ting Wetlands on Acid-Generating Tailings; An Alternative to Encapsulation

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Acknowledgments

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Executive Summary

Background

Current approaches to reclaiming acid generating tailings include permanent water cover or encapsulation with various synthetic liners and/or clay. Although these methods can be effective, some maintenance will be required in perpetuity to ensure that water levels are adequately maintained or that the integrity of any capping system is protected. The successful creation of wetlands in tailings basins offers the possibility of creating a stable environment for the tailings with minimal maintenance.

Approach

Acid-generating tailings from a massive zinc sulfide deposit in Winston Lake, Ontario, were placed in small cylindrical tanks to examine the feasibility and effectiveness of creating wetlands and mitigating acid and metal release. Two uncovered controls were established in addition to the five treatments, which were done in duplicate. Each wetland tank was 117 cm in diameter and contained 61 cm of tailings. Treatments included 61 cm cover of wetland soil, 61 cm of glacial till, 61 cm of tailings, and two tanks with 71 cm of water. One of the water covers included the aquatic macrophytes: *Elodea canadensis*, *Potamegeton sp.*, and *Ceratophyllum demersum*. Cattails (*Typha sp.*) were planted in the tanks with substrate cover, and the initial water level was set at ten centimeters.

Results

Untreated tailings produced highly acidic drainage with an average pH of 3.15, an acidity of 18,000 mg/L and 6,900 mg/L zinc, while the tailings in the treated tanks had average pH values between 6.0 and 6.5, and average zinc concentrations of 0.02 to 0.1 mg/L. Both pH and zinc in the treated tailings were fairly constant over the three years of the study.

Water levels in all tanks fluctuated in response to precipitation and evapotranspiration. In the treatments without cattails, precipitation exceeded evaporation, and water levels generally increased over time and water had to be removed from the tanks to prevent overflow in 1999. In the tanks with cattails, evapotranspiration exceeded precipitation and surface water evaporated in 1998. Water was added to one tank of each treatment to maintain a saturated level above the bottom layer of tailings.

For the six tanks with cover layers, only the tanks with tailings cover (tanks 2, 7) released significant amounts of acid and zinc to surface water. The pH in the surface water of these tanks decreased to less than 4 after the surface of the tailings dried out and oxidation occurred. No transport of sulfate or zinc from the covered tailings to the surface water was observed in the tanks with the peat and glacial till covers.

Water covers were also effective in preventing acidification of the surface water and reducing sulfate and zinc release, particularly when aquatic plants were added to the water cover. The average total

sulfate release from the tanks with water cover and plants (tanks 3, 10) was about one-third the release in the tanks with only water cover (tanks 1, 9). Over the course of the study there was no increase in zinc concentrations in the surface water of the tanks that included vegetation (tanks 3, 10). The presence of the plants also increased surface water pH and produced a cover of organic detritus on the surface of the tailings, which consumes oxygen and limits sulfate oxidation in the underlying tailings.

Conclusions

Wetlands created over acid generating tailings are effective at preventing acid conditions and minimizing metal release. In large tailings basins, covering the shoreline with 60 cm of soil cover and establishing submergent vegetation in the deeper water areas appears to be an effective mitigation approach.

Introduction

Environmental problems caused by acid generating tailings have occurred throughout the world. Many of these mining sites were developed before the magnitude of the acid generating problem was identified, and today control of acid generating tailings is a critical component in the development of any new mine. Extensive testing is required to identify acid generating waste, and reclamation plans must include provisions to prevent or treat any acid produced at the site.

Acid generation occurs when the residual iron sulfide minerals in the tailings are exposed to oxygen and oxidize. This reaction can be represented as:

$$2\ FeS + 3\ H_2O + 9/2\ O_2 = 2\ FeOOH + 4\ H^+ + 2\ SO_4^{-2} \qquad [1]$$

If the tailings do not contain an excess of neutralizing minerals (i.e. calcium carbonate), drainage from the tailings will be acidic and may contain elevated concentrations of trace metals. The production of acidic drainage requires iron sulfides, oxygen, and water. To stop the production of acid, at least one of these three components must be controlled or eliminated.

One approach is to reduce the total amount of iron sulfide in the tailings basin by removing them in a flotation circuit within the processing plant. Although this can be effective, the sulfide fraction is highly reactive and this method may not be cost effective for ore bodies with high iron sulfide content. An alternative approach is to remove the iron sulfides from the final tailings layer, which will then act as a cover for the basin. Experimental tests using lower sulfide tailings have shown an attenuation in the migration of acidity, but some trace metal release has occurred (Davé et al., 1997, Elliot et al., 1997).

Minimizing the volume of water that contacts the tailings, and reducing the transport of reaction products from the tailings, is a strategy which has been implemented at various mine sites. A cover with low permeability is placed over the tailings to limit water infiltration. Cover types include synthetic membrane materials (such as high density polyethylene), compacted clay, or a combination of these materials (Eger et al., 1999; Wilson et al., 1997). In order to ensure that these covers are maintained, an ongoing monitoring and maintenance program is required. In dry climates, covers can be designed to store water during the wet season, and evaporate the water during the dry season (Swanson et al., 1997).

Currently, the most common approach for controlling acid generating tailings is to limit oxygen diffusion into the tailings by utilizing a water cover (Li et al., 1997). Oxygen concentrations in water are generally less than 10 mg/L, or a factor of 20,000 less than the concentration in air. General recommendations call for a water cover of at least 1 meter in depth (Feasby et al., 1997). Although this approach has drastically reduced the oxidation of the tailings, and has generally prevented acid conditions, metal release has still occurred (Aubé et al., 1995). While keeping the tailings totally submerged during operation is achievable, long-term maintenance of water holding dams becomes a concern when mining is completed (Aubertin et al., 1997).

In Minnesota, the maximum depth of water that can be left in a tailings basins at the end of operation is 2 meters, due to dam safety rules. While this may be sufficient to minimize acid production in the center of the tailings basin, it will not provide protection for the tailings along the perimeter of the basin, or the "beach" areas. Creating a wetland over these areas could produce an anoxic layer above the tailings and minimize acid generation.

Objectives

The goal of this project is to evaluate the effectiveness of reclaiming non-ferrous tailings basins by constructing wetlands over them to prevent water quality problems from developing. With this goal in mind, the specific objectives of this project were to:

- Establish wetland vegetation over acid generating tailings.
- Determine the effectiveness of created wetlands, with various substrates and water depths, to reduce acid generation and metal release.

Methods

Materials

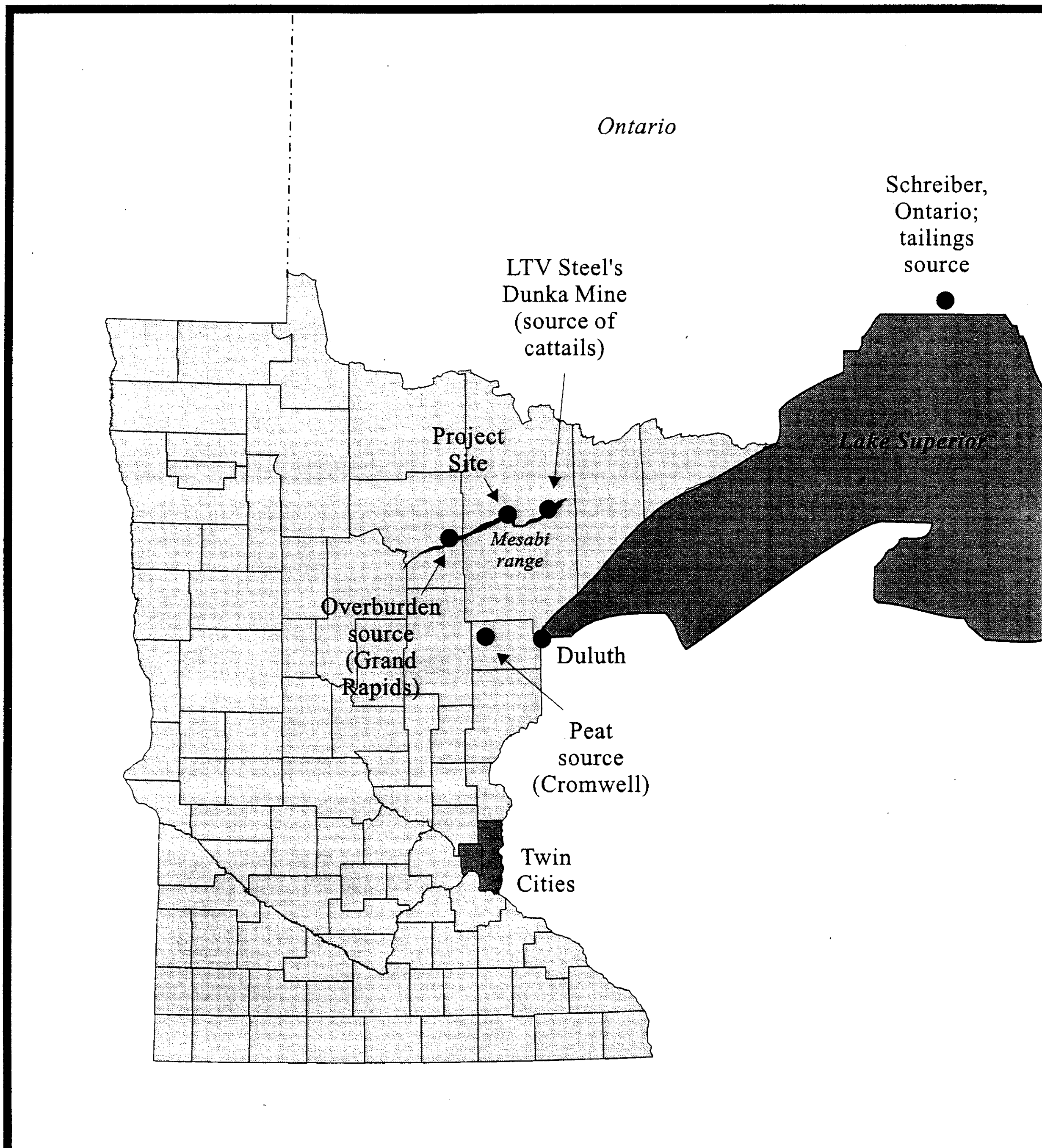
Tailings

Tailings were obtained from the INMET Mining Company, Winston Lake Division, in Schreiber, Ontario (Figure 1). The Winston Lake deposit is a volcanogenic massive sulfide deposit with a typical composition of 30-40% sphalerite, 3-5% chalcopyrite, 15-20% pyrrhotite, and 5-10% pyrite . The ore is crushed, ground, and floated in a standard flotation circuit. The tailings are primarily fine sand and silt, with 41% finer than 74 microns and 22% finer than 37 microns (see attachments A1.1. - A1.3. for additional detail on tailings). The tailings had been produced in early 1997, excavated from a saturated area, and allowed to drain for about a week prior to shipment. Some small areas of visible oxidation were observed, but these were removed prior to loading the tailings into the tanks.

Composite samples of the tailing were taken for chemical analysis while the tanks were being filled. The first sample (composite #1) was a composite of 20 samples taken from around the pile shortly after the tailings were dumped, and prior to removing any tailings. The second sample was a combination of two composite samples (composites 2 and 3); one taken after the first 30.5 cm of tailings had been placed in the tanks, and the second taken just before all the tailings layers were brought up to their final elevation. Each of these two composites were made from 15 grab samples collected from the newly exposed face of the tailings pile. Composite 4 was collected prior to adding the tailings to the on land control tanks, and consisted of 20 grab samples collected around the remaining tailings pile.

The tailings were analyzed by X-ray diffraction and ICP-AES at Midland Research in Nashwauk, MN. The tailings were 25-30% quartz, 15-20% feldspar, and 22-27% pyrrhotite and contained 13%

Figure 1. Locations of project site and sources of materials.



sulfide and 1.8% zinc. The acid production potential was 393 kg $CaCO_3$ per ton, while the neutralization potential was only 11 kg $CaCO_3$ per ton. Sulfur species and CO_2 analyses were determined by Lerch Bros. in Hibbing, MN. Whole rock and trace element analyses were determined by Chemex Labs in Sparks, NV (Tables A3.1. and A3.2), and particle size distribution was determined at Midland Research (Tables A3.5 - A3.8.). Neutralization potential was determined by the Minnesota Department of Natural Resources (DNR) laboratory in Hibbing, MN (attachment A3.1.).

Soil Covers

The peat was a well decomposed reed sedge peat with a pH of 4.3, and was provided by Michigan Peat Co. in Cromwell, MN (Figure 1). The glacial till was a silty clay material with a pH of 7.0 and was obtained from Brink Sand and Gravel Co. in Grand Rapids, MN. Chemical analyses of the peat and glacial till were determined by the University of Minnesota Soil Testing and Research Lab in St. Paul, MN and are presented in Table A3.3. Particle size distribution of the glacial till is tabulated in Table A3.4.

Experimental Design

Wetland Tanks

This experiment is located at the Minnesota Department of Natural Resources (DNR) research site in Hibbing, MN. The installation consists of 12 tanks, 2 of which are duplicate control tanks that contain unsaturated tailings. The other 10 tanks represent 5 different treatments, each of which were also done in duplicate (Figure 2).

The five treatments for the reactive tailings included:

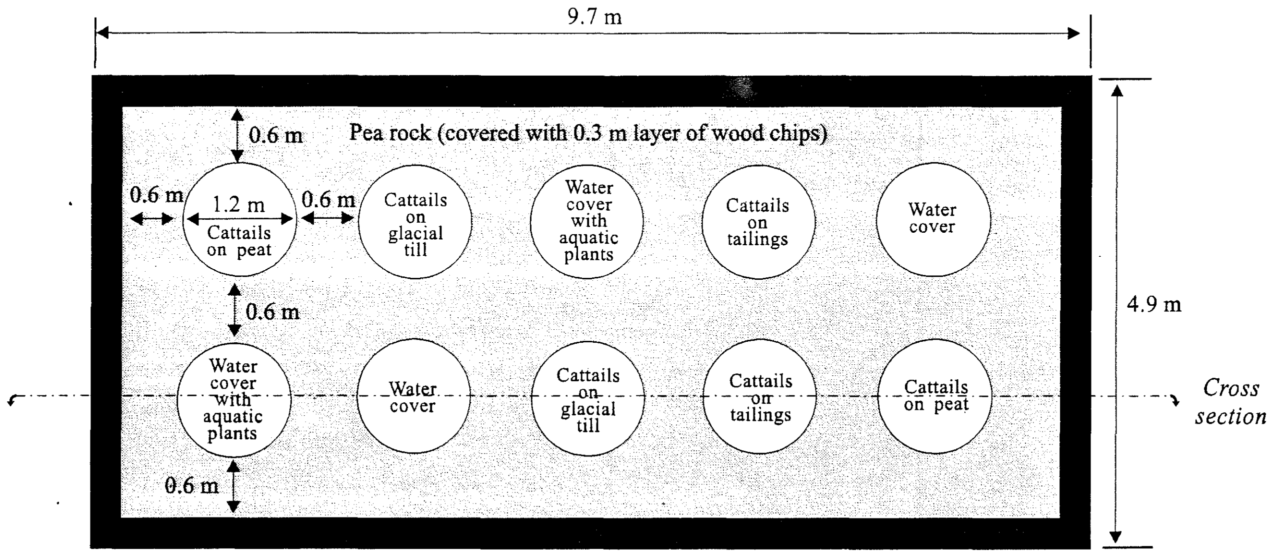
1. Water cover
2. Water cover with submerged aquatics
3. Peat planted with cattails
4. Glacial till planted with cattails
5. Reactive tailings planted with cattails

These treatments were chosen to examine not only the effect of a substrate cover and wetland vegetation, but also the effect of water covers alone. Annual precipitation exceeds evapotranspiration in northeastern Minnesota by 22 cm, so a lined tailings basin should always remain saturated. Locally available soils, both wetland and mineral soil, were used to create a favorable growth media as well as provide a barrier between the acid generating tailings and the surface water. Water levels in northern Minnesota peatlands typically do not fluctuate more than 30 cm annually and the roots of wetland species are generally confined to the upper 30 cm of the soil (Melchert et al., 1997). The 60 cm cover was chosen to protect the underlying tailings from root contact and unsaturated conditions.

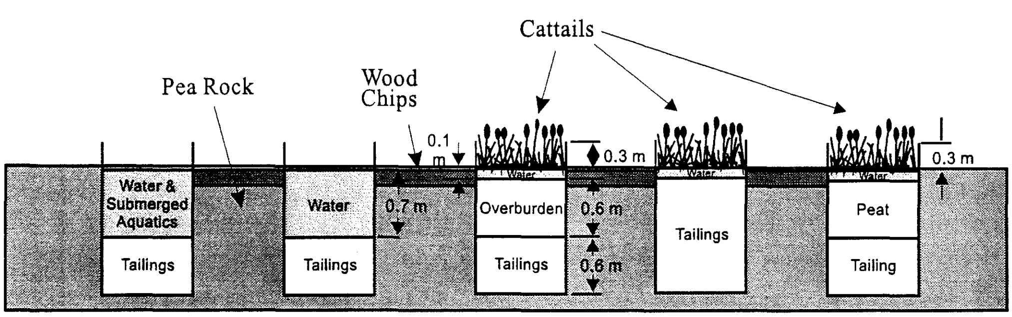
Cylindrical polyethylene open top tanks with a diameter of 117 centimeters and a depth of 163 centimeters were used for the treated plots. An ultraviolet-resistant Supralloy PVC liner (0.76 mm

Figure 2. Experimental design (top view and cross section).

Top View



Cross section



thick) was fitted inside each tank for double containment. The tanks were installed in the ground to simulate natural thermal conditions. The construction design consisted of excavating a hole into which 15 cm of pea rock was placed. A 10 cm diameter drain tile was placed around the bottom of the hole and drained down slope of the plots. The tanks were placed on the 15 cm deep pea rock pad and additional pea rock was added to a depth of 107 cm. A 30.5 cm layer of wood chips was placed over the pea rock (Figure 3).

Each treatment was applied in duplicate. In previous experiments with fairly uniform material, duplicate treatments provided data that was sufficient to determine the effectiveness of the mitigation approach (Lapakko and Eger, 1981; Eger et al., 1984). A split block design was used to randomly assign the location of each treatment (Figure 2).

Each tank was filled to a depth of 61 centimeters with tailings. In order to minimize the variability between the tanks, tailings were shoveled into 20-liter buckets from various portions of the pile and manually placed in the tanks. A sampling well constructed from 1.27 cm schedule 40 PVC well screen was installed horizontally 23 centimeters above the bottom of the tank (Figure 4). The well screen was half-slotted (slots are on one side only) with 0.3 mm wide slots. A groove was made in the tailing for the well screen and then a layer of silica sand (Unimin 4075; 0.45 mm effective filtration size) about 6 mm thick was placed in the groove. The well screen was then seated in the groove with the slots facing down. Additional sand was placed on the sides of the well screen to cover the slots, and then the tanks were filled with approxomately 38 cm of tailings. The tailings were then covered with 61 centimeters of either reed sedge peat, glacial overburden, tailings, or 71 centimeters of water.

For the tanks with soil covers, a 1.27 cm PVC well was installed horizontally 30.5 cm below the surface. Riser pipes extended above the top of the tanks. In order to minimize the chance of water movement down the riser pipe, a 7.5 cm acrylic flange was installed about 18 cm below the tailings surface. This depth was chosen to ensure that the flange would still be covered if extreme settling occurred. (Very little settling occurred during the first ten days after construction and saturation.) Prior to adding the flange, a 5 cm square wooden stake was used to tamp the tailing under the flange to minimize settling. After the flange was in place, moist bentonite (with the consistency of putty) was placed over the flange to seal it to the pipe. The top of the pipe was equipped with a ball valve which remains closed, except when sampling, to prevent direct oxygen transport into the bed. The valve was fitted with a 6 mm hose adaptor to facilitate sampling with a peristaltic sampling pump. Slotted well screens (12-mm diameter) were installed vertically 61 cm into the substrate and approximately 10 cm in from the tank wall in the shallow water tanks, so water levels could be measured when no surface water was present.

Eighty grams of inorganic fertilizer containing 10% nitrogen, 10% phosphorus, and 10% potassium were incorporated to a depth of 5 centimeters in the substrates of the shallow water tanks. Sixteen mature cattails (*Typha sp.*), collected from a constructed wetland used to treat mine drainage at LTV Steel Co.'s Dunka Mine (Figure 1), were transplanted in each of these tanks on 30 cm centers. Prior to planting, the cattails were rinsed to remove the soil and the tops were cut off to leave a 23 cm stem.

Figure 3. Cross section of the wetlands-on-tailings installation.

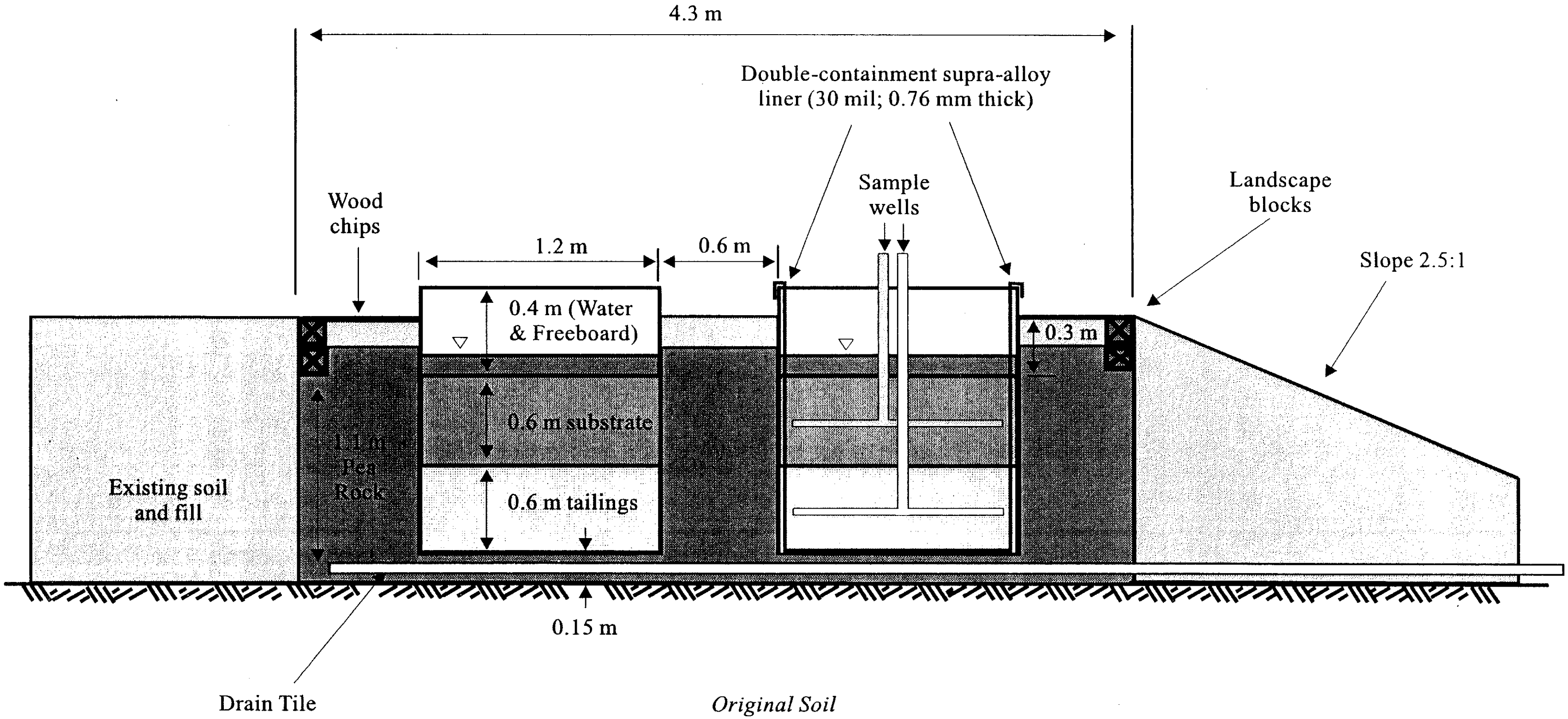
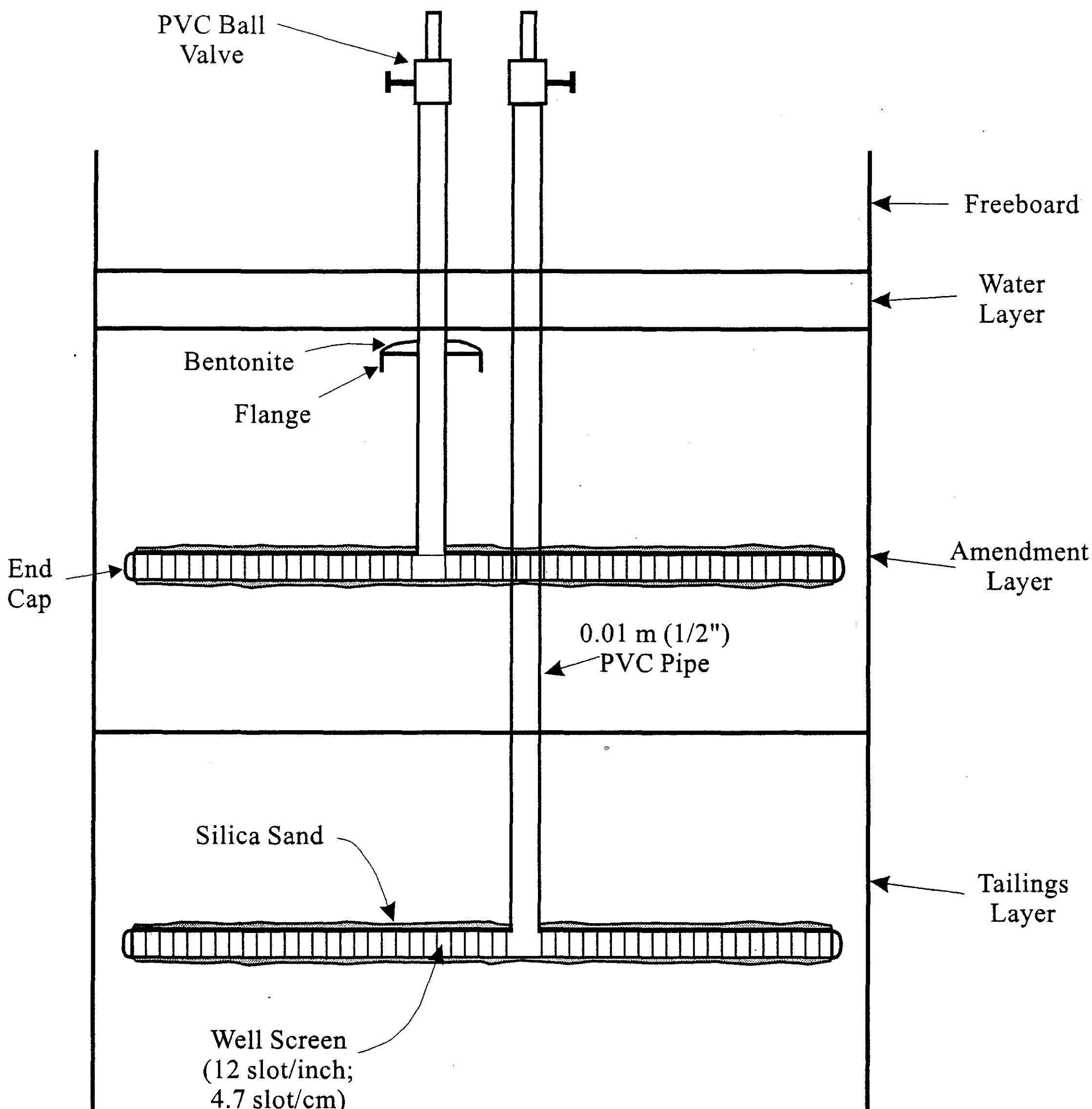


Figure 4. Sampling well design.



The same amount of fertilizer was also added, but not incorporated, to the deep water tanks prior to the addition of the submergent aquatic plants. The submerged plants added to each of tanks 3 and 10 included 580 grams of *Elodea canadensis*, 1345 grams of coontail (*Ceratophyllum demersum*), and 135 grams of long leaf pondweed (*Potamogeton sp.*). (All weights are wet, drained weight.) On a volumetric basis, *Elodea* and coontail were planted at an estimated rate of around 120 m^3/ha and the pondweed was planted at an estimated rate of around 17.5 m^3/ha. These plants were donated by Marshland Transplant Aquatics in Berlin, WI.

All the tanks were then filled to within 30 cm of the top of the tank with water from a groundwater well at the Hibbing research site. About 60 liters of residual water had separated from the tailings during shipment. This water was collected and evenly distributed into the water used to fill the tanks. The final water depths in the shallow water and deep water tanks were about 10 and 71 centimeters, respectively. The groundwater was alkaline (190 mg/L as $CaCO_3$), with a pH of 7.2, 71 mg/L sulfate and <0.02 mg/L zinc (Table A2.2.). Due to drought conditions, additional groundwater was added to tanks 6, 7, and 8 in August and September of 1998 to maintain a saturated cover layer above the tailings. In 1999, despite near record precipitation, additional water was added to the tank with peat (tank 6) in September. In October 1999, 5 to 19 cm of water was removed from all tanks (except 5, 6) to provide 30 cm of freeboard prior to freeze up (Appendix 8).

On-land Control Tanks

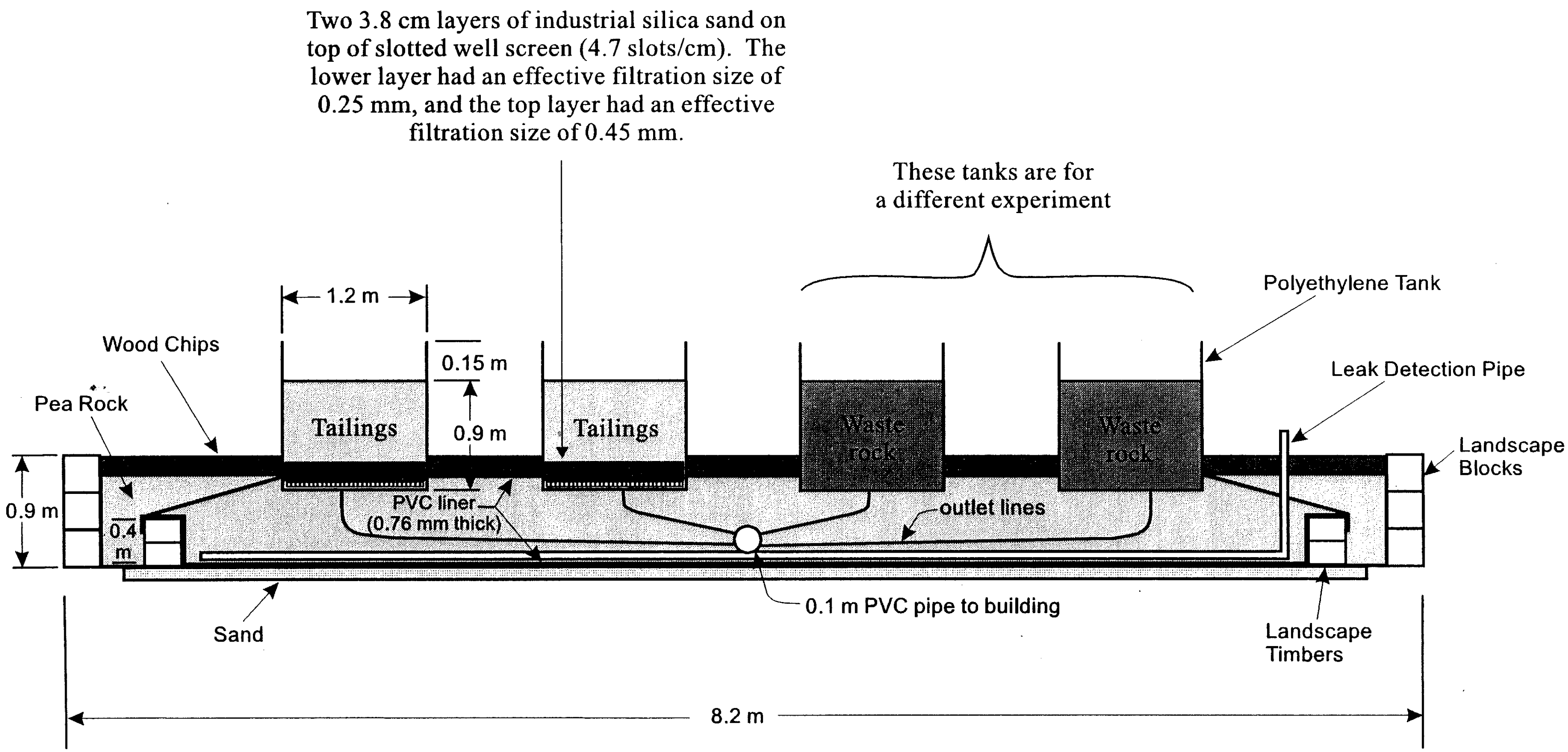
Two cylindrical pothyethylene tanks (d = 122 cm, h = 107 cm) were set up in duplicate as controls to simulate an unsaturated beach area. These tanks (tanks 11 and 12) were equipped with a 1.27 cm half-slotted PVC well screen (0.3 mm slots) covered with a geotextile sock, placed at the bottom of the tank for sample collection. Two 3.8 cm thick layers (68 kg) of industrial silica sand were placed in the bottom of the tank to serve as a filter for the well screen. The lower sand layer had an effective filtration size of 0.25 mm (Unimin 4030) and the higher layer had an effective filtration size of 0.45 mm (Unimin 4075). These tanks are freely draining. Ninety-one centimeters of reactive tailings were added to the tanks (Figure 5). These tanks were kept covered to keep out precipitation until the drainage collection system was complete. A leakage detection system was included as part of the overall design. In spring of 1998, water was discovered in the detection system. The controls were covered until the source of the leak could be found. About 91 liters of distilled water were added sequentially to each tank to determine the source of the leak. An additional 106 liters was added to tank 12 to confirm that this tank was actually leaking. The tailings were then removed and although there was no detectable leak, an acrylic plate was added to better support the weight of the tailings. An additional 106 liters was added to the tailings after the tailings were replaced, and no further leakage has been observed. (Additional details are presented in Appendix 8.)

Water Sampling

Sampling Procedures

Water samples were collected at least once per month from the surface water and the shallow and deep wells in the wetland tanks. A portable Masterflex (Model 7570-10) sampling pump, equipped with 6 mm ID Tygon tubing, was used to pump surface water and well water into a flow cell, where

Figure 5. Unsaturated control tanks; cross-section.



temperature, dissolved oxygen (DO), pH, and Eh readings were taken. Tubing size was changed to 3 mm ID tubing on 8 July 1998 to reduce the amount of air in the line while sampling. The pumping rate was held at around 100 to 150 mL/min to prevent degassing of the liquid, to minimize potential clogging of the screen, and to minimize the development of preferential flow paths in the substrates. The flow cell was constructed of 5 cm diameter clear acrylic, 11 cm long, with end plates equipped with hose adaptors. Four holes were drilled into the chamber to insert the Eh, pH, dissolved oxygen, and temperature probes. A 600 mL purge volume (equivalent to about 3 well volumes) was removed to ensure that stable field measurements and representative samples were collected. Testing showed all field parameters (T, pH, Eh and DO) stabilized after 600 mL were pumped. This purge volume was about 2.2 and 1.7 times the dead volume of the shallow and deep wells (including screen area), respectively. Excluding the screen area, the purge volume is 4.0 and 2.7 times the dead volume, respectively.

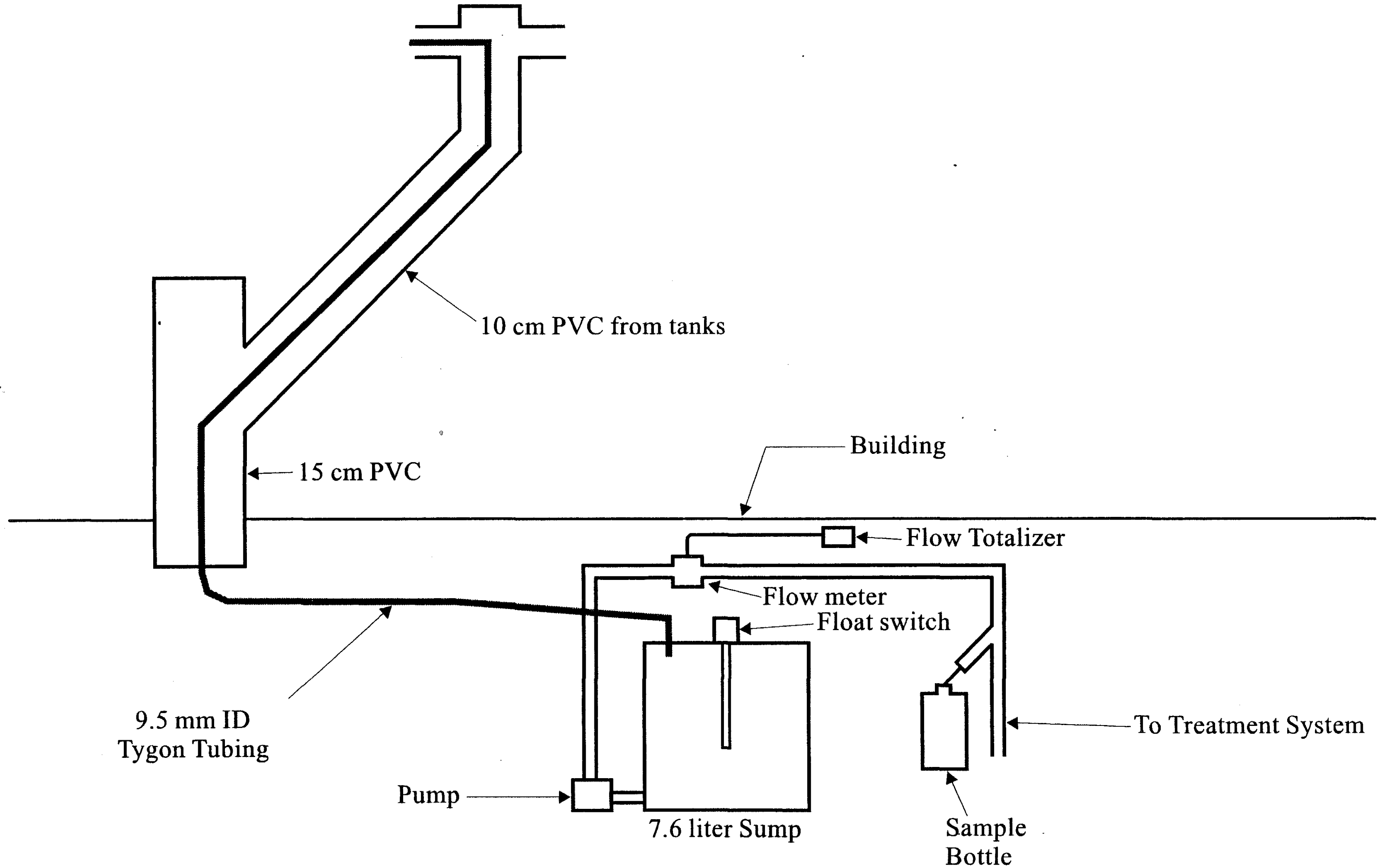
Surface water samples were drawn from about 2.5 cm below the surface. Most of the metal samples collected from the surface were filtered. In the beginning of the study, both total and filtered metals were collected. Surface water samples were turbid at times due to an unsettled substrate and large amounts of algae in the water. In these situations, the sample was allowed to settle before the nutrients and total metals samples were decanted. Depth of the surface water was also measured. Slotted well screens (12-mm diameter, 4.7 slots/cm) were installed vertically 61 cm into the substrate and approximately 10 cm in from the tank wall in the shallow water tanks, so water levels could be measured when no surface water was present.

The unsaturated on-land control tanks were equipped with a 2.5 cm slotted well screen (0.3 mm slots) with the slots facing down and connected to the base of the tank to collect water percolating through the tailing. Six millimeter Tygon tubing was connected to the well screen and plumbed to a 7.5 liter collection sump. The sump was equipped with an Erecta Switch model 50-R-A2410 level switch which triggered a March Manufacturing, Inc. Model 1A-MD pump. During each pump cycle, flow was recorded with a Kobold Instruments, Inc. Model DPL-1250CK flow sensor equipped with a Precision Digital Model PD693-3N flow totalizer (Figure 6). A portion of each pump cycle was diverted to a one liter sample bottle for analysis.

Water Analyses

A Beckman Eh/pH meter (Model 11) equipped with an Orion combination redox electrode (Model 9678BN) was used for Eh analysis, the same meter with a Ross combination pH electrode (Model 8165) was used for pH analysis and with a Beckman (Model 5981150) probe for temperature analysis, a Yellow Springs dissolved oxygen meter (Model 57) was used to measure dissolved oxygen. The samples were analyzed in the laboratory for specific conductance using a Myron L model EP conductivity meter. Alkalinity and acidity were measured using standard titration techniques (APHA et al., 1992). Sulfate and metals samples were filtered through a Gelman Supor 0.45 micron filter. Metals samples were preserved with 0.2 mL of Baker Instr-Analyzed nitric acid per 50 mL of sample. Nutrients samples were unfiltered, and were preserved with 1.0 mL of Baker Analyzed sulfuric acid per 500 mL of sample. Analysis for the composite samples generated by unsaturated controls were conducted in the laboratory using the same equipment, with the exception of pH and DO; pH was analyzed with an Orion (Model 720A) meter and DO was not analyzed.

Figure 6. Water quality and flow monitoring system for the control tanks.



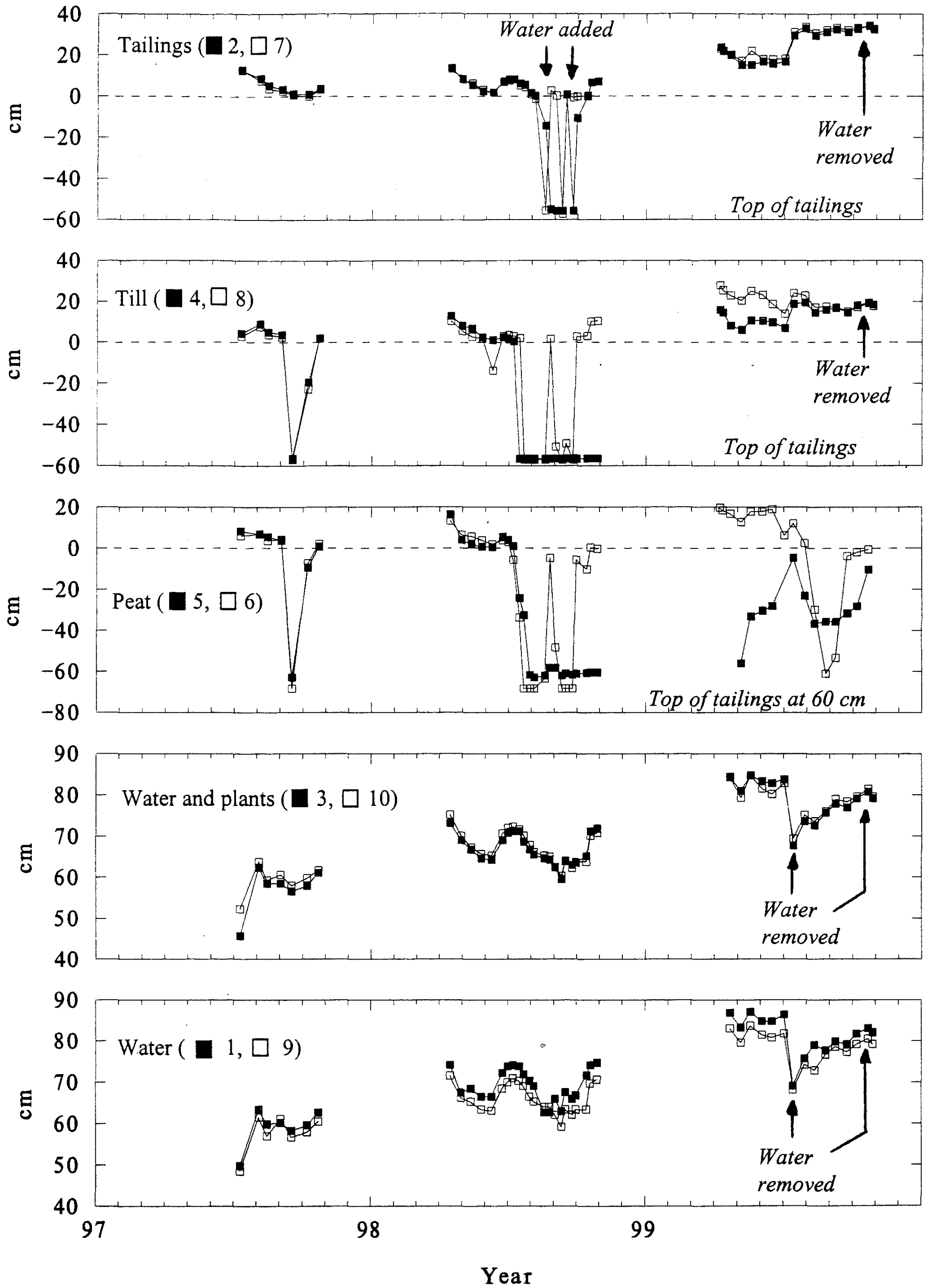
Sulfate was analyzed at the Minnesota Department of Agriculture (MDA) laboratory using the Ion Chromatographic Method (Wastewater Method 4500-SO_4 B) with a Dionex DX300 IC in 1997 and 1998 and a Lachat QuickChem 8000 using the same method in 1999. Metals samples were analyzed at MDA using a Varian 400 SPECTRAA atomic absorption spectrophotometer in the flame mode or a Zeeman GFAA graphite furnace. Nutrient analysis were conducted at MDA using the Automated Cadmium Reduction Method (Wastewater Method 4500-NO_3 F) on a Technicon AA11 for Nitrate + Nitrite Nitrogen, the Ammonia-Selective Electrode Method (Wastewater Method 4500-NH_3 F) on an Accumet 950 pH/ion meter for Ammonia Nitrogen, the Ascorbic Acid Method (Wastewater Method 4500-P E) on a Perkin Elmer 552 Spectrophotometer for Total Phosphorus, and the Semi-Automated Colorimetric Method (EPA 351.2) with a Bran & Luebbe Traacs 800 for Total Kjeldahl Nitrogen (this analysis was sub contracted to Metropolitan Council in St. Paul, MN).

Results

Water Levels

Water levels in all treatments fluctuated in response to precipitation and evapotranspiration (Figure 7). For the one year period, November 1997 through October 1998, the tanks with water covers (1, 3, 9, 10) gained water, while all of the tanks with cattails lost water. A water balance was used to calculated evapotranspiration for each treatment. Evapotranspiration was 92 percent of average lake evaporation in the tanks with water cover, 104 percent in the tanks with cattails planted directly on the tailings (2, 7), 177 percent for the glacial till (tanks 4, 8) and 210 percent for the peat (tanks 5, 6); details are presented in Appendix 11. The high evapotranspiration rate in the peat and till tanks caused water levels to decrease and the water level dropped below the substrate surface in the peat and glacial till tanks in September, 1997. The water level increased in October and rose above the level of substrate in the four tanks (4, 5, 6, 8).

The summer of 1998 was unusually dry and, as a result, all the surface water in the tanks with substrate covers evaporated in July. Water levels continued to fall throughout July and August until there was no water in the shallow wells. In August and September of 1998 groundwater was added to three tanks; one of the tanks with peat (tank 6), glacial till (tank 8) and tailings (tank 7) to minimize the amount of oxygen entering the underlying tailings. The water level in the other set of tanks (2, 4, 5) was not adjusted and represent a "worst case" situation. Water levels in these tanks did not increase until 1999. Since evapotranspiration in the tanks with water covers (1, 9, 3, 10) was much less than that measured in the tanks with cattails, water levels generally increased with time. Precipitation in 1999 was 21.6 cm above normal and on July 3, 1999, 20 cm of rain fell and the water level in all of the tanks with the water covers rose to the top of the tank. In order to prevent future spills, 30 cm of water was removed from these tanks. Prior to freeze up, water was removed from all tanks except those with peat (5, 6), to provide 30 cm freeboard.



Water was added in August and September 1998 to one of each pair of tanks that contained peat, tailings, and till (tanks 6, 7 and 8, respectively). Water was removed from each of the four water tanks (1, 3, 9 and 10) in July 1999 to prevent overflow, and from all tanks except those that contained peat (tanks 5 and 6) in October 1999 to provide freeboard to accomodate input from snow fall.

Figure 7. Water levels in the treatment tanks, 1997-99.

Water Quality

Control tanks

The untreated tailings (controls) produced extremely acidic and contaminated water. The drainage from these tanks had an average pH of 3.15, an average acidity of 18,000 mg/L and 37,000 mg/L sulfate (Table 1). Zinc was the major cation in solution, with an average concentration of 6900 mg/L.

Tailings layer (deep wells)

All the treatments had less acid and metal release than the controls. In the well samples from the tailings layer, with the exception of tank 5, there was little difference in pH and sulfate between the tanks (Figure 8). The average pH ranged from 6.26 to 6.49, and the average sulfate concentration ranged from 2720 to 2930 mg/L. Average zinc concentrations were all less than 0.1 mg/L and varied from 0.030 to 0.089 mg/L (Table 2).

In tank 5, the peat tank where no additional water was added, the water level dropped below the substrate, and the degree of saturation in the peat may not have been sufficient to prevent oxygen transport to the tailings. Sulfate concentrations in the tailings layer increased in 1999, and concentrations exceeded 4000 mg/L by the end of 1999 (Figure 9).

Treatment layer (shallow wells)

Water quality from the shallow wells varied between treatments, but in general the difference appeared related to the chemistry of the substrate rather than release from the underlying tailings (Figure 10). The average pH was lowest in the naturally acidic peat (4.6) and averaged 6.4 in the glacial till and the tailings (Table 3). The average zinc concentrations were highest in the peat (0.12 - 0.15 mg/L) and lowest in the glacial till (<0.015). There was no clear trend in either pH or zinc over the course of the study. Initially sulfate concentrations varied widely between treatments. The average sulfate concentrations were lowest in the peat (60 - 90 mg/L), 400 - 800 mg/L in the glacial till, and between 2400-2700 mg/L in the tailings (Figure 11). Sulfate concentrations increased markedly in both the peat and till covers after the water level decreased in the summer of 1998. Sulfate increased from <10 mg/L in the peat tanks to 150-300 mg/L, and in the glacial till tanks from

Table 1. Drainage quality; average concentrations for the on-land controls, 1997-99.

Tank	SC	pH	DO	SO_4	Cu	Zn	Ca	Mg
11	13938	3.09	NA	36384	0.244	6395	428	2483
12	12191	3.19	NA	37734	0.192	7427	396	2940

Notes: Values that appeared to be anomalous were omitted from the statistics on these tables as well as from the summary statistics presented in Table A4.13. Values that were omitted are noted in bold in the drainage quality tables in Appendix 4. Specific conductance reported in μmhos/cm, pH in standard units and all other concentrations in mg/L.

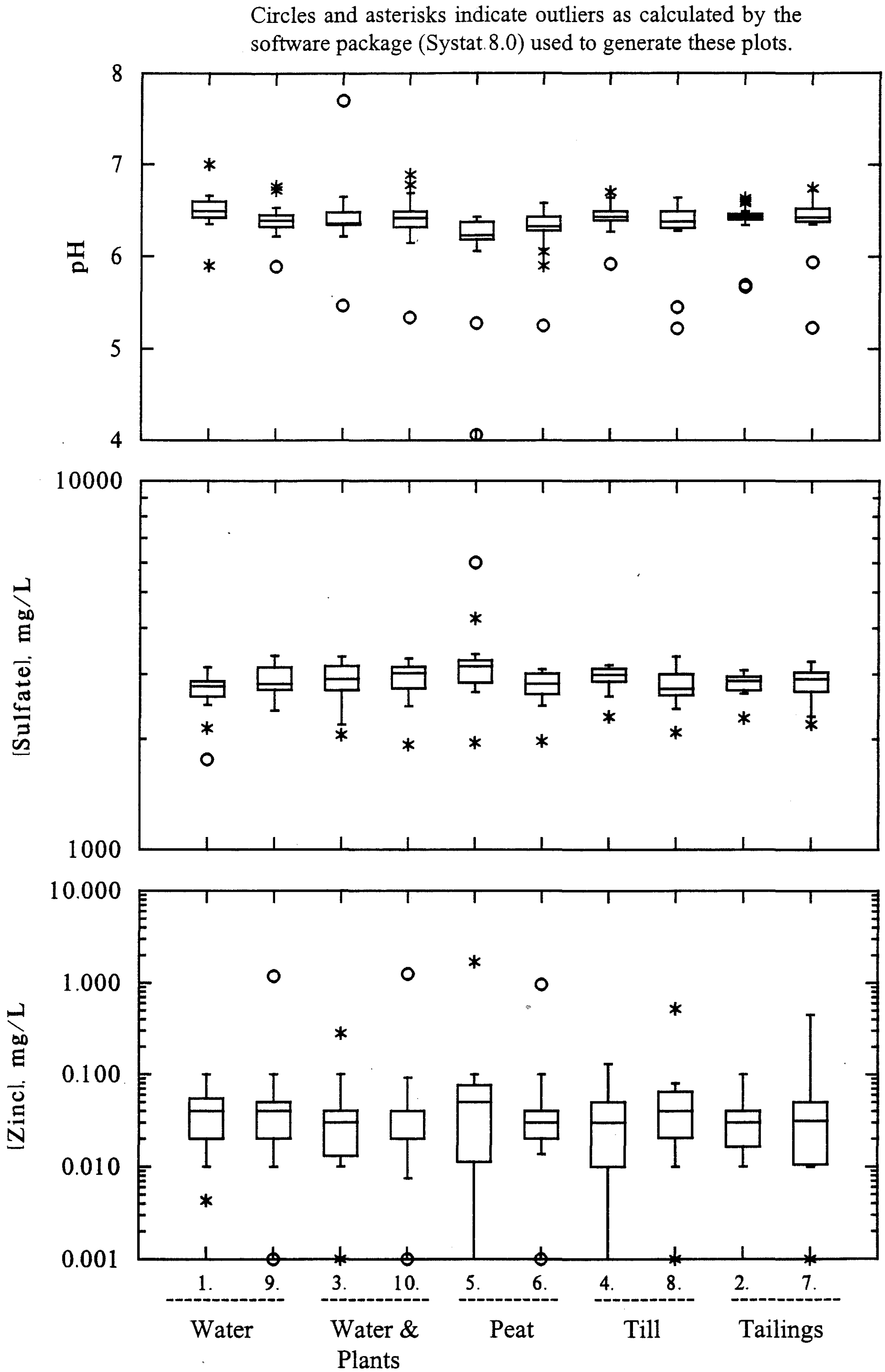


Figure 8. Water quality results (box plots); pH, sulfate and zinc concentrations in the tailings layer, 1997-99.

Dry conditions in the summer of 1998 caused water levels in tanks 5 and 6 to drop below the surface of the substrate. Water was periodically added thereafter to tank 6 to maintain water levels above the surface of the substrate, while tank 5 received no additional water and reflects a "worst case" oxidation scenario.

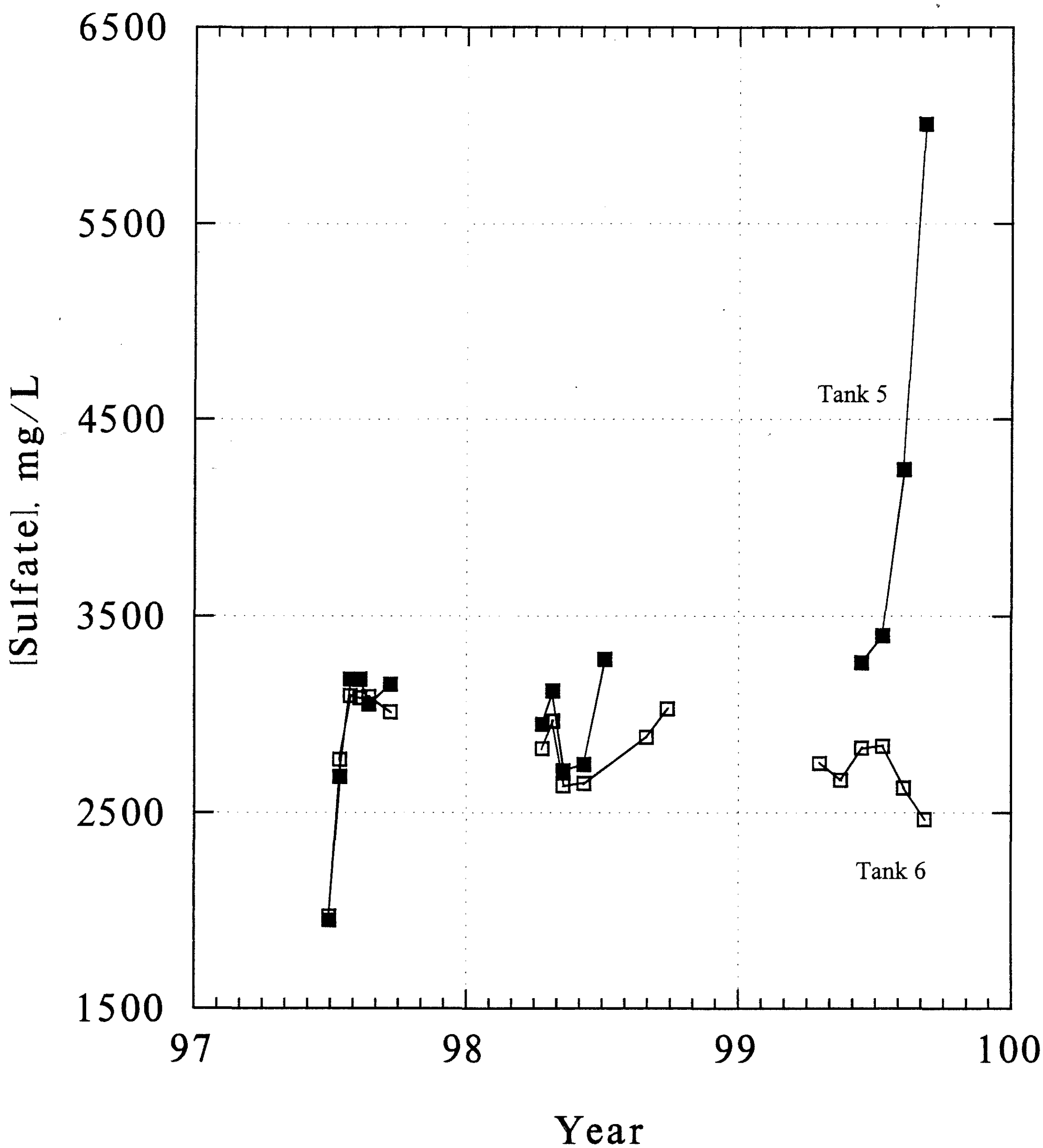


Figure 9. Sulfate concentration vs. time in the tailings layer of the tanks with peat cover (tanks 5, 6), 1997-99.

