State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Division of Environmental Services

Office of Water Quality
Municipal Water Quality Investigations Unit

Modeled Impacts of Delta Peat Island Drainage on Organic Carbon Levels at Selected Delta Municipal Water Intakes

Memorandum Report

October 2003

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State of California The Resources Agency

Memorandum

Date: October 27, 2003

To: Phil Wendt
Chief, Office of Water Quality
Department of Water Resources

Carol DiGiorgio
Staff Environmental Scientist
From: **Department of Water Resources**

Subject: Report on the Modeled Impacts of Delta Peat Island Drainage on Organic Carbon Levels at Selected Delta Municipal Water Intakes

This report examines the modeled impacts on selected municipal water intakes from Delta island drainages in terms of organic carbon concentrations. This was accomplished by running the Department's DSM2 model with and without estimated dissolved organic carbon (DOC) loads from Delta island discharges. It provides a first look at the possible effects of Delta island drainages on municipal water intake DOC concentrations. However, because these are modeled DOC values based on best estimates of Delta island exports, it is inappropriate to use the absolute DOC concentration values. Instead, the data should be used to examine the patterns and relative differences in intake DOC levels with and without Delta island discharges.

Results of these analyses suggest that the hypothetical removal of all DOC in Delta island drainage results in the greatest decreases to intake DOC levels in summer and early fall. These changes are most pronounced in dry years. Decreases in DOC in summer and fall appear to correspond to periods of peak agricultural activity, suggesting that despite contributions from other sources, agricultural drainage into Delta channels has a noticeable impact on summer and early fall municipal intake DOC levels. Summer and fall also correspond to the Department's historical peak demand for water exports. Compared to summer, the winter carbon levels in the Delta are higher and more variable. Results from this report, although preliminary, suggest that further studies with refined estimates of Delta island agricultural drainage volumes, timing, and DOC loads would be worthwhile to more closely determine the relative contribution of DOC from this source at municipal water intakes.

SURNAME DWR 155 (Rev 4/02)				
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Contents

Tables

Figures

Appendix A

Introduction[1]

Organic carbon in the Sacramento-San Joaquin Delta originates from a number of sources, including in-channel algal production and inflows of carbon from storm events. However, the Delta's natural history has also resulted in the creation of carbon-rich peat islands. The organically rich peat soils of these islands were created through the natural cycle of tule growth and decay. Of approximately 738,000 acres of islands and channels making up the Delta today, about 250,000 acres confined to the Delta basin are rich in organic matter. In some cases, decayed vegetation formed peat soil islands over 30-feet deep. These organically rich soils are ideal for agriculture, and many of the peat Delta islands have been intensively farmed for decades. Depending on soil type—mineral soils have less than 10% organic matter while peaty organic soils range between 50% and 80% organic matter—Delta island drainage can exhibit very high levels of dissolved organic carbon (DOC) (DWR 1994). In addition to oxidation, organic matter is carried off the islands as water passes through the peat soils from irrigation, rainfall, flooding, seepage, and leaching. However, the islands' actual contribution to organic carbon loads observed at Delta municipal water intakes is still not well understood.

One of the largest obstacles to understanding Delta island carbon contributions is quantifying the drainage volume of water leaving the islands through pumping or seepage. Access to Delta island agricultural drains can be difficult. Therefore, the Department developed the Delta Island Consumptive Use (DICU) model for lowland agricultural diversions and returns in the Delta. Estimates of lowland Delta drainage volume modeled by DICU have shown general agreement with measured drainage volume estimates and monthly trends observed in studies with actual drainage volume measurements (Jung and Assoc. 1999). The DICU model is part of the Department's larger Delta Simulation Model 2 (DSM2), which provides predictive capabilities for several water quality parameters throughout the Delta including the Delta municipal water intakes.

DICU = Delta Island Consumptive Use

DSM2 = Delta Simulation Model 2

The objective of this study was to provide a first approximation of the effects of Delta island carbon production to observed DOC concentrations at municipal and industrial intakes in the Delta. This was accomplished by running DSM2 with and without DOC in the DICU modeled Delta island drainages. This all-or-nothing approach allowed examination of the theoretical worst-case contribution of Delta islands to DOC levels at the Delta intakes. It was reasoned that if no appreciable changes were observed at Delta intakes under the best- and worst-case scenarios, it was unrealistic to further pursue Delta island carbon contribution modeling. With each model run, monthly concentrations of DOC were examined at 4 Delta municipal and/or industrial intakes: the Harvey O. Banks Pumping Plant (State Water Project [SWP]), the Tracy Pumping Plant (intake for the Central Valley Project [CVP]), Old River at Highway 4, and Old River at Rock Slough.

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[1] Report prepared by Carol DiGiorgio, Staff Environmental Scientist, Municipal Water Quality Investigations Program, Office of Water Quality, Division of Environmental Services.

Funding for this study provided by the State Water Contractors through the MWQI Committee.

Intake DOC was also calculated for the Barker Slough Pumping Plant (intake for the North Bay Aqueduct), but because this area lacks adequate information for the model to perform reliably, NBA results were not included in this paper.

Assumptions used for these modeling runs are detailed in a 2003 Delta Modeling Section memorandum (Suits 2003). Model runs used the typical 16-year planning sequence—water years 1976 through 1991—and assumed that the State Water Project (SWP) was operated under D-1641 conditions. Delta inflows and exports were taken from the CALSIM 2001 level of demand benchmark study (DWR and USBR 2002). The boundary river DOC values illustrated in Figure 1 were developed for planning studies by the Delta Modeling section (DWR 2002). Delta island DOC drainage values used in the model were developed by Marvin Jung and Associates, Inc. (Jung and Assoc. 1999, 2000). Delta islands drainages were divided into 3 categories—low-range, mid-range, and high-range DOC producing areas (Figure 2). DOC values were based on location, season, soil type, and land surface elevation. Island DOC data were collected between 1982 and 1997. Permanent south Delta barriers were assumed to be installed and operating, and the Clifton Court Forebay intake gates were assumed to be open whenever the water level outside the forebay allowed for inflow.

Figure 1 Delta boundary DOC for the simulation period

Figure 2 Drainage DOC values for DSM2

As stated, the objective of this exercise was to provide a first look at the possible affects of Delta island drainages to intake DOC. Although the model provides actual DOC concentration values, these numbers should be approached with caution. Riverine DOC values were developed with some analysis of variation in flow, but Delta island drainages were not. This means that monthly calculated concentration discharges off the islands were repeated yearly over the 16-year time period regardless of year type. However, monthly Delta island carbon concentrations were originally calculated from samples collected over a period spanning all water year types from wet to critical (1982 to 1987). Therefore, the hydrological affects of different year types, especially extremes, are potentially dampened in any year type model run. Additionally, monthly averaging of modeled intake concentrations over 16 years, as was done in this report, would tend to dampen any extremes associated with varying hydrologic or discharge conditions.

Although it is not appropriate to use the DOC concentrations at face value nor to compare actual intake values to the California Bay-Delta Authority's target DOC objective of 3 mg/L, modeling of these data does provide information on potential patterns associated with and without Delta island discharges. Therefore, this paper concentrates on patterns and relative differences observed to intake DOC levels with and without Delta island drainages.

Results

Without exception, removal of DOC from Delta island agricultural drainage resulted in lower DOC concentrations at all modeled Delta intakes. Over the span of the 16-year model run, removal of DOC in agricultural discharges from Delta islands could decrease DOC concentrations at the intakes by as little as 1% or as much as 65% (Table 1). Monthly DOC values with and without DOC in agricultural drainage and the decreases in monthly average DOC as a percent and as mg/L are reproduced from the Department's Delta-Modeling Section memorandum (Suits 2003) in Appendix A. Summary statistics for concentration values are given in Table 2.

To facilitate comparisons, data for the same month were averaged over the 16-year period. Removal of all DOC in Delta island drainage into the Delta resulted in monthly average carbon decreases ranging from 17% to 42% (figures 3–6). Decreases in carbon were similar at 3 of the 4 intakes modeled (SWP, Old River at Hwy 4, and Old River at Rock Slough), with approximately 32% to 35% less carbon occurring at these intakes on a yearly basis. Removing agricultural drainage DOC from the Delta islands had less affect on the CVP intake. However, even at this site, yearly average carbon values fell by 25%. One possible reason for less improvement at the CVP intake is the predominance of San Joaquin River water and less Delta agricultural drainage water pumped out of the Delta by this facility.

To determine what effect, if any, removal of Delta island drainage had under different hydrologic year types, the DWR Sacramento and San Joaquin Valley Water Year Hydrological Indices were used to classify water years 1976 through 1991 into either dry or wet years. For purposes of this comparison, all below-normal, critical, and dry years were classified as dry years and all above-normal and wet years were classified as wet years. With the exception of 1979, both the Sacramento and San Joaquin indices were similar (that is, both indices indicated a year should be classified as wet or dry); therefore, only 1979 was not used in dry and wet year calculations. Dry and wet year classifications are shown in Table 3.

Based on modeling results, removal of DOC in Delta island drainage had the most impact on intake carbon levels during dry years. As shown by tables 4–7, average carbon concentrations were reduced by 19% to 49% during dry years. Removal of agricultural drainage during wet water years also lowered intake carbon levels (between 5% and 42%), but, on average, wet year improvements were always less than dry year improvements.

Table 1 Percent changes in DOC using DSM2 with or without DOC in Delta island drainages, Oct 1975–Sep 1991

Table 2 Summary statistics for DOC (mg/L) using DSM2 with or without DOC in Delta island drainages, Oct 1975–Sep 1991

Figure 3 Average monthly and percent changes in DOC at the Harvey O. Banks Pumping Plant (SWP) using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991

Figure 4 Average monthly and percent changes in DOC in the Tracy Pumping Plant (CVP) using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991

Figure 5 Average monthly and percent changes in DOC at Old River at Highway 4 using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991

Figure 6 Average monthly and percent changes in DOC at Old River at Rock Slough using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991

Table 3 Years classified as either dry or wet based on overlapping Sacramento and San Joaquin Valley water year indices

Table 4 Monthly average changes in DOC at the Harvey O. Banks Pumping Plant (SWP) by year type

Model predictions of summer and fall carbon concentrations at Delta export locations reflected water usage patterns associated with agricultural cycles. The peak irrigation and drainage discharge season associated with crop production is generally in July and August (Jung and Assoc. 1999). Depending on the start of the growing season this period may extend into September. Following the growing season, discharge off the islands is lower until the start of the winter storm season between November and January (Templin and Cherry 1997). Regardless of the year type, removal of DOC in agricultural drainage from July through September generally resulted in greater improvements in intake carbon concentrations than removal from October through December (see tables 4–7). Because all other carbon sources between the 2 modeling runs remained the same, these results suggest that agricultural drainage during peak irrigation periods (July–Sept.) is potentially one of the larger contributors to organic carbon levels at the intakes. Conversely, in the late fall following the peak growing season, agricultural drainage potentially plays a smaller role in intake water quality.

Lower DOC concentrations associated with July–September removal of all Delta island agricultural drainage coincided with the summer peak pumping period at Banks Pumping Plant (see Figure 3). This suggests that, with a reduction in Delta island discharges, improvements in water quality at the intakes could occur during peak demand periods.

With one exception, removal of DOC in Delta island drainage during the summer growing season also resulted in less variability in carbon levels at the intakes. As shown in figures 7–10, quartile and minimum and maximum ranges from July to October were noticeably more compact when DOC in agricultural discharge was removed from the model. The only exception was carbon levels at the CVP, which is less influenced by Delta agricultural discharges. In the remaining months, regardless of whether DOC in agricultural drainages were included in the model, carbon variability increased. These results suggest that during the summer, when DOC in Delta island agricultural drainage is removed from the Delta, background surface water carbon levels are lower and more stable. However, during the peak winter/early spring rainy and runoff period, large and rapidly changing riverine sources dominate intake carbon concentrations, resulting in increased carbon variability.

