MONITORING PROGRAM 1995-96, PHASE V
COMPOSITE SOIL COVER ON WASTE ROCK PILE 7/12
AT HEATH STEELE, NEW BRUNSWICK

MEND Project 2.31.1c

This work was done on behalf of MEND and sponsored by the Canada Centre for Mineral and Energy Technology (CANMET)

February 1998

MONITORING PROGRAM 1995-96, PHASE V
COMPOSITE SOIL COVER ON WASTE ROCK PILE 7/12
AT HEATH STEELE, NEW BRUNSWICK

by

Noranda Technology Centre
240 boulevard Hymus
Pointe-Claire, Québec
H9R 1G5

for

Noranda Mining and Exploration Inc.
Heath Steele Division
PO Box 400
Miramichi, NB
E1V 3M5

and

Natural Resources Canada
Canmet/MEND Secretariat
555 Booth Street
Ottawa, Ontario
K1A 0G1

Contract No. 23440-5-1117/01-SQ
MEND Report 2.31.1c

February 1998

Summary

A waste rock pile at the Heath Steele Division of Noranda Mining and Exploration Inc. was covered with a composite soil cover to test the ability of the cover to limit the rate of sulphide mineral oxidation. The experimental waste rock pile was constructed in 1989. Measurements of pore-gas oxygen, temperature and leachate water quality were conducted for two years, with the composite soil cover placed on the pile in 1991. The cover was designed to impede the ingress of water and oxygen to the pile. After construction of the cover, monitoring continued for another five years to assess the effectiveness of the cover. Additional measurements during the post-construction period included cover water content, soil suction, hydraulic conductivity and infiltration.

Results showed reductions in gaseous oxygen concentrations in the waste rock pile after the cover was built, indicating reduced oxidation rates. Similarly, temperatures in the pile have decreased, now appearing to be controlled primarily by climatic conditions rather than sulphide oxidation rates. These findings indicate that oxidation rates are being controlled by the cover.

Since placement of the cover, concentrations of metals and sulphate in leachate collected at the base of the pile appear to have shown a gradual decline, but have also shown an annual fluctuation that increases in the summer and decreases in the fall and winter. The improvement in porewater quality is expected to continue to be gradual since the porewater flushing rate is low. A rough estimate of the flushing rate was calculated at about 30 years for one pile pore volume, and many pore volumes are needed to dissolve and flush products of sulphide mineral oxidation that precipitated prior to placement of the cover.

Effluent loadings decreased immediately following construction of the cover due to reduced infiltration, and since then, declining porewater concentrations have reduced effluent loadings. These findings indicate a positive performance of the cover for limiting sulphide mineral oxidation in waste rock. Based on improved loadings, a savings in the cost of lime was calculated as $196/yr per 1000 tonnes of waste rock; 94% of the savings was observed shortly after construction of the cover due to reduced flushing flows through the cover. Other benefits for treatment include a low volume of flow to be treated and effluent water quality consistency.

The results of five years of monitoring indicate that composite soil covers on waste rock piles are effective in limiting the rate of sulphide oxidation. For a specific application, the cost and savings, as well as long term stability, need to be evaluated. Four recommendations for future cooperative research are made. The two most important are to continue monitoring of the cover performance and to evaluate the apparent dewatering of part of the cover.

Table of Contents

List of Figures

List of Tables

APPENDIX E:

1. INTRODUCTION

The "Heath Steele Waste Rock Study," was a four phased investigation into the oxidation and acid generating characteristics of reactive waste rock piles, and the effectiveness of a composite soil cover in controlling acid generation. The study was registered within the Canadian Mine Environment Neutral Drainage (MEND) Program and was funded by Brunswick Mining and Smelting Corporation (BMS), and both the governments of New Brunswick and Canada. The project began in 1988 at the Heath Steele Division of Noranda Mining and Exploration Inc., located 50 km north of Miramichi, New Brunswick.

The principal objective of the project was to evaluate the performance in the field of a composite soil cover placed over an existing acid waste rock pile at Heath Steele Mines (HSM), and to assess the cover's effectiveness as a method for long term management of acid generating waste rock. The four phases of the study were as follows:

Phase I	Selection of four waste rock piles for monitoring and evaluation.
Phase II	Installation of monitoring equipment in the four piles identified in Phase I to define waste rock characteristics and background data.
Phase III	Geotechnical and column testing to evaluate the performance characteristics of potential covers.
Phase IV	Placement of soil cover and performance monitoring (at Pile 7/12).