Circles and asterisks indicate outliers as calculated by the software package (Systat 8.0) used to generate these plots.

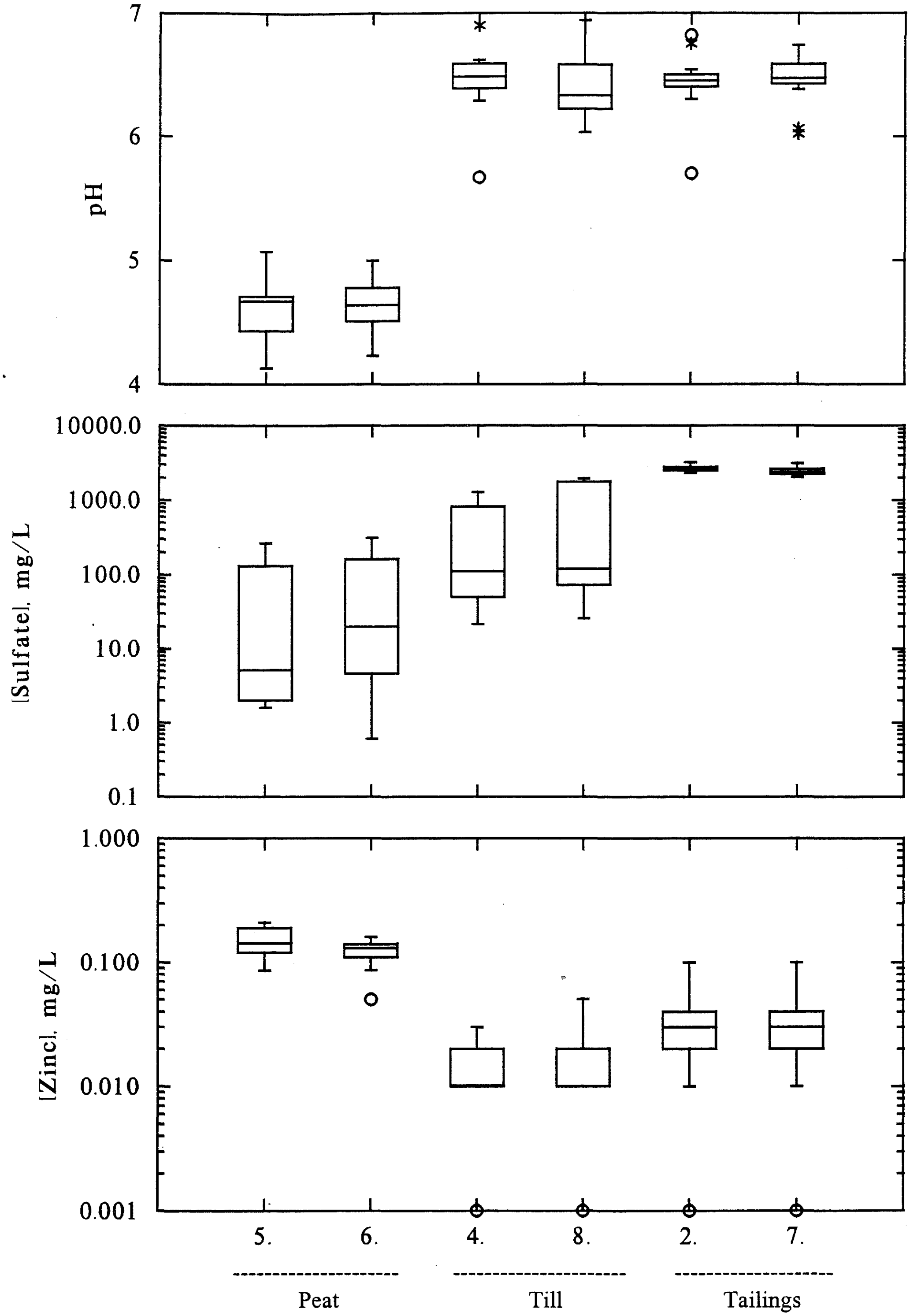


Figure 10. Water quality results (box plots); pH, sulfate and zinc concentrations in the cover layer, 1997-99.

Table 2. Drainage quality; average concentrations in the tailings layer, 1997-99.

Tank	SC	pH	DO	SO_4	Cu	Zn	Ca	Mg
1- Water cover	4614	6.49	1.1	2724	<0.020	0.034	520	247
2- Cattails on tailings	4757	6.37	0.9	2841	<0.015	0.027	520	253
3- Water cover and submerged aquatics	4788	6.42	0.9	2890	<0.022	0.036	514	238
4- Cattails on glacial till	4873	6.42	0.9	2937	<0.016	0.030	502	273
5- Cattails on peat	4890	6.07	0.9	3261	<0.022	0.141	543	373
6- Cattails on peat	4743	6.26	0.9	2788	<0.023	0.089	542	247
7- Cattails on tailings	4833	6.38	0.8	2843	<0.018	0.045	532	256
8- Cattails on glacial till	4710	6.30	0.9	2802	<0.015	0.062	541	239
9- Water cover	4766	6.39	0.9	2885	<0.021	0.086	533	248
10- Water cover and submerged aquatics	4810	6.32	0.9	2928	<0.020	0.089	538	278

Notes: Values that appeared to be anomalous were omitted from the statistics on these tables as well as from the summary statistics presented in Table A4.13. Values that were omitted are noted in bold in the drainage quality tables in Appendix 4. Specific conductance reported in μmhos/cm, pH in standard units and all other concentrations in mg/L.

Table 3. Drainage quality; average concentrations in the cover layer, 1997-99.

Tank	SC	pH	DO	SO_4	Cu	Zn	Ca	Mg
2- Cattails on tailings	4504	6.43	1.0	2663	<0.017	0.027	520	278
4- Cattails on glacial till	1500	6.45	1.6	412	<0.017	0.001	246	81
5- Cattails on peat	381	4.58	0.7	63	0.035	0.152	21	12
6- Cattails on peat	352	4.61	0.7	92	0.013	0.122	21	15
7- Cattails on tailings	4147	6.47	0.8	2438	<0.022	0.031	524	238
8- Cattails on glacial till	1947	6.39	0.9	802	<0.020	0.013	347	117

Notes: Values that appeared to be anomalous were omitted from the statistics on these tables as well as from the summary statistics presented in Table A4.13. Values that were omitted are noted in bold in the drainage quality tables in Appendix 4. Specific conductance reported in μmhos/cm, pH in standard units and all other concentrations in mg/L.

<100 mg/L to 1000 (tank 4) and 1900 mg/L (tank 8). Tank 4 subsequently decreased to around 500 mg/L in the fall of 1999, while tank 8 remained high (Figure 11). Sulfate concentrations in the tailings increased from around 2100 mg/L to 2300 mg/L to around 3100 mg/L in the spring of 1999. Concentrations then decreased throughout 1999 to average values of 2300 mg/L to 2600 mg/L (Figure 11).

Surface water

Concentrations in surface water varied over time due to water level fluctuations, release from the substrate, and the effect of biological activity. Surface water levels dropped faster in the tanks with the largest growth of cattails. As water levels decreased due to evapotranspiration, dissolved concentrations tended to increase. Concentrations generally decreased after rainfall or snow melt, as the surface water in the tank was diluted.

Surface water quality in all the peat and till tanks (tanks 5, 6 and 4, 8) reflected the character of the cover substrate (Figure 12). Surface water quality was also affected in tanks 6 and 8 by the input of groundwater used to stabilize water levels. The pH in both peat tanks was acidic and, prior to groundwater input, generally ranged from 4.2 to 5.0. The pH in tank 6 increased to above 6.0 after groundwater was added, decreased to a low of 4.53 during the summer of 1999 and then increased after additional ground water was added during the fall of 1999 (Figure 13). The pH levels in the duplicate till tanks were generally above 8.0 during the initial year of the study, but decreased in tank 8 to less than 8.0 after groundwater was added (Figure 13). Zinc concentrations in the duplicate till tanks were low throughout the study, averaging 0.008 mg/L. Zinc concentrations were somewhat elevated in the peat tanks at the beginning of the study (0.05-0.1 mg/L), but decreased over time to 0.01 to 0.03 mg/L (Appendix 4). Sulfate concentrations varied in all tanks as water level fluctuated, but were an order of magnitude lower in the peat and till tanks than in the tailings tanks (tanks 2, 7). Average concentrations were less than 65 mg/L in the peat and till tanks, and was 1090 mg/L in the tailings tanks (Table 4).

Surface water in the tanks with cattails planted directly on the tailings (tanks 2, 7) had lower pH and higher zinc concentrations, particularly after the water level dropped below the surface of the tailings. In the tank where no additional water was added (tank 2), the pH decreased to 3.5 when water levels finally rose above the surface in the fall of 1998. The pH in this tank remained depressed between 3.5 and 4.2 throughout 1999. The addition of alkaline groundwater maintained the pH near neutral in tank 7 for a short time, but pH fell from 6.7 to 4.9 in one week in 1998, and decreased to 3.7 within a month (Figure 14). In 1999, pH was generally around 4.2, but increased in August and September to over 6.0. Zinc concentrations, which had always been at least an order of magnitude higher than the other tanks, reached their maximum values when pH decreased (Figure 14). Sulfate concentrations more than doubled, from around 1000 mg/L to over 2700, after water was added and reaction products were dissolved. Sulfate concentrations have decreased over time, as water levels have increased (Figure 14).

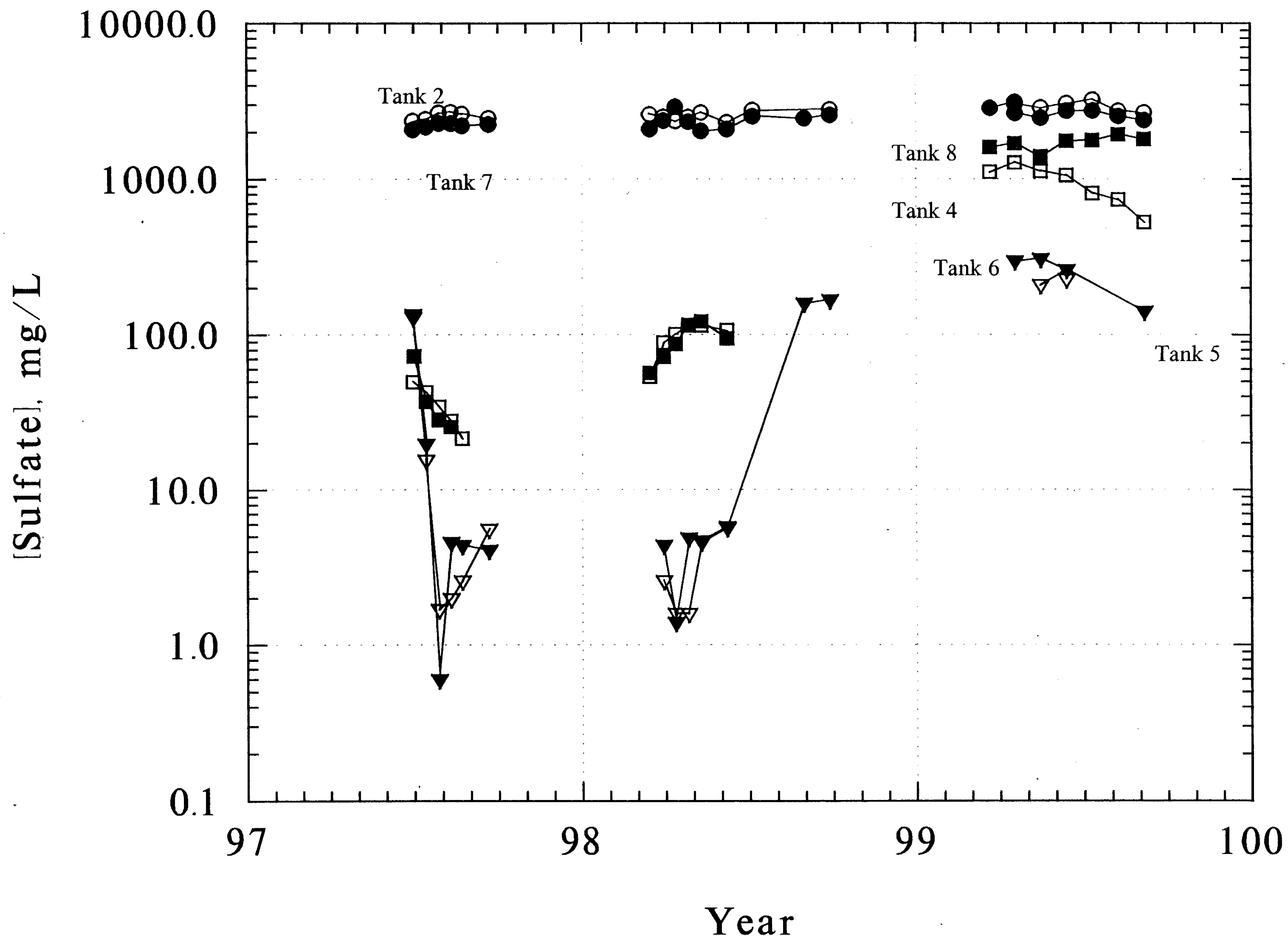


Figure 11. Sulfate concentration vs. time in the substrate layer of the tanks with peat cover (tanks 5, 6), glacial till cover (tanks 4, 8), and tailings cover (tanks 2, 7), 1997-99.

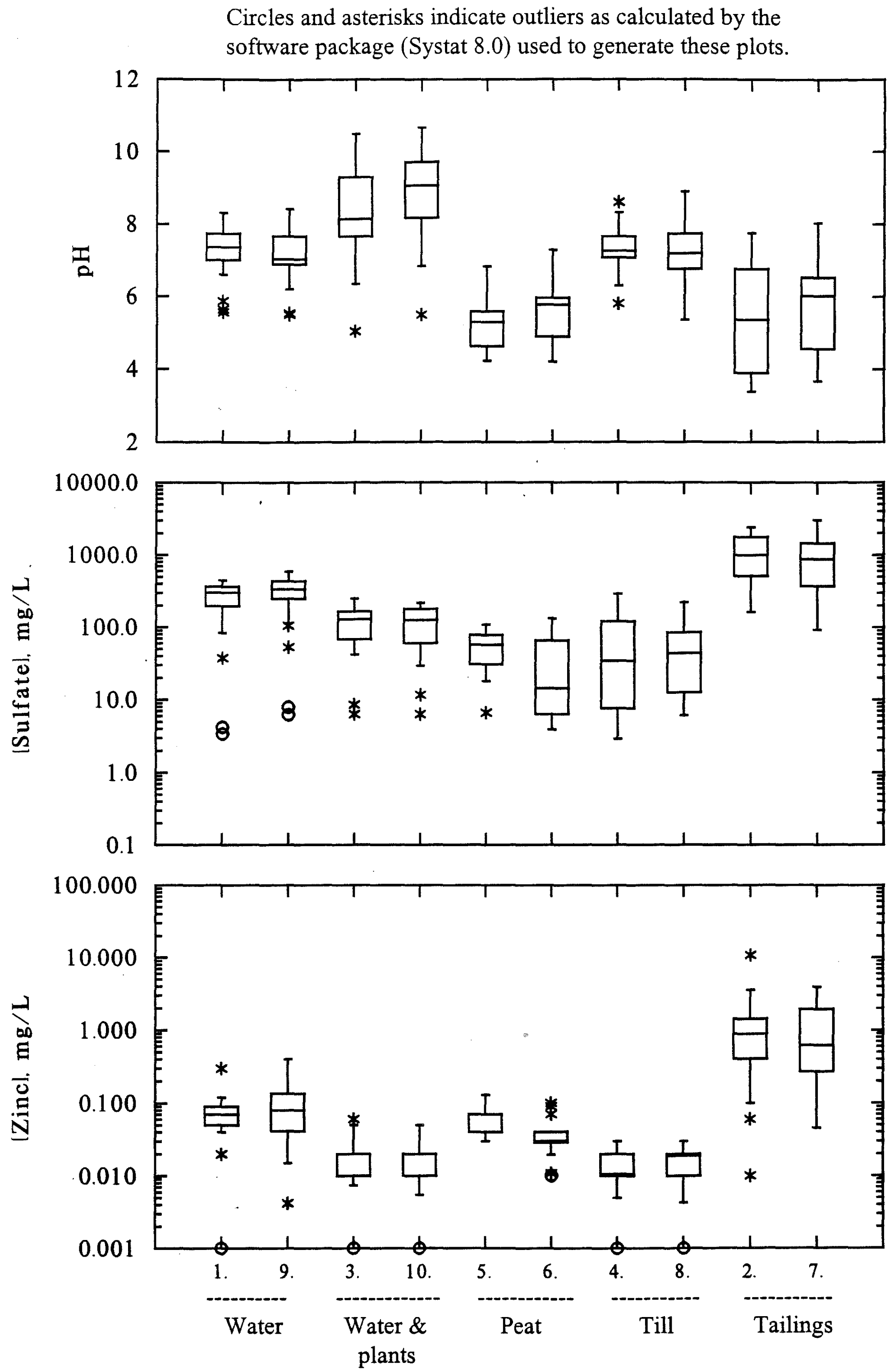


Figure 12. Water quality results (box plots); pH, sulfate and zinc concentrations in surface water, 1997-99.

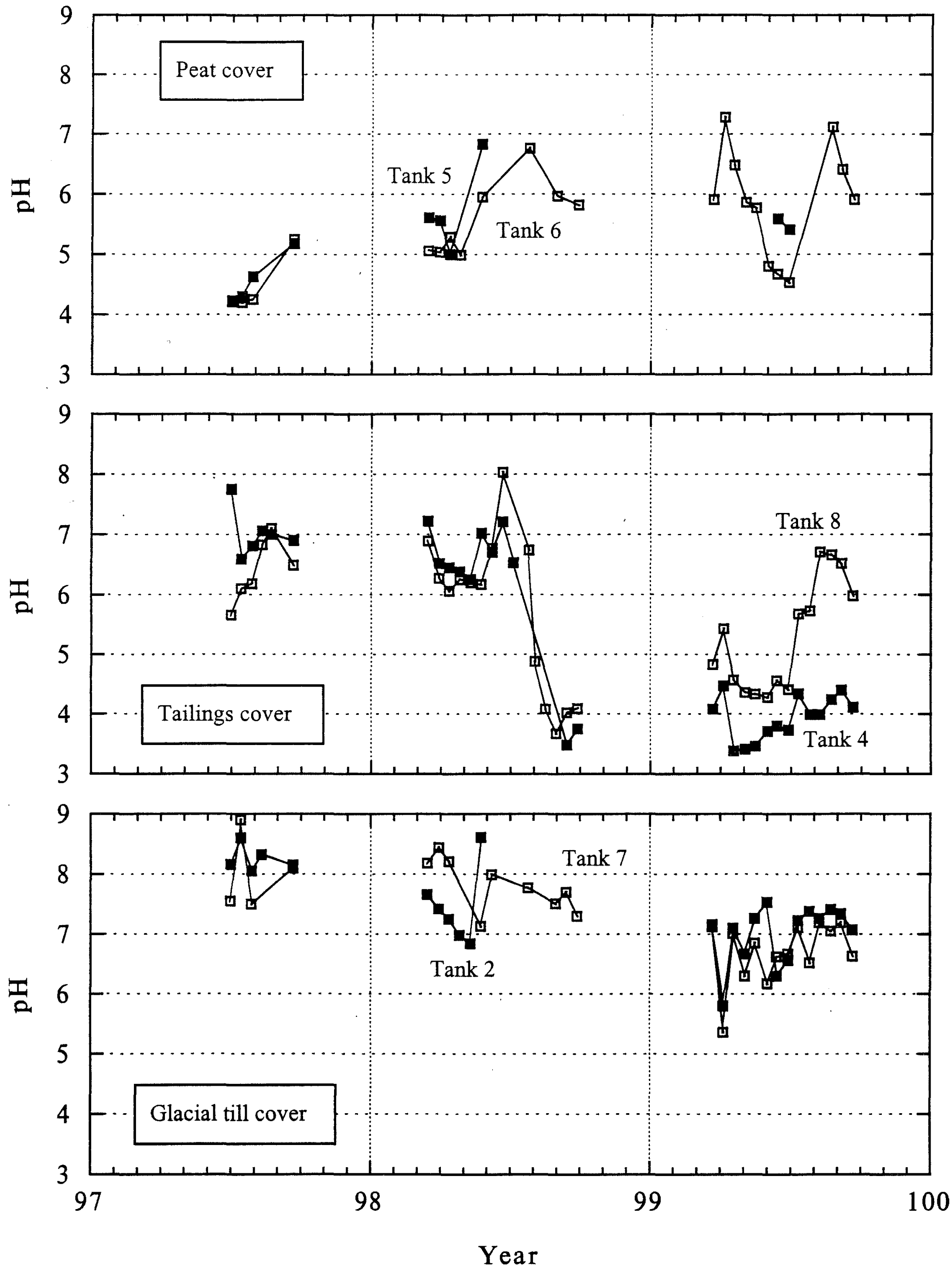


Figure 13. pH vs. time in the surface water of the tanks with peat cover (tanks 5 and 6), glacial till cover (tanks 4 and 8), and tailings cover (tanks 2 and 7), 1997-99.

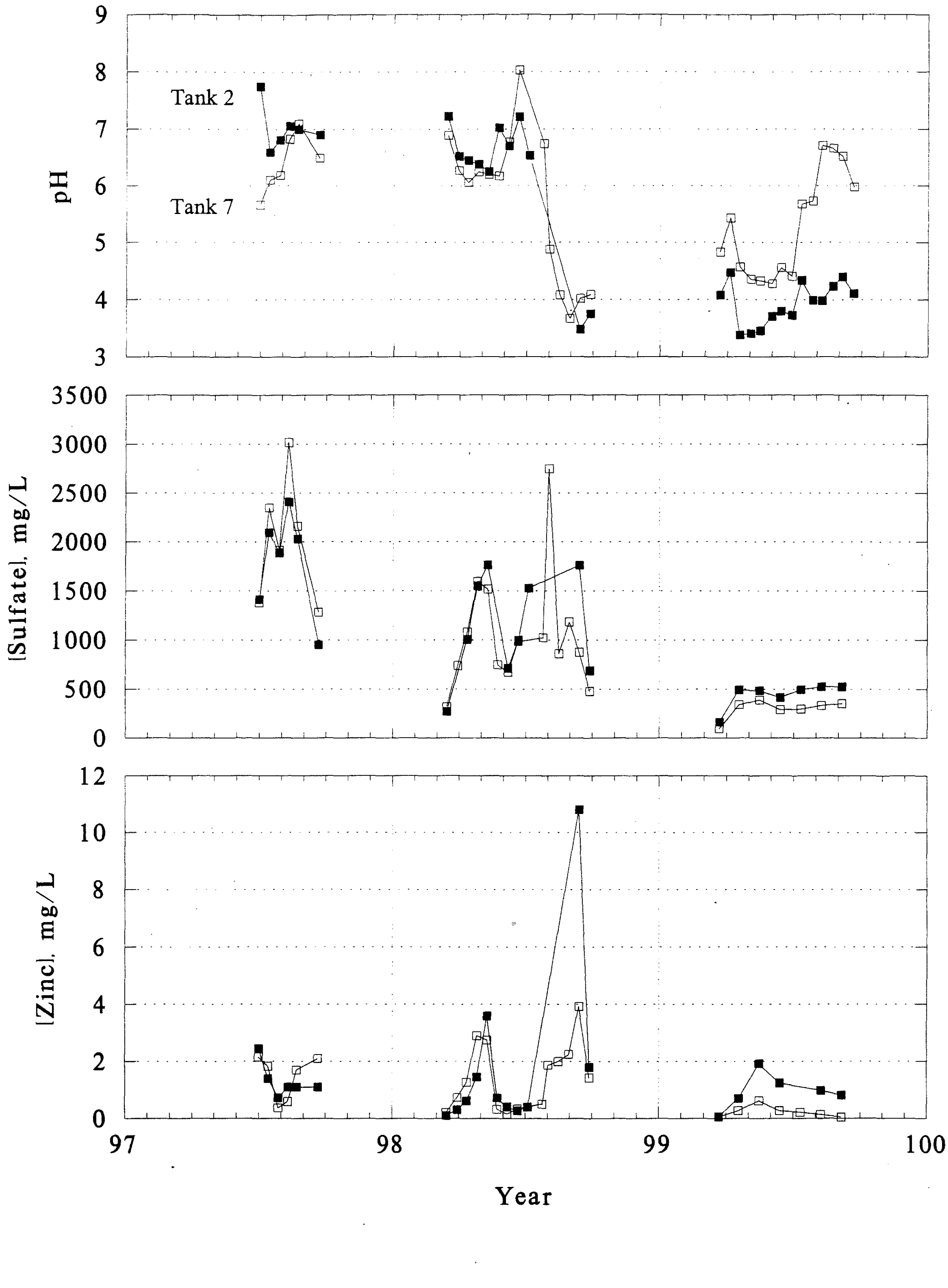


Figure 14. pH, sulfate and zinc concentrations vs. time in the surface water of the tanks with tailings cover (tanks 2, 7), 1997-99.

Table 4. Drainage quality; average concentrations in the surface water, 1997-99.

Tank	SC	pH	DO	SO_4	Cu	Zn	Ca	Mg
1- Water cover	728	7.26	7.0	275	<0.027	0.077	104	30
2- Cattails on tailings	1745	5.31	7.1	1099	<0.008	1.418	367	54
3- Submerged aquatics	489	8.28	9.2	124	<0.029	0.004	50	22
4- Cattails on glacial till	302	7.36	8.1	66	<0.022	0.004	42	19
5- Cattails on peat	338	5.23	5.7	57	0.028	0.061	18	12
6- Cattails on peat	227	5.54	6.0	38	<0.024	0.038	14	10
7- Cattails on tailings	1673	5.66	7.2	1075	<0.005	1.148	343	52
8- Cattails on glacial till	390	7.26	7.9	63	<0.029	0.008	45	21
9- Water cover	841	7.14	6.6	327	<0.033	0.099	126	32
10- Submerged aquatics	495	8.88	9.5	124	<0.031	<0.003	47	26

Notes: Values that appeared to be anomalous were omitted from the statistics on these tables as well as from the summary statistics presented in Table A4.13. Values that were omitted are noted in bold in the drainage quality tables in Appendix 4. Specific conductance reported in μmhos/cm, pH in standard units and all other concentrations in mg/L.

Water covers (tanks 1, 9, 3, and 10) were effective in maintaining neutral pH in the surface water. In the tanks without plants (1, 9) surface pH averaged 7.2, sulfate 300 mg/L, and zinc 0.08 mg/L (Figure 15, Table 4). In the tanks with water covers and submerged plants (3, 10), pH was much higher (average of 8.5), particularly during the growing season, and some measurements greater than 10 were recorded. Average sulfate and zinc concentrations were 125 mg/L and <0.004 mg/L, respectively (Figure 15, Table 4).

Interface

Since the tanks are isolated systems and have a small diameter with high sides, stratification occurred in all the tanks with water covers periodically during the year. Surface samples collected in the spring immediately after the ice had melted had unusually low concentrations of dissolved solids. Specific conductance was less than 100 μmhos/cm and sulfate concentrations were less than 10 mg/L. During the late spring and early summer, samples collected just above the tailings (i.e. at the interface) tended to have lower pH, higher sulfate, and higher zinc concentrations than surface samples . Generally, by late summer and early fall, the water column was fairly well mixed (Appendix 4). The tanks with submerged aquatics (tanks 3, 10) had substantially lower sulfate and zinc concentration at the interface than the tanks with the water cover alone (tanks 1, 9). Average sulfate for the tanks with aquatics was 342 mg/L at the interface, while the value for the water cover alone was 715. The average zinc concentration was over an order of magnitude lower, 0.005 vs 0.164 mg/L (Table 5).

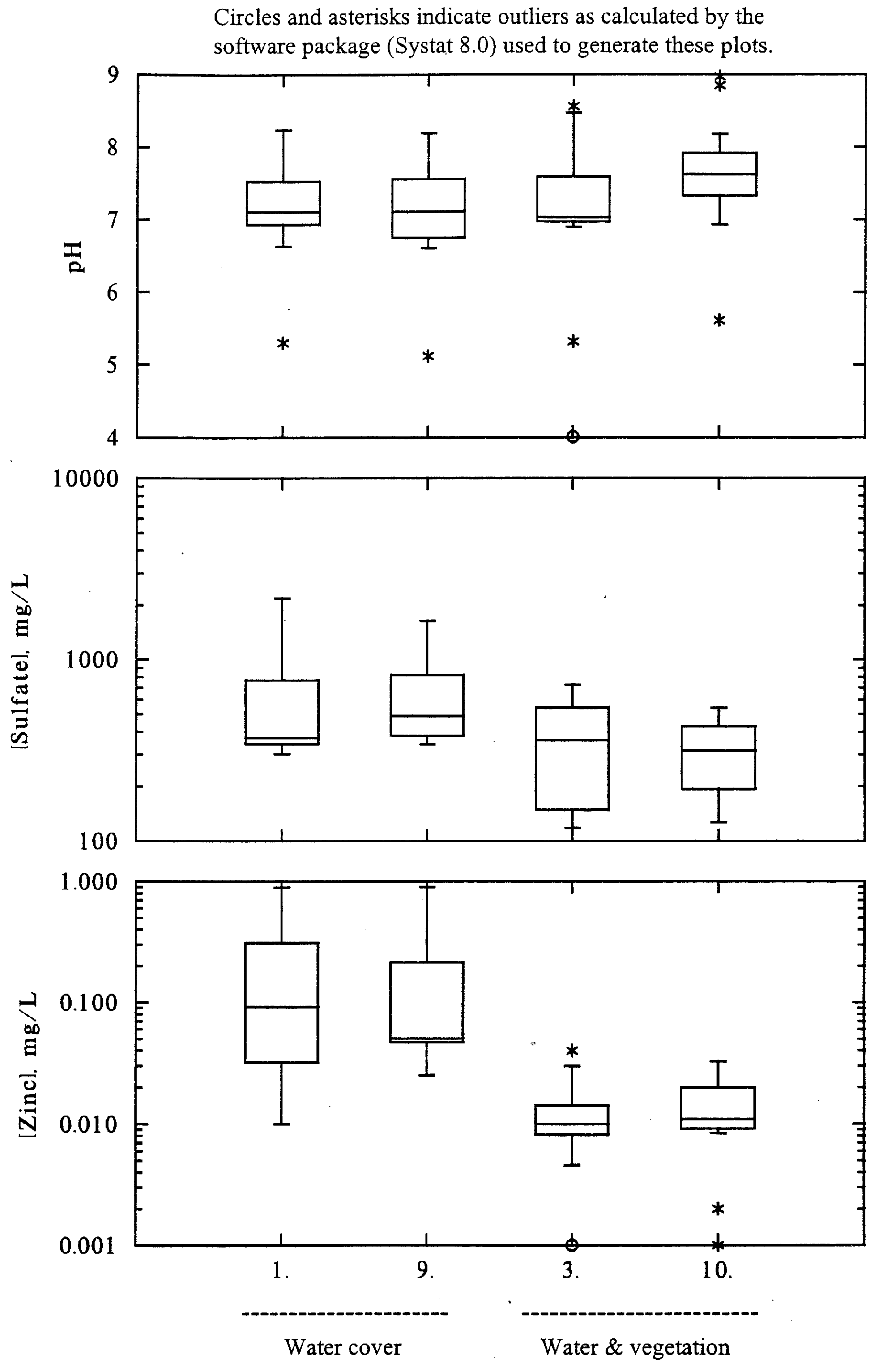


Figure 15. Water quality results (box plots); pH, sulfate and zinc concentrations in samples collected at the tailings interface.

Table 5. Drainage quality; average concentrations in the interface samples, 1997-99.

Tank	SC	pH	DO	SO_4	Cu	Zn	Ca	Mg
1- Water cover	1567	7.14	5.9	733	<0.023	0.244	267	66
3- Water cover and submerged aquatics	1261	7.13	2.8	362	<0.022	0.001	217	75
9- Water cover	1444	7.06	5.8	691	<0.023	0.194	248	58
10- Water cover and submerged aquatics	1262	7.62	5.1	322	<0.020	0.009	164	65

Notes: Values that appeared to be anomalous were omitted from the statistics on these tables as well as from the summary statistics presented in Table A4.13. Values that were omitted are noted in bold in the drainage quality tables in Appendix 4. Specific conductance reported in μmhos/cm, pH in standard units and all other concentrations in mg/L.

Mass Release

The amount of sulfate and zinc released to the surface water was calculated for each water cover tank (1, 3, 9, 10) by multiplying the surface concentration by the volume of water. Corrections were made for the water added or removed (Appendix 2). Mass balances were calculated for the tanks with water covers since there was no movement of water and sulfate into the substrate, as compared to the tanks with substrate covers. The model for the substrate covers is much more complex, and with the exception of the tailings cover, there has been no evidence of migration of zinc or sulfate into the surface water (Appendix 9).

Sulfate mass

Total sulfate mass in the water column at the end of 1999 averaged about 280 g for the water tanks (1, 9), compared to only 60 g for the water tanks with plants (3, 10). Sulfate mass increased in the water cover tanks (1, 9) from 1997 to 1998 but did not change appreciably between 1998 and 1999 (Figure 16). Sulfate mass in the water cover with plants (3, 10) has not changed significantly since the experiment began.

Sulfate mass for the unsaturated controls was calculated by multiplying the flow weighted concentration times the total volume of flow for the sampling period (Appendix 9). Mass release from the controls was about two orders of magnitude greater than the release in the tanks with water covers, and averaged about 24.0 kg of sulfate, compared to 0.06 to 0.28 kg for the water tanks.

Since surface water in the tanks with water covers stratified in the spring, the initial sulfate concentrations reflected ice melt and were less than 10 mg/L. Since the mass is based on the surface concentration, the initial mass is unusually low. The surface stratification usually disappeared by mid to late May, and generally by late July or August the surface and interface concentrations were similar (Appendix 4).

Zinc mass

Zinc release was low and ranged from <5 mg for the water cover with plants to around 50 mg for the water cover alone, but increased in the water covers in the fall (Figure 17). This may be the result of mixing, which incorporated the higher concentration interface water into the water column. Zinc release in the unsaturated controls was about six orders of magnitude greater than in the water covers and averaged 4.8 kg, compared to less than 0.00005 kg in the water cover tanks.

Discussion

Water is an effective cover for acid generating material since the transport of oxygen is over 1000 times slower than through air (Davé, 1997). Despite the slower transport of oxygen, sulfide minerals in the tailings continued to oxidize in the tanks with just the water cover (1, 9). Sulfate concentrations in the surface water of these two tanks increased by about 50% from 1997 to 1998, despite an overall increase in water level. Using the data from late summer and fall of 1998, when the surface water was well mixed, the sulfate release rate was 690 mg $SO_4/m^2/day$. The sulfate mass in the surface water (1, 9) increased from 175 g in 1997 to 280 g in 1998.

Sulfate and metal release was substantially lower in the water covers that contained plants (3, 10). In 1997, sulfate concentrations in these tanks were about 20% lower than in the tanks without plants, and decreased by about 40% in 1998. The total sulfate mass in these tanks was about 70% lower than in the water cover without plants, and the total mass did not change appreciably between 1997 and 1999, although there may be a slight downward trend. Limited data from 1998, when the surface and interface concentrations were the same, showed that during the late summer and fall the sulfate release rate was negative (-270 mg $SO_4/m^2/day$). The lower release rate was most likely related to the deposition of organic matter from dying plant material on top of the tailings. Of the three plant species originally introduced, only *Ceratophyllum demersum* (coontail) became successfully established. Since fertilizer had been added, dense growths of filamentous algae were also produced, and a visible mat of organic material was seen covering the tailings. Dissolved oxygen in the interface samples were about 50% of those in the tanks without plants. Oxygen was consumed as the plant material decayed and, as a result, the rate of oxygen transport to the tailings decreased.

Similar results were observed by St. Germain and Kuyucak (1997). The introduction of submerged aquatic plants into the water cover produced an oxygen consuming layer above the tailings. The plants supplied organic matter to cover the tailings and created a biologically active layer where not only was oxygen consumed, but sulfate was reduced to sulfide. The sulfide can react with metal ions present in the water to form insoluble metal sulfides, which are stable under anaerobic conditions (Kuyucak et al., 1991).

Wetland vegetation will also provide organic material to the surface of the substrate. By establishing vegetation directly on the tailings, a layer of organic material should accumulate and restrict oxygen transport to the tailings. The tanks in which cattails were planted directly on the tailings (tanks 2, 7) were not successful in maintaining acceptable water quality. Vegetation appeared stressed (yellow,

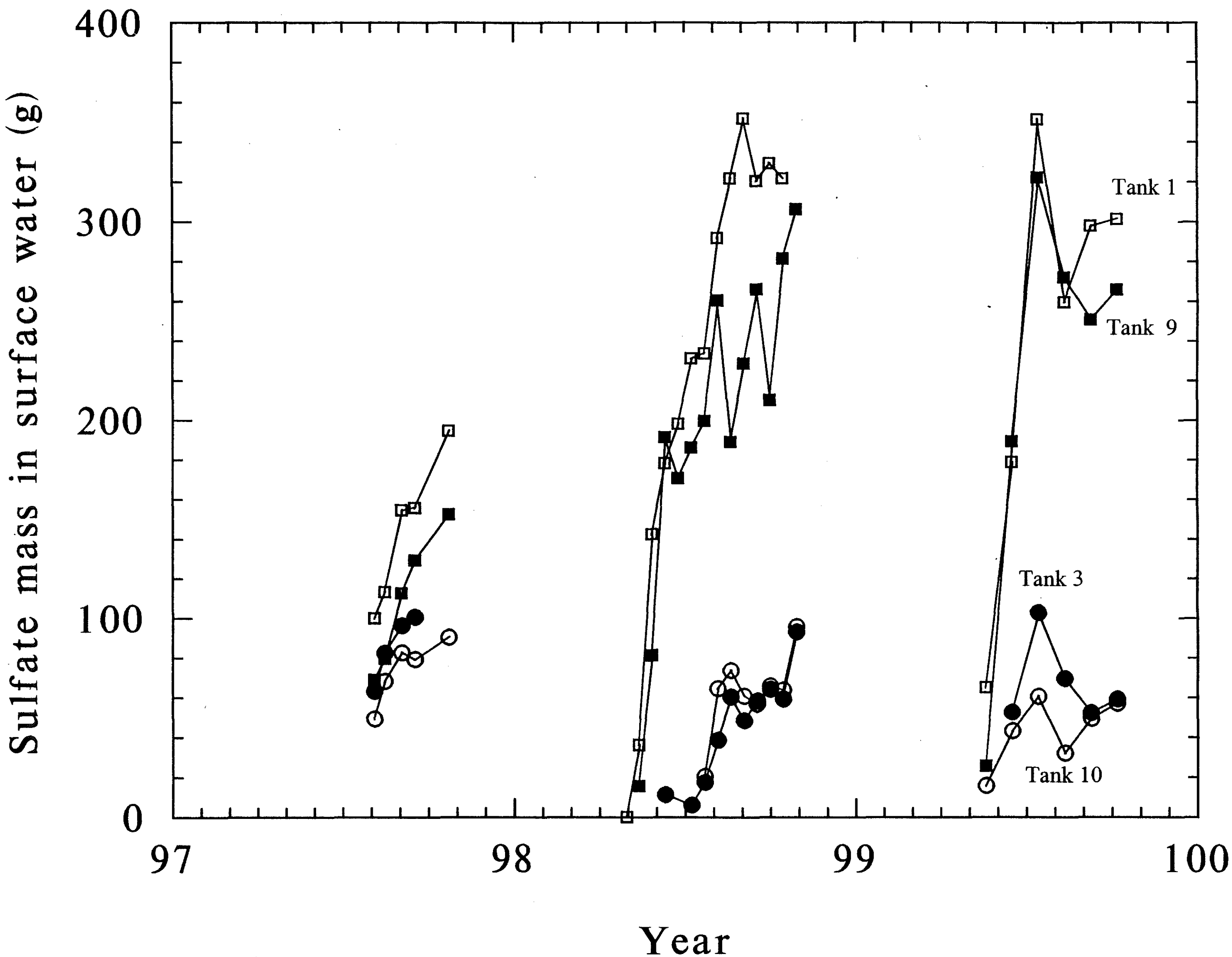


Figure 16. Mass of sulfate released to the surface water, for the tanks with water cover (tanks 1, 9) and for the tanks with water and aquatic plants (tanks 3, 10), 1997-99.

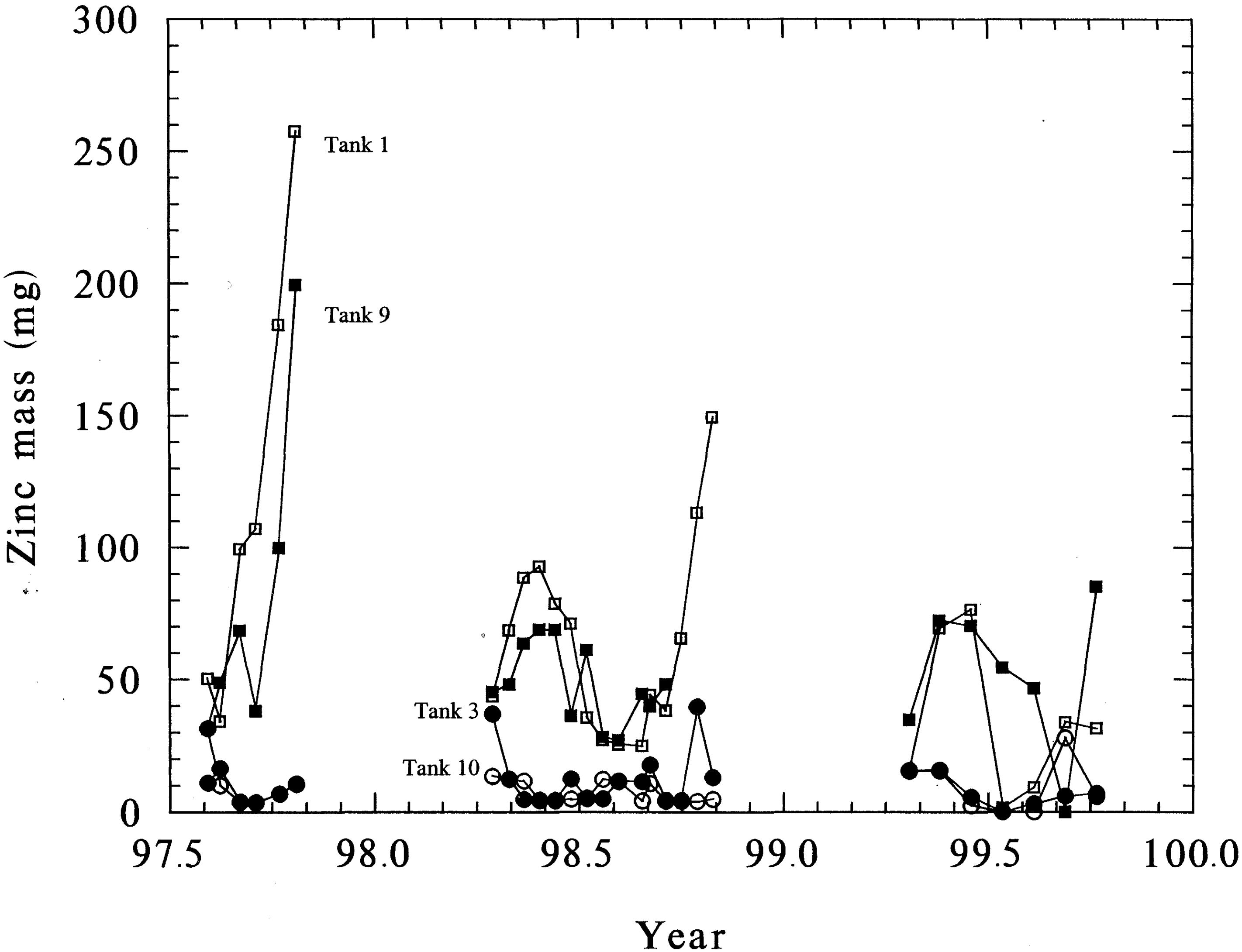


Figure 17. Mass of zinc released to the surface water, for the tanks with water cover (tanks 1, 9) and for the tanks with water and aquatic plants (tanks 3, 10), 1997-99.

stunted) and produced much less biomass than the plots with either peat or glacial till soil covers. When the surface dried, the tailings oxidized and acidified the surface water when the water level increased. In a wetland that naturally developed on a tailings spill, oxidation of the tailings also occurred in the areas with vegetation, although due to the fine grain size and high degree of saturation, the overall rate was low (Davé 1994).

Covering the tailings with a substrate such as glacial till or peat should not only provide a better growth medium for vegetation, but also should reduce oxygen transport to the underlying tailings. In natural wetlands, when the soil is saturated, anoxic conditions typically develop within several centimeters of the surface. A cover of 61 cm of substrate should have been sufficient to maintain saturation above the tailings since typical water level fluctuations in precipitation-dependent wetlands in northern Minnesota are on the order of 30 cm (Boelter and Verry, 1977, Melchert et al., 1997).

The dramatic decrease in water levels in the tanks with glacial till and peat in this experiment was not expected, and would not be expected to occur in an actual tailings basin with a substantial amount of open water. Kadlec and Knight (1996) concluded that evapotranspiration in wetlands characterized by nonwoody emergent vascular plants is about equal to lake evaporation. In northeastern Minnesota, annual lake evaporation is around 56 cm, and in normal years precipitation exceeds lake evaporation by about 22 cm (USDA-SCS, 1975). The tanks in this study are lined and have no interaction with runoff or groundwater, and are a model for any future tailings basins in Minnesota. Water levels depend solely on precipitation and evapotranspiration, and should eventually overflow due to the excess precipitation. Water levels in all the tanks with water covers increased over the course of the study, and 30 cm of water was removed from these tanks in July 1999 to prevent overflow.

Evapotranspiration in the other tanks was affected by the health and growth rates of the cattails. The cattails in the tailings grew poorly, while the cattails in glacial till and peat grew vigorously and were over 2 meters high by the summer of 1998. Evapotranspiration in the tanks with cattails planted directly on tailings (2, 7) was about equal to lake evapotranspiration, and 40 to 50% less than the tanks with the glacial till and peat.

In a large tailings pond, water from the open water area would supply water to the cattails growing along the shore and prevent water levels from dropping substantially. In normal years, water levels in the open water portion of the basin would increase and replenish water lost in the wetland portion of the basin.

Despite the large water level fluctuations in the peat and till tanks, the tailings layer maintained pH above 6 and had low levels of zinc. Water levels decreased below the cover material for about 3 weeks before groundwater was added to tanks 6 and 8. In the tanks that did not receive groundwater (tanks 4, 5), water levels remained below the cover material for 14 weeks in 1998 and did not recover until after the snow melt in April 1999. Oxygen transport was still restricted by the cover layer, and generally no change was observed in the water quality data from the deep tailings layer. At the end of 1999, sulfate concentrations increased in the tailings layer for tank 5, the peat tank that did not receive additional water. In this tank, as the peat dried it separated from the side of the tanks, providing an additional pathway for oxygen to enter the substrate.

Conclusions

Acid and metal release in all the treatments was much lower than from the uncovered, untreated tailings. A soil cover of either peat or glacial till provided a barrier layer above the tailings and produced dense vegetation, and would provide a suitable treatment for the shoreline of a reclaimed tailings basin. Water covers also reduced metal release, but the overall release was lower in the cover that included submerged vegetation. Establishing submerged vegetation in the water-covered portion of a reclaimed tailings basin would create a biologically active layer above the tailings, which should further reduce the transport of oxygen. Monitoring of all of the tanks will continue to determine the long term effectiveness of each treatment.

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Appendix 1

INMET Tailings Information

Attachment A1.1	Letter from Matthew Bliss on tailings composition.
Attachment A1.2	Letter from Matthew Bliss with additional details on tailings.
Attachment A1.3	INMET tailings properties.
Table A1.1	Acid/base accounting on INMET tailings.

INMET

MINING

April 28, 1997

Winston Lake Division

P.O. Bag #2
Schreiber, Ontario P0T 2S0

Minnesota Department of Natural Resources
Division of Minerals
Box 45
500 Lafayette Road
St. Paul, MN 55155

Subject: Winston Lake Zn-Cu Mine - Tailings Composition

Dear Mr. Eger:

Although funding is not (yet?) forthcoming, I have discussed the idea of sending you Winston tailings with my supervisor. We are excited about the wetland/water cover research program that you have proposed and hope that all goes well.

The majority of the tailings is comprised of the following:

30-35%	SiO_2 (quartz and silicates)
30-40%	Fe_2O_3 and FeO (sulphide, biotite, chlorite, amphibole)
10-12%	S (pyrrhotite, pyrite, sphalerite, chalcopyrite)
8-10%	$CaCO_3$ (assume LOI=loss on ignition carbonate/lime)
7-10%	Al_2O_3 (biotite and feldspar)
4-6%	MgO (biotite)
3-4%	CaO (amphibole and feldspar)
2-3%	Na_2O (feldspar and biotite)
1-2%	Zn (sphalerite)

Trace element analyses suggest that metals are as follows:

Cu	1000 - 1500
Co	250 - 400
P	350 - 500
Mn	200 - 300
As	100 - 200
Se	100 - 150
Ni	50 - 100
Pb	40 - 100
Ba	50 - 60
Cr	30 - 50
Sn	10 - 70
Ag	1 - 10
Au	0.6

The tailings has no commercial value that we have been able to determine. Additional recovery methods have been tested in our concentrator facility, however, to date none has been able to pay for itself. The grain size is, of course, quite variable but can be summarized as follows:

Microns	Percent Passing					
300	95+	98	98	98		
212	87	95	93	94	96	98
150	73	89	80	85	91	94
106	59	80	63	73	82	86
75	45	68	44	56	69	73
53	36	58	32	43	55	60
38	28	45	21	30	44	51
32	24	40	0.0	0.0	0.0	0.0
25	20	35				
17	16	27				
12	12	21				
9	11	19				
-9	0.0	0.0				

The Winston deposit is a volcanogenic massive sulphide deposit comprised of 30-40% sphalerite, 3-5% chalcopyrite, 15-20% pyrrhotite, 5-10%, however, sphalerite can be as high as 95%, chalcopyrite 7%, pyrrhotite 80% and pyrite 40%. Sphalerite is typically medium grained while the other sulphides are fine grained. The wallrock can be variable as follows:

hangingwall (50%)	gabbro
hangingwall (50%)	cherty tuff
footwall (60%)	biotite-chlorite altered basalt
footwall (40%)	relatively fresh basalt or cherty tuff

The tailings have a high sulphur content and unless kept under water can be acid generating. Tailings shipment is most convenient for us by tanker (slurry) transport with an expected water content of 50%. I have discussed some of the logistics with Mr. Greg Hood of Trimac Transport at (905) 827-9800 or (905) 827-8038 fax. Trimac has some experience hauling sulphide slurry (concentrate) from near Thunder Bay to Sudbury, Ontario. Shipment date is still in the air, but the end of May is still possible. It is, however, becoming hectic around here. We have had an unfortunate fatality underground this past month and are still not operating.

I intend to call Mr. Hood today and will have him contact you for site details.

Sincerely,

Matthew Bliss

Matthew Bliss

Attachment A1.2. Letter from Matthew Bliss on additional details of tailings composition.

INMET

MINING

May 5, 1997

Winston Lake Division

PO Bag #2
[illegible], Ontario [illegible]

Dave Antonson and Paul Eger
MN DNR, Minerals
Box 45
500 Lafayette Road
St Paul, MN 55155

SUBJECT: WINSTON LAKE TAILINGS - MORE DETAILS

Dear Dave and Paul,

I should have guessed that you would have such questions. The data that was sent to you is representative of the upper 2 m of tailings in the mid-portion of the tailings impoundment area. The samples were taken to characterise tailings areas to be reclaimed (dredged), they are thought to represent general tailings in the basin. We could get into detailed discussions regarding sedimentation rates, channelling, discharge location, etc. but I think that this is the best general grain size distribution data available for tailings. If it helps, note that we get the best efficiencies in the flotation circuit at ~80% passing 200 mesh.

Lime is indeed added to the tailings prior to discharge to the basin during the summer months. We have had the pond go down to pH 3.5 and do our best to avoid that since we recycle ~90% of our water (reclaim from tailings pond) and have some exposure concerns (occupational health and safety concerns) at low pH. Note also that the pH is elevated in the circuits (9.5 to 10) with slaked lime.

The specific gravity (S.G.) of the solids is approximately 3.0 tonnes/m3. I have included some AP and NP data from our closure plan.

I assume from the description of your constructed wetlands that the dykes will be constructed of coarse (cycloned?) tailings. In our tailings basin the fines are nearest the till core dyke and the coarser fraction is at the back of the impoundment where most settling occurs (theoretically).

I appreciate your challenges with regards to slimes. We are doing our best to confront the same challenges. Wallrock, locally, consists of massive biotite-chlorite which gets pulverised to clay in the rod mill and ball mills. No, the tailings fines are not in a separate stream from the coarse fraction. Alternatives 1 and 3 are definitely possibilities, however, committing to them is very difficult since our workforce has recently been minimised. I will discuss them with the Mill Superintendent and Maintenance Supervisor. I will also ask our metallurgist to send you a sample.

Matthew Bliss

P.S. I will be harder to reach during May; I'll be travelling, auditing, conferencing, construc[illegible]

[illegible]

Attachment A1.3. INMET tailings properties.

Solid tailings are typically produced at a rate of about 700 to 750 dry tonnes per day. After clarification in the tailings impoundment, supernatant is drawn into the reclaim system for distribution to the mill process, to underground and to the treatment system.

The estimated in-situ density used for original design of the tailings facilities was 1.35 tonne/m^3. A survey of deposited tailings was conducted in September 1990 as part of the design of the Phase 2 embankment. The actual dry density calculated from this survey for deposited tailings was 1.41 tonne/m^3.

The specific gravity of tailings used for original design of the tailings facilities was 3.31 m^3/tonne based on pilot plant testing. This original estimate of specific gravity and the original estimate of in-situ density (1.35 tonne/m^3) resulted in the calculation of an estimated void ratio of 1.45.

In-situ and laboratory testing of tailings densities was carried out in 1993 by Dennis Netherton Engineering as part of closure planning activities. The results of these tests indicate that the actual tailings density is in the order of 1.6 ti 1.8 tonnes/m^3 with a void ratio of 0.9 to 1.0.

The original in-situ tailings density estimate of 1.35 tonnes/m^3 is used for water balance modeling. This estimated of density (1.3 tonnes/m^3) has been proven to be very conservative (giving larger volume requirement per tonne of tailings).

Acid base accounting analysis of a pilot plant tailings sample (1986) indicated that Winston Lake tailings were potentially acid generation potential (AP) of 445.5 equivalent kg H_2SO_4/tonne. The net neutralization potential (NP - AP) was -362.2 equivalent kg H_2SO_4/tonne.

Subsequent acid base accounting analyses were performed on 8 tailings samples representing January 1991 to August 1993. The results were very consistent and verified that tailings were potentially acid generating. The average acid generation potential for the 8 samples of actual tailings was 443 tons $CaCO_3$ equivalent per 1,000 tons, and the average neutralization potential was 14 tons $CaCO_3$ equivalent per 1,000 tons.

Confirmation testing performed on the pilot plant tailings sample (1986) confirmed that tailings would generate acid.

Acid/base accounting and confirmation test results are listed in Table A1.1.

Table A1.1. Acid/base accounting and confirmation test results on tailings.

ACID/BASE ACCOUNTING					
SAMPLE	Paste pH	%S (Total)	AP*	NP*	NNP*
Pilot Plant 1986	8.13	14.56	4-45.5	83.3	-362.2
Jan - Apr 1991	6.8	16.20	506	10	-496
May - Aug 1991	6.9	12.00	375	18	-357
Sep - Dec 1991	6.4	13.40	419	13	-406
Jan - Apr 1992	6.7	12.10	378	9	-369
May - Aug 1992	7.1	14.40	450	17	-433
Sep - Dec 1992	6.5	15.60	488	13	-475
Jan - Apr 1993	6.7	13.70	428	16	-412
May - Aug 1993	7.0	16.00	500	17	-483
Average of 8	6.8	14.18	443	14	-429
Maximum of 8	7.1	16.20	506	18	-357
Minimum of 8	6.4	12.00	375	9	-496

* All units tons $CaCO_3$ equivalent per 1,000 tons material except 1986 sample kg H_2SO_4/tonne.
* AP = maximum potential acid production.
* NP = maximum neutralization potential.
* NNP = net neutralization potential (NP - AP).

Confirmation Test				
Sample	pH before extra sample	pH add 0.5 x orig. wt.	pH add 1.0 x orig. wt.	Confirmed Acid Producer
Pilot Plant 1986	1.19	1.87	2.00	Yes

Appendix 2

Tailings, Substrate and Water Addition Information

Attachment A2.1	Initial tailings thickness, substrate thickness, and water depth.
Attachment A2.2	Chemical analysis of DNR groundwater well #3.

Table A2.1. Initial tailing thickness, substrate thickness, and water depth above substrate.

Tank	Treatment	Tailings thickness (cm)	Substrate thickness (cm)	Initial Water[1] Depth (cm)
1	Water cover	65	NAp	67.8
2	Cattails on tailings	120	NAp	13.5
3	Water, submerged aquatics	66	NAp	66.7[2]
4	Cattails, glacial till cover	65	54.0	12.8
5	Cattails, peat cover	62	59.5	10.6
6	Cattails, peat cover	62	57.5	12.6
7	Cattails on tailings	120	NAp	13.3
8	Cattails, glacial till cover	63	56.5	12.7
9	Water cover	63	NAp	67.7
10	Water, submerged aquatics	61	NAp	70.2[2]

Nap - not applicable

[1]- Water level adjusted to starting level of 12 inches below top of the tank on 7/11/97.

[2]- Adjusted to final level (12 inches from the top of the tank) on 7/16/97, water level prior to plant addition was approximately 20 cm lower than the final level.

Table A2.2. Chemical analysis of water from DNR ground water well #3 used to saturate tailings, June 1997. Analysis by MN Department of Agriculture, concentrations in ppm unless otherwise noted. pH is reported in standard units.

