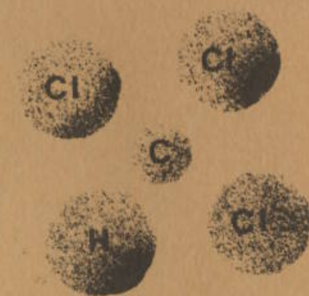
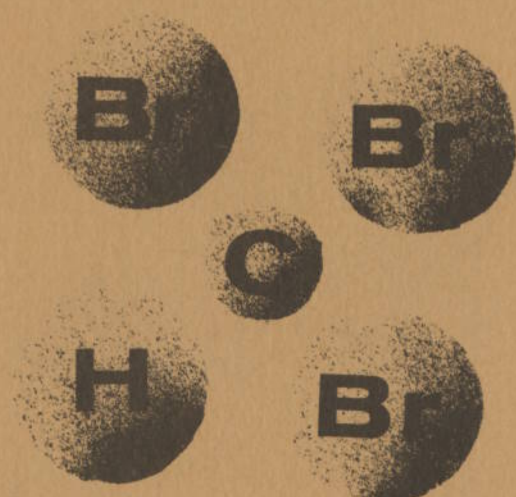
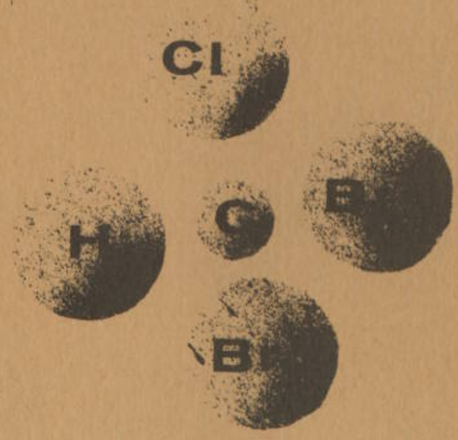
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
CENTRAL DISTRICT

STATE WATER PROJECT TRIHALOMETHANE STUDY







APRIL 1982

STATE WATER PROJECT

TRIHALOMETHANE STUDY

Central District

April 1982

FOREWORD

Trihalomethanes, or THMs, are potential cancer causing chemicals formed in drinking water when certain substances in the water react with chlorine during water treatment. The primary materials that react to form THMs come from decaying plants and organic soils. Chloroform is the most common type of THM found in municipal water supplies. Concern over the widespread occurrence of THMs in drinking water supplies has recently led to Federal regulations limiting their allowable concentrations.

Studies by the California Department of Health Services, the Metropolitan Water District of Southern California, and other agencies have provided evidence that water taken from the southern Sacramento-San Joaquin Delta is higher in THM-forming agents than is water from upstream of the Delta. Treated drinking water from the southern Delta generally fails to meet the new drinking water standard. As a result, agencies supplying drinking water from this source are faced with the possible requirement to provide additional costly treatment for THM removal.

The purposes of the State Water Project Trihalomethane Study were to investigate the sources of THM-forming agents in the State Water Project and to evaluate potential means of reducing their concentrations. In particular, the proposed Peripheral Canal was evaluated in terms of its effects in reducing concentrations of these agents.

The study concluded that operation of the Peripheral Canal would significantly reduce the levels of THMs in the water supplies of Alameda, Contra Costa, and Santa Clara Counties, and Southern California.

Wayne MacRostie

Wayne MacRostie
Chief, Central District

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SUMMARY

Trihalomethanes (THMs) are potential cancer-causing chemicals that are formed in drinking water when naturally occurring substances in the water react with chorine during water treatment. From September 1981 through January 1982, the Department of Water Resources (DWR) conducted a monitoring program to determine:

1. The sources of THM-forming agents (precursors) in the waters of the Sacramento-San Joaquin Delta, Sacramento River, and State Water Project.

2. Whether operational alternatives exist for reducing present concentrations.

DWR monitored five locations in the Delta to measure whether THM precursors result from transporting water through the Delta. This monitoring also helped determine whether the Peripheral Canal or a through-Delta conveyance facility would reduce precursor concentrations in State Water Project waters. The Delta monitoring also indicated that ocean-derived bromide is a significant factor in THM formation.

To examine the probable inputs of THM precursors into the proposed North Bay Aqueduct, DWR monitored three locations in the area of that proposed project.

DWR also evaluated impacts of agricultural discharges into State Water Project source waters by sampling two agricultural drains in the Sacramento River watershed. The effects of urban waste discharges upon THM precursor concentrations in State Water Project waters were evaluated by monitoring effluents of three waste water treatment plants discharging into waters used by the Project.

DWR then took soil samples from the proposed alignment of the Peripheral Canal to determine whether these soils are likely to affect the precursor load in the State Water Project if the Peripheral Canal were operational.

To examine possible seasonal fluctuations in THM precursor concentrations, DWR collected water samples under very dry, fall weather conditions and during very wet, winter conditions. To evaluate possible inputs of precursors from aquatic vegetation, two locations in the California Aqueduct were monitored.

As a result of the study, the Department concluded that:

° Construction and operation of the Peripheral Canal should reduce THM precursor and bromide concentrations in State Water Project waters south of the Delta to levels that would meet drinking water standards in treated water.

° The source of water in the second phase of the North Bay Aqueduct is relatively low in THM precursors. Treated water from this source should meet the drinking water standard for THMs.

° Agricultural drainage and waste water treatment plant effluents contribute measurable amounts of THM precursors to State Water Project waters; however, the most significant source of precursors appears to be runoff from soils.

° The soils that would line the proposed Peripheral Canal contain THM precursors. However, the leaching rate of these precursors into canal water should be minimal.

INTRODUCTION

Trihalomethanes are a family of chemicals named after methane, which consists of a single carbon atom bonded to four hydrogen atoms. THMs consist of a carbon atom bonded to one hydrogen and three halogen atoms. THMs containing the halogens chlorine and bromine are often found in drinking water. Figure 1 demonstrates the types of THMs typically found in drinking water supplies.

Research has demonstrated that THMs are formed in drinking water as a result of the use of chlorine for disinfection. The chlorine acts upon certain organic compounds present in the water supply. These organic compounds, frequently of soil origin, are termed THM precursors /1,2/. Other research has demonstrated that THMs may be capable of causing cancer /3,4,5,6/. Concern over the widespread occurrence of these potentially hazardous chemicals in the drinking water supplies of the nation has led to regulation of their concentrations in drinking water.

The U. S. Environmental Protection Agency (EPA) has established a Maximum Contaminant Level (MCL) of 100 micrograms per litre (ug/L)* of THMs, taken as an arithmetic sum of the concentrations of THMs appearing in Figure 1. This regulation came into effect in November 1981 for water systems supplying 75,000 or more persons; in November 1983, water systems serving populations greater than 10,000 will be likewise regulated /7/.

In compliance with the monitoring requirement of the EPA regulations, treated water of State Water Project origin has been analyzed for THMs. The finding has been that, under some conditions, the established MCL can be exceeded. This observation has led to questions concerning the sources of THM precursors in the State Water Project, and to questions concerning the possible benefits of the proposed Peripheral Canal or other through-Delta conveyance facility in reducing precursor concentrations in the State Water Project.

The purpose of this study is to address the questions that have been raised. The specific objectives of the study are to:

- Estimate the effect implementation of the Peripheral Canal would have in reducing THM precursors in the State Water Project.
- Evaluate the sources of THM precursors to the water supply of the proposed second phase of the North Bay Aqueduct.
- Evaluate the impact of bromides from sea water on THM formation in State Water Project water supplies.
- Evaluate the impacts of agricultural and urban waste discharges upon THM formation in State Water Project water supplies.

*One microgram per litre is approximately one part per billion. The units in this report, conversion between units, and the abbreviations for each unit are presented on the inside of the back cover.

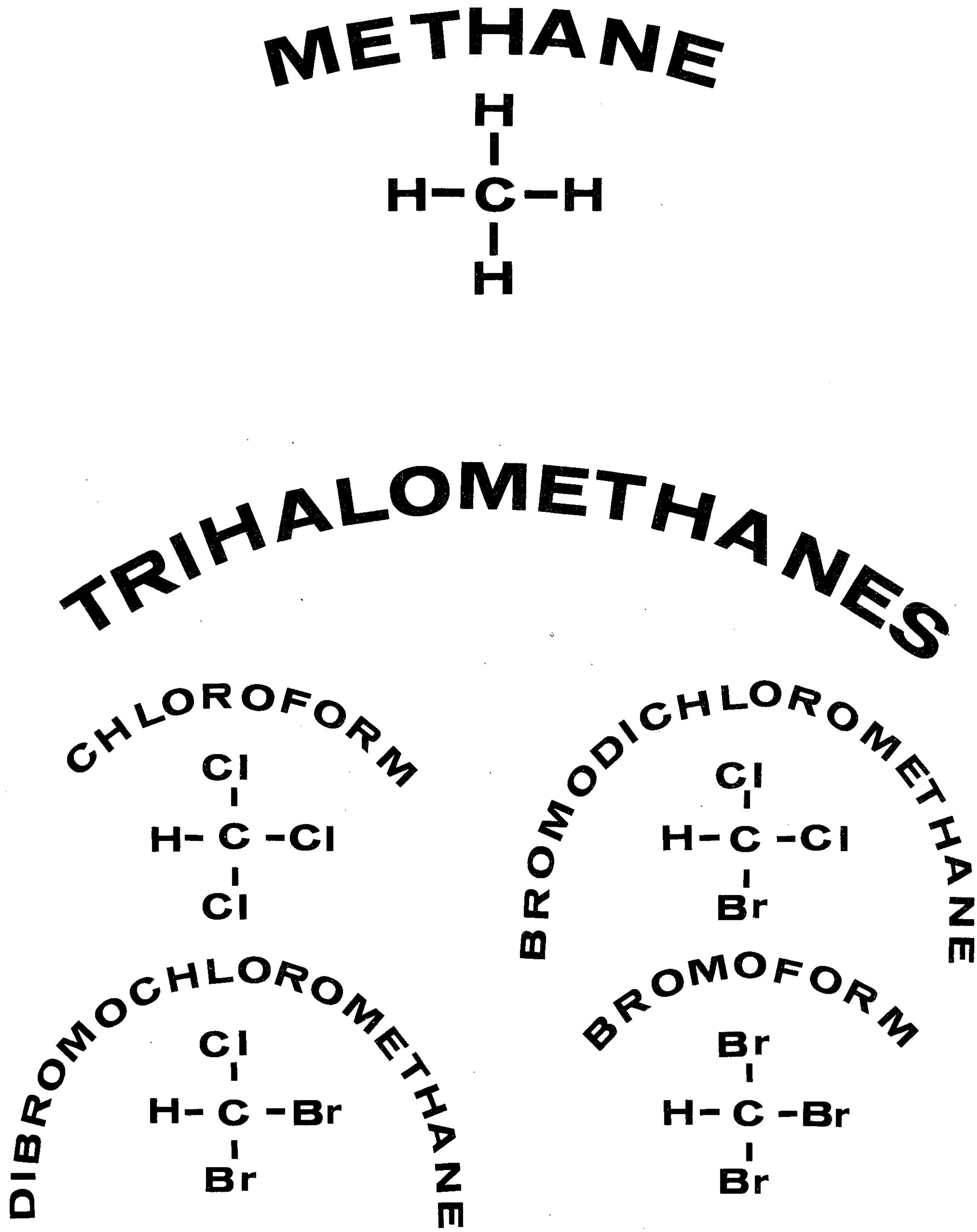
° Evaluate the probable contribution of soils in the proposed Peripheral Canal alignment to THM formation in State Water Project water supplies.

° Determine the sources of variation (seasonal and otherwise) of THM precursors in State Water Project supplies.

This report presents details of the study and its results.

FIGURE I

MOLECULAR STRUCTURES OF METHANE AND TRIHALOMETHANES



C = CARBON H = HYDROGEN Cl = CHLORINE Br = BROMINE

FINDINGS AND CONCLUSIONS

Findings

The findings of the study are summarized as follows:

1. Treated drinking water that comes from the southern Sacramento-San Joaquin Delta is generally higher in THMs than water tested in a nationwide survey. Also, drinking water from this source generally fails to meet the drinking water standard for THMs. This is due to higher than average concentrations of organic precursors and due to the presence in Delta waters of bromides from sea water.

2. Water from Cache Slough has a higher potential of forming THMs than do the waters of Lindsey and Miner Sloughs. However, the City of Vallejo has been able to maintain acceptable THM concentrations in treated water from Cache Slough.

3. Water from the Sacramento River at Hood contains lower concentrations of THM precursors and bromides than does water from more southerly locations in the Sacramento-San Joaquin Delta, including the Harvey O. Banks Delta Pumping Plant Headworks (Headworks).

4. Two agricultural drains that were sampled contained about two to three times the concentrations of THM precursors present in the Sacramento River at Hood.

5. Effluent from three waste water treatment plants contained only moderate concentrations of precursors in filtered samples.

6. The soils that would line the proposed Peripheral Canal contain substantial quantities of THM precursors. Water coming into contact with these soils might pick up the precursors to some extent. However, any such problem would be expected to decrease after a short period of leaching.

7. Seasonal fluctuations in THM precursor concentrations were apparent. Precursor concentrations were observed to increase with increasing riverflow.

Conclusions

The following conclusions are based upon the findings of the study:

1. Because water from the Sacramento-San Joaquin Delta contains abnormally high concentrations of THM precursors and bromides, the water supply of the State Water Project would benefit from reduced contact with the Delta. Because the Peripheral Canal would take water from the Sacramento River at Hood, construction of the canal would result in lower concentrations of THM precursors and bromides in the water supply of the State Water Project. Assuming the Periheral Canal were built, the drinking water standard for THMs could be met in treated water taken from the part of the State Water Project supplied by the Harvey O. Banks Delta Pumping Plant.

2. A through-Delta conveyance alternative other than the Peripheral Canal might reduce THM precursor and bromide concentrations in State Water Project source waters, as compared to current levels. The amount of any reductions would,

however, be less than the benefit provided by the Peripheral Canal because other alternatives being proposed would (a) permit greater intermingling of Sacramento River water with sea water and (b) permit greater contact of State Water Project waters with Delta soils and agricultural drainage containing THM precursors. In addition, because algae are a potential source of precursors, biological productivity in the Delta estuary might be a source of precursors to the waters of an alternative facility. The benefit of an alternative facility in reducing THM precursors and bromides would be in proportion to the degree to which such a facility minimized contact of the export waters with the soils and waters of the Delta.

3. Treated water from the North Bay Aqueduct will likely meet the drinking water limit for THMs. Most of the water diverted from Cache Slough to the North Bay Aqueduct will be supplied from Miner Slough, and will, therefore, be a good quality water similar to that in Miner Slough.

4. Agricultural drainages appear to be significant sources of THM precursors. However, effluents of waste water treatment plants appear not to be major sources.

   Aquatic vegetation was not a significant source of THM precursors at the places and times of our sampling.

   The primary source of THM precursors appears to be surface runoff from land. The primary source of bromides in the State Water Project water supply is sea water intrusion into the Delta.

