Appendix C1. Analysis of Delta Inflow and Export Water Quality Data

C-061680

Appendix C1. Analysis of Delta Inflow and Export Water Quality Data

SUMMARY

This appendix presents a review and summary of available water quality data related to salinity, dissolved organic carbon (DOC) and trihalomethane formation potential (THMFP) in Delta inflows (Sacramento and San Joaquin Rivers) and Delta exports. The general water quality characteristics of the Delta inflows and Delta exports are described, and basic relationships between several related variables are identified. A primary purpose of this appendix is to document observed changes in constituent concentrations as water is transported from Delta inflows to Delta export locations. This change in water quality can be attributed to effects of Delta channel processes and Delta agricultural drainage. This information provides the basis for impact assessment of the DW project.

This appendix also presents the conceptual mass-balance framework for identifying Delta sources of water quality constituents by comparison of constituent concentrations in the Delta inflows and the Delta exports. This mass-balance framework, which is the basis for water quality impact assessment for the Delta Wetlands (DW) project, is formulated as a monthly water quality model of Delta island drainage that is described in Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model".

INTRODUCTION

The primary issue of concern about the DW project with regard to municipal water supplies from the Delta is the potential effect of DW project operations on salinity and concentrations of water quality constituents that are precursors of trihalomethane (THM). THM, which is considered a human health risk, is a disinfection by-product (DBP) formed during the chlorination of water. DOC is considered to be the major organic precursor of DBP, including THM, in treated drinking water.

This appendix provides a conceptual foundation for calculating DW project contributions to salinity and DOC concentrations and THMFP in water that could be exported from the Delta and subsequently treated for municipal use. "Delta exports" refers to exports at the Central Valley Project (CVP) Tracy Pumping Plant to the Delta-Mendota Canal (DMC), the State Water Project (SWP) Banks Pumping Plant, and the SWP North Bay Aqueduct and diversions at the Contra Costa Water District (CCWD) Rock Slough intake.

Delta water quality patterns can be identified most reliably if several measured variables are analyzed concurrently. Conclusions are more reliable if several related parameters exhibit similar patterns of variation; in contrast, conclusions are more doubtful if related parameters exhibit different or conflicting patterns. This appendix presents information on several variables used to analyze Delta water quality patterns.

Following are the sections of this appendix:

- "Available Delta Inflow and Delta Export Data" describes the water quality data collection programs for the Delta and the types of data collected by each.
- "Delta Sources of Water Quality Constituents" provides an overview of sources of water quality constituents between Sacramento River inflows and Delta export locations.
- "Conceptual Framework for Estimating Constituent Contributions from Delta Sources" describes a mass-balance method for approximating net contributions of constituents from Delta sources for a month.
- "Water Quality Changes between Delta Inflow and Delta Export Locations" documents observed differences between water constituents

in inflows and exports that may be attributable to Delta sources.

- "Water Quality Characteristics of Delta Inflows" describes patterns of fluctuations in constituent concentrations of inflows, which account for some of the observed variability in Delta export water quality constituents.

- "Water Quality Characteristics of Delta Exports" details water quality characteristics at CCWD's Rock Slough intake, the SWP Banks Pumping Plant, and the CVP exports to the DMC near Tracy Pumping Plant and identifies the dominant influences of water sources on water quality at these locations.

- "Conclusions" relates the information presented in this appendix to other water quality analyses of the DW environmental impact report/environmental impact statement (EIR/EIS).

AVAILABLE DELTA INFLOW AND DELTA EXPORT DATA

A great amount of water quality data is collected in the Delta each year. The Interagency Ecological Program (IEP) coordinates much of the data collection, as required by the California State Water Resources Control Board (SWRCB) as conditions under various water right decisions and Bay-Delta water quality control plans.

The U.S. Bureau of Reclamation (Reclamation), California Department of Water Resources (DWR), and the U.S. Geological Survey (USGS) operate a network of continuous electrical conductivity (EC) monitoring stations primarily to provide information for operating the Delta (SWP and CVP) in compliance with applicable flow and salinity standards. These EC data have been summarized as monthly averages for the period 1968-1991 and are described in Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project".

DWR's Central District organizes daily records of Delta inflows, Delta exports, and estimated Delta outflows in a database called DAYFLOW, which is used to summarize historical Delta flows. Average monthly Delta inflows, exports, and outflows can be calculated from the daily values and used to represent the monthly water budget for the Delta. The relationship between Delta outflow and salinity intrusion can be characterized with the DAYFLOW values and the EC data from various stations.

DWR's Central District has collected samples monthly (twice monthly during spring and summer) since the early 1970s to compile data on minerals, nutrients, and plankton as part of the Delta sampling required by SWRCB in Water Right Decision 1379 (D-1379) in 1971 and Decision 1485 (D-1485) in 1978. These data, reported and analyzed in a series of annual reports, are primarily used to describe the general patterns of Delta water quality related to biological habitat conditions.

The Interagency Delta Health Aspects Monitoring Program was initiated in 1982 to study the quality of Delta water supplies used for human consumption. The same program is now being administered by DWR's Division of Local Assistance as the Municipal Water Quality Investigations (MWQI) program. MWQI sampling consists of monthly measurements of salinity, DOC, THMFP, and related water quality variables at Delta inflow and export locations and at several channel locations in the Delta. These data are used primarily to describe the Delta water quality variables important for municipal water supply evaluations (DWR 1989, 1993).

Salinity has been the dominant water quality variable of concern for municipal and agricultural water supplies in the Delta. However, the objectives specified in the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP) adequately protect Delta water supplies from salinity intrusion effects during periods of reduced Delta outflow. Therefore, agricultural drainage effects on salinity and DOC concentrations are the major remaining water quality issues of concern for municipal water supplies.

Because the primary issue of concern about the DW project with regard to municipal water supplies from the Delta is a possible increase in DOC, the MWQI data, which include measurements of DOC, THMFP, and related variables, are therefore the most relevant source of Delta water quality information for the DW water quality impact assessment.

The MWQI data have been used by DWR and others to describe increases in DBP precursors that have been observed between Sacramento River inflow and Delta export locations. As is typical of field measurements, the monthly grab-sample MWQI data exhibit considerable scatter from month to month and vary between locations sampled in the same month that would be expected to have similar concentrations.

DELTA SOURCES OF WATER QUALITY CONSTITUENTS

Concentrations of many water quality constituents are often higher in Delta exports than in Sacramento River inflows, which are generally the major source of Delta water. Possible sources of water quality constituents in the Delta are seawater intrusion, inflows from the San Joaquin River and eastside streams, biological production in Delta channels, and agricultural drainage from Delta islands:

- **Seawater intrusion**. Seawater intrusion has been rather extensive during the 1987-1991 period of MWQI sampling, and seawater salts may have caused significant increases in some of the mineral concentrations in export water. Increased bromide (Br^-) concentrations caused by seawater intrusion may contribute to higher THMFP values at the export locations.

- **San Joaquin River and eastside stream inflows**. San Joaquin River concentrations of DOC, Br^-, and related constituents are routinely measured, but the portion of San Joaquin River inflow that is mixed into Delta exports varies. The possible influence of San Joaquin River inflows on export water quality can be estimated through comparison of the magnitude of San Joaquin River inflow with total export pumping. Based on this comparison, a considerable portion of observed increases in export concentrations above Sacramento River concentrations may be attributed to San Joaquin River inflows.

- **Biological production in Delta channels**. Erosion or leaching from channels and biological production of aquatic plants and other decaying materials may add to concentrations of water quality constituents in the Delta. This possible source is difficult to measure directly because it is distributed throughout Delta channels.

- **Agricultural drainage**. The magnitude of the contribution of water quality constituents from agricultural drainage sources can be estimated from the product of the drainage volume and measured drainage concentration. The available data on Delta agricultural drainage water quality are reviewed in Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data". Direct measurements of Delta drainage volumes are not currently available. Data on drainage concentrations are being collected as part of the MWQI program, and USGS and DWR have initiated a demonstration project to measure agricultural water budget terms on several Delta islands (DWR 1994).

The change in constituent concentration between the Sacramento River and Delta export locations can be used to estimate the magnitude of the net contribution from Delta sources. It is not possible, however, to determine from concentration data alone the relative contributions from different sources of increased concentrations observed at the export locations. Additional measurements of the individual sources are required to determine their relative contributions. The following section describes a method for estimating the contributions of water quality constituents from different sources within the Delta.

CONCEPTUAL FRAMEWORK FOR ESTIMATING CONSTITUENT CONTRIBUTIONS FROM DELTA SOURCES

The net contribution of a selected water quality constituent from Delta sources, including agricultural drains, can be estimated from the differences between Delta inflow and Delta export concentrations observed in the DWR MWQI data. Because Sacramento River inflows are generally the largest source of Delta water and have the lowest concentration of DOC and related constituents, the Sacramento River concentrations are used as the basis for determining Delta source contributions. The relationship between observed concentrations in the export water and net source contributions from within the Delta can be developed from available data based on the following mass-balance assumptions:

- The Sacramento River concentrations observed during a month are typical of the monthly average inflow concentrations.

- The Delta export concentrations observed during a month are typical of the monthly average export concentrations.

- Contributions from all Delta sources during a particular month are transported during the same month to Delta exports or Delta outflow.

- It is possible to estimate fractions of contributions from all Delta sources that are mixed with Sacramento River water and transported to the export locations.

- The remaining contributions from all Delta sources are mixed with Sacramento River water transported to Delta outflow past Chipps Island.

A simple mass-balance mixing model can be used to approximate the net contributions of constituents from Delta sources for each month. Delta export measurements are used as a "sample" of southern Delta water quality after some fraction of constituent contributions from Delta sources is mixed with Sacramento River inflow. The net contribution from Delta sources can be estimated from the observed increase in concentration in the exports (above the assumed inflow concentration), the Delta export pumping volume, and the assumed fraction of the Delta source contribution transported to the Delta export locations:

Delta source contribution rate (kg/month) for a 30-day month = export pumping rate (cubic feet per second [cfs]) · concentration change (mg/l) ÷ source fraction · 86,400 sec/day · 0.000001 kg/mg · 28.32 liter/ft^3 · 30 days/month

= export pumping rate (cfs) · concentration change (mg/l) ÷ source fraction · 73.4

For example, if an increase of 1 milligram per liter (mg/l) above the Sacramento River concentration was observed in a monthly average export flow of 5,000 cfs, and if the assumed fraction of export water from the Delta source was 50%, the net contribution from the Delta source would be calculated as follows:

Delta source contribution rate (kg/month) = 5,000 cfs · 1 mg/l ÷ 0.50 · 73.4 = 734,000 kg/month = 734 metric tons/month

If this net contribution occurred uniformly from some known area of the Delta, the average uniform contribution per unit area (g/m^2/month) could be estimated as follows:

Areal contribution rate (g/m^2/month) = mass contribution rate (kg/month) ÷ 4,047 m^2/acre ÷ source area (acres) · 1,000 g/kg = mass contribution rate (kg/month) ÷ source area (acres) ÷ 4.047

For the example given above, with an assumed source area equal to the Delta lowlands (396,000 acres), the average areal contribution rate would be calculated as follows:

Areal contribution rate = 734,000 kg/month ÷ 396,000 acres ÷ 4.047 = 0.458 g/m^2/month

To estimate the monthly areal contribution rate (g/m^2/month) from Delta sources for other observed changes in constituent concentration, export pumping rates, assumed fraction from Delta sources in the export pumping flow, or other source areas, appropriate values can be substituted in these equations. Higher calculated net contributions from Delta sources in Delta exports will result with higher rates of export pumping, higher observed concentration increases between Sacramento River inflows and exports, or higher fractions of Delta sources in Delta exports. Greater areal contribution rates will be estimated for smaller assumed contributing areas.

Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model", describes a systematic framework for estimating these net contributions from Delta sources based on observed concentration changes, Delta inflows, and export pumping rates.

WATER QUALITY CHANGES BETWEEN DELTA INFLOW AND DELTA EXPORT LOCATIONS

Patterns of changes in constituent concentrations between Sacramento River inflow (the selected inflow for estimating water quality changes within the Delta) and Delta export locations for several variables measured in the 1982-1991 DWR MWQI data are shown and described in this section. San Joaquin River inflow is treated as a contributing source within the Delta.

The DWR MWQI data collection program has changed somewhat each year. During 1982, preliminary measurements were collected from the SWP Banks Pumping Plant and the San Joaquin River at Vernalis. The THMFP assay was tested and standardized. Sampling from the Sacramento River and other Delta export locations began in 1983. DOC measurements were added in 1987. Br^- and ultraviolet absorbance (UVA) measurements were added in 1990. The use of UVA data is explained below.

The number of samples collected at each station each year has also changed. At Banks Pumping Plant, for example, five samples were collected in water year 1982, nine samples were collected in water year 1983, and 11 or 12 (monthly) samples were collected in water years 1984-1989. During water years 1990 and 1991, weekly and biweekly sampling was conducted during portions of the year, with a total of 26 samples collected in 1990 and 22 collected in 1991.

To standardize the data analysis, Jones & Stokes Associates (JSA) selected a data set of monthly values for the entire 10-year (1982-1991) period by using the first grab sample collected in each calendar month and eliminating any additional samples collected that month. Samples are often, but not always, collected on about the same day at each of the sampling stations. Table C1-1 gives a summary of the available data. The statistics of the monthly samples were not substantially different from those of the entire data set. The following sections describe the data for electrical conductivity (EC), chloride (Cl^-), Br^-, DOC, THM precursors and THMFP, and turbidity.

Delta Electrical Conductivity Values

Figure C1-1 shows EC measurements for the DWR MWQI samples from Sacramento and San Joaquin River inflows and from three export locations (SWP Banks Pumping Plant; the Central Valley Project [CVP] Delta Mendota Canal [DMC] near the Tracy Pumping Plant; and Rock Slough near Old River, the source of water for the Contra Costa Water District [CCWD] intake).

The EC values for the Sacramento River are generally in the range of 100-200 microsiemens per centimeter (μS/cm), although two measurements in the 1986 flood period were below 100 μS/cm, and several values have been above 200 μS/cm. Figure B2-4 in Appendix B2 indicates that Sacramento River EC measurements generally decrease with higher flows, exhibiting a typical flow-dilution relationship that can be approximated with the following equation:

$$\text{Sacramento River EC } (\mu\text{S/cm}) = 5{,}000 \cdot \text{flow (cfs)}^{-0.35}$$

This equation indicates that for Sacramento River flows of less than 10,000 cfs, the corresponding EC values would be greater than 200 μS/cm. For Sacramento River flows greater than 50,000 cfs, the corresponding EC values estimated from this equation would be less than 100 μS/cm.

The EC values for the San Joaquin River are usually much higher than Sacramento River EC values, fluctuating between 150 μS/cm and 1,300 μS/cm. Figure B2-5 in Appendix B2 indicates that San Joaquin River EC measurements also generally decrease with flow, exhibiting a flow-dilution relationship that can be approximated with the following equation:

$$\text{San Joaquin River EC } (\mu\text{S/cm}) = 25{,}000 \cdot \text{Flow (cfs)}^{-0.5}$$

Several San Joaquin River EC values observed during winter in recent years (1988-1991) have been above 1,000 μS/cm and are as much as 500 μS/cm higher than the EC values estimated with the flow-dilution equation. These elevated EC values suggest that an additional load of salt drainage may have been released into the San Joaquin River during these drought years. Measurements when available are superior to flow-regression estimates of inflow water quality; flow regressions must be used for planning and assessment studies.

Observed EC values at the three export locations have fluctuated between about 200 μS/cm and 1,000 μS/cm. During months when low EC values were measured, corresponding to periods of high Delta outflow, the export locations each had similar EC values. During months when high EC values were measured, EC values at Rock Slough (CCWD) were generally the highest because effects of salinity intrusion are usually strongest at Rock Slough. Local agricultural drainage may also have different effects at each export location.

The DWR MWQI EC data clearly indicate that EC (representing dissolved salts) usually increases between Sacramento River inflow and the export locations. The net source of elevated EC may differ, however, for each month and each export location. DWR MWQI EC data alone are not sufficient to determine the relative monthly contributions from the San Joaquin River, salinity intrusion, and Delta agricultural drainage.

Figure C1-2 shows the monthly DWR MWQI grab samples from the DMC, compared with the monthly range of mean daily EC values recorded at the continuous EC monitor located in the DMC. This figure indicates that the monthly DWR MWQI grab samples may not always be representative of the actual monthly mean value, as measured by the continuous EC monitor at the same location. Therefore, monthly grab samples from other locations may not represent actual monthly average EC values or monthly average concentrations of other measured variables.

