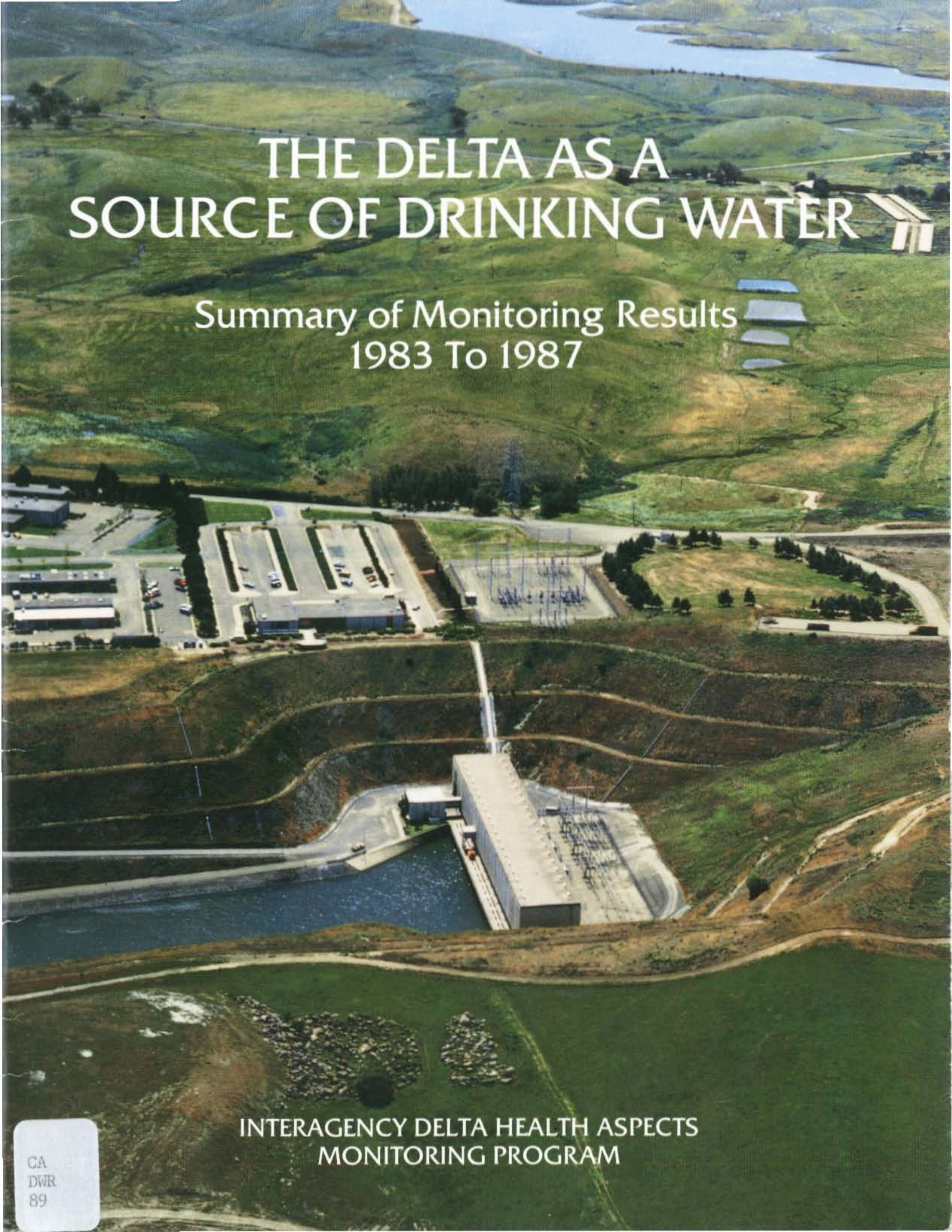
THE DELTA AS A SOURCE OF DRINKING WATER

Summary of Monitoring Results 1983 To 1987



INTERAGENCY DELTA HEALTH ASPECTS MONITORING PROGRAM

ON THE COVER –
Aerial view of the State Water Project's Harvey O. Banks Delta Pumping Plant, a few miles northwest of Tracy.

The Delta as A Source of Drinking Water

Summary of Monitoring Results — 1983 to 1987

INTERAGENCY DELTA HEALTH ASPECTS
MONITORING PROGRAM

Department of Water Resources
Central District

January 1989

Gordon K. Van Vleck
Secretary for Resources
The Resources Agency

George Deukmejian
Governor
State of California

David N. Kennedy
Director
Department of Water Resources

Copies of this report at $2.00 each may be ordered from:

State of California
Department of Water Resources
P. O. Box 942836
Sacramento, CA 94236-0001

Make checks payable to Department of Water Resources.
California residents add sales tax.

FOREWORD

Sound water resources management requires a comprehensive data collection effort to enable understanding of factors that can impact water quality. Toward this goal, the Department of Water Resources, in cooperation with other agencies, initiated the Interagency Delta Health Aspects Monitoring Program in 1983.

This program is integral in meeting the Department's mission of water resource planning and protecting California's drinking water. The program was developed in response to recommendations by a scientific panel appointed by the Director of Water Resources to assess the quality of Delta water supplies as related to human health. The program focuses on sodium, selenium, asbestos, trihalomethane precursors, and pesticides because of their potential effects on public health.

Through the guidance of a Technical Advisory Group representing participating water agencies, study priorities are determined and carried out by the Department. The Department of Health Services, also represented in the Technical Advisory Group, provides guidance on health-related issues and laboratory quality assurance. Future water quality monitoring will continue to respond to health-related concerns identified by the Technical Advisory Group.

June 1988 marked the fifth anniversary of the Interagency Delta Health Aspects Monitoring Program. Two reports have been prepared to mark the anniversary. This report provides an overview of the program and its accomplishments and identifies considerations for the future. The second document, *Interagency Delta Health Aspects Monitoring Program, Project Report*, details the material summarized here and presents more technical discussions and a complete summary of the data. Both reports are available from the Department of Water Resources.

James U. McDaniel
Chief, Central District

CONTENTS

Figures

Tables

ORGANIZATION

State of California
GEORGE DEUKMEJIAN, GOVERNOR
The Resources Agency
GORDON K. VAN VLECK, Secretary for Resources

Department of Water Resources
DAVID N. KENNEDY, Director

Robert G. Potter
Deputy Director

John P. Caffrey
Chief Deputy Director

Larry A. Mullnix
Deputy Director

Salle S. Jantz
Assistant Director

Susan N. Weber
Chief Counsel

DIVISION OF LOCAL ASSISTANCE

James U. McDaniel . . . . Chief

CENTRAL DISTRICT

Jerry Vayder . . . . District Chief
Randall L. Brown . . . . Acting Chief, Environmental Studies Branch

This report was prepared under the supervision of

Richard Woodard . . . . Environmental Program Manager I

By

Judith Heath . . . . Environmental Specialist IV
Bruce Agee . . . . Environmental Specialist IV

And

Marvin Jung, Water Quality Consultant
(DWR Contract B-56213)

MARVIN JUNG & ASSOCIATES, INC.
Sacramento, California

With assistance from

B. J. Archer . . . . Water Quality Engineer
Michael Sutliff . . . . Sanitary Engineer
William McCune . . . . Water Resources Engineering Associate
Robert Atherstone . . . . Water Resources Engineering Associate
Walt Lambert . . . . Water Resources Technician II
Lori Weisser . . . . Water Resources Technician II
Barbara Heinsch . . . . Student Assistant
Hallie Whitfield . . . . Student Assistant
Keith Healy . . . . Student Assistant
David Kemena . . . . Student Assistant
Eric Nichol . . . . Student Assistant

Editing and report production provided by

Vera L. Tharp . . . . Research Writer

ACKNOWLEDGMENTS

The Department of Water Resources is the lead agency conducting the Interagency Delta Health Aspects Monitoring Program.

Program funding and technical assistance are provided by:

East Bay Municipal Water District
Contra Costa Water District
Urban Water Contractors of the State Water Project
including
Metropolitan Water District of Southern California
Santa Clara Valley Water District
Alameda County Water District
Alameda County Flood Control and Water Conservation District, Zone 7

The Department of Health Services participates in the program through its membership in the Technical Advisory Group, which includes representatives of the other participating agencies.

TECHNICAL ADVISORY COMMITTEE

Keith Carns
Director of Water Quality
East Bay Municipal Utility District

John Coburn
Staff Engineer
State Water Contractors

Isabel Gloege, Associate Civil Engineer
Water Quality Division
Santa Clara Valley Water District

Michael Lanier, Supervisor
Water Quality
Alameda County Water District

Edward Means, Assistant Director
Water Quality
The Metropolitan Water District
of Southern California

Dan Peterson, Environmental Specialist IV
Division of Operations and Maintenance
California Department of Water Resources

Andrew Florendo, Water Systems Technician
Alameda County Flood Control and
Water Conservation District, Zone 7

David Spath, Ph.D., Sr. Sanitary Engineer
Public Water Supply Branch
California Department of Health Services

Alexis Milea, Associate Sanitary Engineer
Public Water Supply Branch
California Department of Health Services

Michael G. Volz, Ph.D.
Environmental Biochemist
Sanitation and Radiation Laboratory
California Department of Health Services

Greg Gartrell
Division Engineer
Contra Costa Water District

Introduction

The Sacramento-San Joaquin Delta is the primary source of drinking water for more than 16 million Californians.

Water flows into the Delta from the Sacramento, San Joaquin, and other river systems. In the Delta, water is used for irrigation by local farmers, and it supports wildlife and fisheries. Part of the water is exported from the southern Delta by the State Water Project and the federal Central Valley Project. In addition, Contra Costa Water District diverts Delta water for use in Contra Costa County. Figure 1 is a map showing major water development facilities in the Delta. Figure 2 shows major features of the State Water Project and Central Valley Project throughout the State.