5. The peat and loam soils through which the Peripheral Canal would pass contain significantly high levels of THM precursors. Precursors at the soil-water interface should dissolve into the water and rapidly become exhausted. Thereafter, the diffusion of precursors from the water contained within the soil should be a very slow process which would be slowed further with the deposition of silt contained in the Sacramento River water.

   Once leaching has declined, the Peripheral Canal would have the advantage of being a shorter route through the Delta than is provided by existing channels. Also, the canal will traverse less peat soil than existing channels, and will receive no agricultural drainage from peat soils. Because of these factors, and because of the lower level of soil erosion from wave-wash and scour, construction of the canal should result in substantially reduced THM precursor leaching from the soils as compared to present conditions.

RECOMMENDATIONS

1. A routine program of THM monitoring should be implemented. This monitoring should include, as a minimum, sampling the Sacramento River at Hood, the Harvey O. Banks Delta Pumping Plant Headworks, the San Joaquin River near Vernalis, the Penitencia Water Treatment Plant at the end of the South Bay Aqueduct, Miner Slough, and Cache Slough.

   This monitoring should also include a survey of THM formation potential in the waters of the entire State Water Project. The samples should be analyzed for THM formation potential, and the data should be correlated on an ongoing basis with THM analyses from the City of Sacramento, Santa Clara Valley Water District, Contra Costa Water District, the City of Vallejo, and the Metropolitan Water District of Southern California. This work may enable prediction of finished water THM concentrations based on analyses of raw water.

   The additional monitoring would extend the data base needed to evaluate the effects of the Peripheral Canal or a through-Delta conveyance facility on THM formation in waters of the State Water Project south of the Delta. The additional data would also help in evaluating the potential for THM formation in waters of the North Bay Aqueduct.

2. Monitoring of borrow pits along the alignment of the proposed Peripheral Canal should be performed to further evaluate potential soil contributions of THM precursors.

METHODS

Sampling Methods

Water samples were generally collected in a 1.5 litre steel bucket with a one metre chain attached; the bucket and chain were carefully detergent-washed, wrapped in detergent-washed aluminum foil, and dried for at least two hours in a 105°C oven. This procedure was to insure that the sampling vessel would be as free as possible of organic substances that might contaminate the samples for THM analyses. Sampling involved attaching a small diameter nylon rope to the end of the chain and dipping the bucket into the water to collect the sample. To avoid contamination, the rope was not allowed to enter the water.

The exception to the above sampling procedure occurred at Chipps Island. Because it was necessary to take samples at depth, a dipping bucket was not suitable. Therefore, an ordinary Van Dorn sampler was employed. (A Van Dorn sampler is a plexiglass cylinder stoppered on the ends by rubber closures.) Use of the Van Dorn was avoided in the other sampling because the sampler contains plastic and rubber materials that are generally unsuitable for collection of samples for oganic analyses. To eliminate doubt about sample contamination caused by the sampler, duplicate bucket and Van Dorn samples were taken at the surface of the station. (Analysis of the duplicate samples indicated that the Van Dorn sampler did not contaminate the samples.)

Both unfiltered and filtered samples were taken. The unfiltered samples were poured directly from the sampler into 40 mL glass vials with screw tops and Teflon® septa, as specified by EPA /8/. The vials were completely filled so that no airspace was present.

Filtered samples were obtained by use of a portable stainless steel Millipore® unit employing membrane filters with 0.45 uM pore size. The filtration equipment, like the sampling equipment, was prepared by detergent washing, wrapping in washed foil, and oven drying at 105°C for two or more hours. Following filtration, samples were poured into the 40 mL screw top vials that were earlier described.

Water samples for total organic carbon analyses were poured from the sampler into acid fixed 30 mL glass vials with glass stoppers, then sealed with washed foil. One exception to this procedure occurred at the Contra Costa Canal sampling station where filtered water was taken for total organic carbon analysis, in addition to the raw water sample.

Phytoplankton samples were poured from the sampler into 120 mL glass bottles containing approximately two mL of Lugol's fixative solution. Samples for mineral, color, and suspended solids analyses were poured from the sampler into pint-size polyethylene plastic bottles. Samples for chlorophyll extraction consisted of the 0.45 uM membranes used to filter samples for THM analyses. These membranes, which retained the algae in the raw water sample, were filtered to dryness, inserted into 2x4-inch manila envelopes, stored in a one-litre dessicator, and frozen on dry ice.

Field analyses were performed at the time of sampling. Temperatures were taken by means of a radial thermometer graduated in intervals of 0.5 degrees Celsius. Measurements of pH were performed by the use of a Hellige® colorimetric pH kit. Dissolved oxygen concentrations were determined in the field by the modified Winkler titration method, and electrical conductivity was determined by use of a Beckman SoluBridge®.

The samples for chlorophyll analyses were transported to the Department of Water Resources (DWR) Bryte Laboratory frozen on dry ice. All other samples were transported chilled. In most cases, samples were delivered to the laboratory on the day sampling occurred.

Most soil samples were collected at approximately 0.75 m (2 ft) depth, except where peat soils being sampled did not extend to that depth. In those cases, samples were taken about mid-depth in the peat layer. Core samples of approximately 500 grams were taken by use of a steel hand auger; the samples were placed in glass containers and kept chilled during shipment to the laboratory.

Analytical Methods

Upon delivery to the laboratory, raw water samples for Trihalomethane Formation Potential analysis were chlorinated at approximately 50 milligrams per litre (mg/L) chlorine dosage. The reason for using this high dosage was to assure a chlorine residual after the 7-day incubation period at 25°C. At the end of 7 days, samples were dechlorinated using sodium thiosulfate and analyzed by the purge and trap method of gas chromatographic analysis established by EPA /8,9/.

Finished drinking water samples for THM analyses were similarly analyzed by the purge and trap technique. Table 1 details the gas chromatographic conditions employed in the analyses.

Portions of the eight soil samples that were taken were composited into two samples, one comprised of mineral soils and the other consisting of peat soils from the alignment of the proposed Peripheral Canal. Twenty grams of the composite sample were extracted in one litre of distilled water by continuous tumbling at room temperature for 8 hours. No mixing beads were used.

The sample extracts were then filtered and the filtrate analyzed for Trihalomethane Formation Potential according to procedures already mentioned. Total organic carbon in each of the eight individual soil samples was also determined after the samples were extracted and filtered. (Extraction procedures were the same as those employed for the composite samples.)

All other analyses were performed according to Standard Methods /10/. An analytical quality control program is employed by the DWR laboratory. This program conforms to guidelines established by EPA and by the California Department of Health Services. Review of quality control data collected during this monitoring program indicated that analytical results were well within acceptable limits.

TABLE 1

GAS CHROMATOGRAPHIC CONDITIONS EMPLOYED*

Gas Chromatograph: MT 220 Microtek

Detector: C-200 Dohrman Microcoulometer

Column: 6' Glass tube, pyrex-U, 2 mm I.D.

Column Packing: n-Octane on Porisil-C 100/120 mesh (Supelco, Inc.)

Confirmation - 1% SP-1000 on Carbopack B (Supelco, Inc.)

Temperatures:
Injector - 200° C
Column - n-Octane; 50°C - 4 min, 6°C/min to 170°C, hold 4 min

1% SP-1000; 45°C - 4 min, 8°C/min to 220°C, hold 16 min

Carrier Gas:
N2; Flow - 40 ml/min

Recorder chart speed: 0.5 m/min

Sampler: 25 mls - Tekmar Liquid Sample

Concentrater LSC-2 — Purge 11 min; Desorb 4 min; Bake 10 min

Approximate Retention Times Minutes**

	n-Octane	SP-1000
Chloroform	5.5	13.2
Bromodichloromethane	8.5	15.9
Dibromochloromethane	11.25	18.4
Bromoform	13.75	21.0

*Reference Fed. Reg. Vol. 44, No. 233 - Purgeable Halocarbons Method 601

**Standards
Trihalomethane Mixture 4-8746. Supelco, Inc.,Bellefonte, PA 16823

DISCUSSION OF RESULTS

Comparison of Delta and State Water Project Waters to Nationwide Survey

Widespread concern about organic pollution of drinking water supplies led to a mandate in 1975 by the U. S. Congress for a comprehensive nationwide survey of the extent of the problem. The outgrowth of this mandate was the National Organics Monitoring Survey (NOMS) /11/.

In the NOMS study, water samples from 113 public water systems across the nation were collected and analyzed for organic pollutants. THMs were the pollutants found in the highest concentrations nationwide. In the last phase of the study, samples of finished drinking water were collected and handled in two ways: one set of samples was immediately analyzed for THMs; the other set of samples was allowed to stand 7 days until maximum (terminal) concentrations of THMs were attained. Table 2 demonstrates that the national average of the immediately analyzed samples was 53 ug/L total THMs and that the mean of the incubated (or terminal) samples was 100 ug/L. These data indicate that the THM-producing reaction is a relatively

Table 2

TRIHALOMETHANE CONCENTRATIONS IN DRINKING WATER OF SACRAMENTO-SAN JOAQUIN DELTA ORIGIN AS COMPARED TO NATIONWIDE SURVEY

		Total THM Concentration (μg/L)	
	Source Water	Instantaneous	Terminal
National Average (NOMS)[1]		53	100
Bollman Treatment Plant[2]	Contra Costa Canal	160	-
Patterson Treatment Plant[3]	South Bay Aqueduct	69	160
Del Valle Treatment Plant[3]	South Bay Aqueduct	53	140
Huron[4]	California Aqueduct	75	160
Avenal[4]	California Aqueduct	130	190
Dudley Ridge Farms[4]	California Aqueduct	110	210

[1] See Reference No. 11.
[2] See Reference No. 12.
[3] See Reference No. 13.
[4] See Reference No. 14.

slow one and that, generally, all the chlorine and THM precursors that are present in a freshly treated water supply do not react immediately to produce THMs. These data also indicate that, on a nationwide average, drinking water generally has sufficient chlorine and precursors to equal the established 100 ug/L MCL for drinking water.

Table 2 also presents data from samples taken from various water agencies that take water from the Delta and State Water Project. Contra Costa Water District uses water from the southern Delta; the intake to its system is the Contra Costa Canal, which draws water from Old River through Rock Slough. Samples taken in August 1978 and February 1979 indicated total THM concentrations in the finished drinking water of its Bollman Water Treatment Plant were 205 ug/L and 119 ug/L, respectively, and averaged 160 ug/L /12/. It should be noted, however, that the 205 ug/L value observed in August was higher than has generally been observed in that system. The values from Contra Costa Water District would compare to the immediately analyzed samples in the NOMS study.

Zone 7 of the Alameda County Flood Control and Water Conservation District takes water from the South Bay Aqueduct of the State Water Project. Data supplied from the agency indicates that, on average, both immediately analyzed and terminal samples contain higher THM concentrations than the national average. The average values of seven samples taken between August 1979 and July 1981 were 69 ug/L instantaneous and 160 ug/L terminal in water from their Patterson Treatment Plant. Water collected on the same seven dates from its Del Valle Treatment Plant averaged 53 ug/L for immediate analyzed samples, and 140 ug/L in terminal samples /13/.

Other data presented in Table 2 were collected from water systems supplied by the State Water Project. Huron, Avenal, and Dudley Ridge Farms are located in the San Joaquin Valley, and take water from the California Aqueduct. Analyses of their water supplies were performed by DWR in a manner similar to the NOMS /14/. The results indicate that California Aqueduct water produces higher THM values than the national average, based upon the NOMS work. It should be understood that the THM concentration that will be found in a particular finished water will depend upon variables such as pH, temperature, and system residence time of the water.

Santa Clara Valley Water District also takes water from the South Bay Aqueduct of the State Water Project. Samples are collected from their two treatment plants and from locations within the distribution systems of the two plants. Table 3 presents data from sampling of that system. Based upon monthly averages for 20 months beginning in January 1980, their Rinconada plant and associated distribution system averaged 98 ug/L, and ranged from 40 to 140 ug/L total THMs in samples immediately analyzed. Their Penitencia plant, on the other hand, averaged only 74 ug/L, and ranged from 35 to 120 ug/L total THMs /15/. These data indicate that variables connected with the treatment plants and/or distribution systems can cause varying concentrations of THMs in the final treated water.

The City of Vallejo draws much of its water supply from Cache Slough in the North Delta. Based upon analyses performed in 1978 and 1981, water from the Travis Air Force Base (which uses Cache Slough water) averaged 62 ug/L total THMs, thus meeting the 100 ug/L drinking water standard /16,17/.

The data presented in this section indicate that, in general, treated water from the Sacramento-San Joaquin Delta has higher THM concentrations than does water tested in a nationwide survey. Furthermore, these data indicate that under present conditions, additional treatment to remove THMs will probably

Table 3

TRIHALOMETHANE CONCENTRATIONS IN DRINKING WATER
OF SACRAMENTO-SAN JOAQUIN DELTA ORIGIN

	Average Monthly THM Concentration in Distribution System (µg/L)	Concentration Range (µg/L)
Rinconada Treatment Plant[1]	98	40 - 140
Penitencia Treatment Plant[1]	74	35 - 120
Travis AFB Water Treatment Plant[2]	62	28 - 152

[1] Data from Santa Clara Valley Water District. (Based on 20 months sampling.) See Reference 15.

[2] Data from City of Vallejo and California Department of Health Services. (Based on five samples.) See References 16 and 17.

be required for some or most State Water Project contractors south of the Delta that supply drinking water.

THMs may be eliminated by a number of processes. Selection of the process to be used in a particular treatment plant would depend upon a number of considerations. Three types of treatment that might be used are ammoniation, air stripping, and activated carbon adsorption. Estimated costs of these treatment methods, per million gallons, are $18, $95, and $195, on a January 1982 cost basis /18,19/.