Delta Chloride Data

Figure C1-3 shows DWR MWQI data on Cl^- concentrations for water years 1982-1991 for the two Delta inflow and three Delta export locations. Cl^- concentration patterns are similar but not identical to the EC patterns because each major water source has a different Cl^-/EC ratio value. Figure C1-4 show the Cl^-/EC ratios for each of the monthly DWR MWQI samples. These two figures will be described together.

Sacramento River Cl^- concentrations were usually less than 10 mg/l (Figure C1-3), and the Cl^-/EC value (mg/l:μS/cm) in this inflow averaged about 0.05 (Figure C1-4). Some of the scatter in the Sacramento Cl^-/EC values was caused by the low Cl^- concentrations, which are normally reported as whole numbers.

San Joaquin River Cl^- concentrations fluctuated between about 20 mg/l and 180 mg/l (Figure C1-3) and Cl^-/EC ratio values increased from about 0.08 at low EC values to about 0.15 at high EC values (Figure C1-4). The variability in the Cl^-/EC values of this inflow may be explained by the fact that it is a mixture of San Joaquin River water and Stanislaus River water (from New Melones Reservoir). MWQI samples from the San Joaquin River at Maze, above the confluence with the Stanislaus River, can be estimated to have a constant Cl^-/EC value of 0.15, and by inference, Stanislaus River inflow can be estimated to have a Cl^-/EC value of approximately 0.06. Nevertheless, the Cl^-/EC value of 0.08 to 0.15 for the San Joaquin River inflow is distinct from the lower Cl^-/EC value of about 0.05 for the Sacramento River. The Cl^-/EC value of 1% seawater mixed with 99% Sacramento River water is 0.30 (pure seawater has a Cl^-/EC value of about 0.35) (CRC 1989).

Agricultural drainage is derived from rainfall (without minerals) and applied water that has partially evaporated; the salinity (EC and Cl^- concentration) of drainage water is usually greater than the salinity of the applied water, but the Cl-/EC ratio remains constant (see Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data", for additional discussion). The agricultural drainage salinity is "recycled" salinity from the applied water. There are therefore only three basic sources of Delta salinity: seawater, San Joaquin River water, and Sacramento River water. The Cl^-/EC ratio of agricultural drainage will reflect the Cl^-/EC ratio of the applied water source (or combination of sources). The only source for water in the Delta with a Cl^-/EC ratio value higher than 0.15 is seawater intrusion, and agricultural drainage may also have a Cl^-/EC value above 0.15 if the applied water included substantial seawater intrusion. For a Sacramento River sample with an EC value of 200 μS/cm, the Cl^- concentration would be about 10 mg/l (Cl^-/EC value of 0.05).

The following example illustrates how the Cl^-/EC value changes with the mixture of source water. A sample of San Joaquin River water with an EC of 1,000 μS/cm will have a Cl^- concentration of 150 mg/l (Cl^-/EC value of 0.15). A sample of Mallard Island water (assumed to be seawater diluted with Sacramento River water) with an EC of 1,000 μS/cm will have a Cl^- concentration of about 300 mg/l (Cl^-/EC value of 0.3). If these two water samples are mixed together in various combinations, the EC of the mixture will remain 1,000 μS/cm, but the Cl^- concentration will increase as more Mallard Island water is added to the San Joaquin River water. For a 50/50 mixture, the Cl- concentration will be 225 mg/l ($[0.5 \cdot 150] + [0.5 \cdot 300] = 225$) and the Cl^-/EC value will be 0.225.

The contributions from the three salinity sources can be estimated through the use of three equations to calculate the fractions of the volume of water contributed from each source , the EC value, and the Cl^- concentration of three-way mixtures. For example, if a mixture of these three water sources (with the EC values given above) had an EC of 600 μS/cm, it could be concluded that the Sacramento River water is contributing 50% of the volume, because the other two each had an EC of 1,000 μS/cm ($[0.5 \cdot 200] + [0.5 \cdot 1{,}000] = 600$). The mixture could have a Cl^- concentration of between 80 mg/l (with no Mallard Island water in the mixture) and 155 mg/l (with no San Joaquin River water in the mixture). The measured Cl^- concentration could be used to estimate the mixture of Mallard Island and San Joaquin River water in this example mixture.

Measurements of Cl^- concentrations from the export locations fluctuated between 15 mg/l and about 300 mg/l (Figure C1-3). The Cl^- concentrations in CCWD diversions from Rock Slough were the highest because of the stronger influence of seawater intrusion or local agricultural drainage.

Cl^-/EC values for the export locations were greater than 0.15 (San Joaquin ratio) during periods with the highest Cl^- concentrations (Figure C1-4). These high Cl^-/EC values suggest that the dominant source of Cl^- during these periods is seawater intrusion. CCWD water diverted at Rock Slough usually has a higher Cl^-/EC value than the other export locations, suggesting a slightly higher seawater contribution.

The DWR MWQI data indicate that Delta and San Joaquin River contributions of Cl^- are significant. The relative magnitude of the potential influence by Delta sources on increased Cl^- at the export locations cannot be directly determined, however, from Cl^- concentrations alone. The San Joaquin River, agricultural drainage water, and seawater intrusion water have approximately the same Cl^- concentration. In contrast, the Cl^-/EC values for export water provide more information about the sources of increased Cl^- and can be used to estimate the most likely source of increased Cl^-.

Delta Bromide Data

Figure C1-5 shows DWR MWQI Br^-/Cl^- values, based on Br^- measurements that began in January 1990. Because of drought conditions with relatively high salinity intrusion effects and higher concentrations from San Joaquin River inflows, Br^- concentrations at the export locations have been quite high since measurement began. The Br^-/Cl^- value for concentrations measured from San Joaquin River samples (0.003 to 0.0045) are similar to the Br^-/Cl^- value of about 0.0035 for seawater. Br^-/Cl^- values for Sacramento River inflow were scattered (0.001 to 0.0045) because of low concentrations of Cl^- and Br^- but sometimes were substantially lower (0.0015) than seawater or San Joaquin River water. Although Br^- is more difficult to measure than Cl^-, these DWR MWQI data suggest that Br^- concentrations may be adequately estimated from Cl^- measurements if a Br^-/Cl^- value of about 0.0035 is assumed for all sources for impact assessment purposes.

Delta Dissolved Organic Carbon Data

Figure C1-6 shows DWR MWQI measurements of DOC that were initiated in 1987. DOC is considered to be the major organic precursor of DBP, including THMs. DOC is therefore one of the most important water quality variables for assessment of potential formation of DBP in treated drinking water from the Delta.

DOC concentrations in Sacramento River inflow are generally the lowest measured in the Delta, with concentrations of about 2.0 mg/l often observed (Figure C1-6). American River samples have even lower DOC concentrations (DWR 1989). Sacramento River DOC concentrations are sometimes higher than 2.0 mg/l, with several DOC values above 3.0 mg/l. Daily measurements taken during 1993 have confirmed that Sacramento River DOC concentrations can be elevated above 2.0 mg/l as the result of sources of DOC material in surface runoff (Agee pers. comm.).

DOC concentrations in the San Joaquin River were usually higher than Sacramento River DOC concentrations, with DOC values generally between 3.0 mg/l and 6.0 mg/l. The San Joaquin River is considered a major source of DOC relative to the Sacramento River, which has comparatively low DOC concentrations. Most of the DOC concentrations at the export locations were in the range of 3.0 mg/l to 5.0 mg/l. The DWR MWQI data clearly show that DOC is contributed by Delta sources or San Joaquin River inflow. The relative influences of the various possible sources cannot be easily identified from these data alone.

Delta Trihalomethane Precursor Data

Trihalomethane Formation Potential and Types of Trihalomethane Molecules

To provide a comparative measure of THM precursors in Delta water, the DWR MWQI program developed an assay for determining THMFP, an index of the maximum possible THM concentrations that could be produced by maximum chlorination of Delta water. The assay is performed by spiking a water sample with an initial 120-mg/l concentration of chlorine (Cl_2), holding the sample for 7 days (168 hours) at 25°C, then measuring the THM species with standard U.S. Environmental Protection Agency (EPA) procedures (gas chromatograph purge and trap, EPA method 502.2).

The gas chromatograph method determines concentrations of four types of THM molecules separately (Table C1-2). Each type of THM molecule resembles methane (CH_4), except that three of the four hydrogen atoms are replaced with a halogen (chlorine or bromine). The four types of THM molecules are chloroform ($CHCl_3$), dichlorobromomethane ($CHCl_2Br$), dibromochloromethane ($CHClBr_2$), and bromoform ($CHBr_3$).

Each of these THM molecules has a different weight because of the difference between the molecular weight of chlorine (35.45) and bromine (79.9). Chloroform has a molecular weight of 119.36, whereas bromoform has a molecular weight of 252.71. The chemical properties of the four types of THM molecules are summarized in Table C1-2.

Total THM concentration (by weight) is the basis for current EPA drinking water standards. The greater weight of total THM resulting from increased bromine incorporation, however, complicates comparison of THM precursors from two water samples with different bromine content. One method to normalize the total THM concentrations is to use molar concentrations. This is the standard chemistry method and essentially counts the number (in moles) of THM molecules per liter of water.

A slightly different technique, having equivalent results, is to measure only the carbon weight of each THM molecule because each molecule has one carbon atom. The carbon fractions of the four types of THM molecules are listed in Table C1-2. The carbon-fraction concentrations of the four types of THM molecules are added together to calculate the carbon equivalent of the total THM concentration, called the C-THM concentration. The DWR MWQI program uses the term "total formation potential carbon" (TFPC) for the same variable.

Dividing the C-THM concentration by the initial DOC concentration in a water sample provides a direct estimate of the fraction of the initial DOC concentration in a water sample that was converted to THM molecules during the THMFP assay, an advantage over using the molar THM concentration. The ratio C-THM/DOC is called the THM yield.

Delta C-THM Data

Figure C1-7 shows the 1982-1991 DWR MWQI calculated C-THM concentrations. Sacramento River concentrations of C-THM were usually below 30 $\mu g/l$; however, about a third of the concentrations were above 30 $\mu g/l$. Most export concentrations of C-THM were between about 30 $\mu g/l$ and 90 $\mu g/l$, generally higher than Sacramento River concentrations. San Joaquin River C-THM concentrations were higher than Sacramento River concentrations but were not distinctly higher than export concentrations. Because the C-THM concentrations for Sacramento River inflow fluctuated and because the San Joaquin River C-THM concentrations were similar to those measured at the export locations, it is quite difficult to directly estimate the monthly contributions of C-THM from Delta sources.

Figure C1-8 shows the ratios of C-THM to DOC for the two inflow and three export locations. With allowances made for a certain amount of scatter in both measurements, these ratios for "THM yield" from DOC range from about 0.01 to 0.02, indicating that approximately 1%-2% of DOC became THM molecules during the THMFP assay in most samples. This yield relationship suggests that DOC measurements can be used to estimate the C-THM concentration of the THMFP assay. This relatively constant C-THM/DOC value might be used with more frequent DOC measurements to minimize the need for using the comparatively expensive and time-consuming THMFP assay procedure (see Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project", for more discussion of this topic).

Delta Ultraviolet Absorbance Data

UVA (254-nm wavelength) was added to the DWR MWQI program as a measurement variable in 1990. UVA is measured with a spectrophotometer and reported in units of 1/cm.

UVA, a physical measurement used in the study of humic acids and THM precursors, has been found to be linearly related to DOC concentration (see Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data"). UVA may be a direct measure of the humic and fulvic acid portion of total DOC in a water sample. The ratio of UVA to DOC would therefore be expected to increase with a higher proportion of humic substances. A greater yield of THM molecules would also be expected from samples with higher UVA/DOC values because the humic substances are thought to be the "active" THM precursor.

Figure C1-9 indicates that most Delta inflow and export samples have UVA(1/cm)/ DOC(mg/l) ratios of between 0.02 and 0.04, with an average of about 0.03. The Sacramento and San Joaquin River UVA/DOC values tend to be slightly lower than the UVA/DOC values for the exports.

Appendix C2 describes the ratio of UVA to DOC from Delta agricultural drainage water. The UVA measurement holds great promise as a monitoring variable if additional data confirm a consistent UVA/DOC value for each water source. Because UVA is a relatively simple physical measurement, frequent (daily) data could be inexpensively collected from Delta inflows and exports and from other locations where DOC concentrations are of possible concern.

Delta Turbidity Data

Figure C1-10 shows the DWR MWQI monthly turbidity data collected since 1983 (reported in nephelometric turbidity units [NTU]). Turbidity is a measure of particulate materials that may originate from erosion and surface runoff during storm events, or from channel scour and resuspension of settled materials (inorganic and organic) within the Delta. These data illustrate that turbidity values of the Sacramento River inflow are sometimes higher than turbidity at Delta export locations.

WATER QUALITY CHARACTERISTICS OF DELTA INFLOWS

A portion of the observed variability in Delta export water quality measurements shown in the previous section is caused by variability in the inflowing water concentrations. This section will identify the relationships between related mineral and organic constituents in Sacramento and San Joaquin River inflows and in seawater intrusion measured at Mallard Island (near Chipps Island).

The previous section of this appendix presented the changes in monthly constituent concentrations observed between Sacramento River inflow and Delta export locations. This section, however, presents the patterns of concentration fluctuations in the Delta inflows from the Sacramento and San Joaquin Rivers and at Mallard Island.

The flow-dilution equations for each river inflow (presented above under "Delta Electrical Conductivity Values") indicate how EC values are expected to vary as a function of river flow. Graphing concentrations of other water quality constituents against the corresponding EC measurements for the same samples illustrates a characteristic signature or "waterprint" for the water quality in each inflow, as described below.

Sacramento River Water Quality Characteristics

Figure C1-11 shows the concentrations of several mineral constituents as measured in the 1982-1991 DWR MWQI samples from the Sacramento River at Greene's Landing. The range of EC values was quite limited for the Sacramento River, with EC values usually between 110 μS/cm and 220 μS/cm. Potassium (K^+) concentrations were reported to the nearest 0.1 mg/l, while the concentrations of other variables were reported only to the nearest mg/l.

Each of the mineral concentrations increased linearly with EC. The Cl^- concentrations were approximately 3%-5% of the EC value, giving a Cl^-/EC value of less than 0.05. The K^+ concentrations were about 1% of the EC value, giving a K^+/EC value of 0.01. Calcium (Ca^{2+}), sodium (Na^+), and sulfate (SO_4^{2-}) each had approximately the same concentration, with concentrations equal to between 5% and 7% of the EC value. Concentrations of magnesium (Mg^{2+}) and Cl^- were about the same (3%-5% of EC). The Sacramento River mineral water quality can be characterized with EC measurements and these observed ratios.

Figure C1-12 shows the organic variables, DOC and C-THM, as measured in the 1982-1991 DWR MWQI samples from the Sacramento River. These constituents did not increase with EC values in Sacramento River inflow, as the mineral concentrations did. Therefore, fluctuations in these organic variables were apparently attributable to causes other than flow dilution. Measurements of DOC are therefore required; estimates based on flow or EC monitoring will not be reliable for Sacramento River concentrations of DOC.

San Joaquin River Water Quality Characteristics

Concentrations of several mineral constituents measured in the 1982-1991 DWR MWQI samples from the San Joaquin River at Vernalis are shown in Figure C1-13. The range of San Joaquin River EC values (i.e., 100-1,300 μS/cm or 0.1-1.3 mS/cm as shown in the figure) is quite large compared with the range of Sacramento River EC values. Concentrations of these minerals increased linearly with EC.

At an EC of 1,000 μS/cm (i.e., 1.0 mS/cm), the K^+ concentration was less than 5 mg/l, indicating a very low K^+/EC value of less than .005 in San Joaquin River water. Mg^{2+} concentration was about 25 mg/l at an EC of 1,000 μS/cm, for a Mg^{2+}/EC value of 0.025. Ca^{2+} concentration was about 50 mg/l at an EC of 1,000 μS/cm, for a Ca^{2+}/EC ratio of 0.05.

Na^+, Cl^-, and SO_4^{2-} had approximately the same concentrations, and each exhibited an increasing ratio with EC as the EC value increased. Higher Cl^-/EC ratios at higher EC values were previously attributed to variable mixing of Stanislaus River and San Joaquin River water. At an EC value of 500 μS/cm, each of the three constituents had a ratio with EC of about 0.10. However, at an EC value of 1,000 μS/cm, the Na^+/EC value increased to 0.12, the Cl^-/EC value increased to 0.15, and the SO_4^{2-} value increased to about 0.17.

