigation water distribution facilities.

Fishing Areas--Although there are no designated fishing areas along the canal, the public fishes extensively along the DMC. There are no chemical toilets provided for fishermen.

Miscellaneous Conditions Near Canal--A variety of miscellaneous conditions were noted during the field survey. These observations include residential, commercial, and industrial dwellings; chemical storage tanks; areas of defective canal lining; livestock confinements; unplanned fishing areas; wastewater ponds; and dairies. The DMC may also be exposed to the aerial drift of agricultural chemicals from both airplanes and ground spray rigs in nearby farmed areas.

Summary of Contaminant Sources

The major sources of contaminants to the DMC upstream of the O'Neill Pumping Plant are:

1. Agricultural drainage discharged to the DMC at 191 locations may contribute agricultural chemicals, pathogens, organics, and nutrients to the water.

2. Drainage from county roads discharged to the DMC at 14 locations may contribute solids, metals, oil, and grease to the water.

3. Shallow groundwater seeping into the DMC at numerous locations may contribute minerals and salts to the water.

SUMMARY OF DIRECT SOURCES OF CONTAMINATION TO SWP FACILITIES

A large number and great variety of potential direct sources of contamination to SWP facilities have been identified in this chapter. There are several factors that mitigate the harmful effects of many contaminants on drinking water supplies. These factors were discussed in Chapter 4 and include dilution, sedimentation, adsorption, and storage in reservoirs. The North Bay Aqueduct, the Coastal Branch, and the California Aqueduct between the Kern River Intertie and the East-West Branch bifurcation are relatively free of major direct contaminant sources.

Open Canal Segments

Table 5-11 contains a summary of the contaminant sources, the period of discharge, key contaminants, some factors that mitigate the potential of key contaminants for harming drinking water supplies, and the open canal segments of the SWP affected by the various sources of

Table 5-11. Summary of Contaminant Sources to the Open Canal Sections of the SWP

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	SWP open canal segments affected
Coast Range drainage	Rainfall-induced runoff occurs October through April	Suspended solids	Sedimentation	O'Neill Forebay to end of San Luis Field Division
		Asbestos	Sedimentation	
		Pesticides	Sediment adsorption, biological uptake and degradation	
		Nutrients	None identified	
		Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	
Agricultural drainage	Irrigation-related runoff occurs during the April through October irrigation season. Rainfall-induced runoff occurs October through April.	Dissolved solids	None identified	South Bay Aqueduct, Clifton Court to O'Neill Forebay, O'Neill Forebay to end of San Luis Field Division, and Delta Mendota Canal
		Nutrients	None identified	
		Selenium	Sediment adsorption	
		Metals	Sediment adsorption	
		Pesticides	Sediment adsorption, biological uptake and degradation	
		Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	
Urban runoff	Discrete pulses of stormwater-induced runoff occur October through April. Runoff from irrigation and/or wash-off practices occurs year-round.	Suspended solids	Sedimentation	East Branch
		Pathogens	Rapid die-off of bacteria (except pathogenic cysts	
		Nutrients	None identified	
		Metals	Sediment adsorption	
		Petroleum hydrocarbons	None identified	
		Pesticides	Sediment adsorption, biological uptake and degradation	

Table 5-11. Summary of Contaminant Sources to the Open Canal Sections of the SWP (continued)

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	SWP open canal segments affected
Highway drainage	Discrete pulses of rainfall-induced runoff October through April.	Suspended solids	Sedimentation	Clifton Court to O'Neill Forebay
		Metals	Sediment adsorption	
		Petroleum hydrocarbons	None identified	
	Accidental spills may occur at any time.	Petroleum hydrocarbons	None identified	
		Hazardous materials	None identified	
Shallow groundwater pumped into the Aqueduct	Variable	Dissolved solids	None identified	Clifton Court to Kern River Intertie, West Branch, and Delta Mendota Canal
		Metals	Sediment adsorption	
Canal roadside drainage	Discrete pulses of rainfall-induced runoff October through April.	Suspended solids	Sedimentation	All open canal segments
		Herbicides	Sediment adsorption	
Overcrossings, under-crossings, and siphons	Variable	Petroleum products	None identified	All open canal segments
		Suspended solids	Sedimentation	
		Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	
		Nutrients	None identified	
		Metals	Sediment adsorption	
		Organics	Sediment adsorption	

Table 5-11. Summary of Contaminant Sources to the Open Canal Sections of the SWP (continued)

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	SWP open canal segments affected
Bridges	Accidental spills may occur at any time.	Pesticides	Sediment adsorption, biological uptake and degradation	All open canal segments
		Nutrients	None identified	
		Petroleum hydrocarbons	None identified	
		Hazardous materials	None identified	
	Illegal dumping may occur at any time.	Petroleum hydrocarbons	None identified	
		Hazardous materials	None identified	
Pumped water-service turnouts (potential for chemigation)	April through October irrigation season	Pesticides	Sediment adsorption, biological uptake and degradation	All open canal segments except the West Branch
		Nitrogen	None identified	
		Phosphorus	None identified	
Fishing areas	Variable	Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	All segments of the California Aqueduct south of Clifton Court except the Coastal Branch

contaminants. The most significant potential sources of contamination are described in this section.

Coast Range Drainage. Between O'Neill Forebay and the end of the San Luis Field Division, the California Aqueduct receives drainage from the Arroyo Pasajero, Little Panoche Creek, Cantua Creek, and Salt Creek. These creeks drain intensively farmed areas. The Arroyo Pasajero drains a watershed containing a number of mines and the cities of Huron and Coalinga. These creeks may contribute many different types of contaminants including sediment, asbestos fibers, agricultural chemicals, pathogens, organics, and nutrients to the water during the rain season.

Agricultural Drainage. There are a large number of agricultural drains that discharge into the DMC and the California Aqueduct between O'Neill Forebay and the end of the San Luis Field Division. The South Bay Aqueduct and the California Aqueduct between Clifton Court and O'Neill Forebay also receive agricultural drainage. Agricultural drainage related to crop production occurs primarily during the April through October irrigation season. Rainfall-induced runoff from agricultural fields is generated primarily between October and April. Drainage from dry rangeland likely contains bacteria, parasites, and nutrients from the pasturing of livestock. Overgrazing of dry rangeland can result in erosion during storms and increases in turbidity in the receiving waters. Drainage from intensively farmed areas likely contains dissolved solids, metals including selenium, pesticides, herbicides, and fertilizers. Many of these constituents are removed from the water column by sedimentation.

Urban Runoff. Urban drainage from residential/commercial developments in the Hesperia area is discharged to the East Branch. The 44 large-diameter urban runoff drains in this area likely convey solids, metals, nutrients, and organics to the water. The greatest pollutant loads occur during the first few storms of the fall. Metals concentrations in receiving waters are reduced by adsorption to particulate matter and sedimentation.

Highway Drainage. The California Aqueduct between Clifton Court and O'Neill Forebay receives drainage from Interstate 5 and Highway 205. Highway drainage contributes solids, metals, and petroleum hydrocarbons to the receiving waters when it rains. There is also the potential for a spill of hazardous materials resulting from a trucking accident on these major roadways. In the areas where drainage is diverted to the California Aqueduct, hazardous materials could enter the Aqueduct if the spill was not immediately contained.

Shallow Groundwater. Groundwater is pumped into the California Aqueduct between Clifton Court and the Kern River Intertie. It is also pumped into the West Branch. The greatest number of discharge locations occurs between Clifton Court and O'Neill Forebay. There are weep holes in the DMC which allow shallow groundwater to enter the canal. Shallow groundwater in the western San Joaquin Valley contains high concentrations of dissolved solids and some metals.

Other Potential Sources of Contamination. A number of other potential sources of contaminants was discovered during the field survey of the open canal sections of the SWP. These sources of contaminants appear to be less important than the ones discussed above, based on available information.

Roadside Drainage--Canal roadside drainage is discharged into all open canal segments of the SWP. These drains contribute suspended solids and possibly herbicides used for weed control in the canal right-of-way to the canal water when it rains. Sedimentation of the solids and adsorbed organics reduces the impact of canal roadside drainage on water quality.

Overcrossings--All open canal segments of the SWP are crossed in numerous locations by pipelines and overchutes. Materials conveyed in the pipelines include petroleum products, storm drainage, irrigation water, domestic water, and natural gas. A leak in a pipeline crossing the Aqueduct could result in a discharge of the contents into the water. There have been leaks in petroleum pipelines adjacent to the California Aqueduct that have resulted in minor amounts of petroleum products entering the water. There have been no catastrophic failures of pipelines crossing the SWP facilities or the DMC to date. Storm drainage conveyed across the Aqueduct in overchutes can enter the canal if the overchutes were not designed with sufficient capacity or if the capacity has been reduced by sediment accumulation. Depending upon the source of the runoff (roadside drainage, agricultural drainage), a number of different contaminants can enter the canal.

Undercrossings--There are a number of canal undercrossings. If the underchutes are undersized and therefore not capable of conveying all of the drainage under the canal, drainage can overflow on the upstream side of the canal and enter the canal as overland flow. The number of undersized underchutes has not been determined.

Bridges--There are numerous bridges crossing the SWP facilities and the DMC. These consist of interstate and state highway, county road, and farm bridges. Bridges offer easy access for illegal dumping and vandalism. Motor vehicle accidents can result in spills of petroleum products and potentially hazardous materials into the canals. Motor vehicles have been found in the DMC when portions of it have been dewatered. Motor vehicles have also been found in the East Branch of the California Aqueduct. The extent of this problem and the impacts on water quality have not been determined.

Water-Service Turnouts--Many farmers mix agricultural chemicals into the irrigation systems. This practice is known as chemigation. When water is pumped from the California Aqueduct, there is the potential for these chemicals to flow back into the Aqueduct. The extent of this practice, and the frequency at which chemicals enter the Aqueduct via this route are not known. The greatest potential exists in the segment from O'Neill Forebay to the end of the San Luis Field Division.

Fishing Areas--There are a number of locations along the California Aqueduct that are designated fishing areas. If fishing areas are not equipped with sanitary facilities, there is the potential for human wastes to enter the Aqueduct. This is not thought to be a significant source of contamination to the SWP.

Reservoirs

Table 5-12 contains a summary of the contaminant sources to the SWP reservoirs. The most significant potential sources of contamination are described in this section.

Body Contact Recreation. Body contact recreation in Lake Del Valle, Pyramid Lake, Castaic Lake, Lake Silverwood, and Lake Perris may contribute pathogens and nutrients to the water. Body contact recreation in Lake Perris has resulted in verified cases of Shigellosis and other complaints of human illness after swimming in the lake. These problems have been caused by a combination of overcrowding, inadequate sanitation services at the overcrowded areas, and possibly a lack of sufficient public education and enforcement of public behavior.

Wastewater Handling Facilities. Wastewater handling facilities in the watersheds of Lake Del Valle, Pyramid Lake, Castaic Lake, and Lake Silverwood may contribute pathogens, nutrients, and organics to the water. The piping and pumping stations that convey raw wastewater out of the Lake Silverwood watershed have failed and resulted in wastewater spills to the lake on several occasions. Floating toilets on Pyramid Lake and Castaic Lake may contribute wastewater contaminants to the water.

Highway Drainage. Roadside drainage from Highway 152 may contribute solids, metals, oil, and grease to the water of San Luis Reservoir. A hazardous materials spill on Highway 152 would drain into San Luis Reservoir.

Agricultural Drainage. Agricultural drainage from cattle grazing lands is discharged to Quail Lake and may contribute pathogens, organics, and nutrients to the water.

PROTECTION OF WATER QUALITY DURING EMERGENCIES

It is important to be able to respond effectively to emergency conditions that threaten the sanitary quality of SWP waters. A 1990 Laverty Associates report reviewed DWR's Division of Operations and Maintenance, Emergency Response Plans, for the Oroville Field Division and for the Southern Field Division and the USBR Tracy Office Emergency Response Plan. These emergency response plans address not only conditions which threaten water quality, but also other conditions which imperil the reliable collection, storage, and conveyance of water supplies. DWR had planned to update their emergency response plans prior to the review by Laverty Associates. The Laverty Associates report is in Appendix E.

Table 5-12. Summary of Contaminant Sources to the SWP Reservoirs

Contaminant source	Period of discharge	Key contaminants	Mitigating factors	Reservoir affected
Body contact recreation	Recreation season (April through October)	Pathogens	Rapid die-off of bacteria (except pathogenic cysts)	Lake Del Valle, Pyramid Lake, Castaic Lake, Lake Silverwood, and Lake Perris
		Nutrients	None identified	
Wastewater handling facilities	Continuous, but concentrated during recreation season	Pathogens	None identified	Lake Del Valle, Pyramid Lake, Castaic Lake, and Lake Silverwood
		Nutrients	None identified	
		Organics	None identified	
Highway drainage	Rainfall-induced runoff occurs October through April	Suspended solids	None identified	San Luis Reservoir
		Metals	None identified	
	Accidental spills may occur at any time	Petroleum hydrocarbons	None identified	
		Hazardous materials	None identified	
Agricultural drainage	Rainfall-induced runoff occurs October through April	Pathogens	None identified	Quail Lake
		Nutrients	None identified	
		Pesticides	Sediment adsorption, biological uptake and degradation	

The Laverty Associates report concludes that while the operations of other agencies can impact the quality of the SWP waters, the operations of DWR and USBR directly affect the forebays, afterbays, canals, large dams, and pumping stations that comprise the SWP export facilities.

The major conclusions of the Laverty Associates report are that the three emergency response plans should be reorganized to follow a logical, consistent format; the DWR plans cover past problems and solutions but do not consider potential problems; there is inadequate discussion (or omission) of many areas including identification of vulnerable areas, water quality monitoring during problem events, and public notification. Of particular importance to water quality is the high potential for high concentration contamination of the DMC or California Aqueduct by a tanker truck accident. Existing response plans appear to rely on dilution rather than containment structures at critical points to lessen the effects of such a spill. Failure of Delta levees during an earthquake could result in massive sea water intrusion into the Delta. This would render the Delta unusable as a source of drinking water.

CHAPTER 6

WATER QUALITY OF THE STATE WATER PROJECT SYSTEM

The water quality of the State Water Project (SWP) is described in this chapter. The description of water quality begins in the Sacramento, San Joaquin, and Kern River watersheds tributary to the SWP. The quality of water delivered to contractors at various locations along the California Aqueduct, the North Bay Aqueduct, and the South Bay Aqueduct is described. It is not possible in a study of this breadth to analyze data on each constituent that is, or soon will be, regulated by the U.S. Environmental Protection Agency (EPA) and the California Department of Health Services (DHS). Data on many of the constituents, particularly organics, are simply not available or the number of data points is so small it is statistically unreliable. The available data on constituents of concern in drinking water are discussed in this chapter.

WATER QUALITY DATABASE

A water quality database was developed using data from various government agencies and water contractors that take water out of the SWP. These data sources and the monitoring locations selected for inclusion in this study are discussed in this section.

Data Sources

Water quality data were obtained from the California Department of Water Resources (DWR), many of the SWP contractors, and other water supply agencies such as the East Bay Municipal Utility District (EBMUD) and the City of Sacramento. When data were available, the database analyzed in this study extends back to 1975 to cover the 1976-77 drought.

At the beginning of the study, the project team met with the Sanitary Survey Technical Management Committee (SSTMC) and members of the State Water Contractors Water Quality Committee to discuss the scope of the project and sources of water quality data. Letters were then sent to the SWP contractors and other agencies and cities that were known to have raw water quality data on the SWP, the Delta Mendota Canal (DMC), or the tributaries to the SWP. The letter described the period of record (1975 to 1989) and a list of constituents of concern was attached to the letter. The response was quite varied. Some of the large agencies and water contractors have extensive monitoring programs and they provided a large amount of the data used in this study. Many of the smaller water contractors did not have much data that was of interest to this study. Some agencies blend SWP water with other sources before monitoring the raw water quality so their data could not be used. In cases where an agency did not respond to the data request, a follow-up letter was sent or a phone call was made in an attempt to explain the importance of the data to this study. After carefully reviewing all of the data that were received, data from the agencies, water contractors, and cities described below were used in this study.

Department of Water Resources. Data from four of DWR's monitoring programs were incorporated into the water quality database. These include (1) Interagency Delta Health Aspects Monitoring Program (IDHAMP), (2) Delta Islands Drainage Investigation, (3) Operations Monitoring Program, and (4) Decision 1485 Compliance Monitoring Program.

1. **DWR IDHAMP**--This study, sponsored by many agencies and conducted by DWR, was started in July 1983. Data are collected monthly on trihalomethane formation potential (THMFP), minerals, selenium, and asbestos at a number of locations tributary to the SWP facilities. The data collected from the American River at Nimbus, the Sacramento River at Greene's Landing, Lindsey and Barker Sloughs, the San Joaquin River at Vernalis, the Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant) and the DMC at the Tracy Pumping Plant were used in this study.

2. **DWR Delta Agricultural Drainage Investigation**--In January 1987, DWR began an investigation of THMFP and other characteristics of water discharged into the Sacramento-San Joaquin Delta (Delta) channels from agricultural drains. The data and findings produced by this study were reviewed and used.

3. **DWR Operations Monitoring Program**--DWR field divisions collect monthly data on a number of constituents at various locations along the SWP. General minerals and metals data from the Banks Pumping Plant, South Bay Aqueduct terminal tank facility, the inlet to O'Neill Forebay, San Luis Reservoir, the outlet from O'Neill Forebay Checks 21 and 29 on the Governor Edmund G. Brown California Aqueduct, (California Aqueduct) Tehachapi Afterbay, the inlet to Castaic Lake, Pearblossom Pumping Plant, Devil Canyon Afterbay, and the inlet to Lake Perris were incorporated into the water quality database.

4. **DWR Decision 1485 Compliance Monitoring Program**--Data designed to monitor compliance with California State Water Resources Control Board (State Board) Decision 1485 (D-1485) are collected monthly on a number of constituents at various locations in the Delta by DWR. Metals and pesticide data are collected twice a year. Data from the Sacramento River at Greene's Landing and the San Joaquin River at Vernalis were used in this survey.

State Water Project Contractors. The agencies taking municipal and industrial water out of the SWP were contacted and asked to provide data. The following contractors provided data that were used in this study.

1. **Metropolitan Water District of Southern California** (MWD)--MWD collects data on general minerals, metals, organics, pathogens, and other miscellaneous constituents

at several of the facilities near the terminal reservoirs of the SWP. Data from Castaic Lake, Jensen Filtration Plant, Devil Canyon Afterbay, Mills Filtration Plant, and Lake Perris were used in this survey.

2. **Antelope Valley/East Kern Water Agency (AVEK)**--AVEK collects bacteriological and miscellaneous constituent data on raw water at their Rosamond, Eastside, and Quartz Hill water treatment plants. The raw water bacteriological data from the Eastside and Quartz Hill treatment plants were used in this study.

3. **Kern County Water Agency (KCWA)**--KCWA takes water from both the SWP and the Kern River. General minerals, metals, organics, and miscellaneous constituent data collected by KCWA at the Kern River intake were used in this study.

Other Data Sources. Water quality data were also obtained from the following agencies:

1. **City of Sacramento**--Metals data collected by the City of Sacramento at the Sacramento and American Rivers intakes to their water treatment plants were used in this study.

2. **EBMUD Extended Monitoring Study**--In August 1983, EBMUD initiated its Extended Monitoring Study. Data are collected monthly on a variety of constituents, including THMFP, minerals, nutrients, bacteriological constituents, and pesticides. Data collected by EBMUD on the American River at Nimbus and Sacramento River at Greene's Landing were used in this study.

3. **EPA STORET**--The STORET database contains water quality records from several agencies. General minerals and organics data collected on the Sacramento River at Fremont Weir were used in this survey. General minerals data collected on the American River at Nimbus were also used.

4. **United States Bureau of Reclamation (USBR)**--Total dissolved solids (TDS), sodium, and chloride data collected by USBR at the Tracy Pumping Plant on the DMC were used in the water quality database.

5. **City of Tracy**--Metals and some general minerals data collected by the City of Tracy on the DMC were used in this study.

Monitoring Locations

The water quality monitoring locations selected for this survey are described in this section. The locations are shown on Figure 6-1. They are also shown in Chapter 2 in relation to the water-service turnouts.

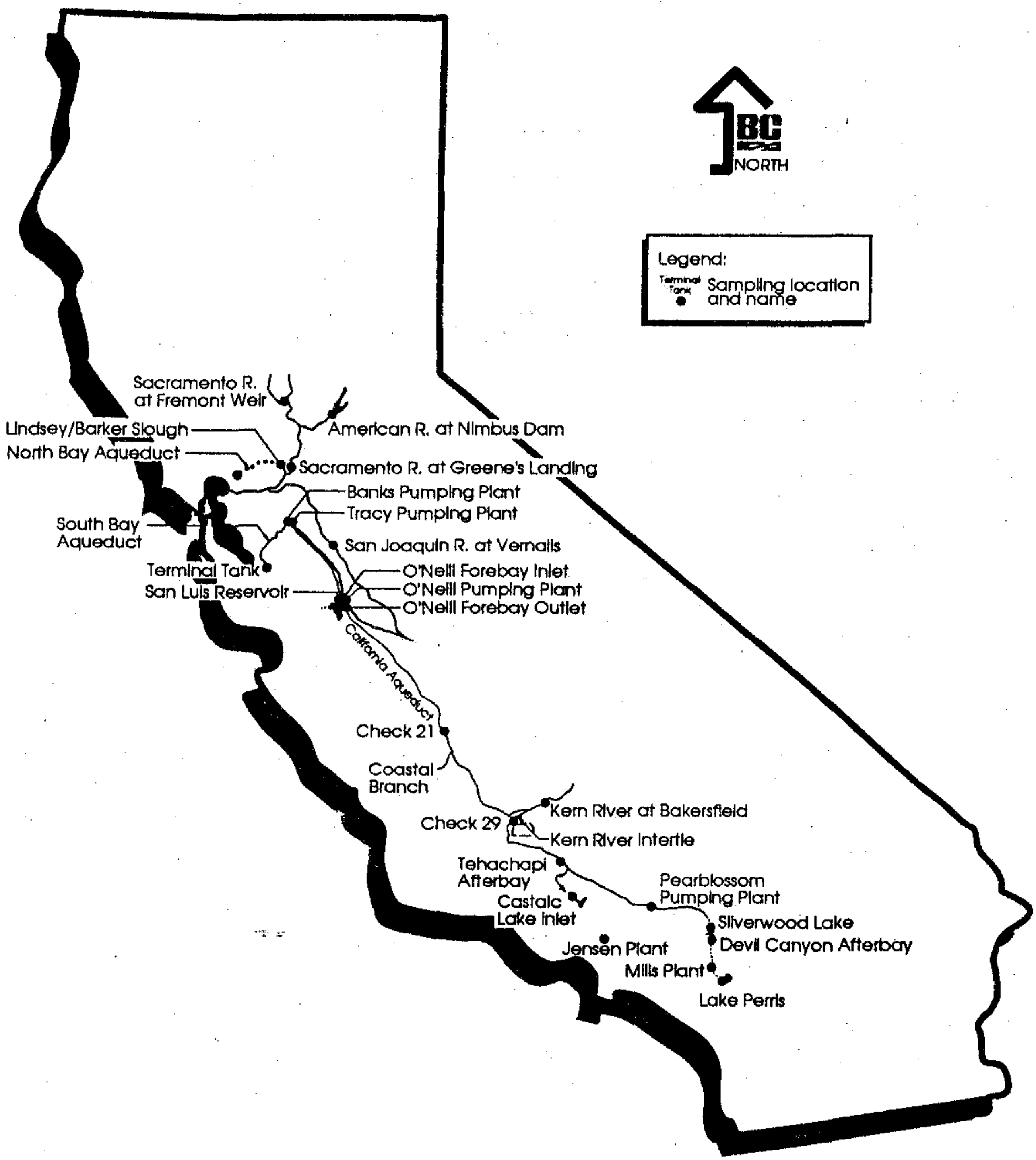


Figure 6-1. Monitoring Locations

Watershed Stations. Data were collected on the quality of water in the major rivers tributary to the Delta. Data were also collected on the Kern River because water can enter the California Aqueduct at the Kern River Intertie near Bakersfield.

1. **Sacramento River at Fremont Weir**--This station is located immediately upstream of the confluence with the Feather River. It represents Sacramento River water quality upstream of the Feather River confluence and Sacramento metropolitan area.

2. **American River at Nimbus**--Data from two sampling locations were included in the database. The first is along the American River below the Nimbus Dam on Lake Natoma. The second location is at the City of Sacramento's Fairbairn Water Treatment Plant intake on the American River. Data from these two stations represent American River water quality.

3. **Sacramento River at Greene's Landing**--This station is located about 15 miles downstream of Sacramento and the confluence of the Sacramento and American Rivers. Data from this station were used to characterize the quality of the Sacramento River as it flows into the Delta.

4. **San Joaquin River at Vernalis**--This station is located immediately upstream of where the San Joaquin River enters the Delta. Data collected at this location were used to characterize the quality of the San Joaquin River before it enters the Delta system. This station is upstream of the cities of Stockton and Tracy.

5. **Kern River**--Data collected at the KCWA intake were used to characterize the quality of the Kern River. As described in Chapter 2, this river can be diverted into the California Aqueduct at the Kern River Intertie near Bakersfield.

North Bay Aqueduct. The North Bay Aqueduct is a pipeline between the Barker slough Pumping Plant and the terminal tank.

1. **Lindsey Slough and Barker Slough**--The data collected at these locations were combined to characterize the water quality of water entering the North Bay Aqueduct and delivered to North Bay Aqueduct contractors. Water flows from Barker Slough into Lindsey Slough. Water is pumped out of Barker Slough at the Barker Slough Pumping Plant.

South Bay Aqueduct. The South Bay Aqueduct consists of both open canal and pipeline segments between the South Bay Pumping Plant and the terminal tank.

1. **South Bay Aqueduct Terminal Tank**--This facility is located at the terminus of the South Bay Aqueduct. Data from this location were used to characterize the quality of water delivered to South Bay Aqueduct contractors.

Delta Mendota Canal. Water from the DMC is pumped into O'Neill Forebay and mixes with the water from the California Aqueduct.

1. **Tracy Pumping Plant**--Data collected at the Tracy Pumping Plant were used to characterize the quality of water entering the DMC.

2. **O'Neill Forebay at O'Neill Pumping Plant**--Data collected at this location represent the quality of water in the DMC that is pumped from the DMC into O'Neill Forebay and mixed with water from the SWP system.

California Aqueduct. Water quality data from a number of locations along the California Aqueduct from the Delta to southern California were analyzed.

1. **Banks Pumping Plant**--Data collected at this location were used to characterize the quality of water leaving the Delta and entering the California Aqueduct and the South Bay Aqueduct.

2. **O'Neill Inlet (Check 12)**--This location is a DWR check point near the inlet to O'Neill Forebay. Data from this location were used to characterize the quality of water entering O'Neill Forebay from the SWP system.

3. **San Luis Reservoir**--This station is located at the outlet of San Luis Reservoir to O'Neill Forebay.

4. **O'Neill Outlet (Check 13)**--This DWR check point is at the O'Neill Forebay outlet. The data characterizes the combined quality of the DMC and SWP water as it enters the San Luis reach of the California Aqueduct.

5. **Check 21**--Check 21 is located on the California Aqueduct near Kettleman City.

6. **Check 29**--This DWR check point is located on the California Aqueduct just below the Kern River Intertie.

7. **Tehachapi Afterbay**--This station is located at the point where the California Aqueduct bifurcates into the east and west branches.

West Branch of the California Aqueduct. The West Branch of the California Aqueduct includes two large reservoirs, Pyramid Lake and Castaic Lake, with a combined residence time of about 2 years.

1. **Castaic Lake Inlet**--Castaic Lake is the terminal reservoir on the West Branch of the California Aqueduct. Water quality data are collected at the inlet to the lake and represent the quality of water leaving Pyramid Lake.

2. **Jensen Filtration Plant**--MWD's Jensen Filtration Plant takes water out of Castaic Lake. These data characterize the quality of water delivered at the terminus of the West Branch.

East Branch of the California Aqueduct. The East Branch of the California Aqueduct includes Silverwood Lake with a 2-month residence time and Lake Perris. There is a pipeline that bypasses Lake Perris.

1. **Pearblossom Pumping Plant**--Data collected at this location characterize the quality of water delivered to contractors in the Antelope Valley.

2. **Devil Canyon Afterbay**--Data from Devil Canyon Afterbay and the Mills Filtration Plant were combined to describe the quality of water leaving Lake Silverwood and delivered to contractors in the San Bernardino and Riverside areas.

3. **Lake Perris Inlet**--Data collected at the inlet describes the water quality before it enters Lake Perris, the terminal reservoir on the East Branch of the California Aqueduct.

4. **Lake Perris**--Lake Perris is located at the terminus of the East Branch of the California Aqueduct.

CONSTITUENTS OF CONCERN

The available data on organic, inorganic, and biological constituents of concern in the SWP system are described in this section. Summary tables of the data presented in this section are in Appendix D. These tables contain information on the constituents sampled, the number of samples, the range of values, median, tenth percentile, and ninetieth percentile. The period of record varies for each location and constituent. In general, the data presented in this section were collected between 1975 and 1989.