Changes to intake DOC water quality in the winter and spring (January–May) were variable. Decreases in intake winter DOC levels associated with the removal of Delta island drainage were generally the most pronounced during dry years (see tables 4-7). In wet years, changes in intake DOC were less pronounced, potentially because Delta island runoff and/or leaching was dwarfed by the large flows and DOC loads from winter rainstorm events and reservoir releases. In the case of the CVP, decreases in DOC averaged only 13%.

Table 5 Monthly average changes in DOC at the Tracy Pumping Plant (CVP) by year type

Table 6 Monthly average changes in DOC at Old River at Highway 4 by year type

Table 7 Monthly average changes in DOC at Old River at Rock Slough by year type

Figure 7 Box plot of Harvey O. Banks Pumping Plant (SWP) DOC (mg/L) with and without agricultural drainage in the model

Figure 8 Box plot of Tracy Pumping Plant (CVP) DOC (mg/L) with and without agricultural drainage in the model

Figure 9 Box plot of DOC (mg/L) at Old River at Highway 4 with and without agricultural drainage in the model

Figure 10 Box plot of Old River at Rock Slough DOC (mg/L) with and without agricultural drainage in the model

Conclusions

The results of this modeling exercise represent a rough, first approximation of the effects that Delta island drainages have on monthly DOC levels at Delta intakes. Because of the assumptions that were required to run the model, comparing the modeled predicted DOC values could be problematic. Instead, the effects of removing all Delta island drainage into the Delta was examined by looking at pattern changes and relative percentage changes in simulated DOC from model runs where DOC was included and then excluded from Delta island drainage. Removal of all DOC in Delta island drainage showed the greatest decreases in intake DOC water quality in the summer and fall. These changes were especially noticeable in dry years. Decreases in organic carbon in the summer and early fall appeared to correspond to periods of peak crop irrigation and drainage. Since the only variable that changed between model runs was the presence of DOC in Delta island drainage, these results suggest that, despite the contributions from other sources (for example, algal primary productivity), agricultural drainage into Delta channels could potentially have a significant impact on summer and early fall intake carbon levels. This period also corresponded to the Department's historical peak pumping period. Compared to summer, winter carbon levels in the Delta were higher and more variable. Results from this study, although preliminary, suggest that further studies with refined estimates of Delta island drainage volumes, timing, and DOC levels would be worthwhile.

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Table 1 Percent changes in dissolved organic carbon using DSM2 with or without DOC in Delta island drainages, Oct 1975–Sep 1991

	Avg % change	Min % change	Max % change
Banks Pumping Plant (SWP)	32	1	62
Tracy Pumping Plant (CVP)	25	1	59
Old River @ Hwy 4	33	1	65
Old River @ Rock Slough	35	8	61

DSM2 = Delta Simulation Method 2

Table 2 Summary statistics for dissolved organic carbon (mg/L) using DSM2 with or without DOC in Delta island drainages, Oct 1975–Sep 1991

	Banks Pumping Plant (SWP)		Tracy Pumping Plant (CVP)	
	With Delta island drainages	Without Delta island drainages	With Delta island drainages	Without Delta Island drainages
Average	3.9	2.6	3.8	2.9
Median	3.6	2.2	3.4	2.4
Minimum	2.4	1.6	2.5	1.6
Maximum	10.4	9.4	10.7	10.4

	Old River at Hwy 4		Old River at Rock Slough	
	With Delta island drainages	Without Delta island drainages	With Delta island drainages	Without Delta island drainages
Average	3.7	2.5	3.5	2.2
Median	3.4	2.0	3.0	1.9
Minimum	3.0	1.6	2.2	1.5
Maximum	10.1	5.4	8.0	4.8

DSM2 = Delta Simulation Method 2

Table 3 Years classified as either dry or wet based on overlapping Sacramento and San Joaquin Valley water year Indices

Water year	Year type	Water year	Year type
1976	D	1978	W
1977	D	1980	W
1981	D	1982	W
1985	D	1983	W
1987	D	1984	W
1988	D	1986	W
1989	D		
1990	D		
1991	D		

Note: D includes dry, below normal, and critical water years
W includes wet and above normal water years
1979 not used in calculations:
Sacramento Valley Water Year Index classified 1979 as dry.
San Joaquin Valley Water Year Index classified 1979 as wet.
Year type information accessed at
http://cdec.water.ca.gov/cgi-progs/iodir?s=wsihist on 7 Mar 2003

Table 4 Monthly average changes in dissolved organic carbon at the Harvey O. Banks Pumping Plant (State Water Project) by year type

a) Dry water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	3.8	2.4	37
Feb	4.5	2.5	44
Mar	5.1	2.8	45
Apr	5.2	3.0	43
May	4.6	2.8	41
Jun	4.0	2.3	43
Jul	3.5	1.8	48
Aug	3.3	1.7	49
Sep	2.9	1.7	43
Oct	2.8	1.8	34
Nov	3.0	2.1	29
Dec	3.5	2.5	28
Avg change	3.9	2.3	41

b) Wet water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	5.8	4.4	24
Feb	6.6	5.5	17
Mar	5.0	4.1	17
Apr	4.2	3.7	10
May	3.8	3.4	10
Jun	3.6	2.8	22
Jul	3.4	2.3	32
Aug	2.9	1.9	35
Sep	2.6	1.8	28
Oct	2.8	2.3	18
Nov	2.9	2.4	18
Dec	3.2	2.7	18
Avg change	3.9	3.1	20

Table 5 Monthly average changes in dissolved organic carbon at the Tracy Pumping Plant (Central Valley Project) by year type

a) Dry water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	3.8	2.7	28
Feb	4.1	3.0	27
Mar	4.9	3.6	27
Apr	4.8	3.3	32
May	4.4	2.7	40
Jun	3.8	2.3	40
Jul	3.4	1.9	45
Aug	3.3	1.8	44
Sep	3.0	1.9	35
Oct	2.8	1.9	32
Nov	3.0	2.2	28
Dec	3.5	2.9	19
Avg change	3.7	2.5	33

b) Wet water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	6.2	5.4	12
Feb	6.5	6.1	5
Mar	4.2	3.9	7
Apr	3.9	3.7	5
May	3.7	3.3	9
Jun	3.4	3.1	10
Jul	3.4	2.5	25
Aug	3.0	2.2	27
Sep	2.9	2.4	17
Oct	2.9	2.5	13
Nov	2.9	2.4	16
Dec	3.3	2.9	14
Avg change	3.9	3.4	13

Table 6 Monthly average changes in dissolved organic carbon at Old River at Highway 4 by year type

a) Dry water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	3.7	2.4	36
Feb	4.6	2.4	47
Mar	4.9	2.7	44
Apr	5.0	2.8	43
May	4.2	2.6	39
Jun	3.6	2.0	43
Jul	3.2	1.7	48
Aug	3.0	1.6	45
Sep	2.7	1.7	37
Oct	2.6	1.8	31
Nov	2.8	2.0	28
Dec	3.4	2.4	28
Avg change	3.6	2.2	39

b) Wet water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	5.6	4.0	29
Feb	6.6	4.4	33
Mar	5.3	3.9	26
Apr	4.4	3.6	18
May	4.0	3.3	18
Jun	3.4	2.6	25
Jul	3.2	2.1	34
Aug	2.7	1.8	32
Sep	2.4	1.8	25
Oct	2.6	2.1	19
Nov	2.8	2.3	18
Dec	3.2	2.6	17
Avg change	3.9	2.9	25

Table 7 Monthly average changes in dissolved organic carbon at Old River at Rock Slough by year type

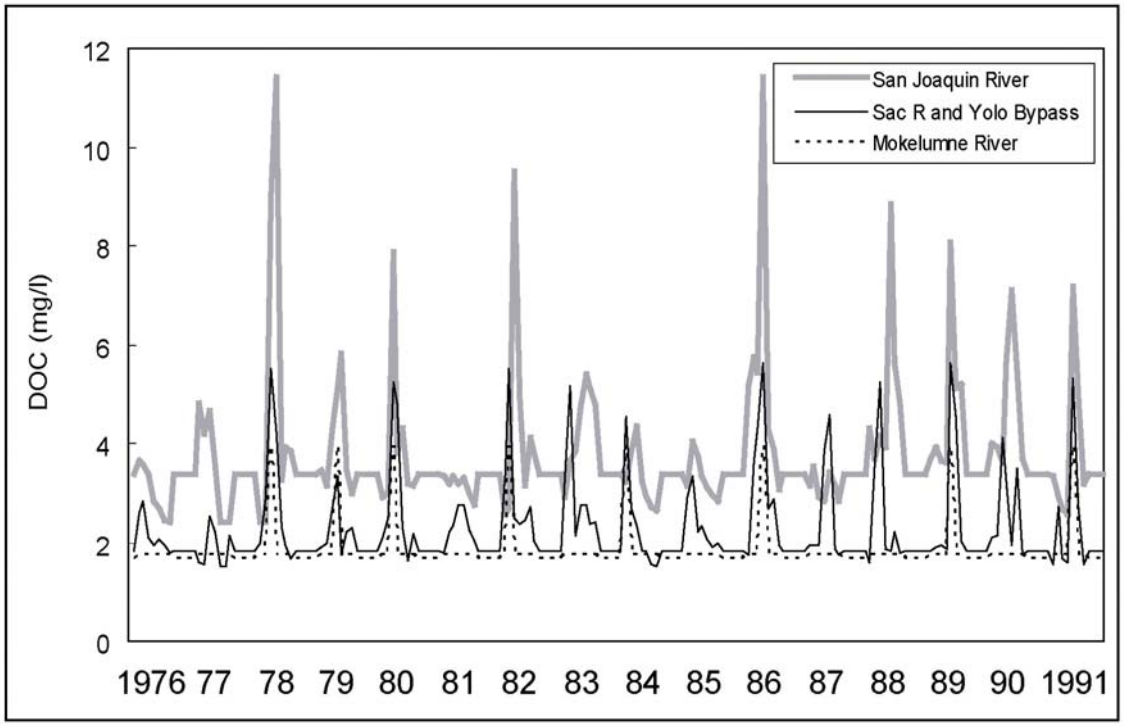
a) Dry water year monthly averages (mg/L)

	With DOC island drainage	Without DOC island drainage	Percent change
Jan	3.4	2.3	33
Feb	4.1	2.4	41
Mar	4.4	2.7	39
Apr	4.4	2.7	38
May	3.8	2.3	39
Jun	3.2	1.9	41
Jul	2.8	1.6	42
Aug	2.7	1.6	42
Sep	2.6	1.6	39
Oct	2.4	1.6	34
Nov	2.5	1.8	31
Dec	3.1	2.2	29
Avg change	3.3	2.1	37

b) Wet water year monthly averages (mg/L)