Phase I was completed in the summer of 1988, followed by Phases II and III at the end of 1990. The final report (MEND Report 2.31.1a 1992) contained Phases I, II and III, and is available from MEND. Phase IV was completed in March 1996. Two reports were issued under Phase IV. The first (MEND Report 2.31.1b 1994) presented the engineering design and construction of the composite soil cover, and some monitoring data; the second report (MEND Report 2.31.1b 1996) was the final Phase IV report. One of the recommendations from the Phase IV report was to continue performance monitoring for an additional two years. The resulting project Phase V (MEND Report 2.31.1c) is described in the present report.

1.1 Study Background

Pile 7/12 comprised about 14,000 tonnes of partially oxidized acid-generating waste rock which was relocated to an experimental site and placed on an impermeable synthetic geomembrane. The cover was designed as an oxygen barrier, utilizing a 60 cm till layer sandwiched between two 30 cm sand layers, and overlain with a 10 cm gravel layer to control erosion (Yanful et al. 1993a). **Figure 1** shows the cover construction in detail. The cover was built in 1991, and the final report issued in 1996 by ADI Nolan Davis (MEND Report 2.31.1b 1996). The construction and monitoring program was described in Yanful et al. (1993b).

In MEND Report 2.31.1a, and in MEND Report 1.22.1a, four waste rock piles located on the Heath Steele Mines property were assessed, namely the covered Pile 7/12, and three uncovered piles 18A, 18B and 17. Pile 18B was chosen as a control to the covered Pile