Parameter	Tank 1	Tank 2	Tank 3	Mean	Well #3[1]
SC (uS)	NA[2]	NA	NA	NA	550
pH	NA	NA	NA	NA	7.15
Eh (mv)	NA	NA	NA	NA	167.9
Alkalinity (mg/L)	NA	NA	NA	NA	190
Calcium	67.1	60.8	63.3	63.7	57.2
Magnesium	28.5	32.4	33.9	31.6	31.9
Sodium	10.5	10.7	9.8	10.3	11.3
Potassium	6.2	7.6	3.1	5.6	3.0
Iron	<0.10	<0.10	<0.10	0.05	NA
Manganese	0.10	0.10	0.10	.010	NA
Aluminum	0.70	0.10	<0.10	0.28	NA
Copper	<0.10	<0.10	<0.10	0.05	<0.05
Zinc	0.10	0.13	<0.02	0.08	<0.02
Nickel	<0.10	<0.10	<0.10	0.05	<0.1
Cobalt (ppb)	1.0	1.0	<1.0	0.70	<1.0
Sulfate	100	103	65.7	89.6	71.4

1- DNR ground water well #3 sampled on 8/28/97.

2- NA = Not analyzed.

Note: If values were less than the detection limit (0.10), then 0.05 was used to calculate the mean.

Note: Water was collected from DNR monitoring well #3 and pumped into 500 gallon holding tanks. The water that was shipped with the tailings was allowed to drain to a collecting area and was collected in 3 - 5 gallon buckets. About 5 gallons was then added to each of the 500 gallon tanks and mixed with the water from well #3.

Appendix 3

Solids Composition

Table A3.1. Whole rock analysis for DNR Winston Lake composite samples 1, 2 & 3, and 4. Sulfur species and CO_2 analysis by Lerch Brothers, Hibbing, MN and whole rock analysis by Chemex Labs, Sparks, NV. Concentrations in percent.

Parameter	Composite 1	Composite 2 & 3	Composite 4	Mean
S Total	12.88	12.67	13.42	12.99
SO_4	0.18	0.17	0.21	0.19
S^{-2}	12.70	12.50	13.22	12.81
CO_2	0.55	0.52	0.50	0.52
SiO_2	30.94	30.65	30.93	30.84
Al_2O_3	8.38	8.51	8.64	8.51
CaO	3.05	3.06	3.07	3.06
Cr_2O_3	0.03	0.03	0.03	0.03
Fe_2O_3	29.00	27.73	28.61	28.45
K_2O	0.55	0.54	0.56	0.55
MgO	4.81	4.82	4.83	4.82
MnO	0.09	0.09	0.09	0.09
Na_2O	2.29	2.30	2.31	2.30
P_2O_5	0.09	0.09	0.09	0.09
SiO_2	37.58	37.66	38.15	37.80
TiO_2	0.47	0.47	0.47	0.47
LOI*	9.10	8.81	8.98	8.96
Total Percent	95.44	94.11	95.83	95.13
NP[1]	11.75	9.6	12.6	11.32
APP[2]	402.5	395.9	419.4	393.3

*LOI = Loss on ignition.

[1]Neutralization potential, analysis by MDNR Hibbing lab.
[2] Calculated acid production potential.

Table A3.2. Trace element analysis of DNR Winston Lake composite samples 1, 2 & 3 and 4. Analysis by Chemex Labs, Sparks, NV. Concentrations are in ppm unless otherwise noted. Mercury analysis by Frontier Geosciences, Inc., Seattle, WA.

Parameter	Composite 1	Composite 2 & 3	Composite 4	Mean
Ag	12	8	9	9.67
Al (pct)	1.41	1.33	1.40	1.38
As	90	60	110	86.67
Ba	20	20	20	20
Be	<5	<5	<5	<5
Bi	30	30	20	28.33
Ca (pct)	1.01	0.94	1.00	0.98
Cd	35	35	35	35
Co	285	285	290	287
Cr	90	60	80	76.7
Cu	1965	1785	1745	1832
Fe (pct)	18.90	18.45	18.80	18.72
Hg (ng/g)	152.3	162.6	155.9	156.9
K (pct)	0.6	0.26	0.26	0.37
Mg (pct)	1.88	1.85	1.91	1.88
Mn	340	320	330	330
Mo	<5	<5	<5	<5
Na (pct)	0.11	0.07	0.10	0.28
Ni	95	85	90	90
P	400	300	300	333
Pb	80	75	80	78.3
Sb	30	30	* <10	21.7
Sc	<5	<5	<5	<5
Sr	10	5	5	6.7
Ti (pct)	0.09	0.08	0.09	0.087
Tl	* <20	20	* <20	13.3
U	<20	<20	<20	<20
V	20	20	40	26.7
W	<20	<20	<20	<20
Zn	18420	19070	17900	18463
Se	7.4	5.4	8.8	7.2
F	900	900	930	910
Tl	0.7	0.5	0.5	0.6

* Half of the detection limit was used to calculate the mean.

Table A3.3. Analysis of peat and overburden. Analysis by University of Minnesota Soil Testing and Research Laboratory. Concentrations in ppm unless otherwise noted. pH reported in standard units.

Parameter	Peat	Overburden
Total Solids (%)	42.7	89.8
pH	4.3	7.0
C.E.C. (meq/100 gm)	66.1	4.56
SO_4-S (ppm)	11	3
$CaCO_3$ Equivalent(%)	*1.21*	2.43
NO_3-N (ppm)*	26	5.6
NH_4-N (ppm)*	40.95	<0.1
% Moisture	57.3	10.2
TKN %N	0.68	0.02
% Ash	46.5	98.4
Total Sulfur %S	0.11	0.001
P	638	219
K	251	119
Ca	2705	810
Mg	627	148
Mn	122	45.53
Al	2111	573
Fe	4887	1021
Na	32.7	13.9
Zn	17.6	2.16
Cu	5.18	0.75
B	3.11	0.97
Pb	7.39	2.69
Ni	4.57	1.03
Cr	5.03	2.06
Cd	0.19	<0.12

* Results expressed on a wet weight basis, all other results are expressed on a dry weight basis.
Note: The peat value for $CaCo_3$ Equivalent appears to be anomalous.

Attachment A3.1. Winston Lake tailing neutralization potential determination by MDNR.

NP for composite samples

NP was determined on the composite samples of tailing taken while the tanks were being loaded. These composites were also analyzed by Midland Research for mineralogy. Two gram samples were used and titrated to an endpoint pH of 6.0 with 1N H_2SO_4 acid using an automatic titrator.

Composite #1 Initial pH = 5.61, NP = 11.75 after 26 hours
Composite #2 Initial pH = 5.44, NP = 17.25 after 26 hours
Composite #3 Initial pH = 5.00, NP = 37.13 after 22 hours
Composite #2&3 Initial pH = 4.94, NP = 9.6 after 11 hours
Composite #4 Initial pH = 5.20, NP = 12.6 after 19 hours

Calculated Acid Producing Potential (AP) in units of kg $CaCO_3$/t = %Sulfur x 31.25
12.99 x 31.25 = 405.9 AP

Note: The 12.99 sulfur content is the mean of the three composite samples.

NP for initial samples obtained from Winston Lake

Two five gallon buckets of tailing from Winston Lake were delivered to the DNR. One contained oxidized beach tailing for an example of the particle size of the 'coarse' type of material that DNR intends to use. The soil/water pH of this oxidized material was 3.24. The other bucket was a sample of the composite tailing straight from the discharge pipe. We decanted the standing water in the bucket and found that the tailing had set up in the bucket and was relatively dry. It obviously had more fines than the oxidized beach material but was not as fine as the fine tailing from area taconite plants where they separate coarse from fine. Moisture content was obtained by drying 100 g in the oven at 95 degrees C. The soil/water pH dried material, the undried material, and the oxidized tailing was determined. An NP of 26 was obtained by the use of the autotitrator (1NH_2SO_4 to endpoint pH 6.00) over a period of approximately 28 hours. The test was performed on the undried solids, calculations were based on dry solids.

% moisture of decanted tailing = 10%

Soil/water pH:
oxidized - 3.24
Oven dried - 7.26
Wet - 8.75

NP(pH6) = 26kg $CaCO_3$/t

Attachment A3.2. Midland Report on Analyses of Composite Tailing Samples

September 18, 1997

Mr. Paul Eger
MnDNR-Division of Minerals
500 Lafayette Road
St. Paul, MN 55155-4045

RE: Preliminary Report on Sample characterization of Winston Lake Tailings Samples

The four Winston Lake tailings samples have been processed as requested. They were dried with any agglomerations broken up, and split into portions for screen structures, assay pulps, and mineralogical studies. During the drying process at 105° C., the samples emitted considerable odiferous sulfur compounds (SO_2). At this temperature any sulfur is very loosely bonded. It takes relatively little sulfur also to create an odor.

Composite samples one (MRC 673) and four (MRC 675) were run individually, while samples two and three were composited (into MRC 674). The three samples all had similar X-ray Diffraction (XRD) patterns to identify mineralogy and analytical chemistry to determine mineral amounts. Screen structures were also similar.

Copies of the chemistry results and screen structures are enclosed. Considerable problems have been encountered in formulating the mineral balances with meaningful results. These will be given at a later time after some additional chemistry checks are carried out. Some uncertainty exists with these numbers for the following reasons.

1. With regard to chemistry, the samples contained high sulfide content which, despite analytical precautions, has a tendency to produce less than accurate results.

2. The samples came from a complex geologic setting compared to normal taconite tailing samples. The Winston Lake host rocks have a wide variation of compositions and mineralogy (various volcanics and sediments). These in turn have been variably altered by a hydrothermal system. Relatively high grade metamorphism has also occurred. In some sense, a mineral balance

would be much easier on a single rock type than tailings from a number of extremely variable rocks.

3. With regard to the XRD patterns identifying mineralogy, peaks occur for the following minerals: quartz, chlorite, pyrite, mica, pyrrhotite, hornblende/anthophyllite, talc, magnetite, calcite, lime?, albitic feldspar, dolomite, sphalerite?, rutile?, granite?, gypsum?, cordierite?, sillimanite?, and garnet?. Because of the large number of peaks and the resulting overlap and interference, many minerals were identified based on one or two identifiable peaks.

4. Many of the silicates have multiple cations and the resulting XRD peaks often were shifted due to composition differences between a given XRD pattern mineral reference and the actual unknown mineral peaks. Thus there is uncertainty as to which side of each spectrum the composition varies from the reference (if there are four different cation bonding sites in a mineral crystal, there are four different dimensions of variability). Consequently, the composition used in the mineral balance may be significantly different from the XRD pattern match (in the range of several percent?).

The eventual mineral balance numbers for this are based on information from the following sources: XRD peaks; chemistry; and visual examination.

Screen Structures

Sample splits of 150 to 200 grams were wet vibrating screened and dry ro-tapped on a standard set of Tyler sieves from 35 mesh through 500 mesh (420 through 25 microns). The particle size structures for the three samples are attached. The structures were similar with less than 1% difference between the corresponding sizes of different samples. About 57-58% of the samples fall within -65 mesh and +270 mesh. About 17-18% is -500 mesh.

XRD Mineralogy

The XRD peaks hint at the following order of abundances:

- **major components (amounts decreasing? downward)**
  - **quartz**
  - **feldspar**
  - **pyrite (and sphalerite; peaks overlap)**

less major components

- **dolomite (dolostone added to tailings?)**
- **biotite/muscovite/paragonite/phlogopite (mica)**
- **chlorite**

minor components

- **calcite (limestone added to tailings?)**
- **hornblende/anthophyllite**
- **pyrrhotite**
- **magnetite**

trace(?) components

- **talc**
- **sillimanite?**
- **cordierite?**
- **garnet?**
- **gahnite?**
- **rutile?**
- **lime? (added to tailings?)**
- **gypsum?**

A number of inconsistencies occur from this. Visual observation indicates that the pyrrhotite amount probably exceeds the pyrite amount. Chemistry also tends to support this since calculations tend to create a deficit in SiO_2 which is also accentuated by assuming a pyrite amount greater than pyrrhotite (pyrite uses up less iron for the same amount of sulfur, with this extra iron needing to be taken up as either silicates or magnetite).

The analyses indicate a small amount of carbonate (indicating a total carbonate content of about 1%), yet the XRD`peaks indicate that the amount may be greater. Visual observation of acid effervescence indicates a greater amount of carbonate (5% carbonate or more?).

Chemistry Analyses

Lerch Brothers, Inc, analyzed all three samples for total sulfur, sulfur in the form of sulfate, sulfur in the form of sulfide, carbon dioxide, and free silica (see results). Chemex Labs, Inc. performed whole rock and trace element analyses (see results). Frontier Geosciences analyzed the samples for mercury (see results).

The samples contained about 13% sulfur, and about .5% CO_2. The sulfur and elevated Zn (about 18000 ppm) and Cu (about 1800 ppm) appear to be the main culprits with regard to making some of the ICP chemistry results reliable (and they're enough to prevent XRF analyses). The Zn phase is probably sphalerite, and the Cu phase is probably chalcopyrite.

Also note that the arsenic content is somewhat elevated at 60 to 110 ppm. The phase is uncertain, but it is probably hidden with the sulfides. All mercury values are less than 1 ppm, but still are probably somewhat elevated over most rocks. Sphalerite containing rocks tend to have elevated mercury.

Boron is sometimes elevated in volcanic massive sulfide deposits, however all analyses were low. Tourmaline, the most likely phase, is very stable anyway.

The whole rock loss on ignition (LOI) was about 9%. This reflects most of the sulfide and carbonate probably. The whole rock totals were about 95%. The missing 5% may be the remaining sulfur and carbonate.

Inquiries have been made with Chemex and Lerch Brothers concerning the analyses. Some analytical checks have not come in yet.

A number of perturbations in creating the mineral balances have been tried. At this point, it will probably be several weeks before the best mineral balance numbers can be obtained.

Sincerely, Barry Frey

Barry Frey
Technical Consultant
cc: Dave Antonson DNR-Minerals Hibbing

Table A3.4. Analysis of particle size distribution of overburden. Analysis by University of Minnesota Soil Testing and Research Laboratory..

Material	Particle size (mm)	Percent	Percent
Sand	1.0 to 2.0	5.48	
	0.45 to 1.0	7.73	
	0.25 to 0.45	13.59	
	0.1 to 0.25	14.16	
	0.05 to 0.1	20.99	61.96
Silt	0.02 to 0.05	19.62	
	0.002 to 0.02	9.38	29.00
Clay	<0.002	9.04	9.04
Total		100.00	100.00

Table A3.5. Mean particle size distribution values for DNR Winston Lake Composite samples 1, 2 & 3, and 4. Analysis by Midland Research Center, Nashwauk, MN.

Mesh size	screen size(mm)	Grams retained	Mean % Wt.	Mean Cum. % Wt.	Mean % Wt. Passing
35 mesh	0.417	8.733	2.52	2.52	97.48
48 mesh	.0.295	10.333	2.98	5.50	84.50
65 mesh	0.208	27.800	8.02	13.52	86.48
100 mesh	0.147	51.567	14.88	28.40	71.60
150 mesh	0.104	59.000	17.02	45.42	54.58
200 mesh	0.074	48.533	14.01	59.43	40.57
270 mesh	0.053	40.500	11.71	71.14	28.86
325 mesh	0.043	11.567	3.34	74.48	25.52
400 mesh	0.038	12.567	3.61	78.09	21.91
500 mesh	0.025	14.967	4.34	82.43	17.57
-500 mesh	<0.025	60.767	17.57	100.00	0.00
Calc. HD		346.167	100.00		
Sa. Wt.		346.167			

Note: Dry ro-tapped on standard Tyler series.

Table A3.6. Particle size distribution of DNR Winston Lake Composite 1 sample. Analysis by Midland Research Center, Nashwauk, MN.

Mesh size	Screen size(mm)	Grams retained	%Wt.	Cum. % Wt.	% Wt. Passing
35 mesh	0.417	10.100	2.93	2.93	97.07
48 mesh	0.295	10.300	2.99	5.92	94.08
65 mesh	0.208	27.300	7.91	13.83	86.17
100 mesh	0.147	50.300	14.58	28.41	71.59
150 mesh	0.104	57.900	16.78	45.19	54.81
200 mesh	0.074	48.300	14.00	59.19	40.81
270 mesh	0.053	40.700	11.80	70.99	29.01
325 mesh	0.043	11.400	3.30	74.29	25.71
400 mesh	0.038	12.300	3.57	77.86	22.14
500 mesh	0.025	14.900	4.32	82.18	17.82
-500 mesh	<0.025	61.500	17.82	100.00	0.00
Calc. HD		345.000	100.00		
Sa. Wt.		345.000			

Table A3.7. Particle size distribution of DNR Winston Lake Composite 2 & 3 sample. Analysis by Midland Research Center, Nashwauk, MN

Mesh size	Screen size(mm)	Grams retained	% Wt.	Cum. % Wt.	% Wt. Passing
35 mesh	0.417	8.900	2.40	2.40	97.60
48 mesh	0.295	11.500	3.10	5.50	94.50
65 mesh	0.208	30.600	8.25	13.75	86.25
100 mesh	0.147	5 7.200	15.41	29.16	70.84
150 mesh	0.104	64.300	17.33	46.49	53.51
200 mesh	0.074	52.900	14.25	60.74	39.26
270 mesh	0.053	42.400	11.43	72.17	27.83
325 mesh	0.043	12.500	3.37	75.54	24.46
400 mesh	0.038	13.100	3.53	79.07	20.93
500 mesh	0.025	15.200	4.10	83.17	16.83
-500 mesh	<0.025	62.500	16.83	100.00	0.00
Calc. HD		371.100	100.00		
Sa. Wt.		371.100			

Table A3.8. Particle size distribution of DNR Winston Lake Composite 4 sample. Analysis by Midland Research Center, Nashwauk, MN.

Mesh size	Screen size(mm)	Grams retained	% Wt.	Cum % Wt.	% Wt. Passing
35 mesh	0.417	7.200	2.23	2.23	97.77
48 mesh	0.295	9.200	2.85	5.08	94.92
65 mesh	0.208	25.500	7.91	12.99	87.01
100 mesh	0.147	47.200	14.64	27.63	72.37
150 mesh	0.104	54.700	16.96	44.59	55.41
200 mesh	0.074	44.40	13.77	58.36	41.64
270 mesh	0.053	38.400	11.91	70.27	29.73
325 mesh	0.043	10.800	3.35	73.62	26.38
400 mesh	0.038	12.000	3.72	77.34	22.66
500 mesh	0.025	14.800	4.59	81.93	18.07
-500 mesh	<0.025	58.300	18.07	100.0	0.00
Calc. HD		322.500	100.00		
Sa.Wt.		322.500			

Appendix 4

Drainage Quality

Table A4.0. Anomalous drainage quality data for wetlands on acid generating tailings. The following data have been verified to be as reported values, and appear to be anomalous. Anomalous data were not included in any data analysis.

Tank	Site	Date	Table	Parameter	Value	Typical Values	Comments
1	Surface	9-10-97	A4.1.	pH	4.80	7.3 - 7.8	Sudden 1-day drop in pH does not make sense; all pH values were abnormally low.
1	Surface	9-16-98	A4.1.	Ca	11.0	140 - 160	
1	Surface	9-30-98	A4.1.	Zn	1.47	0.04 - 0.1	Duplicate tank (9) had values for this period of .1-.2.
1	Surface	10-14-98	A4.1.	Zn	1.58	0.04 - 0.1	Duplicate tank (9) had values for this period of .1-.2.
1	Surface	10-28-98	A4.1.	Zn	1.23	0.04 - 0.1	Duplicate tank (9) had values for this period of .1-.2
1	Surface	4-22-99	A4.1	SC	240	30	Does not fit based on cation/anion balance.
2	Surface	4-30-98	A4.2.	SO_4	3.5	300	Low sulfate concentrations do not balance cations present.
2	Surface	6-24-98	A4.2.	SO_4	268	200	
2	Surface	8-11-99	A4.2.	Zn	0.001	0.8 - 1.2	
3	Surface	10-21-99	A4.3	SO_4	43	250	Duplicate tank (10) had value of 218
5	Surface	8-28-97	A4.5.	SO_4	<1	60 - 90	Does not balance cations.
5	Surface	4-30-98	A4.5.	SC	550	50 - 150	
5	Surface	5-13-98	A4.5.	SC	700	50 - 150	
5	Surface	6-24-98	A4.5.	SO_4	288	20 - 60	Way too high given SC reading and cations concentration.
5	Deep	6-16-99	A4.5.	SC	57	4000 - 5000	
6	Surface	5-19-99	A4.6.	SC	1450	100 - 200	
6	Surface	5-19-99	A4.6.	SO_4	704	10 - 80	
6	Surface	5-19-99	A4.6.	Ca	107	5 - 30	
6	Surface	5-19-99	A4.6.	Mg	93.9	3 - 20	
6	Shallow	9-30-98	A4.6.	Zn	0.57	0.13	
6	Deep	9-8-99	A4.6.	Zn	0.11	0.02 - 0.06	Duplicate tank 5 had value of 0.019
8	Shallow	5-13-98	A4.8.	pH	4.90	6.0 - 6.9	
9	Interface	8-5-98	A4.9.	Ca	1777	140 - 190	
9	Surface	4-22-99	A4.9.	SC	500	50	Based on concentration of cations/anions and data from spring 1998 would expect SC <100.
9	Deep	5-13-98	A4.9.	pH	4.00	6.3 - 6.7	
10	Interface	6-16-99	A4.10	Mg	1040	100	Appears to be off by a factor of 10
10	Deep	5-13-98	A4.10.	pH	4.62	6.2 - 6.5	
2	Surface	10-28-98	A4.12.	Fe	33.7	0.3 - 0.7	
5	Surface	4-15-98	A4.12.	NO_{3_2}	3.35	<0.4	
7	Shallow	6-16-99	A4.12.	Fe	48.3	90 - 200	
7	Deep	9-22-97	A4.12.	Na	19.1	350 - 400	
10	Surface	4-15-98	A4.12.	NO_{3_2}	0.04	<0.4	

Note: All Eh values are raw values (not temperature corrected) taken at the time of sampling.

Table A4.1 Drainage quality from tank 1 (water cover).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
1 Surface	7-29-99	800	7.34												
1 Surface	8-11-99	850	7.04	133.1	35		6.35	69.8	19.3	0.4	382	0.005	0.0581	126	28.2
1 Surface	8-26-99	800	7.08												
1 Surface	9-8-99	650	7.17	158	40		7.25	74.7	17	0.4	353	0.004	<0.002	104	25.1
1 Surface	9-23-99	650	5.56												
1 Surface	10-6-99	790	7.38	96.4		15	8.1	64.8	5.9	0.9	362	0.003	0.1	102	24.7
1 Surface	10-21-99	850	5.64												
1 Interface	7-8-98	700	7.58	60	100	<5	4.86	53.4	20.5	0.8	302	<0.05	0.04	128	35.3
1 Interface	8-5-98	750	8.24	81.9	90		4.81	54.3	21.6	0.4	365	<0.05	0.03	145	40
1 Interface	9-2-98	1100	7.56	-56.1	102.5		6.33	66.6	18	0.4	386	<0.05	0.04	167	43.8
1 Interface	9-30-98	1100	7.70	100.7	85		7.05	63.6	11.1	0.4	451	<0.05	<0.02	160	41
1 Interface	10-28-98	850	7.43	94.5	85		6.6	57.5	9.6	0.4	342	<0.05	0.3	153	38
1 Interface	4-22-99	4400	6.63	184.2	35		6.05	49.6	6.7	0.4	2051		0.89	849	197
1 Interface	5-6-99	2470	5.30												
1 Interface	5-19-99	4000	6.92	160.5	280		5.7	55.3	13.9	0.4	2184		0.76	712	170
1 Interface	6-3-99	3150	6.84												
1 Interface	6-16-99	2800	6.80	188.6	130		4.9	50.5	17	0.4	1308	0.004	0.21	435	118
1 Interface	7-2-99	2200	7.66												
1 Interface	7-14-99	850	7.06	182.3	50		4.21	48.4	22	0.4	342	0.003	0.0244	121	27
1 Interface	7-29-99	750	7.50												
1 Interface	8-11-99	800	7.06	130.1	40		6.45	69.4	19	0.2	375	0.004	0.0341	128	29
1 Interface	8-26-99	750	6.96												
1 Interface	9-8-99	750	7.11	147.5	40		6.45	66.2	16.7	0.4	338	0.003	0.308	102	24.5
1 Interface	9-23-99	800	7.11												
1 Interface	10-6-99	800	7.21	105.4	30	5	7.25	58.2	6.3	0.4	354	0.003	0.31	102	24.5
1 Interface	10-21-99	750	6.95												
1 Deep	7-31-97	5000	6.38	-138			0.7	7.8	20.8	0.85	2580	0.002	0.02	586	193
1 Deep	8-14-97	4800	6.49	-67.5			0.76	7.8	16.8	0.85	2572	<0.1	0.04	544	210
1 Deep	8-28-97	5000	6.46	-41.4	325		0.65	6.7	17.2	0.85	2869	<0.05	<0.02	554	224
1 Deep	9-10-97	4455	5.90	-18.5		530	2.69	27.7	16.6	0.85	2872	<0.05	<0.02	557	230
1 Deep	9-22-97	4376	6.38	-32.1	380		1.48	14.0	13.3	0.85	2887	0.001	0.02	530	230
1 Deep	10-21-97	4560	6.44		325					0.85	2785	<0.05	0.1	544	250
1 Deep	4-15-98	4650	6.65	18.3	262		1	7.5	3.8	0.8	2637	<0.001	0.06	423	240
1 Deep	4-30-98	4800	6.46	-51.7	180		1	10.1	16	0.8	2845	<0.001	0.04	478	257

Table A4.1 Drainage quality from tank 1 (water cover).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

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Tank	Date	SC(µS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
1 Deep	5-13-98	4850	6.38	-46.5	195		1.6			0.8	2805	<0.001	0.04	481	254
1 Deep	5-27-98	4500	6.40	-35.2	165		2.35	24.7	18	0.8	2782	<0.001	0.05	512	252
1 Deep	6-10-98	4350	6.35	-27.7	280		2.26	21.2	12.7	0.8	3012	<0.001	0.07	510	258
1 Deep	7-8-98	4450	6.60	-69.3	190	28.5	0.76	8.6	21.7	0.8	2693	<0.05	0.04	542	261
1 Deep	8-5-98	4400	7.00	-74.7	305		0.48	5.5	22	0.8	3132	<0.05	0.04	553	257
1 Deep	9-2-98	4750	6.59	-80.7	290		1.23	13.0	18.3	0.8	1756	<0.05	0.02	540	272
1 Deep	9-30-98	5000	6.46	-70.8	412		0.47	4.2	10.1	0.8	2749	<0.05	<0.02	550	282
1 Deep	10-28-98	4000	6.51	-73.2	255		0.95	8.9	12.7	0.8	3127	<0.05	0.1	505	274
1 Deep	4-22-99	4650	6.62	-61.6	270		0.95	8.0	7.7	0.8	2138		0.04	465	248
1 Deep	5-19-99	5000	6.66	-108.2	190		0.84	7.9	12.5	0.8	2762		0.06	514	254
1 Deep	6-16-99	4600	6.48	-85.5	288		1.08	10.9	15.7	0.8	2808	0.006	0.0231	458	251
1 Deep	7-14-99	4450	6.50	-79.7	150		0.88	10.0	21.8	0.8	2846	0.007	0.0043	525	245
1 Deep	8-11-99	4800	6.54	-62.4	210		0.47	5.0	18.5	0.8	2951	0.025	0.0267	534	278
1 Deep	9-8-99	4800	6.49	-22.9	200		0.94	9.7	17.1	0.8	2570	0.026	0.06	486	228
1 Deep	10-6-99	3900	6.63	-58	230	230	0.95	7.9	7.2	0.8	2478	0.025	<0.02	579	244

1 Total metals were analyzed for comparison with filtered.

Bold/italic values appear to be anomalous.

Table A4.2 Drainage quality from tank 2 (reacted tailings planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
2 Surface[1]	8-1-97											<0.05	2.1	403	69.9
2 Surface	8-1-97	2690	7.75	84.5			10.4	113.0	20.4	0.8	1414	0.008	2.45	439	74.4
2 Surface[1]	8-14-97											<0.05	1.61	795	117
2 Surface	8-14-97	3450	6.59	35.5			8.2	86.3	18	0.8	2093	<0.1	1.4	671	117
2 Surface[1]	8-28-97											<0.05	0.78	614	99.6
2 Surface	8-28-97	3200	6.81	118.3	20		7.8	86.7	20.9	0.8	1887	<0.05	0.72	591	99.8
2 Surface	9-10-97	4909	7.06	117.8	2		9.8	112.6	22.6	0.8	2411	<0.05	1.1	951	179
2 Surface[1]	9-10-97											<0.05	1.21	963	182
2 Surface[1]	9-22-97											0.018	1.13	637	124
2 Surface	9-22-97	3237	7.00	87.9	15		9.5	109.2	22.9	0.8	2030	<0.001	1.1	600	123
2 Surface	10-21-97	2300	6.90		20					0.5	953	<0.05	1.1	378	58.3
2 Surface[1]	10-21-97											<0.05	1.19	388	58.7
2 Surface	4-15-98	625	7.22	78.3	15		10.4	74.8	2.3	0.7	272	0.004	0.1	100	10.4
2 Surface	4-30-98	1250	6.52	74.6	15		6.7	70.5	17.5	0.4	***3.5***	0.002	0.3	216	23.4
2 Surface	5-13-98	1850	6.45	77.8	20		6.65	67.2	15.8	0.4	1006	<0.001	0.62	325	36.9
2 Surface	5-27-98	2600	6.38	68.3		15	6.05	61.1	16.3	0.4	1551	0.011	1.45	532	62
2 Surface	6-10-98	2550	6.25	55.4		15	6.7	62.0	11.9	0.4	1764	0.006	3.59	584	75.8
2 Surface	6-24-98	1300	7.02	131.3			4.45	44.9	16.4	0.12	***268***	<0.05	0.72	304	36.2
2 Surface	7-8-98	1425	6.70	45.4	25	<5	5.25	59.7	21.9	0.2	714	0.05	0.41	284	33.7
2 Surface	7-22-98	1900	7.21	86.2	25		4.19	44.1	18	0.4	998	<0.05	0.27	409	49.5
2 Surface	8-5-98	2950	6.53	77.2	30		4.32	49.7	22.7	0.4	1527	<0.05	0.4	723	96.3
2 Surface	10-14-98	2650	3.48	304.2		270				0.2	1761	0.1	10.8	533	73.4
2 Surface	10-28-98	1100	3.75	226.5		95	8.75	75.4	9.3	0.4	690	<0.05	1.8	204	14.6
2 Surface	4-22-99	435	4.08	297.2		35	8.2	67.8	7.1	0.9	163		0.06	42.6	4.8
2 Surface	5-6-99	980	4.47												
2 Surface	5-19-99	1000	3.38	294		45	6.45	60.8	12.4	1	492		0.7	152	13.9
2 Surface	6-3-99	1150	3.41												
2 Surface	6-16-99	1300	3.46	243		45	6.3	63.0	15.5	1.3	485	0.035	1.918	197	23.7
2 Surface	7-2-99	1250	3.71												
2 Surface	7-14-99	900	3.80	239.5		40	5.55	66.9	24.4	0.4	414	0.015	1.24	144	17.2
2 Surface	7-29-99	950	3.73												
2 Surface	8-11-99	950	4.34	183.1		20	6.1	65.6	19	0.4	497	0.017	0.001	167	23.2
2 Surface	8-26-99	950	3.99												
2 Surface	9-8-99	1100	3.99	202.3		30	5.35	54.0	16.1	0.4	524	0.014	0.98	154	23

Table A4.2 Drainage quality from tank 2 (tailings planted with cattails).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
2 Surface	9-23-99	1050	4.24												
2 Surface	10-6-99	1100	4.40	160.7		10	8.9	69.5	4.9	0.9	525	0.015	0.813	147	22.4
2 Surface	10-21-99	1000	4.11												
2 Shallow	7-31-97	4800	6.37	-60.5			0.45	5.0	21	0.85	2362	<0.001	<0.02	588	177
2 Shallow	8-14-97	4550	6.33	-100.4			0.6	6.1	16.4	0.85	2425	<0.1	0.04	557	195
2 Shallow	8-28-97	5000	6.42	-66.4	360		0.55	5.7	17.8	0.85	2663	<0.05	<0.02	572	204
2 Shallow	9-10-97	4445	5.70	-5.1		475	2.45	25.0	16.5	0.85	2691	<0.05	<0.02	575	205
2 Shallow	9-22-97	4182	6.31	-51.8	430		0.8	7.5	12.5	0.85	2622	0.002	0.02	526	205
2 Shallow	10-21-97	4165	6.45		365					0.85	2460	<0.05	0.1	528	225
2 Shallow	4-15-98	4625	6.82	45.8	245		1.05	7.6	2.3	0.8	2595	<0.001	0.06	422	307
2 Shallow	4-30-98	4250	6.49	-34.5	220		1.5	14.7	15.4	0.8	2501	<0.001	0.04	493	274
2 Shallow	5-13-98	4425	6.45	-35.6	240		1.61	15.8	15	0.8	2351	<0.001	0.03	514	271
2 Shallow	5-27-98	4450	6.49	-47.4	275		1.98	20.8	18.2	0.8	2498	<0.001	0.04	527	246
2 Shallow	6-10-98	4150	6.39	-50	295		0.62	5.8	12.6	0.8	2663	0.012	0.04	516	267
2 Shallow	7-8-98	4100	6.43	-63.1	267.5	7.5	1.13	12.8	22.1	0.8	2306	<0.05	0.04	544	258
2 Shallow	8-5-98	4000	6.50	-68.2	330		0.59	5.7	13.9	0.8	2760	<0.05	0.03	561	277
2 Shallow	10-28-98	3950	6.50		280		0.8			0.8	2788	<0.05	0.05	529	304
2 Shallow	5-19-99	>5000	6.75	-79.6	230		0.77	7.5	14.1	0.8	3025		0.03	504	357
2 Shallow	6-16-99	5000	6.54	-51.3	265		1.25	12.4	15	0.8	2870	<0.002	0.021	470	340
2 Shallow	7-14-99	4850	6.53	-86.8	225		0.78	9.2	23.5	0.8	3061	0.005	<0.002	514	371
2 Shallow	8-11-99	4950	6.46	-62.7	270		0.78	8.5	19.3	0.8	3227	0.024	0.0273	517	391
2 Shallow	9-8-99	5000	6.41	-65.4	265		0.73	7.5	17.7	0.8	2737	0.021	0.02	481	338
2 Shallow	10-6-99	4200	6.30	-72.1	275	180	0.82	6.8	7.8	0.8	2670	0.018	0.018	465	353
2 Deep	7-31-97	5000	6.63	-59.2			0.4	4.3	19.6	0.85	2277	<0.001	0.07	785	200
2 Deep	8-14-97	4850	6.47	-54			0.75	7.7	16.6	0.85	2673	<0.1	<0.02	567	208
2 Deep	8-28-97	5000	6.41	-57.7	275		0.8	8.2	16.7	0.85	2915	<0.05	<0.02	563	215
2 Deep	9-10-97	4540	5.69	-0.2		600	2.3	23.5	16.4	0.85	2926	<0.05	<0.02	553	219
2 Deep	9-22-97	4318	6.45	-48	355		1	9.6	13.9	0.85	2856	<0.001	0.02	499	222
2 Deep	10-21-97	4446	6.49		270					0.85	2844	<0.05	0.1	522	239
2 Deep	4-15-98	4700	6.60	8.5	232		1.15	8.4	2.4	0.8	2714	0.002	0.07	420	244
2 Deep	4-30-98	4650	6.43	-54.1	160		0.79	7.7	14.6	0.8	2877	<0.001	0.04	477	264
2 Deep	5-13-98	4950	6.40	-53	160		0.59	5.7	14	0.8	2664	<0.001	0.04	503	263
2 Deep	5-27-98	4950	6.43	-53	165		1.65	17.6	18.8	0.8	2925	0.001	0.04	497	259
2 Deep	6-10-98	4800	6.34	-46.3	270		1.17	10.8	11.8	0.8	3027	<0.001	0.04	485	260

Table A4.3 Drainage quality from tank 3 (water cover with submerged aquatics).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
3 Surface[1]	8-1-97											<0.05	<0.02	88.6	35.9
3 Surface	8-1-97	750	9.35	51.5			16.4	182.2	21.4	0.8	171	0.003	0.02	84	35.7
3 Surface[1]	8-14-97											<0.05	0.02	87.7	35.8
3 Surface	8-14-97	825	9.70	-9.8			14.5	155.9	18.8	0.8	213	<0.1	0.03	85.3	35.6
3 Surface[1]	8-28-97											<0.05	<0.02	86.4	38.1
3 Surface	8-28-97	700	9.36	113.4	288		11.3	125.6	21.3	0.8	230	<0.05	<0.02	83.6	36.3
3 Surface	9-10-97	855	8.14	104.8	115		8.5	91.4	19.3	0.8	241	<0.05	<0.02	83.9	41.3
3 Surface[1]	9-10-97											<0.05	<0.02	91.1	40.1
3 Surface	9-22-97	806	8.00	59.2	125		8	80.8	16.4	0.8	250	0.007	<0.02	89.5	43.3
3 Surface[1]	9-22-97											0.008	<0.02	93.3	40
3 Surface[1]	10-21-97											<0.05	0.02	44.6	14.1
3 Surface	10-21-97	850	8.14		125					0.5		<0.05	0.02	43	15
3 Surface	4-15-98	68	7.61	6.2	20		7.8	83.9	3.6	0.7	6.3	0.005	0.05	7.9	1.6
3 Surface	4-30-98	225	7.44	7.3	42.5		9.2	92.9	17.6	0.4	41.6	0.004	0.02	22.1	4
3 Surface	5-13-98	285	8.61	10.3	55		9.91	100.1	16.3	0.4	49	0.009	<0.02	31.6	8.6
3 Surface	5-27-98	315	9.49	-19.2	50		9.28	99.8	18.7	0.4	68.1	0.013	<0.02	35.1	12.8
3 Surface	6-10-98	355	9.76	-53.3	50		12.8	118.5	12.3	0.4	90.9	<0.05	<0.02	40.5	8.3
3 Surface	6-24-98	335	10.49	28.8			8.5	89.5	17.5	0.12	68.1	<0.05	0.02	34.4	12.7
3 Surface	7-8-98	330	9.36	-53.3	55		7.31	84.0	23.1	0.4	75.3	<0.05	<0.02	40.4	13.7
3 Surface	7-22-98	410	10.34	3	55		6.45	70.1	19.6	0.4	93.5	<0.05	<0.02	44.5	16.8
3 Surface	8-5-98	410	10.19	-45.4	45		8.7	102.4	24.2	0.4	128	<0.05	0.02	43.9	19
3 Surface	8-19-98	450	9.24	56.7	50		8.45	88.9	18.4	0.4	161	<0.05	<0.02	44.2	22
3 Surface	9-2-98	435	9.11	-12	50		8.1	87.1	19.4	0.4	149	<0.05	0.03	46.2	26.3
3 Surface	9-16-98	500	8.24	117.7	55					0.2	160	<0.05	<0.02	46.7	28.8
3 Surface	9-30-98	600	7.86	-0.1	87.5		9.5	84.1	10.1	0.2	169	<0.05	<0.02	64.2	33.4
3 Surface	10-14-98	700	8.19	166.8	95					0.2	158	<0.05	0.06	66.8	35.3
3 Surface	10-28-98	650	7.82	-52.5	95		9.85	87.2	9.9	0.4	187	<0.05	0.02	61.3	30
3 Surface	4-22-99	75	6.35	27.3	25		6.9	58.0	7.8	0.9	8.5		0.02	11	1
3 Surface	5-6-99	147	5.04												
3 Surface	5-19-99	270	7.83	3.8	55		8.39	81.5	13.9	0.4	46.1		0.02	30.8	7.8
3 Surface	6-3-99	410	7.03												
3 Surface	6-16-99	550	7.23	2.8	138		6.48	66.1	16.3	0.4	117	<0.002	0.009	58.2	21.4
3 Surface	7-2-99	750	6.96												
3 Surface	7-14-99	600	7.80	-9.3	130		6.65	81.1	25.4	0.4	148	0.003	<0.002	70.9	27.8

Table A4.2 Drainage quality from tank 2 (tailings planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
2 Deep	7-8-98	4850	5.67	-64.1	205	365	0.58	6.4	20.6	0.8	2661	<0.05	0.03	534	251
2 Deep	8-5-98	4100	6.46	-72	290		0.45	5.1	22.7	0.8	2955	<0.05	0.04	549	267
2 Deep	9-30-98	5000	6.34	-54.4	398		0.58	5.1	10.1	0.8	2943	<0.05	<0.05	550	293
2 Deep	10-28-98	4350	6.41	-61.3	250		0.95	8.9	12.4	0.8	3007	<0.05	0.05	516	280
2 Deep	5-19-99	5000	6.58	-77.1	245		0.82	7.7	12.7	0.8	2991		0.03	503	274
2 Deep	6-16-99	5000	6.40	-78.5	318		1.15	11.6	15.9	0.8	2822	0.008	0.0164	437	262
2 Deep	7-14-99	4950	6.42	-94	180		0.62	7.2	22.9	0.8	3064	0.043	0.0259	506	283
2 Deep	8-11-99	5000	6.46	-71.7	235		0.55	5.9	18.9	0.8	3077	0.037	0.0616	508	296
2 Deep	9-8-99	5000	6.43	-81.1	245		0.49	5.1	17.5	0.8	2762	0.032	<0.02	477	249
2 Deep	10-6-99	4450	6.39	-77.5	190	305	0.84	6.9	6.9	0.8	2683	0.029	0.0141	478	267

1 Total metals were analyzed for comparison with filtered.

Bold/italic values appear to be anomalous.

Table A4.3 Drainage quality from tank 3 (water cover with submerged aquatics).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
3 Surface	7-29-99	550	8.86												
3 Surface	8-11-99	500	8.22	-47.2	90		9.75	104.8	19	0.4	155	0.003	0.0074	58.7	27.5
3 Surface	8-26-99	425	7.43												
3 Surface	9-8-99	495	8.23	67.4	85		8.49	87.8	17.3	0.4	124	0.002	<0.02	33.9	23.1
3 Surface	9-23-99	500	8.01												
3 Surface	10-6-99	500	7.72	62.7	90	<5	8.3	68.6	7.3	0.9	130	0.003	0.0108	36.5	23.6
3 Surface	10-21-99	500	6.81												
3 Interface	7-8-98	1950	4.01	-139.8	515	65	0.5	6.0	25	0.8	533	<0.05	<0.02	331	103
3 Interface	8-5-98	1850	7.02	-108.4	640		1.05	12.1	23	0.4	554	<0.05	0.03	313	99.5
3 Interface	9-2-98	1800	7.22	-128.8	605		1.2	12.9	19.1	0.4	392	<0.05	0.04	307	96.1
3 Interface	9-30-98	1300	6.90	-203.7	625		1.58	14.3	11.1	0.4	364	<0.05	<0.02	280	91.1
3 Interface	10-28-98	1150	7.02	-211.7	515		1.62	14.6	11	0.4	246	<0.05	0.02	182	63.9
3 Interface	4-22-99	3450	6.95	-223.3	935		2.2	18.5	7.5	0.4	727		<0.02	422	147
3 Interface	5-6-99	1250	5.32												
3 Interface	5-19-99	2600	7.03	-243.6	815		1.6	15.4	13.4	0.4	637		<0.02	350	125
3 Interface	6-3-99	2050	6.93												
3 Interface	6-16-99	1700	6.99	-284.1	595		2.51	25.4	15.9	0.4	355	<0.002	0.0046	222	72.5
3 Interface	7-2-99	750	7.36												
3 Interface	7-14-99	600	7.47	-103.7	1135		4.6	55.4	24.5	0.4	149	0.002	<0.002	71.6	27.9
3 Interface	7-29-99	550	8.32												
3 Interface	8-11-99	550	7.71	-173.2	125		2.25	25.0	20.6	0.4	149	0.022	0.0069	65	27.6
3 Interface	8-26-99	500	7.14												
3 Interface	9-8-99	450	8.47	-84	80		5.68	58.0	16.6	0.4	118	0.003	<0.02	34.1	23.1
3 Interface	9-23-99	475	8.56												
3 Interface	10-6-99	500	8.06	-87.3	80	<5	8.4	68.9	6.9	0.4	124	0.003	0.0097	36.7	23.1
3 Interface	10-21-99	500	7.03												
3 Deep	7-31-97	5000	7.70	21.7			0.85	9.2	19.7	0.85	2185	<0.001	0.28	912	205
3 Deep	8-14-97	5000	6.33	-100.4			0.6	6.1	16.1	0.85	2860	<0.1	0.07	543	211
3 Deep	8-28-97	5000	6.35	-70.5	245		0.68	7.0	17.1	0.85	3156	<0.05	<0.02	541	215
3 Deep	9-10-97	5080	5.47	-10.7		895	2.54	26.0	16.6	0.85	3247	<0.05	<0.02	545	216
3 Deep	9-22-97	4658	6.22	-50.9	950		0.97	9.2	13.3	0.85	3344	<0.001	<0.02	510	227
3 Deep	10-21-97	4648	6.35		205					0.85	3159	<0.05	0.1	514	231
3 Deep	4-15-98	4800	6.48	-0.8	200		1.3	9.8	4	0.8	2907	<0.001	0.06	422	225
3 Deep	4-30-98	5000	6.36	-58.1	105		0.73	7.2	15.5	0.8	3150	<0.001	0.04	488	250

Table A4.3 Drainage quality from tank 3 (water cover with submerged aquatics).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
3 Deep	5-13-98	5000	6.35	-52.2	105		1.09	10.5	14.3	0.8	2683	<0.001	0.05	372	238
3 Deep	5-27-98	5000	6.42	-65.5	155		1.1	11.5	17.8	0.8	3114	0.001	0.04	498	252
3 Deep	6-10-98	4700	6.30	-45.3	215		2.2	20.2	11.8	0.8	3230	<0.05	0.04	497	244
3 Deep	7-8-98	4450	6.36	-82	100	525	0.27	3.0	20.9	0.8	2744	<0.05	0.03	531	238
3 Deep	8-5-98	4600	6.27	-77.4	170		0.31	3.7	24.2	0.8	3274	<0.05	0.04	432	249
3 Deep	9-2-98	4550	6.65	-83.8	180		0.23	2.5	19.5	0.8	2048	<0.05	0.04	540	262
3 Deep	9-30-98	5000	6.35	-110.8	325		0.65	5.7	9.9	0.8	2824	<0.05	<0.02	530	271
3 Deep	10-28-98	4200	6.41	-122.3	195		0.9	8.4	12.4	0.8	3073	<0.05	0.03	508	261
3 Deep	4-22-99	4950	6.45	-73.1	250		1.63	13.9	8.3	0.8	2657		0.02	456	237
3 Deep	5-19-99	5000	6.54	-119.5	200		0.76	7.3	13.3	0.8	2850		0.04	507	247
3 Deep	6-16-99	5000	6.37	-169.5	250		0.75	7.7	16.6	0.8	2860	0.007	0.021	504	233
3 Deep	7-14-99	4650	6.34	-94.1	160		0.62	7.4	24.6	0.8	2980	0.006	<0.002	509	256
3 Deep	8-11-99	4850	6.48	-89.9	200		0.58	6.5	20.8	0.8	2998	0.028	0.02	507	265
3 Deep	9-8-99	5000	6.58	-79.5	220		0.54	5.5	16.5	0.8	2634	0.026	<0.02	484	207
3 Deep	10-6-99	4000	6.53	-66.6	260	285	0.83	7.0	7.9	0.8	2505	0.023	0.017	486	246

1 Total metals were analyzed for comparison with filtered.

Table A4.4 Drainage quality from tank 4 (glacial till planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
4 Surface[1]	8-1-97											<0.05	<0.02	77.4	36.4
4 Surface	8-1-97	725	8.16	81.6			7.85	90.0	21.9	0.8	121	<0.1	<0.02	77.5	37.8
4 Surface	8-14-97	990	8.60	46			12.3	132.3	18.8	0.8	173	<0.1	0.03	87.2	49
4 Surface[1]	8-14-97											<0.05	0.02	88.9	52.4
4 Surface	8-28-97	750	8.05	125	160		8.98	99.8	21	0.8	152	<0.05	<0.02	79.8	38.9
4 Surface[1]	8-28-97											<0.05	<0.02	82.1	41.4
4 Surface[1]	9-10-97											<0.05	<0.02	146	73.7
4 Surface	9-10-97	1335	8.32	98.1	215		12.5	147.1	24.1	0.8	291	<0.05	<0.02	129	70
4 Surface[1]	10-21-97											<0.05	0.02	45.1	14.4
4 Surface	10-21-97	375	8.15		140					0.5	173	<0.05	0.02	74.4	31.9
4 Surface	4-15-98	265	7.66	20.2	72.5		12	88.9	3.3	0.7	26.3	0.009	0.03	30.8	9.9
4 Surface	4-30-98	430	7.42	-10	115		9.05	93.3	17.1	0.4	45	0.015	0.02	49.2	16.4
4 Surface	5-13-98	450	7.25	-5.1	85		8.3	85.6	17	0.4	46	0.022	0.02	46.8	17.8
4 Surface	5-27-98	395	6.98	-0.2	80		6.21	66.8	18.6	0.4	55.5	0.021	<0.02	47	20.5
4 Surface	6-10-98	290	6.84	-41.2	105		6.05	56.0	12	0.4	48.7	<0.05	0.02	40.5	12.5
4 Surface	6-24-98	205	8.61	83.4			3.56	36.0	16.1	0.12	4.3	<0.05	0.02	29.9	10
4 Surface	4-22-99	95	7.16	8.5	25		9.55	79.9	7.5	0.9	8.5		<0.02	9.5	2.6
4 Surface	5-6-99		5.80												
4 Surface	5-19-99	145	7.10	8.5	45		7.35	72.1	14.5	0.4	15.6		0.02	17	4.6
4 Surface	6-3-99	175	6.67												
4 Surface	6-16-99	135	7.26	-91.7	10		6.25	61.3	14.6	0.4	14.1	0.012	0.005	15.3	5
4 Surface	7-2-99	50	7.53												
4 Surface	7-14-99	50	6.30	-86.5	5				24.9	0.4	3	0.004	<0.002	4.6	1.5
4 Surface	7-29-99	42	6.56												
4 Surface	8-11-99	60	7.23	-4.2	20		5.32	59.6	21	0.4	4.1	0.003	0.0057	6.3	2
4 Surface	8-26-99	45	7.38												
4 Surface	9-8-99	70	7.26	5.1	17.5		4.98	50.3	15.9	0.4	2.9	0.003	<0.02	6.3	2.3
4 Surface	9-23-99	44	7.41												
4 Surface	10-6-99	60	7.34	2.6	10	<5	8.6	68.0	5.5	0.9	7.6	0.003	0.0113	5.8	2.2
4 Surface	10-21-99	75	7.07												
4 Shallow	7-31-97	750	6.29	-13.2			0.51	5.8	22	0.85	49.8	0.003	<0.02	114	33
4 Shallow	8-14-97	980	6.50	-23.7			0.4	4.1	16.6	0.85	42.8	<0.1	0.03	143	43.9
4 Shallow	8-28-97	975	6.51	-34.9	515		0.52	5.7	20	0.85	34.5	<0.05	<0.02	149	10.3
4 Shallow	9-10-97	1143	5.67	-2.7		90	2.91	31.6	19.6	0.85	28	<0.05	<0.02	171	54.5

Table A4.4 Drainage quality from tank 4 (glacial till planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
4 Shallow	9-22-97		6.61	-40.4	615		1.44	13.6	13.4	0.85	21.5	0.001	<0.02	178	56.6
4 Shallow	4-15-98	1025	6.62	56.7	575		1.25	9.5	3.6	0.8	53.7	0.003	0.03	157	59.2
4 Shallow	4-30-98	1250	6.90	-31.9	695		0.59	6.1	17	0.8	89.1	0.002	0.03	197	69
4 Shallow	5-13-98	1325	6.43	-15.8	705		0.89	9.0	16.4	0.8	101	0.001	<0.02	209	71.6
4 Shallow	5-27-98	1350	6.62	-30.7	745		0.71	7.7	20.2	0.8	115	<0.001	0.02	222	76.1
4 Shallow	6-10-98	1350	6.39	-23.8	765		2.9	26.9	12.1	0.8	115	<0.05	0.02	232	72.5
4 Shallow	7-8-98	1400	6.59	-69.1	795	75	0.29	3.3	22.2	0.8	107	<0.05	<0.02	237	72.7
4 Shallow	4-22-99	1950	6.50	79.8	185		6.8	57.6	8	0.8	1112		<0.02	324	107
4 Shallow	5-19-99	2250	6.53	31	220		3.3	32.0	14.2	0.8	1276		0.02	399	130
4 Shallow	6-16-99	2250	6.37	-93.9	332		2.35	24.2	16.7	0.8	1125	0.004	0.0124	329	124
4 Shallow	7-14-99	2150	6.30	-88.8	435		0.66	7.8	23.8	0.8	1059	0.003	<0.002	374	136
4 Shallow	8-11-99	1850	6.42	-46.6	580		0.76	8.4	20.4	0.8	813	0.002	0.0158	345	122
4 Shallow	9-8-99	1900	6.44	-60.8	570		0.65	6.8	17.5	0.8	741	0.002	<0.02	371	116
4 Shallow	10-6-99	1600	6.47	-12.5	570	100	0.98	8.1	7.6	0.8	530	0.002	0.0103	270	101
4 Deep	7-31-97	5000	6.40	-34			0.55	6.0	19.8	0.85	2298	<0.001	0.13	778	202
4 Deep	8-14-97	4900	6.40	-91.1			0.69	7.1	16.7	0.85	2715	<0.1	0.08	561	216
4 Deep	8-28-97	5000	6.38	-74.2	310		0.76	7.9	17.2	0.85	3107	<0.05	<0.02	546	221
4 Deep	9-10-97	5200	5.92	-56.5		1050	2.21	22.6	16.8	0.85	3123	<0.05	<0.02	552	225
4 Deep	9-22-97	4638	6.42	-62.4	380		1	9.6	13.8	0.85	3104	<0.001	<0.02	518	235
4 Deep	10-21-97	4785	6.37		305					0.85	3039	<0.05	0.1	513	243
4 Deep	4-15-98	4625	6.53	3.7	218		1.1	8.3	3.8	0.8	2822	0.002	0.05	429	245
4 Deep	4-30-98	5000	6.40	-64	165		0.45	4.4	15.6	0.8	3177	<0.001	0.05	474	260
4 Deep	5-13-98	4850	6.46	-61.7	105		0.58	5.7	14.7	0.8	2972	<0.001	0.05	370	248
4 Deep	5-27-98	4900	6.43	-56.4	155		1.45	15.4	18.4	0.8	2964	<0.001	0.04	495	244
4 Deep	6-10-98	4650	6.27	-31.2	590		2.21	20.5	12	0.8	3138	<0.05	0.03	510	238
4 Deep	7-8-98	4450	6.36	-70.4	195	445	0.29	3.3	22.5	0.8	2613	<0.05	0.03	536	253
4 Deep	4-22-99	>5000	6.64	-47.2	285		0.75	6.4	8	0.8	2993		0.02	455	318
4 Deep	5-19-99	5000	6.70	-84.6	225		0.67	6.5	13.7	0.8	3147		0.03	483	334
4 Deep	6-16-99	>5000	6.55	-103	265		0.8	8.2	16.7	0.8	2997	0.008	0.0153	412	329
4 Deep	7-14-99	5000	6.48	-105.5	200		0.54	6.2	22	0.8	2703	0.007	<0.002	492	350
4 Deep	8-11-99	5000	6.48	-87.6	245		1.05	11.4	19.6	0.8	2917	0.007	0.0039	495	362
4 Deep	9-8-99	>5000	6.50	-75.7	270		0.47	4.8	16.7	0.8	3052	0.031	<0.02	462	328
4 Deep	10-6-99	4600	6.43	-68.1	290	280	0.78	6.8	9.5	0.8	2934	0.028	0.0173	475	346

1 Total metals were analyzed for comparison with filtered.

Table A4.5 Drainage quality from tank 5 (wetland soil planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
5 Surface[1]	8-1-97											<0.05	0.06	32.2	20.3
5 Surface	8-1-97	525	4.23	209.6			2	23.1	22.6	0.8	109	<0.1	0.11	31.4	21.7
5 Surface	8-14-97	710	4.30	186.1			6	65.2	20.3	0.8	89.5	<0.1	0.07	33.7	23.3
5 Surface[1]	8-14-97											<0.05	0.06	35	26.1
5 Surface[1]	8-28-97											0.06	0.07	35.2	19.8
5 Surface	8-28-97	375	4.63	158.4		250	3.4	40.0	23.7	0.8	***<1***	0.05	0.13	31.9	18.8
5 Surface[1]	10-21-97											<0.05	0.05	17.5	10
5 Surface	10-21-97	225	5.18		15					0.5	67.9	<0.05	0.04	20.8	10.3
5 Surface	4-15-98	138	5.61	132.9	10		10.2	76.7	3.5	0.7	18	0.023	0.04	6	4.3
5 Surface	4-30-98	***550***	5.56	134.2		20	8.7	94.6	20	0.4	57	0.03	0.04	12.2	7
5 Surface	5-13-98	***700***	5.00	120.7		45	8.9	96.7	19.8	0.4	6.6	0.432	0.05	16.3	13
5 Surface	6-24-98	46.5	6.83	143.3			5.55	58.4	17.9	0.12	***288***	<0.05	0.03	4.1	2.9
5 Surface	7-14-99	70	5.59	37.8		20	1.06	13.5	27.7	0.4	52	0.016	0.0386	4.6	3.5
5 Surface	7-29-99	36	5.41												
5 Shallow	7-31-97	375	4.43	82.4			0.5	5.7	21.6	0.85	130	0.072	0.13	22.8	12
5 Shallow	8-14-97	450	4.70	77.8			0.49	5.1	17.2	0.85	15.6	0.1	0.21	23.1	11.2
5 Shallow	8-28-97	390	4.63	88.7		310	0.47	5.0	18.5	0.85	1.7	0.05	0.2	21	10.3
5 Shallow	9-10-97	392	4.28	76.6		450	2.62	27.6	18.3	0.85	2	0.05	0.11	20.4	10.8
5 Shallow	9-22-97	390	4.75	70.8		745	0.3	2.9	15.2	0.85	2.6	0.002	0.14	20.2	9.3
5 Shallow	10-21-97	348	4.79			300				0.85	5.6	0.05	0.2	21.8	12.7
5 Shallow	4-30-98	325	5.07	124.8		275	0.25	2.3	11.9	0.8	2.6	0.077	0.19	15.4	10.1
5 Shallow	5-13-98	360	4.66	123.3		255	0.91	9.0	15.5	0.8	1.6	0.042	0.16	15.5	6.5
5 Shallow	5-27-98	385	4.70	93.5		240	0.61	6.6	19.1	0.8	1.6	<0.001	0.13	16.6	13
5 Shallow	6-10-98	355	4.71	95.6		282.5	0.96	8.9	12.2	0.8	4.7	<0.05	0.12	18.4	10.3
5 Shallow	7-8-98	360	4.53	79.4	20	225	0.08	1.0	24.8	0.8	5.8	0.05	0.12	17.9	8.7
5 Shallow	6-16-99	500	4.13	5.9	135		1.43	15.1	18	0.8	210	0.013	0.184	31.2	21.3
5 Shallow	7-14-99	440	4.14	5.9		135	0.48	5.7	24	0.8	229	0.016	0.145	30	19.9
5 Deep	7-31-97	5000	4.06	-62.6			0.65	7.2	20.8	0.85	1952	<0.001	1.69	1120	218
5 Deep	8-14-97	5000	6.39	-98.3			0.75	7.7	17.1	0.85	2683	<0.1	0.08	624	213
5 Deep	8-28-97	5000	6.40	-106.1	315		0.6	6.2	17.3	0.85	3178	<0.05	<0.02	558	232
5 Deep	9-10-97	5017	5.28	-11		630	2.75	28.5	17.3	0.85	3177	<0.05	<0.02	542	229
5 Deep	9-22-97	4774	6.24	-71.8		725	0.79	7.7	15	0.85	3051	<0.001	0.02	543	234
5 Deep	10-21-97	4760	6.36		260					0.85	3152	<0.05	0.1	509	247