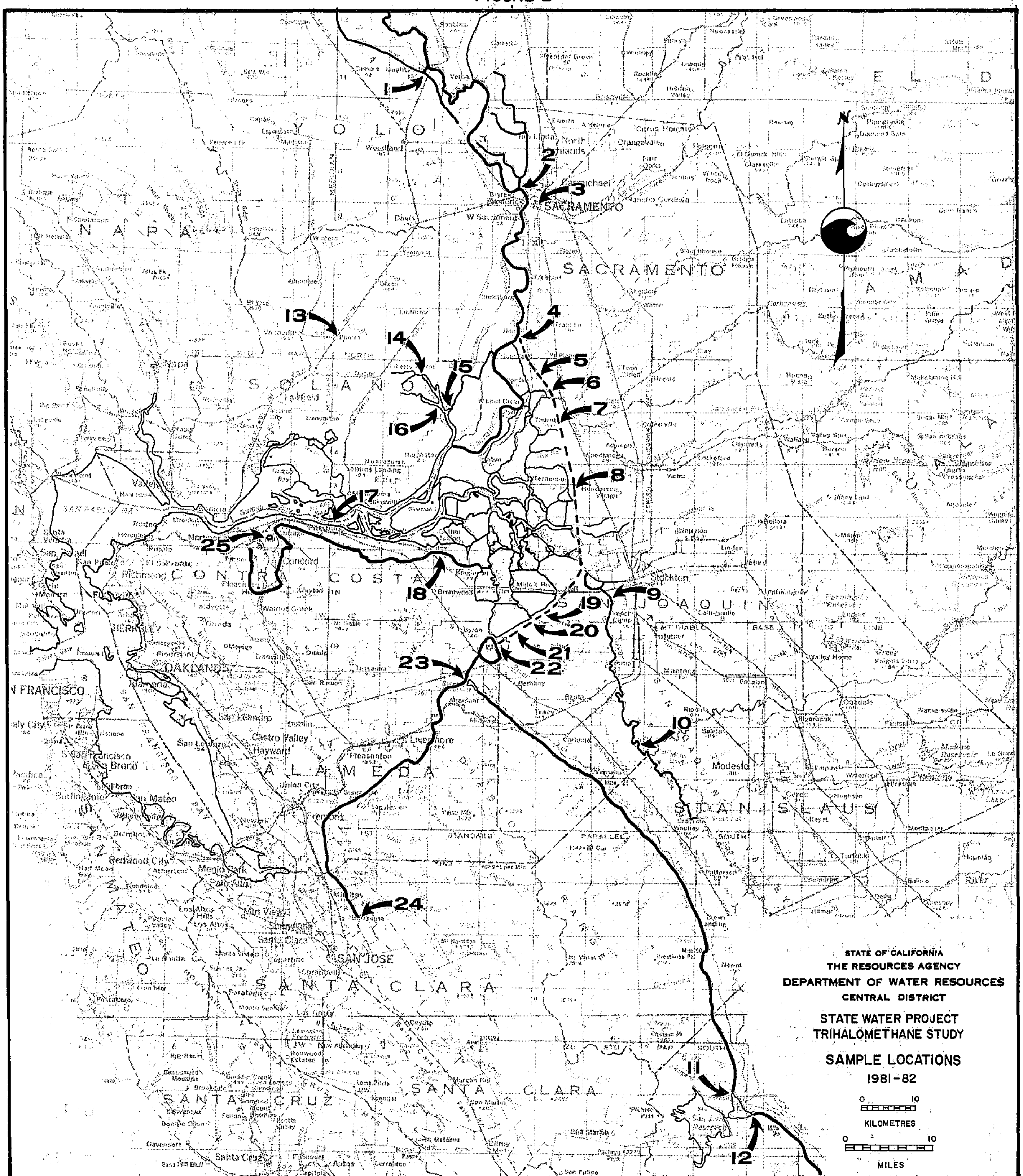
Additions of THM Precursors and Bromides Resulting from Water Transport Through Delta

Five Delta locations were sampled to determine the inputs of THM precursors to the Delta. These were the Sacramento River at Hood, the Sacramento River at Chipps Island, the Contra Costa Canal at Pumping Plant No. 1, the San Joaquin River near Vernalis, and the Harvey O. Banks Delta Pumping Plant Headworks. These locations are shown in Figure 2.

Water samples from these stations were analyzed for Trihalomethane Formation Potential by chlorinating the samples and holding them for 7 days prior to analysis for THMs. This was done to completely convert precursors in the raw water to THMs. This analysis is, therefore, an indirect measurement of the quantities of precursors contained in a raw water supply. Both unfiltered and filtered samples were taken to differentiate between particulate-associated and dissolved precursors. The data from the five Delta stations are summarized in Table 4.

Examination of the data in Table 4 will demonstrate that, on average, the Sacramento River at Hood has a lower THM formation potential than does the water at the other locations. However, it is significant that during wet weather

FIGURE 2


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
CENTRAL DISTRICT
STATE WATER PROJECT
TRIHALOMETHANE STUDY
SAMPLE LOCATIONS
1981-82
KILOMETRES
MILES
SACRAMENTO
SAN JOSE
OAKLAND
Stockton
Modesto
YOLO
NAPA
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
SANTA CRUZ
STANISLAUS
1
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5
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FIGURE 2 (Cont.)

State Water Project Trihalomethane Study
Sample Locations

Sample Location Number	Type of Sample Collected	Station Number	Station Description
1	Water	A0294500	Colusa Basin Drain at Knights Landing
2	Water	A0V83681312	Natomas Main Drain at W. El Camino Avenue
3	Effluent	A0W831513069	Sacramento Main Sewage Treatment Plant
4	Water	B9178000	Sacramento River at Hood
5	Mineral Soil	--	PC ℄ 15 metres s/o Borrow Pit #1 (0.6 metres deep)
6	Mineral Soil	--	PC ℄ 60 metres s/o Borrow Pit #3 (0.6 metres deep)
7	Mineral Soil	--	PC ℄ 10 metres n/o Borrow Pit # 5 (0.6 metres deep)
8	Mineral Soil	--	PC ℄ 10 metres n/o Borrow Pit # 9 (0.6 metres deep)
9	Effluent	B0W756211979	Stockton South Main Sewage Treatment Plant
10	Water	B0702000	San Joaquin River near Vernalis
11	Water	KA006680	California Aqueduct at Check 12
12	Water	KA007089	California Aqueduct at Check 13
13	Effluent	A0W820815429	Vacaville Easterly Sewage Treatment Plant
14	Water	B9D81781448	Cache Slough at Vallejo Pumping Plant
15	Water	B9D81461395	Miner Slough at Ryer Island School Road
16	Water	B9D81481424	Lindsey Slough near Rio Vista
17	Water	E0B80301550	Sacramento River at Chipps Island
18	Water	B9591000	Contra Costa Canal at Pumping Plant #1
19	Peat Soil	--	PC ℄ 50 metres s/o Hwy 4 and 15 metres e/o Tracy Blvd (0.6 metres deep)
20	Peat Soil	--	PC ℄ 100 metres w/o bend in Klein Road and 15 metres s/o pumphouse (0.6 metres deep)
21	Peat Soil	---	PC ℄ 10 m e/o easterly DWR test pond near the end of Calpack Road (0.6 metres deep)
22	Peat Soil	--	PC ℄ 10 metres w/o end of Bonetti Road and 30 metres sw/o pumphouse (0.25 metres deep)
23	Water	KA000331	Harvey O. Banks Delta Pumping Plant Headworks
24	Water	E6P724015001	Penitencia Water Treatment Plant, Santa Clara Valley Water District
25	Water	E4T80082024	Bollman Water Treatment Plant, Contra Costa Water District

TABLE 4

Trihalomethane Formation Potential in Five Delta Locations*

Sampling Location	Sampling Date	Maximum Trihalomethane Formation Potential (μg/L): Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Sacramento R. @ Hood	10/1/81	100	10			110	90	7			97
	11/17/81	260	11			270	300	10			310
	1/7/82	680				680	630				630
	Average	350	7.0			350	340	5.7			350
San Joaquin R. @ Vernalis	10/1/81	280	170	110	11	570	260	180	120	13	570
	11/17/81	590	100	19		710	500	120	29		650
	1/7/82	1 600	84			1 700	1 300	74			1 400
	Average	820	120	43	3.7	990	690	120	50	4.3	870
Delta P.P. Headworks	10/1/81	440	130	89	10	670	380	130	75	7	590
	11/17/81	160	77	29		270	190	96	36		320
	1/7/82	1 500	150	9		1 700	1 400	150	8		1 600
	Average	700	120	42	3.3	880	660	130	40	2.3	840
Contra Costa Canal @ PP	10/1/81	87	68	56	10	220	72	54	44	8	180
	1/11/82	1 600	130	7		1 700	1 900	160	9		2 100
	Average	840	99	32	5.0	960	990	110	26	4	1 100
Sacramento R. @ Chipps Island	11/9/81										
Surface	High Slack Tide		34	340	1,100	1,500		31	310	1,300	1,600
Deep	High Slack Tide	7	69	450	24,000	25,000		19	240	1,400	1,700
Surface	Low Slack Tide						5	84	290	720	1,100
Deep	Low Slack Tide						3	44	190	500	740
	1/5/82										
Surface	**High Slack Tide	590	19			610	550	17			570
Deep	High Slack Tide						460	9			470

* Blank spaces indicate concentrations were below detection limit.

** Sampling was performed at the predicted time of slack tide. Due to high outflow conditions, flow velocity did not reach zero.

conditions that occurred in November 1981 and January 1982, the Hood station had a higher THM formation potential than was observed during dry weather in October 1981. These observations probably reflect runoff from land surfaces and leaching of THM precursors from the soils of the Delta agricultural lands.

Perhaps more important, these data indicate that the water at Hood is essentially free of bromides. In the presence of bromides from sea water, chlorine is replaced in the THM reaction to yield brominated THMs. This phenomenon is significant in that brominated THMs are more toxic than are the chlorinated species /20/. Also, the brominated THMs can be more expensive to remove from a water supply than the chlorinated THMs /21/. Another aspect of the brominated THMs is that, because bromine has approximately twice the molecular weight of chlorine, brominated THMs are heavier and, therefore, count more toward the 100 ug/L drinking water limit for THMs.

Table 4 indicates that, with the exception of Hood, the stations measured have significant concentrations of brominated THMs. Examination of the data for Chipps Island reveals that during November 1981, the THM formation potential at that station was very high, and that brominated THMs were predominant.

The Chipps Island data also reveal that, at least on the occasions when sampling occurred, high THM formation potential and bromides existed regardless of whether the tide was low or high. However, the THM formation potential at high slack tide was higher than at low slack tide, averaging 1 600 and 920 ug/L total THMs, respectively, in filtered water samples. The data also indicate that during the extreme wet weather (high riverflow) conditions existing in January 1982, THM formation potential and bromide concentrations at Chipps Island were significantly lower than were observed in November 1981. The close similarity of the THM formation potentials at Chipps Island and Hood in January indicate the effect of the high Delta outflow in flushing the Delta.

The conclusion based upon data taken in November 1981 is that, at least during lower riverflow conditions, the Bay-Delta system is a major source of THM precursors and bromides.

Expected Effects of the Proposed Peripheral Canal in Reducing THM Concentrations in State Water Project Water Supplies

The data in Table 4 generally confirm work that has previously been done by the California Department of Health Services, Contra Costa Water District, Metropolitan Water District of Southern California, and James Montgomery Engineers. A summary of this previous work is attached as Appendix A to this report.

The DWR work indicates that during dry weather conditions such as those occurring during the October 1981 sampling, precursors were considerably lower at Hood than at the Headworks. Hood water had only 110 ug/L total THM formation potential in the unfiltered sample, as compared to the Headworks sample that had a THM formation potential of 670 ug/L, 230 ug/L of which were brominated. However, during wet weather conditions when riverflows were high, the difference in precursor concentrations was less obvious. At Hood, during a rainy period in November, the THM formation potential was 270 ug/L, the same as the THM formation potential at the Headworks. However, at Hood, only 11 ug/L of the total was brominated, while at the Headworks, 106 ug/L was brominated. These data clearly indicate that the waters at the Headworks are qualitatively different than the water at the Sacramento River at Hood.

The January 1982 sampling occurred during an extremely high outflow period, when Delta Outflow was about 5 700 cubic metres per second (200,000 cubic feet per second). The data indicate that waters at Hood had a THM formation potential of 680 ug/L, as opposed to 1 700 ug/L at the Headworks. During this period, the relatively lower concentrations of brominated THMs (160 ug/L) indicated increased salinity repulsion from the Delta.

An interesting observation is that although the San Joaquin River at Vernalis is upstream of the tidal influence of the Bay-Delta, bromides are present in the water at that location, indicating possible association with sea water. The October sample, for instance, had a THM formation potential of 570 ug/L, of which 290 ug/L were brominated. One likely explanation of this observation is that the lands upstream of the Vernalis station are irrigated with water taken from the southern Delta through the Central Valley Project of the U. S. Bureau of Reclamation. These irrigation waters contain bromides of sea water origin, as evidenced by our data collected at the Headworks. Another contributing factor may be runoff and drainage from marine sediments of the Coast Range.

Pumping Plant No. 1 of the Contra Costa Canal supplies water taken from Old River through Rock Slough in the southern Delta. Samples taken from this location in October 1981 contained considerably smaller concentrations of THM precursors than did the Headworks sample; the Contra Costa Canal sample had a THM formation potential of only 220 ug/L as opposed to 670 ug/L at the Headworks. The differences at these two stations may reflect inputs of surface runoff and agricultural drainages in the waters between the Contra Costa Canal intake at Rock Slough and Clifton Court; or the Contra Costa Canal data might be an anomaly. The January 1982 data from this station indicated much higher precursor concentrations than were observed in October (1 700 ug/L THM formation potential in the unfiltered sample). Most of the increase was in chloroform, an indication of increased precursor concentrations from surface runoff from land /22/.

To summarize, the waters of the western Delta contain higher concentrations of THM precursors and bromides than do the waters of the Sacramento River at Hood, at least during low outflow conditions. Also, agricultural drainages and surface runoff from Delta lands and lands along the San Joaquin River can be expected to contribute THM precursors to waters flowing through Delta channels. Therefore, from the standpoint of THM precursors and bromides, the water supply of the State Water Project and other southern Delta exporters would benefit from maximum isolation from the Bay-Delta system.

The Peripheral Canal would provide maximum hydraulic separation of State Water Project source water from the Delta and would, therefore, be the best apparent alternative for reducing THM precursors and bromides in State Water Project supplies. On the negative side, the Peripheral Canal itself could be capable of contributing precursors to the water flowing through it. This potential problem was examined; a full discussion of this work is presented on page 28 of this report. The conclusion was that the Peripheral Canal would not likely contribute seriously to the precursor load of the State Water Project waters transported through it. Water delivered into the State Water Project through the Harvey O. Banks Delta Pumping Plant should closely resemble the water at the Sacramento River at Hood in terms of precursor loadings and bromide concentrations.

THM data from the City of Sacramento are presented in Table 5. Samples of finished drinking water using the Sacramento River as a water supply indicate that THM concentrations consistently meet the established drinking water standard /23/. Water taken into the Peripheral Canal at Hood will be similar in quality to that taken from the Sacramento River by the City of Sacramento, except that urban and agricultural waste will be discharged into the river between the City of Sacramento's water intake and the Peripheral Canal intake. The largest discharge will be that of the Sacramento Regional Waste Water Treatment Plant, which will be discharging at a location about 13 km (8 mi) upstream of the proposed Peripheral Canal intake. The seasonal dry weather flow from this plant will be 136 million gallons per day (MGD), and the seasonal wet weather flow will be 142 MGD. Agricultural drainages into this stretch of river are considered to be insignificant.

Table 5

TRIHALOMETHANE CONCENTRATIONS IN DRINKING WATER FROM THE SACRAMENTO RIVER AT SACRAMENTO*

Sampling Dates	Average THM Concentrations in Four Distribution Systems Samples (µg/L)**				Total
	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	
April 23, 1980	Not Reported				60
July 22, 1980	Not Reported				58
December 10, 1980	39	7	3		49
April 29, 1981	38	5			43
September 2 and 3, 1981	66	18	<3		>84 <87

* Blank spaces indicate concentrations below detection limit.
** See Reference No. 22.