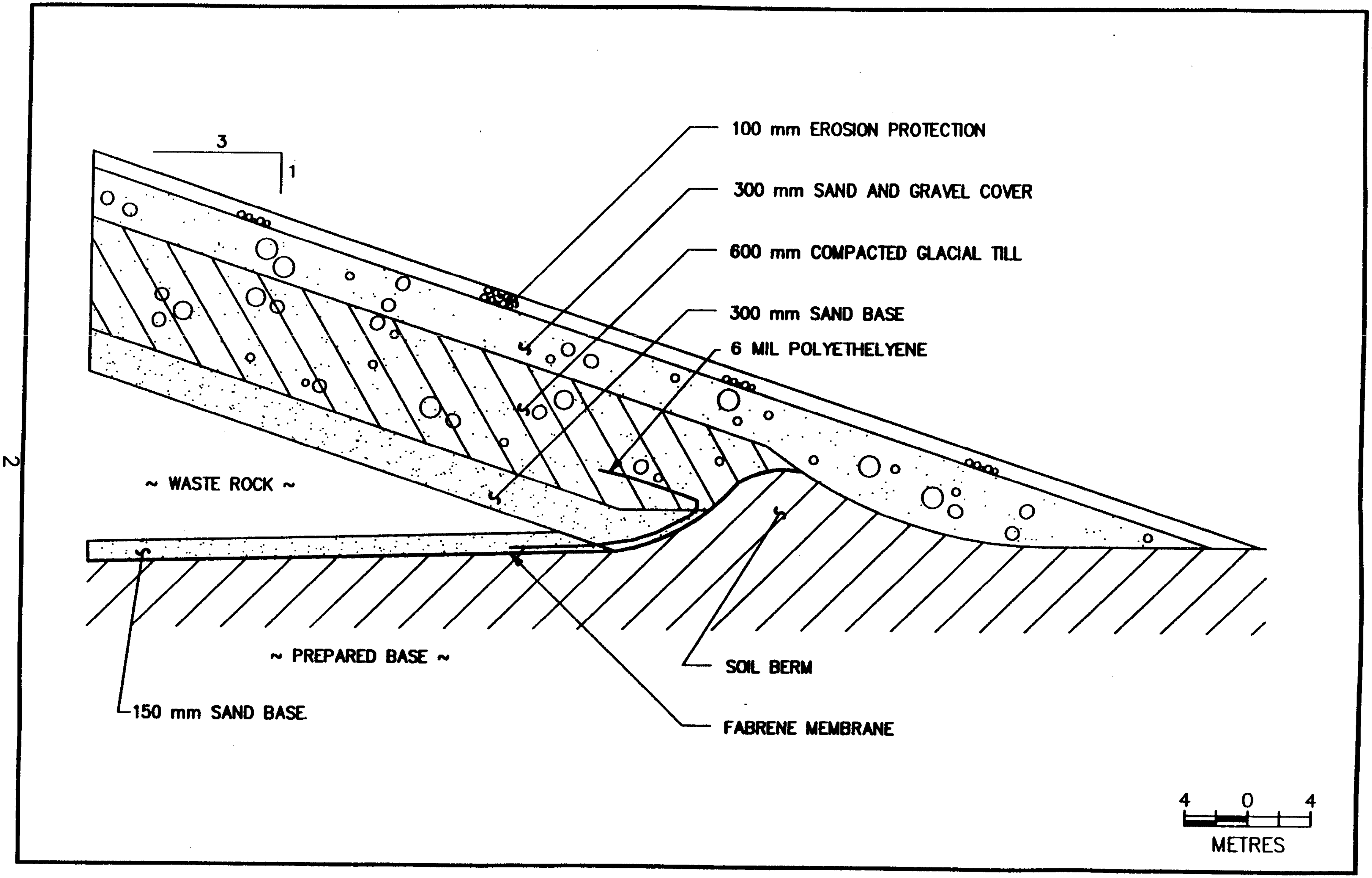

Figure 1. Cover construction detail.

7/12 because it was similar in size, shape and composition. Pile 18B, however, was not relocated or lined.

Results of the waste rock cover project showed reductions of gaseous oxygen concentrations in Pile 7/12 after the cover was built, indicating reduced sulphide mineral oxidation. Similarly, temperatures in the pile decreased; temperatures appeared to be controlled primarily by climatic conditions rather than sulphide oxidation rates. These findings indicated that the cover was controlling oxidation but its effect on porewater quality was not yet observed. This delay was expected, considering that flushing of stored acidity had been low since infiltration through the cover was reduced to about 2% of precipitation. A positive effect of the reduced infiltration rate is lower effluent loadings. Additional monitoring was recommended to confirm improvements in water quality.

The present document reports on Phase V, the continued monitoring of Piles 7/12 and 18B, with the objective of further assessing the effectiveness of the soil cover for controlling AMD. Phase V was funded by Noranda and CANMET through the New Brunswick Mineral Development Agreement. The methods are documented in Mend Report 2.31.1b (1996) and Yanful et al. (1993b). To facilitate comparison, the structure of this report parallels that of MEND Report 2.31.1b, which interpreted data collected through June 1995. The present report interprets the additional data through December 1996, in the context of the previous results.

2. PILE 18B (CONTROL)

Waste rock Pile 18B was used as an non-covered reference to compare to the covered Pile 7/12. Data collected at Pile 18B included pore-gas oxygen concentrations and temperatures. Data from Station 3 were used in the presented figures only because Station 3 was located in the central portion of the pile; other stations showed similar trends. For comparison, data from the centre of Pile 7/12, also Station 3, were plotted in the figures presented in Section 3.

Pile 18B contains 19,500 tonnes of partially oxidized acid-generating waste rock, containing pyrite, pyrrhotite, sphalerite, galena and chalcopyrite. Site preparation consisted of recontouring the waste rock pile to a maximum side slope of about 3H:1V. **Figure 2** shows the pile plan and **Figure 3** shows the cross section. Additional information can be found in MEND Report 1.22.1a (1994).

2.1 Oxygen

Pore-gas oxygen concentrations in Pile 18B were measured on April 13 and June 7 of 1995, and on May 31, July 2, August 14, and September 18 of 1996. These data can be found in Table A-1 (Appendix A) along with previous measurements reported in MEND Report 2.31.1b (1996) in Appendix III and in Figures III-1 through III-6.

Figure 4 shows an annual fluctuation of O_2 concentrations that drops during summer and rises in the fall; higher summer temperatures increase the oxidation rate of sulphide minerals, which in turn consumes more pore-gas oxygen. This annual fluctuation in Pile 18B is further illustrated in **Figure 16** and discussed in Section 4.

2.2 Temperature

Temperatures of Pile 18B were measured on April 10, April 13 and June 7 of 1995, and on February 29, May 31, July 2, August 14, and September 18 of 1996. The data can be found in Table A-2 (Appendix A), along with all previously collected temperature data that were reported in MEND Report 2.31.1b (1996) in Appendix III and in Figures III-7 to III-12.

Figure 5 shows the annual fluctuation in temperature at Station 3. Temperature generally increases correspond to reduced pore-gas oxygen concentrations shown in **Figure 4**. This trend is illustrated in a plot of temperature versus O_2 concentration (**Figure 6**). The low confidence that temperature and O_2 concentration are related (i.e., r^2=0.25) indicates that other factors such as wind, rain and infiltration contribute to the levels of temperature and O_2 in the pile.