Water not used in the Delta or exported from the Delta flows out through San Francisco Bay and into the Pacific Ocean. This portion of the water, called *Delta outflow,* helps to support the Bay's wildlife and fisheries and prevent the Bay's salt water from invading and degrading the Delta water supply.

THE DELTA

The Sacramento-San Joaquin Delta lies at the confluence of the Sacramento, San Joaquin, Mokelumne, and Cosumnes Rivers. About 60 islands and tracts lie in parts of six counties – Sacramento, San Joaquin, Yolo, Solano, Alameda, and Contra Costa.

The Delta extends over 738,000 acres, of which about 550,000 acres is prime agricultural land. Industrial areas have developed on the fringes of the Delta, and towns and other urban developments occupy parts of 12 islands or tracts.

A statistical summary of Delta demography, geography, economy, and wildlife is provided inside the back cover.

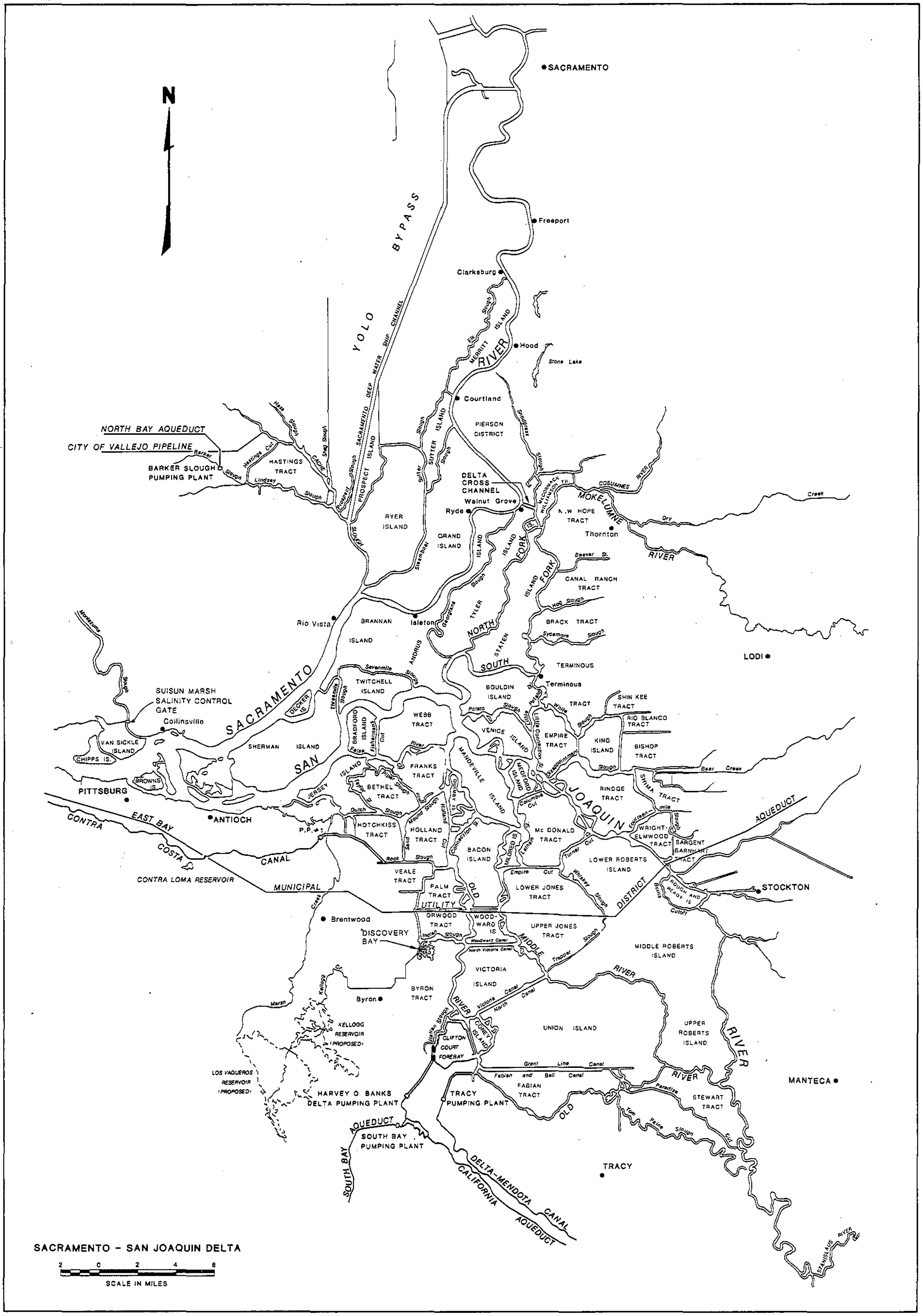


Figure 1. THE DELTA, SHOWING WATER DEVELOPMENT FACILITIES

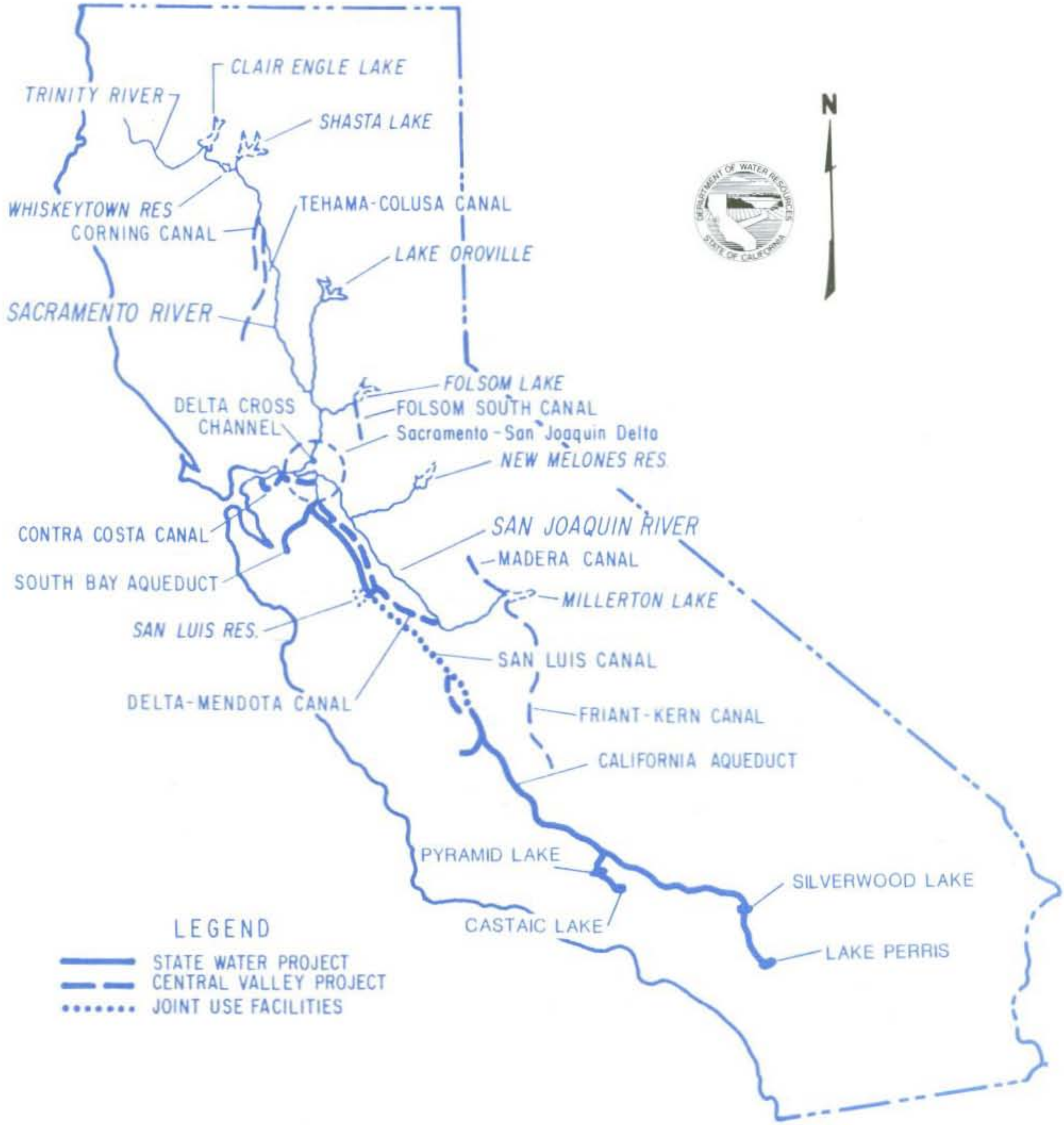


Figure 2. MAJOR FEATURES OF THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT

Several factors can impair the quality of exports from the Delta:

- *River outflows occasionally are not strong enough to prevent salt water intrusion.*
- *The Delta is vulnerable to levee failures, which not only cause property damage, but also reduce the ability of water suppliers to control salt water intrusion.*
- *Municipal, industrial, and agricultural waste water containing a variety of chemicals is discharged upstream and in the Delta itself.*
- *Organic compounds present in Delta water increase the formation of chemicals known as THMs (trihalomethanes) and other disinfection by-products. These chemicals are considered a threat to human health when present in sufficient quantities in drinking water.*

In 1979, the Environmental Protection Agency established a drinking water standard of 100 micrograms per liter for THMs. (The Environmental Protection Agency plans to consider revision of the THM and proposal of new standards for disinfection by-products in 1991.) The Department of Water Resources recognized the THM requirements might present problems for users of Delta water and, accordingly, began a study of THM-forming materials (THM precursors) in Delta water. One finding of the study was that water from the Sacramento River upstream of the Delta contained fewer trihalomethane precursors than did water from the southern Delta.

