TACONITE TAILINGS IN-PIT DISPOSAL

FIELD TANK EXPERIMENTS

Data Summary
June, 1998

Minnesota Department of Natural Resources
Division of Minerals

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1. Executive Summary

Supported by a grant from the Iron Ore Cooperative Research Program, the Minnesota Department of Natural Resources (MN DNR) and the University of Minnesota (U of MN) have been studying the potential water quality implications of disposal of taconite tailings in existing mine pits across the Mesabi Iron Range. In order to simulate a small-scale pit disposal environment, four experiments were performed in large in-ground tanks at the MN DNR field experimental facility in Hibbing, MN.

Results have been compiled from the onset of the first experiments in September, 1996 through March, 1998. Surface water quality remained relatively constant throughout the study period. Fluctuations in the concentrations of most elements were most likely the result of seasonal changes such as wet or dry periods and freezing temperatures during the winter. However, manganese concentrations in surface waters appeared to be controlled by the formation of an oxidized solid phase, MnO_2.

Prolonged contact between taconite tailings and process water tended to improve water quality, particularly with respect to arsenic and molybdenum. Both manganese and fluoride levels appeared to be controlled by mineral phases within the tailings. Manganese concentrations appeared to be controlled by the pH-dependent dissolution of carbonate minerals (e.g. rhodochrosite or ankerite) found in the tailings. The pH of tailings pore waters was believed to be controlled by the oxidation of siderite present in the tailings. The concentration of fluoride in tailings pore waters probably depended upon the solubility of the mineral fluorite in an in-pit disposal environment.

In general, tailings pore waters associated with LTV tailings tended to be higher in dissolved constituents, particularly fluoride and molybdenum, than the Inland tailings pore waters. Furthermore, the tailings pore water quality observed in the tank experiments agrees relatively well with the water quality observed in related laboratory experiments (i.e. process water columns). Monitoring of the tanks is scheduled to continue until June, 1999. Efforts will be directed toward a deeper understanding of the physical, geochemical, and mineralogical factors that control the quality of tailings pore waters.

2. Introduction

The Biwabik Iron Formation in northern Minnesota is a world class resource of iron and taconite ore which has been mined extensively for more than a century and could continue to be mined for another century or more (Ojakangas and Matsch 1982). In addition, the Biwabik Iron Formation serves a less well known but important role as a major regional aquifer (Cotter et al. 1965). Because of this dual function, regional water supply issues must be considered when addressing mining related decisions affecting ground water.

Currently, tailings generated by taconite plants are slurried with water used in ore processing and pumped into large above-ground tailings basins. Suspended tailings settle to the floor of the basin, and the majority of the process water is recycled back to the taconite plant. Largely to avoid the need to construct and maintain these tailings basins, mining companies are exploring the feasibility of using existing mine pits in the Biwabik Iron Formation for tailings deposition and process water recycling. As additional benefits, this approach eliminates the risk of dam failure and also reduces the area of land (including wetlands) disturbed by mining, the amount of energy used for pumping tailings, and the potential for dust generation. Although legal barriers have previously prevented such applications, laws have been modified recently to allow issuance of permits for in-pit disposal of tailings provided it can be shown that ground water in the surrounding Biwabik Iron Formation will not be adversely impacted.

Supported by a grant from the Iron Ore Cooperative Research Program, the Minnesota Department of Natural Resources (MN DNR) and the University of Minnesota (U of MN) have been studying the potential water quality implications of disposal of taconite tailings in existing mine pits across the Mesabi Iron Range (Berndt, 1998; Lapakko et al., 1998; Berndt and Lapakko, 1997a, b). In order to simulate a small-scale pit disposal environment, four experiments were performed in large in-ground tanks at the field experimental facility at the MN-DNR, Hibbing, Minnesota. The experiments began in the fall of 1996, and are scheduled to continue until June 1999. This document summarizes the methods, results and preliminary conclusions from these small-scale tank experiments over the period from September, 1996 through March, 1998.

3. Methods

3.1. Field tanks

The "pits" were simulated by four polyethylene plastic tanks filled with tailings and process waters. The tanks were 3.05 m (10 ft.) tall by 1.22 m (4 ft.) in diameter, and embedded 2.74 m (9 ft.) deep into an embankment (figure 1). Since the experiment was designed to approximate field conditions, the top of each tank was open to the atmosphere. However, to address safety issues, the tanks were covered during the summer months. The covers were constructed of plastic, and had a one inch hole in the center to allow for air and precipitation transfer. During the winter months, the tanks were covered with a 5 cm Styrofoam cover to reduce ice buildup.

Tailings and process waters were obtained from the tailings basins, and transported to the MN DNR Hibbing field experimental facility as a slurry via cement truck. The rotating drum in the cement truck was cleaned and inspected for residual cement before being filled with tailings and associated process water. The rotating drum was thoroughly rinsed with fresh tailings before being used to collect tailings and process waters used in the experiments. Because tailings discharge contains a large fraction of process water, filling the tank in two stages was necessary. In the first stage, the tank was filled to the top and the tailings were allowed to settle out of solution for one week. Water above the tailings was then decanted before filling the tanks with a second batch of tailings and process waters. The entire process of filling the tanks took approximately one week to complete. A composite tailings sample was obtained from each of the tailings additions for each tank.

Four tanks were filled with tailings (Tanks 1- 4). Tanks 1 and 2 were filled with tailings from LTV Steel on September 13 and 16, 1996, while Tanks 3 and 4 were filled with tailings from Inland Steel on October 29 and November 8, 1996. The total depth of tailings in each tank depended on the amount of tailings present in the slurry used to fill the tanks. Total depth of tailings after settling was 152.4, 165.1, 144.8, and 137.2 cm for Tanks 1, 2, 3, and 4, respectively.

3.2. Sampling methods

The initial sampling procedure for Tanks 1 and 2 consisted of opening a valve on the outside of the tank. The valve was connected to a horizontal tube, screened its entire length and positioned at the desired location within the tank (figure 1). Two ports facilitated sampling of fluids at different levels within the settled tailings. The "bottom" port was placed 7.6 cm above the base of the tank at a depth of approximately 1.2 m below the tailings-water interface. The "middle" port was 1.0 m above the base of the tank, within 0.3 m of the tailings-water interface. Surface water samples were obtained approximately 15 to 20 cm below the water-atmosphere interface.

On October 10, 1996, the valve stems broke on both Tank 2 ports. Subsequent design modification involved constructing small sampling wells for both tanks, which were installed October 29, 1996. The wells were constructed of 2.54 cm (1 in.) inner diameter PVC pipe with a 7.6 cm section of slotted well screen (0.03 cm, or 0.012 in. slots) positioned at the sample points (figure 2). On October 24, 1997, a flange was installed just below the surface of the tailings to prevent preferential flow down the well during pumping.

Tanks 3 and 4 were designed with an interior well sampling apparatus prior to tailings addition (October 23, 1996). Two 0.97 m long, 2.54 cm diameter horizontal PVC slotted well screens were attached to a 2.54 cm vertical PVC pipe that extended above the tailings (figure 3). The slotted well screens (0.03 cm slots) were slotted on the bottom side of the screen. This design greatly improved the rate at which water could be extracted from the tank experiments, and reduced the potential for sample contamination caused by preferential downward flow along the well casing.

Once the wells were installed in Tanks 1 and 2, the same sampling method was used for all four tanks. Each well was sealed with a tight end-cap to prevent oxygen transport down the wells between sampling periods. To extract a sample, the end cap was removed and the upper well section was screwed into a female fitting. A 0.1 cm (0.25 in.) PVC pipe equipped with a 0.1 cm hose adaptor and Tygon tubing was used as a feed line to a Model 107090-10 Delrin plastic Guzzler pump (figure 4). Samples were taken periodically from all wells on all four tanks until July 31, 1997. After July 31, only the surface and tailings pore (bottom port) waters were sampled (Appendix 1).

3.3. Analytical methods

3.3.1. Composite tailings samples

Composite tailings samples collected during the filling of the tanks were analyzed for particle size (Lerch Bros.), whole rock and trace elements (Act Labs). These results have not been received at the time of this report.

3.3.2. Analysis of tailings pore water composition

Water samples were analyzed at the MN DNR laboratory in Hibbing, MN for pH, Eh, specific conductance, and alkalinity. An Orion SA 720 pH meter equipped with a Ross combination pH electrode (model 8165) was used for pH analysis. A Beckman Eh meter equipped with an Orion combination redox electrode (model 9678BN) was used for Eh analysis. Specific conductance was measured using a Myron L model EP conductivity meter. Alkalinity was determined using standard titration technique (APHA et al., 1995).

Major and trace elements were analyzed at the University of Minnesota. Cations were filtered and acidified with 0.2 mL of Baker Instra-Analyzed nitric acid per 50 mL and analyzed using an inductively coupled plasma mass spectrometry (ICP-MS, Perkin Elmer mode-SCIEX-Elan 5000). Anions were filtered and measured using ion chromatography (IC, Dionex Ion Chromatograph fitted with GP40 gradient pump, CD20 conductivity detector, and two AS4A anion exchange columns).

4. Results and Discussion

Tanks 1 and 2 represent duplicate experiments with tailings from LTV (Appendix 2). Likewise, Tanks 3 and 4 represent duplicate experiments with tailings from Inland

(Appendix 3). Visual inspection of these figures shows that the tank experiments were reproducible for each tailings source. The surface and tailings pore water samples taken from Tank 4 on December 17, 1997 appeared to have been mislabeled. This supposition could neither be confirmed nor denied. However, for the purposes of this report, the December 17, 1997 surface water sample from Tank 4 will be discussed in the tailings pore water section, and vice versa.

4.1. Manganese

4.1.1. Manganese concentrations in tank surface waters

During the initial stages of the tank experiments, manganese concentrations in surface waters remained constant (figure 5). Average manganese concentrations were 30 ppb over 19 and 28 weeks for LTV Tanks 1 and 2, respectively, and averaged 79 ppb over 8 and 16 weeks for Inland Tanks 3 and 4, respectively. After this initial period, manganese concentrations in all four tanks decreased to levels that were typically less than 4 ppb.

The length of time required for manganese concentrations to decrease to these low levels has not been precisely determined. These data imply that the residence times for manganese in an oxygenated water in contact with taconite tailings were in the range of 19 to 45 weeks in Tank 1, 28 to 45 weeks in Tank 2, 8 to 38 weeks in Tank 3, and 16 to 38 weeks in Tank 4. Assuming no additional manganese inputs (i.e. after tailings input ceases), these observations can be combined to estimate the residence time of dissolved manganese in a hypothetical in-pit disposal environment. The maximum span of time required for manganese to reach acceptable levels could vary from two to eleven months. The minimum residence time can be estimated at seven to nine and a half months. Subsequent experiments will more precisely determine the residence time of dissolved manganese in oxygenated waters of a hypothetical in-pit tailings disposal environment.

The mechanism controlling manganese levels in the tank surface waters is believed to be the oxidation of manganese and subsequent formation of MnO_2. Manganese is unstable in an oxidizing environment, such as the surface waters in these tank experiments. Dissolved manganese will readily react with dissolved oxygen to produce MnO_2. The kinetics for this reaction are slow in the pH range of the tank experiments (Stumm and Morgan, 1995). However, MnO_2 formation is an autocatalytic reaction. Thus, the rate of manganese oxidation should increase as MnO_2 forms. The observed decrease in manganese concentrations in the surface waters of the tank experiments appeared to fit this model.

4.1.2. Manganese concentrations in tailings pore waters

Manganese concentrations generally increased in the tailings pore waters at the base of the tanks (figure 6). Initial concentrations in the LTV tanks averaged 50 ppb (figure 6a). As of week 79, manganese had increased to approximately 118 ppb. Over the same time period, the tailings pore water pH decreased from approximately 8.3 to 8.0.

After an initial increase, manganese concentrations in tailings pore waters from the Inland tanks began to decrease (figure 6b). During the first 21 weeks, manganese concentrations increased from approximately 71 ppb to 111 ppb, and pH decreased from 8.4 to approximately 8.1. From week 21 to week 72, manganese concentrations decreased to approximately 65 ppb the pH increased to 8.5.

These data suggest that a negative correlation exists between manganese concentrations and pH (figure 7). The pH of tailings pore waters is believed to be controlled by the oxidation of siderite present in taconite tailings (Berndt, 1998). Even small quantities of dissolved oxygen will oxidize siderite, producing iron oxide and carbonic acid (reaction 1):

$$FeCO_3 + 1/4\ O_{2(aq)} + 5/2\ H_2O \rightarrow Fe(OH)_3 + H_2CO_{3(aq)} \qquad (1)$$

The production of dissolved carbonic acid lowers pH and elevates alkalinity. Carbonic acid produced by reaction 1 may then react with minerals within the tailings (e.g. carbonates), releasing manganese and other metals into solution (reaction 2).

$$2H_2CO_{3(aq)} + CaMn(CO_3)_2 \rightarrow Ca^{2+}{}_{(aq)} + Mn^{2+}{}_{(aq)} + 4HCO_3^-{}_{(aq)} \qquad (2)$$

Previous mineralogical analyses have identified manganese-containing carbonates such as rhodochrosite and ankerite in taconite tailings from mining operations in northern Minnesota (Mattson, 1996). The idea that siderite oxidation controls pore water pH levels is consistent with field observations regarding the lack of organic matter associated with taconite tailings, and mildly reducing conditions found in seeps and wells associated with tailings basins.

4.2. Fluoride

4.2.1. Fluoride concentrations in surface waters

Fluoride concentrations fluctuated within a fairly constant range throughout the tank experiments, averaging 8.4 ppm in the LTV tanks and 4.5 ppm in the Inland tanks (figure 8). Since surface waters were continually exposed to the elements, concentration variations could have been the result of seasonal events. Precipitation and spring snow/ice melt could have diluted surface waters in the tanks. Evaporation during dry periods and ice formation during the winter could result in concentration of elements in surface waters.

Seasonal effects on surface water quality were evaluated using relative concentration changes (C/C_o) of the elements that were considered generally nonreactive (Cl, Br, Na, and K). The average concentration over the initial four (LTV) and eight (Inland) weeks was used to represent C_o for each element. Seasonal concentration changes were determined by comparing the relative concentration changes for each element to the average relative change for the nonreactive elements. Relative fluoride concentration changes matched those of the nonreactive elements for both sets of experiments. Thus, the observed fluoride concentration fluctuations in surface waters were most likely due to seasonal events such as precipitation and dry or cold periods.

4.2.2. Fluoride concentrations in tailings pore waters

Fluoride concentrations in tailings pore waters from the LTV experiments averaged 7.4 ppm and fluctuated between 6.4 ppm and 10.1 ppm (figure 10a). In the Inland tanks, fluoride levels increased from 4.9 ppm to 7.7 ppm over the first 16 weeks of the experiment, and subsequently dropped to steady concentrations averaging 3.8 ppm and 5.2 ppm for Tanks 3 and 4, respectively (figure 10b).

Earlier work showed that fluoride concentrations in tailings pore waters were controlled by saturation with respect to fluorite,CaF_2 (Berndt, 1998; Lapakko et al., 1998; Berndt and Lapakko, 1997a, 1997b). However, quantification of fluorite solubility has been an issue. Two solubility constants reported in the literature appear to describe fluoride levels in active taconite tailings basins. The Geochemist's Workbench modeling software uses a $K_{sp} = 10^{-10.58}$, while Brown and Roberson (1977) determined a $K_{sp} = 10^{-10.98}$. Both of these experimentally determined solubility constants are considerably lower than the solubility constant calculated from standard Gibbs free energies ($K_{sp} = 10^{-9.8}$; Krauskopf and Bird, 1995). However, these discrepancies often occur due to differences in experimental methods and/or slow kinetics.

The composition of the LTV and most of the Inland tailings pore waters fell between the calculated fluorite saturation curve and those reported in the literature (figure 11). However, an apparent negative correlation between fluoride and calcium in the LTV tailings pore water suggests that these data may represent the "real" fluorite solubility curve for water in intimate contact with taconite tailings. Approximately one third of the tailings pore water samples from the Inland tanks fell on or near the LTV curve. If this curve applies to Inland's tailings, approximately two thirds of the Inland tailings pore water samples were undersaturated with respect to fluorite.

Alternatively, nearly two thirds of the Inland samples fell near the saturation curve determined by Brown and Roberson (1977) (figure 11). If this curve represents the true fluorite solubility curve, then the LTV tailings pore waters were supersaturated with respect to fluorite. However, this does not explain the negative correlation observed between fluoride and calcium in the LTV tailings pore waters. The possibility exists that a single solubility curve cannot reliably describe fluorite saturation in tailings pore waters across the Mesabi Iron Range. Additional sampling during the remainder of the experiment will determine if tailings pore waters will reach saturation with respect to fluorite in the future.

4.3. Arsenic

4.3.1. Arsenic concentrations in surface waters

Arsenic concentrations in surface waters from the LTV tanks averaged 5.8 ppb (figure 12). Fluctuations in these concentrations were primarily due to seasonal events (see discussion in section 3.2.1; figure 13).

In the Inland tanks, arsenic concentrations averaged 2.0 ppb for the first 38 weeks, and subsequently began to increase reaching maximums of 11.5 ppb and 13.9 ppb in Tanks 3 and 4, respectively. The large difference between the arsenic relative concentration changes and those of the nonreactive elements implies that the increase in arsenic concentration in the Inland tanks was not a seasonal event (figure 13). This increase may have been related to increasing pH of the Inland tank surface waters (Figure 14). After an initial decrease, the pH of the surface waters increased from approximately 8.3 to 8.8, exceeding the zero point of charge for most iron oxides (Langmuir, 1997). At a pH of 8.8, any adsorbed arsenic could be released into solution. This relationship will be examined further as additional data are gathered during the upcoming year.

4.3.2. Arsenic concentrations in tailings pore waters

Arsenic concentrations decreased over time in the LTV tailings pore waters, reaching 1.8 ppb as early as week 12 (figure 15a). This decrease was most likely due to adsorption of dissolved arsenic by iron oxide minerals present in the tailings. Taconite tailings used in related experiments contained 5-19 wt% iron oxide minerals (Berndt and Lapakko, 1997a), providing an ample number of sorption sites.

The sharp increase in arsenic concentrations that occurred between weeks 12 and 19 was most likely caused by surface contamination of the tailings pore waters. Surface water may have percolated downward through channels created during the installation of new sampling wells on October 29, 1996 (week 8). However, arsenic concentrations in subsequent samples continued to decrease and appeared to be approaching a constant concentration of approximately 1.8 ppb. These data suggest that LTV taconite tailings contain adequate amounts of iron oxide minerals to sequester dissolved arsenic in a pit disposal environment.

Arsenic concentrations in the Inland tailings pore waters remained relatively constant, averaging 2.3 ppb with a minimum of 0.6 ppb and a maximum of 4.2 ppb (figure 15b). However, arsenic concentrations appear to be increasing between weeks 52 and 72. Future monitoring will help determine whether or not this trend is real.

4.4. Molybdenum

Molybdenum concentrations fluctuated within a constant range in the surface waters of all four tank experiments (figure 16). The average molybdenum concentrations were 295 ppb and 68 ppb for the LTV and Inland experiments, respectively. A comparison of relative concentration changes for molybdenum and the nonreactive elements indicated that the fluctuations were the result of seasonal factors (see discussion section 3.2.1; figure 17).

Molybdenum concentrations decreased over time in the LTV tailings pore waters (figure 18a). As with arsenic, molybdenum levels are believed to be controlled by adsorption to iron oxides. Initial concentrations averaged 285 ppb, and rapidly decreased to approximately 68 ppb by week 12. The surface contamination described in section 3.3.2 was also evident with molybdenum. However, as of week 79, molybdenum concentrations in Tanks 1 and 2 were 91 ppb and 27 ppb, respectively. Molybdenum concentrations in the Inland tailings pore waters remained relatively constant at an average of 25 ppb, ranging from 13 ppb to 45 ppb (figure 18b).

5. Water Quality Associated with LTV Tailings Relative to Inland Tailings

The quality of water associated with the tailings varied somewhat with respect to the source of the tailings. In general, water in contact with tailings from LTV tended to be higher in dissolved constituents, particularly fluoride and molybdenum (figure 19). Fluoride levels were approximately 7 ppm in the LTV experiments compared to 5 ppm in water from the Inland experiments. Molybdenum concentrations in water from the LTV tanks were approximately five times higher than the water from Inland's tanks. Manganese, arsenic, calcium, and pH levels appeared to be independent of the tailings source (table 1).

6. Water Quality Relative to Laboratory Process Water Column Experiments

6.1. LTV experiments

Tailings pore waters from the wells at the base of each tank experiment were compared to laboratory column experiments using tailings and process water from the corresponding taconite operation. Overall, the quality of LTV tailings pore waters from the field tank was similar to the laboratory column experiments (figure 20). Manganese and pH were the exceptions. Manganese concentrations in the tank waters were nearly one third the concentrations observed in column effluents (table 2). Lower manganese concentrations may have been due to the slightly higher pH of tailings pore waters in the tank experiments, resulting in less dissolution of manganese carbonate minerals.

Temporal concentration trends were also very similar between the LTV tank and column experiments (figure 22). However, a discrepancy was noted for manganese concentration changes over time. Manganese increased during the tank experiments. However, after an initial sharp increase at the onset of the column experiments, manganese concentrations began to decrease.

6.2. Inland experiments

The quality of water that evolved due to contact with Inland tailings in the tank did not match that of the laboratory column experiments using Inland tailings (figure 21). Manganese, arsenic, molybdenum, and calcium concentrations were lower in the tank tailings pore waters than observed in column effluents. Manganese levels were approximately one fifth of those observed in column effluents. Once again, it is believed that the higher pH in the tank tailings pore waters inhibited manganese carbonate dissolution, resulting in lower manganese levels. Arsenic and molybdenum levels were nearly half that of the column experiments. Fluoride concentrations were nearly twice as high as observed in column effluents (table 3).

Although the water quality of the tailings pore waters associated with Inland tailings differed from that of the column effluents, the temporal changes in water quality were fairly similar. Manganese concentrations generally increased over time. However, manganese levels began to decrease after 21 weeks in the tank experiment. Fluoride levels decreased overall in both experiments. Although arsenic and molybdenum concentrations decreased in the column effluents, they had not yet reached the levels observed in the tank tailings pore waters. The constant arsenic and molybdenum concentrations observed in the tanks may represent an equilibrium level to which the column effluents were approaching. These discrepancies will be the focus of further investigation as these experiments continue.

7. Future Monitoring

Monitoring of all four tank experiments is scheduled to continue on a quarterly basis until June 1999. Excluding fluctuations caused by changing weather conditions, the composition of the surface waters are expected to remain constant for the duration of the experiment. The pH of the tailings pore waters is expected to steadily decrease, providing further data to evaluate processes that may be pH controlled. Special attention will be paid to manganese and arsenic concentrations relative to pH of the tailings pore fluids. Finally, additional data will be gathered to evaluate controls on fluoride levels in taconite tailings pore waters.

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Table 1. Water quality associated with tailings from LTV was generally higher in dissolved constituents than waters associated with Inland's tailings.

Element	Mine	N	Average	Maximum	Minimum
Mn (ppb)	LTV	25	93.9	254	43.4
	Inland	26	78.6	117	49.7
F (ppm)	LTV	23	7.3	10.1	6.3
	Inland	24	5.1	9.0	3.7
As (ppb)	LTV	25	3.5	7.7	1.3
	Inland	26	2.2	4.2	0.6
Mo (ppb)	LTV	25	120	305	18.2
	Inland	26	25.2	45.1	12.6
Ca (ppm)	LTV	23	24.0	28.1	18.4
	Inland	24	25.8	30.6	22.7
pH	LTV	25	8.2	8.5	8.0
	Inland	24	8.4	8.6	7.8

Table 2. Water quality was similar from both the tank and column experiments using tailings from LTV.