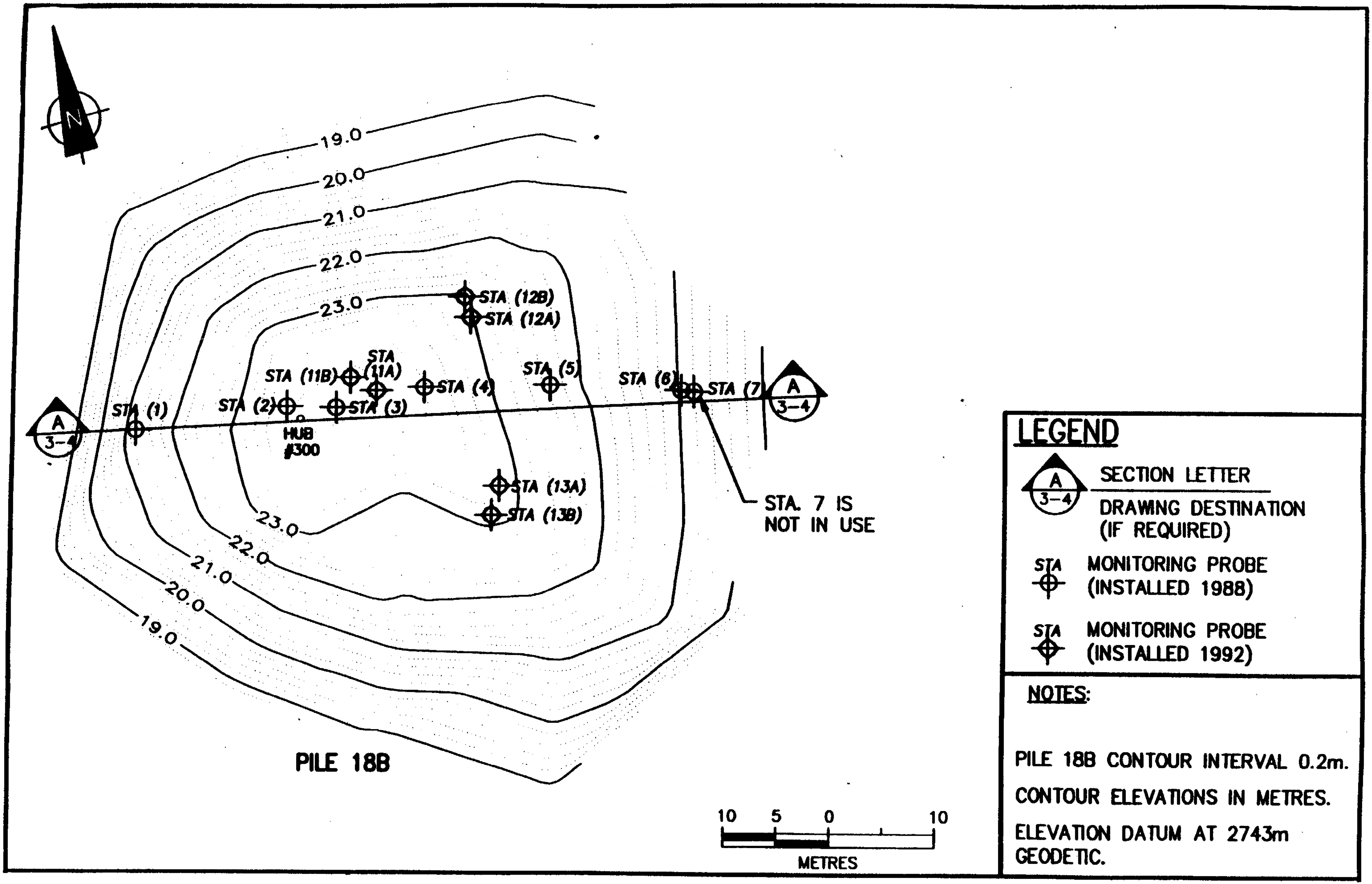

Figure 2. Site plan and instrument cluster locations at Pile 18B.

