Appendix C2. Analysis of Delta Agricultural Drainage Water Quality Data

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SUMMARY

This appendix presents an analysis of available data on Delta agricultural drainage to provide background information for the analysis of potential effects of Delta Wetlands (DW) project discharges on Delta water quality. The relationships between agricultural drainage and other water budget terms are described and data from Delta island drainage measurements, including measurements from the DW islands, are assessed. The appendix shows the relationships between dissolved organic carbon (DOC) and other water quality variables, and identifies correlations between measurements of different variables that can be used to estimate trihalomethane formation potential (THMFP) of DW discharges.

INTRODUCTION

This appendix presents an analysis of available data on Delta agricultural drainage water quality. These data will be used to assess impacts of the DW project on Delta water quality. A potential water quality impact of primary concern is the project's contribution to the formation of trihalomethane (THM) in municipal water supplies from the Delta. The constituent of particular interest in water discharged from the DW project islands is DOC, which is the major organic precursor of THM.

This appendix reviews and summarizes available data on Delta agricultural drainage water quality, including measurements from drainage pumps on the four DW project islands, Bouldin and Bacon Islands and Webb and Holland Tracts. Also evaluated are water quality data from the California Department of Water Resources (DWR) 1955 Delta Drainage Study and the DWR Municipal Water Quality Investigations (MWQI) program for water years1986-1991 (DWR 1994).

Delta drainage is only one component of the complete water budget for Delta agricultural lands. Understanding the water budget terms is important for interpreting data on salt and DOC in agricultural drainage. This appendix first discusses the water budget for Delta islands in agricultural production and then describes the 1955 data on drainage salinity and estimated total dissolved solids (TDS) and the 1986-1991 data on drainage electrical conductivity (EC), DOC, THMFP, and other water quality variables.

DELTA AGRICULTURAL WATER BUDGET

General Water Budget Terms

Figure C2-1 shows a conceptual diagram of the generalized water budget for Delta agricultural islands. The equations at the bottom of the figure summarize the soil water balance, soil salt (EC) balance, and soil DOC balance terms. These terms are described in the following sections. The water budget terms include evapotranspiration (ET), rainfall, soil moisture storage, seepage from Delta channels, leaching to shallow groundwater, irrigation water, water applied for salt leaching, and pumped drainage water. Shallow groundwater underlying agricultural land may contribute water to soil moisture as seepage from Delta channels, or may receive water as leachate from excess soil moisture.

Identifying the magnitude of these water budget terms, even on a monthly average basis averaged across the Delta islands, is uncertain. The most commonly measured terms are rainfall (at weather stations) and drainage volume (calculated using electrical power consumption and efficiency tests at specific drainage pumps). Crop ET terms are often estimated from pan evaporation data, meteorological conditions, or assigned assumed values for each crop type.

Few measurements of water application rates are available. Water applied for irrigation or salt leaching is obtained from numerous siphons around island margins;

C-061718

C-061718

flows through the siphons vary with the tidal cycle. Soil moisture storage can be estimated from soil moisture probes (e.g., neutron probes) used for special studies at specific locations, but such data are not routinely available. Seepage from shallow groundwater and drainage to shallow groundwater are virtually impossible to measure and are often estimated as the difference between other water budget terms.

A reasonably accurate water budget could be estimated from the combination of rainfall, assumed ET, and drainage volumes. Unfortunately, drainage volumes are not routinely measured in the Delta. DWR roughly estimates consumptive use of channel water from the rainfall and assumed ET values, adjusted by assumed patterns of maximum and minimum soil moisture storage on the islands. DWR used this technique in the monthly consumptive use model that is applied to the Delta lowland and upland areas (DWR 1979). The results are used as inputs for the DWRSIM model (see Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project").

The difference between the water demand needed to supply ET and the available water from soil moisture is the minimum irrigation amount required to supply the assumed crop ET. The DWR consumptive use model does not estimate excess water applied during the irrigation season, nor does it estimate the water applied for salt leaching in winter; these terms must be specified as model assumptions.

An irrigation efficiency coefficient can be specified to represent the drainage volume associated with irrigation water. A common estimate of irrigation efficiency is 70%. For each inch of irrigation water applied, 0.7 inch supplies the ET demand, while 0.3 inch leaches to the shallow groundwater or flows into drainage canals to be pumped back to Delta channels.

Delta Water Budget Terms from 1955 DWR Studies

DWR investigated Delta water budget terms in a series of five studies conducted during 1954-1955 to determine the basic hydrology and water quality characteristics of the Delta (DWR 1956). Because there has not been a more recent intensive measurement program for Delta water use, the results from this series of studies will be summarized as the best available estimates of Delta agricultural water use patterns.

Water year 1955 was a dry year according to the four-river Sacramento Basin Index. Historical monthly average Delta outflow estimates (from DWR's DAYFLOW database) for water year 1955 are as follows:

October 1954	8,900 cfs
November 1954	17,800 cfs
December 1954	27,400 cfs
January 1955	30,200 cfs
February 1955	18,100 cfs
March 1955	13,900 cfs
April 1955	13,000 cfs
May 1955	19,000 cfs
June 1955	7,000 cfs
July 1955	2,300 cfs
August 1955	3,100 cfs
September 1955	6,000 cfs
Annual average	13,800 cfs

Report No. 4, "Quantity and Quality of Waters Applied to and Drained from the Delta Lowlands", provided estimates of monthly Delta water budget terms for 24 groups of Delta islands and tracts, occupying 469,000 acres in the Delta lowlands. Delta channels occupied 42,000 acres, drainage channels and ponds occupied 7,000 acres, and drained land occupied the remaining 419,000 acres. During 1955, approximately 374,000 acres were in agricultural use and, of these, about 292,000 acres were irrigated.

The four DW project islands were located in four different study units for the DWR (1956) study: Bacon Island in unit 22, Bouldin Island in unit 18, Holland Tract in unit 16, and Webb Tract in unit 15 (Figure C2-2).

DWR (1956) estimated drainage data for each month from May 1954 to October 1955 from power consumption and pump efficiency tests. This effort remains the most comprehensive drainage study attempted by DWR. Irrigation volumes were measured, however, on only a few fields (3,369 acres total) for each month between May and October of 1954. Neither preseason irrigation used to increase soil moisture nor water applied for salt leaching in winter was measured.

The other water budget terms for the 1955 DWR study were rainfall measurements and estimated monthly ET values for each crop. A balanced water budget should have resulted, but the sum of the rainfall and applied water terms (measured inflows) was substantially less (40% less) than the sum of the ET and drainage volumes (total outflows). The combination of seepage and unmeasured applied water (unmeasured inflows) was a major water budget term, which can be estimated as the difference between the other terms.

Table C2-1 shows the estimated annual (water year 1955) Delta lowlands water budget terms for each study unit in the DWR investigation (DWR 1956). Values for the water budget terms have been converted to inches of water for the entire area of each study unit so that the water budgets for each study unit can be compared. The average estimated water budget terms for the entire Delta lowlands drained area (419,000 acres) for water year 1955 were:

- Outflows: 20.1 inches of drainage water and 33.2 inches of assumed ET and
- Inflows: 14.2 inches of rain and 18.8 inches of applied irrigation water in the April-October period.

An imbalance in the water budget occurred because a total of 53.3 inches of water losses were estimated but only 33.0 inches of rainfall and applied water were estimated. This required that 20.3 inches of unmeasured seepage, preseason irrigation, or leaching water be assumed to balance the water budget.

The amount of estimated drainage varied dramatically between the study units (Table C2-1). The highest annual drainage was 74.4 inches from study unit 22, and the lowest annual drainage was 1.7 inches from study unit 2. Some variation in drainage estimates was caused by differing percentages of units under irrigation, and some was the result of differing crops, soils, and irrigation practices.

Table C2-1 indicates that water budgets for some study units were reasonably well balanced (i.e., values of "missing water" were near zero). Two units (2 and 27) had greater inflows than estimated losses. Many of the study units, however, had much higher drainage volumes than estimated inflows of water, suggesting that unmeasured water was applied during irrigation or supplied as seepage from Delta channels. Estimates of missing water ranged from less than 5 inches for some study units to more than 75 inches for study unit 22 (which included Bacon Island).

Figure C2-3 shows estimates of monthly irrigation depths for the four study units containing the DW project islands. The water was applied predominantly from June through September. Irrigation estimates were quite uniform for the four study units, differing only because of crop acreage. Cumulative estimates of applied water ranged from 16.7 inches for study unit 22 containing Bacon Island to 22.9 inches for study unit 18 containing Bouldin Island.

Figure C2-4 shows the corresponding measured monthly drainage depths for the four study units containing the DW project islands. Drainage occurred predominantly during winter (from excess rainfall and leaching practices) and the irrigation season. Measured cumulative drainage depths differed widely among the four study units, ranging from 15.8 inches for study unit 16 containing Holland Tract to 74.4 inches for study unit 22 containing Bacon Island.

DW Project Island Drainage Records from 1986 to 1992

Jones & Stokes Associates (JSA) obtained monthly pumping records from the four DW islands for the 1986-1992 period. Monthly pumping records from Bouldin Island are available beginning in 1986, Bacon Island pumping records begin in 1988, and Webb and Holland Tract records start in 1990. These data are summarized as inches of drainage in Table C2-2 and are compared with the estimates for the 1955 DWR study units. Inches of drainage are calculated from the drainage volume (in acre-feet [af]) and area (in acres) as follows:

$$\text{Inches of drainage} = \text{drainage volume (af)} \cdot 12 \text{ inches/foot} \div \text{total area (acres)}$$

The estimated monthly drainage depths for the DW islands were quite variable between islands as well as between months. Monthly pumping estimates have varied from less than 1 inch to more than 10 inches. Annual estimates for individual islands have varied from 11 inches to more than 75 inches. Drainage volumes have generally followed a double-peak pattern, with high pumping in winter because of excess rainfall and salt leaching practices and high summer pumping in response to excess irrigation.

Estimated pumping on Bacon Island during the irrigation season is extremely high, averaging more than 6 inches per month for 5 months each year (Table C2-2). High summer pumping is apparently caused by the water management required for the types of row crops grown on Bacon Island. Pumping for Bouldin Island in 1990 and for Webb and Holland Tracts in 1990 and 1991 was lower than normal because of reduced agricultural use during levee rehabilitation and participation in the DWR emergency water bank program. Variations in irrigation practices, leaching practices, and seepage account for major differences between islands.

The annual pumping estimates shown at the bottom of Table C2-2 indicate that drainage volumes have been relatively uniform on each DW project island. This uniformity indicates that the pattern of irrigation and leaching practices may be generally identified for each Delta agricultural island with this type of monthly

C-061720
C-061720

pumping monitoring. Additional pumping during winters of wet years is expected, as shown for Bouldin Island in 1986, but only dry year records were available for the other three islands.

DELTA AGRICULTURAL SALT BUDGET

Salt budget terms are directly associated with the water budget terms, as shown in Figure C2-1, and each of the water budget terms has an associated salt concentration (or EC value). Salt is normally measured as TDS or EC.

Soil Salt

Soil salt is the salt associated with the soil moisture water storage term. Rainfall and ET are assumed to have salt concentrations of zero, so soil moisture salt concentrations are diluted by rain but are increased as soil moisture is lost to ET. The combination of applied water (irrigation or seepage) and ET water loss are therefore the basic mechanisms for soil salt buildup.

Applied water adds to the soil salt storage in proportion to the channel water salt concentration. Seepage from channels to shallow groundwater adds to the soil salt storage in proportion to the shallow groundwater salt concentration. Seawater intrusion or upstream sources contribute indirectly to the salt budget by increasing the salt concentration of water in Delta channels and shallow groundwater.

For soil salt to maintain a long-term balance, drainage water must carry away all the salt brought into islands in applied or seepage water. The amount of salt in applied irrigation water or seepage water left behind in the soil as the water is lost to ET must be drained away from the soil moisture salt storage term sometime during the year.

Soil salt concentrations can be measured in saturated soil sample extracts or with EC probes placed in the soil column. Soil moisture salt measurements are not routinely available, however, for the Delta agricultural islands. The salt concentration of applied water can easily be estimated from Delta channel EC measurements. Seepage salt concentrations from shallow groundwater are more difficult to estimate. The applied and seepage water volumes are not measured directly, however, so the applied salt load is difficult to calculate.

If 2 feet of applied water are needed to supply ET and the applied water has an average TDS concentration of 200 milligrams per liter (mg/l), the applied salt load is calculated as follows:

$$\text{Applied salt (tons/acre)} = 2 \text{ af} \cdot 200 \text{ mg/l} \cdot 0.00136 = 0.544 \text{ tons/acre}$$

where 0.00136 is the appropriate conversion between these units.

If more applied water is necessary to supply ET or if the applied water has a higher average salt concentration, a greater load of salt is delivered and must be drained away to maintain a salt balance.

An excess salt load may remain in the soil column until rainfall or leaching water is applied during winter if it is not drained away during the irrigation period. Soil salt may accumulate for several months and then be removed by leaching practices.

The Delta corn salt tolerance experiments (Hoffman et al. 1983) demonstrated that soil salt concentrations depend on the irrigation methods used. Sprinklers or furrow irrigation provide continual drainage of excess soil salt, whereas sub-irrigation using "spud" ditches allows salt to accumulate during the growing season.

Salt concentrations in drainage water are highly variable because: 1) the salt concentration in applied irrigation water changes with upstream sources or salinity intrusion in the Delta, 2) the amount of excess salt that is removed from the soil salt storage varies with irrigation scheduling and farming practices, and 3) the amount of excess water siphoned into Delta island irrigation ditches is unpredictable. Drainage salt concentrations will therefore fluctuate between relatively low values characteristic of the applied water salt concentration and very high values characteristic of the soil salt concentrations at the end of the growing season (or after a sequence of years) when a maximum of salt has accumulated.

If drainage volumes and associated salt concentrations are carefully monitored for several years, the average salt load in the drainage water should equal the average applied salt load, unless a source of salt exists in Delta croplands (e.g., salt originating from fertilizer application or from dissolution of minerals in the soil). There would be seasonal and year-to-year changes in soil salt and drainage salt concentrations.

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C-061721

Salt Concentrations in Irrigation and Drainage Water

DWR Report No. 4 (DWR 1956) provided estimates of applied and drained salt budget terms for water year 1955 for the 24 groups of Delta islands and tracts. Some of the drainage salt estimates were extremely high compared with the expected accumulation from ET or the estimated applied salt terms.

Figure C2-5 shows estimates of average monthly applied irrigation salt concentrations in TDS for the four study units containing the DW project islands for water year 1955. The TDS concentrations ranged from 100 mg/l to 500 mg/l and were apparently estimated from measured channel salt concentrations for each study unit area. Other study units in the Delta had different TDS concentrations because of salinity intrusion effects and different drainage and salt leaching practices (Table C2-1).

Figure C2-6 shows the estimates of average monthly drainage salt concentrations for the four study units containing the DW project islands for water year 1955. These drainage TDS concentrations, estimated from measured drainage salt concentrations, ranged from 200 mg/l to 1,400 mg/l. Other study units had different drainage concentrations because of salinity intrusion effects and different drainage and salt leaching practices (Table C2-1).

The ratio between average drainage TDS concentration and average applied TDS concentration is a general indicator of the volume of drainage compared with the volume of applied water (including seepage) if the salt load is balanced. For example, if the drainage volume was one-third of the applied water volume, the drainage salt concentration should be three times as high as the average salt concentration in the applied water if the salt load is balanced. Table C2-1 indicates that the average ratio of drainage salt to applied salt concentration ranged from about 1 to 6, although the majority of the study units had ratios between 2 and 4.

Salt Loads in Irrigation and Drainage Water

Table C2-1 indicates that the annual applied salt load for all the study units averaged 0.44 tons/acre, but ranged from about 0.2 tons/acre to 2.0 tons/acre.

Figure C2-7 shows the estimates of average monthly applied irrigation salt loads (tons/acre) for the four study units containing the DW project islands for water year 1955. The monthly salt loads, ranging from 0.05 tons/acre to 0.25 tons/acre, were estimated from measured channel salt concentrations and the estimated irrigation volumes for each study unit area during the irrigation season. The salt load from seepage or other missing water is not included. Other study units had different monthly salt loads because of salinity intrusion effects and different drainage and salt leaching practices.

Figure C2-8 shows the average monthly drainage salt loads (tons/acre), estimated from measured drainage salt concentrations and volumes, for the four study units containing the DW project islands for water year 1955. The monthly drainage salt loads ranged from 0.05 tons/acre to 0.60 tons/acre. Other study units had different drainage salt loads because of salinity intrusion effects and different drainage and salt leaching practices.