Figure C1-14 shows the organic variables, DOC and C-THM, as measured in the 1982-1991 DWR MWQI samples from the San Joaquin River. The range of DOC and C-THM concentrations was greater for the San Joaquin River than for the Sacramento River. Concentrations of DOC and C-THM did not increase with EC values. Because the range of unexplained fluctuation is quite large, monthly samples may not reliably reveal patterns for organic parameters in the San Joaquin River. Estimates of DOC based on flow or EC monitoring will not be reliable for San Joaquin River concentrations of DOC.

Mallard Island Water Quality Characteristics

Mallard Island, located near Chipps Island, is the Delta outflow station sampled in the DWR MWQI program. Figure C1-15 shows the mineral concentrations at this station plotted against EC values. The mineral concentrations clearly increased linearly with EC, and mineral/EC values were similar to those of seawater (CRC 1989). Cl^- had the greatest concentration, and the Cl^-/EC value was about 0.30 at an EC of 10,000 μS/cm. The Na^+ concentration was about 1,800 mg/l at an EC of 10,000 μS/cm, so the Na^+/EC ratio was 0.18. SO_4^{2-} had the next highest concentration, and the ratio of SO_4^{2-} to EC was about 0.05. The ratio of Mg^{2+} to EC was about 0.025. Ca^+ and K^+ concentrations were relatively low, and their ratios to EC were less than 0.01.

Figure C1-16 show the organic variables, DOC and C-THM. in the Mallard Island samples. The lowest EC values at Mallard Island indicate that the sample was dominated by Sacramento and San Joaquin River water, whereas the highest EC values indicate that the sample was dominated by seawater. DOC concentrations were generally quite low, between 2.0 mg/l and 3.0 mg/l, for the entire range of EC values and similar to Sacramento River DOC concentrations, suggesting that seawater intrusion was not a significant source of DOC.

This review of the DWR MWQI data demonstrates that river inflows and seawater intrusion as Delta sources have distinctive mineral characteristics, as summarized by Cl^-/EC ratios. These mineral characteristics may be used to identify the sources of water samples from Delta exports. This source identification technique is important for estimating expected changes in export concentrations of water quality constituents because the DW project operations are expected to change the source contributions of water at the export locations.

WATER QUALITY CHARACTERISTICS OF DELTA EXPORTS

The differences between the observed export concentrations of water quality constituents and the inflow concentrations provides a means to estimate the magnitude of contributions from other Delta sources (channel processes and agricultural drainage). Inflow water quality changes with flow, and the mixture of water at each export location changes with inflows and export pumping each month. Therefore, estimates of source tracking and mixed export concentrations must be calculated for each month. This methodology will be demonstrated as part of the Delta island drainage water quality monthly model DeltaDWQ in Appendix C4 and used for DW project water quality impact assessment.

Water Quality Characteristics of CCWD Diversions at Rock Slough

Figure C1-17 shows mineral concentrations from the 1982-1991 DWR MWQI data for CCWD diversions at Rock Slough. Comparison of this figure with Figures C1-11, C1-13, and C1-15, showing concentrations for the three major Delta water sources (Sacramento and San Joaquin Rivers and Mallard Island), indicates that the dominant source of elevated salinity (i.e., EC above 400 μS/cm or 0.4 mS/cm) was seawater intrusion. Because the Cl^-/EC value was above 0.15, most Cl^- in Rock Slough could not have originated from the San Joaquin River. In addition, Na^+ concentrations were much lower than Cl^- concentrations, which is characteristic of seawater (Figure C1-15). For lower EC values (lower than 400 μS/cm), the mixture of source water in Rock Slough is not as easily detected from the mineral graph.

Figure C1-18 shows the organic parameters, DOC and C-THM, measurements for Rock Slough water samples. Because none of the Delta water sources exhibited any pattern in DOC or C-THM with increasing EC, no reason exists to expect a pattern in DOC or C-THM at the export locations. One way to estimate the change caused by in-Delta processes is to calculate increases in DOC and C-THM between Sacramento and San Joaquin River inflows and Rock Slough for each monthly sample. Increases will depend on the mixture of source water and the measured DOC and C-THM in the sources and exports that month. This will provide an estimate of the contributions from agricultural drainage and channel processes.

Water Quality Characteristics of SWP Banks Pumping Plant Exports

Figure C1-19 shows the mineral concentrations from the 1982-1991 DWR MWQI data for the SWP Banks Pumping Plant. The range of EC observed for Banks Pumping Plant was smaller than that observed for Rock Slough, with EC values between 200 μS/cm and 900 μS/cm. Comparison of this figure with Figures C1-11, C1-13, and C1-15, showing concentrations for the three major Delta water sources, indicates that the dominant source of the elevated salinity (EC above 400 μS/cm) was seawater intrusion. Because the Cl^-/EC value exceeds 0.15 for EC greater than 400 μS/cm, most Cl^- in these samples could not have originated from the San Joaquin River, which has a maximum Cl^-/EC value of 0.15. In addition, Na^+ concentrations are much lower than Cl^- concentrations, which is characteristic of seawater (Figure C1-15).

For lower EC values (lower than 400 μS/cm), the mixture of source water at Banks Pumping Plant is not easily detected from the mineral graph. The influence of San Joaquin River inflow is evident in some samples with nearly equal concentrations of Cl^-, Na^+, and SO_4^{2-}, with each about 10% of the EC value.

Figure C1-20 shows the organic variables, DOC and C-THM, measured at Banks Pumping Plant. Because none of the Delta water sources exhibited a pattern in DOC or C-THM with increasing EC, no pattern exists in DOC or C-THM at Banks Pumping Plant. One way to estimate the change caused by in-Delta processes is to calculate increases in DOC and C-THM between Sacramento and San Joaquin River inflows and Rock Slough for each monthly sample. Increases will depend on the mixture of source water and the measured DOC and C-THM in the sources and exports that month. This will provide an estimate of the contributions from agricultural drainage and channel processes

Water Quality Characteristics of CVP Tracy Pumping Plant Exports

Figure C1-21 shows the mineral concentrations from the 1982-1991 DWR MWQI data for the DMC near the CVP Tracy Pumping Plant. The range of EC observed for the DMC was about the same as that observed the SWP Banks Pumping Plant, with EC values between 200 μS/cm and 900 μS/cm. Comparison of this figure with Figures C1-11, C1-13, and C1-15 showing the three major Delta water sources, indicates that the dominant source of the elevated salinity (EC above 400 μS/cm) can be identified as a combination of seawater intrusion and San Joaquin River inflow. Whenever the Cl^-/EC value is above 0.15, most Cl^- in a sample could not have originated from the San Joaquin River, which has a maximum Cl^-/EC value of 0.15. In addition, Na^+ concentrations are often much lower than Cl^- concentrations, which is characteristic of seawater (Figure C1-15).

Several samples from the DMC have elevated EC values but nearly equal Cl^- and Na^+ concentrations at about 10% of the EC value. These water samples were apparently dominated by San Joaquin River inflows (Figure C1-13).

For lower EC values (less than 400 μS/cm), the mixture of source water at the DMC is not easily detected from the mineral graph. The influence of San Joaquin River inflow is evident in some samples with nearly equal concentrations of Cl^-, Na^+, and SO_4^{2-}, with each about 10% of the EC value. The comparison of San Joaquin inflow EC value with the DMC export EC value may provide an estimate of the dilution that has occurred with Sacramento River water.

Figure C1-22 shows the organic parameters, DOC and C-THM, measured in the DMC samples. One way to estimate the change caused by in-Delta processes is to calculate increases in DOC and C-THM between Sacramento and San Joaquin River inflows and Rock Slough for each monthly sample. Increases will depend on the mixture of source water and the measured DOC and C-THM in the sources and exports that month. This will provide an estimate of the contributions from agricultural drainage and channel processes.

CONCLUSIONS

The DWR MWQI measurements for minerals, DOC, THMFP, and associated water quality constituents provide the best available characterization of these constituents in Delta inflows and Delta exports. The observed differences between the inflow and export values are related to the mixture of water from different sources (river inflows and salinity intrusion) at the export locations. However, the source contributions at each export location change with Delta inflows and exports, making it difficult to estimate from these water quality measurements the magnitude of the contribution of DOC resulting from Delta channel processes and agricultural drainage.

Mineral characteristics of each river inflow and seawater intrusion are generally distinct and could be used to estimate the likely contributions of water from different sources at the export locations. The estimates of changes in source contributions that would result from DW project operations could then be used to estimate changes in DOC concentrations at the exports. However, because DOC concentrations in the river inflows cannot be reliably estimated from flow or EC monitoring data, inflow measurements are required for accurate prediction of export DOC concentrations.

The concepts of inflow source contributions and Delta source loads from channels or agricultural drainage were introduced in this appendix to explain the observed differences between inflow concentrations and export concentrations. Possible Delta source loads will be further explored in Appendix C2, "Analysis of Delta

Agricultural Drainage Water Quality Data", and Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project". Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model", presents results from a monthly Delta agricultural drainage water quality model that combines calculations of Delta inflow source contributions and agricultural drainage to estimate Delta export water quality for minerals (EC, Br^-) and organics (DOC). These estimated export concentrations are then used to estimate likely THM concentrations in treated drinking water exported from the Delta. These results are presented in Appendix C5, "Modeling Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water".

CITATIONS

Printed References

California. Department of Water Resources. 1989. The Delta as a source of drinking water. Monitoring results 1983 to 1987. Interagency Delta Health Aspects Monitoring Program. Central District. Sacramento, CA.

__________. Department of Water Resources. 1993. Annual Report of the Municipal Water Quality Investigations Program: summary of monitoring results January 1990-December 1990. Division of Local Assistance. Sacramento, CA.

__________. Department of Water Resources. 1994. Five-year report of the Municipal Water Quality Investigations Program (1987-1991). Division of Local Assistance. Sacramento, CA.

CRC. 1989. Handbook of Chemistry and Physics. 70th edition. Table F-169, "Elements in Seawater". CRC Press, Inc. Boca Raton, FL.

Personal Communication

Agee, Bruce. Program manager. Water Quality Assessment, Division of Local Assistance, California Department of Water Resources. Sacramento, CA. May 1993 - computer disk file.

Table C1-1. Mean Values for DWR MWQI 1982-1991 Data

	Sacramento River at Greene's Landing		San Joaquin River at Vernalis		Rock Slough (CCWD Intake)		Banks Pumping Plant (SWP Export)		Delta Mendota Canal (CVP Export)		Mallard Island
	All Data n=112	Selected Monthly Data n=88	All Data n=130	Selected Monthly Data n=96	All Data n=125	Selected Monthly Data n=96	All Data n=138	Selected Monthly Data n=105	All Data n=127	Selected Monthly Data n=97	All Data n=101
EC (μS/cm)	167.0	164.0	683.0	645.0	554.0	518.0	483.0	454.0	537.0	507.0	9,018
Turbidity (NTU)	12.0	12.0	20.5	18.8	9.1	9.9	11.0	11.7	14.0	14.5	19.0
DOC (mg/l)	2.3	2.3	3.7	3.6	3.1	3.1	3.6	3.5	3.6	3.6	2.6
C-THM (μg/l)	31.5	32.1	49.4	49.0	48.5	48.0	55.8	54.1	52.4	50.9	49.6
UVA (cm^{-1})	0.052	0.043	0.085	0.074	0.1	0.1	0.12	0.12	0.112	--	0.085
Na^+ (mg/l)	10.8	10.6	82.5	79.0	68.5	62.9	56.6	52.8	61.6	58.1	1,570
Cl^- (mg/l)	7.2	7.1	92.1	85.8	109.6	100.3	82.5	74.6	84.5	77.1	2,852
Ca^{2+} (mg/l)	12.1	12.5	39.8	38.7	17.5	17.2	20.1	19.6	24.1	25.7	74
Mg^{2+} (mg/l)	7.1	7.1	22.0	21.2	17.2	16.7	15.6	15.4	17.4	17.3	207
K^+ (mg/l)	1.5	1.5	3.3	3.2	4.0	3.8	3.8	3.8	3.6	3.6	56
SO_4^{2-} (mg/l)	10.1	10.0	114.0	112.5	32.2	32.6	36.0	35.9	48.6	52.3	398
Br^- (mg/l)	0.02	0.02	0.44	0.43	0.54	0.52	0.39	0.39	0.38	0.37	12.5
Ratios (calculated for selected data only)											
Cl^-/EC		0.04		0.12		0.16		0.15		0.14	0.30
UVA/DOC		0.02		0.023		0.031		0.031		0.029	0.033
Br^-/Cl^-		0.0032		0.0033		0.0035		0.0034		0.0034	0.0038
C-THM/DOC		0.013		0.014		0.016		0.015		0.015	0.020

n = number of samples; some parameters were not measured in each sample.

-- = no measurements.

C-061693

Table C1-2. Characteristics of Trihalomethane Molecules

THM Molecule Name	Chemical Symbol	Molecular Weight	Percent H	Percent C	Percent Cl	Percent Br
Chloroform	$CHCl_3$	119.36	0.84	10.06	89.10	0.00
Dichlorobromomethane	$CHCl_2Br$	163.81	0.61	7.33	43.28	48.78
Dibromochloromethane	$CHClBr_2$	208.26	0.48	5.76	17.02	76.74
Bromoform	$CHBr_3$	252.71	0.40	4.75	0.00	94.85

Molecular weight:

C = 12.01
H = 1.0
Cl = 35.45
Br = 79.90

C-061694

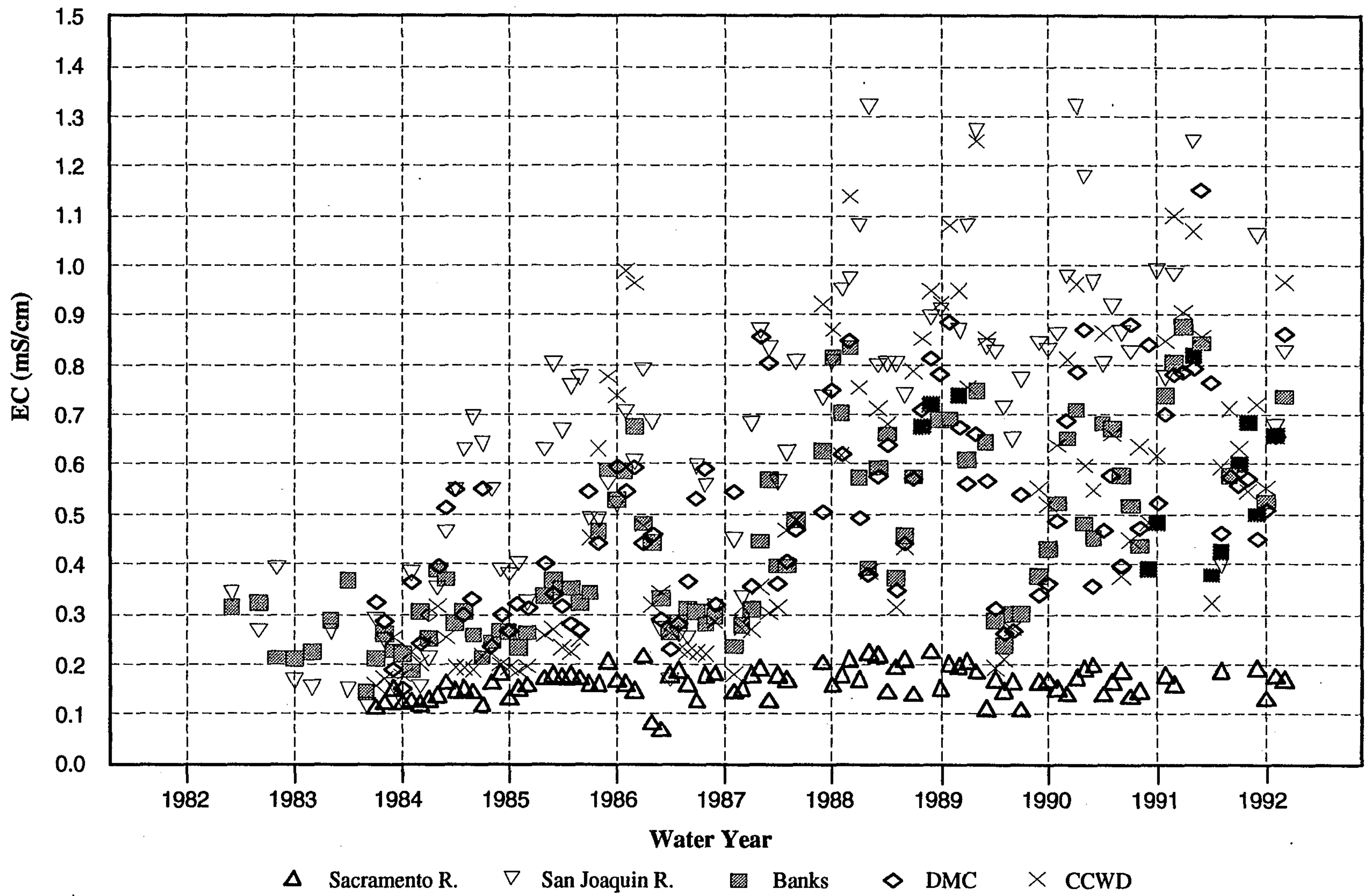


Figure C1-1.
EC Values of 1982-1991 MWQI Monthly Samples
from the Sacramento and San Joaquin Rivers and Delta Exports