Table A4.5 Drainage quality from tank 5 (wetland soil planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
5 Deep	5-13-98	4800	6.19	-46.6		855	1.05	10.2	14.7	0.8	2950	<0.001	0.1	373	248
5 Deep	5-27-98	4950	6.42	-54.7	130		1	10.5	17.7	0.8	3119	<0.001	0.06	488	262
5 Deep	6-10-98	4750	6.22	-34.6		632.5	1.55	14.2	11.8	0.8	2714	<0.05	0.07	496	275
5 Deep	7-8-98	4550	6.43	-73.4	180	500	0.46	5.3	23.2	0.8	2745	<0.05	0.05	519	257
5 Deep	8-5-98	4750	6.24	-72.9		750	0.38	4.5	24.7	0.8	3280	<0.05	0.05	543	279
5 Deep	6-16-99	***57***	6.26	-85		230			15.1	0.8		0.005	0.0187	491	499
5 Deep	7-14-99	>5000	6.18	-84.3		215	0.77	9.1	23.9	0.8	3263	0.005	<0.002	487	594
5 Deep	8-11-99	>5000	6.20	-57.8		470	0.62	6.7	19.4	0.8	3401	0.005	0.0127	485	631
5 Deep	9-8-99	>5000	6.19	-54.8		820	0.48	4.9	17.1	0.8	4244	0.019	<0.02	474	739
5 Deep	10-6-99	>5000	6.06	-16.5	605	1415	0.85	7.7	11	0.8	6007	0.018	0.0725	445	826

1 Total metals were analyzed for comparison with filtered.
Bold/italic values appear to be anomalous.

Table A4.6 Drainage quality from tank 6 (wetland soil planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
6 Surface	7-31-97	375	4.46	92.7			0.4	4.4	21.3	0.85	136	0.058	0.14	21.9	12.2
6 Surface	8-1-97	500	4.21	213.3			2	23.0	23	0.8	112	<0.1	0.1	29.8	21
6 Surface[1]	8-1-97											<0.05	0.05	31.7	21.8
6 Surface[1]	8-14-97											<0.05	0.08	38.2	28
6 Surface	8-14-97	750	4.20	192.6			8.6	90.5	18.2	0.8	133	<0.1	0.09	40.5	30.9
6 Surface[1]	8-28-97											<0.05	0.04	19.3	12.3
6 Surface	8-28-97	325	4.25	143.6		65	6.7	78.8	24	0.8	6.6	<0.05	0.07	19.6	13.2
6 Surface	10-21-97	150	5.25			25				0.5	17.2	<0.05	0.03	12	6.2
6 Surface[1]	10-21-97											<0.05	0.03	8.8	5.6
6 Surface	4-15-98	122	5.06	170.4	5		7	53.8	4.6	0.7	11.4	0.017	0.03	4.5	3.2
6 Surface	4-30-98	150	5.04	160.1		20	7.95	88.3	21.2	0.4	5.7	0.02	0.04	7.6	5.3
6 Surface	5-13-98	265	5.29	130.9		20	9.85	107.1	20.3	0.4	9.6	0.035	0.04	12	8.4
6 Surface	5-27-98	145	4.99	118.3		27.5	7.1	81.6	22.8	0.4	6	0.052	0.04	7.4	4.5
6 Surface	6-24-98	29.5	5.95	166.5			4.7	48.5	16.7	0.12	3.9	<0.05	0.03	2.6	2.8
6 Surface	8-25-98	370	6.76	145.1	65					0.2	73.3	<0.05	0.03	30	21
6 Surface	9-30-98	390	5.97	-6.6	12.5		6.6			0.2	82.8	<0.05	<0.02	23.2	16
6 Surface	10-28-98	245	5.82	46.8		15	4.45	41.2	12.2	0.4	58.5	<0.05	0.04	12.8	10.3
6 Surface	4-22-99	180	5.91	120.1		15	4.95	43.8	10	0.9	13.8		0.02	3.1	2.3
6 Surface	5-6-99	113	7.28												
6 Surface	5-19-99	***1450***	6.48	24.6		30	4.47	44.3	14.9	0.4	***704***		0.04	***107***	***93.9***
6 Surface	6-3-99	140	5.86												
6 Surface	6-16-99	62	5.77	38.7		10	5.4	55.1	16.2	0.4	14.8	0.011	0.0195	5	3
6 Surface	7-2-99	24	4.80												
6 Surface	7-14-99	45.5	4.67	180.5		15	3.26	39.8	25.5	0.4	5.8	0.005	0.0108	1.2	0.6
6 Surface	7-29-99	26	4.53												
6 Surface	9-23-99	290	7.12												
6 Surface	10-6-99	290	6.41	40.6	10	15	7.15	56.5	5.5	0.9	53.4	0.007	0.0286	13.2	11.1
6 Surface	10-21-99	375	5.91												
6 Shallow	8-14-97	450	4.65	60.5			0.5	5.3	17.6	0.85	19.8	<0.1	0.14	20.1	12.2
6 Shallow	8-28-97	350	4.58	85.6		400	0.46	4.9	18.7	0.85	0.6	<0.05	0.13	20.1	10.6
6 Shallow	9-10-97	368	4.30	79.4		540	2.65	27.9	18.1	0.85	4.6	0.07	0.13	21.3	11.5
6 Shallow	9-22-97	360	4.51	75.6		605	0.88	8.9	15.6	0.85	4.4	0.043	0.12	22.6	10
6 Shallow	10-21-97	348	4.78			460				0.85	4.1	0.06	0.1	22.7	12.7

Table A4.6 Drainage quality from tank 6 (wetland soil planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
6 Shallow	4-30-98	275	4.82	115		295	0.19	1.8	13.6	0.8	43.9	0.035	0.13	15.7	8.4
6 Shallow	5-13-98	335	4.69	108.2		270	0.42	4.3	16.7	0.8	1.4	0.041	0.13	17.4	11.1
6 Shallow	5-27-98	350	4.91	91.2		200	0.46	5.0	20.4	0.8	4.9	0.087	0.13	17.8	13.4
6 Shallow	6-10-98	360	4.61	85.6		282.5	0.39	3.6	12.4	0.8	4.6	<0.05	0.14	18.8	10.6
6 Shallow	7-8-98	320	5.00	83.8	15	190			23.2	0.8	5.7	0.06	0.13	19.6	12.6
6 Shallow	9-30-98	500	4.23	90.8		72.5	1.95	17.6	11.3	0.4	160	<0.05	***0.57***	31.5	44.2
6 Shallow	10-28-98	405	4.31	115.2		75	0.53	5.1	13.9	0.8	168	<0.05	0.15	24.3	20
6 Shallow	5-19-99	315	4.79	-57.6		145	0.7	6.8	14	0.8	299		0.05	19.6	13.6
6 Shallow	6-16-99	310	4.64	-85.6		188	0.66	6.9	17.5	0.8	310	0.026	0.16	29	15
6 Shallow	7-14-99	265	4.68	-27.4		240	0.27	3.2	24.5	0.8	263	0.015	0.0861	26	16.9
6 Shallow	10-6-99	300	4.53	24.3		130	0.88	7.8	9.9	0.8	142	0.007	0.0864	16.3	13.3
6 Deep	7-31-97	5000	6.58	-63.6			0.52	5.6	19.6	0.85	1972	<0.001	0.96	937	202
6 Deep	8-14-97	4900	6.42	-88.9			0.7	7.3	17.6	0.85	2770	<0.1	0.02	578	208
6 Deep	8-28-97	5000	6.30	-291.1	300		0.6	6.3	17.5	0.85	3094	<0.05	0.03	559	228
6 Deep	9-10-97	4979	5.90	-9		650	2.6	27.1	17.6	0.85	3084	<0.05	0.03	556	224
6 Deep	9-22-97	4712	6.43	-81.9	395		0.74			0.85	3089	<0.001	0.03	535	227
6 Deep	10-21-97	4536	6.37		295					0.85	3012	<0.05	0.1	499	228
6 Deep	5-13-98	4450	6.08	-45.1		545	1.23	12.4	16	0.8	2826	<0.001	0.05	475	245
6 Deep	5-27-98	4900	6.45	-43.6	157.5		2.42	27.9	23.1	0.8	2966	0.001	0.04	495	256
6 Deep	6-10-98	4700	5.25	-38.2		630	0.62	5.7	12	0.8	2637	<0.05	0.04	505	258
6 Deep	7-8-98	4750	6.50	-69.9	240	395	0.13	1.5	22.4	0.8	2649	<0.05	0.04	533	260
6 Deep	9-30-98	5000	6.30	-61.5	350		0.58	5.6	14.4	0.8	2884	<0.05	0.06	538	275
6 Deep	10-28-98	4100	6.34	-69.1	215		1.12	11.0	14.7	0.8	3028	<0.05	0.02	519	274
6 Deep	5-19-99	4950	6.50	-73.3	300		0.59	5.8	14.6	0.8	2751		0.04	526	275
6 Deep	6-16-99	4900	6.29	-93	250		0.92	9.1	15.3	0.8	2666	0.007	0.0137	518	258
6 Deep	7-14-99	4650	6.28	-85		200	0.68	7.8	22.1	0.8	2829	0.006	<0.002	511	269
6 Deep	8-11-99	4750	6.31	-70.3	335		0.66	7.2	19.4	0.8	2838	<0.002	<0.002	464	262
6 Deep	9-8-99	4900	6.36	-59.8	340		0.58	5.9	16.4	0.8	2626	0.024	***0.11***	501	245
6 Deep	10-6-99	4200	6.05	-57.7	380	320	0.82	7.4	10.9	0.8	2465	0.023	0.02	511	263

1 Total metals were analyzed for comparison with filtered.

Bold/italic values appear to be anomalous.

Table A4.7 Drainage quality from tank 7 (tailings planted with cattails).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
7 Surface	8-11-99	650	5.68	103.5		7.5	6.32	70.9	21	0.4	298	0.005	0.217	99.4	12.7
7 Surface	8-26-99	650	5.73												
7 Surface	9-8-99	700	6.71	88.1	<5		7.61	74.6	15.2	0.4	332	0.002	0.13	107	13.2
7 Surface	9-23-99	550	6.66												
7 Surface	10-6-99	750	6.52	13.4	15	10	8.65	73.6	8.6	0.4	353	0.002	0.0454	117	13.2
7 Surface	10-21-99	750	5.98												
7 Shallow	7-31-97	3950	6.43	-74.5			0.4	4.4	21.1	0.85	2078	<0.001	<0.02	608	150
7 Shallow	8-14-97	3850	6.47	-45.1			0.43	4.5	17.9	0.85	2163	<0.1	<0.02	598	166
7 Shallow	8-28-97	4000	6.40	-72.4	315		0.48	5.2	19.2	0.85	2282	<0.05	0.02	601	178
7 Shallow	9-10-97	3838	6.06	-27.5		330	2.12	21.9	17.3	0.85	2276	<0.05	0.03	586	179
7 Shallow	9-22-97	3738	6.40	-68.5	395		0.49	4.8	14.5	0.85	2205	<0.001	0.03	588	186
7 Shallow	10-21-97	3648	6.44		355					0.85	2246	<0.05	0.1	548	191
7 Shallow	4-15-98	4125	6.69	-25.4	240		0.95	7.4	4.9	0.8	2093	<0.001	0.05	437	279
7 Shallow	4-30-98	3850	6.60	-64.1	225		0.52	5.6	18.9	0.8	2367	<0.001	0.05	509	232
7 Shallow	5-13-98	3850	6.02	-51.4		90	0.64	6.7	17.9	0.8	2913	<0.001	0.04	517	234
7 Shallow	5-27-98	4000	6.61	-57.3	215		1.84	20.4	20.9	0.8	2329	<0.001	0.06	545	233
7 Shallow	6-10-98	3850	6.58	-48.9	360		1.69	16.4	14.5	0.8	2034	<0.05	0.04	249	226
7 Shallow	7-8-98	3850	6.74	-81.5	300	65	0.26	3.1	25.5	0.8	2088	<0.05	0.04	566	242
7 Shallow	8-5-98	3700	6.45	-89.8	325		0.23	2.8	26.9	0.8	2523	<0.05	0.03	577	252
7 Shallow	9-30-98	5000	6.44	-29.9	295		0.62	5.3	9.4	0.8	2446	<0.05	0.07	552	271
7 Shallow	10-28-98	3800	6.44	-68.7	265		0.82	7.8	13.5	0.8	2570	<0.05	0.02	539	252
7 Shallow	4-22-99	>5000	6.50	-61.3	325		0.58	5.0	9	0.8	2854		0.02	453	269
7 Shallow	5-19-99	5000	6.59	-89.9	275		0.65	6.4	14.9	0.8	3128		0.03	498	281
7 Shallow	5-19-99	4650	6.71	-95.1	240		0.6	6.1	16	0.8	2642		0.03	520	299
7 Shallow	6-16-99	4500	6.51	-98.8	142		1	10.6	17.4	0.8	2469	0.005	0.0168	529	271
7 Shallow	7-14-99	4250	6.38	-114.7	220		0.51	6.6	28.9	0.8	2732	0.005	<0.002	526	275
7 Shallow	8-11-99	4450	6.42	-80.2	240		0.85	9.4	20.1	0.8	2743	0.033	0.0312	516	270
7 Shallow	9-8-99	4650	6.55	-64.4	240		0.89	8.9	15.7	0.8	2525	0.017	0.0331	495	257
7 Shallow	10-6-99	3850	6.50	-60.1	275	225	0.8	6.6	9.1	0.8	2382	0.016	0.0162	496	287
7 Deep	7-31-97	5000	6.50	-72.2			0.7	7.6	20.1	0.85	2193	0.001	0.45	931	201
7 Deep	8-14-97	4950	6.44	-124.2			0.57	6.0	17.8	0.85	2725	<0.1	<0.02	563	212
7 Deep	8-28-97	5000	6.35	-73.2	315		0.98	10.3	18.1	0.85	3020	<0.05	<0.02	557	224
7 Deep	9-10-97	4998	5.94	-23.4		460	2.25	23.7	18	0.85	3006	<0.05	<0.02	544	220
7 Deep	9-22-97	4713	6.38	-88.3	375		0.59	0.1	15.8	0.85	2887	<0.001	<0.02	531	227

Table A4.7 Drainage quality from tank 7 (reactive tailings planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
7 Surface	8-1-97	2750	5.66	252.4			6.85	80.8	23.5	0.8	1381	<0.1	2.15	462	77.6
7 Surface[1]	8-1-97											<0.05	2.7	412	72.5
7 Surface[1]	8-14-97											0.05	2.22	766	131
7 Surface	8-14-97	3850	6.10	125			8.6	93.5	20	0.8	2349	<0.1	1.83	748	132
7 Surface[1]	8-28-97											<0.05	0.44	654	106
7 Surface	8-28-97	3150	6.18	163.7		15	7.9	91.9	23.5	0.8	1914	<0.05	0.37	572	102
7 Surface[1]	9-10-97											<0.05	0.59	974	244
7 Surface	9-10-97	4704	6.83	84.9	2		8.5	97.7	23.3	0.8	3018	<0.05	0.59	776	232
7 Surface	9-22-97	3328	7.10	111.4	10		9.2	101.1	19.5	0.8	2160	0.01	1.7	650	134
7 Surface[1]	9-22-97											<0.001	1.92	669	134
7 Surface[1]	10-21-97											<0.05	2.2	433	52.7
7 Surface	10-21-97	2225	6.49		10					0.5	1283	<0.05	2.1	411	52.5
7 Surface	4-15-98	700	6.89	133.7	15		10.6	82.8	5	0.7	319	0.005	0.2	116	11.4
7 Surface	4-30-98	1250	6.27	104.4	10		7.2	81.8	21.6	0.4	740	0.011	0.73	259	26.8
7 Surface	5-13-98	1950	6.06	87.2		415	7.95	88.3	21	0.4	1082	0.013	1.27	373	42.3
7 Surface	5-27-98	2450	6.25	79.8		20	5.82	66.9	23.4	0.4	1597	0.008	2.9	577	70.8
7 Surface	6-10-98	2650	6.20	65.8		15	7.26	69.8	14.1	0.4	1517	<0.05	2.75	587	76.1
7 Surface	6-24-98	1500	6.17	151.8			4.15	42.8	16.8	0.12	749	<0.05	0.32	303	37.3
7 Surface	7-8-98	1050	6.77	55.5	20	<5	4.08	52.3	28.7	0.4	674	<0.05	0.16	273	35.4
7 Surface	7-22-98	1900	8.03	76.5	15		4.45	47.8	18.7	0.4	985	<0.05	0.34	412	48.3
7 Surface	8-25-98	1600	6.74	162.4	27.5					0.2	1024	<0.05	0.5	334	45.2
7 Surface	9-2-98	2500	4.88	154.8		20	6.41			0.2	2748	0.16	1.87	624	85
7 Surface	9-16-98	1375	4.08	236.6		125				0.2	862	0.1	2	322	13.9
7 Surface	9-30-98	5000	3.67	171.6		80	7.4	63.8	9	0.4	1184	0.1	2.25	321	41.9
7 Surface	10-14-98	1650	4.02	275.7		45				0.2	876	0.1	3.92	316	44.8
7 Surface	10-28-98	800	4.09	169.8		35	8.45	78.2	11.9	0.4	478	<0.05	1.43	139	15.3
7 Surface	4-22-99	240	4.83	201.5		12.5	8	71.7	10.6	0.9	92.3		0.06	27.8	3.1
7 Surface	5-6-99		5.43												
7 Surface	5-19-99	700	4.57	139.5		<0.1	7.6	77.0	16	0.4	340		0.27	112	13
7 Surface	6-3-99	800	4.36												
7 Surface	6-16-99	850	4.33	113		<0.4	6.7	68.7	16.8	0.4	388	0.015	0.618	130	17.3
7 Surface	7-2-99	950	4.28												
7 Surface	7-14-99	600	4.56	173.7		15	4.81	62.1	28.8	0.4	289	0.006	0.27	104	12.3
7 Surface	7-29-99	650	4.41												

Table A4.7 Drainage quality from tank 7 (reactive tailings planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
7 Deep	4-15-98	4800	6.58	-23.9	162		1.3	10.0	4.7	0.8	2672	<0.001	0.05	413	247
7 Deep	4-30-98	4850	6.53	-77.3	195		0.48	5.2	19.4	0.8	3057	0.003	0.05	479	255
7 Deep	5-13-98	4950	5.23	-58.8		300	0.54	5.5	16.3	0.8	2307	<0.001	0.05	470	258
7 Deep	5-27-98	4850	6.53	-61.8	155		1.36	15.3	21.2	0.8	3092	<0.001	0.05	508	258
7 Deep	6-10-98	4450	6.50	-43.5	310		1.5	14.4	14	0.8	2634	<0.05	0.04	503	262
7 Deep	7-7-98	4750	6.72	-71.6	225	285	0.17	2.0	24.2	0.8	2634	<0.05	0.04	529	263
7 Deep	8-5-98	4450	6.37	4.2	295		0.43	5.1	25.1	0.8	3066	<0.05	0.05	541	272
7 Deep	9-2-98	4850	6.74	-71.5	275		0.5	5.6	21	0.8	2713	<0.05	0.04	549	288
7 Deep	9-30-98	5000	6.38	-64.7	295		0.68	6.3	11.7	0.8	2943	<0.05	0.07	529	286
7 Deep	10-28-98	4550	6.40	-65.8	250		0.78	7.6	14.7	0.8	2979	<0.05	0.02	509	281
7 Deep	5-19-99	5000	6.59	-89.9	275		0.65	6.4	14.9	0.8	3128		0.03	498	281
7 Deep	6-16-99	>5000	6.42	-90.7	320		0.78	8.1	17.1	0.8	2942	0.009	0.011	512	268
7 Deep	7-14-99	5000	6.38	-103.1	210		0.53	6.2	23.4	0.8	3249	0.009	<0.002	501	290
7 Deep	8-11-99	5000	6.43	-78.2	275		0.76	8.3	19.5	0.8	3106	0.063	0.025	482	273
7 Deep	9-8-99	5000	6.51	-64.2	230		0.68	6.9	15.8	0.8	2858	0.036	0.019	479	264
7 Deep	10-6-99	4500	6.41	-57.2	320	225	0.75	6.8	10.9	0.8	2786	0.033	0.014	512	276

1 Total metals were analyzed for comparison with filtered.

Table A4.8 Drainage quality from tank 8 (glacial till planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.
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Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
8 Surface[1]	8-1-97											<0.05	<0.02	81.6	36.1
8 Surface	8-1-97	775	7.55	158.6			8.4	98.8	24.1	0.8	139	<0.1	<0.02	87.4	38
8 Surface	8-14-97	1075	8.90	88.1			13.2	143.5	19.8	0.8	223	<0.1	<0.02	84.4	49.1
8 Surface[1]	8-14-97											<0.05	<0.02	85.9	52.6
8 Surface	8-28-97	800	7.50	155.1	145		9.2	108.2	23.6	0.8	174	<0.05	<0.02	82.9	40.5
8 Surface[1]	8-28-97											<0.05	<0.02	86.7	41.6
8 Surface	10-21-97	625	8.10		125					0.5	75.7	<0.05	0.02	63.3	27.2
8 Surface[1]	10-21-97											<0.005	<0.02	65.2	27.2
8 Surface	4-15-98	378	8.18	-47.6	90		12.1	96.8	6.3	0.7	46.2	0.014	0.02	39.7	14.5
8 Surface	4-30-98	800	8.44	5	95		10.25	117.8	22.7	0.4	73.3	0.018	0.02	58.8	24.7
8 Surface	5-13-98	1100	8.21	14.4	65		11.85	134.7	21.6	0.4	120	0.035	0.02	65.6	35.6
8 Surface	6-24-98	385	7.13	-74.5			4.95	51.0	17.2	0.12	8.2	<0.05	0.02	52.4	19.3
8 Surface	7-8-98	290	7.99	1.9	157.5		4.66	59.0	28.2	0.4	6.1	<0.05	0.02	43.7	15.9
8 Surface	8-25-98	550	7.77	132.3	182.5					0.2	95.8	<0.05	0.02	59.4	29.7
8 Surface	9-30-98	580	7.51	-33.8	165		8.55	79.2	11.7	0.2	72.9	<0.05	0.03	57.2	30.6
8 Surface	10-14-98	550	7.70	169.5	165					0.2	67.6	<0.05	0.02	58.5	28
8 Surface	10-28-98	360	7.30	-31.5	115		8.35	77.3	12.3	0.4	42.1	<0.05	<0.02	42.7	18.3
8 Surface	4-22-99	125	7.12	35.3	25		9.7	85.8	10.8	0.9	13.4		<0.02	11.6	4
8 Surface	5-6-99	213	5.36												
8 Surface	5-19-99	235	7.01	41.6	95		7.36	75.1	16.1		28.7		0.02	26.7	7.9
8 Surface	6-3-99	240	6.30												
8 Surface	6-16-99	185	6.85	24.5	55		5.8	60.0	17	0.4	27.6	0.007	0.006	20.5	8.4
8 Surface	7-2-99	180	6.17												
8 Surface	7-14-99	120	6.62	-2.2	40		7.21	93.0	28.5	0.4	14.1	0.003	<0.002	12.6	5
8 Surface	7-29-99	100	6.67												
8 Surface	8-11-99	135	7.11	-17.5	40		2.75	30.2	19.7	0.4	8.8	0.004	0.0043	12.2	5.4
8 Surface	8-26-99	110	6.52												
8 Surface	9-8-99	155	7.19	-21.2	40		3.12	30.6	15.2	0.4	10.8	0.002	0.0179	13.5	6
8 Surface	9-23-99	125	7.05												
8 Surface	10-6-99	155	7.19	-24.2	30	<5	6.95	57.0	7	0.9	11.8	0.004	0.0146	14.5	6.1
8 Surface	10-21-99	185	6.63												
8 Shallow	8-1-97	725	6.50	-7.1			1.9	21.1	21	0.85	73	0.002	<0.02	113	36.4
8 Shallow	8-14-97	1050	6.47	-46.4			0.45	5.0	20	0.85	37.2	<0.1	<0.02	157	47.6
8 Shallow	8-28-97	925	6.43	-44.6	550		0.62	7.2	22.6	0.85	28.2	<0.05	<0.02	164	49.2

Table A4.8 Drainage quality from tank 8 (glacial till planted with cattails).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units,

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
8 Shallow	9-10-97	1160	6.03	-14.5		110	1.96	22.5	21.7	0.85	25.6	<0.05	<0.02	161	50.2
8 Shallow	4-15-98	1100	6.58	-69	135		1.05	8.3	5.5	0.8	56.8	0.001	0.02	173	65.9
8 Shallow	4-30-98	1200	6.72	-75.3	725		0.32	3.5	19.9	0.8	72.3	0.013	0.04	205	65.7
8 Shallow	5-13-98	1300	***4.90***	-69.8		45	0.46	5.1	19.6	0.8	87.4	<0.001	0.02	222	74.3
8 Shallow	5-27-98	1450	6.62	-83.7	790		0.39	4.6	23.7	0.8	116	<0.001	0.02	246	84.5
8 Shallow	6-10-98	1500	6.66	-61.4	835		0.64	6.2	14	0.8	122	<0.05	0.02	251	80.3
8 Shallow	7-8-98	1550	6.94	-88.6	830	35	0.08	0.9	24.1	0.8	94.8	<0.05	0.02	261	86.9
8 Shallow	10-28-98	2550	6.18	-1.9		40	1.23	11.6	13.4	0.8	1755	<0.05	0.02	522	176
8 Shallow	4-22-99	2550	6.26	108.2		30	1	8.5	8.4	0.8	1602		0.02	436	144
8 Shallow	5-19-99	2950	6.30	-40	225		1.29	12.8	15	0.8	1699		0.03	519	171
8 Shallow	6-16-99	2950	6.12	-87.2		30	1.23	12.6	16.3	0.8	1398	0.003	0.0182	560	186
8 Shallow	7-14-99	3000	6.10	-35.8		60	0.56	6.8	25.1	0.8	1760	0.003	<0.002	553	194
8 Shallow	8-11-99	3150	6.22	-43.6		115	0.68	7.4	19.3	0.8	1776	0.007	0.0254	536	186
8 Shallow	9-8-99	3150	6.31	-48.7	430		0.76	7.7	16.7	0.8	1934	0.005	0.0506	616	199
8 Shallow	10-6-99	2800	6.33	-38.7	430	75	1	8.6	8.9	0.8	1807	0.004	0.0138	546	200
8 Deep	7-31-97	5000	6.52	-66.1			0.7	7.6	20.1	0.85	2082	<0.001	0.52	1020	216
8 Deep	8-14-97	5000	6.37	-118.5			0.52	5.5	18.4	0.85	2865	<0.1	0.08	577	216
8 Deep	8-28-97	5000	6.30	-73.1	345		0.65	6.7	17.1	0.85	3177	<0.05	<0.02	559	228
8 Deep	9-10-97	5046	5.45	-23.7		630	2.45	25.8	18	0.85	3190	<0.05	<0.02	547	227
8 Deep	9-22-97	4940	6.30	-69.7	350		0.53	5.4	16	0.85	3351	0.001	0.02	532	230
8 Deep	4-15-98	4850	6.48	-58.6	630		1.1	8.7	5.4	0.8	2695	<0.001	0.07	447	251
8 Deep	4-30-98		6.38	-61.7	155		0.75	8.0	18.3	0.8	3030	<0.001	0.07	472	246
8 Deep	5-13-98	4950	5.22	-50.3			0.55	5.6	16.7	0.8	2975	0.002	0.07	474	258
8 Deep	5-27-98	5000	6.44	-45.9	190		1.77	19.9	21.5	0.8	3270	<0.001	0.06	508	253
8 Deep	6-11-98	4750	6.57	-26	280		2.1	20.2	13.7	0.8	2652	<0.05	0.05	489	257
8 Deep	7-8-98	4650	6.64	-67.9	185	352.5	0.3	3.6	24	0.8	2700	<0.05	0.06	524	268
8 Deep	10-28-98	4150	6.40	-44.9	247.5		1.5	14.3	13.4	0.8	2851	<0.05	0.03	547	244
8 Deep	4-22-99	4650	6.50	-34.7	290		0.58	4.9	8.1	0.8	2632		0.06	467	238
8 Deep	5-19-99	4700	6.54	-71.8	230		0.88	8.7	14.7	0.8	2741		0.04	523	250
8 Deep	6-16-99	4700	6.34	-71.9	215		0.8	8.2	16.6	0.8	2633	0.008	0.0166	498	225
8 Deep	7-14-99	4450	6.28	-102.8		180	0.25	3.0	25	0.8	2908	0.006	<0.002	513	242
8 Deep	8-11-99	4650	6.37	-70.7	275		0.62	6.6	18.8	0.8	2466	0.034	0.0231	491	221
8 Deep	9-8-99	4550	6.41	-58.1	265		0.52	5.4	17.3	0.8	2618	0.022	0.0374	563	242
8 Deep	10-6-99	3750	6.32	-41.8	285	255	0.79	6.8	10.3	0.8	2418	0.022	0.021	532	242

1 Total metals were analyzed for comparison with filtered.

Bold italic values appear to be anomalous.

Table A4.9 Drainage quality from tank 9 (water cover).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
9 Surface	8-1-97	775	7.72	142.5			5.3	63.1	25.2	0.8	208	<0.1	0.08	108	36.4
9 Surface[1]	8-1-97											<0.05	0.07	109	37.4
9 Surface[1]	8-14-97											<0.05	0.15	120	41.3
9 Surface	8-14-97	1000	7.90	106.2			6.5	68.4	18	0.8	246	<0.1	0.06	117	41.2
9 Surface[1]	8-28-97											<0.05	0.18	125	39.7
9 Surface	8-28-97	900	7.70	136.3	150		6.97	77.4	21.3	0.8	271	<0.05	0.15	119	38.8
9 Surface	9-10-97	990	5.53	91.8		1.5	8.21	86.4	18	0.8	313	<0.05	0.16	123	40.8
9 Surface[1]	9-10-97											<0.05	0.16	135	42
9 Surface	9-22-97	982	7.82	69.2	155		7.2	72.7	15.7	0.85	320	0.008	0.2	141	42.9
9 Surface[1]	9-22-97											<0.05	0.22	141	41
9 Surface[1]	10-21-97											<0.05	0.44	143	40.3
9 Surface	10-21-97	950	7.84		170					0.5	357	<0.05	0.4	152	38.5
9 Surface	4-15-98	33	7.00	33.3	5		8.65	72.7	7.6	0.7	6.2	0.003	0.06	3	0.6
9 Surface	4-30-98	210	6.90	26.8	7.5		8.05	87.5	19.8	0.4	52.9	0.001	0.1	22	6.8
9 Surface	5-13-98	900	6.88	8.2	45		7.55	81.2	19.1	0.4	105	0.003	0.13	48.8	14.1
9 Surface	5-27-98	750	6.20	-5.1	75		7.26	82.5	22	0.4	264	0.004	0.14	90.8	27
9 Surface	6-11-98	900	7.50	3.6	90		7.8	75.0	13.7	0.4	318	<0.05	0.12	132	37.7
9 Surface	6-24-98	925	7.46	38.2			7.15	75.3	17.6	0.12	320	<0.05	0.1	134	36.7
9 Surface	7-8-98	1000	7.36	-37.2	100		2.75	33.5	26.1	0.4	352	<0.05	0.05	150	39.4
9 Surface	7-22-98	1050	8.42	52.3	90		4.2	45.7	19.9	0.2	365	<0.05	0.04	163	42
9 Surface	8-5-98	1050	7.25	73.2	95		4.29	52.3	25.9	0.2	469	<0.05	0.04	173	45.4
9 Surface	8-19-98	950	7.99	91.7	100		9.3	100.0	19.4	0.4	522	<0.05	0.04	172	40.1
9 Surface	9-2-98	1150	7.63	-10.9	102.5		4.62	52.5	21.7	0.4	583	<0.05	0.07	188	49.1
9 Surface	9-16-98	1075	7.89	130.7	100					0.2	525	<0.05	0.06	187	47.2
9 Surface	9-30-98	1350	6.90	-31.4	85		6.8	61.3	11.2	0.4	538	<0.05	0.1	192	47.7
9 Surface	10-14-98	1200	7.78	174.6	90					0.2	527	<0.05	0.17	191	46.7
9 Surface	10-28-98	1050	7.46	-41.8	80		1.95			0.4	587	<0.05	0.2	177	44.1
9 Surface	4-22-99	500	7.04	94.8	5		8.8		11	0.9	7.9		0.02	2.6	0.4
9 Surface	5-6-99	220	5.49												
9 Surface	5-19-99	345	7.03	42.3	20		7.65		17	0.4	114		0.08	40.8	7
9 Surface	6-3-99	550	6.88												
9 Surface	6-16-99	750	7.00	22.1	110		6.8		17.8	0.4	249	0.003	0.091	90.4	22.6
9 Surface	7-2-99	1100	6.40												
9 Surface	7-14-99	900	6.84	-15.1	65		5.35		29.4	0.8	372	0.003	0.004	141	29.7

Table A4.9 Drainage quality from tank 9 (water cover).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
9 Surface	7-29-99	850	7.38												
9 Surface	8-11-99	850	6.97	-26.5	35		6.95	33.9	20.5	0.4	379	0.004	0.015	114	28
9 Surface	8-26-99	800	6.38												
9 Surface	9-8-99	900	7.00	-26.5	30		6.39	67.3	18	0.4	397	0.003	0.0426	120	28.8
9 Surface	9-23-99	800	6.90												
9 Surface	10-6-99	850	7.02	-19.5	30	5	8.3	69.7	7.8	0.9	398	0.003	0.04	242	28.4
9 Surface	10-21-99	850	6.53												
9 Interface	7-8-98	1000	7.81	4.4	95	<5	2.55	29.1	22.7	0.4	341	<0.05	0.05	140	37.6
9 Interface	8-5-98	1100	7.62	110.8	205		4.46	53.2	25.2	0.4	482	<0.05	0.05	*1777*	42.2
9 Interface	9-2-98	1100	8.19	11.2	95		5.25	58.8	21.3	0.4	492	<0.05	0.05	190	48.2
9 Interface	9-30-98	1350	7.53	-13.3	80		7.6	68.7	11.2	0.4	539	<0.05	0.09	188	46.6
9 Interface	10-28-98	1100	7.61	-14.9	85		6.8			0.4	539	<0.05	0.2	174	42.4
9 Interface	4-22-99	3550	6.74	92.2	240		4.47		10.6	0.4	1479		0.9	622	136
9 Interface	5-6-99	2470	5.12												
9 Interface	5-19-99	3150	6.90	77.9	180		6.25		16.2	0.4	1638		0.6	563	126
9 Interface	6-3-99	2550	6.88												
9 Interface	6-16-99	2325	6.76	53.7	100		4.9		17.2	0.4	1244	0.004	0.229	349	99
9 Interface	7-2-99	1100	6.66												
9 Interface	7-14-99	850	7.21	28.5	40		6		25.6	0.4	372	0.004	0.0442	142	29.7
9 Interface	7-29-99	850	7.58												
9 Interface	8-11-99	850	7.11	0.8	40		6.7	72.8	20.1	0.4	384	0.006	0.0252	113	27.5
9 Interface	8-26-99	800	6.61												
9 Interface	9-8-99	800	7.17	-6.3	35		6.25	64.1	16.7	0.4	401	0.003	0.0509	121	28.4
9 Interface	9-23-99	800	7.03												
9 Interface	10-6-99	850	7.13	0.2	25	5	8.2	68.9	8.1	0.4	376	0.003	0.0331	122	27
9 Interface	10-21-99	850	6.64												
9 Deep	8-1-97	5000	6.43	-48			0.75	8.2	19.9	0.85	2531	<0.001	1.18	1030	222
9 Deep	8-14-97	5000	6.37	-87.3			0.71	7.3	17.3	0.85	2821	<0.1	0.07	609	223
9 Deep	8-28-97	5000	6.22	7		550	0.8	8.6	18.6	0.85	3222	<0.05	<0.02	549	230
9 Deep	9-10-97	4884	5.89	-11.9		640	3.1	32.6	18.3	0.85	3255	<0.05	0.02	542	228
9 Deep	9-22-97	4973	6.23	-69.9		830	0.45	4.4	15.2	0.85	3179	<0.001	0.02	532	234
9 Deep	10-21-97	4814	6.35		195					0.85	3159	<0.05	0.1	512	246
9 Deep	4-15-98	4700	6.47	-46.3	105		1.35	11.1	7.4	0.8	2730	<0.001	0.05	421	241
9 Deep	4-30-98	4550	6.36	-74.8	125		0.75	8.0	18.4	0.8	3001	0.005	0.05	468	252

Table A4.9 Drainage quality from tank 9 (water cover).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
9 Deep	5-13-98	4900	***4.00***	-66.6		525	0.66	6.8	16.8	0.8	2824	<0.001	0.06	477	247
9 Deep	5-27-98	5000	6.45	-61.5	155		1.43	15.7	20.6	0.8	3364	<0.001	0.04	499	257
9 Deep	6-10-98	4750	6.45	-27.5	235		1.45	13.9	14	0.8	2723	<0.05	0.04	501	247
9 Deep	7-8-98	4650	6.72	-68.1	170	320	0.35	4.0	21.7	0.8	2651	<0.05	0.05	532	259
9 Deep	8-5-98	4550	6.31	10.6	215		0.38	4.4	23.6	0.8	3161	<0.05	0.05	528	263
9 Deep	9-2-98	4700	6.76	-69.6	235		0.5	5.8	23.7	0.8	2794	<0.05	0.04	534	264
9 Deep	9-30-98	5000	6.32	-34.7	280		0.7	6.5	11.9	0.8	2861	<0.05	0.04	532	270
9 Deep	10-28-98	4150	6.32	-44.4	240		1.32			0.8	3100	<0.05	0.04	516	272
9 Deep	4-22-99	5000	6.45	-52.8	265		0.62	5.5	9.7	0.8	2721		0.05	470	241
9 Deep	5-19-99	4950	6.53	-79.9	205		0.78	7.8	15.6	0.8	2878		0.03	522	259
9 Deep	6-16-99	5000	6.33	-81	162		0.89	9.6	19.1	0.8	2721	0.006	0.0118	505	235
9 Deep	7-14-99	4600	6.27	-110.1		205	0.57	7.2	28.7	0.8	2989	0.007	<0.002	513	268
9 Deep	8-11-99	4750	6.41	-68.4	240		0.58	6.3	19.3	0.8	2584	0.04	0.0203	487	230
9 Deep	9-8-99	4700	6.48	-56.4	260		0.59	6.1	17.6	0.8	2698	0.026	0.0264	499	265
9 Deep	10-6-99	4000	6.44	-36	265	225	0.95	8.4	10	0.8	2390	0.023	0.0143	482	251

1 Total metals were analyzed for comparison with filtered.

Bold/italic values appear to be anomalous.

Table A4.10 Drainage quality from tank 10 (water cover with submerged aquatics).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
10 Surface	8-1-97	600	9.72	88.8			9.5	119.5	27	0.8	152	<0.1	<0.1	58.3	32.8
10 Surface	8-1-97											<0.05	<0.02	65	36
10 Surface	8-14-97											<0.05	0.04	54	37.3
10 Surface	8-14-97	775	10.30	55.4			14.8	155.8	18	0.8	192	<0.1	0.02	53.3	36.3
10 Surface	8-28-97											<0.05	<0.02	48.8	36.5
10 Surface	8-28-97	575	9.48	124.9	60		9.4	106.8	22.3	0.8	203	<0.05	<0.02	36.9	36.9
10 Surface	9-10-97											<0.05	<0.02	50.9	40.3
10 Surface	9-10-97	683	6.84	98.6	50		13.5	150.0	20.7	0.8	217	<0.05	<0.02	47	40.5
10 Surface	9-22-97											0.004	<0.02	56.3	40.5
10 Surface	9-22-97	655	9.11	29.7	75		11.98	126.1	17.7	0.8	211	0.005	<0.02	54.1	40.8
10 Surface	10-21-97	700	8.89		95					0.5	218	<0.05	0.02	64.7	41.4
10 Surface	10-21-97											<0.05	<0.02	65.2	39.2
10 Surface	4-15-98	75	7.48	1.6	30		8.9	73.0	7.4	0.7	6.3	0.006	0.02	9	1
10 Surface	4-30-98	235	9.64	-28.4	32.5		9.2	104.5	22.4	0.4	29.3	0.007	0.02	22.5	3.6
10 Surface	5-13-98	220	8.92	-41.1	80		11.4	123.9	19.9	0.4	39.1	0.011	0.02	23.9	7.4
10 Surface	5-27-98	245	10.55	-52.5	75		9.3	103.3	20.9	0.4	50.9	0.011	<0.02	26.8	13
10 Surface	6-11-98	290	10.42	-14.4	60		9.6	92.3	14.1	0.4	61.4	<0.05	<0.02	28.3	10.2
10 Surface	6-24-98	250	10.66	-24.4			8.3	87.4	18.2	0.12	48.9	<0.05	<0.02	23.7	10.7
10 Surface	7-8-98	280	10.41	-80.4	35		4.65	58.9	28.4	0.4	58.7	<0.05	<0.02	27	12.8
10 Surface	7-22-98	480	8.73	39.5	75		5.5	59.8	19.9	0.4	99.2	<0.05	0.02	49.4	23.4
10 Surface	8-5-98	600	8.50	64.8	125		7.1	86.6	25.7	0.4	167	<0.05	0.02	64.9	29.8
10 Surface	8-19-98	600	7.73	89.7	132.5		4.85	52.7	19.5	0.4	182	<0.05	<0.02	62.8	31.7
10 Surface	9-2-98	750	7.63	13.3	175		2.32	26.4	21.7	0.4	171	<0.05	0.02	82.2	40.7
10 Surface	9-16-98	800	7.72	138.7	215					0.2	161	<0.05	<0.02	92.2	42.8
10 Surface	9-30-98	1000	7.34	-50.4	230		4.27	39.5	11.9	0.2	175	<0.05	<0.02	98.9	45.5
10 Surface	10-14-98	900	8.06	166	240					0.2	172	<0.05	<0.02	102	45.9
10 Surface	10-28-98	800	8.57	-75.4	210		11.6			0.4	197	<0.05	<0.02	95.8	43.1
10 Surface	4-22-99	185	7.33	-90.6	10		9.9	88.4	10.5	0.9	11.6		0.02	6.1	1.1
10 Surface	5-6-99	220	5.50												
10 Surface	5-19-99	365	9.71	-47.2	90		12.3	125.0	16.3	0.4	76.9		0.02	32.1	13
10 Surface	6-3-99	390	9.31												
10 Surface	6-16-99	500	9.39	-29.6	65		9.2	100.0	19.5	0.4	113	0.011	0.006	30.7	20.9
10 Surface	7-2-99	500	10.28												
10 Surface	7-14-99	420	9.70	-50.8	60		9.75	128.3	28.8	0.4	111	0.007	<0.002	30.6	20.8

Table A4.10 Drainage quality from tank 10 (water cover with submerged aquatics).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
10 Surface	7-29-99	400	9.77												
10 Surface	8-11-99	460	9.31	-80.3	50		12.3	136.7	20.9	0.4	109	0.009	<0.002	27.5	21.7
10 Surface	8-26-99	410	9.06												
10 Surface	9-8-99	500	9.06	-75.2	55		12.1	126.0	17.6	0.4	122	0.008	0.0357	30.9	25
10 Surface	9-23-99	470	9.01												
10 Surface	10-6-99	500	8.61	-66.2	55	<8.3	14.6	129.2	10.2	0.4	130	0.008	0.0096	35	27.4
10 Surface	10-21-99	500	8.29												
10 Interfac	7-8-98	1825	7.77	-299.9	600	10	0.47	5.3	21.1	0.4	387	<0.05	<0.02	259	104
10 Interfac	8-5-98	1250	6.93	-20.9	395		2.78	32.4	23.6	0.4	338	<0.05	0.03	183	71.5
10 Interfac	9-2-98	800	7.71	-128.8	170		1.75	19.0	20	0.4	173	<0.05	0.02	82.1	40.3
10 Interfac	9-30-98	950	7.35	-31.2	220		1.25	11.7	12.4	0.4	182	<0.05	0.02	102	46.1
10 Interfac	10-28-98	750	8.18	-2	220		7			0.4	206	<0.05	0.02	92.5	42.7
10 Interfac	4-22-99	2150	7.26	-146.9	665		1.9	16.7	9.6	0.4	521		<0.02	272	104
10 Interfac	5-6-99	1560	5.61												
10 Interfac	5-19-99	1950	7.47	49.2	525		11.5	111.4	13.9	0.4	542	0.003	0.0118	262	98.7
10 Interfac	6-3-99	2150	7.26												
10 Interfac	6-16-99	1750	7.31	34.3	455		5.4	55.9	17	0.4	472	0.004	0.0084	253	
10 Interfac	7-2-99	1450	7.92												
10 Interfac	7-14-99	1350	7.56	32.3	390		5.79	69.3	24.5	0.4	379	0.003	<0.002	183	75.2
10 Interfac	7-29-99	1250	7.56												
10 Interfac	8-11-99	1150	7.91	1.2	330		4.65	47.3	19.8	0.4	293	0.004	0.002	136	62
10 Interfac	8-26-99	900	7.74												
10 Interfac	9-8-99	950	7.62	-12.7	245		3.95	41.6	17.9	0.8	239	0.004	0.0327	107	48.4
10 Interfac	9-23-99	800	7.94												
10 Interfac	10-6-99	500	8.97	-19	55	<8.3	14.2	126.8	10.6	0.8	127	0.008	0.0102	33.5	26.4
10 Interfac	10-21-99	500	8.85												
10 Deep	8-1-97	5000	6.48	-45.3			0.7	7.5	18.9	0.85	1927	0.001	1.25	1080	217
10 Deep	8-14-97	5000	6.38	-110.8			0.59	6.1	16.6	0.85	2737	<0.1	0.06	630	223
10 Deep	8-28-97	5000	6.15	-158.2		500	0.7	7.4	18.4	0.85	3240	<0.05	<0.02	557	229
10 Deep	9-10-97	4956	5.34	-35.7		680	3.15	33.2	17.9	0.85	3201	<0.05	0.02	541	227
10 Deep	9-22-97	4839	6.28	-79.1		780	1.8	18.2	16.3	0.85	3159	<0.001	0.02	541	231
10 Deep	10-21-97	4845	6.34		220					0.85	3258	<0.05	0.04	501	245
10 Deep	4-15-98	4850	6.48	-40.9	50		1.3	10.7	7.2	0.8	2978	0.001	0.06	410	237
10 Deep	4-30-98	4950	6.38	-75.1	110		1.08	11.7	19.3	0.8	3106	0.001	0.04	464	256

Table A4.10 Drainage quality from tank 10 (water cover with submerged aquatics).
Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
10 Deep	5-13-98	4950	***4.62***	-69.6		620	1.03	10.4	15.8	0.8	3097	<0.001	0.05	475	247
10 Deep	5-27-98	4950	6.49	-64.9	105		1.43	15.7	20.5	0.8	3306				
10 Deep	6-11-98	4800	6.46	-45.8	240		1.45	13.7	13	0.8	2756	<0.05	0.04	503	204
10 Deep	7-8-98	4600	6.89	-194.9	155	385	0.09	1.0	21.2	0.8	2716	<0.05	0.04	521	261
10 Deep	8-5-98	4550	6.32	11.1	220		0.5	5.9	23.9	0.8	3119	<0.05	0.04	548	271
10 Deep	9-2-98	4850	6.78	-70.4	205		0.55	6.1	20.8	0.8	3026	<0.05	0.04	545	279
10 Deep	9-30-98	5000	6.28	-38.6	335		0.68	6.3	12.1	0.8	3020	<0.05	0.04	541	274
10 Deep	10-28-98	4350	6.33	-54.9	155		1.43			0.8	3156	<0.05	0.04	515	265
10 Deep	4-22-99	4950	6.49	-71.1	215		0.38	3.3	9.2	0.8	2802		0.03	459	242
10 Deep	5-19-99	5000	6.55	-85.6	185		0.58	5.8	15.7	0.8	2887	0.006	0.0238	478	255
10 Deep	6-16-99	5000	6.34	-79.7	165		0.75	7.9	17.9	0.8	3061	0.008	0.0173	503	950
10 Deep	7-14-99	4650	6.28	-102		255	0.66	8.2	26.5	0.8	2985	0.007	<0.002	499	268
10 Deep	8-11-99	4750	6.48	-73.8	215		0.68	7.6	20.4	0.8	2644	0.037	0.0184	482	233
10 Deep	9-8-99	4800	6.59	-49.4	230		0.62	6.5	17.9	0.8	2716	0.025	0.0075	554	264
10 Deep	10-6-99	4000	6.69	-49.4	250	225	0.85	7.6	10.6	0.8	2458	0.046	0.092	488	245

1 Total metals were analyzed for comparison with filtered.

Bold/italic values appear to be anomalous.

Table A4.11. Drainage quality from tanks 11 and 12 (on-land controls).

Concentrations are in mg/L unless otherwise indicated. pH is in standard units.

Tank	Date	SC(μS)	pH	Eh(mV)	ALK	ACY	DO	DOSAT(%)	TEMP(°C)	VOLOUT(L)	SO4	CU	ZN	CA	MG
11 Control	6-25-98	17200	3.03	337.7		6960				22	32260	1.55	2420	412	6400
11 Control	10-16-98	>5000	2.99	322.8		20740				36	46320	0.18	7850	377	4000
11 Control	11-30-98	>5000	3.13	333.3		29400				60.4	45660	0.08	10400	463	4710
11 Control	4-12-99	41000	3.20			20600				263	31240		8820	329	3295
11 Control	7-7-99	12000	2.69	394.6		12400				99	65290	0.1	5000	441	994
11 Control	8-2-99	12000	2.97	341.3		10520				48.5	48840	0.005	3720	466	532
11 Control	8-16-99	14000	3.31	257.7		10900				48	12639	0.016	5300	440	491
11 Control	9-13-99	12500	3.40	282.1		20820				34	23300	0.009	4970	443	982
11 Control	9-28-99	6750	3.14	295.2		23800				1	21910	0.014	9080	477	950
12 Control	9-18-98	>5000	4.43	222.6		11680				127		0.4	4720	307	4270
12 Control	9-28-98	>5000	3.02	353.1		22100				57.3	44000	0.2	8590	441	6090
12 Control	10-12-98	>5000	3.24	273.1		17320				6	51050	0.17	8510	372	4740
12 Control	10-16-98	>5000	3.23	314.4						17	49530	0.1	8440	362	4330
12 Control	10-16-98	>5000	3.36	275.8		23360				13	47480	0.15	7530	373	5110
12 Control	10-19-98	>5000	3.35			20000				39.3	38110	0.1	8230	407	3680
12 Control	10-26-98	>5000	3.18	325.8		20100				9.6	36940	0.1	8100	397	3610
12 Control	10-28-98	>5000	3.48	334.9		19600				11.7	32700	0.07	8320	475	3190
12 Control	11-30-98	>5000	2.75	406.6		22100				6.7	31720	0.49	8990	528	3300
12 Control	12-7-98	45000	2.91	364.6		18250				75	27990	0.6	7890	141	2670
12 Control	4-12-99	31000				17300				227.5	26290		7270	351	2177
12 Control	7-7-99	12500	2.83	398.2		9020				83.5	67100	0.27	5950	432	928
12 Control	8-2-99	14500	3.10	359.2		11040				55.9	60670	0.06	6120	487	620
12 Control	8-16-99	13250	3.23	299.3		9800				6.8	12431	0.056	7590	401	508
12 Control	9-13-99	>5000	3.19	306.5		15700				30.1	18130	0.008	5160	438	1040
12 Control	9-28-99	21000	3.23	297.7		18500				2	21880	0.111	7430	431	791
12 Control	10-25-99	20000	2.52	452.7		18700				0.21					

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.
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TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
1 SURFACE	8-1-97	-0.1	0.001	14.7	6.7	0.1	0.2	-0.1	0.02	-0.4		
1 SURFACE	8-14-97								0.06	-0.4		
1 SURFACE	8-28-97								0.02	-0.4		
1 SURFACE	9-10-97								0.05	-0.4		
1 SURFACE	9-22-97			18	10.7	0.1	0.2	1.9				
1 SURFACE	9-22-97			17.7	10.3	0.2	0.1	0.3	0.01	-0.4		
1 SURFACE	10-21-97								0.03	-0.4		
1 SURFACE	4-15-98								0.11	0.1	0.21	0.07
1 SURFACE	4-30-98								-0.01	0.1	-0.2	0.05
1 SURFACE	5-27-98	-0.1	-0.1	14.7								
1 SURFACE	10-28-98	-0.1	-0.1	22.6	14.7	-0.1	-0.05	0.2				
1 SURFACE	4-22-99								0.02	-0.4	-0.2	0.03
1 SURFACE	6-16-99	0.0186	0.0022	16.7	19.5	0.025	0.078	0.422				
1 INTERFACE	10-28-98	-0.1	-0.1	22.2	12.9	-0.1	-0.05	0.1				
1 INTERFACE	6-16-99	0.0202	-0.002	63.3	28.1	-0.025	1.2	2.699				
1 DEEP	7-31-97	-0.1	-0.001	362	70.9	-0.1	14.3	102				
1 DEEP	9-22-97			370	65.9	0.1	17.4	198				
1 DEEP	5-27-98	-0.1	-0.1	314								
1 DEEP	10-28-98	-0.1	-0.1	282	61.6	-0.1	4.6	145				
1 DEEP	6-16-99	0.0087	-0.002	223	63.4	-0.025	2.6	114				
2 SURFACE	8-1-97	-0.1	0.003	49.8	65.3	0.2	1	0.7	0.15	-0.4		
2 SURFACE	8-14-97								0.16	-0.4		
2 SURFACE	8-28-97								0.08	-0.4		
2 SURFACE	9-10-97								0.14	-0.4		
2 SURFACE	9-22-97			83.9	76.9	0.2	0.6	0.3	0.07	-0.4		
2 SURFACE	9-22-97			87.1	76.3	0.1	0.6	0.3				
2 SURFACE	10-21-97								0.06	-0.4		
2 SURFACE	4-15-98								0.02	0.03	0.2	0.02
2 SURFACE	5-27-98	-0.1	-0.1	47.3								
2 SURFACE	10-28-98	-0.1	-0.1	5.7	16.5	0.2	1.46	***33.7***				
2 SURFACE	4-22-99								0.01	-0.4	0.47	0.38
2 SURFACE	6-16-99	0.0137	0.008	11.6	21.9	0.99	1.2	0.4				

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.
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TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
2 SHALLOW	7-31-97	-0.1	-0.001	271	60.9	-0.1	13.1	134				
2 SHALLOW	9-22-97			259	58.5	0.1	16	198				
2 SHALLOW	5-27-98	-0.1	-0.1	255								
2 SHALLOW	10-28-98	-0.1	-0.1	211	61.2	-0.1	2.87	106				
2 SHALLOW	6-16-99	0.0062	-0.002	259	72.5	-0.025	1.3	34.6				
2 DEEP	7-31-97	-0.1	0.001	340	71.4	-0.1	12.7	98.8				
2 DEEP	9-22-97			326	66.3	0.1	18.8	209				
2 DEEP	5-27-98	-0.1	-0.1	352								
2 DEEP	10-28-98	-0.1	-0.1	306	65.8	-0.1	5.76	184				
2 DEEP	6-16-99	0.0081	-0.002	352	66.6	-0.025	3.2	132				
3 SURFACE	8-1-97	-0.1	-0.001	12.1	16.1	0.2	-0.1	-0.1	0.89	-0.4		
3 SURFACE	8-14-97								0.27	-0.4		
3 SURFACE	8-28-97								0.29	-0.4		
3 SURFACE	9-10-97								0.43	-0.4		
3 SURFACE	9-22-97			16.6	15.8	-0.1	-0.1	0.1				
3 SURFACE	9-22-97			16.5	15.9	-0.1	-0.1	0.1	0.47	-0.4		
3 SURFACE	10-21-97								0.28	-0.4		
3 SURFACE	4-15-98								0.18	0.02	0.2	-0.02
3 SURFACE	5-27-98	-0.1	-0.1	8.2								
3 SURFACE	10-28-98	-0.1	-0.1	16.8	11.6	0.2	-0.05	0.2				
3 SURFACE	4-22-99								0.19	-0.1	0.62	0.02
3 SURFACE	6-16-99	0.0021	-0.002	13.8	13.2	-0.025	0.008	0.388				
3 INTERFACE	10-28-98	-0.1	-0.1	28.4	24.3	0.2	1.16	0.1				
3 INTERFACE	6-16-99	0.0032	-0.002	39.4	29	-0.025	12.2	1.2				
3 DEEP	7-31-97	-0.1	-0.001	365	74.5	-0.1	16.6	148				
3 DEEP	9-22-97			334	66.7	0.2	23	390				
3 DEEP	5-27-98	-0.1	-0.1	330								
3 DEEP	10-28-98	-0.1	-0.1	282	64.5	0.2	6.35	273				
3 DEEP	6-16-99	0.0079	-0.002	202	63.6	-0.025	2.8	162				

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.

TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
4 SURFACE	8-1-97	-0.1	-0.001	14.2	7.5	0.3	-0.1	-0.1	0.07	-0.4		
4 SURFACE	8-14-97								0.09	-0.4		
4 SURFACE	8-28-97								0.07	-0.4		
4 SURFACE	9-10-97								0.17	-0.4		
4 SURFACE	10-21-97								0.06	-0.4		
4 SURFACE	4-15-98								0.05	0.02	0.31	-0.02
4 SURFACE	5-27-98	-0.1	-0.1	9.8								
4 SURFACE	4-22-99								0.07	-0.4	0.79	0.02
4 SURFACE	6-16-99	0.002	-0.002	2	1.1	-0.025	0.019	0.324				
4 SHALLOW	7-31-97	-0.1	0.002	8	3.1	-0.1	4.2	0.7				
4 SHALLOW	9-22-97			8.7	2.4	0.1	16.8	3.4				
4 SHALLOW	5-27-98	-0.1	-0.1	8.6								
4 SHALLOW	6-16-99	0.0138	0.0046	16.3	0.6	-0.025	0.263	2.5				
4 DEEP	7-31-97	-0.1	0.001	386	74.4	-0.1	15.9	129				
4 DEEP	9-22-97			353	66.9	0.3	21.2	304				
4 DEEP	5-27-98	-0.1	-0.1	323								
4 DEEP	6-16-99	0.0094	-0.002	350	60.9	-0.025	2.9	78.7				
5 SURFACE	8-1-97	-0.1	-0.001	16.8	26.7	0.9	1	6.3	1.14	-0.4		
5 SURFACE	8-14-97								2.97	-0.4		
5 SURFACE	8-28-97								5.21	-0.4		
5 SURFACE	10-21-97								0.64	-0.4		
5 SURFACE	4-15-98								0.82	***3.55***	2.1	0.04
5 SHALLOW	7-31-97	-0.1	0.008	8	18.6	4.3	1.3	30.7				
5 SHALLOW	9-22-97			7.9	17.4	5	1.2	45				
5 SHALLOW	5-27-98	-0.1	-0.1	7.3								
5 SHALLOW	6-16-99	0.0223	0.0227	87.3	46.2	1.3	0.007	30.3				
5 DEEP	7-31-97	-0.1	-0.001	380	79.1	-0.1	16.9	114				
5 DEEP	9-22-97			355	67.7	0.1	22.8	334				
5 DEEP	5-27-98	-0.1	-0.1	327								
5 DEEP	6-16-99	0.006	-0.002	250	62.1	-0.025	1.21	124				

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.
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TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
6 SURFACE	8-1-97	-0.1	-0.001	14.6	27.6	0.6	1	3.1	1.3	-0.4		
6 SURFACE	8-14-97								1.73	-0.4		
6 SURFACE	8-28-97								1.89	-0.4		
6 SURFACE	10-21-97								0.46	-0.4		
6 SURFACE	4-15-98								0.89	0.07	1.8	0.03
6 SURFACE	5-27-98	-0.1	-0.1	7.9								
6 SURFACE	10-28-98	-0.1	-0.1	6.2	16.7	0.3	0.6	0.4				
6 SURFACE	4-22-99								0.36	-0.4	1	0.03
6 SURFACE	6-16-99	0.003	-0.002	0.2	-0.1	0.069	2.7	0.71				
6 SHALLOW	7-31-97	-0.1	0.009	7.8	18.6	3.1	1.5	30.2				
6 SHALLOW	9-22-97			7.6	15.3	5.1	1.3	46.4				
6 SHALLOW	5-27-98	-0.1	-0.1	7.6								
6 SHALLOW	10-28-98	-0.1	-0.1	9.5	0.6	1.1	1.5	20				
6 SHALLOW	6-16-99	0.0309	0.0213	14.5	1	3.4	0.017	51.6				
6 DEEP	7-31-97	-0.1	0.002	378	75.1	0.2	14.5	99.9				
6 DEEP	9-22-97			363	69.1	0.3	21.3	304				
6 DEEP	5-27-98	-0.1	-0.1	331								
6 DEEP	10-28-98	-0.1	-0.1	293	65.2	0.2	4.79	197				
6 DEEP	6-16-99	0.0066	-0.002	268	55.5	-0.025	0.348	134				
7 SURFACE	8-1-97	-0.1	0.004	32.2	70.5	0.2	2.7	1.6	0.18	-0.4		
7 SURFACE	8-14-97								0.29	-0.4		
7 SURFACE	8-28-97								0.18	-0.4		
7 SURFACE	9-10-97								0.18	-0.4		
7 SURFACE	9-22-97			65.7	84.8	-0.1	1.5	0.1				
7 SURFACE	9-22-97			66.7	80.1	-0.1	1.4	-0.1	0.08	-0.4		
7 SURFACE	10-21-97								0.07	-0.4		
7 SURFACE	4-15-98								0.02	0.03	0.43	-0.02
7 SURFACE	5-27-98	-0.1	-0.1	34.4								
7 SURFACE	10-28-98	-0.1	-0.1	6.5	16.4	0.8	1.79	1.1				
7 SURFACE	4-22-99								0.03	-0.4	0.23	-0.02
7 SURFACE	6-16-99	0.008	0.0063	14.5	9.4	0.226	2.9	0.194				

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.

TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
7 SHALLOW	7-31-97	-0.1	-0.001	141	46.2	0.2	10.8	87.3				
7 SHALLOW	9-22-97			156	49.8	0.3	13.4	125				
7 SHALLOW	5-27-98	-0.1	-0.1	209								
7 SHALLOW	10-28-98	-0.1	-0.1	164	53.6	0.2	4.66	104				
7 SHALLOW	6-16-99	0.0085	-0.002	202	63.8	-0.025	1.7	***48.3***				
7 DEEP	7-31-97	-0.1	0.003	408	76.5	0.1	13.8	91.2				
7 DEEP	9-22-97			***19.1***	70	0.4	19.1	219				
7 DEEP	5-27-98	-0.1	-0.1	390								
7 DEEP	10-28-98	0.1	-0.1	358	69.3	0.2	5.96	188				
7 DEEP	6-16-99	0.0053	-0.002	391	66.5	-0.025	0.981	138				
8 SURFACE	8-1-97	-0.1	-0.001	15.2	9.2	0.3	-0.1	-0.1	0.11	-0.4		
8 SURFACE	8-14-97								0.13	-0.4		
8 SURFACE	8-28-97								0.14	-0.4		
8 SURFACE	10-21-97								0.09	-0.4		
8 SURFACE	4-15-98								0.04	0.03	0.95	-0.02
8 SURFACE	10-28-98	-0.1	-0.1	4.6	11.6	-0.1	-0.05	0.1				
8 SURFACE	4-22-99								0.07	-0.4	0.45	-0.02
8 SURFACE	6-16-99	-0.002	-0.002	2	0.2	0.025	3.7	0.313				
8 SHALLOW	8-1-97	-0.1	0.005	11.6	5	0.1	6.3	0.8				
8 SHALLOW	5-27-98	-0.1	-0.1	12.3								
8 SHALLOW	10-28-98	-0.1	-0.1	46.8	1	-0.1	4.39	-0.1				
8 SHALLOW	6-16-99	0.0269	0.0102	54.3	1.1	-0.025	0.011	-0.025				
8 DEEP	7-31-97	-0.1	0.001	388	78.3	-0.1	16.8	126				
8 DEEP	9-22-97			369	72.2	0.4	22.9	354				
8 DEEP	5-27-98	-0.1	-0.1	354								
8 DEEP	10-28-98	-0.1	-0.1	239	57.4	0.1	4.77	195				
8 DEEP	6-16-99	0.0075	-0.002	244	52.5	-0.025	1.02	135				
9 SURFACE	8-1-97	-0.1	0.001	11.5	7.5	0.2	0.3	-0.1	0.07	-0.4		
9 SURFACE	8-14-97								0.13	-0.4		
9 SURFACE	8-28-97								0.07	-0.4		

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.

TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
9 SURFACE	9-10-97								0.09	-0.4		
9 SURFACE	9-22-97			16.1	11.2	-0.1	0.3	-0.1	0.01	-0.4		
9 SURFACE	10-21-97								0.03	-0.4		
9 SURFACE	4-15-98								-0.01	0.1	-0.02	0.02
9 SURFACE	5-27-98	-0.1	-0.01	14.3								
9 SURFACE	10-28-98	-0.1	-0.1	21.4	14.4	-0.1	-0.05	0.1				
9 SURFACE	4-22-99								0.02	-0.4	0.2	0.1
9 SURFACE	6-16-99	0.0028	-0.002	19.2	9.7	-0.025	3.2	0.741				
9 INTERFACE	10-28-98	-0.1	-0.1	21.2	14.4	-0.1	-0.05	-0.1				
9 INTERFACE	6-16-99	0.0138	0.002	41.8	21.9	-0.025	0.024	4.12				
9 DEEP	8-1-97	-0.1	-0.001	390	76.6	0.1	17.2	119				
9 DEEP	9-22-97			342	68.1	0.3	22.7	389				
9 DEEP	5-27-98	-0.1	-0.1	314								
9 DEEP	10-28-98	-0.1	-0.1	277	63.9	-0.1	5.3	218				
9 DEEP	6-16-99	0.0054	-0.002	259	57.8	-0.025	4.2	136				
10 SURFACE	8-1-97	-0.1	0.002	11.2	9.6	0.2	-0.1	-0.1	0.18	-0.4		
10 SURFACE	8-14-97								0.15	-0.4		
10 SURFACE	8-28-97								0.08	-0.4		
10 SURFACE	9-10-97								0.11	-0.4		
10 SURFACE	9-22-97			16.7	14.1	-0.1	-1	0.1				
10 SURFACE	9-22-97			17.9	16.9	0.1	-0.1	-0.1	0.19	-0.4		
10 SURFACE	10-21-97								0.15	-0.4		
10 SURFACE	4-15-98								0.12	0.04	-0.2	0.02
10 SURFACE	5-27-98	-0.1	-0.1	7								
10 SURFACE	10-28-98	-0.1	-0.1	23.5	20.4	-0.1	-0.05	0.1				
10 SURFACE	4-22-99								0.05	-0.4	0.76	0.05
10 SURFACE	6-16-99	-0.002	-0.002	15.7	10.7	-0.025	2.6	0.398				
10 INTERFACE	10-28-98	-0.1	-0.1	22.6	21.1	-0.1	-0.05	-0.1				
10 INTERFACE	6-16-99	0.0059	-0.002	51.8	37.3	-0.025	2	2.33				

Table A4.12. Additional water quality parameters run on selected samples.
Results are in mg/L.

TANK	DATE	NI	CO	NA	K	AL	MN	FE	TP	NO3_2	TKN	NH3_N
10 DEEP	8-1-97	-0.1	0.001	388	77.8	0.1	16.9	106				
10 DEEP	9-22-97			361	67.8	0.3	22.3	376				
10 DEEP	10-28-98	-0.1	-0.1	284	63.6	-0.1	5.97	232				
10 DEEP	6-16-99	0.0093	-0.002	264	61.3	-0.025	4.1	156				
12	10-19-98	30.9	3.5	233	141	117	140	2920				
12	10-26-98	32.1	4.3	220	114	151	132	2730				

Note: Values in bold/italic appear to be anomalous

Table A.4.13 (Page 1 of 16) Drainage quality summary statistics

The following results are for:
TANK$ = 1SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	35	34	27	21	6	25	25	25	28
Minimum	28.000	5.560	-29.200	5.000	-5.000	4.800	51.613	2.400	3.400
Maximum	1050.000	8.310	196.000	195.000	30.000	9.850	102.151	22.700	446.000
Mean	728.429	7.258	110.333	78.833	8.583	7.019	69.767	15.744	275.536
95% CI Upper	829.942	7.482	132.299	102.934	21.523	7.588	74.712	17.929	326.561
95% CI Lower	626.915	7.034	88.368	54.732	-4.357	6.450	64.822	13.559	224.510
Standard Dev	295.517	0.642	55.526	52.947	12.331	1.379	11.980	5.293	131.591

	CU	ZN	CA	MG
N of cases	26	25	27	28
Minimum	-0.100	-0.002	2.000	0.100
Maximum	0.008	0.300	168.000	47.600
Mean	-0.027	0.077	103.996	30.218
95% CI Upper	-0.014	0.099	123.344	35.806
95% CI Lower	-0.039	0.054	84.649	24.630
Standard Dev	0.031	0.054	48.909	14.412

The following results are for:
TANK$ = 1INTERFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	19	19	12	12	2	12	12	12	12
Minimum	700.000	5.300	-56.100	30.000	-5.000	4.210	48.391	6.300	302.000
Maximum	4400.000	8.240	188.600	280.000	5.000	7.250	69.355	22.000	2184.000
Mean	1566.842	7.138	114.967	88.958	0.000	5.888	57.752	15.200	733.167
95% CI Upper	2151.725	7.425	158.736	132.314	63.531	6.512	62.294	18.755	1179.485
95% CI Lower	981.959	6.851	71.197	45.603	-63.531	5.264	53.210	11.645	286.849
Standard Dev	1213.489	0.595	68.889	68.236	7.071	0.982	7.149	5.595	702.454

	CU	ZN	CA	MG
N of cases	10	12	12	12
Minimum	-0.050	-0.020	102.000	24.500
Maximum	0.004	0.890	849.000	197.000
Mean	-0.023	0.244	266.833	65.675
95% CI Upper	-0.003	0.434	430.367	104.244
95% CI Lower	-0.043	0.054	103.300	27.106
Standard Dev	0.028	0.300	257.384	60.704

The following results are for:
TANK$ = 1DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	23	23	22	20	3	22	21	21	23
Minimum	3900.000	5.900	-138.000	150.000	28.500	0.470	4.167	3.800	1756.000
Maximum	5000.000	7.000	18.300	412.000	530.000	2.690	27.732	22.000	3132.000
Mean	4614.826	6.494	-58.514	255.100	262.833	1.113	10.810	15.262	2724.174
95% CI Upper	4744.072	6.576	-43.920	288.757	889.723	1.384	13.673	17.548	2854.628
95% CI Lower	4485.581	6.412	-73.107	221.443	-364.056	0.842	7.948	12.976	2593.720
Standard Dev	298.880	0.190	32.915	71.914	252.357	0.611	6.289	5.022	301.674

	CU	ZN	CA	MG
N of cases	21	23	23	23
Minimum	-0.100	-0.020	423.000	193.000
Maximum	0.026	0.100	586.000	282.000
Mean	-0.020	0.034	520.435	247.478
95% CI Upper	-0.004	0.048	537.890	256.705
95% CI Lower	-0.035	0.019	502.979	238.252
Standard Dev	0.035	0.034	40.366	21.337

The following results are for:
TANK$ = 2SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	31	31	23	10	12	22	22	22	22
Minimum	435.000	3.380	35.500	2.000	-5.000	4.190	44.105	2.300	163.000
Maximum	4909.000	7.750	304.200	30.000	270.000	10.400	113.043	24.400	2411.000
Mean	1745.194	5.314	143.000	18.700	51.250	7.091	71.135	16.195	1098.682
95% CI Upper	2126.955	5.877	180.691	24.200	97.844	7.954	79.879	18.878	1400.281
95% CI Lower	1363.432	4.751	105.309	13.200	4.656	6.229	62.392	13.513	797.082
Standard Dev	1040.780	1.534	87.161	7.689	73.334	1.946	19.721	6.050	680.236

	CU	ZN	CA	MG
N of cases	22	24	24	24
Minimum	-0.100	0.001	42.600	4.800
Maximum	0.100	10.800	951.000	179.000
Mean	-0.008	1.418	368.650	53.829
95% CI Upper	0.012	2.331	467.902	72.347
95% CI Lower	-0.028	0.506	269.398	35.311
Standard Dev	0.044	2.161	235.047	43.853

The following results are for:
TANK$ = 2SHALLOW

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	20	20	18	17	3	19	18	18	20
Minimum	3950.000	5.700	-100.400	220.000	7.500	0.450	5.000	2.300	2306.000
Maximum	5000.000	6.820	45.800	430.000	475.000	2.450	25.000	23.500	3227.000
Mean	4504.600	6.432	-53.061	284.559	220.833	1.014	10.245	15.617	2663.750
95% CI Upper	4679.211	6.532	-36.869	313.645	808.108	1.270	13.056	18.110	2779.129
95% CI Lower	4329.989	6.332	-69.253	255.473	-366.441	0.758	7.434	13.124	2548.371
Standard Dev	373.088	0.215	32.561	56.570	236.410	0.531	5.653	5.013	246.528

	CU	ZN	CA	MG
N of cases	19	20	20	20
Minimum	-0.100	-0.020	422.000	177.000
Maximum	0.024	0.100	588.000	391.000
Mean	-0.017	0.027	520.150	278.250
95% CI Upper	-0.001	0.041	539.339	308.597
95% CI Lower	-0.034	0.014	500.961	247.903
Standard Dev	0.034	0.029	41.001	64.843

The following results are for:
TANK$ = 2DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	21	21	20	18	3	20	20	20	21
Minimum	4100.000	5.670	-94.000	160.000	305.000	0.400	4.315	2.400	2277.000
Maximum	5000.000	6.630	8.500	398.000	600.000	2.300	23.469	22.900	3077.000
Mean	4757.333	6.376	-57.435	246.833	423.333	0.881	8.664	15.270	2841.095
95% CI Upper	4885.558	6.487	-45.913	279.852	810.638	1.094	10.810	17.647	2925.797
95% CI Lower	4629.109	6.265	-68.957	213.815	36.028	0.669	6.518	12.893	2756.393
Standard Dev	281.692	0.243	24.619	66.397	155.911	0.453	4.585	5.078	186.079

	CU	ZN	CA	MG
N of cases	20	21	21	21
Minimum	-0.100	-0.050	420.000	200.000
Maximum	0.043	0.100	785.000	296.000
Mean	-0.015	0.027	520.429	253.095
95% CI Upper	0.003	0.043	553.061	265.557
95% CI Lower	-0.033	0.010	487.796	240.633
Standard Dev	0.038	0.037	71.690	27.377

The following results are for:
TANK$ = 3SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	35	35	27	25	1	25	25	25	28
Minimum	68.000	5.040	-53.300	20.000	-5.000	6.450	57.983	3.600	6.300
Maximum	855.000	10.490	166.800	288.000	-5.000	16.400	182.222	25.400	250.000
Mean	489.314	8.285	21.763	82.840	-5.000	9.180	94.889	16.596	124.350
95% CI Upper	561.729	8.693	44.488	105.278	-5.000	10.168	106.108	18.846	150.821
95% CI Lower	416.900	7.876	-0.962	60.402	-5.000	8.193	83.671	14.346	97.879
Standard Dev	210.807	1.188	57.446	54.358	.	2.392	27.178	5.452	68.266

	CU	ZN	CA	MG
N of cases	26	28	28	28
Minimum	-0.100	-0.020	7.900	1.000
Maximum	0.013	0.060	89.500	43.300
Mean	-0.029	0.004	49.968	21.882
95% CI Upper	-0.016	0.013	58.631	26.591
95% CI Lower	-0.041	-0.005	41.305	17.173
Standard Dev	0.031	0.024	22.340	12.144

The following results are for:
TANK$ = 3INTERFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	19	19	12	12	2	12	12	12	12
Minimum	450.000	4.010	-284.100	80.000	-5.000	0.500	5.952	6.900	118.000
Maximum	3450.000	8.560	-84.000	1135.000	65.000	8.400	68.852	25.000	727.000
Mean	1261.842	7.132	-165.967	555.417	30.000	2.766	27.189	16.217	362.333
95% CI Upper	1675.338	7.638	-123.560	765.619	474.717	4.236	40.615	20.252	497.290
95% CI Lower	848.346	6.626	-208.373	345.214	-414.717	1.296	13.763	12.182	227.377
Standard Dev	857.903	1.050	66.743	330.835	49.497	2.313	21.131	6.351	212.406

	CU	ZN	CA	MG
N of cases	10	12	12	12
Minimum	-0.050	-0.020	34.100	23.100
Maximum	0.022	0.040	422.000	147.000
Mean	-0.022	0.001	217.867	74.983
95% CI Upper	-0.001	0.014	304.698	101.909
95% CI Lower	-0.044	-0.013	131.036	48.058
Standard Dev	0.030	0.021	136.662	42.378

The following results are for:
TANK$ = 3DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	23	23	22	20	3	22	22	22	23
Minimum	4000.000	5.470	-169.500	100.000	285.000	0.230	2.486	4.000	2048.000
Maximum	5080.000	7.700	21.700	950.000	895.000	2.540	25.971	24.600	3344.000
Mean	4788.522	6.420	-72.782	234.500	568.333	0.915	8.877	15.505	2890.522
95% CI Upper	4912.253	6.574	-54.134	317.571	1331.709	1.170	11.269	17.812	3035.036
95% CI Lower	4664.790	6.266	-91.430	151.429	-195.042	0.660	6.486	13.197	2746.008
Standard Dev	286.129	0.355	42.060	177.496	307.300	0.575	5.393	5.204	334.189

	CU	ZN	CA	MG
N of cases	21	23	23	23
Minimum	-0.100	-0.020	372.000	205.000
Maximum	0.028	0.280	912.000	271.000
Mean	-0.022	0.036	514.609	238.522
95% CI Upper	-0.006	0.063	556.254	246.788
95% CI Lower	-0.038	0.010	472.963	230.255
Standard Dev	0.035	0.062	96.305	19.117

The following results are for:
TANK$ = 4SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	24	25	17	15	1	16	16	17	18
Minimum	42.000	5.800	-91.700	5.000	-5.000	3.560	35.960	3.300	2.900
Maximum	1335.000	8.610	125.000	215.000	-5.000	12.500	147.059	24.900	291.000
Mean	302.333	7.364	14.124	73.667	-5.000	8.053	80.425	16.106	66.200
95% CI Upper	445.515	7.647	44.515	108.920	-5.000	9.471	95.837	19.281	106.978
95% CI Lower	159.151	7.082	-16.268	38.413	-5.000	6.636	65.014	12.931	25.422
Standard Dev	339.082	0.684	59.111	63.660	.	2.660	28.922	6.176	82.001

	CU	ZN	CA	MG
N of cases	16	18	18	18
Minimum	-0.100	-0.020	4.600	1.500
Maximum	0.022	0.030	129.000	70.000
Mean	-0.022	0.004	42.050	18.606
95% CI Upper	-0.000	0.014	59.684	28.299
95% CI Lower	-0.045	-0.005	24.416	8.912
Standard Dev	0.042	0.019	35.461	19.492

The following results are for:
TANK$ = 4SHALLOW

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	17	18	18	15	3	18	18	18	18
Minimum	750.000	5.670	-93.900	185.000	75.000	0.290	3.295	3.600	21.500
Maximum	2250.000	6.900	79.800	795.000	100.000	6.800	57.627	23.800	1276.000
Mean	1499.882	6.453	-23.406	553.467	88.333	1.551	14.901	16.183	411.856
95% CI Upper	1745.529	6.573	-0.985	658.100	119.591	2.357	21.983	18.929	645.578
95% CI Lower	1254.236	6.333	-45.826	448.833	57.075	0.744	7.818	13.437	178.133
Standard Dev	477.770	0.241	45.085	188.943	12.583	1.622	14.242	5.522	469.994

	CU	ZN	CA	MG
N of cases	16	18	18	18
Minimum	-0.100	-0.020	114.000	10.300
Maximum	0.004	0.030	399.000	136.000
Mean	-0.017	0.001	245.611	80.856
95% CI Upper	-0.000	0.012	290.578	98.788
95% CI Lower	-0.034	-0.009	200.644	62.923
Standard Dev	0.032	0.021	90.424	36.060

The following results are for:
TANK$ = 4DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	19	19	18	16	3	18	18	18	19
Minimum	4450.000	5.920	-105.500	105.000	280.000	0.290	3.314	3.800	2298.000
Maximum	5200.000	6.700	3.700	590.000	1050.000	2.210	22.643	22.500	3177.000
Mean	4873.579	6.427	-64.994	262.687	591.667	0.908	8.943	15.417	2937.632
95% CI Upper	4967.379	6.504	-51.671	321.781	1598.764	1.180	11.607	17.804	3045.213
95% CI Lower	4779.779	6.351	-78.318	203.594	-415.431	0.636	6.280	13.029	2830.050
Standard Dev	194.612	0.158	26.792	110.897	405.411	0.547	5.356	4.801	223.205

	CU	ZN	CA	MG
N of cases	17	19	19	19
Minimum	-0.100	-0.020	370.000	202.000
Maximum	0.031	0.130	778.000	362.000
Mean	-0.016	0.030	502.947	273.526
95% CI Upper	0.002	0.050	542.694	299.123
95% CI Lower	-0.034	0.010	463.201	247.929
Standard Dev	0.035	0.041	82.464	53.107

The following results are for:
TANK$ = 5SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	10	10	8	2	4	8	8	8	7
Minimum	36.000	4.230	37.800	10.000	20.000	1.060	13.503	3.500	6.600
Maximum	710.000	6.830	209.600	15.000	250.000	10.200	96.739	27.700	109.000
Mean	337.550	5.234	140.375	12.500	83.750	5.726	58.532	19.438	57.143
95% CI Upper	530.015	5.781	183.026	44.266	261.105	8.554	84.508	25.383	90.840
95% CI Lower	145.085	4.687	97.724	-19.266	-93.605	2.898	32.557	13.492	23.446
Standard Dev	269.047	0.764	51.017	3.536	111.458	3.383	31.070	7.111	36.435

	CU	ZN	CA	MG
N of cases	9	9	9	9
Minimum	-0.100	0.030	4.100	2.900
Maximum	0.432	0.130	33.700	23.300
Mean	0.028	0.061	17.889	11.644
95% CI Upper	0.152	0.088	27.225	17.783
95% CI Lower	-0.096	0.034	8.552	5.506
Standard Dev	0.162	0.036	12.146	7.985

The following results are for:
TANK$ = 5SHALLOW

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	14	14	13	2	11	13	13	13	14
Minimum	265.000	4.130	-27.400	20.000	135.000	0.080	0.952	11.900	1.600
Maximum	500.000	5.070	124.800	135.000	745.000	2.620	27.579	24.800	263.000
Mean	381.071	4.586	69.023	77.500	314.318	0.721	7.538	18.523	62.557
95% CI Upper	413.881	4.737	96.847	808.107	422.930	1.128	11.785	21.117	119.889
95% CI Lower	348.262	4.435	41.199	-653.107	205.706	0.313	3.292	15.930	5.225
Standard Dev	56.824	0.261	46.044	81.317	161.671	0.674	7.027	4.292	99.297

	CU	ZN	CA	MG
N of cases	14	14	14	14
Minimum	-0.050	0.086	15.400	6.500
Maximum	0.100	0.210	31.200	21.300
Mean	0.035	0.152	21.450	12.357
95% CI Upper	0.057	0.174	24.287	14.799
95% CI Lower	0.012	0.129	18.613	9.915
Standard Dev	0.038	0.039	4.913	4.229

The following results are for:
TANK$ = 5DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	15	16	15	5	11	14	14	15	15
Minimum	4550.000	4.060	-106.100	130.000	215.000	0.380	4.492	11.000	1952.000
Maximum	5017.000	6.430	-11.000	605.000	1415.000	2.750	28.497	24.700	6007.000
Mean	4890.067	6.070	-62.027	298.000	658.409	0.907	9.329	17.740	3261.067
95% CI Upper	4970.819	6.389	-46.922	528.737	880.434	1.258	12.842	20.004	3759.176
95% CI Lower	4809.315	5.751	-77.132	67.263	436.384	0.556	5.816	15.476	2762.958
Standard Dev	145.819	0.599	27.276	185.829	330.489	0.608	6.085	4.088	899.469

	CU	ZN	CA	MG
N of cases	16	16	16	16
Minimum	-0.100	-0.020	373.000	213.000
Maximum	0.019	1.690	1120.000	826.000
Mean	-0.022	0.141	543.562	373.937
95% CI Upper	-0.004	0.363	630.486	485.348
95% CI Lower	-0.040	-0.080	456.639	262.527
Standard Dev	0.035	0.415	163.125	209.079

The following results are for:
TANK$ = 6SHALLOW

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	17	17	16	1	15	16	16	16	17
Minimum	265.000	4.230	-85.600	15.000	72.500	0.000	0.000	9.900	0.600
Maximum	500.000	5.000	115.200	15.000	605.000	2.650	27.895	24.500	310.000
Mean	352.118	4.617	58.581	15.000	272.867	0.709	7.095	16.794	92.471
95% CI Upper	382.509	4.727	91.657	15.000	362.890	1.068	10.690	19.034	150.562
95% CI Lower	321.727	4.507	25.505	15.000	182.844	0.350	3.501	14.554	34.379
Standard Dev	59.109	0.214	62.072	.	162.561	0.674	6.746	4.204	112.984

	CU	ZN	CA	MG
N of cases	16	16	17	17
Minimum	-0.100	0.050	15.700	8.400
Maximum	0.087	0.160	31.500	44.200
Mean	0.013	0.122	21.453	14.606
95% CI Upper	0.042	0.137	23.667	18.766
95% CI Lower	-0.017	0.107	19.239	10.446
Standard Dev	0.055	0.028	4.307	8.091

The following results are for:
TANK$ = 6SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	22	23	16	4	11	15	14	14	16
Minimum	24.000	4.200	-6.600	5.000	10.000	2.000	22.989	4.600	3.900
Maximum	750.000	7.280	213.300	65.000	65.000	9.850	107.065	25.500	133.000
Mean	226.682	5.545	117.844	23.125	23.409	6.012	60.878	16.793	37.987
95% CI Upper	305.845	5.936	153.874	67.823	33.550	7.170	74.848	20.661	60.484
95% CI Lower	147.519	5.154	81.813	-21.573	13.269	4.854	46.908	12.925	15.491
Standard Dev	178.546	0.904	67.617	28.090	15.094	2.090	24.196	6.699	42.218

	CU	ZN	CA	MG
N of cases	15	17	16	16
Minimum	-0.100	-0.020	1.200	0.600
Maximum	0.052	0.100	40.500	30.900
Mean	-0.024	0.038	14.031	9.987
95% CI Upper	0.003	0.052	20.188	14.531
95% CI Lower	-0.050	0.023	7.875	5.444
Standard Dev	0.047	0.028	11.554	8.526

The following results are for:
TANK$ = 6DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	18	18	17	12	6	17	16	16	18
Minimum	4100.000	5.250	-291.100	157.500	200.000	0.130	1.484	10.900	1972.000
Maximum	5000.000	6.580	-9.000	395.000	650.000	2.600	27.880	23.100	3094.000
Mean	4743.167	6.262	-76.529	296.458	456.667	0.912	9.602	17.100	2788.111
95% CI Upper	4877.680	6.413	-46.154	341.081	646.486	1.246	13.549	18.996	2924.634
95% CI Lower	4608.653	6.111	-106.904	251.836	266.847	0.579	5.655	15.204	2651.588
Standard Dev	270.494	0.304	59.078	70.231	180.877	0.649	7.407	3.559	274.535

	CU	ZN	CA	MG
N of cases	17	18	18	18
Minimum	-0.100	-0.002	464.000	202.000
Maximum	0.024	0.960	937.000	275.000
Mean	-0.023	0.089	542.222	247.611
95% CI Upper	-0.005	0.198	593.238	259.023
95% CI Lower	-0.041	-0.020	491.206	236.199
Standard Dev	0.035	0.219	102.589	22.948

The following results are for:
TANK$ = 7SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	33	34	26	10	16	23	22	22	27
Minimum	240.000	3.670	13.400	-5.000	-5.000	4.080	42.784	5.000	92.300
Maximum	5000.000	8.030	275.700	27.500	415.000	10.600	101.099	28.800	3018.000
Mean	1673.394	5.663	134.450	11.950	50.594	7.153	74.462	18.045	1075.270
95% CI Upper	2113.584	6.051	159.618	18.402	105.344	7.872	81.231	20.861	1389.169
95% CI Lower	1233.204	5.275	109.282	5.498	-4.157	6.433	67.694	15.230	761.372
Standard Dev	1241.425	1.112	62.310	9.020	102.748	1.663	15.266	6.350	793.501

	CU	ZN	CA	MG
N of cases	25	27	27	27
Minimum	-0.100	0.045	27.800	3.100
Maximum	0.160	3.920	776.000	232.000
Mean	-0.005	1.148	343.415	52.200
95% CI Upper	0.022	1.568	430.002	72.405
95% CI Lower	-0.031	0.727	256.828	31.995
Standard Dev	0.064	1.063	218.883	51.077

The following results are for:
TANK$ = 7SHALLOW

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	23	23	22	19	4	22	22	22	23
Minimum	3648.000	6.020	-114.700	142.000	65.000	0.230	2.840	4.900	2034.000
Maximum	5000.000	6.740	-25.400	395.000	330.000	2.120	21.856	28.900	3128.000
Mean	4147.783	6.475	-66.795	276.158	177.500	0.790	8.005	16.977	2438.609
95% CI Upper	4340.282	6.549	-56.419	305.660	374.163	1.009	10.284	19.585	2565.719
95% CI Lower	3955.283	6.401	-77.172	246.656	-19.163	0.570	5.726	14.370	2311.498
Standard Dev	445.156	0.171	23.403	61.209	123.592	0.494	5.140	5.881	293.943

	CU	ZN	CA	MG
N of cases	20	23	23	23
Minimum	-0.100	-0.020	249.000	150.000
Maximum	0.033	0.100	608.000	299.000
Mean	-0.022	0.031	524.043	238.261
95% CI Upper	-0.005	0.042	556.498	256.950
95% CI Lower	-0.038	0.020	491.589	219.571
Standard Dev	0.034	0.026	75.051	43.220

The following results are for:
TANK$ = 7DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	20	20	20	16	4	20	20	20	20
Minimum	4450.000	5.230	-124.200	155.000	225.000	0.170	0.065	4.700	2193.000
Maximum	5000.000	6.740	4.200	375.000	460.000	2.250	23.684	25.100	3249.000
Mean	4833.050	6.387	-65.470	262.937	317.500	0.816	8.044	17.440	2843.450
95% CI Upper	4926.494	6.535	-52.117	296.155	477.218	1.036	10.423	19.710	2968.219
95% CI Lower	4739.606	6.239	-78.823	229.720	157.782	0.597	5.665	15.170	2718.681
Standard Dev	199.661	0.316	28.532	62.338	100.374	0.470	5.084	4.850	266.592

	CU	ZN	CA	MG
N of cases	20	20	20	20
Minimum	-0.100	-0.020	413.000	201.000
Maximum	0.063	0.450	931.000	290.000
Mean	-0.018	0.045	532.100	256.250
95% CI Upper	0.001	0.091	579.043	268.564
95% CI Lower	-0.036	-0.002	485.157	243.936
Standard Dev	0.040	0.099	100.302	26.312

The following results are for:
TANK$ = 8SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	27	27	19	17	1	17	17	17	20
Minimum	100.000	5.360	-74.500	25.000	-5.000	2.750	30.220	6.300	6.100
Maximum	1100.000	8.900	169.500	182.500	-5.000	13.200	143.478	28.500	223.000
Mean	390.037	7.262	30.200	95.882	-5.000	7.906	82.238	17.753	62.955
95% CI Upper	509.438	7.567	66.302	123.413	-5.000	9.466	99.077	21.197	91.551
95% CI Lower	270.636	6.956	-5.902	68.352	-5.000	6.346	65.398	14.309	34.359
Standard Dev	301.832	0.772	74.902	53.546	.	3.034	32.752	6.699	61.101

	CU	ZN	CA	MG
N of cases	18	20	20	20
Minimum	-0.100	-0.020	11.600	4.000
Maximum	0.035	0.030	87.400	49.100
Mean	-0.029	0.008	45.380	20.710
95% CI Upper	-0.009	0.016	57.365	27.137
95% CI Lower	-0.048	-0.001	33.395	14.283
Standard Dev	0.040	0.018	25.609	13.733

The following results are for:
TANK$ = 8SHALLOW

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	18	17	18	9	9	18	18	18	18
Minimum	725.000	6.030	-88.600	135.000	30.000	0.080	0.941	5.500	25.600
Maximum	3150.000	6.940	108.200	835.000	115.000	1.960	22.477	25.100	1934.000
Mean	1947.778	6.398	-41.561	550.000	60.000	0.868	8.917	17.511	802.461
95% CI Upper	2394.691	6.526	-18.931	752.369	85.494	1.124	11.693	20.349	1224.000
95% CI Lower	1500.865	6.271	-64.192	347.631	34.506	0.612	6.141	14.674	380.922
Standard Dev	898.700	0.248	45.508	263.273	33.166	0.515	5.582	5.706	847.675

	CU	ZN	CA	MG
N of cases	16	18	18	18
Minimum	-0.100	-0.020	113.000	36.400
Maximum	0.013	0.051	616.000	200.000
Mean	-0.020	0.013	346.722	116.500
95% CI Upper	-0.002	0.024	436.610	147.703
95% CI Lower	-0.037	0.003	256.834	85.297
Standard Dev	0.033	0.021	180.756	62.747

The following results are for:
TANK$ = 8DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	18	19	19	14	4	19	19	19	19
Minimum	3750.000	5.220	-118.500	155.000	180.000	0.250	3.027	5.400	2082.000
Maximum	5046.000	6.640	-23.700	630.000	630.000	2.450	25.789	25.000	3351.000
Mean	4710.333	6.307	-60.958	281.607	354.375	0.914	9.201	16.495	2802.842
95% CI Upper	4877.473	6.480	-49.613	348.116	667.614	1.207	12.215	18.864	2956.492
95% CI Lower	4543.194	6.134	-72.302	215.098	41.136	0.621	6.187	14.125	2649.192
Standard Dev	336.102	0.359	23.537	115.191	196.854	0.608	6.254	4.916	318.786

	CU	ZN	CA	MG
N of cases	17	19	19	19
Minimum	-0.100	-0.020	447.000	216.000
Maximum	0.034	0.520	1020.000	268.000
Mean	-0.015	0.062	541.211	239.684
95% CI Upper	0.003	0.118	599.679	246.873
95% CI Lower	-0.034	0.007	482.742	232.496
Standard Dev	0.036	0.115	121.307	14.915

The following results are for:
TANK$ = 9SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	35	35	27	24	2	25	20	24	28
Minimum	33.000	5.490	-41.800	5.000	1.500	1.950	33.537	7.600	6.200
Maximum	1350.000	8.420	174.600	170.000	5.000	9.300	100.000	29.400	587.000
Mean	841.571	7.143	41.622	76.458	3.250	6.592	67.921	18.487	327.357
95% CI Upper	939.893	7.366	66.348	96.163	25.486	7.362	76.079	20.806	391.616
95% CI Lower	743.250	6.919	16.896	56.753	-18.986	5.821	59.764	16.169	263.098
Standard Dev	286.224	0.651	62.505	46.666	2.475	1.866	17.430	5.491	165.719

	CU	ZN	CA	MG
N of cases	26	28	28	28
Minimum	-0.100	0.004	2.600	0.400
Maximum	0.008	0.400	242.000	49.100
Mean	-0.033	0.099	126.229	32.432
95% CI Upper	-0.020	0.130	149.499	38.063
95% CI Lower	-0.046	0.068	102.958	26.801
Standard Dev	0.032	0.080	60.012	14.521

The following results are for:
TANK$ = 9INTERFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	19	19	12	12	2	12	7	11	12
Minimum	800.000	5.120	-14.900	25.000	-5.000	2.550	29.076	8.100	341.000
Maximum	3550.000	8.190	110.800	240.000	5.000	8.200	72.826	25.600	1638.000
Mean	1444.474	7.068	28.767	101.667	0.000	5.786	59.377	17.718	690.583
95% CI Upper	1870.839	7.380	56.657	146.478	63.531	6.772	73.186	21.697	990.738
95% CI Lower	1018.108	6.756	0.876	56.855	-63.531	4.800	45.568	13.740	390.428
Standard Dev	884.604	0.647	43.896	70.528	7.071	1.552	14.931	5.922	472.410

	CU	ZN	CA	MG
N of cases	10	12	11	12
Minimum	-0.050	0.025	113.000	27.000
Maximum	0.006	0.900	622.000	136.000
Mean	-0.023	0.194	247.636	57.550
95% CI Upper	-0.003	0.369	370.574	82.594
95% CI Lower	-0.043	0.018	124.699	32.506
Standard Dev	0.028	0.275	182.995	39.416

The following results are for:
TANK$ = 9DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	23	22	22	16	7	22	21	21	23
Minimum	4000.000	5.890	-110.100	105.000	205.000	0.350	3.950	7.400	2390.000
Maximum	5000.000	6.760	10.600	280.000	830.000	3.100	32.632	28.700	3364.000
Mean	4766.130	6.389	-53.527	209.500	470.714	0.895	8.969	17.495	2885.087
95% CI Upper	4883.051	6.466	-40.381	237.680	684.522	1.156	11.774	19.804	2996.469
95% CI Lower	4649.210	6.312	-66.673	181.320	256.906	0.633	6.164	15.186	2773.705
Standard Dev	270.378	0.174	29.649	52.884	231.182	0.591	6.162	5.073	257.571

	CU	ZN	CA	MG
N of cases	21	23	23	23
Minimum	-0.100	-0.020	421.000	222.000
Maximum	0.040	1.180	1030.000	272.000
Mean	-0.021	0.086	533.043	248.000
95% CI Upper	-0.005	0.190	582.444	254.772
95% CI Lower	-0.038	-0.018	483.643	241.228
Standard Dev	0.036	0.240	114.239	15.661

The following results are for:
TANK$ = 10SURFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	35	35	27	25	1	25	24	24	28
Minimum	75.000	5.500	-90.600	10.000	-8.300	2.320	26.364	7.400	6.300
Maximum	1000.000	10.660	166.000	240.000	-8.300	14.800	155.789	28.800	218.000
Mean	495.229	8.887	3.856	95.200	-8.300	9.453	100.003	19.146	124.475
95% CI Upper	570.790	9.291	33.768	122.866	-8.300	10.798	114.608	21.485	150.427
95% CI Lower	419.668	8.482	-26.057	67.534	-8.300	8.108	85.398	16.806	98.523
Standard Dev	219.966	1.177	75.615	67.023	.	3.258	34.587	5.540	66.927

	CU	ZN	CA	MG
N of cases	26	28	28	28
Minimum	-0.100	-0.100	6.100	1.000
Maximum	0.011	0.036	102.000	45.900
Mean	-0.031	-0.003	47.021	25.721
95% CI Upper	-0.017	0.007	57.597	31.365
95% CI Lower	-0.045	-0.014	36.446	20.078
Standard Dev	0.035	0.027	27.273	14.554

The following results are for:
TANK$ = 10INTERFACE

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	19	19	12	12	2	12	11	11	12
Minimum	500.000	5.610	-299.900	55.000	-8.300	0.470	5.293	9.600	127.000
Maximum	2150.000	8.970	49.200	665.000	10.000	14.200	126.786	24.500	542.000
Mean	1262.368	7.627	-45.367	355.833	0.850	5.053	48.853	17.309	321.583
95% CI Upper	1514.518	7.967	18.167	472.557	117.112	7.712	75.719	20.733	411.283
95% CI Lower	1010.219	7.288	-108.901	239.110	-115.412	2.395	21.988	13.885	231.884
Standard Dev	523.149	0.705	99.995	183.710	12.940	4.184	39.990	5.096	141.177

	CU	ZN	CA	MG
N of cases	11	12	12	11
Minimum	-0.050	-0.020	33.500	26.4
Maximum	0.008	0.033	272.000	104
Mean	-0.020	0.009	163.758	65
95% CI Upper	-0.001	0.020	216.453	83.9
95% CI Lower	-0.039	-0.001	111.063	46.9
Standard Dev	0.028	0.017	82.936	27.5

The following results are for:
TANK$ = 10DEEP

	SC	PH	EH	ALK	ACY	DO	DOSAT	TEMP	SO4
N of cases	23	23	22	16	7	22	21	21	23
Minimum	4000.000	4.620	-194.900	50.000	225.000	0.090	1.004	7.200	1927.000
Maximum	5000.000	6.890	11.100	335.000	780.000	3.150	33.158	26.500	3306.000
Mean	4810.435	6.323	-72.005	190.937	492.143	0.955	9.551	17.148	2928.478
95% CI Upper	4916.774	6.526	-53.063	226.897	689.651	1.239	12.601	19.303	3063.483
95% CI Lower	4704.095	6.120	-90.946	154.978	294.634	0.670	6.500	14.993	2793.473
Standard Dev	245.910	0.469	42.721	67.484	213.558	0.641	6.701	4.734	312.199

	CU	ZN	CA	MG
N of cases	21	22	22	22
Minimum	-0.100	-0.020	410.000	204.000
Maximum	0.046	1.250	1080.000	950.000
Mean	-0.020	0.089	537.955	278.318
95% CI Upper	-0.003	0.204	595.234	345.419
95% CI Lower	-0.037	-0.027	480.675	211.217
Standard Dev	0.038	0.260	129.189	151.341

The following results are for:
TANK$ = 11CONTROL

	SC	PH	EH	ALK	ACY	SO4
N of cases	9	9	8	0	9	9
Minimum	5000.000	2.690	257.700	.	6960.000	12639.000
Maximum	41000.000	3.400	394.600	.	29400.000	65290.000
Mean	13938.889	3.096	320.587	.	17348.889	36384.333
95% CI Upper	22376.831	3.256	355.841	0.000	23059.881	49024.944
95% CI Lower	5500.947	2.935	285.334	0.000	11637.897	23743.723
Standard Dev	10977.357	0.209	42.168	.	7429.725	16444.824

	CU	ZN	CA	MG
N of cases	8	9	9	9
Minimum	0.005	2420.000	329.000	491.000
Maximum	1.550	10400.000	477.000	6400.000
Mean	0.244	6395.556	427.556	2483.778
95% CI Upper	0.688	8489.714	464.283	4155.912
95% CI Lower	-0.200	4301.397	390.828	811.644
Standard Dev	0.531	2724.400	47.781	2175.366

The following results are for:
TANK$ = 12CONTROL

	SC	PH	EH	ALK	ACY	SO4
N of cases	17	16	15	0	16	15
Minimum	5000.000	2.520	222.600	.	9020.000	12431.000
Maximum	45000.000	4.430	452.700	.	23360.000	67100.000
Mean	12191.176	3.191	332.300	.	17160.625	37734.733
95% CI Upper	18070.923	3.411	364.932	0.000	19564.837	46368.893
95% CI Lower	6311.430	2.970	299.668	0.000	14756.413	29100.573
Standard Dev	11435.802	0.414	58.926	.	4511.881	15591.276

	CU	ZN	CA	MG
N of cases	15	16	16	16
Minimum	0.008	4720.000	141.000	508.000
Maximum	0.600	8990.000	528.000	6090.000
Mean	0.192	7427.500	396.437	2940.875
95% CI Upper	0.289	8108.827	443.223	3884.000
95% CI Lower	0.096	6746.173	349.652	1997.750
Standard Dev	0.174	1278.616	87.800	1769.923

Table A4.14. Specific conductance and pH profile survey conducted on 10/4/97.

Depth(in.)	Parameter	Water cover		Water cover, submerged aquatics	
		Tank 1	Tank 9	Tank 3	Tank 10
6"	pH	7.80	7.61	9.03	9.61
	S.C.	823	929	755	708
12"	pH	7.85	7.73	8.91	9.74
	S.C.	844	925	779	708
18"	pH	7.88	7.75	8.71	9.55
	S.C.	866	933	787	713
Bottom	pH	7.88	7.77	7.83	9.61
	S.C.	867	934	823	716

Note: Bottom measurements taken for Tanks 1 and 3 were at 22 inches, and for Tanks 9 and 10 at 23 inches. All bottom measurements were taken approximately 1 inch above the substrate.

Table A4.16. Specific conductance, temperature, and pH profile survey conducted on 5/6/99.

Depth	Parameter	Water cover		Submerged Aquatics	
		Tank 1	Tank 9	Tank 3	Tank 10
Surface	pH	7.07	5.49	5.04	5.50
	S.C./temp.(C)	61/14.5	220/14.5	147/14.5	220/14
6"	pH	6.52	5.70	4.93	5.63
	S.C./temp.(C)	126/13.5	163/13.5	155/14	223/14
12"	pH	6.38	5.63	5.14	5.84
	S.C./temp.(C)	127/13	165/13	159/13	216/13
18"	pH	6.22	5.62	5.23	5.92
	S.C./temp.(C)	129/12.5	167/12.5	120/12	221/12
24"	pH	6.03	5.57	5.33	5.80
	S.C./temp.(C)	143/12	247/12	202/12	780/12
Bottom	pH	5.30	5.12	5.32	5.61
	S.C./temp.(C)	2470/12	2470/12	1250/11.5	1560/12

Note: Bottom measurements were taken approximately 3 to 4 inches above the substrate.

Table A4.15. Specific conductance, dissolved oxygen, and pH profile conducted on 6/25/98.

Depth(in.)	Parameter	Water cover		Water cover, submerged aquatics	
		Tank 1	Tank 9	Tank 3	Tank 10
6"	pH	5.65	8.26	9.18	9.66
	S.C.	780	800	300	250
	D.O.	8.35	8.20	10.60	11.30
12"	pH	5.97	8.19	9.60	9.91
	S.C.	780	800	300	250
	D.O.	8.35	7.80	12.90	11.30
18"	pH	6.09	8.17	9.83	8.68
	S.C.	750	800	300	375
	D.O.	8.15	8.20	11.90	5.25
Bottom	pH	6.18	8.08	8.05	7.38
	S.C.	780	850	1100	1200
	D.O.	7.10	7.90	3.70	0.80

Notes: Measurements for Tanks 1 and 9 were taken in the center of the tank. Bottom measurements were taken 26 inches below the surface and approximately 1 to 2 inches above the substrate.

Measurements for Tanks 3 and 10 were taken at the edge of the tank due to the mat of aquatic vegetation. Bottom measurements were taken 24 inches below the surface and approximately 3 to 4 inches above the substrate.

The pH readings in Tank 1 appear to be low compared to the readings when the tanks were sampled on the previous day.

Figure A4.1. pH, Sulfate, and Zinc vs. time for tanks 1 and 9 (surface).

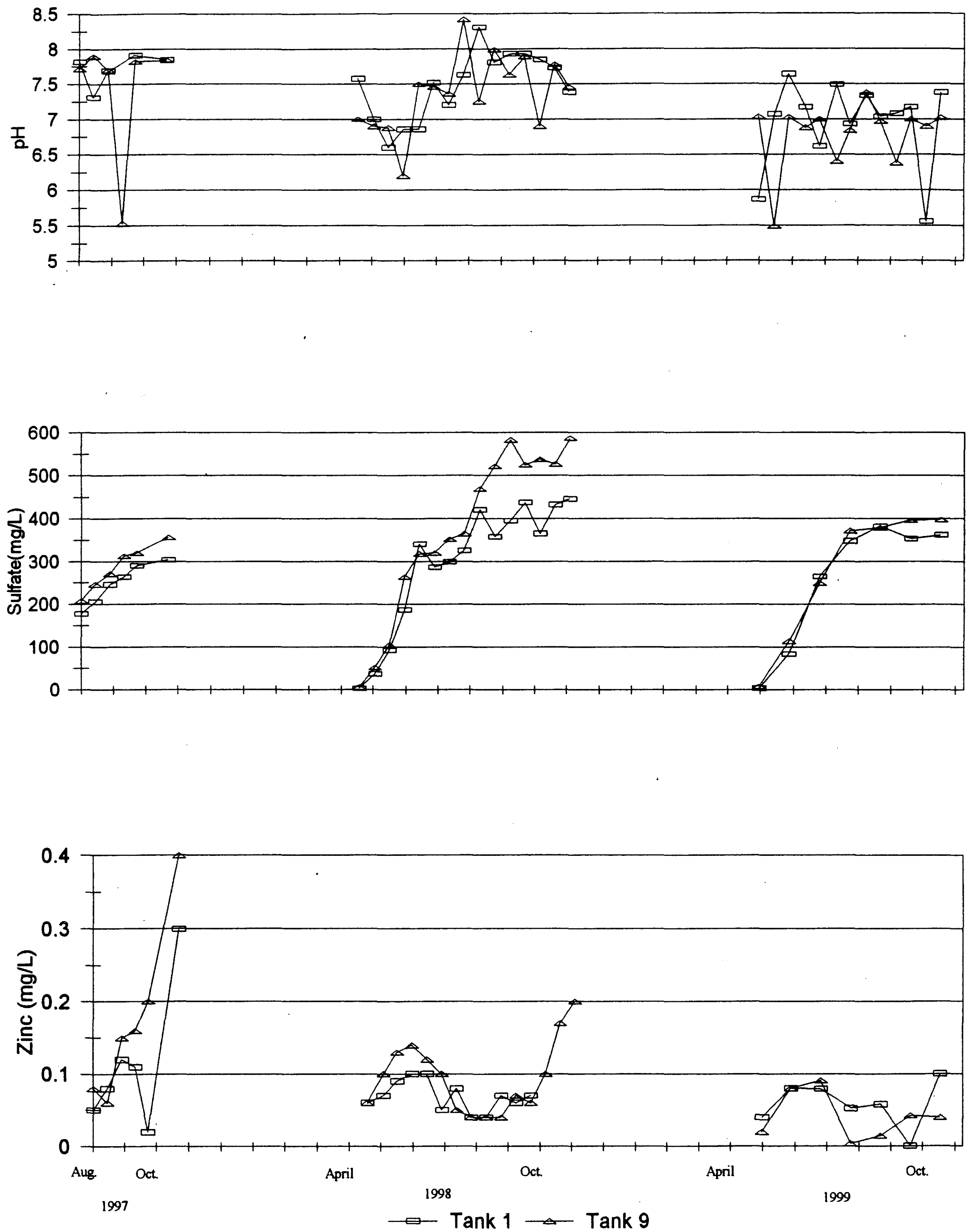


Figure A4.2. pH, Sulfate, and Zinc vs. time for tanks 1 and 9 (interface).

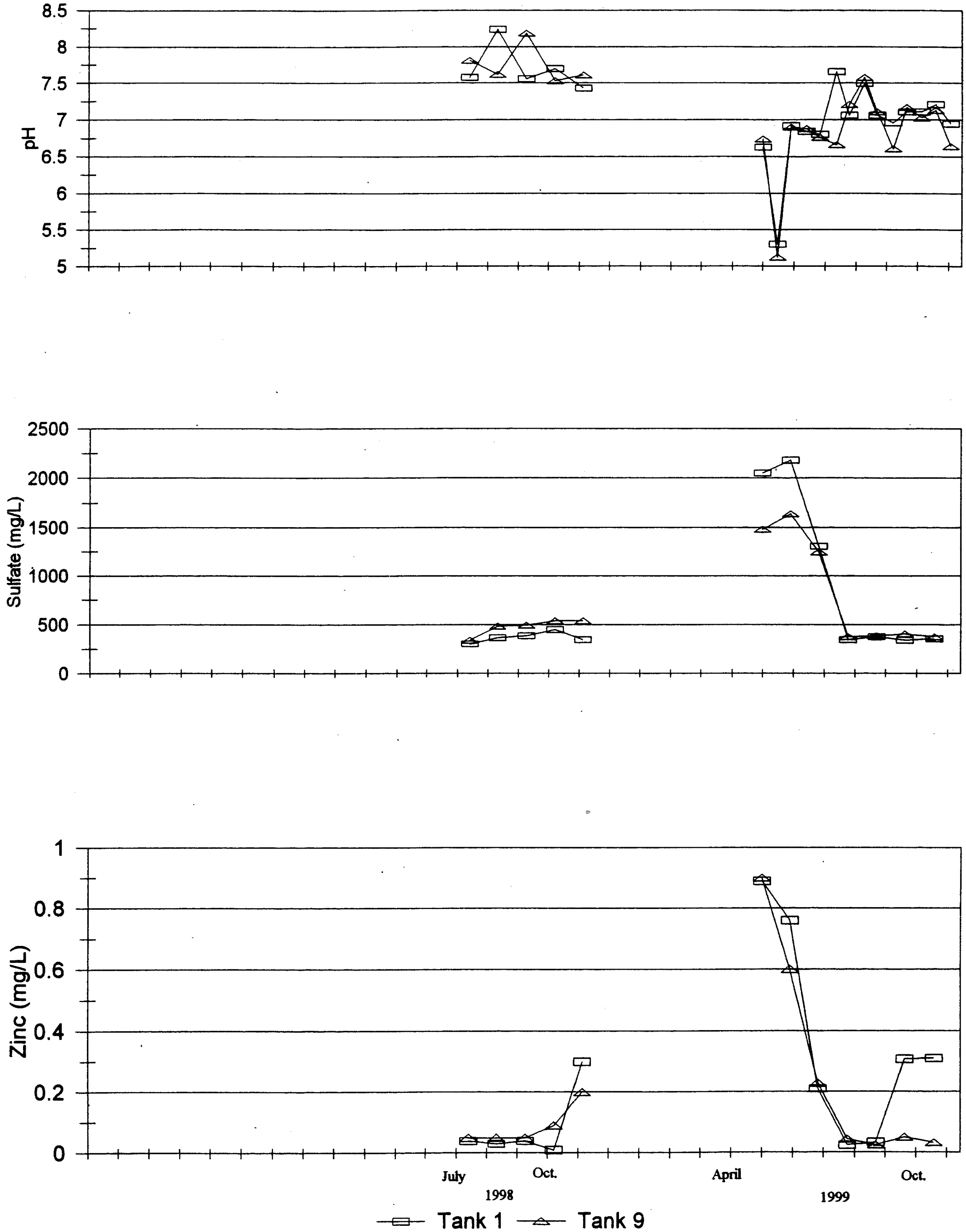


Figure A4.3. pH, Sulfate, and Zinc vs. time for tanks 1 and 9 (deep).