Table C2-1 indicates that the annual drainage salt load for all the DWR (1956) study units averaged 1.27 tons/acre, but ranged from about 0.2 to more than 4.0 tons/acre. The large difference between the measured drainage salt load and the estimated applied salt load for some of the study units indicates that the salt budget is out of balance, just as the water budget terms did not balance for some of the study units. If the missing water is assumed to have the same average salt concentration as the applied water, a substantial portion of the missing salt term can be accounted for.

The Delta drainage water and salt measurements indicate that the amount of water and salt drained from various study units varies widely. Nevertheless, the water and salt budgets must be balanced and consistent. Monthly drainage salt concentrations vary dramatically, but the average drainage salt concentration is approximately 2-4 times as high as the average applied salt concentration (Figures C2-5 and C2-6), suggesting that the drainage volume is 25%-50% of the applied water if the overall Delta lowlands salt load was in balance during the study period.

DELTA AGRICULTURAL DISSOLVED ORGANIC CARBON BUDGET

The DOC budget terms for Delta agricultural islands are identical to the salt budget terms, with the addition of source terms representing residues of vegetation decay and peat soil decomposition and sink terms representing the decomposition of DOC (to carbon dioxide or methane) (Figure C2-1). If the decomposition of DOC is assumed to be relatively slow (see Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved

Organics and Trihalomethane Precursors for the Delta Wetlands Project"), then DOC in the soil column is diluted by rainfall and concentrated by ET water loss, just as soil salt is. DOC is added to the soil DOC storage term by the applied irrigation and seepage water, just as salt is added.

In addition, DOC is added to the soil column from crop vegetation residues and from decomposition of organic peat soil. Although most decomposition of vegetation or peat soil produces carbon dioxide that is lost from the soil, a small amount of DOC is added to the soil column by decomposition. DOC may accumulate in the soil column or be leached out of the soil column like salt.

Drainage water DOC concentrations are determined by initial DOC concentration in Delta channel water, effects of accumulation from ET and leaching from the crop root zone, the addition of DOC from vegetation decay and peat decomposition, and the possible accumulation of the DOC in the soil column. If sources or sinks of DOC existed, drainage DOC concentrations would be expected to fluctuate just as the drainage salt concentrations do, reflecting the same patterns of accumulation and leaching from the soil column.

Island drainage from peat soils is a likely source of DOC. Therefore, drainage concentrations of DOC in excess of those calculated from the drainage EC and DOC/EC ratios for applied water provide a direct measure of the fraction of the drainage DOC originating from various sources of DOC. Alternatively, the accumulation or decomposition of applied DOC in the soil column can be calculated as the difference between the DOC concentration expected from the drainage EC and the applied water channel DOC/EC ratio and the measured drainage DOC.

For example, assume that Sacramento River water with an average EC value of 200 μS/cm and an average DOC concentration of 2.5 mg/l is applied onto Bouldin Island as irrigation water. If drainage water samples from Bouldin Island had an EC value of about 450 μS/cm, the expected DOC concentration (assuming no source or loss of DOC) would be 6.25 mg/l ($450/200 \cdot 2.5 = 6.25$). Each drainage sample would have a different EC value, indicating some salinity increase from ET and salt leaching.

The DOC concentration in each drainage sample is expected to increase accordingly. If the observed DOC concentration is higher than the expected DOC concentration, a source of DOC is indicated. If the observed DOC concentration is less than the expected DOC concentration, a loss of DOC is indicated. The average DOC concentration increase (above the expected DOC concentration) can be multiplied by the drainage depth (m) to estimate the source of DOC in units of g/m2. Several examples of these DOC source calculations are given in the next section.

Peat soils in the central Delta may produce more than the average Delta drainage volume per acre (Table C2-1). DWR (1990) therefore suggested that the mass loading of DOC from the central Delta would be correspondingly higher. This prediction can only be demonstrated by a combination of higher drainage volume and equal or greater drainage concentrations. The DWR (1990) report does not provide drainage volume estimates; therefore, the relative contribution of various Delta islands and tracts remains uncertain.

DWR MWQI AGRICULTURAL DRAINAGE MEASUREMENTS FROM 1986 TO 1991

Figure C2-2 shows locations where Delta agricultural drainage samples were collected by the DWR MWQI program during the 1986-1991 period (the study is ongoing). The data are summarized in Table C2-3 by groups of drainage pumps sampled and are described in this section. Data collection goals and protocols are described in a series of reports from the MWQI program (DWR 1990).

The MWQI measurements of drainage EC from many of the drains show a strong seasonal pattern, with the highest EC values in drainage water during winter (DWR 1990). EC values for each group of drainage pumps generally range from the low values characteristic of Delta channel water (200-400 μS/cm) to much higher values (1,000-2,000 μS/cm). This range in drainage EC values is expected because of the variation in Delta irrigation, leaching, and drainage practices.

Bacon Island

Figure C2-9 shows drainage measurements for chloride (Cl^-) and DOC as a function of the drainage EC value in Bacon Island samples. The range of drainage EC values varied from about 0.4 mS/cm to 1.0 mS/cm, with a mean EC value for these samples of about 0.65 mS/cm.

Cl^- is used as an indicator of the source of irrigation water, as described in Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data". The Cl^-/EC ratio of almost 0.2 in the drainage water indicates a substantial influence from seawater intrusion in Bacon Island drainage (at least during the drought period sampled).

DOC is used as the general indicator of organic compounds in drainage samples that may form disinfection byproducts (DBP) such as THM when water is chlorinated. DOC concentrations are plotted as a function of EC to investigate the possible relationship between drainage EC and DOC. If DOC behaves as a conservative dissolved substance, it is reasonable to suppose that DOC accumulates in soil moisture in the same manner that salt does.

The same leaching and drainage processes that eventually return salt to Delta channels in agricultural drainage should also return accumulated DOC material. A range of DOC values should be observed, just as a range of EC values is measured. Whereas no significant source or sink for salt exists on Delta islands, a significant source or sink for DOC material may exist. If an island source of DOC exists, DOC concentrations in drainage water would exceed DOC values expected based on DOC concentrations in applied irrigation water.

Figure C2-9 indicates that DOC concentrations in Bacon Island drainage are variable but do not increase with drainage sample EC values. The mean Bacon Island drainage DOC concentration of 9.4 mg/l is higher than concentrations in Delta inflows (discussed in Appendix C1) but only moderately high relative to other drainage samples (see Table C2-3). The average of the drainage sample DOC concentrations only roughly approximates the average DOC concentration from Bacon Island because the volume of drainage associated with each sample is not known.

The mean EC value in drainage water can be used to estimate the expected average increase from channel EC values to drainage EC values. For example, if the average channel EC value used for irrigation of Bacon Island was assumed to be similar to the lowest EC value of about 400 μS/cm observed in drainage and the average drainage EC value is 650 μS/cm, the ratio of drainage EC to applied EC would be 1.62. This ratio is near the low end of the typical ratio values identified in the 1955 DWR study of Delta drainage (see last column in Table C2-1).

This moderate increase in drainage EC values above channel EC values for Bacon Island drainage is consistent with the measured 1988-1992 Bacon Island drainage volumes. The drainage volumes from Bacon Island were very high (69 inches) compared with those from other DW islands (see annual summary at the bottom of Table C2-2) and other DWR study units (Table C2-1). Therefore, the expected increase in drainage salt concentration from Bacon Island would be relatively low because of the dilution effect.

If the drainage-to-applied EC ratio is used with the measured DOC concentrations, the expected average increase from channel DOC to drainage DOC concentrations would also be a factor of 1.62. If the average channel DOC concentration was assumed to be 3 mg/l (Appendix C1), an average of 4.8 mg/l (3 x 1.62) of DOC would be expected in drainage water if a source of DOC did not exist on the island.

The difference between the measured DOC (9.4 mg/l) and the expected DOC (4.8 mg/l) of 4.6 mg/l (g/m^3) can be used as an estimate of the contribution of DOC from agricultural practices. Thus, the DOC concentrations being discharged in drainage water can be partitioned into estimates of the agricultural contribution of DOC and the channel contribution of DOC. Multiplying the source concentration by the average drainage depth gives a DOC loading estimate for Bacon Island of about 8 grams per square meter per year (g/m^2/year) (4.6 g/m^3 x 69 inches x 0.25 m/inch = 8 g/m^2).

Bouldin Island

Figure C2-10 shows drainage measurements of DOC, Cl^-, and EC for Bouldin Island. Sampling at the Bouldin Island drainage pumps began in 1986, so more samples have been collected and analyzed for the three constituents. Drainage EC values are generally 200-300 μS/cm in the summer irrigation season, suggesting very little increase above EC concentrations in water diverted onto the island in summer (the assumed source of Bouldin Island irrigation water is the Sacramento and Mokelumne Rivers). Winter EC values in Bouldin Island drainage are generally several times higher than summer values, with a maximum observed EC of about 950 μS/cm. The average EC value was 430 μS/cm, about 2.5 times the minimum observed value of 180 μS/cm. This ratio of drainage-to-applied EC is larger than the Bacon Island ratio and consistent with the average measured volume of Bouldin Island drainage of 33 inches, less than half of the average drainage volume for Bacon Island (Table C2-2).

The average Cl^- concentration was 32 mg/l and the Cl^-/EC value for Bouldin Island drainage samples was less than 0.1, indicating that Sacramento River was the primary source of irrigation water.

Figure C2-10 indicates that the drainage DOC concentrations generally increased with drainage EC values; the mean of 34.3 mg/l is much greater than the average DOC for Bacon Island. Because Sacramento River DOC concentrations (see Appendix C1) are relatively constant at about 2.3 mg/l (with an EC value of 163 μS/cm), the expected DOC concentration in drainage water having a EC value of 1,000 μS/cm would be 14 mg/l (1,000/163 x 2.3).

A line can be drawn on Figure C2-10 from the origin through the assured source water quality (2.3 mg/l DOC at 163 μS/cm EC). Drainage DOC concentrations above this line would suggest a source of DOC; drainage DOC concentrations below this line would suggest a sink of DOC. DOC concentrations in all of the Bouldin Island drainage samples are located above this line (i.e., greater than expected DOC concentrations), suggesting a major source of DOC.

Based on the mean values shown in Figure C2-10, the expected DOC at an EC of 430 μS/cm would be about 6.5 mg/l. Apparently, the additional 27.8 mg/l (34.3 - 6.5) represents the average DOC concentration contributed by sources on Bouldin Island. Multiplying the source concentration by the average drainage depth gives a DOC loading estimate for Bouldin Island of 23 g/m^2/year (27.8 g/m^3 x 33 inches x 0.025 m/inch = 23 g/m^2).

Holland Tract

Drainage EC values for Holland Tract were much higher than for Bacon and Bouldin Islands, with values between about 600 and 2,000 μS/cm (Figure C2-11). The average drainage EC value was 1,090 μS/cm, about 1.8 times the minimum observed value of 600 μS/cm (assumed EC of applied water). Holland Tract is located across the Old River channel from Bacon Island, so water quality of applied irrigation water is assumed to be similar. Irrigation practices are apparently much different, however, yielding a different drainage quality. The higher EC values in Holland Tract drainage are consistent with the lower average measured volume of Holland Tract drainage water of less than 20 inches.

The average Cl^- concentration in Holland Tract drainage water was 199 mg/l; the Cl^-/EC value for Holland Tract drainage samples was about 0.2, similar to the value for Bacon Island. This Cl^-/EC value indicates that seawater intrusion was a significant source of salt in Holland Tract irrigation water.

Figure C2-11 indicates that the drainage DOC concentrations generally did not increase dramatically with drainage EC values, with a mean of only 19.3 mg/l, about twice the average DOC for Bacon Island. The expected DOC at an EC of 1,000 μS/cm would be about 5 mg/l. The estimated source loading of DOC would be about 6 g/m^2/year ([19.3-5] x 16 inches x 0.025 m/inch).

Webb Tract

Most drainage EC values for Webb Tract ranged between about 500 μS/cm and 1,500 μS/cm, but three values were between 2,000 μS/cm and 2,500 μS/cm (Figure C2-12). The Webb Tract drainage concentrations were similar to those in the Holland Tract samples. The concentration similarity is generally consistent with the similar source for irrigation water and the measured drainage volumes of less than 20 inches for both islands.

For Webb Tract drainage samples, the average Cl^- concentration was 160 mg/l; the Cl^-/EC value was about 0.2, similar to the values for Holland Tract and Bacon Island. Thus, seawater intrusion was also a significant source of salt in Webb Tract irrigation water.

Figure C2-12 indicates that the drainage DOC concentrations generally did not increase dramatically with drainage EC values; the mean of 25.1 mg/l is slightly higher than Holland Tract DOC concentration and more than twice the average DOC concentration for Bacon Island. The expected DOC concentration in Webb drainage at an average EC of 1,000 μS/cm would be about 5 mg/l. The estimated source loading of DOC would be about 10 g/m^2/year (20 g/m^3 x 20 inches x 0.025).

Other Delta Island Drainage Samples

Figures C2-13 through C2-24 show drainage EC and concentrations of Cl^- and DOC from 12 additional Delta locations. Some data are from a single island, while others are from several nearby islands. Table C2-3 provides a summary of the average values of water quality measurements for each group of drainage samples. The entire data set used to perform this analysis of Delta agricultural drainage is available from the lead agencies.

For each set of drainage measurements, the range of drainage EC values corresponds to variations in drainage and leaching practices. The average EC value is typically two to three times the minimum observed EC. The Cl^-/EC values given in Table C2-3 indicate the likely source of the irrigation water applied to each island. Cl^-/EC values are normally between 0.05 (Sacramento River source) and 0.15 (San Joaquin River source);

values approaching 0.20 indicate a significant seawater influence (or a groundwater source).

Average DOC values indicate the magnitude of the on-island source of organic precursors of DBP. If the DOC average is greater than two or three times the assumed channel DOC concentrations (3-4 mg/l), a significant source of DOC is present. Interestingly, some islands have average drainage DOC concentrations that are less than the values expected based on the average EC increase, suggesting that some of the applied DOC is adsorbed, retained, or otherwise lost from the drainage on these islands.

DWR MWQI AGRICULTURAL DRAINAGE MEASUREMENTS OF UVA AND C-THM

Important variables related to the presence of organic precursors of DBP are ultraviolet absorbance (UVA, at a wavelength of 254 nanometers [nm]) and the carbon portion of THM molecules (C-THM). The available drainage measurements suggest that both of these variables are directly related to DOC (see Figures C2-25 through C2-29). Because UVA and DOC are both relatively easy to measure in comparison with the 7-day chlorination and analytical procedure for THM concentrations, additional attention should be given to UVA and DOC as monitoring variables for potential sources of THM precursors in the Delta.

Figure C2-25 shows the relationships of UVA (1/cm) and C-THM (μg/l) with DOC (mg/l) concentrations for Bacon Island. As a general guide, the C-THM concentration in a water sample, after a 7-day chlorination with an initial chlorine dose of 120 mg/l, is about 1% of the DOC concentration. The Bacon Island drainage samples appear to follow this rule.

Also as a general guide, the UVA value, in units of 1/cm, is about 5% of the DOC concentration (mg/l). The data from Bacon Island drainage samples also follow this rule.

Figure C2-26 shows the UVA and C-THM data from Bouldin Island drainage samples. The available UVA values (measurements began in 1990) follow the relationship of 5% of DOC to maximum observed DOC concentrations of about 55 mg/l.

The relationship between C-THM and DOC appears reasonably linear at DOC concentrations of less than 30 mg/l (see Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project"); about 1% of the DOC ends up as C-THM, for DOC values of less than about 30 mg/l (Figure C2-26). For higher DOC concentrations, however, a plateau of C-THM values is apparent, with an average of about 300 μg/l of C-THM for all DOC values above 30 mg/l. This apparent "saturation" effect of the C-THM measurements at high DOC concentrations has been explored in recent studies by DWR and the Metropolitan Water District of Southern California (MWD) (DWR 1992). These studies have found that a certain amount of chlorine is required to fully process DOC and yield the maximum possible THM molecules. Recent MWQI measurement procedures have incorporated this effect of variable chlorine dose.

To overcome the saturation effect, MWD has selected a chlorine dose of three times the DOC concentration for its THMFP testing program. In contrast, as drainage DOC concentration increases above 40 mg/l, the standardized chlorine dose in the THMFP test used by DWR (120 mg/l of chlorine) is insufficient to fully process the DOC and form the maximum THM concentration. The standard test for THMFP used by DWR is an adequate indicator of organic precursors for DOC concentrations below about 30 mg/l, representing the majority of Delta drainage samples (see Appendix C3 for additional discussion).

Figure C2-27 shows UVA and C-THM data from Holland Tract drainage samples. The UVA values follow the 5% of DOC guideline, and the C-THM values are slightly greater than 1% of the DOC concentrations. The relationship between C-THM and DOC remains linear because no DOC values above 40 mg/l were detected, and thus the standard THMFP test with 120 mg/l of chlorine provided the maximum yield of C-THM.