UNITS OF MEASURE

μg/L or ppb: Organic chemicals such as THMs are measured in micrograms per liter or in parts per billion. One part per billion is roughly equivalent to 2 drops in a large backyard swimming pool (25,000 gallons).

mg/L or ppm: Trace elements such as selenium are measured in milligrams per liter or in parts per million. One part per million is about the same as 1/3 to 1/2 cup in a 25,000-gallon swimming pool.

The THM study raised a number of broader questions concerning use of the Delta as a drinking water source. In the latter part of 1982, the Department commissioned a panel of seven independent scientists to evaluate human health aspects of Delta water supplies. In its report, the panel identified sodium, asbestos, and trihalomethane-forming materials as water quality parameters of health concern. Because of insufficient data, the panel could not determine whether pesticides or other chemicals pose a threat to drinking water supplies from the Delta.

The Interagency Delta Health Aspects Monitoring Program was implemented in 1983 to determine whether any of these constituents could, in fact, threaten Delta water supplies. Somewhat later, selenium entered the public spotlight as concerns over environmental damage at Kesterson Wildlife Refuge were aired. Consequently, selenium was added to the list of chemicals examined in this program.

TRIHALOMETHANES AND OTHER DISINFECTION BY-PRODUCTS

Disinfection of drinking water using chlorine causes the formation of a wide range of chemicals collectively known as *disinfection by-products*. These chemicals are formed by the reaction of precursor materials in the water with chlorine used in disinfection. Precursor materials include organic material derived from sources such as peat soils or decaying vegetation.

Trihalomethanes – or THMs – are the disinfection by-products addressed in this study. Disinfection of most fresh water results in formation of *chloroform* as the major THM. Chloroform can cause cancer in animals and is a suspected carcinogen in humans.

If *bromides* are present in the water, *brominated THMs* are formed in addition to chloroform or other by-products. Significant quantities of bromides are found in sea water and in the San Joaquin River. The presence of brominated THMs in drinking water complicates treatment procedures and may present a greater health risk than chloroform.

The Interagency Delta Health Aspects Monitoring Program is also geared to identify possible sources of these chemicals and the processes by which they are introduced into water supplies from the Delta.

Overall, the Interagency Delta Health Aspects Monitoring Program studies have shown the Delta to be an acceptable source of water, which, when treated, meets existing drinking water standards. In the future, however, water exported from the Delta may be more difficult and expensive to treat if expected new water quality standards are adopted. Also, export water quality could be affected by certain proposed new construction, such as enlargement of Clifton Court Forebay, and by water project operations in the Delta.

Findings

During the past five years, the Interagency Delta Health Aspects Monitoring Program has characterized water quality throughout the Delta. Major program findings and conclusions are:

- Proposed drinking water standards for THMs and disinfection by-products may necessitate modifications in drinking water treatment processes or in the operation of Delta export facilities.
- Data from a few Delta island agricultural drains suggest that peat soils contain high concentrations of organic THM precursors. Organic THM precursors are also carried into the Delta by river inflows and saltwater intrusion.
- Bromides enter the Delta during episodes of saltwater intrusion and increase brominated THM production. The San Joaquin River is a freshwater source of bromides, the origin of which is unknown. Brominated THMs can be difficult to treat because they form readily during conventional disinfection processes.
- Pesticides and industrial chemicals are detected infrequently in Delta water. When detected, concentrations are very low and do not exceed drinking water standards.
- Sodium is rarely a problem in Delta export water, except to people on very strict low-sodium diets. However, during low outflows, sodium concentrations may rise to levels of concern to those with moderate sodium restrictions.

- Asbestos fiber counts are often high in Delta water. However, properly operated water treatment facilities can meet the proposed drinking water standard for asbestos.
- Selenium is barely measurable in Delta export water. The San Joaquin River does contain measurable amounts of selenium, but it does not exceed drinking water standards.

The Interagency Delta Health Aspects Monitoring Program has changed over the years to help answer water quality questions as they have arisen. Ancillary studies, such as the agricultural drainage study, have been initiated to answer specific questions concerning potential sources of THM precursors and ways to minimize their effect on water quality. Further studies will be necessary to further understand Delta flows and the sources of THM precursors and other constituents of water quality concern. In these studies, the program will continue to respond to the needs of all users of Delta water.

Factors Affecting Delta Water Quality

As water flows throughout the Delta, it may carry contaminants such as selenium, asbestos, pesticides, and other organic chemicals including THM precursors. Some of these contaminants are introduced by nature, some by people.

The major factors affecting water quality in the Delta are:

- *Hydrology (inflow and outflow, tides, diversions and exports, and disasters such as levee breaks and floods);*
- *Industrial and agricultural activities; and*
- *Actions to protect water quality.*

Hydrologic Factors

Water flowing through the Delta comes primarily from the Sacramento and San Joaquin Rivers and their tributaries, which drain most of the Central Valley and contribute about 47 percent of the total runoff of the State. Inflows vary seasonally, depending on precipitation, but they are also influenced significantly by State Water Project releases from Lake Oroville and Central Valley Project releases from Shasta Lake (see Figure 2). Flow in the San Joaquin and Mokelumne River systems is also controlled by the operation of several reservoirs.

Some of the fresh water entering the Delta is exported by the State Water Project from the southern Delta through the California Aqueduct and from the northern Delta through the North Bay Aqueduct. Water is also exported by the Central Valley Project from the southern Delta via the Delta-Mendota Canal. Contra Costa Water District diverts water from the central Delta to serve its customers, and the City of Vallejo diverts from Cache Slough. In addition, there are more than 1,800 agricultural diversions throughout the Delta.

Much of the remaining water flows out through San Francisco Bay to the Pacific Ocean. Saline water from the Bay is kept from flowing into the Delta by this freshwater outflow. When sea water intrudes, it increases the salinity of Delta water and brings in organic THM precursors and bromides. Sea water intrusion also increases scaling and corrosion in pipes and tanks, and it can damage salt-sensitive crops.

The Delta is part of a tidal estuary, where water levels and direction of flow vary with the ocean tidal cycle. Many of the islands and tracts lie as much as 20 to 25 feet below the mean tide level of the surrounding water, which is held back by the levees. High tides, floods, and earthquakes can threaten levees. Levee breaks and island flooding can bring sea water into the western Delta.

Industrial and Agricultural Activities

Delta water quality is affected by activities both inside and outside the Delta. Discharges from waste water treatment facilities or from industrial sites often contain small amounts of trace elements and organic chemicals. Surface runoff from cities and some rural areas can contain solvents, pesticides, and other organic chemicals, as well as trace elements considered undesirable in drinking water.

Agricultural activities play a major role in Delta water quality. Water for irrigation is diverted to Delta islands, and the excess is returned to Delta channels. Agricultural drain water often contains high levels of salts and THM precursors. Some contains detectable levels of pesticides. Runoff from farms in the Sacramento and San Joaquin Valleys similarly affects Delta water quality.

Many industrial and agricultural chemicals may be found in river sediments. These chemicals adhere to the sediments and usually are only slightly water soluble. Some of the chemicals are detected in Delta vegetation and other aquatic life. Because of low water solubility, the chemicals are generally not detected in Delta water or are detected in very small concentrations.

Actions to Protect Delta Water Quality

In conjunction with operation of the Central Valley Project by the U.S. Bureau of Reclamation, the Department of Water Resources operates the State Water Project in such a way as to minimize saltwater intrusion into the Delta. Using indicators measured at key locations, flows are adjusted to protect water quality in the Delta. Also, the Department conducts monitoring and environmental investigations in the Delta and in Suisun Bay to provide additional information on the possible impact of project operations on Delta water quality.

Many actions to protect Delta water quality are related to Water Right Decision 1485, adopted by the State Water Resources Control Board in 1978. Among other things, the decision requires that Delta flows into San Francisco Bay be sufficient to repel most seawater intrusion. The underlying principle of Decision 1485 is that water quality in the Delta should be at least as good as it would have been if the State Water Project and Central Valley Project had not been built.

The State Water Resources Control Board is reviewing current Delta standards in Decision 1485. As part of the review, the Board will also determine whether standards are needed to protect San Francisco Bay. Any changes in Decision 1485 could affect operations of the State Water Project and Central Valley Project.

Drinking Water Standards

Drinking water standards generally apply directly to treated drinking water, rather than to drinking water sources, such as the Delta. Water from the Delta is treated to meet these standards before water agencies supply it to the public.

Drinking water standards for trihalomethanes have been established by the Environmental Protection Agency. The current allowable concentration of THMs in drinking water is 100 μg/L. This standard is being reviewed, and a new, stricter THM standard will probably be proposed in 1991. The Environmental Protection Agency has also proposed new drinking water standards for asbestos, selenium, and various pesticides. The proposed standard for selenium could be less strict than it is now.

The Environmental Protection Agency is developing regulations that include disinfection by-products. These regulations could lead to a standard that would force many drinking water utilities to change disinfectants or consider alternative treatment technologies, ranging from improved conventional treatment to granular activated carbon adsorption. Depending on the criteria adopted, new treatment processes may be expensive.

The California Department of Health Services also establishes drinking water standards and is considering standards for a number of chemicals of public health concern, such as atrazine and simazine.

DRINKING WATER STANDARDS AND ADVISORIES

Chemical	State Maximum Contaminant Level	Federal Maximum Contaminant Level	National Academy of Sciences Advisory
THMs	100 ug/L	100 ug/L	--
Asbestos	--	7.1 MFL (proposed)	--
Sodium*	--	--	100 mg/L (Mod.) 20 mg/L (Sev.)
Selenium	10 ug/L	10 ug/L (current) 50 ug/L (proposed)	
Pesticides	Listed in Table 1, Page 27.		