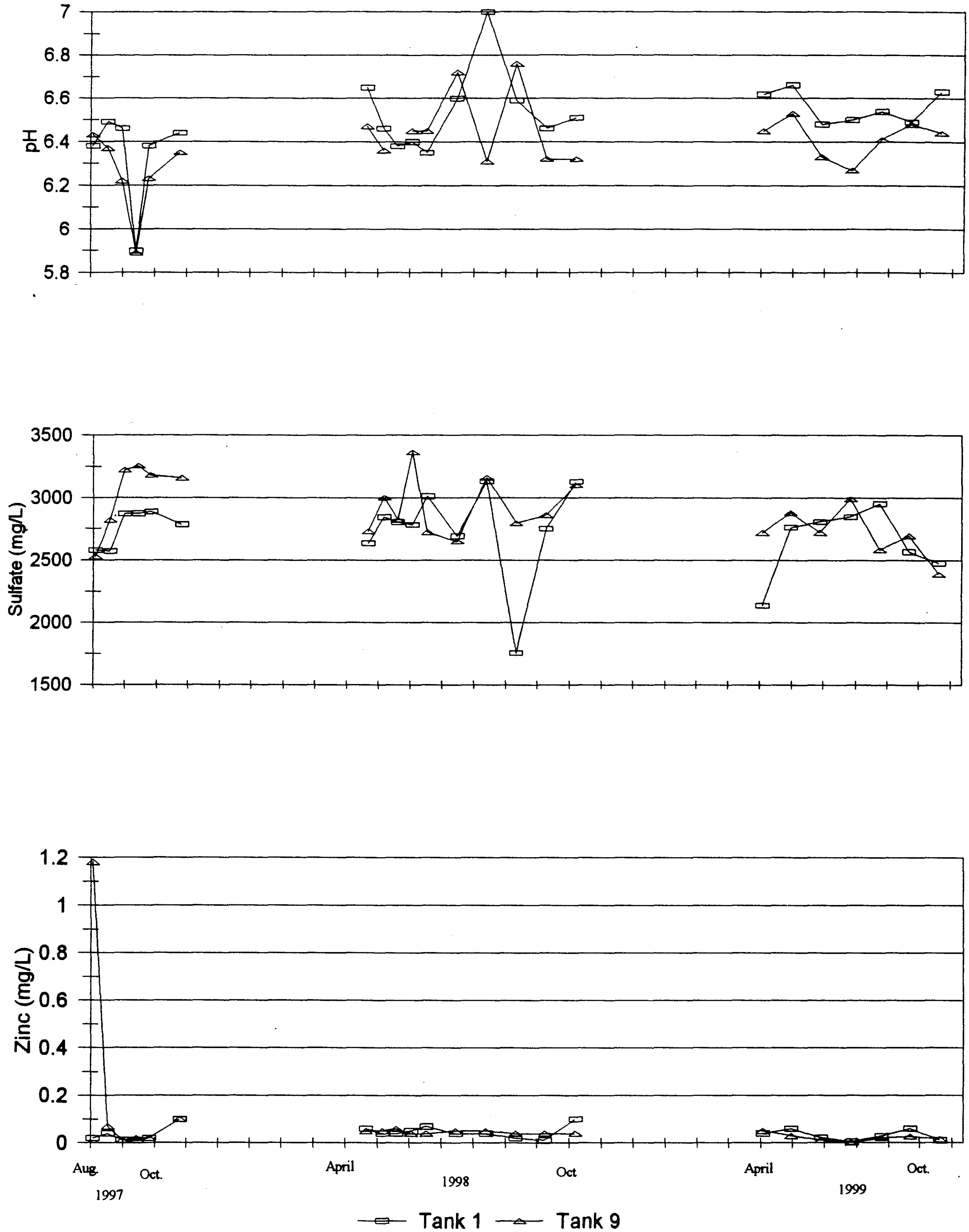


Figure A4.4. pH, Sulfate, and Zinc vs. time for tanks 2 and 7(surface).

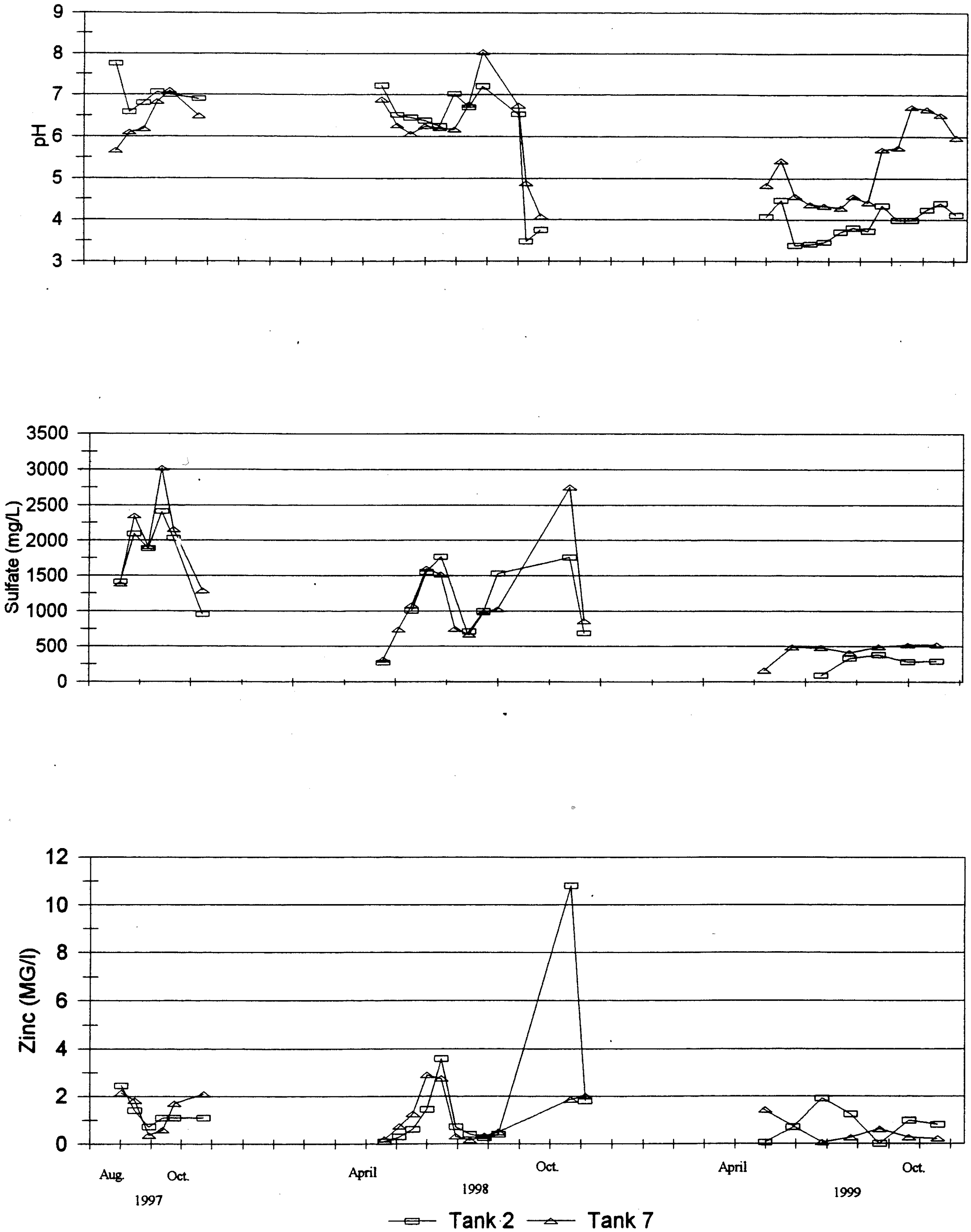


Figure A4.4. pH, sulfate and zinc vs. time for tanks 2 and 7 (surface).

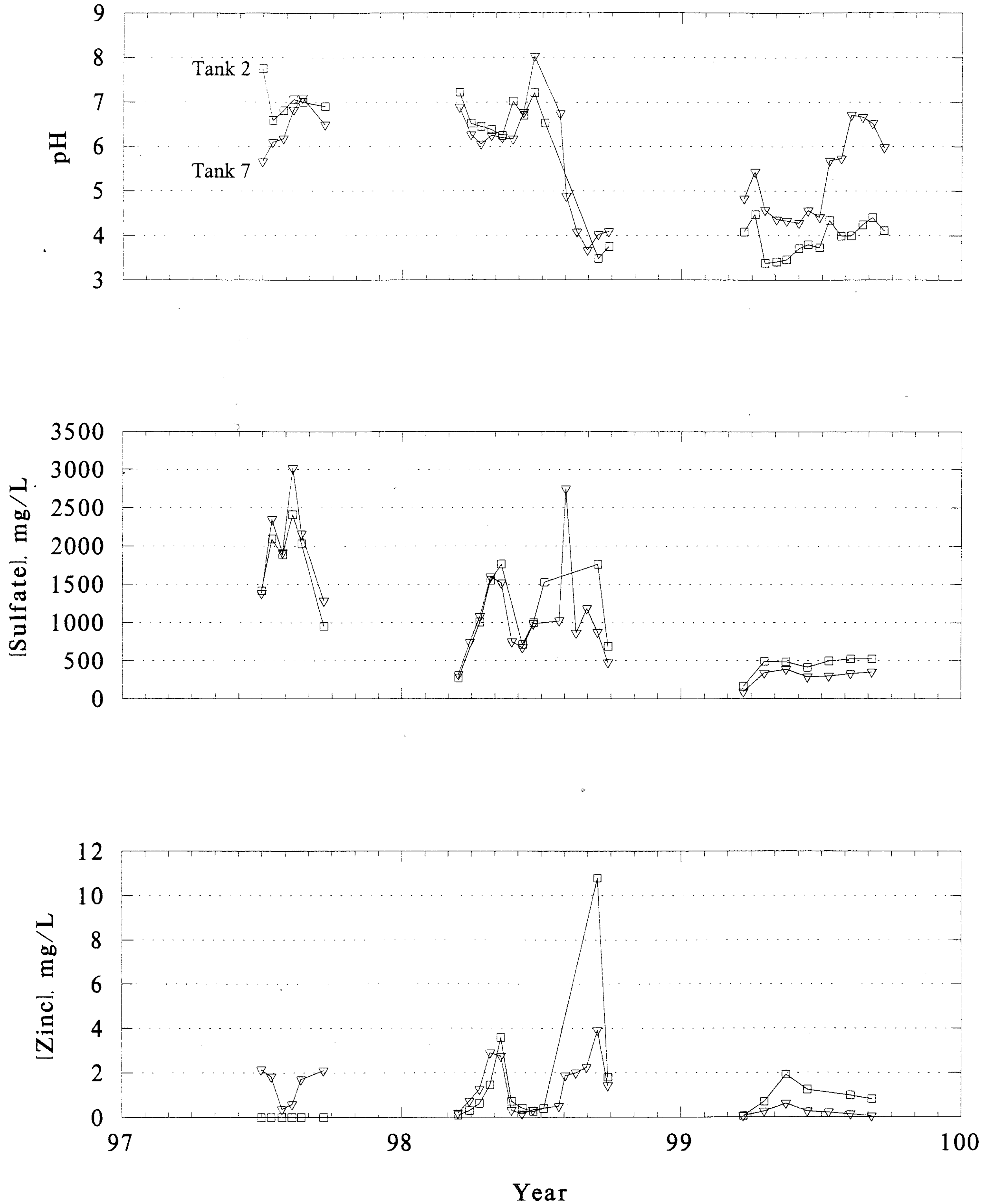


Figure A4.5. pH, Sulfate, and Zinc vs. time for tanks 2 and 7(shallow).

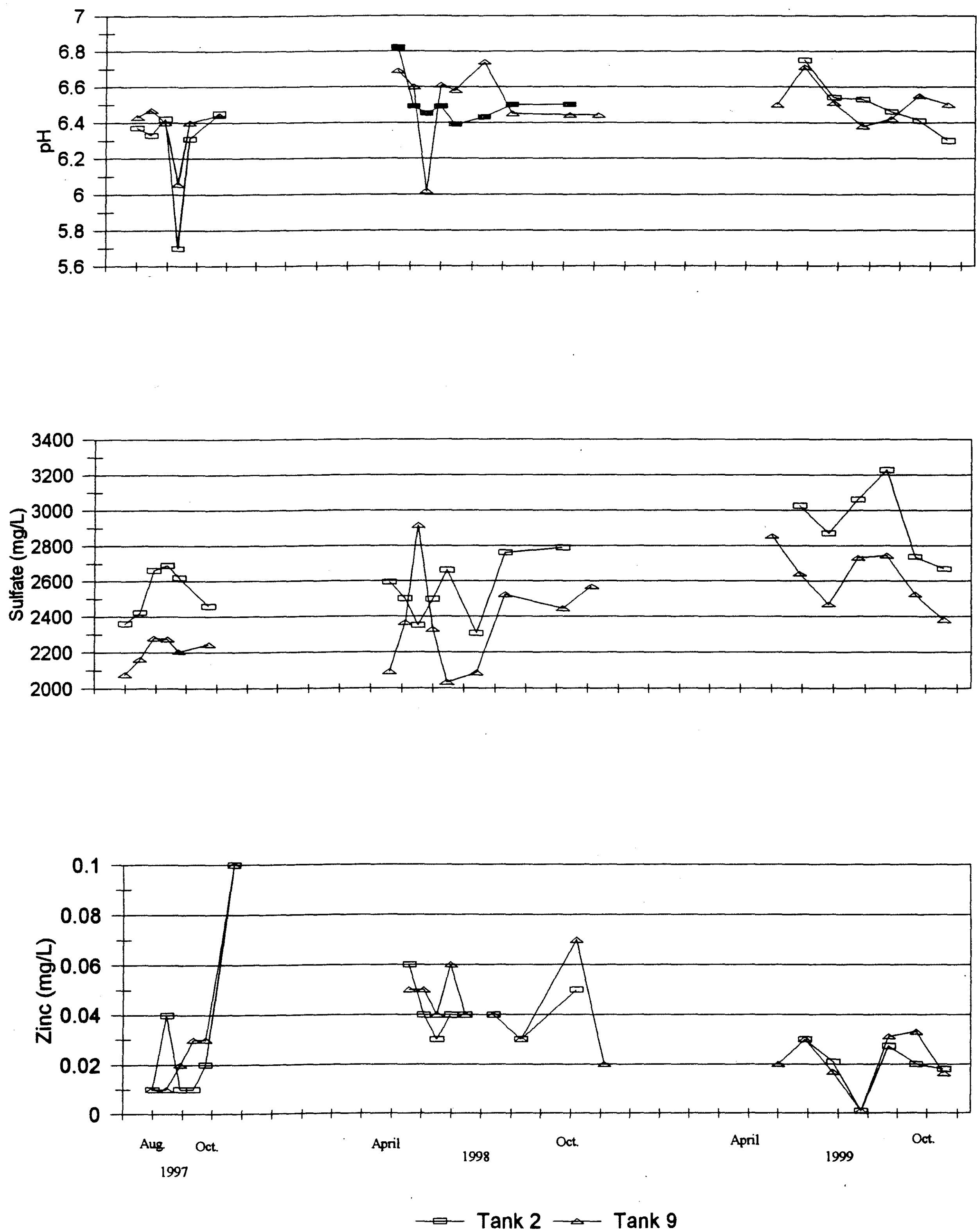


Figure A4.6. pH, Sulfate, and Zinc vs. time for tanks 2 and 7 (deep).

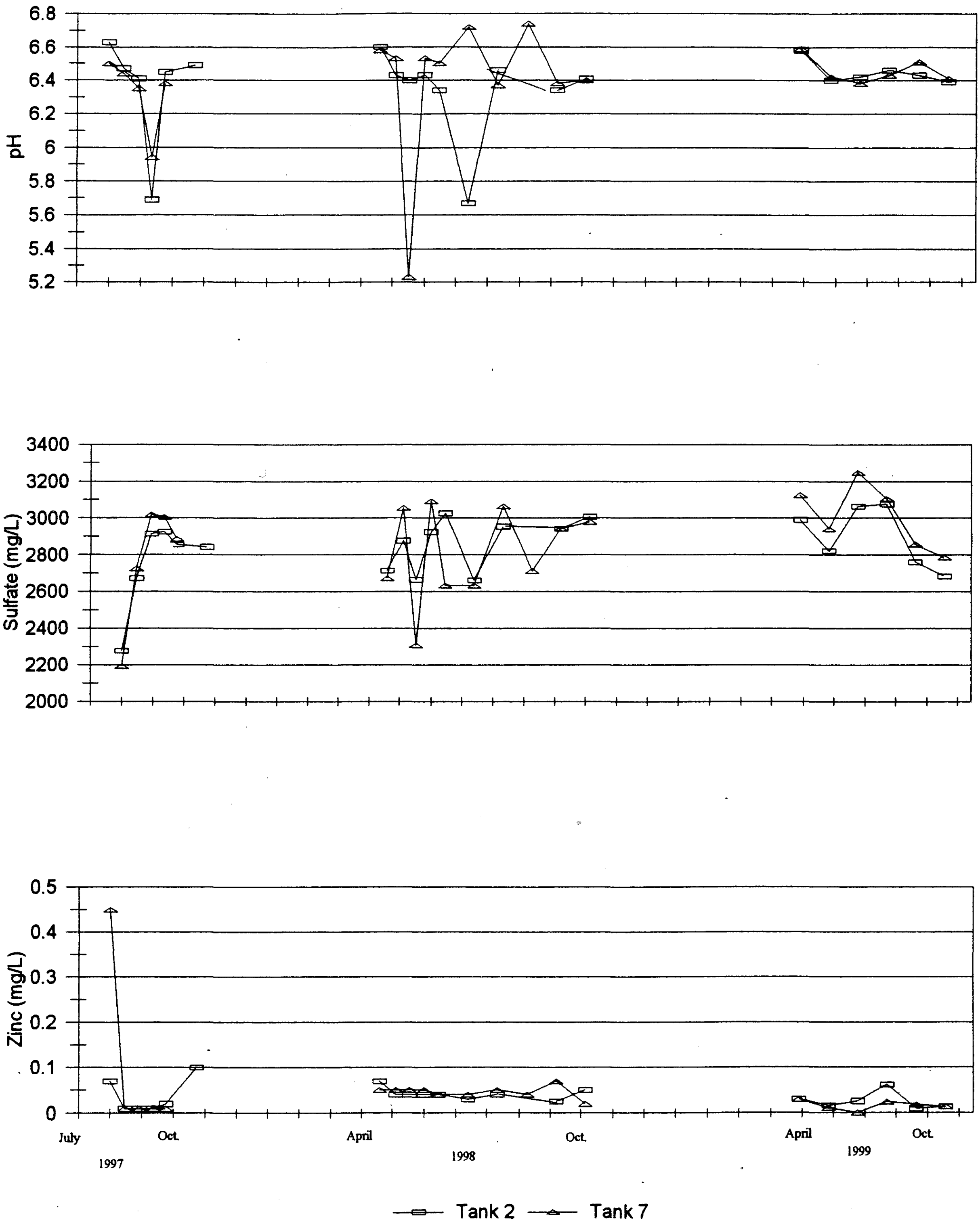


Figure A4.7. pH, Sulfate, and Zinc vs. time for tanks 3 and 10(surface).

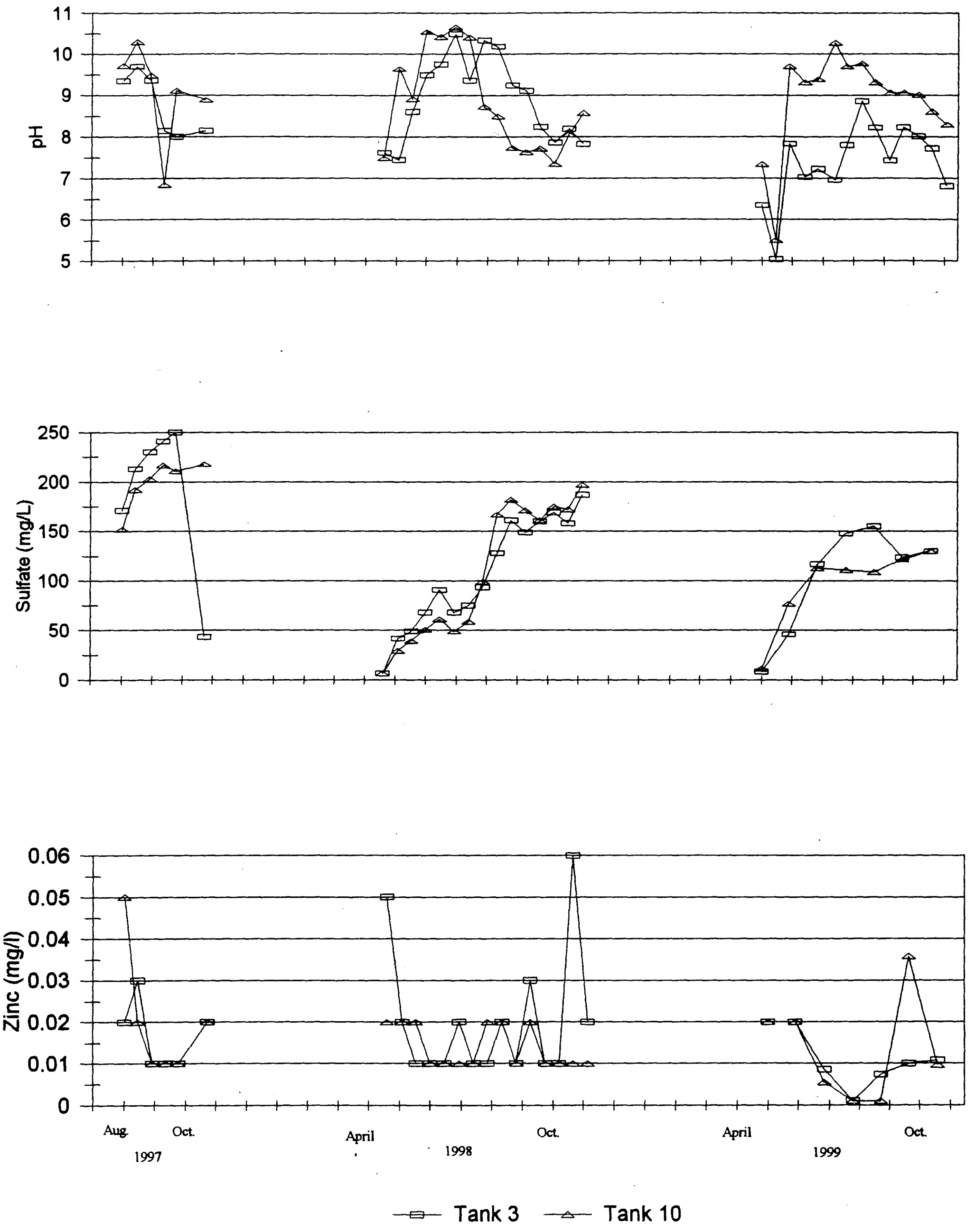


Figure A4.8. pH, Sulfate, and Zinc vs. time for tanks 3 and 10(interface).

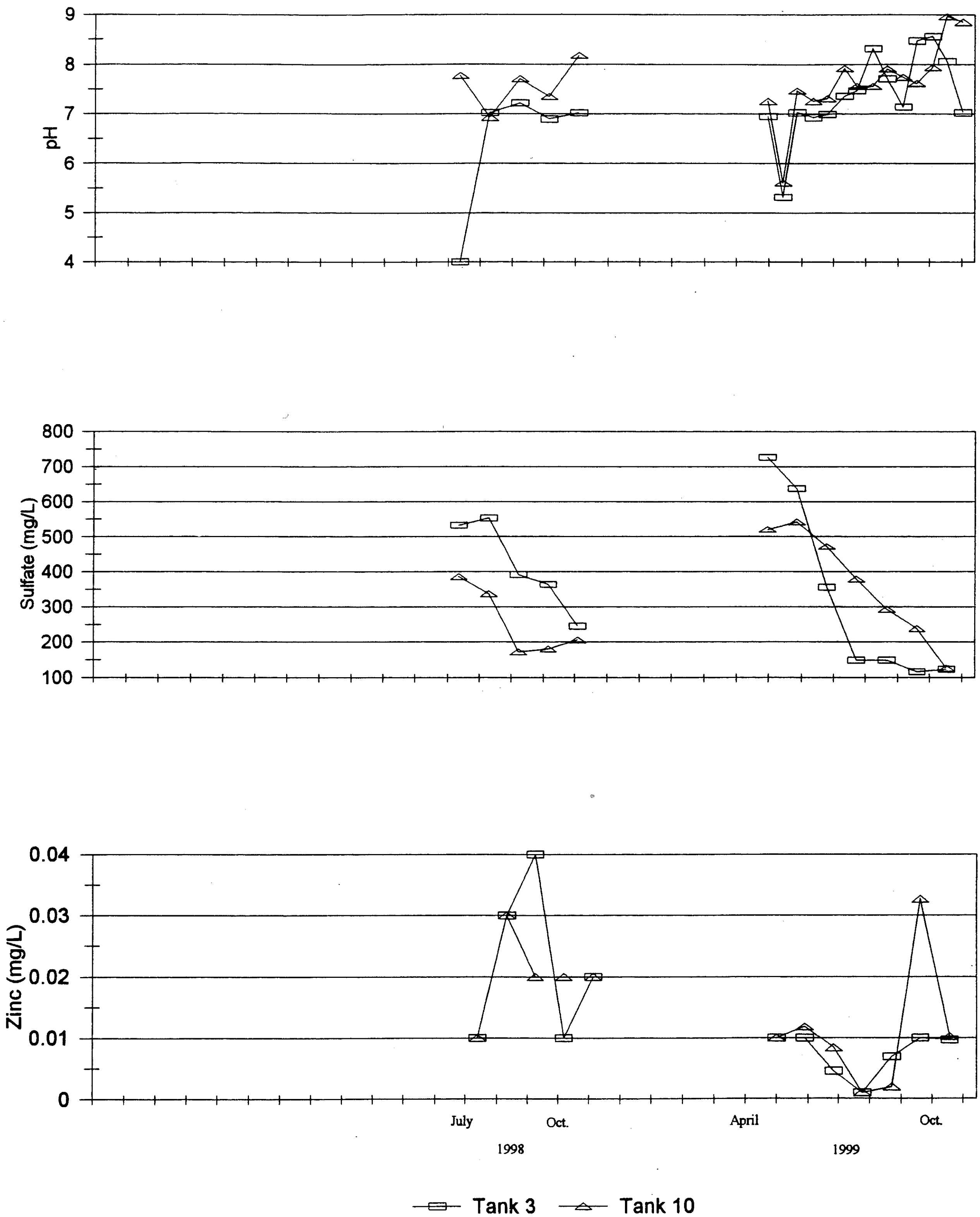


Figure A4.9. pH, Sulfate, and Zinc vs. time for tanks 3 and 10 (deep).

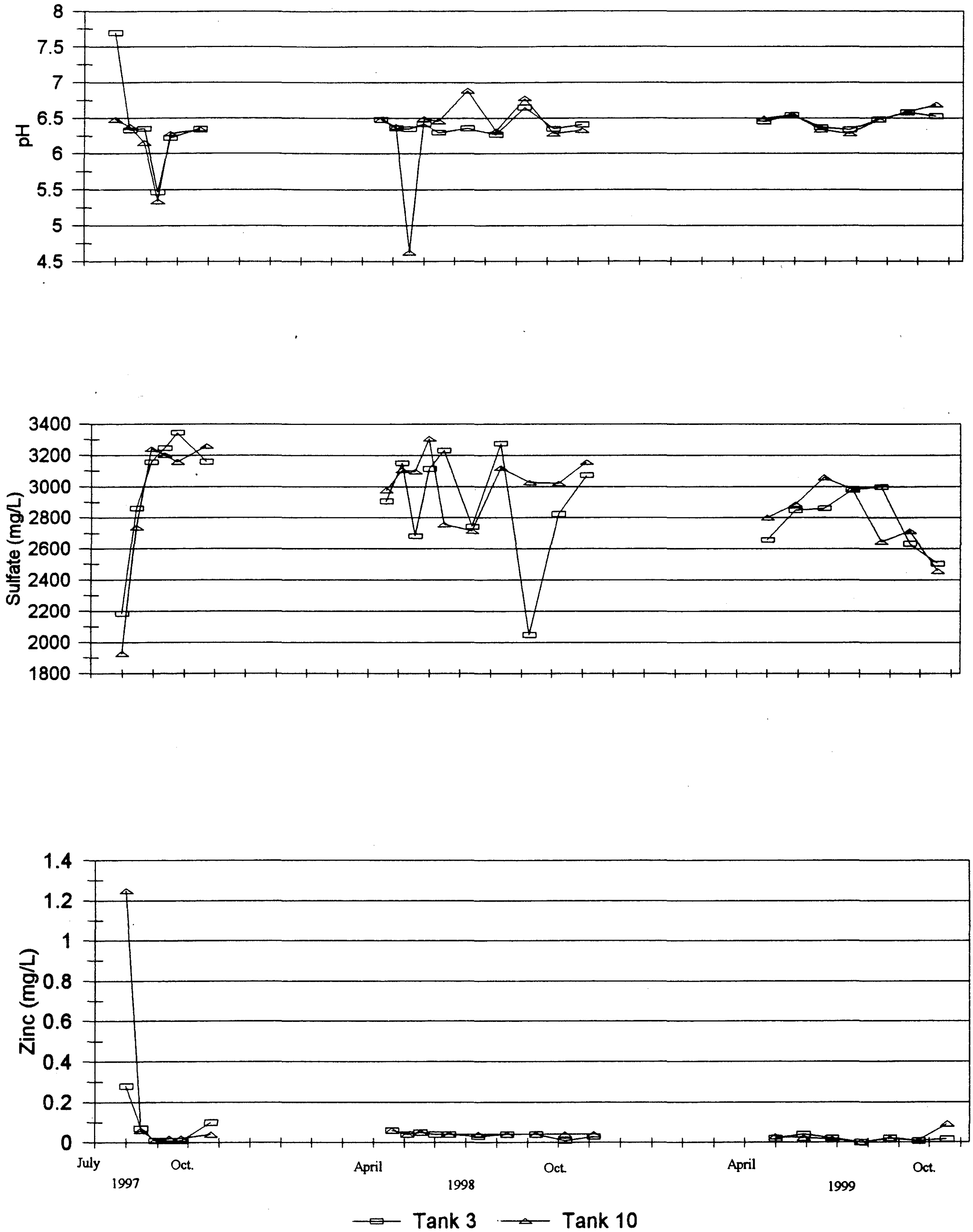


Figure A4.10. pH, Sulfate, and Zinc vs. time for tanks 4 and 8(surface).

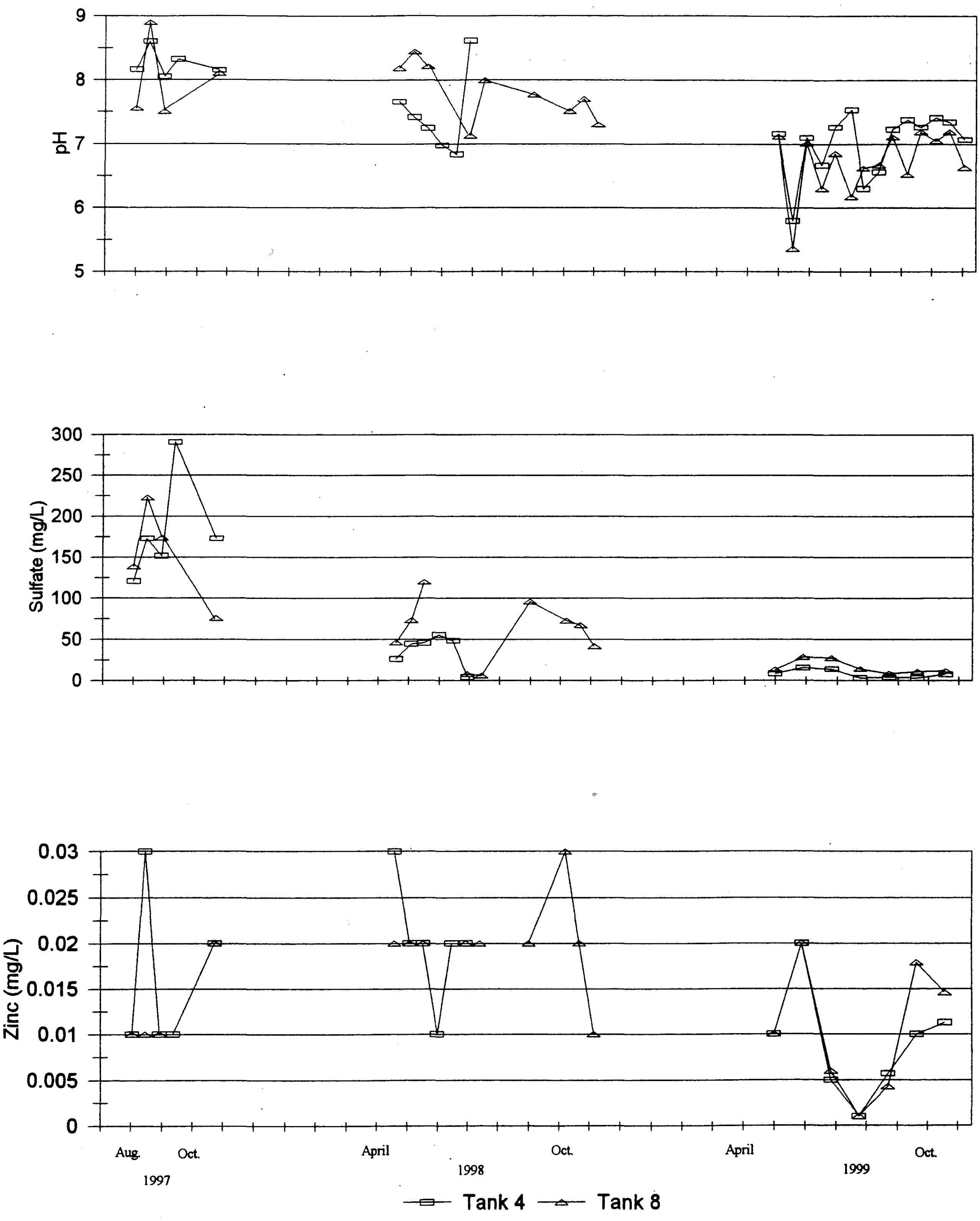


Figure A4.11. pH, Sulfate, and Zinc vs. time for tanks 4 and 8(shallow).

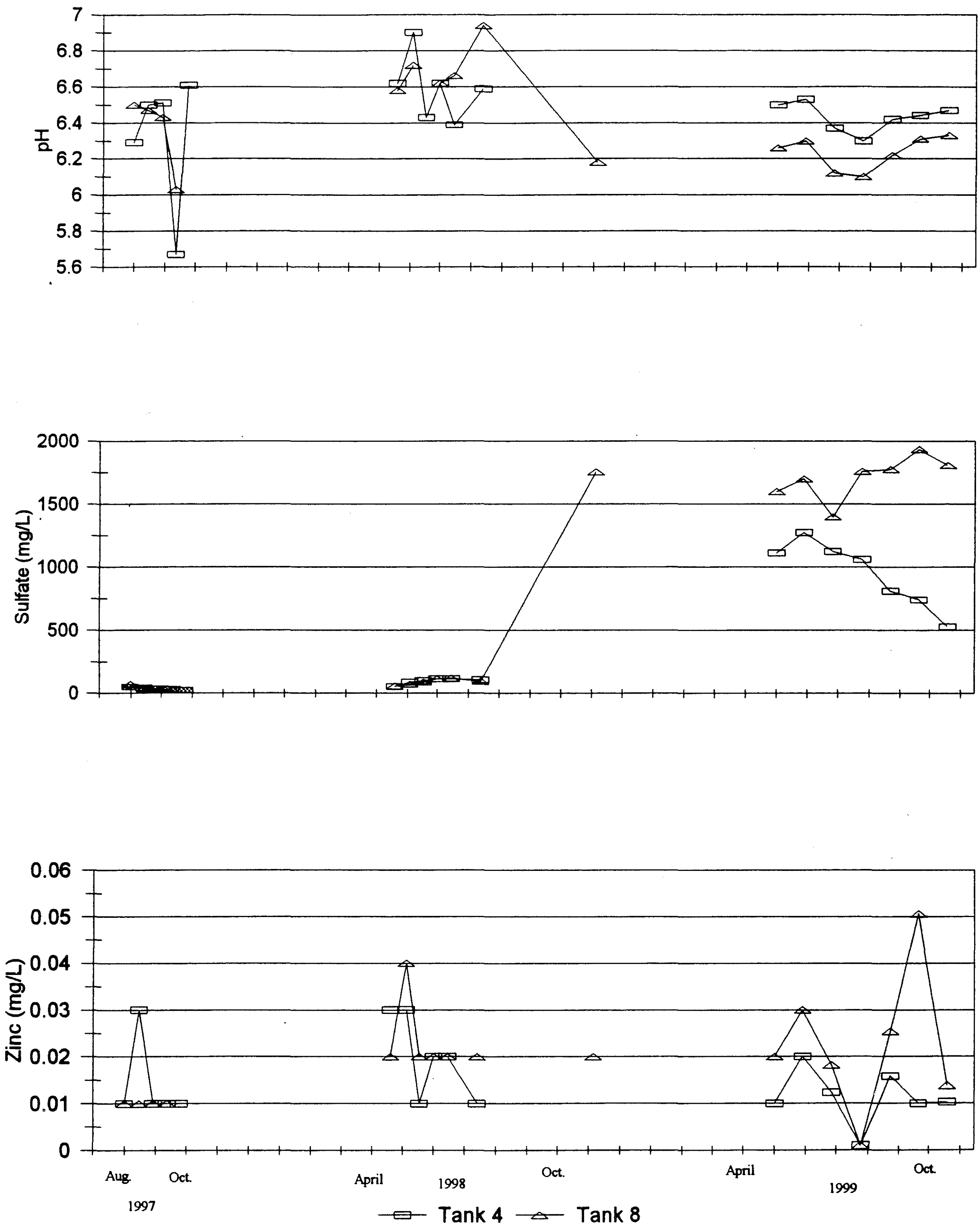


Figure A4.12. pH, Sulfate, and Zinc vs. time for tanks 4 and 8 (deep).

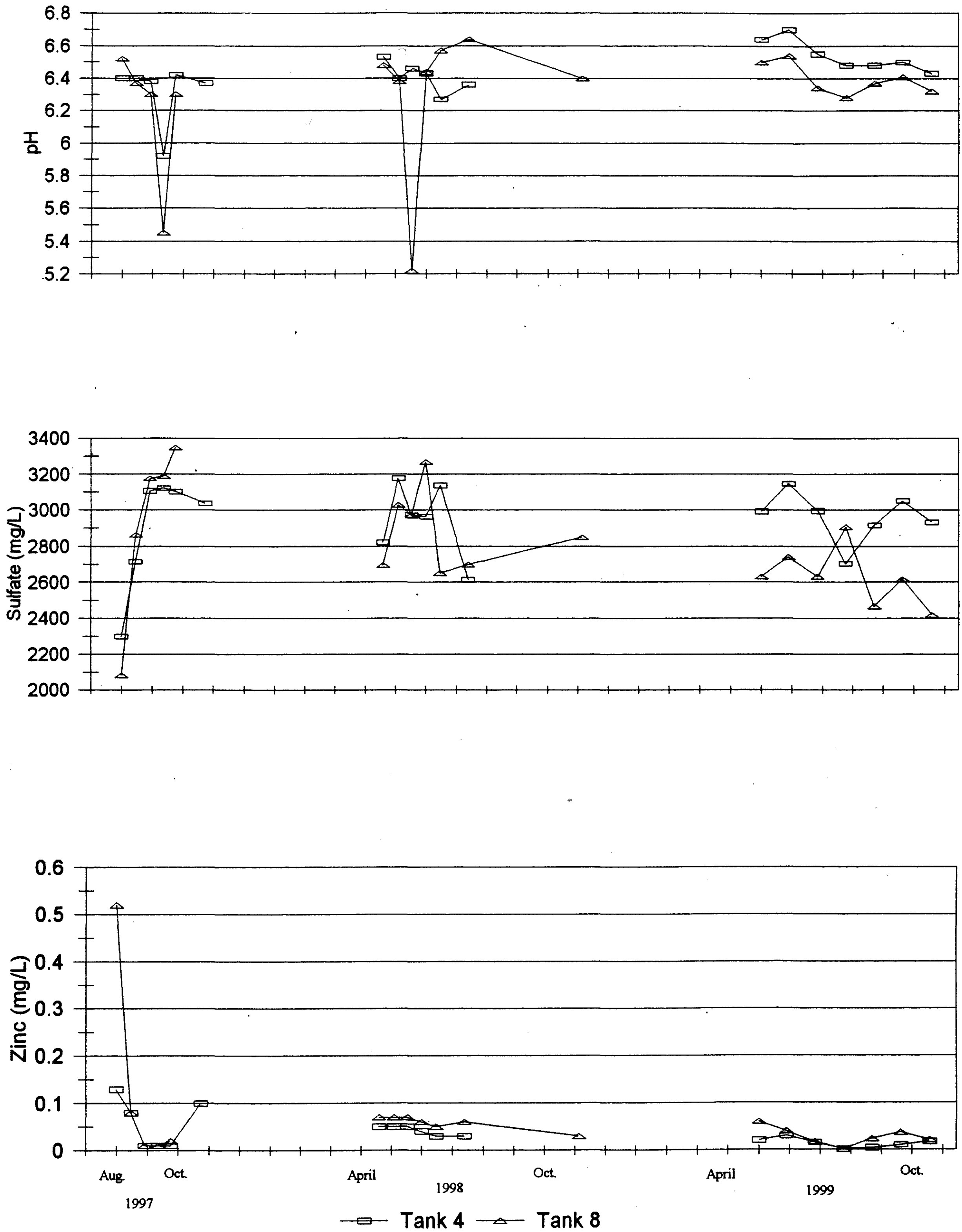


Figure A4.13. pH, Sulfate, and Zinc vs. time for tanks 5 and 6(surface).

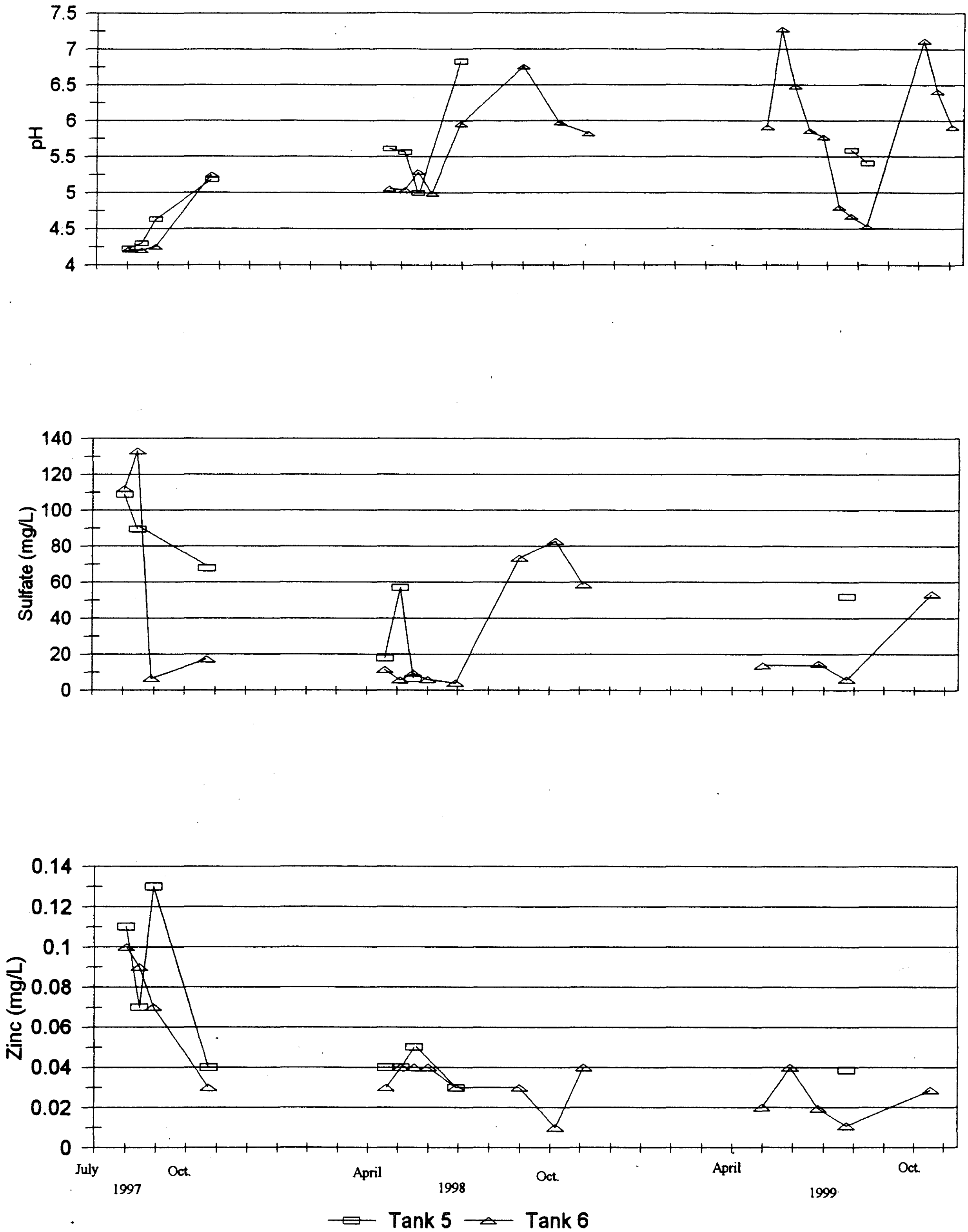


Figure A4.14. pH, Sulfate, and Zinc vs. time for tanks 5 and 6(shallow).

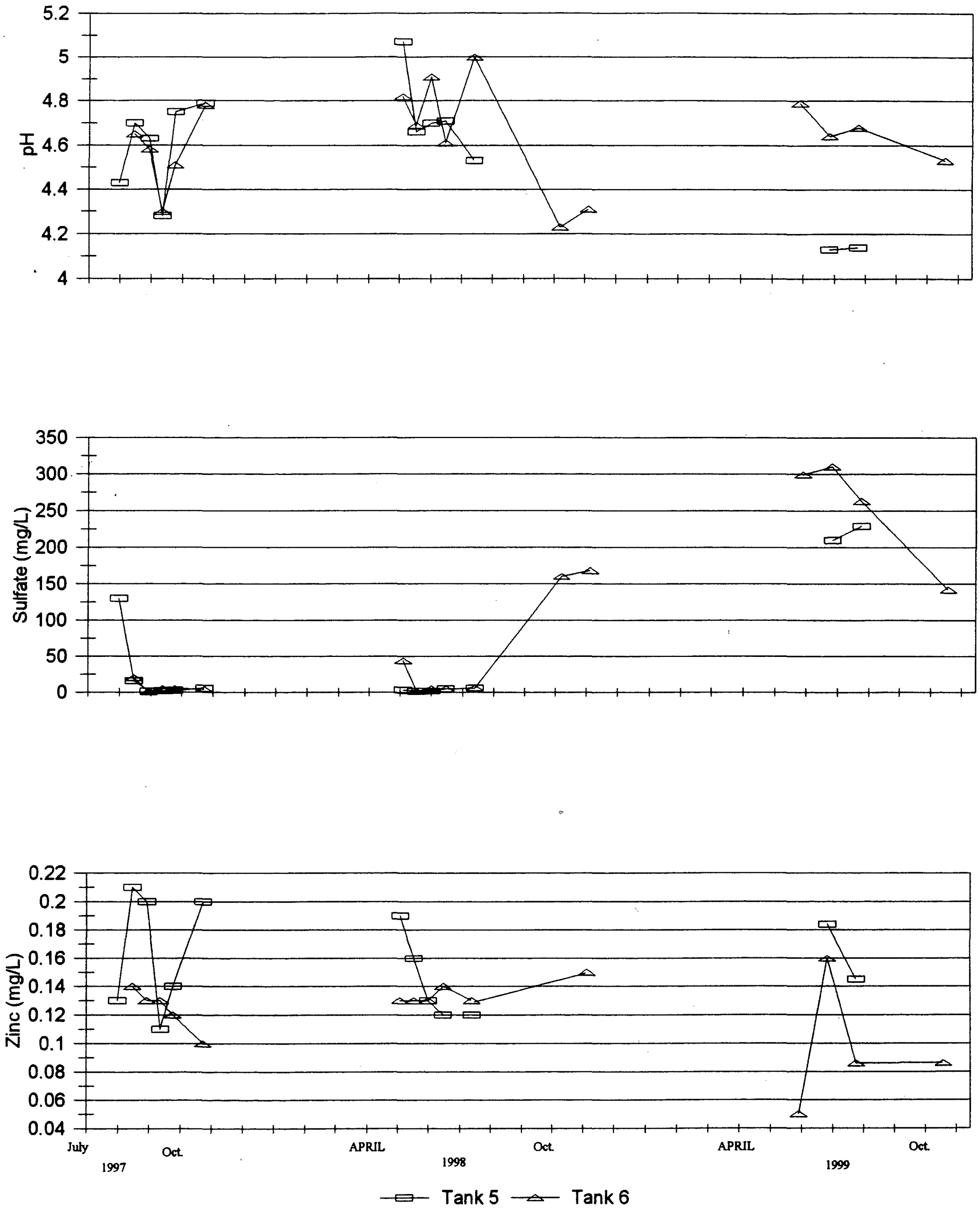


Figure A4.15. pH, Sulfate, and Zinc vs. time for tanks 5 and 6 (deep).

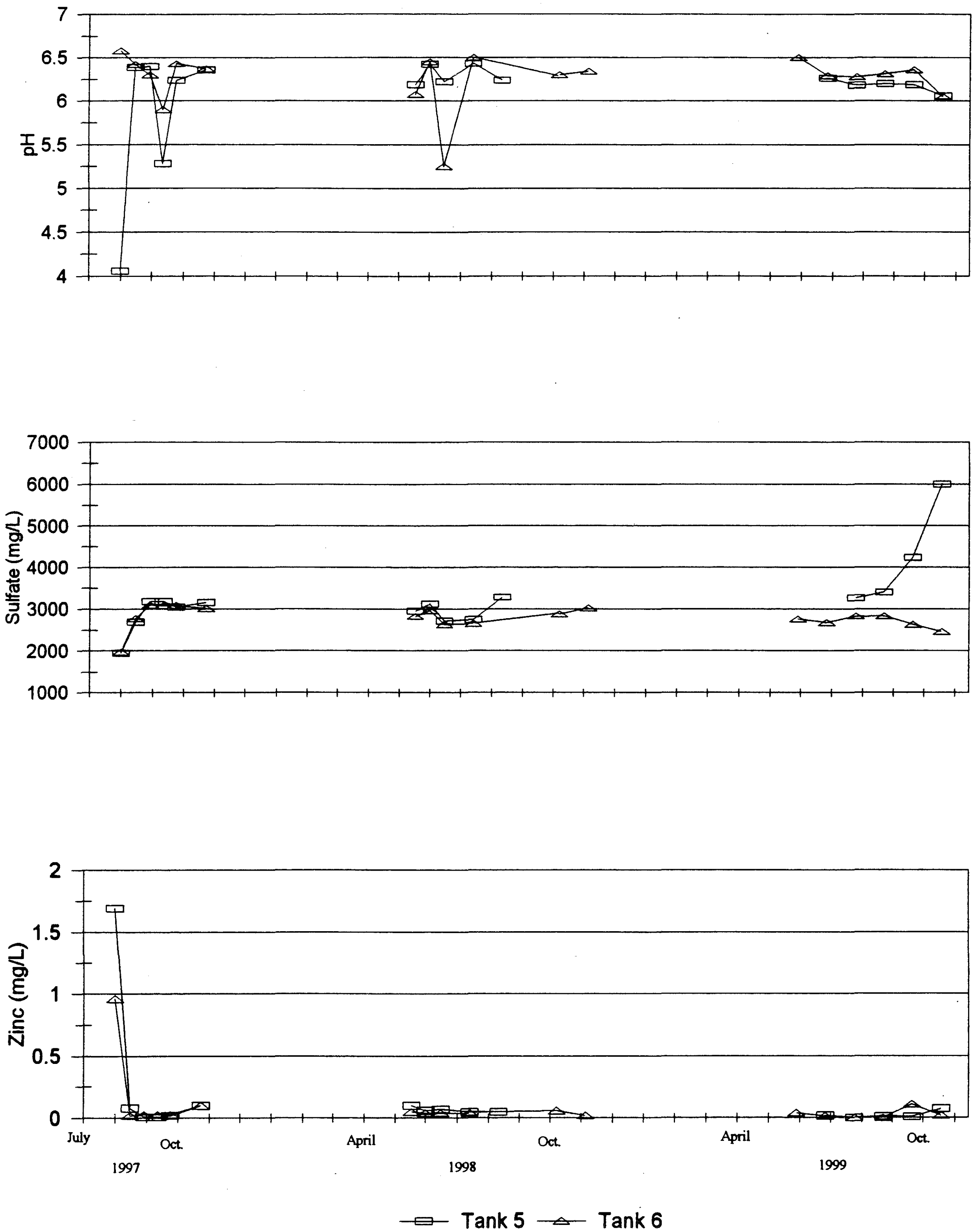
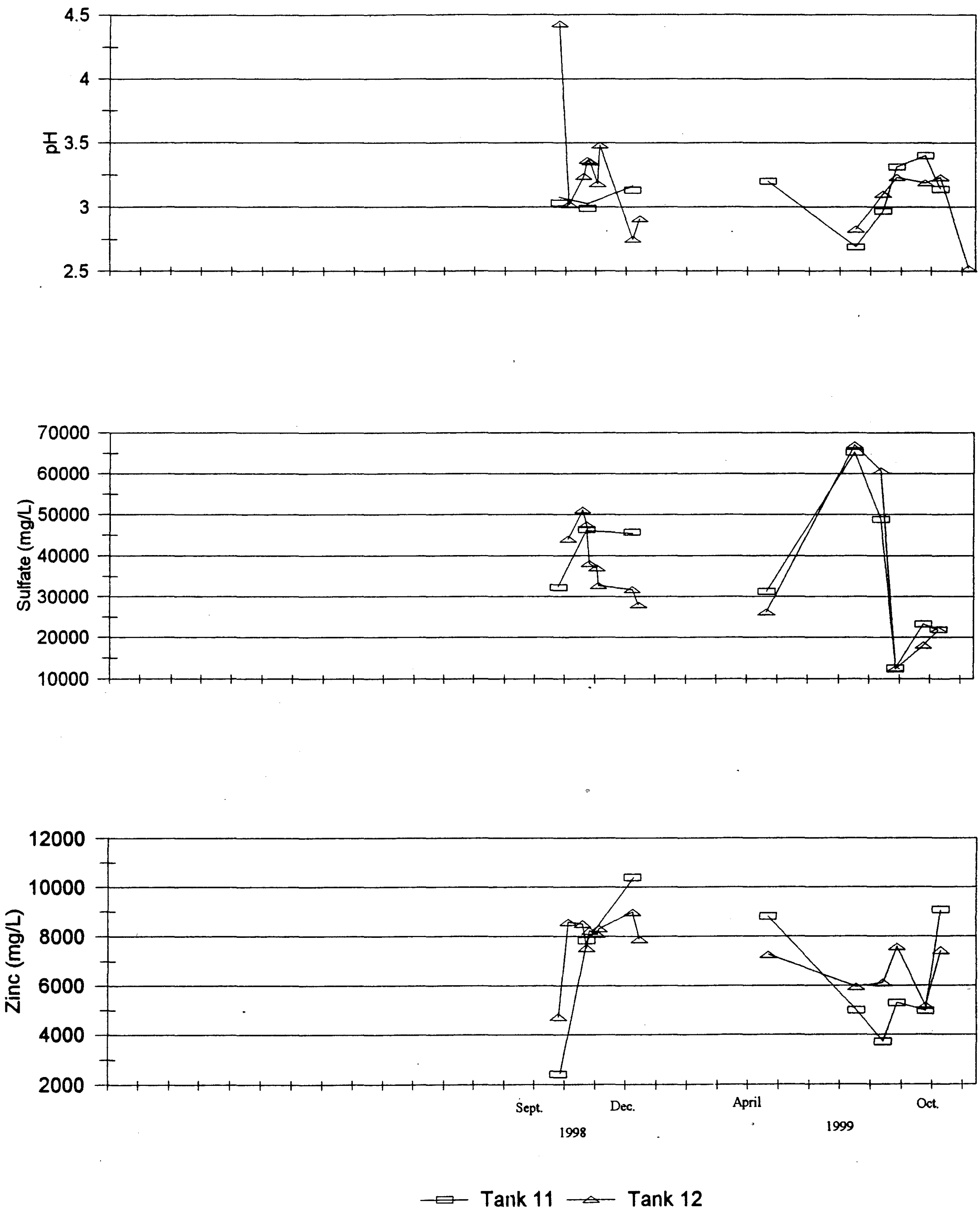


Figure A4.16. pH, Sulfate, and Zinc vs. time for tanks 11 and 12(controls).



Appendix 5

Vegetation

Table A5.1. Vegetation observations made during 1997 sampling season.

Amendments/tank	Date			
	8/4/97	8/15/97	9/2/97	9/16/97
Cattails on tailings Tank 2	Cattails approx. 20" in ht., aquatic insects present.	Cattails approx. 26" in ht., no aquatic insects present.	Cattails approx. 28" in ht., roots on top of tailings.	Cattails approx. 27" in ht., roots are on top of surface.
Submerged aquatics Tank 3	Green bubbles on surface, aquatic insects present.	Aquatics look healthy, green slime and bubbles, insects.	Aquatics almost submerged, slight film on top.	Aquatics have sunk below surface, very dark green.
Cattails on Till Tank 4	Water clear, aquatic insects present	Cattails approx. 34" in ht., aquatic insects present.	Cattails approx. 40" in ht., water clear.	Cattails approx. 50" in ht., roots are below over burden.
Cattails on Peat Tank 5	Cattails approx. 20"-30" in ht., brown film on surface.	Cattails approx. 30" in ht., cattail roots are on surface.	Cattails approx. 37' in ht., no surface water.	Cattails approx. 40" in ht., no surface water.
Cattails on Peat Tank 6	Cattails approx. 22" in ht., water dark and cloudy with brown film on surface.	Cattails approx. 28" in ht., cattail roots are on surface.	Cattails approx. 36" in ht., 10% of surface covered with water.	Cattails approx. 43" in ht., no surface water.
Cattails on tailings Tank 7	Cattails approx. 20"-30" in ht. Water cloudy. Aquatic insects present.	Cattails approx. 33" in ht., roots are on the surface. Aquatic insects present.	Cattails approx. 38" in ht., roots are on top of the surface.	Cattails approx. 37" in ht., roots are on top of surface, 75% surface water covered.
Cattails on Till Tank 8	Cattails approx. 20" in ht., Water clear. Aquatic insects present.	Cattails approx. 28" in ht. Aquatic insects present.	Cattails approx. 40" in ht., water clear.	Cattails approx. 32" in ht.
Submerged aquatics Tank 10	Water clear with thin film on surface.	Aquatics appear healthy, aquatic insects, green slime and green bubbles.	Aquatics partially submerged, green slime on top.	Aquatics submerged below surface.

Note: Aquatics refers to submerged plants and algae.

Table A5.2. Page 1 of 3. Vegetation observations made during 1998 sampling season.