Figure C2-28 shows UVA and C-THM data from Webb Tract drainage samples. The UVA values again represent about 5% of the DOC concentration, and the C-THM values are approximately 1% of the DOC concentrations. The relationships between DOC and both UVA and C-THM appear to be consistent for drainage samples from the four DW project islands.

Figure C2-29 indicates that the relationships between DOC and UVA measurements and C-THM yield from DWR's standardized test procedure for THMFP are relatively consistent for the DWR MWQI program samples. These samples, with DOC concentrations ranging from less than 5 mg/l to more than 50 mg/l and from a wide variety of Delta drainage locations in all seasons of the year, show a consistent pattern between these three variables.

It is possible that the C-THM values could be adjusted to estimate the maximum yield of C-THM from a sufficiently high chlorine dose. This adjustment would allow all historical THMFP measurements to be used. The possibility of relying on the physical UVA measurement and the semi-automatic DOC analyzer results for monitoring of Delta drainage and other effluents with suspected organic precursors should be actively pursued. The measurement difficulties and delay times between sampling and analyses associated with the traditional THMFP testing may thus be avoided for routine monitoring and control applications.

SUMMARY OF AGRICULTURAL DRAINAGE DATA ANALYSIS

Although much more about Delta agricultural drainage needs to be studied, the following conclusions can be drawn from the available information:

- Agricultural drainage volume within the Delta is highly variable because of differences in irrigation method, seepage, salt leaching practices, and other factors related to soil type and crop requirements. Drainage concentrations of salt are variable because of seasonal irrigation, accumulation of soil salt from ET, drainage of excess water following rainfall events, and periodic leaching practices. The ratio of drainage water EC to applied water EC can be used to indicate the net effect of these variable processes on drainage water quality. The volume of drainage cannot be determined, however, from the salt concentration itself; direct measurements of the drainage volume are needed to estimate drainage loads of salt or other water quality variables of interest in the Delta.

- The range of measured monthly drainage volumes from the four DW islands during 1986-1991 (dry years) was similar to the range of drainage estimates from DWR's Report No. 4 (DWR 1956) for water year 1955. Drainage estimates differed greatly, however, between islands and between years. Based on the DWR 1955 study, drainage EC averaged between 2 and 4 times applied water EC. This relationship indicates that drainage volumes were generally 25%-50% of the applied water volume during 1955. Average drainage EC values for the four DW islands during the 1986-1991 drought period were also about 2 to 4 times the applied water EC values. Drainage volumes will increase with excess rainfall and excess irrigation and during salt leaching. Direct measurements are required to accurately determine drainage volumes.

- DOC concentrations in Delta agricultural drainage have been measured only since 1986. Measured DOC concentrations are highly variable because of the processes that influence salt concentrations and the variable sources and sinks for DOC on Delta islands. The expected drainage DOC concentration, based on the measured drainage EC value, can be used to estimate the net increase of DOC concentration in each drainage sample. Because the drainage volume associated with each sample is not known, however, accurate estimates of the net contribution of DOC mass from island sources cannot be determined.

- UVA values and DOC concentrations are strongly correlated, and C-THM and DOC concentrations are apparently directly related. Therefore, relatively simple UVA and DOC measurements may be preferable to more expensive and time-consuming THMFP measurements for monitoring the concentrations of potential DBP in Delta water.

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Table C2–1. Summary of Delta Island Water Budgets and Salt Budgets for Water Year 1955

DW Island Location	DWR–4 Unit No.	Drained Land (acres)	Irrigated Land (%)	DWR Drainage Water (inches)	DWR Applied Water (inches)	Missing Water[1] (inches)	DWR Drainage Salt (mg/l)	DWR Drainage Salt (tons/acre)	DWR Applied Salt (mg/l)	DWR Applied Salt (tons/acre)	Missing Salt[2] (tons/acre)	Salt in Missing Water[3] (tons/acre)	Ratio of Drainage to Applied Salt Conc.
	2	11,202	48	1.7	24.2	−4.1	835	0.16	132	0.18	−0.02	−0.06	6.3
	3	5,465	75	10.8	17.5	12.3	193	0.24	126	0.25	−0.01	0.18	1.5
	6	33,027	75	4.4	18.5	4.9	535	0.26	119	0.25	0.01	0.07	4.5
	7	7,510	80	4.8	19.9	3.9	443	0.24	119	0.27	−0.03	0.05	3.7
	8	22,103	75	15.9	19.7	15.2	240	0.43	117	0.26	0.17	0.20	2.1
	9	16,085	48	8.5	14.2	13.3	440	0.42	132	0.21	0.21	0.20	3.3
	10	11,067	76	6.9	16.4	9.5	327	0.26	133	0.25	0.01	0.14	2.5
	11	14,365	78	10.2	23.2	6.0	337	0.39	119	0.31	0.08	0.08	2.8
	12	16,877	77	20.7	23.0	16.7	324	0.76	121	0.31	0.45	0.23	2.7
	13	16,641	63	10.2	20.7	8.5	377	0.44	129	0.30	0.14	0.12	2.9
	14	14,671	29	16.2	7.6	27.6	932	1.71	912	0.78	0.93	2.85	1.0
Webb Tract	15	26,424	51	17.1	18.0	18.1	806	1.56	246	0.50	1.06	0.50	3.3
Holland Tract	16	18,343	74	15.8	21.8	13.0	818	1.46	260	0.64	0.82	0.38	3.1
	17	10,191	60	24.9	12.8	31.1	1,046	2.95	230	0.33	2.62	0.81	4.5
Bouldin Island	18	18,504	69	37.7	22.9	33.8	365	1.56	140	0.37	1.19	0.54	2.6
	19	17,917	72	17.5	21.8	14.7	483	0.96	121	0.30	0.66	0.20	4.0
	20	21,302	78	52.7	22.6	49.1	688	4.11	164	0.42	3.69	0.91	4.2
	21	14,846	72	41.2	16.6	43.6	549	2.56	193	0.36	2.20	0.95	2.8
Bacon Island	22	19,357	75	74.4	16.7	76.7	374	3.15	183	0.35	2.80	1.59	2.0
	23	24,493	81	22.9	17.2	24.7	501	1.30	211	0.41	0.89	0.59	2.4
	24	32,879	73	15.9	18.4	16.5	753	1.36	281	0.58	0.78	0.53	2.7
	25	33,212	78	10.7	19.1	10.6	670	0.81	321	0.70	0.11	0.39	2.1
	26	2,810	23	8.7	9.4	18.3	737	0.73	310	0.33	0.40	0.64	2.4
	27	10,148	85	6.6	29.2	−3.6	776	0.58	587	1.94	−1.36	−0.24	1.3
Average			70	20.1	18.8	20.3	556	1.27	225	0.44	0.83	0.49	3.0
Total		419,439											

Source: DWR 1956.

Notes: Rainfall in the Delta for water year 1955 was 14.2 inches, and average evapotranspiration was 33.2 inches, resulting in a net evapotranspiration of 19 inches.

[1] Missing Water = Net Evaporation (19 inches) + Drainage − Applied

[2] Missing Salt = Drainage Salt − Applied Salt

[3] Salt in Missing Water = Missing Water (inches) * Applied Salt (mg/l) * 0.0014

Table C2–2. Drainage Pumping Estimates for the DW Project Islands for 1986–1992 based on PG&E Pumping Tests (af/kWh) and Power Consumption Records

Water Year	Month	Bouldin Island 5,985 acres (af)	Bouldin Island (inches)	Bacon Island 5,539 acres (af)	Bacon Island (inches)	Webb Tract 5,469 acres (af)	Webb Tract (inches)	Holland Tract 4,187 acres (af)	Holland Tract (inches)
1986	OCT	87	0.2						
	NOV	2,217	4.4						
	DEC	3,387	6.8						
	JAN	2,125	4.3						
	FEB	2,771	5.6						
	MAR	3,944	7.9						
	APR	558	1.1						
	MAY	1,292	2.6						
	JUN	1,553	3.1						
	JUL	2,688	5.4						
	AUG	2,939	5.9						
	SEP	1,102	2.2						
1987	OCT	245	0.5						
	NOV	1,932	3.9						
	DEC	3,419	6.9						
	JAN	2,074	4.2						
	FEB	3,736	7.5						
	MAR	1,377	2.8						
	APR	837	1.7						
	MAY	909	1.8						
	JUN	804	1.6						
	JUL	1,113	2.2						
	AUG	1,740	3.5						
	SEP	1,125	2.3						
1988	OCT	621	1.2	1,834	4.0				
	NOV	1,248	2.5	655	1.4				
	DEC	1,785	3.6	3,243	7.0				
	JAN	2,701	5.4	2,185	4.7				
	FEB	574	1.2	590	1.3				
	MAR	501	1.0	721	1.6				
	APR	758	1.5	1,852	4.0				
	MAY	378	0.8	2,981	6.5				
	JUN	542	1.1	1,506	3.3				
	JUL	1,064	2.1	5,624	12.2				
	AUG	780	1.6	4,679	10.1				
	SEP	54	0.1	3,412	7.4				
1989	OCT	449	0.9	2,085	4.5				
	NOV	1,177	2.4	216	0.5				
	DEC	2,960	5.9	1,042	2.3				
	JAN	3,929	7.9	4,265	9.2				
	FEB	690	1.4	2,292	5.0				
	MAR	272	0.5	1,294	2.8				
	APR	647	1.3	1,755	3.8				
	MAY	702	1.4	4,091	8.9				
	JUN	1,451	2.9	4,309	9.3				
	JUL	2,072	4.2	3,486	7.6				
	AUG	1,775	3.6	3,618	7.8				
	SEP	408	0.8	3,932	8.5				

Table C2-2. Continued

Water Year	Month	Bouldin Island 5,985 acres (af)	(inches)	Bacon Island 5,539 acres (af)	(inches)	Webb Tract 5,469 acres (af)	(inches)	Holland Tract 4,187 acres (af)	(inches)
1990	OCT	81	0.2	1,520	3.3	0	0.0	216	0.6
	NOV	304	0.6	923	2.0	36	0.1	269	0.8
	DEC	51	0.1	3,843	8.3	46	0.1	840	2.4
	JAN	1,226	2.5	2,286	5.0	1,545	3.4	525	1.5
	FEB	486	1.0	1,698	3.7	830	1.8	506	1.4
	MAR	757	1.5	972	2.1	733	1.6	477	1.3
	APR	1,376	2.8	1,594	3.5	733	1.6	473	1.3
	MAY	458	0.9	2,938	6.4	730	1.6	488	1.4
	JUN	367	0.7	3,640	7.9	81	0.2	301	0.9
	JUL	1,169	2.3	3,380	7.3	188	0.4	146	0.4
	AUG	821	1.6	3,532	7.7	188	0.4	171	0.5
	SEP	138	0.3	4,079	8.8	85	0.2	124	0.4
1991	OCT	798	1.6	1,465	3.2	233	0.5	218	0.6
	NOV	2,596	5.2	897	1.9	1,230	2.7	722	2.0
	DEC	2,596	5.2	5,316	11.5	2,223	4.9	549	1.6
	JAN	1,873	3.8	2,197	4.8	2,042	4.5	1,317	3.7
	FEB	1,831	3.7	1,845	4.0	1,487	3.3	1,701	4.8
	MAR	1,831	3.7	1,281	2.8	1,360	3.0	544	1.5
	APR	368	0.7	786	1.7	245	0.5	160	0.5
	MAY	158	0.3	4,268	9.2	78	0.2	157	0.4
	JUN	724	1.5	4,153	9.0	80	0.2	293	0.8
	JUL	1,650	3.3	4,153	9.0	52	0.1	64	0.2
	AUG	2,757	5.5	4,995	10.8	44	0.1	675	1.9
	SEP	65	0.1	3,940	8.5	69	0.2	347	1.0
1992	OCT	128	0.3	1,424	3.1	203	0.4	284	0.8
	NOV	1,547	3.1	442	1.0	788	1.7	232	0.7
	DEC	1,940	3.9	4,051	8.8	1,871	4.1	290	0.8
	JAN	1,811	3.6	1,936	4.2	1,891	4.1	616	1.7
	FEB	3,287	6.6	1,826	4.0	1,279	2.8	1,001	2.8
	MAR	3,287	6.6	1,826	4.0	2,699	5.9	906	2.6
	APR	264	0.5	1,275	2.8	2,349	5.2	508	1.4
	MAY	122	0.2	5,147	11.2	456	1.0	359	1.0
	JUN	1,061	2.1	4,295	9.3	291	0.6	391	1.1
	JUL	1,614	3.2	2,486	5.4	416	0.9	436	1.2
	AUG	1,245	2.5	3,433	7.4	582	1.3	430	1.2
	SEP	1,250	2.5	3,807	8.2	413	0.9	287	0.8
Annual Totals									
1986		24,663	49						
1987		19,311	39						
1988		11,006	22	29,282	63				
1989		16,532	33	32,385	70				
1990		7,234	15	30,405	66	5,195	11	4,536	13
1991		17,247	35	35,296	76	9,143	20	6,747	19
1992		17,556	35	31,948	69	13,238	29	5,740	16
Average		16,221	33	31,863	69	9,192	20	5,674	16

Combined DW Islands (21,180 acres)

Annual Pumping (inches)		
	1990	27
	1991	39
	1992	39

Table C2–3. Summary of Average DWR MWQI Data on Water Quality of Delta Island Drainage for 1986–1991

Drainage Location	DWR–4 Unit No.	Drainage Samples	EC (μS/cm)	Cl^- (mg/l)	Br^- (mg/l)	Cl^-/EC Ratio	Br^-/EC Ratio	DOC (mg/l)	UVA (1/cm)	Color (Units)	C–THM (μg/l)	THMFP (μg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)
Bacon Island	22	23	652	114	0.40	0.18	0.0036	9.4	0.36	92	107	1,077	63.5	7.4
Bouldin Island	18	89	431	32	0.19	0.07	0.0064	34.3	1.41	217	253	2,348	61.0	11.1
Holland Tract	16	39	1,090	199	0.65	0.18	0.0034	19.3	0.90	153	224	2,220	92.0	4.3
Webb Tract	15	22	1,036	160	0.58	0.16	0.0042	25.1	1.05	225	220	2,150	169.0	13.7
Brannan Island	13	89	708	100	0.37	0.14	0.0041	18.8	0.87	159	170	1,612	73.0	16.1
Egbert Tract	9	48	758	44	––	0.06	––	16.4	––	79	181	1,667	114.0	6.6
Empire Island	20	101	1,361	291	1.02	0.18	0.0038	46.7	1.34	202	301	2,847	106.0	15.6
Grand Island	12	83	433	25	––	0.05	––	11.9	––	72	151	1,358	44.0	7.6
Jones Tract	23	52	730	115	0.31	0.16	0.0032	11.3	0.49	101	134	1,287	81.0	8.1
King Island	20	73	639	77	0.33	0.10	0.0054	10.9	0.43	78	127	1,230	28.0	8.3
Mossdale Tract	24	81	1,054	138	––	0.13	––	8.0	––	42	81	803	94.0	8.6
Pescadero Tract	27	69	1,869	355	1.14	0.19	0.0033	6.5	0.16	52	68	795	234.0	13.6
Rindge Tract	21	43	954	161	0.70	0.16	0.0050	21.4	1.11	121	202	1,963	95.0	5.8
Rio Blanco Tract–Shima Tract	21	26	856	116	––	0.12	––	6.1	––	35	76	774	36.0	6.3
Terminous Tract	20	24	728	118	––	0.16	––	13.2	––	88	169	1,624	38.0	9.2
Tyler Island	13	25	553	61	––	0.10	––	17.5	––	108	217	2,006	58.0	15.0
Mandeville Island	22	8	523	74	0.27	0.14	0.0036	22.0	1.15	227	263	2,489	48.0	––
McCormick Tract–Pierson Dist	8	32	353	22	––	0.06	––	7.3	––	55	88	811	24.0	6.3
Prospect Island–Ryer Island	11	11	648	24	––	0.04	––	10.5	––	63	141	1,181	84.0	6.2
Woodward Island–Palm Tract	25	13	771	127	0.37	0.17	0.0030	8.4	0.39	110	121	1,220	89.0	––
Staten Island–Venice Island	18	9	440	58	0.21	0.12	0.0035	17.3	0.93	181	189	1,800	22.0	––
Clifton Court [1]	17	21	4,845	1131	3.06	0.23	0.0029	9.4	0.49	76	103	1,432	530.0	33.0
Netherland	10	22	648	82	––	0.10	––	4.5	––	31	65	635	45.0	3.0

Source: DWR MWQI data, 1986–1991 (analyzed in spreadsheet file AGDRAINS.WK1)

Notes: –– = No data available.