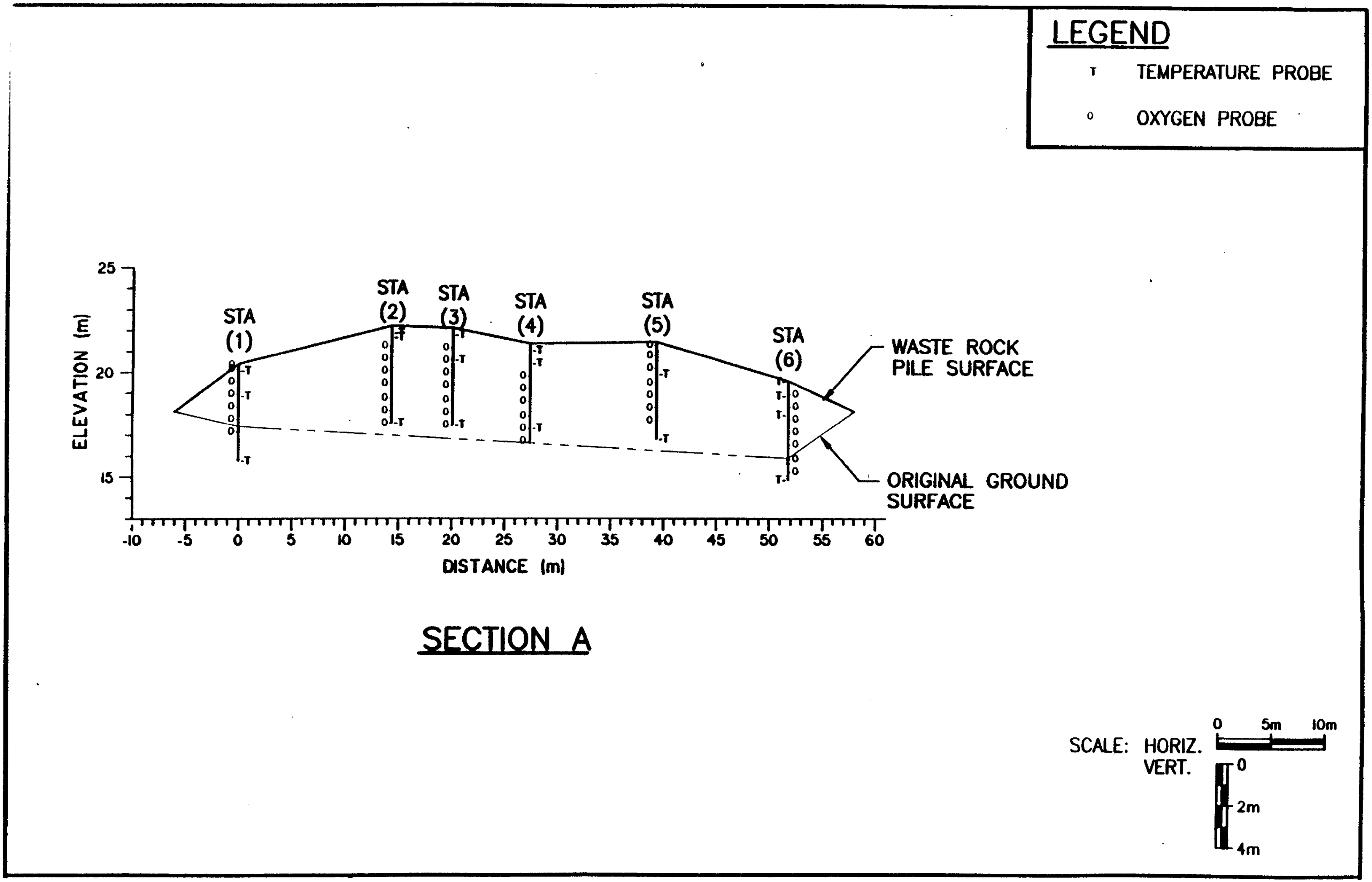

Figure 3. Cross section at Pile 18B.