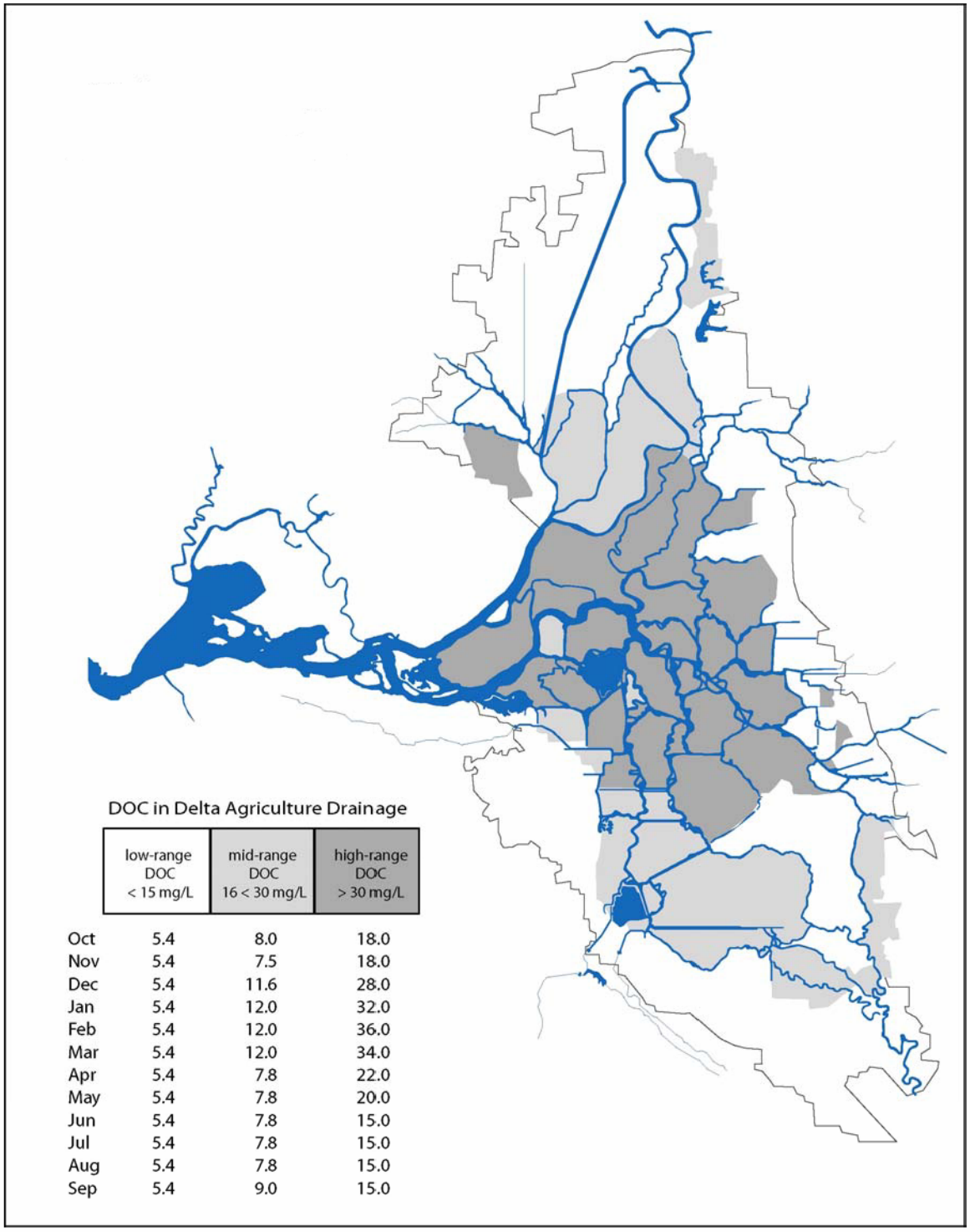
	With DOC island drainage	Without DOC island drainage	Percent change
Jan	5.3	3.2	40
Feb	6.2	3.5	42
Mar	5.4	3.2	40
Apr	4.6	3.2	30
May	4.1	3.0	27
Jun	3.3	2.4	28
Jul	2.9	1.9	34
Aug	2.5	1.7	32
Sep	2.3	1.7	27
Oct	2.4	1.8	24
Nov	2.7	2.1	23
Dec	3.1	2.3	27
Avg change	3.7	2.5	31

Figure 1 Delta boundary dissolved organic carbon for the simulation period



Reproduced from memorandum "DSM2 DOC modeling results for MWQI's study of DOC in agriculture drainage contribution to DOC at Delta exports" (Suits 2003)

Figure 2 Drainage dissolved organic carbon values for DSM2

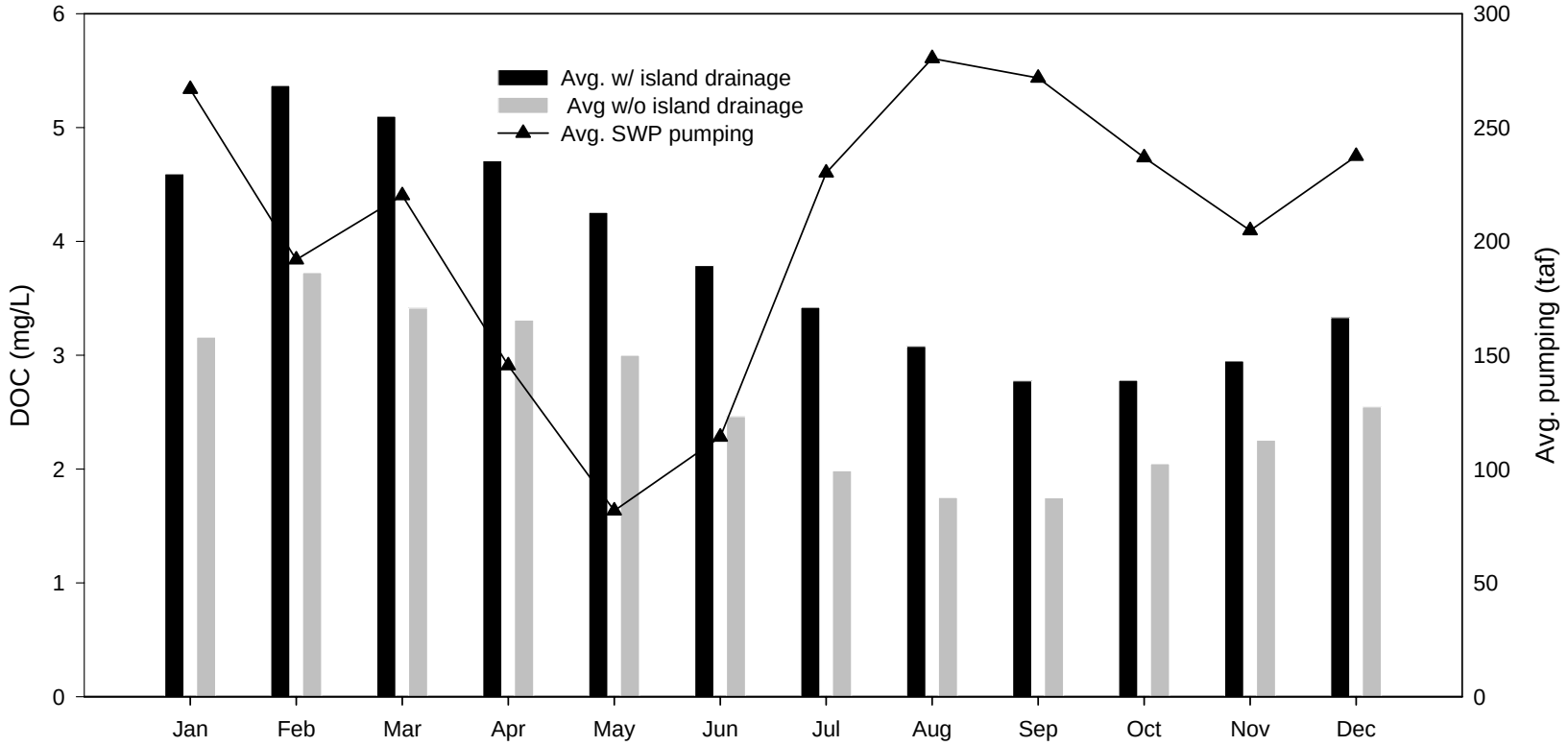


DOC in Delta Agriculture Drainage

	low-range DOC < 15 mg/L	mid-range DOC 16 < 30 mg/L	high-range DOC > 30 mg/L
Oct	5.4	8.0	18.0
Nov	5.4	7.5	18.0
Dec	5.4	11.6	28.0
Jan	5.4	12.0	32.0
Feb	5.4	12.0	36.0
Mar	5.4	12.0	34.0
Apr	5.4	7.8	22.0
May	5.4	7.8	20.0
Jun	5.4	7.8	15.0
Jul	5.4	7.8	15.0
Aug	5.4	7.8	15.0
Sep	5.4	9.0	15.0

Reproduced from memorandum "DSM2 DOC modeling results for MWQI's study of DOC in agriculture drainage contribution to DOC at Delta exports" (Suits 2003)
DSM2 = Delta Simulation Model 2

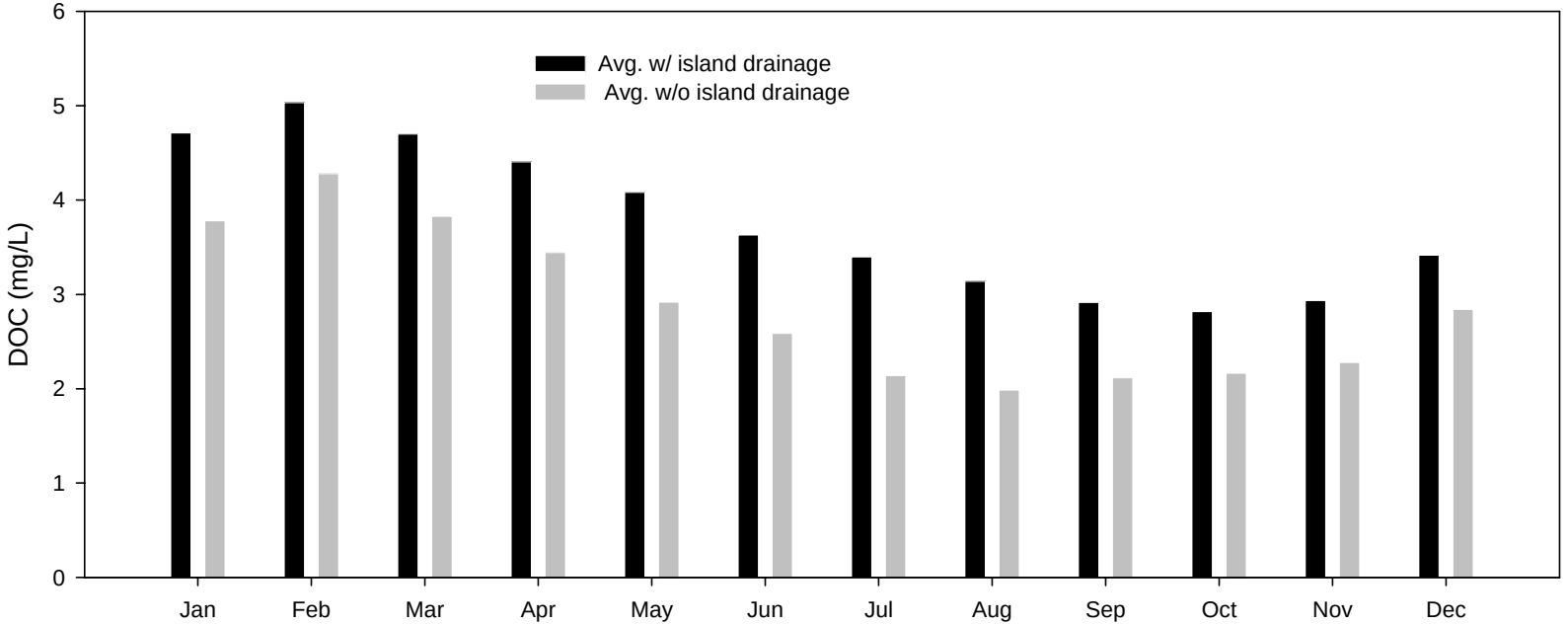
Figure 3 Average monthly and percent changes in dissolved organic carbon at the Harvey O. Banks Pumping Plant (State Water Project) using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991