[1] Agricultural drainage into Clifton Court does not represent export water quality.

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C – 0 6 1 7 3 3

C-061734

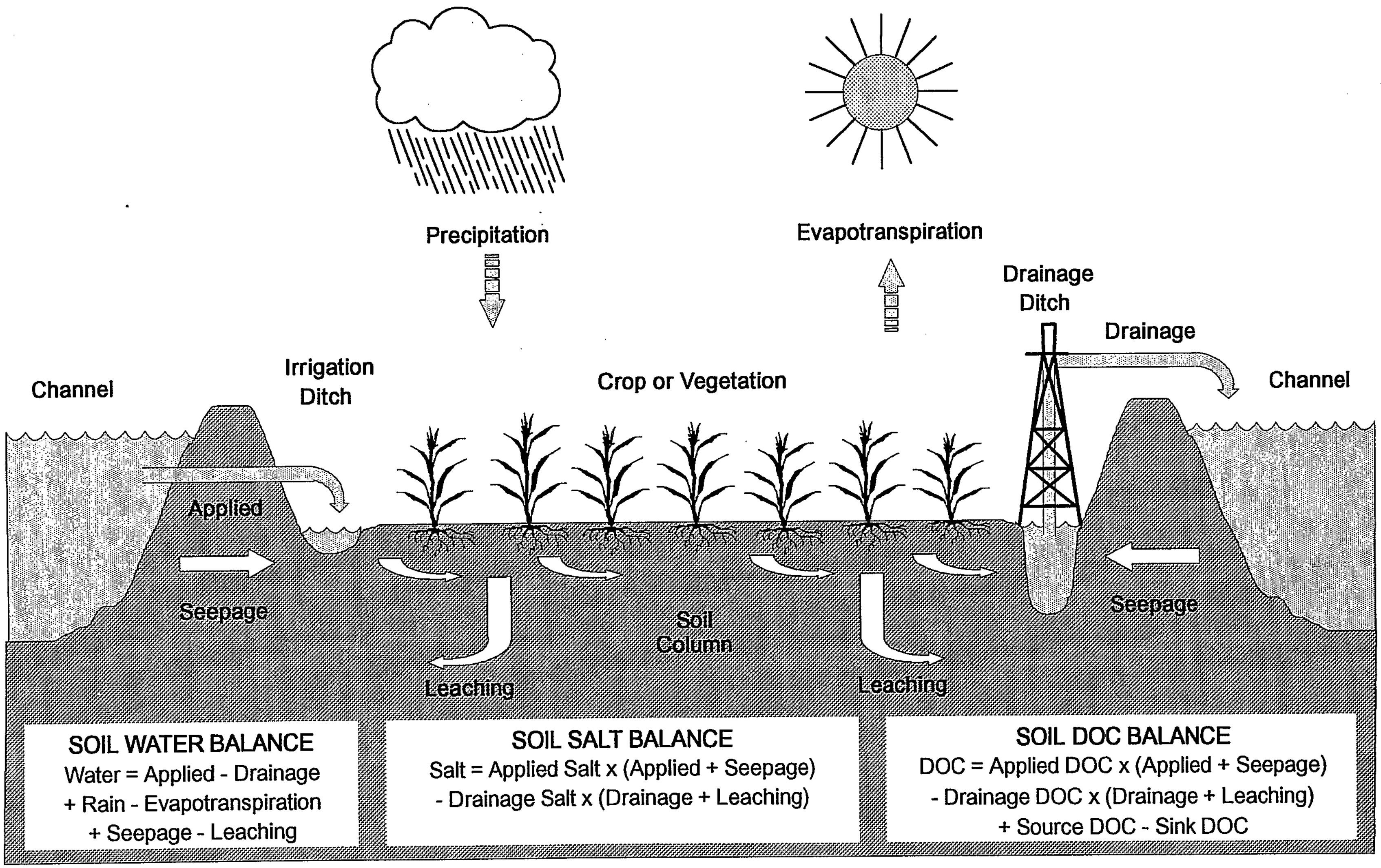

Figure C2-1.
Conceptual Water, Salt, and Dissolved Organic Carbon Budgets for Delta Agricultural Islands

C—061734

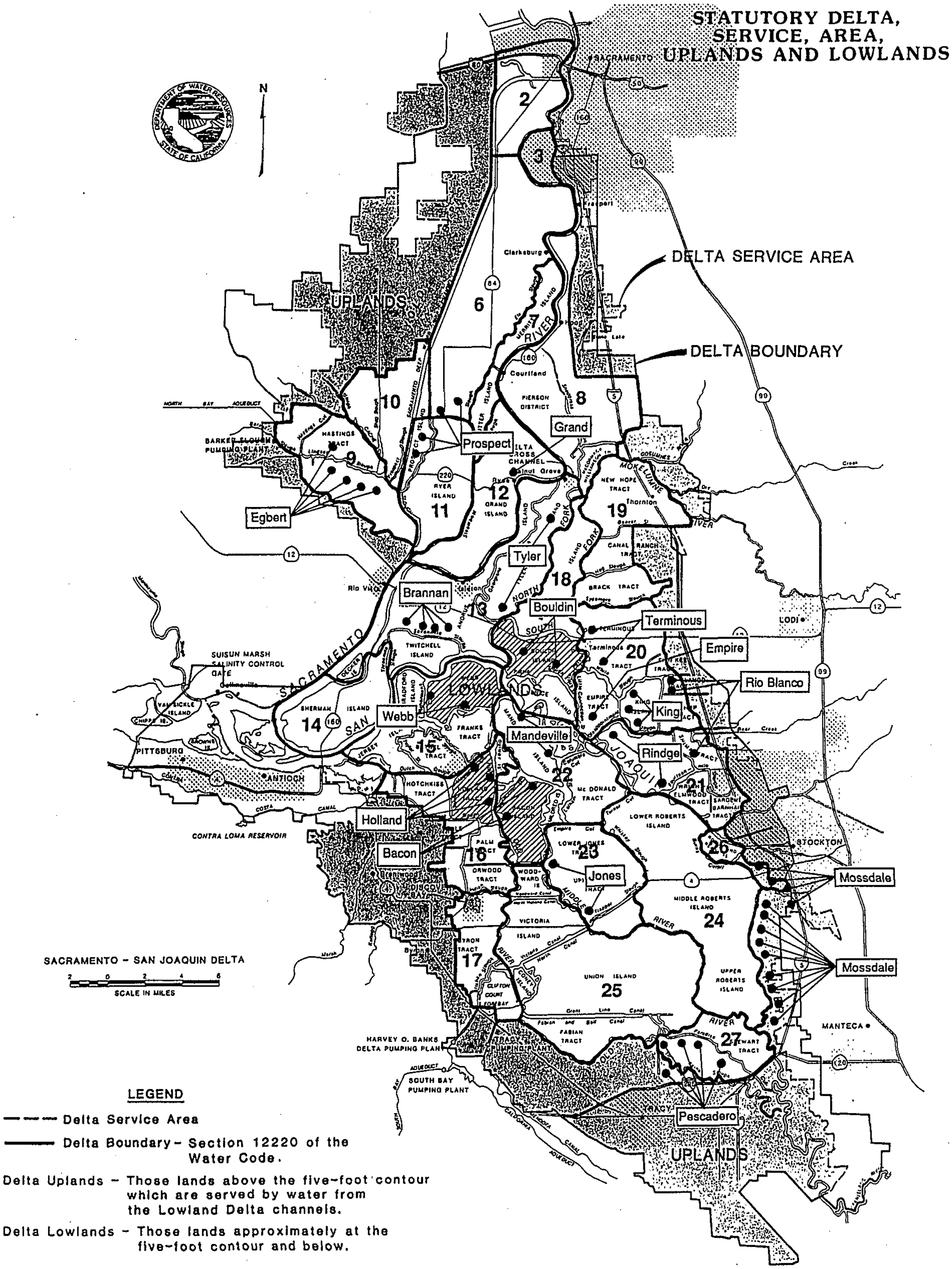

Figure C2-2.
Location of DWR Report No. 4 Study Unit Areas (1955) and DWR Municipal Water Quality Investigation Drainage Samples (1986–1991)

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

Figure C2-3.
Delta Lowlands Monthly Irrigation Depth Estimates
from DWR Report No. 4 for Water Year 1955

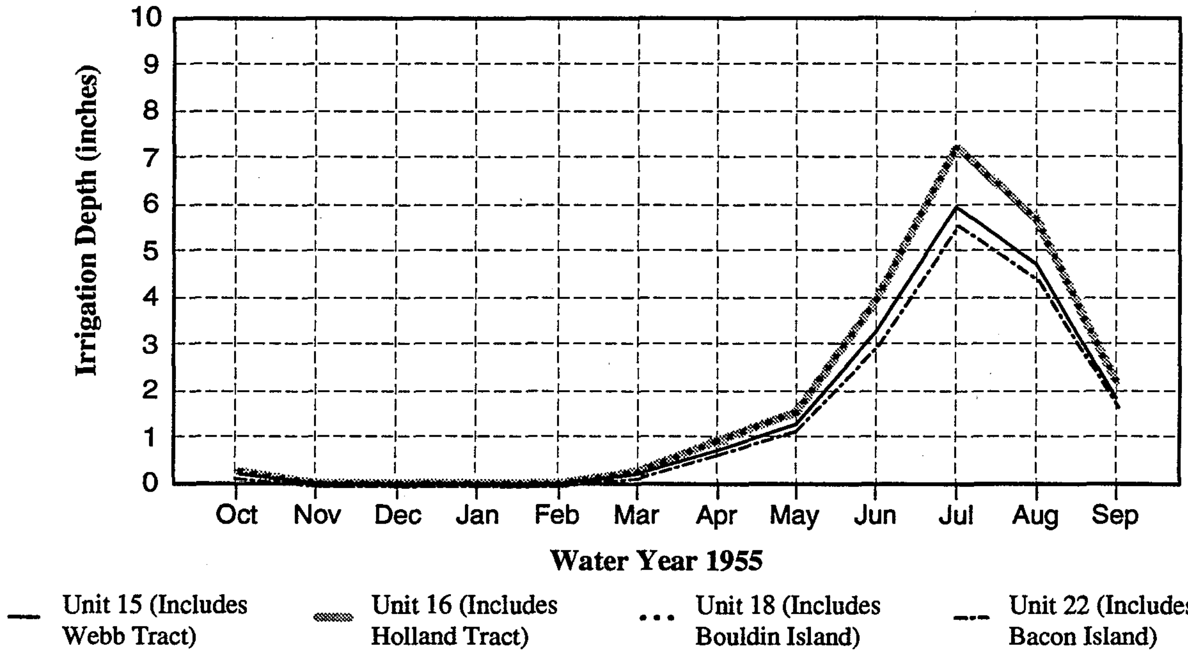

Figure C2-4.
Delta Lowlands Monthly Drainage Depth Estimates
from DWR Report No. 4 for Water Year 1955

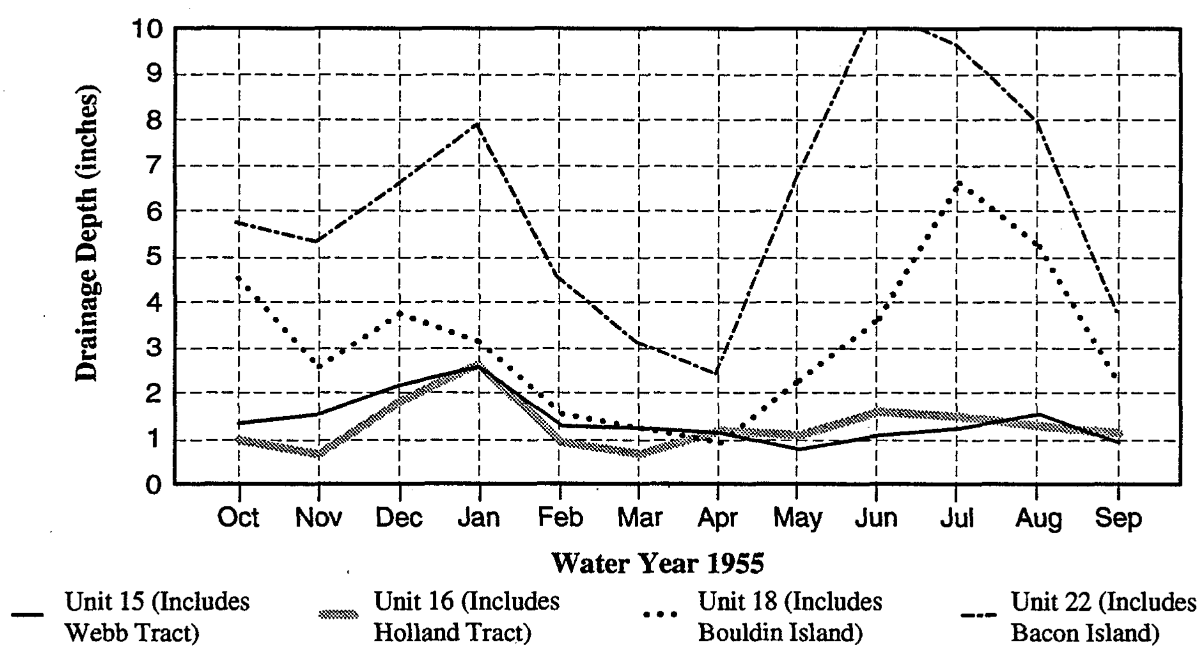

Figure C2-5.
Delta Lowlands Monthly Irrigation TDS Concentrations
from DWR Report No. 4 for Water Year 1955

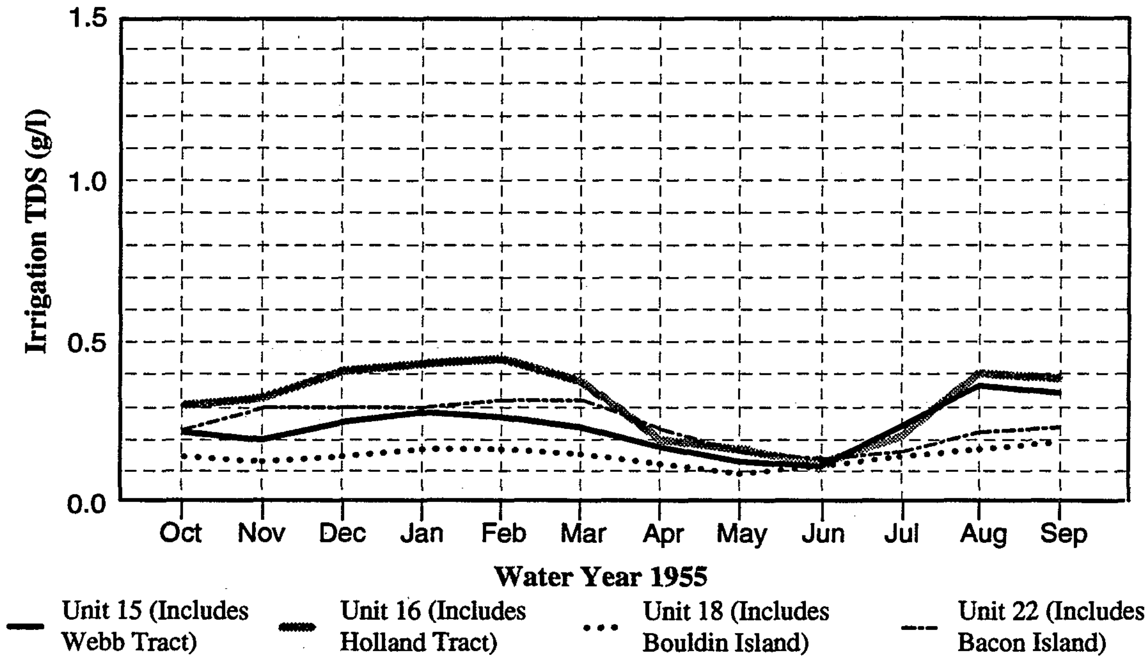

Figure C2-6.
Delta Lowlands Monthly Drainage TDS Concentrations
from DWR Report No. 4 for Water Year 1955

