WATER QUALITY OF SOUTH SAN FRANCISCO BAY AND COYOTE CREEK AFTER FAILURE OF THE SAN JOSE-SANTA CLARA WATER POLLUTION CONTROL PLANT

I. 17 SEPTEMBER - 10 OCTOBER 1979

U.S. Geological Survey

Open-File Report 79-1600

Prepared as part of a continuing
San Francisco Bay estuarine study

November 1979

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. WILLIAM MENARD, Director

OPEN-FILE REPORT

For additional information write to:

Regional Hydrologist
Water Resources Division
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

CONTENTS

	Page
Abstract	4
Introduction	5
Methods	7
References	11

TABLES

Table 1.	Tides at Alviso Slough	13
2.	Equation for the calculation of percent oxygen saturation	14
3.	Methods for nutrient analyses	15

FIGURES

Figure 1.	Locations of sampling stations	16

APPENDIX

Appendix A.	Water-quality data	18
B.	Oxygen production and respiration data	25

WATER QUALITY OF SOUTH SAN FRANCISCO BAY AND COYOTE CREEK AFTER FAILURE OF THE SAN JOSE-SANTA CLARA WATER POLLUTION CONTROL PLANT

I. 17 SEPTEMBER - 10 OCTOBER 1979

By James E. Cloern and Brian E. Cole

ABSTRACT

Data are presented to document some short-term biological and chemical consequences of a sewage spill in the southern area of San Francisco Bay and its receiving-water tributary, Coyote Creek. Sampling was conducted at fixed U.S. Geological Survey stations in South Bay, and at six new stations in Coyote Creek, on 17, 20, 25, 26 September and 3, 10 October 1979. Measured water-quality parameters were: salinity; temperature; turbidity; concentrations of selected dissolved gases (oxygen, carbon dioxide, methane, nitrous oxide, ethylene, ethane); concentrations of dissolved inorganic nutrients (ammonia, nitrate, nitrite, phosphate, silicate); and concentrations of chlorophyll *a* and phaeopigments, total coliforms, fecal coliforms, and fecal streptococci. Rates of oxygen utilization and photosynthetic production were measured at selected stations.

INTRODUCTION

From 2 September to 9 October 1979, the water pollution control plant serving San Jose-Santa Clara, California, experienced a breakdown in the secondary-treatment process that resulted in the discharge of partially-treated sewage into Coyote Creek, a tributary to the southern area of San Francisco Bay (Figure 1). The waste had received primary treatment before its release. During initial stages of the breakdown, commercial fishermen reported die-offs of planktonic invertebrates in Coyote Creek and its tributary sloughs. This report, the first of a series, presents data compiled in a study that was initiated to document (1) some short-term biological and chemical consequences of this sewage spill, and (2) the geographic extent of water-quality problems associated with the spill in southern South San Francisco Bay and its tributaries.

This report presents data collected on 17, 20, 25, 26 September and 3, 10 October 1979. Although this study is ongoing, data presented herein were compiled quickly to provide local, State, and Federal regulatory agencies with information on selected short-term consequences of this sewage spill. Subsequent data reports in this series will document and interpret ecological changes that occur over longer time scales.

An effort was made to measure all water-quality parameters within our capabilities that are required to define the important biological and chemical consequences of a sewage spill. The following properties were measured: salinity, temperature, and turbidity; concentrations of selected dissolved gases (oxygen, carbon dioxide, methane, nitrous oxide, ethylene, ethane); concentrations of dissoved inorganic nutrients (ammonia, nitrate, nitrite, phosphate, silicate); and concentrations of chlorophyll _a_ and phaeopigments, total particulate organic carbon, and three bacterial

indicators of enteric pathogens from human waste (total coliforms, fecal coliforms, fecal streptococci). In addition, water samples at selected stations were incubated in darkness and sunlight to provide estimates of community respiration (utilization of oxygen) and photosynthetic oxygen production by phytoplankton.

A caveat is offered to readers attempting to infer consequences of the treatment plant failure from these data. Although the U.S. Geological Survey has an historical base of water-quality data collected from stations within San Francisco Bay (Smith et al., 1979), little long-term quantitative information exists on the benthic fauna and quality of waters in Coyote Creek, particularly at the time prior to the plant failure. Therefore, assessments of the sewage spill will involve interpretation solely of data that were collected after the breakdown at the plant.

The following persons were directly responsible for the collection and computation of the data presented in this report: A. E. Alpine, chlorophyll, phaeopigments; J. E. Cloern, oxygen, data reduction; B. E. Cole, data reduction; D. D. Harmon, P. Cascos, and S. W. Hager, nutrients; A. Hutchinson and S. M. Wienke, oxygen; L. Lapp, bacteria; C. Culburtson and R. Oremland, dissolved gases.