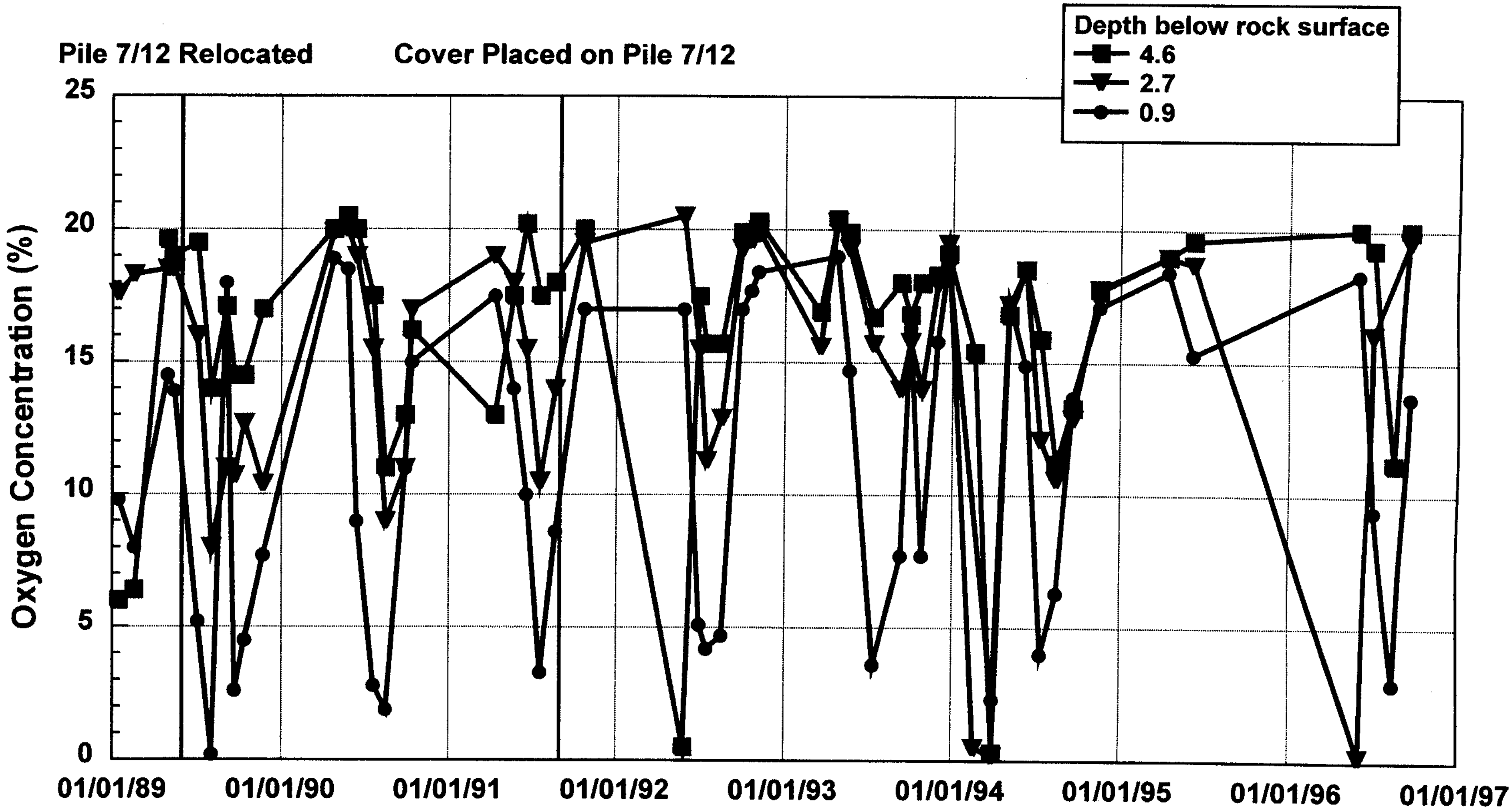

Figure 4. Pore-gas oxygen concentrations at Station 3 of Pile 18B.