* The National Academy of Sciences advises a maximum of 100 mg/L for people who must restrict their sodium intake to a moderate degree and a maximum of 20 mg/L for those who must severely restrict their sodium intake.
ug/L = micrograms per liter
mg/L = milligrams per liter
MFL = million fibers per liter

Interagency Delta Health Aspects Monitoring Program

The Interagency Delta Health Aspects Monitoring Program has been collecting water quality data from the Delta since 1983. Data collected over the past five years represents water quality under a variety of hydrologic conditions and events. The program has monitoring stations in fresh water, brackish water, bay water, and agricultural drainage. Primary monitoring stations of the program are shown in Figure 3.

Station Location Number	Station Name Station Number
1	American River at Water Treatment Plant A0714010
2	Sacramento River at Greene's Landing B9D82071327
3	Cache Slough at Vallejo Pumping Plant B9D81781448
4	Lindsey Slough at Hastings Cut B9D81581462
5	Agricultural Drain on Grand Island B9V81321357
6	Agricultural Drain on Tyler Island B9V80791347
7	Little Connection Slough at Empire Tract B9D80361300
8	Agricultural Drain on Empire Tract B9V80361299
9	Rock Slough at Old River B9D75841348
10	Clifton Court Intake KA000000
11	Delta-Mendota Intake at Lindeman Road B9C74901336
12	H.O.Banks Delta Pumping Plant at Headworks KA000331
13	Middle River at Borden Highway B9D75351293
14	San Joaquin River near Vernalis B0702000
15	Lake Del Valle Stream Release DV004000
16	Mallard Slough at Contra Costa Water District Pumping Plant B8X80221556
17	Sacramento River at Mallard Island E0B80261551
18	North Bay Interim Pumping Plant Intake KG000000
19	Barker Slough at Pumping Plant B9D81651476
20	Natomas Main Drain (Agricultural) A0V83681312

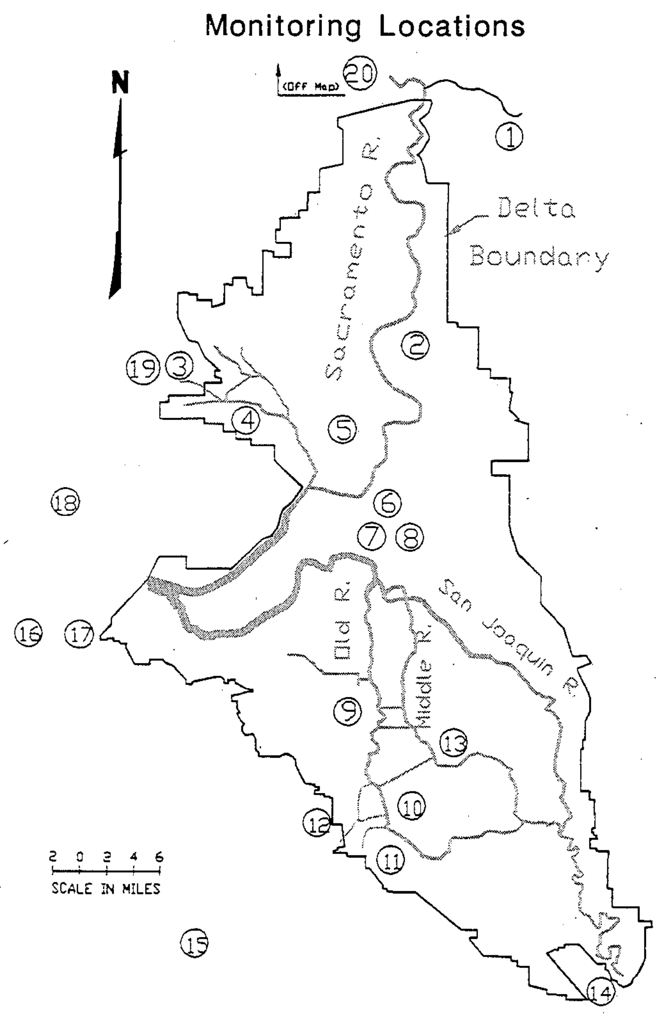


Figure 3. INTERAGENCY DELTA HEALTH ASPECTS MONITORING PROGRAM STATION LOCATIONS

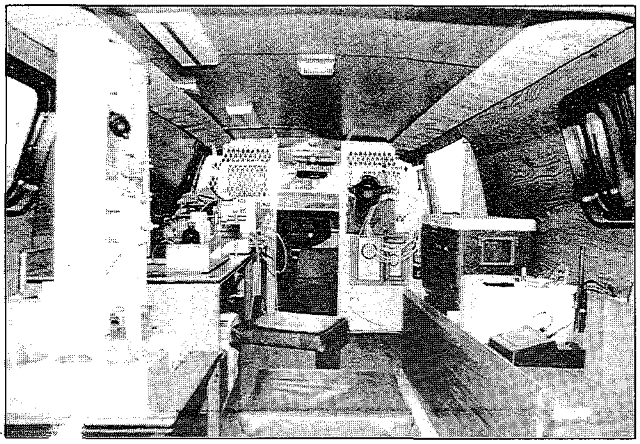
Sampling Schedule

Sampling is conducted monthly for trihalomethane formation potential, minerals, metals, turbidity, color, electrical conductivity, pH, and dissolved oxygen.

Pesticide analyses are performed on samples collected:

- *During June through September, to coincide with summer pesticide application;*
- *After the first major rainfall (December or January) to coincide with winter surface water runoff; and*
- *In April or May, to coincide with spring pre-emergent herbicide application.*

Field and Laboratory Activities



Water quality parameters are measured on-site in the DWR mobile laboratory van *(above)*; then chemists in the laboratories carefully analyze the samples, using modern equipment such as the gas chromatograph/mass spectrometer *(below)*.

Field measurements of basic water quality parameters such as dissolved oxygen, pH, and temperature are made on-site at each station in a mobile laboratory van. Samples are treated with preservatives or are filtered and stored in accordance with approved methods for each type of analysis. Samples are delivered to the laboratories within 24 hours after collection. For quality assurance testing, duplicate samples and spiked reference samples are also delivered to the labs.

Modern equipment and standard methodologies are used in laboratory analyses. Analytical quality is monitored using strict quality control techniques. The Department of Health Services evaluates laboratory performance.

Delta Water Quality - 1983 to 1987

This section summarizes information collected by the Interagency Delta Health Aspects Monitoring Program during the five years beginning January 1983 and ending December 1987.

THM Precursors

Organic THM precursors are found in soils and other sources, such as decaying vegetation. They may also be a product of algal activity. Peat, a highly organic soil, is found throughout the Delta, both on the islands and in the channels. Also, freshwater inflows and saltwater intrusion bring organic THM precursors into the Delta.

Preliminary data from agricultural drains on Tyler, Empire, and Grand Islands suggest that peat soils contribute high concentrations of THM precursors to drain water, and possibly to Delta water. In 1987, the Agricultural Drainage Investigation was initiated as part of the Interagency Delta Health Aspects Monitoring Program to determine the agricultural contribution of THM precursors to Delta channels. Findings will be published when the study is completed in 1989.

THM precursors contributed by sea water or estuarine water also contain bromides, which enhance brominated THM production during the disinfection process. Bromides are also found in freshwater inflows, particularly the San Joaquin River.

THM formation potential is a measure of THM precursors. THM formation potential should <u>not</u> be compared directly with the THM drinking water standard, which applies only to water supplied to consumers.

Influence of Delta Flows on THM Formation Potential

THM formation potential can most easily be understood by looking at the water quality at key locations in the Delta (Figure 4). Five stations have been chosen to represent conditions in various parts of the Delta. Water flowing into the Delta is represented by stations in the Sacramento River at Greene's Landing and the San Joaquin River at Vernalis. Sea water influences are measured at the Mallard Island station. Export water quality is represented by stations at Rock Slough (intake to Contra Costa Canal) and Banks Pumping Plant (State Water Project).

Figure 4 shows the median THM formation potential at each key station. The area of each pie represents the 5-year median THM formation potential. The pies are divided into two slices. The shaded slices show the fraction of the total that contains brominated THMs. The unshaded slices show the fraction that contains only chloroform (a chlorinated THM).

The figure shows that the Greene's Landing station has the smallest THM formation potential. The highest is at the Mallard Island station. The median Mallard Island THM formation potential is about 3-1/2 times the Greene's Landing potential. Water quality at the export stations (Rock Slough and Banks Pumping Plant) lies somewhere between the Greene's Landing station and the Mallard Island station. THM formation potential at Vernalis was about the same as at Banks Pumping Plant.

Figure 4 also shows that the brominated portion of THM formation potential measured at Sacramento River at Greene's Landing is very low (6%) – similar to typical concentrations of bromides in rainfall. In contrast, the brominated portion at Mallard Island is very high (90%) – indicative of the strong influence of sea water at Mallard Island, because sea water contains bromides.

Median bromide levels in the San Joaquin River (30%) are much higher than those in the Sacramento River at Greene's Landing. The median brominated fraction in the San Joaquin River is somewhat higher than for the export water at Banks Pumping Plant (18%) and Rock Slough (14%). Sources of San Joaquin River bromides are not known; two possibilities are marine sediments found in the San Joaquin drainage and bromide-containing Delta water used in San Joaquin agriculture.