Disinfection By-Products

The regulation of disinfectants and disinfection by-products (DBPs) by the EPA and DHS and the ability to meet the drinking water standards that will likely be promulgated for these constituents is of utmost concern to many of the water contractors using SWP water. The water contractors will be faced with meeting the stringent disinfection requirements for Giardia and virus inactivation imposed by the Surface Water Treatment Rule, while at the same time minimizing the formation of potentially toxic and possibly carcinogenic DBPs.

Disinfectant and Disinfection By-Product Regulations. Trihalomethanes (THMs) are halogenated organic compounds formed in drinking water when chlorine used for disinfection during the water treatment process reacts with organic compounds in the water. These organic compounds, mainly naturally occurring humic and fulvic acids, resulting from plant decay, are generally referred to as organic THM precursors. Delta water supplies also contain bromides, which are mainly of sea water origin. Recent studies have shown that the presence of bromide greatly affects the species of THMs formed and also increases the total amount of THMFP (Luong et al., 1982; Amy, et al., 1985). There are four varieties of regulated THMs produced in drinking water diverted from the Delta; chloroform ($CHCl_3$), bromodichloromethane ($CHCl_2Br$), dibromochloromethane ($CHBr_2Cl$), and bromoform ($CHBr_3$).

EPA has determined that THMs are capable of causing cancer in test animals and are suspected human carcinogens. As discussed in Chapter 3, THMs are the only DBPs that are currently regulated. The existing maximum contaminant level (MCL) is 100 micrograms per liter (μg/l) expressed as a running annual average of quarterly samples. At the October 11, 1989 meeting of the Science Advisory Board Drinking Water Committee, EPA introduced the Strawman Rule for disinfectants and DBPs (D-DBPs). In the Strawman Rule, EPA has stated that it will reduce the current MCL for total THMs (TTHMs) from 100 μg/l to either 25 or 50 μg/l (EPA, 1989). The MCL will be proposed in September 1991 and finalized in 1992 or 1993.

It is also likely that EPA will propose MCLs for other DBPs which are suspected carcinogens, mutagens, or teratogens, in addition to THMs. Likely candidate by-products for regulation are those included in EPA's Drinking Water Priority List: halonitriles; halogenated acids, alcohols, aldehydes, and ketones; chloropicrin; and 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX). MX is being found in current research to be the strongest mutagen commonly existing in chlorinated surface water supplies. In the Strawman Rule for D-DBPs, EPA indicated that MCLs will likely be set for haloacetic acids, chloride dioxide, chlorite, chlorate, chlorine, and chloramine. Potential additional contaminants include chloropicrin, cyanogen chloride, hydrogen peroxide, bromate, iodate, and formaldehyde. It is likely that many DBPs will be regulated on a class basis, rather than on an individual species basis. The standards will remain on a weight basis.

Trihalomethane Formation Potential. Since untreated water does not generally contain significant THMs, waters of the Delta and its tributaries are analyzed for THMFP, which is a test of the capacity of a water source to form THMs upon chlorination. The analytical method for determining THMFP is not rigidly prescribed or clearly defined. The method used by DWR yields results which are indicative of the maximum amount of THMs that could be produced in a given source water. This analysis is useful for comparing water sources. Actual THM concentrations in treated drinking water are much lower than the values produced in the DWR THMFP test for a number of reasons, including lower chlorine dosages and shorter reaction times that generally occur in drinking water treatment and distribution systems. A potential problem with the DWR THMFP test is that the THM formation "driving force," as measured by the ratio of chlorine dose to organic carbon concentration, is much higher for cleaner waters (e.g., American River) than for water containing higher organic precursor concentrations.

Figure 6-2 presents the DWR THMFP data for the Delta source waters and the Tracy and Banks Pumping Plants. The figure shows a statistical array of data from each location, and indicates the median value, the range from the observed maximum value to the observed minimum value, and the range which encompasses the 80 percent of the data falling between the tenth and ninetieth percentiles.

These data show that the THMFP of the American River is low with a median value of 210 µg/l, respectively. The THMFP of the Sacramento River at Greene's Landing is slightly higher with a median value of 255 µg/l. The median THMFP concentration in Lindsey Slough is quite high at 870 µg/l. The median THMFP concentration in the San Joaquin River, Tracy Pumping Plant, and Banks Pumping Plant are about equal, ranging from 470 to 500 µg/l. These data show that THMFP increases dramatically as the water of the Sacramento River travels through the Delta to the pumping plants. There are limited THMFP data available for SWP facilities south of the pumping plants. MWD conducted a brief monitoring program on THMFP and other DBPs in agricultural drains, Delta source waters, and SWP facilities in the spring and summer of 1987. THMFP concentrations in samples from the Banks Pumping Plant, O'Neill Forebay, and Devil Canyon Afterbay were essentially equal in the limited number of samples collected. These data are too limited to draw conclusions on changes in THMFP concentrations in SWP facilities. DWR started a monitoring program on THMFP in SWP facilities south of the Delta in April 1990. Samples are collected monthly at five locations and quarterly at four locations. Samples are also collected at the North Bay Aqueduct Barker Slough Pumping Plant. These data will provide valuable information on changes in THMFP due to conveyance and storage in reservoirs. The data will also show the contribution of THMFP from the DMC.

Organic Carbon. The increase in THMFP in the Delta is discussed in detail in Chapter 4. It is likely due to the increased organic carbon content of Delta waters compared to Sacramento River water and to the presence of bromide in sea water that intrudes into the Delta during periods of low outflow. Organic carbon is the basic and essential precursor in the formation of THMs during water treatment. Waters high in organic carbon may be highly colored and usually contain substantial quantities of humic and fulvic acids that produce DBPs upon chlorination. Figure 6-3 presents the total organic carbon (TOC) data for the Delta source waters, the Banks Pumping Plant, and the terminal facilities in southern California. The TOC concentration of a water supply source is a rough indication of the potential to form THMs, since the TOC measurement includes the organic THM precursors. The rivers have a much greater range of TOC concentrations than the SWP facilities. The median TOC concentration increases as the water flows through the Delta, from 2.0 milligrams per liter (mg/l) in the Sacramento River at Greene's Landing to 3.9 mg/l at the Banks Pumping Plant. The terminal facilities have median TOC concentrations ranging from 2.6 to 3.7 mg/l.

Dissolved organic carbon concentrations in the Delta source waters and the Delta are shown on Figure 6-4. These data show the same pattern of increasing carbon content as the water flows through the Delta. The highest concentrations are at Lindsey/Barker Slough, where the median is 5.7 mg/l.

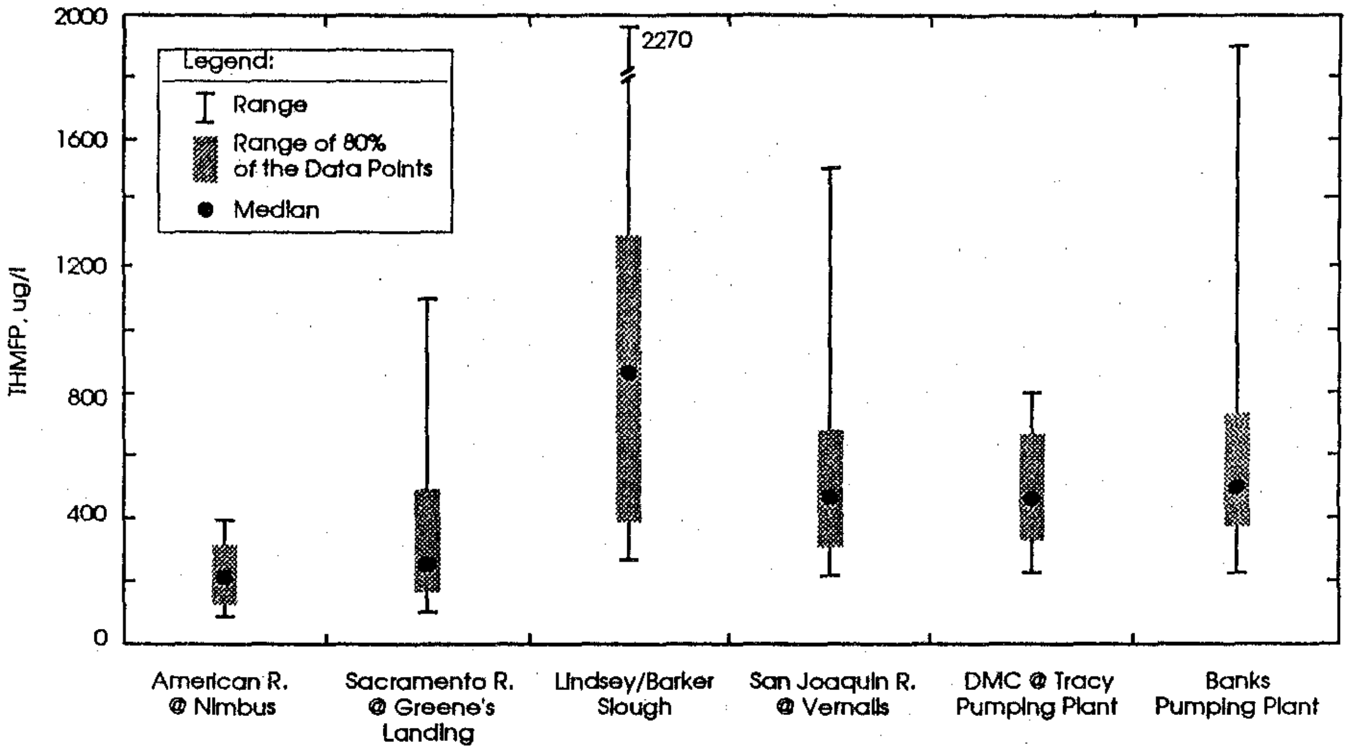


Figure 6-2. THMFP in the State Water Project and Tributaries

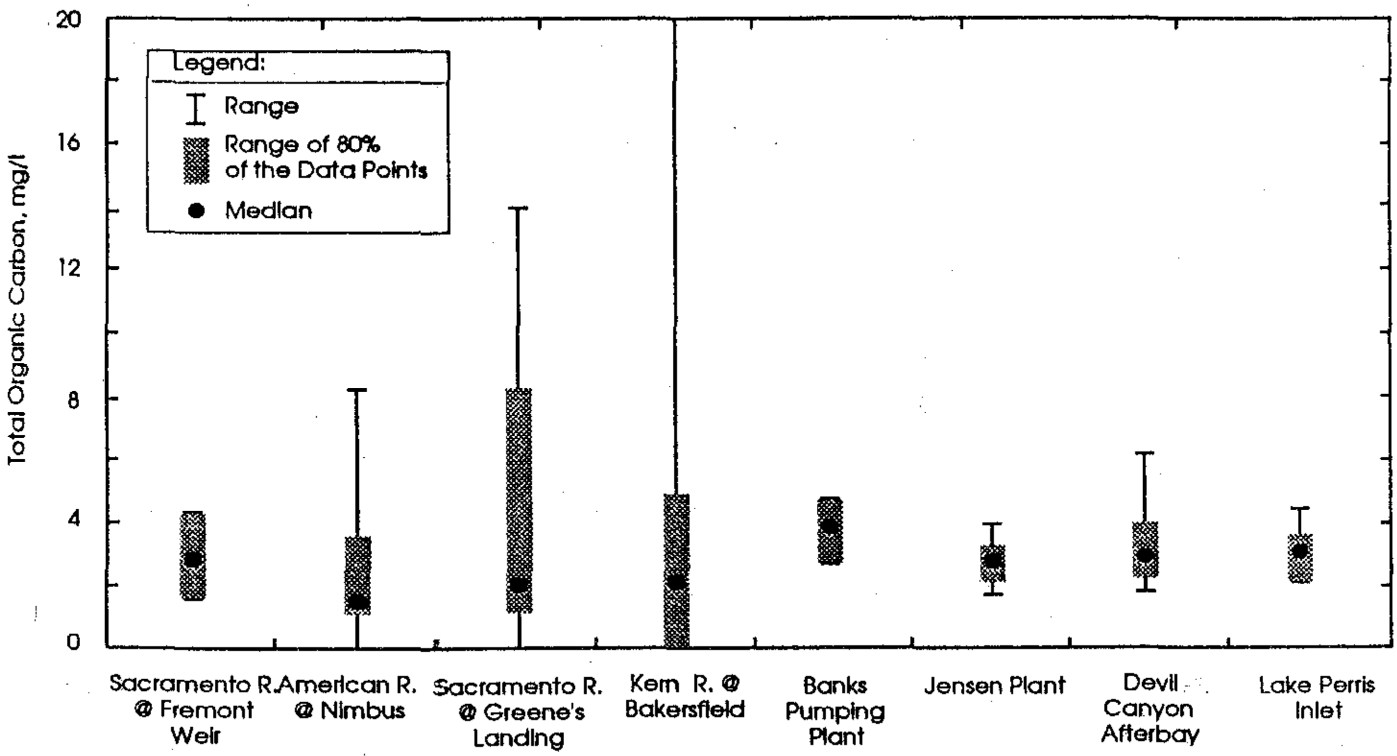


Figure 6-3. Total Organic Carbon in the State Water Project and Tributaries

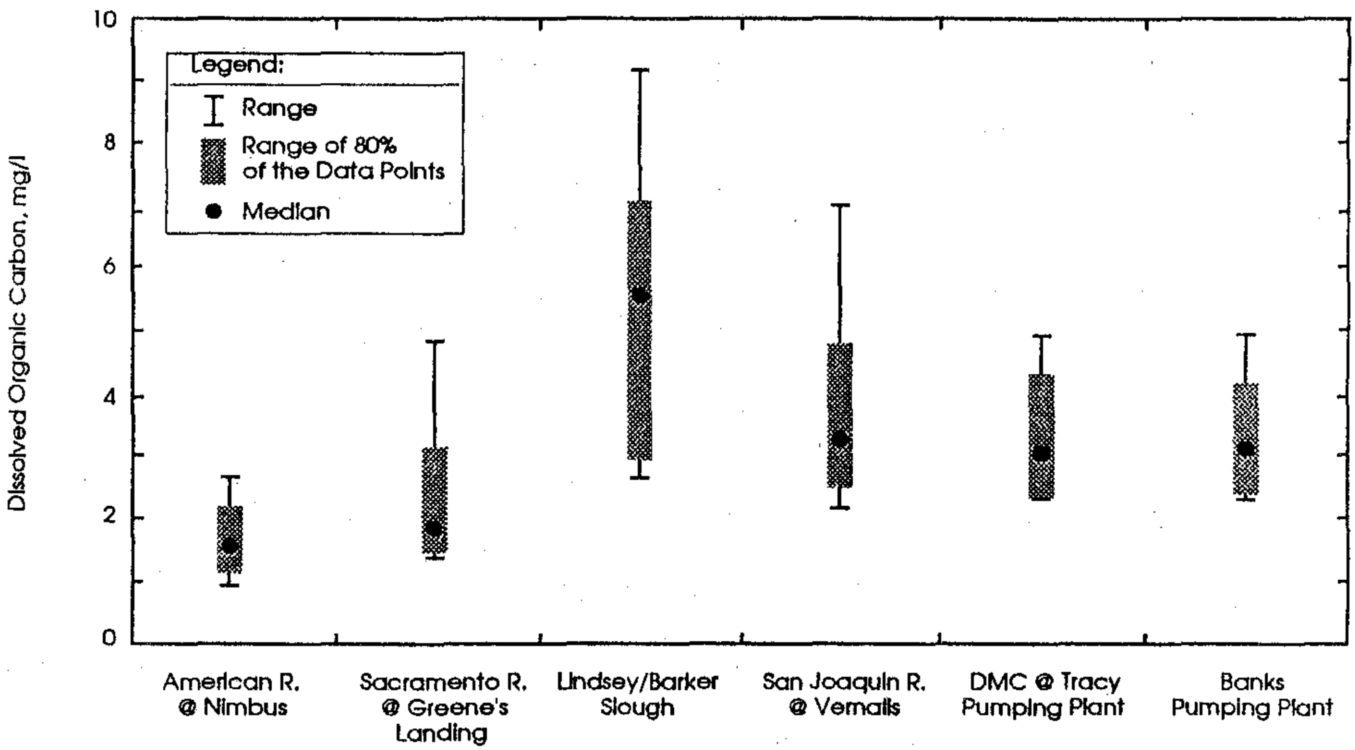


Figure 6-4. Dissolved Organic Carbon in the State Water Project and Tributaries

The increased organic carbon content of Delta waters is partially due to the discharge of agricultural drainage into the Delta. Some is also contributed by municipal and industrial dischargers. An additional amount results from the growth of algae and aquatic plants in Delta waters and the contact between the water and the rich organic peat soils of the Delta channels and levees. The exact contribution from each of these sources is largely unknown. The DWR agricultural drainage study is addressing some of these unknowns. A preliminary analysis of data collected in 1988 showed that agricultural drainage increased the THM carbon in Delta channels by 67 percent (DWR, 1990).

Bromide and Brominated THMFP. During periods of reduced freshwater outflow, the operation of water project pumps in the southern Delta causes the flow of the San Joaquin River and other channels to reverse their normal direction. When this occurs, sea water containing bromides more easily enters the Delta from the estuary and mixes with Delta waters. Recent studies have shown that the presence of bromide results in the formation of brominated THM species and also increases the total amount of THMFP (Luong et. al., 1982; Amy et. al., 1985). In the presence of bromide, free chlorine reacts with the bromide ion to form hypobromous acid. The hypobromous acid reacts with organics to form brominated DBPs. Very recent work by MWD has shown that the presence of bromide also results in the formation of many different brominated DBPs, including bromate, when ozone is used for disinfection (McGuire, et al., 1990).

Since the atomic weight of bromine (79.909) is more than twice that of chlorine (35.453), the substitution of bromine for chlorine in a molecule increases the molecular weight. Drinking water standards are set on a weight basis. Thus, a 100-µg/l THM standard that is met when no bromide is present may not be met during periods of sea water intrusion when the heavier brominated THMs are formed. For example, THM levels in treated SWP water have been higher during the current drought because of elevated bromides coming from the Delta as a result of sea water intrusion (McGuire, et al., 1990). The Castaic Lake Water Agency recently violated the current 100 µg/l THM MCL due to elevated bromide levels.

Bromide is present in sea water at concentrations about three one-thousandths (0.003) times the concentration of chloride. Measurements by agencies using Delta water show a bromide/chloride ratio of about 0.003 (McGuire, et al., 1990). Historic chloride measurements of Delta waters have been used to predict bromide concentrations using the bromide/chloride ratio of 0.003. Figure 6-5 shows the predicted bromide measurements in source waters, the Delta, and various SWP facilities. The impact of sea water intrusion can clearly be seen in the increase in bromide concentration between Greene's Landing (median of 0.02 mg/l) and the Banks Pumping Plant (median of 0.16 mg/l). Although the median bromide concentrations are fairly low in the SWP facilities, the maximum concentrations approach 1 mg/l at the Aqueduct monitoring locations. Bromide concentrations near 1 mg/l can result in significant levels of brominated THMs and other DBPs.

Figure 6-6 presents the concentrations of brominated THMFP in the Delta and source waters. The median THMFP and brominated THMFP concentrations for the five years (1985 to 1987) of IDHAMP data analyzed to date are shown on this figure. Also shown are the

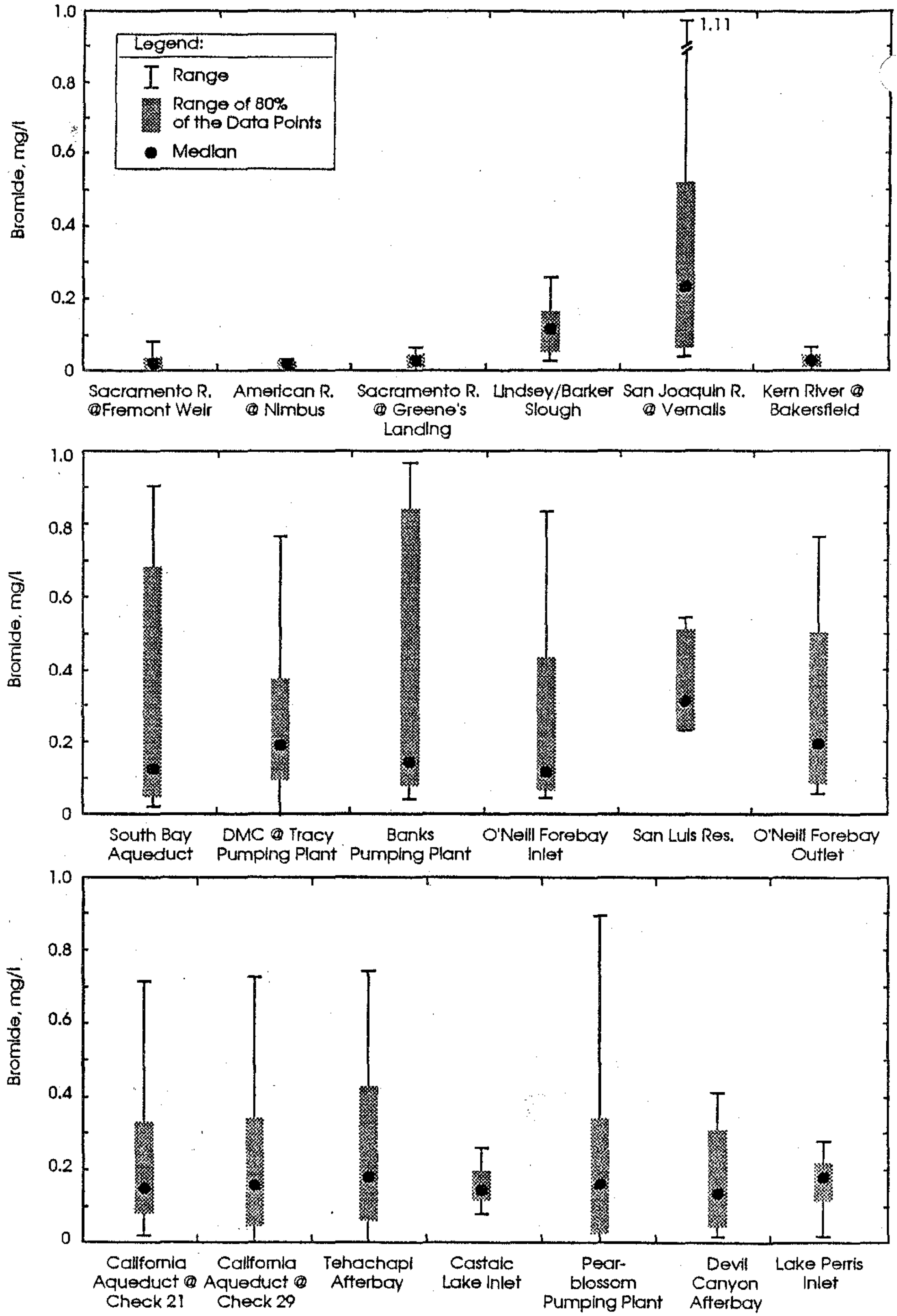
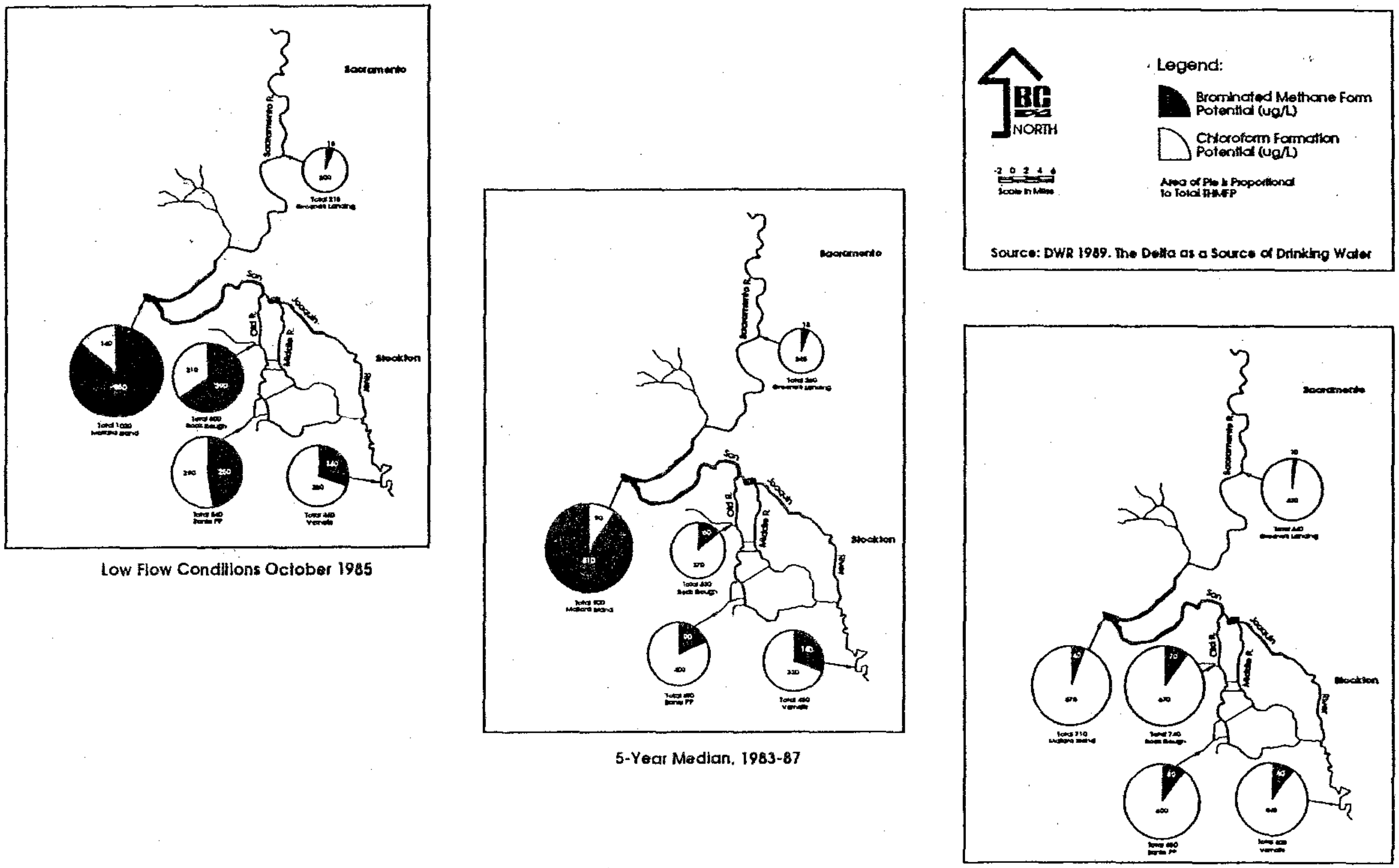


Figure 6-5. Predicted Bromide in the State Water Project and Tributaries



Low Flow Conditions October 1985

5-Year Median, 1983-87

High Flow Conditions, March 1986

Figure 6–6. Brominated THMFP in Delta Source Waters

corresponding concentrations during periods of high Delta outflow and low Delta outflow. The influence of sea water intrusion on the formation of brominated THMFP in the Delta is quite dramatic. During high flow conditions, brominated THMFP makes up 12 percent of total THMFP at the Banks Pumping Plant, whereas under low flow conditions it makes up 46 percent.

Other Disinfection By-Products. There are a limited amount of data on other DBPs in SWP water. MWD conducted an investigation of other DBPs in SWP waters in the spring and summer of 1987. Formation potential tests for dihaloacetonitrile, dichloroacetic acid (DCAA), and trichloroacetic acid (TCAA) were run in a manner similar to the THMFP test, in which chlorine (120 mg/l) was added to the samples which were incubated for 7 days. Table 6-1 shows the results of this study. The significance of the concentrations presented in Table 6-1 is not known because EPA has not yet proposed MCLs for any of these DBPs. Trends in the Delta source waters and the SWP facilities cannot be determined from these limited data.

Table 6-1. Formation Potential Disinfection By-Products in SWP Waters

Location	Median concentration, µg/l		
	Dihaloacetonitrile	Dichloroacetic acid	Trichloroacetic acid
Greene's Landing	4.5	55	54
Vernalis	1.5	58	37
Banks Pumping Plant	1.6	57	45
Devil Canyon	1.5	34	24

MWD used a broad-spectrum method developed at MWD's laboratory to analyze samples for other DBPs. Samples were collected from the Banks Pumping Plant in June 1987, and from Greene's Landing and Vernalis in October 1987. The results of this study showed that all the formation potential samples contained relatively high levels of DCAA and TCAA. Benzaldehyde, chloroacetic acid, bromoacetic acid, dibromoacetic acid, chloropicrin, and 1,1,3-trichloroacetone were also detected.

MWD conducted a study on the occurrence and control of DBPs in California drinking waters for DHS (MWD and James M. Montgomery Consulting Engineers, 1989). The study was conducted in conjunction with a similar study involving 25 utilities around the country, funded by EPA and the Association of Metropolitan Water Agencies. Although data from individual utilities are not available from the study, a number of DBPs were found in this study. On a weight basis, THMs represented the largest class of DBPs measured in this study. The next significant fraction was haloacetic acids. Almost all utilities had detectable levels of formaldehyde and acetaldehyde. Chloramines have been used to limit the formation of THMs and other DBPs but in most waters, cyanogen chloride was found to increase in the presence of chloramines. The presence of bromide shifted the distribution of THMs, haloacetonitriles, and haloaceticacids to the more brominated species.

Ability to Meet Standards. Most SWP contractors are able to meet the current THM standard of 100 µg/l most of the time. Sea water intrusion carries bromide into the SWP during dry years making it more difficult to meet the existing THM standard. Many of the water supply agencies will have to modify their treatment processes to meet either the 50 µg/l or 25 µg/l standards discussed in the Strawman Rule. It may not be possible to meet these standards during periods of sea water intrusion.

There are no existing standards for other DBPs and EPA has not yet published the list of DBPs that will be regulated. There is also very limited information on the levels of DBPs in SWP water supplies. It is not possible to speculate on the ability of the SWP contractors to meet the future DBP standards.

Minerals

Although there are many constituents that fall under the minerals category, only the key constituents are discussed in this section. Data on the concentrations of some of the minerals not discussed in this section are presented in Appendix D.

Total Dissolved Solids and Hardness. TDS is a measure of the residue present after filtering and evaporating a water sample. Although it is not precisely equivalent to the technical definition of salinity, TDS is often termed the salinity of water. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs because of corrosion or the necessity for treatment for corrosion control and softening. The federal and state secondary (nonmandatory) standard for TDS includes several levels; the lowest is a suggested limit of 500 mg/l. This limit was set primarily on the basis of taste thresholds.

Hardness is an important constituent of concern in drinking water supplies. It is defined as the sum of the polyvalent metallic ions dissolved in water, expressed as calcium carbonate. In fresh waters these are principally calcium and magnesium, although other ions such as iron and manganese contribute to the extent that appreciable concentrations are present.

TDS is the constituent used in the DWR water quality model of the Delta. Figure 6-7 presents the TDS data for the source waters, the Delta, and SWP facilities. The median TDS concentrations in the source waters vary from 48 mg/l in the American River to 376 mg/l in the San Joaquin River. The Sacramento River median concentration of 100 mg/l is almost double that of the Sierra streams but only one fourth of the median concentration in the San Joaquin River. The San Joaquin River has the greatest range of concentrations with a maximum of 1,150 mg/l. The median TDS concentrations at the three pumping plants in the Delta range from about 250 mg/l at the Banks and Tracy Pumping Plants, to 313 mg/l at the Barker Slough Pumping

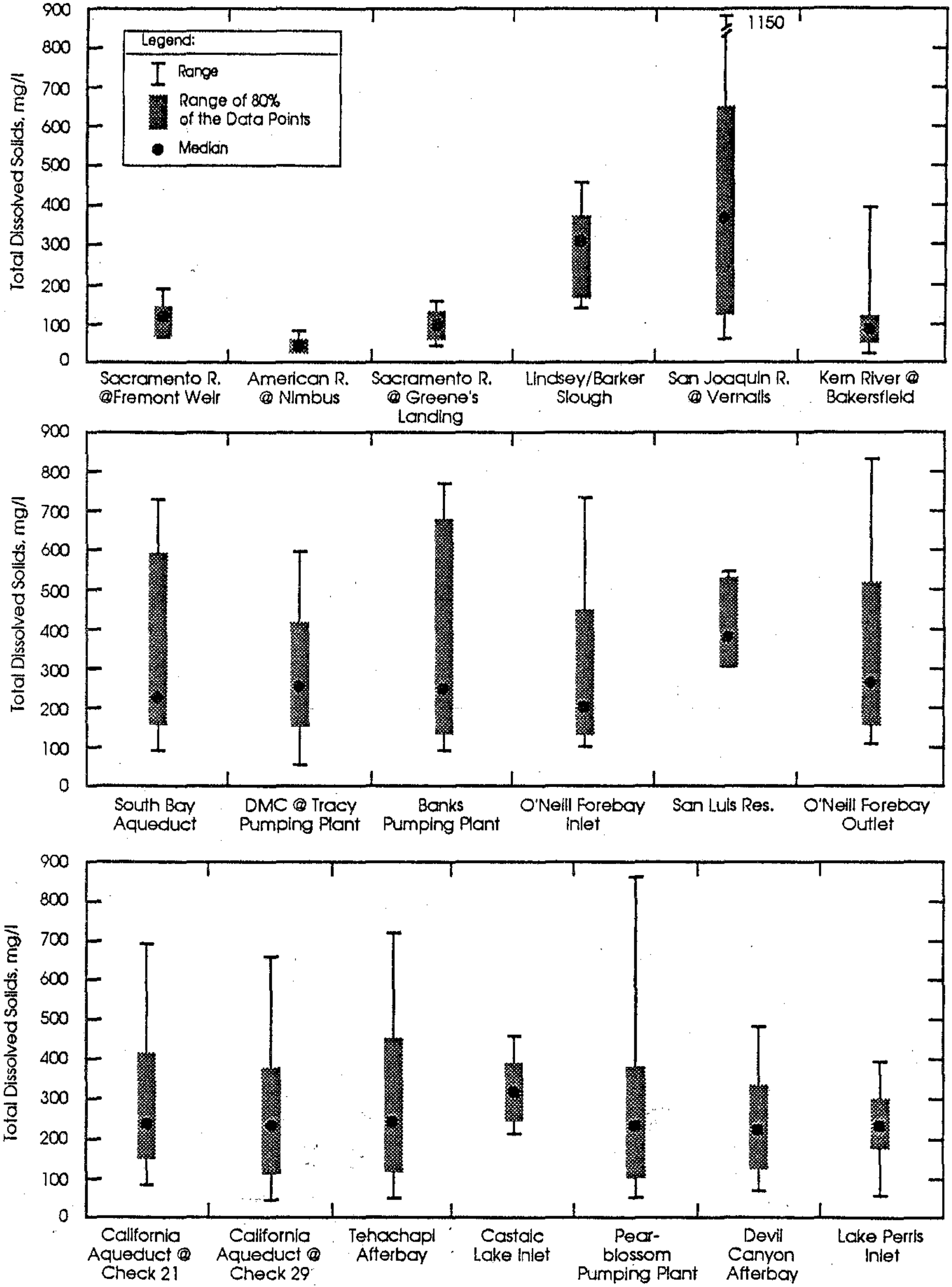


Figure 6-7. Total Dissolved Solids in the State Water Project and Tributaries

Plant. There are only 3 years of data collected between 1984 and 1988 at the Barker Slough Pumping Plant whereas there are 14 years of data at the other pumping plants. The median TDS concentrations are near 250 mg/l at various locations along the California Aqueduct. About 10 percent of the time, TDS concentrations exceed the secondary standard of 500 mg/l. As shown on Figure 6-7, the median TDS concentrations of San Luis Reservoir and Castaic Lake are higher than the concentrations in the Aqueduct. The water leaving Lake Silverwood and entering Lake Perris is similar in quality to the California Aqueduct water.

The watershed of the American River is sparsely developed compared to other Delta tributaries. This is one factor reflected in the low TDS concentrations found in this river. The Sacramento River receives urban and agricultural runoff which results in higher TDS concentrations than in the Sierra streams. The high TDS concentrations in the San Joaquin River are largely due to the extensive amount of agricultural drainage that is discharged into the river. The TDS concentrations found at the pumping plants are due partially to the influence of the San Joaquin River, partially to sea water intrusion, and partially to salt concentrations in Delta agricultural discharges. Delta outflow is the primary factor controlling TDS concentrations at the pumping plants (DWR, 1989). There are no apparent increases in the TDS concentrations along the California Aqueduct as a result of the discharges into the Aqueduct.

Chloride. Chloride has traditionally been used as the water quality constituent for evaluation of the Delta water supplies. The chloride levels in drinking water sources supplied from the Delta are directly related to sea water intrusion. High chloride levels are associated with high levels of cations, mainly sodium, and a saline taste is noticed by customers when chloride levels increase. High chloride levels also result in increased corrosion of distribution systems, home plumbing systems, and industrial facilities.

The secondary (nonmandatory) drinking water standard for chloride is 250 mg/l. Decision 1485 requires that the chloride concentration not exceed 150 mg/l at the Contra Costa Water District intake at Rock Slough, at certain times and conditions. The recently published Draft Water Quality Control Plan for Salinity establishes a 150 mg/l chloride criterion at Rock Slough (State Board, 1990). The 150 mg/l level can be exceeded 44 percent of the time in wet years and 58 percent of the time in critically dry years. The experience of Contra Costa Water District shows that customer complaints increase when the chloride level reaches 100 to 150 mg/l (Brown and Caldwell, 1989). There is no practical treatment for reduction of chloride in urban supplies.

Figure 6-8 presents a summary of chloride concentrations in the source waters, the Delta, and the SWP facilities. With the exception of the San Joaquin River, chloride levels are extremely low in all of the source waters. The median concentration of chloride in the San Joaquin River is 80 mg/l and the maximum concentration is 383 mg/l, well in excess of the secondary standard of 250 mg/l. Chloride concentrations are consistently well below the secondary standard at the headworks of the North Bay Aqueduct. At the terminal tank of the South Bay Aqueduct, chloride concentrations are less than 250 mg/l about 90 percent of the time. The median chloride concentrations along the California Aqueduct range from 39 to 66 mg/l.

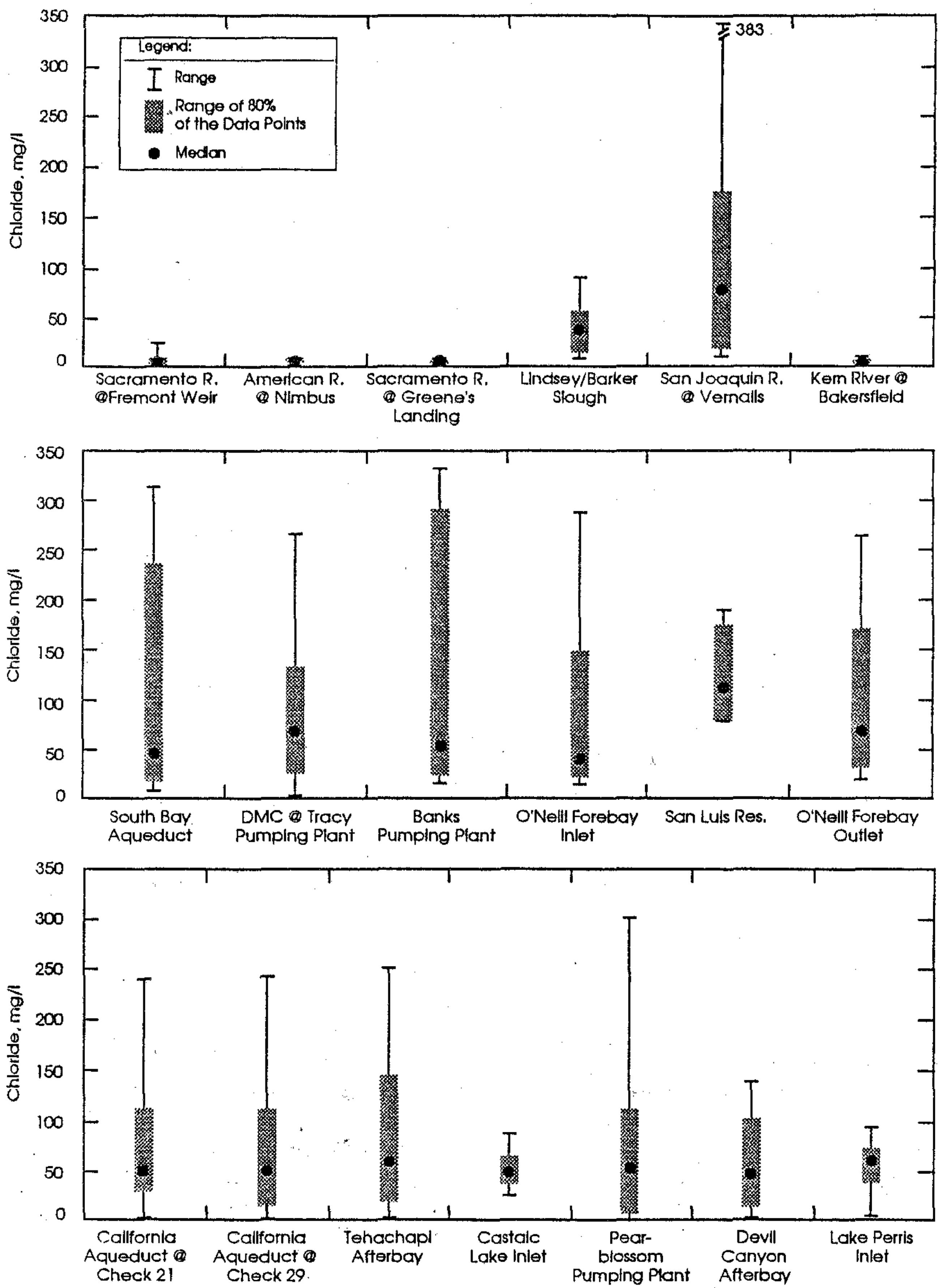


Figure 6-8. Chloride in the State Water Project and Tributaries

The maximum concentrations are generally at or slightly above the 250 mg/l standard. The maximum concentrations in the reservoirs are well below the standard.

Sodium. High levels of sodium can corrode pipes and make water unfit for human consumption. Evidence from epidemiologic, clinical, and animal studies suggests that there is a relationship between daily dietary intake of sodium and high blood pressure (hypertension). Drinking water generally contributes only a small portion of total dietary intake of sodium, but that portion can be important for persons on restricted sodium diets. There are no federal or state drinking water standards for sodium. In fact, EPA removed sodium from the list of 83 contaminants to be regulated by 1989. The National Academy of Sciences (NAS) recommends that persons on moderately restricted sodium diets should drink water containing no more than 100 mg/l of sodium (NAS, 1977). EPA and NAS recommend a sodium limit in drinking water of 20 mg/l for persons on severely restricted diets (EPA, 1976; NAS, 1977).

The median sodium concentrations in the source waters, the Delta, and the SWP facilities are shown on Figure 6-9. The median and maximum sodium concentrations in the American River and the Sacramento River at Greene's Landing are below the 20 mg/l level recommended for people on severely restricted sodium diets. The median concentration of 82 mg/l in the San Joaquin River is near the NAS recommended limit of 100 mg/l for persons on moderately restricted diets. The maximum concentration of 177 mg/l is well above that limit. Sodium concentrations at the headworks of the North Bay Aqueduct are consistently greater than 20 mg/l and less than 100 mg/l. At the South Bay Aqueduct terminal tank and the Banks and Tracy Pumping Plants, the median concentrations range from 36 to 50 mg/l and the 100 mg/l recommended limit is exceeded about 10 percent of the time. The increase in sodium concentrations in the Delta is due to sea water intrusion and waste discharges from industries, cities, and farms. The median concentrations along the California Aqueduct range from 34 to 50 mg/l with the 100 mg/l limit being exceeded about 10 percent of the time. There is little change in sodium concentrations between the Banks Pumping Plant and the bifurcation of the California Aqueduct. San Luis Reservoir has a relatively high median concentration of 77 mg/l and a maximum concentration of 120 mg/l. The terminal reservoirs of the SWP have maximum chloride concentrations below 100 mg/l, but concentrations exceed 20 mg/l 90 to 100 percent of the time. Water that is pumped during periods of low Delta outflow (high sodium concentrations) is blended in the reservoirs with lower sodium-level water pumped during periods of high Delta outflow.

Sodium concentrations in the SWP facilities do not generally pose a threat to consumers of drinking water. During periods of low Delta outflow, sodium concentrations may increase to levels of concern to people on moderately restricted sodium diets. The SWP water supplies usually contain more than 20 mg/l of sodium. People on severely restricted sodium diets (less than 500 mg day total sodium intake from all sources) generally understand the role of drinking water sodium in their diet and use demineralized water.

Fluoride. The federal MCL for fluoride is 4 mg/l. The City of Sacramento monitors fluoride in the American and Sacramento Rivers. The concentration is consistently less than

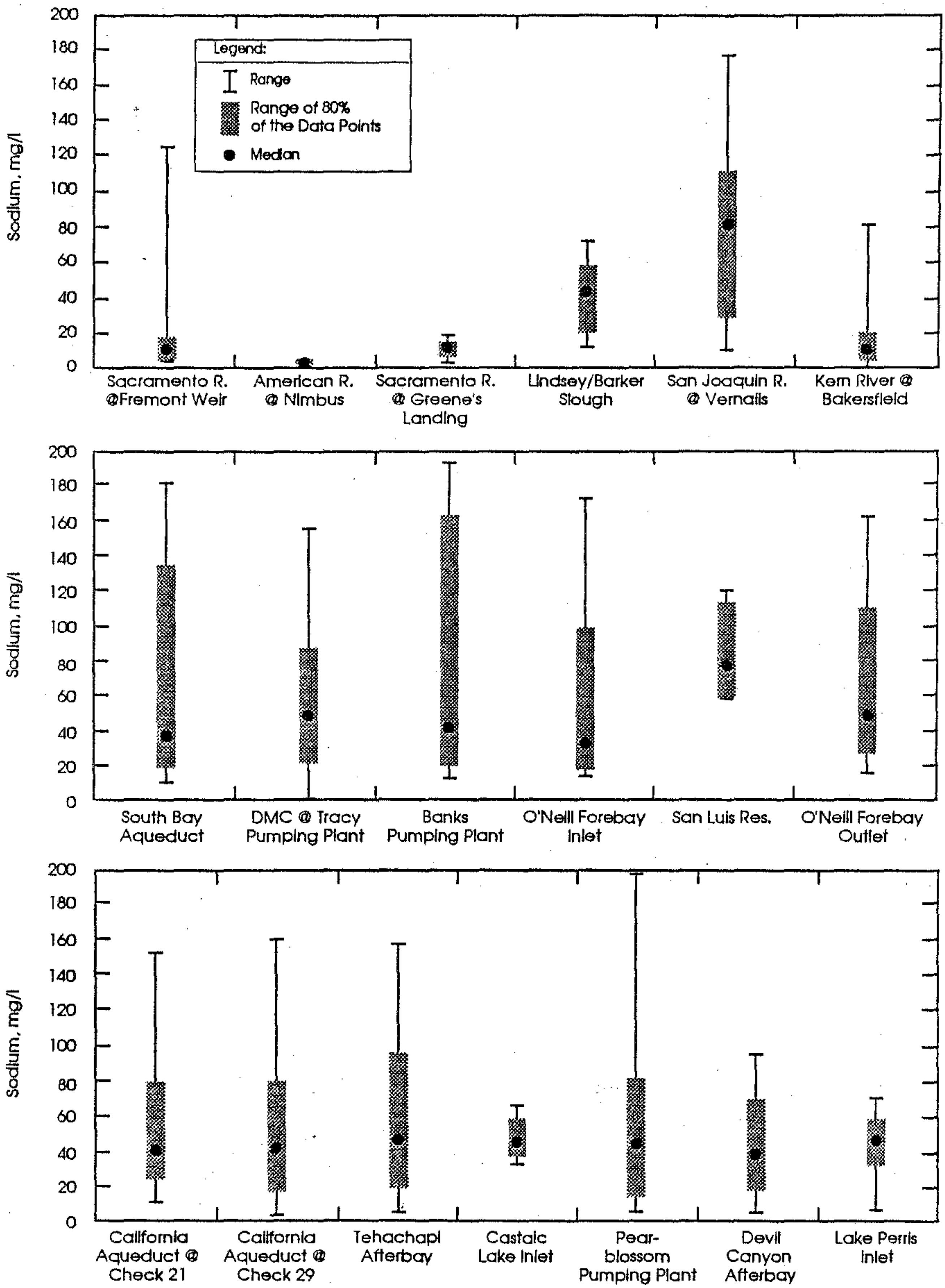


Figure 6-9: Sodium in the State Water Project and Tributaries

0.1 mg/l. Data from Kern County Water Agency show Kern River fluoride concentrations consistently less than 0.5 mg/l and generally less than 0.1 mg/l. MWD data on the terminal reservoirs show fluoride concentrations less than 0.5 mg/l. High fluoride concentrations are generally not found in western surface waters.

Turbidity. Turbidity is a measure of light scatter caused by suspended matter such as clay, silt, organic particulates, plankton, and microorganisms. Turbidity is of concern in drinking water because it is a surrogate measure of potential pathogen levels, particularly with respect to removal effectiveness in filtration plants. It also 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. EPA is proposing to regulate turbidity under the Surface Water Treatment Rule, rather than with an MCL. According to the proposed Surface Water Treatment Rule, the maximum filtered water turbidity level must be less than or equal to 0.5 nephelometric turbidity units (NTU) in 95 percent of the measurements taken every month and it must not exceed 5 NTU at any time.

Figure 6-10 presents a summary of the turbidity data in the source waters, the Delta, and the SWP facilities. The median turbidity levels in the American and Kern Rivers are 2 and 4 NTU, respectively, which are significantly lower than the other sites. The American River sampling location is just downstream of Nimbus and Folsom Dams. The median turbidity levels at the other river sampling locations range from 8 NTU in the Sacramento River at Greene's Landing to 18 NTU in the San Joaquin River at Vernalis. Turbidity in the rivers is highly variable and varies seasonally in relation to flow. As the flow of the river increases, the amount of sediment suspended in the river increases leading to higher turbidity levels, especially for several days following major storms. Maximum turbidity levels in the rivers range from 30 NTU in the Kern River to 230 NTU in the Sacramento River at Fremont Weir.

At the headworks of the North Bay Aqueduct, the median turbidity level is 29 NTU, compared to 11 NTU at the Banks Pumping Plant. The median turbidity increases 100 percent to 23 NTU between the Banks Pumping Plant and the terminal tank of the South Bay Aqueduct. High winds that resuspend bottom sediments in the shallow Bethany Reservoir are thought to be the primary reason for this increase in turbidity. Bethany Reservoir is essentially a wide spot in the Aqueduct rather than a typical reservoir. Storage in reservoirs greatly reduces median turbidity levels to 1 to 2 NTU. Ninety-percentile concentrations range from 1 to 7 NTU. The impact of San Luis Reservoir with a median turbidity of 2 NTU can clearly be seen. The California Aqueduct water entering O'Neill Forebay has a median turbidity level of 18 NTU. Incoming DMC water has a median of 12 NTU. The water leaving O'Neill Forebay has a median turbidity of 8 NTU. There are no significant changes in turbidity levels along the California Aqueduct between the outlet of O'Neill Forebay (Check 13) and southern California.

Color. Color is a gross indicator of the organic content of a water source. Figure 6-11 presents the true color data for the source waters, the Delta, and the SWP facilities. The median color of the rivers ranges from 5 color units in the American River to 12.5 color units in the San

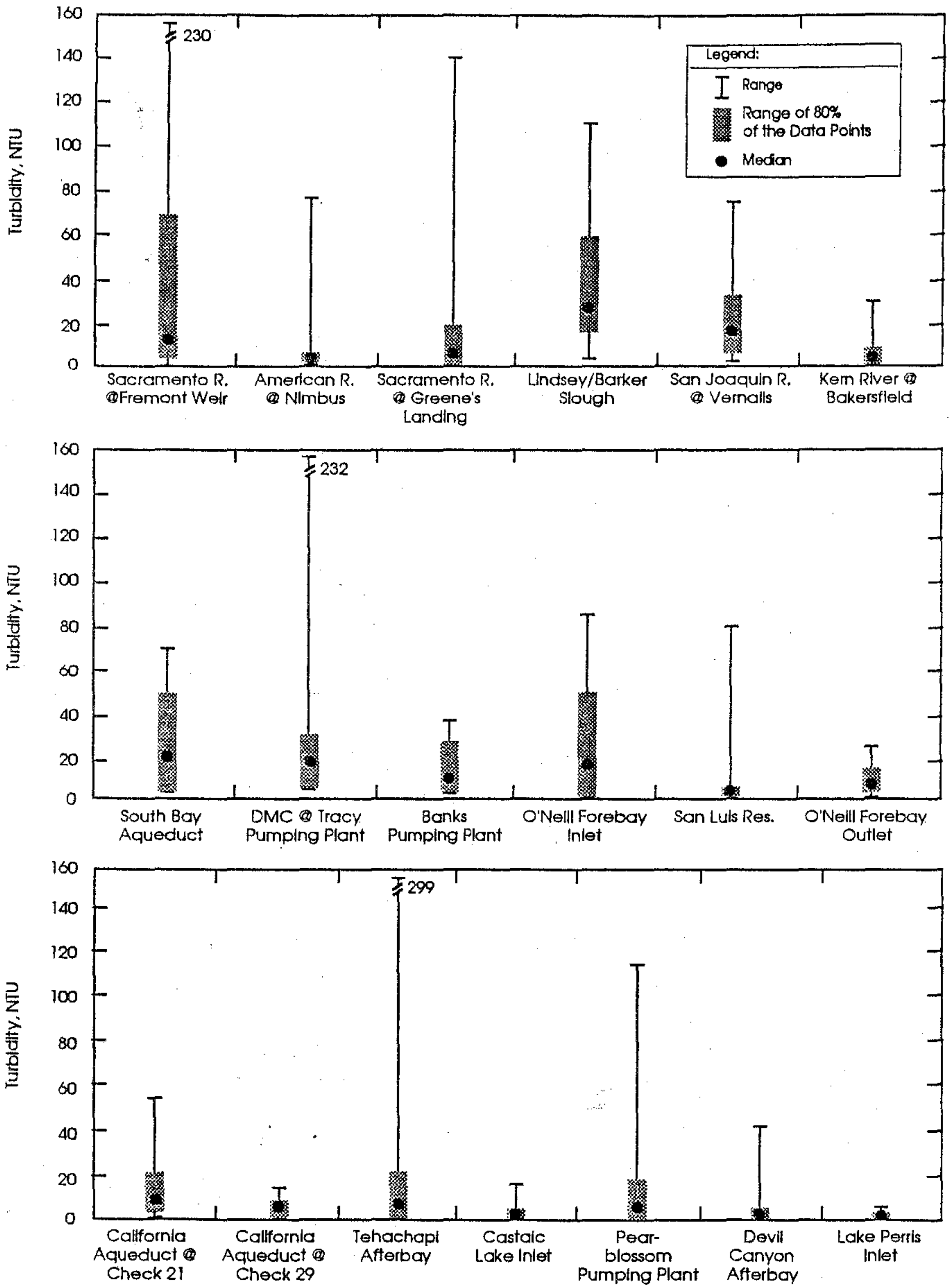


Figure 6-10. Turbidity in the State Water Project and Tributaries

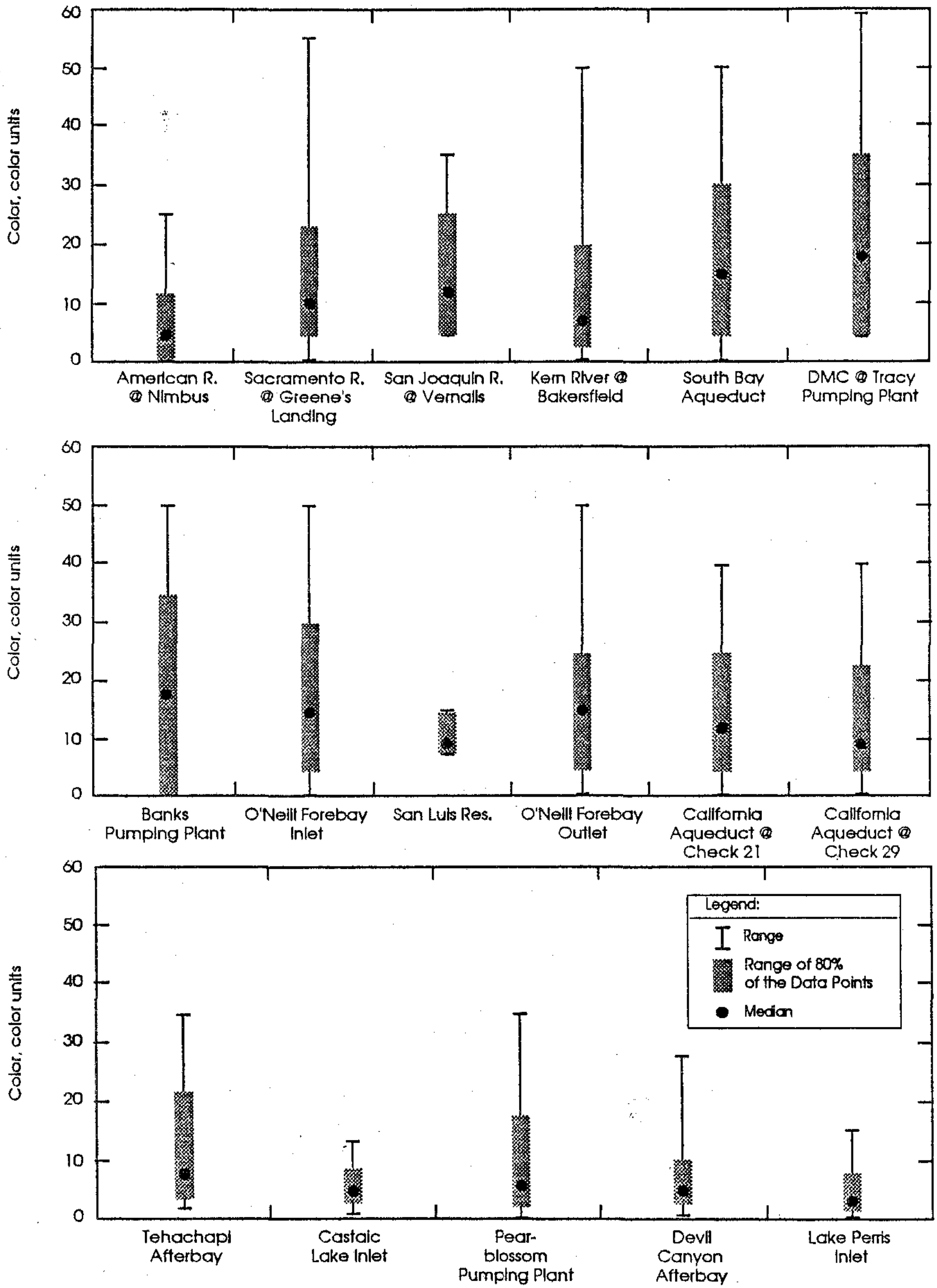


Figure 6-11. Color in the State Water Project and Tributaries

Joaquin River. Color increases as the Sacramento River flows through the Delta from a median of 10 at Greene's Landing to 18 at the Banks and Tracy Pumping Plants. The median and maximum color concentrations decrease steadily from the Banks Pumping Plant to the terminal reservoirs. The median color concentrations in the terminal reservoirs range from 4 to 6 color units.

Algae and Nutrients

Large algal populations can lead to taste and odor problems, increased turbidity, increased concentrations of organic THM precursors, and filter clogging problems in water treatment plants. Nitrogen and phosphorus are the two nutrients that most often limit algal growth at low concentrations and trigger algal growth at elevated concentrations.

Chlorophyll a. There are a limited amount of chlorophyll data on the Delta source waters. The highest concentrations (median of 15 µg/l) are found in the San Joaquin River, most likely due to the high nutrient concentrations found in this river. The concentrations in the American River and Sacramento River at Greene's Landing are quite low (median of 1 to 2 µg/l). High chlorophyll concentrations generally do not develop in flowing waters so the concentrations at these locations may not be indicative of the concentrations that could result in terminal storage reservoirs. Nutrient concentrations in source waters are probably more indicative of the potential chlorophyll concentrations that could result in terminal reservoirs.

Nutrients. Nitrogen is typically the most important nutrient in California surface waters although phosphorus is also important to algal growth. Generally, as nutrient concentrations increase, algal productivity increases, leading to larger algal populations and the problems associated with them. Figure 6-12 shows the nitrate concentrations (as N) in the source waters and SWP facilities. Nitrate concentrations are quite low in the American River (median of 0.04 mg/l) and the Sacramento River (median of 0.18 mg/l). Much higher concentrations are present in the San Joaquin River (median of 1.68 mg/l and maximum of 3.84 mg/l). As described in Chapter 4, agricultural drainage discharged into the San Joaquin River results in extremely high concentrations of nitrate (2 to 3 mg/l) in the upper reaches. The east side tributaries reduce the nitrate to the levels seen at Vernalis by dilution of the agricultural drainage with higher quality water. There is a wide range of nitrate concentrations in the Kern River with a median of 0.36 mg/l. Nitrate concentrations increase slightly in O'Neill Forebay and then remain fairly constant at about 0.5 mg/l along the California Aqueduct. Retention in San Luis Reservoir and Pyramid Lake results in lower nitrate concentrations in the water leaving the reservoirs. Maximum nitrate concentrations are consistently less than 5 mg/l from the source waters to the terminal reservoirs with the exception of one extremely high value (46.5 mg/l) in the Kern River. With the exception of this one value, the MCL of 10 mg/l for nitrate (as N) is always met. Nitrite is converted to nitrate by nitrifying bacteria so nitrite concentrations are generally low in surface waters. The proposed MCL for nitrite is 1 mg/l. The limited data on nitrite in the SWP facilities and tributaries show that the maximum concentration detected was 0.21 mg/l in the Kern River. Generally, nitrite concentrations are less than 0.01 mg/l in SWP facilities.

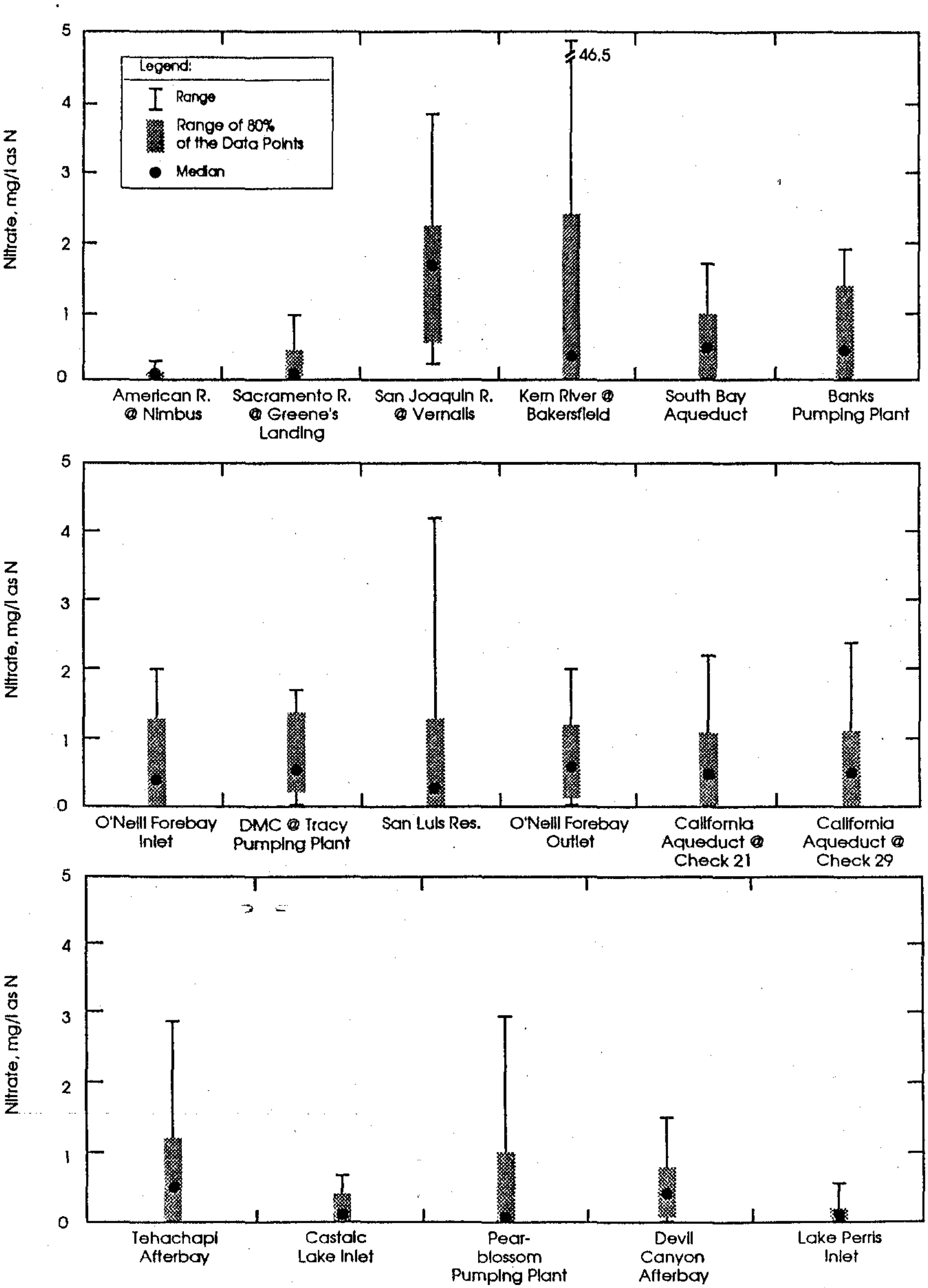


Figure 6-12. Nitrate as N in the State Water Project and Tributaries

Figure 6-13 shows the total phosphorus concentrations (as P) in the source waters and SWP facilities. As expected, the total phosphorus concentrations in the American River is low (median of 0.01 mg/l). The highest median concentration (0.23 mg/l) occurs in the San Joaquin River. The total phosphorus concentrations remain fairly constant along the California Aqueduct (0.11 to 0.14 mg/l). The median concentrations decrease slightly as a result of reservoir storage.

Taste and Odor

The occurrence of objectionable tastes and odors in SWP drinking water is a common and widespread problem. Most biological taste and odor problems result from the bacterial degradation of algae, algal by-products, actinomycetes, and other microorganisms. Other sources of taste, odor, and aesthetic problems in drinking water are corrosion products and small amounts of metals, hydrogen sulfides, rice herbicides, and some other organics. Consumer piping is the largest source of lead, copper, and corrosion products.

The Santa Clara Valley Water District has noted a direct relationship between chlorophyll concentrations (measured by fluorescence) in Delta water and taste and odor problems in water taken from the South Bay Aqueduct. Neither Alameda County Water District nor Alameda County Flood Control and Water Conservation District, Zone 7 has noted taste and odor problems. Algal blooms in the Delta move rapidly through the South Bay Aqueduct into the treatment systems in Alameda and Santa Clara counties. Water has occasionally been released from Lake Del Valle into the South Bay Aqueduct to reduce the algal numbers and chloride levels. Copper sulfate is applied regularly to the South Bay Aqueduct during the summer months to control algal blooms.

MWD has conducted extensive studies on algal populations and 2-methylisoborneol (MIB) and geosmin concentrations in Lake Perris. Taste and odor problems developed in Lake Perris in the summer of 1980 and have been a problem in most subsequent summers from mid-May through October. Geosmin and MIB are responsible for the earthy-musty tastes and odors from Lake Perris. Both planktonic and benthic blue-green algae have been shown to produce MIB (Izaquirre, 1985). Planktonic blue-green algae are responsible for geosmin production (Jones, 1989). Control measures that have been used include rapid drawdown of the lake elevation and exposure of the benthic algal growths to sunlight and the application of copper sulfate to the pelagic area of the lake. MWD often bypasses Lake Perris during the summer months to avoid aesthetically unacceptable water.

Pathogens

Total coliform bacteria measurements indicate the general level of urban and animal contamination of a water supply. Coliform bacteria are generally not harmful to humans, however, they are indicators that other pathogenic organisms may be present. There are a limited amount of data on coliforms in the Delta source waters and SWP facilities. MWD has collected a very limited amount of data on other pathogenic organisms.

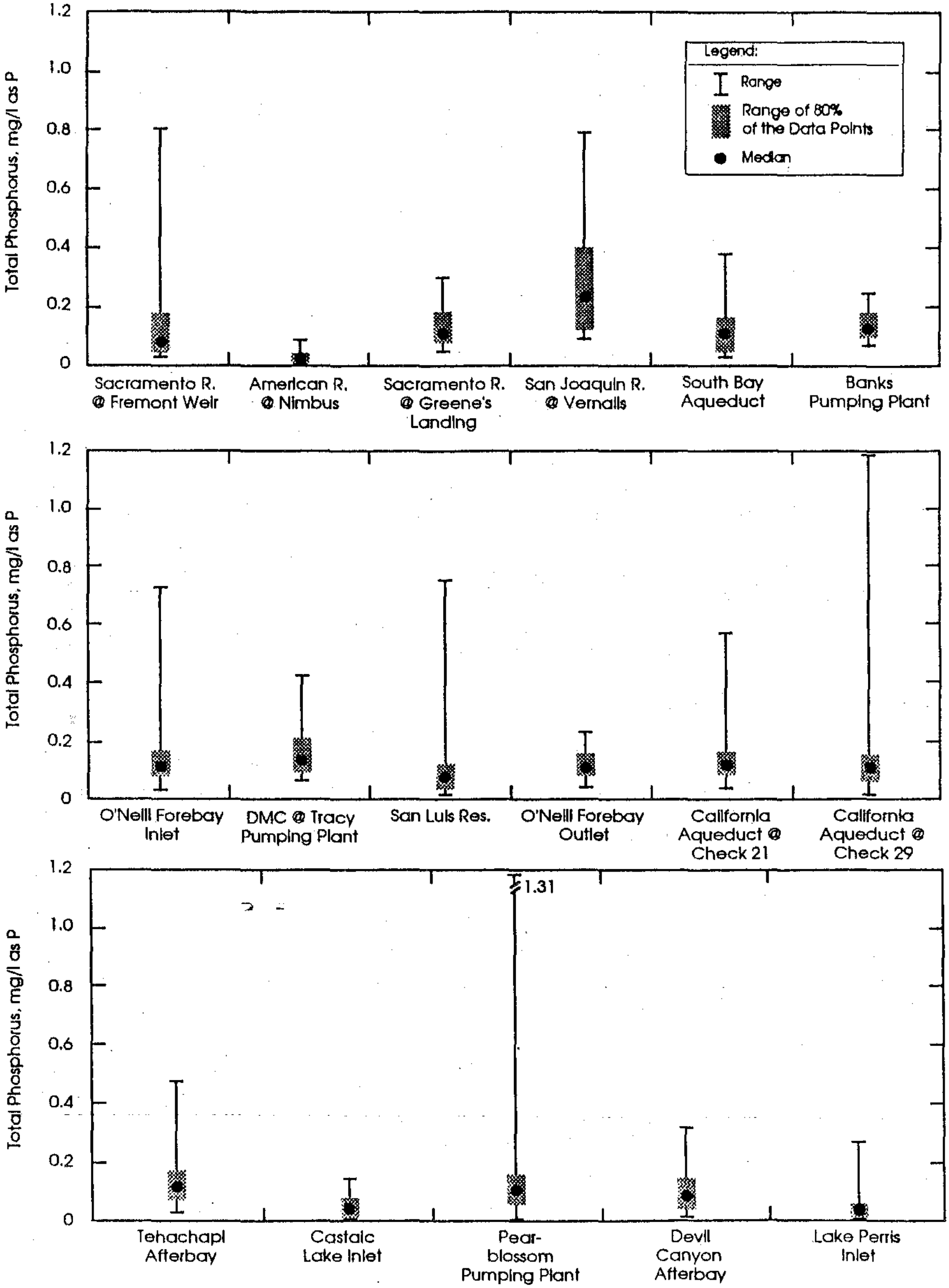


Figure 6-13. Total Phosphorus as P in the State Water Project and Tributaries

Coliforms. EPA will regulate coliform bacteria by a new presence/absence determination under the coliform rule, which will become effective on December 31, 1990. With coliform bacteria, it is not appropriate to compare a raw source water measurement to a standard for treated drinking water. Raw water values are generally vastly higher and are valuable in the selection of treatment processes to provide pathogen-free finished water.

There are a limited amount of total coliform data available on the source waters and the Delta. East Bay Municipal Utility District has collected data on total coliform numbers in the American River at Nimbus, the Sacramento River at Greene's Landing, and Clifton Court Forebay. These data show that the American River is least affected by waste contamination (total coliform numbers range from less than 2 to 4,000/100 ml). The total coliform numbers in the Sacramento River at Greene's Landing are quite high (less than 2 to 17,000/100 ml). This may be due in part to the upstream discharge from the Sacramento Regional Wastewater Treatment Plant, the Sacramento combined (sanitary/storm) sewers, and many urban storm drains. The coliform numbers are reduced (less than 2 to 5,000/100 ml) by the time the water reaches Clifton Court, probably due to dilution and die-off of the bacteria.

Total coliform data are collected on the raw SWP water by several SWP contractors. Alameda County Water District data show total coliform counts ranging from 17 to greater than 2,400/100 ml in South Bay Aqueduct Water. AVEK data on the East Branch of the California Aqueduct show total coliform counts generally ranging from less than 2 to 350/100 ml. Counts greater than 2,400/100 ml occur occasionally. Castaic Lake Water Agency data are similar to the AVEK results. MWD monthly median coliform counts ranged from less than 2 to 60/100 ml in water taken from both the East Branch and the West Branch. The treated water coliform counts from these agencies are always less than 2/100 ml.

Pathogenic Microorganisms. The federal and state Surface Water Treatment Rule (SWTR) establish MCLGs of 0 for Giardia lamblia, viruses, and Legionella. Treatment techniques are established in place of MCLs. Treatment must achieve at least 99.9 percent reduction by removal and inactivation of Giardia cysts and 99.99 percent reduction by removal and inactivation of viruses.

In the fall and spring of 1985, MWD conducted a study to determine if enteric viruses were present in the SWP and Colorado River source waters. Samples were collected from Castaic Lake, Lake Perris, and several reservoirs storing Colorado River water. No enteric viruses were detected in any of the samples.

MWD conducted a study in the summer of 1987 to determine if Giardia and Cryptosporidium were present in Lake Perris, the influent to the Jensen Filtration Plant (water from Castaic Lake), and the treated Jensen Filtration Plant water. Giardia was not found in any of the samples. Cryptopsporidium was detected at 0.00800 cysts/l in the Jensen Plant influent, but was not detected in the treated drinking water.

Asbestos and Metals

Asbestos has been identified as a constituent of concern in Delta source and SWP facilities due to asbestos in some Coast range drainage water. Selenium is a constituent of concern in San Joaquin River water.

Asbestos. Asbestos is a fibrous siliceous material that is present in serpentine and amphibole materials. Chrysotile asbestos is the type most frequently found in California waters and is derived largely from erosion of the serpentine rock that is present throughout the state. Asbestos has been demonstrated to be a carcinogen when asbestos fibers greater than 5 microns in length are inhaled. There has been concern that ingestion of asbestos in drinking water might be a cause of gastrointestinal cancer in humans. Although epidemiologic and animal studies have failed to demonstrate any consistent relationship between asbestos ingestion and increased incidence of cancer, the possibility of long-delayed effects of asbestos ingestion through water has led EPA to propose an MCL of 7 million medium and long fibers/l (10 or more microns in length).

Asbestos data have been collected by DWR on some of the source waters and the SWP facilities. These data are summarized in Table 6-2. The median concentrations vary from 110 million fibers/l in the American River to 3,500 million fibers/l in Lindsey Slough. Maximum concentrations of 3,200 and 3,300 million fibers/l were found in the Sacramento River at Greene's Landing and the San Joaquin River, respectively. A maximum of 7,500 million fibers/l was found at Lindsey Slough. The value of the asbestos data has been questioned by DWR (1986a) because asbestos analyses done in triplicate on the same water samples differed significantly. The analytical techniques for measuring asbestos need to be improved before the asbestos data will be considered reliable. The data cannot be compared to the proposed MCL of 7 million medium and long fibers/l because the monitoring results are for total asbestos fibers. Between 1980 and 1988, MWD conducted a study of asbestos fibers in the Jensen and Mills filtration plant influents and effluents, Pyramid Lake influent and effluent, Devil Canyon Afterbay, and Lake Perris effluent. In 1981, samples were collected about every 2 weeks for a 6-month period at all sites except Pyramid Lake. Total asbestos fibers ranged from less than 0.1 to 1,900 million fibers/l in the untreated water supplies and less than 0.02 to 58 million fibers/l in the treated water. Larger asbestos fibers (greater than 10 μ) were rarely found in the untreated water and never found in the treated water. This study also showed that the terminal reservoirs help reduced asbestos levels.

In 1980, MWD conducted a limited study of asbestos levels at various locations along the California Aqueduct. The highest total fiber levels (up to 15,000 million fibers/l) were found between Coalinga and the Kern River Intertie. The highest large fiber levels (up to 67 million fibers/l) were also found in this segment of the California Aqueduct.

Between 1981 and 1989, DWR collected asbestos data on the Banks Pumping Plant, the outlet from O'Neill Forebay, an AVEK turnout at 170th Street West, and the headworks of the Santa Ana pipeline. The highest total fibers were found at the AVEK turnout (8,400 million

Table 6-2. Asbestos Concentrations in SWP Facilities and Source Waters

Location	Total asbestos fibers, million fibers/l			Number of samples
	Low	High	Median	
American River	12	2,200	110	18
Greene's Landing	110	3,200	380	15
Lindsey Slough	1,160	7,500	3,500	5
Vernalis	270	3,300	870	17
DMC-Tracy	370	1,800	700	15
Banks Pumping Plant	230	1,400	625	8
Jensen Plant	0	0	0	29
Mills Plant	0	8.8	0	74
Lake Perris	0	0	0	36

fibers/l). The fibers greater than 5 μ were often below the detection limit and often less than 7 million fibers/l at the Banks Pumping Plant, the outlet from O'Neill Forebay, and the headworks of the Santa Ana pipeline. At the AVEK turnout, fibers greater than 5 μ were usually greater than 7 million fibers/l. The maximum count was 300 million fibers/l.

These data show that long asbestos fibers (greater than 10 μ) are usually not found in untreated water levels exceeding the proposed MCL of 7 million fibers/l for treated water. Treated water concentrations of asbestos are much lower because conventional treatment processes including coagulation, sedimentation, and filtration generally reduce asbestos concentrations by 99 percent or more (DWR, 1989).

Selenium. The discovery that reproductive failure in water fowl using Kesterson Reservoir was due to high levels of selenium has focused attention on the possibility that the San Joaquin River is a source of selenium in SWP waters. Selenium, in high concentrations, can cause liver and kidney damage in humans; however, selenium is also an essential nutrient. The current MCL for selenium is 10 μg/l. EPA has proposed a revised MCL of 50 μg/l, because the bulk of scientific data indicate that selenium concentrations in drinking water are generally lower than is desirable for nutrition.

The selenium concentrations in source waters and the Delta have been below the current MCL of 10 μg/l and have generally been below the detection limit of 1 μg/l. As described in Chapter 4, the highest concentrations of selenium have been detected in the lower San Joaquin River, Mud Slough, and Salt Slough. Dilution and natural removal processes result in lower concentrations in the San Joaquin River at Vernalis. The median concentration at Vernalis is 2 μg/l. Although selenium has the potential to cause ecological problems in the San Joaquin River watershed, it appears to present no problems currently in Delta waters used for drinking water. Data collected by MWD at the inlets to the Jensen (West Branch) and Mills (East Branch) filtration plants have generally been below the detection limit of 1 μg/l.

Other Metals. As discussed in Chapter 3, there are drinking water standards for several metals. Many of the metals cause liver and kidney damage. Lead is a probable human carcinogen and can cause irreversible brain damage.

There are a limited amount of data on metals concentrations in the source waters and SWP facilities. Selenium is the one exception and it has been discussed previously.

Aluminum--EPA has not promulgated a standard for aluminum; however, DHS has established an MCL of 1 mg/l. The limited aluminum data collected on Delta source waters and SWP facilities, show that aluminum concentrations are generally far below the MCL of 1 mg/l

Antimony--EPA has proposed two alternative MCLs for antimony (0.01 mg/l and 0.05 mg/l). There is no state MCL for antimony and there are no antimony data on the SWP facilities.

Arsenic--The federal and state MCL for arsenic is 0.05 mg/l. There are extensive data on arsenic concentrations in the Delta source waters and the SWP facilities. The maximum concentration found in the source waters is 0.02 mg/l in the San Joaquin River. Dissolved arsenic concentrations are measured by DWR at many locations along the California Aqueduct. A maximum concentration of 0.05 mg/l was found at the Banks Pumping Plant. Generally, concentrations are less than 0.002 mg/l. The median arsenic concentration at MWD's Jensen and Mills filtration plant intakes is 0.003 mg/l.

Barium--The federal MCL for barium is 5 mg/l and the state MCL is 1 mg/l. Barium has been measured in the Delta source waters and at the Jensen and Mills filtration plants. The maximum concentration (0.23 mg/l) is well below the 1 mg/l state standard.

Beryllium--EPA has proposed an MCL of 0.001 mg/l for beryllium. The City of Sacramento has collected data on the American and Sacramento Rivers and found that beryllium is always below the analytical detection limit of 0.01 mg/l. There are no other data on beryllium in SWP facilities.

Cadmium--EPA has proposed an MCL for cadmium of 0.005 mg/l. The existing California MCL is 0.01 mg/l. Cadmium has been measured in the Delta source waters, the Kern River, and at the Mills and Jensen filtration plants. The concentrations are generally less than 0.005 mg/l.

Chromium--EPA has proposed an MCL for chromium of 0.1 mg/l. The existing California standard is 0.05 mg/l. Chromium concentrations in the Delta source waters are generally less than 0.005 mg/l and always below 0.01 mg/l. Dissolved chromium concentrations are measured by DWR at many locations along the California Aqueduct. A maximum concentration of 0.02 mg/l was found at the Banks Pumping Plant. The median chromium concentration at the Jensen and Mills filtration plants is less than 0.0001 mg/l.

Copper--EPA has proposed an MCL of 1.3 mg/l for copper. There is currently no state standard. Copper is measured in the source waters and the SWP facilities. The copper concentrations are always well below the proposed MCL.

Cyanide--EPA has proposed an MCL of 0.2 mg/l for cyanide. There is no corresponding state standard. There are no cyanide data on SWP facilities.

Lead--EPA has proposed a lead standard of 0.005 mg/l. The current state MCL is 0.05 mg/l. Lead concentrations in the source waters are generally less than 0.001 mg/l. The median dissolved lead concentrations along the California Aqueduct vary from less than 0.005 mg/l to 0.025 mg/l with maximum concentrations of up to 0.16 mg/l. Data collected by MWD at the Jensen and Mills filtration plants show median lead concentrations of less than 0.0002 mg/l and maximum concentrations of 0.001 mg/l.

Mercury--The proposed federal and existing state MCL for mercury is 0.002 mg/l. The limited data collected on source waters and SWP facilities show that the median concentrations are generally less than 0.001 mg/l and the maximum concentrations are less than 0.002 mg/l.

Nickel--EPA has proposed an MCL for nickel of 0.1 mg/l. A limited amount of nickel data were collected by MWD on the terminal reservoirs and the influent of the filtration plants. The concentrations were generally less than 0.001 mg/l and always less than 0.002 mg/l. There are no other nickel data on SWP facilities.

Silver--The existing federal and state MCL for silver is 0.05 mg/l. EPA removed silver from the original list of 83 contaminants for which MCLs were to have been set by 1989. A limited amount of silver data have been collected on the American and Kern Rivers. Silver concentrations were generally below the detection limit of 0.01 mg/l. Data collected by MWD at the Jensen and Mills filtration plants have shown that silver concentrations are below the detection limit of 0.005 mg/l.

Thallium--EPA has proposed two alternative MCLs for thallium (0.002 mg/l and 0.001 mg/l). There is no state MCL for thallium and there are no data on thallium concentrations in the SWP facilities.

Based on the limited amount of data available, it appears that metals concentrations do not currently pose a problem in drinking water taken from the Delta or source waters. However, a study conducted by DWR (1987a) on metals and organics concentrations in fish, benthic organisms, and sediment at various locations in the SWP, showed that metals were found in the sediment samples and that cadmium, copper, mercury, selenium, and zinc were found in all fish samples.

The State Water Resources Control Board (State Board) proposed water quality objectives for arsenic, cadmium, chromium, copper, mercury, nickel, selenium, and silver in the Inland Surface Waters Plan (State Board, 1990). Many of these objectives are lower than drinking water standards. If municipal wastewater agencies have to comply with these extremely stringent objectives in the future, water supply agencies may be targeted as one of the contributors of the heavy metals in the influent to the wastewater treatment plants.

Pesticides and Herbicides

EBMUD has collected data on pesticides in the American River, Sacramento River, and Clifton Court Forebay. All pesticides have been below or near the laboratory detection limits in these samples. Rice herbicides have been monitored by the City of Sacramento at the Sacramento River Filtration Plant intake. As described in Chapter 4, the concentrations of molinate and thiobencarb are well below drinking water standards for these contaminants.

DWR has conducted pesticide monitoring in the Delta source waters, the Delta, and the agricultural drains discharging to Delta channels. The DWR monitoring program is based on extensive data on pesticide usage patterns and environmental behavior rather than random sampling for pesticides. The monitoring program focused on the summer pesticide application period, with additional sampling to include the first major winter runoff and the spring pre-emergent herbicide applications. The few pesticides found in Delta water samples were at concentrations marginally above laboratory detection limits and considerably below drinking water standards (DWR, 1989). The San Joaquin River has the reputation of being heavily laden with pesticide residues due to the agricultural nature of its watershed. However, pesticide monitoring conducted by DWR has failed to detect pesticides either frequently or in concentrations exceeding drinking water standards or state action levels.

MWD analyzed samples from Devil Canyon Afterbay, the Jensen Filtration Plant influent and effluent, Lake Perris effluent, and the Mills Plant effluent for pesticides on a quarterly basis between April 1985 and February 1987. The samples have been analyzed for organochlorine pesticides, organophosphorus pesticides, triazine herbicides, and fumigants. No pesticides or herbicides have ever been present at concentrations exceeding state action levels or federal or state MCLs. Atrazine, simazine, and Dacthal were detected at low levels in some samples. Dibromochloropropane was detected in one sample.

USBR conducted a synoptic survey of pesticide concentrations in the DMC at 15 locations in August 1987. The sampling occurred at the time of the year when the drainage is normally at its highest level. Simazine was the only pesticide detected and it was present at concentrations well below drinking water standards.