Average Percent Change of DOC at Banks Pumping Plant of the SWP

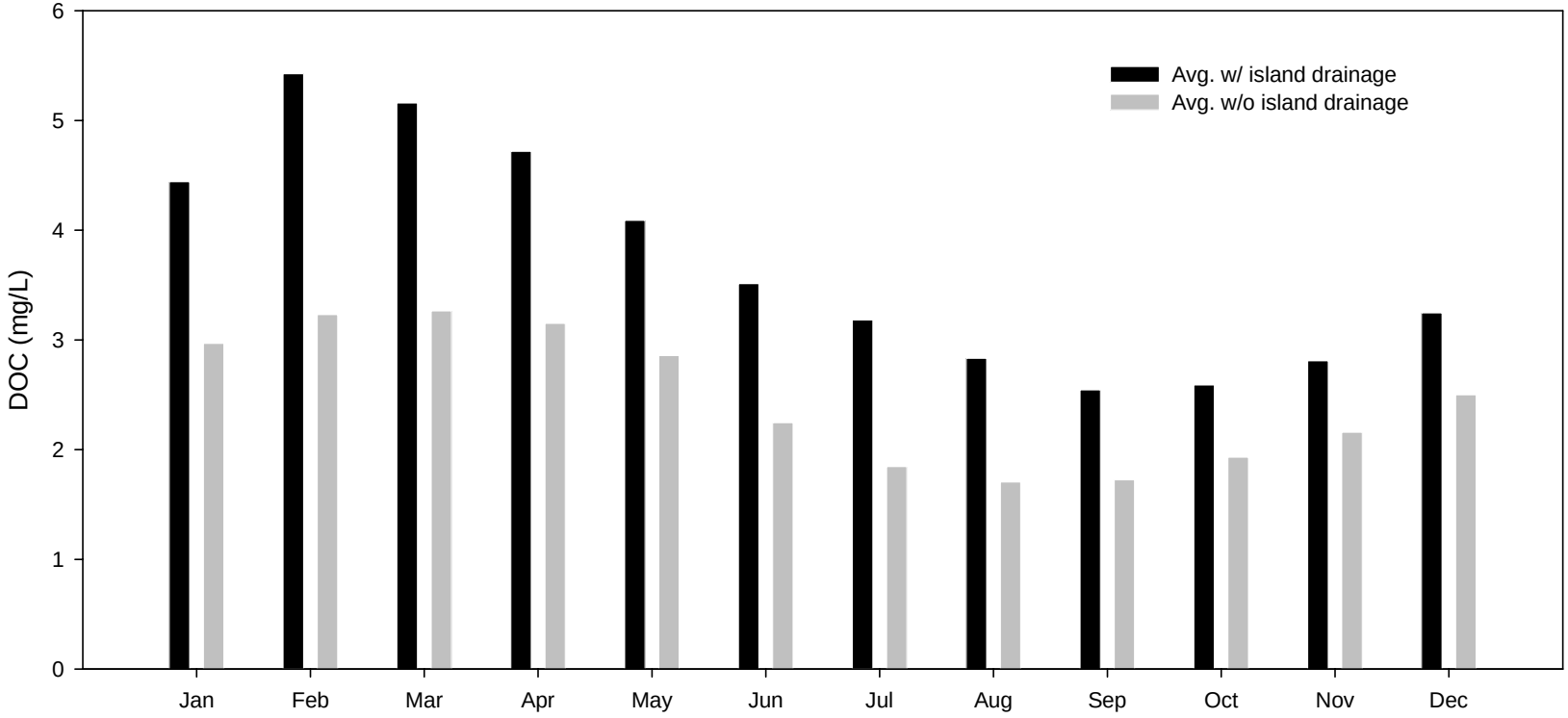
Month	% Change
Jan	32
Feb	33
Mar	33
Apr	30
May	29
Jun	35
Jul	42
Aug	42
Sep	36
Oct	26
Nov	23
Dec	23
Avg. overall % change	32

Figure 4 Average monthly and percent changes in dissolved organic carbon at the Tracy Pumping Plant (Central Valley Project) using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991



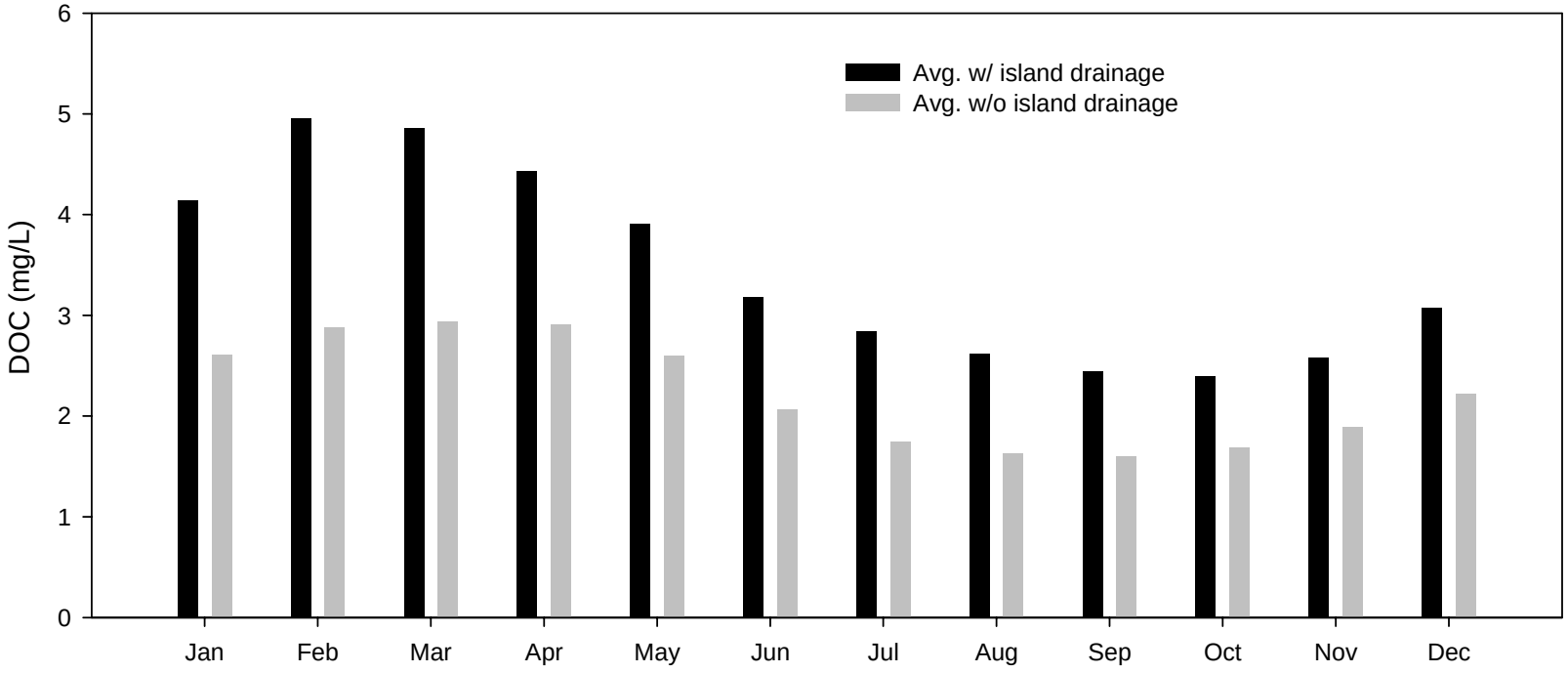
Average Percent Change of DOC at CVP	
Month	% Change
Jan	22
Feb	17
Mar	19
Apr	22
May	28
Jun	28
Jul	36
Aug	36
Sep	27
Oct	23
Nov	22
Dec	17
Avg. overall % change	25

Figure 5 Average monthly and percent changes in dissolved organic carbon at Old River at Highway 4 using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991



Month	% Change
Jan	33
Feb	40
Mar	36
Apr	33
May	31
Jun	36
Jul	42
Aug	39
Sep	31
Oct	25
Nov	23
Dec	24
Avg. overall % change	33

Figure 6 Average monthly and percent changes in dissolved organic carbon at Old River at Rock Slough using DSM2 with and without Delta island drainages, Oct 1975–Sep 1991



Average Percent Change of DOC at Old River at Rock Slough

Month	% Change
Jan	37
Feb	42
Mar	39
Apr	35
May	35
Jun	36
Jul	38
Aug	37
Sep	34
Oct	29
Nov	27
Dec	28
Avg. overall % change	35

Figure 7 Box plot of Harvey O. Banks Pumping Plant (State Water Project) dissolved organic carbon (mg/L) with and without agricultural drainage in the model

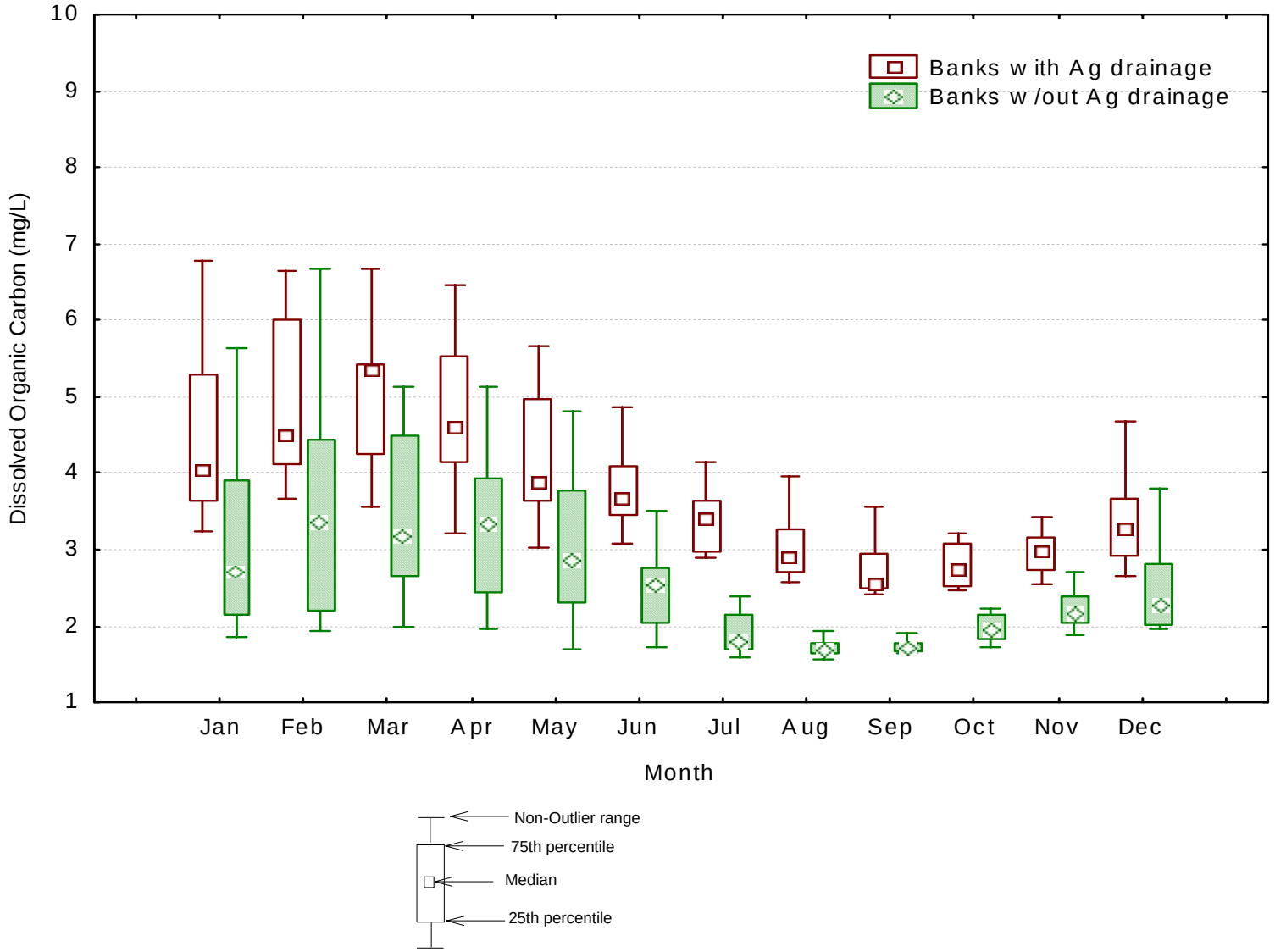


Figure 8 Box plot of Tracy Pumping Plant (Central Valley Project) dissolved organic carbon (mg/L) with and without agricultural drainage in the model