Amendments/tank	Date			
	5/13/98	5/27/98	6/10/98	6/24/98
Cattails on tailings Tank 2	All cattails are sprouting approx. 12"-15" in ht.	All cattails are growing approx. 20"-28" in ht.	Most cattails growing approx. 24"-32" in ht.	Approx. 2/3 of cattails growing 30"-36" in ht.
Submerged aquatics Tank 3	Approx. ½ tank covered with aquatics. Live snails.	Aquatics cover most of tank, live snails and aquatic insects.	Aquatics covering tank surface, live snails on floating aquatics.	Aquatics covering most of tank, approx. 3 dozen live snails on vegetation.
Cattails on Till Tank 4	All cattails are sprouting approx. 14"-16" in ht.	All cattails are growing approx. 32"-36" in ht.	All cattails are growing approx. 42"-48" in ht.	All cattails are growing approx. 48"-60" in ht.
Cattails on Peat Tank 5	3/4 of cattails are sprouting approx. 6"-8" in ht.	3/4 of cattails are growing approx. 16"-24" in ht.	All cattails are growing approx. 16"-36" in ht. No surface water.	All cattails are growing approx. 24"-36' in ht.
Cattails on Peat Tank 6	All cattails are sprouting approx. 10"-14" in ht.	All cattails are growing approx. 24"-32" in ht.	All cattails are growing approx 36"-42" in ht. No surface water.	All cattails are growing approx. 36"-48" in ht. Surface water murky.
Cattails on tailings Tank 7	All cattails are sprouting approx. 8"-12" in ht.	Most cattails are growing approx. 16"-20" in ht.	Most cattails are growing approx. 26"-36" in ht.	Half the cattails are growing lighter green in color, approx 26"-36" in ht.
Cattails on Till Tank 8	½ of cattails are sprouting approx. 8"-12" in ht.	2/3 of cattails are growing approx. 20"-32" in ht.	½ to 2/3 of cattails are growing, approx. 24"-36" in ht., surface dry.	½ of cattails are growing approx. 36"-48" in ht.
Submerged aquatics Tank 10	Approx. ½ tank covered with aquatics.	Aquatics cover most of tank, live snails.	Aquatics cover most of tank surface, live snails.	Aquatics cover most of tank, Approx. 2 dozen on aquatics.

Table A5.2. Page 2 of 3. Vegetation observations made during 1998 sampling season.

Amendments/tank	Date			
	7/8/98	7/22/98	8/5/98	9/5/98
Cattails on tailings Tank 2	2/3 of cattails are growing approx. 24"-32" in ht.	½ cattails growing, approx. 24"-32" in ht. 25 stalks counted.	½ cattails growing, approx. 24"-36" in ht. and light green in color,	½ cattails growing, approx. 24"-36" in ht. And light green to yellow in color.
Submerged aquatics Tank 3	Aquatics cover tank, live snails and insects present.	½ the aquatics floating, ½ have sunk to bottom of tank.	All aquatics floating on top of tank, snails and insects.	Aquatics cover most of surface, live snails.
Cattails on Till Tank 4	All cattails growing, approx. 60" in ht., no surface water.	No surface water, cattails 66" in ht.,37 stalks counted.	No surface water, cattails 72" high, 2 seed heads.	Cattails turning light green to yellow on color.
Cattails on Peat Tank 5	Cattails growing, 24"-48" in ht., peat surface moist.	Cattails growing are 36"-60" in ht., 39 stalks counted.	Cattails are 48"-66" in ht., dark green. No surface water	Cattails lighter green, 66"-72" in ht.
Cattails on Peat Tank 6	All cattails growing, 48"-60" in ht., Surface moist, no water.	Cattails growing are 52"-66" in ht. 43 stalks were counted. No water in deep well.	Cattails growing are 66"-72" in ht. Surface dry, Cattails are dark green in color.	Cattails are 66"-72" in ht. and are dark in color. No surface water.
Cattails on tailings Tank 7	½ the cattails are growing, 24"-46" in ht., very small and thin, light green in color.	½ the cattails growing, 24"-36" in ht.23 growing stalks were counted.	Cattails are light green in color 24"-36" in ht. No surface water.	½ the cattails growing, light green in color
Cattails on Till Tank 8	Half the cattails are growing, 36"-48" in ht.	Cattails are 36"-48" in ht. 23 stalks were counted.	Cattails 66"-72" in ht. Color is not as dark green as tank 5 cattails.	Cattails are 72"-80" in ht. An dare lighter green in color.
Submerged aquatics Tank 10	Aquatics cover all of tank. Live snails on top.	Aquatics have sunk to the bottom of tank.	Most of the aquatics remain at the bottom of tank.	All the aquatics are the bottom of the tank.

Table A5.2. Page 3 of 3. Vegetation observations made during 1998 sampling season.

Amendments/tank	Date		
	9/16/98	9/30/98	10/28/98
Cattails on tailings Tank 2	Cattails are light green to yellow in color	Cattails are brown and dried-up.	Cattails are dead, approx. 3.3" of water above substrate
Submerged aquatics Tank 3	Aquatics have sunk to bottom of tank.	Aquatics remain at bottom of tank.	Aquatics remain at bottom of tank.
Cattails on Till Tank 4	Cattails are mostly yellow in color and drying.	Cattails are brown and dried-up.	Cattails are dead, no surface water.
Cattails on Peat Tank 5	Cattails are light green in color.	Cattails are brown and dried-up.	Cattails are dead, no surface water.
Cattails on Peat Tank 6	Cattails are dark green, surface dry.	Cattails are turning brown on tips.	Cattails are dead, approx. 4.75" of water above substrate
Cattails on tailings Tank 7	Cattails are turning light green to yellow in color.	Cattails are turning brown on tips.	Cattails are dead, approx. 3.75' of water above substrate.
Cattails on Till Tank 8	Cattails are light green in color.	Cattails are turning brown on tips	Cattails are dead, approx. 4.75" of water above substrate
Submerged aquatics Tank 10	Aquatics remain at the bottom of the tank.	Aquatics remain at the bottom of the tank.	Aquatics remain at the bottom of the tank.

Table A5.3. Page 1 of 4. Vegetation observations made during 1999 sampling season.

Amendments/tank	Date			
	4/22/99	5/6/99	5/19/99	6/3/99
Cattails on tailings Tank 2	No cattail growth. Water clear.	No cattail growth. Surface of substrate looks oxidized.	No cattail growth. Same orange oxidized look to the substrate.	Approx. 27 cattails growing from 10" to 20" in ht. Same orange look to substrate.
Submerged aquatics Tank 3	Water cloudy. Small amt. of decaying matter on surface.	Water cloudy.	Water cloudy, green matter on bottom of tank.	Water cloudy, aquatics still on bottom of tank.
Cattails on Till Tank 4	No cattail growth. Water clear.	No cattail growth.	Sample clear. No cattail growth.	Approx. 12 cattails growing from 12" to 24" in ht.
Cattails on Peat Tank 5	No surface water. Cattails are dry, no growth.	No surface water. No new cattail growth.	No surface water. No new cattail growth.	Approx. 12 cattails growing from 8" to 12" in ht.
Cattails on Peat Tank 6	No cattail growth. Sample clear. Measuring well frozen 24" down from top of tank.	No cattail growth.	No cattail growth. Sample cloudy and slightly brown in color.	Approx. 30 cattails growing from 10" to 20" in ht.
Cattails on tailings Tank 7	No cattail growth. Surface water clear.	No cattail growth. Surface of substrate looks oxidized.	No cattail growth. Same orange oxidized look to the substrate.	Approx. 30 cattails growing from 16" to 24" in ht.
Cattails on Till Tank 8	Sample clear. Measuring well is frozen 30" from top of tank.	No new cattail growth,	No cattail growth.	Approx 48 cattails growing from 16" to 28" in ht.
Submerged aquatics Tank 10	Water cloudy, unable to see bottom of tank.	Water cloudy. Small amt. of decaying matter on surface.	Water cloudy. Larger amt. of decaying matter on surface.	Aquatics from bottom of tank floating on top of the tank.

Table A5.3. Page 2 of 4. Vegetation observations made during 1999 sampling season.

Amendments/tank	Date			
	6/16/99	7/2/99	7/14/99	7/29/99
Cattails on tailings Tank 2	Cattails growing are approx. 20" to 36" in ht.	Cattails growing are approx. 36" to 48" in ht.	Cattails are same ht. and are lighter green in color.	Cattails are same ht. and are lighter green in color.
Submerged aquatics Tank 3	Water cloudy, aquatics still remain on bottom of tank.	Water clear, aquatics still remain on bottom of tank.	Water clear, Star duckweed growing, also live snails.	Star duckweed covers 1/3 of tank. Aquatic insects and snails living in tank. Coontail growing near the surface.
Cattails on Till Tank 4	Approx. 24 cattails growing from 32" to 48" in ht.	Cattails are from 48" to 66" in ht. 4 seed heads forming	Cattails are 56" to 72" in ht. Approx. 14 seed head forming.	Cattails are the same ht. 7 large and 8 smaller seed heads forming.
Cattails on Peat Tank 5	Approx. 20 cattails growing from 32" to 48" in ht.	Cattails are from 48" to 60" in ht. and dark green .	Cattails are 60" to 72" in ht. and dark green in color. Approx. 10 seed head forming	Cattails approx. same ht. and darker green in color. 9 seed heads forming.
Cattails on Peat Tank 6	Cattails growing are approx. 36" to 42" in ht.	Cattails are dark green and are 56" to 72" in ht.	Cattails are 60" to 76" in ht. and are dark green in color. Several seed heads forming.	Cattails are thick, dark green, and 60" to 80" in ht. 8 seed heads forming.
Cattails on tailings Tank 7	Cattails growing are approx. 24" to 32" in ht.	Cattails are lighter green in color and are 24" to 36" in ht.	Cattails are lighter green in color and 28" to 40" in ht.	Cattails approx. the same ht. and lighter green. Water cloudy.
Cattails on Till Tank 8	Cattails growing are approx. 36" to 48" in ht.	Cattails are lighter green in color, from 48" to 72" in ht., 4 seed heads forming.	Cattails are lighter green in color, from 56" to 72" in ht. 12 seed heads forming.	Cattails approx. the same ht. 23 seed heads forming.
Submerged aquatics Tank 10	Some new aquatic growth on the surface.	Surface covered with aquatics.	Surface covered with aquatics.	Surface covered with aquatics. Live snails in tank.

Table A5.3. Page 3 of 4. Vegetation observations made during 1999 sampling season.

Amendments/tank	Date			
	8/11/99	8/26/99	9/8/99	9/23/99
Cattails on tailings Tank 2	Cattails are the same ht. Water clear.	Cattails are the same ht. Water clear. Approx. 1/4 of leaves are turning brown.	Cattails are dying. Water cloudy.	Cattails are almost dead.
Submerged aquatics Tank 3	Tank remains the same from last sampling.	Star duckweed covers ½ of the tank. Coontail has reached the surface.	Star duckweed covers ½ the tank and the Coontail covers the other ½.	Tank has not changed since last sampling.
Cattails on Till Tank 4	Cattails are approx. 60" to 76" in ht. Same number of seed heads.	Cattails are the same ht. Shorter leaves are turning brown.	Cattails are dying, half the leaves are brown.	Cattails are dying off, Most of the leaves are brown.
Cattails on Peat Tank 5	Cattails are approx. 64" to 76" in ht. No surface water.	Cattails are the same ht. !/4 of leaves are brown.	Half the cattails have brown leaves.	Cattails are almost dead.
Cattails on Peat Tank 6	Cattails are thick and dark green and approx. 66" to 84" in ht.	Cattails are approx the same ht. Shorter leaves are turning brown.	Half the cattails have brown leaves.	Cattails are almost dead.
Cattails on tailings Tank 7	Cattails are approx. the same as last time.	Cattails are the same ht. and turning lighter green. Water cloudy.	Leaves are turning brown.	Water cloudy. Leaves are turning brown.
Cattails on Till Tank 8	Cattails are approx. the same ht. The leaves appear lighter green in color.	Cattails are the same ht. The leaves are turning brown.	More leaves are turning brown.	Half the leaves are brown.
Submerged aquatics Tank 10	Tanks remains the same as last sampling.	Algae covers tank, 2 to 3 dozen snails living on the surface.	Coontail showing thru the algae bloom.	Tank remains the same.

Table A5.3. Page 4 of 4. Vegetation observations made during 1999 sampling season.

Amendments/tank	Date
	10/6/99
Cattails on tailings Tank 2	Cattails are dead. Thin layer of ice covers tank.
Submerged aquatics Tank 3	Vegetation starting to sink to bottom of tank.
Cattails on Till Tank 4	Cattails are dead.
Cattails on Peat Tank 5	Cattails are dead.
Cattails on Peat Tank 6	Cattails are dead.
Cattails on tailings Tank 7	Cattails are dead.
Cattails on Till Tank 8	Cattails are dead.
Submerged aquatics Tank 10	Algae appears to be still alive.

Appendix 6

Water and Substrate Depth Measurements

Table A6.1. Average of measurements from the top of the tanks to the substrate from field notes on 10/06/97. All measurements are in inches.

Tank #	Measurement location											
	a1[1]	a2	a3	b1	b2	b3	b4	c1	c2	c3	Average	Avg.(cm)
1	38.5	38.5	38.5	39.0	38.5	37.9	38.5	39.0	38.5	40.1	38.7	98.3
2	17.5	17.3	17.3	17.8	17.8	17.3	17.1	17.3	17.0	17.0	17.3	44.0
3	38.0	38.3	38.5	38.0	38.1	38.1	38.3	38.9	38.5	38.0	38.3	97.2
4	16.4	16.9	16.8	17.5	17.3	17.3	16.9	17.3	17.1	17.1	17.0	43.3
5	16.4	16.1	15.8	16.5	16.1	16.3	16.1	16.0	16.5	16.1	16.2	41.1
6	16.5	18.8	17.5	16.1	16.5	17.0	17.4	15.8	16.8	17.3	17.0	43.1
7	16.5	17.1	17.9	16.6	17.2	17.8	18.5	16.3	17.1	17.4	17.2	43.8
8	17.8	17.9	17.5	16.8	16.9	17.1	17.4	15.8	16.4	16.5	17.0	43.2
9	38.0	37.9	38.9	38.1	38.0	39.0	40.1	38.9	38.1	39.8	38.7	98.2
10	38.9	38.8	39.2	39.9	39.8	39.4	40.1	38.9	40.5	41.0	39.6	100.7

1 - See figure A6.1. for the sketch showing the measurement layout pattern.

Table A6.2. Average of measurements from the top of the tanks to the substrate in the shallow water tanks on 7/16/98. Measurements are in inches.

Tank #	Measurement location										
	a1[1]	a2	a3	b1	b2	b3	b4	c1	c2	c3	Average	Avg(cm)
2	17.3	17.5	17.1	18.0	17.9	17.9	17.6	17.8	17.8	17.6	17.7	45.0
4	17.6	17.5	17.4	18.6	17.8	17.8	17.8	17.9	17.9	17.6	17.8	45.2
5	18.6	18.4	17.8	18.3	17.6	17.5	17.2	17.8	17.6	17.6	17.8	45.3
6	17.3	18.8	18.4	17.8	18.5	19.5	19.2	17.5	19.3	19.8	18.6	47.3
7	16.9	18.6	17.9	17.1	17.6	18.1	19.0	17.1	17.8	18.4	17.9	45.5
8	16.1	16.9	17.0	17.5	17.4	17.5	17.4	18.0	18.3	18.3	17.4	44.2

1- See figure A6.1. for the sketch showing the measurement layout pattern.

Figure A6.1. Depth to Substrate Measurement Points.

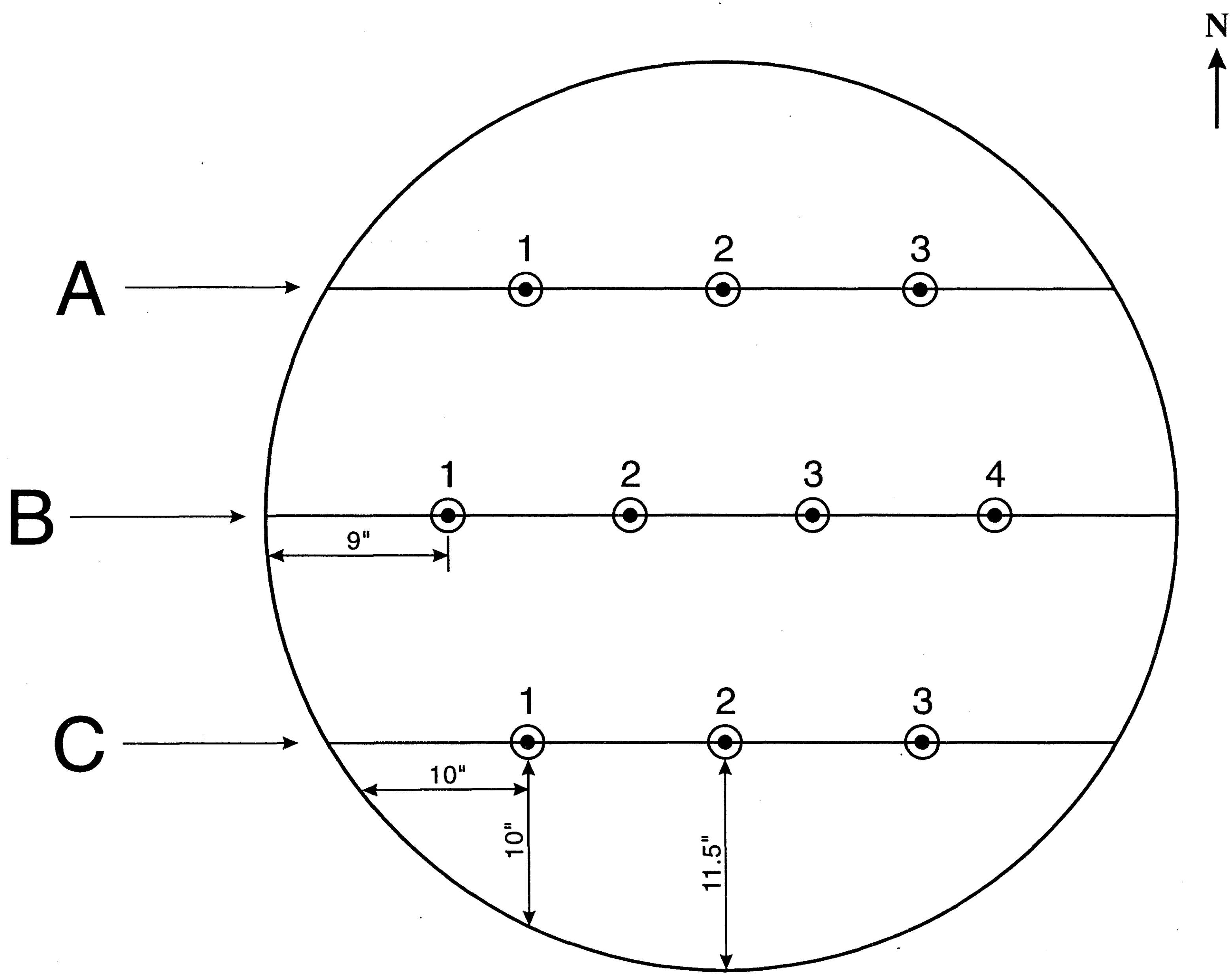


Table A6.3. Page 1 of 4. Water level depths above substrate.

Water depth (cm)										
Tank	1	2	3	4	5	6	7	8	9	10
Treatment / Date	Water Cover	Cattails on Tailings	Water Cover, submerged Aquatics	Cattails on Till	Cattails on Peat	Cattails on Peat	Cattails on Tailings	Cattails on Till	Water Cover	Water Cover, submerged Aquatics
7/11/97	67.8	13.5	66.7	12.8	10.6	12.6	13.0	12.7	48.5	70.2
8/04/97	63.4	8.7	62.4	9.0	6.7	6.9	7.5	7.6	61.5	63.8
8/15/97	59.9	5.2	58.5	5.1	5.6	3.7	3.7	3.8	57.0	59.3
9/02/97	60.2	3.3	58.5	3.8	3.7	4.3	2.4	2.5	61.2	60.6
9/16/97	58.3	1.1	56.6	0.0[1]	0.0[1]	0.0[1]	0.5	0.0[1]	56.7	58.0
10/07/97	59.6	0.9	57.9	-19.4[2]	-9.5	-7.3	-0.1	-22.9	58.0	59.8
10/22/97	62.7	3.6	61.1	1.9	0.7	2.1	3.4	2.1	60.5	61.7
4/15/98	74.2	13.5	73.2	13.0	16.4	13.3	13.2	10.5	71.6	75.2
4/30/98	67.5	8.4	69.0	8.3	4.0	6.4	8.1	5.7	66.2	70.1
5/13/98	68.5	5.4	66.8	7.0	1.8	5.7	6.2	2.9	65.3	67.3
5/27/98	66.5	2.3	64.6	2.5	0.8	3.8	3.1	1.9	63.4	65.7
6/10/98	66.5	1.7	64.3	1.3	0.5	1.9	1.8	-13.7	63.1	65.3
6/24/98	72.3	7.1	69.0	2.5	5.6	3.8	6.9	3.2	68.5	70.7
7/01/98	73.9	8.1	70.9	1.6	4.0	2.9	7.5	3.8	70.0	72.0
7/08/98	74.2	8.1	71.2	0.6	1.1	-5.7	8.1	3.2	71.0	72.3

1 - Surface was dry, no water present.
2 - Negative measurements indicate water levels below substrate depth; measuring wells were installed to monitor water levels below the surface of the substrate.

Table A6.3. Page 2 of 4. Water level depths above substrate.

Water depth (cm)										
Tank	1	2	3	4	5	6	7	8	9	10
Treatment / Date	Water Cover	Cattails on Tailings	Water Cover, submerged Aquatics	Cattails on Till	Cattails on Peat	Cattails on Peat	Cattails on Tailings	Cattails on Till	Water Cover	Water Cover, submerged Aquatics
7/16/98	73.9	6.1	71.2	<-56.5[2]	-24.3[1]	-33.7	5.3	2.2	70.4	71.7
7/22/98	71.9	5.6	68.7	<-56.5	-32.5	<-68.3	4.3	<-57.1	69.1	70.1
7/30/98	70.4	1.5	66.8	<-56.5	-61.7	<-68.3	0.8	<-57.1	66.5	67.9
8/05/98	69.1	0.1	65.5	<-56.5	<-63.0	<-68.3	-1.4	<-57.1	65.3	66.1
8/19/98	62.7	-14.5	64.6	<-56.5	-62.0	-63.5[3]	-55.7[3]	<-57.1[3]	64.0	65.3
8/26/98	62.7	-55.1	64.3	<-56.5	-58.2	-4.8	2.7	1.9	64.0	65.0
9/02/98	66.0	<-55.8	62.4	<-56.5	-58.2	-48.3	0.2	-50.8	62.1	62.5
9/11/98	63.0	<-55.8	59.5	<-56.5	-62.0	<-68.3	-57.3	<-57.1	59.2	60.3
9/16/98	67.6	0.8[4]	63.9	<-56.5	-61.1	<-68.3	0.5[4]	-49.2	63.4	64.1
9/25/98	66.0	<-55.8	63.0	<-56.5	-61.7	<-68.3[3]	-0.8	<-57.1[3]	62.1	62.2
9/30/98	66.9	-10.7[4]	63.6	<-56.5	-61.1	-5.7	-0.1	2.9	63.4	63.8
10/14/98	71.7	-0.2	65.2	<-56.5	-60.8	-10.2	0.2	3.2	63.4	63.8
10/19/98	74.2	6.5	71.2	<-56.5	-60.5	0.3	6.5	10.2	69.7	70.1
10/28/98	74.8	7.1	71.9	<-56.5	-60.5	-0.3	7.2	10.5	70.7	70.8

1- Negative measurements indicate water levels below substrate depth; measuring wells were installed to monitor water levels below the surface of the substrate.
2- A less than measurement indicates the water level was below the bottom of the measuring well.
3- Due to the lack of rainfall, water from the DNR well on site was added to tanks 6,7, and 8. Water was also added to tank 6 on 8/20 and 8/24, and to tank 8 on 8/20 and 8/21.
4- Water appears to be perched above substrate.

Table A6.3. Page 3 of 4. Water level depths above substrate.

	Water depth (cm)									
Tank	1	2	3	4	5	6	7	8	9	10
Treatment / Date	Water Cover	Cattails on Tailings	Water Cover, submerged Aquatics	Cattails on Till	Cattails on Peat	Cattails on Peat	Cattails on Tailings	Cattails on Till	Water Cover	Water Cover, submerged Aquatics
4/8/99	Ice	23.6	Ice	15.9	Well froze	19.7	22.9	27.9	Ice	Ice
4/12/99	Ice	21.7	Ice	14.6	Well froze	18.4	22.1	25.4	Ice	Ice
4/22/99	86.9	19.8	84.3	8.3	Well froze	16.8	20.2	22.9	83.1	84.4
5/6/99	83.4	15	81.1	6	-56[1]	12.7	17	20.3	79.6	79.3
5/19/99	87.2	15.4	84.9	10.8	-33.1	17.8	22.1	25.1	83.7	84.7
6/3/99	85	16.6	83.3	10.5	-30.3	17.8	20.2	23.2	81.5	81.5
6/16/99	85	15.7	82.7	9.8	-28.1	19.1	18	18.7	80.8	80.3
7/2/99	86.2	16.6	83.9	7	-26.2	6.4	18.3	14	81.8	82.8
7/14/99	69.1[3]	29.3	67.8[3]	18.7	0.13	12.1	31.3	24.1	68.1[3]	69.5[3]
7/29/99	75.8	33.1	73.8	19.4	-4.6	2.5	33.8	22.9	74.2	75.2
8/11/99	73.9	29.3	72.5	14.6	-3.6	-29.8	30.7	17.1	72.9	73.6
8/26/99	77.7	31.2	75.7	15.9	-36.6	-61	32.3	17.5	76.7	76.1
9/8/99	79.9	32.5	77.9	16.8	-35.7	-53.3	33.5	17.1	78.6	79
9/23/99	79.2	31.2	77	14.6	-31.6	-3.8[2]	32.3	15.2	77.3	78.4

1- Negative measurements indicate water levels below substrate depth; measuring wells were installed to monitor water levels below the surface of the substrate.
2- Due to the lack of rainfall, water from the DNR well on site was added to tank 6 on 9/15/99.
3- Due to excessive rainfall, water was removed to maintain one foot of freeboard from tanks 1,3,9, and 10 on 7/6/99.

Table A6.3. Page 4 of 4. Water level depths above substrate.

Water depth (cm)										
Tank	1	2	3	4	5	6	7	8	9	10
Treatment / Date	Water Cover	Cattails on Tailings	Water Cover, submerged Aquatics	Cattails on Till	Cattails on Peat	Cattails on Peat	Cattails on Tailings	Cattails on Till	Water Cover	Water Cover, submerged Aquatics
10/6/99	81.8	32.8	79.2	18.1	-28.1[1]	-1.9	33.5	17.1	79.2	79.6
10/21/99	83.1	34.4	80.8	19.4	-10.3	-0.6	34.2	19.1	80.5	81.5
10/27/99	82.1[2]	32.5[2]	79.2[2]	18.4[2]	NA	NA	32.9[2]	17.8[2]	79.2[2]	79.6[2]

1- Negative measurements indicate water levels below substrate depth; measuring wells were installed to monitor water levels below the surface of the substrate.
2- Due to excessive rainfall, water was removed to maintain one foot of freeboard from tanks 1,2,3,4,7,8,9, and 10 on 10/27/99. The measurements indicated were taken before water removal.

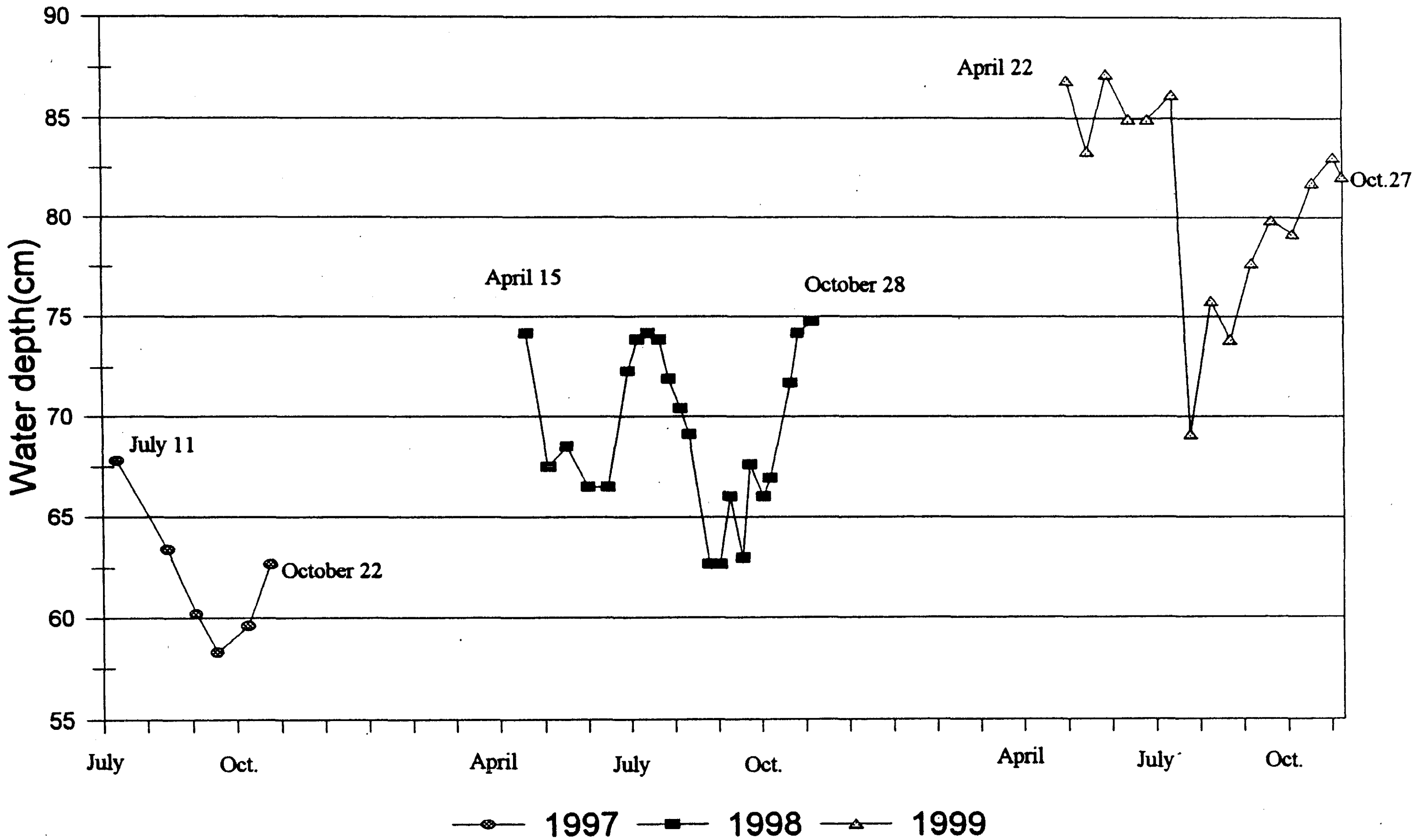
Table A6.4. Summary of water additions and removal.

TANK	DATE	H_2O REMOVED (cm)	H_2O REMOVED (gal.)	H_2O ADDED (cm)	H_2O ADDED (gal.)
1	7-6-99	31.1	88.1	NA	NA
1	10-27-99	14.3	40.5	NA	NA
2	10-27-99	19.1	53.9	NA	NA
3	7-6-99	29.2	82.8	NA	NA
3	10-27-99	12.4	35.1	NA	NA
4	10-27-99	5.7	16.2	NA	NA
6	8-19-98	NA	NA	21.7	61.6
6	8-20-98	NA	NA	5.8	16.5
6	8-24-98	NA	NA	3.2	9.2
6	9-25-98	NA	NA	16.9	47.8
6	9-15-99	NA	NA	5.3	15.0
6	9-16-99	NA	NA	6.6	18.8
7	8-19-98	NA	NA	5.2	14.7
7	10-27-99	19.7	55.7	NA	NA
8	8-19-98	NA	NA	7.8	22.1
8	8-20-98	NA	NA	6.5	18.4
8	8-21-98	NA	NA	6.5	18.4
8	9-25-98	NA	NA	7.1	20.2
8	9-28-98	NA	NA	2.9	8.3
8	10-27-99	5.1	14.4	NA	NA
9	7-6-99	29.2	82.8	NA	NA
9	10-27-99	11.4	32.4	NA	NA
10	7-6-99	26.7	75.7	NA	NA
10	10-27-99	9.5	27.0	NA	NA

NOTES: Water removed on 7/6/99 was a result of a heavy rain on 7/4/99, and was done to prevent tanks from overflowing.

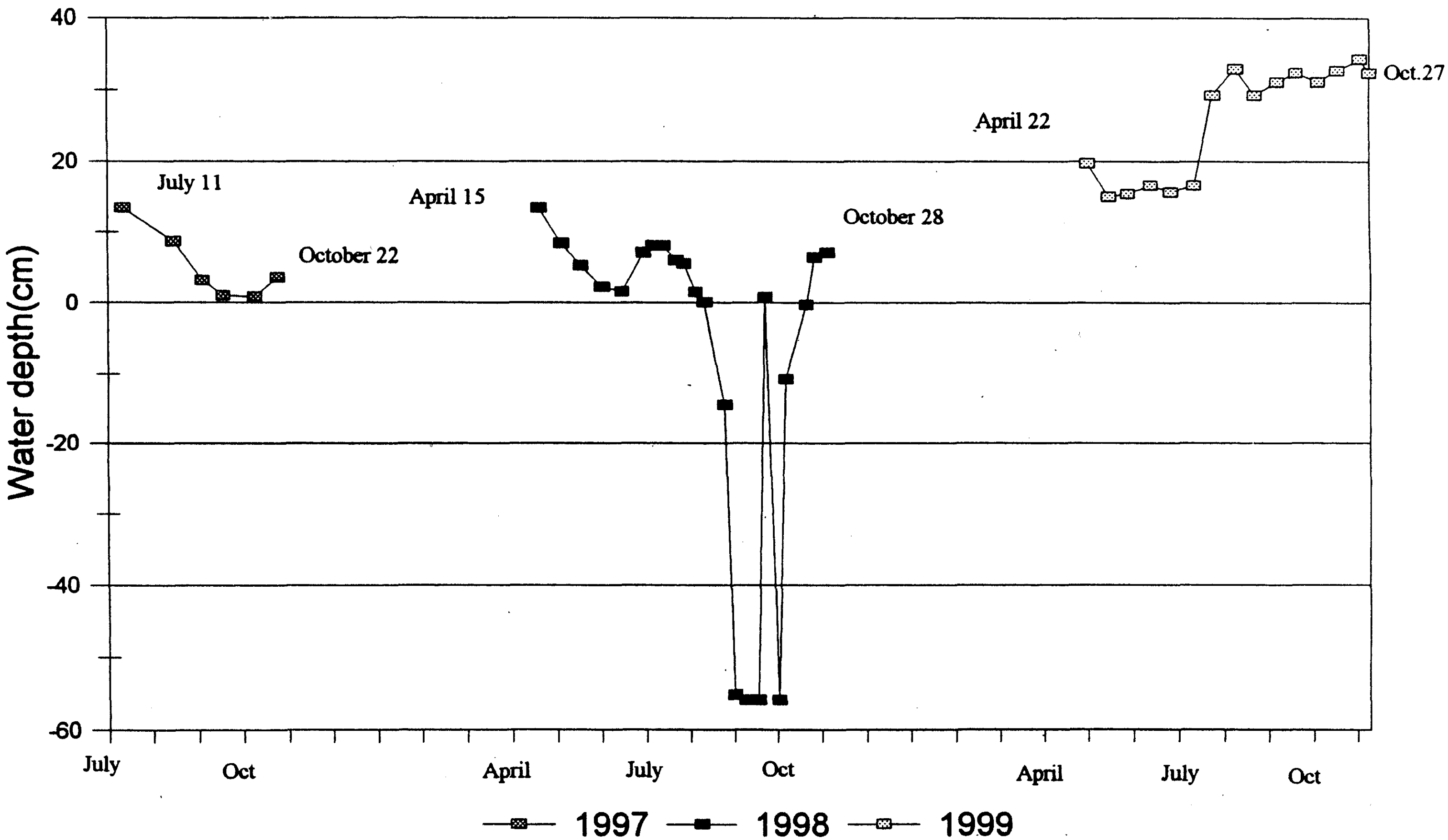
Water removed on 10/27/99 was done to create a 12 inch freeboard in each tank to avoid any overflowing in the spring.

Figure A6.2. Water level from substrate surface vs time for tank 1 (water cover).



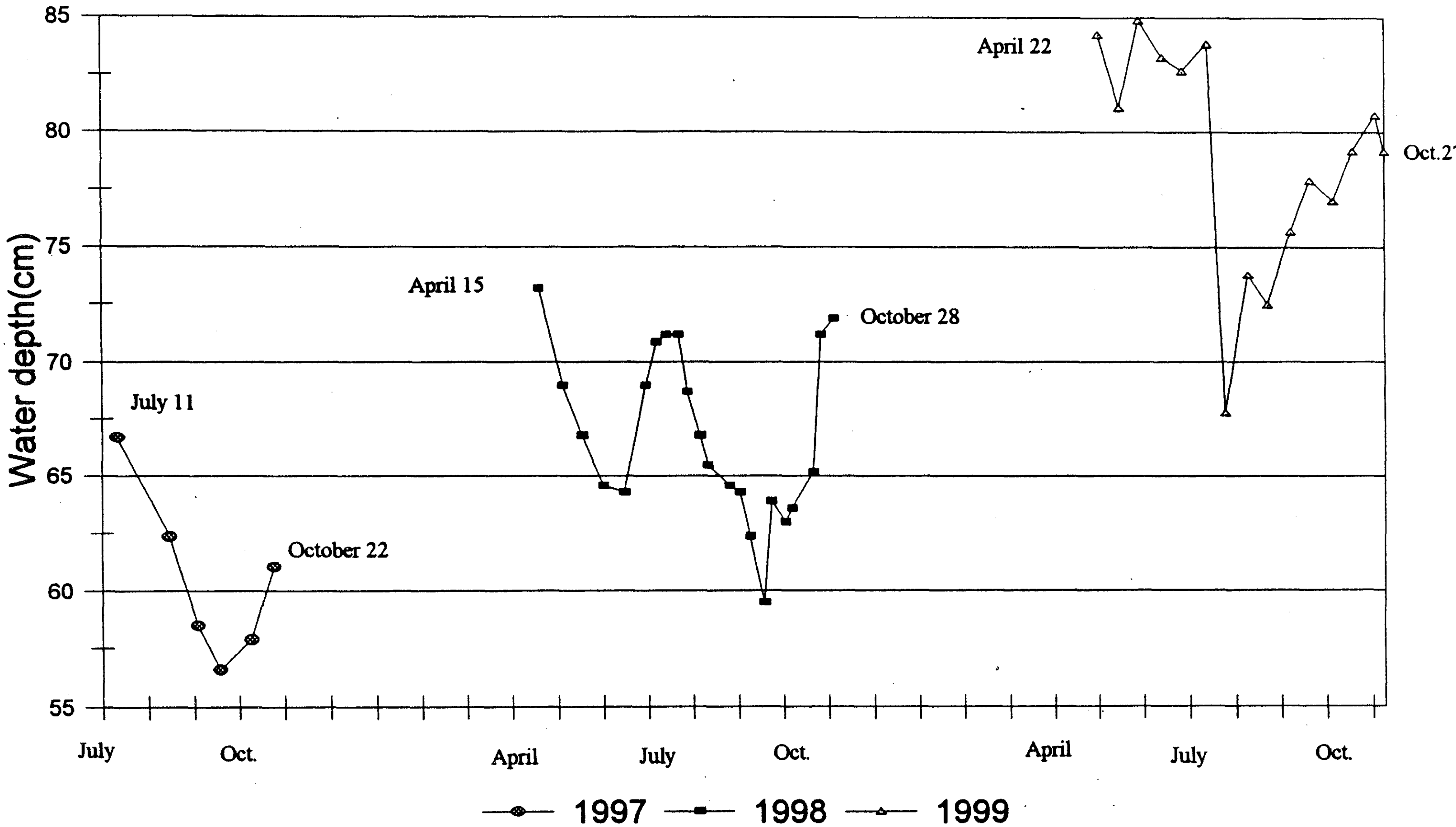
Note: To maintain one foot of freeboard, 31.1 cm. and 14.3 cm. were removed on 7/6/99 and 10/27/99 respectively.

Figure A6.3. Water level from substrate surface vs time for tank 2 (cattails on tailings).



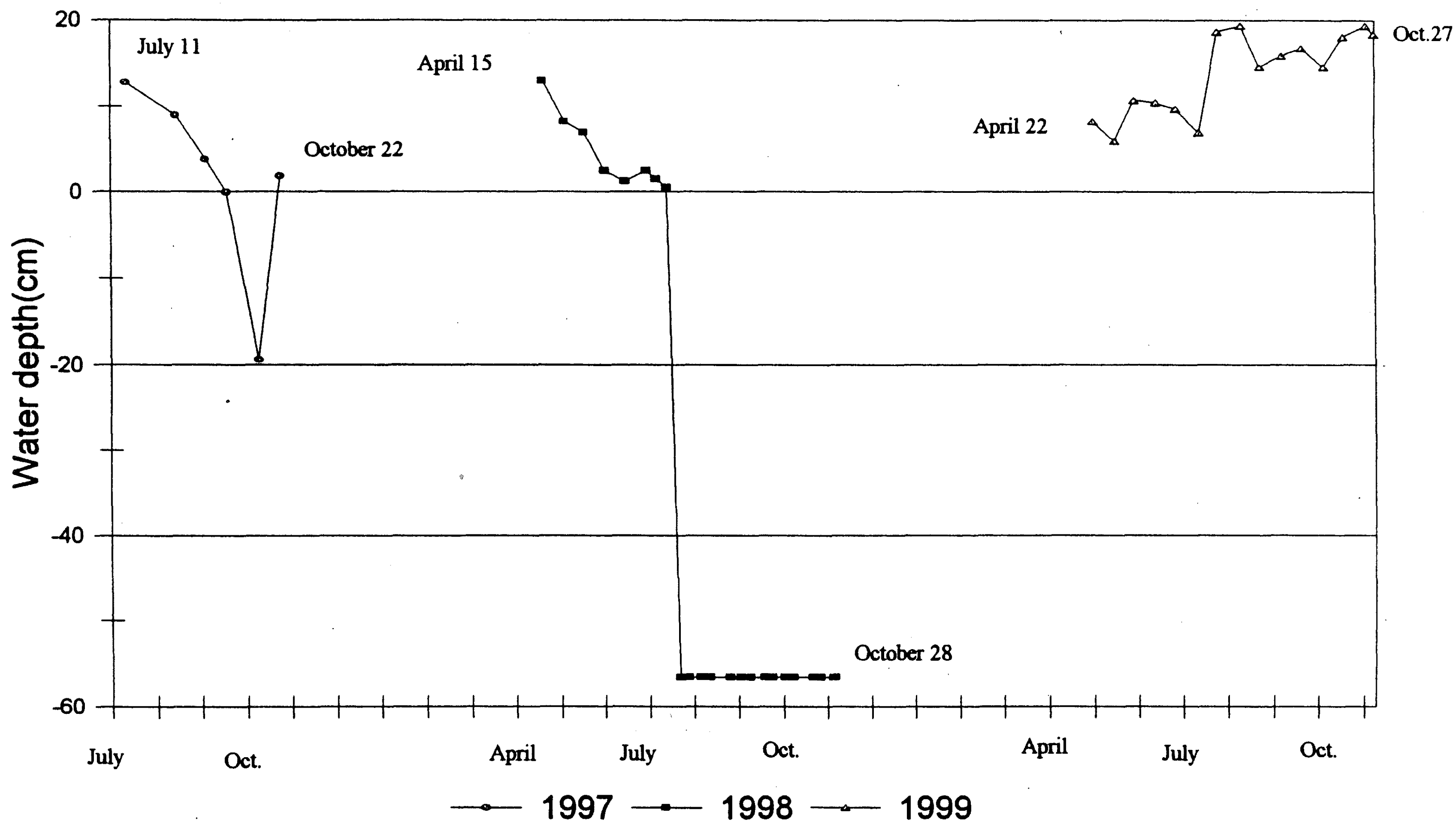
Note: On 9/16/98 and 9/30/98, water appears to be perched on top of substrate. 12.4 cm. of water was removed on 10/27/99. -55.8 cm is the measurement from the substrate to the bottom of the measuring well.

Figure A6.4. Water level from substrate surface vs time for tank 3 (submerged aquatics).



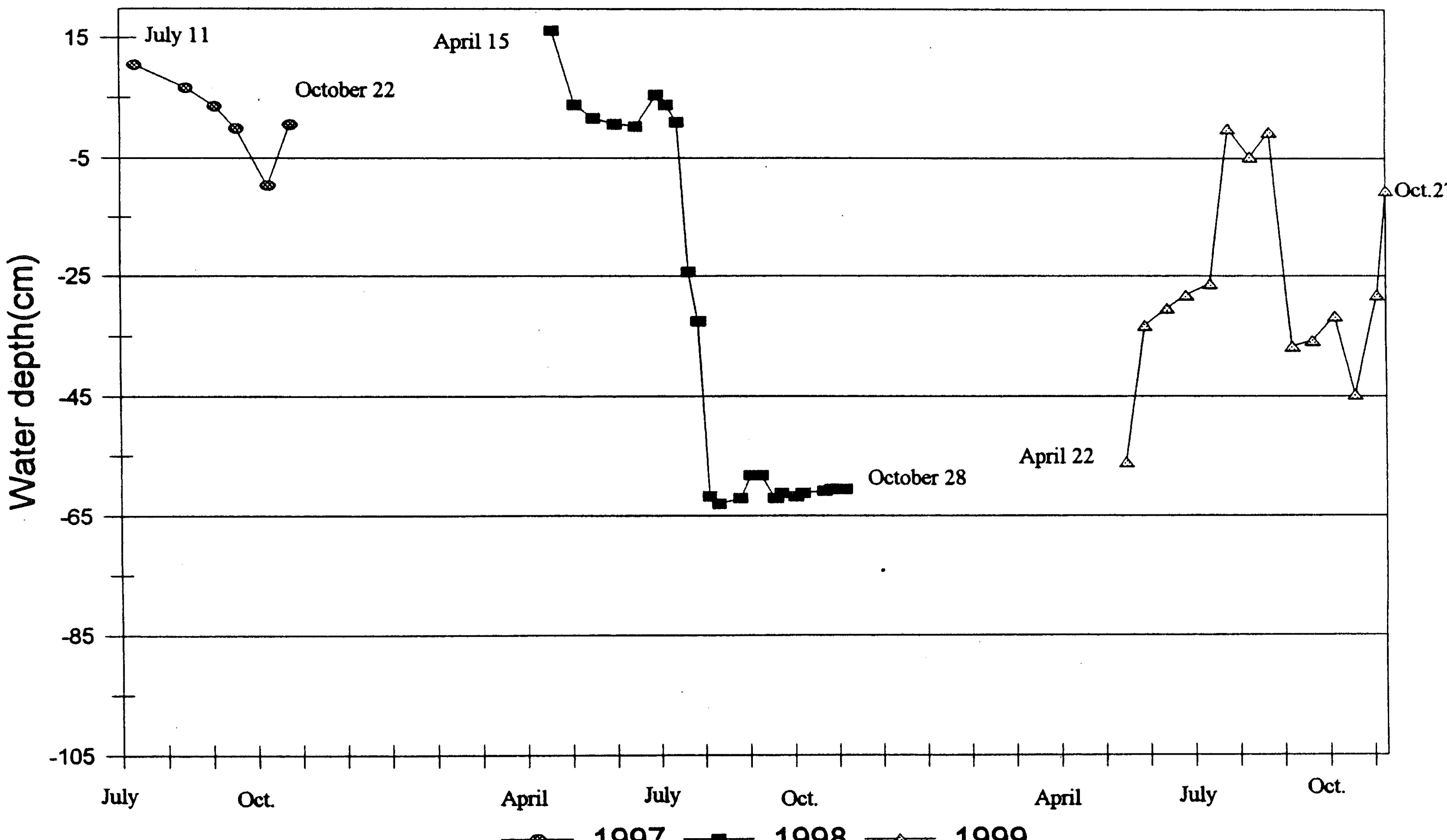
Note: To maintain one of freeboard, 29.2 cm. and 11.03 cm. were removed on 7/6/99 and 10/27/99 respectively.

Figure A6.5. Water level from substrate surface vs time for tank 4 (cattails on till).



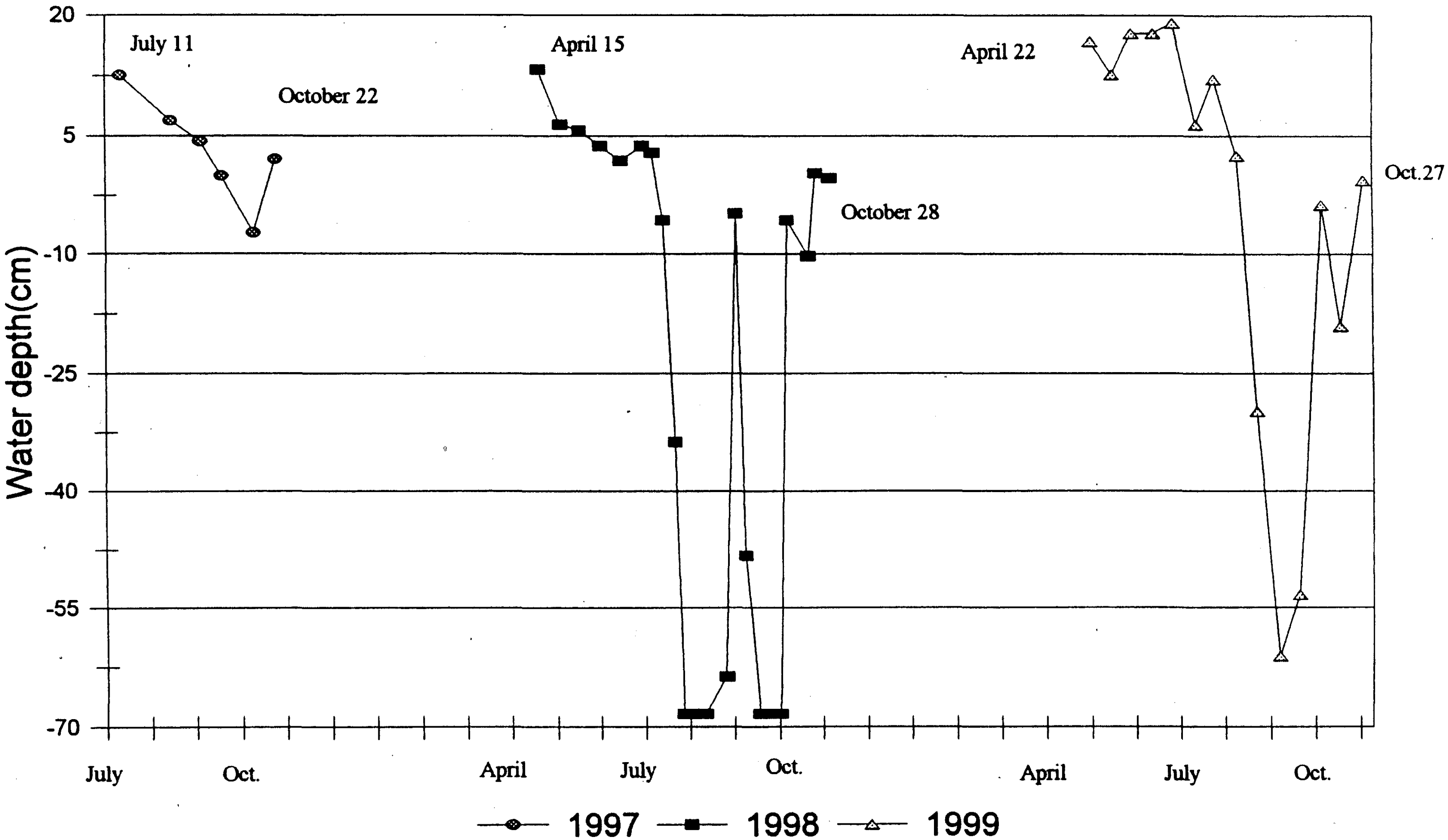
Note: To maintain one foot of freeboard, 5.7 cm. was removed on 10/27/99. -56.5 cm. is the measurement from the substrate to the bottom of the measuring well.

Figure A6.6. Water level from substrate surface vs time for tank 5 (cattails on peat).



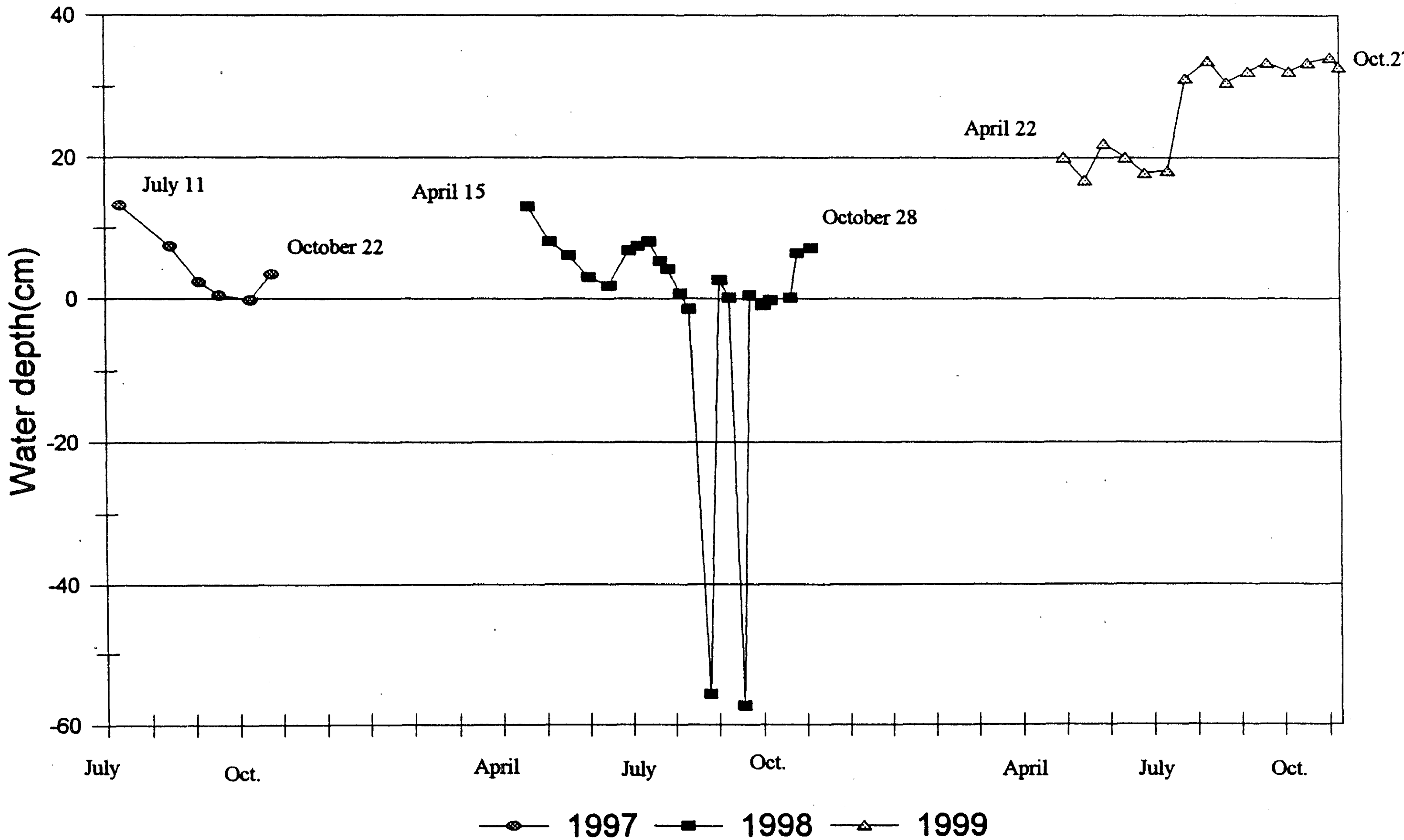
-63 cm. is the measurement from the substrate to the bottom of the measuring well.

Figure A6.7. Water level from substrate surface vs time for tank 6 (cattails on peat).



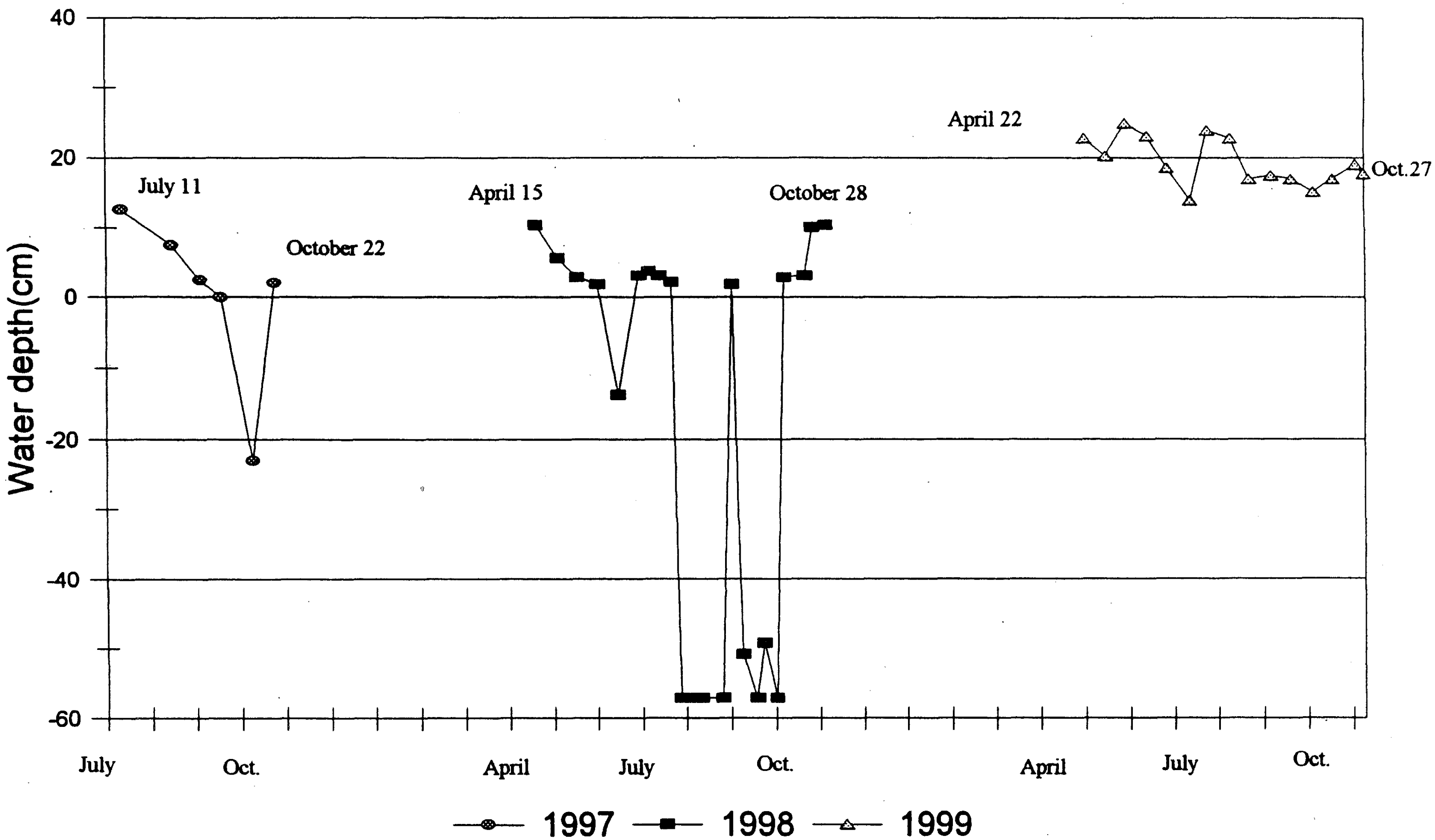
Note: Due to lack of rainfall, water was added to tank 6 on 8/19, 8/20, 8/24, 9/25/98 and 9/15/99. -68.3 cm. is the measurement from the substrate to the bottom of the measuring well.