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

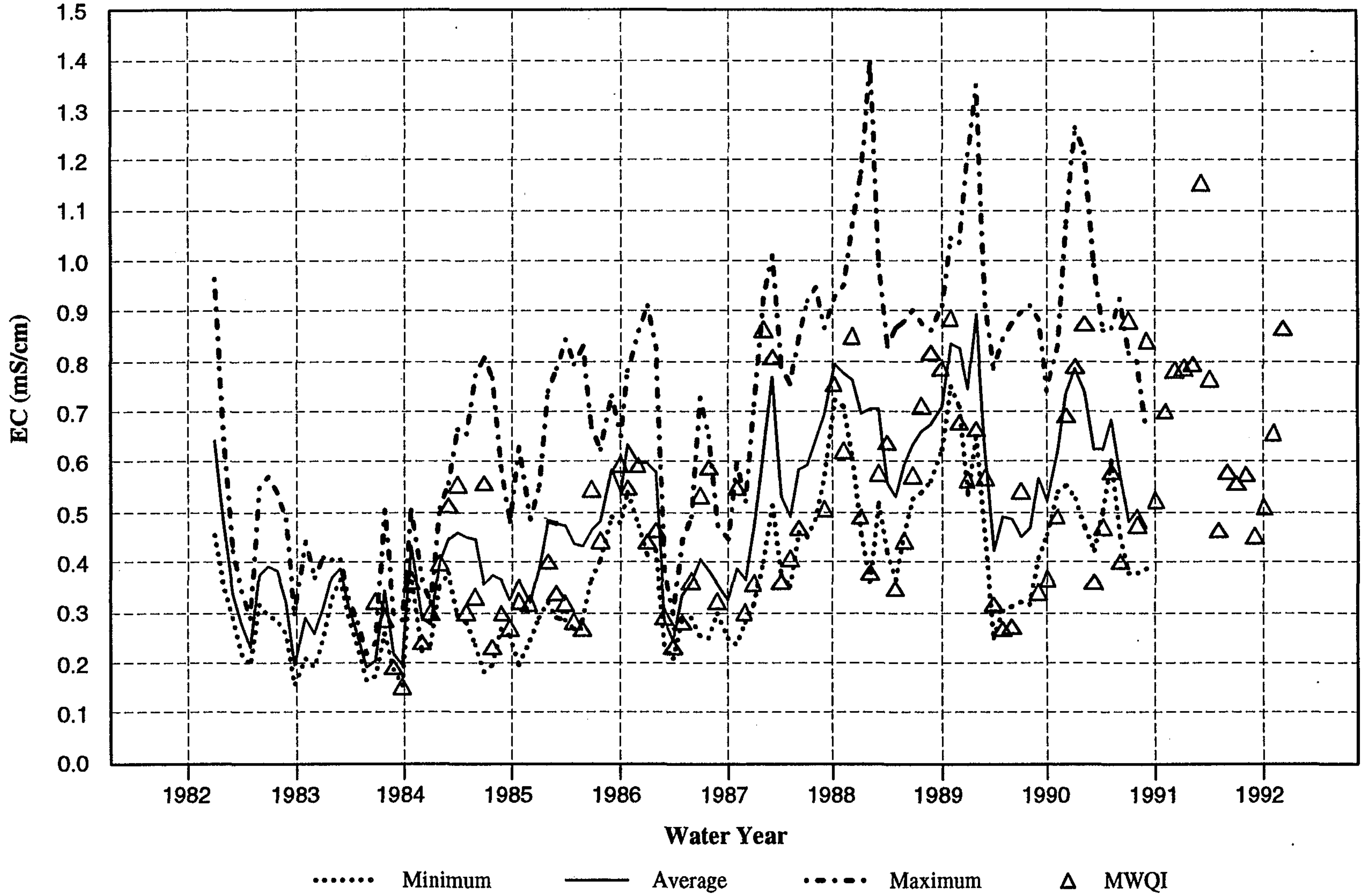


Figure C1-2.
Comparison of 1982-1991 MWQI Sample EC Values with Monthly Range of Daily Mean EC Values from Continuous Monitoring at the DMC

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

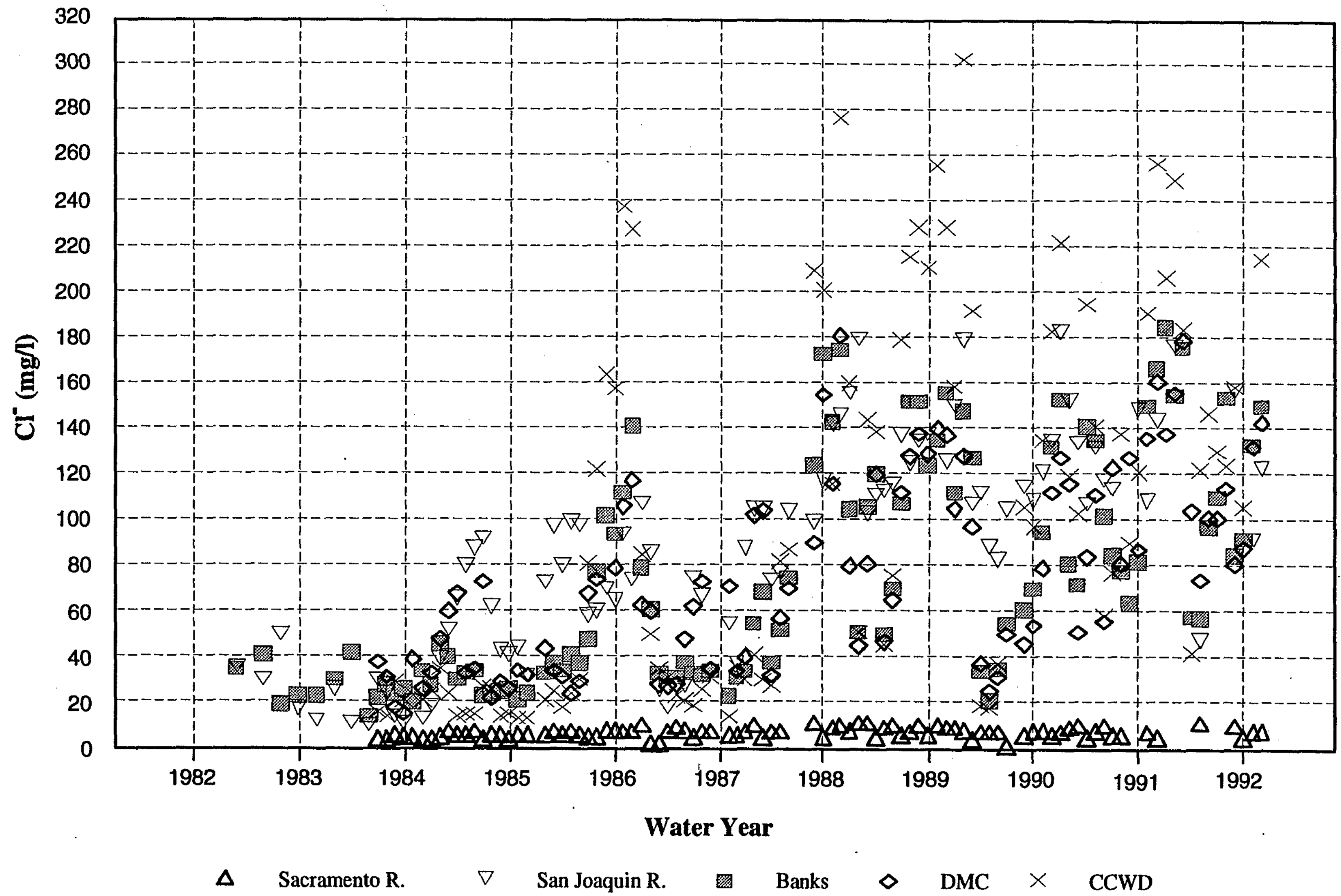


Figure C1-3.
Chloride Concentrations of 1982-1991 MWQI Monthly Samples from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

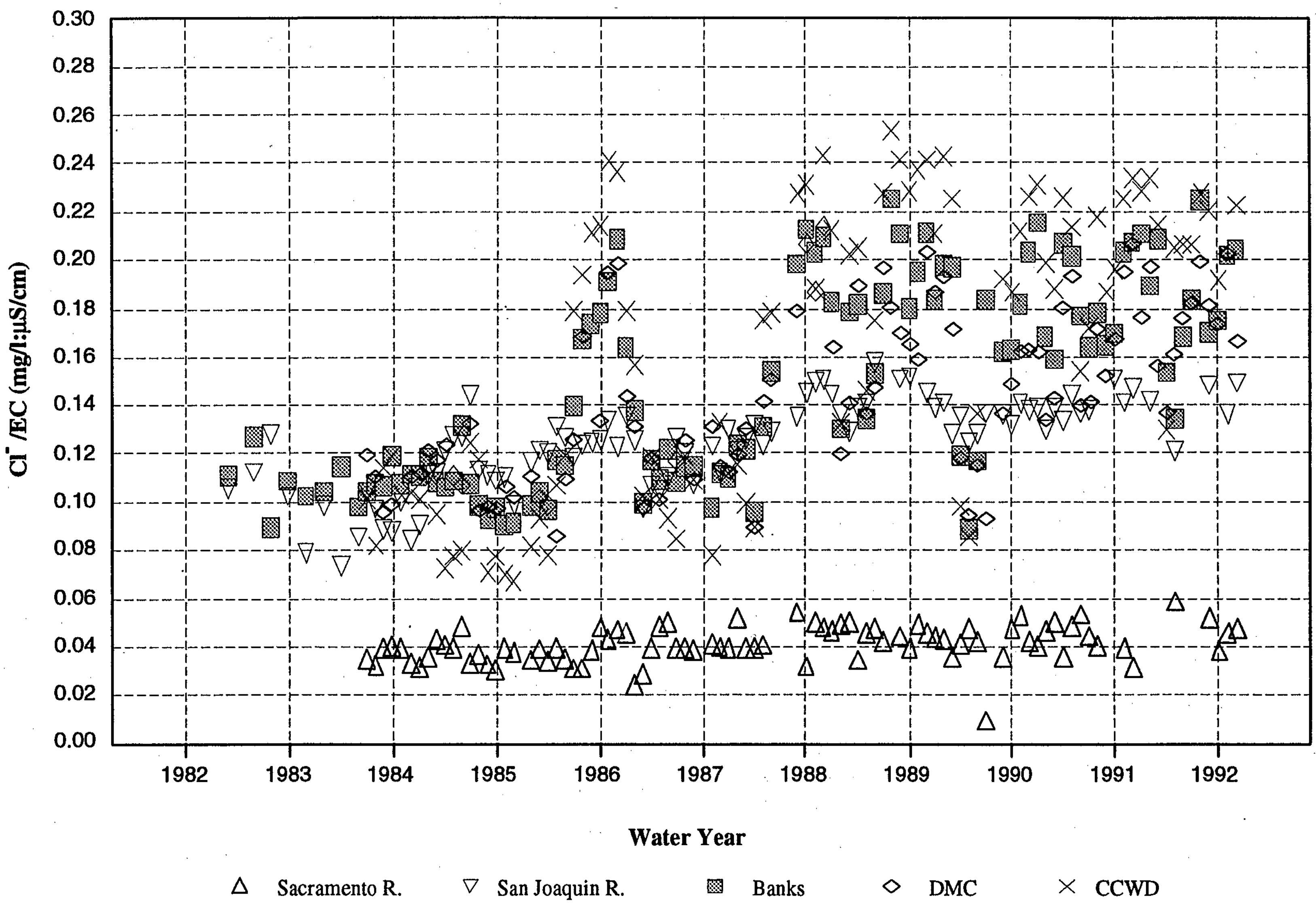


Figure C1-4.
Chloride-to-EC Ratios for 1982-1991 MWQI Monthly Samples from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061698

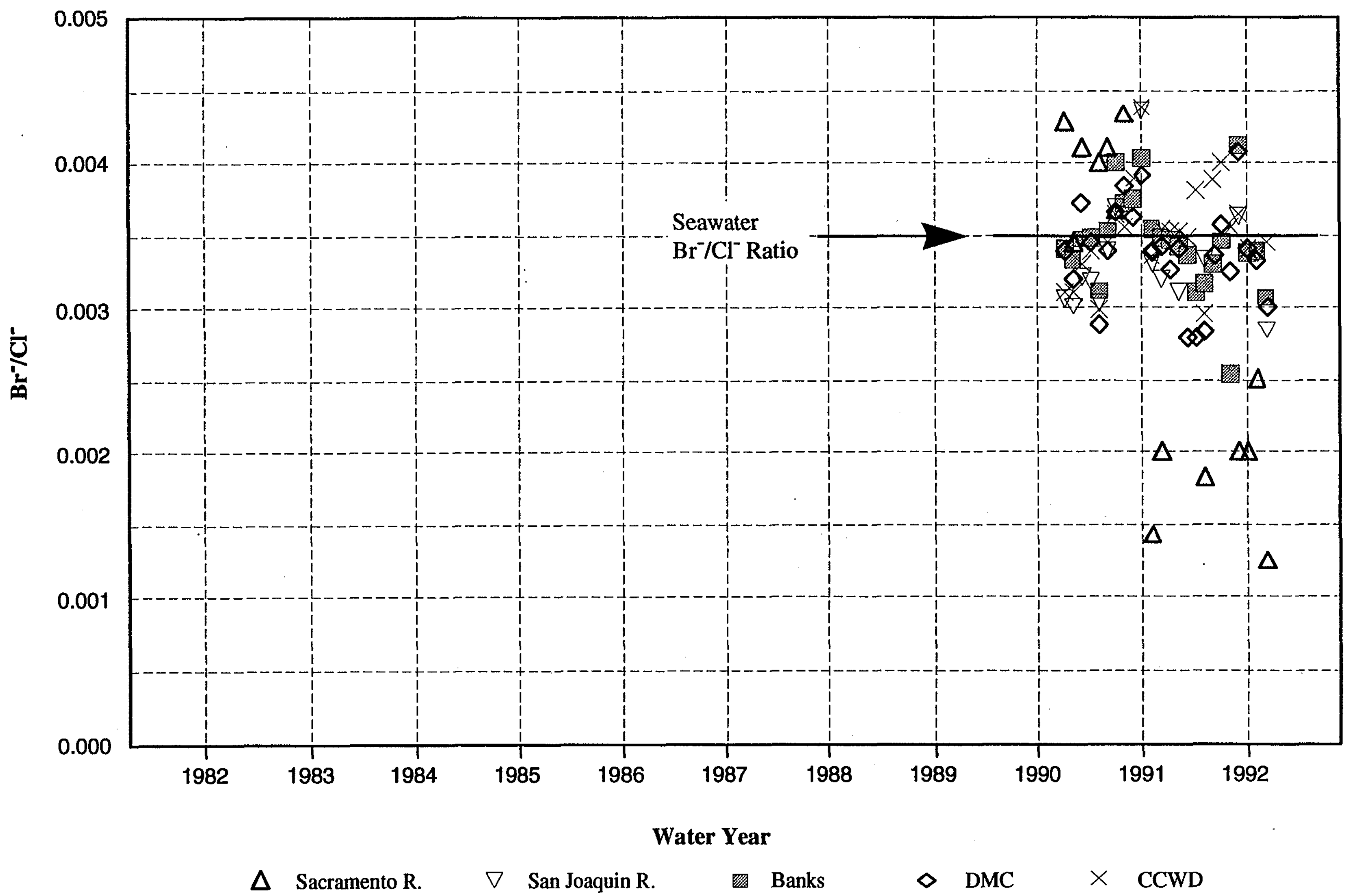


Figure C1-5.
Bromide-to-Chloride Ratios for 1982-1991 MWQI Monthly Samples from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061699