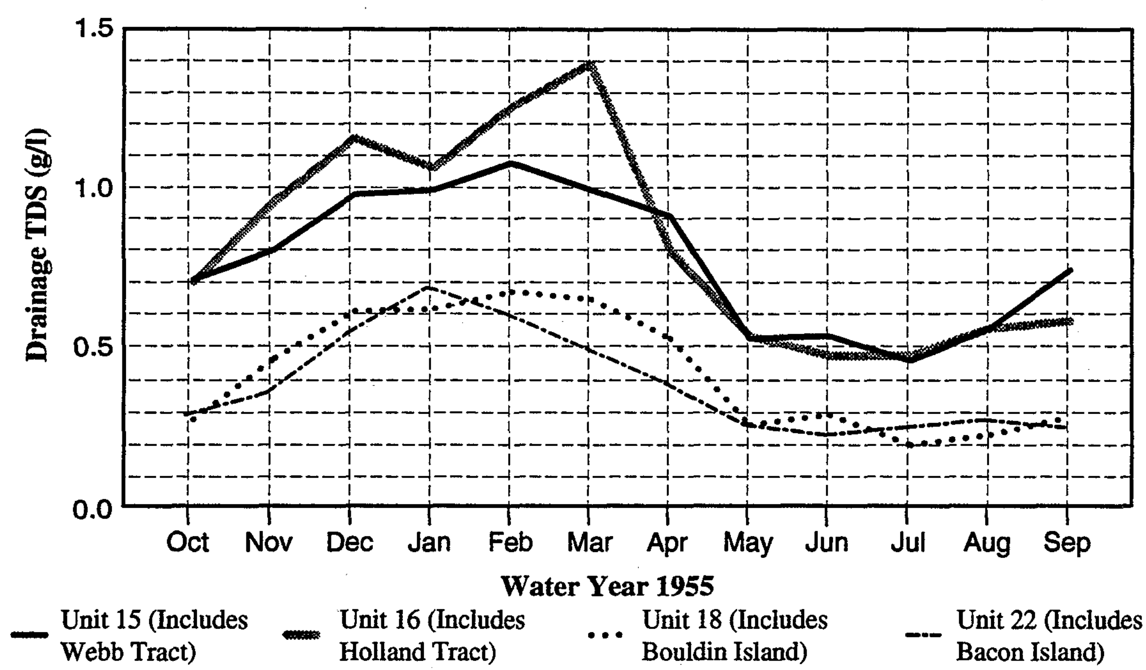

Figure C2-7.
Delta Lowlands Monthly Irrigation Salt Load
from DWR Report No. 4 for Water Year 1955

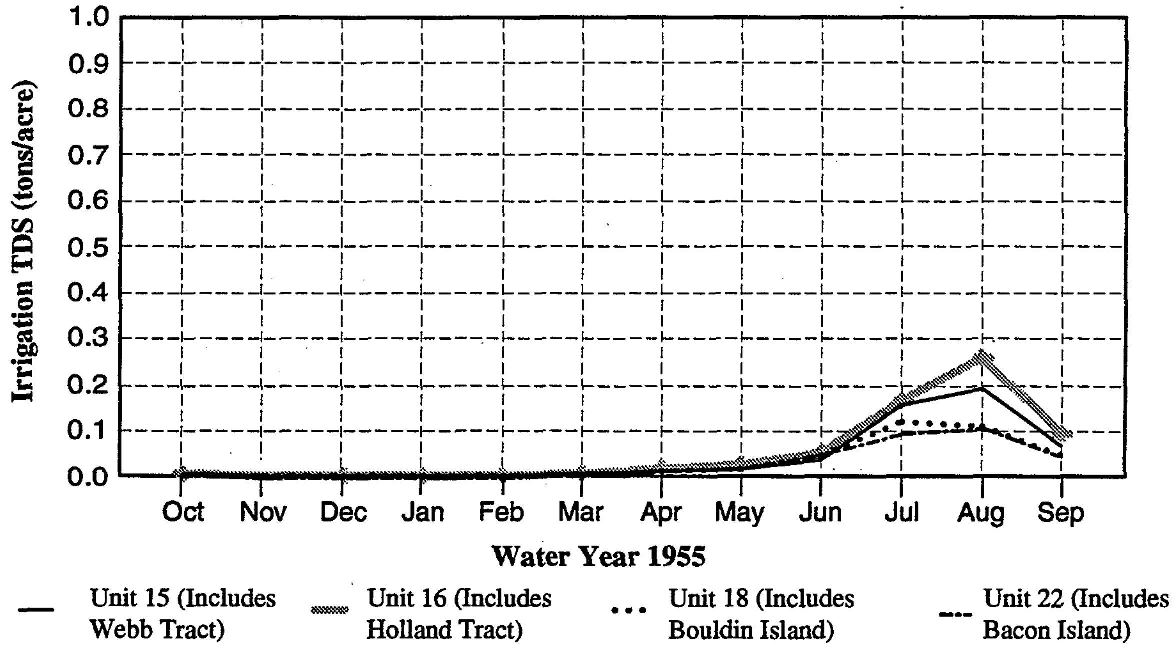

Figure C2-8.
Delta Lowlands Monthly Drainage Salt Load
from DWR Report No. 4 for Water Year 1955

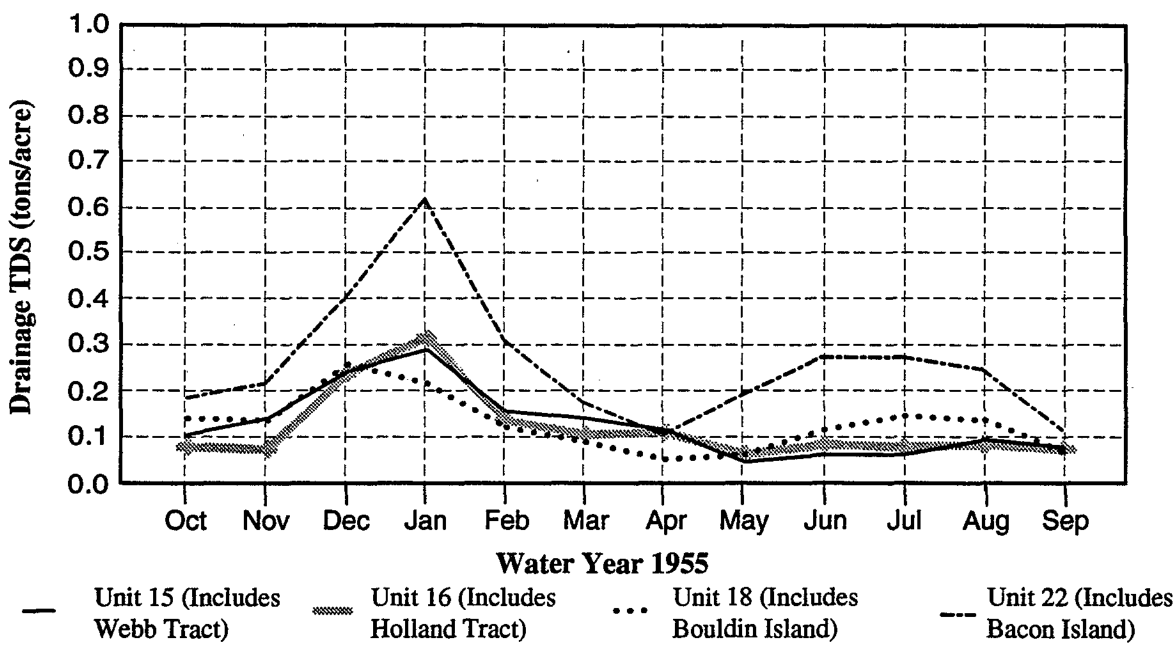

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Figure C2-9.
DOC and Chloride Concentrations
in Bacon Island Drainage Based on DWR MWQI 1986-1991 Data

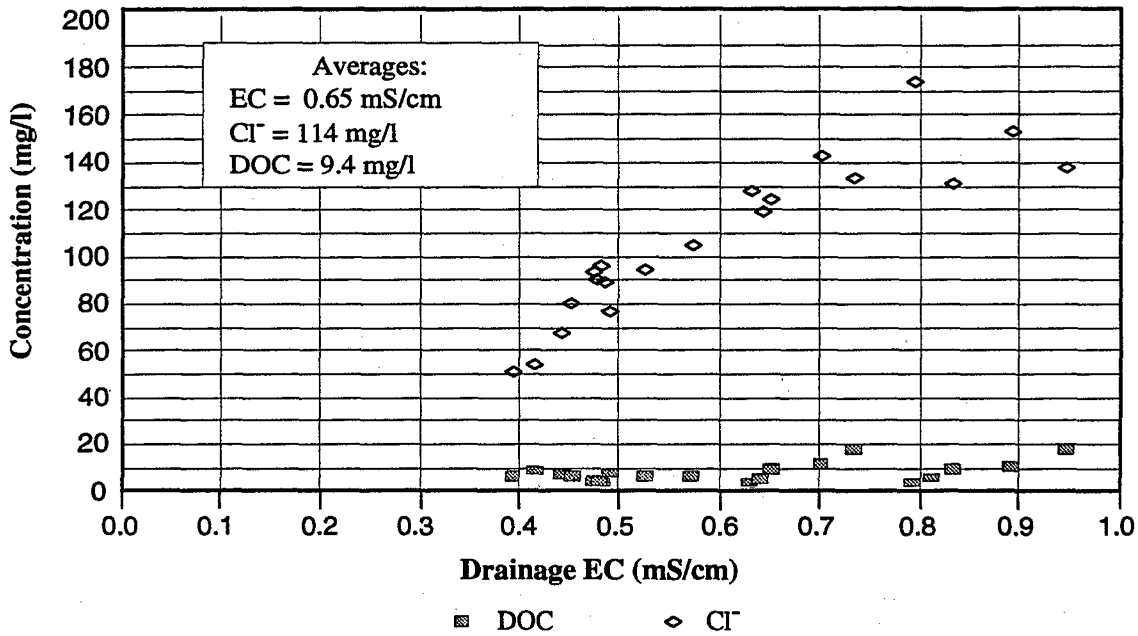

Figure C2-10.
DOC and Chloride Concentrations
in Bouldin Island Drainage Based on DWR MWQI 1986-1991 Data

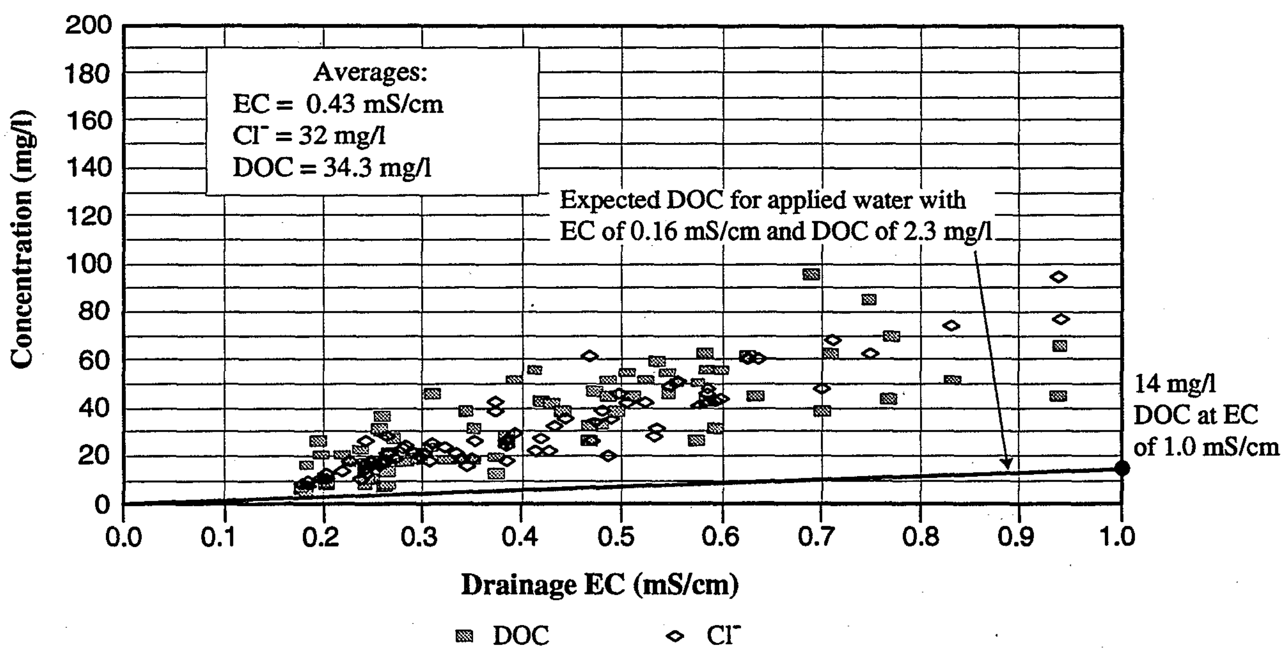

Figure C2-11.
DOC and Chloride Concentrations
in Holland Tract Drainage Based on DWR MWQI 1986-1991 Data

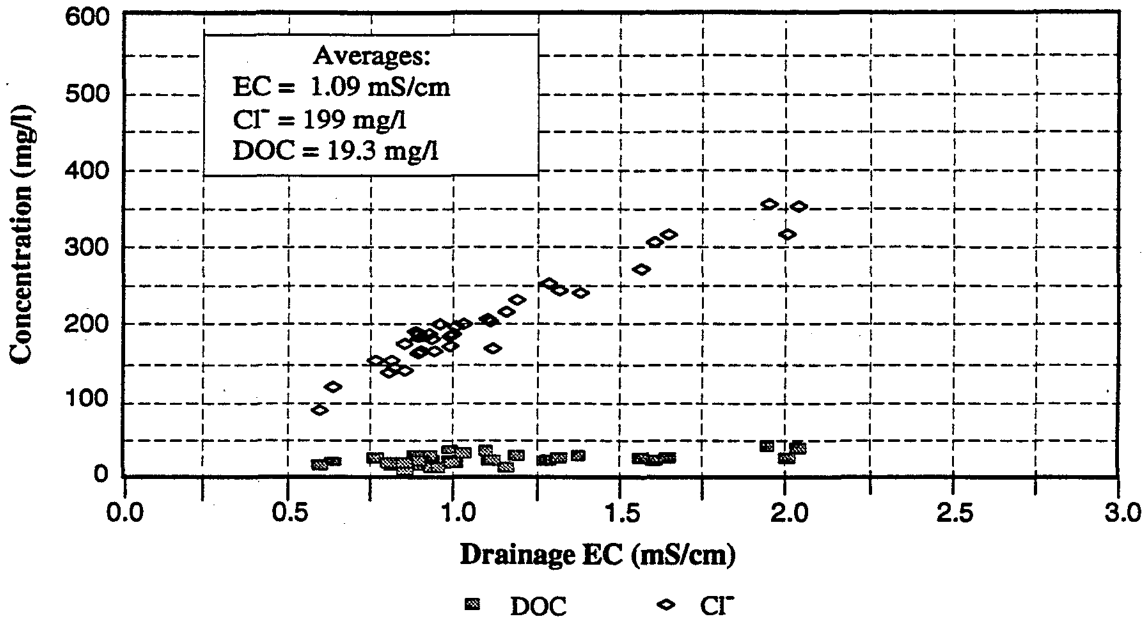

Figure C2-12.
DOC and Chloride Concentrations
in Webb Tract Drainage Based on DWR MWQI 1986-1991 Data

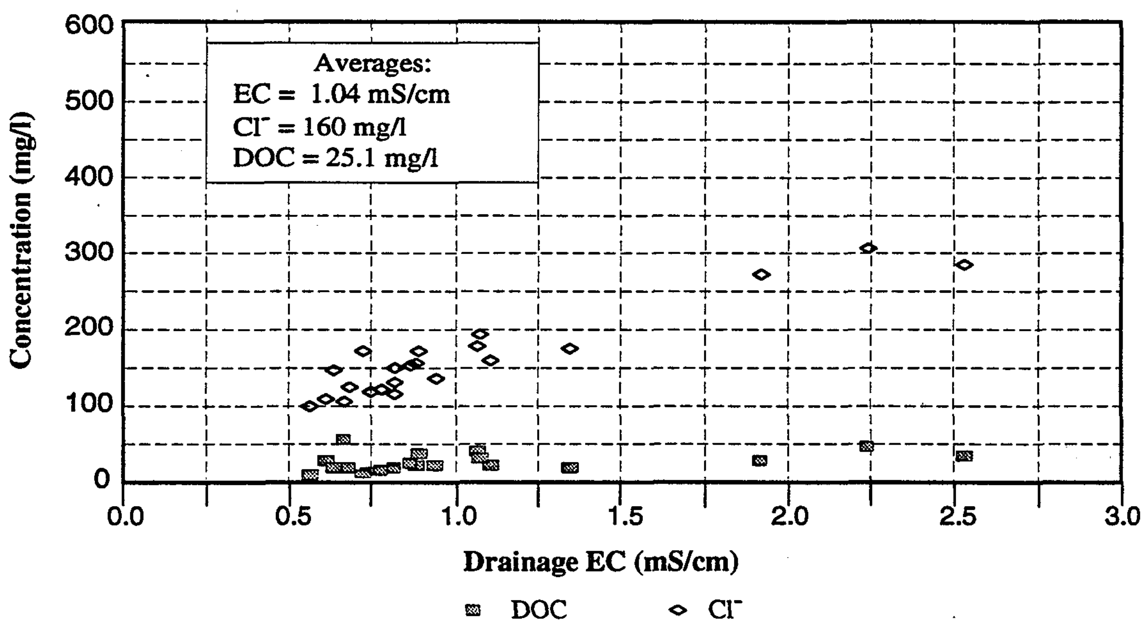

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Figure C2-13.
DOC and Chloride Concentrations
in Grand Island Drainage Based on DWR MWQI 1986-1991 Data