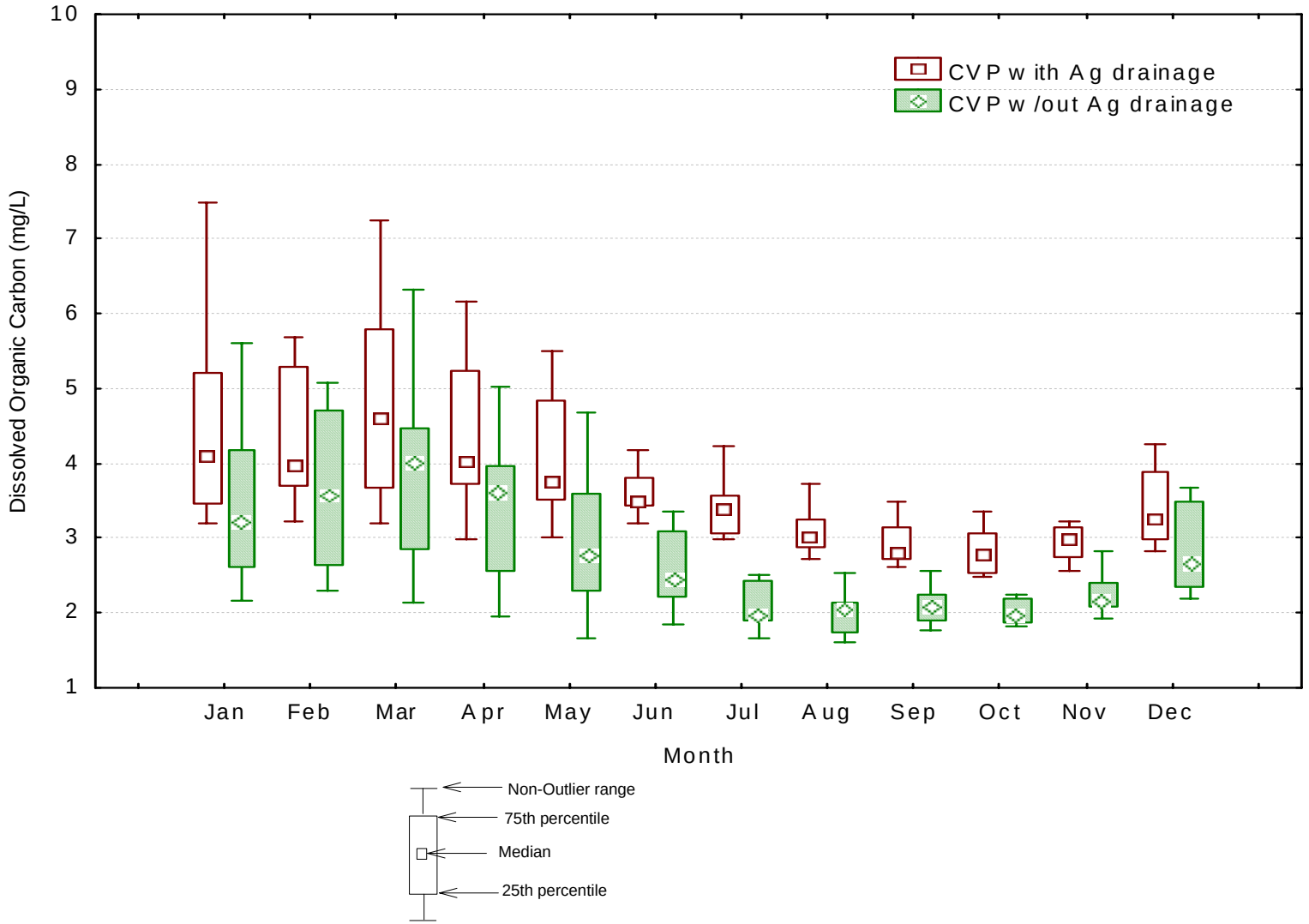


Figure 9 Box plot of dissolved organic carbon at Old River at Highway 4 with and without agricultural drainage in the model

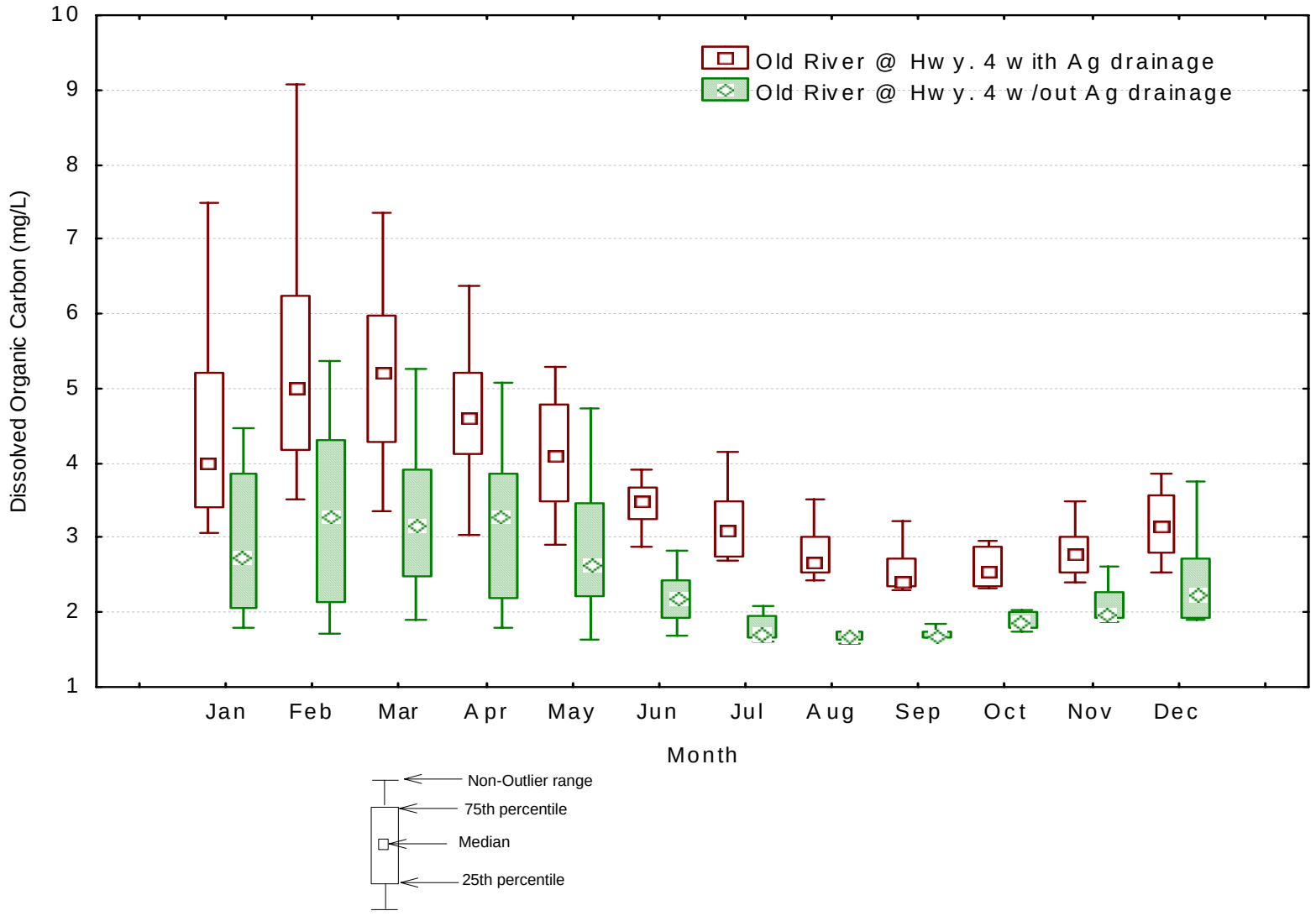
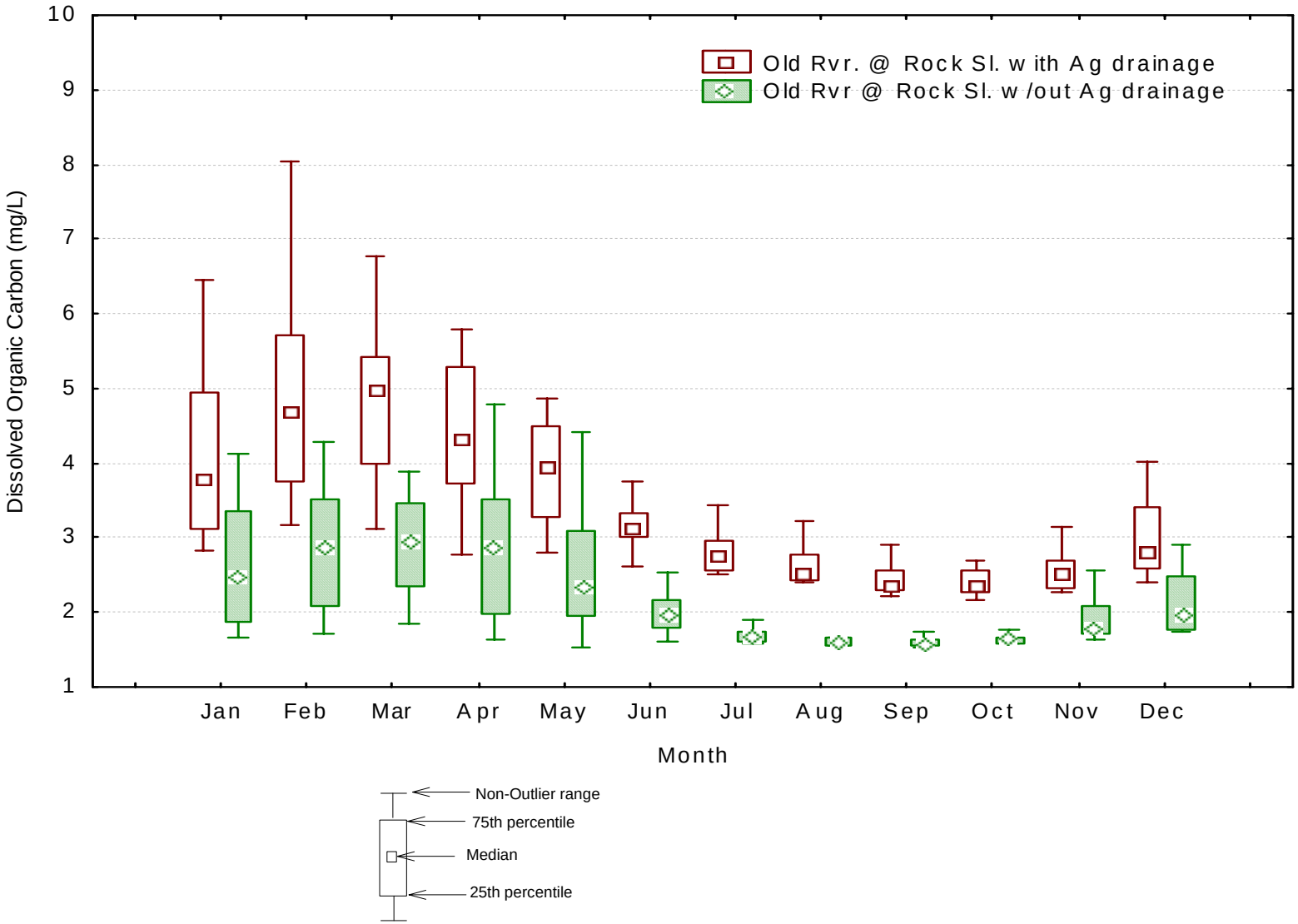


Figure 10 Box plot of Old River at Rock Slough dissolved organic carbon (mg/L) with and without agricultural drainage in the model



Appendix A

These tables are reproduced from a memorandum: “DSM2 DOC modeling results for MWQI’s study of DOC in agriculture drainage contribution to DOC at Delta exports” (Suits 2003)