Effluent from the City of Sacramento's main waste water treatment facility was measured for THM precursors. The results indicate that, although the effluent contains THM precursors, their concentrations would not have a marked effect upon the precursor load of the Sacramento River, especially during times of high riverflow, when exports through the Peripheral Canal would be at a maximum. Based upon typical flows in the Sacramento River and projected flow data for the new Regional Treatment Plant, the plant will contribute about 8 ug/L to the precursor load of the Sacramento River during low water conditions (15,000 cfs), and about 1 ug/L during high flow conditions (80,000 cfs). This estimate assumes the THM formation potential of the Sacramento Main Waste Water Treatment Plant is indicative of the THM formation potential that will be present in the effluent of the new regional plant. The new plant, which is not yet operational, will treat waste water that is now being treated at the Sacramento Main plant, along with waste water now being treated at several other plants. Because not all of the added precursors will be converted to THMs in the actual treatment process, the contributions of precursors from the regional plant should be negligible. (The effects of waste water treatment plant effluents on THM precursor inputs are examined separately on page 27 of this report.)

Based upon the above discussion, implementation of the Peripheral Canal would probably result in a water supply that would consistently meet the drinking water standard, at least for points of delivery in the northern part of the State Water Project.

Because algae are capable of forming THM precursors, there is some question as to whether long distance transport of the water might be accompanied by increasing precursor concentrations in the water. This question was examined, and is discussed on page 31 of this report. The DWR investigation failed to indicate evidence of algal-derived precursors. However, a study by the Metropolitan Water District of Southern California (MWD), summarized in Appendix A, suggests that algal productivity in the State Water Project may lead to increased THM formation potential with increased transport distance. The MWD study therefore implies that the effects of the Peripheral Canal in reducing THM precursor concentrations in the waters delivered to Southern California are somewhat less predictable than for northern points of delivery.

Assuming algae or other plants may contribute THM precursors, nutrient concentrations would be highly significant factors influencing the amounts of plant growth. Table 6 compares nutrient concentrations in the Sacramento River at Green's Landing (near the proposed Peripheral Canal intake) to nutrient concentrations at the Headworks. Based upon these data, water taken through the Peripheral Canal would have only about one-fourth the concentration of nitrates as water currently being taken into the State Water Project through the Headworks.

Table 6

NUTRIENT COMPARISON
SACRAMENTO RIVER AT HOOD VS.
HARVEY O. BANKS DELTA PUMPING PLANT

Sampling Location	Mean Nutrient Concentration (mg/L)* Dissolved Nitrates (as N)	Ammonia + Organic N (as N)	Dissolved Ortho-phosphates (as P)	Total Phosphorus	
Sacramento River at Green's Landing	0.15	0.43	0.08	0.16	mean
	0.08	0.20	0.04	0.09	standard deviation
Harvey O. Banks Delta Pumping Plant Headworks	0.59	0.47	0.08	0.13	mean
(Headworks)	0.49	0.17	0.02	0.03	standard deviation

* Based on 70 months of sampling data collected from April 1972 through January 1979.

The lower concentration of nitrates resulting from implementation of the Peripheral Canal should markedly reduce aquatic growths in the State Water Project; therefore, precursor inputs from this source would be correspondingly reduced. This benefit would be evident even at distant points of delivery; and, even for more distant points, the Peripheral Canal would be effective in reducing bromides of sea water origin. In consideration of these factors the Peripheral Canal should enable significant reductions in THM concentrations even for more distant contractors such as MWD. Contractors that presently experience THM concentrations marginally higher than the drinking water limit should be able to meet the limit without additional treatment.

Expected Effects of Alternative Delta Facilities in Reducing THM Concentrations in Water Supplies of the State Water Project

Through-Delta conveyance facilities have been proposed as alternatives to the Peripheral Canal for improving the efficiency of water transport through the Delta and of meeting water quality criteria of the State Water Resources Control Board. These alternatives would have two advantaqges over present conditions: (1) reverse flows in the lower San Joaquin River would be reduced or eliminated; therefore, THM precursors and bromides coming from the western Delta would be reduced; and (2) travel time of the water across the Delta would be reduced, resulting in less exposure of the water to precursors from Delta soils and agricultural drainages.

Examination of the data in Table 4 will demonstrate that, during the relatively low Delta outflow (25,000 cfs) occurring in November 1981, the Sacramento River at Chipps Island was high in THM precursors and bromides. The average THM formation potential of the filtered samples was 1 300 ug/L, as opposed to 310 ug/L and 320 ug/L, respectively, in the Sacramento River at Hood and at the Headworks. Brominated THMs predominated at Chipps Island. During these flow conditions, a through-Delta conveyance facility that reduced contact between waters of the State Water Project and western Delta would be beneficial in reducing THM formation of project waters. By eliminating reverse flows in the lower San Joaquin River, a through-Delta conveyance facility would have that effect.

During the high outflow conditions experienced in January (200,000 cfs), the waters of the Sacramento River at Chipps Island and at Hood are similar in THM formation potential. Therefore, during these flow conditions, the waters of the State Water Project would not be greatly affected by intermixing with waters from the Chipps Island vicinity.

Further examination of Table 4 will show that there was a marked difference in THM potential in January between the Sacramento River at Hood and the Headworks (630 ug/L and 1 600 ug/L, respectively). These data indicate that Delta and northern San Joaquin Valley agricultural drainages are important sources of THM precursors, especially during high flow conditions. Unlike the Peripheral Canal, a through-Delta conveyance facility would not prevent these sources from entering the State Water Project.

To summarize, during low flow conditions, a through-Delta conveyance facility would be beneficial in reducing THM precursors and bromides from the western Delta. However, such a facility would not eliminate agricultural drainages which, during high flow conditions, can be especially important sources of THM precursors.

Sources of THM Precursors to the Proposed Second Phase of the North Bay Aqueduct

Three sloughs in the area of the proposed second phase of the North Bay Aqueduct were monitored to determine possible sources of THM precursors; also, the Vacaville Easterly Waste Water Treatment Plant, which discharges into the area, was monitored. Figure 2 shows the sampling locations. Table 7 summarizes data from the sampling that was done in Cache, Lindsey, and Miner Sloughs. Cache Slough at Vallejo Pumping Plant intake had generally higher THM formation potential than was found at Lindsey or Miner Sloughs. The averages of three samplings were 630 ug/L total THM formation potential for Cache, 480 ug/L for Lindsey, and 440 ug/L for Miner Slough, in filtered samples. The concentrations of THM precursors at Lindsey and Miner Sloughs appear similar and probably reflect typical concentrations in the area. The reason for apparent elevated concentrations in Cache Slough water is not known. A possible explanation is that, as the Cache Slough water has a longer residence time than the waters of Miner and Lindsey Sloughs, higher concentrations of precursors may be picked up from the soils. This possibility was suggested by Nelson and Khalifa /24/.

It will be proposed that the second phase of the North Bay Aqueduct divert water from Cache Slough. Operation of the North Bay Aqueduct with that diversion point will cause higher flows into Cache Slough from Miner Slough. The quality of North Bay Aqueduct water will, therefore, closely resemble the present quality of the water in Miner Slough.

Effluent of the Easterly Waste Water Treatment Plant discharging into Cache Slough through Alamo Creek had a THM formation potential of 320 ug/L in the filtered sample, well below the THM formation potential found in the slough (see Table 9). Therefore, the Easterly plant is apparently not a major source of THM precursors in Cache Slough. Because plans exist to relocate the Easterly plant discharge to Lindsey Slough by way of Barker Slough, this discharge will not be a continuing

TABLE 7

TRIHALOMETHANE FORMATION POTENTIAL AT THREE NORTH DELTA LOCATIONS*

Sampling Location	Sampling Date	Maximum Trihalomethane Formation Potential (µg/L)									
		Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Cache Slough @ Vallejo P.P.	10/1/81	540	43	5.0		590	550	62	5.0		620
	11/9/81						450	47			500
	1/6/82	860	20			880	750	20			770
	Average	700	32	2.5		740	580	43	1.7		630
Lindsey Slough nr. Rio Vista	10/1/81	260	19			280	270	36			310
	11/9/81						280	22			300
	1/6/82	1 000				1 000	840				840
	Average	630	9.5			640	460	19			480
Miner Slough	10/1/81	270	16			290	240	19			260
	11/9/81	370	24			390	270	13			280
	1/6/82	700				700	770				770
	Average	450	13			460	430	11			440

* Blank spaces indicate concentrations below detection limit.

source of THM precursors to the North Bay Aqueduct.

Agricultural runoff may prove to be the most important source of THM precursors in Cache Slough. The recommendations section of this report suggests other monitoring that may help to determine the sources of elevated THM precursors in Cache Slough.

Agricultural Drains as Sources of THM Precursors

Agricultural drains are common throughout the Sacramento River and San Joaquin River basins, and within the Delta. In this monitoring program, two agricultural drains were sampled to determine the concentrations of precursors contributed from these sources. The drains sampled were the Colusa Basin Drain, which discharges into the Sacramento River at Knights Landing, and the Natomas Main Drain, which discharges into the Sacramento River about 2 km (1 mi) upstream of the American River. Locations of these drains are shown in Figure 2.

Each of these drains was sampled on two occasions: once during dry weather in October, and again during wet conditions in December 1981. Table 8 presents the data resulting from these samplings.

The sample from the Natomas Drain taken in October showed three times as much THM formation potential as was found in the sample from the Sacramento River at Hood: 330 ug/L and 110 ug/L, respectively, in unfiltered samples (see Table 4).

Colusa Drain waters contained concentrations (420 ug/L) similar to Natomas Drain water. The December samples from these drains had THM formation potentials of 1 500 ug/L and 1 200 ug/L in unfiltered samples. By contrast, an unfiltered sample taken from the Sacramento River at Hood on January 7, 1982, had a THM formation potential of only 680 ug/L.

These data indicate that agricultural drainages might be expected to contain two to three times the concentrations of THM precursors in the Sacramento River at Hood. However, as filtration of the drain samples reduced the THM formation potential by about 25 percent, not all of the precursor loading from the drains would be expected to survive a water treatment process employing coagulation and filtration.

TABLE 8

TRIHALOMETHANE FORMATION POTENTIAL IN AGRICULTURAL DRAINAGE*

Sampling Location	Sampling Date	Maximum Trihalomethane Formation Potential (µg/L) Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Natomas Main Drain @ W. El Camino	10/14/81	270	50	10		330	240	53	13		310
	12/30/81	1 500	36			1 500	900	42			940
	Average	880	43	5.0		920	570	48	6.5		620
Colusa Basin Drain @ Knights Landing	10/14/81	390	32			420	420	34			450
	12/30/81	1 100	66	1.6		1 200	710	41	1.4		750
	Average	740	49	1		810	560	38	1		600

* Blank spaces indicate concentrations below detection limit.

At certain times, total drainage flows into the Sacramento River are large, and can have a significant effect upon the precursor loading of the water supplies of the State Water Project. Increased THM formation potential in the waters of the Sacramento River at Hood during high runoff conditions occurring in January may in part reflect agricultural drainage.

Agricultural drainages in the Sacramento-San Joaquin Delta and northern San Joaquin Valley are probably important sources of THM precursors. These drainages would be eliminated as sources to the State Water Project if the Peripheral Canal is built.

Waste Water Treatment Plant Discharges as Sources of THM Precursors

Three waste water treatment plant discharges were monitored to determine the effects of these discharges in contributing THM precursors to State Water Project water supplies. The three were the Sacramento Main, the Stockton East, and the Easterly waste water treatment facilities. (The Easterly plant treats waste water from the City of Vacaville.)

Table 9 displays the data from this monitoring. The data demonstrate that bromides are present in the effluents, as evidenced by the presence of brominated THMs in the treated samples. The sources of the bromides are not evident from these data.

Filtration greatly reduced the THM formation potential in the samples, from 830 ug/L to 230 ug/L, total THMs as an average of the total THM concentrations in effluents from the three plants. This represents an approximate 70 percent reduction of precursors in filtered water. These data indicate that although waste water treatment plants contribute relatively high levels of precursors to the receiving waters (up to 1 000 ug/L at the Easterly plant), the precursors are to a large degree associated with particulates in the water. We may, therefore, conclude that most of the precursors would be removed in a water treatment plant employing coagulation and filtration processes. Based upon these data, contributions to State Water Project water supplies from waste water treatment facilities would not constitute an important source of precursors as compared to other sources.

TABLE 9

TRIHALOMETHANE FORMATION POTENTIAL OF WASTE WATER TREATMENT PLANT EFFLUENTS*

Maximum Trihalomethane Potential (μg/L)

Treatment Plant	Sampling Date	Unfiltered Sample				Filtered Sample			
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	Total
Sacramento Main	10/6/81	860	32		890	98	12		110
Stockton South	10/6/81	520	79	8	610	200	39	18	260
Easterly (City of Vacaville)	10/6/81	760	260		1 000	280	31	5	320
	Average	710	120	2.7	830	190	27	7.7	230

* Blank spaces indicate concentrations below detection limit.

Expected Contribution of THM Precursors from Soils Lining the Peripheral Canal

To investigate the possible contributions of precursors from the soils of the proposed Peripheral Canal, soil samples were taken at various points along the proposed alignment. Figure 2 displays the proposed alignment, shows the soil types of the area, and shows the locations of the samples taken.

In all, eight soil samples were collected: four along the northern portion of the alignment where soils are generally of a mineral character, and four along the southern part of the alignment where peat soils exist. In the peat soil area, the depth of the peat ranges from 0 to about 3 metres in thickness; the average depth of the peat soils along the proposed Peripheral Canal alignment is probably on the order of one metre. Generally, very fine clay was observed below the peat soils in areas where the sampler was able to penetrate the peat layer. Table 10 presents the THM precursor data from water extracts made from the soil. The data show that, indeed, the soils contain considerable amounts of precursors. Total THM formation potential was 61 000 ug/kg in the peat composite sample and 27 000 ug/kg in the composite sample of mineral soils.

TABLE 10

TRIHALOMETHANE FORMATION POTENTIAL OF SOILS IN PROPOSED PERIPHERAL CANAL ALIGNMENT*

Sampling Location	Sampling Date	Maximum Trihalomethane Formation Potential (μg/Kg) Filtered Soil Extract				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Composite Sample of Mineral Soils Along Northern Alignment	12/1/81	27,000				27,000
Composite Sample from Peat Soils Along Southern Alignment	12/1/81	61,000				61,000

* Blank spaces indicate concentrations below detection limit.

When interpreting these data, it should be realized that the above values represent the total THM precursor concentrations contained in the soil samples. Whether and to what extent the precursors would enter the water would depend upon numerous factors.

A factor that would enhance leaching of THM precursors from some unlined channels is erosion due to wave-wash caused by winds and boating activities. Such erosion occurs in many of the present Delta channels because of steep side slopes and a lack of rooted aquatic plants. The Peripheral Canal embankments would have side slopes of 3:1 and in certain recreational areas 8:1. These more gentle slopes would provide shallow margins that would encourage growths of rooted aquatic plants which should dampen waves near the shores and greatly reduce erosion due to wave-wash.

A similar factor that would increase leaching is scour -- the erosion resulting from high water velocities. In the present Delta channels, particularly during lower flow conditions, the greatest velocities are due to tidal oscillation. The Peripheral Canal would be free of tidal influence and its slope and cross-sectional area will be designed to keep velocities below levels that would cause scour. Thus, scour would not be an important cause of THM precursor leaching in the Peripheral Canal.