The cities of Huron and Avenal analyzed their raw water supplies for pesticides in 1989. No pesticides were detected in these samples.

The Kern County Water Agency measures endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP monthly on the Kern River. These constituents are always below detection limits. Less frequent monitoring for these constituents by other water supply agencies on SWP supplies shows similar results.

Certain toxics accumulate and greatly concentrate in fish flesh and organs, so fish studies have provided early warning of pesticide contamination at levels below drinking water concern. DWR has found chlordane, Dacthal, dieldrin, DDT, lindane, polychlorinated biphenyls, and toxaphene in fish taken from the SWP reservoirs (DWR, 1987a). Continuance of well designed pesticide monitoring programs, such as the DWR Delta monitoring, will provide additional data on the occurrence, transport, and chronic health significance of these toxic compounds. There is no current evidence that pesticides constitute a threat to the health of humans presently consuming SWP waters.

Volatile and Synthetic Organics

EPA has promulgated MCLs for eight volatile organics and proposed MCLs for a number of other volatile and synthetic organic chemicals. DWR and EBMUD have collected a limited amount of data on volatile and synthetic organics in the Delta and source waters. The DWR monitoring program has not detected their presence. EBMUD has detected toluene and xylene in the American River, Sacramento River at Greene's Landing, and Clifton Court, but the concentrations have been significantly lower than the proposed MCLs. Trichloroethylene (TCE) has been routinely detected at about 0.2 µg/l in the American River at the City of Sacramento's water treatment plant intake. The source of the TCE is thought to be the inflow of contaminated groundwater from the Aerojet site in Rancho Cordova. The MCL for TCE is 5 µg/l.

USBR conducted a synoptic survey of volatile and synthetic organic chemicals in the DMC at 15 locations in August 1987. No volatile or synthetic organics were detected.

MWD sampled various locations along the SWP from the Sacramento River at Hood to the terminal reservoirs for synthetic organics in 1979 and 1980. The samples were essentially free of synthetic organics, although trace levels of polynuclear aromatic hydrocarbons were found in some samples. MWD monitored the Jensen Filtration Plant influent and effluent, Devil Canyon Afterbay, the Mills plant effluent, and Lake Perris for volatile organics between 1985 and 1988. No volatile organic chemicals were detected in the south waters. THMs were the only volatile organic detected in the treated water.

Radiological Constituents

Prior to 1986, EPA established primary drinking water standards for Beta particles and photon radioactivity, gross alpha particle activity, and radium. EPA is expected to propose MCLs for five radionuclides in February 1991. DHS has established MCLs for gross alpha and beta particle activity, radium, strontium, tritium, and uranium.

There are very limited data on radiological constituents in the SWP. MWD monitored the terminal reservoirs and the Jensen and Mills filtration plant influent and effluent in 1982, 1983, and 1986. All radiological constituents were well below the federal and state drinking water standards. One time sampling by the City of Tracy on the DMC and the Castaic Lake Water Agency on Castaic Lake showed the same results.

SUMMARY OF SWP SOURCE WATER QUALITY

The previously presented data show that the quality of source water degrades for some constituents as it flows into and through the Delta. The American River is a high quality stream with low concentrations of minerals, nutrients, metals, and organics. The THMFP of this water is so low that additional treatment for THM or precursor removal is not needed beyond the reduction afforded by conventional treatment to meet the current MCL of 100 µg/l, or a revised MCL of 50 µg/l. With the exception of turbidity and coliform bacteria, drinking water quality standards for the constituents examined in this study, are consistently met in the American River prior to treatment.

The Sacramento River water quality is good, although the constituent concentrations are higher than in the Sierra streams. Most drinking water standards for the constituents examined in this study are consistently met before and after conventional treatment. Additional treatment for THM removal is not needed for the Sacramento River water withdrawn from the river at Sacramento unless the finished water THM standard is reduced below 50 μg/l.

While water from the San Joaquin River, the Banks Pumping Plant, and the Barker Slough Pumping Plant can be treated to meet drinking water standards, they can be of significantly poorer quality for some parameters than the Sacramento River. The Delta water quality varies greatly in response to river flows, sea water intrusion, and agricultural drainage. Water diverted from the Delta requires additional treatment to reduce THMs in finished water to acceptable levels. The drinking water standards for turbidity and coliforms, are frequently exceeded in untreated Delta waters, although conventional treatment controls these constituents. The secondary standards for chloride (250 mg/l) and TDS (500 mg/l) are approached frequently and exceeded occasionally in the raw water supplies. The consumer acceptance levels for these constituents are sometimes exceeded. The NAS recommended criterion of 100 mg/l of sodium for people on moderately restricted sodium diets is exceeded 10 percent of the time.

The data presented in this chapter generally show that no further degradation of water quality occurs between the Delta pumping plants and the terminal reservoirs and tanks. The quality of water in the storage reservoirs is much less variable than water taken directly from the Aqueduct.

Evaluation of Direct Sources of Contamination

A large number and a great variety of potential direct sources of contamination to SWP facilities were identified in the field survey. The more significant sources are discussed below.

Coast Range Drainage. Between O'Neill Forebay and the end of the San Luis Field Division, the California Aqueduct receives agricultural, urban, and mine drainage from the Arroyo Pasajero, Little Panoche Creek, and Salt Creek. These creeks may contribute many different types of contaminants including sediment, asbestos fibers, agricultural chemicals, pathogens, organics, and nutrients to the SWP during the rain season. Degradation in water quality in the California Aqueduct between O'Neill Forebay and the end of the San Luis Field Division was not seen from the available data. However, it would be necessary to monitor water quality conditions in the creeks and upstream and downstream of the discharges during periods of discharge to determine the impact on the water quality of the California Aqueduct. There may be a significant short-term impact from these discharges that is not detected in routine monthly monitoring programs.

Agricultural Drainage. There are a large number of agricultural drains that discharge into the DMC and the California Aqueduct between O'Neill Forebay and the end of the San Luis Field Division. The South Bay Aqueduct and the California Aqueduct between Clifton Court and O'Neill Forebay also receive agricultural drainage. The quantity and quality of drainage discharged is unknown. The existing water quality data on the DMC are too limited to compare the quality at the Tracy Pumping Plant to the quality at the O'Neill Pumping Plant so it is not possible to determine if agricultural drainage or any other sources of contamination degrade the water quality of the DMC. Although there are more data on the quality of the California Aqueduct and South Bay Aqueduct, it is still not possible to assess the impacts of agricultural drainage. It would be necessary to simultaneously monitor the quality of key drains and the California Aqueduct for constituents typically found in agricultural drainage such as nutrients, organic carbon, THMFP, and occasionally, metals and pesticides to assess the impacts on drinking water quality.

Urban Runoff. Urban drainage from residential/commercial developments in the Hesperia area is discharged to the East Branch of the California Aqueduct. These 44 large-diameter urban runoff drains likely convey solids, metals, nutrients, and organics to the water. The greatest pollutant loads likely occur during the first few storms in the fall. Monitoring of key contaminants during and immediately after storm events would be needed to determine the quality of urban runoff discharged to the Aqueduct and the impact on drinking water supplies.

Highway Drainage. The California Aqueduct receives drainage from part of Interstate 5 and Highway 205 between the Banks Pumping Plant and O'Neill Forebay. Drainage from part of Highway 152 flows into San Luis Reservoir. Highway drainage contributes solids, metals, and petroleum hydrocarbons to the receiving waters when it rains. There is also the potential for a spill of hazardous materials to enter the SWP from a trucking accident. The severity of the problem would depend upon the material spilled and the location of the nearest water service turnout. Routine monitoring data cannot determine the impacts of spills on drinking water supplies. Monitoring of key constituents specific to the spill would be needed.

Shallow Groundwater. Groundwater is pumped into the California Aqueduct between Clifton Court and the Kern River Intertie. It is also pumped into the West Branch. There are weep holes in the DMC which allow shallow groundwater to enter the canal. The quality of the shallow groundwater can be marginal. High concentrations of salts and metals have been found in the shallow groundwater of the western San Joaquin Valley. The greatest number of discharge locations occurs between Clifton Court and O'Neill Forebay. There are no obvious changes in this segment of the Aqueduct. Data on the quantity and quality of groundwater entering the California Aqueduct would be needed to determine the effects on water quality.

Body Contact Recreation. Body contact recreation in Lake Del Valle, Pyramid Lake, Castaic Lake, Lake Silverwood, and Lake Perris may contribute pathogens to the water. Body contact recreation in Lake Perris has resulted in verified cases of Shigellosis and other complaints of human illness after swimming in the lake. Despite the potential for bacteriological contamination, the bacteriological quality of raw water supplies is quite good along the SWP. Treated water coliform levels are consistently less than 2/100 ml, indicating that existing treatment processes successfully reduce coliforms to acceptable levels.

Sewage Handling Facilities. Sewage handling facilities in the watersheds of Lake Del Valle, Pyramid Lake, Castaic Lake, and Lake Silverwood are potential sources of pathogens, nutrients and organics. Floating toilets in Pyramid Lake and Castaic Lake may also contribute these contaminants. The only documented problems are in the Lake Silverwood watershed. The piping and pumping stations that convey raw sewage out of the watershed have failed and resulted in sewage spills to the lake on several occasions. Elevated coliform levels have been detected in the lake following sewage spills. This has not resulted in coliform problems at downstream water treatment plants.

Other Potential Sources of Contamination. Additional, less important potential sources of contamination documented during the field survey include canal roadside drainage, overcrossings (particularly petroleum pipelines), undercrossings, bridges water-service turnouts, and fishing areas. Canal roadside drainage is discharged into all open canal segments of the SWP. This drainage is likely to contain little more than suspended solids since canal roads are infrequently travelled. With the exception of canal roadside drainage, contaminants would only enter the SWP if (1) facilities were improperly designed or operated, (2) human error or deliberate action resulted in a spill of a harmful substance, or (3) catastrophic failure of a pipeline occurred.

CHAPTER 7

EFFECTIVENESS OF EXISTING REGULATIONS

The effectiveness of current regulatory programs to (1) assure that high quality water is provided to the State Water Project (SWP) export pumps and (2) operate the SWP facilities to protect that water quality is assessed in this chapter.

The primary basis for evaluating the effectiveness of current regulatory programs is the information collected and evaluated in this study. The assessment of contaminant sources in the watershed (Chapter 4), direct sources of contamination including emergency response plans (Chapter 5), and water quality of the SWP system (Chapter 6) provide the main sources of information used to evaluate the effectiveness of existing regulatory programs. A summary of what sources of pollutants are regulated by which statutes and regulations is contained in Table 10 of Appendix C.

Regulating and Monitoring Sources of Contamination in the Watersheds

The two main components of water quality regulation of the water bodies tributary to the SWP are (1) the establishment of standards for those water bodies and (2) the adoption and enforcement of effluent limitations or other control measures which will assure the attainment of those standards.

Establishment of Standards. Water quality standards under the federal Clean Water Act are comprised of beneficial uses and the numeric criteria or objectives adopted to protect the various beneficial uses. Beneficial uses are defined and listed for each major water body in the two Basin Plans for the Central Valley. As part of the Basin Plan approval process, the beneficial uses have been adopted by the California Regional Water Quality Control Board, Central Valley Region (Regional Board), by the State Water Resources Control Board (State Board) and by the U.S. Environmental Protection Agency (EPA). The list of beneficial uses varies among the water bodies, but is comprised of the following broad categories: municipal and domestic supply, agricultural supply, industrial supply, recreation, and aquatic life including fish migration and spawning. The most sensitive beneficial use affected by a potential contaminant may be municipal water supply or may be some other use such as aquatic life or public health from the bioaccumulation of toxics in fish or other aquatic life consumed by people.

Beneficial uses may be designated as "existing" or "potential." Existing beneficial uses include uses actually attained in the water body. Potential beneficial uses are uses which have not been confirmed to exist. The lower Sacramento River, the east-side streams (Calaveras, Mokelumne, and Cosumnes river), the Sacramento-San Joaquin Delta (Delta), the California Aqueduct, and the Delta Mendota Canal (DMC) are all designated as having an existing municipal water supply beneficial use. The lower San Joaquin River, however, is designated as having a potential municipal water supply beneficial use. The California Department of Health Services (DHS) requires advanced treatment techniques for the use of lower San Joaquin River water for drinking water.

The Water Quality Act of 1987 which amended the Clean Water Act requires that water quality standards be adopted for priority pollutants by February 1990. The State Board is in the process of complying with this requirement by the development of an "Inland Surface Waters Plan" which contains proposed water quality objectives for about half of the priority pollutants that have been listed (State Board, 1990). The adoption of this plan is expected to occur in 1990 or 1991.

Regulation of Pollutants. This section discusses the effectiveness of existing controls on the major sources of contamination identified in Chapter 4.

Municipal and Industrial Discharges--As described in Chapter 4, the Regional Boards develop and administer National Pollutant Discharge Elimination System (NPDES) permits which contain effluent limits to regulate the quality of wastewater discharged by municipal and industrial (M&I) facilities. One of the considerations in establishing effluent limits is the dilution attained in the receiving water and the proximity of the discharge to municipal water intakes. Comments from DHS are relied upon in establishing effluent requirements protective of municipal water supplies.

The Sacramento Regional Wastewater Treatment Plant discharges about half of the total municipal treated wastewater discharged to surface water bodies in the Central Valley. This facility and the three other municipal wastewater treatment plants closest to the SWP facilities comprise about 70 percent of all municipal wastewater discharged to surface water bodies in the Central Valley. As described in Chapter 4, all four plants are meeting all of their NPDES permit requirements except for residual chlorine levels in effluent from the Vacaville Easterly Sewage Treatment Plant.

About half of the industrial flow to surface water bodies in the Central Valley is from cooling water discharged by the PG&E Contra Costa Power Plant located near the confluence of the Sacramento and San Joaquin Rivers. The requirements and reported level of compliance of this industrial discharge and two other key industrial facilities were reviewed in Chapter 4. The conclusion is that these three facilities are meeting all of their NPDES permit requirements.

The Regional Boards have developed an effective program for regulating the discharge of treated wastewater from M&I facilities. The key element in the program is the adoption of NPDES permits with effluent limits designed to attain water quality objectives and the reasonable protection of beneficial uses. NPDES permits also require the collection of monitoring data by the permittee and the notification of the Regional Board or the state Office of Emergency Services in case of chemical or sewage spills or treatment process bypasses or failures. The monitoring data required to be collected by the M&I dischargers is quite limited. There are currently no requirements for monitoring bacteriological constituents, other than coliform bacteria. The Surface Water Treatment Rule requires water supply agencies to achieve 99.9 percent reduction by removal and inactivation of Giardia cysts and 99.99 percent reduction by removal and inactivation of viruses. Cryptosporidium may be regulated in the future. There are currently limited data on the relative contribution of these organisms from M&I discharges and agricultural activities.

Discharges From Urban Runoff--A new regulatory program which will result in the adoption of NPDES permits for urban runoff from cities with populations greater than 100,000 is required by the Water Quality Act of 1987. This program is the first step in the regulation of nonpoint sources of pollution such as urban runoff. The Sacramento County Water Agency and the cities of Sacramento, Folsom, and Galt have already obtained an NPDES permit for urban runoff discharges. Cities greater than 100,000 in population will have until November 1991 to file a Part 1 application for an NPDES permit for their urban runoff discharges.

While programs such as the Nationwide Urban Runoff Project have been conducted to characterize the quality of urban runoff, there have been few studies documenting the cost and effectiveness of methods of minimizing the introduction of contaminants into urban runoff or of treating urban runoff. The State Board and the American Public Works Association's Stormwater Quality Task Force intend to develop a manual of best management practices for urban runoff for California. Because control measures have not yet been identified or implemented, the effectiveness of the regulatory program to control the water quality of urban runoff cannot yet be assessed.

Agricultural Drainage--Agricultural drainage is not regulated under an effluent limitation system such as the NPDES permits. The extensive use and reuse of the rivers for agricultural irrigation, the number of agricultural drains and responsible parties, and the variability of agricultural drainage quality with crop-specific practices are more suitable to best management practices control measures to reduce the overall loads of contaminants from agricultural drains.

Agricultural drainage can significantly increase the trihalomethane formation potential (THMFP) of SWP water because of the organic material present in drainage water. An increase of about 70 percent in THMFP has been determined to result from agricultural drainage in the Delta, particularly from areas with rich organic peat soils. One of the purposes of the Delta Islands Drainage Investigation being conducted by the California Department of Water Resources (DWR) is to determine the effects of agricultural drainage from Delta islands on water quality and to identify agricultural management practices to control THMFP. The study is ongoing and improved management practices have not yet been identified or implemented.

The Central Valley Regional Board and the Department of Food and Agriculture have investigated and are in the process of implementing best management practices to control seasonal drainage from rice fields in the Sacramento Valley. This program has resulted in declines in the concentrations of rice herbicides since about 1986. Further declines in the concentrations of rice herbicides are expected as best management practices are extended to include more cultivated land and as additional improved management practices are identified and implemented.

The Central Valley Regional Board is currently investigating and developing best management practices for agricultural surface runoff and subsurface discharges to the San Joaquin River system. The heterogeneity of agricultural uses and practices in the San Joaquin Basin makes control of agricultural contaminants in that basin especially complex. The locations of agricultural drains in areas of predominant agricultural land use have been surveyed and water quality characterization studies are ongoing. The pattern of episodic rather than consistent detections of pesticides in the San Joaquin River may result from illegal discharges or be slugs of pesticides from recently treated fields. The one exceptional area is in the San Joaquin River near Patterson where pesticides have been found in samples collected monthly between February and April and toxicity was also detected using bioassay tests. The Regional Board plans to try to determine which streams the pesticides are coming from and to work with other agencies to modify agricultural management practices to control this source.

The Regional Board, the DWR, and the Department of Food and Agriculture appear to be doing an effective job characterizing the quality and impacts of agricultural drainage, prioritizing the most serious impacts, and beginning to identify and implement management practices to control adverse effects of these wastewaters.

Cattle Grazing, Feedlots, and Dairies--As no comprehensive studies have been conducted on the water quality effects of grazing in the Central Valley watersheds, the significance of water quality impairments from this source are not known. There are no regulatory programs for cattle grazing designed to protect water quality. The discharge of dairy or feedlot wastes to surface waters is illegal. Due to staffing constraints, the Regional Board responds to reported violations but does not have an active enforcement program.

Mine Drainage--Many reaches of streams tributary to the Sacramento and San Joaquin Rivers have been listed by the Central Valley Regional Board and the State Board as impaired water bodies because of the presence of metals from mine drainage at levels toxic to aquatic life. Most of the water quality impacts are attributable to inactive mines.

Drainage from active and inactive mines are regulated under various statutes. The Regional Board regulates discharges from active and inactive mines by adopting Waste Discharge Requirements and NPDES permits. Drainage from the largest inactive mine (Iron Mountain Mine) and from two asbestos mines (Atlas and Coalinga Mines) are also regulated under the state and federal Superfund programs. Release of drainage from the Iron Mountain Mine is controlled to maximize dilution and to prevent salmon kills in the Sacramento River. Several other major inactive mines are regulated by the state Superfund program.

The regulatory program to control acid drainage from inactive mines does not appear very effective considering the current list of water bodies impaired by these sources. As described in Chapter 4, the primary impacts appear to be on aquatic life and not on the quality of water that reaches the SWP. If municipal wastewater agencies have to comply with the extremely stringent metals objectives contained in the Inland Surface Waters Plan, metals concentrations in source waters will have to be reduced or water supply agencies will be targeted as one of the contributors of the heavy metals in the influent to the wastewater treatment plants.

The Atlas and Coalinga Mines drain to Arroyo Pasajero which discharges to the California Aqueduct during wet years. EPA is preparing remedial action plans for these Superfund sites. In addition, DWR is completing a study which identifies alternatives for preventing Arroyo Pasajero from draining into the California Aqueduct during flows up to and including 100-year flood events. DWR appears to have an effective program to identify and implement drainage controls for the Arroyo Pasajero watershed.

Sea Water Intrusion--The primary impacts of sea water intrusion on the quality of water pumped from the Delta are an increase in salt content and an increase in the production of trihalomethanes (THMs) and other disinfection by-products (DBPs) in finished water. If an earthquake caused massive failure of Delta levees, sea water from San Francisco Bay would surge into the Delta and render the Delta unusable as a source of drinking water.

A significant amount of effort has been and continues to be spent in trying to equitably resolve competing water quality and quantity needs in the Delta. The regulatory program which has had most effect on the amount of sea water intrusion allowed to occur in the Delta is the Delta Plan and Water Rights Decision 1485 (D-1485) adopted by the State Board in 1978. D-1485 and the Delta Plan place certain conditions on the amount of water that can be pumped from the Delta by both requiring certain amounts of outflow and by establishing chloride objectives for municipal and industrial use. The State Board is currently considering a Water Quality Control Plan for Salinity which reconsiders the issues addressed in the Delta Plan and D-1485 (State Board, 1990). The existing D-1485 standards have allowed water supply agencies to meet the THM standard of 100 micrograms per liter (μg/l) most of the time. High bromide concentrations during periods of low Delta outflow have resulted in some violations of the existing standard. Sea water intrusion will create major problems for water supply agencies in the future when they have to meet a THM standard of 25 or 50 μg/l and possibly standards for other DBPs.

Program to Operate the SWP to Protect Water Quality

The DWR operates the SWP facilities primarily to supply the quantities of water required while complying with the outflow and water quality conditions imposed by D-1485. While the facilities are primarily operated to transfer water, there are some operating procedures which affect water quality. Although the practice of opening the Clifton Court Forebay intake gates during receding high tides is primarily to achieve other goals, this is also the period when tidal influences have maximized Sacramento River backflow up to this area. Along with the high quality Sacramento River water, however, sea water intrusion is also high during this period. The practice of meeting part of the summer demand by storing water in San Luis Reservoir in winter months has a beneficial impact on water quality because of the generally higher quality of Delta water in the winter. Delta agricultural drainage, however, is also high during the winter.

Aquatic plant control programs are operated by DWR Field Divisions to control weeds and phytoplankton in the South Bay Aqueduct, the Coastal Branch of the SWP, and at Lake Perris. The dosages and timing of copper sulfate treatments is based on either a fixed schedule developed from historic practices or on an as-needed basis.

The SWP facilities are not operated by DWR under any standards or practices suggested or required by DHS. DHS exerts control of the sanitary quality of SWP waters indirectly by their control of the water permits issued to municipal users. DWR currently has no formal program to evaluate and implement changes to address direct sources of contamination, such as those identified in Chapter 5.

Protection of Water Quality During Emergencies

Most of this evaluation of the ability to respond effectively to emergency conditions is based on the evaluation of DWR's and the U.S. Bureau of Reclamation's (USBR) emergency response plans, conducted in May 1990 by Laverty Associates (Appendix E). The Laverty Associates report reviewed the USBR's Tracy Office Emergency Response Plan and DWR's Division of Operations and Maintenance, Emergency Response Plans, for the Oroville Field Division and for the Southern Field Division. These emergency response plans address not only conditions which threaten water quality, but also other conditions which imperil the reliable collection, storage, and conveyance of water supplies. DWR had planned to update their emergency response plans prior to the review by Laverty Associates.

The Laverty Associates report concluded that the DWR and USBR emergency plans reviewed provide reasonable planning for response to events threatening water quality. The report noted that the format could be improved to aid in training, to aid in finding information during an emergency, and to make updating easier. The report also noted that greater detail should be provided for some potential events particularly those which could affect delivery and water quality (such as the potential for high concentration contamination of the DMC or California Aqueduct by a tanker truck accident).

Pipeline leaks, truck spills, or discharges of inadequately treated M&I wastewaters to rivers tributary to the SWP export pumps may also constitute emergencies. NPDES permits contain requirements to notify the Regional Board staff or the Office of Emergency Services (OES) if treatment unit bypasses or emergency conditions occur that affect the ability to comply with permit conditions. Similarly, all permitted dischargers or other parties must also comply with the Water Code's requirements to report to OES other spills or releases that threaten or affect water quality. The OES, which coordinates and communicates emergency response actions, would then notify DWR regarding emergency conditions. A number of federal statutes which require spill reporting to EPA serve as a backup to the state process. These existing regulatory programs appear to provide the basic framework to respond to emergency conditions that threaten SWP water quality.

Attainment of Standards

As described previously, an effective program should be able to demonstrate whether drinking water quality standards are either attained in the untreated SWP water or can be met following treatment. This criterion is evaluated mainly by reviewing the information on water quality contained in Chapter 6. As described in that chapter, a water quality database was developed using data from various government agencies and from water contractors that take water from the SWP. The list of constituents of concern was based on guidance from DHS engineers and from the State Water Contractors Water Quality Technical Committee. Information on the following water quality constituents was reviewed: DBPs, minerals [total dissolved solids (TDS), hardness, chloride, and sodium], turbidity, algae and nutrients, taste and odor, pathogens, asbestos and metals, pesticides and herbicides, volatile and synthetic organic chemicals, and radiological constituents.

The most important water quality concern is the formation of DBPs, principally THMs from SWP waters. As described in Chapter 6, the Castaic Lake Water Agency recently violated the current 100 µg/l Maximum Contaminant Level (MCL) for total THMs because of elevated bromides originating from sea water intrusion of the Delta. The MCL for total THMs is expected to decrease to either 25 or 50 µg/l, and the SWP may be unable to deliver water capable of meeting these low levels without expensive additional treatment systems. The water contractors will be faced with minimizing the formation of THMs and other DBPs, while at the same time meeting the stringent disinfection requirements for Giardia and virus inactivation.

The review of information on key constituents representative of mineral quality indicates that the secondary standard for TDS of 500 milligrams per liter (mg/l) is exceeded about 10 percent of the time at various locations along the California Aqueduct. The secondary standard for chloride of 250 mg/l is consistently attained at the headworks of the North Bay Aqueduct, is exceeded about 10 percent of the time at the terminal tank of the South Bay Aqueduct, and is generally not exceeded in the California Aqueduct.

Some constituents in the untreated SWP water which cannot meet the drinking water standards are not a concern because the standards are achieved following treatment. For example, the mean turbidities at the headworks to the North Bay Aqueduct (29 NTU) and at the Banks Pumping Station (11 NTU) exceed the value that is likely to be required by the Surface Water Treatment Rule (0.5 NTU). This is not a significant water quality issue because low turbidity can be achieved in the water following treatment. Similar to turbidity, the coliform and asbestos concentrations of the source water exceed the current and likely future standards for finished water, but these standards can be achieved following treatment.

The concentration of selenium in the source waters and the Delta have been well below the current state and federal MCL of 10 µg/l. Based on the limited amount of information available for metals, it appears that drinking water standards for metals are generally achieved in the source water and in the Delta. DWR developed a sophisticated program to monitor pesticide concentrations in the Delta and Delta source waters which considered pesticide usage patterns and the environmental fate and transport of pesticides. The results of this monitoring program showed that pesticide concentrations are considerably below drinking water standards.

Information on the concentrations of some of the chemicals currently regulated or proposed for regulation is not available or is very limited in the source waters and the Delta. This is particularly true about the concentrations of synthetic organic chemicals. Xylenes and toluene have been consistently detected in the source waters and at Clifton Court at concentrations significantly lower than the proposed Maximum Contaminant Level Goals.

The collection and compilation of information about the quality of the source water, water at the headworks to the North Bay Aqueduct and the Banks Pumping Station, and water at various locations within the SWP facilities appears to be scattered among a number of different sources. In addition, for some water quality constituents, information on the quality of source and SWP waters to compare with current and proposed drinking water standards is lacking or incomplete. The source waters and SWP waters meet drinking water standards for metals, pesticides, and a few other synthetic organic chemicals for which there are data. The mineral quality generally meets the secondary standards for TDS and for chloride with exceedances occurring up to about 10 percent at some locations. The greatest water quality concern is the high THMFP of the Delta source waters which make attaining future standards for total THMs difficult, particularly if sea water intrusion worsens. Similarly, the ability to comply with future standards for other DBPs, which are currently under development, is uncertain.

SUMMARY

The information contained in this chapter is summarized in Table 7-1. This table provides a simplified outline of the criteria evaluated and divides the regulatory program basically between those aspects which deal with protection of source water quality and the protection of SWP water quality.

It should be recognized that there is not a specific identifiable program to monitor, to assess, and to regulate the quality of the water tributary to the SWP. For example, the Basin Plans and the Regional Board regulatory programs deal with comprehensive water quality issues and the protection of multiple beneficial uses. Pieces of regulatory programs within the Regional Board, the State Board, EPA, and other agencies have important potential effects on the sanitary quality of the source waters as described in this report. The situation on the control of the sanitary quality of the water as it enters and is transported through the SWP's facilities is easier to track since it is under the control of only one agency, the DWR although, the USBR controls the quality of water in the DMC.