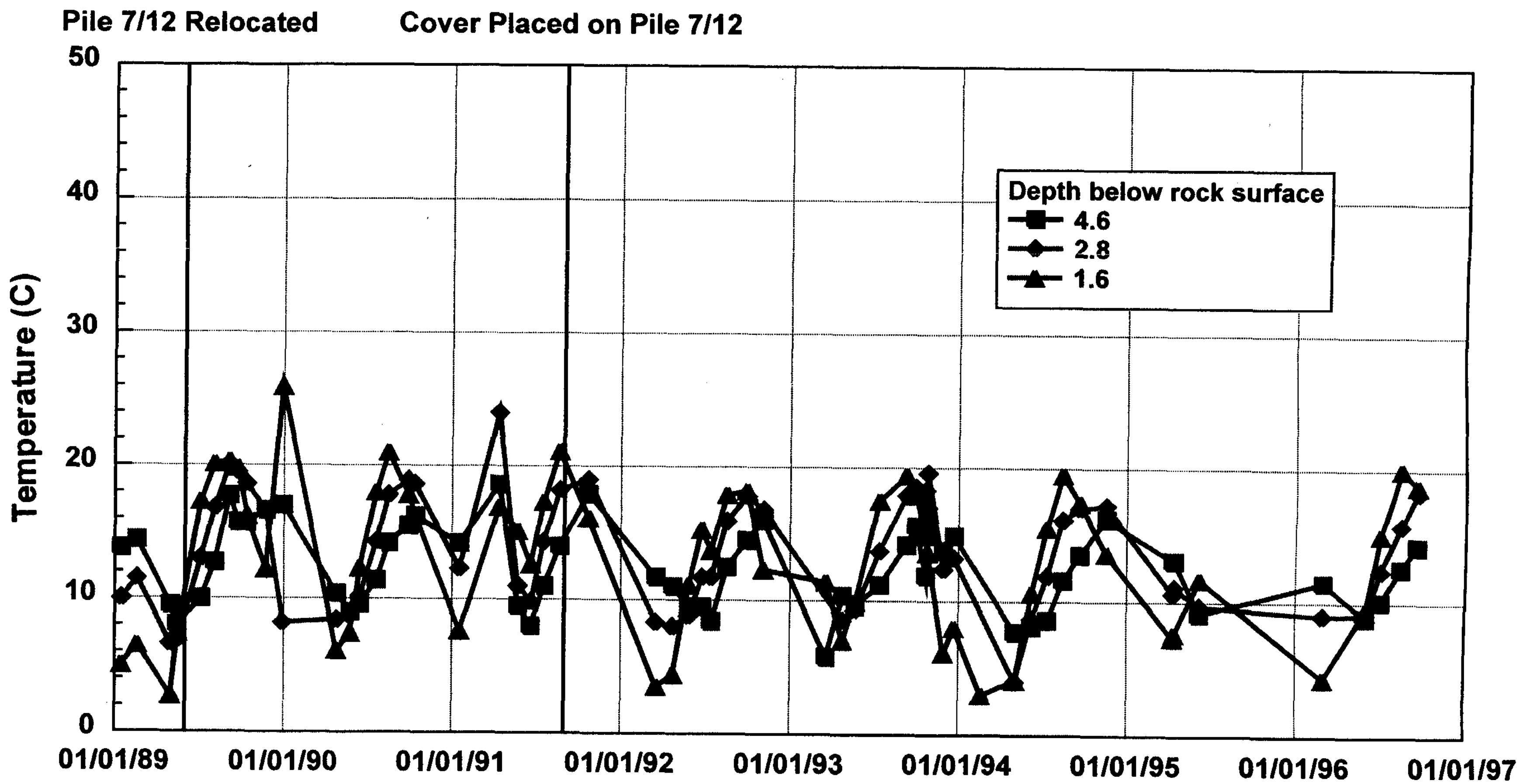

Figure 5. Temperature measurements at Station 3 of Pile 18B.