Element	Experiment	N	Average	Maximum	Minimum
Mn (ppb)	Tank	25	93.9	254	43.4
	Column	18	249	388	67.5
F (ppm)	Tank	23	7.3	10.1	6.3
	Column	18	7.2	9.3	6.1
As (ppb)	Tank	25	3.5	7.7	1.3
	Column	18	3.5	5.9	0.9
Mo (ppb)	Tank	25	120	305	18.2
	Column	18	66.5	338	12.3
Ca (ppm)	Tank	23	24.0	28.1	18.4
	Column	18	38.9	47.8	17.4
pH	Tank	25	8.2	8.5	8.0
	Column	18	7.9	8.4	7.4

Table 3. Manganese, arsenic, and molybdenum concentrations in the Inland tank experiments were one half to one fifth of those observed in column effluents. The range of fluoride concentrations in the tanks was higher than in the columns, while pH covered the same range in both experiments.

Element	Experiment	N	Average	Maximum	Minimum
Mn (ppb)	Tank	26	78.6	117	49.7
	Column	18	425	698	112
F (ppm)	Tank	24	5.1	9.0	3.7
	Column	18	3.1	3.7	2.8
As (ppb)	Tank	26	2.2	4.2	0.6
	Column	18	5.8	11.5	2.1
Mo (ppb)	Tank	26	25.2	45.1	12.6
	Column	18	42.8	100	14.9
Ca (ppm)	Tank	24	25.8	30.6	22.7
	Column	18	37.9	49.3	26.1
pH	Tank	24	8.4	8.6	7.8
	Column	18	8.0	8.3	7.6

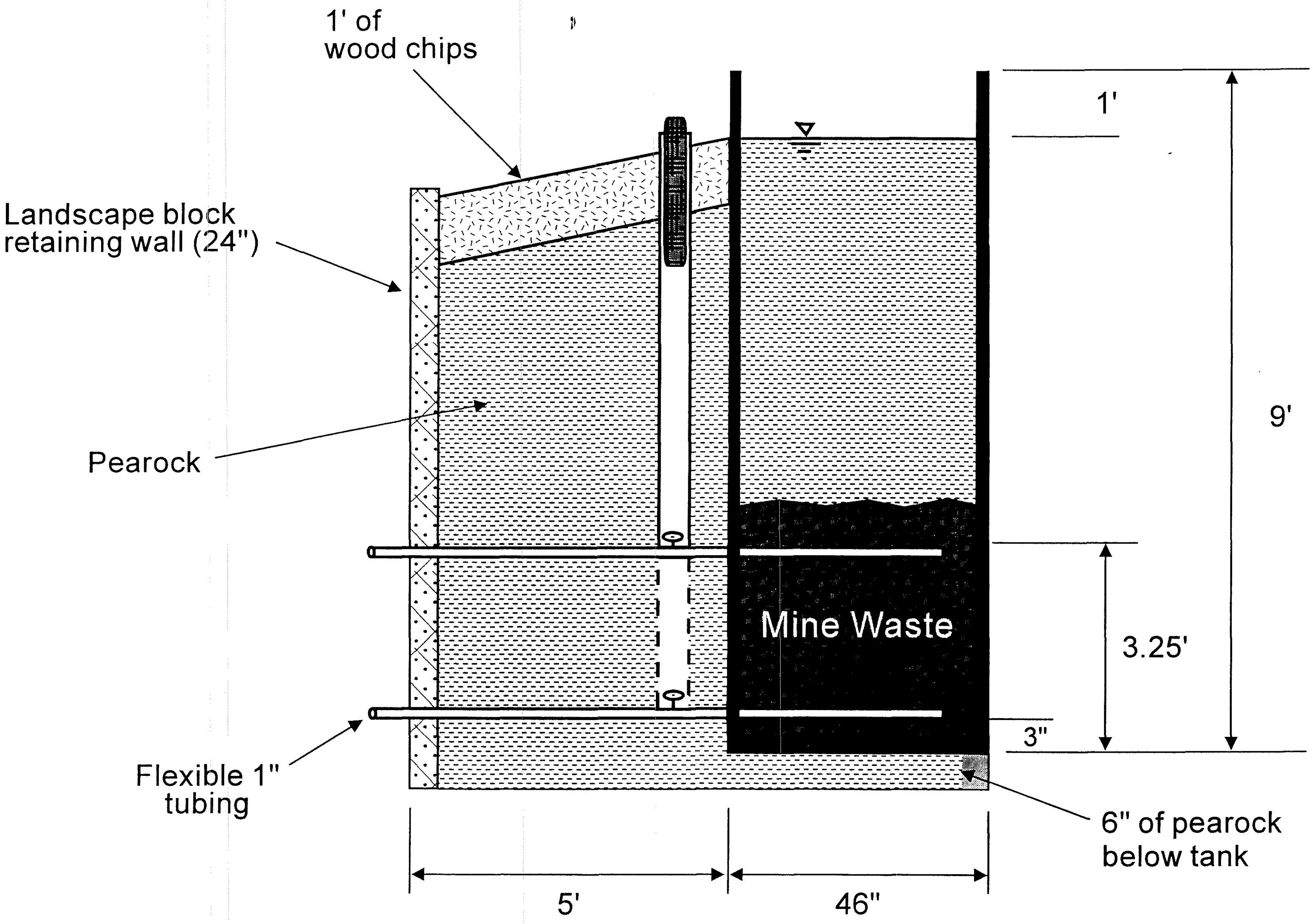


Figure 1. End view of underwater disposal facility at DNR-Minerals research site.

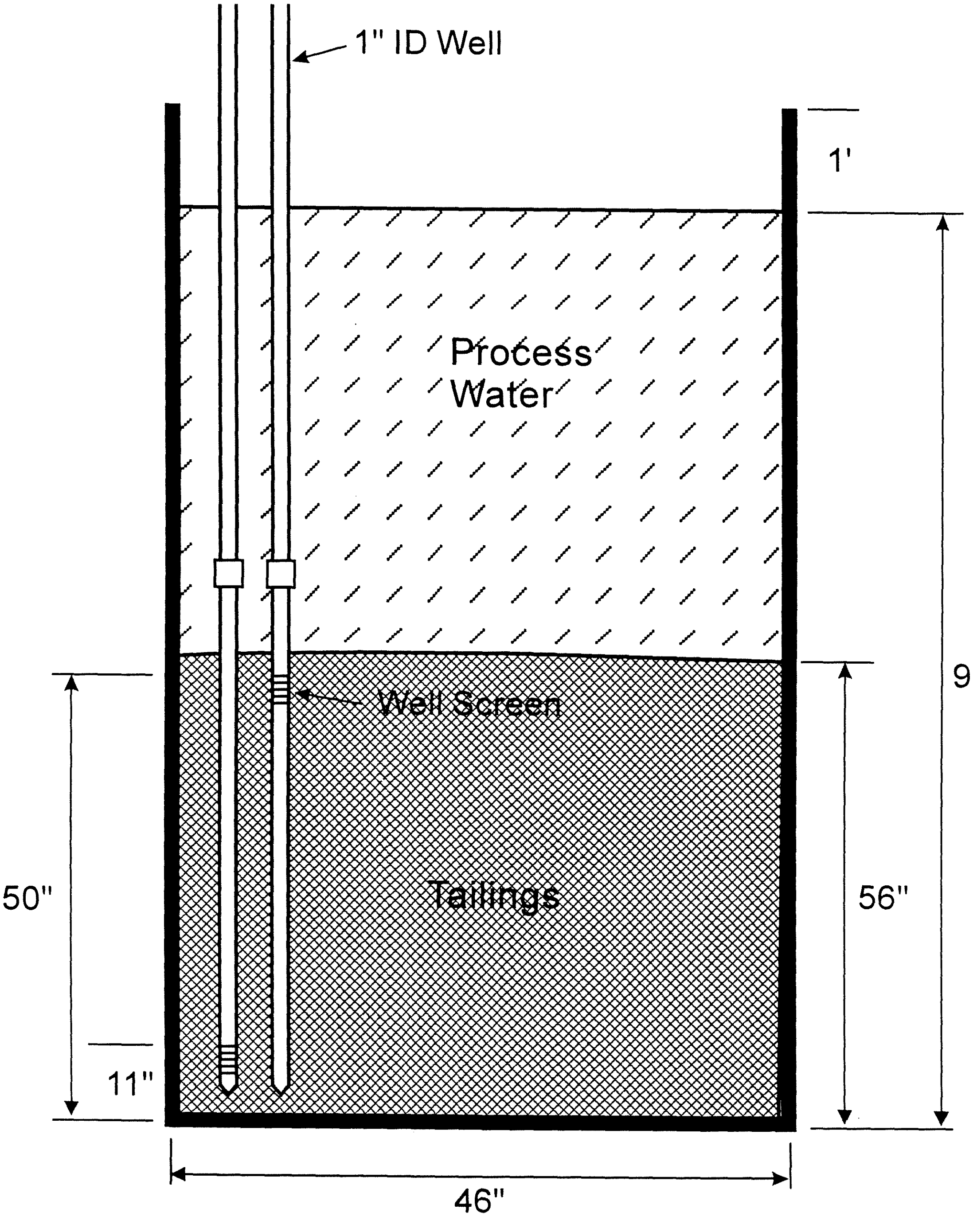


Figure 2. Interior sampling wells installed in LTV Tanks 1 and 2 on October 29, 1996.

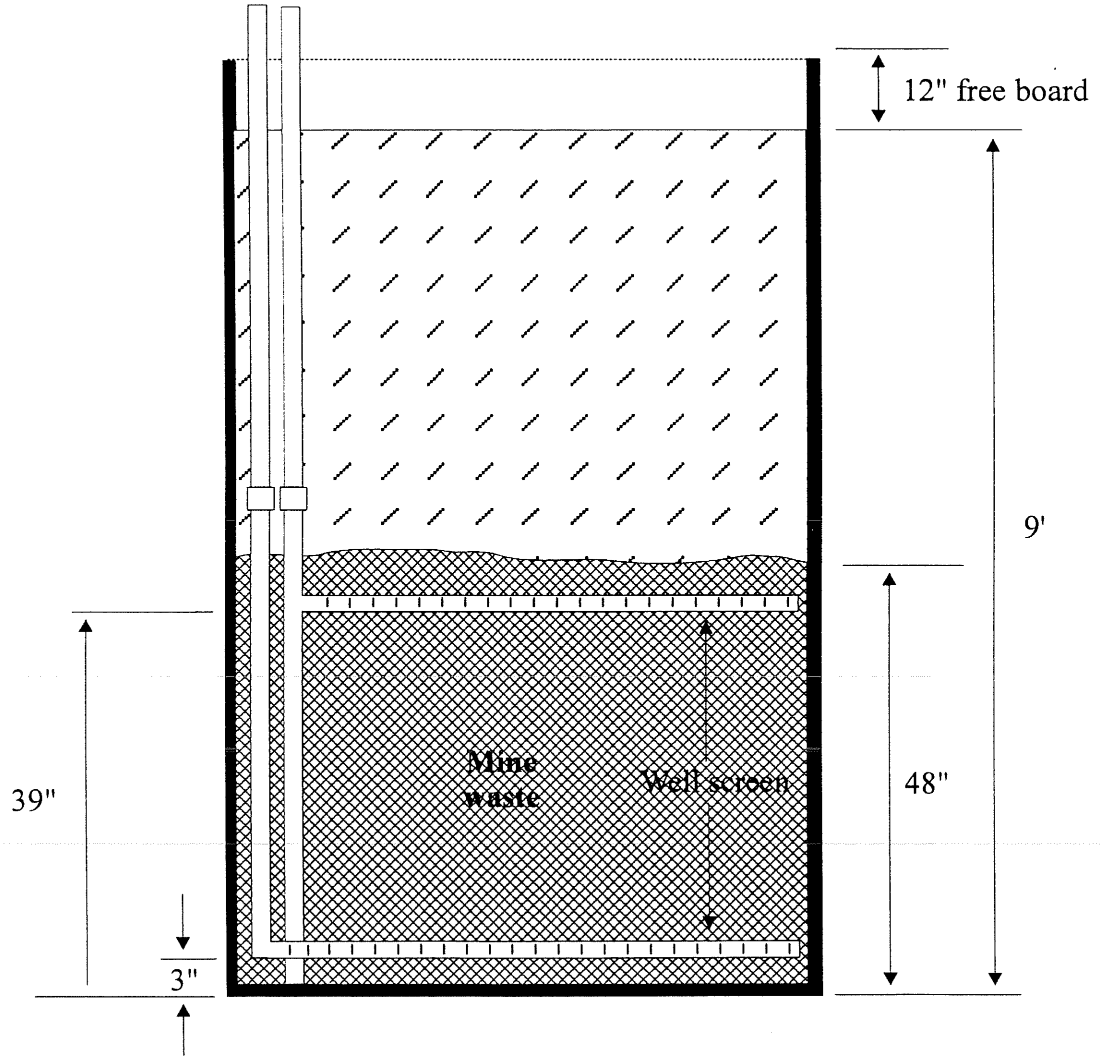


Figure 3. Interior well sampling apparatus designed for Inland Tanks 3 and 4. This apparatus was installed prior to filling the tanks with tailings.

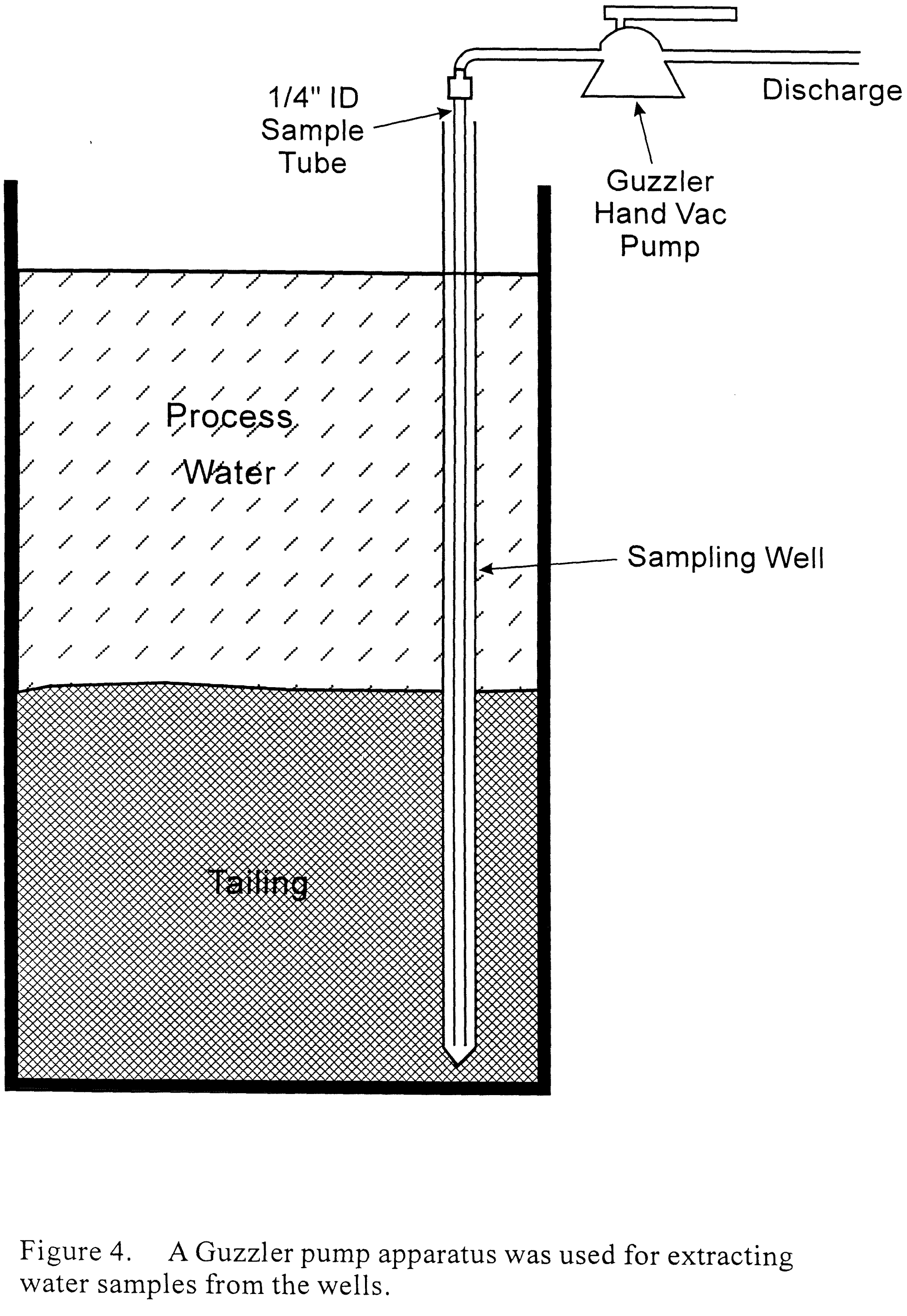


Figure 4. A Guzzler pump apparatus was used for extracting water samples from the wells.

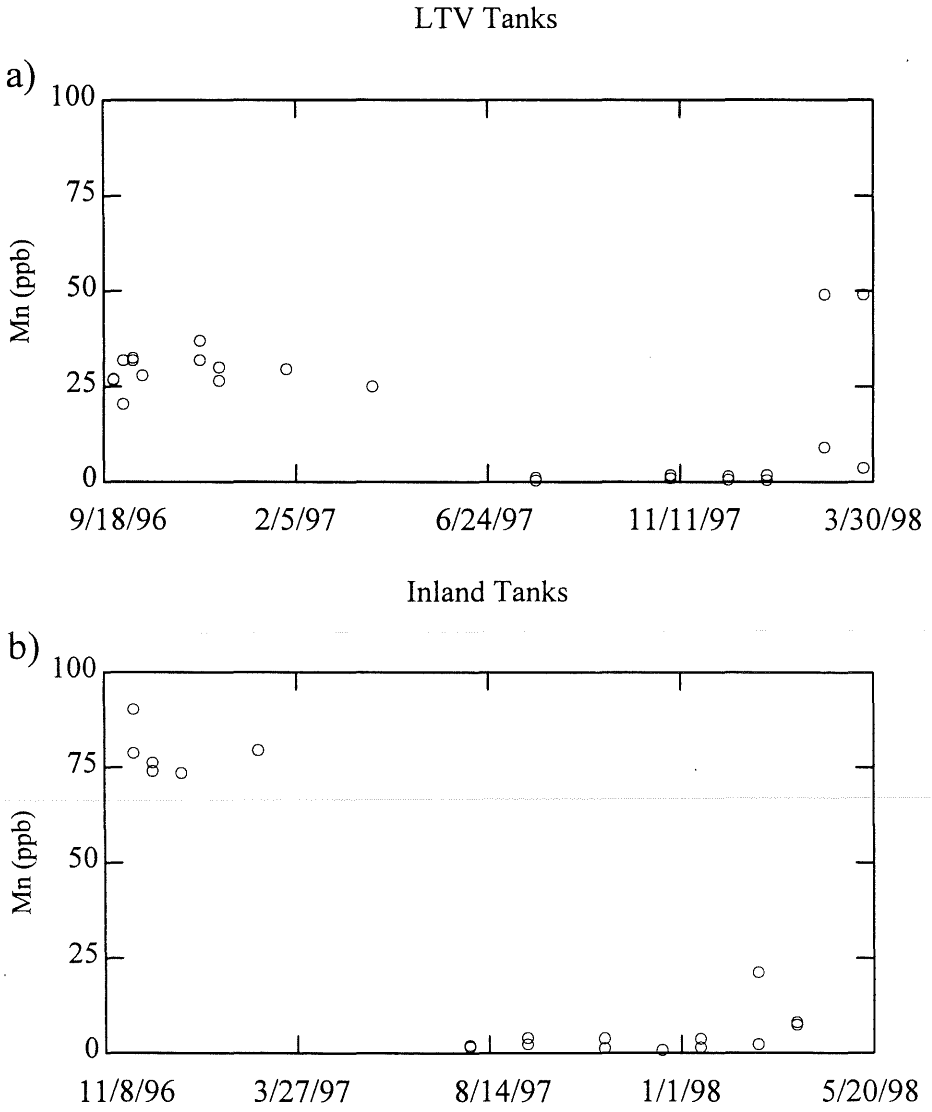


Figure 5. Manganese concentrations in surface waters of the (a) LTV and (b) Inland tank experiments decreased rapidly after 28 and 16. weeks, respectively. The decrease was most likely due to MnO2 precipitation.

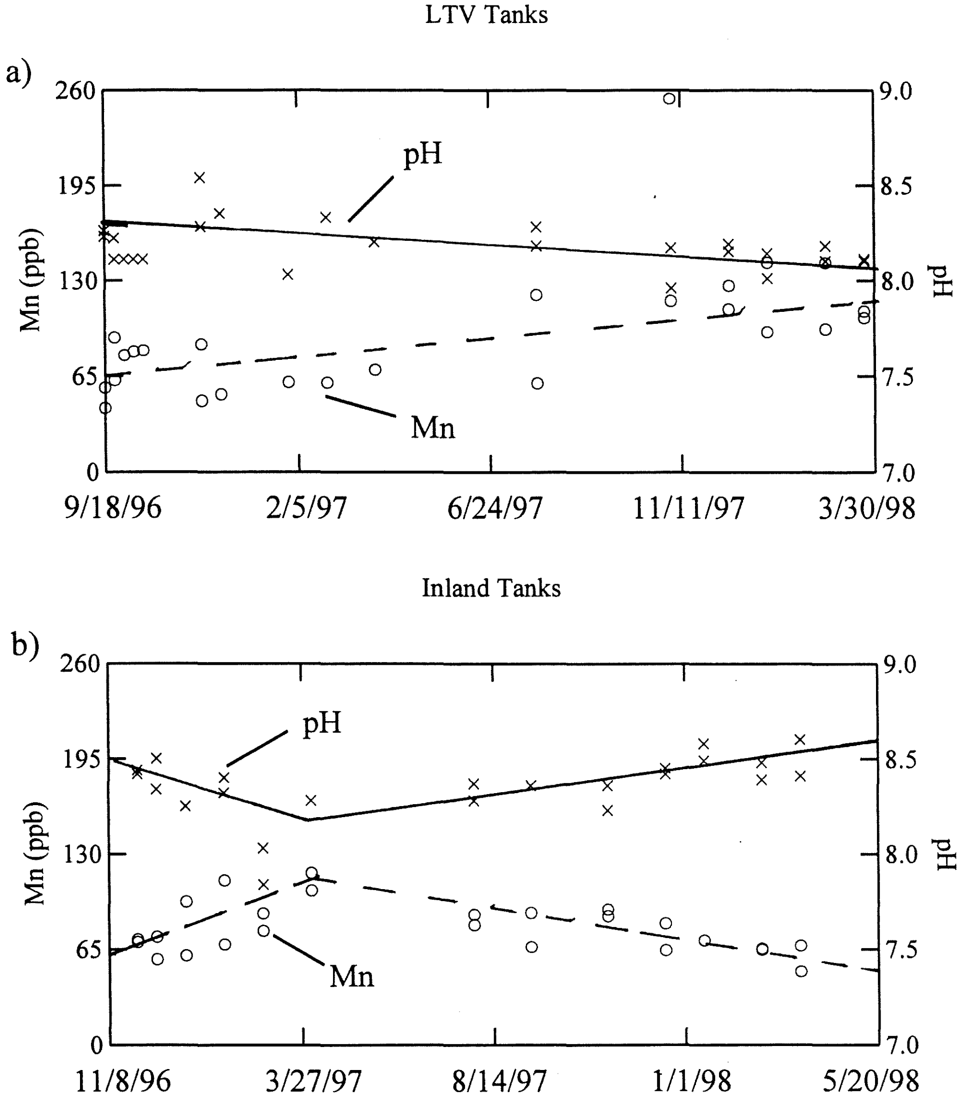


Figure 6. Manganese concentrations in tailings pore waters of the (a) LTV and (b) Inland tank experiments generally increased over time. Manganese levels appeared to be controlled by the pH-dependent dissolution of a manganese carbonate mineral.

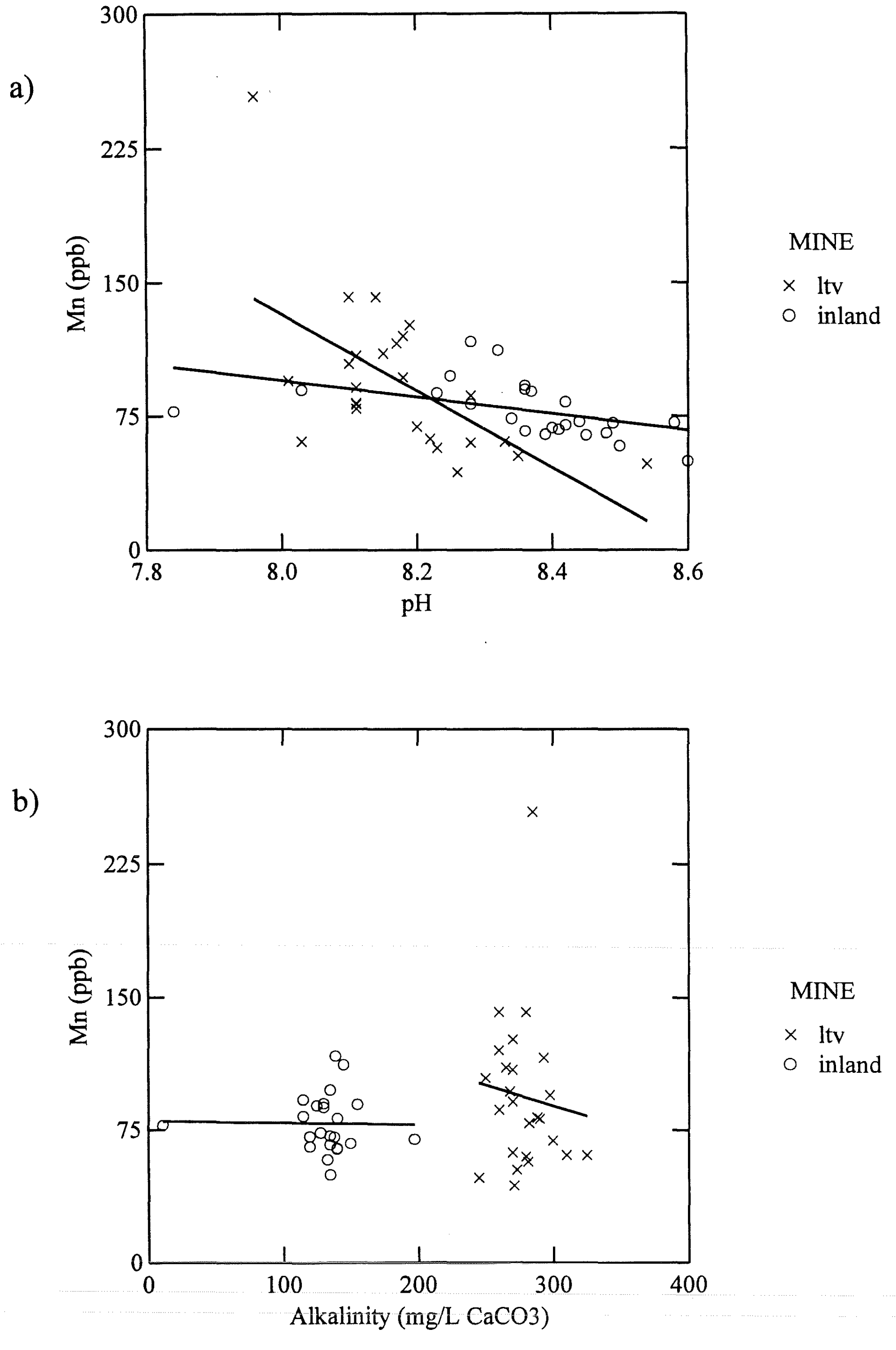
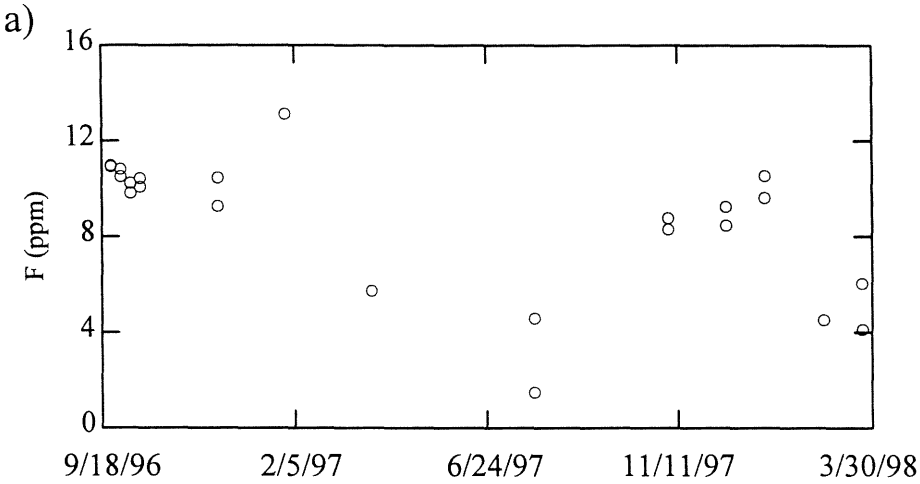


Figure 7. (a) Manganese generally decreased as pH increased in tailings pore waters of the LTV and Inland tank experiments (R2 = 0.35 and 0.22, respectively). (b) However, the same correlation could not be determined between manganese and alkalinity.

LTV Tanks



Inland Tanks

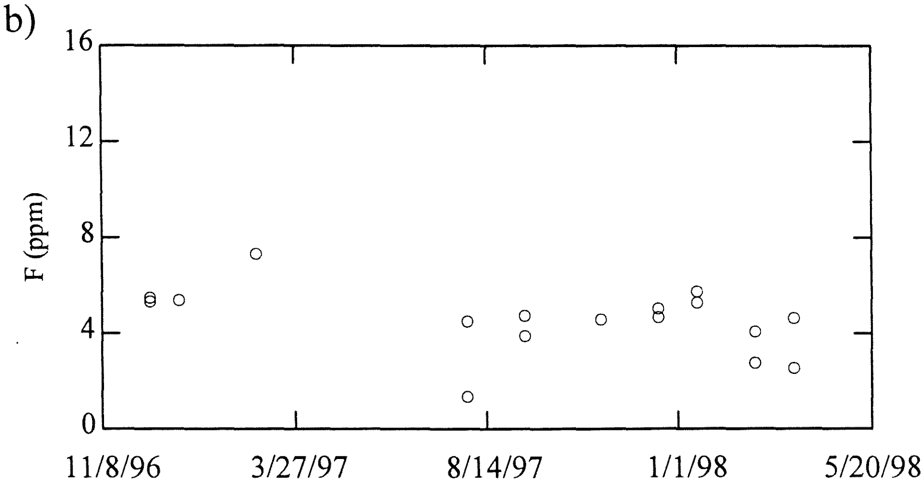


Figure 8. Fluoride concentrations in surface waters of the (a) LTV and (b) Inland tank experiments fluctuated within a fairly constant range.

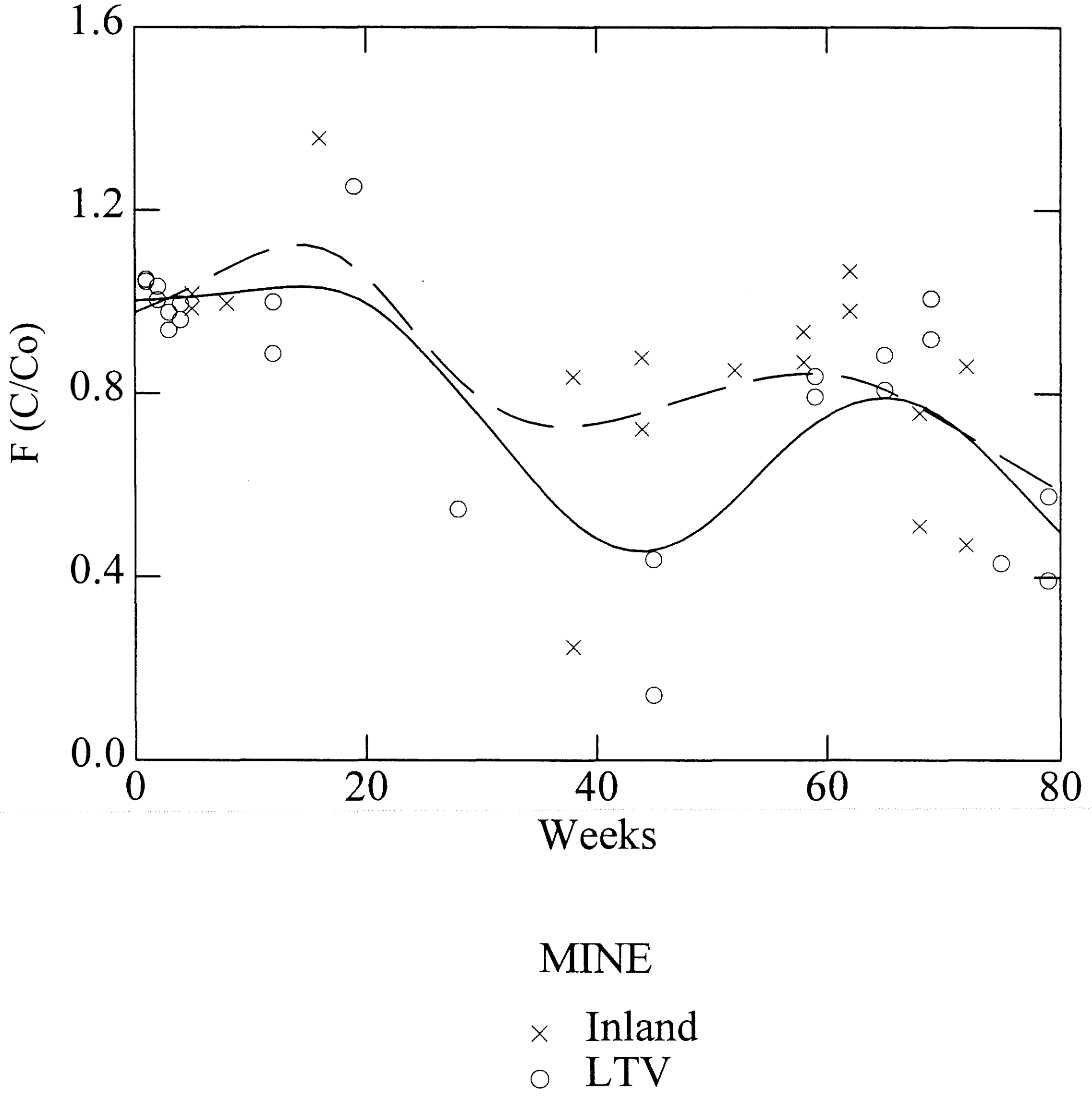


Figure 9. Fluctuations in fluoride concentrations were probably due to seasonal factors. These factors were estimated using average concentration ratios for nonreactive elements, where the solid line represents LTV and the dashed line represents Inland.

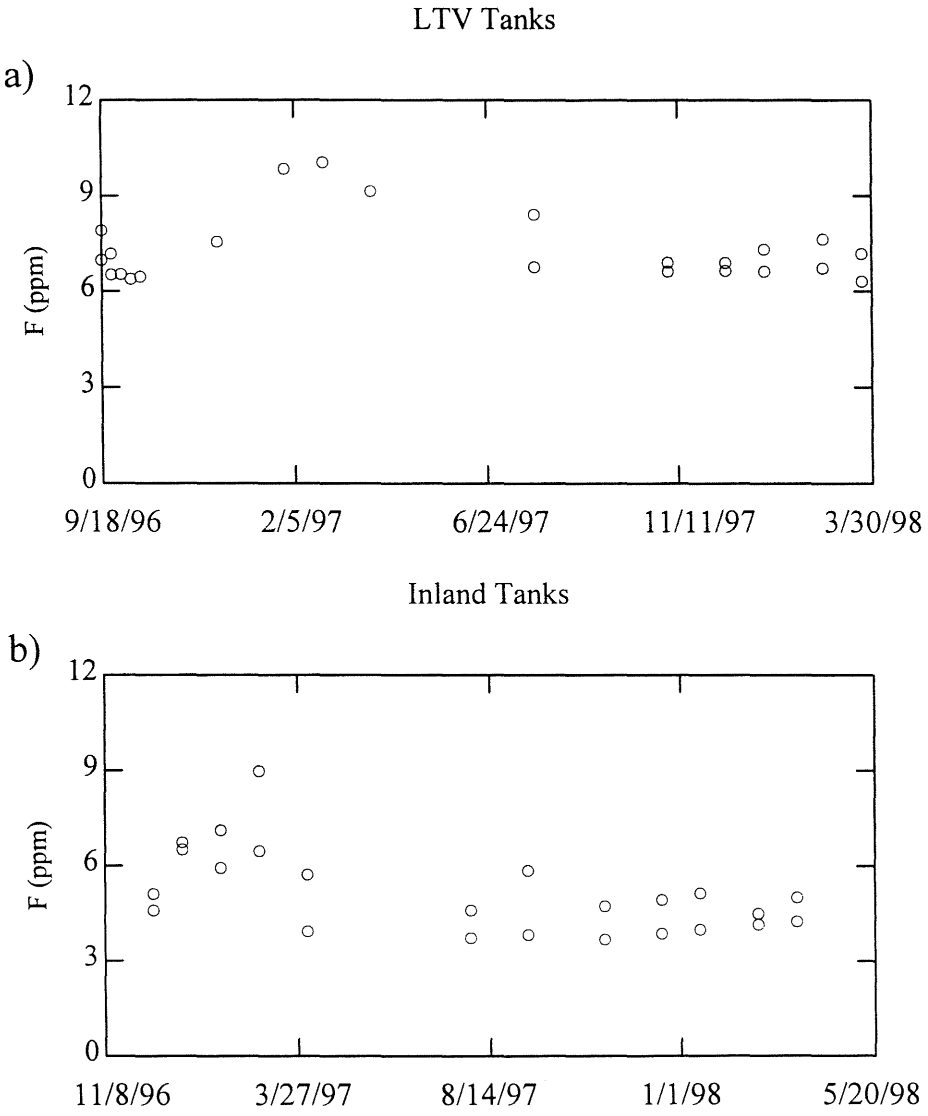


Figure 10. After an initial increase, fluoride concentrations decreased to relatively constant levels in (a) LTV and (b) Inland tailings pore waters.

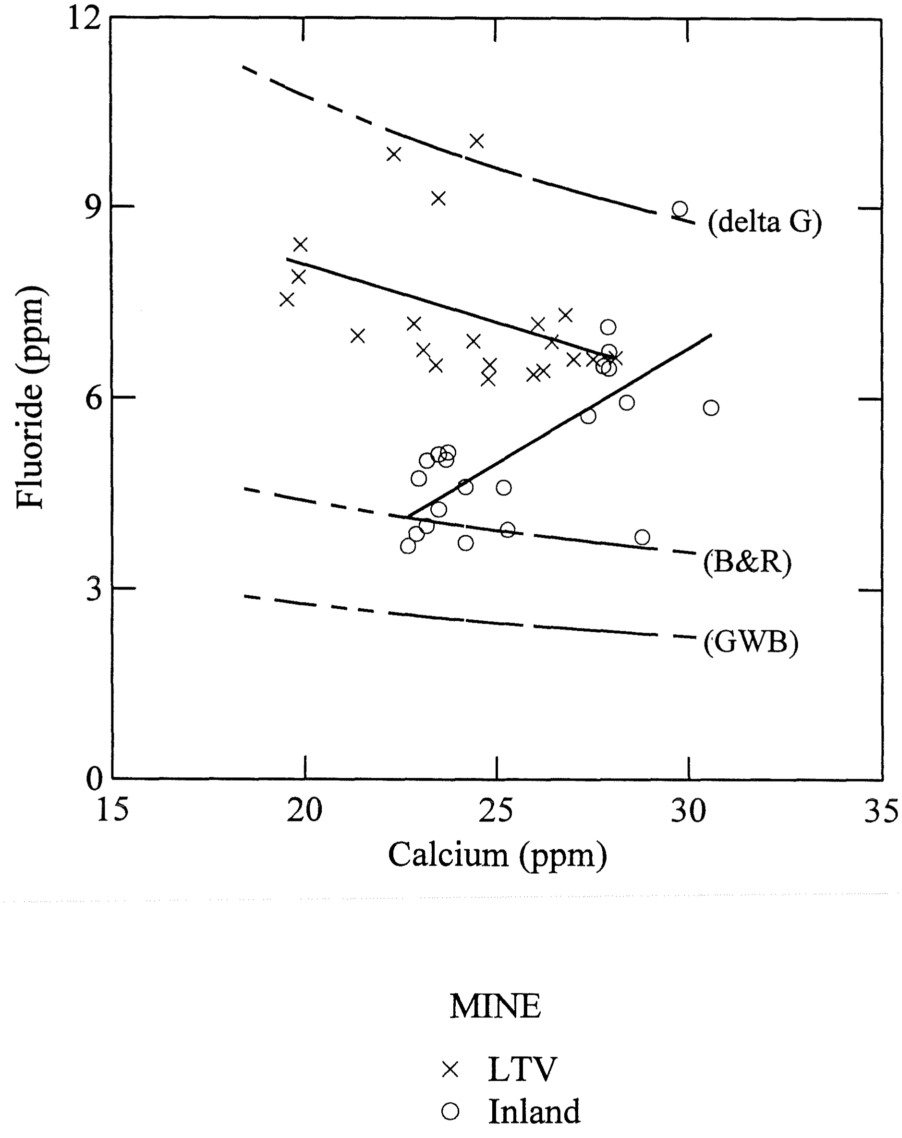


Figure 11. Tailings pore waters were generally supersaturated with respect to experimentally determined fluorite saturation curves (GWB and B&R). However, they tended to be undersaturated when compared to the saturation curve calculated from Gibbs free energies (delta G). Tailings pore waters from the LTV tank experiments appeared to be at saturation with respect to fluorite, while tailings pore waters from Inland may have been undersaturated.

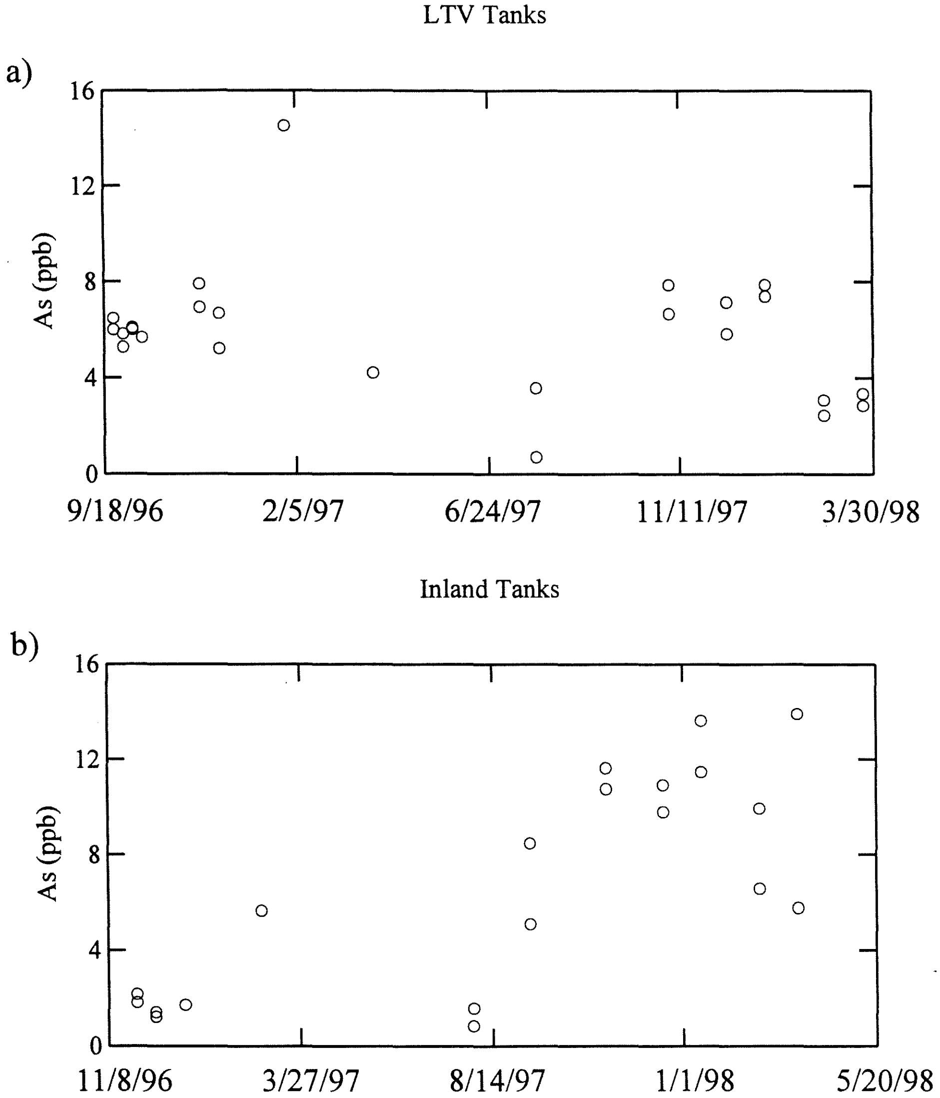


Figure 12. a) Arsenic concentrations in surface waters of the LTV tank experiments fluctuated within a fairly constant range, averaging 5.8 ppb.
b) Arsenic concentrations generally increased in surface waters of the Inland tank experiments.

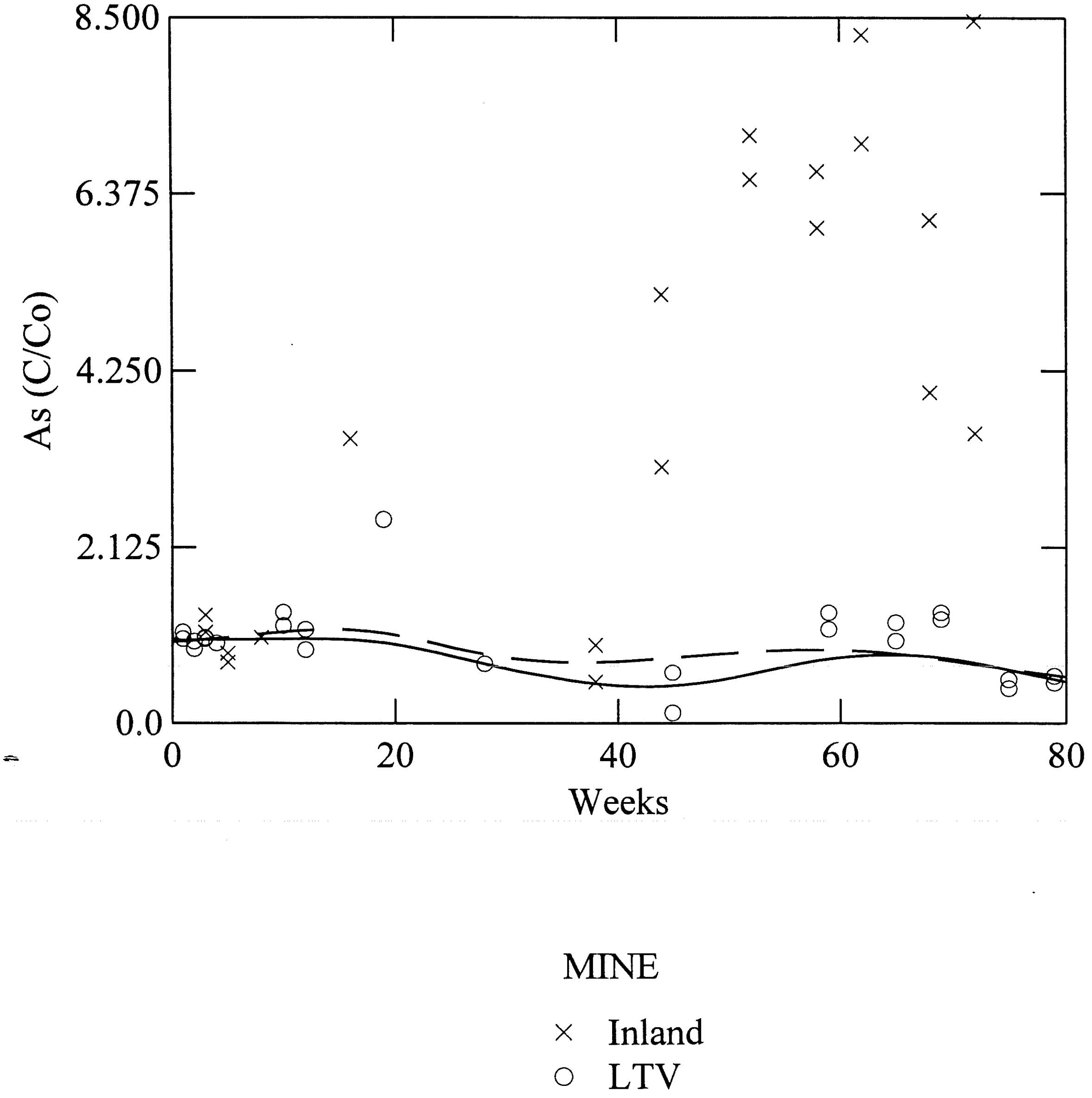


Figure 13. Fluctuations in arsenic concentrations in the LTV tank surface waters were probably due to seasonal factors. However, the Inland arsenic concentrations became highly concentrated relative to the nonreactive elements. The solid line represents the average nonreactive element concentration ratios for LTV, and the dashed line represents Inland.

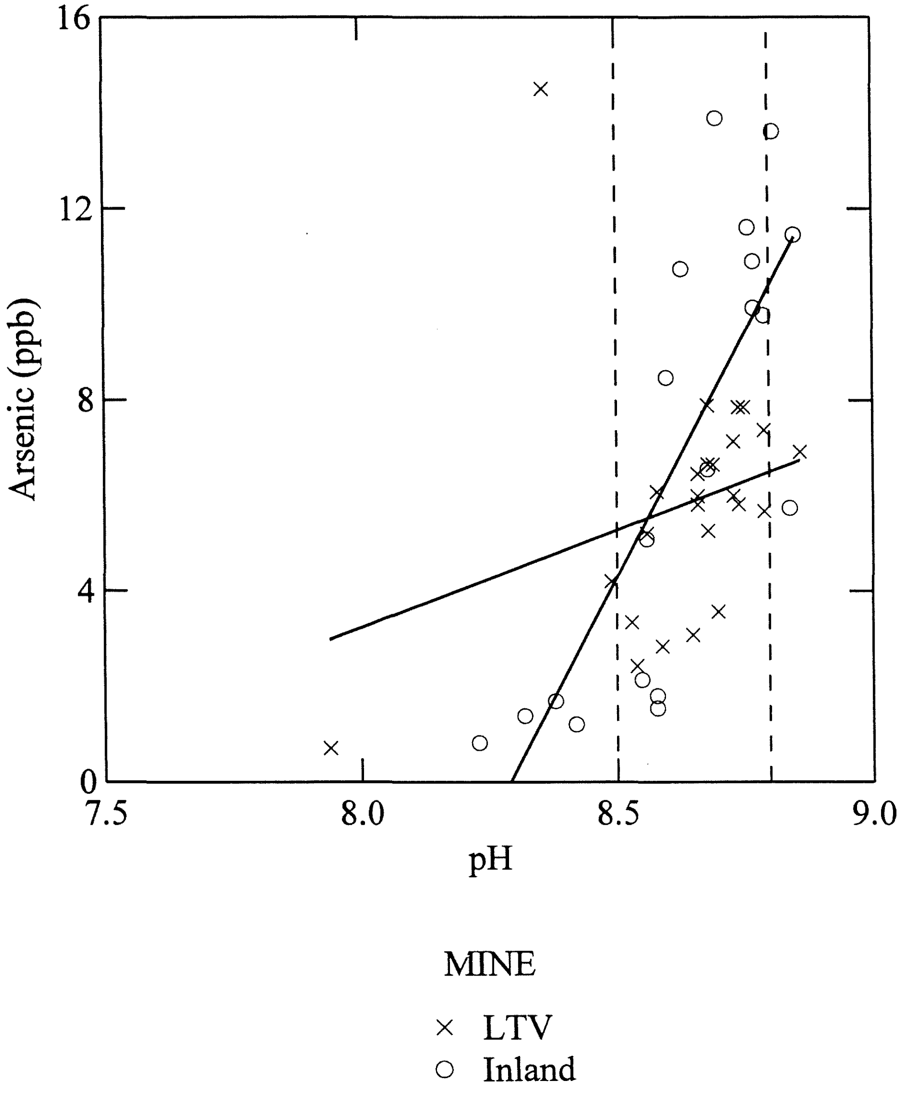


Figure 14. Arsenic concentrations appeared to be somewhat dependent upon the surface water pH from the Inland tank experiments (R2 = 0.08 for LTV and 0.62 for Inland). The dashed line represents the expected range of zero point charge for Fe(OH)3 (Langmuir, 1997).

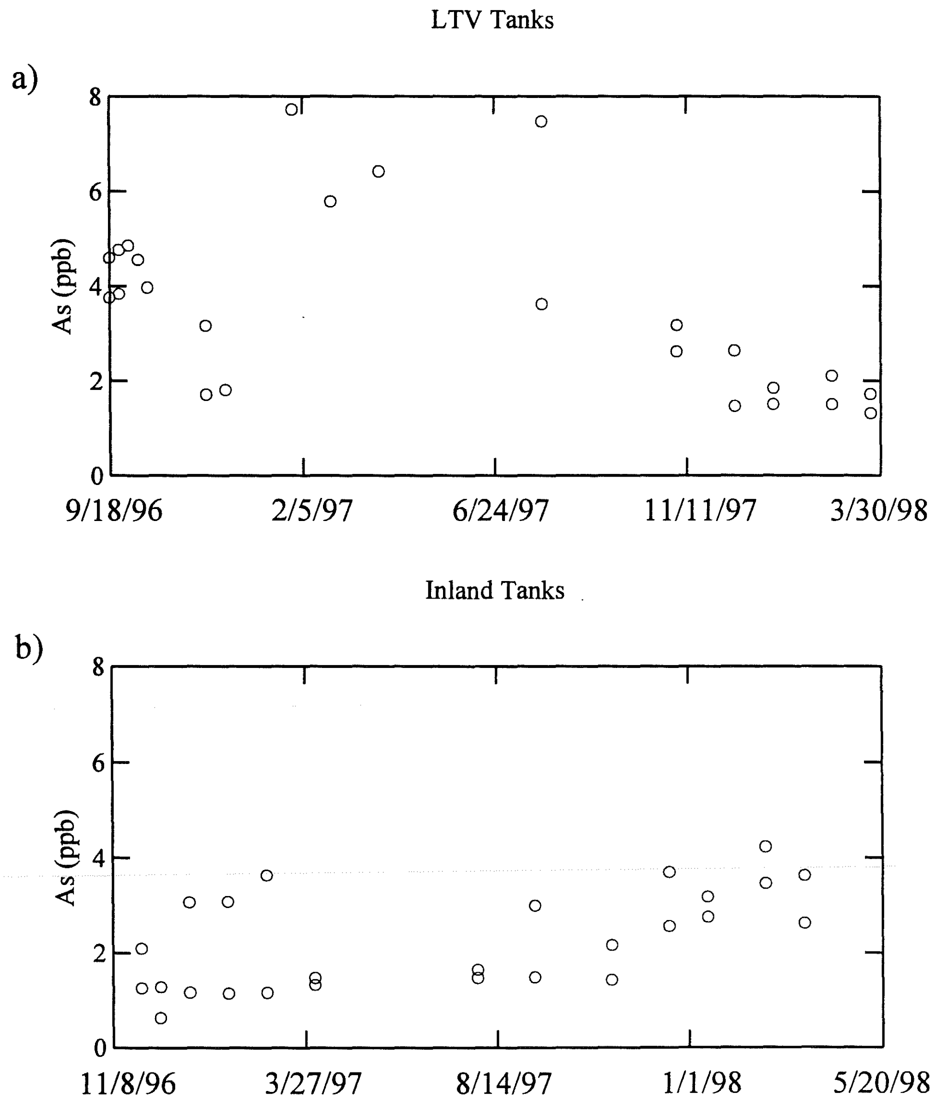


Figure 15. a) Despite surface contamination in November, 1996, arsenic concentrations decreased after limited contact with LTV tailings. b) The average arsenic concentration was 2.3 ppb in tailings pore waters from the Inland experiments.

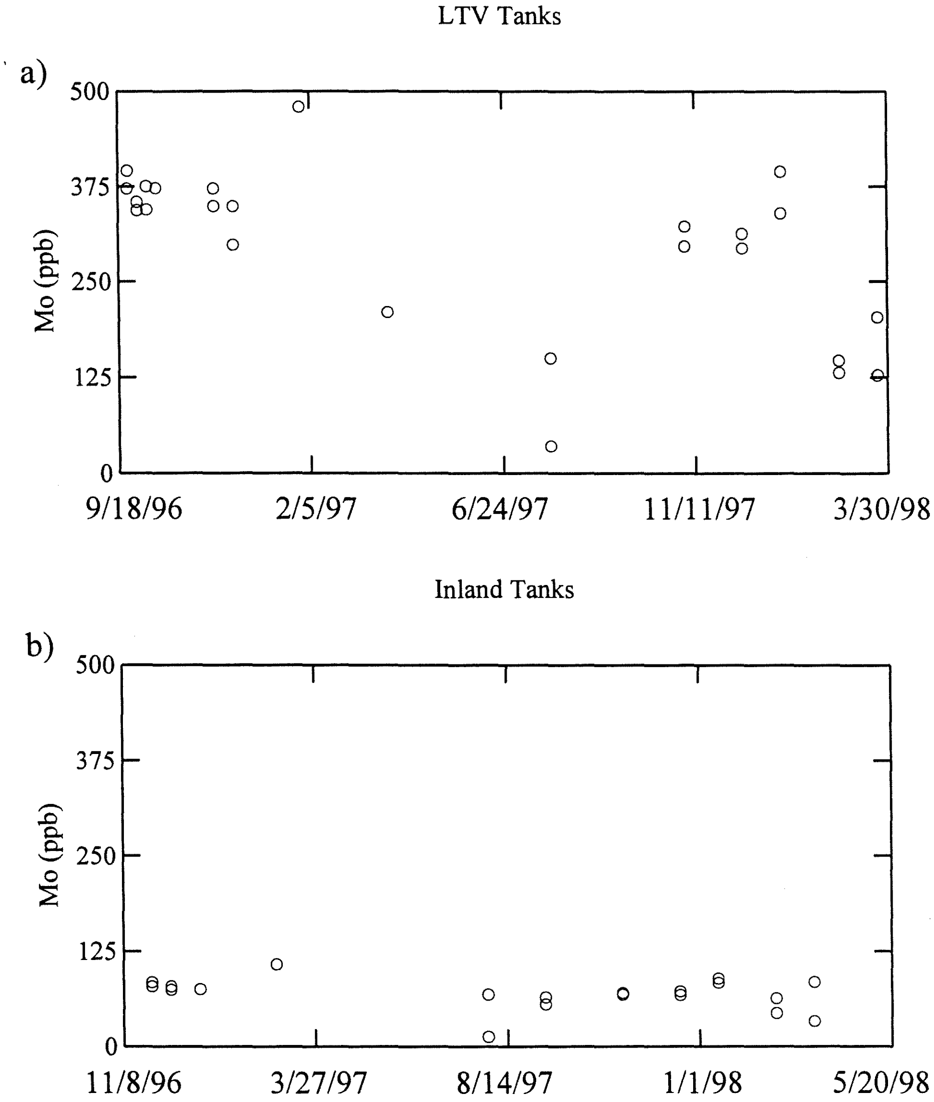


Figure 16. a) Molybdenum concentrations in surface waters of the (a) LTV and (b) Inland tank experiments fluctuated within a fairly constant range, averaging 295 ppb and 68 ppb, respectively.

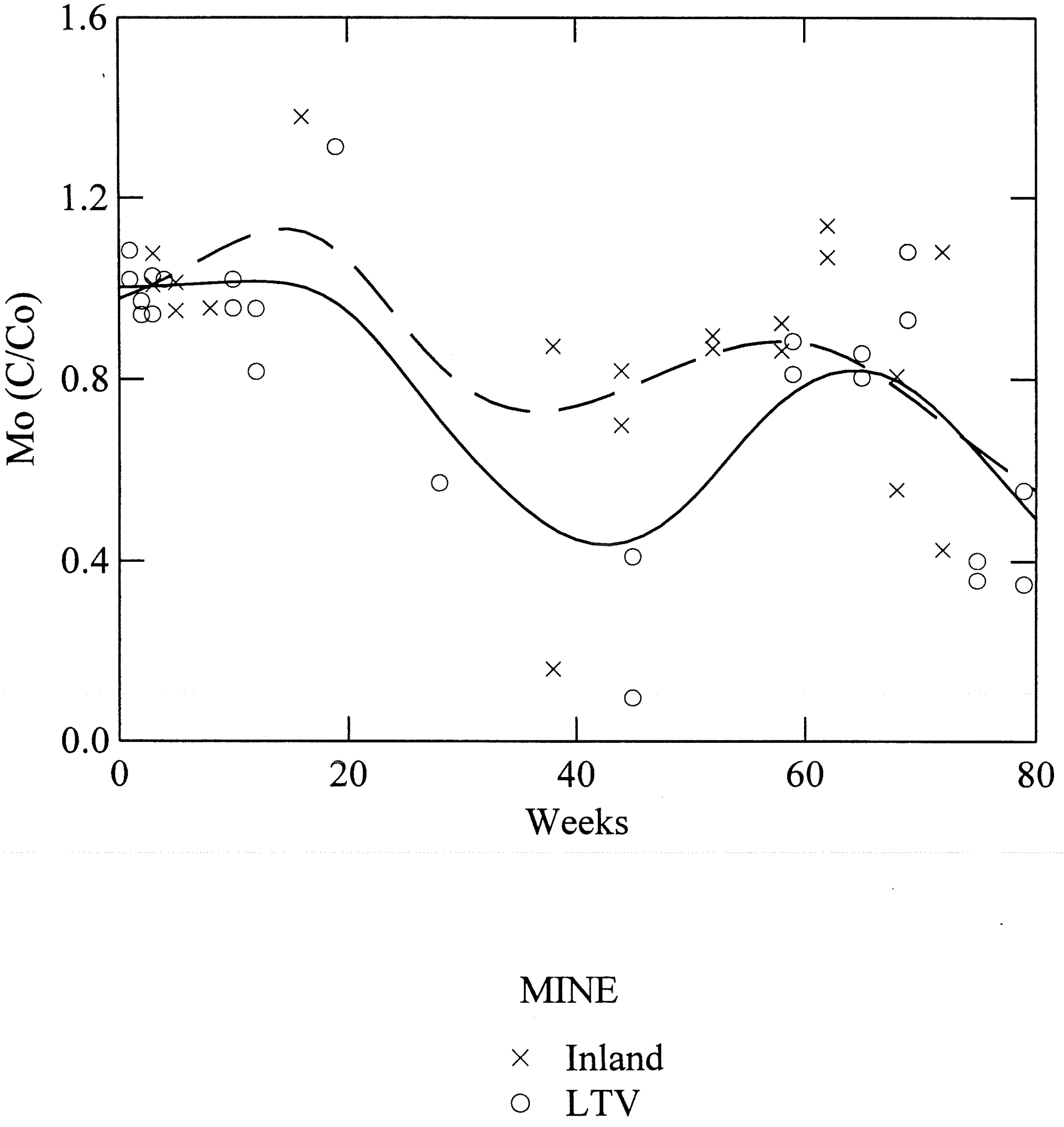


Figure 17. Fluctuations in molybdenum concentrations in the surface waters of the (a) LTV and (b) Inland tanks were probably due to seasonal factors. These effects were estimated using average concentration ratios for nonreactive elements, where the solid line represents LTV and the dashed line represents Inland.

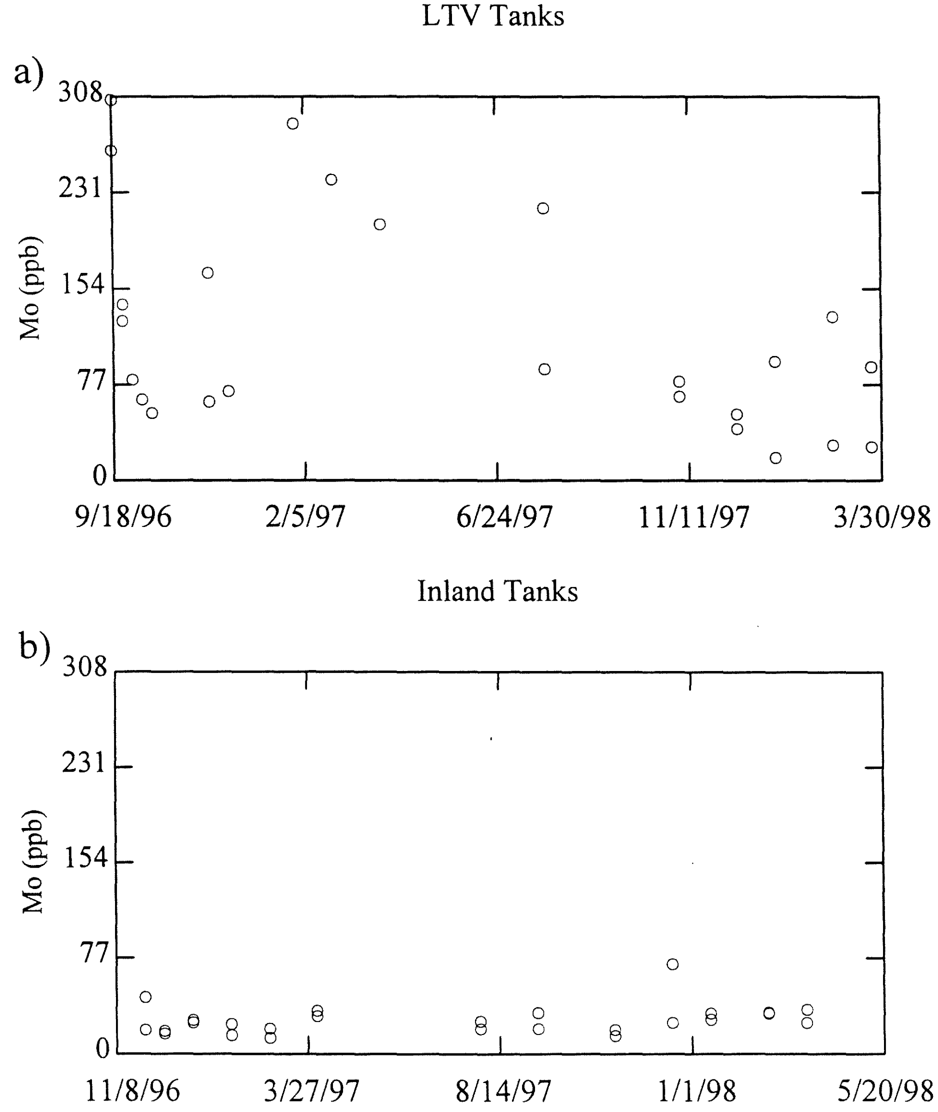


Figure 18. a) Despite surface contamination in November, 1996, molybdenum concentrations decreased over time in the LTV tailings pore waters. b) However, molybdenum concentrations averaged 25 ppb in tailings pore waters from the Inland experiments.

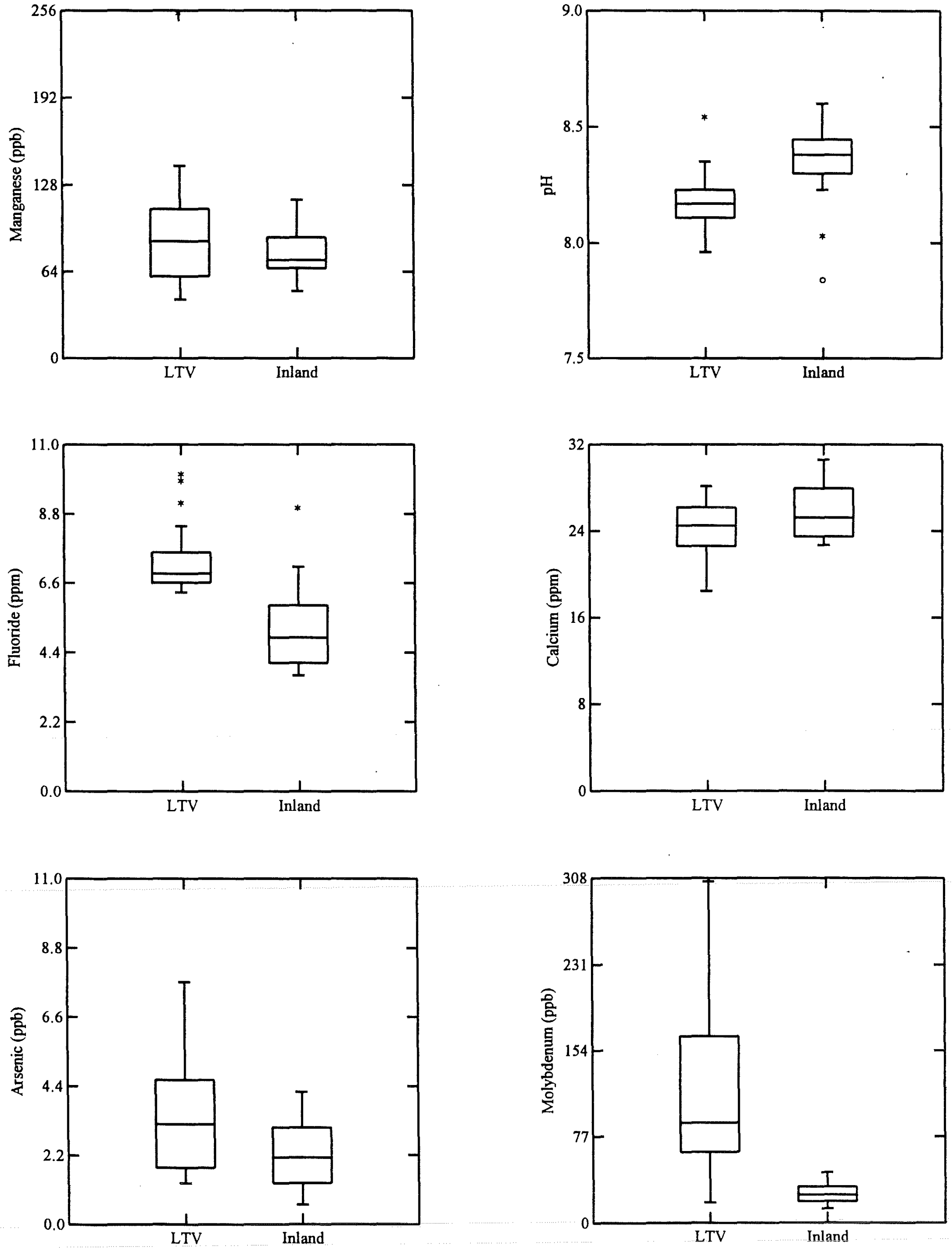


Figure 19. Fluoride and molybdenum levels were higher and pH was lower in the LTV tanks than in the Inland tanks. Manganese, arsenic and calcium appeared to be independent of the tailings source.

LTV EXPERIMENTS

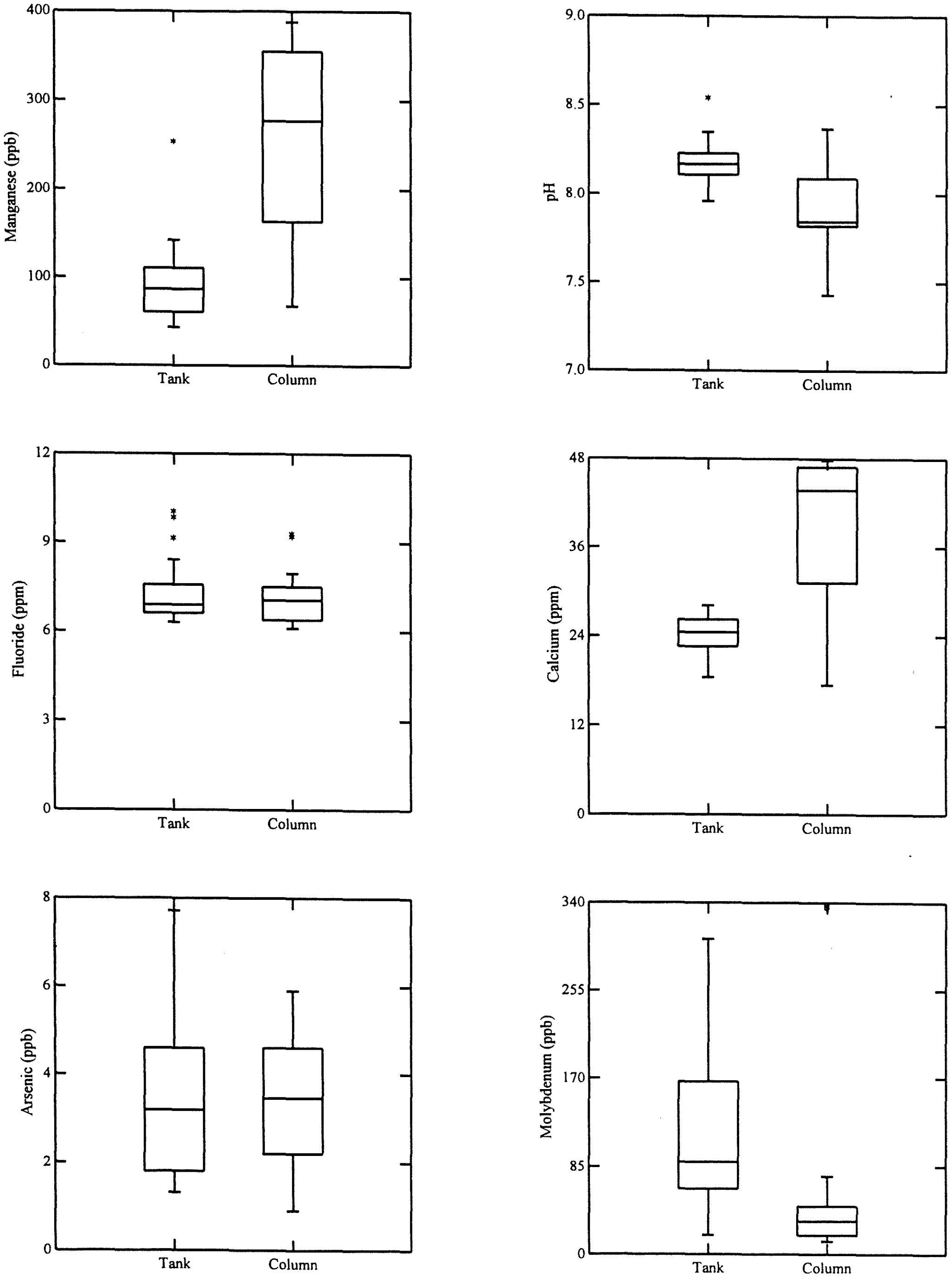


Figure 20. LTV tank tailings pore water quality was similar to that observed in column experiments using tailings and process water from LTV. However, manganese and calcium concentrations were lower, while molybdenum and pH levels were higher in the tank experiments.

INLAND EXPERIMENTS

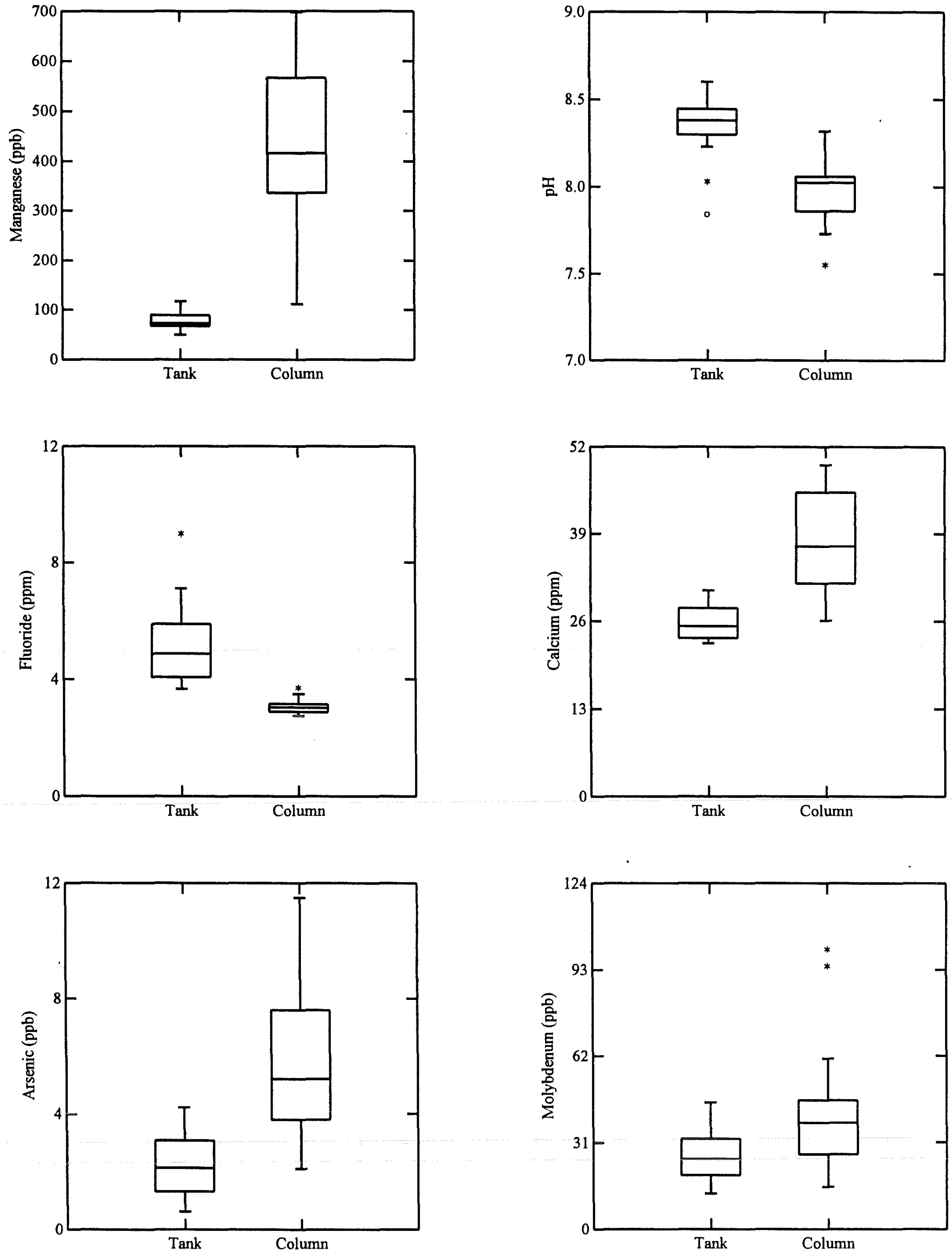


Figure 21. The tailings pore water quality of the Inland tank experiments differed from the water quality observed in the column experiments. Fluoride and pH levels were higher, and manganese, arsenic, molybdenum and calcium concentrations were lower in the tank experiments.

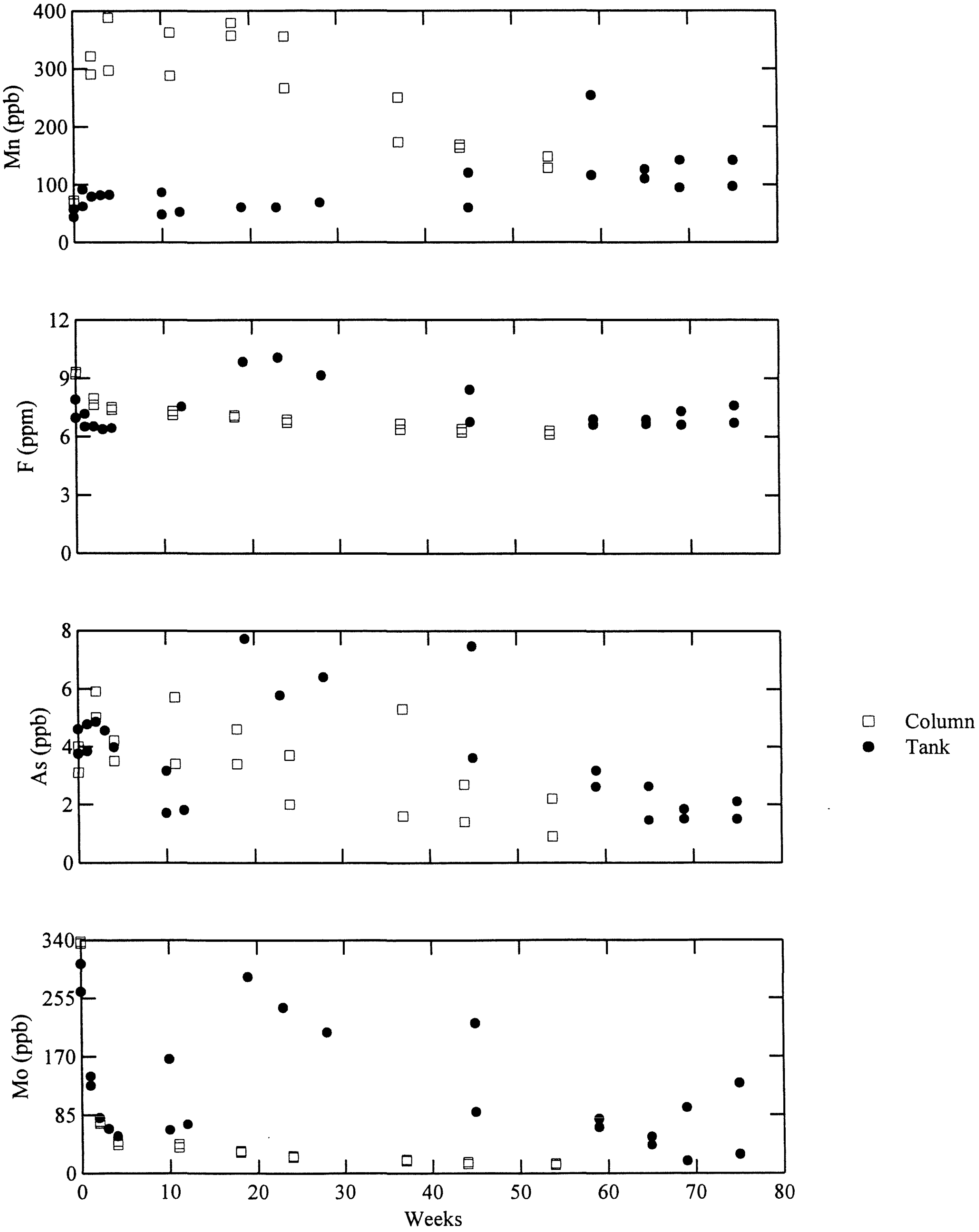


Figure 22. With the exception of manganese, concentration trends over time in the LTV tank experiments were in good agreement with those of the laboratory column effluents.

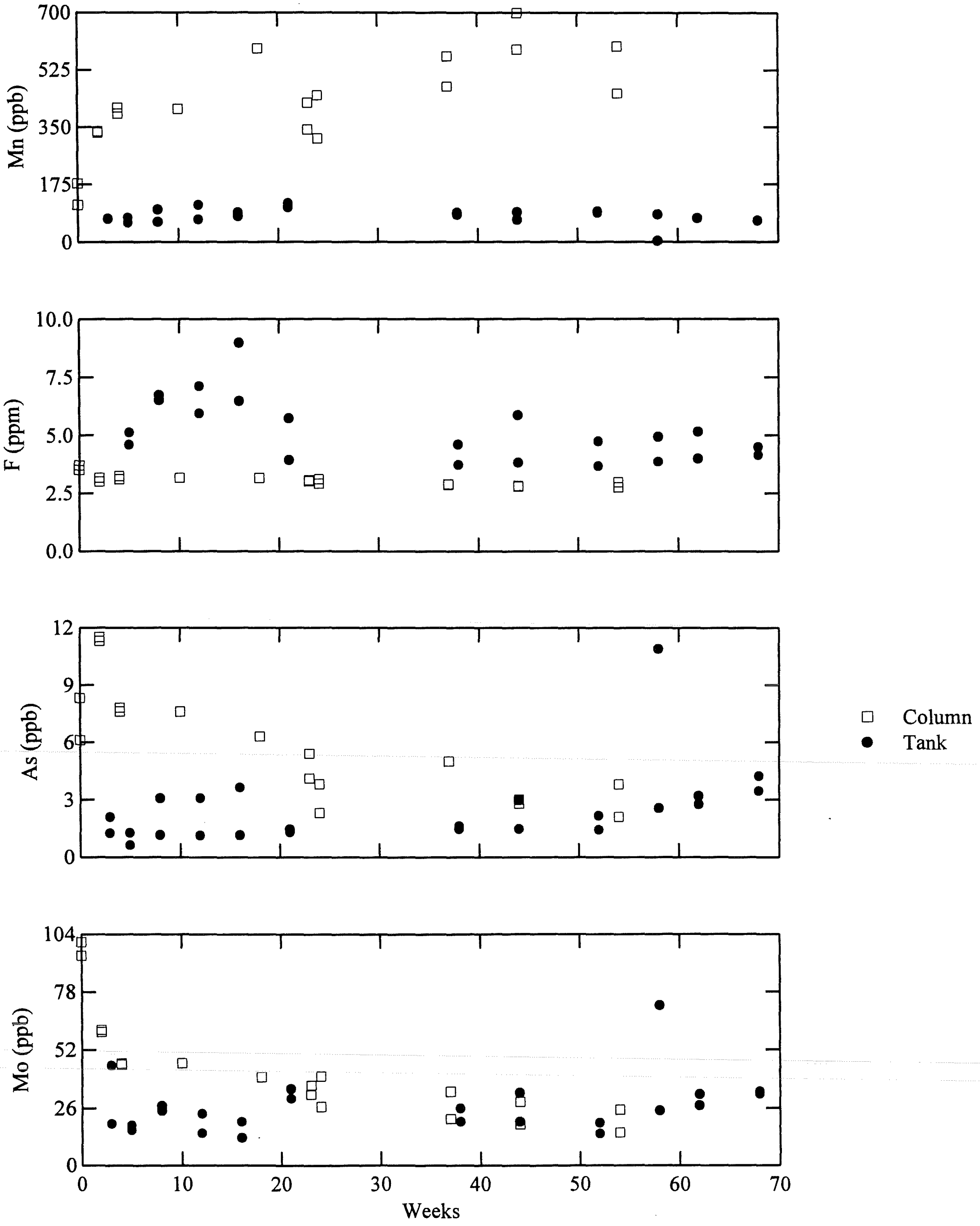


Figure 23. With the exceptions of manganese and arsenic, concentration trends over time in the Inland tank experiments were in good agreement with those observed in the laboratory column effluents.

Appendix 1

Tank Experiment Time Lines

A1.1. LTV TAILINGS

09/13/96 - Filled cement truck with tailings from LTV's spigot line to the tailings basin. The truck was initially filled half full, rinsed for five minutes, and then emptied. There was no noticeable traces of cement from the truck. A five gallon pail of tailings from Area 2 West was added to the fresh tailings for seed. Filled Tank 1 and then Tank 2 with 29" of slurry, . There was approximately 10-12" of water above the coarse tails. Waited 45 minutes and filled Tank 2 to a depth of 53", there were still coarse tailings present. Filled Tank 1 to a depth of 53", the majority of which was water and fine tailings. Measurements of the depth of coarse tailings at this time were 21" in Tank 1 and 35" in Tank 2. The tanks were allowed to sit for 45 minutes and then filled to a depth of approximately 85" with mostly water and fine tailings. Since the slurry was relatively uniform the remainder of the tanks were filled after 15 minutes. The depth of coarse tailings in Tank 1 was 25" and Tank 2 was 39". A composite sample was taken from each of the four tailings additions for both tanks. At this time there was no way to determine how much the fine tailings would add to the overall bed depth. It was decided that to achieve the desired bed depth that we would need more tailings.

09/16 - Pumped approximately 72" of water out of each tank to make room for more tailings. The cement truck was not rinsed before the tailings addition due to problems encountered with the piping plugging during the first sample. There was still no noticeable cement when the tailings were emptied into the tanks. The truck was overloaded to ensure enough tailings and providing a higher coarse tailing to fine tailing ratio than the first load. Started filling Tank 1 with the hopes of obtaining a similar bed depth of coarse tailings in both tanks. Added approximately three feet to both tanks and then filled them to within a foot of the top of the tank. The coarse tailings depths were 60" in Tank 1 and 65" in Tank 2. A composite sample was taken from both tanks.

09/18 - Week 0 sampling: Sampled tanks 1 and 2 using the valve sampling apparatus (figure 1). The initial purge volume was measured in a graduate, the sample was taken, and then the remaining water in the line was measured and added to the purge volume. The flow rate was based on the time the valve was opened to the end of the sample when the valve was closed. Surface samples were taken approximately 6 - 8" below the surface. The tailings measurements were to the top of the coarse tailings. It was difficult to determine the depth of fine fluffy tailings above the coarse due top cloudy water conditions, a reasonable estimate was 6" based on the amount of tailings on the sample rod.

09/25 - Tank 1: Middle Port - Flow started fast then decreased, sample was very cloudy with tailings present. Bottom Port - Flow started fast then decreased, sample was very cloudy with tailings present. Tank 2: Middle Port - No flow surge, flow was constant and clear. Bottom Port - Very fast flow, cloudy with some tailings present.

10/02 - Tank 1: Middle Port - Slow flow, cloudy with tailings present. Bottom Port - Flow started fast then decreased, sample was very cloudy with tailings present. Tank 2 : Middle Port - Flow was slow, constant, and clear. Bottom Port - Flow was slow, constant, and clear.

10/03 - Since the depth of tailings in tanks 1 and 2 would not leave much room for water above the tailings if the tanks froze to a depth of four feet, it was decided to remove a portion of the bed depth. The fine tailings were stirred until the majority of the tailings were suspended and then pumped to a holding tank using a submersible pump. The tanks were pumped down to the top of the coarse tailing leaving only traces of fine tailings on the surface. 14" of coarse tailings were removed from Tank 1 and 24" from Tank 2, which left 48" of coarse tailing in each tank. There was very little sign of fine tailings mixed in with the coarse. The coarse tailing was very compact when stood on. The water and fine tailings were then pumped back into the tanks.
Both tanks were about 100 gallons shy of the desired water depth so additional water was obtained from LTV's Area 2 West tailings pond and added to the tanks.

10/10 - Tank 1: Middle Port - Slow flow with some cloudiness. Bottom Port - Slow flow and clear. Tank 2: Both valve stems were broken so only a surface sample was collected.

10/16 - Tank 1: Middle Port - Slow flow and clear. Bottom Port - Flow started fast and then decreased, medium cloudiness present.

10/29 - Due to the valve failure on 10/10, new sampling wells were installed in tanks 1 and 2 (figure 2). The wells are constructed of 1" ID PVC pipe with a 3" section of slotted well screen (.012" slots) positioned at the sample points. The wells consist of two sections, the bottom permanent section containing the well screen is 63" in height and is equipped with a female PVC fitting for securing the upper section during sampling and an end cap between sampling periods. The purpose of the end cap is to stop oxygen transport down the wells between sample periods. These wells will be used at least throughout the winter months.

11/27 - Sampled both tanks using the new sampling method. NEW SAMPLING METHOD: A hole was drilled in the ice directly above the sample ports. The end cap was removed and the upper well section was screwed into the female fitting. A 1/4" PVC pipe equipped with a 1/4" hose adaptor to which Tygon tubing was attached and used as a feed line to a Model 107090-10 Delrin plastic Guzzler pump was inserted down the well to remove the sample (figure 4). A predetermined purge volume was removed and the appropriate samples taken. Depth of the tailings bed was determined and the end cap was reinstalled. When placing the PVC pipe down the wells to remove the bottom samples in both tanks it felt like there was about 4 - 5" of tailings in the well screens. The bottom samples from both tanks were cloudy and contained tailings, the middle samples from both tanks were slightly cloudy with very little tailings.

12/12 - Tank 1: Middle Port - Purge volume was very cloudy and well was pumped dry after removing 780 mLs. Bottom Port - The upper sampling section was cross-threaded and didn't seal to allow for removal of the purge volume or sample. When attempting to remove the upper section the entire well began moving so the well was left in place until 12/13 at which time the tailings had resettled around the well and stabilized it to allow removal of the upper section. No sample was taken from this port. Tank 2: Middle Port - Purge volume was very cloudy and well was pumped dry. Bottom Port - Purge volume was slightly cloudy and was pumped dry.

01/30/97 - Tank 1: Ice thickness = 19". Water depth = 101". Bottom Port - Started very cloudy then began to clear up. Tank 2: Ice thickness = 7". Water depth = 103". Started very cloudy then began to clear up.

02/26 - Purge volume of 1500 mLs for both tanks. Tank 1: Ice thickness = 18". Water depth =100". Tank 2: Ice thickness = 9". Water depth = 103" Used a new Eh electrode, check BLM notebook for reference check results.

04/02 - Purge volume of 1500 mLs for both tanks.

07/31 - The data from both tanks is confusing. One explanation for this could be that the sample water was being pulled from the surface down the well to the sampling port. In order to address this problem both wells were removed from both tanks for redesign. When removing the wells from tank 2 it was discovered that there was a mixup in the well identification. The bottom port was being sampled as the middle port and vice versa.

10/24 - Installed the bottom sampling wells in both tanks. A flange was added to the sampling wells just below the surface of the tailings to prevent preferential flow down the well during pumping. The flanges were installed 16.5" below the top of the stand pipes.

11/05 - Tank 1: The purge and sample volumes were very cloudy with fine tailings present. Tank 2: The purge and sample volumes were slightly cloudy.

12/17 - Tank 1: Ice thickness = 2". Purge and sample volumes were clear. Tank 2: Ice thickness = ½". Purge volume was slightly cloudy.

01/15/98 - Tank 2: Purged 1200 mLs and port went dry, waited for port to recharge and took remaining purge volume before sampling. Samples from both tanks were cloudy. Ice thickness on both tanks was 10 - 12".

02/26 - Both purge volumes were slightly cloudy. Ice thickness on both tanks was 12".

03/26 - Ice thickness on both tanks was about 10" and free floating.

A1.2. INLAND TAILINGS

10/23/96 - Installed interior well sampling apparatus. A different design was used for these tanks since they were able to be installed before the tailings addition (figure 3). The slotted well screens (.012" slots) are only slotted on the bottom side of the screen and no geotextile sleeve was used. The same sampling apparatus and procedure was used for the Inland tanks (tanks 3 and 4) as was used for the LTV tanks.

10/29 - Filled cement truck with tailings from Inland's spigot line to the basin. The truck was filled approximately half full, rinsed, and discharged. The truck was then filled with tailings and five gallons of tailings from the old portion of the basin was added for seed. Filled Tank 3 with 25" of tailings and Tank 4 with 31". There was about 4 - 5" of coarse tailing in the bottom of Tank 3 and 1 - 2" in the bottom of Tank 4. It appeared at this time that the majority of the coarse tailings was in this addition. Switched to Tank 3 and filled to a depth of 49" then to Tank 4 to a depth of 56", both tanks were then filled to the top starting with Tank 3. After the tanks were filled there was about 19" of tailing in each tank, this was extremely hard to judge because of the fine fluffy nature of the tailing. A composite sample was taken from each tank for the first addition and the second and third additions combined.

10/31 - Measured about 34" of tailing in each tank.

11/01 - Measured about 39" of tailing in each tank.

11/08 - A second truck was needed to provide a sufficient bed depth in both tanks. The truck was rinsed once with tailing. Emptied 52" of water out of each tank and added 2 feet of tailing to each tank starting with Tank 4. Both tanks were then filled to within one foot of the top of the tank. One composite sample was taken for each tank.

11/27 - Sampled tanks (week 3), Tank 3: Middle Port - sample was slightly cloudy. Bottom Port - when inserting the 1/4" sample tube it felt like about one foot of tailing in the bottom on the well. The sample was very cloudy and contained a high percentage of tailings, (maybe as high as 50 - 60%). No nutrient sample was taken from this port due to the high percentage of tailings present. Tank 4: Middle Port - sample was slightly cloudy. Bottom Port - there was also about one foot of tailing in the bottom of the well. The sample was cloudy but didn't contain as much tailing as Tank 3. The depth of tailings was 56" in both tanks. The sample procedure was to purge all ports, wait one hour for recharge, and then sample.

12/12 - Tank 3: Middle Port - sample was clear, unable to purge dry. Bottom Port - very cloudy with lots of tailing in sample, unable to purge dry. Estimated about one foot of tailing in the bottom of the well. Tank 4: Middle Port - sample was cloudy, unable to purge dry. Bottom Port - Started clear then turned cloudy, unable to purge dry. Waited one hour between purge and samples.

01/02/97 - Tank 3: Ice thickness = 6". Middle Port - Slightly cloudy, unable to purge dry. Bottom Port - Very cloudy with tailings present, unable to purge dry. Tank 4: Ice thickness = 9". Middle Port - Clear, unable to purge dry. Bottom Port - Slightly cloudy, unable to purge dry. All ports were sampled immediately after purging. Placed end caps on the middle and bottom wells of Tank 4 and the bottom of Tank 3, was unable to cap the middle port on Tank 3 due to cloudiness from tailings disturbance while measuring tailings depth, the ports were previously left open. Tailings depth: Tank 3 = 56.5" Tank 4 = 53.5".

01/30 - Tank 3: Ice thickness = 7". Water depth = 103". Bottom Port - Very cloudy purge volume and sample, when inserting the sample tube you can at least a foot of tailing in the well. Tank 4: Ice thickness = 12". Water depth = 96". Bottom Port - Purge volume was slightly cloudy.

02/26 - Tank 3: Ice thickness = 9". Water depth = 104". Purge volume was very cloudy, pumped sample port dry while purging, sampled after port recharged. Tank 4: Ice thickness = 16". Water depth = 99". A new Eh probe was used, see BLM notebook for reference check results.

04/02 - Purge volume for both tanks was 2000 mLs. Tank 3: After chopping through the ice the surface water appeared cloudy. Tank 4: The surface water under the ice was cloudier than tank 3.

07/31 - Tank 3: The well cap for the bottom sampling port was off. Replaced the cap after sampling.

11/05 - The purge and sample volumes were clear for both tanks.

12/17 - Both tanks had about ½" of ice on the surface. The purge volume for tank 4 started out cloudy and cleared up after about 1000 mLs.

01/15/98 - Both tanks had about 10 - 12" of ice on the surface.

02/26 - Ice thickness was 12" in both tanks.

03/26 - Ice thickness was about 10" in both tanks and free floating.

Appendix 2

Water Quality of the LTV Tank Experiments

Table A2.1. Composition of the Tank 1 (LTV) surface waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 1-Top													
Date	9/25/96	10/2/96	10/8/96	10/16/96	11/27/96	12/12/96	1/30/97	8/1/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	1	2	3	4	10	12	19	45	59	65	69	75	79
pH	8.66	8.68	8.58	8.79	8.68	8.68	8.36	7.94	8.69	8.74	8.79	8.54	8.53
Alkalinity	258	251	256	256	265	289	355	340	235	235	255	130	165
Eh	170	193	194	232	144	na	na	264	na	185	140	171	145
majors (ppm)													
Al	0.000	0.006	0.000	0.000	0.003	0.006	0.005	0.000	0.004	0.001	0.003	0.000	0.004
Si	9.63	9.24	9.68	9.44	9.55	9.65	10.62	0.32	1.44	1.41	1.42	0.69	1.17
P	0.011	0.000	0.008	0.001	0.004	0.003	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.03	0.00	0.01	0.00	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.27
Mn	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.01	0.05
Sr	0.11	0.10	0.11	0.11	0.13	0.12	0.15	0.01	0.09	0.09	0.11	0.05	0.06
Ba	0.007	0.007	0.007	0.007	0.007	0.007	0.009	0.001	0.004	0.004	0.004	0.002	0.003
Ca	14.9	14.5	14.1	14.2	17.4	16.4	21.1	2.2	11.6	12.4	14.7	6.2	8.3
Mg	31.7	30.4	33.0	33.3	38.0	36.9	46.8	3.3	31.3	33.1	37.8	14.9	21.2
Na	127.5	121.3	124.3	124.4	136.4	131.9	165.7	18.4	107.8	111.1	125.4	58.1	72.1
K	18.9	17.9	16.2	16.2	17.5	16.7	20.5	3.1	13.4	14.4	18.3	11.5	10.4
F	10.92	10.81	10.22	10.41	na	10.45	13.10	1.48	8.76	9.24	10.54	4.50	6.03
Cl	40.07	39.16	41.16	41.96	na	41.82	53.20	7.20	35.05	36.57	44.43	22.51	25.83
NO2-N	0.13	0.15	0.16	0.15	na	0.07	0.04	na	na	na	0.00	0.00	0.00
Br	0.17	0.17	0.18	0.18	na	0.19	0.22	0.03	0.15	0.14	0.18	0.08	0.10
NO3-N	1.29	0.13	1.12	1.17	na	3.80	1.65	0.10	0.72	0.23	0.54	0.05	0.49
SO4	118.8	116.4	122.5	124.5	117.0	126.5	162.4	12.0	111.0	114.5	132.4	52.7	73.1
trace (ppb)													
Li	79.8	78.0	93.3	85.8	84.3	63.2	112.0	8.2	54.4	62.3	76.1	27.6	35.8
Be	0.00	0.00	0.00	0.06	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
B	464.0	349.2	489.5	497.8	526.6	436.0	764.0	55.6	393.0	415.7	413.0	198.5	176.8
Sc	0.09	0.10	0.11	0.10	0.09	0.11	0.10	0.10	0.39	0.56	0.40	0.19	0.24
Ti	0.11	0.13	0.15	0.15	0.09	0.14	0.03	0.95	1.69	1.99	2.41	1.04	1.22
V	0.36	0.28	0.70	0.76	0.81	0.70	0.80	0.00	0.21	0.31	0.35	0.18	0.11
Cr	3.69	1.35	3.25	1.72	2.54	0.94	8.56	0.00	1.40	0.72	1.48	0.80	0.43
Mn	26.70	20.44	32.50	27.90	31.90	26.50	29.50	1.04	1.75	1.40	1.74	8.79	48.96
Fe	32.60	0.00	0.00	0.00	37.50	5.40	7.20	7.65	27.75	32.01	26.24	30.66	580.60
Co	0.17	0.61	0.69	0.45	0.34	0.23	0.43	0.42	0.24	0.62	0.31	0.48	5.50
Ni	0.76	1.27	0.58	0.56	0.96	1.10	0.00	0.18	0.63	0.97	1.02	2.08	2.52
Cu	2.84	2.38	1.81	1.44	2.21	1.20	1.03	1.14	2.85	4.08	3.65	3.43	5.80
Zn	1.74	1.68	28.11	54.20	48.70	45.30	28.80	1.48	20.04	44.96	16.53	16.22	95.56
Ga	0.04	0.05	0.05	0.03	0.04	0.21	0.05	na	na	na	0.04	na	0.01
Ge	0.30	0.31	0.27	0.30	0.27	0.24	0.47	0.01	0.12	0.10	0.16	0.04	0.08
As	6.46	5.26	6.08	5.67	7.89	6.66	14.50	0.70	6.65	5.82	7.37	2.43	3.33
Se	1.07	1.68	0.13	0.00	0.94	0.00	0.00	0.00	1.17	0.00	0.98	0.37	0.00
Rb	22.20	20.07	17.30	17.50	19.07	15.80	21.80	3.64	15.23	16.35	17.24	8.93	10.34
Sr	108.3	103.8	113.4	108.8	129.9	114.0	159.2	15.7	94.4	98.8	115.5	50.0	62.7
Y	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.00	0.00	0.01	0.01	na	0.03
Zr	0.13	0.14	0.17	0.16	0.04	0.11	0.08	na	na	na	na	na	0.81
Nb	0.01	0.01	0.01	0.01	0.00	0.00	0.02	na	na	na	na	na	0.01
Mo	395.4	354.7	374.8	372.0	372.1	348.6	479.2	35.1	322.3	312.7	394.1	146.3	202.7
Ag	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.58	0.58	0.08
Cd	0.35	0.42	0.34	0.36	0.52	0.42	0.37	0.06	0.15	0.27	0.43	0.16	0.30
Sn	0.05	0.35	0.18	0.09	0.18	0.12	0.30	0.00	0.33	0.32	0.40	0.23	0.85
Sb	0.63	0.30	0.26	0.28	0.13	0.18	0.06	0.01	0.09	0.08	0.09	0.04	0.05
Te	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	na	0.00
Cs	3.23	2.97	2.29	2.16	2.29	1.72	2.11	0.37	1.48	1.35	1.53	0.72	0.74
Ba	6.56	5.94	6.50	6.76	6.75	6.73	8.32	0.90	3.60	3.50	4.25	1.96	2.38
W	4.87	4.84	5.54	5.38	5.50	5.76	6.59	0.39	3.86	3.28	4.57	1.37	2.10
Re	0.00	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	na	0.00
Tl	0.00	0.01	0.01	0.00	0.01	0.00	0.00	na	na	na	na	na	0.01
Pb	0.06	0.00	0.18	2.62	0.34	0.14	0.00	0.05	0.01	0.02	0.06	0.34	0.45
Bi	0.00	0.00	0.00	0.00	0.00	0.01	0.00	na	na	na	na	na	0.01
Th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	na	0.01
U	0.53	0.26	0.33	0.32	0.28	0.15	1.80	0.02	0.25	0.27	0.30	0.28	0.45

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Table A2.2. Composition of the Tank 2 (LTV) surface waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 2-Top													
Date	9/25/96	10/2/96	10/10/96	10/16/96	11/27/96	12/12/96	4/2/97	8/1/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	1	2	3	4	10	12	19	45	59	65	69	75	79
pH	8.66	8.66	8.73	8.80	8.86	8.56	8.49	8.70	8.75	8.73	8.74	8.65	8.59
Alkalinity	258	243	249	252	270	271	170	125	210	225	240	122	120
Eh	171	191	191	230	150	na	160	205	na	171	142	163	133
majors (ppm)													
Al	0.000	0.004	0.000	0.000	0.009	0.006	0.003	0.004	0.004	0.000	0.002	0.002	0.001
Si	9.83	9.35	9.01	9.00	8.30	7.90	5.35	1.44	1.57	1.67	1.88	0.79	0.61
P	0.007	0.013	0.002	0.003	0.009	0.004	0.012	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn	0.03	0.02	0.03	0.03	0.04	0.03	0.02	0.00	0.00	0.00	0.00	0.01	0.00
Sr	0.11	0.10	0.11	0.11	0.13	0.12	0.08	0.05	0.10	0.10	0.12	0.05	0.05
Ba	0.01	0.01	0.01	0.07	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	15.0	14.7	20.0	14.2	17.5	16.1	11.4	7.7	12.4	13.1	15.5	7.2	6.7
Mg	32.3	31.4	33.6	34.0	37.2	35.0	21.7	15.7	32.8	33.7	37.8	17.5	15.6
Na	124.2	119.2	116.1	117.6	123.4	114.0	69.7	59.3	101.7	103.9	116.4	58.7	54.0
K	18.3	17.5	14.8	15.2	15.6	14.5	8.6	8.1	12.6	13.0	14.7	8.0	7.9
F	10.97	10.50	9.81	10.05	na	9.27	5.73	4.58	8.29	8.45	9.61	4.50	4.11
Cl	40.20	38.50	39.90	40.70	na	37.50	23.10	20.54	33.33	34.12	39.00	20.28	19.31
NO2-N	0.138	0.165	0.161	0.151	na	0.068	0.009	0.110	na	na	0.000	0.000	0.000
Br	0.176	0.165	0.173	0.177	na	0.160	0.108	0.106	0.149	0.144	0.171	0.090	0.082
NO3-N	2.72	1.46	0.99	1.02	na	4.68	1.22	0.13	0.24	1.35	0.05	0.20	0.56
SO4	120.0	115.0	119.0	120.7	na	116.3	72.2	53.1	107.6	110.1	124.8	55.0	51.5
trace (ppb)													
Li	81.2	84.4	86.0	na	72.0	61.0	38.6	31.6	63.1	58.2	71.9	28.3	33.8
Be	0.01	0.04	0.00	na	0.15	0.05	0.50	0.00	0.00	0.02	0.00	0.14	0.00
B	514.0	465.0	459.0	na	461.0	388.0	375.0	183.0	382.0	342.6	372.5	225.5	142.4
Sc	0.09	0.10	0.10	na	0.08	0.08	0.06	0.40	0.54	0.62	0.52	0.19	0.14
Ti	0.75	0.12	0.17	na	0.10	0.10	0.84	0.06	1.81	0.09	2.67	1.23	0.05
V	0.25	0.68	0.69	na	0.66	0.58	0.24	0.41	0.41	0.35	0.44	0.21	0.10
Cr	3.15	2.21	1.86	na	0.84	0.39	4.30	1.03	0.50	0.95	2.19	2.59	0.00
Mn	27.00	31.80	31.80	na	37.00	30.00	25.00	0.35	0.89	0.50	0.42	9.09	3.66
Fe	0.00	0.00	0.00	na	7.70	0.00	2.30	21.10	17.34	9.07	20.28	14.64	0.00
Co	0.12	0.71	4.01	na	0.52	0.21	0.29	1.34	0.43	0.28	0.27	0.31	0.40
Ni	0.85	0.61	1.21	na	1.10	1.60	1.20	0.35	1.68	0.52	0.68	2.54	0.49
Cu	1.90	1.65	3.38	na	2.30	0.94	0.70	2.03	3.17	2.95	2.23	2.54	1.27
Zn	2.30	26.78	51.43	na	42.50	52.10	25.00	3.20	32.52	22.01	16.59	26.09	36.57
Ga	0.07	0.04	0.03	na	0.04	0.03	0.00	na	na	na	na	na	0.02
Ge	0.28	0.27	0.28	na	0.24	0.23	0.16	0.06	0.00	0.07	0.15	0.08	0.06
As	5.99	5.81	6.00	na	6.92	5.20	4.20	3.56	7.85	7.14	7.85	3.07	2.83
Br	na	na	na	na	na	na	na	98.40	151.50	144.80	155.20	79.83	72.89
Rb	21.60	15.60	15.80	na	15.91	13.30	9.93	9.09	13.73	13.44	15.36	9.01	7.22
Sr	110.0	111.1	112.2	na	132.2	109.0	92.3	60.1	109.7	107.3	118.0	55.8	53.6
Y	0.01	0.01	0.01	na	0.02	0.02	0.01	0.00	0.01	0.01	0.01	na	0.00
Zr	0.17	0.16	0.39	na	0.29	0.10	0.20	na	na	na	na	na	0.22
Nb	0.01	0.01	0.01	na	0.01	0.00	0.02	na	na	na	na	na	0.00
Mo	372.0	343.7	344.4	na	349.1	298.0	209.0	149.6	296.0	293.2	339.8	130.4	127.3
Ag	0.00	0.00	0.00	na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05
Cd	0.34	0.33	0.34	na	0.31	0.32	1.60	0.19	0.23	0.32	0.23	0.16	0.16
Sn	0.15	0.16	0.11	na	0.04	0.05	0.21	0.30	0.19	0.19	0.14	0.16	0.00
Sb	0.24	0.25	0.27	na	0.12	0.17	0.02	0.06	0.07	0.08	0.07	0.04	0.01
Te	0.01	0.00	0.00	na	0.00	0.00	0.01	0.00	0.00	0.00	0.00	na	0.00
Cs	3.22	2.08	2.18	na	1.80	1.48	1.03	0.92	1.39	1.31	1.39	0.70	0.60
Ba	6.74	6.88	7.12	na	7.74	6.50	5.08	3.51	4.05	3.69	4.69	2.50	1.96
W	4.65	5.50	5.39	na	5.16	4.57	2.18	1.83	3.69	2.92	4.13	1.49	1.51
Re	0.00	0.00	0.00	na	0.00	0.00	0.00	na	na	na	na	na	0.00
Tl	0.01	0.01	0.00	na	na	0.00	0.02	na	na	na	na	na	0.00
Pb	0.08	0.05	0.33	na	0.20	8.34	0.04	4.70	0.00	0.03	0.00	0.11	0.06
Bi	0.01	0.00	0.01	na	0.00	0.00	0.00	na	na	na	na	na	0.01
Th	0.01	0.01	0.01	na	0.00	0.00	0.01	na	na	na	na	na	0.00
U	0.46	0.32	0.31	na	0.20	0.10	0.24	0.15	0.24	0.22	0.24	0.29	0.29

Table A2.3. Composition of the Tank 1 (LTV) tailings pore waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 1-Bottom															
Date	9/18/96	9/25/96	10/2/96	10/10/96	10/16/96	11/27/96	1/30/97	2/26/97	4/2/97	8/1/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	0	1	2	3	4	10	19	23	28	45	59	65	69	75	79
pH	8.26	8.22	8.11	8.11	8.11	8.28	8.03	8.33	8.20	8.18	7.96	8.15	8.01	8.18	8.11
Alkalinity	271	270	282	290	288	260	310	325	300	260	285	265	297.5	268	270
Eh	195	173	197	199	237	151	na	198	231	178	na	188	144	185	151
majors (ppm)															
Al	0.000	0.000	0.003	0.000	0.000	0.004	0.065	0.015	0.004	0.002	0.330	0.000	0.022	0.001	0.002
Si	9.39	9.04	8.96	9.01	8.51	7.86	8.29	8.36	8.85	7.68	11.90	6.34	5.85	5.31	5.48
P	0.013	0.012	0.000	0.007	0.017	0.013	0.007	0.011	0.004	0.000	0.029	0.000	0.000	0.006	0.007
Fe	0.03	0.06	0.01	0.03	0.01	0.06	0.04	0.01	0.01	0.00	5.21	0.00	0.11	0.00	0.00
Mn	0.05	0.07	0.09	0.08	0.09	0.09	0.06	0.07	0.07	0.13	0.27	0.12	0.10	0.09	0.12
Sr	0.26	0.31	0.34	0.35	0.37	0.34	0.24	0.28	0.27	0.31	0.39	0.40	0.36	0.34	0.36
Ba	0.012	0.013	0.014	0.014	0.013	0.010	0.011	0.012	0.010	0.011	0.011	0.008	0.008	0.009	0.009
Ca	21.4	23.4	24.8	26.0	26.2	24.9	22.4	24.5	23.5	23.1	27.5	28.1	26.8	25.4	26.1
Mg	32.7	35.1	36.4	38.3	38.3	38.0	42.6	47.6	43.1	36.6	41.4	43.4	43.2	43.3	42.5
Na	119.1	114.9	109.2	109.6	108.7	97.9	134.6	135.6	120.7	93.1	88.7	89.4	94.5	98.0	90.3
K	11.2	9.9	8.9	8.5	8.0	6.3	12.6	12.8	11.0	7.8	6.8	5.9	7.8	7.8	6.9
F	6.96	6.51	6.52	6.37	6.43	na	9.84	10.05	9.14	6.75	6.61	6.63	7.30	7.62	7.16
Cl	34.13	34.08	34.90	36.35	37.00	na	45.20	45.70	42.70	34.90	36.14	36.83	38.84	38.59	38.27
NO2-N	0.16	0.04	0.02	0.00	0.00	na	0.02	0.01	0.04	na	na	na	0.00	0.00	0.00
Br	0.14	0.14	0.14	0.14	0.15	na	0.19	0.22	0.19	0.16	0.16	0.16	0.17	0.17	0.17
NO3-N	4.28	0.83	0.14	0.12	0.02	na	0.89	3.90	0.65	0.23	0.31	1.46	0.03	0.38	0.15
SO4	113.0	113.3	115.1	118.9	120.2	112.0	136.5	142.0	131.0	102.2	104.0	104.2	109.8	111.1	105.9
trace (ppb)															
Li	58.4	55.0	56.2	57.7	67.0	44.7	88.0	43.2	59.0	41.1	39.9	39.8	41.1	45.1	38.6
Be	0.02	0.11	0.11	0.02	0.00	0.03	0.00	0.36	0.00	0.00	0.06	0.00	0.11	0.16	0.00
B	491.0	562.0	488.0	561.0	564.0	411.0	506.4	464.0	538.0	410.0	462.0	607.5	384.6	597.5	331.6
Sc	0.09	0.08	0.10	0.10	0.10	0.08	0.07	0.07	0.10	2.23	3.50	2.49	1.48	1.37	1.22
Ti	0.11	0.10	0.13	0.13	0.14	0.08	0.00	1.68	1.61	3.10	4.12	3.72	4.10	3.80	3.36
V	0.19	0.09	0.00	0.33	0.31	0.26	0.47	0.29	0.30	0.22	0.92	0.20	0.28	0.19	0.17
Cr	3.56	3.96	1.71	5.42	1.45	1.61	9.62	1.21	9.27	0.37	2.05	2.00	3.07	4.25	1.44
Mn	43.40	62.11	78.95	81.50	82.20	86.40	60.60	60.50	69.00	120.00	254.0	110.3	94.73	96.70	109.00
~~Fe~~	29.60	29.70	14.60	20.18	10.27	19.70	10.99	0.00	10.10	16.00	5300	24.03	135.1	34.99	17.83
Co	0.10	0.34	0.49	0.54	0.65	0.36	1.16	0.51	0.38	0.40	0.78	0.18	0.30	0.33	1.52
Ni	0.57	1.26	0.76	0.59	0.59	1.78	1.47	1.78	2.81	2.70	4.36	2.22	1.73	6.34	2.44
Cu	1.56	1.30	2.94	0.77	0.80	1.68	0.00	0.00	0.00	0.67	0.59	0.42	0.68	1.30	2.16
Zn	1.19	1.16	1.00	0.44	48.40	42.88	33.70	75.95	54.50	6.80	28.74	25.46	18.22	21.94	33.42
Ga	0.40	0.03	0.01	0.04	0.05	0.01	0.04	0.03	0.01	na	na	na	0.01	na	0.00
Ge	0.27	0.31	0.30	0.39	0.36	0.38	0.34	0.39	0.37	0.31	0.56	0.32	0.27	0.20	0.26
As	3.75	4.76	4.85	4.55	3.97	1.70	7.72	5.78	6.41	3.62	3.18	1.46	1.84	2.09	1.31
Se	0.45	0.00	0.11	0.74	0.00	0.00	0.00	1.11	1.18	159.00	167.1	151.3	0.61	1.26	0.00
Rb	12.64	11.27	10.08	9.69	8.88	6.17	12.87	12.30	11.50	8.80	7.74	6.24	8.41	8.51	6.46
Sr	237.2	274.7	300.3	346.8	343.0	306.0	269.0	281.5	299.9	328.0	390.0	378.2	346.0	331.4	316.9
Y	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.05	0.03	0.03	0.31	0.03	0.04	0.04	0.02
Zr	0.09	0.09	0.11	0.13	0.09	0.10	0.07	0.13	0.06	na	na	na	0.20	na	0.14
Nb	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	na	na	na	0.01	na	0.00
Mo	264.3	141.2	80.7	64.9	54.1	63.2	286.2	241.0	205.0	89.2	67.2	53.1	95.5	131.1	91.1
Ag	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Cd	0.23	0.14	0.10	0.01	0.04	0.04	0.18	0.16	0.15	0.10	0.03	0.05	0.08	0.04	0.10
Sn	11.53	16.70	6.53	2.28	0.00	0.04	0.31	0.66	0.01	2.97	1.59	1.78	0.80	1.23	1.23
Sb	0.19	0.18	0.14	0.11	13.30	0.03	0.04	0.02	1.87	0.03	0.02	0.01	0.03	0.03	0.02
Te	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	na	0.00
Cs	2.26	1.89	1.74	1.70	1.50	1.04	1.39	1.67	1.47	1.46	1.49	1.08	1.54	1.60	1.14
Ba	11.41	12.43	13.28	13.30	12.93	9.76	10.19	10.62	9.94	9.49	10.66	7.46	7.06	8.15	8.24
W	4.67	3.64	3.08	2.71	2.50	2.12	4.71	3.25	2.80	1.87	2.14	1.44	2.12	2.15	1.92
Re	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	na	0.00
Tl	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	na	na	na	na	na	0.00
Pb	0.04	0.02	0.03	0.02	0.05	0.06	0.01	0.10	0.01	0.00	0.10	0.03	0.01	0.10	0.01
Bi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	na	0.00
Th	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	na	na	na	na	na	0.01
U	0.18	0.11	0.05	0.06	0.05	0.03	0.81	0.65	0.27	0.16	0.07	0.04	0.06	0.27	0.21

Table A2.4. Composition of the Tank 2 (LTV) tailings pore waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 2-Bottom

Date	9/18/96	9/25/96	11/27/96	12/12/96	8/1/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	0	1	10	12	45	59	65	69	75	79
pH	8.23	8.11	8.54	8.35	8.28	8.17	8.19	8.14	8.14	8.10
Alkalinity	281	270	245	273	280	293	270	280	260	250
Eh	190	172	151	na	132	na	173	132	179	130
majors (ppm)										
Al	0.000	0.000	0.004	0.012	0.001	0.002	0.004	0.004	0.001	0.004
Si	9.26	9.17	7.79	9.26	10.51	7.00	6.78	6.41	6.16	5.29
P	0.005	0.062	0.009	0.042	0.000	0.000	0.000	0.000	0.000	0.009
Fe	0.01	0.02	0.02	0.05	0.00	0.00	0.00	0.00	0.02	0.00
Mn	0.06	0.10	0.05	0.06	0.06	0.12	0.14	0.14	0.14	0.12
Sr	0.22	0.29	0.18	0.21	0.21	0.35	0.39	0.36	0.36	0.30
Ba	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ca	19.9	22.9	18.4	19.6	19.9	24.4	26.5	27.0	26.5	24.8
Mg	31.4	34.4	38.7	41.4	40.7	40.5	43.2	44.9	45.1	45.5
Na	126.0	117.4	106.9	102.1	106.6	87.7	84.8	73.6	77.7	66.5
K	12.0	9.3	9.3	7.4	10.3	6.5	5.3	4.9	5.0	4.9
F	7.90	7.16	na	7.54	8.41	6.89	6.88	6.61	6.71	6.30
Cl	36.20	35.50	na	38.00	38.40	36.20	37.87	44.62	42.83	49.63
NO2-N	0.030	0.000	na	0.000	na	na	na	0.000	0.000	0.000
Br	0.151	0.150	na	0.157	0.179	0.168	0.165	0.236	0.216	0.291
NO3-N	0.76	0.08	na	2.44	0.22	0.98	0.51	0.04	0.46	0.17
SO4	116.0	113.3	na	111.3	116.0	91.6	91.1	78.2	84.4	72.4
trace (ppb)										
Li	62.0	55.0	56.0	46.0	58.2	39.0	31.8	28.0	26.4	26.7
Be	0.00	0.02	0.01	0.01	0.00	0.00	0.05	0.00	0.00	0.00
B	471.0	494.0	431.0	391.0	443.0	477.0	400.0	347.1	531.8	253.8
Sc	0.09	0.08	0.07	0.09	2.82	2.09	2.30	1.47	1.48	1.15
Ti	0.10	0.10	0.12	0.11	2.52	0.14	3.14	3.37	3.94	0.09
V	0.11	0.00	0.42	0.37	0.71	0.18	0.26	0.21	0.23	0.29
Cr	4.90	3.59	0.53	0.37	6.78	2.17	1.32	2.04	4.91	1.42
Mn	57.00	91.00	48.00	52.40	60.00	116.00	126.20	141.90	141.80	104.40
Fe	197.00	16.40	15.00	15.00	6.79	12.60	10.65	27.34	13.08	7.52
Co	0.11	0.28	0.16	0.20	0.18	0.37	0.26	0.73	0.34	0.38
Ni	0.57	0.58	1.03	1.46	1.49	1.24	0.90	1.90	2.41	0.82
Cu	1.60	0.50	1.50	0.40	0.74	0.60	0.45	0.71	0.54	0.50
Zn	1.50	0.31	44.90	45.00	1.30	29.40	25.82	24.45	22.92	24.94
Ga	0.04	0.38	0.02	0.01	na	na	na	0.02	na	0.02
Ge	0.22	0.45	0.25	0.22	0.24	0.31	0.24	0.34	0.31	0.31
As	4.59	3.83	3.16	1.80	7.47	2.62	2.63	1.50	1.54	1.71
Br	na	na	na	na	192.00	167.00	161.00	208.80	182.50	240.50
Rb	13.20	9.47	8.88	6.88	11.75	6.24	5.44	4.79	5.03	4.94
Sr	214.0	268.0	175.0	193.0	225.2	343.0	380.1	335.3	317.2	292.7
Y	0.02	0.02	0.02	0.01	0.03	0.02	0.02	0.02	na	0.02
Zr	0.11	0.07	0.05	0.06	na	na	na	na	na	0.20
Nb	0.01	0.00	0.00	0.00	na	na	na	na	na	0.01
Mo	305.0	127.7	166.6	71.5	218.2	79.2	41.3	18.2	27.9	26.6
Ag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cd	0.23	0.17	0.18	0.04	0.31	0.06	0.06	0.03	0.04	0.03
Sn	19.20	66.09	0.19	0.00	2.73	0.67	1.00	0.57	0.65	0.68
Sb	0.19	0.13	0.06	0.04	0.06	0.02	0.01	0.01	0.01	0.01
Te	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	na	0.01
Cs	2.54	1.67	1.22	1.16	2.21	1.06	1.13	1.00	1.04	1.01
Ba	10.90	12.10	9.31	9.60	14.00	7.95	7.26	6.77	8.71	7.56
W	4.51	3.15	4.52	4.19	4.48	1.75	1.35	1.10	1.21	1.27
Re	0.00	0.00	0.00	0.00	na	na	na	na	na	0.00
Tl	0.00	0.01	0.01	0.00	na	na	na	na	na	0.01
Pb	0.03	0.06	0.22	0.29	0.00	0.03	0.02	0.00	0.06	0.01
Bi	0.00	0.00	0.00	0.01	na	na	na	na	na	0.01
Th	0.00	0.00	0.00	0.00	na	na	na	na	na	0.00
U	0.17	0.04	0.08	0.00	0.18	0.08	0.06	0.03	0.07	0.12

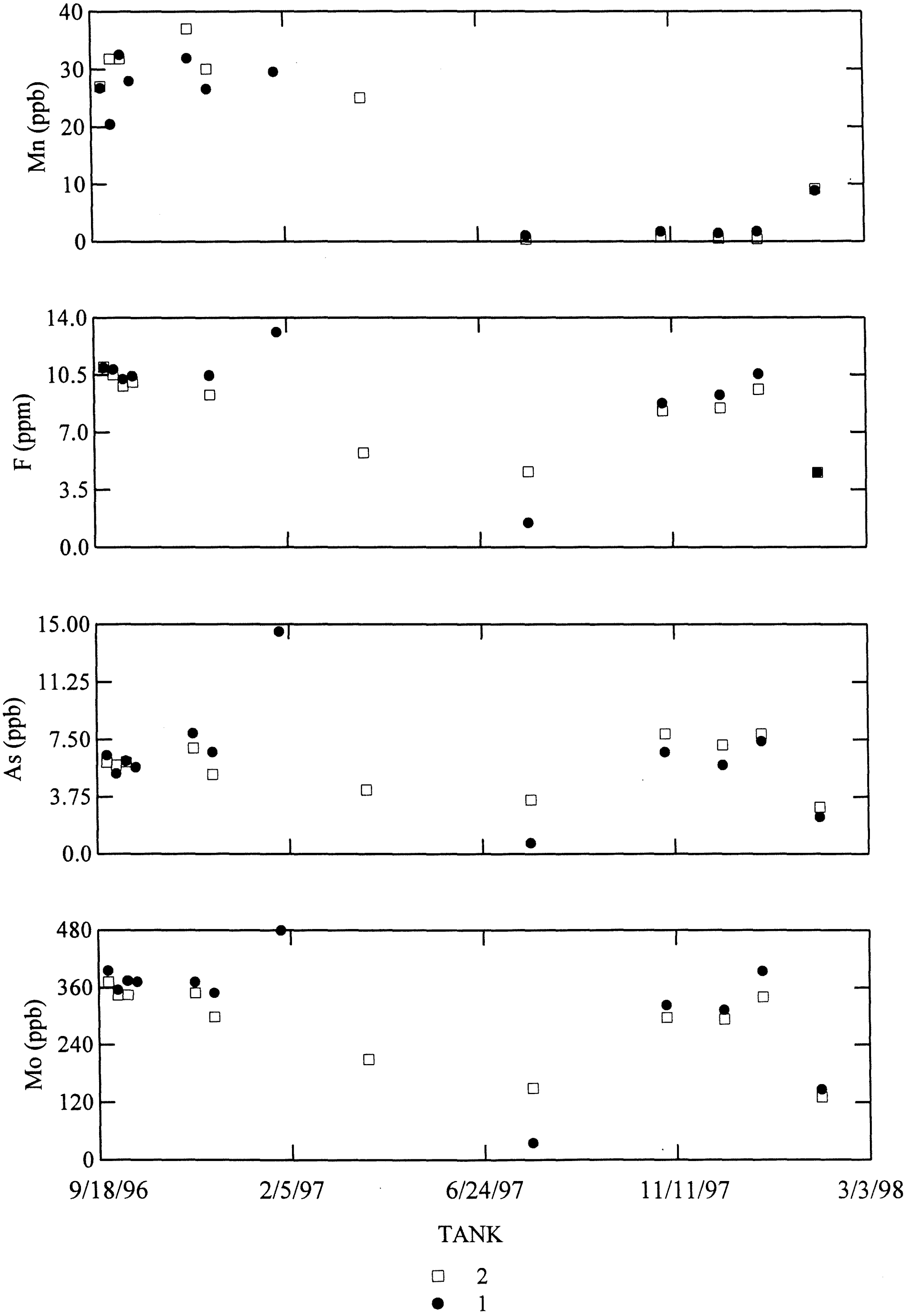

Figure A2.1. Surface water quality was reproducible for Tanks 1 and 2 (LTV).

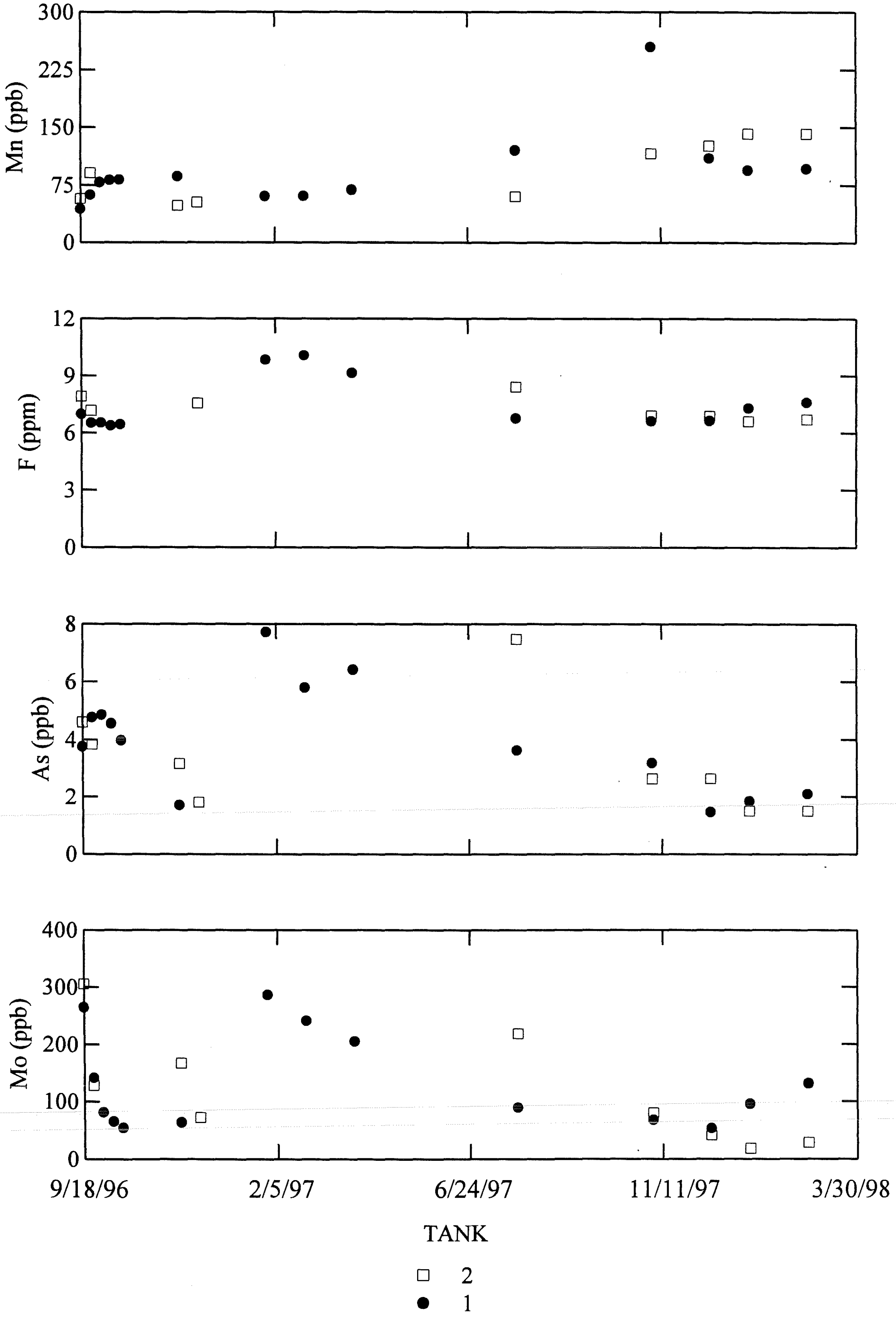

Figure A2.2. Tailings pore water quality was reproducible for Tanks 1 and 2 (LTV).

Appendix 3

Water Quality of the Inland Tank Experiment

Table A3.1. Composition of the Tank 3 (Inland) surface waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 3-Top										
Date	11/27/96	12/12/96	1/2/97	8/1/97	9/10/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	3	5	8	38	44	52	58	62	68	72
pH	8.58	8.42	8.38	8.58	8.56	8.63	8.79	8.85	8.77	8.84
Alkalinity	218	201	195	170	170	160	158	170	142	90
Eh	143	na	na	154	226	na	157	117	161	112
majors (ppm)										
Al	0.005	0.010	0.003	0.000	0.002	0.002	0.000	0.036	0.000	0.002
Si	9.50	9.20	8.86	6.70	6.45	3.47	3.02	2.42	1.94	1.30
P	0.006	0.013	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Mn	0.10	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sr	0.16	0.14	0.14	0.12	0.13	0.13	0.12	0.14	0.11	0.07
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	40.3	35.3	35.7	30.6	31.2	26.8	26.7	30.0	23.9	14.6
Mg	57.5	51.2	50.4	44.8	47.5	48.8	49.0	54.5	43.1	26.1
Na	41.3	36.8	36.4	32.4	33.3	32.8	33.1	36.8	29.3	18.2
K	15.8	14.5	14.4	12.5	12.9	12.4	12.5	14.2	11.5	8.0
F	na	5.30	5.36	4.49	4.72	4.57	4.67	5.27	4.07	2.53
Cl	na	94.03	95.20	79.40	84.00	8139.00	84.47	94.64	74.65	47.04
NO2-N	na	0.088	0.090	0.024	0.028	na	na	0.000	0.000	0.000
Br	na	0.63	0.64	0.60	0.63	0.62	0.60	0.69	0.55	0.35
NO3-N	na	4.21	1.35	1.09	2.35	0.63	1.69	0.46	1.27	0.38
SO4	66.8	58.3	59.2	50.6	53.7	53.3	54.8	61.3	47.9	28.1
trace (ppb)										
Li	33.4	27.7	28.0	24.4	24.8	29.2	25.2	30.3	22.2	13.4
Be	0.00	0.02	0.05	0.14	0.02	0.05	0.00	0.08	0.00	0.16
B	141.0	120.8	135.0	97.4	94.5	112.0	155.4	122.4	82.7	59.9
Sc	0.10	0.09	0.10	2.11	2.19	1.01	1.21	0.66	0.53	0.31
Ti	0.10	0.08	0.10	3.00	2.97	2.72	3.76	4.02	3.48	1.96
V	0.73	0.64	0.72	0.61	0.39	0.35	0.62	0.55	0.42	0.21
Cr	0.70	0.89	2.34	1.18	0.59	1.08	0.80	2.18	2.78	0.67
Mn	90.20	76.20	73.50	1.58	2.25	1.24	0.69	1.43	2.18	7.31
Fe	24.70	15.50	7.38	0.00	11.57	22.86	19.51	38.43	24.60	0.00
Co	0.18	0.21	0.19	1.76	0.19	0.19	0.21	0.24	0.37	1.96
Ni	1.54	2.18	1.77	1.06	1.50	0.87	0.64	1.26	1.49	1.24
Cu	2.33	2.58	3.05	5.46	5.88	6.13	5.83	7.48	7.15	4.83
Zn	44.70	43.60	25.20	4.94	2.93	27.28	33.58	18.53	21.05	53.37
Ga	0.01	0.00	0.01	na	na	na	na	0.01	na	0.01
Ge	0.18	0.15	0.14	0.12	0.14	0.09	0.08	0.09	0.07	0.00
As	1.80	1.20	1.69	1.54	5.08	10.74	9.78	11.45	9.93	5.74
Br	na	na	na	624.00	657.00	595.00	539.10	625.30	458.90	282.50
Rb	12.40	10.60	11.25	9.82	10.50	10.47	10.14	11.49	9.03	5.74
Sr	158.0	151.0	146.4	135.0	131.1	143.2	131.3	145.9	116.1	78.8
Y	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.00	na	0.01
Zr	0.54	0.07	0.09	na	na	na	na	0.66	na	0.04
Nb	0.00	0.00	0.01	na	na	na	na	0.00	na	0.00
Mo	78.4	74.0	74.4	67.9	63.7	69.7	67.1	83.1	62.7	33.1
Ag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.13
Cd	0.07	0.11	0.09	0.14	0.12	0.07	0.09	0.08	0.09	0.10
Sn	0.00	0.00	0.06	0.13	0.04	0.09	0.06	0.06	0.15	0.11
Sb	0.06	0.08	0.07	0.07	0.07	0.05	0.05	0.05	0.05	0.02
Te	0.00	0.06	0.05	0.00	0.00	0.00	0.00	0.00	na	0.00
Cs	1.49	1.30	1.36	1.12	1.20	1.04	0.97	1.06	0.78	0.49
Ba	4.00	3.90	3.81	3.30	3.44	2.46	2.36	2.46	2.21	1.21
W	1.59	1.57	0.02	1.09	1.58	1.44	1.06	1.44	1.13	0.64
Re	0.00	0.00	0.00	na	na	na	na	0.00	na	0.00
Tl	0.01	0.00	0.00	na	na	na	na	0.00	na	0.00
Pb	0.12	0.13	0.03	0.00	0.00	0.02	0.02	0.05	0.07	0.06
Bi	0.00	0.00	0.01	na	na	na	na	0.00	na	0.00
Th	0.02	0.00	0.00	na	na	na	na	0.01	na	0.00
U	0.05	0.05	0.06	0.11	0.13	0.11	0.08	0.08	0.20	0.13

Table A3.2. Composition of the Tank 4 (Inland) surface waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 4-Top										
Date	11/27/96	12/12/96	2/26/97	8/1/97	9/10/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	3	5	16	38	44	52	58	62	68	72
pH	8.55	8.32	nd	8.23	8.60	8.76	8.77	8.81	8.68	8.70
Alkalinity	198	207	nd	50	140	160	160	190	95	160
Eh	135	na	na	156	145	na	101	122	159	117
majors (ppm)										
Al	0.005	0.010	0.004	0.001	0.003	0.006	0.001	0.007	0.001	0.002
Si	9.18	9.69	12.02	0.23	2.48	0.87	0.25	0.51	0.46	1.50
P	0.013	0.016	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00
Mn	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.01
Sr	0.15	0.15	0.20	0.03	0.11	0.12	0.13	0.16	0.08	0.12
Ba	0.00	0.00	0.01	0.00	2.41	0.00	0.00	0.00	0.00	0.00
Ca	37.7	36.6	48.3	9.8	23.6	24.4	26.0	31.2	16.3	25.2
Mg	53.7	54.4	70.7	11.6	40.5	49.0	52.4	61.0	29.6	49.5
Na	39.7	39.2	51.9	10.4	29.4	33.6	35.9	41.2	20.8	33.6
K	15.5	15.3	20.6	5.2	12.1	12.8	13.6	16.1	8.9	13.5
F	na	5.47	7.30	1.33	3.88	4.57	4.93	5.74	2.75	4.62
Cl	na	99.10	130.00	25.40	74.25	84.50	90.86	106.95	52.05	86.56
NO2-N	na	0.097	0.041	0.010	0.024	0.010	na	0.000	0.000	0.000
Br	na	0.66	1.00	0.20	0.56	0.64	0.65	0.80	0.39	0.64
NO3-N	na	4.11	2.06	1.17	1.67	1.89	1.35	0.25	0.31	0.94
SO4	61.9	61.0	82.9	10.5	44.5	55.0	58.7	68.7	33.5	54.9
trace (ppb)										
Li	32.1	29.4	30.6	7.2	21.4	28.3	28.2	32.0	13.9	28.6
Be	0.00	0.01	0.03	0.00	0.10	0.00	0.00	0.12	0.10	0.00
B	101.0	123.4	199.0	28.6	100.2	124.5	134.2	150.0	82.9	83.1
Sc	0.10	0.10	0.11	0.09	0.74	0.30	0.08	0.15	0.16	0.35
Ti	0.08	0.11	3.20	0.00	0.09	2.68	3.37	4.42	0.05	0.06
V	0.63	0.74	0.45	0.15	0.19	0.31	0.56	0.57	0.17	0.38
Cr	1.25	0.76	1.65	0.83	0.70	0.95	0.78	1.95	0.94	7.89
Mn	78.70	74.00	79.50	2.01	3.87	3.78	3.02	3.62	21.13	7.98
Fe	5.03	364.00	2.80	11.20	16.80	54.20	39.33	38.86	27.74	18.81
Co	0.29	0.20	0.49	1.74	0.77	0.22	0.38	0.29	0.59	1.56
Ni	1.81	1.83	2.40	0.83	1.76	0.94	1.12	1.03	1.17	1.24
Cu	1.95	1.37	1.36	3.40	4.68	5.00	5.51	5.72	3.94	4.60
Zn	49.80	51.50	49.32	8.83	9.76	26.10	34.19	17.06	21.45	13.63
Ga	0.02	0.00	0.00	na	na	na	na	0.00	na	0.01
Ge	0.14	0.12	0.12	0.00	0.07	0.06	0.08	0.09	0.03	0.04
As	2.14	1.38	5.64	0.81	8.47	11.61	10.90	13.61	6.55	13.89
Br	673.0	777.0	869.0	207.0	536.0	651.0	619.6	718.9	317.7	577.1
Rb	11.80	11.70	16.30	4.71	9.80	11.05	11.46	14.39	6.99	11.37
Sr	150.0	162.0	208.0	40.6	97.7	132.7	142.8	167.0	82.9	137.1
Y	0.02	0.01	0.02	0.00	0.01	0.01	0.01	0.01	na	0.01
Zr	0.08	0.09	0.09	na	na	na	na	0.32	na	0.10
Nb	0.00	0.00	0.00	na	na	na	na	0.00	na	0.01
Mo	83.8	78.8	107.4	12.5	54.4	67.5	71.8	88.5	43.4	84.1
Ag	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.06	0.06
Cd	0.10	0.15	0.09	0.04	0.17	0.05	0.11	0.10	0.06	0.05
Sn	0.00	0.03	0.00	0.07	0.00	0.10	0.28	0.00	0.17	0.17
Sb	0.05	0.09	0.02	0.01	0.04	0.04	0.04	0.05	0.02	0.04
Te	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	na	0.00
I	61.00	989.00	224.00	na	na	na	na	na	na	na
Cs	1.42	1.33	1.94	0.47	1.11	0.99	0.98	1.12	0.53	0.89
Ba	3.94	4.02	4.53	0.95	2.02	2.35	2.00	2.39	2.32	2.07
W	1.55	1.65	1.65	0.09	0.83	1.04	1.02	1.45	0.51	5.27
Re	0.00	0.00	0.00	na	na	na	na	na	na	0.00
Tl	0.00	0.01	0.01	na	na	na	na	na	na	0.01
Pb	0.31	0.94	0.14	0.06	0.04	0.05	0.08	0.08	0.15	0.13
Bi	0.00	0.01	0.00	na	na	na	na	na	na	0.00
Th	0.01	0.00	0.00	na	na	na	na	na	na	0.00
U	0.06	0.04	0.47	0.03	0.07	0.09	0.16	0.10	0.13	0.23

Table A3.3. Composition of the Tank 3 (Inland) tailings pore waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 3-Bottom													
Date	11/27/96	12/12/96	1/2/97	1/30/97	2/26/97	4/2/97	8/1/97	9/10/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	3	5	8	12	16	21	38	44	52	58	62	68	72
pH	8.42	8.50	8.25	8.32	8.03	8.28	8.37	8.36	8.36	8.42	8.58	8.48	8.60
Alkalinity	198	133	135	145	155	139	125	130	115	115	120	120	135
Eh	138	na	na	na	na	168	130	208	na	156	117	162	118
majors (ppm)													
Al	0.005	0.005	0.007	0.001	0.005	0.003	0.000	0.011	0.006	0.003	0.001	0.000	0.005
Si	8.86	4.03	7.60	5.60	4.75	4.94	5.15	11.37	4.20	3.57	3.08	2.99	3.15
P	0.012	0.016	0.016	0.017	0.010	0.009	0.000	0.013	0.000	0.000	0.000	0.000	0.016
Fe	0.03	0.05	0.11	0.01	0.00	0.01	0.00	0.04	0.03	0.00	0.00	0.00	0.00
Mn	0.07	0.06	0.10	0.11	0.09	0.12	0.09	0.09	0.09	0.08	0.07	0.07	0.05
Sr	0.14	0.16	0.16	0.15	0.17	0.10	0.09	0.20	0.08	0.08	0.09	0.10	0.10
Ba	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	27.0	23.5	27.8	28.4	28.0	25.3	24.2	28.8	22.7	22.9	23.2	23.4	23.5
Mg	59.0	54.6	57.9	58.7	60.0	47.1	42.7	64.3	41.1	42.4	43.3	43.7	44.9
Na	29.8	23.6	22.6	21.1	18.8	12.4	11.4	14.6	9.4	12.6	14.9	16.2	18.3
K	9.7	6.2	7.7	5.6	4.4	3.0	3.1	4.6	2.3	3.5	4.8	5.2	7.1
F	na	5.11	6.50	5.93	6.46	3.93	3.72	3.82	3.67	3.86	3.99	4.15	4.25
Cl	na	95.00	63.60	92.10	95.50	77.80	75.50	95.10	75.85	78.40	81.36	82.67	84.91
NO2-N	na	0.200	0.000	0.020	0.000	0.000	na	na	na	na	0.000	0.000	0.000
Br	na	0.65	0.63	0.62	0.76	0.56	0.56	0.72	0.57	0.55	0.60	0.60	0.62
NO3-N	na	1.26	1.17	0.12	1.55	0.49	0.23	1.68	1.60	0.93	0.14	0.17	1.13
SO4	60.0	57.3	55.8	52.8	52.0	34.1	18.5	38.9	7.3	13.0	18.3	21.6	25.8
trace (ppb)													
Li	16.0	10.3	10.5	7.3	9.3	8.0	6.1	9.4	5.7	7.8	10.5	11.2	12.7
Be	0.07	0.05	0.12	0.40	0.00	0.60	0.00	0.00	0.00	0.00	0.11	0.00	0.00
B	128.0	98.0	101.4	100.0	112.0	64.9	79.0	169.0	109.0	88.9	85.7	63.7	84.0
Sc	0.09	0.05	0.09	0.05	0.05	0.05	1.56	3.43	1.17	1.39	0.82	0.75	0.68
Ti	0.07	0.06	0.06	0.03	1.97	1.23	2.57	2.31	2.17	2.75	3.27	3.18	2.76
V	0.77	0.60	0.85	0.23	0.30	0.21	0.66	0.67	0.25	0.38	0.35	0.51	0.43
Cr	1.41	0.45	1.55	2.21	2.05	4.00	1.61	1.35	1.27	1.38	1.35	1.99	0.99
Mn	69.80	58.08	97.60	112.00	89.40	117.00	88.70	90.00	92.20	82.78	71.08	65.38	49.67
Fe	44.70	418.00	445.00	2.00	2.85	5.46	0.00	38.00	37.70	15.76	31.52	2.79	0.00
Co	0.15	0.19	0.15	0.26	0.30	0.29	0.14	0.14	0.26	0.32	0.29	0.36	0.42
Ni	1.14	1.62	1.18	0.93	1.89	2.25	1.06	2.78	1.17	0.80	1.59	1.45	1.35
Cu	0.77	0.84	0.71	0.00	0.00	0.00	0.40	10.33	0.24	0.61	0.82	1.86	1.69
Zn	45.70	50.91	31.00	43.73	44.75	33.10	1.94	1.99	33.60	24.77	22.91	32.12	38.52
Ga	0.01	0.00	0.01	0.00	0.00	0.01	na	na	na	na	0.01	na	0.01
Ge	0.23	0.21	0.25	0.26	0.34	0.28	0.34	0.27	0.38	0.29	0.28	0.25	0.18
As	2.09	1.27	3.06	3.08	3.63	1.31	1.46	2.99	2.16	2.56	2.75	3.45	3.62
Br	na	na	na	na	na	na	547.00	759.00	528.00	508.10	543.30	517.40	540.10
Rb	8.20	5.03	7.00	4.40	3.55	2.42	2.55	4.33	2.05	2.75	3.85	3.77	4.72
Sr	142.0	163.3	167.6	165.0	183.1	116.6	104.0	209.0	97.7	90.8	98.5	101.3	113.4
Y	0.01	0.10	0.02	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	na	0.01
Zr	0.04	0.07	0.06	0.06	0.09	0.07	na	na	na	na	0.14	na	0.12
Nb	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	0.00	na	0.00
Mo	45.1	18.2	25.0	23.5	19.9	34.7	26.0	32.9	19.2	24.9	32.2	32.3	35.7
Ag	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cd	0.03	0.03	0.03	0.00	0.00	0.00	0.05	0.01	0.00	0.04	0.03	0.07	0.04
Sn	0.00	0.12	0.26	0.00	0.09	0.55	0.77	0.94	0.74	0.99	0.65	0.73	0.90
Sb	0.04	0.03	0.04	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Te	0.02	0.04	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00	na	0.00
Cs	1.11	0.72	1.05	0.61	0.52	0.31	0.37	0.84	0.28	0.29	0.40	0.35	0.38
Ba	2.36	2.70	3.06	2.47	2.55	2.34	1.61	4.05	1.68	1.86	1.70	2.91	2.40
W	1.58	1.23	1.90	1.27	1.03	0.58	0.87	2.08	1.04	0.82	0.86	0.94	1.00
Re	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	0.00	na	0.00
Tl	0.00	0.02	0.00	0.00	0.01	0.01	na	na	na	na	0.01	na	0.00
Pb	0.20	2.54	0.03	0.00	0.07	0.11	0.03	0.90	0.00	0.02	0.01	0.12	0.01
Bi	0.00	0.00	0.01	0.02	0.00	0.00	na	na	na	na	0.00	na	0.00
Th	0.00	0.00	0.00	0.00	0.00	0.01	na	na	na	na	0.00	na	0.00
U	0.07	0.03	0.03	0.18	0.10	0.03	0.03	0.09	0.03	0.03	0.01	0.09	0.10

Table A3.4. Composition of the Tank 4 (Inland) tailings pore waters. Alkalinity in units of mg/L $CaCO_3$. "na" = not available.

Tank 4-Bottom													
Date	11/27/96	12/12/96	1/2/97	1/30/97	2/26/97	4/2/97	8/1/97	9/10/97	11/5/97	12/17/97	1/15/98	2/26/98	3/26/98
weeks	3	5	8	12	16	21	38	44	52	58	62	68	72
pH	8.44	8.34	na	8.40	7.84	na	8.28	8.36	8.23	8.45	8.49	8.39	8.41
Alkalinity	135	128	na	na	11	na	140	135	130	140	138	140	150
Eh	125	na	na	na	-2	na	144	111	na	79	24	127	46
majors (ppm)													
Al	0.016	0.006	0.003	0.003	0.008	0.002	0.000	0.017	0.011	0.003	0.022	0.000	0.005
Si	5.68	3.65	3.16	2.69	2.36	5.84	5.30	4.31	4.51	2.82	2.49	2.67	2.61
P	0.022	0.021	0.012	0.024	0.021	0.005	0.000	0.019	0.000	0.000	0.000	0.000	0.011
Fe	0.09	0.00	0.00	0.00	0.01	0.01	0.03	0.02	0.16	0.19	0.17	0.16	0.13
Mn	0.08	0.08	0.06	0.07	0.08	0.11	0.09	0.07	0.09	0.07	0.07	0.07	0.07
Sr	0.15	0.16	0.17	0.19	0.21	0.12	0.11	0.21	0.10	0.10	0.10	0.11	0.09
Ba	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	26.0	25.2	28.0	27.9	29.8	27.4	24.2	30.6	23.0	23.7	23.7	24.5	23.2
Mg	53.7	53.7	53.5	50.6	51.6	52.2	46.8	48.8	48.2	50.3	50.6	52.4	51.4
Na	26.8	25.1	33.6	25.6	23.3	14.2	10.8	14.6	9.1	15.9	15.1	17.6	14.2
K	6.6	5.3	7.8	5.0	4.2	3.5	3.0	3.3	2.3	5.1	5.2	6.2	4.8
F	na	4.59	6.72	7.11	8.98	5.72	4.60	5.85	4.73	5.03	5.14	4.50	5.01
Cl	na	97.26	99.00	97.60	98.00	83.50	77.45	92.70	80.60	84.84	88.18	92.02	89.06
NO2-N	na	0.030	0.030	0.000	0.000	0.000	na	na	na	na	0.000	0.000	0.000
Br	na	0.66	0.67	0.67	0.77	0.62	0.58	0.70	0.62	0.72	0.67	0.68	0.67
NO3-N	na	2.06	1.85	0.12	1.89	0.30	0.31	1.28	1.50	2.62	0.11	0.96	0.82
SO4	59.2	58.2	60.3	56.9	57.2	22.6	8.5	29.9	4.7	18.0	16.0	20.5	13.7
trace (ppb)													
Li	13.0	11.0	18.0	5.6	7.6	9.8	5.4	6.8	5.1	10.0	9.5	10.9	10.3
Be	0.00	0.03	0.00	0.17	0.82	0.68	0.00	0.00	0.00	0.00	0.03	0.06	0.00
B	98.0	91.0	102.0	81.9	73.0	83.0	85.6	135.4	115.0	97.8	102.4	94.1	51.8
Sc	0.06	0.05	0.05	0.02	0.02	0.06	1.70	1.46	1.39	1.25	0.69	0.62	0.60
Ti	0.13	0.09	0.06	0.03	1.96	1.56	2.52	2.61	0.23	0.06	0.03	0.02	0.05
V	0.66	0.58	0.73	0.21	0.22	0.16	0.57	0.28	0.34	0.44	0.30	0.34	0.37
Cr	2.68	0.40	2.25	2.47	1.40	4.78	1.57	0.45	0.91	0.94	1.91	2.27	1.21
Mn	71.70	73.40	60.71	68.30	77.50	105.00	81.60	66.60	87.80	64.19	71.01	64.62	67.35
Fe	103.00	16.00	17.00	5.80	15.60	10.70	46.09	22.50	209.00	209.70	187.10	262.60	133.40
Co	0.18	0.19	0.08	0.15	0.44	0.30	0.14	0.17	0.27	0.15	0.43	0.21	0.33
Ni	1.39	2.30	1.50	1.00	1.44	1.13	0.93	1.39	1.26	2.55	3.17	1.07	1.63
Cu	0.96	0.73	0.76	0.00	0.00	0.00	0.30	0.25	0.52	1.18	1.25	0.89	1.63
Zn	59.40	44.00	22.90	29.00	43.05	29.19	2.42	1.74	24.90	27.37	25.83	22.16	29.11
Ga	0.01	0.01	0.02	0.01	0.00	0.01	na	na	na	na	0.00	0.01	0.02
Ge	0.18	0.19	0.16	0.14	0.21	0.47	0.27	0.29	0.37	0.22	0.32	0.32	0.31
As	1.25	0.62	1.15	1.14	1.15	1.46	1.63	1.47	1.42	3.69	3.18	4.22	2.62
Br	631.0	770.0	792.0	809.0	662.0	575.0	611.0	718.0	629.0	561.1	569.2	587.8	557.4
Rb	5.30	4.12	5.75	3.72	3.11	2.94	2.44	2.91	1.94	3.91	3.92	4.23	3.06
Sr	147.0	181.0	180.3	201.0	214.0	141.0	122.1	222.0	112.2	105.9	104.0	121.7	96.0
Y	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	na	0.01
Zr	0.05	0.03	0.07	0.03	0.07	0.04	na	na	na	na	0.10	na	0.12
Nb	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	0.00	na	0.00
Mo	19.0	16.0	27.1	14.6	12.6	30.3	20.0	20.0	14.4	27.0	27.3	33.4	25.1
Ag	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Cd	0.01	0.05	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.12	0.08	0.01
Sn	0.00	0.14	0.26	1.60	0.15	0.32	0.71	0.37	0.67	0.75	0.57	0.84	0.77
Sb	0.03	0.04	0.03	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Te	0.01	0.07	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	na	0.00
I	177.00	1874.00	1403.00	391.00	195.00	598.00	na	na	na	na	na	na	na
Cs	0.78	0.64	0.86	0.39	0.38	0.30	0.29	0.39	0.21	0.33	0.35	0.33	0.27
Ba	2.76	4.02	4.48	4.60	5.04	2.70	1.83	3.18	1.84	1.66	1.97	3.04	2.38
W	0.85	1.06	1.15	0.89	0.69	0.37	0.54	1.12	0.68	0.55	0.69	0.65	0.67
Re	0.00	0.00	0.00	0.00	0.00	0.00	na	na	na	na	0.00	na	0.00
Tl	0.01	0.01	0.00	0.00	0.00	0.01	na	na	na	na	0.01	na	0.01
Pb	0.44	0.09	0.00	1.60	0.05	0.01	0.02	0.05	0.05	0.06	0.06	0.07	0.04
Bi	0.00	0.01	0.00	0.00	0.00	0.00	na	na	na	na	0.00	na	0.00
Th	0.00	0.00	0.00	0.01	0.00	0.01	na	na	na	na	0.00	na	0.01
U	0.02	0.00	0.00	0.05	0.04	0.06	0.03	0.06	0.02	0.03	0.03	0.06	0.06

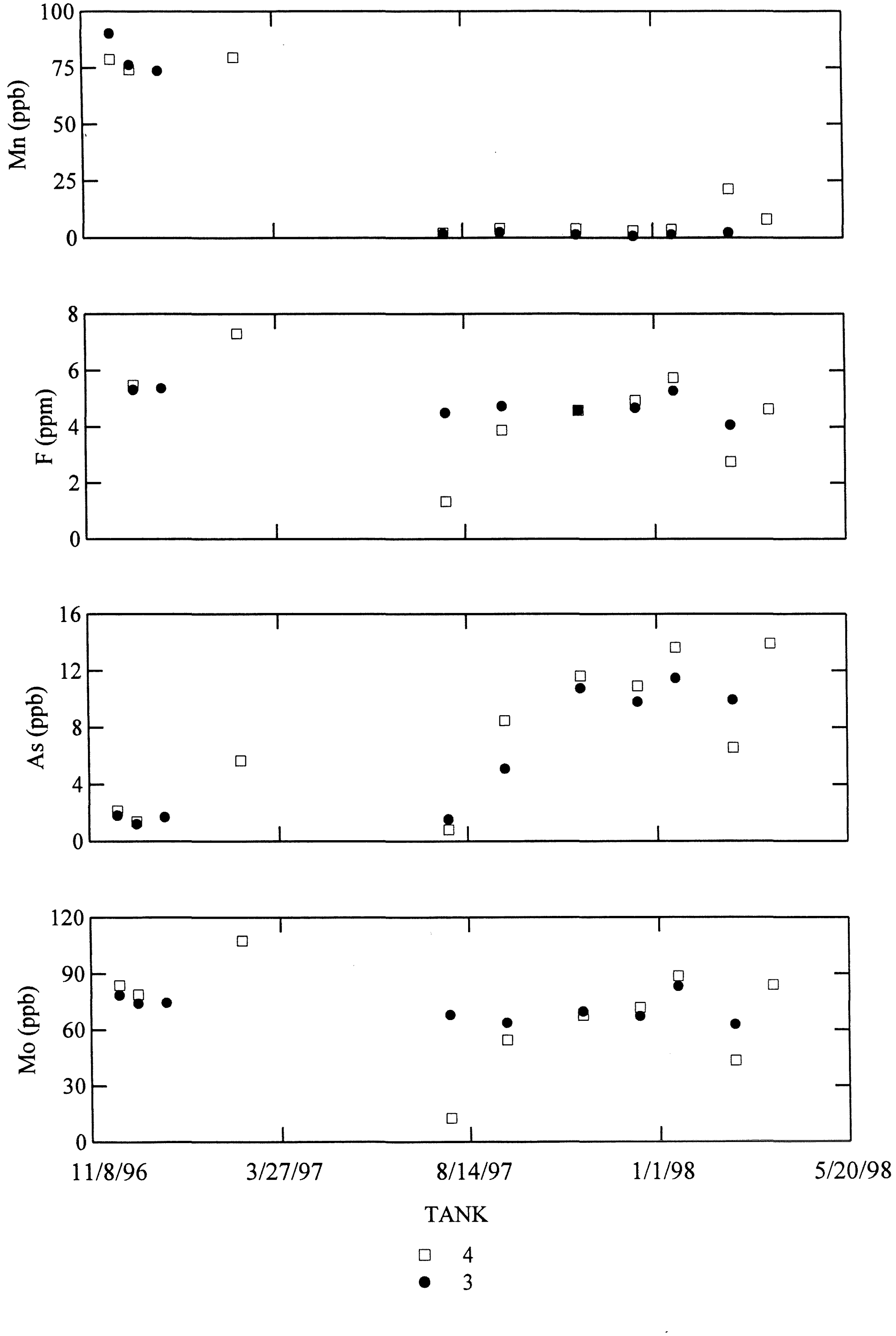

Figure A3.1. Surface water quality was reproducible for Tanks 3 and 4 (Inland).

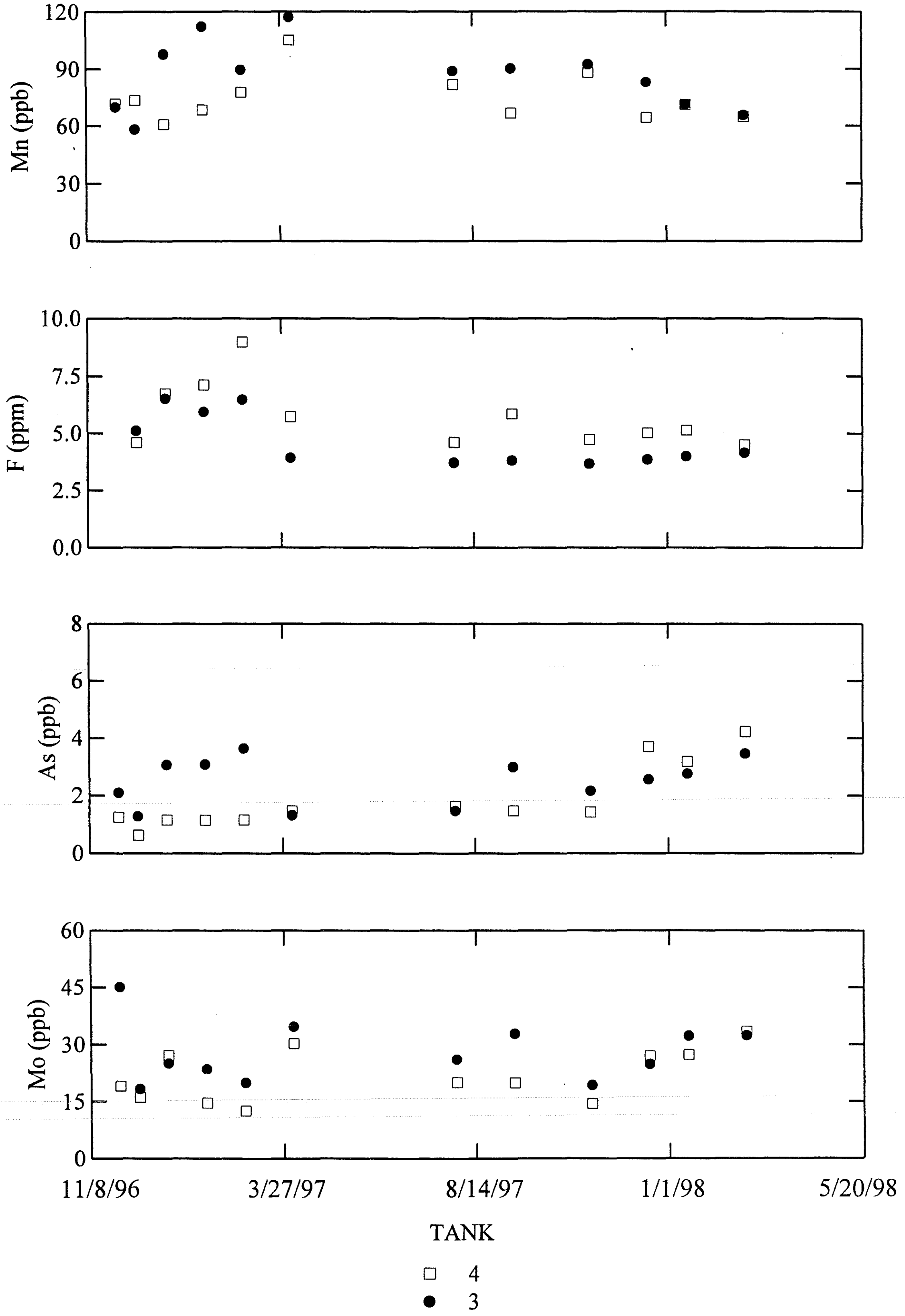

Figure A3.2. Tailings pore water quality was reproducible for Tanks 3 and 4 (Inland).