Tables

Table A-1 Dissolved organic carbon results at Harvey O. Banks Pumping Plant (State Water Project intake)

Monthly average DOC with DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.61	2.74	3.16	3.52	3.66	3.57	3.52	3.65	3.70	3.46	2.93	2.55
1977	2.77	3.20	3.67	3.74	4.38	5.40	5.03	4.01	3.59	3.49	3.37	3.17
1978	3.07	3.19	3.25	6.77	9.83	7.25	4.08	3.88	3.88	3.60	2.85	2.52
1979	2.73	2.76	2.81	4.15	5.65	6.19	4.88	3.56	3.38	3.01	2.68	2.49
1980	2.53	2.55	2.87	6.57	4.33	4.23	4.18	3.43	3.47	3.31	2.78	2.54
1981	2.79	2.74	2.65	3.40	4.01	4.26	4.29	3.63	3.39	2.89	2.65	2.47
1982	2.52	3.00	4.68	8.11	6.34	4.51	4.12	3.87	3.74	3.20	2.73	2.55
1983	3.07	3.43	3.64	3.91	4.64	5.31	5.20	4.86	3.59	3.56	3.14	2.74
1984	3.18	3.26	3.77	4.28	4.11	3.57	3.22	3.03	3.07	2.92	2.75	2.56
1985	2.52	3.01	3.91	4.36	4.11	4.11	4.20	3.68	3.44	2.89	2.61	2.42
1986	2.51	2.78	3.64	5.22	10.39	4.92	4.18	3.70	3.62	3.66	3.01	2.50
1987	2.62	2.69	2.73	3.24	4.18	5.41	5.87	5.59	4.18	3.31	2.95	2.71
1988	2.75	2.92	3.27	5.36	6.64	6.68	6.03	4.92	4.49	4.14	3.95	3.57
1989	3.16	3.10	3.00	3.30	3.82	5.41	6.41	5.66	4.02	2.90	2.57	2.43
1990	2.46	2.69	2.98	3.79	5.25	5.42	4.92	5.01	4.86	4.63	4.44	3.72
1991	3.20	3.15	3.28	3.78	4.57	5.37	6.45	5.60	4.19	3.76	3.85	3.43
Avg	2.78	2.95	3.33	4.59	5.37	5.10	4.79	4.25	3.79	3.42	3.08	2.77

Monthly average DOC without DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.15	2.34	2.59	2.45	2.12	1.98	1.96	1.89	1.74	1.60	1.68	1.72
1977	2.00	2.42	2.78	2.06	2.04	2.07	1.96	1.70	1.71	1.60	1.57	1.64
1978	1.81	2.04	2.14	4.07	6.68	4.82	3.72	3.80	3.13	2.38	1.76	1.79
1979	2.16	2.18	2.03	2.44	3.96	4.85	3.78	2.75	2.27	1.75	1.70	1.73
1980	1.93	2.04	2.16	5.45	4.11	4.16	3.40	2.73	2.51	2.07	1.80	1.81
1981	2.22	2.16	1.96	2.22	2.39	2.64	2.58	2.45	2.05	1.67	1.65	1.71
1982	1.91	2.49	3.81	5.64	4.90	3.22	4.00	3.78	3.09	2.14	1.78	1.92
1983	2.73	2.72	3.53	3.66	4.48	5.12	5.14	4.80	3.52	3.23	2.31	2.06
1984	2.79	3.18	3.70	4.24	3.43	2.67	2.28	2.15	1.88	1.70	1.73	1.75
1985	1.93	2.28	2.82	2.80	2.28	2.21	2.10	2.19	2.02	1.67	1.65	1.71
1986	1.91	2.16	2.68	3.46	9.38	4.79	3.86	3.18	2.60	2.17	1.77	1.77
1987	2.06	2.10	1.97	1.86	2.25	3.18	3.30	2.96	2.16	1.71	1.67	1.69
1988	1.82	2.06	2.41	3.75	4.40	3.86	3.11	2.86	2.66	2.11	1.71	1.63
1989	1.73	2.04	2.02	1.85	1.93	3.27	4.70	4.19	2.65	1.73	1.63	1.67
1990	1.83	1.97	2.15	2.63	3.33	2.97	2.64	2.84	2.88	2.36	1.93	1.72
1991	1.76	1.88	1.99	1.98	1.93	2.82	4.42	3.74	2.54	1.87	1.65	1.65
Avg	2.05	2.25	2.55	3.16	3.73	3.41	3.31	3.00	2.46	1.98	1.75	1.75

DOC = dissolved organic carbon

Table A-2 Decrease in monthly average dissolved organic carbon at Harvey O. Banks Pumping Plant (State Water Project intake) without dissolved organic carbon in agricultural drainage

Decrease in DOC (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	0.46	0.41	0.57	1.07	1.53	1.59	1.56	1.76	1.96	1.86	1.24	0.83
1977	0.77	0.78	0.89	1.67	2.34	3.32	3.07	2.31	1.88	1.90	1.79	1.53
1978	1.27	1.14	1.11	2.71	3.15	2.43	0.36	0.08	0.75	1.22	1.09	0.73
1979	0.56	0.57	0.78	1.71	1.68	1.34	1.10	0.82	1.11	1.27	0.98	0.76
1980	0.60	0.51	0.71	1.12	0.22	0.07	0.78	0.71	0.96	1.24	0.98	0.73
1981	0.57	0.57	0.69	1.18	1.62	1.62	1.71	1.18	1.34	1.22	1.00	0.76
1982	0.61	0.51	0.87	2.47	1.45	1.29	0.12	0.08	0.65	1.05	0.95	0.64
1983	0.35	0.71	0.11	0.26	0.16	0.19	0.07	0.06	0.07	0.33	0.83	0.68
1984	0.39	0.09	0.07	0.05	0.68	0.90	0.94	0.88	1.20	1.22	1.01	0.81
1985	0.59	0.73	1.08	1.56	1.83	1.90	2.10	1.49	1.42	1.22	0.96	0.71
1986	0.60	0.62	0.96	1.76	1.01	0.12	0.32	0.52	1.02	1.49	1.24	0.73
1987	0.55	0.59	0.76	1.38	1.93	2.23	2.57	2.63	2.02	1.60	1.28	1.02
1988	0.93	0.85	0.86	1.61	2.24	2.82	2.92	2.06	1.84	2.04	2.24	1.94
1989	1.43	1.06	0.98	1.45	1.89	2.14	1.70	1.47	1.37	1.17	0.94	0.77
1990	0.63	0.71	0.83	1.17	1.93	2.45	2.28	2.17	1.98	2.27	2.51	2.00
1991	1.44	1.27	1.29	1.80	2.64	2.54	2.03	1.86	1.65	1.89	2.20	1.78
Avg	0.73	0.70	0.79	1.43	1.64	1.69	1.48	1.25	1.33	1.44	1.33	1.03

DOC decrease (percent)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	17.6	14.9	18.0	30.4	41.9	44.6	44.4	48.1	52.9	53.7	42.5	32.5
1977	27.7	24.3	24.2	44.8	53.4	61.6	61.0	57.5	52.3	54.3	53.3	48.3
1978	41.3	35.9	34.3	40.0	32.0	33.5	8.8	2.1	19.4	33.9	38.3	28.9
1979	20.7	20.7	27.7	41.2	29.8	21.6	22.6	22.9	32.9	42.0	36.5	30.6
1980	23.5	20.0	24.7	17.1	5.0	1.6	18.6	20.6	27.7	37.4	35.2	28.8
1981	20.5	21.0	26.0	34.7	40.4	38.1	39.9	32.5	39.5	42.2	37.7	30.7
1982	24.3	16.8	18.6	30.5	22.8	28.6	2.9	2.2	17.4	33.0	34.7	24.9
1983	11.3	20.8	3.0	6.5	3.4	3.6	1.3	1.3	1.9	9.4	26.3	24.9
1984	12.2	2.7	2.0	1.1	16.6	25.3	29.1	29.1	38.9	41.8	36.9	31.5
1985	23.5	24.1	27.7	35.8	44.5	46.2	50.0	40.5	41.3	42.3	36.8	29.4
1986	23.9	22.1	26.5	33.7	9.7	2.5	7.6	14.0	28.1	40.7	41.1	29.1
1987	21.2	22.0	28.0	42.5	46.1	41.3	43.8	47.1	48.4	48.3	43.3	37.7
1988	33.7	29.3	26.3	30.0	33.7	42.3	48.5	41.9	40.8	49.2	56.7	54.3
1989	45.3	34.1	32.7	44.0	49.6	39.6	26.6	26.0	34.1	40.4	36.4	31.5
1990	25.7	26.6	27.9	30.8	36.7	45.2	46.4	43.3	40.8	49.0	56.6	53.9
1991	45.0	40.5	39.4	47.6	57.8	47.4	31.4	33.3	39.4	50.2	57.2	51.8
Avg	26.1	23.5	24.2	31.9	32.7	32.7	30.2	28.9	34.8	41.7	41.8	35.6

DOC = dissolved organic carbon

Table A-3 Dissolved organic carbon results at Tracy Pumping Plant (Central Valley Project intake)

Monthly average DOC with DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.63	2.75	3.28	3.48	3.37	3.29	3.22	3.59	3.62	3.48	3.04	2.71
1977	2.81	3.22	4.00	4.05	3.92	3.61	3.97	3.73	3.53	3.46	3.31	3.15
1978	3.08	3.17	3.02	7.38	10.67	4.67	3.89	3.87	3.51	3.53	2.97	2.80
1979	2.75	2.73	2.93	4.18	5.15	5.83	4.08	3.52	3.39	3.09	2.85	2.73
1980	2.54	2.55	2.91	7.50	4.02	4.28	3.61	3.41	3.45	3.35	2.94	2.83
1981	2.81	2.71	2.82	3.40	3.74	3.84	3.74	3.54	3.37	3.00	2.82	2.69
1982	2.55	3.02	4.11	8.61	5.17	3.28	4.08	3.78	3.48	3.27	2.92	2.93
1983	3.37	3.14	3.60	4.00	4.77	5.41	5.16	4.75	3.42	3.38	3.19	3.16
1984	3.37	3.23	3.84	4.32	3.40	3.21	2.98	3.01	3.19	3.06	2.93	2.79
1985	2.53	3.03	3.94	4.16	3.84	3.72	3.74	3.61	3.43	3.00	2.79	2.65
1986	2.54	2.80	4.25	5.32	10.73	4.52	3.90	3.23	3.46	3.62	3.11	2.76
1987	2.64	2.68	2.95	3.19	3.78	4.66	4.78	4.91	3.82	3.39	3.17	2.86
1988	2.79	2.93	3.40	5.08	5.69	7.25	5.82	4.73	4.17	3.81	3.72	3.25
1989	3.08	3.08	3.23	3.45	3.68	6.03	6.17	5.49	3.94	3.00	2.72	2.61
1990	2.48	2.75	3.21	3.81	5.40	5.80	5.30	4.94	4.49	4.23	4.02	3.49
1991	3.12	3.18	3.17	3.46	3.23	5.80	6.04	5.20	3.82	3.67	3.73	3.23
Avg	2.82	2.94	3.42	4.71	5.03	4.70	4.41	4.08	3.63	3.40	3.14	2.91