Table 7-1. Summary of Effectiveness of Current Regulatory Programs

Criteria	Aspects	Primary responsible agencies: Protection of source water quality; Regional Board, State Board, EPA, DWR	Primary responsible agencies: Protection of SWP water quality: DWR
1. Regulating and monitoring existing and potential sources of contamination	Program exists	Yes, but not integrated	Some pieces of a program exist (weed control, Arroyo Pasajero)
	Program documented	Yes, as pieces	Pieces exist
	Overall effectiveness	Generally appears good	Difficult to judge due to insufficient data
2. Emergency plans	Plans exist	Yes	Yes
	Overall effectiveness	Generally appears good	Basic components in place
3. Attainment of Water Quality Standards	Monitoring program exists	Yes, data fragmented among agencies	Yes, though not currently oriented for drinking water constituents
	Monitoring program documented	Yes, for individual monitoring studies	Yes
	Attainment of standards	Generally good, main problem is THMFP	Generally good

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

This Sanitary Survey of the State Water Project (SWP) examined sources of contamination in the watersheds tributary to the SWP export pumps in the Sacramento-San Joaquin Delta (Delta); operational features of the SWP which affect drinking water quality; direct sources of contamination to SWP facilities; the water quality of the source waters and SWP facilities; and the effectiveness of existing regulations to protect drinking water quality. The conclusions and recommendations from this study are presented in this chapter.

Many sources of contamination and potential contamination were documented. The overall significance of sources of contamination to water quality at the Delta export pumps has been evaluated. The recommendations which focus on water quality at the Delta export pumps are made with the specific interest of SWP water quality in mind. There are many competing uses for Delta water and the balancing of these competing uses is not taken into account in these recommendations. The significance of the direct sources of contamination to the SWP export facilities to drinking water quality could not be determined from the existing water quality data. Although it is good sanitary engineering practice to minimize these direct discharges, the costs of removing direct discharges must be balanced with the expected improvement in drinking water quality. Therefore, recommendations made regarding the direct discharges are general and focus on gathering additional data. It would be inappropriate to recommend specific corrective actions before problems are better documented.

The Sanitary Survey of the SWP was a reconnaissance level study. Additional work remains to be done. A State Water Project Sanitary Action Committee (SWPSAC) should be formed by the State Water Contractors (SWC). This committee should be a standing committee charged with protecting the drinking water quality of SWP water. This committee should consist of government agency and water contractor representatives similar to the SWC Water Technical Committee. Government agencies which should be represented on this committee include the California Department of Water Resources (DWR); California Department of Health Services (DHS); Office of Drinking Water; the California Regional Water Quality Control Board, Central Valley Region (Regional Board), the California State Water Resources Control Board (State Board); the U.S. Bureau of Reclamation (USBR); and the U.S. Environmental Protection Agency. This committee should review the results of this report, arrange for the collection of additional data and information as needed, evaluate the need for and the feasibility of corrective actions, and prioritize the implementation of corrective measures as regards their benefit to SWP water quality. Constituents of particular concern to water agencies treating SWP water are disinfection by-products (DBPs) (including trihalomethanes (THMs), brominated DBPs, and those caused by ozonation), pathogens, (including Cryptosporidium, Giardia, and viruses), and, if the drinking water standards become increasingly restrictive, organic constituents. Metals concentrations, although not a drinking water quality problem in SWP water, may be a problem for cities and industries treating waste carried in SWP water, particularly if effluent standards become more restrictive. The recommendations outlined in this chapter are intended to focus the SWPSAC on the most urgent problems documented in this study.

SOURCE WATERS

The two major river systems that contribute water to the SWP export pumps in the Delta are hydrologically very different. The hydrologic differences result in great differences in water quality.

The Sacramento River is the major source stream, contributing about 80 percent of the water flowing into the Delta. In addition to water originating in the Sacramento Basin watershed, high quality water from the Trinity River is imported into the Sacramento River downstream of Shasta Dam. Although Sacramento River system water is diverted at numerous locations for both agricultural and municipal and industrial (M&I) uses, unused water is eventually returned to the Sacramento River. The exception is the Folsom South Canal which is the only diversion out of the Sacramento Basin. The water quality of the Sacramento River at Greene's Landing, although not as good as the quality of the Sierra streams that feed the river, is quite good. The river receives many waste discharges. However, there is sufficient dilution and assimilation capacity to maintain excellent drinking water quality as the river flows into the Delta.

The San Joaquin River is a much smaller river, contributing about 20 percent (including the east side streams) of the water flowing into the Delta. Almost all of the source water for the San Joaquin River is diverted in the Friant-Kern and Madera canals at Millerton Dam. Much of this water is exported from the San Joaquin Basin. The flow in the river downstream of Millerton Dam is maintained at minimal levels sufficient to satisfy local downstream water rights. When agricultural drainage is discharged into the San Joaquin River at Mud and Salt Sloughs, there is essentially no higher quality dilution water in the river. In addition, water of much poorer quality than the river's natural sources is imported into the basin via the Delta Mendota Canal (DMC). As the Sierra tributaries flow into the San Joaquin River, they dilute the agricultural drainage in the river. However, some of the water in the Sierra tributaries is diverted in aqueducts to the San Francisco Bay Area, exported out of the San Joaquin Basin, and never reaches the river. The water quality of the San Joaquin River improves from upstream to downstream due to the diluting effects of the Sierra tributaries; however, unlike the Sacramento River, the San Joaquin River as it flows into the Delta cannot meet most drinking water standards without advanced treatment.

Sacramento Basin Upstream of Greene's Landing

Although the Sacramento River at Greene's Landing meets most drinking water standards and with treatment, meets all of the standards, the quality of the river is not as good as the quality of its major Sierra tributaries. This point is illustrated in this report by comparing the quality of the American River at Nimbus with the quality of the Sacramento River at Greene's Landing. It is difficult to pinpoint the waste discharges most responsible for this degradation in quality because there are currently insufficient data for a basin-wide comprehensive mass loading estimate for all major pollutants and sources.

- Recommendation--The Regional Board's efforts to develop a mass loading estimate of key contaminants for the Sacramento Basin should be supported and expanded. The contributions of key contaminants from M&I discharges, urban runoff, agricultural drainage, and mine discharges can then be better determined.

Municipal and Industrial Discharges--There are numerous M&I discharges to the Sacramento River, most of which are located downstream of the major reservoirs. The largest single discharger (the Sacramento Regional Wastewater Treatment Plant) currently discharges 150 million gallons per day (mgd) and will soon discharge 181 mgd to the river about 8 miles upstream of Greene's Landing. This plant consistently meets its effluent limitations. Based on the constituents measured, the water quality data do not show any significant impact on the quality of the Sacramento River from this plant's effluent discharge. Overall, M&I discharges in the Sacramento Basin upstream of Greene's Landing do not appear to have a significant impact on the drinking water quality of SWP water delivered to the Delta pumps. However, there are no data on the contribution of Giardia, Cryptosporidium, and viruses from M&I wastewater discharges.

- Recommendation--Monitoring requirements for National Pollutant Discharge Elimination System (NPDES) discharges, such as municipal wastewater treatment plants, should be increased to cover Giardia, Cryptosporidium, and viruses. The SWPSAC should encourage the Regional Board to include these constituents in discharge compliance monitoring programs.

Urban Runoff Discharges--The major urban runoff discharges to the Sacramento River upstream of Greene's Landing are from the Sacramento metropolitan area. Limited data currently exist to characterize the volume and contaminant loads in this urban runoff. More data on the impacts of this urban runoff on drinking water quality in the Sacramento River will soon be available. Urban runoff discharges from the Sacramento area are now regulated by an NPDES permit that requires monitoring of the American and Sacramento Rivers. Presently, there is a lack of direct evidence that urban runoff in the Sacramento Basin significantly impairs the drinking water quality of SWP water.

- Recommendation--As the Sacramento area urban runoff water quality data become available, the SWPSAC should reevaluate the impacts of urban runoff discharges into the Sacramento Basin.

Agricultural Drainage--The single largest use of the Sacramento River in the Sacramento Basin is for the irrigation of crops. Sacramento River water is used and reused for agricultural irrigation throughout the Sacramento Valley floor. An estimated 80 percent of the agricultural drainage into the Sacramento Basin discharges into the Sacramento River between the Colusa Basin drain outfall and Suisun Bay. The discharge of agricultural drainage is a primary cause of the heavy silt load carried in the lower Sacramento River but does not appear to significantly affect the ability of Sacramento River water at Greene's Landing to meet drinking water standards. Seasonal rice herbicide levels have been decreasing as a result of best management practices and are well under drinking water standards.

- Recommendation--None.

Mine Discharges--There are numerous documented and probably many undocumented discharges of mine drainage to the upper reaches of the Sacramento River system above major reservoirs. Runoff from Iron Mountain Mine, the largest single source of acid mine drainage in the Sacramento Basin, enters the Sacramento River below Lake Shasta and is not appreciably mitigated by impoundment. The impacts of mine drainage, however, are primarily local and/or affect aquatic life. Mine discharges in the Sacramento Basin do not appear to adversely affect the drinking water quality of Sacramento River water. A concern for water supply agencies with regard to metals concentrations is that if municipal wastewater agencies have to comply with the extremely stringent metals objectives contained in the Inland Surface Waters Plan, (State Board, 1990) metals concentrations in source waters will have to be reduced or water supply agencies will be targeted as one of the contributors of the heavy metals in the influent to the wastewater treatment plants.

- Recommendation--None.

San Joaquin Basin Upstream of Vernalis

Although San Joaquin River water quality at Vernalis is improved over the quality of the river in the south San Joaquin Valley, the beneficial effects of Sierra tributary water are insufficient to enable the San Joaquin River at Vernalis to be of good drinking water quality. The volume and quality of westside agricultural subsurface discharges, the major upstream diversions of San Joaquin River system water out of the San Joaquin Basin, and the importation of poorer quality Delta water into the Basin are the primary factors responsible for the poor drinking water quality of the San Joaquin River as it enters the Delta.

- Recommendation--The San Joaquin River at Vernalis is not designated as having an existing beneficial use of municipal water supply. Yet this water, exported at the south Delta pumps, is used for drinking water purposes. The Regional Board should recognize this use and adopt standards that project the municipal water supply beneficial use classification of the San Joaquin River at Vernalis.

- Recommendation--A mass loading estimate of key contaminants from discharges to the San Joaquin Basin should be developed by the Regional Board.

Municipal and Industrial Discharges--Municipal discharges to the San Joaquin River above Vernalis are mostly located downstream of the major reservoirs. Because of the already poor quality of the San Joaquin River, San Joaquin Basin municipal effluent limitations are generally more restrictive than for the Sacramento Basin. The major industrial discharges in terms of volume have low contaminant concentrations. Although M&I discharges into the San Joaquin Basin add contaminants to the system, they do not appear to be a major factor in the degradation of the river. There are no data, however, on the contribution of Giardia, Cryptosporidium, and viruses from M&I wastewater discharges.

- Recommendation--Monitoring requirements for NPDES discharges, such as municipal wastewater treatment plants, should be increased to cover Giardia, Cryptosporidium, and viruses. The SWPSAC should encourage the Regional Board to include these constituents in discharge compliance monitoring programs.

Urban Runoff Discharges--The major urban runoff discharges to the San Joaquin River system are located downstream of Vernalis in the Delta area. There is presently no direct evidence that urban runoff is a primary factor responsible for the poor drinking water quality of the San Joaquin River at Vernalis.

- Recommendation--None.

Agricultural Drainage--The single largest use of San Joaquin River system water in the San Joaquin Basin is for the irrigation of crops. In addition, the Delta water imported to the west side of the San Joaquin Basin is used almost solely for crop irrigation. Surface and subsurface agricultural drainage is discharged to the San Joaquin River from Mud and Salt Sloughs and constitutes most of the flow in the river immediately upstream of the Sierra tributaries. Subsurface agricultural drainage is also discharged to the San Joaquin River from the west side of the basin between Mud Slough and the Delta. Subsurface agricultural drainage is the primary source of salts and trace elements to the San Joaquin River. Elevated levels of these constituents are the major reason San Joaquin River water at Vernalis is of poor drinking water quality. The Sierra tributaries which receive only surface runoff from agricultural irrigation are of significantly higher quality.

- Recommendation--Because the west side subsurface agricultural discharges into the San Joaquin River are the single largest cause of the poor water quality of the San Joaquin River at Vernalis, the Regional Board's and USBR's efforts to find solutions for these discharges should be supported and monitored by the SWPSAC.

Mine Discharges--As with the Sacramento Basin, there are numerous documented and probably many undocumented discharges of mine drainage to the upper reaches of the San Joaquin River system above the major reservoirs. The impacts of this drainage are primarily local and/or affect aquatic life, and do not appear to have a significant effect on the drinking water quality of the San Joaquin River.

- Recommendation--None.

The Tulare Basin

Water from the Kings River and the Friant-Kern Canal, which is occasionally diverted into the San Joaquin River, is of good drinking water quality. This water is almost entirely excess Sierra runoff and probably improves, to a limited degree, the San Joaquin River water quality. M&I, urban runoff, and mine discharges in the Tulare Basin are not significant contributors to this water. As discussed in Chapter 4, agricultural drainage is contained within the Tulare Basin.

- Recommendation--None.

The Delta

The quality of water at the SWP Delta export pumps is clearly degraded over the quality of water in its major source stream, the Sacramento River. The major causes of the deterioration of water quality in the Delta are agricultural drainage from Delta islands, sea water intrusion, possibly local discharges to Cache Slough (north Delta) and the poor quality of San Joaquin River water (primarily south Delta). The water quality data for Barker Slough in the north Delta consists of only three year's of data (primarily dry years), whereas the water quality data for the Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant) in the south Delta is averaged over the last 15 years (which includes all types of water years). The apparently poorer quality of water in Barker Slough compared to Banks Pumping Plant may reflect the reduced dilution available under drought conditions, as well as the impact of local drainages into Cache Slough. Cache Slough, which feeds Barker Slough, receives agricultural discharges, municipal wastewater treatment plant effluent from the Vacaville Easterly Plant, and urban runoff. Downstream of Vernalis, the San Joaquin River receives urban runoff and municipal wastewater treatment plant effluent from the Stockton area. Backflow conditions in the San Joaquin River downstream of Vernalis, caused by tidal influences and aggravated by south Delta exports, limit the flushing of water in this section of the San Joaquin River.

- Recommendation--As allowed by the Clean Water Act, the Regional Board should consider expanding the areas where NPDES permits for urban runoff are required to include rapidly urbanizing areas in and near the Delta with populations under 100,000. The approach used in Sacramento County to adopt a county-wide permit would address this need if followed in other urbanizing counties in the area.

- Recommendation--The SWPSAC should initiate a water-year type study of south Delta water quality data to aid in making an evaluation of whether the limited Barker Slough water quality data are representative. This study will also help identify problems particular to low flow conditions in the south Delta area. If this study indicates that the apparently relatively poorer quality of SWP water in the North Bay Aqueduct is not due to drought conditions, then the Regional Board should more extensively evaluate the local discharges into Cache Slough.

Agricultural Drainage--The DWR has determined that drainage from Delta islands can increase trihalomethane formation potential (THMFP) in the Delta by as much as about 67 percent during worst-case conditions. This finding is of particular concern because water supply agencies using SWP water from the Delta may have difficulty meeting a future more restrictive THM standard. The impact of agricultural drainage on other disinfection by-products has yet to be determined.

- Recommendation--The Delta Islands Drainage Investigation project is critically important to understanding the degradation of Delta water and the impact of agricultural drainage on SWP drinking water quality. This project should be supported and, if possible, accelerated.

Sea Water Intrusion--Sea water intrusion increases the salt content of SWP water supplies and is the major source of bromide that results in the brominated forms of THMs in treated Delta water. Brominated forms of THMs compound the problem of meeting the THM standard. Sea water intrusion also raises sodium, chloride, and total dissolved solids concentrations above levels recommended for drinking water during periods of low Delta outflow. Sea water intrusion could render the Delta unusable as a drinking water supply if Delta levees fail in an earthquake.

- Recommendation--It is in the best interest of the drinking water quality of SWP water to improve salinity standards in the Delta. The SWC have recommended to the State Board a 50 milligram per liter (mg/l) chloride standard, when feasible, to control bromide from sea water intrusion. When feasible means when facilities are installed in the Delta to isolate SWP export water from sea water intrusion effects. The State Board should adopt the recommended 50 mg/l chloride standard.

- Recommendation--It is in the best interest of the drinking water quality of SWP water to reduce the seismic vulnerability of Delta levees and protect SWP water supplies from catastrophic sea water intrusion.

OPERATION OF THE STATE WATER PROJECT FACILITIES

The operation of the SWP was examined to determine how the operation of the system affects the water quality of SWP facilities.

Clifton Court Forebay

The practice of opening the Clifton Court Forebay intake gates at receding high tide minimizes adverse physical impacts on the south Delta and maximizes the Sacramento River contribution to the export pumps. Dependent on Delta outflow at the time, sea water intrusion may adversely affect the quality of Sacramento River water at the export pumps. Various alternatives for reducing the effects of sea water intrusion on SWP drinking water supplies have been studied. Recently, DWR and USBR released a draft environmental impact report on alternatives, such as Delta channel improvements to improve the Sacramento River flow through the east Delta to the south Delta pumps (DWR and USBR, 1990).

- Recommendation--SWPSAC should work with DWR and USBR to identify the most feasible method of reducing sea water intrusion.

O'Neill Forebay

At O'Neill Forebay, CVP water from the DMC enters the SWP system. On an average annual basis, the DMC contributes 35 percent of the water entering O'Neill Forebay from the SWP and CVP. The DMC water consists of a higher percentage of San Joaquin River water whereas SWP water consists of a higher percentage of Sacramento River water. This, combined with the numerous agricultural drains that discharge to the DMC between the Delta and O'Neill Forebay, indicate that CVP water entering O'Neill Forebay may be of poorer quality than SWP water entering O'Neill Forebay. Unfortunately, there are a limited amount of data on the quality of DMC water entering O'Neill Forebay so no conclusions can be drawn on the impact of the DMC water on SWP water quality at O'Neill Forebay and south of O'Neill Forebay.

- Recommendation--DWR is currently expanding its monitoring program at O'Neill Forebay. The SWPSAC should monitor DWR's new program for its effectiveness in determining the impact of DMC water on the drinking water quality of the SWP.

Kern River Intertie

During periods of high flows in the Kern River, Kern River water is diverted through the Kern River Intertie and transferred into the California Aqueduct near Bakersfield. During these periods, Kern River water has a lower salt content and produces lower THM concentrations than SWP water. Kern River water is softer and carries a higher silt load than SWP water and downstream treatment plants that usually receive SWP water must adjust for this. However, Kern River water does not appear to degrade the drinking water quality of SWP water supplies.

- Recommendation--None.

FIELD SURVEY OF THE STATE WATER PROJECT FACILITIES

A detailed field survey, conducted to identify potential direct sources of contamination to SWP export facilities, resulted in a comprehensive inventory of such potential sources. Table 8-1 lists the total number of potential sources of contamination to SWP open canal sections. The direct discharges to the DMC are not included in this table.

Table 8-1. Potential Sources of Contamination to SWP Open Canal Sections

Drain inlets	
Canal roadside drainage	2,173
Agricultural drainage (South Bay Aqueduct, Clifton Court to end of San Luis Canal)	119
Other - including highway drainage (Clifton Court to O'Neill Forebay) groundwater (Clifton Court to Kern River Intertie, West Branch), urban runoff (East Branch), Coast Range drainage (O'Neill Forebay to end of San Luis Canal)	132
Bridges	215
Overcrossings (includes pipelines and overchutes)	507
Undercrossings	309
Water service turnouts	252

The North Bay Aqueduct, the Coastal Branch, and the California Aqueduct between the Kern River Intertie, and the East-West Branch bifurcation are relatively free of contaminant sources.

The contribution of each source to water quality degradation and the relative importance of various sources could not be determined from the available water quality data. Whether the drinking water quality of SWP water is impaired by these discharges should be further investigated so that corrective actions are based on documented need. Further investigations may consist of supporting, expanding, and/or modifying existing monitoring programs or of proceeding with special-purpose monitoring studies. Key areas for the SWPSAC to consider for further investigation are:

Coast Range Drainage

Between O'Neill Forebay and the end of the San Luis Field Division near Kettleman City, the California Aqueduct receives agricultural, urban, and mine drainage from the Arroyo Pasajero, Little Panoche Creek, Cantua Creek, and Salt Creek. The routine monthly monitoring programs show no obvious degradation in water quality in the California Aqueduct between O'Neill

Forebay and the end of the San Luis Field Division. There may however be a significant short-term impact from these discharges that is not detected in the routine monthly monitoring programs.

- Recommendation--Existing monitoring programs should be modified to determine the impact on SWP drinking water quality of the Coast Range drainage.

Agricultural Drainage

There are 108 agricultural drains that discharge into the California Aqueduct between Clifton Court Forebay and the end of the San Luis Canal. The South Bay Aqueduct receives agricultural discharges from 11 drains. The quantity and quality of drainage discharge is unknown. The existing monthly monitoring program is inadequate to determine the impacts of agricultural drainage on the SWP because key agricultural constituents are not monitored and sampling is not timed to coincide with agricultural discharges.

- Recommendation--Existing monitoring programs should be modified to determine the impact on SWP drinking water quality of agricultural discharges (particularly in the San Luis Canal).

Urban Runoff

Urban drainage from residential/commercial developments is discharged to the East Branch of the California Aqueduct. The impact on SWP water quality cannot be determined from the routine monthly monitoring data.

- Recommendation--Existing monitoring programs should be modified to determine the impact on SWP drinking water quality of these urban runoff discharges.

Highway Drainage

The California Aqueduct receives drainage from sections of Interstate 5 and Highway 205 between the Banks Pumping Plant and O'Neill Forebay. Drainage from part of Highway 152 flows into San Luis Reservoir. These highways are major trucking routes. In addition to routine roadside drainage, there is potential for a spill of hazardous materials to enter the SWP from a trucking accident.

- Recommendation--DWR should consider the recommendations of the Laverty Associates Report in updating and standardizing their Emergency Response Plans. The value of developing a geographical information system which identifies potential drains that could allow tanker truck spillage to reach SWP facilities should be evaluated. Such information may speed the identification of which drainage inlets to block during spills. DWR should also consider constructing containment structures at vulnerable points.

Less important direct sources of potential contamination are:

Other Potential Sources of Contamination to Open Canal Segments

Groundwater is pumped into several segments of the California Aqueduct. The greatest number of discharge locations occurs between Clifton Court and O'Neill Forebay. The routine monitoring program does not show an increase in total dissolved solids or metals that are typically found in groundwater between Clifton Court and O'Neill Forebay.

Additional, less important potential sources of contamination documented during the field survey include canal roadside drainage, overcrossings, undercrossings, bridges, water service turnouts, and fishing areas. Canal roadside drainage is discharged into all open canal segments of the SWP. This drainage is likely to contain little more than suspended solids since canal roads are infrequently travelled. With the exception of canal roadside drainage, contaminants from the sources listed above would only enter the SWP if (1) facilities were improperly designed or operated, (2) human error or deliberate action resulted in a spill of a harmful substance, or (3) catastrophic failure of a pipeline occurred.

- Recommendation--The SWPSAC should consider the potential for contamination of the SWP from these sources as priorities permit.

Body Contact Recreation in the SWP Reservoirs

Body contact recreation in Lake Del Valle, O'Neill Forebay, San Luis Reservoir, Pyramid Lake, Castaic Lake, Lake Silverwood, and Lake Perris may contribute pathogens to the water. Body contact recreation in Lake Perris has resulted in verified cases of Shigellosis and other complaints of human illness after swimming in the lake. Despite the potential for bacteriological contamination of the reservoirs, the bacteriological quality of raw water supplies is quite good along the SWP. Treated water coliform levels are consistently less than 2/100 ml, indicating that existing treatment processes successfully reduce coliforms to acceptable levels.

- Recommendation--The SWPSAC should consider the potential for contamination of the SWP from these sources as priorities permit.

Wastewater Handling Facilities

Wastewater handling facilities in the watersheds of Lake Del Valle, Pyramid Lake, Castaic Lake, and Lake Silverwood are potential sources of pathogens, nutrients, and organics. Floating toilets in Pyramid Lake, Castaic Lake, and Lake Silverwood may also contribute these contaminants. The only documented problems are in the Lake Silverwood watershed. The piping and pumping stations that convey raw wastewater out of the watershed have failed and resulted in wastewater spills to the lake on several occasions. Elevated coliform levels have been detected in the lake following wastewater spills. This has not resulted in coliform problems at downstream water treatment plants.

- Recommendation--The SWPSAC should consider the potential for contamination of the SWP from these sources as priorities permit.

WATER QUALITY

Water quality data, collected at a number of locations from the source waters and the SWP facilities, were reviewed and analyzed.

Water Quality Degradation

Water quality is degraded as Sacramento River system water runs from the Sierra streams, through the valley, and through the Delta to the pumps of the SWP. The most significant degradation occurs in the Delta. The major sources of water quality degradation in the Delta which have been discussed previously in this chapter include:

1. Delta islands agricultural drainage
2. Sea water intrusion
3. The poor quality of San Joaquin River water
4. Local discharges into the Cache Slough and Stockton areas of the Delta

- Recommendation--The committee should be particularly concerned with the well documented degradation of the drinking water quality of SWP water in the Delta. Data collected by the Delta Islands Drainage Investigation, existing monitoring programs, and studies recommended by this report should be routinely evaluated to better define the causes of water quality degradation in the Delta.

Water quality degradation between the Delta export pumps and the terminal reservoirs cannot be identified based on the available data.

- Recommendation--Studies recommended by this report to determine the impacts of direct sources of contamination to the SWP should be implemented.

Drinking Water Standards

Most drinking water standards are met by untreated SWP water supplies. The secondary standards for chloride (250 milligrams per liter (mg/l)) and total dissolved solids (500 mg/l) are approached frequently and exceeded occasionally in the raw water between the Delta export pumps and southern California. The consumer acceptance levels for these constituents are sometimes exceeded. The National Academy of Sciences recommended criterion of 100 mg/l of sodium for people on moderately restricted diets is exceeded about 10 percent of the time. The greatest known problem SWP contractors will face is meeting the future THM standard. It is not yet known if the future standard will be 25 or 50 μg/l. It is unlikely that SWP water contractors will be able to meet the future standard without expensive modifications to existing water treatment plants. The heavier brominated THMs are formed during periods of sea water intrusion. This adds to the problem of meeting the THM standard. The ability to meet future disinfection by-product standards with SWP water is unknown due to lack of information on what the standards will be and lack of data on concentrations in SWP source waters. Sea water intrusion and agricultural drainage in the Delta are the two primary sources of contaminants that will prevent water contractors from meeting future DBP standards. In the future, there may be other drinking water standards that will be difficult to meet with SWP water supplies. Recommendations to reduce sea water intrusion effects and determine the impacts of Delta agricultural drainage have been made previously in this chapter.

- Recommendation--The SWPSAC should stay abreast of the EPA and DHS drinking water standards programs. As drinking water standards are proposed for new constituents and lowered for existing constituents, the SWPSAC should revise SWP monitoring programs to collect data on these constituents.

Water Quality Monitoring Programs

Historically, the DWR monitoring programs have concentrated on ecological monitoring of the Delta and SWP supplies. There is a wealth of mineral and phytoplankton data. Recently, the emphasis has changed to drinking water quality monitoring. The Interagency Delta Health Aspects Monitoring Program, the Delta Islands Drainage Investigation, and the recently initiated THMFP monitoring south of the Delta are examples. The historic DWR monitoring programs were not designed to evaluate the impacts of the potential sources of contamination identified in this sanitary survey.

- Recommendation--DWR has begun and should continue to elevate the drinking water monitoring of the SWP system. DWR should consider the centralization and coordination of ecological, operational, and drinking water monitoring programs, and special water quality investigations under the supervision of a water quality program manager responsible for coordination of water monitoring programs, identification of needed studies, implementation of the studies, and management of the data in a centralized data bank.

EFFECTIVENESS OF REGULATIONS

This section discusses the establishment of water quality standards and the control of contaminant sources.

Water Quality Standards

The regulatory programs that require the establishment of drinking water standards and ambient water quality criteria have been effectively implemented by DHS, the State Board, and the Regional Boards. Drinking water standards established by EPA and DHS are extremely protective of public health and drinking water regulations are rigorously enforced by DHS. In addition, the State Board's Inland Surface Waters Plan proposes water quality objectives that protect both human health and aquatic life. The aquatic life objectives are in many cases more stringent than the drinking water standards.

- Recommendation--None.

Control of Contaminant Sources

The Regional Board has developed an effective program for regulating the discharge of treated wastewater from M&I facilities through the issuance of NPDES permits and the collection of effluent monitoring data by the permittees. Although coliform monitoring of M&I discharges is required, NPDES permittees are not yet required to monitor their effluents for pathogenic microorganisms.

EPA is expected to issue draft regulations in October, 1990, that will require many industries and all municipalities with populations greater than 100,000 to apply for and obtain NPDES permits for urban runoff discharges. The Regional Board will implement these regulations in California.

Agricultural drainage is not regulated under an effluent limitation system such as the NPDES permits. Best management practices (BMPs) to control the loads of contaminants are more suited to agricultural drainage because of the extensive use and reuse of the rivers for agricultural irrigation, the number of agricultural drains and responsible parties, and the variability of agricultural drainage quality with crop specific practices. The Regional Board and the Department of Food and Agriculture are in the process of implementing BMPs to control seasonal drainage from rice fields in the Sacramento Valley. This program has resulted in declines in the concentrations of rice herbicides since about 1986. The Regional Board is currently investigating and developing BMPs for agricultural surface runoff and subsurface discharges to the San Joaquin River system. The variety of agricultural uses and practices in the San Joaquin Basin makes control of agricultural contaminants in that basin especially complex. The study to characterize Delta islands agricultural drainage and identify BMPs to control the effects of that drainage is also ongoing.