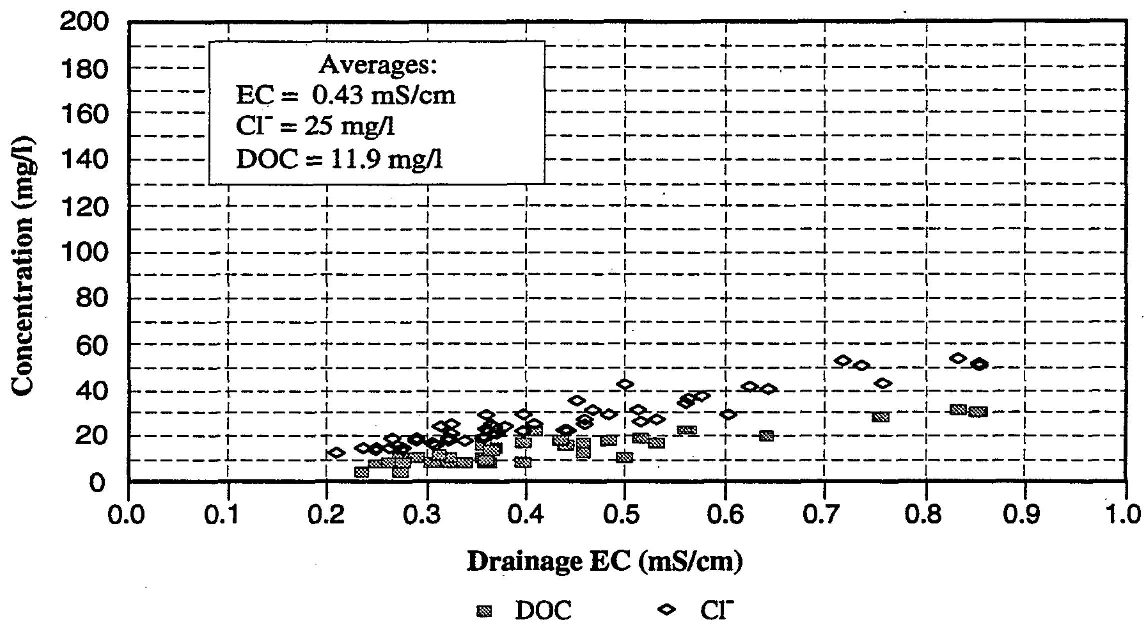

Figure C2-14.
DOC and Chloride Concentrations
in Tyler Island Drainage Based on DWR MWQI 1986-1991 Data

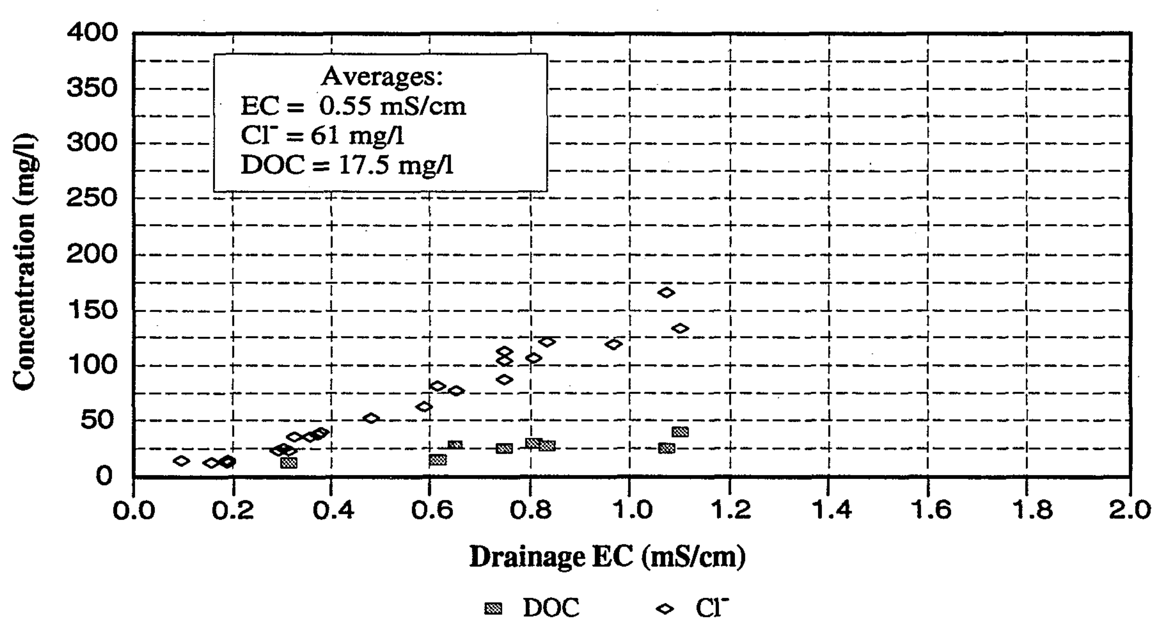

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Figure C2-15.
DOC and Chloride Concentrations
in Brannan Island Drainage Based on DWR MWQI 1986-1991 Data

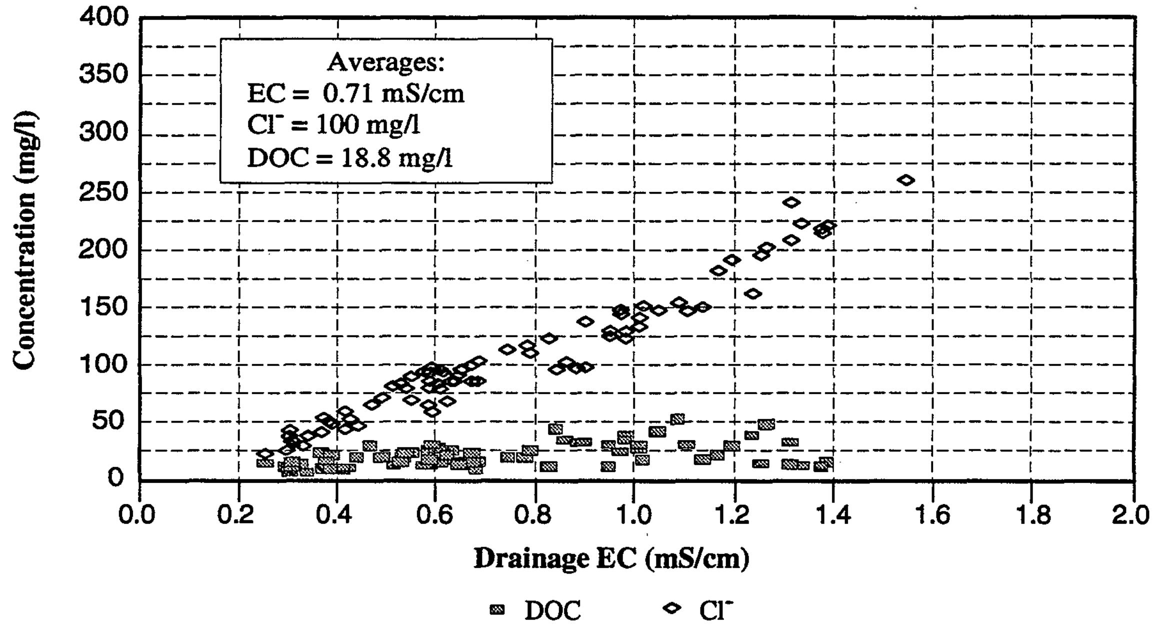

Figure C2-16.
DOC and Chloride Concentrations
in Egbert Tract Drainage Based on DWR MWQI 1986-1991 Data

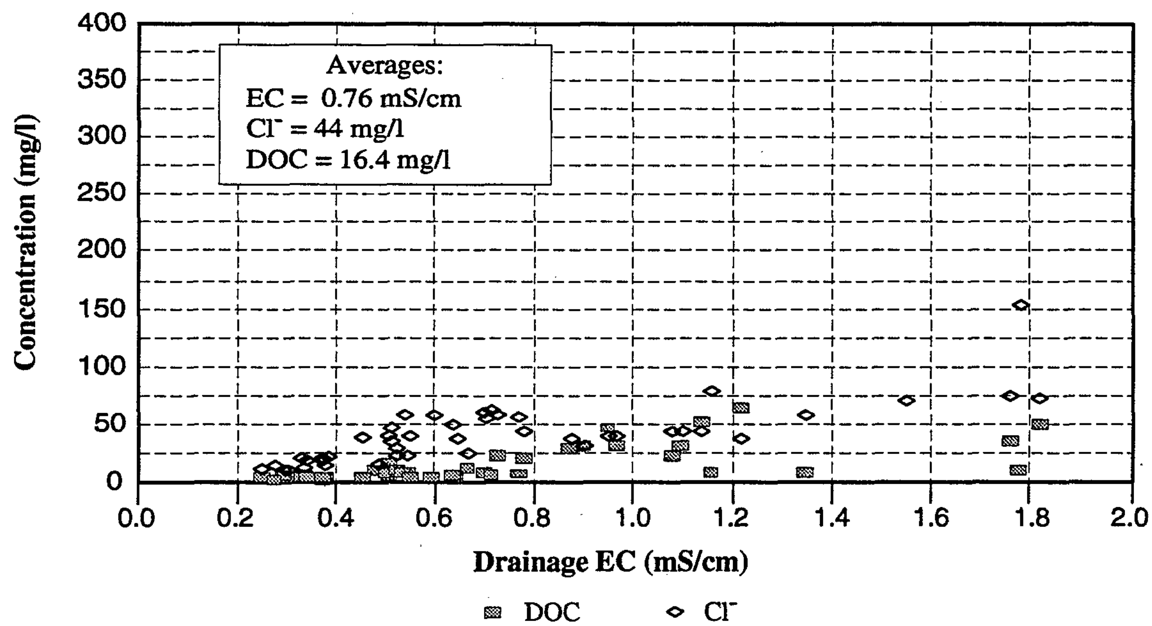

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Figure C2-17.
DOC and Chloride Concentrations
in Empire Island Drainage Based on DWR MWQI 1986-1991 Data

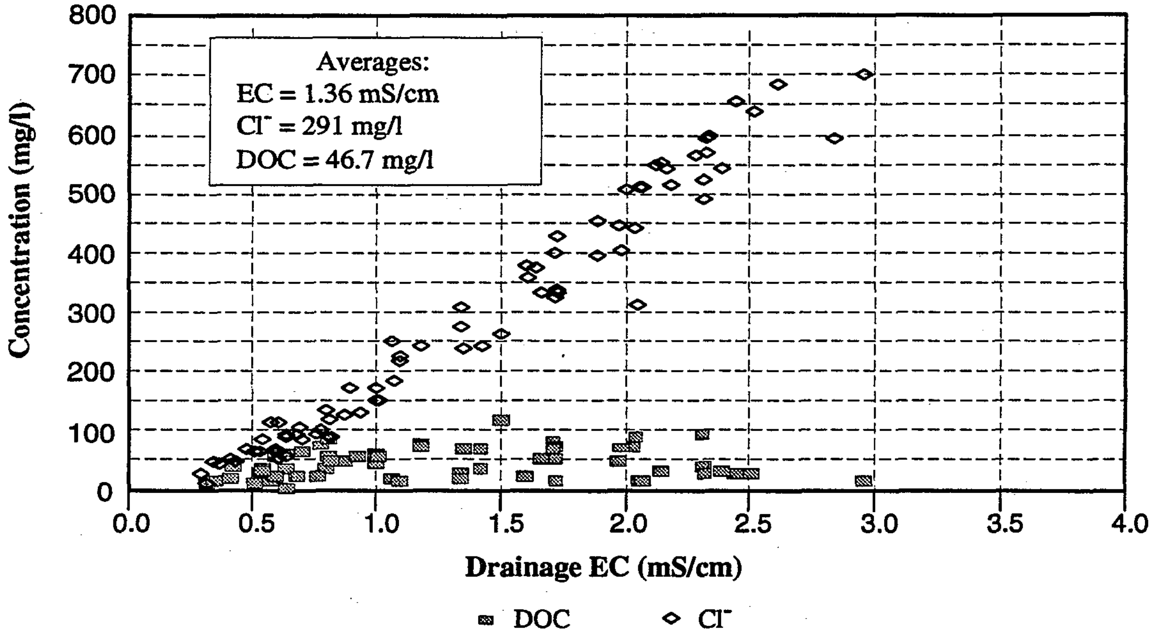

Figure C2-18.
DOC and Chloride Concentrations
in Pescadero Tract Drainage Based on DWR MWQI 1986-1991 Data

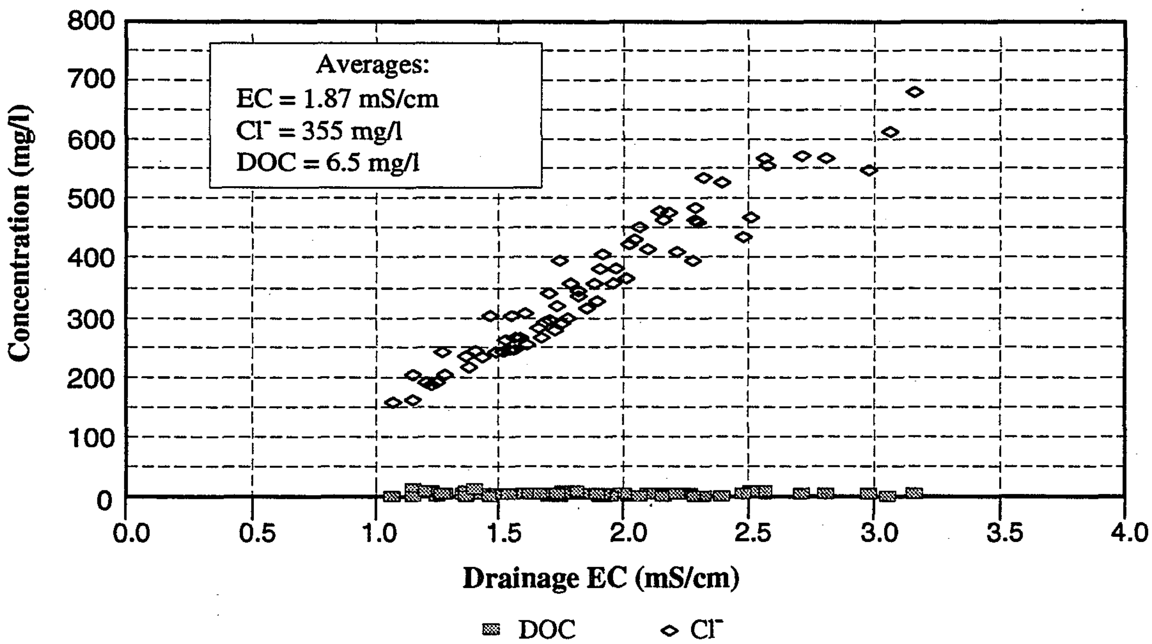

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Figure C2-19.
DOC and Chloride Concentrations
in Jones Island Drainage Based on DWR MWQI 1986-1991 Data

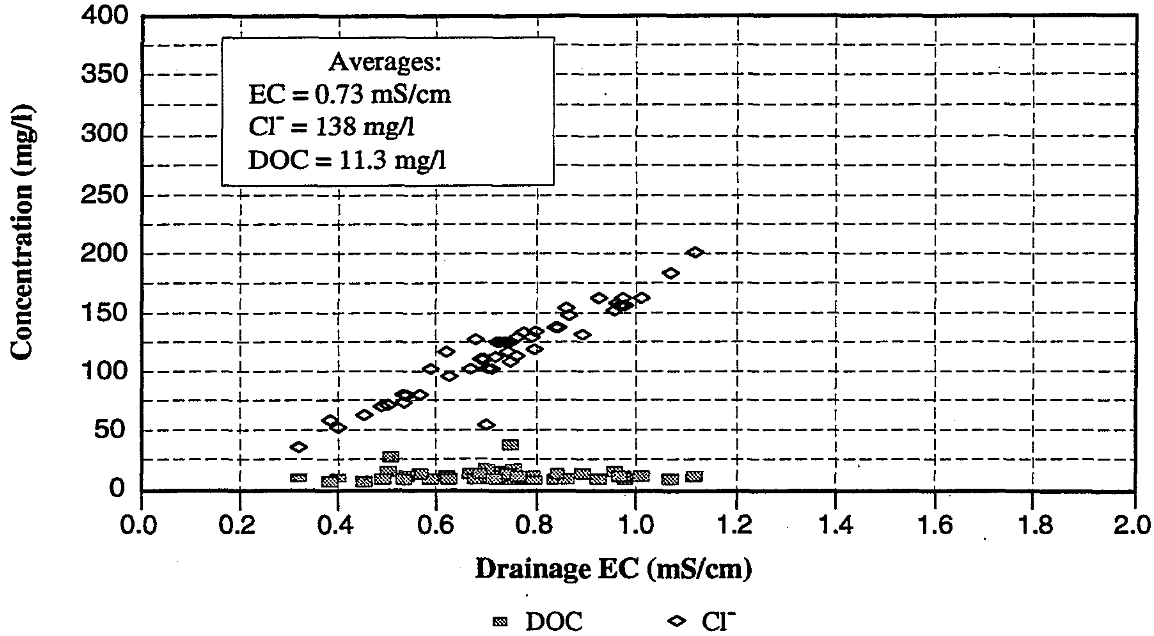


Figure C2-20.
DOC and Chloride Concentrations
in Mossdale Tract Drainage Based on DWR MWQI 1986-1991 Data

