CITY OF WASECA

CLEAR LAKE RESTORATION PROJECT

EPA NO. S804691-01-0

1981 CLEAR LAKE WATER QUALITY AND 1981 TREATMENT MARSH ASSESSMENT

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INTRODUCTION

In 1976, the City of Waseca was awarded a grant of $269,075 by the Environmental Protection Agency as 50% of the funding for the Clear Lake Restoration Project. A grant of $134,537 or 25% of the project cost was awarded by the State of Minnesota. These grants were later increased to $358,682 and $164,537 respectively to cover increased project costs.

Preliminary studies by National Biocentric Inc. (1974) indicated that the primary cause of the eutrophication of Clear Lake was the excess phosphorus loading to the lake from storm water runoff. Approximately 50% of the phosphorus load to the lake entered through a large 72 inch storm sewer which discharged to Clear Lake at a point appropriately named Andy's Stink (National Biocentric Inc. 1974). Subsequent studies indicated that removal of 80% of the phosphorus from this inflow water would significantly improve the water quality of Clear Lake (National Biocentric, Inc., 1978, 1979).

The phosphorus removal was to be accomplished by diverting the nutrient laden runoff in the 72 inch storm sewer into a peat marsh where the water was to be filtered before being pumped into Clear Lake. Preliminary work in the marsh indicated that phosphorus removal rates of up to 98% were possible (National Biocentric, Inc. 1978).

The final design and construction specifications for the Clear Lake Restoration Project were completed in March, 1979, by National Biocentric, Inc. The construction phase of the project was completed on December 23, 1980, and the diversion of storm runoff water into the marsh was initiated on June 26, 1981.

The purpose of this report is to detail the initial start-up problems of the treatment marsh, assess the success of the marsh in removing nutrients, and assess the effect of the nutrient removal on the water quality of Clear Lake.

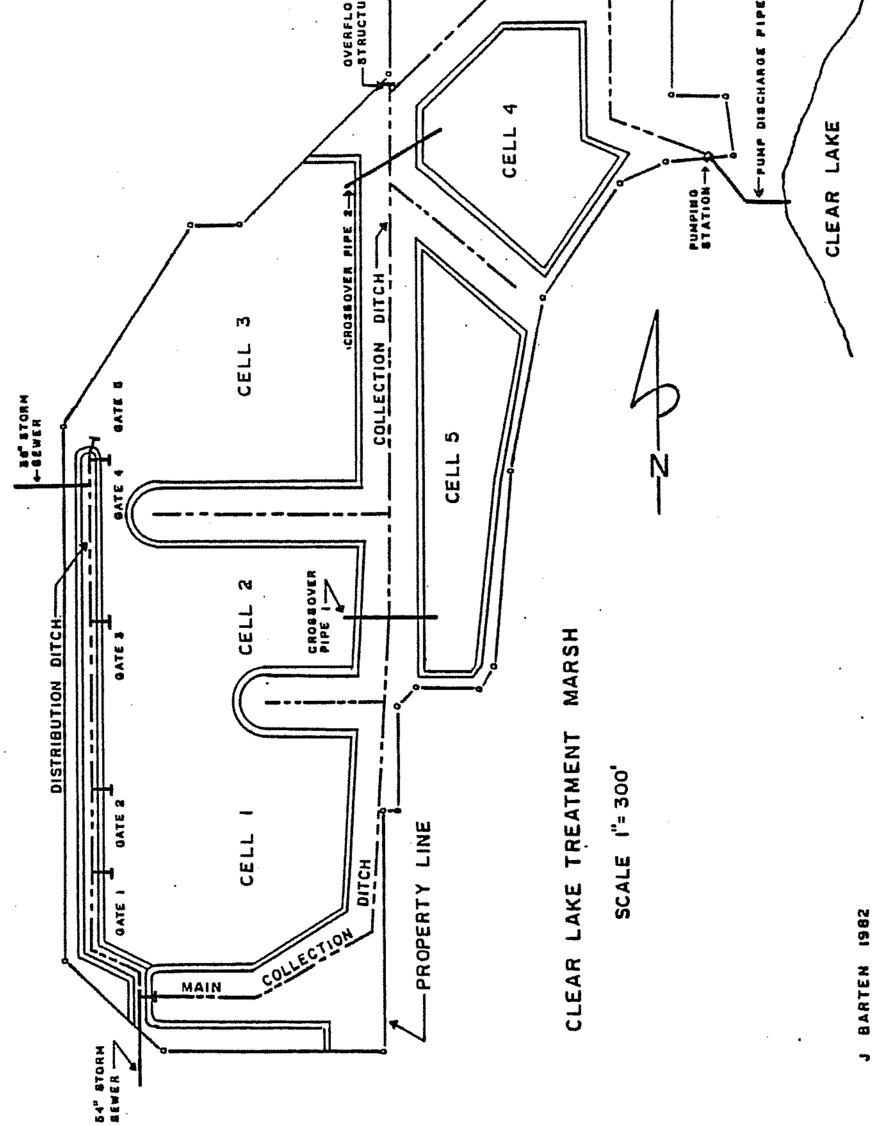
METHODS

Project Description

A detailed description of the watershed area of Clear Lake, the marsh location in the watershed, and the project location in the State of Minnesota can be found in the Waseca Lake Study (National Biocentric, Inc., 1974).

As designed, the Clear Lake Restoration Project involved diverting storm water, currently flowing directly into Clear Lake, to a peat marsh on the northwest side of the lake. The storm water was to be filtered by percolation through the peat to remove a major portion of its nutrient and suspended solids load, and then pumped into Clear Lake. To accomplish this, the marsh was divided into five separate cells by ditches, dikes and natural elevation. (Figure I). Each cell was to be separate from the others and water flow to each cell could be controlled by opening and closing the five gates along the distribution ditch. Water diverted into the marsh would be prevented from flowing overland into the collection ditches by the dikes which surround each cell. The water would then have to percolate through the peat to reach the collection ditches. Two 3000 GPM lift pumps would pump the filtered water from the collection ditch to the lake. The nutrients removed by the peat and the marsh vegetation were in turn to be removed from the marsh by harvesting the vegetation. Because of its ability to withstand periods of alternating dry and wet conditions and its market value as cattle fodder, the marsh was seeded to Phalaris arundinacea prior to the diversion of water into the marsh. To insure that homes adjacent to the marsh would not be flooded, an overflow structure was installed at the north end of the

FIGURE I



marsh at an elevation one foot below the level of the lowest basement. This overflow structure also contained a gate which, when opened, could discharge water to Rice Lake.

Sampling Procedure

Marsh inflow samples were collected monthly at the discharge end of the 54" storm sewer at the south end of the treatment marsh. Samples were also collected during one rainstorm event. Only monthly samples of inflow water were collected because a large data base regarding the chemical parameters of the storm water had been previously collected by National Biocentric, Inc. (1974, 1978, 1979) and Environmental Research Group (1980, 1981). Samples collected in 1981 were used to verify the average nutrient concentration determined by Environmental Research Group (1980, 1981) for the marsh inflow water.

Marsh outflow samples were collected biweekly at the pumping station at the east end of the collection ditch. Samples were collected at varying intervals with an ISCO automatic sampler. The sampling intervals were varied to determine if day-night and day-day fluctuationsin nutrient concentrations existed and what the magnitude of the fluctuations were.

Water volumes leaving the marsh were determined from the hours of operation of the pumps. It was assumed that the pumps were 80% efficient and that 10% of all water pumped would backflow to the pump pit. Therefore, each pump was actually discharging 2160 GPM rather than the 3000 GPM theoretical capacity.

Samples from Clear Lake (Figure 2) were collected at the same sites, at approximately the same dates, and following the same procedure as outlined by Environmental Research Group (1980, 1981). This allowed a good post-operational vs. pre-operational comparison of Clear Lake water quality. All chemical analyses of water samples followed procedures from APHA Standard Methods (1975)

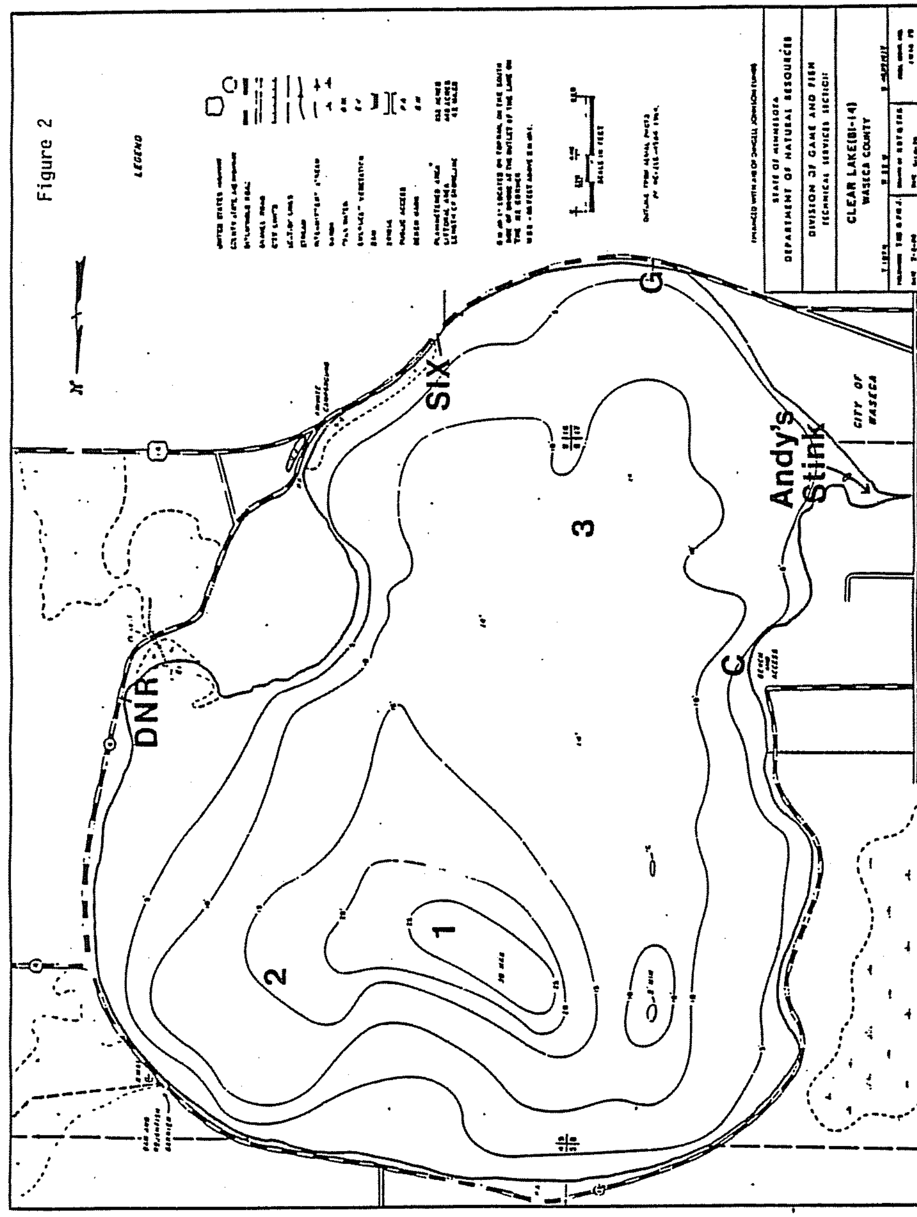


Figure 2

RESULTS

Treatment Marsh

The diversion of water into the treatment marsh was initiated on June 26, 1981. The delay between the completion of the marsh construction on December 23, 1980, and the diversion of water into the marsh was caused by the slow germination and growth of the reed canary grass. To prevent the drowning out of the grass, diversion of water into the marsh was delayed until the plants were approximately six inches high.

The intitial flooding of the marsh revealed a number of problems which affected the operation and management of the marsh. Six of the major problems are described below.

1. A shaft on one of the pumps was destroyed because of the lack of backflow valves on the pump discharge pipes. The backflow of water down the impeller shaft caused the pump to turn backwards. When the pump was automatically started by rising water levels, the resulting forward and backward pressure destroyed the shaft. Because one of the pumps was not functional and pumping capacity was limited, only the "first flush" of rainwater was diverted into the marsh until the pump was repaired on July 15, 1981. Non-reversing rachets were also installed in both pumps on July 15, to prevent reoccurrence of the problem.
2. It was discovered that the sump pit was not large enough to allow the pumps to work as designed. Within 35-45 seconds of the onset of pumping, the water level in the sump pit was lowered to the elevation of the shutoff float without substantially lowering the water level in the ditch 100 feet from the pumping

station. Therefore, approximately three minutes after the pump shut off, the water level in the pit was again high enough to cause one of the pumps to start. Rather than running a maximum of three times per hour as designed, each pump runs from seven to nine times an hour.
3. The percolation rate of water through the marsh was much slower than expected. National Biocentric, Inc., (1978) calculated the percolation rate in the marsh to be 0.12 ft. water/unit surface area/day. Using this rate and a combined area of 33.8 acres for the five marsh cells, 1,325,095 gallons of water should be leaving the marsh daily when the cells are filled with water. However, the lift pumps ran at an average rate of 1.3 hrs./day when percolation alone supplied water to the collection ditch. Using the calculated pump discharge rate of 2160 GPM, only 168,480 gallons of water were percolating out of the marsh daily. The actual percolation rate was 0.015 ft. water/unit surface area/ day. Because of the 500,000 gallons/day Birds Eye cooling water discharge into the storm sewer system, the water level in the marsh increased rather than decreased between rainstorms. Therefore, water would overtop the dikes during rainfall periods and flow directly into the collection ditches. The treatment of this runoff water was minimal and phosphorus levels remained high in the discharge water (Table 2). On July 15, 1981, a trench was dug through the dike in cell 3, 150 feet south of the crossover pipe. This lowered the water level in the marsh about eight inches, but because of the ground elevation at that point did not completely drain the cells and water continued to overtop the dikes during rainstorm events.

The discharge rate increased to 1,231,200 gallons/day when water was flowing through the trench.

4. The slow percolation rate in the marsh prevented the lowering of the water table to a depth where the operation of harvesting equipment in the marsh was possible. Therefore, no harvesting of vegetation was done in 1981.
5. The five cells in the marsh are not separated by natural topography as the design indicated they would be. Therefore, when water was diverted into any one of the three cells along the distribution ditch, it immediately spread out into all of the other cells making different management schemes in different cells impossible.
6. The overflow structure at the north end of the marsh washed-out in early spring allowing water from Rice Lake to enter the collection ditch and be pumped into Clear Lake. Wet weather prevented the repair of the structure until July 30, 1981. Therefore, no samples of outflow water were collected until August, 1981. The structure was again washed-out during a heavy rainstorm in early September, allowing the backflow of water from Rice Lake. The structure was repaired approximately two weeks later, however, the collection of outflow samples was again delayed.

Approximately 523.9 acre feet of water were pumped out of the marsh in 1981 (Table 1). The largest volumes were pumped in August and September, the months in which the largest rainfalls occurred. It was not possible to estimate the quantity of water which originated from Rice Lake. The figure for June includes snowmelt water, early spring rainfall water falling directly on the marsh, and all water entering the marsh through the 36 inch storm sewer on the west side of the marsh.

The phosphorus removal rate in the marsh was 52% based on an average phosphorus concentration in the influent storm sewer water of 0.588 mg/l (Environmental Research Group, 1981). The average phosphorus concentration in the discharge water was 0.307 mg/l in 1981 (Table 2). Nutrient concentrations in the influent stormsewer water were similar to those determined in previous years (Table 3). There was a difference of 0.131 mg/l total phosphorus between samples collected at the same time on August 15, 1981, in the pumping station and at the discharge end of the pump pipe. A difference of 0.151mg/l total phosphorus existed between samples collected on October 20, 1981, in the pumping station and in cell 5. These differences indicate some degree of contamination of the samples is occurring in the pumping station.

Clear Lake Water Quality

The water quality of Clear Lake improved significantly in 1981 as compared to previous years. The Students-t test was used to test for a difference between the means for the chemical parameters in Clear Lake for the years 1973 to 1980 and the parameters determined in 1981 at the ($P>0.05$)significance level. Confidence Intervals were then developed for the 1973-1980 mean values and plotted with the 1981 mean values (Figures 3 to 9). Total phosphorus, ortho-phosphorus, and nitrate + nitrite nitrogen values were significantly lower in 1981 for all months except October (Figures 3, 4 and 5). The chlorphyll "a" concentration in 1981 was significantly lower for all months except May and October (Figure 8). Ammonia concentrations, TKN concentrations, and Secchi disc depth did not change significantly in 1981 during most of the growing season (Figures 6, 7 and 10). The actual values for the chemical parameters measured in 1981 are shown in Table 4.

Clear Lake stratified in early June of 1981, and remained stratified until mid July (Table 8). Long term stratification of the lake is a phenomenon not observed prior to 1981. The total phosphorus concentration at the 25 and 30 foot depths in Clear Lake were found to be much higher than surface total phosphorus concentrations during stratification and on most other sampling dates (Table 8).

No blue-green algae blooms occurred on Clear Lake until August 20, 1981, approximately three weeks later than the formation of algae blooms in 1979 and 1980. The type and numbers of algae found in Clear Lake in 1981 are shown in Appendix A.

Extremely low levels of aquatic macrophytes were observed in Clear Lake in 1981. The amount of macrophytes in the lake were not quantified, but visual observation during sampling trips indicated virtually no plants in areas which had extensive macrophyte beds in 1979 and 1980.

Table 1. Hours of operation and volumes of water pumped at the Clear Lake treatment marsh lift station in 1981.

		Volume pumped	
Date	Hours of operation	Gallons	Acre Feet
June	106	1.43×10^7	43.9
July	227	3.06×10^7	93.9
August	324	4.37×10^7	134.1
September	300	4.05×10^7	124.3
October	220	2.97×10^7	91.2
November	48	0.65×10^7	19.9
December	40	0.54×10^7	16.6
TOTAL	1265	17.08×10^7	523.9

TABLE 2 Chemical Parameters for Treatment Marsh Outlet Samples for 1981

	Date	Total Phosphorus mg/l	Dissolved Phosphorus mg/l	Ortho Phosphorus mg/l	NO_2+ NO_3-N mg/l	NH_3-N mg/l	TKN mg/l	pH	S.S.
*	08-10	0.298	0.122	0.096	0.121	0.480	2.06	7.71	36.9
*	08-10 to 08-11	0.301	0.163	0.130	0.106	0.804	1.79	7.53	20.7
**	08-15	0.374	0.196					6.83	33.3
**	08-15	0.243							
***	09-15	0.223	0.144	0.121	0.079	0.772	2.16		
****	10-12 PM	0.277	0.146	0.173		1.46	2.53	7.77	
	10-13 AM	0.213		0.114				7.58	
	10-13 PM	0.517		0.224			4.81	7.54	
	10-14 AM	0.210		0.073		1.77		7.50	
	10-14 PM	0.327		0.169				7.65	
	10-15 AM	0.498	0.312	0.246			2.93	7.19	
***	10-20	0.202	0.093	0.131	0.398	1.08	2.17	6.59	
*****	10-20	0.051	0.047	0.032	0.000	0.092	0.65		

* Samples were collected at one half hour intervals from 10:00 AM on August 10, 1981 until 8:00 A.M. on August 11, 1981. The samples collected from 10:00 A.M. to 8:00 P.M. on August 10 were composited and the samples collected from 8:00 P.M. on August 10 to 8:00 A.M. on August 11 were composited.

** Grab samples collected at the pumping station and the outlet end of the pump discharge pipe.

*** 24 hour composite samples with samples taken every hour.

**** Samples were collected at four hour intervals beginning at 1:40 P.M. on October 12, 1981. Three samples were composited to form each A.M. and P.M. sample.

*****Sample collected in Cell 5.

TABLE 3 Chemical Parameters for Marsh Inlet Samples for 1981

Date	Total Phosphorus (mg/l)	Dissolved Phosphorus (mg/l)	Ortho Phosphorus (mg/l)	NO_2+ NO_3-N (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	pH	S.S.
08-06*	0.617	0.281	0.248	0.249	0.105	2.34	7.54	81.5
08-10**	0.686		0.166	0.123	0.612	4.91	7.33	26.0
08-10** to 08-11	0.873	0.569	0.402	0.162	0.190	3.91	7.70	31.7
09-15***	0.374	0.230	0.206	0.148	0.033	1.85		
10-20***	0.327	0.169	0.121	1.10	0.208	0.692	7.23	

* Grab sample during rainstorm.

** Samples were collected at one half hour intervals from 10:00 A.M. on 10 August 1981 until 8:00 A.M. on 11 August, 1981. The samples collected from 10:00 A.M. to 8:00 P.M. on 10 August were composited and the samples collected from 8:00 P.M. on 10 August to 8:00 A.M. on 11 August were composited.

***Grab samples taken at inlet to marsh.

TABLE 4 · Clear Lake Chemical Parameters for 1981

Date	Site	Secchi Disc (ft)	Chlr A (ug/l)	Total p (ug/l)	Diss p (ug/l)	Ortho p (ug/l)	NO_2+ NO_3-N (ug/l)	NH_3-N (ug/l)	TKN (mg/l)	ALK (mg/l)	pH	Surf Temp °C	Surf D.O. (mg/l)
01-07-81	1		3.2	52	30	8	2	67		182.0	7.49	1.3	13.4
	2		4.0	53	28	6	2	68		180.8	7.87		
	3		4.0	55		9	2	60		187.1	7.80		
	Mean		3.7	53	29	8	2	65		183.3	7.80		
	Std. Dev.		0.46	1.53	1.41	1.53	0.00	4.36		3.35	0.20		
02-19-61	1			48	38	0	13	115	1.45	120.0	7.77	4.5	12.2
04-02-81	1	3.9	16.8	34	17	2	0	21	1.27	180	7.9	7.7	10.6
	2	3.9	22.5	48	30	8	0	38	1.45	180	7.9		
	3	4.0	16.8	48	18	8	0	18	1.23	184	8.0		
	Mean	3.9	18.7	43	22	6	0	26	1.32	182	7.9		
	Std. Dev.	0.06	3.29	8.01	7.20	3.46	0	10.8	0.117	2.22	.058		
04-21-81	1	5.8	8.6	123	18	0	0	11	1.69	180	7.9	10.0	11.8
	2	5.8	9.2	65	24	5	0	12	1.97	181			
	3	5.2	10.7	45	18	3	0	32	1.99	180	7.9		
	Mean	5.6	9.5	77.6	20	3	0	18	1.88	180	7.9		
	Std. Dev.	.346	1.08	40.5	3.46	2.52	0	11.85	0.168	0.586	0.00		
05-12-81	1	6.0	14.3	59	27	1	8	18	1.69	181	7.7	12.8	10.6
	2	5.9	13.8	58	21	2	5	18	1.16	185	7.8		
	3	5.9	12.4	59	32	2		18	1.08	183	7.8		
	Mean	5.9	13.5	59	27	2	7	18	1.31	183	7.8		
	Std. Dev.	0.058	0.985	0.578	5.51	0.577	2.120	0	0.332	1.595	0.115		
06-09-81	1	4.5	15.2	66	26	1	0	115	1.59	187	7.8	20.8	7.0
	2	4.2	18.0	87	24	1	0	94	1.32	184	7.8		
	3	4.7	16.3	73	35	1	0	97	1.36	184	7.8		
	Mean	4.5	16.5	75	28	1	0	102	1.42	185	7.8		
	Std. Dev.	0.250	1.410	10.70	5.860	0	0	11.36	0.145	1.274	0		

TABLE 4 CONTINUED: Clear Lake Chemical Parameters for 1981

Date	Site	Secchi Disc (ft)	Chlr A (ug/l)	Total p (ug/l)	Diss p (ug/l)	Ortho p (ug/l)	NO_2+ NO_3-N (ug/l)	NH_3-N (ug/l)	TKN (mg/l)	ALK (mg/l)	pH	Surf Temp	Surf D.O. (mg/l)
07-07-81	1	6.0	3.5	64	42	1	0	42	1.55	178	7.5	26.3	7.8
	2	5.9	4.2	75	54	1	0	53	1.41	176	7.4		
	3	4.0	5.1	62	58	0	0	64	1.00	180	7.5		
	Mean	5.3	4.3	67	51	1	0	53	1.32	178	7.5		
	Std. Dev.	1.127	0.802	7.000	8.330	0.557	0	11.00	0.286	2.00	0.075		
08-11-81	1	3.1	10.8	90	34	0	0	20	1.37	171	7.5	23.0	8.6
	2	3.0	17.6	88	28	0	13	10	1.16	173	7.7		
	3	2.9	18.4	84	30	0	0	9	1.88	169	7.8		
	Mean	3.0	15.6	87	31	0	4	13	1.47	171	7.7		
	Std. Dev.	0.100	4.180	3.06	3.06	0	7.50	6.08	0.37	2.21	0.123		
09-15-81	1	2.5	31.7	115	40	0	0	76	1.91	160	7.6	20.2	8.6
	2	2.3	38.1	110	41	0	0	68	1.40	164	7.7		
	3	2.3	43.3	107	38	0	1	37	1.78	161	7.7		
	Mean	2.4	37.7	111	40	0	1	60	1.70	162	7.6		
	Std. Dev.	0.115	5.81	4.04	1.53	0	0.58	0.265	2.08	0.06			
10-20-81	1	3.0	24.7	92	41	16	12	164	1.31	175	7.9	9.4	10.7
	2	2.9	25.3		33	13	29	178	1.90	174	7.9		
	3	2.9	26.7	95	37	12	37	142	1.18	175	7.9		
	Mean	2.9	25.6	94	37	14	26	161	1.46	175	7.9		
	Std. Dev.	0.06	1.03	2.12	4.00	2.08	12.8	18.1	0.384	0.42	0.01		
12-22-81	1			68	29	2		137	1.84	183	7.8		13.9
	2			55	30	16		209	1.40	184	7.7	1.9	
	Mean			62	30	9		173	1.62	184	7.8		
	Std. Dev.			7.84	0.71	9.90		509	0.31	0.71	0.71		

TABLE 5 Chemical parameters for Clear Lake Outlet grab samples for 1981

Date	Total Phosphorus (mg/l)	Dissolved Phosphorus (mg/l)	Ortho Phosphorus (mg/l)	NO_2+ NO_3-N (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	pH
01-07	0-030		0.004	0.000	0.054	1.68	
02-19	0.034	0.025	0.000	0.051	0.120	1.65	7.67
04-02	0.093	0.013	0.006	0.000	0.017	1.33	7.93
04-20	0.094	0.020	0.003	0.000	0.074	2.15	7.81
05-12	0.060	0.029	0.004	0.001	0.019	1.04	8.07
06-09	0.053	0.026	0.001	0.000	0.047	0.99	
07-07	0.143	0.051	0.001	0.000	0.017	1.39	
08-11	0.169		0.000	0.000	0.10	1.53	7.74
09-15	0.122	0.041	0.000	0.001	0.034	1.37	
10-20	0.095	0.044	0.009	0.012	0.137	1.24	
12-22	0.193		0.003		0.154	1.60	8.13

TABLE 6 Chemical Parameters for Site G, Gaiter Lake Inlet, Grab Samples for 1981

Date	Total Phosphorus (mg/l)	Dissolved Phosphorus (mg/l)	Ortho Phosphorus (mg/l)	NO_2+ NO_3-N (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	pH
02-19	0.501	0.220	0.321	1.270	0.457	3.56	
04-02	0.473	0.322	0.220	1.210	0.093	0.95	6.84
04-20	0.385	0.223	0.207	1.240	0.046	3.37	6.84
05-12	0.465	0.409	0.393	1.290	0.069	2.51	
06-09	0.803	0.662	0.615	0.768	0.143	2.77	6.71
07-08	0.313	0.223	0.257	1.080	0.369	2.17	6.98
08-11	0.440	0.334	0.295	0.811	0.250	2.09	6.64
09-15	0.640	0.5230	0.524	0.523	0.117	2.13	
10-20	0.517	0.433	0.434	1.280	0.149	1.94	6.64
12-22	1.07	0.641	1.108		1.490	3.77	6.71

TABLE 7 Chemical Parameters for Andy's Stink grab samples for 1981*

Date	Total Phosphorus (mg/l)	Dissolved Phosphorus (mg/l)	Ortho Phosphorus (mg/l)	NO_2+ NO_3-N (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	pH
01-07	0.238		0.072	0.112	0.241	2.16	
02-19	0.130	0.113	0.099	0.232	0.275	1.44	
04-02	0.100	0.083	0.030	0.193	0.372	1.92	7.26
04-20	0.115	0.081	0.050	0.903	0.186	1.45	7.39
05-12	0.131	0.021	0.012	0.445	0.244	1.32	
06-09	0.246	0.150	0.117	0.013	0.146	0.82	
07-07	0.255	0.153	0.114	0.077	0.036	1.45	

*After July 30 of 1981, Andy's Stink flow was diverted to the Clear Lake Treatment Marsh.

TABLE 8 Temperature, dissolved oxygen, conductivity and total phosphorus profiles at Site 1, Clear Lake, for 1981.

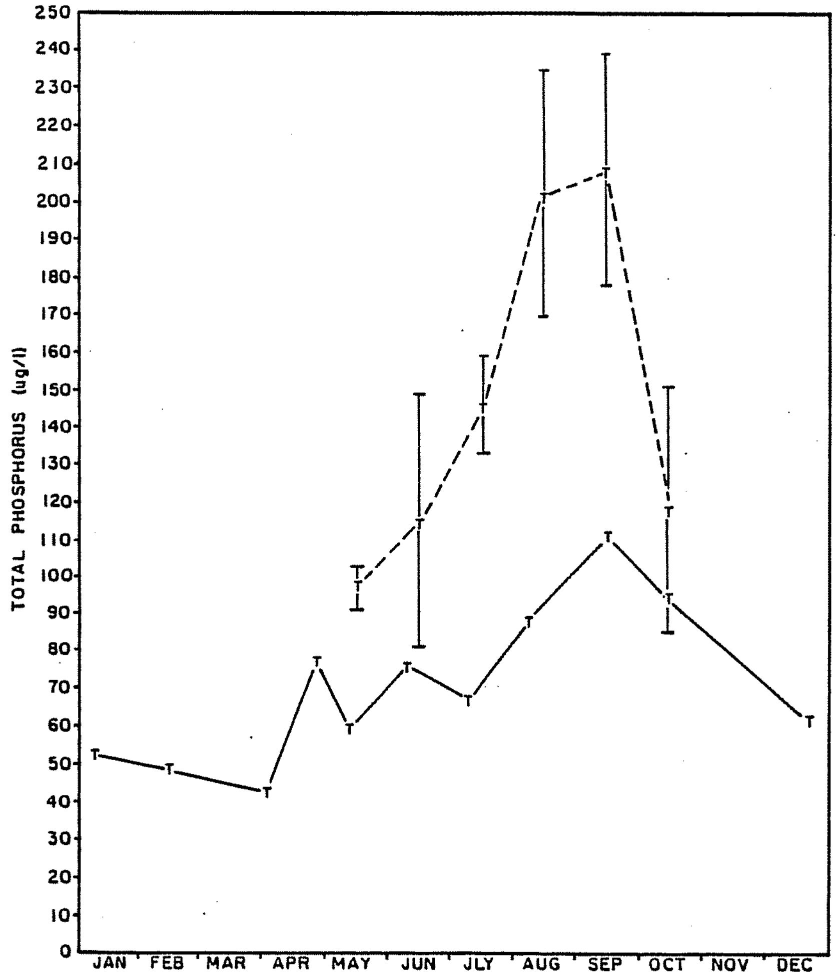
Depth (ft.)	Tem (°C)	D.O. (mg/l)	Conductivity (umho/cm)	TP (ug/l)
Date 01-07				
0	1.3	13.4		71
5	3.0	12.9		61
10	3.0	12.3		35
15	3.0	7.6		40
20	3.0	7.3		64
25	3.5	4.7		67
Date 02-19				
0	4.5	12.2		30
5	4.5	12.2		41
10	4.0	12.0		34
15	4.0	9.5		64
20	4.3	5.1		80
25	4.8	2.2		108
30	5.0	2.0		83
Date 04-02				
0	7.7	10.6	315	79
5	7.7	12.3	319	112
10	7.6	12.4	320	64
15	7.5	11.8	320	100
20	7.3	11.0	321	48
25	7.2	9.8	321	78
30	7.2	7.2	321	
Date 04-21				
0	10.0	11.8	325	63
5	10.0	12.4	340	49
10	10.0	13.8	342	60
15	10.0	13.8	345	61
20	10.0	12.6	348	72
25	10.0	12.0	350	67
30	10.0	10.8	375	212

TABLE 8 CONTINUED: Temperature, dissolved oxygen, conductivity and total phosphorus profiles at Site 1, Clear Lake, for 1981 - continued:

Depth (ft.)	Tem (°C)	D.O. (mg/l)	Conductivity (umho/cm)	TP (ug/l)
Date 05-12				
0	12.8	10.6	361	56
5	12.8	10.6	370	55
10	12.6	10.7	370	99
15	12.6	10.6	370	55
20	12.2	10.2	370	53
25	12.1	10.0	370	62
30	12.0	9.5	415	131
Date 06-09				
0	20.8	7.0	450	61
5	20.8	7.1	451	65
10	20.8	7.1	451	67
15	20.8	7.1	453	69
20	20.5	6.8	453	70
25	19.7	0.3	453	100
30	18.0	0.0	590	103
Date 07-07				
0	26.3	7.9	510	57
5	26.3	7.6	510	79
10	26.2	7.7	510	116
15	22.2	0.1	460	79
20	21.2	0.0	465	72
25	21.0	0.0	695	97
30	20.5	0.0	700	138
Date 08-11				
0	23.0	8.6	455	85
5	23.0	8.5	455	72
10	23.0	8.4	455	83
15	23.0	8.4	455	87
20	23.0	8.4	455	85
25	23.0	8.4	455	102
30	22.5	1.1	455	140

TABLE 8 CONTINUED: Temperature, dissolved oxygen, conductivity and total phosphorous profiles at Site 1, Clear Lake, for 1981

Depth (ft.)	Tem (°C)	D.O. (mg/l)	Conductivity (umho/cm)	TP (ug/l)
Date 09-15				
0	20.2	8.6	590	125
5	20.2	8.4	590	119
10	20.2	8.3	590	119
15	20.2	8.3	580	147
20	20.2	8.1	580	110
25	20.1	7.8	580	105
30	20.1	6.2	590	138
Date 10-20				
0	9.4	10.7	316	90
5	9.6	10.6	329	87
10	9.6	10.5	330	100
15	9.6	10.4	331	95
20	9.7	10.3	331	93
25	9.7	10.0	333	95
30	9.8	9.0	345	359
Date 12-22				
0	0.8	13.9	285	47
5	1.9	11.8	285	49
10	2.6	10.4	290	61
15	2.8	4.0	305	56
20	2.8	2.3	312	83
25	3.0	1.1	332	144
30	3.8	0.5	350	158

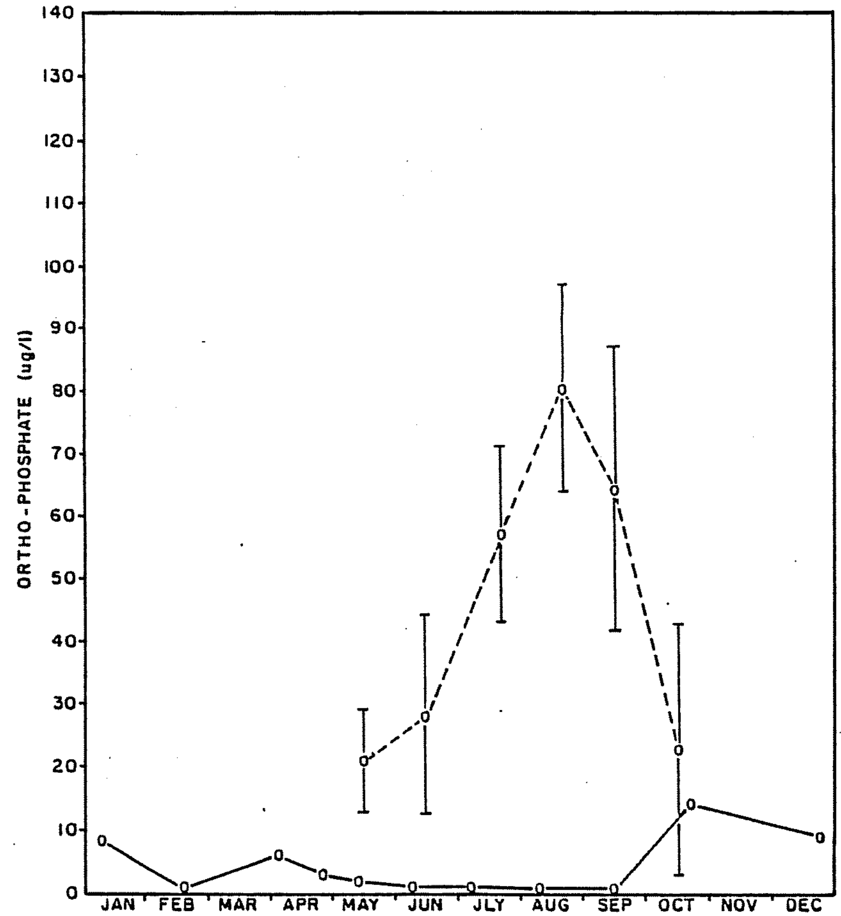


KEY:

T---T 1973–1980 MEAN TOTAL PHOSPHORUS CONCENTRATION

T—T 1981 MEAN TOTAL PHOSPHORUS CONCENTRATION

Figure 3. Mean total phosphorus concentrations in Clear Lake in 1981 and in 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.



KEY:

O----O 1973–1980 MEAN ORTHO-PHOSPHORUS CONCENTRATION

O—O 1981 MEAN ORTHO-PHOSPHORUS CONCENTRATION

Figure 4. Mean ortho-phosphorus concentrations in Clear Lake in 1981 and 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.

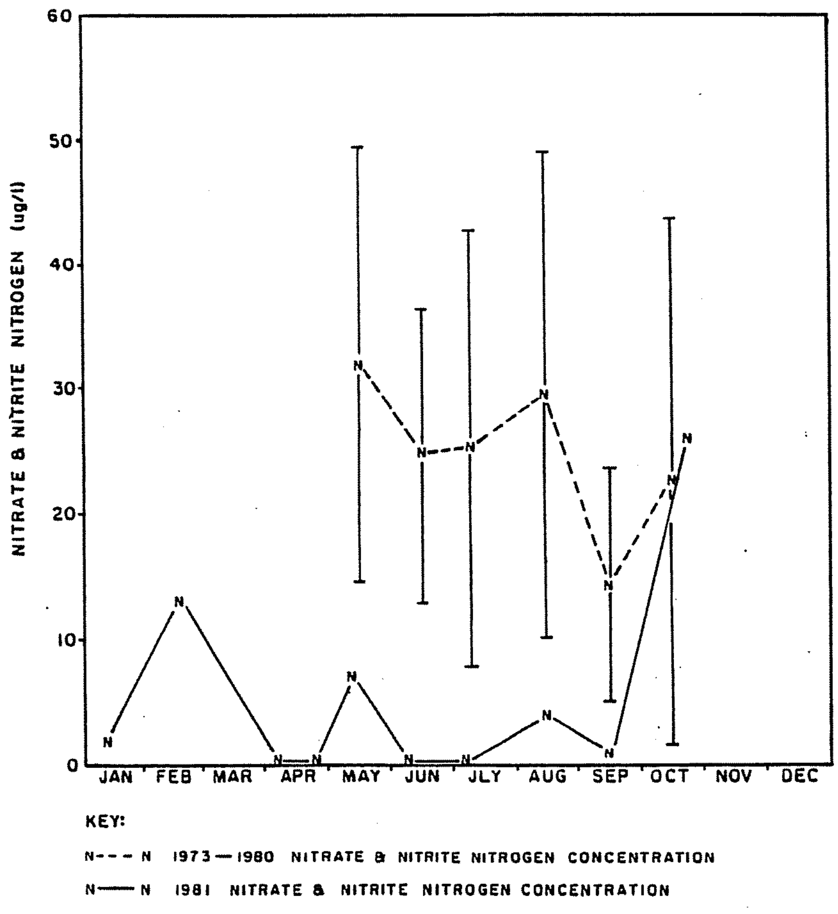


Figure 5. Mean nitrate & nitrite nitrogen concentrations in Clear Lake in 1981 and 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.

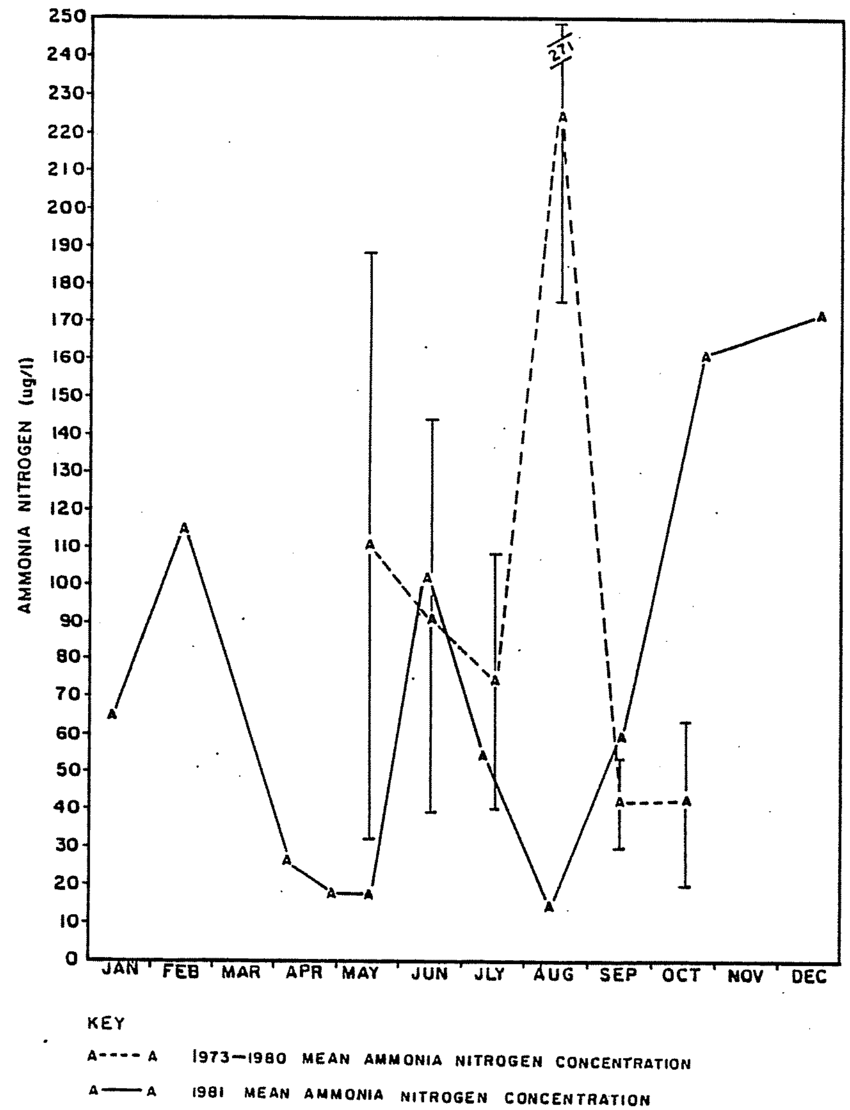


Figure 6. Mean ammonia concentrations in Clear Lake in 1981 and 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.

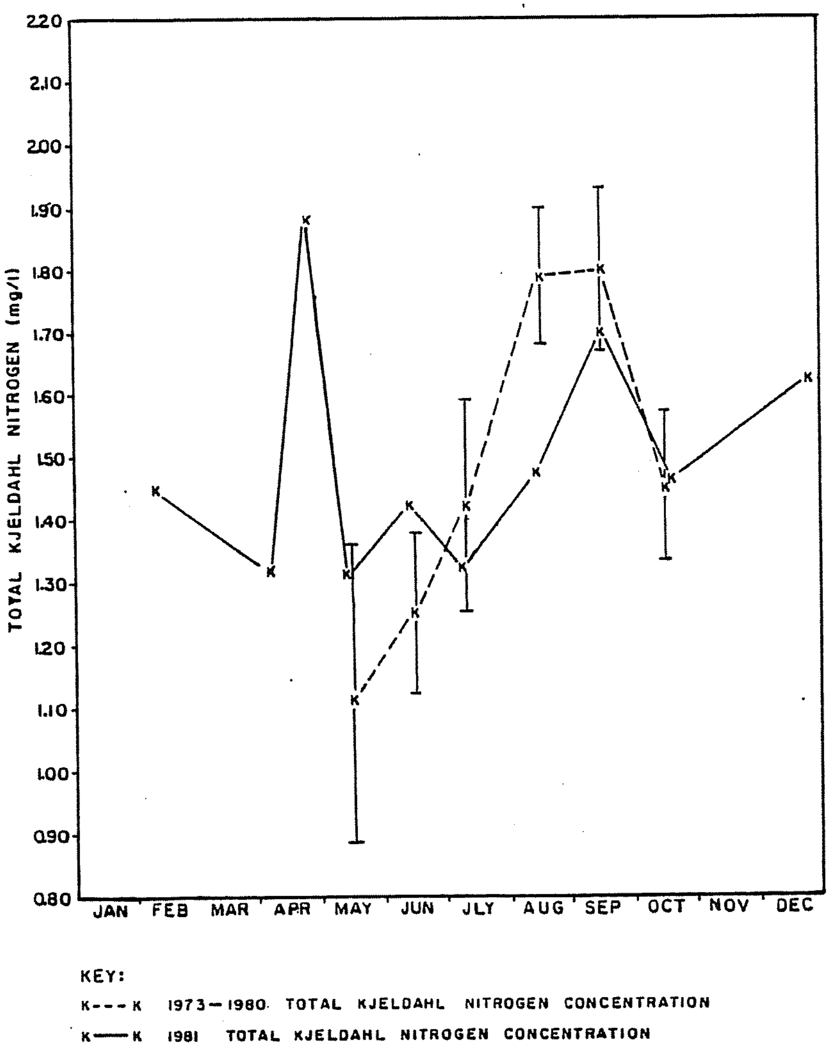


Figure 7. Mean TKN concentrations in Clear Lake in 1981 and 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.

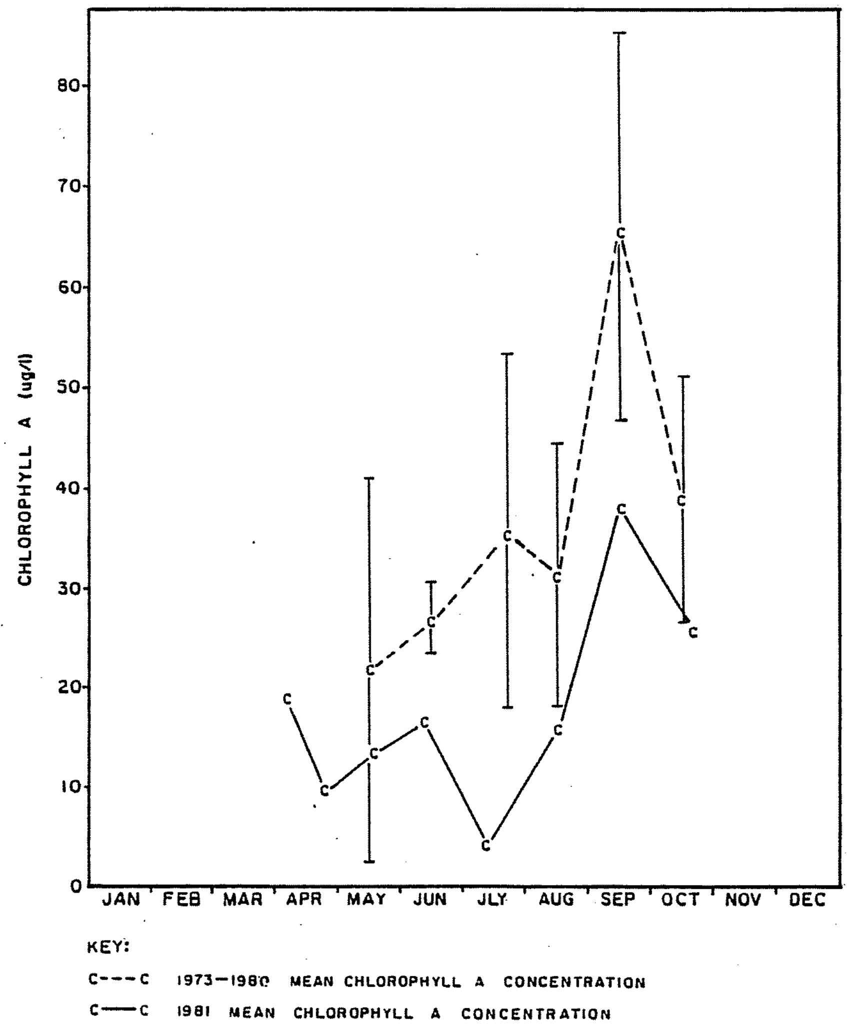


Figure 8. Mean chloraphyll "a" concentrations in Clear Lake in 1981 and 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.

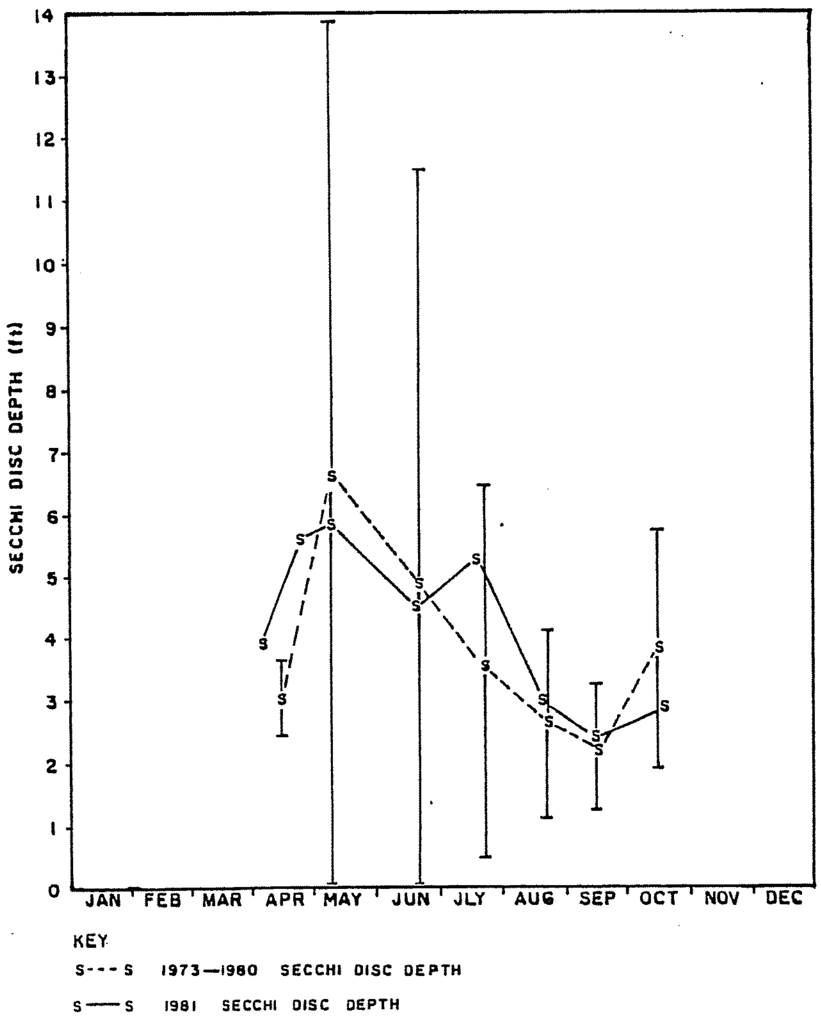


Figure 9. Mean Secchi disc depths in Clear Lake in 1981 and 1973 to 1980. Vertical lines represent 95% confidence intervals for the means.

DISCUSSION

Treatment Marsh

The marsh filtration system was considerably less efficient in terms of water percolation and nutrient removal than originally anticipated. A preliminary study by National Biocentric, Inc. (1978) indicated that phosphorus removal rates of greater than 80% could be expected in the marsh. The low 52% phosphorus removal rate is probably the result of a number of factors including:

1. The slow percolation rate in the marsh which results in water overtopping the dikes;
2. The fact that the sampling method of the pumping station may not yield representative phosphorus values.

During rainfall events when water was overtopping the dikes, storm water runoff water was flowing almost directly from the sewer outlet to the collection ditch. The residence time of stormwater in the marsh was less than 24 hours during rainfall events, insufficient time to allow for contact between the stormwater and the peat. Phosphorus removal was, therefore, incomplete. In order to eliminate the dike overflow problem, three weirs will be installed in the marsh, one each in cell 1, 3 and 5. These weirs will be closed to hold back water in the cells until the phosphorus concentration decreases to approximately 80% of the inflow concentration. At this time the weirs will be opened and the water in the marsh drained into the collection ditch. The weirs are sized to allow the marsh to drain in approximately four days. Assuming a residence time of approximately eight days to allow for 80% phosphorus removal (Wile, Palmateer and Miller, 1981) and a four day discharge time, no overtopping of the dikes should occur with average intensity and frequency rainfall events.

The high phosphorus valves in samples taken in the pumping station in relation to samples taken at the pipe discharge point and in cell 5 indicate that some contamination of the samples is occurring in the pumping station. This contamination may be due to the backflow of water through the pump shaft when only one pump is running. Approximately 240 GPM is backflowing and this water agitates the water in the sump pit and mixes silt, debris, and benthic algae into the water where it is drawn into the sample. The high phosphorus concentrations may also be partially due to the small peat particles which are constantly sloughing off at the collection ditch banks and flowing to the pumping station. As the ditches become more overgrown with vegetation, the amount of peat in the water should decrease. In 1982, the marsh outflow samples will be collected 150 ft. upstream from the pumping station to avoid collecting the disturbed silt in the station.

A small 200 GPM pump was installed at the pump site in early November, 1981, to correct the undersized sump pit problem. This pump will run during low flow conditions when only percolation is providing water to the collection ditches. The small pump will be able to hold the ditch water levels at a lower elevation than the larger pumps and should therefore increase the percolation rate by increasing the hydraulic gradient between the water level in the cells and the water level in the collection ditch.

The Phalaris arundinacea which was seeded in the marsh grew well in cell 5 and in parts of cells 1, 2 and 3. However, in most of the marsh, cattails (Typha) became the dominant species. Areas which had been scarified during construction to remove existing stands of cattails were almost completely covered with the plants by the end of the summer. The take over of cattails was probably due, at least in part, to the fact that once the marsh was flooded in July, it

remained covered with water until early November providing excellent growing conditions for cattails. In addition, Bevis and Kadlek (1979) reported that a Typha sp. monoculture developed along the effluent drainage path in a Northern Michigan wetland. Typha apparently can utilize high nutrient concentrations more efficiently than other plants. Some willows (Salix sp.) have also begun to infest some areas of cells 1 and 2. Because of the lack of separation between the cells, harvesting of the vegetation and therefore control of the willows and cattails will be very difficult.

Clear Lake Water Quality

The significantly lower values of phosphorus, nitrate and nitrite nitrogen, and chlorophyll "a" in 1981 compared to the means of the pre-operational data indicate the improving water quality of Clear Lake. It is probably too early to credit the improvement completely to the treatment marsh. The mild winter of 1980-81, the lack of high nutrient snowmelt runoff and the lack of hard spring rainfall all contributed to the good water quality of Clear Lake. However, the delay in the formation of algae blooms following heavy rainstorms which occurred in late July and early August do indicate the positive effect the marsh is having on the lake water quality. Personal observations during 1979 and 1980 indicate that algae blooms occur on Clear Lake approximately five days after a heavy (1.5" in 24 hours) rainfall. In 1981, the bloom on August 20 was preceded by five heavy rainfall events in July and August.

The decrease in the chlorophyll "a" concentration following a decrease in the total phosphorus concentration indicate that phosphorus is the limiting nutrient in Clear Lake. The 1979 and 1980 Environmental Research Group report on Clear Lake indicated the possibility that nitrogen and not phosphorus was the limiting nutrient in the lake. However, in 1981 the ortho-phosphorus concentration, the total phosphorus concentration and the chlorophyll "a" concentration decreased significantly from 1973 - 1980 mean values while the ammonia and TKN concentrations did not, indicating that nitrogen concentrations do not control algae growth. It appears from the 1981 data that if phosphorus concentrations in the lake can be decreased, the lake water quality will increase.

Table 8 shows the high phosphorus concentrations near the lake bottom relative to the concentrations near the surface. This indicates that phosphorus release from the sediments is occurring especially during stratification and during the winter. An attempt will be made in 1982 to quantify the sediment phosphorus release.

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APPENDICES

Appendix A1

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 04-02-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	3	80	14.28
Cyanophyta (Blue-Green Algae)	0	0	
Bacillariophyta (Diatoms)	4	360	64.28
Chrysophyta (Yellow-Brown Algae)	0	0	
Pyrrhophyta (Dinoflagellates)	1	10	1.78
Cryptophyta (Cryptomonads)	1	100	17.88
Euglenophyta (Euglenoids)	1	10	1.78
Other	0	0	0
Undetermined	0	0	0
Total	10	560	100.00

Taxon Name	Units/ml	Percent of Population
Pediastrum	30	5.36
Staurastrum	10	1.78
Closterium	40	7.14
Fragilaria	210	37.50
Melosira	110	19.64
Stephanodiscus	30	5.36
Navicula	10	1.78
Glenodinium	10	1.78
Trachelomonas	10	1.78
Monomastix	100	17.88

Appendix A2

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 04-20-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	7	500	12.29
Cyanophta (Blue-Green Algae)			
Bacillariophyta (Diatoms)	5	3350	82.31
Chrysophyta (Yellow-Brown Algae)			
Pyrrhophyta (Dinoflagellates)			
Cryptophyta (Cryptomonads)	1	120	2.95
Euglenophyta (Euglenoids)	1	100	2.45
Total	14	4070	100.00

Taxon Name	Units/ml	Percent of Population
Cosmarium	10	0.25
Staurastrum	10	0.25
Pediastrum	20	0.49
Chlorella	10	0.25
Chlamydomonas	10	0.25
Crucigenia	340	8.35
Ankistrodesmus	100	2.45
Melosira	220	5.40
**Fragilaria*	2940	72.23
Stephanodiscus	170	4.18
Cyclotella	10	0.25
Cocconeis	10	0.25
Trachelomonas	100	2.45
Cryptomonas	120	2.95

* *The Fragilaria colonies usually contained only 2-4 cells. These were probably broken off of larger colonies when the sample was mixed.*

Appendix A3

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 05-12-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	6	550	64.71
Cyanophyta (Blue-Green Algae)	2	20	2.35
Bacillariophyta (Diatoms)	3	180	21.18
Chrysophyta (Yellow-Brown Algae)			
Pyrrhophyta (Dinoflagellates)			
Cryptophyta (Crytomonads)	1	100	11.76
Euglenophyta (Euglenoids)			
Total	12	850	100.00

Taxon Name	Units/ml	Percent of Population
Oocystis	100	11.76
Ankistrodesmus	350	41.18
Crucigenia	10	1.18
Staurastrum	10	1.18
Selenastrum	20	2.35
Chlorella	60	7.06
Fragilaria	130	15.29
Melosira	30	3.53
Rhizosolenia	20	2.35
Anabaena	10	1.18
Anacystis	10	1.18
Cryptomonas	100	11.76

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 06-09-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	4	170	9.94
Cyanophyta (Blue-Green Algae)	1	940	54.97
Bacillariophyta (Diatoms)	3	440	25.73
Chrysophyta (Yellow-Brown Algae)			
Pyrrhophyta (Donoflagellates)			
Cryptophyta (Cryptomonads)	1	80	4.68
Euglenophyta (Euglenoids)	1	80	4.68
TOTAL	10	1710	100.00

Taxon Name	Units/ml	Percent of Population
Oocystis	90	5.26
Chlamydomonas	60	3.51
Cosmarium	10	0.58
Pediastrum	10	0.58
Fragilaria	260	15.20
Melosira	90	5.27
Stephanodiscus	90	5.27
Anabaena	940	54.97
Cryptomonas	80	4.68
Tracheolomonas	80	4.68

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 07-07-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophya (Green Algae)	6	470	88.68
Cyanophyta (Blue-Green Algae)			
Bacillariophyta (Diatoms)	2	30	5.66
Chrysophyta (Yellow-Brown Algae)			
Phrrhophyta (Dinoflagellates)	1	10	1.89
Cryptophyta (Cryptomonads)	1	20	3.77
Euglenophyta (Euglenoids)			
TOTAL	10	530	100.00

Taxon Name	Units/ml	Percent of Population
Cosmarium	40	7.55
Sphaerocystis	330	62.26
Pediastrum	30	5.66
Selenastrum	10	1.89
Oocystis	50	9.43
Ankistrodesmus	10	1.89
Fragilaria	10	1.89
Cocconeis	20	3.77
Cryptomonas	20	3.77
Glenodnium	10	1.89

Appendix A6

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 08-11-81

Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	5	160	7.08
Cyanophyta (Blue-Green Algae)	2	90	3.98
Bacillariophyta (Diatoms)	7	1960	86.73
Chrysophyta (Yellow-Brown Algae)	1	20	0.88
Phrrhophyta (Dinoflagellates)	1	30	1.33
Cryptophyta (Cryptomonads)			
Euglenophyta (Euglenoids)			
TOTAL	16	2260	100.00

Taxon Name	Units/ml	Percent of Population
Staurastrum	60	2.65
Pediastrum	10	0.45
Sphaerocystis	10	0.45
Chlorella	60	2.65
Arthrodesmus	20	0.88
Navicula	1210	53.54
Melosira	380	16.82
Fragilaria	20	0.88
Cymbella	60	2.65
Stephunodiscus	10	0.45
Cocconeis	160	7.08
Synedra	120	5.31
Anabaena	30	1.33
Anacystis	60	2.65
Synura	20	0.88
Peridinium	30	1.33

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 09-15-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	5	110	2.25
Cyanophyta (Blue-Green Algae)	2	4200	85.89
Bacillariophyta(Diatoms)	3	470	9.61
Chrysophyta (Yellow-Brown Algae)			
Pyrrhophyta (Dinoflagellates)	2	110	2.25
Cryptophyta (Cryptomonads)			
Euglenophyta (Euglenoids)			
TOTAL	12	4890	100.00

Taxon Name	Units/ml	Percent of Population
Cosmarium	30	0.61
Sphaerocystis	40	0.82
Ankistrodesmus	10	0.21
Pediastrum	10	0.21
Staurastrum	20	0.41
Melosira	180	3.68
Fragilaria	190	3.89
Cocconeis	100	2.04
Anabaena	3300	67.48
Anacystis	900	18.40
Glenodinium	100	2.04
Gloeodinium	10	0.21

PHYTOPLANKTON UNIT (CLUMP) COUNT

Clear Lake 10-20-81
Site 1 Zero to six foot composite sample

Division	Number of Taxa	Units/ml	Percent of Population
Chlorophyta (Green Algae)	7	300	17.96
Cyanophyta (Blue-Green Algae)	2	760	45.51
Bacillariophyta (Diatoms)	4	480	28.74
Chrysophyta (Yellow-Brown Algae)			
Pyrrhophyta (Dinoflagellates)	1	40	2.40
Cryptophyta (Cryptomonads)	1	90	5.39
Euglenophyta (Euglenoids)			
TOTAL	15	1670	100.00

Taxon Name	Units/ml	Percent of Population
Quadrigula	30	1.80
Closterium	100	5.99
Oocystis	20	1.20
Dictyosphaerium	30	1.80
Sphaerocystis	80	4.78
Pediastrum	30	1.80
Chlamydomonas	10	0.60
Melosira	130	7.78
Fragilaria	60	3.58
Stephanodiscus	280	16.77
Navicula	10	0.60
Anacystis	20	1.20
Anabaena	740	44.31
Cryptomonas	90	5.39
Gloeodinium	40	2.40