Although the peat soils have more than twice the THM formation potential found in the inorganic soils, the depth of the peat layer averages only about one metre (three feet). Because of the thinness of the peat soils, they would constitute only a small portion of the wetted perimeter of the canal. This would minimize the amount of precursors these soils would introduce into the overall volume of canal water.

During initial operation of the Peripheral Canal, precursors in the soil directly in contact with the water (soil-water interface) can be expected to quickly dissolve into the water. Consequently, precursor concentrations in the water would increase, perhaps dramatically. This phenomenon should be very short-lived, however, as the soluble precursors at the interface would be rapidly exhausted.

After the initial phase of precursor extraction from soils in direct contact with the water, the rate of precursor leaching into the water would be controlled by diffusion of THM precursors through the interstitial water of the canal soils. (Interstitial water is water that occupies small spaces between soil particles.) Such control has been demonstrated in similar cases involving nutrient release from submerged soils /25/. Because diffusion is a very slow process, the leaching rate would be much lower during this leaching phase.

Interstitial diffusion of precursors would be further reduced by siltation from the 544 000 tonnes (600,000 tons) of silt that would be carried annually into the Peripheral Canal from the Sacramento River system /26/. Because the elevation of the water in the Peripheral Canal would be above the elevation of the local ground water, silt-laden water will initially flow out of the canal and into the adjacent soils. Besides sealing leakage from the canal, the silt in the seepage water would displace the interstitial water and, thereby, greatly reduce diffusion of THM precursors into the canal water*.

As the elevation of the canal water will be higher than the adjacent ground water, there will always be pressure acting against the walls of the canal that will further reduce diffusion.

While the time required to reach stability cannot be accurately estimated, we expect the process would take from a few months to one year. This expectation is based upon previous experience in the initial filling of State Water Project reservoirs. In those reservoirs, initial filling has generally been accompanied by elevated nutrient release from the soils. After operating for a few months, however, the nutrient levels have dropped to normal. The leaching process in the Peripheral Canal should closely resemble that found in new reservoirs.

The distance traveled and the route traversed by waters of the State Water Project are two additional factors which affect the amount of THM precursors added to these waters by contact with Delta soils. The Peripheral Canal would provide a shorter route through these soils than the route currently traveled through existing channels. Furthermore, the canal would traverse less of the peat soils than are currently traversed by the existing Delta channels. Because of these factors, the Peripheral Canal would reduce exposure to the soils of the Delta and, therefore, decrease leaching from those soils into the State Water Project. In consideration of the fact that the Peripheral Canal would also eliminate Delta agricultural drains, the canal would obviously be the best alternative for minimizing the effects of Delta soils upon the State Water Project.

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*Silt deposition is expected to occur during the early years of operation of the Peripheral Canal when canal flows are below design capacity. In later years of operation, under higher flows, no net silt deposition is anticipated. Due to these considerations, the need for dredging for silt removal is not foreseen.

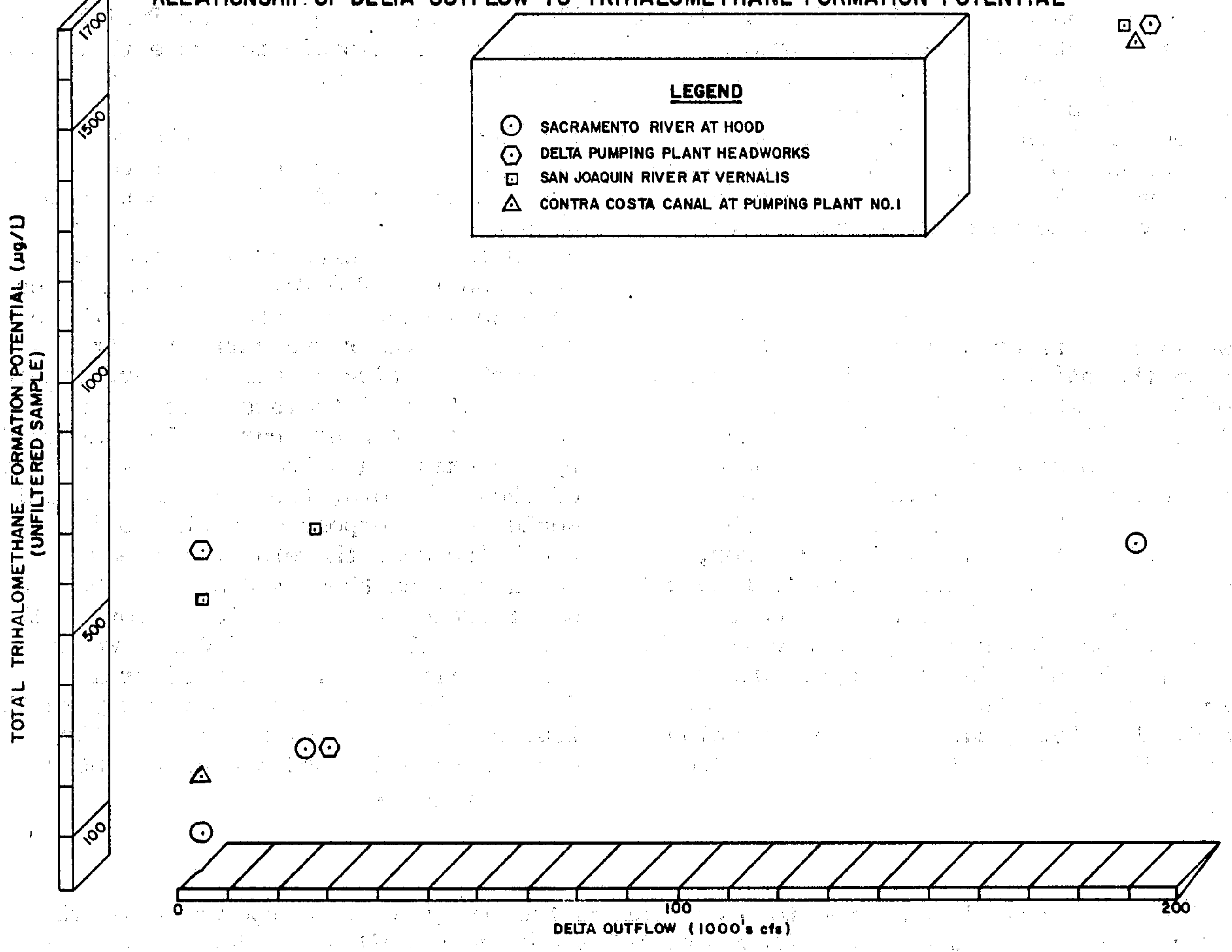
Seasonal Fluctuations in Precursor Concentrations

Fluctuations Related to Seasonal Precipitation

Sampling was conducted during both very dry and very wet weather to evaluate the effects of changing water flows on THM precursor concentrations in waters of the State Water Project. Figure 3 depicts the observed relationship between the Delta Outflow Index and THM formation potential. Although the data are somewhat sparse, there is an apparent relationship between higher outflows and higher THM formation potentials. The studies by Contra Costa Water District and the California Department of Health Services, summarized in Appendix A, indicated an opposite relationship. These studies occurred during the last part of the 1976-77 drought when Delta outflows were low, generally less than 5,000 cfs. During that period, increasing Delta outflows were accompanied by decreased THM concentrations in drinking water of Delta origin.

FIGURE 3

RELATIONSHIP OF DELTA OUTFLOW TO TRIHALOMETHANE FORMATION POTENTIAL



An hypothesis advanced by Nelson and Khalifa was that increased residence time of the water, associated with lower outflows, would cause greater precursor pickup from the Delta.

The apparent conflict in these data can be understood in light of the fact that the DWR sampling was conducted over a Delta outflow range much larger than the former work. The residence time of the water in the Delta probably is related to precursor pickup from Delta soils. Certainly the DWR soil sampling data indicate that those soils contain significant amounts of precursors. However, during periods of high surface runoff from the soils of the valley watersheds, it appears that even more precursors are derived from this source than from Delta soils.

Therefore, according to this hypothesis, the effects of residence time in the Delta are overpowered during periods of high runoff, and the net effect is a total precursor loading that increases with increasing Delta outflow. The DWR data further imply that fixed volume discharges such as those of waste water treatment plants are not primary sources of THM precursor inputs. If they were, one would expect concentrations in the receiving water to decline with increasing riverflow, in response to dilution.

Evidently, based upon the information collected in this program, the primary source of THM precursors to the water supplies of the State Water Project is runoff from land surfaces.

Fluctuations Related to Seasonal Plant Growths

Questions have also arisen as to whether aquatic growths in the proposed Peripheral Canal could contribute THM precursors. A recent paper suggests that algae may be an important source of precursors /27/. Quite likely, rooted aquatic plants also contribute precursors because of their similarity to algae in organic makeup. Because the proposed Peripheral Canal would be unlined, growths of algae and rooted plants would seem likely to occur.

To investigate this potential problem, a test site was studied. O'Neill Forebay is located near Los Banos in the San Luis Field Division of the State Water Project. Figure 4 shows the location. Inflows to O'Neill Forebay can come from Check 12 of the California Aqueduct, from adjacent San Luis Reservoir, and from the U. S. Bureau of Reclamation's Delta Mendota Canal (DMC) through the O'Neill Pumping Plant. Outflows from the reservoir can be through Check 13 of the California Aqueduct, pumping into San Luis Reservoir and releases into the DMC through O'Neill Pumping Plant.

O'Neill Forebay is a shallow reservoir with a surface area of about 890 hectares (2,200 acres). Light penetration to the reservoir bottom occurs over perhaps 50 percent of the surface area of the reservoir. This configuration is conducive to extensive growths of rooted aquatic plants and algae, which grow each spring and summer then decay during each fall. O'Neill Forebay was selected as a good place to determine whether aquatic growths are major contributors of THM precursors to waters of the State Water Project.

An assumption was made that during the fall, precursor contributions from plant growths would be at a maximum, associated with the annual plant decay pattern. Accordingly, water samples were collected from Check 12 and from Check 13, the inlet and outlet of O'Neill Forebay, respectively, on September 30, 1981. At that time the weed growths in the Forebay were decaying, but extensive growths were still observed to be present. Table 11 presents the data that were collected.

THM formation potential did not differ markedly from the inlet to the outlet of the forebay. In fact, the THM formation potential appeared somewhat smaller at the outlet (500 ug/L at the outlet, as compared to 580 ug/L at the inlet in unfiltered samples). This may have been due to analytical variation or to dilution of forebay waters with water flowing in from O'Neill Pumping Plant. The effect of the water flowing in from the DMC should have been minimal, however, because that inflow on September 30 was only 1 400 dam^3, as opposed to the 4 400 dam^3 inflow that came in through Check 12 that day /28/. Also, during the previous week's operations, only 4 070 dam^3 of DMC water was pumped into O'Neill Forebay, while 31 700 dam^3 of State Water Project water entered the reservoir during the same time period. No water releases from San Luis Reservoir had occurred for the previous week. Total O'Neill Forebay storage on September 30 was about 59 000 dam^3. Therefore, the quantity of water that flowed into the forebay during the last week in September constituted about half of the volume of the forebay.

It appears reasonable that the September 30 samples at Check 13 would have contained maximum precursor concentrations due to plant growths in the forebay. As elevated THM formation potentials were not observed, aquatic growths in O'Neill Forebay were evidently not an important source of precursors at the time of our sampling. To reach a firm conclusion on whether and to what extent aquatic plant growths may add THM precursors to the water, additional monitoring will be required.

TABLE 11

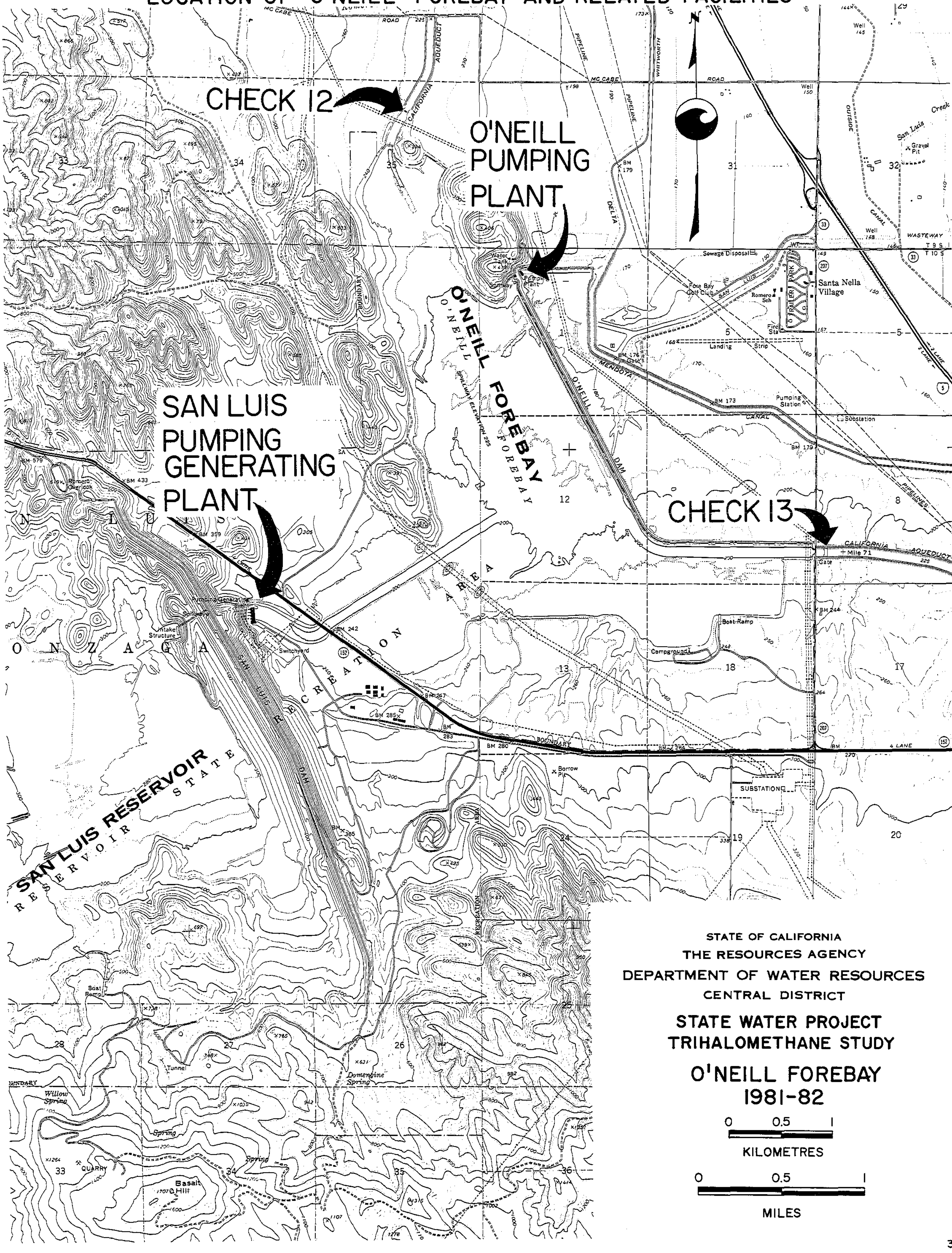
Trihalomethane Formation Potential
Associated with Aquatic Vegetation

Maximum Trihalomethane Potential (µg/L)

Location	Sampling Date	Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBR_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Check 12 Cal. Aq.	9/30/81	300	150	110	20	580	270	140	91	14	520
Check 13 Cal. Aq.	9/30/81	190	160	130	17	500	230	200	120	16	570

FIGURE 4

LOCATION OF O'NEILL FOREBAY AND RELATED FACILITIES



REFERENCES

1. Rook, J. J., "Formation of Haloforms During Chlorination of Natural Water". Water Treatment and Examination. 23-Part 2 (1974) 234-243.