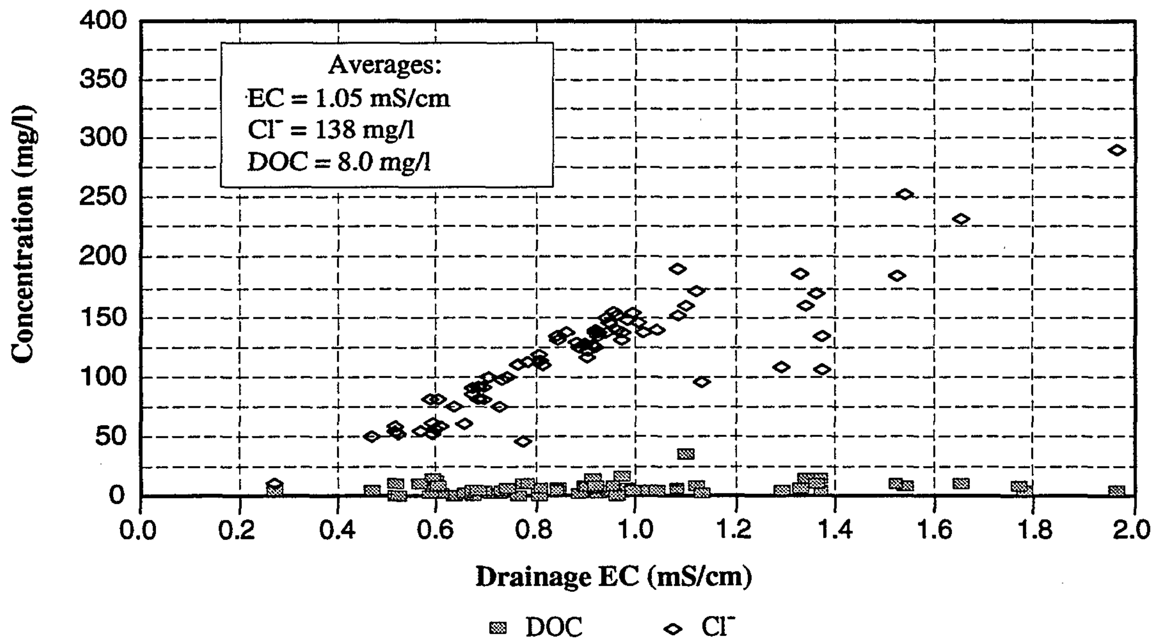


Figure C2-21.
DOC and Chloride Concentrations
in King Island Drainage Based on DWR MWQI 1986-1991 Data

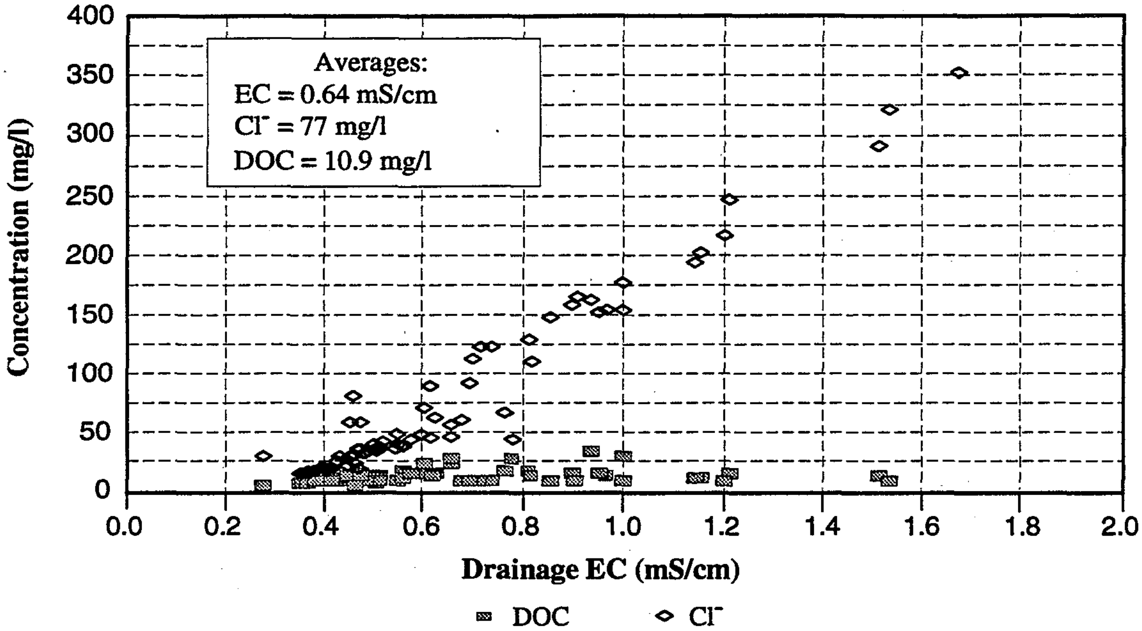


Figure C2-22.
DOC and Chloride Concentrations
in Rindge Tract Drainage Based on DWR MWQI 1986-1991 Data

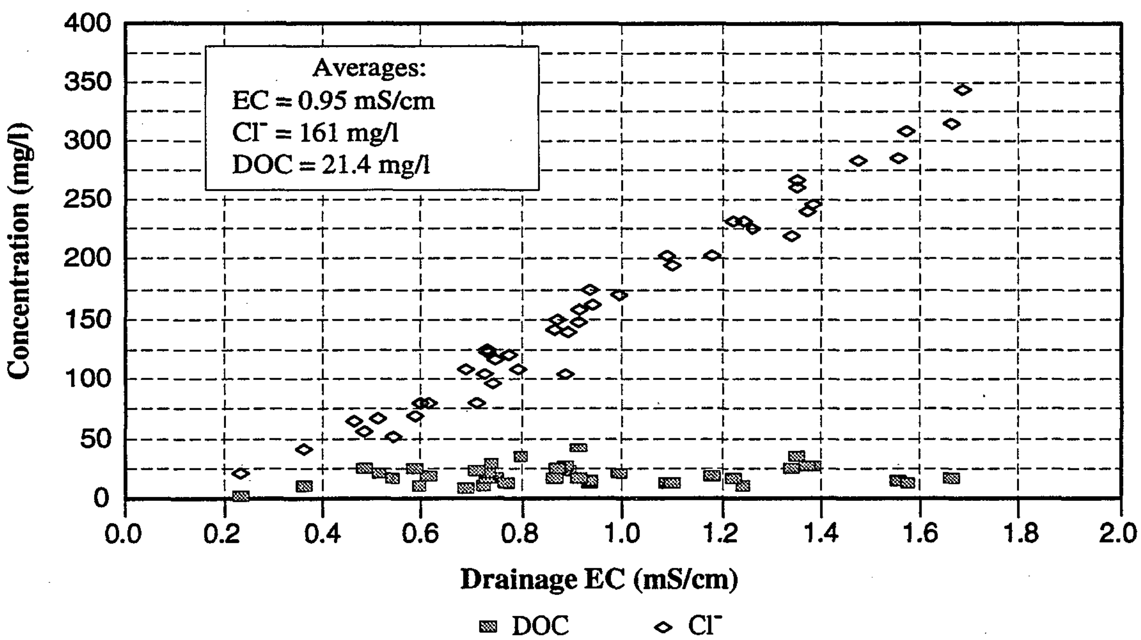


Figure C2-23.
DOC and Chloride Concentrations
in Rio Blanco Tract Drainage Based on DWR MWQI 1986-1991 Data

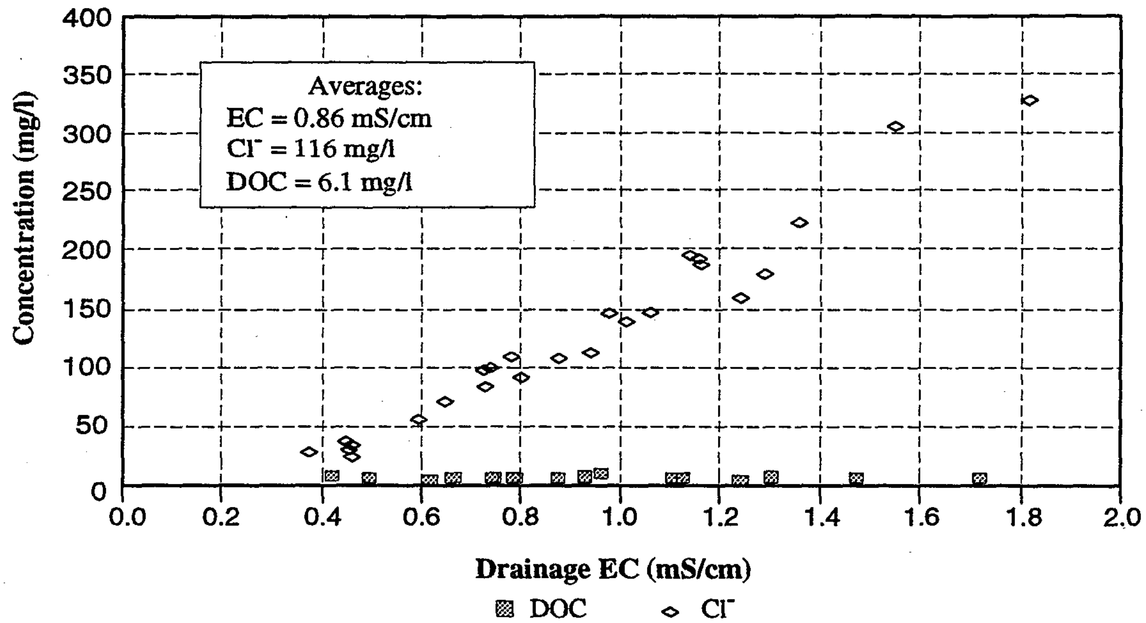
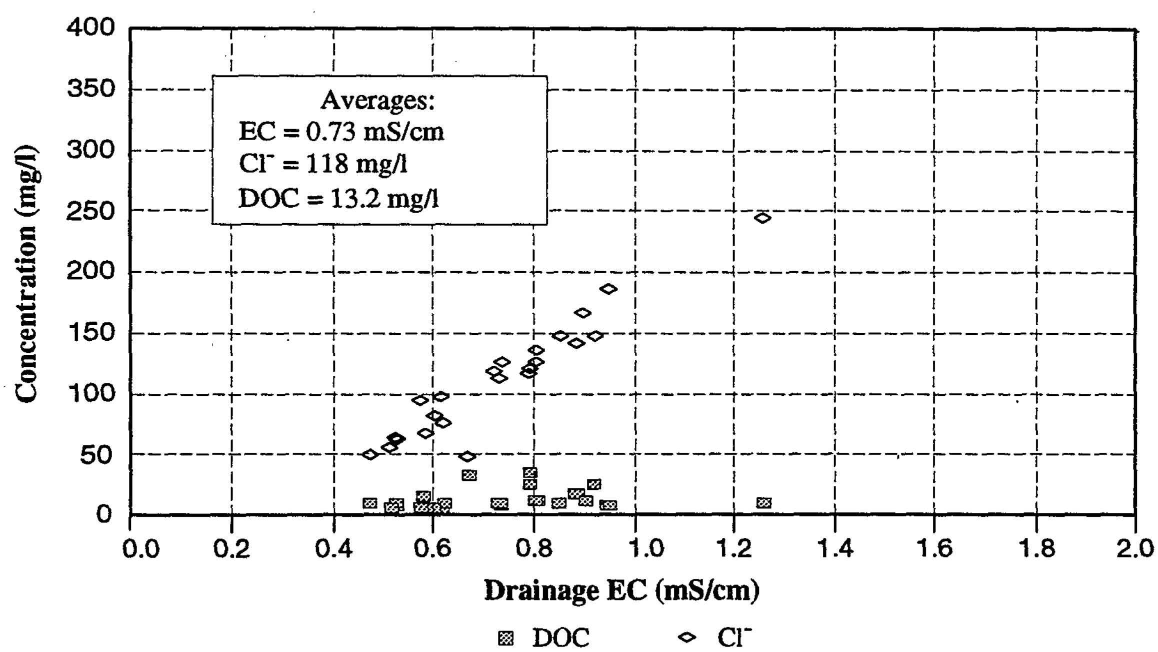


Figure C2-24.
DOC and Chloride Concentrations
in Terminous Island Drainage Based on DWR MWQI 1986-1991 Data



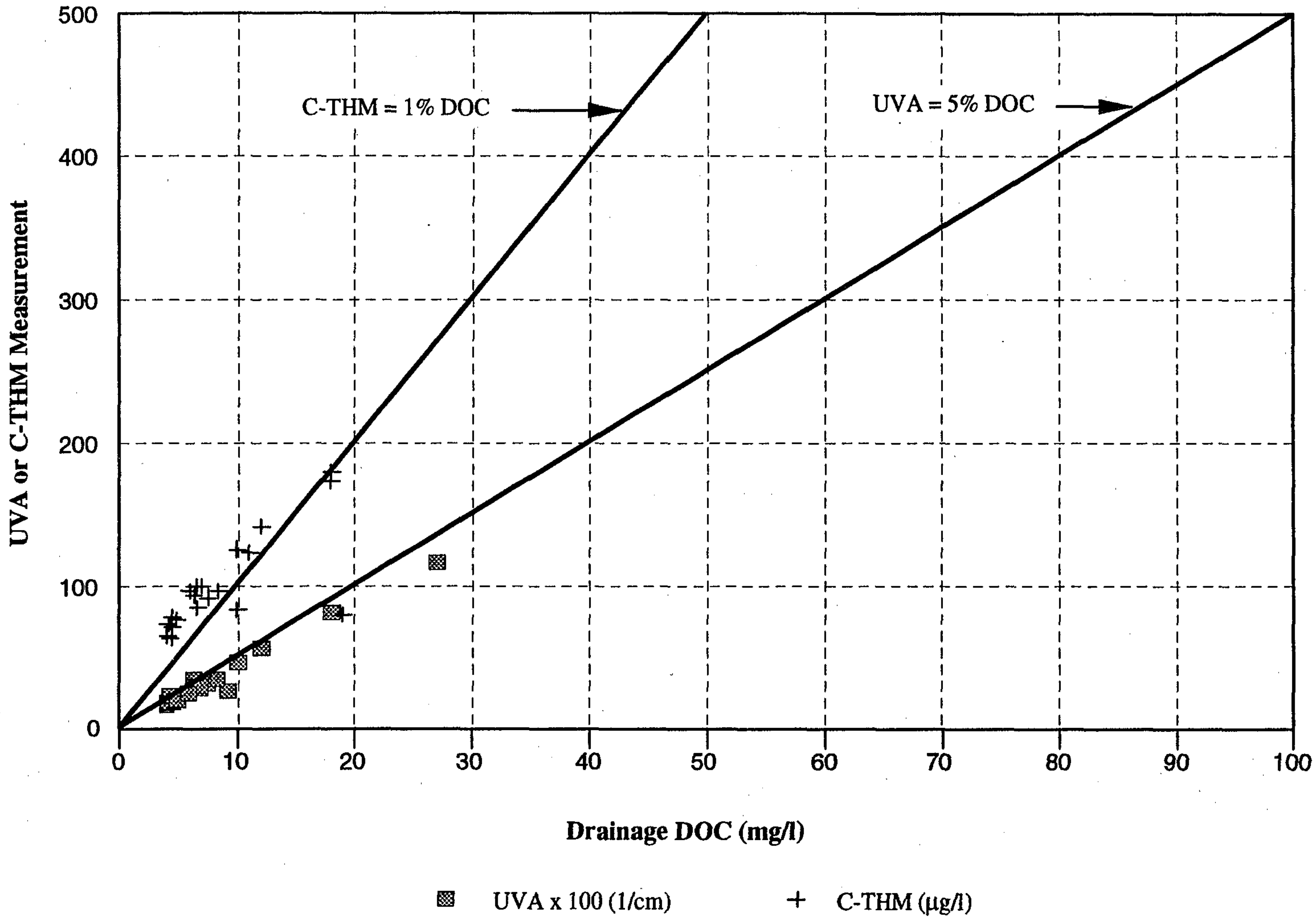


Figure C2-25.
Observed UVA Values and C-THM Concentrations
as a Function of DOC Concentrations from Bacon Island
DWR MWQI Drainage Samples for 1986-1991