C-061699

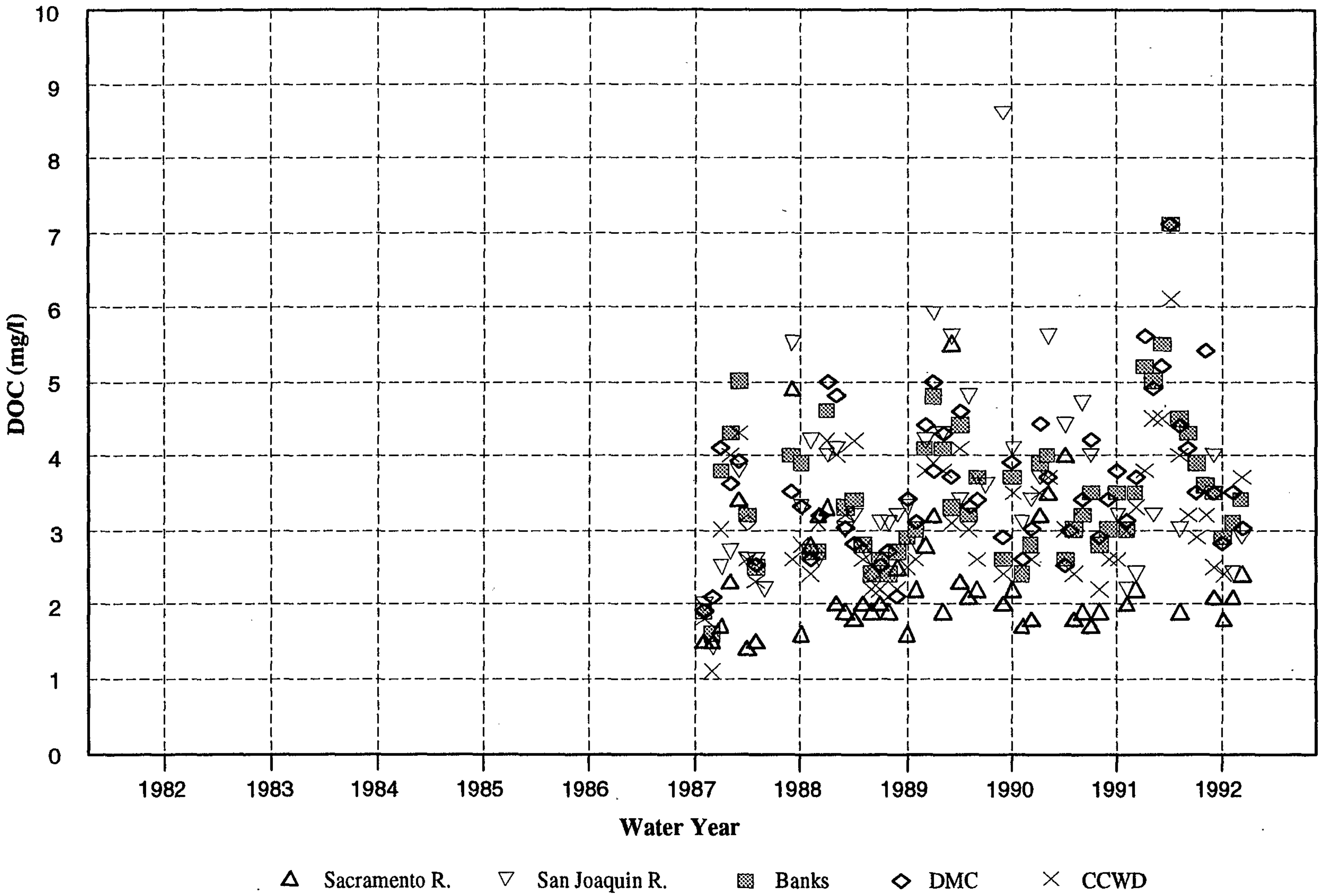


Figure C1-6.
DOC Concentrations of 1982-1991 MWQI Monthly Samples
from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061700

C-061700

C — 0 6 1 7 0 1

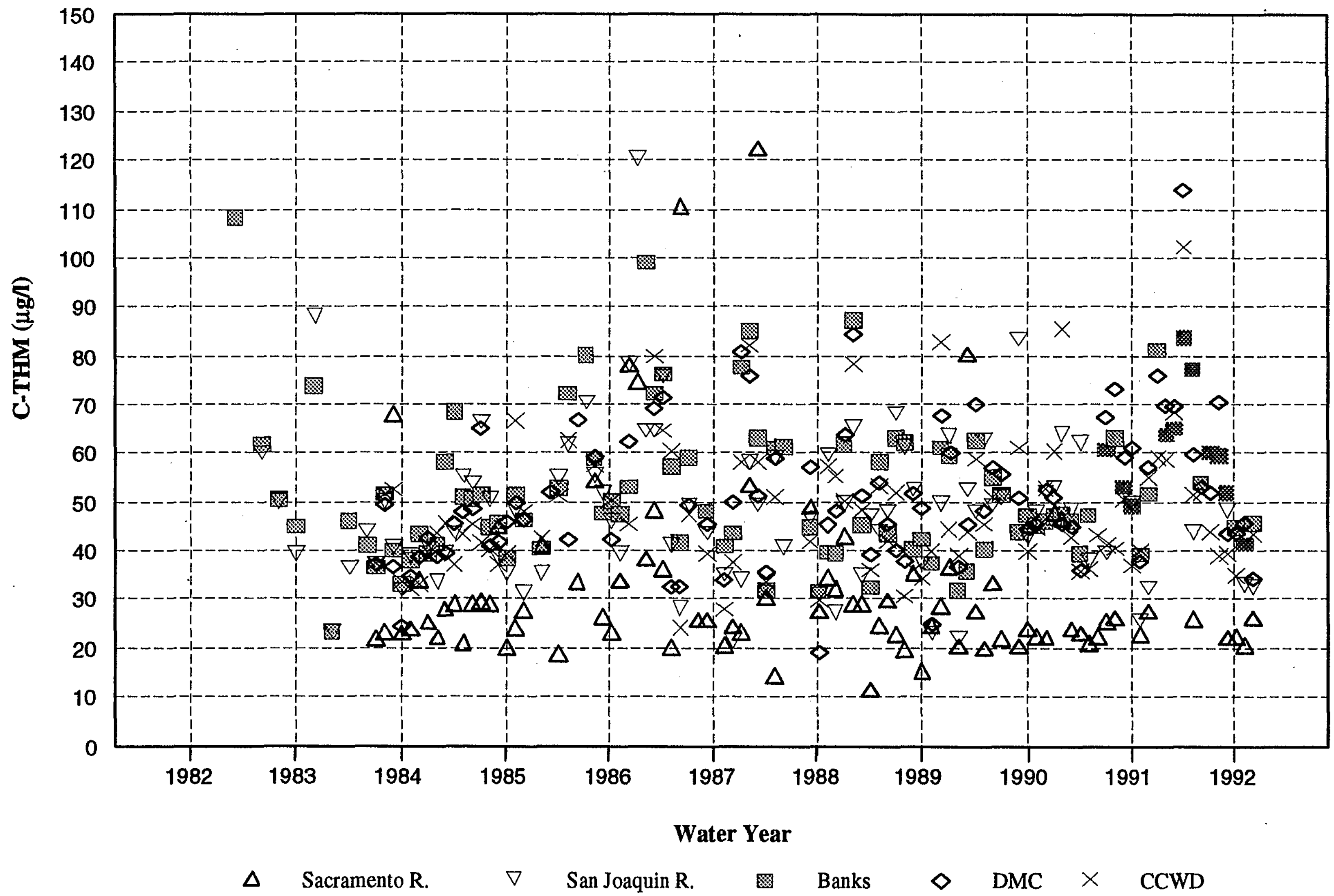


Figure C1-7.
C-THM Concentrations Calculated from 1982-1991 MWQI Monthly Samples from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

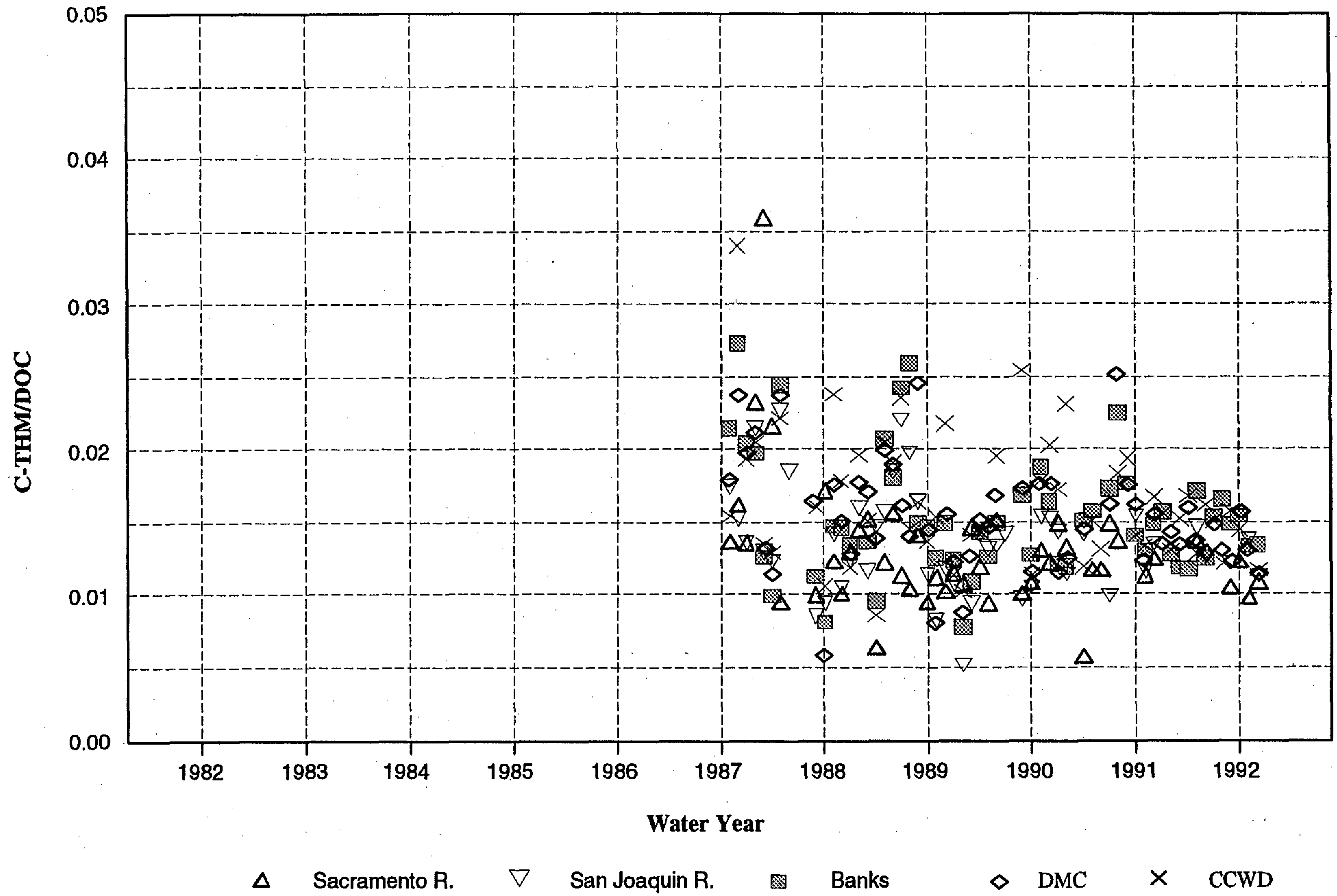


Figure C1-8.
C-THM-to-DOC Ratios Calculated for 1982-1991 MWQI Monthly Samples from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

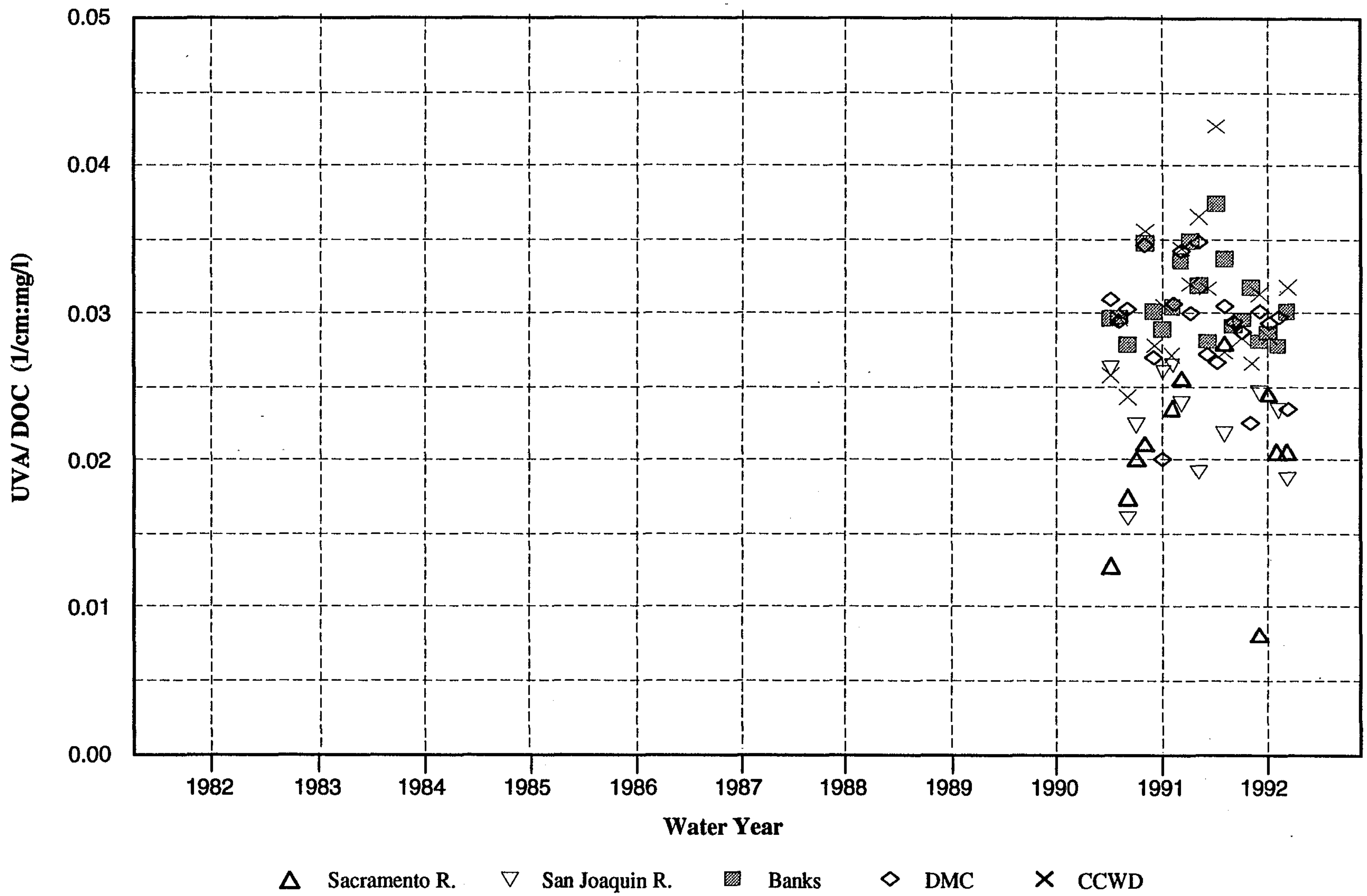


Figure C1-9.
UVA-to-DOC Ratios of 1982-1991 MWQI Monthly Samples
from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