2. Beller, T. A., et al, "The Occurrence of Organohalides in Chlorinated Drinking Water". J. American Water Works Assn. 66:703-706 (December 1974).

3. National Cancer Institute, 1976, "Report on Carcinogenesis Bioassay of Chloroform".

4. Buncher, C. R., 1975, "Cincinnati Drinking Water -- An Epidemiologic Study of Cancer Rates". University of Cincinnati Medical Center, Cincinnati, Ohio.

5. Canter, K., et al, 1978, "Association of Cancer Mortality with Halomethanes". J. of National Cancer Inst. 61:979-985.

6. DeRowen, T. A., and Diem, J. F., 1975, "The New Orleans Drinking Water Controversy: A Statistical Perspective". American Journal of Public Health. 65:(No. 10):1060.

7. Federal Register. 44, No. 231 (November 29, 1979). 68624-68707.

8. Federal Register 44, No. 231 (November 29, 1979) Appendix C, Part III. 68690-68691.

9. Federal Register 44, No. 231 (Thursday, November 19, 1979). Appendix C, Part I. 68672-68682.

10. "Standard Methods for the Analysis of Water and Waste Water". 15th Ed. American Public Health Association, Washington, D. C.

11. National Organics Monitoring Survey. Federal Register 44, No. 231 (Thursday, November 29, 1979). Attachment 7. 68690-68694.

12. "Contra Costa County Water District Water Quality Study, Volume 1, November 1980. James M. Montgomery, Consulting Engineers, Inc. pp. 3-1 through 3-32.

13. Unpublished data. Courtesy of Mr. Mun J. Mar, General Manager, Zone 7, Alameda County Flood Control and Water Conservation District. 1404 Concannon Boulevard, Livermore, California 94550.

14. Unpublished data. DWR (1981). Average of ten samples collected from August 1979 to July 1981.

15. Unpublished data. Courtesy of Ms. Elizabeth Haden, Santa Clara Valley Water District, Rinconada Water Treatment Plant. 400 More Avenue, Los Gatos, California 95030.

16. Unpublished data. Courtesy of Mr. Phil Harten, City of Vallejo, Fleming Hill Water Treatment Plant, 202 Fleming Hill Road, Vallejo, California 94589.

17. Nelson, S. J., Khalifa, S. (undated). "Trihalomethane Levels in Sacramento River System Water Supplies". Memorandum Report. California Department of Health Services, 2151 Berkeley Way, Berkeley, California 94704.

18. Clark, R. M., "Evaluating Costs and Benefits of Alternative Disinfectants". J. American Water Works Assn. 73:2:92 (February 1981).

19. Argo, D. G., "Cost of Wastewater Reclamation at Water Factory 21". Orange County Water District, Fountain Valley, California. Memorandum Report.

20. Federal Register. 44, No. 231 (November 29, 1979). 68628,68696-7.

21. Symons, J. M., et al. (1981). "Removing Trihalomethanes from Drinking Water - An Overview of Treatment Techniques". Water Engineering and Management. July 1981, p. 56.

22. Borchardt, J. A., et al., ed. (1977). "Viruses and Trace Contaminants in Water and Wastewater". Ann Arbor Science Publ., pp. 78-85.

23. Unpublished data. Courtesy of Mr. Lee J. Harry, City of Sacramento, Division of Water and Sewers, American River Water Treatment Plant, 1301 Jedsmith Drive, Sacramento, California 95819.

24. Nelson, S. J., Khalifa, S. (1980). "Trihalomethane Levels in Public Water Supplies Drawn from the Sacramento River System". J. American Water Works Assn. 72:7:423-426 (July 1980).

25. Stumm, W., Leckie, J. O. (1971). "Phosphate Exchange with Sediments; its Role in the Productivity of Surface Waters". In: Proc. 5th International Water Pollution Research Conference. July-August 1970. Publ. 1971, Pergammon Press. p. III-26/13.

26. DWR (1980), Memorandum Report, "Peripheral Canal-Seepage", May 1980.

27. Hoehn, R. C., et al., (1980). "Algae as Sources of Trihalomethane Precursors". J. American Water Works Assn. 72:6:344-350. (June 1980).

28. DWR, "State Water Project Report of Operations". September 1981. (Table 25), p. 25.

29. Lange, A. L., Kawczynski, E., "Controlling Organics: The Contra Costa County Water District Experience". J. American Water Works Assn. 70:11:653-660. (November 1978).

30. McGuire, M. J., et al. (1980). "Surface Water Supply Trace Organics Survey, Phase I - Maximum Trihalomethane Potential". The Metropolitan Water District of Southern California, P. O. Box 54153, Los Angeles, California 90013.

31. Shepherd, B. M., et al. (1981). "Surface Water Supply Trace Organics Survey, Phase II - Maximum Trihalomethane Potential". The Metropolitan Water District of Southern California, P. O. Box 54153, Los Angeles, California 90013.

APPENDIX A

SUMMARY OF PREVIOUS STUDIES

APPENDIX A

SUMMARY OF PREVIOUS STUDIES

Department of Health Services Study /17/

Raw water and finished water samples were collected from nine water treatment facilities. These facilities obtain their water from the Sacramento River system or from the Delta. The samples were tested for trihalomethanes, using a toluene liquid-liquid extraction. Figure A-1 presents the total trihalomethane (TTHM) concentrations in the treated waters during four different sampling periods. The figure shows that the four treatment plants located upstream of Delta influence produced finished water with lower TTHM concentrations than did the five plants affected by the Delta. Figure A-2 depicts the concentrations of TTHMs in the finished water of the Sacramento River Water Treatment Plant in Sacramento and of the Alameda County Flood Control and Water Conservation District Zone No. 7 Treatment Plant. (This plant treats water from the South Bay Aqueduct of the SWP.) It will be observed that the THM concentrations from the Zone 7 plant exceeded those in water from the Sacramento plant, and on one sampling occasion, Zone 7 water exceeded the EPA standard. It should be pointed out that the quality of the waters sampled during this study was probably affected considerably by the 1976-77 drought.

Contra Costa Water District Study /29/

A testing program for trihalomethanes was started in November 1974. From then through the middle of 1976 the TTHM concentration met the EPA standard of 100 ug/L. From late 1976 through January 1978 the THM concentration failed to meet the standard. This latter period occurred in the final two-thirds of the 1976-77 drought. Analysis for chlorides indicated that concentrations of this ion rose and fell in fairly good correlation with the TTHM values. The study concluded that this correlation indicated that the higher TTHM values had been the result of increased sea water intrusion during the drought. Figure A-3 graphically presents the chloride and TTHM concentrations observed from January 1975 through January 1978. The TTHM analysis included liquid-liquid extraction followed by gas chromatography.

J. M. Montgomery Consulting Engineers Study /12/

Raw water was collected from various stations in the Sacramento River and Delta on four occasions in 1979. The samples from each station were divided; part of the sample was treated with coagulant and allowed to settle. The other part of the sample was not altered. Then, both parts of the sample were subjected to chlorination and allowed to stand for 7 days. At the end of that time, the samples were analyzed for THMs. Figure A-4 presents the data for the Clifton Court and Sacramento River (at Walnut Grove) stations that were sampled. Figure A-4 indicates that there was considerable variation in THM formation potential among the periods sampled. Looking only at the raw water data, Sacramento River and Clifton Court waters appear not much different in maximum values; however, the settled Sacramento River water is consistently lower in THM formation potential than is settled Clifton Court water. These data indicate that there are qualitative differences in THM precursors at the two stations, and that the settled water values may be a better indication of the expected THM concentrations in finished water.

The Metropolitan Water District of Southern California Study /30,31/

Raw water samples were collected during the dry weather conditions of October 1979 and during the wet conditions of February 1980. Several stations were sampled including the Sacramento River at Hood and the Delta Pumping Plant Headworks. Figure A-5 presents data for these two stations. During October 1979, Delta Pumping Plant samples had about twice the THM formation potential as Sacramento River samples. During February 1980, both samples had higher THM formation potentials; although the Sacramento River had a somewhat lower potential than the Delta Pumping Plant sample, the difference was minor.

Figure A-6 summarizes data from samples collected in February 1980 at various points along the Sacramento River and State Water Project. THM formation potential increased between the Headworks and O'Neill Forebay, a possible indication of THM precursor contributions by biological growths in the aqueduct. THM formation potential apparently decreased in O'Neill Forebay, possibly due to the effects of impoundment of the water in the forebay or in San Luis Reservoir. THM formation potential was still higher at Tehachapi Afterbay and at Devil Canyon, further indicating possible inputs of THM precursors from biological growths. However, THM formation potential in water from Castaic Lake was lower, perhaps reflecting effects of reservoir impoundment of the water.

The samples collected in February had a large content of suspended material so a glass filtered sample was collected at each of the ten sampling locations. An unfiltered control sample was collected at two of the stations. Hexane was used in the liquid-liquid extraction.

FIGURE A-1
DEPARTMENT OF HEALTH SERVICES STUDY

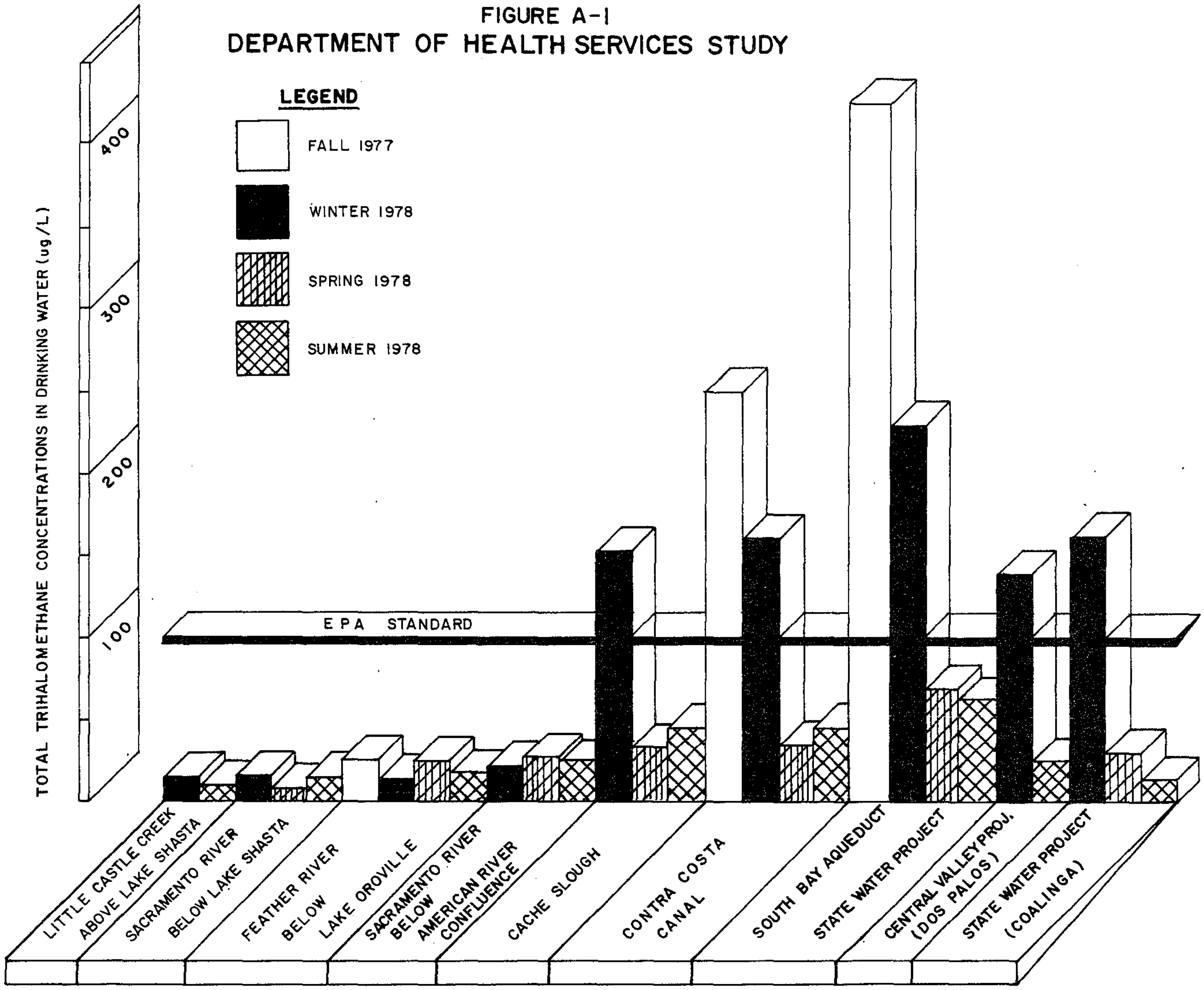
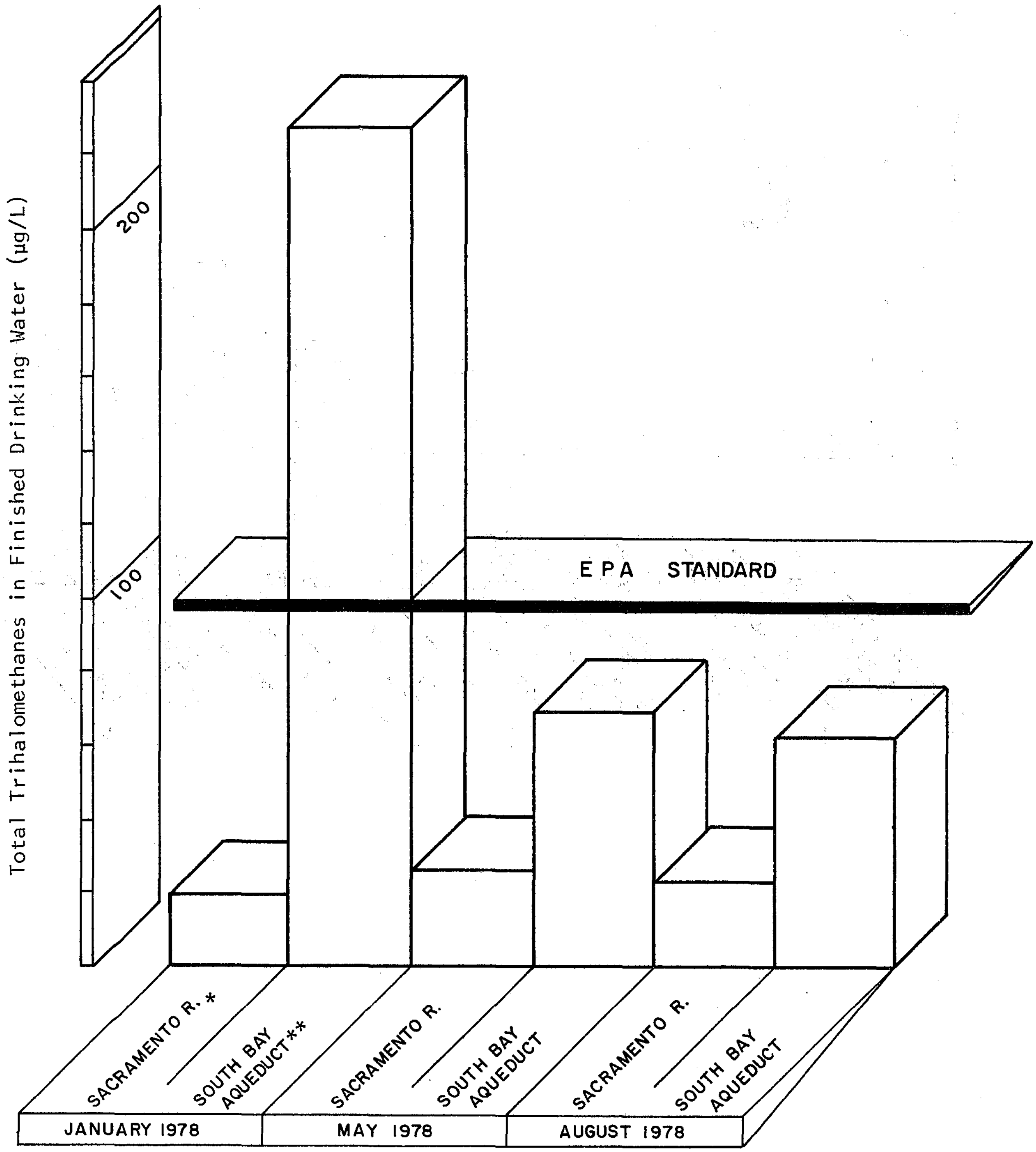