METHODS

Between September 17 and October 10, 1979, selected stations (Figure 1) in the southern apex of San Francisco Bay were sampled at approximately weekly intervals. Sampling locations were selected which (1) have an historical data base that can be used in assessing the effects of recent perturbations, (2) would reflect the immediate impact of the sewage spill on the aquatic system, and (3) would indicate the extent of the intrusion of the waste water into adjoining sloughs and waterways.

Sampling was typically conducted from a shallow-draft boat. Where water depth was sufficient, salinity, temperature, and dissolved oxygen were measured at the surface and 1 m from the bottom. Sampling, particularly in the middle reach of Coyote Creek, was conducted as near as possible to the times of low tide (Table 1). On September 17th and 26th, water from stations 30-36 was collected using a continous sampling system described by Schemel and Dedini (1979).

Salinity and Temperature - Measurements of salinity and temperature were made with a Beckman[R1/] electrodeless salinometer-temperature probe lowered to the desired depth.

Secchi-disc Depth - As a measure of the turbidity of the water, a weighted white disc, 30 cm in diameter, was lowered into the water to the depth at which it is no longer visible.

Tidal Conditions - The tidal state at the time of sampling is indicated by a +, 0, or - for a flood, slack, or ebb tide condition, respectively.

1/ The mention of brand names is for identification purposes and does not constitute endorsement by the U.S. Geological Survey.

Dissolved Oxygen - Dissolved oxygen was measured by (1) Carpenter's (1965) modification of the Winkler titration, and (2) using a Yellow Springs Instrument® model 51B oxygen meter. Sample water was collected with a Niskin® sampler, from which subsamples were dispensed into separate bottles for the two analyses. Oxygen measurements with the probe were made in a 1-L bottle within 5 minutes of collection. Samples for the Winkler titration were "fixed," then held in stoppered BOD bottles for up to 5 hours before acidification and titration with 0.02-N thiosulfate to a starch endpoint. Precision for the analysis is 0.22 mg/L. Nitrite is known to interfere with the analysis. In comparisons made with the azide modification of the Winkler method (American Public Health Association, 1972) the error was found to be stoichiometric, i.e., 1 µg-at/L (NO_2) in the sample results in a 0.016 mg/L error in the measured oxygen value. In most areas in the Bay the error is insignificant (<0.03 mg/L), but in waters which have nitrite concentrations of 5 to 20 µg-at/L, dissolved-oxygen determinations may be as much as 5 percent high. The data have not been corrected for this error.

Percent Oxygen Saturation - Percent saturation is an expression of the closeness of an observed oxygen concentration to the equilibrium or saturation concentration. Percent saturation is the ratio of the observed value to the saturation value (Table 2). Values for percent saturation were calculated from the Winkler titration oxygen data.

Nutrients - Samples for dissolved nutrient analysis were collected in 2-L Nalgene® bottles immersed in the surface waters, then stored on ice for 1-5 hours until filtered. The samples were double filtered, first through a Gelman® type-AE glass-fiber filter and then through a Nuclepore® membrane

filter of 0.4μ pore size. The samples were analyzed using a Technicon AutoAnalyzer II[R] according to the methods outlined in Table 3.

Bacteria - Samples for the determination of the number of total coliforms, fecal coliforms, and fecal streptococci were collected from the surface waters. Sterile bottles were held below the water's surface with the mouth of the bottle directed into the current. Following collection, the sample was held on ice until returned to the laboratory. Bacterial enumerations were determined using the following tests: (1) total coliform bacteria test B-0025-77 (Ehlke and others, 1977a); (2) fecal coliform bacteria test B-0050-77 (Ehlke and others, 1977b); and (3) fecal streptococcal bacteria test B-0055-77 (Ehlke and others, 1977c).

Dissolved gases - Samples for analysis of dissolved gases were taken from the Niskin[R] sampler. Into a 50-ml plastic syringe was drawn a 25-ml sample, 2 ml of 6-N HCl, and 25 ml of air. The HCl caused the liberation of CO_2 from the sample. The syringe was stoppered and shaken for 7 minutes to liberate the other gases. The gases in the syringe were purged into a 10-ml stoppered serum bottle. The samples were analysed the same day as collected. Methane, CH_4, ethylene, C_2H_4, and ethane, C_2H_6, were measured on a Hewlett-Packard[R] 5730A gas chromatograph equipped with a flame-ionization detector. Carbon dioxide, CO_2, was detected with this gas chromatograph equipped with a thermal conductivity detector. Nitrous oxide, N_2O, was analysed with a Perkin Elmer[R] model 3920 gas chromatograph equipped with a Nickle-63 electron-capture detector.