The regulatory program to control drainage from inactive mines does not appear very effective since many reaches of streams tributary to the Sacramento and San Joaquin Rivers have been listed by the Regional Board and the State Board as impaired water bodies because of the presence of metals from mine drainage at levels toxic to aquatic life. Controlling mine drainage can be technically complex and extremely costly. Often, locating responsible parties financially able to pay cleanup costs is not possible.

The discharge of dairy or feedlot wastes to surface waters is illegal. Due to staffing constraints, the Regional Board responds to reported violations but does not have an active enforcement program.

In summary, programs to control point source discharges are in place. The Regional Board is currently developing programs to regulate and reduce nonpoint source discharges.

- Recommendation--The Regional Board will need increased funding to bring nonpoint source pollution under regulation.

As drinking water standards become more stringent, it will be necessary to more fully characterize discharges and receiving waters with respect to the constituents being regulated. The Regional Board may need to revise discharge limitations for both point and nonpoint discharges to protect source water quality. This increased protection of source water quality may be necessary for water supply agencies to meet future drinking water standards.

- Recommendation--The Regional Board will need increased funding to conduct studies to determine if discharge limitations must be lowered for water supply agencies to meet more stringent drinking water standards with SWP source water.

Sea water intrusion is currently regulated by the Delta Plan and Water Rights Decision 1485 (D-1485). D-1485 and the Delta Plan establish water quality objectives for various beneficial uses of Delta water. The Delta water quality objectives vary according to year type. For example, the number of days the chloride objective can be exceeded is greater in dry years. The water quality objectives were established at levels considered representative of natural Delta water quality prior to SWP and CVP projects. The State Board is currently considering a Water Quality Control Plan for Salinity which reconsiders the issues addressed in the Delta Plan and D-1485 (State Board, 1990).

- Recommendation--As discussed previously, the State Board should adopt the 50 mg/l chloride standard recommended by the SWC to protect the drinking water quality of SWP water.

APPENDIX A

REFERENCES

REFERENCES

Amy, G.L., et. al. 1985. "Factors Affecting Incorporation of Bromide into Brominated Trihalomethanes During Chlorination," a chapter in Water Chlorination: Environmental Impact and Health Effects. Vol. 5.

Brown and Caldwell. 1984. Fresno Nationwide Urban Runoff Program Project. Prepared for Fresno Metropolitan Flood Control District.

Brown and Caldwell. 1989. Delta Drinking Water Quality Study. Prepared for California Urban Water Agencies.

Buer, S., S. Philippe, and T. Pinkos. 1979. Inventory and Assessment of Water Quality Problems Related to Abandoned and Inactive Mines in the Central Valley Region of California. California Central Valley Regional Water Quality Control Board.

California Central Valley Regional Water Quality Board. 1988. Quality of Agricultural Drainage Discharges to the San Joaquin River from Area East of the River in Stanislaus, Merced and Madera Counties, California, January 1986 to September 1988.

California Central Valley Regional Water Quality Control Board. 1988. Water Quality Survey of Tile Drainage Discharges in the San Joaquin River Basin.

California Central Valley Regional Water Quality Control Board. 1989. Beneficial Use Assessment Report. 1988/1989.

California Department of Food and Agriculture. 1989. 1989 Program to Prevent Off-Site Movement of Pesticides from California Rice Fields. Draft Report.

California Department of Health Services. 1975. "Sewage Spill of Lake Silverwood." Internal Memorandum by Steve Nelson.

California Department of Health Services. 1976. "Sewage Spill at Lake Silverwood." Internal Memorandum by Steve Nelson.

California Department of Health Services. 1977. "Sewage Spill at Lake Silverwood." Internal Memorandum by Ray Feeser.

California Department of Health Services. 1978. "Domestic Water Supply Permit No. 78-061, City of Tracy."

California Department of Health Services. 1982. "Surface Water Inflow Data, California Aqueduct and Tributary Waterways." Internal Memorandum by Ted Andrews.

California Department of Health Services. 1984. Inspection of Domestic Water Reservoir Facilities--Castaic Lake."

California Department of Health Services, California Department of Water Resources, and Riverside County Department of Health. 1987. Cooperative Bacteriological Study--Lake Perris State Recreation Area--8/27/86 to 9/8/86. Draft Report.

California Department of Water Resources. 1974. Draft Environmental Impact Report, Peripheral Canal Project.

California Department of Water Resources. 1975. "Sewage Spill at Lake Silverwood." Internal Memorandum by Joseph H. Sherraro.

California Department of Water Resources. 1987. Evaluation of Toxic Substances in Fish, Benthic Organisms, and Sediment in the State Water Project.

California Department of Water Resources. 1989. The Delta as a Source of Drinking Water, Monitoring Results--1983 to 1987. Interagency Delta Health Aspects Monitoring Program.

California Department of Water Resources. 1990. Delta Islands Drainage Investigation Report. Interagency Delta Health Aspects Monitoring Program.

California Department of Water Resources and U.S. Bureau of Reclamation. 1990. South Delta Water Management Program, Draft Environmental Impact Report.

California State Water Resources Control Board and California Central Valley Regional Water Quality Control Board. 1990. Sacramento River Toxic Chemical Risk Assessment Project.

California State Water Resources Control Board. 1990. Proposed 1990 Water Quality Assessment.

California State Water Resources Control Board. 1990. Water Quality Control Plan for Salinity, San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Revised Draft.

Camp, Dresser and McKee. 1986. Final Report--Water Treatment Plant Expansion Study-City of Benicia.

County of San Bernardino, Special Districts Department. 1982. Letter to the Lahontan Regional Water Quality Control Board--Untreated Sewage Discharge to Lake Silverwood.

County of San Bernardino, Special Districts Department. 1983. Letter to the Lahontan Regional Water Quality Control Board--Sewage Overflow to Lake Silverwood.

APPENDIX C

ANNOTATED BIBLIOGRAPHY

SANITARY SURVEY REPORT INFORMATION FROM THE OFFICE OF DRINKING WATER--CALIFORNIA DEPARTMENT OF HEALTH SERVICES

Prepared by:

Boyle Engineering Corporation
1300 East Shaw Avenue
Suite 176
Fresno, California 93710
(209) 222-8436

This document is available at the office of the State Water Contractors

555 Capitol Mall, Suite 725
Sacramento, California 95814
Contact Mr. John Coburn at (916) 447-7357

Crooks, William H. and Dennis W. Westcot. 1989. Regulation of Agricultural Subsurface and Surface Drainage in the San Joaquin Basin. California Central Valley Regional Water Quality Control Board.

Foe, Christopher. 1988. "Preliminary 1988 Colusa Basin Drain Rice Season Biotoxicity Results." California Central Valley Regional Water Quality Control Board.

Hanson, B.R., T.I. Farouk, J. Cornelius, and W. Shannon. 1989. Nonpoint Source Pollution from Agricultural Drainage in California: Defining the Problem and Assessing the Need. California State Water Resources Control Board Nonpoint Source Conference.

Izaquirre, G. 1985. Progress Report, Lake Perris MIB Project: Developments in 1984. Metropolitan Water District of Southern California.

Jones, R.M., 1989. "1989 Taste and Odor Monitoring Program for Lake Perris, Live Oak Reservoir, and Castaic Lake." Metropolitan Water District of Southern California.

Luong, Tieu V., Christopher J. Peters, and Roger Perry. 1982. "Influence of Bromide and Ammonia Upon the Formation of Trihalomethanes Under Water Treatment Conditions," Environmental Science and Technology. Vol. 16, No. 8.

McGuire, Michael J., Stuart W. Krasner, Jill T. Gramith. 1990. "Comments on Bromide Levels in State Project Water and Impacts on Control of Disinfection By-Products." Metropolitan Water District of Southern California.

Metropolitan Water District of Southern California and James M. Montgomery Consulting Engineers. 1989. Disinfection By-Products in U.S. Drinking Waters.

Montoya, Barry L. 1987. Urban Runoff Discharges from Sacramento, California. Prepared for California Central Valley Regional Water Quality Control Board. Publication Number CVRWQCB 87-1SPSS.

Montoya, Barry M., Fred J. Blatt, Gregory E. Harris. 1988. A Mass Loading Assessment of Major Point and Non-Point Sources Discharging to Surface Waters in the Central Valley, California, 1985. Prepared for California Central Valley Regional Water Quality Control Board. Draft Report.

National Academy of Sciences. 1977. Drinking Water and Health.

National Research Council. 1982. Drinking Water and Health. Volume 4. Safe Drinking Water Committee, Washington, D.C. National Academy Press.

Personal Communication, 1989. Rich Haberman. California Department of Health Services.

Personal Communication. 1989. Gary Yamomoto. California Department of Health Services.

Rose, Joan B. Feb. 1988. "Occurrence and Significance of Cryptosporidium in Water." Journal of the American Water Works Association.

Sacramento Area Consultants. 1975. Combined Wastewater Control System: Sacramento Regional Wastewater Management Program.

San Joaquin River Basin Technical Committee. 1987. Regulation of Agricultural Drainage to the San Joaquin River. Prepared for California State Water Resources Control Board Order No. WQ 85-1.

Santa Clara Valley Water District. 1988. "Permit Application for Domestic Water Supply."

Silverman, Gary P. Sept. 1988. "The Industry's New Superbug." Opflow, American Water Works Association. Volume 14, No. 9.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water.

U.S. Environmental Protection Agency. 1983. Results of the Nationwide Urban Runoff Program.

U.S. Environmental Protection Agency. 1989. "Discussion of Strawman Rule for Disinfectants and Disinfection By-Products." Science Advisory Board Drinking Water Committee, Meeting of October 11, 1989.

The University of California at Berkeley Mining Waste Study Team. 1988. Mining Waste Study. Prepared for California State Water Resources Control Board, California Department of Health Services, and the California Department of Conservation.

APPENDIX B

WATER QUALITY SUMMARY TABLES

Table B-1. Sacramento River at Fremont Weir Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total organic carbon, mg/l	14	1.70 - 4.70	2.70	1.70	4.50	4/77 - 4/82
Total dissolved solids, mg/l	130	66.00 - 190.00	118.00	76.00	148.00	1/75 - 5/87
Sodium, mg/l	131	4.60 - 124.00	12.00	7.00	18.00	1/75 - 5/87
Chloride, mg/l	131	2.00 - 24.00	6.00	3.00	9.00	1/75 - 5/87
Bromide, mg/l	131	0.01 - 0.08	0.02	0.02	0.03	1/75 - 5/87
Turbidity, NTU	60	2.00 - 230.00	12.50	5.00	70.00	1/75 - 4/87
Total phosphorus, mg/l as P	98	0.03 - 0.80	0.08	0.05	0.18	1/75 - 4/87

Table B-2. American River at Nimbus/American River Plant Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
THMFP (DWR), ug/l	59	80.00 - 390.00	210.00	130.00	310.00	1/82 - 12/88
THMFP (EBMUD), ug/l	63	39.00 - 113.00	50.00	41.00	80.00	8/83 - 12/88
Total organic carbon, mg/l	103	0.00 - 8.30	1.60	1.20	3.70	9/77 - 12/88
Dissolved organic carbon, mg/l	25	1.00 - 2.70	1.60	1.20	2.30	1/87 - 12/88
Total organic halogens, ug/l	44	0.00 - 500.00	2.00	0.00	50.00	12/84 - 12/88
TOXFP, ug/l	46	140.00 - 1100.00	215.00	160.00	430.00	12/84 - 12/88
Total dissolved solids, mg/l	119	30.00 - 76.80	47.70	36.00	62.30	9/77 - 12/88
Sodium, mg/l	73	2.00 - 5.00	2.00	2.00	3.60	1/82 - 12/88
Chloride, mg/l	73	1.00 - 5.00	2.00	1.00	4.00	1/82 - 12/88
Bromide, mg/l	73	0.01 - 0.02	0.01	0.01	0.02	1/82 - 12/88
Turbidity, NTU	71	0.51 - 76.00	2.00	0.83	6.00	1/82 - 12/88
Electrical conductivity, umhos/cm	73	0.00 - 102.00	66.00	42.00	82.00	1/82 - 12/88
pH	46	6.80 - 7.80	7.40	7.08	7.60	8/83 - 12/88
Alkalinity, mg/l as CaCO3	46	13.00 - 31.00	23.00	18.00	30.00	8/83 - 12/88
Hardness, mg/l as CaCO3	46	13.00 - 36.00	23.00	18.00	31.00	8/83 - 12/88
Color, color units	99	0.00 - 25.00	5.00	0.00	12.00	7/83 - 12/88
Chlorophyll a, ug/l	49	0.00 - 7.90	1.30	0.20	5.10	8/83 - 12/88
Nitrite, mg/l as N	5	0.00 - 0.02	0.01	0.00	0.02	12/83 - 12/88
Nitrate, mg/l as N	41	0.00 - 0.28	0.04	0.00	0.11	12/83 - 12/88
Ammonia, mg/l	20	0.00 - 0.10	0.02	0.00	0.04	12/83 - 12/88
Orthophosphate, mg/l as P	19	0.00 - 0.11	0.01	0.00	0.04	10/83 - 12/88
Total phosphorus, mg/l as P	50	0.00 - 0.08	0.01	0.01	0.03	2/78 - 12/88
Odor, odor units	18	1.00 - 16.00	2.00	1.00	5.00	8/83 - 3/85
Aluminum, ug/l	78	0.00 - 860.00	0.00	0.00	240.00	1/75 - 6/89

Table B-2. American River at Nimbus/American River Plant Data Summary, continued

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Arsenic, ug/l	91	0.00 - 0.00	0.00	0.00	0.00	7/77 - 6/89
Barium, ug/l	93	0.00 - 0.00	0.00	0.00	0.00	2/78 - 6/89
Beryllium, ug/l	57	0.00 - 0.00	0.00	0.00	0.00	7/84 - 6/89
Cadmium, ug/l	98	0.00 - 0.00	0.00	0.00	0.00	7/77 - 6/89
Chromium, ug/l	98	0.00 - 0.00	0.00	0.00	0.00	7/77 - 6/89
Copper, ug/l	131	0.00 - 110.00	0.05	0.00	40.00	7/77 - 6/89
Iron, ug/l	144	0.00 - 1500.00	75.00	0.01	360.00	1/75 - 6/89
Lead, ug/l	131	0.00 - 4.00	0.00	0.00	0.00	7/77 - 6/89
Manganese, ug/l	122	0.00 - 170.00	0.00	0.00	10.00	7/77 - 6/89
Mercury, ug/l	87	0.00 - 0.00	0.00	0.00	0.00	7/77 - 6/89
Selenium, ug/l	134	0.00 - 5.00	0.00	0.00	0.00	7/77 - 6/89
Silver, ug/l	92	0.00 - 0.00	0.00	0.00	0.00	7/77 - 6/89
Zinc, ug/l	109	0.00 - 0.00	0.00	0.00	0.00	7/77 - 6/89
Asbestos, mF/l	14	12.00 - 2200.00	110.00	12.00	1100.00	10/83 - 7/86

Table B-3. Sacramento River at Greene's Landing

Constituent, units	N	Range	Median	Percentiles		Period
				Tenth	Ninety	of Record
THMFP (DWR), ug/l	64	110.00 - 1100.00	255.00	180.00	490.00	7/83 - 10/88
THMFP (EBMUD), ug/l	62	55.00 - 230.00	76.00	60.00	110.00	8/83 - 12/88
Total organic carbon, mg/l	37	0.00 - 14.00	2.00	1.20	8.30	7/83 - 12/88
Dissolved organic carbon, mg/l	25	1.40 4.90	1.90	1.50	3.30	1/87 10/88
Total organic halogens, ug/l	25	0.00 - 100.00	23.00	12.00	58.00	12/84 - 12/88
TOXFP, ug/l	37	220.00 - 1800.00	300.00	240.00	600.00	12/84 - 12/88
Total dissolved solids, mg/l	300	45.00 - 160.00	100.00	78.00	128.00	1/75 - 12/88
Sodium, mg/l	115	3.00 - 18.00	10.00	7.00	15.00	7/83 - 12/88
Chloride, mg/l	275	1.50 - 18.00	6.00	4.00	10.00	1/75 - 12/88
Bromide, mg/l	275	0.01 - 0.06	0.02	0.02	0.04	1/88 - 12/88
Calc. Bromide, mg/l	321	0.00 - 0.05	0.02	0.01	0.03	1/75 - 12/88
Turbidity, NTU	168	0.00 - 140.00	7.55	2.80	19.00	7/83 - 12/88
Electrical conductivity, umhos/cm	162	70.00 - 251.00	178.00	128.00	196.00	7/83 - 12/88
pH	46	7.00 - 7.90	7.61	7.44	7.80	7/83 - 12/88
Alkalinity, mg/l as CaCO3	79	30.00 - 84.00	61.00	49.00	79.00	8/83 - 12/88
Hardness, mg/l as CaCO3	79	28.00 - 84.00	59.00	47.00	74.00	8/83 - 12/88
Color, color units	99	0.00 - 55.00	10.00	5.00	23.00	7/83 - 12/88
Chlorophyll a, ug/l	262	0.50 - 39.00	2.05	1.00	6.00	1/75 - 12/88
Nitrite, mg/l as N	20	0.00 - 0.01	0.01	0.00	0.01	5/87 - 12/88
Nitrate, mg/l as N	96	0.00 - 0.97	0.18	0.08	0.52	7/83 - 12/88
Ammonia, mg/l	45	0.01 - 0.60	0.22	0.07	0.45	7/83 - 12/88
Orthophosphorus, mg/l as P	46	0.02 - 0.21	0.05	0.06	0.15	1/85 - 12/88
Total phosphorus, mg/l	170	0.05 - 0.30	0.11	0.08	0.18	1/75 - 12/86

Table B-3. Sacramento River at Greene's Landing, continued

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Odor, odor units	18	1.00 - 13.00	3.00	1.00	4.00	8/83 - 3/85
Arsenic, ug/l	27	0.00 - 10.00	0.00	0.00	0.00	1/75 - 9/86
Cadmium, ug/l	27	0.00 - 0.00	0.00	0.00	0.00	1/75 - 9/86
Chromium, ug/l	27	0.00 - 10.00	0.00	0.00	10.00	1/75 - 9/86
Copper, ug/l	27	0.00 - 40.00	10.00	0.00	20.00	1/75 - 9/86
Iron, ug/l	27	240.00 - 3700.00	770.00	360.00	1500.00	1/75 - 9/86
Lead, ug/l	33	0.00 - 10.00	0.00	0.00	10.00	6/78 - 12/88
Manganese, ug/l	27	10.00 - 180.00	20.00	20.00	80.00	1/75 - 9/86
Mercury, ug/l	24	0.00 - 0.30	0.00	0.00	0.10	1/75 - 9/86
Selenium, ug/l	46	0.00 - 1.00	0.00	0.00	0.00	7/83 - 12/88
Zinc, ug/l	27	0.00 - 50.00	10.00	0.00	20.00	1/75 - 9/86
Asbestos, mF/l	14	110.00 - 3200.00	460.00	110.00	2200.00	10/83 - 10/88

Table B-4. Lindsey Slough and Barker Slough Data Summary

Constituent, units	N	Range			Median	Percentiles Tenth	Percentiles Ninety	Period of Record		
THMFP, ug/l	65	260.00	-	2700.00	870.00	390.00	1300.00	7/84	-	12/88
Dissolved organic carbon, mg/l	39	2.70	-	9.30	5.70	3.00	7.20	1/87	-	12/88
Total dissolved solids, mg/l	72	141.00	-	460.00	313.00	170.00	378.00	7/84	-	12/88
Sodium, mg/l	68	12.00	-	72.00	44.00	21.00	58.00	7/84	-	12/88
Chloride, mg/l	68	9.00	-	89.00	38.50	18.00	58.00	7/84	-	12/88
Bromide, mg/l	68	0.03	-	0.26	0.12	0.06	0.17	7/84	-	12/88
Turbidity, NTU	65	5.00	-	110.00	29.00	18.00	60.00	7/84	-	12/88
Electrical conductivity, umhos/cm	68	208.00	-	734.00	494.00	259.00	593.00	7/84	-	12/88
Selenium, ug/l	23	0.00	-	0.00	0.00	0.00	0.00	9/84	-	12/88

Table B-5. San Joaquin River at Vernalis Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
THMFP, ug/l	87	210.00 - 1500.00	470.00	320.00	680.00	6/82 - 11/88
Dissolved organic carbon, mg/l	39	2.20 - 7.10	3.30	2.60	4.90	1/87 - 11/88
Total dissolved solids, mg/l	264	69.00 - 1150.00	376.00	130.00	661.00	1/75 - 11/88
Sodium, mg/l	88	11.00 - 177.00	82.00	28.00	111.00	6/82 - 11/88
Chloride, mg/l	266	10.00 - 383.00	79.50	21.00	176.00	1/75 - 11/88
Bromide, mg/l	266	0.04 - 1.11	0.24	0.07	0.52	1/75 - 11/88
Turbidity, NTU	121	3.00 - 75.00	18.00	9.00	33.00	6/82 - 11/88
Electrical conductivity, umhos/cm	72	117.00 - 1340.00	563.50	166.00	868.00	6/82 - 11/88
Alkalinity, mg/l as CaCO3	51	39.00 - 145.00	107.00	52.00	130.00	6/82 - 11/88
Hardness, mg/l as CaCO3	51	45.00 - 347.00	186.00	74.00	217.00	6/82 - 11/88
Color, color units	63	5.00 - 35.00	12.50	5.00	25.00	7/83 - 11/88
Chlorophyll a, ug/l	208	2.00 - 371.00	15.00	4.00	80.00	1/75 - 12/86
Nitrate, mg/l as N	48	0.27 - 3.84	1.68	0.59	2.26	3/86 - 11/88
Total phosphorus, mg/l as P	170	0.09 - 0.79	0.23	0.12	0.40	1/75 - 11/88
Arsenic, ug/l	6	0.00 - 20.00	0.00	0.00	0.00	1/76 - 9/77
Barium, ug/l	24	0.00 - 0.00	0.00	0.00	0.00	7/86 - 11/88
Chromium, ug/l	32	0.00 - 10.00	0.00	0.00	10.00	1/76 - 11/88
Copper, ug/l	32	0.00 - 20.00	0.00	0.00	10.00	1/76 - 11/88
Iron, ug/l	32	0.02 - 8400.00	10.00	0.02	3800.00	1/76 - 11/88
Manganese, ug/l	32	0.02 - 950.00	18.00	0.02	170.00	1/76 - 11/88
Mercury, ug/l	11	0.00 - 0.20	0.00	0.00	0.10	1/76 - 11/88
Selenium, ug/l	70	0.00 - 6.00	2.00	0.00	4.00	6/82 - 11/88
Zinc, ug/l	33	0.00 - 121.00	11.00	0.00	45.00	1/76 - 11/88
Asbestos, mF/l	14	270.00 - 3300.00	885.00	270.00	1800.00	6/82 - 11/88

Table B-6. Kern River Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total organic carbon, mg/l	47	0.00 - 20.00	2.10	0.00	5.00	4/82 - 12/88
Total dissolved solids, mg/l	77	23.00 - 400.00	86.00	54.00	120.60	1/78 - 12/88
Sodium, mg/l	83	0.00 - 80.00	11.00	5.60	21.20	1/77 - 12/88
Chloride, mg/l	76	1.70 - 17.70	4.80	3.00	10.00	1/78 - 12/88
Bromide, mg/l	76	0.01 - 0.06	0.02	0.02	0.04	1/78 - 12/88
Turbidity, NTU	76	0.64 - 30.00	3.80	1.80	9.00	1/78 - 12/88
Electrical conductivity, uhmos/cm	67	49.00 - 220.00	96.00	68.00	140.00	3/79 - 12/88
pH	75	7.10 - 8.80	7.90	7.54	8.30	1/78 - 12/88
Hardness, mg/l as CaCO3	77	18.00 - 90.00	36.00	22.00	57.00	1/78 - 12/88
Color, color units	75	0.00 - 50.00	7.00	3.00	20.00	1/78 - 12/88
Nitrite, mg/l as N	76	0.00 - 0.21	0.00	0.00	0.01	1/78 - 12/88
Nitrate, mg/l as N	76	0.00 - 46.50	0.36	0.00	2.43	1/78 - 12/88
Orthophosphate, mg/l as P	76	0.00 - 0.44	0.06	0.01	0.18	1/78 - 12/88
Odor, odor units	77	1.40 - 24.00	3.00	1.40	8.00	1/78 - 12/88
Aluminum, ug/l	48	0.00 - 870.00	35.00	0.00	200.00	6/78 - 12/88
Arsenic, ug/l	82	0.00 - 10.00	0.00	0.00	0.00	1/77 - 12/88
Barium, ug/l	82	0.00 - 89.00	0.00	0.00	0.00	1/77 - 12/88
Cadmium, ug/l	82	0.00 - 10.00	0.00	0.00	0.00	1/77 - 12/88
Copper, ug/l	82	0.00 - 750.00	0.00	0.00	250.00	1/77 - 12/88
Iron, ug/l	82	0.00 - 2772.00	157.50	0.00	520.00	1/77 - 12/88
Lead, ug/l	82	0.00 - 14.00	0.00	0.00	0.00	1/77 - 12/88
Manganese, ug/l	82	0.00 - 140.00	0.00	0.00	20.00	1/77 - 12/88
Mercury, ug/l	81	0.00 - 0.00	0.00	0.00	0.00	1/77 - 12/88
Selenium, ug/l	81	0.00 - 0.01	0.00	0.00	0.00	1/77 - 12/88
Silver, ug/l	76	0.00 - 0.05	0.00	0.00	0.00	1/78 - 12/88
Zinc, ug/l	82	0.00 - 170.00	0.00	0.00	10.00	1/77 - 12/88

Table B-7. South Bay Aqueduct Terminal Tank Facility Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	183	94.00 - 724.00	227.00	160.00	595.00	1/75 - 12/88
Sodium, mg/l	183	11.00 - 181.00	36.00	19.00	135.00	1/75 - 12/88
Chloride, mg/l	183	7.00 - 312.00	44.00	18.00	236.00	1/75 - 12/88
Bromide, mg/l	183	0.03 - 0.91	0.13	0.05	0.69	1/75 - 12/88
Turbidity, NTU	19	0.00 - 70.00	22.50	5.00	50.00	'75-'76 & '87-'88
pH	179	6.90 - 8.90	8.00	7.40	8.60	1/75 - 12/88
Color, color units	155	0.00 - 50.00	15.00	5.00	30.00	1/75 - 12/88
Nitrate, mg/l as N	49	0.00 - 1.70	0.50	0.13	1.00	1/75 - 12/88
Total phosphorus, mg/l as P	155	0.03 - 0.38	0.11	0.05	0.16	1/75 - 12/88
Arsenic, (dissolved), ug/l	158	0.00 - 30.00	2.00	0.00	2.00	1/75 - 12/88
Chromium, (dissolved), ug/l	20	0.00 - 5.00	5.00	0.00	5.00	1/75 - 12/88
Copper, (dissolved), ug/l	158	0.00 - 40.00	10.00	0.00	20.00	1/75 - 12/88
Lead, (dissolved), ug/l	157	0.00 - 30.00	5.00	0.00	5.00	1/75 - 12/88
Manganese, (dissolved), ug/l	158	0.00 - 70.00	10.00	0.00	20.00	1/75 - 12/88
Selenium, (dissolved), ug/l	158	0.00 - 30.00	10.00	0.00	10.00	1/75 - 12/88
Zinc, ug/l	158	0.00 - 360.00	19.50	0.00	30.00	1/75 - 12/88

Source: DWR Operations

Table B-8. Delta Mendota Canal/Tracy Pumping Plant Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
THMFP, ug/l	57	220.00 - 800.00	470.00	330.00	670.00	7/83 - 12/88
Dissolved organic carbon, mg/l	26	1.90 - 5.00	3.10	2.40	4.10	7/83 - 12/88
Total dissolved solids, mg/l	109	59.00 - 594.00	255.60	159.00	424.00	2/75 - 12/88
Sodium, mg/l	99	0.00 - 156.00	50.00	23.00	89.00	2/75 - 12/88
Chloride, mg/l	101	0.00 - 265.00	66.00	26.00	132.00	2/75 - 12/88
Bromide, mg/l	101	0.00 - 0.77	0.20	0.10	0.39	2/75 - 12/88
Turbidity, NTU	95	6.50 - 232.00	18.00	8.00	31.00	2/75 - 12/88
Electrical conductivity, umhos/cm	85	151.00 - 3901.00	421.00	238.00	710.00	2/75 - 12/88
pH	96	6.80 - 8.30	7.40	7.20	7.70	2/75 - 12/88
Color, color units	57	5.00 - 60.00	18.00	5.00	35.00	7/83 - 12/88
Selenium, ug/l	79	0.00 - 5.00	0.00	0.00	1.00	7/83 - 12/88
Asbestos, mF/l	94	0.00 - 1800.00	0.00	0.00	590.00	7/83 - 12/88