Monthly average DOC without DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.18	2.34	2.87	2.69	2.39	2.15	2.07	1.86	1.97	1.98	2.04	2.01
1977	2.07	2.46	3.66	2.78	3.39	2.32	1.96	1.66	1.84	1.66	1.65	1.85
1978	1.88	2.08	2.20	5.59	9.56	3.87	3.87	3.80	3.31	2.44	2.09	2.27
1979	2.20	2.17	2.32	3.32	4.88	5.60	3.48	2.71	2.43	1.99	2.04	2.11
1980	1.96	2.05	2.38	7.32	3.83	4.25	3.16	2.69	3.02	2.48	2.15	2.31
1981	2.25	2.14	2.32	2.55	2.65	2.89	2.70	2.41	2.17	1.93	1.96	2.06
1982	1.95	2.52	3.45	7.82	5.08	3.11	4.06	3.68	3.30	2.51	2.16	2.57
1983	3.35	2.82	3.52	3.44	4.55	5.06	5.03	4.68	3.34	3.29	2.55	2.87
1984	3.35	3.20	3.66	4.26	3.26	2.82	2.40	2.13	2.27	2.04	2.10	2.14
1985	1.96	2.30	3.15	3.05	2.64	2.56	2.35	2.17	2.25	1.93	1.97	2.06
1986	1.95	2.18	3.54	4.08	10.39	4.41	3.86	3.07	3.14	2.43	2.14	2.21
1987	2.09	2.09	2.36	2.18	2.46	3.17	3.08	2.59	2.19	2.15	2.18	2.00
1988	1.88	2.10	2.73	3.84	4.11	6.32	3.88	2.86	2.50	1.84	1.61	1.77
1989	1.87	2.08	2.46	2.37	3.21	4.50	4.84	4.02	2.73	1.91	1.82	1.95
1990	1.86	2.02	2.59	2.92	3.76	4.11	3.71	2.88	2.62	1.92	1.66	1.88
1991	1.82	1.93	2.27	2.27	2.31	4.10	4.66	3.49	2.29	1.77	1.67	1.81
Avg	2.16	2.28	2.84	3.78	4.28	3.83	3.44	2.92	2.59	2.14	1.99	2.12

DOC = dissolved organic carbon

Table A-4 Decrease in monthly average dissolved organic carbon at Tracy Pumping Plant (Central Valley Project intake) without dissolved organic carbon in agricultural drainage

Decrease in DOC (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	0.44	0.41	0.41	0.79	0.98	1.13	1.15	1.73	1.65	1.50	1.00	0.70
1977	0.75	0.77	0.34	1.26	0.53	1.29	2.01	2.07	1.69	1.80	1.67	1.30
1978	1.20	1.09	0.82	1.78	1.11	0.80	0.02	0.07	0.20	1.09	0.89	0.53
1979	0.55	0.57	0.61	0.86	0.26	0.23	0.60	0.80	0.96	1.10	0.81	0.62
1980	0.58	0.51	0.53	0.18	0.19	0.04	0.45	0.72	0.42	0.87	0.78	0.52
1981	0.55	0.57	0.51	0.85	1.08	0.95	1.04	1.13	1.20	1.07	0.86	0.63
1982	0.60	0.50	0.66	0.79	0.09	0.16	0.02	0.10	0.19	0.77	0.76	0.37
1983	0.02	0.32	0.08	0.56	0.22	0.35	0.12	0.08	0.07	0.09	0.65	0.29
1984	0.02	0.03	0.18	0.06	0.14	0.38	0.58	0.88	0.92	1.02	0.83	0.64
1985	0.58	0.73	0.79	1.11	1.20	1.16	1.39	1.44	1.18	1.07	0.83	0.59
1986	0.59	0.61	0.71	1.24	0.34	0.11	0.03	0.16	0.32	1.19	0.96	0.54
1987	0.54	0.59	0.59	1.01	1.32	1.49	1.70	2.32	1.62	1.24	0.99	0.86
1988	0.90	0.83	0.67	1.24	1.59	0.93	1.94	1.87	1.68	1.97	2.11	1.48
1989	1.22	1.00	0.76	1.08	0.47	1.53	1.33	1.47	1.21	1.09	0.89	0.66
1990	0.62	0.73	0.62	0.89	1.64	1.69	1.59	2.07	1.88	2.31	2.37	1.62
1991	1.29	1.25	0.90	1.19	0.92	1.70	1.38	1.71	1.53	1.90	2.06	1.42
Avg	0.65	0.66	0.57	0.93	0.75	0.87	0.96	1.16	1.04	1.26	1.15	0.80

DOC decrease (percent)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	16.9	14.8	12.6	22.6	29.2	34.5	35.8	48.2	45.6	43.0	33.0	25.8
1977	26.6	23.9	8.4	31.2	13.4	35.7	50.5	55.5	47.8	52.1	50.3	41.3
1978	38.9	34.5	27.3	24.2	10.4	17.2	0.6	1.8	5.8	30.9	29.9	19.0
1979	20.0	20.8	20.9	20.5	5.1	4.0	14.8	22.9	28.3	35.7	28.4	22.6
1980	22.8	19.8	18.2	2.4	4.6	0.9	12.5	21.1	12.3	26.0	26.7	18.4
1981	19.8	21.0	17.9	25.1	29.0	24.8	27.8	32.0	35.7	35.7	30.5	23.3
1982	23.6	16.5	16.0	9.1	1.8	4.9	0.6	2.5	5.3	23.4	26.0	12.6
1983	0.5	10.2	2.1	13.9	4.6	6.5	2.4	1.6	2.1	2.7	20.2	9.1
1984	0.7	0.9	4.6	1.5	4.1	12.0	19.6	29.2	28.8	33.3	28.3	23.0
1985	22.7	24.1	20.1	26.7	31.3	31.3	37.1	39.9	34.3	35.7	29.6	22.1
1986	23.3	22.0	16.8	23.3	3.2	2.4	0.8	4.9	9.2	32.9	31.1	19.7
1987	20.6	22.1	19.9	31.8	34.9	32.1	35.5	47.2	42.5	36.7	31.3	30.1
1988	32.4	28.4	19.8	24.4	27.9	12.8	33.4	39.6	40.2	51.8	56.7	45.4
1989	39.4	32.5	23.6	31.2	12.8	25.4	21.6	26.8	30.8	36.3	32.9	25.4
1990	24.9	26.6	19.4	23.4	30.3	29.1	29.9	41.8	41.7	54.7	58.8	46.3
1991	41.4	39.3	28.5	34.4	28.6	29.3	22.8	32.9	40.0	51.8	55.2	44.0
Avg	23.4	22.3	17.3	21.6	16.9	18.9	21.6	28.0	28.2	36.4	35.6	26.8

DOC = dissolved organic carbon

Table A-5 Dissolved organic carbon at Old River at Rock Slough

Monthly average DOC with DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.19	2.42	2.98	3.17	3.16	3.12	3.18	3.28	3.11	2.80	2.55	2.40
1977	2.42	2.58	2.74	3.05	4.51	4.92	3.74	3.03	3.03	2.82	2.74	2.60
1978	2.58	2.64	3.05	5.66	7.71	6.60	5.01	4.87	3.70	2.94	2.49	2.32
1979	2.35	2.30	2.45	3.63	5.55	5.79	4.07	3.36	2.95	2.56	2.39	2.34
1980	2.27	2.26	2.73	5.62	5.70	5.03	4.39	3.20	3.04	2.72	2.43	2.31
1981	2.37	2.37	2.40	3.03	3.49	3.70	3.73	3.41	2.97	2.54	2.46	2.39
1982	2.28	2.72	5.03	6.46	5.83	5.25	4.59	4.52	3.40	2.65	2.40	2.21
1983	2.57	3.38	4.01	4.83	4.94	5.50	5.19	4.82	3.75	3.71	2.83	2.31
1984	2.67	3.14	3.75	4.38	4.72	3.31	2.77	2.81	2.62	2.50	2.42	2.28
1985	2.23	2.83	3.74	3.91	3.50	3.46	3.45	3.29	2.97	2.55	2.43	2.34
1986	2.28	2.32	3.00	4.74	8.04	6.77	5.37	4.48	3.18	2.95	2.54	2.23
1987	2.27	2.32	2.49	2.91	3.75	5.09	5.76	4.29	3.25	2.70	2.61	2.52
1988	2.45	2.46	2.85	5.07	5.74	5.34	4.20	3.63	3.17	3.06	3.04	2.83
1989	2.69	2.57	2.55	2.83	3.76	4.89	5.68	4.87	3.14	2.52	2.40	2.27
1990	2.17	2.34	2.61	3.55	4.62	4.31	3.92	4.23	3.67	3.44	3.22	2.92
1991	2.62	2.69	2.76	3.50	4.36	4.70	5.80	4.39	3.04	2.98	3.00	2.80
Avg	2.40	2.58	3.07	4.15	4.96	4.86	4.43	3.91	3.19	2.84	2.62	2.44

Monthly average DOC without DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	1.77	2.05	2.50	2.36	1.95	1.84	1.84	1.74	1.63	1.57	1.61	1.57
1977	1.58	1.74	1.76	1.65	1.89	1.95	1.63	1.52	1.64	1.58	1.60	1.59
1978	1.62	1.75	2.05	2.72	4.28	3.85	2.92	3.17	2.55	1.89	1.66	1.62
1979	1.67	1.76	1.80	1.90	2.87	3.51	2.83	2.33	2.00	1.69	1.64	1.58
1980	1.61	1.79	2.06	4.12	3.37	3.31	3.06	2.31	2.09	1.72	1.66	1.63
1981	1.68	1.72	1.81	2.00	2.34	2.55	2.42	2.13	1.84	1.63	1.54	1.55
1982	1.60	2.11	4.34	3.34	3.78	2.88	3.35	3.53	2.51	1.80	1.67	1.71
1983	2.10	2.37	2.47	1.88	2.89	3.30	4.46	4.41	3.43	2.84	2.04	1.75
1984	2.11	2.57	2.90	3.62	3.29	2.15	1.82	1.72	1.60	1.62	1.65	1.64
1985	1.65	2.19	2.84	2.75	2.21	2.08	1.87	1.86	1.80	1.62	1.55	1.56
1986	1.59	1.65	1.86	3.37	3.69	3.89	3.52	3.02	2.08	1.75	1.66	1.66
1987	1.66	1.71	1.76	1.73	2.40	3.43	3.52	2.34	1.81	1.65	1.57	1.55
1988	1.59	1.68	1.98	3.94	4.26	2.83	2.09	2.07	1.86	1.62	1.56	1.53
1989	1.57	1.73	1.74	1.73	1.71	3.60	4.78	3.74	2.16	1.68	1.57	1.60
1990	1.67	1.76	1.93	2.63	3.35	2.81	2.18	2.77	2.17	1.71	1.59	1.57
1991	1.61	1.70	1.76	1.96	1.77	3.03	4.27	2.95	1.91	1.62	1.58	1.54
Avg	1.69	1.89	2.22	2.61	2.88	2.94	2.91	2.60	2.07	1.75	1.63	1.60

DOC = dissolved organic carbon

Table A-6 Decrease in monthly average dissolved organic carbon at Old River at Rock Slough without dissolved organic carbon in agricultural drainage

Decrease in DOC (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	0.42	0.37	0.48	0.81	1.21	1.29	1.34	1.54	1.49	1.23	0.94	0.83
1977	0.84	0.85	0.98	1.40	2.61	2.97	2.11	1.51	1.39	1.23	1.14	1.01
1978	0.96	0.89	1.00	2.94	3.44	2.75	2.10	1.70	1.15	1.05	0.83	0.70
1979	0.68	0.54	0.65	1.73	2.68	2.28	1.24	1.03	0.95	0.87	0.75	0.76
1980	0.66	0.47	0.67	1.50	2.33	1.71	1.33	0.90	0.95	0.99	0.77	0.68
1981	0.70	0.66	0.58	1.03	1.14	1.15	1.31	1.28	1.14	0.91	0.92	0.84
1982	0.68	0.61	0.69	3.12	2.06	2.37	1.24	0.99	0.89	0.86	0.73	0.50
1983	0.47	1.01	1.54	2.95	2.05	2.21	0.73	0.41	0.32	0.87	0.80	0.56
1984	0.56	0.57	0.86	0.75	1.43	1.16	0.95	1.09	1.02	0.88	0.76	0.65
1985	0.59	0.64	0.91	1.16	1.29	1.37	1.58	1.43	1.17	0.94	0.88	0.78
1986	0.69	0.67	1.14	1.37	4.36	2.88	1.85	1.46	1.10	1.20	0.88	0.57
1987	0.61	0.62	0.73	1.18	1.35	1.66	2.25	1.96	1.44	1.06	1.04	0.97
1988	0.86	0.79	0.87	1.13	1.48	2.52	2.11	1.56	1.31	1.44	1.48	1.30
1989	1.12	0.84	0.81	1.10	2.04	1.29	0.90	1.13	0.98	0.84	0.83	0.67
1990	0.50	0.58	0.68	0.93	1.26	1.51	1.73	1.46	1.50	1.73	1.63	1.35
1991	1.01	0.98	1.00	1.53	2.59	1.67	1.53	1.43	1.13	1.36	1.41	1.26
Avg	0.71	0.69	0.85	1.54	2.08	1.92	1.52	1.31	1.12	1.09	0.99	0.84

DOC decrease (percent)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	19.1	15.2	16.1	25.7	38.4	41.2	42.1	46.9	47.8	43.8	36.8	34.5
1977	34.8	32.8	35.7	45.9	58.0	60.5	56.4	49.8	45.9	43.7	41.6	38.8
1978	37.3	33.5	32.9	51.9	44.5	41.7	41.8	35.0	31.2	35.7	33.3	30.1
1979	29.0	23.5	26.6	47.7	48.3	39.4	30.4	30.7	32.2	34.0	31.5	32.4
1980	29.0	20.8	24.5	26.8	40.9	34.1	30.4	28.0	31.3	36.6	31.6	29.3
1981	29.3	27.6	24.4	33.8	32.8	31.1	35.2	37.6	38.2	35.8	37.3	35.2
1982	29.9	22.5	13.8	48.3	35.3	45.1	27.1	22.0	26.1	32.3	30.5	22.7
1983	18.4	30.0	38.4	61.1	41.5	40.1	14.1	8.4	8.6	23.5	28.1	24.3
1984	21.0	18.0	22.8	17.2	30.3	35.1	34.4	38.9	38.9	35.2	31.5	28.3
1985	26.3	22.7	24.2	29.6	37.0	39.7	45.8	43.6	39.3	36.6	36.1	33.5
1986	30.2	29.0	38.1	28.8	54.2	42.5	34.4	32.6	34.7	40.7	34.5	25.7
1987	26.8	26.6	29.5	40.5	35.9	32.6	39.0	45.6	44.4	39.1	39.8	38.5
1988	35.1	32.0	30.6	22.2	25.9	47.1	50.2	42.9	41.3	47.1	48.6	45.8
1989	41.5	32.7	31.8	38.9	54.4	26.5	15.9	23.3	31.1	33.3	34.5	29.4
1990	23.0	24.7	26.1	26.1	27.4	35.0	44.3	34.5	40.8	50.4	50.7	46.3
1991	38.5	36.6	36.3	43.9	59.5	35.6	26.4	32.7	37.2	45.8	47.1	45.1
Avg	29.3	26.8	28.2	36.8	41.5	39.2	35.5	34.5	35.6	38.4	37.1	33.7

DOC = dissolved organic carbon

Table A-7 Dissolved organic carbon results at Old River at Highway 4

Monthly average DOC with DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.41	2.61	3.08	3.33	3.51	3.36	3.59	3.56	3.49	3.17	2.68	2.40
1977	2.62	2.94	3.32	3.51	5.07	5.77	4.62	3.50	3.37	3.22	3.09	2.90
1978	2.89	2.98	3.19	6.60	9.07	7.35	4.18	4.04	3.92	3.30	2.64	2.37
1979	2.52	2.52	2.69	4.02	6.01	6.27	4.53	3.42	3.18	2.79	2.51	2.35
1980	2.36	2.41	2.81	6.17	4.28	4.43	4.58	3.31	3.31	3.02	2.58	2.38
1981	2.57	2.49	2.53	3.25	3.83	4.12	4.10	3.48	3.19	2.70	2.49	2.33
1982	2.36	3.02	5.01	7.49	6.45	6.18	4.16	4.16	3.65	2.93	2.55	2.38
1983	2.84	3.49	3.71	3.92	4.76	5.40	5.14	4.80	3.44	3.87	2.93	2.54
1984	2.97	3.24	3.84	4.35	4.94	3.51	3.03	2.91	2.87	2.71	2.58	2.40
1985	2.35	2.97	3.85	4.11	3.80	3.88	3.94	3.50	3.22	2.70	2.46	2.29
1986	2.35	2.54	3.44	5.07	10.07	5.11	5.25	4.84	3.47	3.43	2.75	2.35
1987	2.43	2.48	2.60	3.07	4.09	5.52	6.14	4.71	3.69	3.02	2.74	2.53
1988	2.61	2.70	3.17	5.35	6.45	6.41	5.15	4.31	3.89	3.61	3.51	3.00
1989	2.91	2.85	2.80	3.10	4.26	5.27	6.07	5.28	3.55	2.71	2.43	2.29
1990	2.32	2.60	2.78	3.78	5.12	4.82	4.64	4.79	4.37	4.14	3.83	3.22
1991	2.91	3.08	3.12	3.96	5.08	5.13	6.38	4.83	3.58	3.57	3.52	2.96
Avg	2.59	2.81	3.25	4.44	5.42	5.16	4.72	4.09	3.51	3.18	2.83	2.54

Monthly average DOC without DOC in agriculture drainage (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	2.01	2.24	2.57	2.39	2.01	1.91	1.87	1.87	1.68	1.61	1.69	1.70
1977	1.91	2.19	2.27	1.86	1.86	2.01	1.80	1.65	1.70	1.60	1.61	1.65
1978	1.79	1.96	2.16	3.78	5.38	4.46	3.61	3.61	2.82	2.09	1.73	1.75
1979	1.99	1.98	1.93	2.25	3.22	3.98	3.31	2.59	2.13	1.73	1.69	1.70
1980	1.84	1.95	2.16	4.48	3.83	3.84	3.24	2.58	2.34	1.92	1.75	1.76
1981	2.03	1.95	1.92	2.12	2.37	2.57	2.50	2.34	1.94	1.67	1.65	1.70
1982	1.83	2.58	4.20	4.26	4.35	3.13	4.04	3.66	2.79	1.98	1.75	1.85
1983	2.38	2.63	3.47	3.65	4.67	5.25	5.09	4.74	3.39	3.01	2.16	1.96
1984	2.43	3.14	3.75	4.17	3.40	2.38	2.07	2.00	1.75	1.69	1.72	1.72
1985	1.84	2.29	2.89	2.75	2.25	2.14	2.00	2.12	1.92	1.66	1.65	1.70
1986	1.83	1.98	2.54	3.48	4.82	4.47	3.66	3.20	2.34	1.97	1.73	1.74
1987	1.92	1.93	1.89	1.83	2.42	3.39	3.29	2.55	1.93	1.68	1.66	1.67
1988	1.79	1.94	2.41	3.96	4.26	3.24	2.54	2.62	2.23	1.72	1.59	1.66
1989	1.78	1.94	1.89	1.79	1.71	3.59	4.76	3.96	2.38	1.71	1.64	1.68
1990	1.78	1.93	2.03	2.75	3.32	2.83	2.34	2.94	2.47	1.83	1.64	1.68
1991	1.74	1.87	1.92	1.98	1.81	3.06	4.27	3.29	2.11	1.67	1.63	1.67
Avg	1.93	2.16	2.50	2.97	3.23	3.26	3.15	2.86	2.25	1.84	1.71	1.72

DOC = dissolved organic carbon

Table A-8 Decrease in monthly average dissolved organic carbon at Old River at Highway 4 without dissolved organic carbon in agricultural drainage

Decrease in DOC (mg/L)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	0.40	0.36	0.51	0.95	1.50	1.45	1.72	1.69	1.81	1.57	1.00	0.70
1977	0.71	0.75	1.05	1.65	3.21	3.76	2.81	1.85	1.67	1.62	1.48	1.25
1978	1.10	1.02	1.03	2.82	3.69	2.89	0.57	0.43	1.10	1.20	0.91	0.61
1979	0.52	0.53	0.76	1.76	2.80	2.29	1.22	0.83	1.05	1.06	0.82	0.65
1980	0.52	0.46	0.65	1.69	0.45	0.59	1.34	0.73	0.97	1.10	0.83	0.62
1981	0.54	0.54	0.61	1.13	1.46	1.56	1.60	1.14	1.25	1.04	0.84	0.63
1982	0.53	0.44	0.81	3.23	2.10	3.05	0.12	0.50	0.86	0.95	0.80	0.53
1983	0.46	0.87	0.24	0.26	0.09	0.15	0.06	0.06	0.05	0.86	0.77	0.58
1984	0.54	0.10	0.09	0.19	1.53	1.13	0.96	0.91	1.12	1.02	0.85	0.68
1985	0.51	0.67	0.96	1.36	1.55	1.74	1.94	1.38	1.30	1.04	0.81	0.59
1986	0.52	0.56	0.90	1.59	5.25	0.64	1.58	1.64	1.13	1.46	1.02	0.61
1987	0.51	0.55	0.71	1.23	1.66	2.13	2.84	2.17	1.76	1.35	1.08	0.86
1988	0.82	0.76	0.76	1.39	2.19	3.17	2.61	1.69	1.66	1.89	1.92	1.34
1989	1.13	0.91	0.91	1.31	2.55	1.68	1.31	1.31	1.18	1.00	0.79	0.62
1990	0.54	0.67	0.75	1.03	1.80	1.99	2.31	1.85	1.90	2.31	2.19	1.54
1991	1.16	1.21	1.20	1.98	3.28	2.07	2.11	1.54	1.47	1.91	1.89	1.30
Avg	0.66	0.65	0.75	1.47	2.19	1.89	1.57	1.23	1.27	1.34	1.13	0.82

DOC decrease (percent)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1976	16.8	14.0	16.5	28.4	42.8	43.2	47.8	47.5	51.8	49.4	37.1	29.3
1977	27.3	25.7	31.7	47.0	63.4	65.1	61.0	52.9	49.6	50.3	47.9	43.0
1978	38.2	34.3	32.3	42.8	40.7	39.3	13.5	10.6	28.1	36.5	34.4	25.9
1979	20.8	21.2	28.3	43.9	46.5	36.5	27.0	24.4	33.1	38.1	32.6	27.6
1980	22.0	18.9	23.2	27.4	10.5	13.4	29.3	22.0	29.3	36.4	32.0	26.0
1981	21.0	21.5	24.2	34.8	38.2	37.7	39.1	32.8	39.2	38.3	33.8	27.1
1982	22.5	14.5	16.3	43.1	32.5	49.4	3.0	12.1	23.6	32.5	31.4	22.3
1983	16.2	24.8	6.4	6.8	1.9	2.9	1.1	1.2	1.6	22.3	26.4	22.8
1984	18.1	3.1	2.3	4.3	31.0	32.2	31.6	31.4	39.0	37.6	33.2	28.4
1985	21.9	22.6	24.9	33.1	40.8	44.9	49.3	39.4	40.4	38.4	32.8	25.8
1986	22.3	21.9	26.2	31.4	52.1	12.6	30.2	33.8	32.7	42.6	37.0	26.0
1987	20.8	22.1	27.3	40.3	40.7	38.7	46.3	46.0	47.6	44.5	39.6	34.0
1988	31.4	28.2	24.0	25.9	34.0	49.4	50.7	39.1	42.7	52.4	54.7	44.8
1989	38.7	32.0	32.6	42.2	59.8	31.9	21.6	24.9	33.1	36.8	32.5	27.0
1990	23.3	25.9	27.0	27.3	35.1	41.3	49.7	38.6	43.5	55.9	57.2	47.9
1991	40.0	39.2	38.3	50.0	64.5	40.3	33.1	31.9	41.0	53.4	53.8	43.8
Avg	25.1	23.1	23.8	33.0	39.6	36.2	33.4	30.5	36.0	41.6	38.5	31.4

DOC = dissolved organic carbon