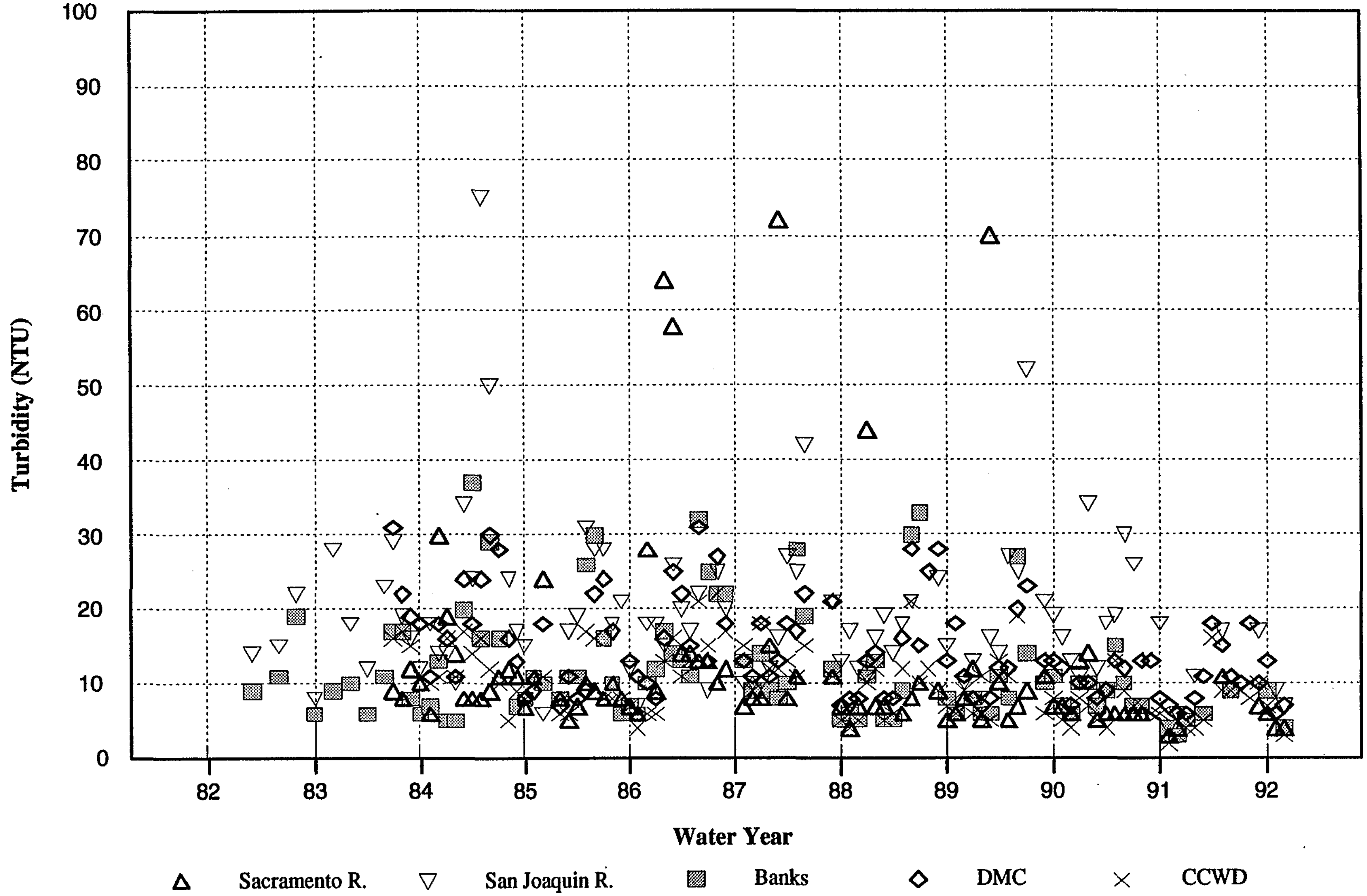


Figure C1-10.
Turbidity Values of 1982-1991 MWQI Monthly Samples from the Sacramento and San Joaquin Rivers and Delta Export Locations

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

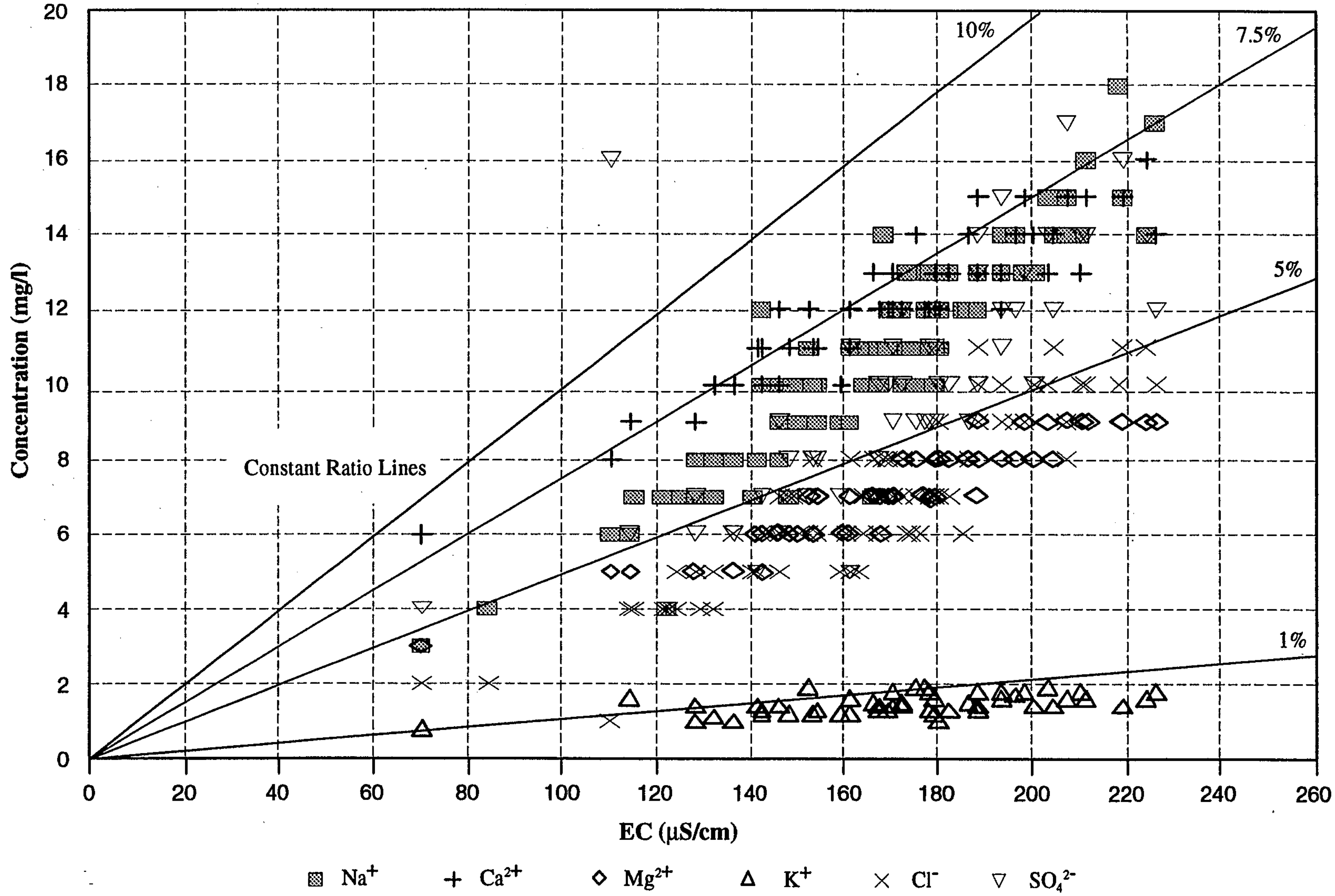
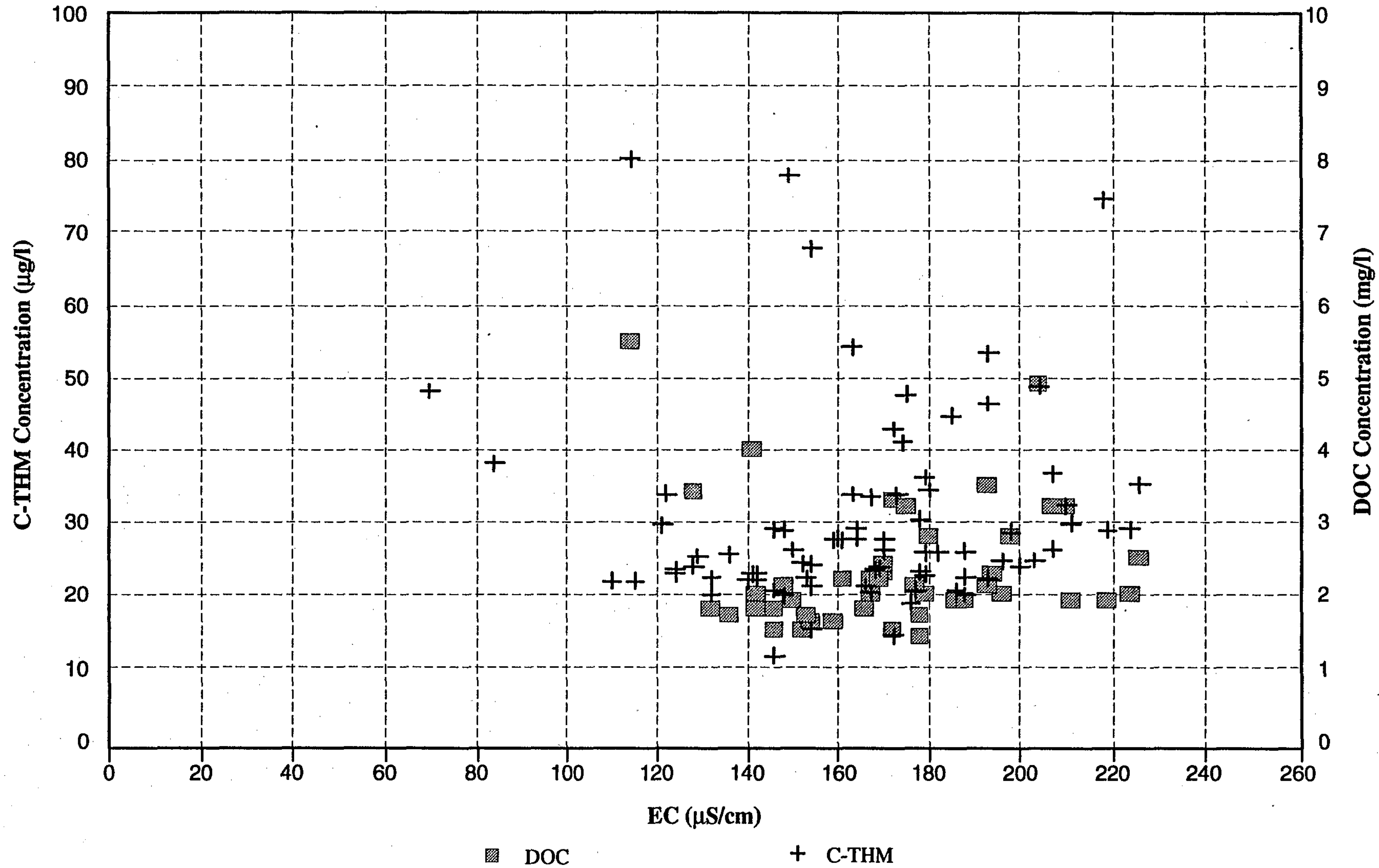


Figure C1-11.
Mineral Concentrations of 1982-1991 MWQI
Monthly Samples from the Sacramento River at Greene's Landing

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates



C — 0 6 1 7 0 6

Figure C1-12.
DOC and C-THM Concentrations of 1982-1991 MWQI
Monthly Samples from the Sacramento River at Greene's Landing

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

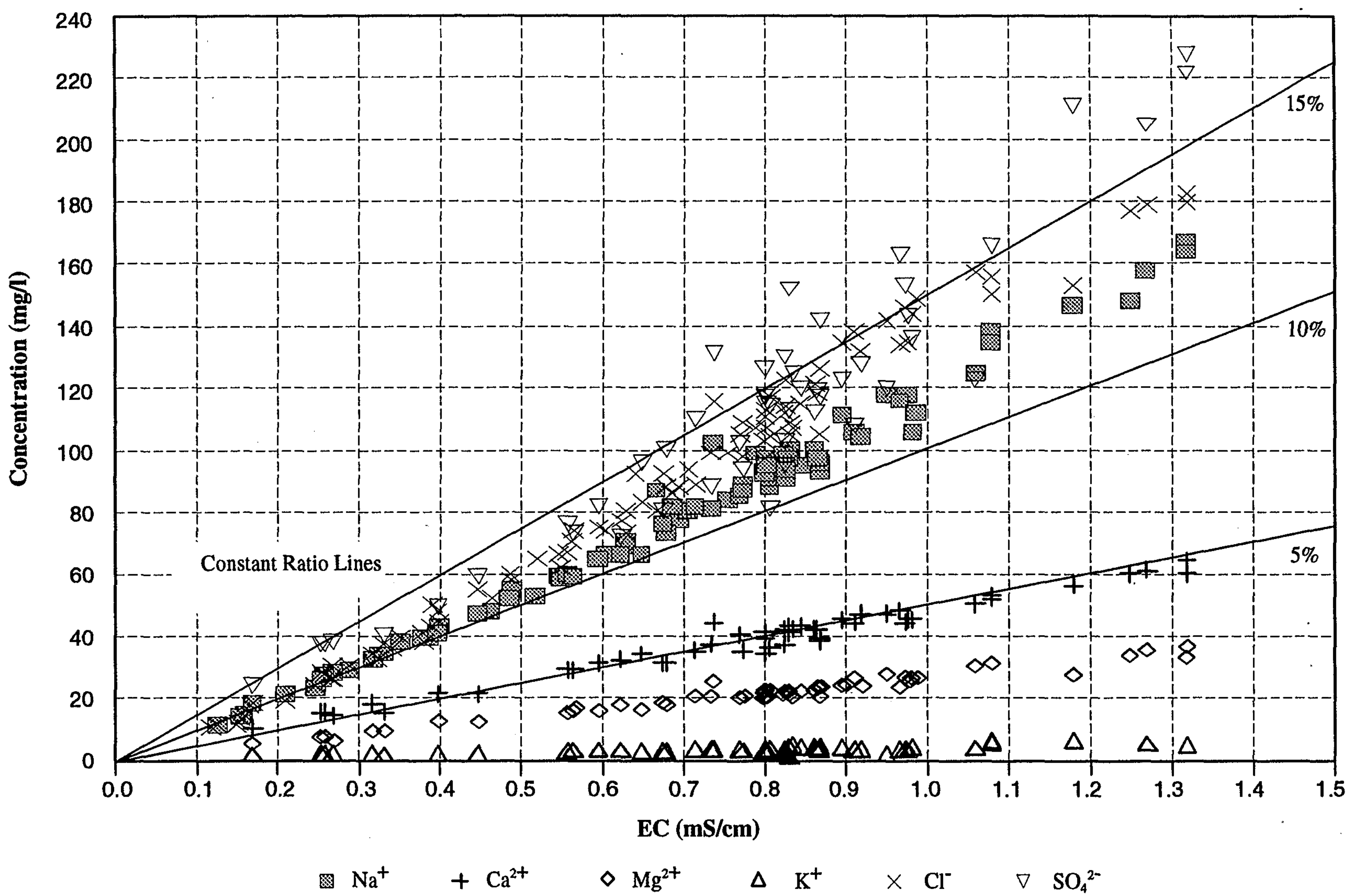


Figure C1-13.
Mineral Concentrations of 1982-1991 MWQI
Monthly Samples from the San Joaquin River at Vernalis

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061707

C-061707

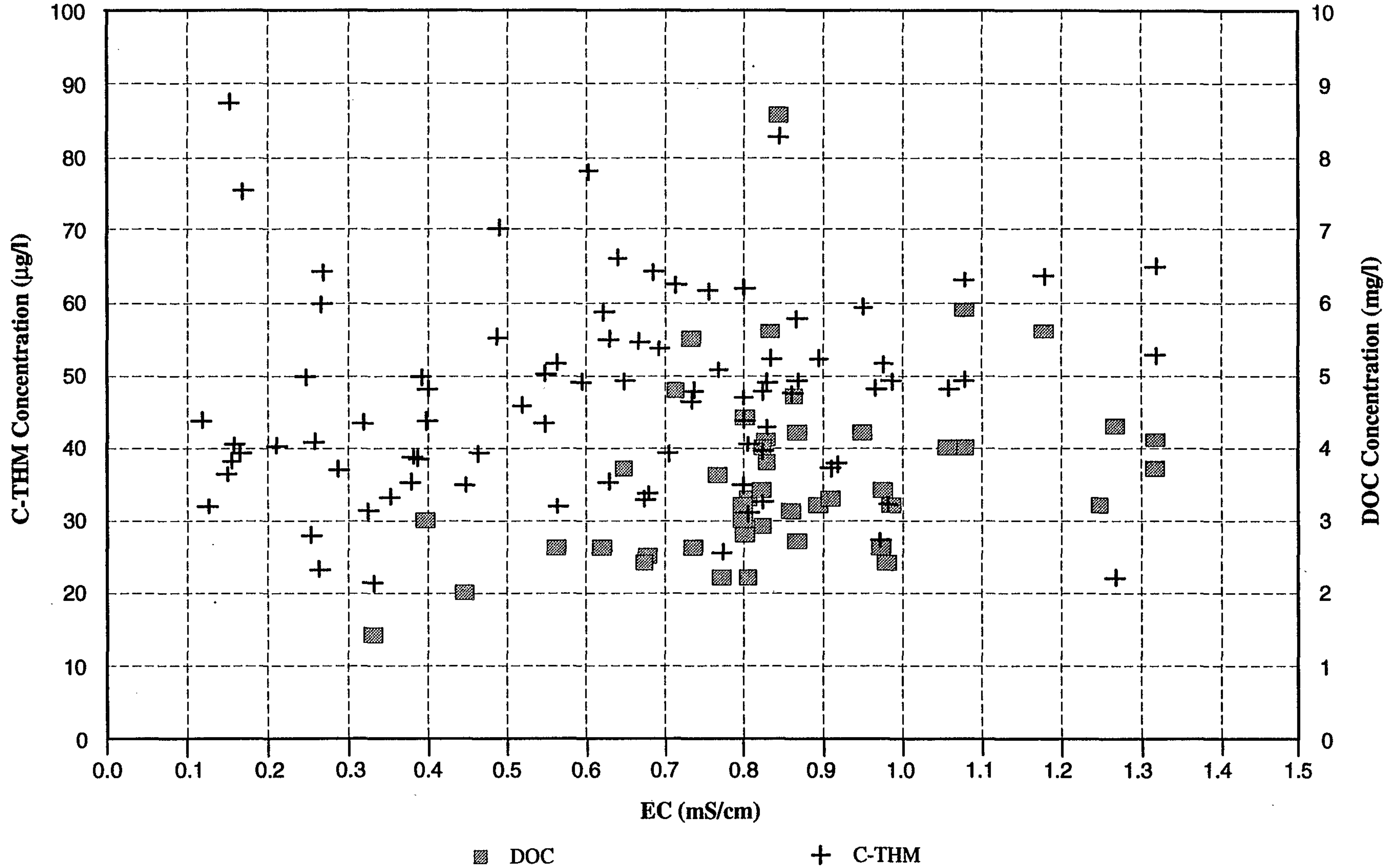


Figure C1-14.
DOC and C-THM Concentrations of 1982-1991 MWQI Monthly Samples from the San Joaquin River at Vernalis