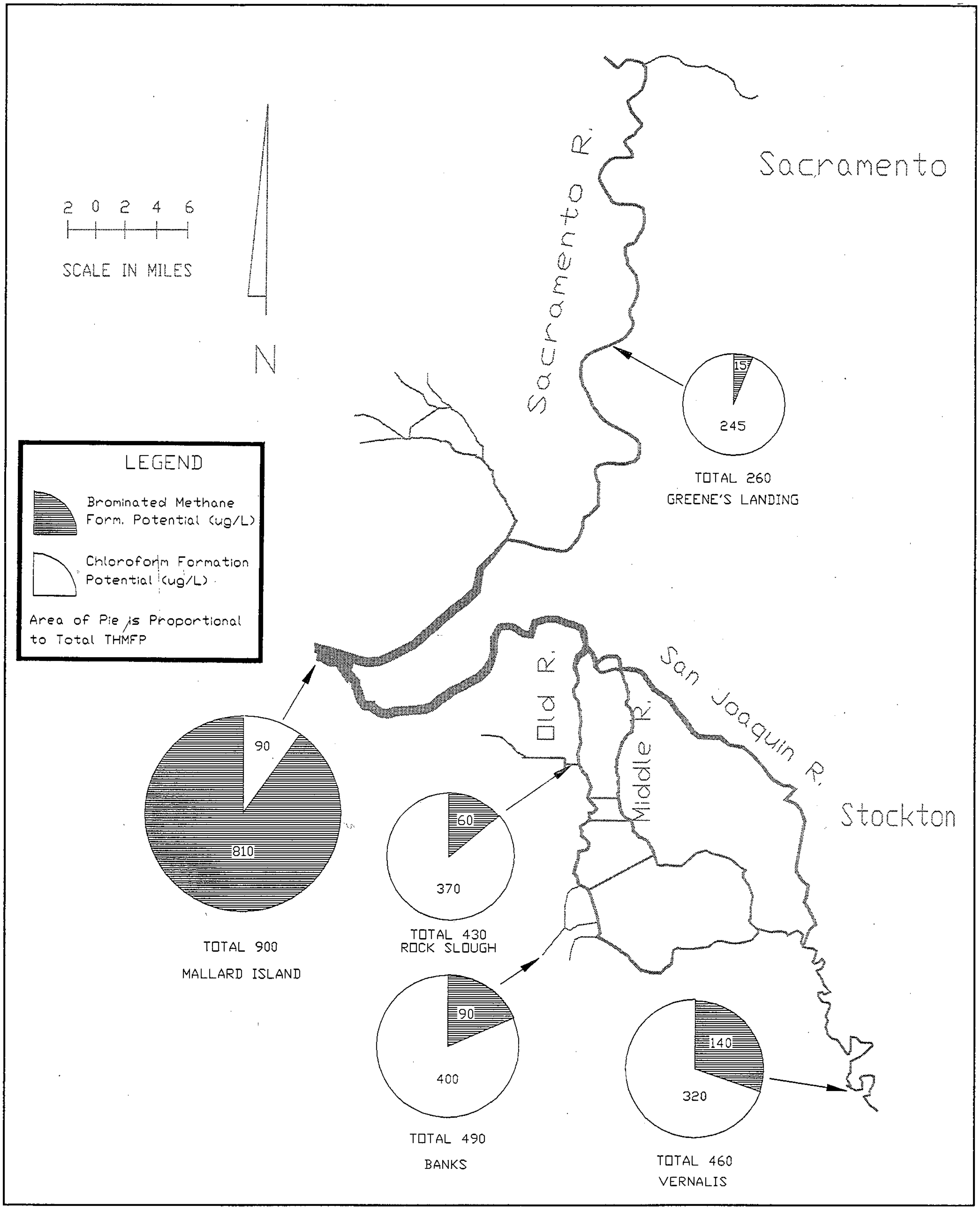


Figure 4. THM FORMATION POTENTIAL IN THE DELTA, 5-YEAR MEDIAN, 1983-1987

Brominated THM formation potentials change dramatically under conditions of low or high outflow from the Delta. Low flows similar to those during the 1976 drought were seen from October through December 1985. Salinity at Mallard Island rose to unusually high levels, indicating significant seawater intrusion. Figure 5 shows total and brominated THM formation potentials measured during October 1985. As a result of sea water beginning to push into the Delta, brominated THMs increased 3 times the median value at Banks Pumping Plant and 6 times the median value at Rock Slough. In contrast, THM formation potentials in the Sacramento and San Joaquin Rivers remained near median values.

The intrusion of bromides into the Delta continued (and increased) until the floods of February 1986 flushed large quantities of fresh water through the Delta. In March 1986, outflows caused by February floods were so high that water at the Mallard Island station became fresh. Figure 6 shows that the Mallard Island station brominated fraction dropped from a median of 90 percent to only 6 percent. THM formation potential at Mallard also dropped to the same level measured at the export stations.

Data indicate that during high rainfall runoff, organic THM precursors are washed from the soils and into streams. As illustrated in Figure 6, THM formation potentials measured at the river and export stations were elevated during March 1986.