Chlorophyll a and Phaeopigments - Samples for phytoplankton biomass, chlorophyll a and phaeopigments were collected in bottles immersed in the ambient surface waters. The samples were held for 1-5 hours before being

returned to the laboratory for filtration. Absorbances of the pigment extract were measured spectrophotometrically using a Varian^{R} 635D spectrophotometer. Chlorophyll a and phaeopigment values were determined using the equations of Lorenzen (1967).

Oxygen Production and Respiration - Samples from selected stations (Appendix B) were incubated for 3 hours (23 hours on September 26) in a sunlit, water-cooled incubator. Changes in dissolved oxygen were determined by the light- and dark-bottle method (Strickland and Parsons, 1972, p. 263). Oxygen content of duplicate light- and dark-bottle samples was measured by a Winkler titration (Carpenter, 1965).

REFERENCES

American Public Health Association, Inc., 1972, Standard methods for examination of water and waste water: New York, p. 405-415.

Atlas, E. L., Hager, S. W., Gordon, T. L., and Park, P. K., 1971, A practical manual for use of the Technicon AutoAnalyzer in seawater nutrient analyses, revised: Department of Oceanography, Oregon State University, Ref. 71-22.

Carpenter, J. H., 1965, The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method: Limnology and Oceanography, v. 10, p. 141-143.

Ehlke, T. A., Ehrlich, G. G., and Greeson, P. E., 1977a, Total coliform bacteria (membrane filter method) B-0025-77, *in* Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter A4, Methods for collection and analysis of aquatic biological and microbiological samples, p. 29-33.

_____, 1977b, Fecal coliform bacteria (membrane filter method) B-0050-77, *in* Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter A4, Methods for collection and analysis of aquatic biological and microbiological samples, p. 53-57.

_____, 1977c, Fecal streptococcal bacteria (membrane filter method) B-0055-77, *in* Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter A4, Methods for collection and analysis of aquatic biological and microbiological samples, p. 59-62.

Head, P. C., 1971, An automated phenolhypochlorite method for the determination of ammonia in seawater: Deep-Sea Research, v. 18, p. 531.

Lorenzen, C. J., 1967, Determination of chlorophyll and phaeopigments: Spectrophotometric equations: Limnology and Oceanography, v. 12, p. 343-346.

Schemel, L. E., and Dedini, L. A., 1979, A continuous water sampling and multiparameter-measurement system for estuaries: U.S. Geological Survey Open-File Report 79-273.

Smith, R. E., Herndon, R. E., and Harmon, D. D., 1979, Physical and chemical properties of San Francisco Bay waters, 1969-1976: U.S. Geological Survey Open-File Report 79-511.

Solorzano, L., 1969, Determination of ammonia in natural waters by the phenolhypochlorite method: Limnology and Oceanography, v. 14, p. 799-801.

Strickland, J. D. H. and Parsons, T. R., 1972, A practical handbook of seawater analysis (2nd edition): Fisheries Research Board of Canada, Bulletin 167, 310 p.

Technicon Instruments Corporation, 1973, Nitrate and nitrite in water and waste waters: Technicon AutoAnalyser II, Industrial Method No. 100-70W: New York, 3 p.

_____, 1976, Silicates in water and wastewater: Technicon AutoAnalyser II, Industrial Method No. 105-71WB, released February 1973, revised January 1976: New York, 2 p.

U.S. Department of Commerce, 1978, Tide tables 1979, High and low-water predictions, West coast of North and South America, National Oceanographic and Atmospheric Administration, National Ocean Survey, Rockville, Maryland.

Weiss, R. R., 1970, The solubility of nitrogen, oxygen, and argon in water and seawater: Deep Sea Research, v. 17, p. 721-735.

TABLE 1. Tides at Alviso Slough (U.S. Department of Commerce, 1978)

DATE	TIME (High Water)	HT.* (High Water)	TIME (Low Water)	HT. (Low Water)	TIME (High Water)	HT. (High Water)	TIME (Low Water)	HT. (Low Water)
Sep. 17			0553	0.5	1157	8.3	1807	2.2
20			0730	0.6	1325	8.4	1957	1.4
25			1014	2.2	1546	8.7	2300	0.8
26	0454	7.6	1052	2.6	1626	8.7		
Oct. 3			0555	-0.1	1153	8.9	1820	1.1
10	0530	8.1	1126	2.6	1639	9.0		

*Height in feet relative to mean lower low water.