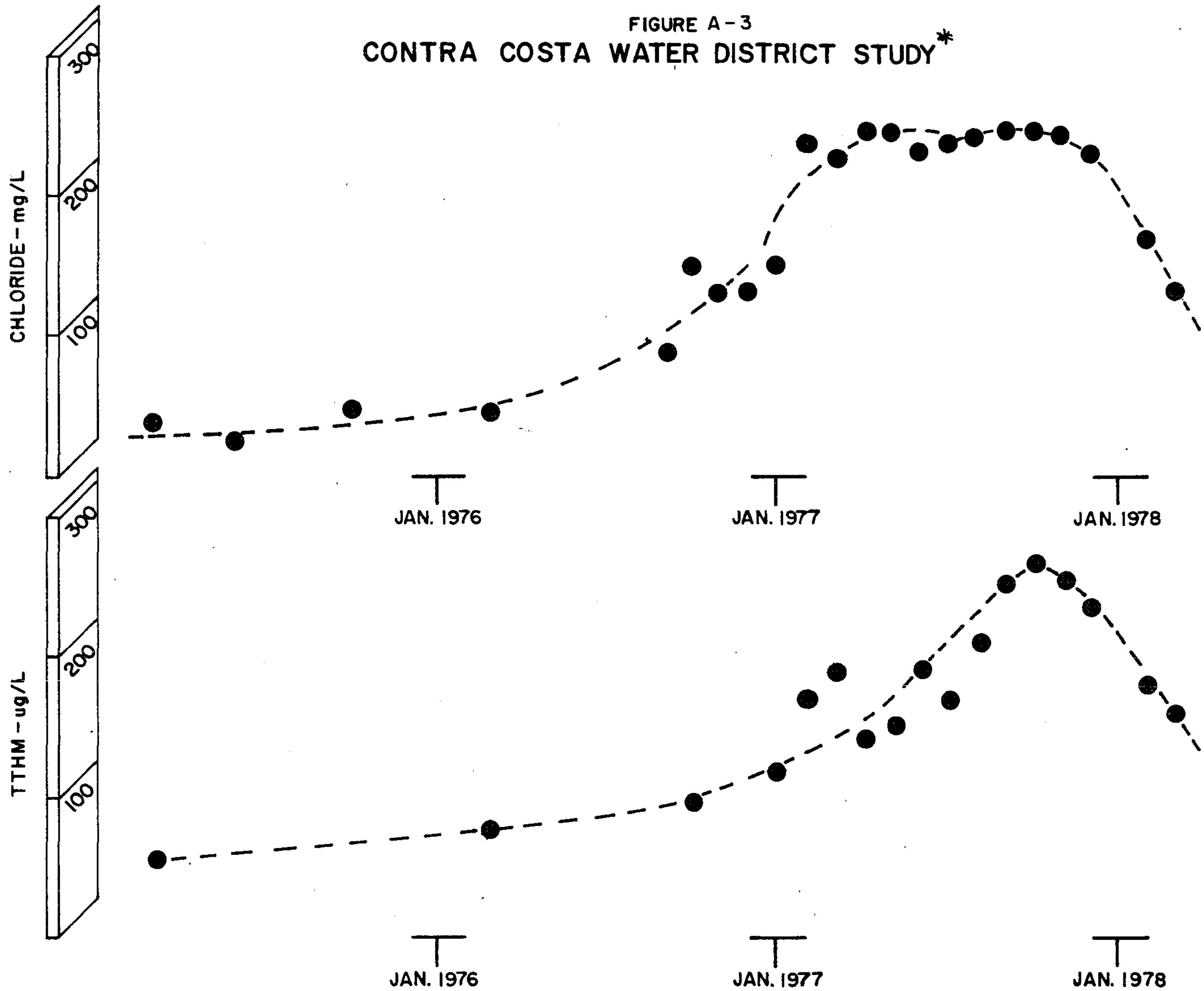
FIGURE A-2

DEPARTMENT OF HEALTH SERVICES STUDY



* Sampled from the Sacramento River Water Treatment Plant, Sacramento.
** Sampled from the Alameda County Flood Control and Water Conservation District Zone No. 7 Treatment Plant.

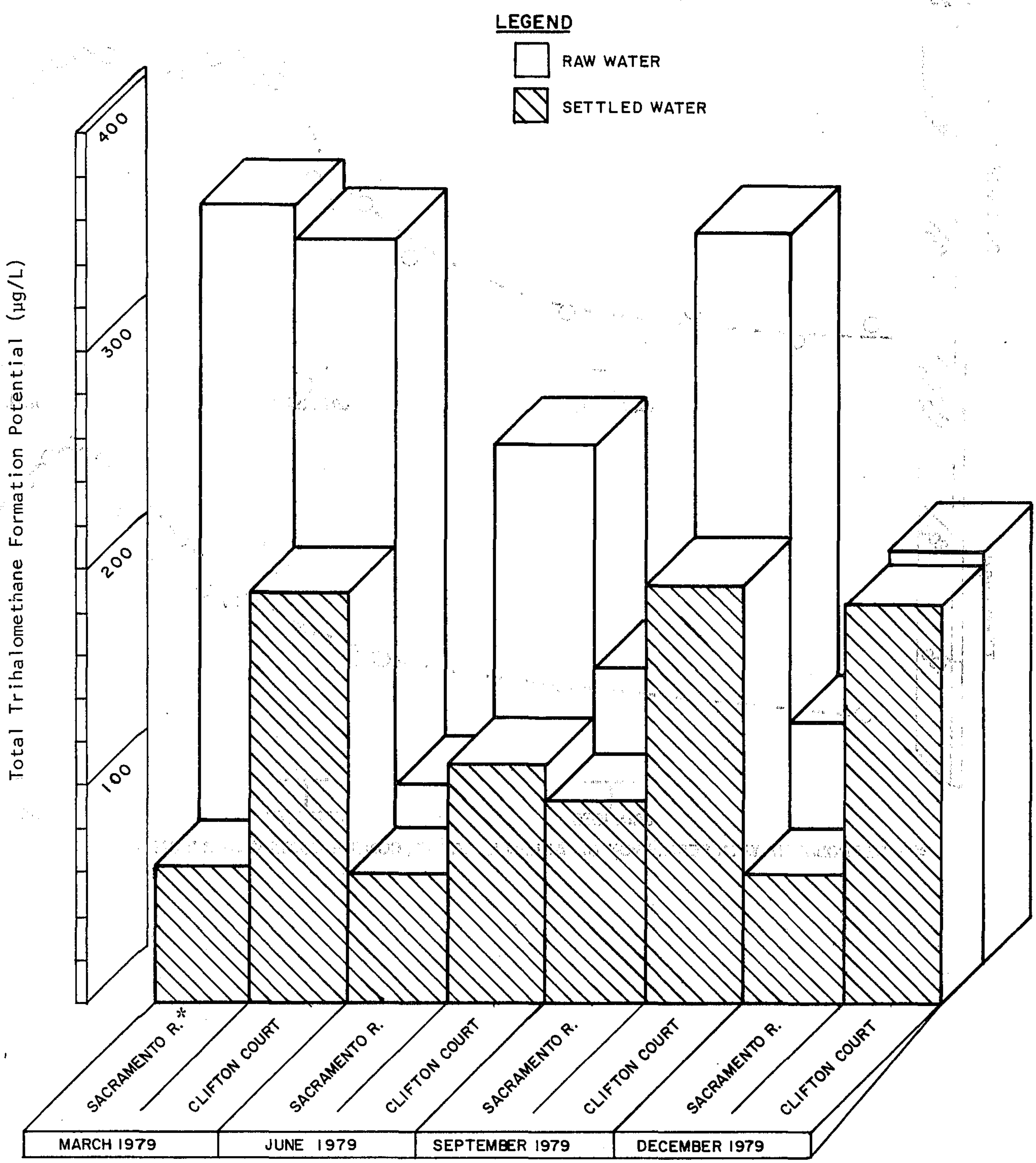
FIGURE A-3
CONTRA COSTA WATER DISTRICT STUDY*



* - REPRODUCED WITH PERMISSION OF ALLEN L. LANGE, CONTRA COSTA WATER DISTRICT.

FIGURE A-4

J. M. MONTGOMERY CONSULTING ENGINEERS STUDY

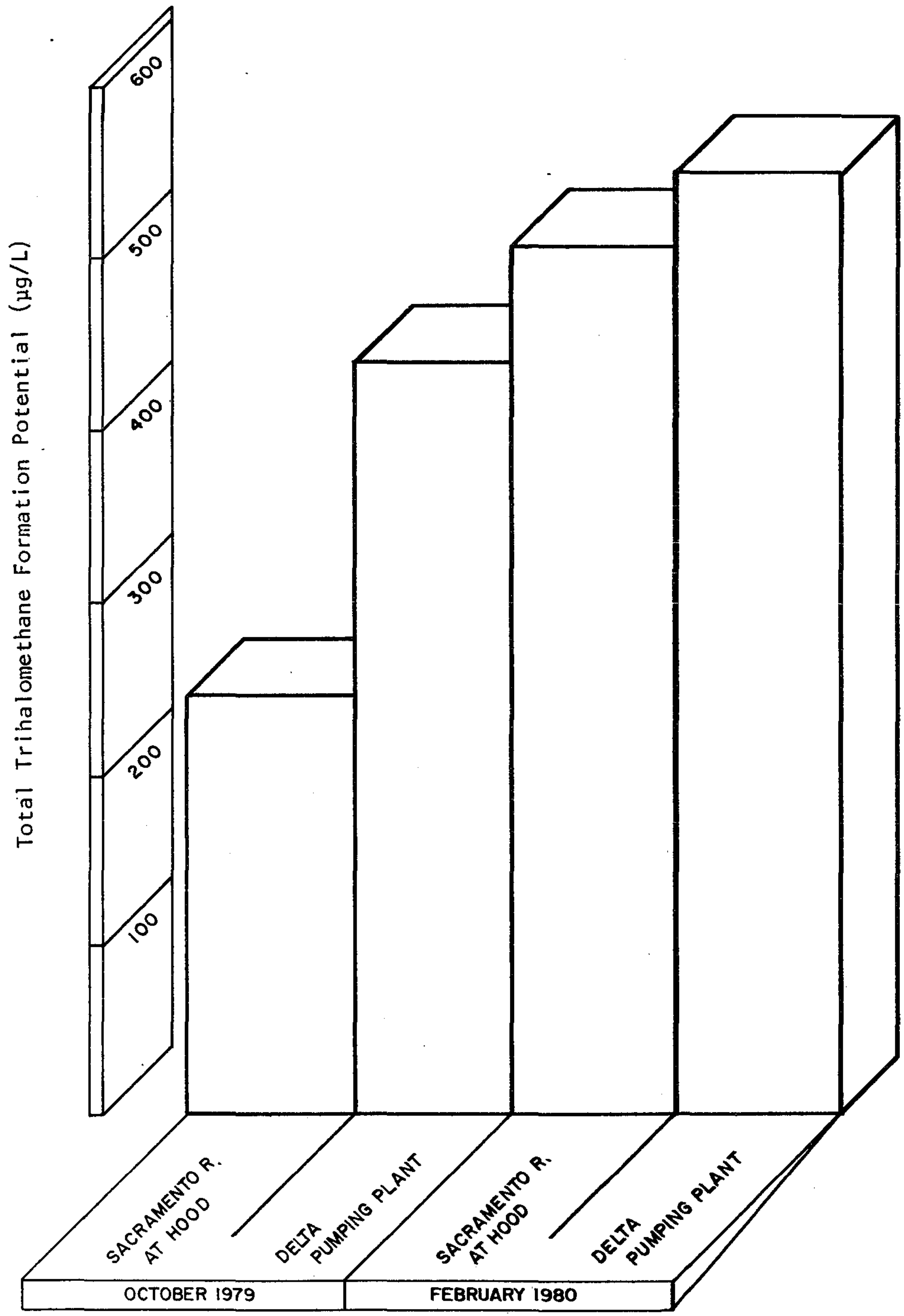


Note: Raw water samples were chlorinated at 10 mg/L; settled water samples were chlorinated at 7.5 mg/L; all samples incubated for seven days.

* Sacramento River at Walnut Grove.