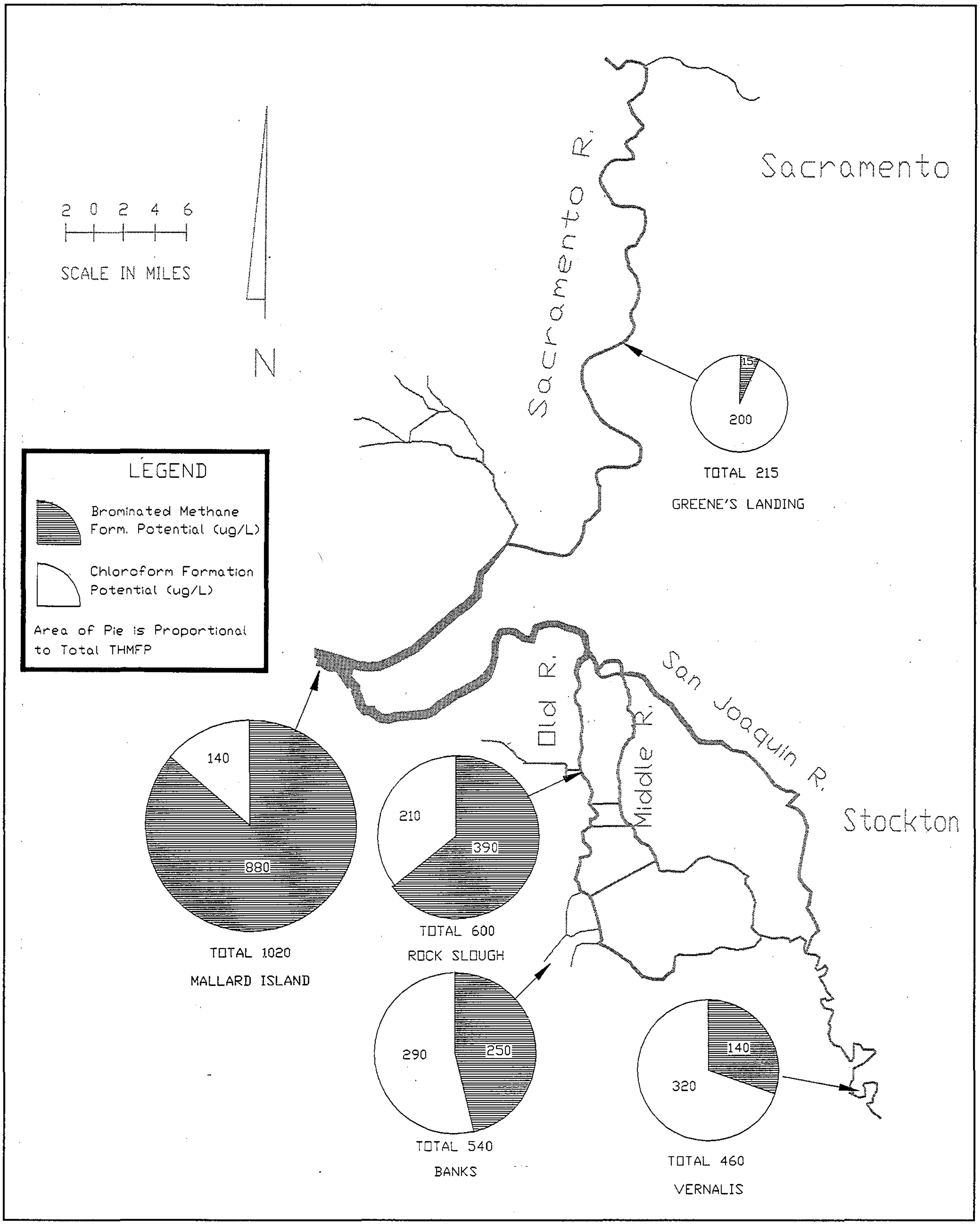


Figure 5. THM FORMATION POTENTIAL IN THE DELTA UNDER LOW FLOW CONDITIONS , OCTOBER 1985

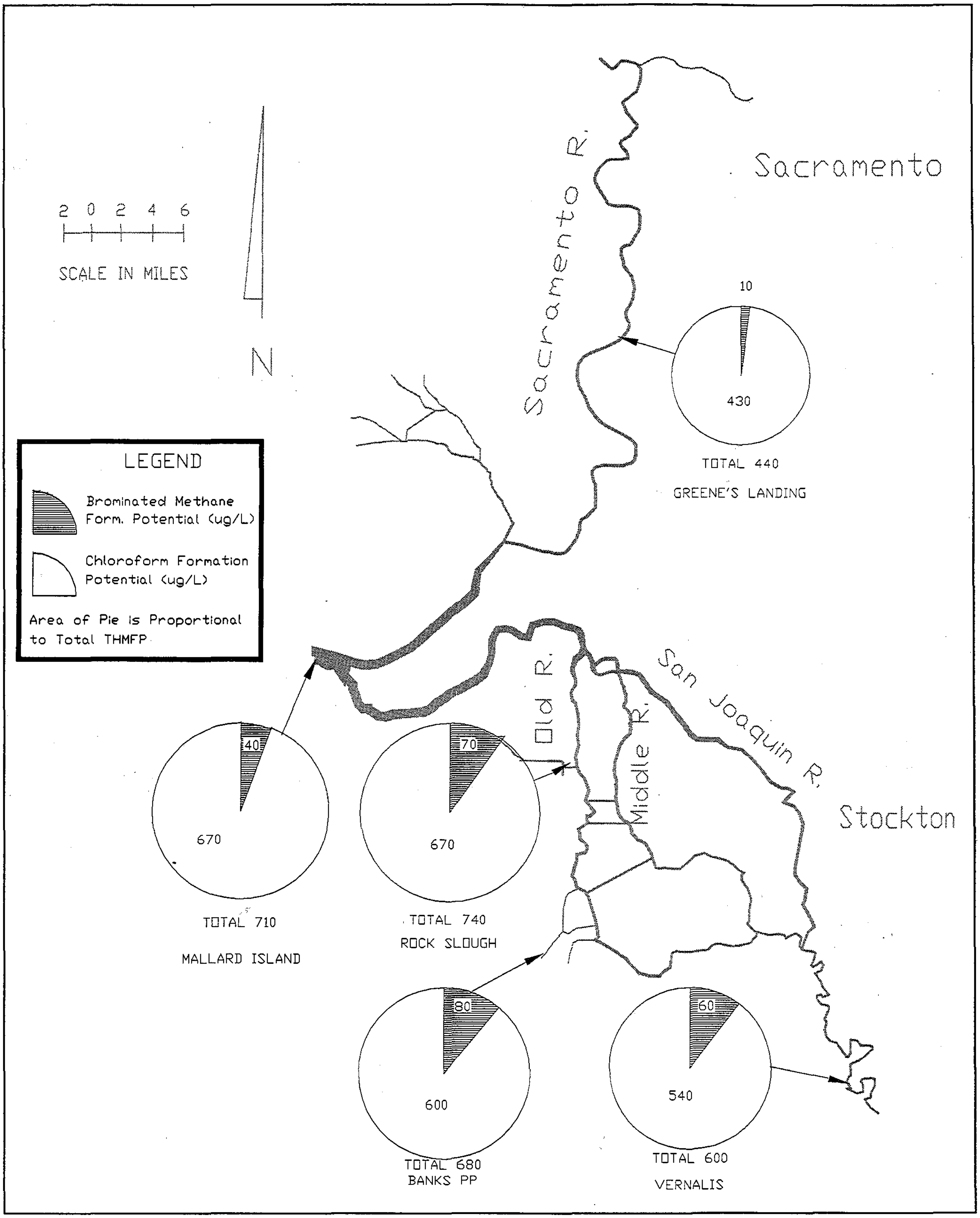


Figure 6. THM FORMATION POTENTIAL IN THE DELTA UNDER HIGH FLOW CONDITIONS, MARCH 1986

5-Year Record of THM Formation Potential

Although single events such as high or low flows can provide insight into some processes governing THM formation potential in Delta water, they do not show all of the processes involved. Agricultural activities and other processes not yet understood may affect THM formation potential in the Delta. Figure 7 shows the highest, median, and lowest total THM formation potential concentrations for each year at the five key stations. The range of concentrations at a given station can vary widely over the course of each year.

Figure 8 shows the lowest, median, and highest brominated THM formation potential concentrations, by year, at the five stations. Brominated THM formation potential reflects the range of seawater and San Joaquin River influences at the export stations. Brominated fractions for Sacramento River at Greene's Landing remained very low during the entire study.