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C-061747

C — 0 6 1 7 4 7

C-061748

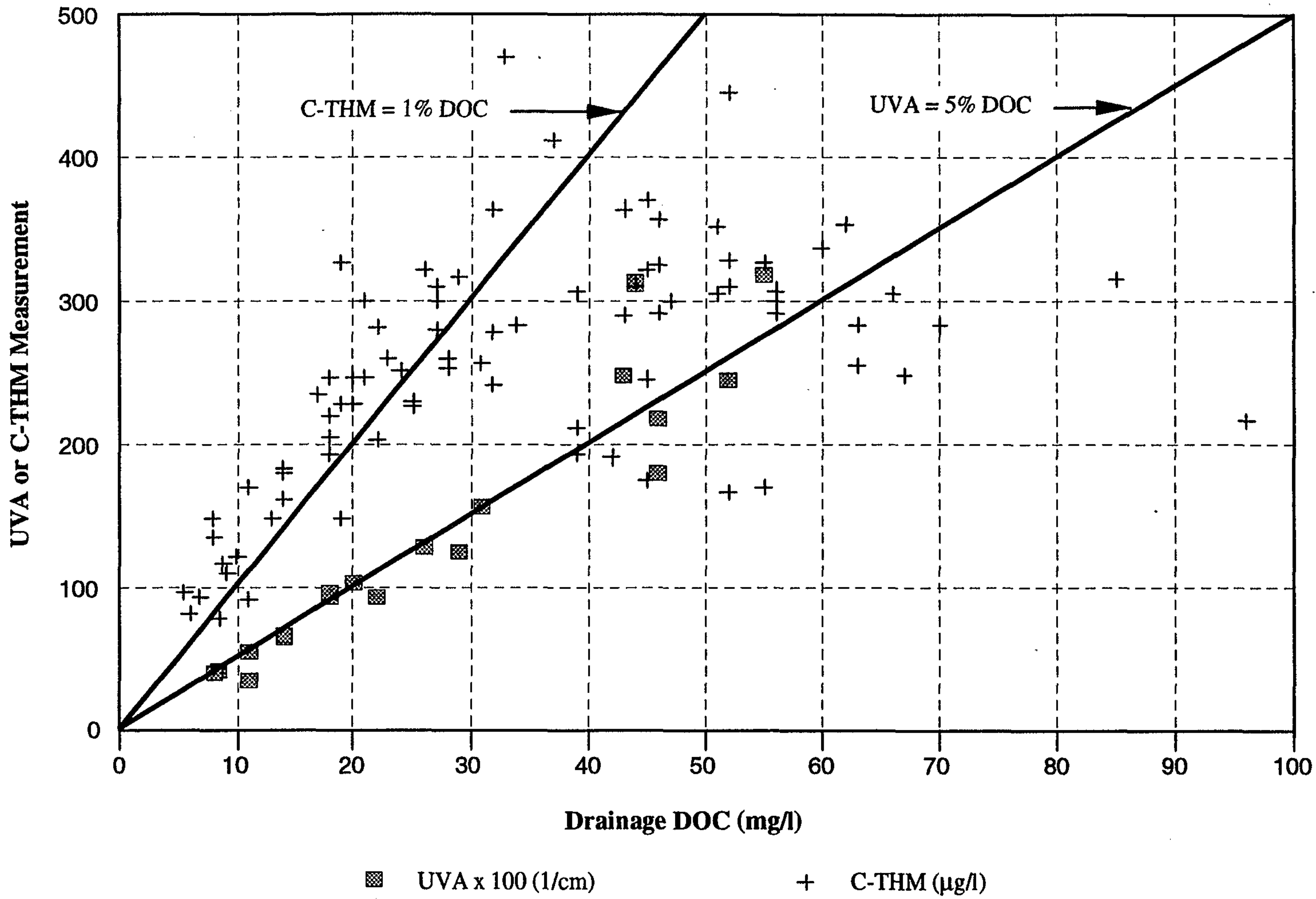

Figure C2-26.
Observed UVA Values and C-THM Concentrations
as a Function of DOC Concentrations from Bouldin Island
DWR MWQI Drainage Samples for 1986-1991

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C — 0 6 1 7 4 8

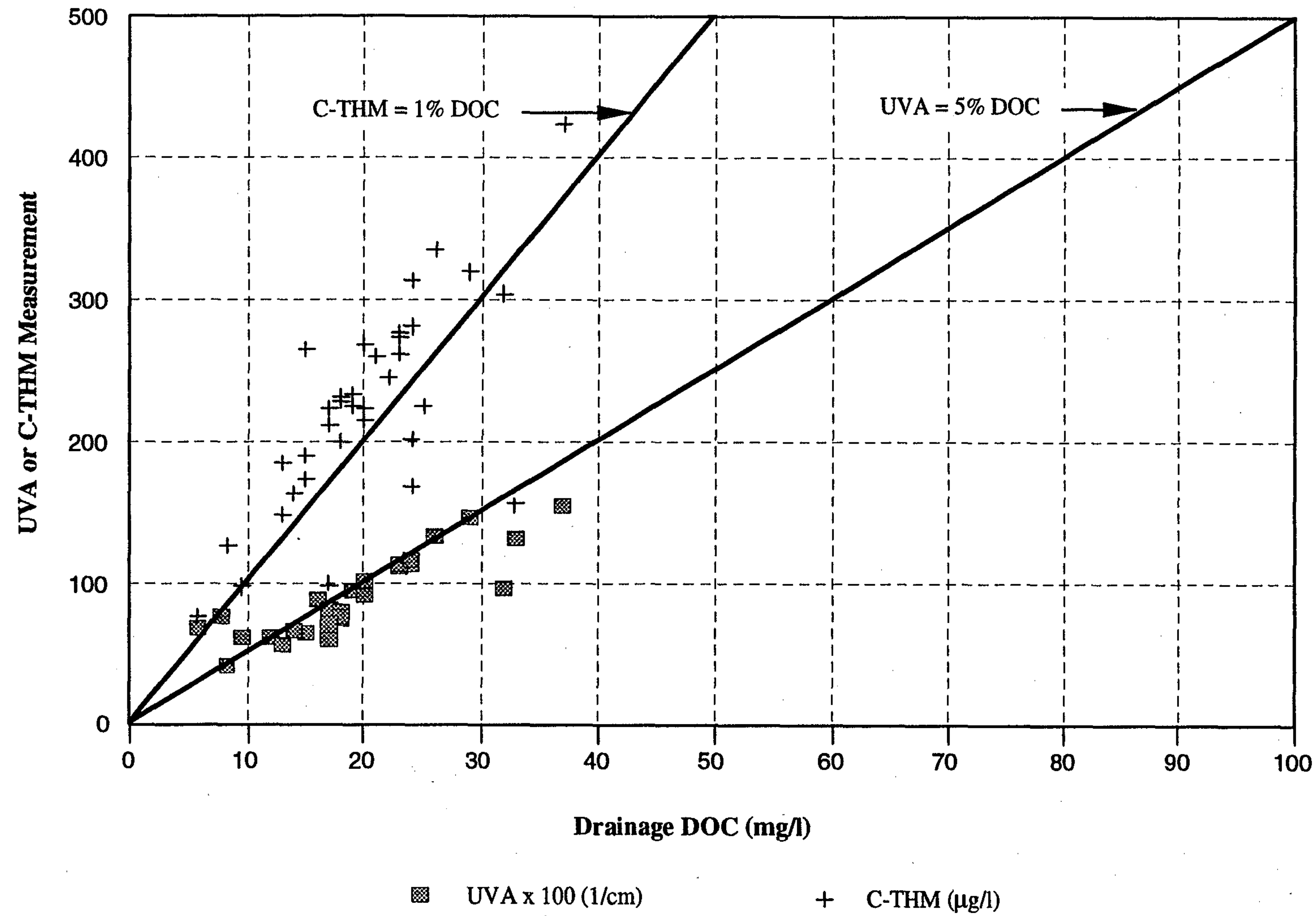

Figure C2-27.
Observed UVA Values and C-THM Concentrations as a Function of DOC Concentrations from Holland Tract DWR MWQI Drainage Samples for 1986-1991

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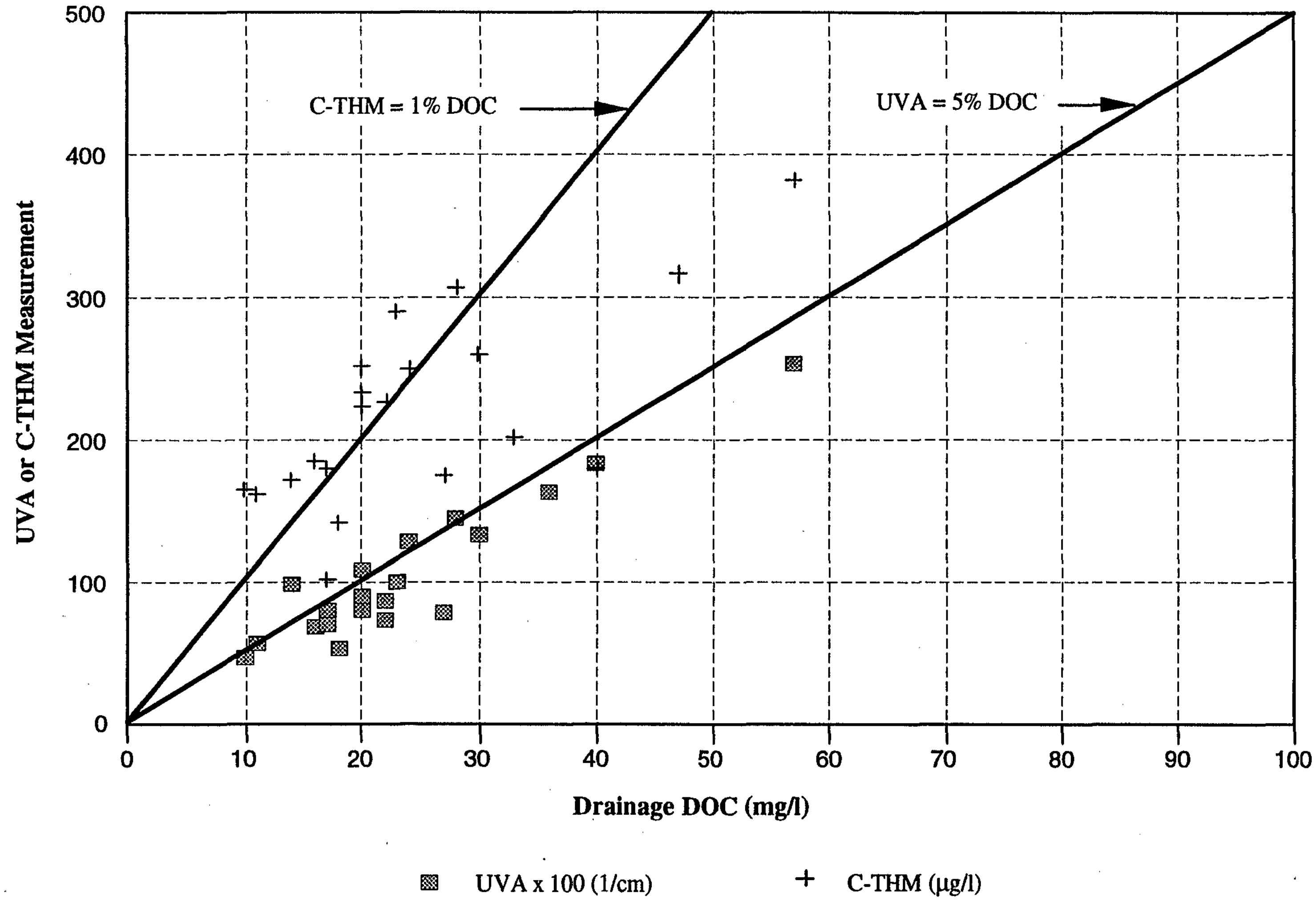
C-061749

C-061749

C-061750



C — 0 6 1 7 5 0

Figure C2-28.
Observed UVA Values and C-THM Concentrations as a Function of DOC Concentrations from Webb Tract DWR MWQI Drainage Samples for 1986-1991

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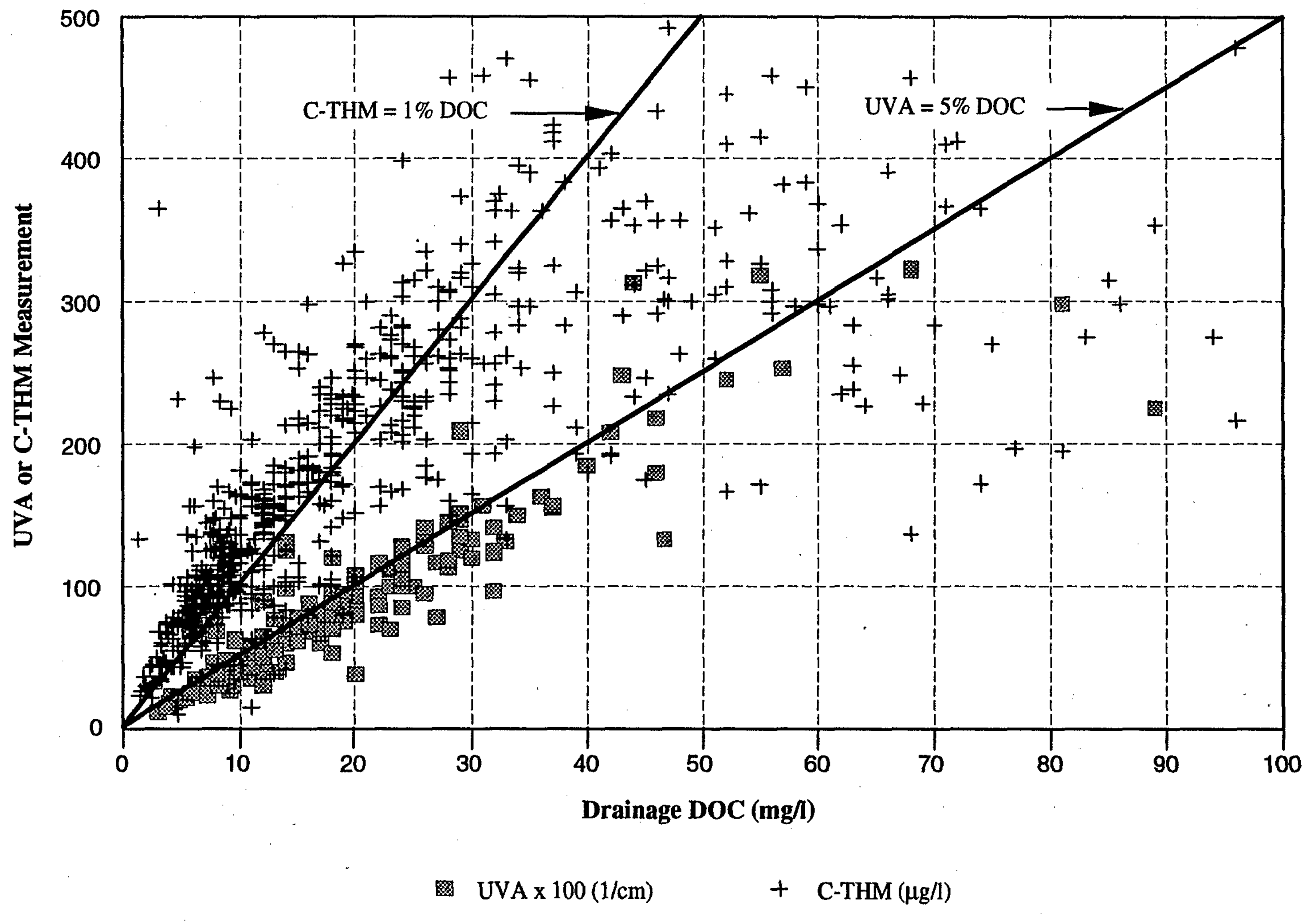

C — 0 6 1 7 5 1

Figure C2-29.
Observed UVA Values and C-THM Concentrations as a Function of DOC Concentrations from All DWR MWQI Drainage Samples for 1986-1991

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