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061708

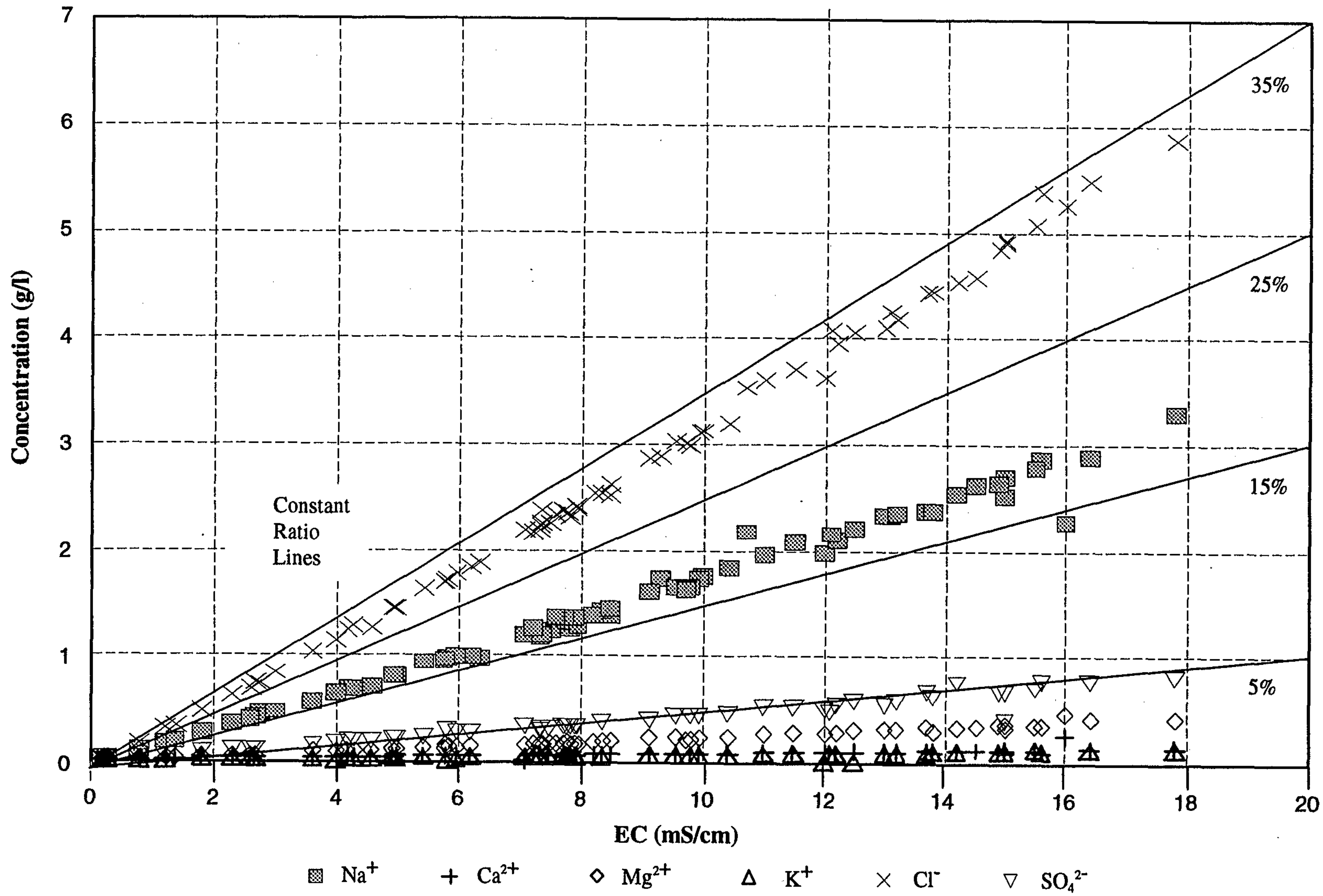


Figure C1-15.
Mineral Concentrations of 1982-1991 MWQI
Monthly Samples from Mallard Island (Chipps Island)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

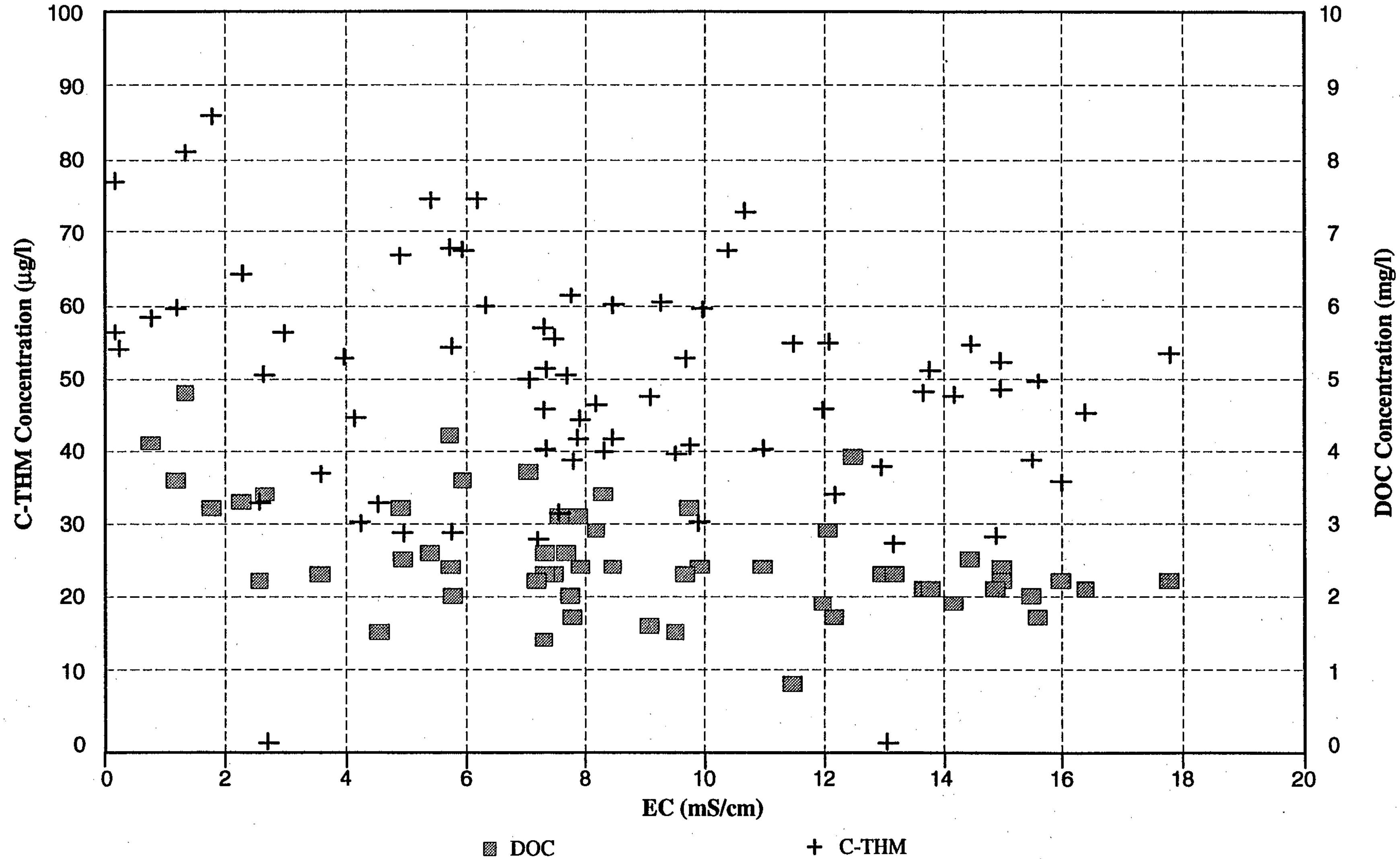


Figure C1-16.
DOC and C-THM Concentrations of 1982-1991 MWQI Monthly Samples from Mallard Island (Chipps Island)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061710

C-061710

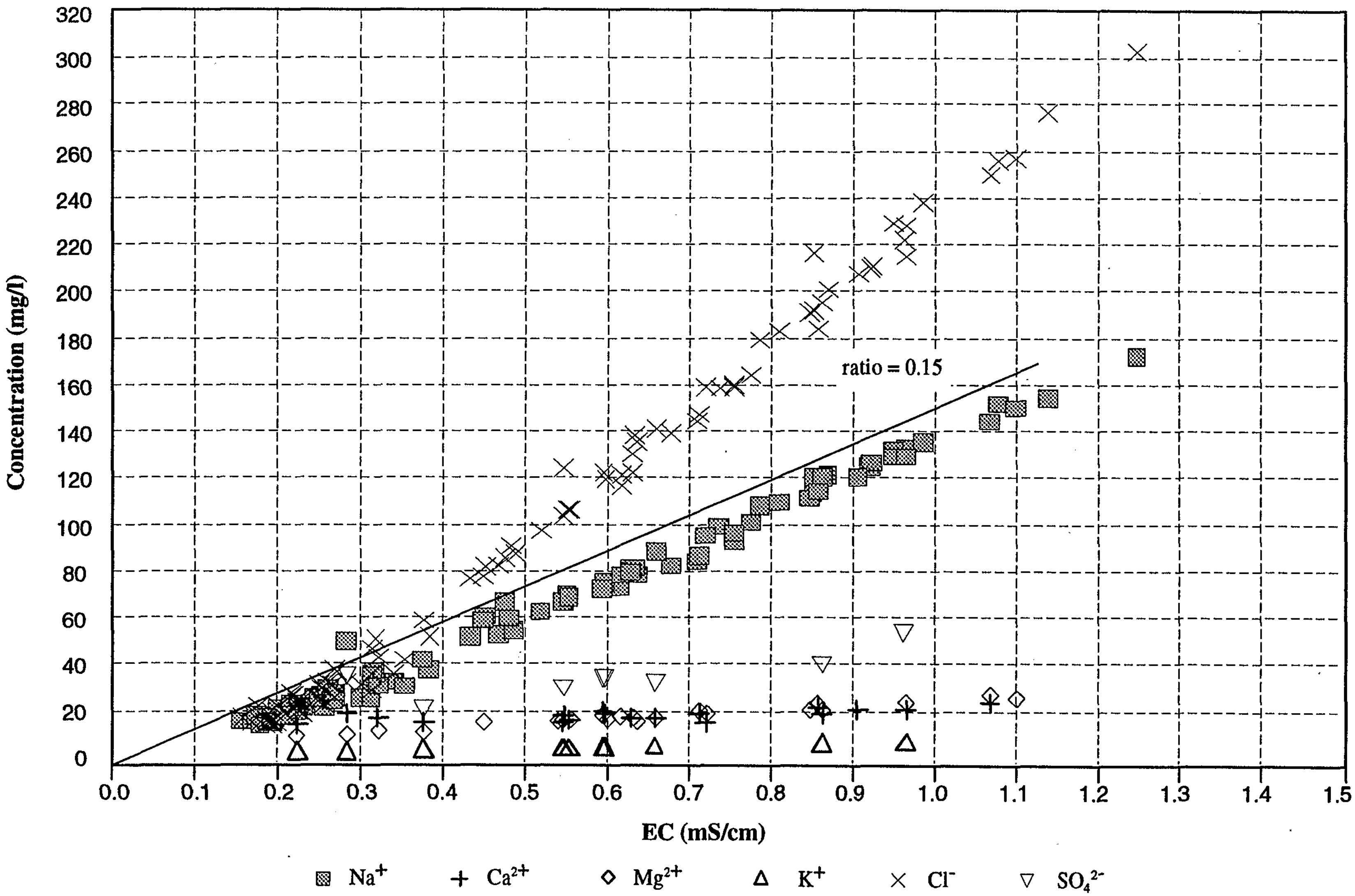


Figure C1-17.
Mineral Concentrations of 1982-1991 MWQI
Monthly Samples from Rock Slough (CCWD Delta Diversions)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061711

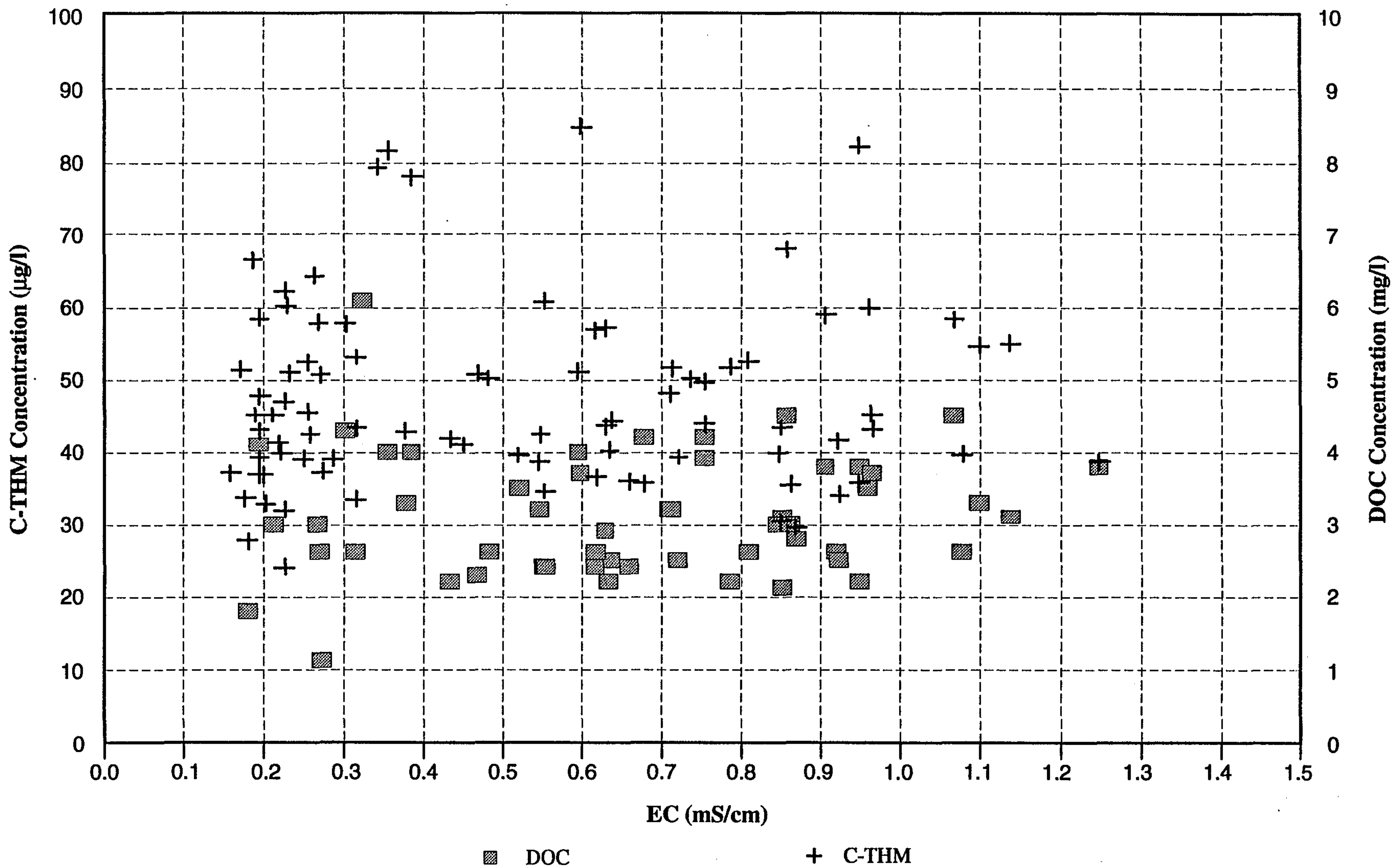


Figure C1-18.
DOC and C-THM Concentrations of 1982-1991 MWQI
Monthly Samples from Rock Slough (CCWD Delta Diversions)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061712