Figure A6.8. Water level from substrate surface vs time for tank 7 (cattails on tailings).



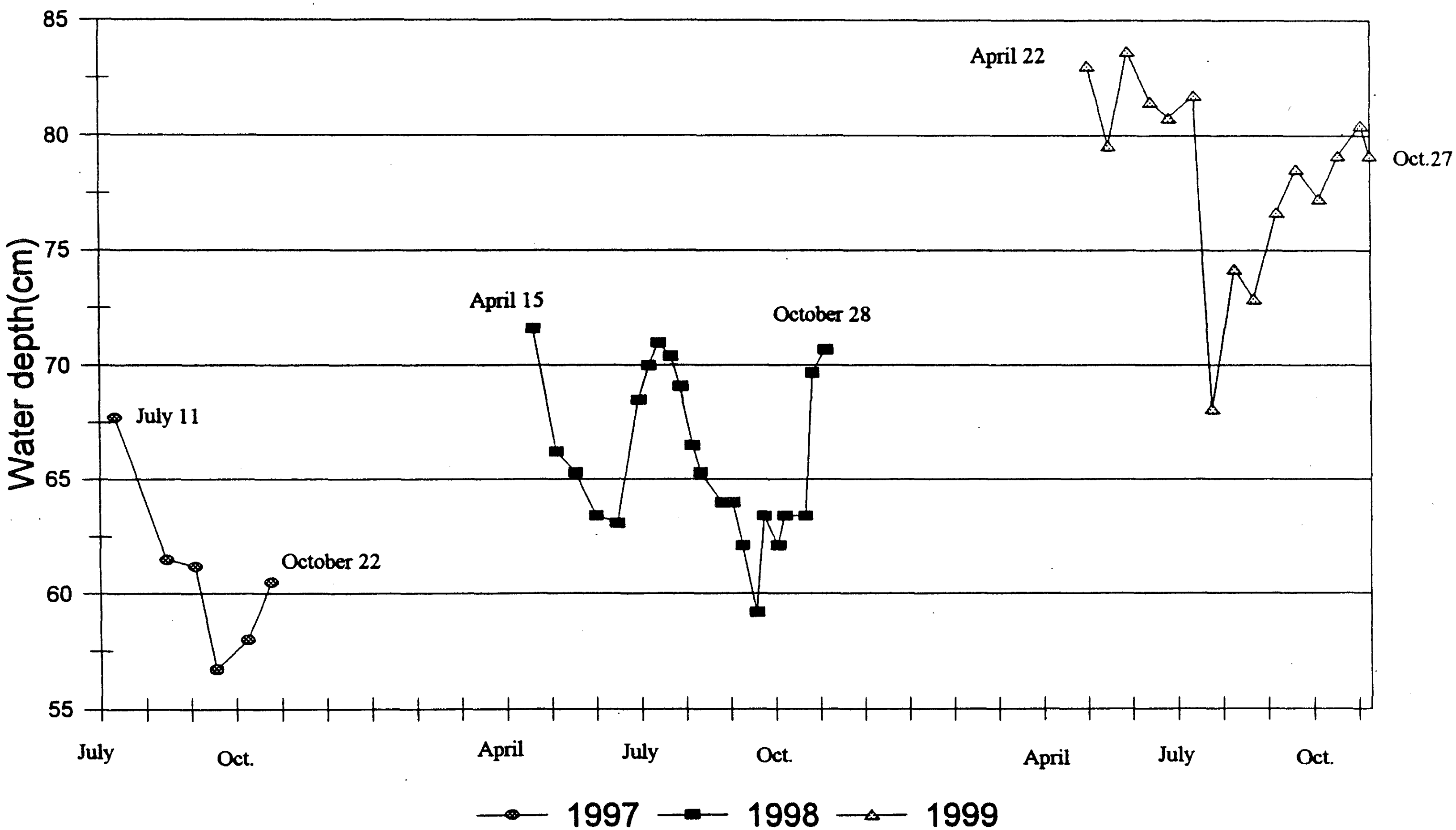
Note: Due to lack of rainfall, water was added to tank 7 on 8/19/98. On 9/16/98, water appears to be perched on top of the substrate. To maintain one foot of freeboard, 19.7 cm. was removed on 10/27/99.

Figure A6.9. Water level from substrate surface vs time for tank 8 (cattails on till).



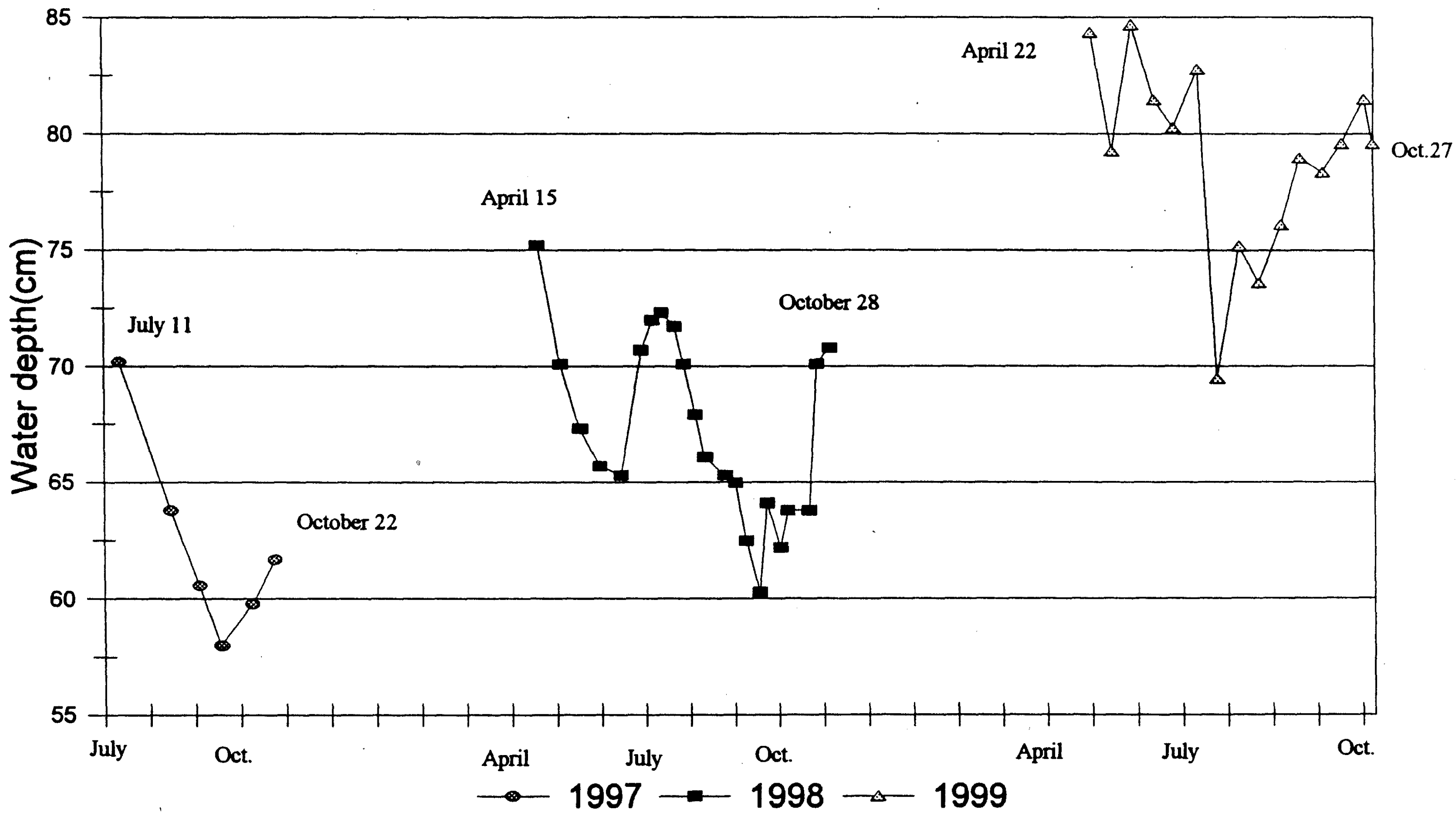
Note: Due to lack of rainfall, water was added to tank 8 on 8/19, 8/20, 8/21, 9/25/, and 9/28/98. To maintain one of freeboard, 5.1 cm. was removed on 10/27/99. -57.1 cm. is the measurement from the substrate to the bottom of the measuring well.

Figure A6.10. Water level from substrate surface vs time for tank 9 (water cover)



Note: To maintain one of freeboard, 29.2 cm. and 11.4 cm. were removed on 7/6/66 and 10/27/99 respectively.

Figure A6.11. Water level from substrate surface vs time for tank 10 (submerged aquatics)



Note: To maintain one foot of freeboard, 26.7 cm. and 9.5 cm. were removed on 7/6/99 and 10/27/99 respectively.

Appendix 7

Precipitation Data

Table A7.1. Daily precipitation data for 1997. Precipitation data from the Hibbing-Chisholm Airport. Precipitation recorded in inches.

Day	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1	0.01	T	0.28				0.43		0.11		0.15	
2			T				0.24				0.10	T
3			0.29				0.70	T		0.05	T	0.02
4	0.87		0.12	0.06		0.52						0.03
5	0.17	T	T	0.51	0.12	0.08	0.07			0.34		T
6			T	0.07					0.01	0.01	T	T
7				T	0.15		0.05		T	0.05		
8	0.01		T	0.01	0.22		T		T	0.09	T	T
9	0.03				T			0.11		0.03	T	
10	0.02	0.07	0.12		T						T	
11	T	T			0.24	T		T		0.89		T
12	T				T		0.09	0.06		0.86		
13	T	T	0.08		0.06		0.36		T	0.29	T	
14	T	T	0.05		0.23		T	T	0.10	0.07	0.01	
15	T	0.07		T		0.85		0.11	0.02		T	
16		0.01	T	T	T	T	0.09	0.06	0.92		T	
17		T			0.02	0.64						T
18		0.02		0.23	0.38				0.16		T	
19	T	T			0.15	0.03	0.15	0.80	T	T	T	
20								0.02		T		
21	T		T			0.01				T	0.22	
22	0.20	T	0.02		0.05	0.14	T			T	0.10	
23	0.14			T	0.22	0.91		0.06		T	T	
24	0.03		0.26			1.46	T	T		0.03		
25			0.02			0.02	0.05	0.07				0.02
26	T	T		0.01			0.51					
27	0.03	T		0.12		0.15	T		0.08		0.04	
28		0.37				1.15			0.34			0.06
29	T		T						0.14	T		0.01
30	0.07		0.05	T		T		T	T	0.09		0.01
31	0.18									0.42		T
Total	1.85	0.54	1.29	1.01	1.84	5.96	2.74	1.29	1.88	3.22	0.62	0.15

T = trace, blanks = 0.0 ppt.
Annual total = 22.39, Annual average for Hibbing = 26.93

Table A7.2. Daily precipitation data for 1998. Precipitation data from the DNR research site. Precipitation recorded in inches.

Day	Month											
	Jan.[1]	Feb.[1]	Mar.[1]	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1			.01			0.85						
2						0.70						
3			.01									
4												
5	.05		.07					0.05		0.94		
6	.04		.13		0.15		0.65					
7				0.25								0.50
8												
9	.02						0.15					
10	.03										0.09	
11	.05					0.34						
12			.08			0.42						
13		.05	.08	0.37	0.78		0.01					
14	.07	.15					0.82	0.45	2.02	0.26		
15		.02			0.38	0.04				0.12		
16	.05	.15				0.16				1.38		
17	.02	.01				0.03		0.70				
18					0.75							
19						1.62				1.24		
20							0.10	0.23				
21	.01								0.23			
22	.04		.01			0.49						
23	.03	.11										
24							0.02	0.30				
25	.04	.08	.03			0.47			0.06			
26		.54	.02			0.14						
27		.47					0.10					
28								0.11	0.26			0.75
29			.75			0.64	0.25					
30			.09			0.12	0.05		0.02	0.12		
31			.12									
Total	.45	1.58	1.40	0.62	2.06	6.02	2.15	1.84	2.33	4.06	0.09	1.25

Blank = 0.0 ppt.

Annual total = 23.67, Annual average for Hibbing = 26.93

[1]-Precipitation data obatained from Hibbing Taconite Company.

Table A7.3. Daily precipitation data for 1999. Precipitation data from the DNR research site. Precipitation recorded in inches.

Day	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
1						0.22	0.04					
2									0.56			
3								0.01				
4										0.01		
5												
6					0.89			0.70				
7					0.34	0.93	5.70		1.37			
8										1.05		
9							1.53	0.48	0.31			
10					0.55	0.77		0.45				
11					0.57							
12				2.50	0.80		0.06	0.04				
13								1.87	0.58			
14									0.11			
15												
16						0.05	2.36	0.47				
17					0.81							
18				0.13				0.13				
19								0.20				
20					0.23				0.02			
21				0.05								
22						0.85					0.05	
23							0.03	0.10				
24												
25					0.73					0.01		
26							1.96					
27									1.90			
28						0.90	0.33					
29												
30						1.05						
31								0.24				
Total	NA	NA	NA	2.68	4.92	4.77	12.01	4.69	4.85	1.42	.05	NA

Blank = 0.0 ppt. Annual total = 35.39, Annual average for Hibbing = 26.93

Note: The 2.50 inches on April 12th represents the total for all winter months.

Appendix 8

Activity Timelines

Attachment A8.1	Activity timeline for amended tanks.
Attachment A8.2	Activity timeline for control tanks.

Attachment A8.1. Activity timeline for amended tanks.

1997

6/17 Tailings removed from beach of tailings basin, stockpiled and allowed to drain.

6/23 Tailings loaded for transport to Minnesota.

6/24 Material delivered to Hibbing research site.

6/25 Added tailing and installed deep wells. The screen length is about 37 inches, installed horizontally, and oriented east-west. Wetland tanks were filled with water.

6/26 Added final amounts of tails (deep layer) to get them to appropriate levels. Installed 3 1/16" acrylic flanges around the 3/4" PVC well riser pipes and about 7 inches below the surface of the tailing. The tailing around the risers was compacted prior to adding the flange. The joint between the riser pipe and the flange was sealed with moist bentonite. Started filling the tanks with water at 1400 hrs. The water used was pumped from monitoring well #3 and stored for a day or so in three 500 gallon plastic tanks. By the end of the day, tanks 1-5 were filled about to the top of the tailing to minimize oxidation and promote settling.

6/27 Finished adding water to the tailings (lower layer). Water above the tailings ranged from 1-4". Added additional tailing and installed the shallow wells in tanks 2 and 7. The well screen was oriented north-south. The wells were similar to the deep wells, except the top of the riser pipe ended up about 4 inches higher than the one for the deep well.

7/03 Added enough water to cover the tailings in tanks 2 and 7.

7/07 Obtained well decomposed reed sedge peat from stockpile at Michigan Peat in

Cromwell, MN.

7/08 Added amendments (peat and overburden) to the shallow water tanks. Prior to adding amendments removed existing water that was above the tailings layer (residual water ~ ½") and smoothed surface of tailings with board. Wells were installed 28" from top of tank. A groove was made for the well. About 1/4" fine silica sand placed under well, then well was pressed into place. Additional sand was added as needed to cover the slots in the pipe. (The bottom half of the well was covered.) Composite samples of the peat and overburden were collected. A series of grab samples were collected from the trailer holding the overburden. Peat and till added to 16" from top of the tank. Overburden was Des Moines lobe material obtained from Brink Sand and Gravel's pit west of Grand Rapids, MN.

7/09 Collected cattails from Dunka Mine just upstream of the old wetland treatment cells (W-3D, W-4 area). The cattails were rinsed at Dunka and the tops were cut off to leave about a 9 inch stem.

Decided to remove all water that was covering tailings (tanks without amendments). By doing this, the initial conditions for all tanks would be the same. When the water was removed all tailings were grey except for tank 2 which contained a thin layer of oxidized tailings. These were removed with a peristaltic pump. 80 grams of 10-10-10 fertilizer was added to peat, till and tailings (fertilizer recommendation from Steve Dewar based on low fertility soil). Material was sprinkled evenly on top and then incorporated to a depth of about 2". A small amount (<10%) of fertilizer for Plot 6 was lost and not applied.) 16 cattails were planted on one foot spacing in each tank (except the deep water tanks).

7/10 Adding water to completely saturate all of the substrates. Conducted a water level and substrate survey in each of the tanks.

7/11 Topped off all tanks except #3 and #10 to bring the water level to 12 inches from the top of the tank. The water in tanks 3 and 10 were left about 8 inches lower to make it easier to add the submergent plants.

7/14 Noticed an orange (probably oxidation) around the Typha stems and leaves in the tailing tanks.

7/16 Noticed mosquito larvae in every tank and water striders in some tanks. About half of the typha are growing. Noted minor oxidation in tanks 2, 3, 7, and 10. Algal growth exists in tanks 2, 4, 7, with substantial algae in tanks 5 and 8. Tanks 3 and 10 were topped off to the 12 inch level (about 8 inches was added).

7/17 Conducted a pH and S.C. survey of the surface water.

7/25 Added submergent plants (Elodea, coontail, and long leaf pondweed) to tanks 3 and 10. The plants were simply placed into the water. The approximate moist weight (and volume) of Elodea, coontail, and pondweed added to each tank was 580 g (3.5 gal), 1345 g (3.5 gal), and 135 g (0.5 gal), respectively. Added 80 g of 10-10-10 fertilizer to tank 10 prior to adding the plants, and to tank 3 after the plants were added. The Elodea sank just below the water surface. The coontail generally sank to the bottom. The leaves of the pondweed floated. Cattails in Tank 3 (overburden) do not appear to be doing as well as other plots. This was the last tank planted and as a result received the less robust leftover plants.

7/28 Noticed dark brownish green scum layer floating in tanks 5 and 6. Tank 7 has a thin floating green algal layer covering about 40% of the water surface. Tank 2 had algae like tank 7, but less of it. The water was clear with no algae in tanks 1, 3, 4, 8, 9, 10. All plants look good. *Typha* rhizomes have emerged from the water in the peat and tails tanks. The rhizomes are not as mature (still under water) in the overburden tanks.

7/31	First sampling. Eh, pH, DO, and temperature were measured in the field using a flow cell.
8/04	Water levels of the surface water were measured and field observations taken.
8/8	Holding tanks for water addition: (#1)- S.C.= 650, PH = 7.44 (#2)- S.C.= 675, PH = 6.85 (#3)- S.C.= 650, PH = 7.79
8/14	Routine sampling period.
8/15	Routine water level measurements and comments.
8/27	Samples 90001-90005, 90007, 90009, 90011-90013, 90015,90016,90022,90030-90034, 90036, 90038, 90040-90042, 90044, 90045, 90050, 90051 All have rust ppt. forming on the bottom of the sample bottle.
8/28	Routine sampling period.
9/02	Routine water level measurements and comments.
9/03	Samples 90079-90083, 90085, 90087, 90089-90091 All have rust ppt. forming on the bottom of sample bottle.
9/08	The valves for the shallow wells in tanks 7 and 10 were open, closed valves. The coontail and *Elodea* look good. The pondweed is being grazed upon by lots of snails. The peat tanks were dry (i.e., no standing water) and the overburden tanks were almost dry. The *Typha* in tanks 2 and 7 (tails) is chlorotic and less vigorous than in the other tanks. Many cattail roots are growing above the surface in the tailings tanks (tanks 2 and 7).

9/09	Eh probe did not have solution in it on sampling day 8/14. Eh for this day are not accurate.
9/10	Routine sampling period.
9/11	Sample 90122 & 90124, SO4 and Metals are not filtered. Sample turned green with thick ppt. formed at end of filtration. Sample indicated by green below Alk/Acidity.
9/16	Routine water level measurements and comments.
9/22	Routine sampling period.
9/23	Samples 90115, 90119, 90121, 90123, 90125, 90127, 90129, 90130 all have rust ppt. forming on the bottom of sample bottle.
10/04	Conducted a SC and pH profile of the surface water in the deep water tanks.
10/06	Conducted a depth to substrate survey.
10/07	Routine water level measurements and comments.
10/21	Last sampling period for the season. Did not use flow cell, analyzed parameters in the lab.
1998	
4/30	Cattails sprouting in all cattail tanks.
7/08	Used 1/8" tubing for flow cell to check and see if the dissolved oxygen readings changed.

7/16	Tank 3 has most of the aquatics sunk to the bottom of the tank, approx. 1/4 are still floating. Tank 10 has all the aquatics sunk to the bottom. Tank 4 has no water in the measuring well. Tanks 5 and 6 have less than 1" in measuring wells.
7/22	Tanks 4,5,6,8 have no surface water for sampling.
7/23	Measuring wells installed in tanks 2,4,5,6,7,8.
8/19	Added water to Tanks 6,7,8 to approx. 1" above. Tank diameter = 46.5" (7.35 gal of water per inch). Tank 6 - start at 12:50, stop at 13:15 ht = 8 3/8" Vol. added 61.6 gal. 2.5" of water above substrate at deep well. Tank 7 - start at 13:15, stop at 13:25 ht = 2" Vol. added 14.7 gal. 2.25" of water above substrate at deep well. Tank 8 - start at 13:25, stop at 13:40 ht = 3" Vol. added 22.05 gal. 3" of water above substrate at deep well. Tank 6 had visible air bubbles when surface was covered with water. Tank 8 was similar but not as much. Tank 7 had no visible air bubbles.
8/20	Sample 90396 was from DNR well #3 at the research site. Cond. 500 pH 6.98 Eh 147 mg/L Alk. 210 mg/L Water addition to tanks 6,7, & 8. Tanks 6 and 8 have no surface water. Tank 7 has approx. 2 1/4" of water above substrate, measurement taken at the deep well pipe. Tank 6 - 16.5 gal added. Tank 8 - 18.4 added.

8/21 Tank 6 - water level at 1.75" above substrate at deep well.

Tank 7 - water level at 2" above substrate at deep well.

Tank 8 - no water at surface, added 18.4 gallons of water. After adding water the reading was 3" above substrate at deep well.

8/24 Tank 6 - Surface mostly free of water. Measurement in well to water 19".

Tank 7 - 2" of water above substrate at deep well. Measuring well - 15.5" to water in well.

Tank 8 - water level at 2.5" above substrate at deep well. 15.25" to water in measuring well.

<u>After water addition to Tank 6</u>

1.25" of water added. (9.2 gal.)

2.75" of water above substrate at deep well.

9/25 Tank 6 - Added 6.5" from tank. {6.5", 7.35 gal = 47.8 gal

Tank 7 - 2.75" of water above substrate at deep well.

Tank 8 - Added 2.75" from tank. (2.75", 7.35 ga = 20.2 gal.

3" of water above substrate at deep well.

9/28 Tank 6 has 1 ½" of water above substrate, no water was added to tank 7.

Tank 8 8.3 gal added.

Total water added since 8/19:

Tank 6 135.1 gal.

Tank 7 14.7 gal.

Tank 8 69 gal.

12/03 All tanks have ice on them except for tanks 4 and 5, which have no water on the surface.

1999

4/12 Depth to water from top of tank.

Tank	Depth to water(inches)
1	Large chunk of ice covers tank
2	8 $^3/_4$"
3	Large chunk of ice covers tank
4	11 $^1/_4$"
5	No surface water, measuring froze
6	9 $^3/_4$"
7	8 $^3/_8$"
8	7"
9	Ice covering 50% of tank
10	Thin layer covering 25% of tank

4/22 Nutrients were taken on all surface sites except for tank 5, where no surface water was present.

5/6 Conducted pH, S.C., and temperature survey every on the surface and interface sites. Depth profile for pH, S.C., and temperature every 6" for tanks 1,3,9, and 10. Both on land tanks have a small amount of salt residue on them.

After conducting profile on tank 4, checked pH calibration. Both buffer readings were right on.

7/6 Due to a large amount of rainfall, water was removed from tanks 1,3,9, and 10 to give one foot of freeboard.

Tank	Water removed
1	12$^1/_4$"(31.1cm.)
3	11$^1/_2$"(29.2cm.)
9	11$^1/_2$"(29.2cm.)

10	$10^1/_2$"(26.7cm.)

7/14 Tanks 4,5,6, and 8 have cattails all approx. the same height. Tanks 4 and 8 have numerous seed heads forming(a dozen per tank). Tanks 5 and 6 the cattails are darker green in color as compared with tanks 4 and 8.

8/11 The cattails in tanks 4,5,6, and 7 have brown tips on them.

9/15 Water addition to tank 6. Water was pumped from the DNR well on site into a polyethylene tank and syphoned into the tank with a garden hose. The well water pH was 7.14, S.C. was 450, and the alkalinity was 205 mg/L. The initial measurement to water in the measuring well was $40^1/_2$". 15 gallons of water was added at 1445 hours. The water measurement at 1515 hours was $20^3/_4$".

9/16 Water level measurement at 0800 hours was $22^3/_8$". Another 15 gallons of water was added in the same manner as the day before. The water measurement after addition was $17^3/_4$" at 0845 hours. At 1430 hours the water measurement was the same, $17^3/_4$". 3.75 gallons of water was again added to raise the water level. The final water measurement was $17^1/_2$".

10/27 To maintain one foot of freeboard, water was removed from tanks 1,2,3,4,7,8,9, and 10.

Tank	Water removed(gallons)
1	40.5
2	53.9
3	35.1
4	16.2
7	55.7
8	14.4
9	32.4
10	27.0

Attachment A8.2. Activity timeline for on-land control tanks.

1997

8/19 Installed plumbing in both tanks.

8/27 Added silica sand to cover the plumbing and then added approximately 36" of tailing to both tanks.

1998

5/07 Discovered a leak in the leak detection pipe. Pumped water and analyzed to determine which tanks the leak was coming from. Based on the analyses it appears that the leak is not coming from the tailing tanks.

6/11 There has been no flow from either tank. This may mean that either the tanks are leaking or there is a problem with the plumbing plugging. Covered both tanks.

6/18 In order to determine if the tank was leaking 12 gallons of distilled water was added to tank #12 (south tailing tank) at 8:15 and covered to prevent rain water from entering while conducting the leak test. No water had entered the sump as of 12:30 so an additional 12 gallons of distilled water was added and the tank covered..

6/19 The water in the leak detection pipe had a SC of 3700, and had a brownish tint to it. This may mean that there is a leak in one of the tailings tanks. No water had entered the sump as of 10:30. Pinched off the input line to the sump to see if additional water enters the leak detection pipe.

6/22 SC in the leak detection pipe was >5000 and there was no water in the #12 sump.

6/23 Detection pipe SC = >5000, pH = 3.74. Added 12 gallons to tank #11 at 1:10, waited 30 minutes and no flow to the sump, added another 12 gallons. Flow to the sump started at 2:30, ran two sump fulls of water and then pinched off the input line. Took a grab sample from the sump. SC = 17,200, pH = 3.03, Eh = 337.7, and ACY = 6,960. This tank may not be the cause of the leak.

7/04 Pinched off input line to the sump on Tank #12 to check for leaks. Added 28 gallons of distilled water to tailings tank #12 and covered tank.

7/06 Leak detection pipe sample had a pH of 3.26 and SC of 10,000. Uncovered Tank #11 because it appears that Tank #12 is the tank that is leaking.

7/22 Drained tailings tank #12 and removed tailings to check for possible leak. Covered tank.

7/24 Cleaned the remaining fines from tailings tank #12.

7/29 Added 5" of tap water to check for leaks. No sign of leaks and water flowed freely to the sump. Meter reading was 120L. Plugged outlet from the tank and filled the tank approximately 1/2 full and marked the water line to see if we lose water over time with additional head.

7/30 The tank level has dropped 1/4" and the meter reading is 127L. 7/8" of water in the leak detection. This indicates that the tank is not leaking substanially unless it is due to the added weight of the tailings.

7/31 The water levels in the tank and the leak detection are the same as on 7/30. Filled the tank to within 1" of the top.

8/03 The water level in the tank decreased by 3/8" since 7/31 and the leak deteciton level is at 1".

8/05 The water in the tank is holding steady.

8/12 1" of water in the leak detection.

8/17 1 1/8" of water in the leak detection. Pumped 26L down to 3/16". Took a sample, pH = 3.27 and SC = 6500.

8/24 3/4" of water in the leak detection.

8/25 Water level in the leak deteciton is unchanged.

8/26 Patched the tailings tank #12. Placed a 1" thick acrylic plastic plate around the outlet of the tank to allow for better support for the weight of the tailings. The plate was secured to the tank with Vulcuum cement both on the bottom and the edges to create a better seal. Will allow this to dry for several days before adding the tailings back to the tank.

9/02 Added the tailing to tailing tank #12 and covered the tank.

9/04 Pinched off the outlet line, added 28 gallons of distilled water to the tank and covered.

9/18 1/2" of water in the leak detection. Removed cover and clamp on the outlet line of tailing tank #12. Flow started into the sump. The meter reading of 127 will be considered the 0 flow point due to earlier tests. The flow stopped with a meter reading of 184L. (Total flow = 57 liters) The leak is apparently fixed.

10/16 Took a sample from the leak detection pipe and it had a pH of 6.28 and SC of

1950. This is an indication that Tank#12 is no longer leaking It is possible that the liner itself is leaking and the elevated SC is a result of residual contamination from previous leakage or leakage from the rock tanks.

<u>1999</u>

3/29 First flow of the spring was recorded.

4/01 The flow to the sump appears to be either air locked or partially plugged on both tanks. Disconnected the tubing and reconnected it and flow began.

5/6 Both tanks have a slight sulfur odor to them.

5/12 Same problem as on 4/01. Back flushed input line with about ½ gallon of distilled water and flow began.

5/17 There appears to be a continual problem with the output lines for both tanks either being air locked or partially plugged. Bled air from lines and flow began. Installed a tee in the lines and ran tubing up to above the sump to allow the air in the lines to have an exit port.

6/3 Both on land tanks have a slight sulfur odor to them.

6/10 The air release line doesn't appear to be helping the flow from the tanks. Back flushed output lines with distilled water and flow began.

7/27 Both tanks have generated some flow but it still seems to be slower than it should be. Bled air from lines and flow increased.

9/03 Back flushed output lines with distilled and flow increased.

9/13	Bled air from lines and flow began.
9/23	Both on land tanks have a salt like residue on the surface.
9/27	Bled air from lines and flow began.
9/27	Bled air from lines and flow began.
10/25	Bled air from lines and received no flow from either tank. Will have to try to determine the air locking or plugging problem and correct it before next field season.

Appendix 9

Quality Assurance

Attachment A9.1	Minnesota Department of Agriculture quality assurance program.
Attachment A9.2	Minnesota Department of Natural Resources quality assurance program.

Attachment A9.1.

Minnesota Department of Agriculture
Quality Assurance Program

Quality Assurance Objectives

Precision, accuracy, completeness, data comparability and sample representativeness are necessary attributes to ensure that analytical data are reliable, scientifically sound, and defensible. Each analytical result or set of results generated for this project should be fully defensible in any legal action, whether administrative, civil or criminal.

1. Definitions
   1.1 Precision
   Whenever possible, a minimum of one duplicate sample should be run in order to determine precision. It is understood that in some cases there may be insufficient sample to run duplicates and therefore a determination of precision would not be possible.
   1.2 Accuracy
   Whenever possible, a minimum of one matrix spike should be run in order to determine accuracy. It is understood that in some cases there may be insufficient sample to run matrix spikes and therefore a determination of accuracy would not be possible.
   1.3 Completeness
   Should be 100% ideally. Realistically a minimum level of 90% is expected.
   1.4 Comparability
   Should be ensured by adherence to method protocols.
   1.5 Representativeness
   Should be ensured by adherence to standard laboratory sub-sampling protocols. The nature of the material being sampled must be taken into account when subsampling.

The precision and accuracy of each method is dependent on the sample matrix and analyte concentration. Therefore, for these types of analyses, the matrix and concentration determine the values of precision and accuracy (bias) which are acceptable.

2. Parameter List, Matrix Type, Required Action Limits, Method Detection Limits

   Parameters
   Metals, sulfates and nutrients.

   Matrices
   Aqueous and Solids

   Required Action Limit
   Required action limits will be determined by the MDNR personnel prior to the analysis of samples by MDA. Action limits will be communicated to the Laboratory by the Minerals Reclamation Laboratory QA Officer.

   Method Detection Limit
   Method detection limits are determined by the laboratory following guidelines defined in EPA CFR 40 Part 136, Appendix B. Reporting limits are based on the lab MDLs and requirements for the program.

3. Laboratory Methods
   The laboratory will follow methods based on EPA methodologies and Standard Methods for the Examination of Water and Wastewater.

4. Samples
   4.1 Required Turn-Around Time for Analysis
   "Regular" parameters: 30 days after MDA receipt.
   "Permit" parameters within the stated time listed in the MPCA permit.

5. Quality Control Samples
   5.1 Field Blanks: One blank for every 50 samples of each experiment.
   5.2 Laboratory QC requirements and minimum volume of sample needed:
   - Metals- 60 mL
   - Sulfates- 60 mL

   5.3 Blind Set Points: One submitted with every box of samples.

Field Sampling Requirements

1. Type of Samples to be Collected.
   Aqueous samples will be colleted.

2. Field Sampling Requirements: NA

3. NPDES samples will require chain of custody and proper preservation as required for permit samples. This is required in the QA plan approved by Minnesota Department of Health.

4. Preservation
   All metals samples will be preserved with ultra pure nitric acid. Samples requiring refrigeration (storage at 4°C ± 2°) will be shipped on ice or cool packs to the MDA laboratory.

Sample Custody Requirements

1. Transportation of Samples from Field to Laboratory
   Regulator samples will either be shipped by State contract courier or hand delivered by Minerals personnel to MDA within 2 working days.
   Permit samples will wither be shipped by State contract courier or hand delivered by Minerals personnel to MDA within 2 working days of shipment. The samples will be sent on ice.

2. Notification Procedure
   MDA will be notified by the MDNR Program Coordinator or MDNR QA Officer when *Permit* samples are being shipped. MDNR will also alert MDA when "non regular" samples are being shipped.

3. Sample Log-in Procedure
   Upon receipt of the sample(s), the sample custodian inspects the shipping container(s), the sample(s), the official seal(s), and documentation related to the sample(s) and other records. If accepted for analysis, the sample(s) are entered by the sample custodian into the sample logbook, database and assigned a unique laboratory number.

Samples are to be properly documented, preserved, packaged, maintained under custody and transferred to the laboratory in a defensible manner. The Laboratory Information Section Supervisor should notify the MDNR Program Coordinator, appropriate MDNR Field Project Leader or Reclamation Laboratory QA Officer when problems are encountered with the quality of incoming samples or when laboratory problems arise that could affect the reliability and/or defensibility of analytical results.

4. Analysis
   A supervisor assigns the sample(s) to an analyst. After assignment, the sample custodian retrieves the sample(s) and transfers it to the analyst who completes the appropriate lines on the custody form. If the sample(s) is assigned to a different analyst, the appropriate lines in the second column of the custody form are completed by the new analyst. Similarly, the third column or even additional sheets can be used to document additional sample transfers within the laboratory. The original seal(s) should be kept with the sample(s) and maintained in a legible condition. Upon completion of the analysis, any remaining sample is placed in the appropriate storage location.

Calibration Procedures and References

1. Field Equipment Calibration
   None

2. Laboratory Calibration
   Each instrument used routinely in the laboratory should be monitored, calibrated, and maintained. Specifications for instrument maintenance, calibration and monitoring are described in manufacturer's manuals, in analytical methods, and/or appropriate standard operating procedures. If an instrument malfunctions, or if improper sensitivity, resolution and/or reproducibility is detected, corrective action is necessary before analyses are attempted. Any corrective action taken will be documented in the appropriate instrument manual.

   Analytical standards used to prepare calibration or standard solutions are obtained from the National Institute for Standards and Technology (NIST), EPA, USDA, FDA or other reliable sources. Stock standard solution(s) are prepared as specified in the SOP. All inform on their preparation is recorded in the designated logbook(s).

Depending on the method, a three to five point calibration curve will be used.

Analytical Procedures

1. Analytical Procedures
   All analyses for permit samples will be done according to methods approved by the Minnesota Department of Health as written in the MDA methods manual. These methods are based on approval EPA methodologies and Standard Methods for the Examination of Water and Wastewater.

   Other analyses will be done using laboratory methods based on EPA, ASTM, AOAC, etc. methodologies.

Data Analysis, Validation and Reporting

This section describes the basic procedures for data analysis, validation and reporting for this project.

1. Data Analysis
   Data analysis is performed on a batch run basis for samples analyzed using FAA and GFAA. Out of range samples are diluted manually for FAA and automatically for GFAA. Colorimetric autoanalysis usually relies on batch data analysis where confirmatory samples are then redirected to another automated method (IC) or a manual method. Manual methodology requires a sample by sample data analysis procedure, with confirmation by an alternate method if indicated. Details of data analysis are contained individual methods.

2. Validation of Results
   Validation of data is described in detail in the laboratory standard operating procedures. In most cases, data validation consists of a review of the analytical method. calculations and quality control results. Initial review is done by the analyst, and final review by the Chemistry Supervisor or a designated Senior Analyst. Certain samples or cases may be validated by the Laboratory Quality

Assurance Officer if required or desirable. When a review indicates a need, the analysis is repeated using either the same method or an alternate method. Questionable data may result from the condition of the sample, inadequacy of the method, lack of validation, time constraints or other factors.

Any questionable data will be clearly identified and qualified. The Laboratory Quality Assurance Officer conducts periodic in-depth audits to assure compliance with the validation requirements.

3. Reporting
   Analytical data is reported according to the format(s) provided in the standard operating procedures. In addition to the analytical results, the reference for the method and quality control results are reported. Quality control results may include spike recovery, results of duplicate analyses, analysis of reagent blanks, but are not limited to these. When the compound(s) of interest is not detected in the sample(s), it is reported as such with the method detection limit. Any pertinent observations about the samples or the analytical process are also reported.

   All written reports will be sent to the MDNR Program Coordinator.

Internal Quality Control Checks

The internal quality control (QC) checks are a systematic in-house approach to ensure the production of high quality data. The objectives of these control checks are:

- To provide reliable and defensible analytical results,
- To provide a measure of the precisions and accuracy of the analytical methods,
- To monitor the accuracy and precision of the analyst,
- To identify problematic methods which can be flagged for further research,
- To detect training needs within the laboratory,
- To provide a permanent record of instrument performance which is used for validating data and projecting instrument repair or replacement needs,
  To monitor the effectiveness of the quality assurance program and laboratory performance and provide a basis for modifications of the quality

assurance program.

The quality control procedures for analytical methods used for misuse cases may include:

- Demonstration of analytical capability,
- Analysis of a quality control check sample, when available,
- Daily instrument check,
- Recoveries of or matrix spikes,
- Analysis of reagent blank,
- Duplicate analysis,
- Analysis of laboratory control standards,
- Blind performance evaluation samples,
- Analysis of instrument quality control standards,
- Confirmation of analyte.

Performance and System Audits

The Minnesota Department of Agriculture is committed to participate in the evaluation of the laboratory quality assurance program and to lend itself to any coordinated on-site systems audits by qualified representatives of MDNR. The department is also committed to using the results of such performance and systems audits to improve the reliability, defensibility, capability and efficiency of the laboratory and filed operations. A quality assurance/quality control manual will also be available to the MDNR-mineral for review.

LSD will maintain accreditation with the Minnesota Department of Health with respect to clean water requirements including participation in EPA WP and WS proficiency samples.

Systems and laboratory audits along with analytical data and record review, may be performed by qualified representatives of MDNR which reserves such audit rights. The audit is conducted upon joint consent of both agencies. The report of all findings and recommendations are made promptly to the MDA. The systems audit includes areas in the laboratory immediately impacting overall quality assurance.

The Laboratory Quality Assurance Officer performs in-house systems audits to identify strengths, weaknesses, potential problems and solutions to problems. The audits provide an evaluation of the adequacy of the overall measurement systems to provide data of sufficient quantity and quality to meet the comprehensive laboratory pesticide program's objectives. The in-house systems audits are the basis for quality assurance reports to management.

The in-house systems audit consist of observing the various aspects of the laboratory activities related to this project. Check lists which delineate the critical aspects of each procedure are used during the audit and serve to document all observations. At a minimum, the following topics will be evaluated during the internal audit:

1. GENERAL PROCEDURES
   A. Procedures for Sampling and Sample Documentation
   B. Documentation of Procedures
   C. Sample Receipt and Storage
   D. Sample Preparation
   E. Sample Tracking

2. ANALYTICAL PROCEDURES
   A. General Instrumentation Procedures
   B. Calibration Procedures
   C. Internal Quality Control
   D. Data Handling Procedures

Preventative Maintenance Procedure and Schedule

1. Field Maintenance
   None

2. Laboratory Instrument Maintenance
   The primary objective of a comprehensive maintenance program is to ensure the timely and effective completion of a measurement effort. Preventive

maintenance is described in the laboratory or field standard operating procedures (SOPs) and appropriated instrument manual. It is designed to minimize the down time of crucial sampling and/or analytical equipment due to component failure. The focus of the program is in four primary areas:

- Establishment of maintenance responsibility.
- Establishment of maintenance schedules for major and/or critical instrumentation and apparatus.
- Establishment of an adequate inventory of critical spare parts and equipment.
- Documentation and filing of all service and maintenance records.

The Agronomy Laboratory supervisor is responsible for maintenance of laboratory instruments and equipment. The appropriate program managers are responsible for the maintenance of field equipment. With assistance from the Laboratory and Reclamation Laboratory Services Quality Assurance Officers, the Agronomy Laboratory establishes maintenance procedures and schedules for each piece of major equipment. Responsibility for individual items is delegated to technical personnel. The manufacture's recommendations and/or the protocols for instrument maintenance and calibration are followed. Each piece of major equipment is designated a repair and maintenance logbook where all maintenance activities are dated and documented by laboratory or filed personnel.

In the interest of maintaining instruments in top operating condition, it is management's policy to secure annual service contracts with instrument manufacturers whenever financially possible. The service contracts are especially desirable for laboratory instruments. Under the service contracts, certified service engineers perform preventive maintenance, calibration and repair for instruments. Laboratory personnel perform routine maintenance and repair between manufacturers' service to ensure correct performance of an instrument.

Analytical balances are serviced by certified service engineers at least once a year. In addition to performing repair and maintenance, the engineer calibrates and certifies each analytical balance. Laboratory personnel check the calibration of the balance with a class S weight at least four times a year. Digital pH meters are checked before each use with standards and calibrated according to the manufacturer's directions. Freezers and refrigerators are monitored to assure that proper temperatures are maintained and that failure has not occurred.

An adequate inventory of spare parts is maintained to minimize equipment down time. This inventory emphasizes those parts which:

- Are subject to frequent failure,
- Have limited useful lifetime,
- Cannot be obtained in a timely manner should failure occur.

Assessment of Data

An objective of the laboratory is to demonstrate that performance on all analyses is in statistical control. Routine procedures used to assess reliability and quality of data are specified in the laboratory standard operating procedures (SOPs).

For residue analysis, duplicates are used to establish precision, spike sample recoveries are used to establish accuracy and blanks are analyzed to assure non-interference from solvents, reagents and laboratory environment.

Precision refers to the reproducibility of replicate results about a mean which is not necessarily the true value. Duplicate analysis is the primary means of evaluating measurement data variability or precision. Two commonly used measures of variability which adjust for the magnitude of analyte concentration are coefficient of variation and relative percent difference.

The coefficient of variation is used most often when the size of the standard deviation changes with the magnitude of the mean. Coefficient of variation (CV), also called relative standard deviation (RSD), is defined:

$$CV \ or \ RSD = \left(\frac{s}{y}\right) * 100$$

where: y = mean of replicate analyses
s = sample standard deviation, defined as:

$$S = \sqrt{\sum_{i=1}^{N} \frac{(y_i - y)^2}{n - 1}}$$

where: y_i = measured valued of the ith replicate
y = mean of replicate analyses
n = number of replicates

Sample standard deviation (s) and coefficient of variation (CV) are used when there are at least three replicate measurements.

The second measure of variability which adjusts for the magnitude of the analyte is relative percent difference (RPD) or relative range (RR). This measure is used when duplicate measurements are made and is defined:

$$RR \ or \ RPD = \frac{|A - B|}{\left(\frac{A + B}{2}\right)} * 100$$

where: A = First observed values
B = Second observed values

Precision is monitored by plotting control charts for repetitive analysis. A warning limit of ±2s is established with a control limit of ±3s (see Section 3).

Accuracy is the nearness of a result to the true value and is often described as error, bias or percent recovery. Accuracy estimates are frequently based on the recovery of surrogate spikes and/or the recovery of know analytes. The percent recovery is calculated as:

$$\% R = \left(\frac{SSA - S}{SA}\right) * 100$$

where: SSA = measured concentration in spiked aliquot
S = measured concentration in unspiked aliquot

SA = actual concentration of spike added

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under correct, normal conditions. For all measurements, completeness is defined:

$$\% C = \left(\frac{V}{n} \right) * 100$$

where: %C = percent completeness
V = number of measurements judged valid
n = number of measurements necessary to achieve a specified statistical level of confidence in decision making

To determine "n" a judgment must be made regarding the amount of data required to provide adequate evidence that a system is in control. Completeness is calculated for monitoring programs where similar analyses are performed on a regular basis. Loss of data due to such occurrences as breakage of containers, spilling of the sample, contamination, instrument failure or exceeding holding time before analysis must account for no more than 10 percent of all requested analysis. If excessive loss of data occurs, the reasons must be identified and evaluated and, if necessary, action must be taken to solve the problem(s).

Corrective Action

Corrective action is taken whenever data is determined as unacceptable.

Corrective action is taken in the order listed below.
Review of sample collection procedures.
Review of analytical raw data and calculations.
Review of laboratory procedures - Was the analytical method followed?
Review of analytical method - Is it applicable?
Review of instrument operation, calibration and maintenance.
Review of the calibration standard(s) used.
Review of quality control measurement (spike, duplicate, surrogate, etc.).

As a result of the above review, further corrective action may be identified and pursued as necessary:

Repeat the sampling and corresponding documentation.
Issuing an amended analytical report.
Repeat analysis (confirmation methods).
Repair, recalibration or replacement of instrumentation.
Additional training of staff.

Persistent problems require a thorough review of all field and analytical data (including quality control measurements and procedures), increased check sample and reference material analyses and additional field and/or analytical system evaluations by outside agencies or individuals.

QA Reports to Management

A quality assurance report is generated by the Minnesota Department of Agriculture and Laboratory Services Division and sent to MDA and MDNR management at least once a year.

The report may contain the following:

- Changes in Quality Assurance Project Plan,
- Summary of quality assurance/quality control programs, training and accomplishments,
- Results of technical systems and performance evaluation audits,
- Significant quality assurance/quality control problems, recommended solutions and results of corrective actions,
- Summary of data quality assessment for precision, accuracy, representativeness, completeness, comparability and method detection limit,
- Discussion of whether the quality assurance objectives were met and the resulting impact on technical and enforcement areas,
- Limitations on use of the measurement data and discussion of the effects of such limitations on the defensibility of the data.

The MDNR Reclamation Laboratory QA Officer and MDA QA Officer will review this plan once a year.

Guide to analytical Values for Flame and Zeeman GFAA

Matrix Water
Date December 1995
The following detection limits were determined by analyzing the corresponding analyses on Flame and Zeeman GFAA.
Seven standard solutions of the same concentration, alternating with seven blanks were used to get the corresponding absorbance.
From the absorbance reading each detection limit was calculated using the Method Detection Limits according to US EPA recommendation.

Analyze	Method	Method Description	Detection Limit ug/L	Method	Method Description	Detection Limit ug/L
Al	3111D	Flame/Nitrous oxide	500			-
As				3113B	Furnace Zeeman	0.8
Ca	3111B	Flame/Acetylene	100			
Ca	3111D	Flame/Nitrous oxide	80			
Cd	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.4
Co	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.4
Cu	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.4
Fe	3111D	Flame/Acetylene	100			
Hg				2452	Auto Cold Vapor	0.5
K	3111B	Flame/Acetylene	50	3113B		
Mg	3111B	Flame/Acetylene	80	3113B		
Mn	3111B	Flame/Acetylene	100	3113B		
Na	3111B	Flame/Acetylene	50	3113B		
Ni	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.8
Pb	3111B			3113B	Furnace Zeeman	0.8
Sb				3113B	Furnace Zeeman	0.4
Zn	3111B	Flame/Acetylene	50	3113B		

Key:
- 3111B = Flame analyses using Air/acetylene gas
- 3111D = Flame analyses using Acetylene/Nitrous oxide gas
- 3113D = Zeeman Graphite Furnace analyses using argon gas

Source:
1) Standard Methods for the examination of water and wastewater 18th Ed. 1993.
   Greenberg, E. Arnold: Clesceri, S. Lenore and Easton, D. Andrew.
2) Analytical Methods for Graphite Tube Atomizers, Varian. 1988.
   Rothery, R. Varian Australia Pty. Ltd.
3) Analytical Methods Flame Atomic Absorption Spectrometry. 1989.
   Rothery, E. Varian Australia Pty. Ltd.
4) Methods for the determination of metals in environmental samples. 1992.
   U. S. Environmental Protection Agency.
   Smoley, C. K.

$$MDL = (t) * (s)$$

Where t = Student's t value for a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom. (t - 3.14 for several replicates).
s = standard deviation of the replicate analyses.

Attachment A9.2.

Department of Natural Resources
Laboratory Quality Assurance Program

Laboratory Calibration

- pH and specific conductance (SC) analysis of laboratory distilled water.
- Reference checks of Eh meter and probe.
- Daily calibration of pH meters with standard buffer solutions.
- Calibration of conductivity meters with standard reference solutions.
- Precision comparison between pH meters.
- Calibration at any time meter or probe is suspect.
- Accuracy check with inter-laboratory set point standards for pH, SC and alkalinity.
- Dissolved oxygen meters are calibrated before each sampling.

Laboratory Instrument Maintenance

- pH probes are cleaned according to probe manual instructions (EDTA) plus additional cleaning when used for measuring pH of extraordinarily dirty or organic samples (HCL).
- SC meters are cleaned using a mild cleaning solution when needed.

Analytical set points and distilled water blanks

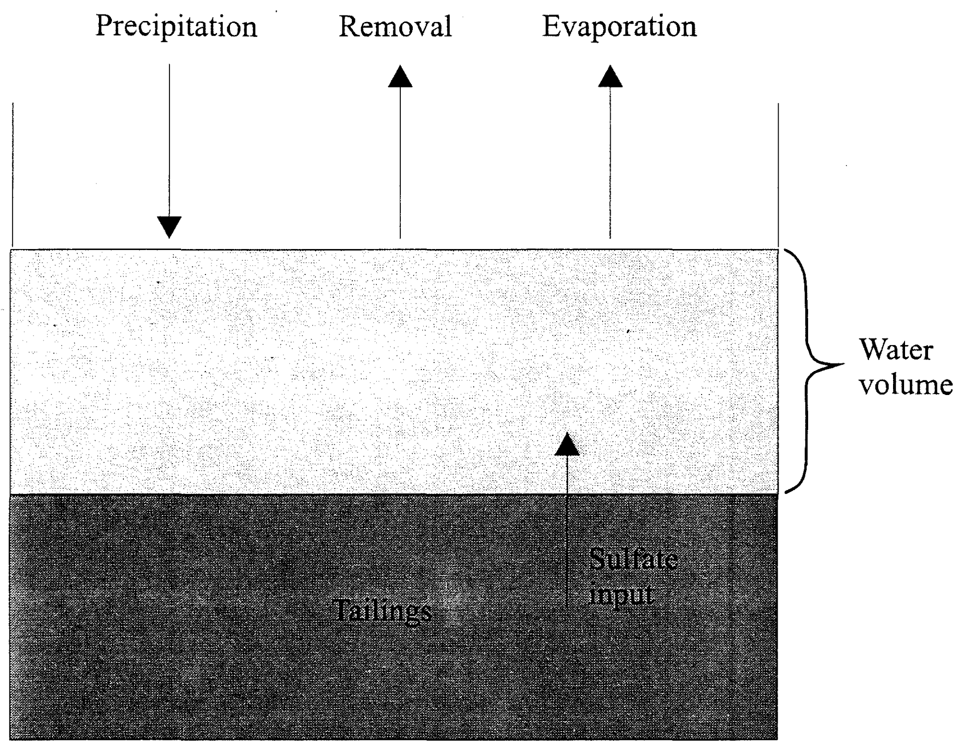
- One masked set point per 50 metals or sulfate samples sent to the Minnesota Dept. of Agriculture.
- One masked distilled water blank per 50 samples sent to the Minnesota Dept. of Agriculture to monitor for contamination from sample collection or laboratory washing procedures.

Appendix 10

Mass Release Model

Appendix 10
Mass Release Model

Deep water tanks:



Mass sulfate (t) = concentration (t) x volume (t)

Volume (t_{i+1}) = volume (t_i) + precipitation = evaporation - removal

Mass sulfate (t_{i+1}) = mass sulfate (t_i) + (volume precipitation x (C_{ppt})) - (volume evaporation x (C_{evap}))
- (volume removal ($C(t_i)$)) + release from tailings

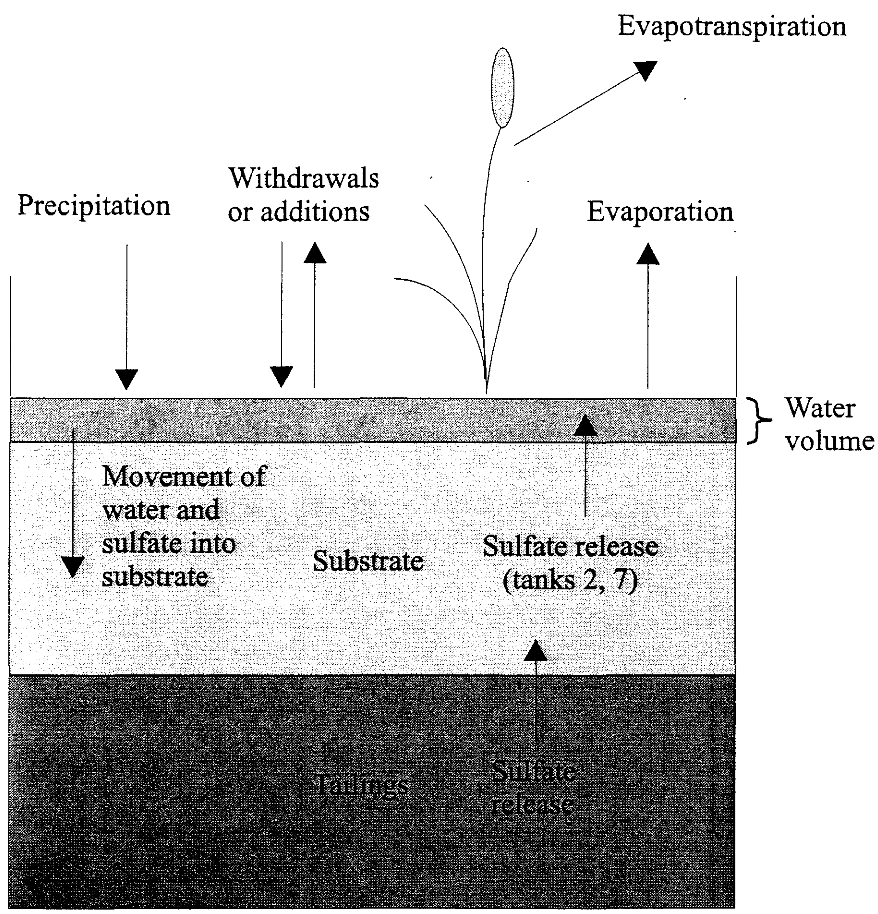
The volume (m^3) from precipitation and evaporation is determined by multiplying the values in meters by the collecting area (m^2).

The concentrations in precipitation and evaporation are small and, therefore, the mass contribution of these terms are negligible. If there was no withdrawal of water during the time period, the change in mass is equal to:

mass sulfate (t_{itl}) - mass sulfate (t_i) = release from tailings

Tanks with vegetation:

For tanks with vegetation, the model is more complex since sulfate can be transferred into the substrate as the water level decreases. In the tanks where the tailings are covered by a non-reactive substrate, (tanks 5,6,4,8), the sulfate release occurs at depth and may only slowly be transferred to the surface water. Since there is only one monitoring point in both the cover and the tailings layer, it is difficult to calculate the mass in each layer since concentrations may vary with respect to depth in the layer.



Appendix 11

Water balance

Attachment A11.1	Water balance calculations.
Table A11.1	Water balance.

Attachment A11.1
Water balance calculations

Water balances were calculated for all tanks, with the exception of tanks 6, 7 and 8, which had water added to them. Rates calculated from the tanks were compared to long term average data, which was taken from *Hydrology Guide for Minnesota* (1975.USDA.SCS), Chapter 8, pp. 8.1-8.16.

Average pan evaporation = 71 cm

Pan coefficient = 0.78

Long term average lake evaporation = pan coefficient x average pan evaporation

Long term average lake evaporation = 55.4 cm

Hibbing airport precipitation data: 11/97 - 10/98 = 61 cm

Table A11.1 Water balance.

Treatment	Tank	Change in water level (cm)	Precipitation input (cm)	Evapotranspiration (cm)	Lake evaporation (cm)	(Evapotranspiration/ Lake evaporation) x 100%
Cattails on tailings	2	+3.5		57.5		104
Cattails on glacial till	4	<-36.8 [A]		97.8 [A]		>177
Cattails on peat	5	<-55.2 [A]	61.0	116.2 [A]	55.4	>210
Water cover	1, 9	+11.2		49.8		90
Water cover + plants	3, 10	+9.6		51.4		93

[A] Water level dropped below substrate and monitoring well. To calculate the amount of moisture in cm, a porosity of 0.95 was assumed for peat, and 0.35 for glacial till.

Note: Tanks 6, 9 and 8 are not included in this table since they received periodic additions of water.