FIGURE A-5

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA STUDY

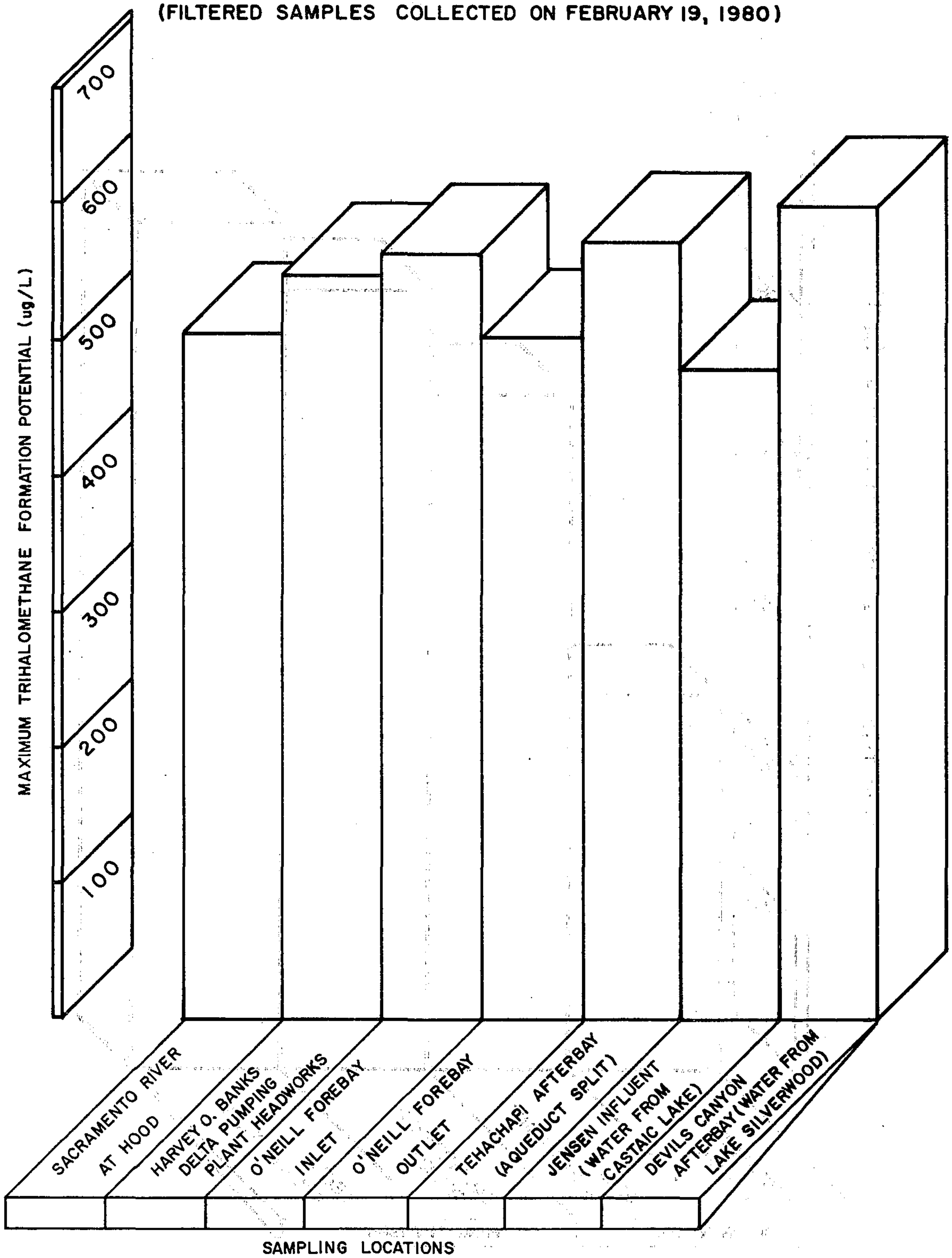


Note: The October 1979 samples were unfiltered; the February 1980 samples were filtered. Samples were chlorinated at 15 mg/L; the October 1979 samples were incubated for 14 days; the February 1980 samples were incubated for 16 days.

FIGURE A-6

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA STUDY

(FILTERED SAMPLES COLLECTED ON FEBRUARY 19, 1980)



APPENDIX B

DATA

Table B-1

STATE WATER PROJECT TRIHALOMETHANE STUDY
TOTAL TRIHALOMETHANE FORMATION POTENTIAL DATA

I. Fresh Water

Total THM Formation Potential (μg/L)

Sampling Location	Sampling Date	Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Sacramento River at Hood B9178000	10/1/81	100	10			110	90	7			97
	11/17/81	260	11			270	300	10			310
	1/7/82	680				680	630				630
San Joaquin River near Vernalis B0702000	10/1/81	280	170	110	11	570	260	180	120	13	570
	11/17/81	590	100	19		710	500	120	29		650
	1/7/82	1 600	84			1 700	1 300	74			1 400
H. O. Banks Delta Pumping Plant Headworks KA000331	10/1/81	440	130	89	10	670	380	130	75	7	590
	11/17/81	160	77	29		270	190	96	36		320
	1/7/82	1 500	150	9		1 700	1 400	150	8		1 600
Contra Costa Canal at Pumping Plant 1 B9591000	10/1/81	87	68	56	10	220	72	54	44	8	180
	1/11/82	1 600	130	7		1 700	1 900	160	9		2 100
Miner Slough B9D81461395	10/1/81	270	16			290	240	19			260
	11/9/81	370	24			390	270	13			280
	1/6/82	700				700	770				770
Lindsey Slough near Rio Vista B9D81481424	10/1/81	260	19			280	270	36			310
	11/9/81						280	22			300
	1/6/82	1 000				1 000	840				840
Cache Slough at Vallejo P.P B9D81781448	10/1/81	540	43	5		590	550	62	5		620
	11/9/81						450	47			500
	1/6/82	860	20			880	750	20			770
Check 12, Cal. Aq. KA006680	9/30/81	300	150	110	20	580	270	140	91	14	520
Check 13, Cal. Aq. KA007089	9/30/81	190	160	130	17	500	230	200	120	16	570

Table B-1 (Cont.)

STATE WATER PROJECT TRIHALOMETHANE STUDY
TOTAL TRIHALOMETHANE FORMATION POTENTIAL DATA

II. Estuary Water

Total THM Formation Potential (μg/L)

Sampling Location	Sampling Date	Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Sacramento River at Chipps Island E0B80301550											
Surface-high Slack tide	11/9/81		34	340	1 100	1 500		31	310	1 300	1 600
Surface-high Slack tide (Bucket Sample)	11/9/81		29	290	1 100	1 400					
Deep-high Slack tide	11/9/81	7	69	450	24 000	25 000		19	240	1 400	1 700
Surface-low Slack tide	11/9/81						5	84	290	720	1 100
Deep-low Slack tide	11/9/81						3	44	190	500	740
Surface-high Slack tide	1/5/82	590	19			610	550	17			570
Deep-high Slack tide	1/5/82						460	9			470
III. Waste Water Treatment Plant Effluents											
Sacramento Main S. T. P. A0W831513069	10/6/81	860	32			890	98	12			110
Stockton South S. T. P. B0W756211979	10/6/81	520	79	8		610	200	39	18		260
Easterly S. T. P Vacaville A0W820815429	10/6/81	760	260			1 000	280	31	5		320
IV. Agricultural Drains											
Natomas Main Drain at W. El Camino Ave. A0V83681312	10/14/81	270	50	10		330	240	53	13		310
	12/30/81	1 500	36			1 500	900	42			940
Colusa Basin Drain at Knights Landing A0294500	10/14/81	390	32			420	420	34			450
	12/30/81	1 100	66	1.6		1 200	710	41	1.4		750

Table B-1 (Cont.)

STATE WATER PROJECT TRIHALOMETHANE STUDY
TRIHALOMETHANE DATA

V. Water Treatment Plants

Total THM Formation Potential (μg/L)

Sampling Location	Sampling Date	Unfiltered Sample					Filtered Sample				
		$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Penitencia W. T. P. E6P724015001	12/3/81	480	120	41		640	590	150	43		780
Raw Water Intake	12/17/81	500	140	25		660	480	130	20		630
Penitencia W. T. P. E6P724015008											
After plant filtration	12/17/81	470	180	48		700					

Total THMs in Finished Drinking Water

Sampling Location	Sampling Date	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	Total
Penitencia W. T. P. E6P724015009	12/3/81	22	39	37		98
Finished water	12/17/81	47	52	26		120

Table B-1 (Cont.)

STATE WATER PROJECT TRIHALOMETHANE STUDY
TRIHALOMETHANE DATA

VI. <u>Soil Extracts</u>		THM Formation Potential of Soil Extracts (μg/Kg)				
Sampling Location	Total Organic Carbon (mg/L)	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBR_3$	Total
60 m S/O ℄ Borrow Pit No. 3, 0.6 m depth	259					
15 m S/O ℄ Borrow Pit No. 1, 0.6 m depth	230	27 000		Composite Sample		27 000
10 m N/O ℄ Borrow Pit No. 5, 0.6 m depth	243					
10 m N/O ℄ Borrow Pit No. 9, 0.6 m depth	312					
100 m W/O bend in Klein Road, 15 m S/O pumphouse 0.6 m depth	814					
10 m E/O east DWR test pond, near end of Calpack Road, 0.6 m depth	662	61 000		Composite Sample		61 000
10 m W/O end Bonetti Road 30 m S/W of pumphouse 0.25 m depth	355					
50 m S/O Hwy. 4, 15 m E/O Tracy Blvd., 0.6 m depth	710					

Table B-2

STATE WATER PROJECT TRIHALOMETHANE STUDY
MISCELLANEOUS DATA

Sampling Location	Date	Time (PST)	Temp. (°C)	Field EC (μS/cm)	pH	D.O. (mg/L)	Cl (mg/L)	EC (μS/cm)	S.S. (mg/L)	V.S.S. (mg/L)	Color (C.U.'s)	T.O.C. (mg/L)	Phytoplankton No/mL	Phytoplankton CSU's/mL	Chl a (μg/L)	Pheo a (μg/L)
Sacramento River at Hood B9178000	10/1/81	1215	20.0	200	7.7	7.8	10	198	21	2	5	3.1	410	23	5.97	8.75
	11/17/81	1320	15.5	170	7.1	8.2	10	171	75	12	25	7.1	1,000	92	7.1	16.8
	1/7/82	1445	8.2	80	7.3	11.5	3	81	48	3	25	4.3	270	16	12.2	17.3
San Joaquin River near Vernalis B0702000	10/1/81	0820	19.0	840	7.7	7.8	121	828	62	7	10	5.9	9 600	550	33.19	19.65
	11/17/81	1000	17.0	750	7.3	7.1	101	723	71	14	25	11	17 000	570	54.3	49.8
	1/7/82	1240	9.0	330	7.4	9.8	34	327	100	9	35	10	1,800	77	14.8	46.2
H. O. Banks Delta Pumping Plant Headworks KA000331	10/1/81	0930	20.5	520	7.7	8.1	87	481	6	2	5	3.6	730	17	4.41	2.15
	11/17/81	1145	16.5	540	7.3	8.7	88	530	1	0	15	4.0	960	13	2.1	3.9
	1/7/82	1105	8.5	410	7.9	11.1	51	408	37	4	30	6.6	210	11	6.9	31.9
Contra Costa Canal at Pumping Plant 1 B9591000	10/1/81	1045	21.0	600	7.6	7.6	117	623	17	2	8	4.1	730	13	7.56	11.20
	1/11/82	1100	6.5	470	7.3	10.5	51	472	8	0	25	5.7	510	12	17.7	10.4
Miner Slough B9D81461395	10/1/81	1315	20	218	7.4	7.8	-	-	20	3	5	3.8	-	-	-	-
	11/9/81	1345	16	218	7.4	8.6	15	220	15	8	8	3.8	-	-	-	-
	1/6/82	1630	7.8	84	7.5	11.0	3	81	79	7	20	5.4	550	56	-	-
Lindsey Slough near Rio Vista B9D81481424	10/1/81	1100	20	284	8.0	8.8	-	-	20	2	5	4.3	-	-	-	-
	11/9/81	1200	16	255	7.6	9.2	19	257	18	7	5	4.0	-	-	-	-
	1/6/82	1300	6.1	82	7.4	11.1	6	84	252	25	40	8.6	340	51	-	-
Cache Slough at Vallejo P.P. B9D81781448	10/1/81	0915	18	603	8.0	7.7	-	-	71	7	10	8.4	-	-	-	-
	11/9/81	1010	14	806	8.1	8.9	90	807	65	14	8	6.1	-	-	-	-
	1/6/82	1105	5.6	202	7.7	11.6	10	207	266	23	25	2.8	270	13	-	-
Check 12, Cal. Aq. KA006680	9/30/81	1500	22.0	550	8.1	8.8	97	550	7	2	5	3.7	890	50	10.63	3.82
Check 13, Cal. Aq. KA007089	9/30/81	1405	22.0	590	8.1	8.7	110	586	3	1	2	3.6	1 400	28	6.81	3.66

STATE WATER PROJECT TRIHALOMETHANE STUDY
MISCELLANEOUS DATA

Sampling Location	Date	Time (PST)	Temp. (°C)	Field EC (μS/cm)	pH	D.O. (mg/L)	Cl (mg/L)	EC (μS/cm)	S.S. (mg/L)	V.S.S. (mg/L)	Color (C.U!s)	T.O.C. (mg/L)	Phytoplankton No/mL	Phytoplankton CSU's/mL	Chl a (μg/L)	Pheo a (μg/L)
Sacramento River at Chipps Island E0B80301550																
Surface-high Slack tide	11/9/81	1400	16.0	15 000	7.3	8.8	4 710	15 000	24	6	5	2.8	930	60	7.80	2.70
Deep-high Slack tide	11/9/81	1410	-	-	7.3	8.6	5 540	16 900	55	15	8	3.6	1 200	35	7.80	14.10
Surface-low Slack tide	11/9/81	2100	17.0	6 840	7.3	8.7	2 380	7 700	27	22	5	3.2	690	300	3.80	8.50
Deep-low Slack tide	11/9/81	2045	17.0	-	7.3	8.8	2 560	8 220	60	10	8	4.2	1 000	45	7.20	7.10
Surface-high Slack tide	1/5/82	1130	8.0	130	7.9	11.3	4	136	116	10	8	4.8	-	-	0.0	3.8
Deep-high Slack tide	1/5/82	1155	7.9	130	7.5	11.2	6	138	148	14	10	5.0	-	-	0.0	3.5
Sacramento Main S. T. P. A0W831513069	10/6/81	1330	24.5	750	6.8	6.4	-	-	-	-	-	74	-	-	-	-
Stockton South S. T. P. B0W756211979	10/6/81	0930	20.0	1 500	6.1	7.8	-	-	-	-	-	29	-	-	-	-
Easterly S.T.P. Vacaville A0W820815429	10/6/81	1145	20.0	1 100	7.5	9.8	-	-	-	-	-	24	-	-	-	-
Natomas Main Drain at W. El Camino A0V83681312	10/14/81	1205	17.5	750	7.7	6.7	72	740	28	-	8	6.8	-	-	-	-
	12/30/81	1120	11.0	415	7.9	8.5	36	415	278	34	30	12	-	-	-	-
Colusa Basin Drain at Knights Landing A0294500	10/14/81	0940	16.5	515	8.1	9.1	25	502	63	-	35	7.4	-	-	-	-
	12/30/81	0925	11.0	600	7.8	9.1	36	605	17	2	30	5.9	-	-	-	-
Penitencia W.T.P.																
E6P724015001 Raw Water Intake	12/3/81	0930	12.0	550	7.6	11.0	86	561	6	1	8	3.3	260	9	2.1	6.7
	12/17/81	0855	15.0	525	7.5	11.1	70	547	3	1	10	3.1	290	180	4.14	3.59
E6P724015008 After Plant Filtration	12/17/81	0915	13.5	595	8.1	11.1	-	-	-	-	-	-	-	-	-	-
E6P724015009	12/3/81	0930	12.5	550	8.2	11.2	-	-	-	-	-	-	-	-	-	-
Finished Water	12/17/81	0920	14.5	585	7.9	11.3	-	-	-	-	-	-	-	-	-	-