TABLE 2. Equation for the calculation of Percent Oxygen Saturation

$POS = O_2/O_2' \times 100$

O_2 is observed oxygen concentration

O_2' is oxygen saturation concentration (Weiss, 1970)

$$\ln O_2' = A_1 + A_2 (100/T) + A_3 \ln(T/100) + A_4 (T/100) + S [B_1 + B_2(T/100) + B_3 (T/100)^2]$$

T is absolute temperature (^oK)

S is salinity ($^o/oo$)

$A_1 = -173.4292$ $B_1 = -0.033096$

$A_2 = 249.6339$ $B_2 = 0.014259$

$A_3 = 143.3483$ $B_3 = -0.0017000$

$A_4 = 21.8492$

TABLE 3. Methods for Nutrient Analyses

	DESCRIPTION
AMMONIA	The method is an automated adaptation of the phenolhypochlorite method of Solorzano (1969), similar to that of Head (1971). Precision of the analysis is ± 1 percent for concentrations greater than 2 µg-at/L.
NITRATE plus NITRITE	The method is essentially Technicon (1973) method number A11 100-70W, with one additional 20 turn coil added for better stability with respect to room temperature. Precision of the analysis is ± 1 percent for concentrations greater than 2 µg-at/L.
NITRITE	The method is an adaptation of Technicon (1973) method number A11 100-70W, with the cadmium column removed. Due to the desirability of fitting all five analyses on a single Technicon proportioning pump, the nitrite samples - ammonium chloride mixture is drawn from the debubbler which precedes the cadmium column in the nitrate plus nitrite analysis. Precision of the analysis is ± 1 percent for concentration greater than 1 µg-at/L.
PHOSPHATE	The method is a modification of the method of Atlas et al. (1971), using ascorbic acid (70 g/L with 50 mL acetone/L) instead of hydrazine sulfate as a reductant. The change was made to allow us to analyze samples pre-digested with hydrogen peroxide and ultraviolet light. The method also measures a high percentage (> 80 percent) of the arsenate ($AsO_4^{\equiv}$) in the sample as phosphate. Precision of the analysis is ± 2 percent for concentrations greater than 2 µg-at/L.
SILICATE	The method is similar to Technicon (1976) method A11 105-71W. The sample tube has been reduced to half the delivery rate used in that method to extend the range of linear Absorbance/Concentration. Precision of the analysis is ± 1 percent for concentrations greater than 5 µg-at/L.
	The analyses appear to be sensitive to both room and sample temperature. With all the methods, except possibly NH_3, sensitivity increases with increased room temperature. Frequent standarizations compensate for room temperature changes recorded in our laboratory.

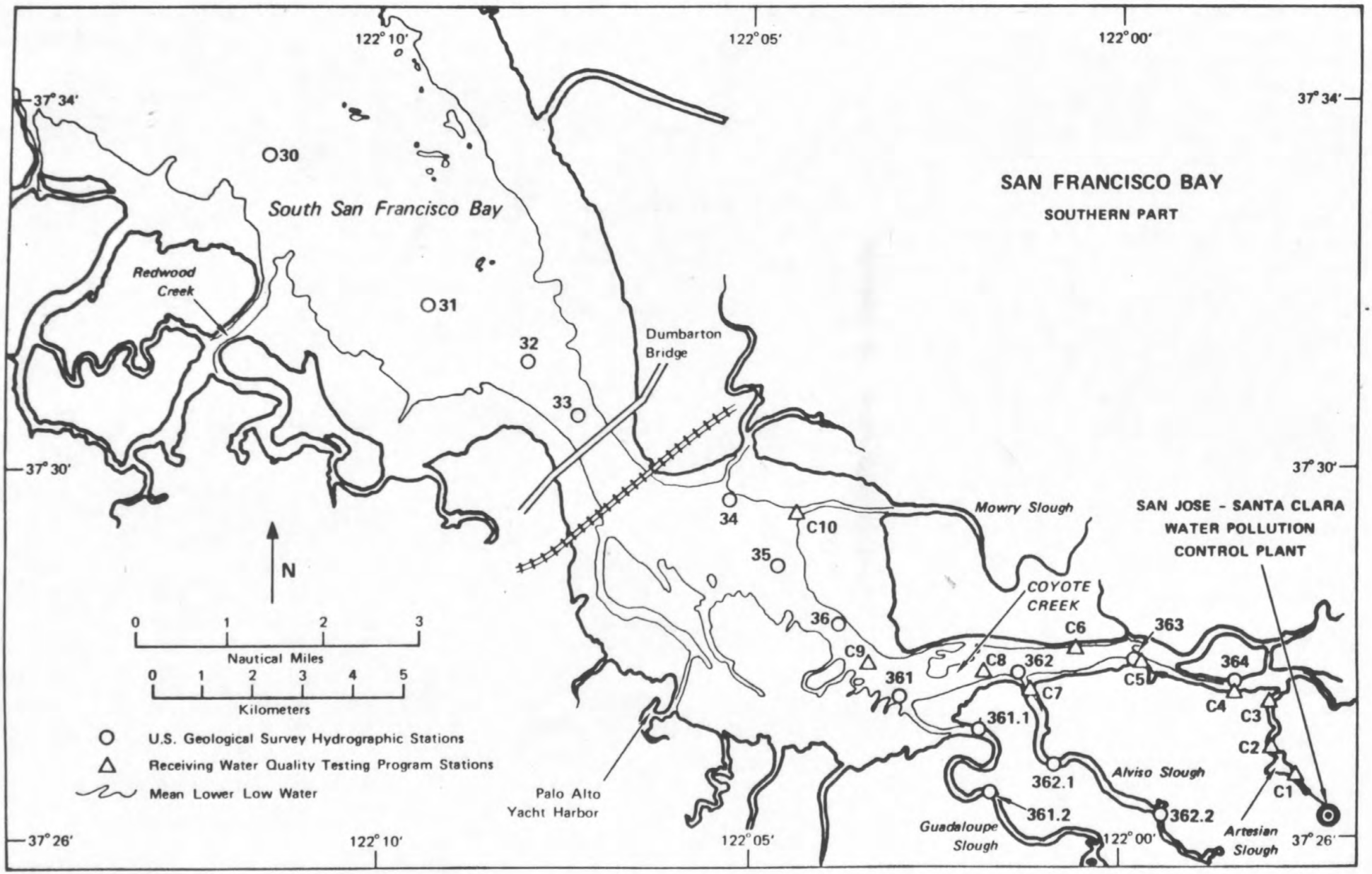

FIGURE 1. Locations of sampling stations.

Appendix A. Water Quality Data

DATE *September 17, 1979*

STATION	30	31	32	33	34	35	36	361	361.1	361.2	362	362.1	362.2	363	364
TIME	1141	1102	1036	1017	1002	0956	0948	0948			0930			0909	
SALINITY (^{o}/oo) (surface)	31.0	30.7	30.6	30.6	30.0	29.7	28.6	29.2			26.3			20.2	
(bottom)	31.0		30.8				29.0	29.0			27.8				
TEMPERATURE (^{o}C)(surface)	22.1	22.5	22.6	22.6	22.9	22.9	23.0	23.0			23.1			23.2	
(bottom)	21.9		22.4				23.0	23.3			23.1			0.6	
DEPTH (m)	10.0		10.0				5.0	3.0			4.0				
SECCHI DEPTH (cm)								120			65			50	
TIDAL CONDITION	+	+	+	+	+	+	+	+			+			+	
DISSOLVED OXYGEN (mg/L)															
Winkler (surface)															
(bottom)															
Probe (surface)															
(bottom)															
PERCENT SATURATION															
NUTRIENTS (µM/L)															
Nitrate	19.9		25.0				33.2	33.1			17.7			0.75	
Nitrite	0.86		1.07				2.84	3.11			3.22			0.33	
Ammonia	7.71		5.89				26.4	31.4			68.5			131	
Phosphate	16.6		21.3				37.5	40.2			58.9			105	
Silicate	137		155				187	193			219			274	
DISSOLVED GASES															
Ethane (n M/L)															
Ethylene (n M/L)															
Nitrous Oxide (n M/L)															
Methane (µ M/L)															
Carbon Dioxide (µ M/L)															
BACTERIOLOGY (count/100 mL)															
Total Coliforms															
Fecal Coliforms															
Fecal Streptococci															
CHLOROPHYLL a (ug/L)	1.49		2.40				4.05								
PHEOPIGMENTS (ug/L)	1.31		1.85				1.72								

DATE September 20, 1979

STATION	36	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
TIME	1045	1026	1111	1123	1233	1139	1152	1202			
SALINITY (°/oo) (surface)	29.3	29.6	29.0	27.5	27.0	26.5	21.4	18.1			
(bottom)		29.6	29.0	27.9	28.0	26.7	21.6	18.5			
TEMPERATURE (°C)(surface)	22.6	22.3	23.5	22.4	22.6	22.4	22.9	23.3			
(bottom)		22.3	23.5	22.3	23.0	22.2	22.7	22.8			
DEPTH (m)		1	2.5	4	1.25	4	1	26			
SECCHI DEPTH (cm)		100	90	80	90	85	60	60			
TIDAL CONDITION											
DISSOLVED OXYGEN (mg/L)											
Winkler (surface)											
(bottom)											
Probe (surface)											
(bottom)											
PERCENT SATURATION											
NUTRIENTS (µM/L)											
Nitrate	30.3	30.4	30.7	26.5	25.3	26.8	0.35	0.0			
Nitrite	3.85	3.02	4.01	4.46	4.24	4.14	0.24	0.55			
Ammonia	34.3	28.4	36.8	64.2	69.4	65.4	126	150			
Phosphate	38.3	37.0	39.1	55.1	56.1	54.4	97.4	135			
Silicate	194	188	195	215	214	214	263	294			
DISSOLVED GASES											
Ethane (n M/L)											
Ethylene (n M/L)											
Nitrous Oxide (n M/L)											
Methane (µ M/L)											
Carbon Dioxide (µ M/L)											
BACTERIOLOGY (count/100 mL)											
Total Coliforms											
Fecal Coliforms											
Fecal Streptococci											
CHLOROPHYLL a (ug/L)											
PHEOPIGMENTS (ug/L)											

DATE September 25, 1979

STATION	30	31	32	33	34	35	36	361	361.1	361.2	362	362.1	362.2	363	364
TIME	0927		0958				1027	1050			1108	1137	1202	1228	1245
SALINITY (^{o}/oo) (surface)	31.5		29.7				25.2	22.2			20.6	21.0	18.1	19.9	10.2
(bottom)							26.3	24.9			24.0	21.9			
TEMPERATURE (^{o}C)(surface)	21.4		21.2				20.7	20.8			20.8	20.8	20.4	21.1	22.2
(bottom)							20.8	20.8			20.8	20.9			
DEPTH (m)	3.0		3.0				3.0	<2.0			3.5	3.0			
SECCHI DEPTH (cm)															
TIDAL CONDITION	-		-				0	+			+	+	+	+	+
DISSOLVED OXYGEN (mg/L)															
Winkler (surface)	6.20		6.21				3.94	2.25			0.95	2.18	3.73	2.11	0.00
(bottom)	6.21		6.10				4.27				1.68	2.61			
Probe (surface)	5.8		5.4				3.4	2.05			1.05	1.95	3.1	1.9	0.15
(bottom)	5.8		5.4				3.8				1.5	2.2			
PERCENT SATURATION (surface)	84		83				51	29			12	28	44	27	0
(bottom)	84		82				56				22	33			
NUTRIENTS (uM/L)															
Nitrate															
Nitrite															
Ammonia															
Phosphate															
Silicate															
DISSOLVED GASES															
Ethylene															
Nitrous Oxide															
Methane															
Carbon Dioxide															
BACTERIOLOGY (count(100 mL)															
Total Coliforms															
Fecal Coliforms															
Fecal Streptococci															
CHLOROPHYLL a (ug/L)	1.31		2.39				8.97	11.0					37.4		8.97
PHEOPIGMENTS (ug/L)	1.76		0.98				2.69	2.38					14.2		2.09

DATE September 26, 1979

STATION	30	31	32	33	34	35	36	361	361.1	361.2	362	362.1	361.2	363	364
TIME	0950	1054	1125		1231	1334	1430	1027	1104		1132	1207		1234	1259
SALINITY (^{0}/oo) (surface)	29.85	29.56	29.41		28.68	27.96	28.72	23.1	23.1		22.6	20.8		19.8	8.6
(bottom)	30.84		29.96		29.34		29.14	27.4	28.4		26.0	22.4		23.8	
TEMPERATURE (^{0}C)(surface)	20.8	20.8	20.7		20.4	20.7	20.7	20.4	20.3		20.6	21.1		21.4	23.4
(bottom)	20.8		20.8		20.6		20.7	20.4	20.8		20.4	20.4		20.6	
DEPTH (m)	13.0		10.0		5.0		5.0	2.5	3.5		3.0	3.0		2.0	
SECCHI DEPTH (cm)	160		125		100		95	70	50		65	75		40	
TIDAL CONDITION	-	-	+		+		+	-	+		+	+		+	+
DISSOLVED OXYGEN (mg/L)															
Winkler (surface)	6.23	6.28	6.11		5.59		5.81	3.05	4.41		1.81	2.80		2.15	0.0
(bottom)	6.12		6.09		5.73		5.79	4.28	4.50		2.54	2.45		2.16	
Probe (surface)								1.5	4.05		1.55	2.55		2.2	0.2
(bottom)								3.5	4.05		2.45	2.3		2.0	
PERCENT SATURATION (surface)	83	84	81		74		77	39	55		23	36		27	0
(bottom)	82		81		76		77	56	60		33	31		28	
NUTRIENTS (uM/L)															
Nitrate	25.9	29.6	30.5		32.9		33.7	24.4	94.2		9.12	14.4		1.69	0.74
Nitrite	1.31	1.99	2.25		3.08		3.21	8.24	7.46		7.14	14.5		2.02	0.71
Ammonia	8.89	14.6	17.9		27.5		29.2	132	53.3		155	142		162	162
Phosphate	22.0	28.8	30.3		30.0		37.3	102	101		137	114		176	233
Silicate	156	172	175		186		188	261	177		303	277		339	417
DISSOLVED GASES															
Ethane (n M/L)	0	8.1	6.1		6.1		5.1	6.1	10		6.1	4.0		7.1	4.0
Ethylene (n M/L)	2.9	0	0		4.4		4.4	22	38		29	41		27	77
Nitrous Oxide (n M/L)	19	18	23		23		26	48	44		55	66		53	18
Methane (μ M/L)	0.15	0.15	0.12		0.13		0.15	2.0	.65		2.6	2.0		3.9	6.9
Carbon Dioxide (μ M/L)	710	740	740		780		780	1090	940		1170	1170		1250	1580
BACTERIOLOGY (count/100mL)															
Total Coliforms															
Fecal Coliforms	<1*	<1*	2*	10*	82*	100*	220	5.2×10^5*	1.1×10^4*		1.5×10^5	5.6×10^4*		3.8×10^5	1.4×10^6*
Fecal Streptococci	<1*	<1*	<1*	1*	1*	<10*	100*	180*	100*		500*	150*		3200	6500
CHLOROPHYLL a (ug/L)	1.71	2.38	1.80		1.71		2.51	11.5	3.59		15.2	20.0		13.0	4.44
PHEOPIGMENTS (ug/L)	1.24	1.04	1.85		2.41		2.12	2.64	4.67		1.91	5.13		2.20	0.58

*Estimated count based upon nonideal colony count.

DATE October 3, 1979

STATION	30	31	32	33	34	35	36	361	361.1	361.2	362	362.1	362.2	363	364
TIME	1152		1125				1035	0940	1005		0843	0915		0822	0748
SALINITY (^{0}/oo) (surface)	31.2		31.2				29.6	29.2	27.7		26.4	21.2		15.7	2.7
(bottom)							29.8	29.4	27.9		26.8	22.8		15.7	2.8
TEMPERATURE (^{0}C)(surface)	21.4		21.4				21.5	21.3	21.1		21.0	21.0		21.1	23.2
(bottom)							21.5	21.4	21.1		21.1	21.0		21.1	23.2
DEPTH (m)							4.5	2	3		3	3.5		1.5	1.5
SECCHI DEPTH (cm)	130		110				100	100	50		50	40		30	15
TIDAL CONDITION	0		0				+	+	+		+	+		+	+
DISSOLVED OXYGEN (mg/L)															
Winkler (surface)	6.37		6.67				6.52	6.43	5.87		5.10	4.29		3.30	2.21
(bottom)							6.60	6.48	5.92		5.51	4.38			
Probe (surface)	5.6		6.0				6.0	6.4	5.2		4.8	4.0		7.6	2.8
(bottom)							6.2	6.15			5.1	3.4			
PERCENT SATURATION (surface)	87		91				88	86	78		67	55		41	26
(bottom)							89	87	78		73	56			
NUTRIENTS (uM/L)															
Nitrate	24.3		30.0				49.1	52.6	95.1		185	319		553	1104
Nitrite	2.71		2.96				5.05	4.99	7.58		9.16	13.2		15.7	10.3
Ammonia	9.93		8.58				19.0	23.3	35.7		48.0	74.2		107	88.6
Phosphate	19.7		27.6				41.0	42.6	57.0		67.0	88.7		130	184
Silicate	150		172				199	202	223		241	278		330	428
DISSOLVED GASES															
Ethane (n M/L)	0		5.3				2.1	8.5	0		2.1	4.3		2.1	4.3
Ethylene (n M/L)	6.3		15				14	11	10		7.8	12		7.8	6.3
Nitrous Oxide (n M/L)	15		15				15	20	35		58	120		170	350
Methane (μ M/L)	0.24		.16				.16	0.20	0.25		0.51	0.85		1.2	1.2
Carbon Dioxide (μ M/L)	820		810				840	910	380		1040	1120		1140	1200
BACTERIOLOGY (count/100 mL)															
Total Coliforms	180		<10				<10	100	550		6000	3700		4.9×10^{4}	6.3×10^{5}
Fecal Coliforms	12		66				2	3	52		250	480		1200	2.3×10^{5}
Fecal Streptococci	14		2				2	1	20		64	260		590	580
CHLOROPHYLL a (ug/L)	1.82		2.28				5.07	4.27	6.78		8.71	9.06		20.7	23.6
PHAEOPIGMENTS	1.21		1.27				2.11	2.87	3.39		4.32	13.9		8.27	6.77

DATE October 10, 1979

STATION	30	31	32	33	34	35	36	361	361.1	361.2	362	362.1	362.2	363	364
TIME	1305		1247		1230		1216	1203	1031		1149	1050		1132	1111
SALINITY (^{o}/oo) (surface)	31.8		31.0		29.4		27.2	27.1	19.4		22.4	18.4		11.5	12.8
(bottom)															
TEMPERATURE (^{o}C)(surface)	20.6		19.6		19.4		20.2	19.7	19.5		19.9	19.9		21.6	20.6
(bottom)															
DEPTH (m)															
SECCHI DEPTH (cm)	150		125		85		90	70	60		45	50		30	35
TIDAL CONDITION	+		+		+		+	+	-		0	-		0	-
DISSOLVED OXYGEN (mg/L)															
Winkler (surface)	6.52		6.43		5.61		5.23	4.84	3.47		3.95	3.05		6.13	6.32
(bottom)															
Probe (surface)	5.85		5.80		4.85		4.6	4.2	2.95		3.3	2.7		4.95	5.1
(bottom)															
PERCENT SATURATION (surface)	88		84		73		68	62	42		50	37		75	73
(bottom)															
NUTRIENTS (uM/L)															
Nitrate	32.8		47.3		93.0		152	252	144		631	223		1350	1530
Nitrite	1.29		2.02		4.02		5.63	8.38	9.65		11.5	17.5		7.95	11.3
Ammonia	11.3		15.5		24.4		33.8	52.2	38.2		77.8	77.7		70.9	56.3
Phosphate	22.0		29.8		41.3		50.6	68.3	30.5		100	61.0		181	192
Silicate	164		186		213		231	259	202		316	314		390	417
DISSOLVED GASES															
Ethane (n M/L)	2.0		4.0		2.0		7.1	4.0	10		10	6.1		20	4.0
Ethylene (n M/L)	4.5		1.5		1.5		3.0	6.0	110		99	4.5		6.7	3.8
Nitrous Oxide (n M/L)	21		25		25		39	56	69		140	140		210	240
Methane (μ M/L)	0.24		0.14		0.19		0.30	0.37	0.69		0.90	0.86		1.4	1.1
Carbon Dioxide (μ M/L)	740		740		820		860	920	1010		1060	1110		1140	1180
BACTERIOLOGY (count/100 mL)															
Total Coliforms			7		9		45	110	470		790	720		$4x10^{4}$	$2.5x10^{5}$
Fecal Coliforms			4		7		64	160	190		530	480		$2.2x10^{4}$	$1.7x10^{5}$
Fecal Streptococci			1		21		21	57	94		150	110		340	230
CHLOROPHYLL a (ug/L)	1.03		1.48		2.62		2.22	2.73	1.45		10.0	1.79		58.5	44.7
PHEOPIGMENTS (ug/L)	2.12		0.67		1.13		1.17	1.81	2.55		2.74	3.05		6.12	3.86

Appendix B. Oxygen Production and Respiration Data

OXYGEN PRODUCTION AND RESPIRATION

DATE	STATION	INCUBATION PERIOD (HR)	DARK UPTAKE ($mg\ L^{-1}\ hr^{-1}$)	LIGHT PRODUCTIVITY ($mg\ L^{-1}\ hr^{-1}$)
Sep. 26	34	23.3	*-0.017	.44
	362	23	*-0.104	.243
Oct. 3	36	2.9	- .012	.189
	362	3.1	- .038	.407
	364	3	- .138	.417
Oct. 10	34	3.1	- .016	.040
	362	2.9	- .037	.345
	364	2.7	- .046	.875

*Due to the long incubation period these samples became oxygen limited by the end of the incubation.