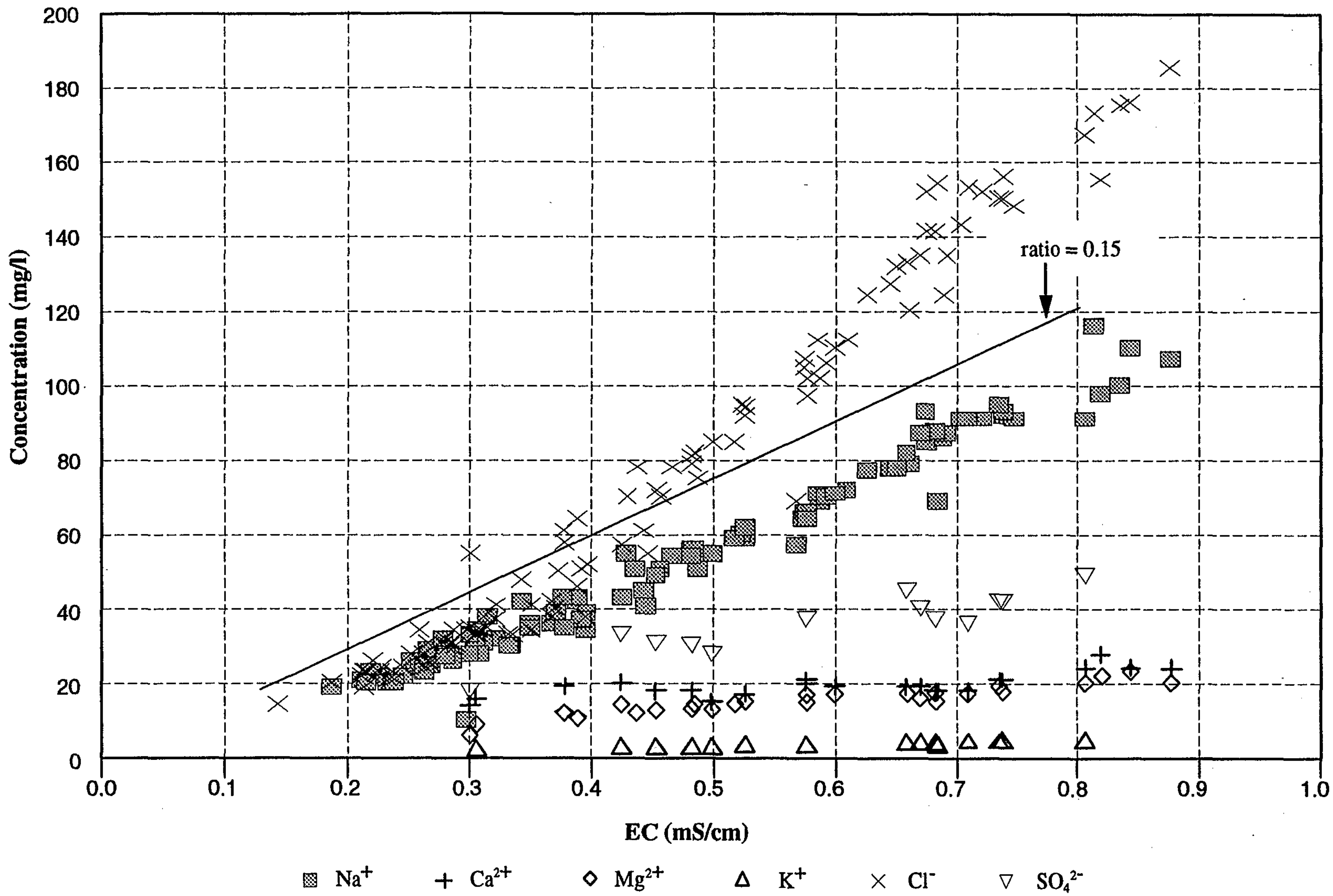


Figure C1-19.
Mineral Concentrations of 1982-1991 MWQI
Monthly Samples from Banks Pumping Plant (SWP Delta Exports)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

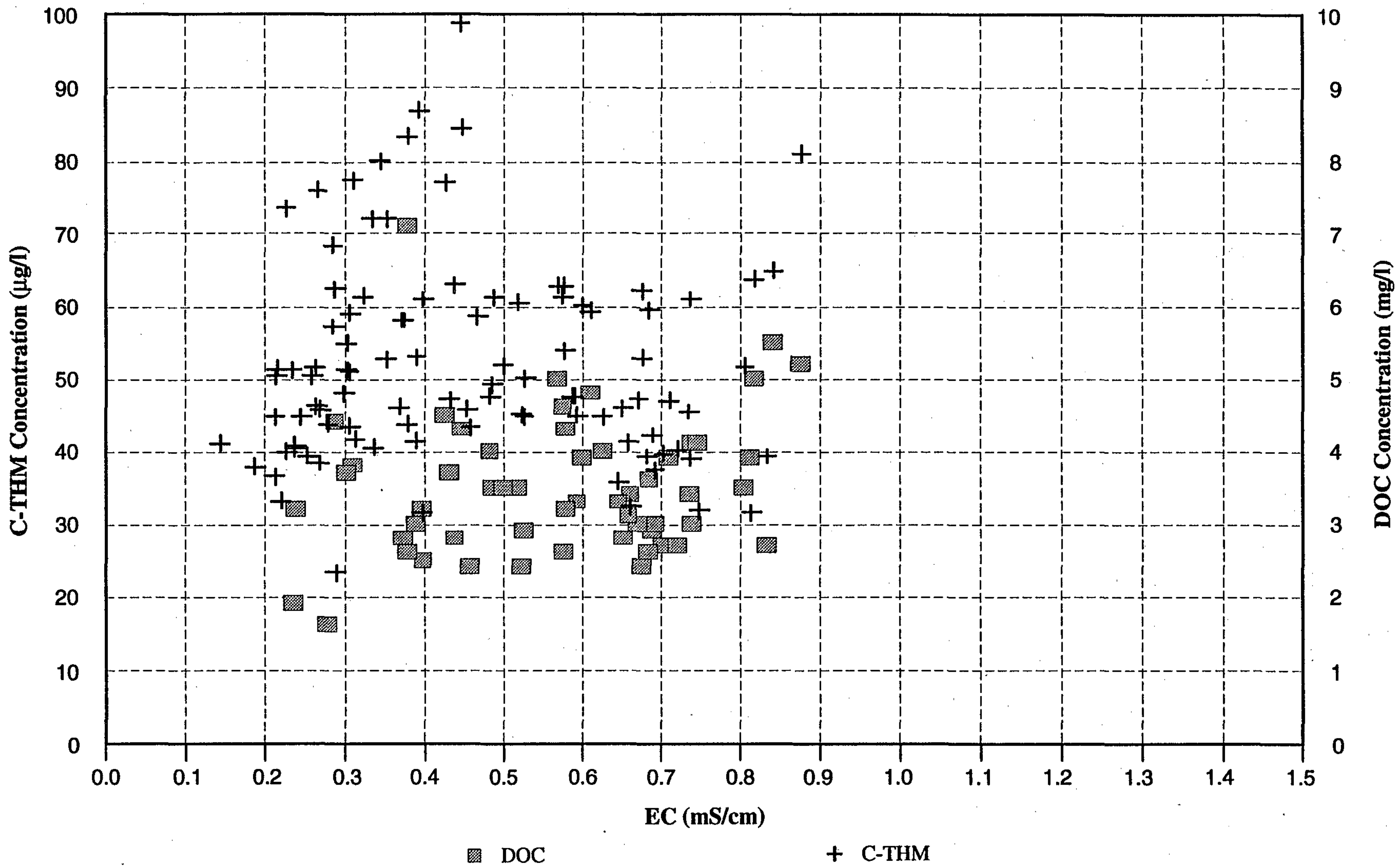


Figure C1-20.
DOC and C-THM Concentrations of 1982-1991 MWQI
Monthly Samples from Banks Pumping Plant (SWP Delta Exports)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

C-061714

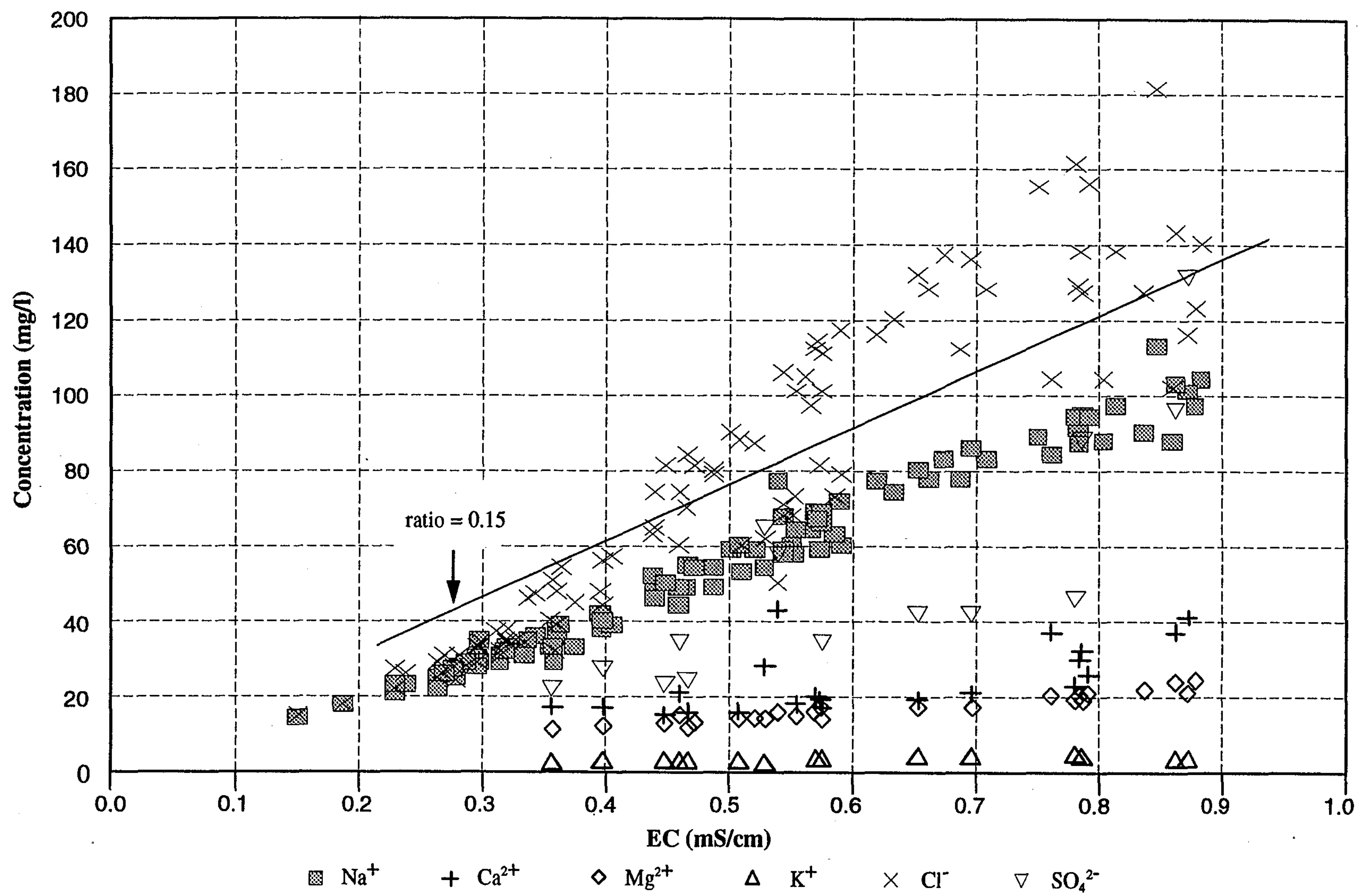


Figure C1-21.
Mineral Concentrations of 1982-1991 MWQI
Monthly Samples from Delta Mendota Canal (CVP Tracy Exports)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

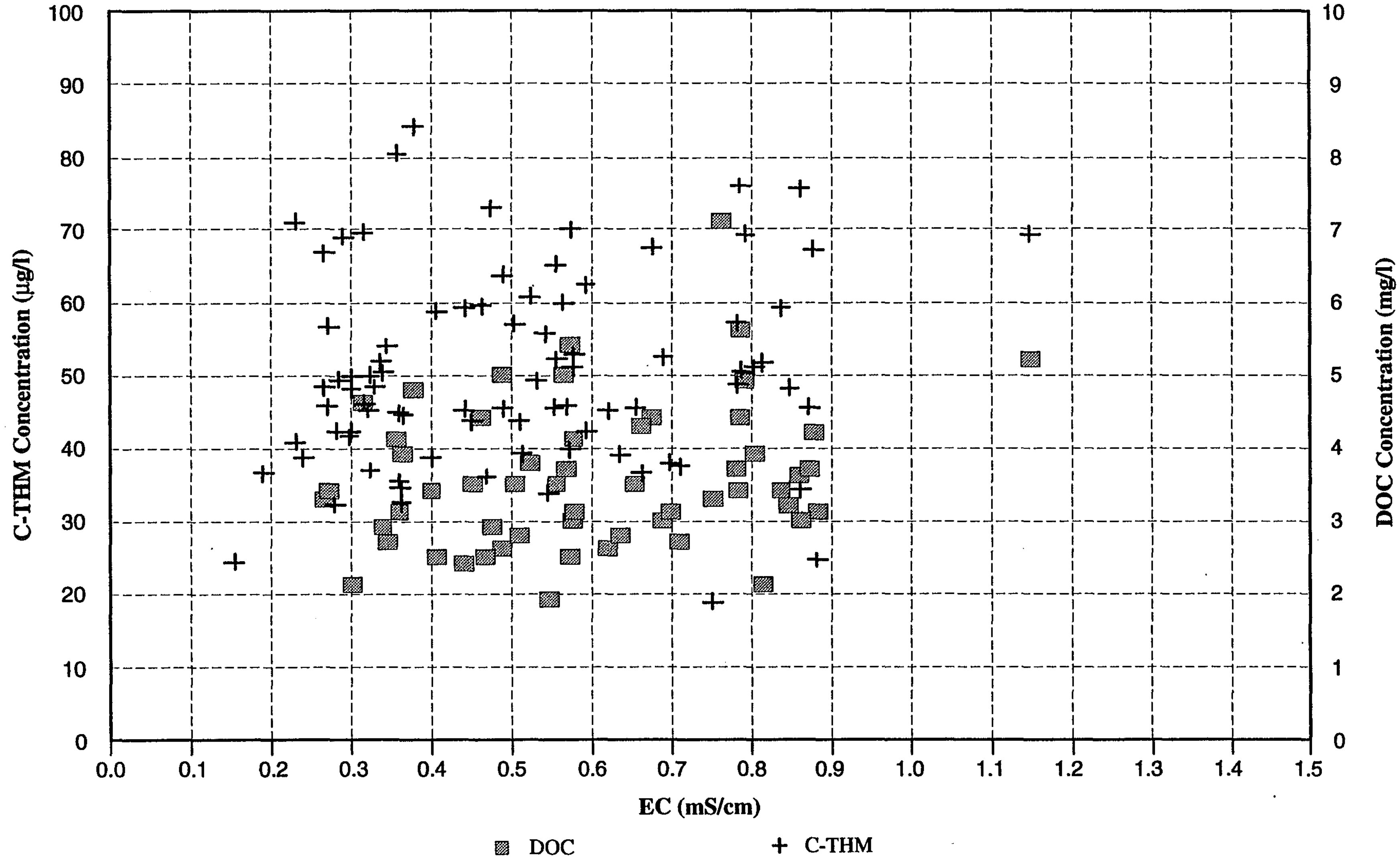


Figure C1-22.
DOC and C-THM Concentrations of 1982-1991 MWQI
Monthly Samples from Delta Mendota Canal (CVP Tracy Exports)

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates