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BACKGROUND FOR THE HOGEN PROCESS®™

Minnesota Pollution Control Agency

August 5, 2005
Elise M. Doucette
520 Lafayette Road North
St Paul, Minnesota 55155

RE; Jennie Lake-Iron/Magnetite Treatment

Dear Ms. Doucette

It is interesting that the one non-polluting mechanism for sequestering and / or removing unwanted nutrients from Minnesota's lakes should end up being regulated by the municipal wastewater section.

I will attempt to answer your questions as best I can and will add additional information where necessary to help you to better understand the Hogen Process®™ C.W.T.I is proposing for the rehabilitation of Jennie Lake, MN 47-15.

The project will be done in two segments, with two different materials. The near-shore region of Lake Jennie, waters less than ten feet in depth will be treated with elemental iron powder which we purchase from Prospect Foundry in Minneapolis. The powder is a byproduct of the foundry castings which require clean up of the castings prior to final machining. The product is pure iron and would be reused for cast iron if we were not purchasing it as bagged in approximately 2,400 pound supersacks. Clear Water Technologies, Inc. has been using this byproduct since 1987 for the treatment of lakes and ponds. Our product is collected and the large pieces separated from a large vacuum conveyance system which is used to transport the iron particles to 14 cubic foot supersacks on pallets for subsequent storage and shipping. Prospect Foundry goes to great lengths to quality assure their iron for long term consistency so that it may be turned into high quality castings for the manufacturing companies they serve.

Projects	Treatment Dates
Trillium Lake	
Permit dates	
Feb 15, 1988	mapped 1970
Nov 21, 1990	Jun 1990
	First Treat 1 Oct 1991

Jan 10, 1992 April 1992
Dec 16, 1997 Jun 1994

Lake Martha

Jan 9, 1992 Mar 15, 1992 6.2 gm / sq ft
Jul 22, 1997 Sept 10, 1997 30.0 gm/sq ft

Deep Haven Pond
1990 Jun 15, 1990
Verbal Permit < 2 acres

Peavey Lake
1992
Permit MDNR/MPCA
Aug 1992 Oct 20 1992

Heine Pond
Permit MDNR/MPCA Nov 5, 2000

Lake Benton
Sept 1998 October 1998 treatment
Permit MDNR/MPCA

- | | |
|--------------------------------------|---|
| 1.a Source of iron | Prospect Foundry |
| 1.b Source of Magnetite | USS National Steel Pellet |
| 2.a Material Testing | Furnace AA analysis and TCLP test |
| 2.b Material Testing | Furnace AA analysis and TCLP test |
| 3. Map of Jennie Lake | See Attachment |
| 4.Area dose rate Iron | 35 gm/ square foot limnetic zone 619 acres |
| 4.Area dose rate magnetite | 8.5 gm/square foot deeper than 10' 454 acres |
| 5. Dose rate of iron Lbs / acre | 3,358 pounds / acre |
| 5. Dose rate of magnetite / acre | 815 pounds / acre |
| 6.Total iron used | 1,040 tons |
| 6. Total magnetite used | 185 tons |
| 7. Method of application | Spread from a catamaran style pontoon boat. |
| 8. Time of treatment | During the open water season, mid-September 2005 to the end of October 2005 if possible. If this timing does not work, then spring after ice out of 2006. |
| 9. Anticipated depth of mix, iron | 20 to 30 cm for an <u>iron</u> fraction at 21.6 liters per sq ft of 1.6 grams / liter. |
| 9. anticipated depth of mix, mag | 20 to 30 cm for a magnetite fraction at 21.6 liters per sq ft of 0.39 grams / liter. |
| 10. anticipated iron in water column | |

A short term

B Long Term

78 ug / liter in the pore water (from TCLP Test results)
< 35 ug / liter in the water column, our experience is less iron in the water column following treatment than prior to treatment.
See Trillium Lake Results.

11 A Laboratory Test

Numerous jar tests under both aerobic and anaerobic conditions

11.b TCLP tests 2 ea

One by Instrumental Research Laboratories, one by Braun Testing

Instrumental Research Results confirmed Braun Testing results.

11.c Small scale field tests

Deep Haven Pond, Plot tests on Lake Martha, Plot tests on Lake Benton, Plot tests on Eagle Lake, Plot tests on Orchard Lake, Plot tests on Lee Lake.

Small scale tests on Heine Pond, Eagan 24 acres, small scale test on Peavey lake, Minnetonka

12. Anticipated Benefits

Trillium Lake Reduced nutrients phosphorus, nitrogen, sulfur
Reduction sustained over 17 year period to date

Lake Martha Reduced nutrients phosphorus, nitrogen, sulfur
Reduction sustained over 8 year period to date.
This was the second treatment on Lake Martha as the first was only 6 grams per square foot of iron which was not sufficient to control the nutrients in Lake Martha. This resulted in a greatly reduced curly leaf population and increased water clarity.
See CLMP data

Heine Pond Reduction of available nutrients and subsequent
reduction in curly leaf pondweed (Potamogeton crispus) and an increase in water clarity.

Deephaven Pond Nutrient reduction and particularly removal of
noxious hydrogen sulfide odor resulted in about a 90 % reduction of Lemna minor and Wolfia as well as an almost complete loss of Eurasian watermilfoil (Myriophyllum spicatum).

Peavy Lake Nutrient reduction and particularly removal of
hydrogen sulfide odor resulted in about a 40 to 50 % reduction of curly leaf pondweed and about a 80% reduction in Eurasian watermilfoil.

APPENDIX A

Theory of method

In conjunction with a suitable microbial consortium, Fe^{+3} is utilized as the terminal electron acceptor in anaerobic sediments or an anaerobic hypolimnion. The reduced iron is made available to the anions sulfide and phosphate as a precipitating agent. The virtually complete removal of ionized sulfide from the water column allows the previously adsorbed phosphorus to remain in place, thus removing a major component in the internally recycling phosphorus from the annual water column loading. At a total sulfide concentration of 0.47 mg/l in the presence of an excess of iron there is an ionized concentration of 0.003 mg/l. This value was calculated and experimentally measured from the solubility product of 1×10^{-19} . Sulfide in the presence of calcium as the dominant cation has a solubility of 2.91×10^{-3} moles per liter, or 93 mg/liter. The first dissociation constant of hydrogen sulfide which is 1×10^{-7} then dictates the ionized portion. The molar ionized sulfide becomes 3.16×10^{-4} . Since sulfur has a molecular weight of 32 grams per mole, the ionized sulfide concentration can become 10 milligrams per liter.

The iron released by the heterotrophic bacteria continues to recycle in the water column from the hypolimnion to the metalimnion where it is reoxidized to Fe^{+3} and precipitated as the hydroxide or phosphate. The iron will continue to recycle in this manner until,

- A. It is used up in the process of binding sulfur and phosphorus,
- B. The surface available to react is completely coated with sulfide and phosphorus,
- C. The hypolimnetic biological oxygen demand has been reduced sufficiently to allow a sustained oxygen concentration to shut down the anaerobic oxidation processes which is driven by the iron reducing bacteria. This is apparently the process currently going on in Trillium Lake.

Small amounts of elemental iron were retrieved from the sediments at the treatment sites. The material was retrieved from the lake and pond sediments with a magnet. Analysis shows that the chemical activity on the iron is at the surface, as the particles are essentially intact, but are covered with a coating of sulfide and phosphorus.

APPENDIX B

Soluble Reactive Phosphorus Test

One of the most interesting results of our testing following the lake treatments is that the currently accepted test to describe soluble reactive phosphorus (SRP) may need to be revised. A sample collected from the hypolimnion of Trillium Lake was analyzed under the conditions and time restraints specified in the EPA guidelines for sample collection and analysis.

Six subsamples were analyzed for soluble reactive phosphorus by 0.45 μ filtration followed by colorizing with the ascorbic acid-molybdate reagent. The result was 188 \pm 2 μ g/liter. The pH of the samples following colorization was 0.76.

Six new subsamples were treated in the same manner except that they were passed over columns of a strong anion exchange resin, Bio-Rad, DOWEX 1-X8 20 to 50 mesh, chloride form, to remove all of the ionized phosphorus prior to colorization. The results of these six tests was a concentration of 185 \pm 2 μ g/l. The anion exchange resin had taken up 3 μ g/liter of ionized phosphate showing that the remaining 185 μ g/l was not ionized or available. One hundred percent of the PO_4^{-3} should have been adsorbed to the exchange resin at a pH of 10.3 or less, seventy-five percent of the HPO_4^{-2} should have been adsorbed to the resin at a pH of 6 or less, and about one percent of the $\text{H}_2\text{PO}_4^{-1}$ should have adsorbed to the resin. One point six percent of the total SRP actually was retained on the column. Total suspended solids of 3 milligrams per liter verified the observation that the nutrient was tightly bound and not soluble or reactive.

It is our belief that in the presence of an excess of iron, the vast majority of the nutrient phosphorus is bound, and that this colloidal form is not available as a nutrient for Eurasian watermilfoil and curly-leaf pondweed.

APPENDIX C

Further Data and Analysis for Phosphorus and Sulfur Reduction in Trillium Lake

This appendix provides an analytical basis for reduction in water column iron and nutrient concentrations along with supporting water chemistry data for Trillium Lake.

The appendix contains the following information:

1. Solubility analyses for ferrous sulfide, ferrous phosphate, and hydrogen sulfide. The significance of these analyses is that there is a considerable difference between the solubility products and dissociation constants of the normal calcium/magnesium system. Ferrous sulfide has a very low dissociation constant, but has a potential for high concentrations as colloidal suspensions. These are not chemically reactive.
2. Recycling of phosphorus also explained. Possible concern for sulfate treatments, e.g., FeSO_4 , Al_2SO_4 (Alum) and CuSO_4 . (Caraco 1989)
3. Low concentration of iron in epilimnetic zone waters is also explained.

TRILLIUM LAKE HYPOLIMNETIC SULFIDE, PRE AND POST TREATMENT

Determine the soluble molar concentration of iron from ferrous sulfide which has a solubility product K_{sp} of 6×10^{-18} at atmospheric pressure and 25 degrees Celsius. The water measured was at 4 atmospheres, 5 degrees Celsius, a pH of 5.1, and a reduction / oxidation potential of -176 mv. This is a strongly reducing environment. In this case both the iron and the sulfide are equally charged and can be evaluated by taking the square root of the solubility product. The solubility product for our treatment lake can be back calculated from the field data collected prior to treatment. The calculated solubility product under these circumstances drops to 6.8×10^{-10} .

$$K_{sp} = 6.8 \cdot 10^{-10}$$

$$x = \sqrt{K_{sp}}$$

$$x = 2.608 \cdot 10^{-5}$$

$$\text{Fe} = 55.85 \text{ grams per mole}$$

$$\text{S} = 32.06 \text{ grams per mole}$$

$$\text{grams_Fe} = \text{Fe} \cdot x$$

$$\text{grams_S} = \text{S} \cdot x$$

$$\text{grams_Fe} = 0.001$$

$$\text{grams_S} = 8.36 \cdot 10^{-4}$$

The common ion effect is based on the fact that the solubility product is also the equilibrium constant for the salt. If the iron concentration is raised the sulfide concentration is forced down
micrograms=ug

$$\text{ug_Fe} = \text{grams_Fe} \cdot 10^6$$

$$\text{ug_S} = \text{grams_S} \cdot 10^6$$

$$\text{ug_Fe} = 1.456 \cdot 10^3$$

$$\text{ug_S} = 836.023$$

The other major sulfide salt in the deepest hypolimnetic part of the bay is calcium sulfide which has a solubility product of 7.8×10^{-8}

$$K_{sp} = 5.6 \cdot 10^{-8}$$

$$x = \sqrt{K_{sp}}$$

$$x = 2.366 \cdot 10^{-4}$$

$$\text{Ca} = 40.08 \text{ grams per mole}$$

$$\text{S} = 32.06 \text{ grams per mole}$$

$$\text{grams_Ca} = \text{Ca} \cdot x$$

$$\text{grams_S} = \text{S} \cdot x$$

$$\text{grams_Ca} = 0.009$$

$$\text{grams_S} = 0.008$$

$$\text{ug_Ca} = \text{grams_Ca} \cdot 10^6$$

$$\text{ug_S} = \text{grams_S} \cdot 10^6$$

$$\text{ug_Ca} = 9.485 \cdot 10^3$$

$$\text{ug_S} = 7.587 \cdot 10^3$$

Total sulfide concentration, the sum of the soluble ferrous sulfide and the soluble calcium sulfide, becomes 8423 ug/liter which is very close to the 8 milligrams per liter (8000 ug / liter) measured in the southwest bay of Trillium Lake before the iron treatment.

$$K_{sp} = 6.8 \cdot 10^{-10}$$

$$x = \sqrt{K_{sp}}$$

$$x = 2.608 \cdot 10^{-5}$$

$$Fe = 55.85 \text{ grams per mole}$$

$$S = 32.06 \text{ grams per mole}$$

$$Total_S = 8421 \text{ ug/liter}$$

$$Moles_S = \frac{Total_S}{1 \cdot 10^6 \cdot S}$$

$$Moles_S = 2.627 \cdot 10^{-4}$$

$$Moles_Fe = \frac{K_{sp}}{Moles_S}$$

$$Moles_Fe = 2.589 \cdot 10^{-6}$$

$$Gm_Fe = Moles_Fe \cdot Fe$$

$$Gm_Fe = 1.446 \cdot 10^{-4}$$

$$ug_Fe = Gm_Fe \cdot 1 \cdot 10^6$$

$$ug_Fe = 145$$

By adding iron as magnetite Fe_3O_4 and allowing the heterotrophic microbes to utilize it as an electron acceptor, there is a greatly enhanced solubilized iron concentration as ferrous acetate. The acetate is the major organic product from the microbial growth and respiration.

$$Moles_Fe = \frac{.039}{Fe}$$

$$Moles_Fe = 6.983 \cdot 10^{-4}$$

$$K_{sp} = 6.8 \cdot 10^{-10}$$

$$Moles_S = \frac{K_{sp}}{Moles_Fe}$$

$$Moles_S = 9.738 \cdot 10^{-7}$$

$$Gm_S = Moles_S \cdot S$$

$$Gm_S = 3.122 \cdot 10^{-5}$$

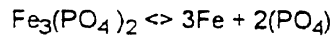
$$ug_S = Gm_S \cdot 10^6$$

$$ug_S = 31.22$$

The remaining soluble concentration was determined by passing the anaerobic sample over a strong anion exchange resin (Dow ex 50) and then fixing the sample to be analyzed for total sulfide. The total sulfide concentration in the eluent was not detectably different from the fixed neat sample. The nondetectable difference is in keeping with the calculated value of 31 ug / liter of ionized sulfide.

TRILLIUM LAKE HYPOLIMNETIC PHOSPHORUS, PRE AND POST TREATMENT

Determine the soluble molar concentration of iron from ferrous phosphate which has a solubility product K_{sp} of 6×10^{-10} at atmospheric pressure, 25 degrees Celsius and an oxidation potential of 175 mv.. The water measured was at 4 atmospheres and 5 degrees celsius and an oxidation potential of -176 mv.. Back calculating puts the K_{sp} for ferrous phosphate at 2×10^{-22} .



$$[\text{Fe}]^2 \times [\text{PO}_4]^3 = K_{sp}$$

$$K_{sp} = 2.0 \cdot 10^{-22}$$

$$\text{Fe} = \sqrt{\frac{K_{sp}}{(3.43 \cdot 10^{-5})^3}}$$

$$\text{Fe} = 7.04 \cdot 10^{-5}$$

$$\text{Fe_MW} = 55.85 \text{ grams per mole}$$

$$\text{grams_Fe} = \text{Fe} \cdot \text{Fe_MW}$$

$$\text{grams_Fe} = 0.004$$

$$\text{grams per mole}$$

$$P = \left[\frac{K_{sp}}{(7.04 \cdot 10^{-5})^2} \right]^{\frac{1}{3}}$$

$$P = 3.43 \cdot 10^{-5}$$

$$P_mw = 32.06$$

$$\text{grams_P} = P \cdot P_mw$$

$$\text{grams_P} = 0.001$$

micrograms=ug

$$\text{ug_Fe} = \text{grams_Fe} \cdot 10^6$$

$$\text{ug_Fe} = 3.932 \cdot 10^3$$

$$\text{ug_P} = \text{grams_P} \cdot 10^6$$

$$\text{ug_P} = 1.1 \cdot 10^3$$

The phosphorus concentration as calculated was very close to the pretreatment value of 1138 ug / Liter. The common ion effect is based on the fact that the solubility product is also the equilibrium constant for the salt. If the iron concentration is raised the sulfide concentration is forced down. Increasing the iron concentration by a factor of ten drives the soluble phosphorus concentration down

$$K_{sp} = 9.8 \cdot 10^{-30}$$

$$\text{Fe} = \sqrt{\frac{K_{sp}}{(5.86 \cdot 10^{-6})^3}}$$

$$\text{Fe} = 2.207 \cdot 10^{-7}$$

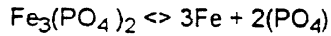
$$\text{Fe_MW} = 55.85 \text{ grams per mole}$$

$$\text{grams_Fe} = \text{Fe} \cdot \text{Fe_MW}$$

$$\text{grams_Fe} = 1.233 \cdot 10^{-5}$$

$$\text{ug_Fe} = \text{grams_Fe} \cdot 10^6$$

$$\text{ug_Fe} = 12.325$$



$$[\text{Fe}]^2 \times [\text{PO}_4]^3 = K_{sp}$$

$$\text{grams per mole } \frac{1}{3}$$

$$P = \left[\frac{K_{sp}}{(1.05 \cdot 10^{-4})^2} \right]^{\frac{1}{3}}$$

$$P = 9.615 \cdot 10^{-8}$$

$$P_mw = 32.06$$

$$\text{grams_P} = P \cdot P_mw$$

$$\text{grams_P} = 3.083 \cdot 10^{-6}$$

$$\text{ug_P} = \text{grams_P} \cdot 10^6$$

$$\text{ug_P} = 3.083$$

Post treatment hypolimnetic total phosphorus concentrations were measured at 188 ug / liter. A new water sample from the bottle was filtered as for a soluble reactive phosphorus (SRP) test, and was colorized and measured. The concentration was measured at 183 ug / l, 97% of the total phosphorus. A third sample was passed over a strong anion exchange column, Dowex 8X, which should extract all of the ionized phosphorus and in this case leave none in solution.

When a sample of this water was run over the Dowex 8X anion exchange column and retested for SRP, the concentration was 180 ug/l, a 98% recovery. This result shows that there is actually very little actual SRP remaining in the lake. The bulk of the phosphorus is bound as solid $\text{Fe}_3(\text{PO}_4)_2$ and in a colloidal suspension rather than as a soluble ion.

The measured concentration of 3 ug / l forces the solubility product down from 10^{-20} to 10^{-30} , proving that it has produced a very insoluble phosphate complex in the treated sediments. The lack of ionized sulfide in this post treatment condition should allow the phosphorus to remain in the sediments.

Another interesting result is that the soluble iron in the post treatment lake is down to 12 ug/l as soluble Fe^{2+} . This is borne out by the lack of iron in the wells surrounding Trillium Lake.

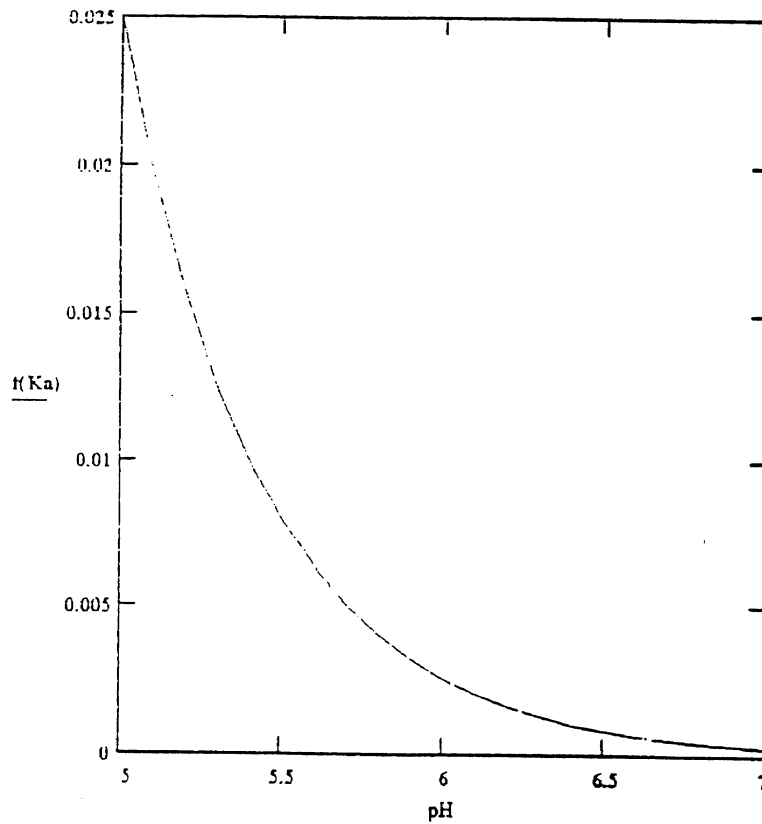
Develop a solubility curve for H₂S and HS⁻

$$K_a = 1 \cdot 10^{-7}$$

$$pH = 5.0, 5.1, \dots, 7$$

$$f(pH) = 10^{-pH}$$

$$f(K_a) = \frac{10^{-pH} \cdot (2.5 \cdot 10^{-4})}{K_a}$$



pH	f(pH)	f(Ka)
5	$5 \cdot 10^{-10}$	0.025
5.1	$3.894 \cdot 10^{-10}$	0.02
5.2	$3.033 \cdot 10^{-10}$	0.016
5.3	$3.033 \cdot 10^{-10}$	0.013
5.4	$2.364 \cdot 10^{-10}$	0.01
5.5	$1.843 \cdot 10^{-10}$	0.008
5.6	$1.437 \cdot 10^{-10}$	0.006
5.7	$1.121 \cdot 10^{-10}$	0.005
5.8	$8.751 \cdot 10^{-11}$	0.004
5.9	$8.751 \cdot 10^{-11}$	0.003
6	$6.831 \cdot 10^{-11}$	0.003
6.1	$5.334 \cdot 10^{-11}$	0.002
6.2	$4.167 \cdot 10^{-11}$	0.002
6.3	$3.255 \cdot 10^{-11}$	0.001
6.4	$3.255 \cdot 10^{-11}$	$9.953 \cdot 10^{-4}$
6.5	$2.544 \cdot 10^{-11}$	$7.906 \cdot 10^{-4}$
6.6	$1.989 \cdot 10^{-11}$	$6.28 \cdot 10^{-4}$
6.7	$1.555 \cdot 10^{-11}$	$4.988 \cdot 10^{-4}$
6.8	$1.216 \cdot 10^{-11}$	$3.962 \cdot 10^{-4}$
6.9	$9.515 \cdot 10^{-12}$	$3.147 \cdot 10^{-4}$
7	$7.445 \cdot 10^{-12}$	$2.5 \cdot 10^{-4}$
	$5.827 \cdot 10^{-12}$	
	$4.561 \cdot 10^{-12}$	
	$3.571 \cdot 10^{-12}$	

APPENDIX D MATERIALS AND METHODS

Instrumental Research, Inc.

State Laboratory No. 027-003-130

TRILLIUM REPORT: Aquatic Chemistry Data From 1991 Treatment Project

Materials and Methods

FIELD SAMPLING EQUIPMENT

Surface Samples - 2 meter composite sampler w/teflon check.

Metalimnion & Hypolimnetic Samples - Van Doran sampler

Sediment Samples - Ekman grab sampler

Dissolved Oxygen / Temperature Meter - YSI Model 57 DO meter w/100 ft cable.

Conductivity Meter - YSI Model 33 S-C-T meter w/100 ft cable

pH Meter - Fisher Scientific Model 107 Digital pH Meter.

ANALYTICAL PROCEDURES

1. Dissolved Oxygen - profiled at three foot intervals, surface to sediment.
2. Temperature - profiled at three foot intervals, surface to sediment.
3. Conductivity - profiled at three foot intervals, surface to sediment.
4. Total Phosphorus - Persulfate digestion followed by an ascorbic acid finish.
5. Total Kjeldahl Nitrogen - Macro Kjeldahl, digested on a Tecator digester, Tecator distillation system, finished with an Orion selective ammonia probe.
6. Ammonia - Direct reading with an Orion selective ammonia electrode using the known addition technique.
7. Nitrate - Direct reading with an Orion selective nitrate electrode using the known addition technique.
8. Sulfate - Standard Methods turbidometric / spectrophotometric technique.
9. Sulfide - Standard Methods Iodometric method.

10. Total Iron - Standard Methods Phenanthroline method.

A complete explanation of all field preparations, calibrations, laboratory methods and procedures, sample management, quality assurance, and quality control is on file with the Minnesota Department of Health as a part of our Minnesota laboratory certification package.

APPENDIX E

TCLP Sediment Test Results and Procedure

A Toxicity Characteristic Leaching Procedure, USEPA Method 1311, has been run on sediment from the limnetic zone of the main bay of Trillium Lake. Sediment samples were treated with elemental iron in doubling doses. Control (no additional iron), 7.71 grams per square foot, 15.4 grams per square foot, and 30.8 grams per square foot. The results are summarized in the attached graph. The heavy metals extracted from the sediments either declined in extracted values compared with the control as the iron treatment concentration increased, or remained substantially the same as the control. The importance is that the sediments as treated with elemental iron from a foundry do not release increased amounts of heavy metals to the lake water.

Sediment samples were collected from the limnetic zone of the main bay of Trillium Lake using an Ekman grab sampler. Sediment samples were deposited in and transported to the laboratory in 20-liter polyethylene buckets with covers. At the laboratory the samples were screened through a 20-mesh sieve to remove seeds, roots, rhizomes, and aquatic plant fragments.

Surface water was collected from the limnetic zone of the main bay of Trillium Lake using a polypropylene diaphragm pump, driven by a twelve volt dc motor. This water was deposited in and transported to the laboratory in 20-liter polyethylene jugs.

Samples were set up in a laboratory series of four bottles each in two replicate series. Each four-liter bottle was established with 500 cc of sediment and 3500 cc of water. The series consisted of two controls (no additional iron added), two bottles treated with an equivalent dose of 7.71 grams of elemental iron per sample, two bottles treated with an equivalent dose of 15.4 grams per square foot of elemental iron, and two bottles treated with an equivalent dose of 30.8 grams per square foot.

The bottles were allowed to equilibrate for two months in the laboratory at which time the top water was siphoned off and the sediments treated as described in the TCLP document.

Additional samples of elemental iron and blank TCLP extraction fluid were tumbled on the rotary agitator and subjected to extraction and subsequent metal analysis. From the TCLP extraction of pure elemental iron, only the extract concentrations of iron and manganese deviated significantly from the treated sediment samples. The TCLP extract from the elemental iron sample was 780,000 ug/liter iron extracted and 7,900 ug/liter of manganese extracted. The sediment samples contained 40 ug/liter of iron

and 350 ug/liter of manganese. The TCLP test is only valid as a decision making test in conjunction with the sediments where it will become the treatment mechanism.

The attached tables summarize the chemical analysis and the graphics, which have been normalized. There is no significant change in the extract fluid as the iron concentration goes from control through treatment level, double treatment level, and quadruple treatment level.

The final two tables include all the conditions for the metal analysis, including duplicates, controls, blanks, and spikes. AA parameters are included with wave lengths and operation conditions.

SEDIMENT TCLP EXTRACTION

	Ele iron	Control	Fe 7.71 gm/sq ft	Fe 15.4 gm/sq ft	Fe 30.8 gm/sq ft
	ug/liter	ug/liter	ug/liter	ug/liter	ug/liter
Mercury	0.89				
Top water		1.47	1.19	0.51	0.33
Pore water		3.79	0.52	0.70	1.73
TCLP Extract		0.33	0.43	0.81	0.83
Zinc	101				
Top water		<1	<1	<1	3
Pore water		61	50	40	44
TCLP Extract		187	148	138	194
Lead	90				
Top water		<60	<60	<60	<60
Pore water		<60	<60	<60	<60
TCLP Extract		<60	<60	<60	<60
Nickel	76				
Top water		<15	<15	<15	<15
Pore water		16	18	23	22
TCLP Extract		55	56	75	66
Manganes	7290				
Top water		<12	<12	<12	<12
Pore water		40	29	33	32
TCLP Extract		387	338	414	349
Iron	788000				
Top water		<35	<35	<35	<35
Pore water		<35	<35	<35	62
TCLP Extract		35	41	42	78
Copper	27				
Top water		<11	<11	<11	<11
Pore water		39	45	62	38
TCLP Extract		<11	<11	<11	19
Chromiurr	47				
Top water		<7	<7	<7	<7
Pore water		14	13	11	8
TCLP Extract		30	28	26	23
Cadmium	22				
Top water		<5	<5	<5	<5
Pore water		<5	<5	<5	<5
TCLP Extract		9	8	10	9
% solids	100	18.1	16.75	17.19	18.38

TCLP1296.XLS

Sample	sample wt grams	Solids wt grams	% solids dewatered	grams of dewatered	ml ext. fluid #1	% solids dry
Control #1	280.76	107.64	38.34%	48.050	950	18.10%
Control #2			38.34%	48.050	950	18.10%
7.71 gm/sq ft	278.33	125.40	45.05%	42.130	843	16.75%
15.4 gm/ft sq	283.78	136.26	48.02%	45.420	908	17.19%
30.8gm/ft sq	287.49	154.45	53.72%	44.130	882	18.38%
ele iron	45	45.00	100.00%	45.000	900	100.00%

	Con/Abs	Con/Abs	Con/Abs	Det	Spike	Lambda	Vert	Slit	Air P	Acet P
Cadmium	5 /.498	0.5 /.073	.005 /.009	0.005	0.5	229.0	7.0	0.7	46.0	21.0
Chromium	10 /.390	1.0 /.047	.005 /.005	0.067	0.5	357.9	6.9	0.7	41.0	38.0
Copper	10 /.427	1.0 /.047	0.10 /.005	0.011	0.5	324.8	7.0	0.7	40.0	20.0
Iron	10 /.253	1.0 /.024	0.10 /.002	0.035	0.5	248.3	7.0	0.2	38.0	36.0
Manganese	10 /.546	1.0 /.067	0.10 /.007	0.012	0.5	279.5	7.0	0.2	33.0	30.0
Nickle	10 /.217	1.0 /.023	0.10 /.002	0.015	0.5	232.2	9.0	0.2	40.0	18.0
Lead	20 /.141	2.0 /.015	0.20 /.002	0.099	0.5	283.3	6.5	0.7	32.0	30.0
Zinc	5 /.648	0.5 /.093	.05 /.013	0.001	0.5	213.9	8.2	0.7	40.0	20.0
Mercury	.010 /.126	.005 /.063	.001 /.021	0.000004	0.001	253.6	6.0	0.7		

	Hi	Mid	Low	Ext fl #1	ug/l	ug/l	ug/l	ug/l
Cadmium	mg/l	mg/l	mg/l	#1 <5	Top H2O	Pore H2O	Extract	22.0
CON	5.000	0.500	0.050	Spike	500 Cont #1	<5	Cont #1	9
ABS	0.438	0.063	0.006		489	7.71 <5	7.71 <5	7.71
						15.40 <5	15.40 <5	15.40
						30.80 <5	30.80 <5	30.80
								10
								9
Chromium	mg/l	mg/l	mg/l	Ext fl #1	ug/l	ug/l	ug/l	ug/l
CON	1.000	0.100	0.010	#1 <7	Top H2O	Pore H2O	Extract	47
ABS	0.043	0.004	0.000	Spike	500 ug/l Cont #1	<7 Cont #1	14 Cont #1	30
					510	7.71	<7 7.71	13 7.71
						15.40	<7 15.40	11 15.40
						30.80	<7 30.80	8 30.80
								23
Copper	mg/l	mg/l	mg/l	Ext fl #1	ug/l	ug/l	ug/l	ug/l
CON	1.000	0.100	0.010	#1 <11	Top H2O	Pore H2O	Extract	27
ABS	0.092	0.009	0.001	Spike	500 ug/l Cont #1	<11 Cont #1	39 Cont #1	<11
					501	7.71	<11 7.71	45 7.71
						15.40	<11 15.40	62 15.40
						30.80	<11 30.80	38 30.80
								19
Iron	mg/l	mg/l	mg/l	Ext fl #1	ug/l	ug/l	ug/l	ug/l
CON	1.000	0.100	0.010	#1 <35	Top H2O	Pore H2O	Extract	788000
ABS	0.029	0.003	0.000	Spike	500 ug/l Cont #1	<35	Cont #1 <35	Cont #1 <35
					502	7.71	<35 7.71	<35 7.71
						15.40	<35 15.40	<35 15.40
						30.80	<35 30.80	62 30.80
								78
Manganese	mg/l	mg/l	mg/l	Ext fl #1	ug/l	ug/l	ug/l	ug/l
CON	1.000	0.100	0.010	#1 <12	Top H2O	Pore H2O	Extract	7290
ABS	0.031	0.003	0.000	Spike	500 ug/l Cont #1	<12	Cont #1	40 Cont #1
					508	7.71	<12 7.71	29 7.71
						15.40	<12 15.40	33 15.40
						30.80	<12 30.80	32 30.80
								349
Nickel	mg/l	mg/l	mg/l	Ext fl #1	ug/l	ug/l	ug/l	ug/l
CON	1.000	0.100	0.010	#1 <15	Top H2O	Pore H2O	Extract	72
ABS	0.032	0.003	0.000	Spike	500 ug/l Cont #1	<15	Cont #1	16 Cont #1
					495	7.71	<15 7.71	18 7.71
						15.40	<15 15.40	23 15.40
						30.80	<15 30.80	22 30.80
								66

TCLP1296.XLS

Lead	mg/l			Ext fl #1	ug/l	Top H2O	ug/l	ug/l		Extract	ug/l
	CON	ABS	Spike		<60		Cont #1	Pore H2O	Cont #1		90
CON	2.000	0.200	0.020	500	480	7.71	<60	7.71	<60	7.71	<60
ABS	0.170	0.017	0.002			15.40	<60	15.40	<60	15.40	<60
						30.80	<60	30.80	<60	30.80	<60

Zinc	mg/l			Ext fl #1	ug/l	Top H2O	ug/l	ug/l		Extract	ug/l
	CON	ABS	Spike		<1		Cont #1	Pore H2O	Cont #1		101
CON	5.000	0.500	0.050	500	486	7.71	<1	7.71	50	7.71	148
ABS	0.643	0.093	0.009			15.40	<1	15.40	40	15.40	138
						30.80	3	30.80	44	30.80	194

Mercury	ug/l			Ext fl #1	<0.004	Top H2O	ug/l	ug/l		Extract	ug/l
	CON	ABS	Spike		1.00		Cont #1	Pore H2O	Cont #1		0.89
CON	5.000	2.000	1.000	1.00	0.98	7.71	1.190	7.71	0.520	7.71	0.43
ABS	1.456	0.577	0.286			15.40	0.510	15.40	0.700	15.40	0.81
						30.80	0.330	30.80	1.730	30.80	0.83

TCLP SEDIMENT EXTRACTS

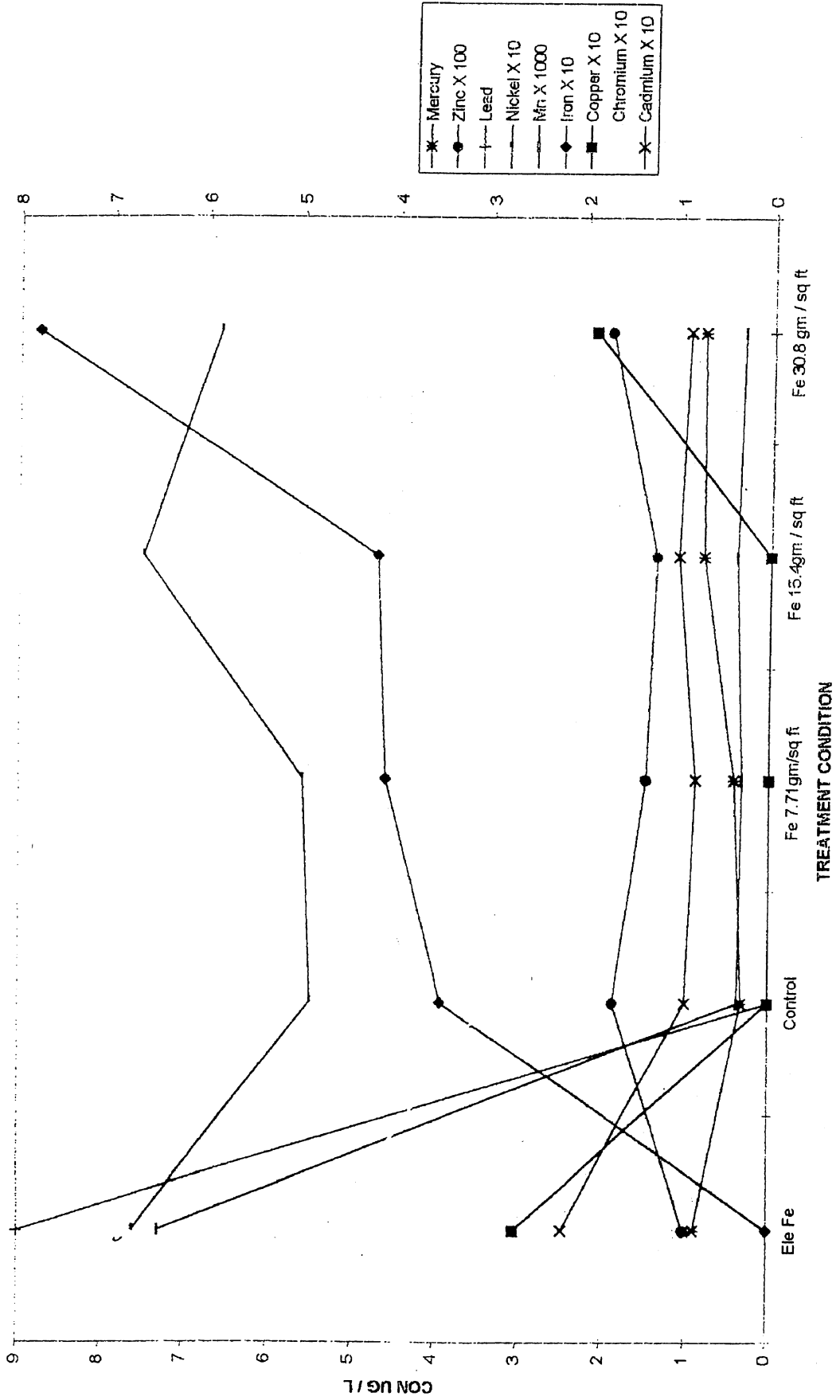


FIGURE 1

TRILLIUM LAKE: (S. BAY) SULFIDE RESPONSE TO IRON TREATMENT

Trillium Lake (S Bay) Sulfide Response to Iron Treatment

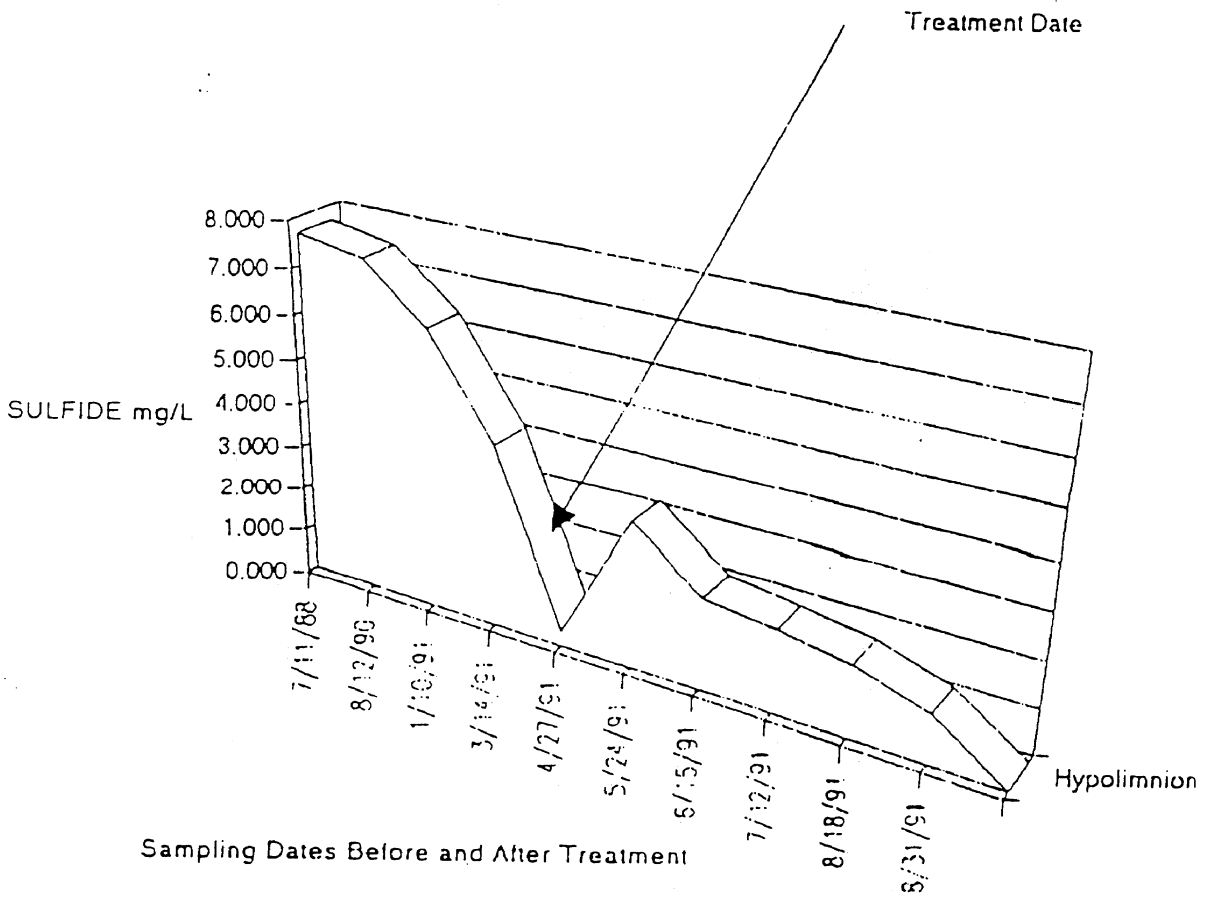


FIGURE 2
 TRILLIUM LAKE: (S. BAY) SULFATE RESPONSE TO IRON TREATMENT

Trillium Lake (S Bay) Sulfate Response to Iron Treatment

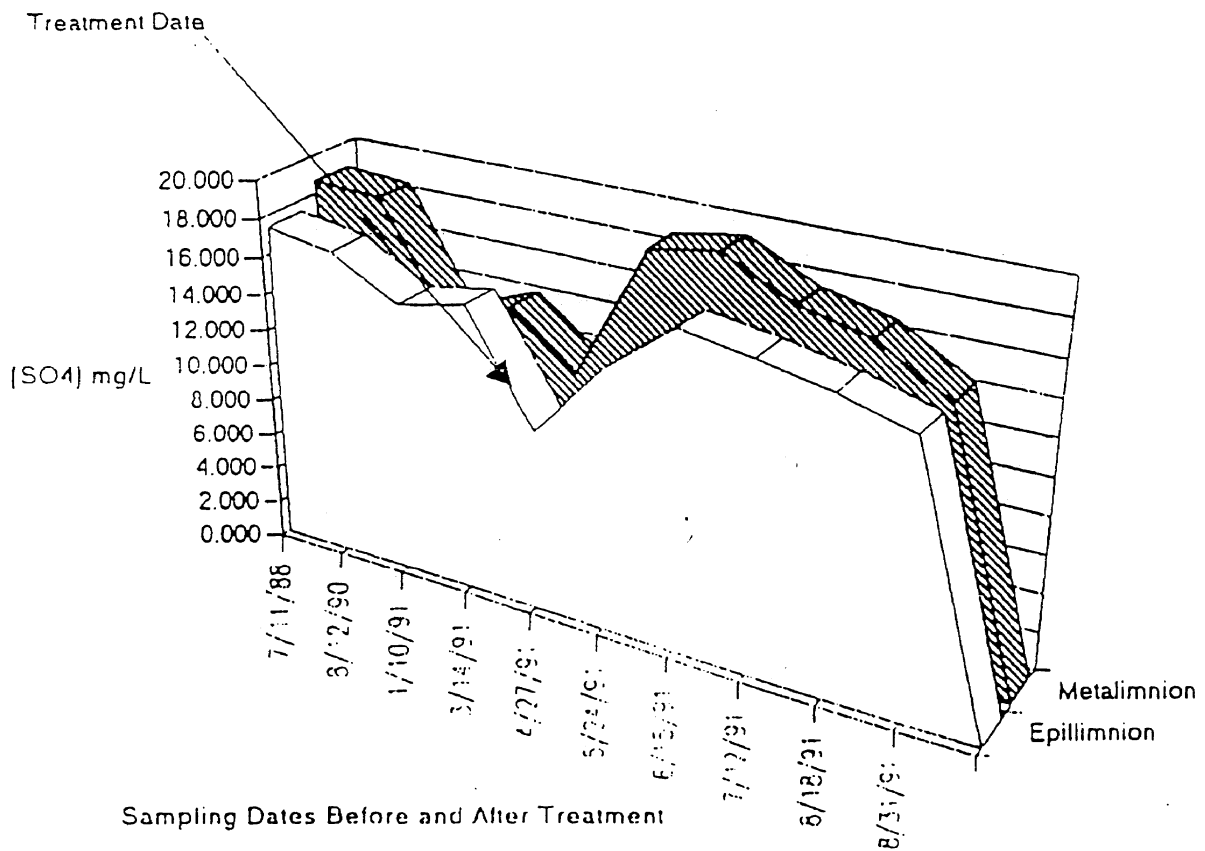


FIGURE 3
 TRILLIUM LAKE: (S. BAY) PHOSPHORUS RESPONSE TO IRON
 TREATMENT

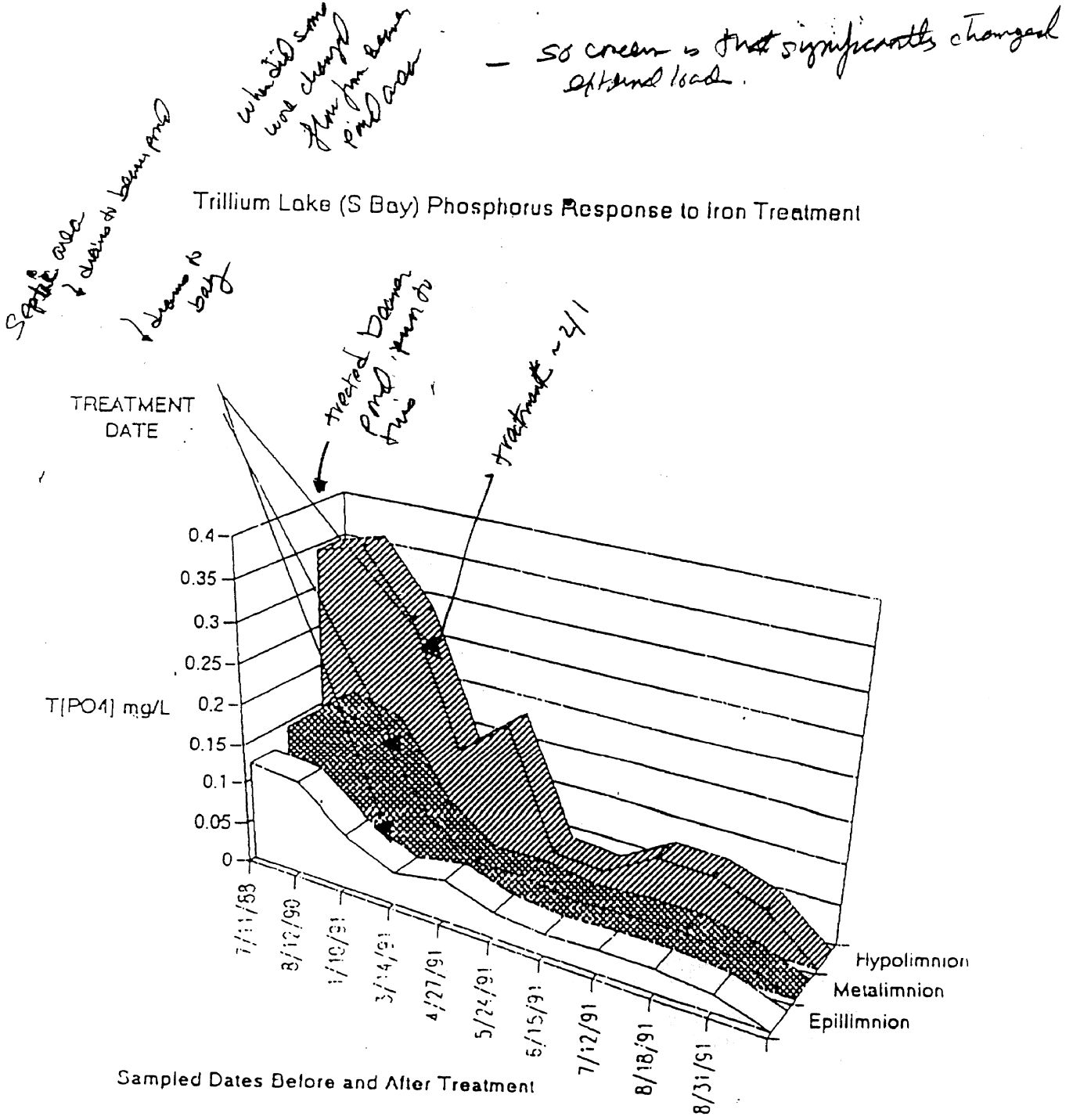


FIGURE 4
 TRILLIUM LAKE: CHANGE IN AVERAGE SUMMER SECCHI DISK
 DEPTH FROM 1988-1991 TO 1992-1995 PERIOD

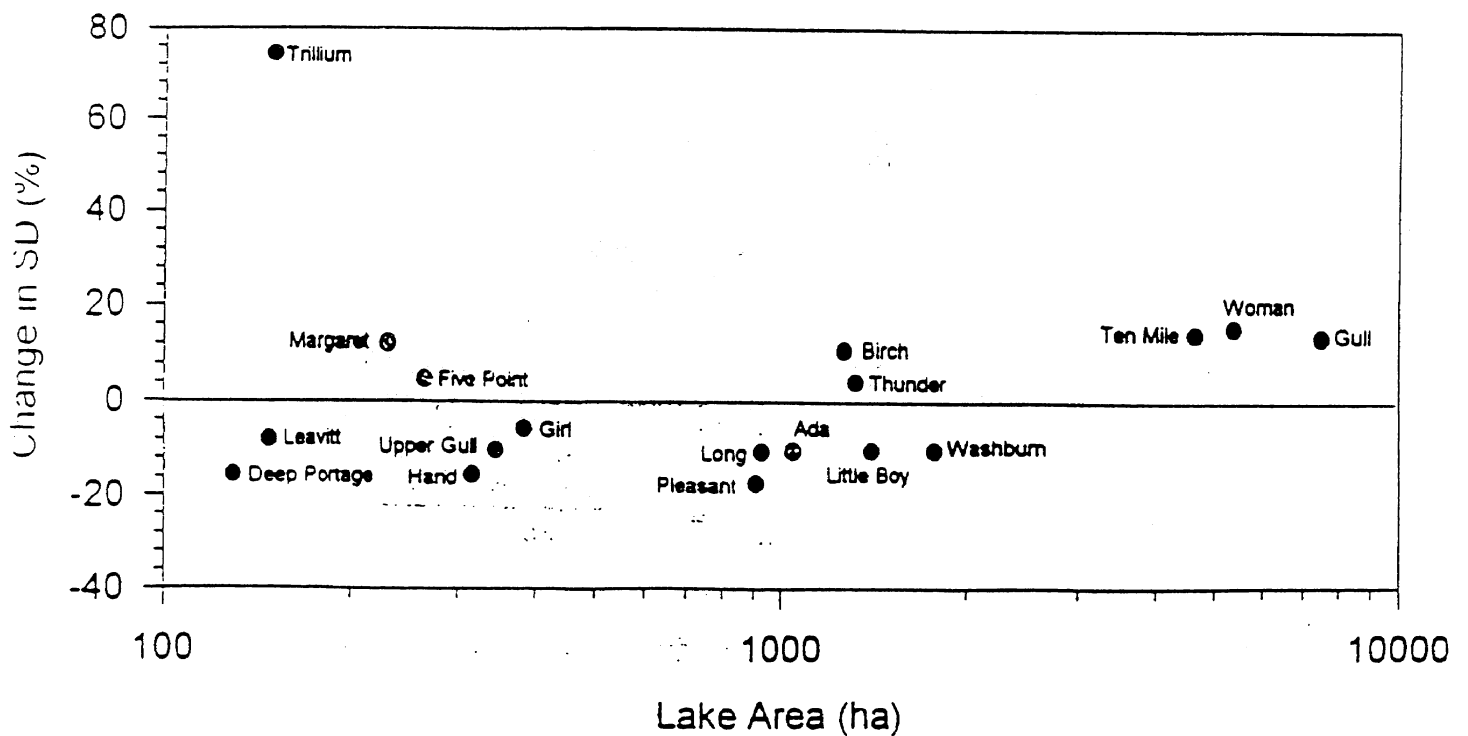
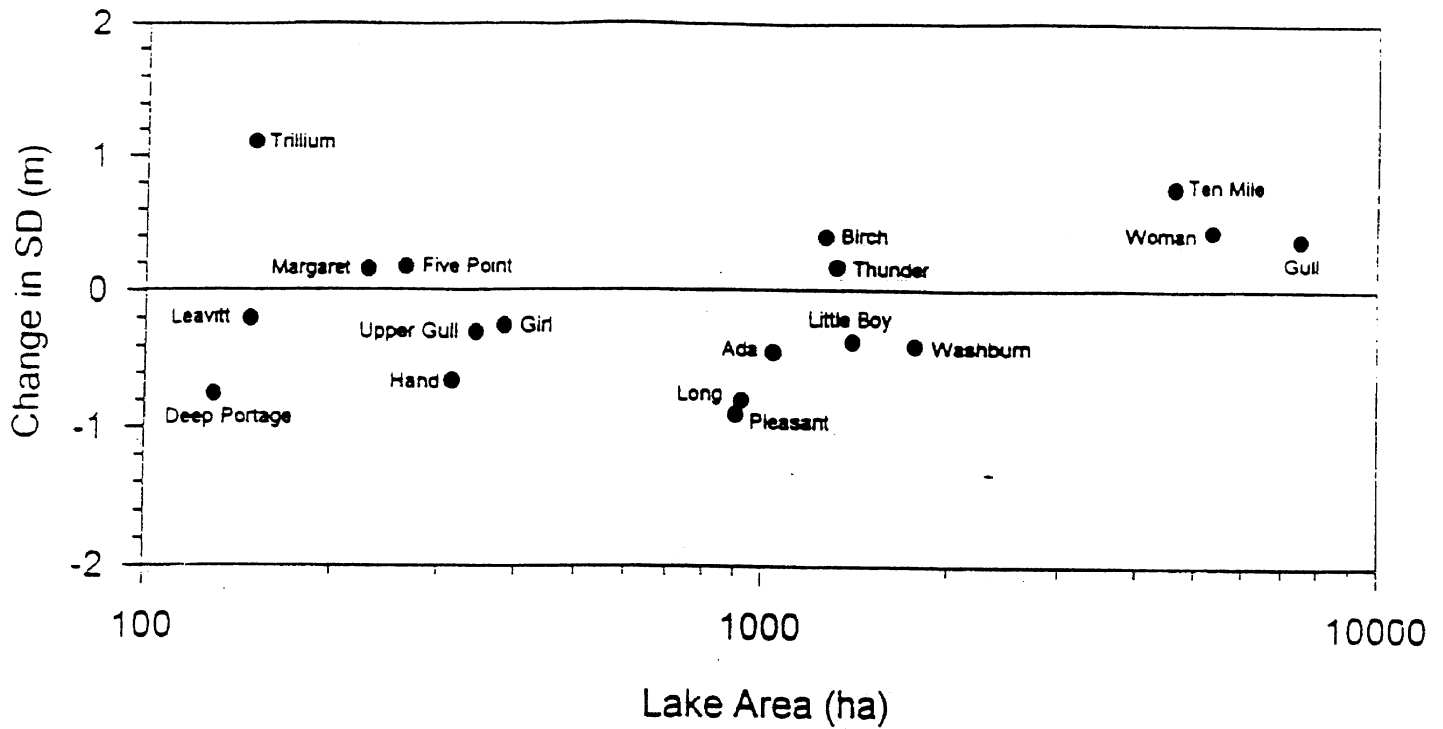


FIGURE 5
TRILLIUM LAKE: MONTHLY MEAN SECCHI DISK DEPTH AND RANGE
FOR THE PRE-TREATMENT PERIOD (1988-1991) IS SHOWN ALONG WITH
THE MEAN VALUES IN THE FIRST THREE POST-TREATMENT YEARS
(1992-1994)

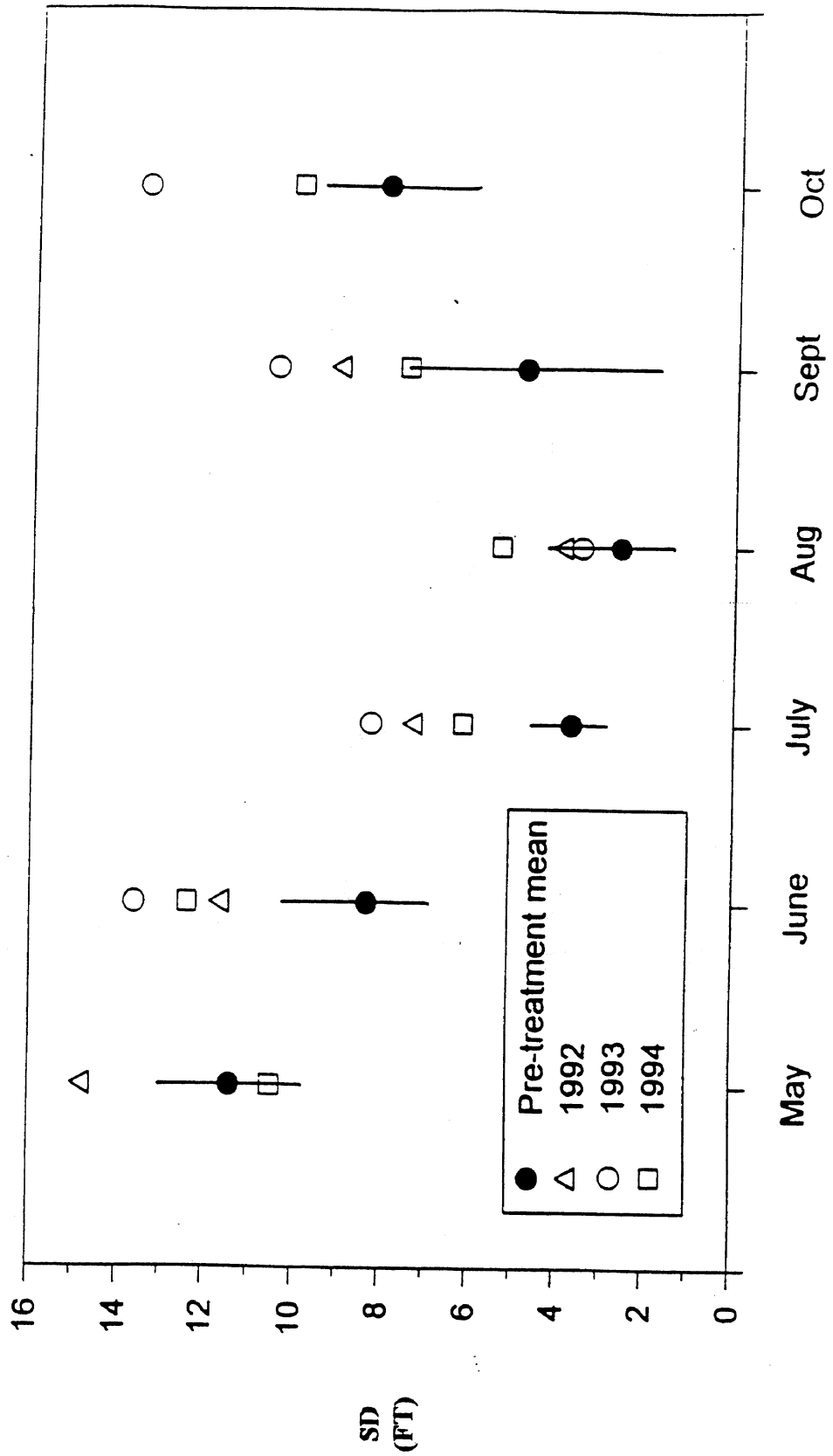


FIGURE 6
WATER COLUMN DATA

TRILLIUM LAKE MAIN BAY

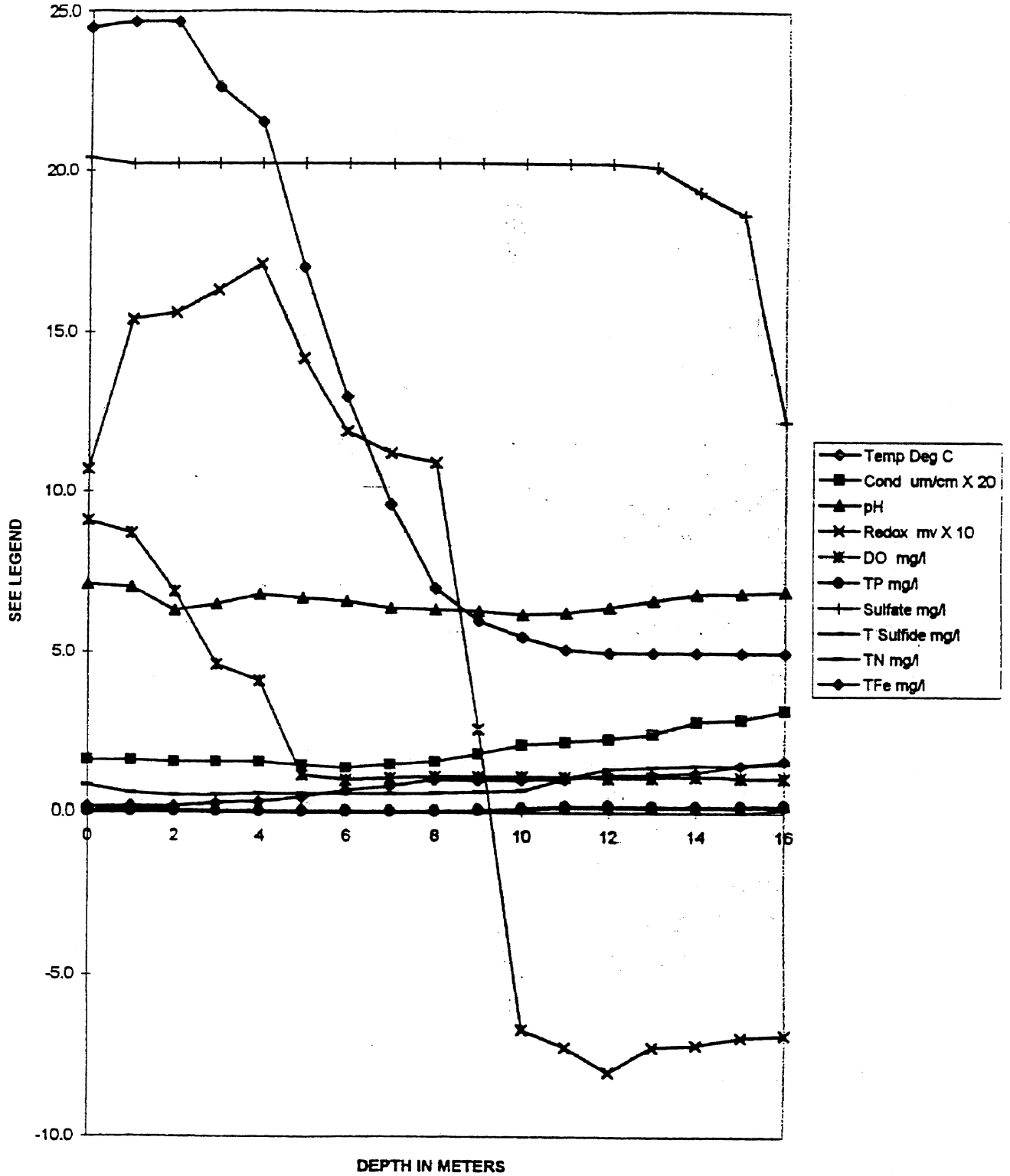


FIGURE 7
WATER COLUMN DATA

Trillium Lake 8/17/96
South Bay