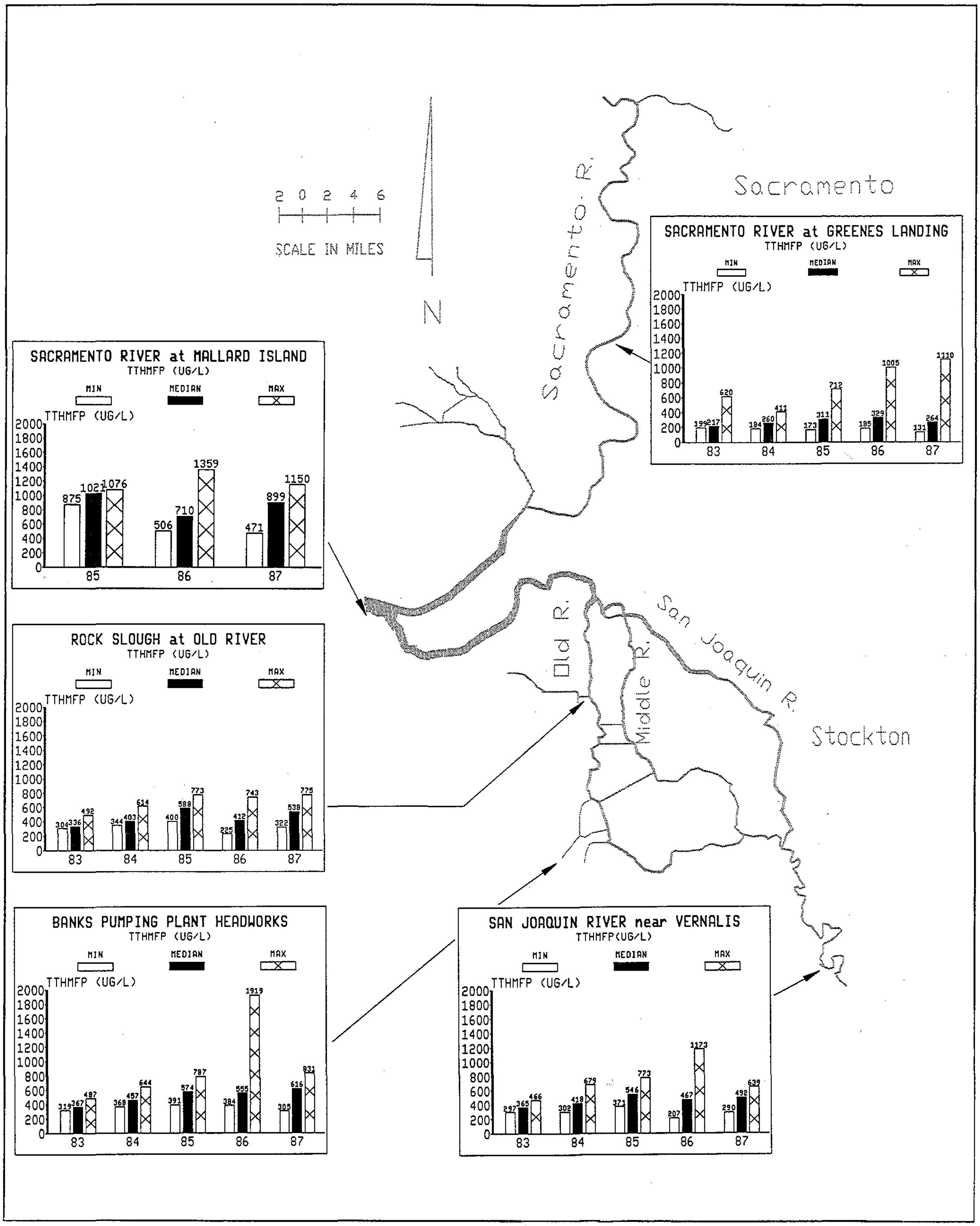


Figure 7. TOTAL THM FORMATION POTENTIAL IN THE DELTA, 1983-1987 MAXIMUM, MINIMUM, MEDIAN

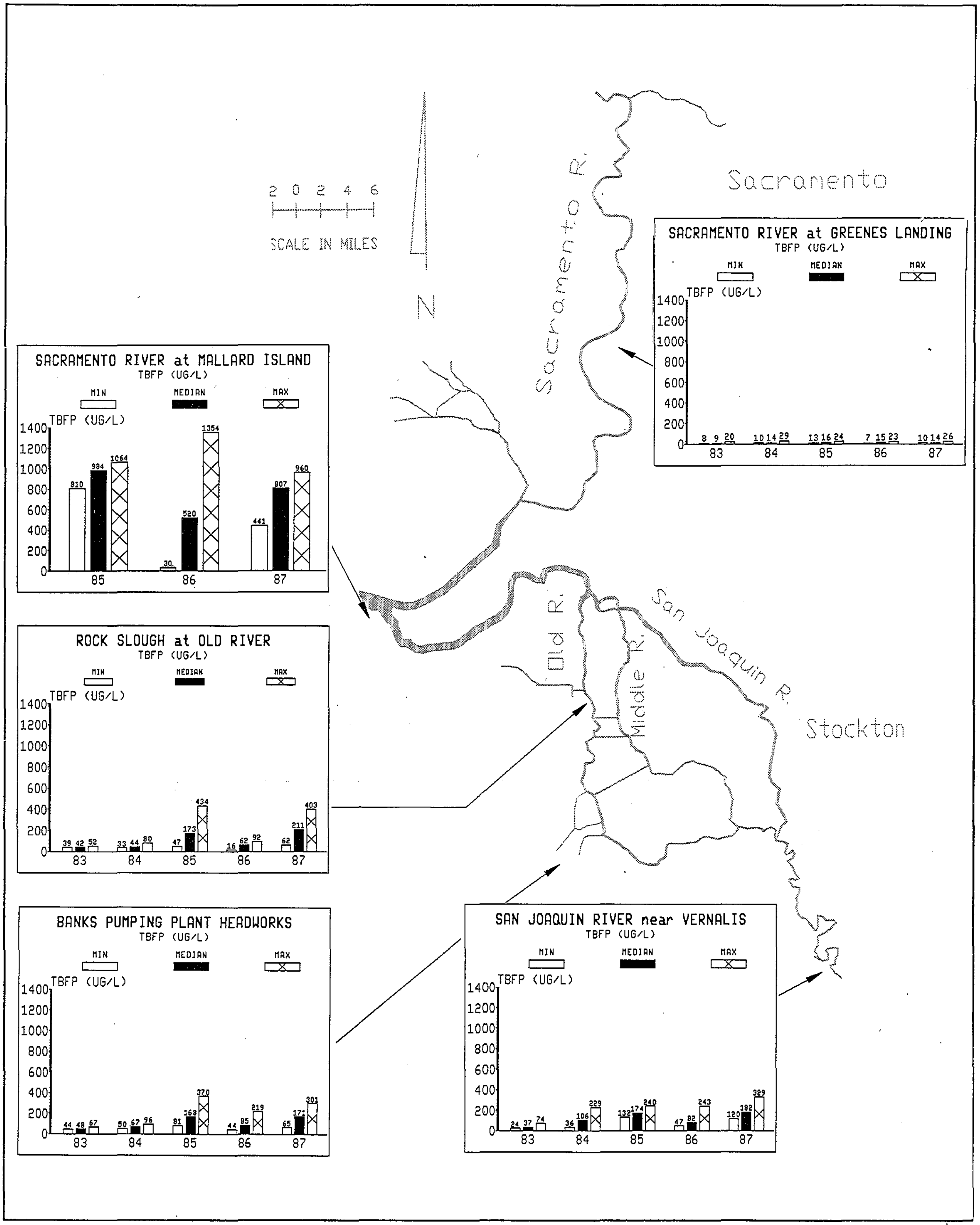


Figure 8. BROMINATED THM FORMATION POTENTIAL IN THE DELTA, 1983-1987 MAXIMUM, MINIMUM, MEDIAN

Organic Chemicals – Pesticides and Industrial Chemicals

Pesticides (herbicides, insecticides, etc.) are used on crops, irrigation ditches, and levees. Runoff from these applications can enter agricultural drains, rivers, and the Delta. In addition, herbicides have been applied to control water weeds in Delta channels. Industrial chemicals are also found from time to time in water throughout the State.

Many pesticides have been monitored and analyzed in the Interagency Delta Health Aspects Monitoring Program. Early program analyses included industrial chemicals such as PCB and pesticides such as DDT, which are known to persist for many years in the environment. Some of these pesticides were detected at very low concentrations. This type of chemical is nearly insoluble in water, and is likely to adsorb (adhere) onto sediment particles, rather than dissolve in the water. Insoluble pesticides and industrial chemicals are found in greater concentrations in Delta fish and sediment than in Delta water.

Pesticides presently registered for use in California tend to be more water soluble than their predecessors, and they have a relatively short persistence in the environment. The few soluble pesticide contaminants found during the Interagency Delta Health Aspects Monitoring Program were at concentrations marginally above laboratory detection limits, but considerably below health-based drinking water standards. Overall, about 4 percent of the analyses showed detectable concentrations of organic chemicals (both water soluble and insoluble). Table 1 compares the 5-year summary of pesticide monitoring results and applicable drinking water standards.

Table 1
PESTICIDE MONITORING RESULTS, 1983-1987
Interagency Delta Health Aspects Monitoring Program

Chemical	Times Sampled	Times Detected	Highest Concentration (ug/L)	Location (Found Above Detection Limit Once At Each Location Unless Noted)	Drinking Water Standards* (ug/L)
2,4-D	83	6	1.0	BR, BN, L, AGE(2), CS	70(PFMCL); 100(SMCL)
4,4'-DDD	47	1	0.004	V	
4,4'-DDE	47	2	0.007	V, RS	
4,4'-DDT	47	0			
Alachlor	21	0			0.2(LOQ)
Aldrin	47	0			0.05(LOQ)
Atrazine	17	1	0.18	AGE	3(PFMCL); 3(SMCL)
Bentazon	71	8	2.8	GR(2), AGE, V, BN(2), RS, AGT	18(SMCL)
BHC-alpha	60	4	0.003	V, DMC, CS, CC	
BHC-beta	47	3	0.006	V, DMC, CC	
BHC-gamma	47	13	0.006	L, GR, DMC, RS(2), CS, MO(2), H(2), NB, CC(2)	
BHC-delta	47	0			
Bolero (thiobencarb)	87	2	1.7	AGG, V	70(SMCL)
Captan	21	0			350(SAL)
Carbaryl	18	0			60(SAL)
Carbofuran	96	2	1.33	V, CS	40(PFMCL); 18(PSMCL)
Chlordane	47	0			0.1 (PSMCL)
Chloropicrin	59	0			50(SAL)
Copper Dacthal	21	0			
D-D Mixture	29	0			
Dacthal	51	1	0.15	AGG	
Diazinon	45	8	0.1	V, BN, DMC, RS(2), CS, NB, CC	14(SAL)
Dichlorovos	23	0			
Dicofol	21	0			
Dieldrin	47	3	0.005	V, DMC, CC	0.05(LOQ)
Dimethoate	23	1	0.046	V	140(SAL)
Dinoseb	21	0			
Diphenamid	23	0			
Diquat	18	0			
Disulfoton	41	0			
Dithiocarbamate	18	0			
Endosulfan 01	35	1	0.004	V	
Endosulfan 02	38	4	0.005	DMC, RS, CS, CC	
Endosulfan	47	2	0.01	V, RS	
Endosulfan-A	12	0			
Endosulfan-B	12	0			
Endrin	47	0			
Endrin Aldehyde	47	0			
Ethion	23	0			
Glyphosate	6	1	10.0	AGE	700(SAL)
Guthion	23	1	0.02	RS	
Heptachlor	47	0			0.4(PFMCL); 0.01(SAL); 0.01(PSMCL)
Heptachlor Epoxide	47	0			0.01(PSMCL)
Malathion	23	0			160(SAL)
MCPA	55	0			
Metalaxyl	51	0			
Methamidophos	45	0			
Methomyl	18	0			
Methyl Bromide	29	0			
Methyl Parathion	82	6	2.5	V(2), DMC, RS, CS, CC	30(SAL)
Ordram (molinate)	69	14	1.4	MA, L, GR, AGG, AGE(2), V(2), BN(2), DMC, RS(2), MI	20(SMCL)
Paraquat	72	2	74.0	V(2)	
Parathion	45	6	0.035	V, DMC, RS(2), CS, CC	30 (SAL)
PCB-1216	12	0			0.5(PFMCL)
PCB-1221	12	0			0.5 (PFMCL)
PCB-1232	12	0			0.5 (PFMCL)
PCB-1242	12	0			0.5 (PFMCL)
PCB-1248	12	0			0.5 (PFMCL)
PCB-1254	12	0			0.5 (PFMCL)
PCB-1260	12	0			0.5 (PFMCL)
Propanil	16	0			
Propham	18	0			
Simazine	17	2	0.36	DMC(2)	10(SMCL)
Toxaphene	47	0			5(PFMCL); 5(SMCL)
Xylene	29	0			440 (FMCLG); 1750(SMCL)

* PFMCL = Proposed Federal Maximum Contaminant Level
FMCLG = Federal Maximum Contaminant Level Goal
PSMCL = Proposed State Maximum Contaminant Level
SMCL = State Maximum Contaminant Level
SAL = State Action Level
LOQ = Limit of Quantification

LOCATION ABBREVIATIONS
AGE = Agricultural Drain at Empire Tract
AGG = Agricultural Drain at Grand Island
AGT = Agricultural Drain at Tyler Island
BN = Banks Pumping Plant
BR = Barker Slough
CC = Clifton Court
CS = Cache Slough
DMC = Delta-Mendota Canal
GR = Greene's Landing
H = Honker Cut
L = Lindsey Slough
MA = Mallard Island
MI = Middle River
MO = Mokelumne River
NB = North Bay Pumping Plant
RS = Rock Slough
V = Vernalis

Sodium and Salt

Excess salt can harm crops, corrode pipes, and make water unfit to drink. In addition, excess sodium in the diet can cause health problems for people with high blood pressure.

The National Academy of Science recommends that people on moderately restricted sodium diets drink water with less than 100 milligrams per liter (mg/L) sodium. People on severely restricted sodium diets should consume water with less than 20 mg/L sodium. No State or Federal standards for sodium in drinking water are being considered at this time. Drinking water usually supplies only a small fraction of the total daily intake of sodium.

There are two major sources of salts and sodium in the Delta: sea water and agricultural drainage. Sodium levels in State Water Project exports from the Delta are acceptable for drinking water; in fact, much higher levels can be tolerated. Taste is the major limiting factor.

Table 2 shows the range of sodium concentrations at 15 locations sampled by the Interagency Delta Health Aspects Monitoring Program.

At Banks Pumping Plant, the 100 mg/L recommended limit was exceeded twice out of the 55 times water was sampled. Both samples were collected in the fall of 1987, when Delta outflow was low because of an extended dry period. Sodium levels usually fell in the 20 to 99 mg/L range, which is safe for most people.

The data show only three stations with sodium concentrations consistently less than 20 mg/L: American River (Water Treatment Plant), Sacramento River (Greene's Landing), and North Bay Interim Pumping Plant. Sodium concentrations at Rock Slough, Clifton Court, Banks Pumping Plant, and the Delta-Mendota Canal Intake exceeded the 100 mg/L National Academy of Sciences advisory during extremely low flows at the end of the extended dry period in 1987. Sodium concentrations at Rock Slough also exceeded the advisory during low flows in 1985.

Sodium concentrations exceeded 100 mg/L 90 percent of the time at Sacramento River at Mallard Island. However, this location was selected because it is subject to influence from San Francisco Bay. It is not a drinking water source.

Overall, sodium concentrations in the Delta are not of health concern at the major export stations and other freshwater dominated sources. However, during low outflow conditions, sodium may rise to levels of concern to individuals with moderate sodium restrictions. People on very restricted sodium diets (e.g. less than 500 mg/day total sodium from all sources) usually consume sodium-free bottled water.