Table B-9. Harvey O. Banks Delta Pumping Plant Data Summary

Constituent, units	N	Range			Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total organic carbon, mg/l	9	2.80	-	4.90	3.90	2.80	4.90	1983 & 1984
Total dissolved solids, mg/l	212	94.00	-	763.00	252.00	141.00	675.00	1/75 - 12/88
Sodium, mg/l	221	13.00	-	192.00	42.00	21.00	165.00	1/75 - 12/88
Chloride, mg/l	221	14.00	-	334.00	53.00	24.00	292.00	1/75 - 12/88
Bromide, mg/l	221	0.05	-	0.97	0.16	0.08	0.85	1/75 - 12/88
Turbidity, NTU	33	4.00	-	110.00	20.00	5.00	55.00	1/75 - 12/88
pH	191	6.60	-	9.70	7.80	7.20	8.40	1/75 - 12/88
Color, color units	164	0.00	-	50.00	18.00	8.00	35.00	1/75 - 12/88
Nitrate, mg/l as N	49	0.00	-	1.90	0.44	0.12	1.40	1/75 - 1/79
Total phosphorus, mg/l as P	156	0.07	-	0.25	0.13	0.10	0.18	1/75 - 12/88
Arsenic (dissolved), ug/l	169	0.00	-	50.00	2.00	0.00	2.00	1/75 - 12/88
Chromium (dissolved), ug/l	20	0.00	-	20.00	5.00	0.00	5.00	1/79 - 12/88
Copper (dissolved), ug/l	169	0.00	-	40.00	10.00	0.00	20.00	1/75 - 12/88
Lead (dissolved), ug/l	169	0.00	-	20.00	5.00	0.00	5.00	1/75 - 12/88
Manganese (dissolved), ug/l	169	0.00	-	100.00	24.00	10.00	60.00	1/75 - 12/88
Selenium (dissolved), ug/l	170	0.00	-	30.00	10.00	0.00	10.00	1/75 - 12/88
Zinc, ug/l	169	0.00	-	50.00	20.00	0.00	30.00	1/75 - 12/88

Source: DWR Operations

Table B-10. Harvey O. Banks Delta Pumping Plant Data Summary

Constituent	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
THMFP, ug/l	74	220.00 - 1900.00	500.00	370.00	740.00	3/82 - 12/88
Dissolved organic carbon, mg/l	25	2.40 - 5.00	3.20	2.50	4.30	1/87 - 12/88
Total dissolved solids, mg/l	78	102.00 - 521.00	233.00	151.00	425.00	3/82 - 12/88
Sodium, mg/l	97	10.00 - 116.00	42.00	23.00	91.00	3/82 - 12/88
Chloride, mg/l	104	14.00 - 180.00	53.50	24.00	144.00	3/82 - 12/88
Bromide, mg/l	104	0.05 - 0.53	0.16	0.08	0.42	3/82 - 12/88
Turbidity, NTU	77	4.00 - 37.00	11.00	6.00	28.00	3/82 - 12/88
Electrical conductivity, umhos/cm	77	143.00 - 835.00	351.00	225.00	676.00	3/82 - 12/88
Color, color units	63	5.00 - 60.00	20.00	5.00	35.00	7/83 - 12/88
Selenium, ug/l	68	0.00 - 18.00	0.00	0.00	1.00	3/82 - 12/88
Asbestos, mF/l	5	230.00 - 860.00	780.00	230.00	860.00	10/83 - 7/86

Table B-11. California Aqueduct Check 12 (O'Neill Inlet) Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	158	102.00 - 726.00	206.5	135.00	454.00	1/75 - 12/88
Sodium, mg/l	158	14.00 - 173.00	34.00	21.00	100.00	1/75 - 12/88
Chloride, mg/l	158	14.00 - 288.00	39.00	23.00	150.00	1/75 - 12/88
Bromide, mg/l	158	0.05 - 0.84	0.12	0.07	0.44	1/75 - 12/88
Turbidity, NTU	25	0.00 - 85.00	17.50	5.00	50.00	1987 & 1988
pH	168	2.40 - 9.60	8.00	7.30	8.90	1/75 - 12/88
Color, color units	156	0.00 - 50.00	15.00	5.00	30.00	1/75 - 12/88
Nitrate, mg/l as N	49	0.00 - 2.00	0.43	0.01	1.30	1/75 - 1/79
Total phosphorus, mg/l as P	153	0.04 - 0.72	0.12	0.08	0.17	1/75 - 12/88
Arsenic (dissolved), ug/l	160	0.00 - 10.00	2.00	0.00	2.00	1/75 - 12/88
Chromium (dissolved), ug/l	20	0.00 - 5.00	5.00	0.00	5.00	1/75 - 12/88
Copper (dissolved), ug/l	160	0.00 - 40.00	10.00	0.00	20.00	1/75 - 12/88
Lead (dissolved), ug/l	160	0.00 - 50.00	5.00	0.00	5.00	1/75 - 12/88
Manganese (dissolved), ug/l	160	0.00 - 80.00	10.00	0.00	20.00	1/75 - 12/88
Selenium (dissolved), ug/l	160	0.00 - 40.00	10.00	0.00	10.00	1/75 - 12/88
Zinc, ug/l	160	0.00 - 60.00	20.00	0.00	30.00	1/75 - 12/88

Source: DWR Operations

Table B-12. Delta Mendota Canal at O'Neill Pumping Plant Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Turbidity, NTU	122	2.00 - 58.00	11.50	5.00	24.00	1/77 - 12/88
pH	156	6.60 - 8.40	7.50	7.20	8.00	1/75 - 12/88
Nitrate, mg/l as N	49	0.02 - 1.70	0.55	0.26	1.40	1/75 - 1/79
Total phosphorus, mg/l as P	155	0.07 - 0.42	0.14	0.10	0.21	1/75 - 12/88

Source: DWR Operations

Table B-13. San Luis Reservoir at Trash Racks

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	14	308.00 - 544.00	381.5	308.00	535.00	1/77 - 12/78
Sodium, mg/l	14	60.00 - 120.00	76.50	60.00	115.00	1/77 - 12/78
Chloride, mg/l	14	81.00 - 189.00	110.00	81.00	177.00	1/77 - 12/78
Bromide, mg/l	14	0.24 - 0.55	0.32	0.24	0.52	1/77 - 12/78
Turbidity, NTU	120	0.00 - 80.00	2.00	1.00	7.00	1/77 - 12/88
pH	154	7.00 - 9.40	7.90	7.40	8.40	1/75 - 12/88
Color, color units	3	8.00 - 15.00	10.00	8.00	15.00	1/77 - 12/77
Nitrate, mg/l as N	38	0.01 - 4.20	0.32	0.05	1.30	1/75 - 12/81
Total phosphorus, mg/l as P	153	0.02 - 0.75	0.09	0.05	0.12	1/75 - 12/88
Arsenic, (dissolved), ug/l	3	0.00 - 0.00	0.00	0.00	0.00	1/77 - 12/77
Copper, (dissolved), ug/l	5	0.00 - 10.00	10.00	0.00	10.00	1977 & 1982
Lead, (dissolved), ug/l	6	0.00 - 0.00	0.00	0.00	0.00	1977, 1982 & 1984
Manganese, (dissolved), ug/l	5	0.00 - 10.00	10.00	0.00	10.00	1977 & 1982
Selenium, (dissolved), ug/l	3	0.00 - 0.00	0.00	0.00	0.00	1/77 - 12/77
Zinc, ug/l	5	0.00 - 10.00	10.00	0.00	10.00	1977 & 1982

Source: DWR Operations

Table B-14. California Aqueduct Check 13 (O'Neill Outlet) Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	204	109.00 - 826.00	269.00	162.00	519.00	1/75 - 12/88
Sodium, mg/l	202	16.00 - 162.00	50.00	27.00	112.00	1/75 - 12/88
Chloride, mg/l	204	18.00 - 264.00	66.00	30.00	173.00	1/75 - 12/88
Bromide, mg/l	204	0.06 - 0.77	0.20	0.09	0.51	1/75 - 12/88
Turbidity, NTU	120	0.00 - 25.00	8.00	4.00	15.00	1/75 - 12/88
pH	212	6.70 - 8.50	7.60	7.30	8.10	1/75 - 12/88
Color, color units	154	0.00 - 50.00	15.00	5.00	25.00	1/75 - 12/88
Nitrate, mg/l as N	49	0.06 - 2.00	0.60	0.20	1.20	1/75 - 1/79
Total phosphorus, mg/l as P	155	0.05 - 0.23	0.12	0.09	0.16	1/75 - 12/88
Arsenic (dissolved), ug/l	160	0.00 - 10.00	2.00	0.00	2.00	1/75 - 12/88
Chromium (dissolved), ug/l	19	0.00 - 5.00	5.00	0.00	5.00	1/79 - 12/88
Copper (dissolved), ug/l	158	0.00 - 70.00	10.00	5.00	20.00	1/75 - 12/88
Lead (dissolved), ug/l	160	0.00 - 70.00	5.00	0.00	10.00	1/75 - 12/88
Manganese (dissolved), ug/l	158	0.00 - 110.00	20.00	0.00	30.00	1/75 - 12/88
Selenium (dissolved), ug/l	160	0.00 - 20.00	10.00	0.00	10.00	1/75 - 12/88
Zinc, ug/l	158	0.00 - 110.00	10.00	0.00	20.00	1/75 - 12/88

Source: DWR Operations

Table B-15. California Aqueduct Check 21 Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	157	90.00 - 692.00	242.00	159.00	418.00	1/75 - 12/88
Sodium, mg/l	156	11.00 - 151.00	41.50	25.00	80.00	1/75 - 12/88
Chloride, mg/l	157	3.00 - 243.00	49.00	27.00	113.00	1/75 - 12/88
Bromide, mg/l	157	0.02 - 0.71	0.15	0.08	0.33	1/75 - 12/88
Turbidity, NTU	119	1.00 - 55.00	10.00	5.00	23.00	1/77 - 12/88
pH	171	7.20 - 8.80	7.80	7.50	8.50	1/75 - 12/88
Color, color units	155	0.00 - 40.00	12.00	5.00	25.00	1/75 - 12/88
Nitrate, mg/l as N	49	0.08 - 2.20	0.50	0.11	1.10	1/75 - 1/79
Total phosphorus, mg/l as P	151	0.04 - 0.57	0.12	0.09	0.17	1/75 - 12/88
Arsenic (dissolved), ug/l	159	0.00 - 10.00	2.00	0.00	2.00	1/75 - 12/88
Chromium (dissolved), ug/l	19	0.00 - 5.00	5.00	0.00	5.00	1/79 - 12/88
Copper (dissolved), ug/l	157	0.00 - 80.00	10.00	0.00	20.00	1/75 - 12/88
Lead (dissolved), ug/l	157	0.00 - 80.00	5.00	0.00	10.00	1/75 - 12/88
Manganese (dissolved), ug/l	156	0.00 - 110.00	10.00	0.00	10.00	1/75 - 12/88
Selenium (dissolved), ug/l	158	0.00 - 20.00	10.00	0.00	10.00	1/75 - 12/88
Zinc, ug/l	155	0.00 - 110.00	10.00	0.00	30.00	1/75 - 12/88

Source: DWR Operations

Table B-16. California Aqueduct Check 29 Data Summary

Constituent, units	N	Range			Median	Percentiles Tenth	Percentiles Ninety	Period of Record		
Total dissolved solids, mg/l	156	50.00	-	657.00	240.50	125.00	386.00	1/75	-	12/88
Sodium, mg/l	156	4.00	-	158.00	42.00	17.00	80.00	1/75	-	12/88
Chloride, mg/l	156	0.00	-	247.00	52.00	15.00	114.00	1/75	-	12/88
Bromide, mg/l	156	0.01	-	0.72	0.16	0.05	0.34	1/75	-	12/88
Turbidity, NTU	16	2.00	-	15.00	3.00	2.00	10.00	1/82	-	12/88
pH	160	2.70	-	9.20	7.80	7.00	8.60	1/75	-	12/88
Color, color units	152	0.00	-	40.00	9.00	5.00	23.00	1/75	-	12/88
Nitrate, mg/l as N	154	0.00	-	2.40	0.54	0.02	1.13	1/75	-	12/88
Total phosphorus, mg/l as P	154	0.02	-	1.20	0.12	0.07	0.16	1/75	-	12/88
Arsenic, (dissolved), ug/l	154	0.00	-	20.00	0.00	0.00	0.00	1/75	-	12/88
Copper, (dissolved), ug/l	154	0.00	-	40.00	10.00	10.00	20.00	1/75	-	12/88
Lead, (dissolved), ug/l	154	0.00	-	160.00	10.00	0.00	20.00	1/75	-	12/88
Manganese, (dissolved), ug/l	154	0.00	-	3700.00	10.00	0.00	10.00	1/75	-	12/88
Selenium, (dissolved), ug/l	154	0.00	-	30.00	10.00	0.00	10.00	1/75	-	12/88
Zinc, ug/l	154	0.00	-	70.00	20.00	0.00	30.00	1/75	-	12/88

Source: DWR Operations

Table B-17. California Aqueduct Tehachapi Afterbay Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	229	56.00 - 720.00	250.00	129.00	458.00	1/75 - 12/88
Sodium, mg/l	229	5.00 - 156.00	47.00	19.00	96.00	1/75 - 12/88
Chloride, mg/l	229	1.00 - 254.00	59.00	19.00	148.00	1/75 - 12/88
Bromide, mg/l	229	0.01 - 0.74	0.18	0.06	0.43	1/75 - 12/88
Turbidity, NTU	223	0.00 - 299.00	8.00	1.00	23.00	1/75 - 12/88
pH	184	6.80 - 9.90	8.20	7.40	9.00	1/75 - 12/88
Color, color units	197	2.00 - 35.00	8.00	4.00	22.00	1/75 - 12/88
Nitrate, mg/l as N	181	0.00 - 2.89	0.52	0.07	1.22	1/75 - 12/88
Total phosphorus, mg/l as P	181	0.03 - 0.47	0.12	0.07	0.17	1/75 - 12/88
Arsenic, (dissolved), ug/l	154	0.00 - 10.00	0.00	0.00	0.00	1/75 - 12/88
Copper, (dissolved), ug/l	155	0.00 - 390.00	10.00	0.00	10.00	1/75 - 12/88
Lead, (dissolved), ug/l	156	0.00 - 90.00	25.00	0.00	0.00	1/75 - 12/88
Manganese, (dissolved), ug/l	155	0.00 - 260.00	10.00	0.00	20.00	1/75 - 12/88
Selenium, (dissolved), ug/l	154	0.00 - 30.00	0.00	0.00	0.00	1/75 - 12/88
Zinc, ug/l	156	0.00 - 370.00	10.00	0.00	30.00	1/75 - 12/88

Source: DWR Operations

Table B-18. Castaic Lake Inlet Data Summary

Constituent, units	N	Range		Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	228	213.00	- 455.00	317.50	251.00	391.00	1/75 - 12/88
Sodium, mg/l	231	33.00	- 64.00	46.00	38.00	59.00	1/75 - 12/88
Chloride, mg/l	231	26.00	- 87.00	50.00	40.00	67.00	1/75 - 12/88
Bromide, mg/l	231	0.08	- 0.26	0.15	0.12	0.20	1/75 - 12/88
Turbidity, NTU	226	0.00	- 16.00	2.00	1.00	4.00	1/75 - 12/88
pH	226	7.10	- 10.60	8.50	7.70	9.20	1/75 - 12/88
Color, color units	224	1.00	- 13.00	5.00	3.00	8.00	1/75 - 12/88
Nitrate, mg/l as N	227	0.00	- 0.68	0.14	0.04	0.43	1/75 - 12/88
Total phosphorus, mg/l as P	228	0.00	- 0.14	0.05	0.02	0.08	1/75 - 1/80
Arsenic (dissolved), ug/l	46	0.00	- 0.00	0.00	0.00	0.00	1979 & 1980
Copper (dissolved), ug/l	2	0.00	- 0.00	0.00	0.00	0.00	1979 & 1980
Lead (dissolved), ug/l	2	0.00	- 0.00	0.00	0.00	0.00	1979 & 1980
Manganese (dissolved), ug/l	2	0.00	- 10.00	10.00	0.00	10.00	1/75 - 1/80
Selenium (dissolved), ug/l	46	0.00	- 0.00	0.00	0.00	0.00	1979 & 1980
Zinc, ug/l	2	10.00	- 10.00	10.00	10.00	10.00	1/75 - 12/88

Source: DWR Operations

Table B-19. Castaic Lake Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Nitrate, mg/l as N	25	0.07 - 0.50	0.26	0.15	0.44	7/83 - 6/85
Orthophosphate, mg/l as P	7	0.01 - 0.05	0.02	0.01	0.03	8/83 - 5/85

Table B-20. Jensen Plant Influent Data Summary

Constituents, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total organic carbon, mg/l	49	1.71 - 3.83	2.63	2.07	3.17	8/81 - 5/89
Aluminum, ug/l	14	0.00 - 250.00	61.00	0.00	210.00	1/81 - 11/88
Arsenic, ug/l	14	0.00 - 24.00	2.50	0.00	3.00	1/81 - 11/88
Barium, ug/l	14	0.00 - 225.00	32.50	0.00	50.00	1/81 - 11/88
Cadmium, ug/l	14	0.00 - 0.00	0.00	0.00	0.00	1/81 - 11/88
Chromium, ug/l	14	0.00 - 0.20	0.00	0.00	0.10	1/81 - 11/88
Copper, ug/l	14	0.00 - 5.00	0.00	0.00	0.00	1/81 - 11/88
Iron, ug/l	14	0.00 - 120.00	59.00	0.00	120.00	1/81 - 11/88
Lead, ug/l	14	0.00 - 1.00	0.00	0.00	0.00	1/81 - 11/88
Manganese, ug/l	14	0.00 - 12.00	0.00	0.00	12.00	1/81 - 11/88
Mercury, ug/l	14	0.00 - 0.00	0.00	0.00	0.00	1/81 - 11/88
Selenium, ug/l	14	0.00 - 3.00	0.00	0.00	0.00	1/81 - 11/88
Silver, ug/l	14	0.00 - 0.00	0.00	0.00	0.00	1/81 - 11/88
Zinc, ug/l	14	0.00 - 0.00	0.00	0.00	0.00	1/81 - 11/88
Asbestos, mF/l	29	0.00 - 0.00	0.00	0.00	0.00	4/80 - 9/88

Table B-21. California Aqueduct Pearblossom Pumping Plant Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	154	58.00 - 859.00	237.50	110.00	383.00	1/75 - 12/88
Sodium, mg/l	155	6.00 - 195.00	44.00	14.00	82.00	1/75 - 12/88
Chloride, mg/l	155	1.00 - 307.00	53.00	8.00	114.00	1/75 - 12/88
Bromide, mg/l	155	0.01 - 0.89	0.16	0.03	0.34	1/75 - 12/88
Turbidity, NTU	154	0.00 - 115.00	6.00	2.00	20.00	1/75 - 12/88
pH	131	1.10 - 10.40	8.50	7.70	9.20	1/75 - 12/88
Color, color units	154	2.00 - 35.00	6.00	3.00	18.00	1/75 - 12/88
Nitrate, mg/l as N	156	0.00 - 2.98	0.40	0.02	1.04	1/75 - 12/88
Total phosphorus, mg/l as P	156	0.01 - 1.31	0.11	0.06	0.16	1/75 - 12/88
Arsenic, (dissolved), ug/l	157	0.00 - 10.00	0.00	0.00	0.00	1/75 - 12/88
Copper, (dissolved), ug/l	159	0.00 - 250.00	10.00	0.00	10.00	1/75 - 12/88
Lead, (dissolved), ug/l	159	0.00 - 50.00	0.00	0.00	0.00	1/75 - 12/88
Manganese, (dissolved), ug/l	159	0.00 - 4300.00	10.00	0.00	20.00	1/75 - 12/88
Selenium, (dissolved), ug/l	157	0.00 - 20.00	0.00	0.00	0.00	1/75 - 12/88
Zinc, ug/l	158	0.00 - 210.00	10.00	0.00	20.00	1/75 - 12/88

Source: DWR Operations

Table B-22. California Aqueduct Devil Canyon Afterbay Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	151	75.00 - 487.00	227.00	128.00	340.00	1/75 - 12/88
Sodium, mg/l	152	6.00 - 94.00	38.50	18.00	70.00	1/75 - 12/88
Chloride, mg/l	152	3.00 - 141.00	47.50	16.00	105.00	1/75 - 12/88
Bromide, mg/l	152	0.02 - 0.41	0.14	0.05	0.31	1/75 - 12/88
Turbidity, NTU	152	0.00 - 42.00	2.00	1.00	4.00	1/75 - 12/88
pH	122	6.40 - 9.50	8.00	7.40	8.70	1/75 - 12/88
Color, color units	150	1.00 - 28.00	5.00	3.00	10.00	1/75 - 12/88
Nitrate, mg/l as N	153	0.02 - 1.49	0.41	0.11	0.81	1/75 - 12/88
Total phosphorus, mg/l as P	153	0.02 - 0.32	0.09	0.05	0.15	1/75 - 12/88
Arsenic, (dissolved), ug/l	155	0.00 - 0.00	0.00	0.00	0.00	1/75 - 12/88
Copper, (dissolved), ug/l	155	0.00 - 30.00	10.00	0.00	10.00	1/75 - 12/88
Lead, (dissolved), ug/l	156	0.00 - 10.00	0.00	0.00	0.00	1/75 - 12/88
Manganese, (dissolved), ug/l	156	0.00 - 160.00	10.00	0.00	20.00	1/75 - 12/88
Selenium, (dissolved), ug/l	155	0.00 - 0.00	0.00	0.00	0.00	1/75 - 12/88
Zinc, ug/l	156	0.00 - 90.00	10.00	0.00	30.00	1/75 - 12/88

Source: DWR Operations

Table B-23. Devil Canyon Afterbay/Mills Plant Influent Data Summary

Constituent, units	N	Range			Median	Percentiles		Period		
						Tenth	Ninety	of Record		
Total organic carbon, mg/l	62	1.85	-	6.20	2.90	2.27	4.05	8/81	-	5/89
Nitrate, mg/l as N	10	0.03	-	0.42	0.25	0.03	0.40	7/83	-	6/85
Orthophosphate, mg/l as P	9	0.01	-	0.08	0.03	0.01	0.06	7/83	-	6/85
Aluminum, ug/l	28	0.00	-	1000.00	161.00	81.00	650.00	1/81	-	11/88
Arsenic, ug/l	28	0.00	-	4.00	3.00	1.00	3.00	1/81	-	11/88
Barium, ug/l	28	0.00	-	62.00	28.50	6.00	46.00	1/81	-	11/88
Cadmium, ug/l	28	0.00	-	5.00	0.00	0.00	0.00	1/81	-	11/88
Chromium, ug/l	28	0.00	-	1.00	0.00	0.00	0.90	1/81	-	11/88
Copper, ug/l	28	0.00	-	5.00	0.00	0.00	0.00	1/81	-	11/88
Iron, ug/l	28	31.00	-	500.00	137.00	46.00	370.00	1/81	-	11/88
Lead, ug/l	28	0.00	-	1.00	0.00	0.00	0.90	1/81	-	11/88
Manganese, ug/l	28	0.00	-	52.00	10.00	0.00	22.00	1/81	-	11/88
Mercury, ug/l	28	0.00	-	1.60	0.00	0.00	0.00	1/81	-	11/88
Selenium, ug/l	28	0.00	-	0.00	0.00	0.00	0.00	1/81	-	11/88
Silver, ug/l	28	0.00	-	0.00	0.00	0.00	0.00	1/81	-	11/88
Zinc, ug/l	28	0.00	-	9.00	0.00	0.00	0.00	1/81	-	11/88
Asbestos, mF/l	74	0.00	-	8.80	0.00	0.00	0.00	4/80	-	9/88

Table B-24. California Aqueduct Lake Perris Inlet Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total dissolved solids, mg/l	225	63.00 - 396.00	239.00	183.00	308.00	1/75 - 12/88
Sodium, mg/l	225	8.00 - 70.00	48.00	33.00	59.00	1/75 - 12/88
Chloride, mg/l	225	4.00 - 94.00	61.00	38.00	75.00	1/75 - 12/88
Bromide, mg/l	225	0.02 - 0.28	0.18	0.12	0.22	1/75 - 12/88
Turbidity, NTU	226	0.00 - 6.00	1.00	0.00	1.00	1/75 - 12/88
pH	236	6.70 - 9.90	8.50	7.70	9.10	1/75 - 12/88
Color, color units	218	0.00 - 15.00	4.00	2.00	8.00	1/75 - 12/88
Nitrate, mg/l as N	226	0.00 - 0.54	0.11	0.00	0.20	1/75 - 12/88
Total phosphorus, mg/l as P	226	0.00 - 0.27	0.04	0.02	0.06	1/75 - 12/88
Arsenic, (dissolved), ug/l	217	0.00 - 0.00	0.00	0.00	0.00	1/75 - 12/88
Copper, (dissolved), ug/l	235	0.00 - 20.00	10.00	0.00	10.00	1/75 - 12/88
Lead, (dissolved), ug/l	235	0.00 - 10.00	0.00	0.00	0.00	1/75 - 12/88
Manganese, (dissolved), ug/l	235	0.00 - 50.00	0.00	0.00	0.00	1/75 - 12/88
Mercury, ug/l	144	0.00 - 2.00	0.00	0.00	0.00	1/80 - 12/88
Selenium, (dissolved), ug/l	219	0.00 - 20.00	0.00	0.00	0.00	1/75 - 12/88
Zinc, ug/l	235	0.00 - 60.00	10.00	0.00	10.00	1/75 - 12/88

Source: DWR Operations

Table B-25. Lake Perris Data Summary

Constituent, units	N	Range			Median	Percentiles Tenth	Percentiles Ninety	Period of Record		
Total organic carbon, mg/l	30	2.09	-	4.90	3.66	3.10	4.55	8/81	-	2/89
Nitrate, mg/l as N	11	0.05	-	0.85	0.25	0.05	0.60	7/83	-	4/85
Orthophosphate, mg/l as P	8	0.00	-	0.09	0.03	0.00	0.07	8/83	-	6/85
Asbestos, mF/l	36	0.00	-	0.00	0.00	0.00	0.00	6/80	-	9/88

Table B-25. Lake Perris Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Total organic carbon, mg/l	30	2.09 - 4.90	3.66	3.10	4.55	8/81 - 2/89
Nitrate, mg/l as N	11	0.05 - 0.85	0.25	0.05	0.60	7/83 - 4/85
Orthophosphate, mg/l as P	8	0.00 - 0.09	0.03	0.00	0.07	8/83 - 6/85
Asbestos, mF/l	36	0.00 - 0.00	0.00	0.00	0.00	6/80 - 9/88

Table B-26. Sacramento Water Treatment Plant Influent Data Summary

Constituent, units	N	Range	Median	Percentiles Tenth	Percentiles Ninety	Period of Record
Aluminum, ug/l	71	0.00 - 2100.00	0.00	0.00	400.00	7/79 - 6/89
Arsenic, ug/l	77	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Barium, ug/l	78	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Beryllium, ug/l	47	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Cadmium, ug/l	83	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Chromium, ug/l	83	0.00 - 10.00	0.00	0.00	0.00	7/79 - 6/89
Copper, ug/l	106	0.00 - 70.00	0.00	0.00	20.00	7/79 - 6/89
Iron, ug/l	128	0.00 - 2900.00	280.00	0.08	860.00	7/79 - 6/89
Lead, ug/l	82	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Manganese, ug/l	107	0.00 - 170.00	0.00	0.00	20.00	7/79 - 6/89
Mercury, ug/l	75	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Selenium, ug/l	75	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Silver, ug/l	81	0.00 - 0.00	0.00	0.00	0.00	7/79 - 6/89
Zinc, ug/l	83	0.00 - 40.00	0.00	0.00	0.00	7/79 - 6/89

APPENDIX D

REVIEW OF STATUTES AND REGULATIONS

Prepared by:

EOA, Inc.
1410 Jackson Street
Oakland, California 94612
(415) 832-2852

June 1990

This document is available at the office of the State Water Contractors

555 Capitol Mall, Suite 725
Sacramento, California 95814
Contact Mr. John Coburn at (916) 447-7357

APPENDIX E

ANALYSIS OF EMERGENCY PLANS OF AGENCIES OPERATING STATE WATER PROJECT FACILITIES

Prepared by:

Gordon L. Laverty
Laverty Associates
4540 Mountain View Avenue
Oakland, California 94605
(415) 531-4860

May 1990

This document is available at the office of the State Water Contractors

555 Capitol Mall, Suite 725
Sacramento, California 95814
Contact Mr. John Coburn at (916) 447-7357

APPENDIX F

FIELD SURVEY FORMS, MAPS, AND SUMMARY TABLES

Prepared by:

Boyle Engineering Corporation
1300 East Shaw Avenue
Suite 176
Fresno, California 93710
(209) 222-8436

This document is available at the office of the State Water Contractors

555 Capitol Mall, Suite 725
Sacramento, California 95814
Contact Mr. John Coburn at (916) 447-7357