Table 2
FREQUENCY OF SODIUM CONCENTRATIONS
1983 - 1987
Interagency Delta Health Aspects Monitoring Program

Station	Range Of Concentrations (mg/L) ≤20	20-99	≥100	Total Samples
Agricultural Drain at Empire Tract	0	14	19	33
Agricultural Drain at Grand Island	4	30	0	34
Agricultural Drain at Tyler Island	6	17	0	23
American River at Water Treatment Plant	45	0	0	45
Banks Pumping Plant	2	51	2	55
Clifton Court Intake	4	47	2	53
Delta-Mendota Canal Intake	2	49	1	52
Lindsey Slough at Hastings Cut	0	44	0	44
Little Connection Slough	27	3	0	30
Middle River at Borden Highway	0	31	0	31
North Bay Aqueduct Interim Pumping Plant	47	0	0	47
Rock Slough at Old River	13	34	7	54
Sacramento River at Greene's Landing	54	0	0	54
Sacramento River at Mallard Island	2	1	26	29
San Joaquin River at Vernalis	4	46	3	53

Asbestos

Asbestos is a naturally occurring mineral that appears as minute fibers under a transmission electron microscope. The Environmental Protection Agency has proposed a drinking water standard for asbestos of 7.1 million fibers per liter (MF/L) in water (for fibers longer than 10 microns). However, the link between cancer and asbestos in drinking water is weak.

The Interagency Delta Health Aspects Monitoring Program began sampling for asbestos before the long-fiber asbestos drinking water standard was proposed, so the data include all fibers and not just those longer than 10 microns. As a rule of thumb, only about 1 percent of total asbestos fibers are long fibers.

The range of total asbestos fiber concentrations found during this study is shown in Table 3. In general, total asbestos fiber concentrations varied from 12 to 26,000 MF/L. The highest concentration was measured in December 1983 at Mallard Slough, which is a drinking water source. Even if only 1 percent of the fibers were long fibers, 38 percent of samples throughout the study area could have exceeded the proposed drinking water standard.

While the numbers are high, asbestos concentrations in untreated water bear little resemblance to concentrations in water reaching the consumer. Conventional treatment processes, including coagulation, flocculation, sedimentation, and filtration, reduce asbestos concentrations by 99 percent or more. Water agencies producing drinking water from the Delta successfully treat the water to meet the proposed new standard.

Table 3
RESULTS OF ASBESTOS SAMPLING
1984 - 1986
Interagency Delta Health Aspects Monitoring Program

Station	Total Asbestos Fibers (Million Fibers per Liter) High	Low	Median	Number of Samples
Agricultural Drain at Empire Tract	300	76	92	3
Agricultural Drain at Grand Island	3,100	630	2,100	3
Agricultural Drain at Tyler Island	530	190	410	3
American River at Water Treatment Plant	2,200	12	110	14
H.O. Banks Delta Pumping Plant	860	230	635	6
Cache Slough at Vallejo Pumping Plant	4,000	650	1,550	8
Clifton Court Intake	960	230	520	14
Delta-Mendota Canal Intake	1,800	370	715	14
Lake Del Valle Stream Release	310	54	181	2
Lindsey Slough at Hastings Cut	7,500	1,160	3,500	5
Little Connection Slough	220	68	140	3
Mallard Slough at Contra Costa Water District Pumping Plant	26,000	690	1,350	4
Middle River at Borden Highway	540	100	210	3
North Bay Interim Pumping Plant	6,000	200	1,600	14
Rock Slough at Old River	1,100	140	550	14
Sacramento River at Greene's Landing	3,200	110	530	14
Sacramento River at Mallard Island	3,490	240	1,865	2

Selenium

Selenium is a natural element that, in high concentrations, can cause deformities in animals and birds. In humans, high concentrations cause gastrointestinal problems and hair and nail loss. Conversely, selenium at low concentrations is an essential element, and deficiencies can cause infertility and a number of other conditions.

In 1984, the U.S. Fish and Wildlife Service discovered deformed bird embryos at the Kesterson Wildlife Refuge, near Los Banos, California. The deformities were attributed to high selenium levels discovered there and in the San Luis Drain, which emptied into Kesterson Reservoir. The source of the selenium was agricultural drain water from high-selenium soils in the western part of the San Joaquin Valley. Both Kesterson Wildlife Refuge and the San Luis Drain have since been closed.

Selenium has been monitored in the San Joaquin River and the Delta since July 1984 in response to public concern stemming from the problems at Kesterson. Table 4 summarizes results of the selenium sampling. During the study, selenium values never exceeded the drinking water standard of 10 $\mu g/L$ at any station sampled. These data indicate that, from a human health standpoint, selenium concentrations are not a threat to Delta water quality.

Table 4
FREQUENCY OF SELENIUM CONCENTRATIONS
1984 - 1987
Interagency Delta Health Aspects Monitoring Program

Station	ND*	Range of Concentrations (ug/L) 1	2	3**	Total Samples
Agricultural Drain at Empire Tract	10	1	-	-	11
Agricultural Drain at Grand Island	13	1	-	-	14
Agricultural Drain at Tyler Island	7	-	-	-	7
American River at Water Treatment Plant	5	-	-	-	5
H.O. Banks Delta Pumping Plant	24	3	1	1	29
Cache Slough at Vallejo Pumping Plant	1	5	-	-	6
Clifton Court Intake	17	4	-	-	21
Delta-Mendota Canal Intake	21	8	2	1	32
Lake Del Valle Stream Release	2	-	-	-	2
Lindsey Slough at Hastings Cut	22	-	-	-	22
Little Connection Slough	1	1	-	-	2
Mallard Slough at Contra Costa Water District Pumping Plant	2	-	-	-	2
Middle River at Borden Highway	7	3	-	-	10
North Bay Interim Pumping Plant	8	1	-	-	9
Rock Slough at Old River	16	1	-	-	17
Sacramento River at Greene's Landing	20	2	-	-	22
Sacramento River at Mallard Island	12	-	-	-	12
San Joaquin River at Vernalis	11	15	6	2	34
Totals	199	45	9	4	257

* ND = Not detected at 1 ug/L detection limit.
**Selenium did not exceed 3 ug/L at any of these locations.

Future Directions

During the past five years, the Interagency Delta Health Monitoring Program has been successful in characterizing water quality at several locations throughout the Delta.

The Technical Advisory Group has provided funding and technical guidance for the program and has recommended program priorities. The program has been changed over the years to help answer water quality questions as they have arisen.

In terms of known potential human health and water treatment problems, THM formation potential is the most important water quality parameter examined by this program. As some of the large-scale processes that affect THM formation potential in Delta water begin to be understood, new questions arise. The program is moving forward on two issues of immediate interest:

- *Initiation of the Agricultural Drainage Investigation to quantify the contribution of THM precursors from agricultural drainage to Delta channels.*
- *Temporary modification of sampling schedules during the current drought to quantify these "worst case" conditions. Additional efforts will be necessary should the drought continue into a third year.*

With the guidance and support of the Technical Advisory Group, future areas of study may address topics such as:

- *Sources of organic THM precursors and bromides in the San Joaquin River and the influence of San Joaquin River water on Delta export water quality.*
- *Algal productivity as a potential source of organic THM precursor materials in the Delta, Suisun Marsh, and State Water Project.*
- *Relationship between THM precursors at Banks Pumping Plant and THM precursors delivered to Southern California.*

- *Effects of planned new construction and altered water project operations on the quality of Delta drinking water supplies.*

The strength of the Interagency Delta Health Aspects Monitoring Program has been the flexibility to evaluate water quality questions as they arise. In conducting these and future studies, the program will continue to be responsive to the needs of all users of Delta water.

DELTA STATISTICS

DEMOGRAPHY

Population: 200,000
Counties: Alameda, Contra Costa, Sacramento, San Joaquin, Solano, Yolo
Incorporated Cities Entirely Within the Delta: Antioch, Brentwood, Isleton, Pittsburg, Tracy
Major Cities Partly Within the Delta: Sacramento, Stockton, West Sacramento
Unincorporated Towns and Villages: 14

GEOGRAPHY

Area

(acres)		
	Agriculture	520,000
	Cities and Towns	35,000
	Water Surface	50,000
	Undeveloped	133,000
	Total Acres	738,000

Levees

(miles)		
	Project	165
	Direct Agreement	110
	Nonproject	825
	Total Miles	1,100

Rivers Flowing Into the Delta: Sacramento, San Joaquin, Mokelumne, Cosumnes, Calaveras
(These plus their tributaries carry 47% of the State's total runoff.)

Diversions Via Aqueducts Through or Around the Delta
- San Francisco Public Utilities Commission
- East Bay Municipal Utility District

Diversions Directly From the Delta
- Western Delta Industry
- City of Vallejo
- 1,800+ Agricultural Users
- Contra Costa Canal
- State Water Project
- Central Valley Project

ECONOMY

Valuation

(1980)		
	Land	$1,600,000,000
	Pipelines	100,300,000
	Marinas	100,000,000
	Roads	68,000,000
	Gas Wells	26,900,000
	Railroads	11,000,000
	Utilities	1,300,000
	Total	$1,907,500,000

Recreation

User-Days Annually	12 million
Registered Pleasure Boats	82,000
Commercial Recreation Facilities	116
Public Recreation Facilities	22
Private Recreation Associations	22
Berths	8,534
Docks	119
Launch Facilities	27

Agriculture
Average Annual Gross Value $375 million

Main Crops:

Corn	Grain and Hay
Sugarbeets	Alfalfa
Pasture	Tomatoes
Asparagus	Fruit
	Safflower

Transportation

Interstate Highways	5, 80, 205
State Highways	4, 12, 84, 113, 160, 220
Railroads	Southern Pacific
	Western Pacific
	Atchison, Topeka & Santa Fe
	Union Pacific

Deep-water ship channels to Sacramento and Stockton transport 6 million tons annually

FISH AND WILDLIFE

Birds	200 species
Reptiles	15 species
Mammals	45 species
Amphibians	8 species
Fish	45 species
Flowering Plants	150 species

Major Anadromous Fish
- Salmon
- Striped Bass
- Steelhead Trout
- American Shad
- Sturgeon