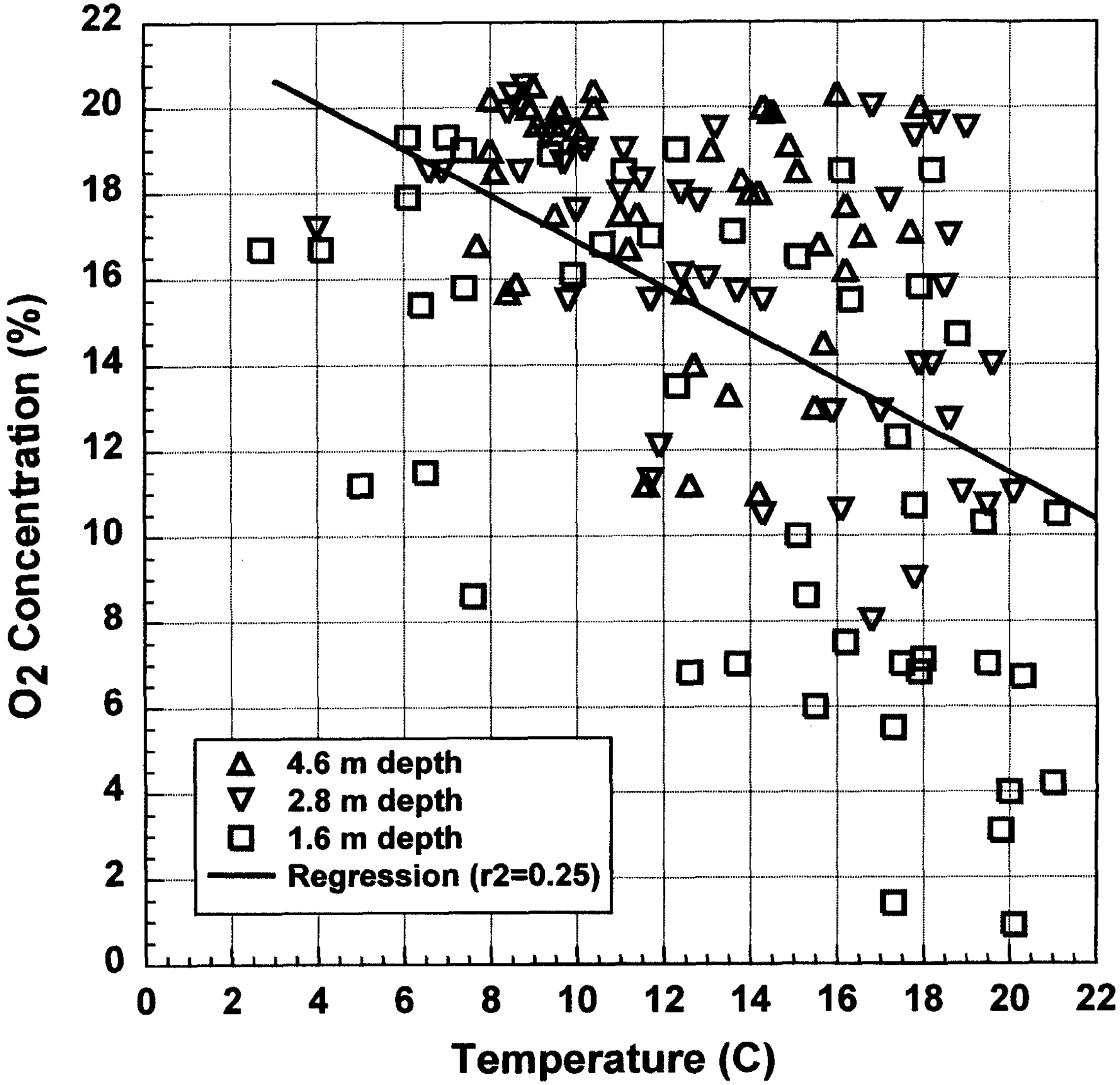

Figure 6. Temperature versus oxygen at Station 3 of Pile 18B.

3. PILE 7/12 (COVERED)

A cover was placed on waste rock Pile 7/12 in 1991. The pile consisted of 14,000 tonnes of partially oxidized acid-generating waste rock that was moved and placed on a geomembrane to a height of about 5 m with 3H:1V side slopes . **Figure 7** shows a plan view and **Figure 8** a cross section. Additional information can be found in MEND Report 2.31.1b (1996) and in Yanful et al. (1993b). Data collected at Pile 7/12 were grouped in three categories: (1) waste rock pile; (2) soil cover; and (3) leachate.

3.1 Waste Rock Pile Data

Pile data included pore-gas oxygen measurements and temperature measurements in the waste rock pile, and analyses of leachate collected from the four drains. The centre drain receives water collected by the liner at the base of the pile; the perimeter drain contains runoff water from the ditch at the base of the pile; the east and west lysimeter drains receive water from the bottom of the lysimeters.

3.1.1 Oxygen

Pore-gas oxygen measurements in the waste rock were conducted on April 13, June 7 and July 20 of 1995, and on May 30, June 27, August 15, and September 19 of 1996. Data can be found in Table A-3b and A-3b (Appendix A) along with all previously collected oxygen data that were reported in MEND Report 2.31.1b (1996).

Figure 9 shows a trend of greatly decreased oxygen concentrations (typically less than 1% O_2) after the placement of the cover. The lower O_2 concentrations, which is contrary to the annual fluctuation noted before the construction of the cover and at Pile 18B (**Figure 4**), indicates that the cover is effective in reducing oxygen entry. In contrast to Pile 18B, O_2 concentrations dropped across the cover and reached a minimum at the base of the cover (at the top of the pile), not at 1 m depth in the cover (**Figure 16**). Minor elevated values (up to 2.2% O_2) measured at some of the ports on July 20, 1995 were not observed in 1996.

3.1.2 Temperature

Manual measurements of temperature in the waste rock pile were conducted on June 7 and August 31 of 1995, and on May 30, June 27, August 15 of 1996. Temperature data can be found in Table A-4b (Appendix A) along with all previously collected data that were reported in MEND Report 2.31.1b (1996).

The thermocouples at Pile 7/12 were also connected to a datalogger that was programmed to conduct measurements at every 5 seconds and record the daily averages. Data were collected from August 31, 1995 to April 30, 1996. These data were summarized in Table C-1 for 1995 and Table C-2 for 1996 (Appendix C). Manual measurements taken on August 31, 1995 were used to calibrate the datalogger measurements. The calibration

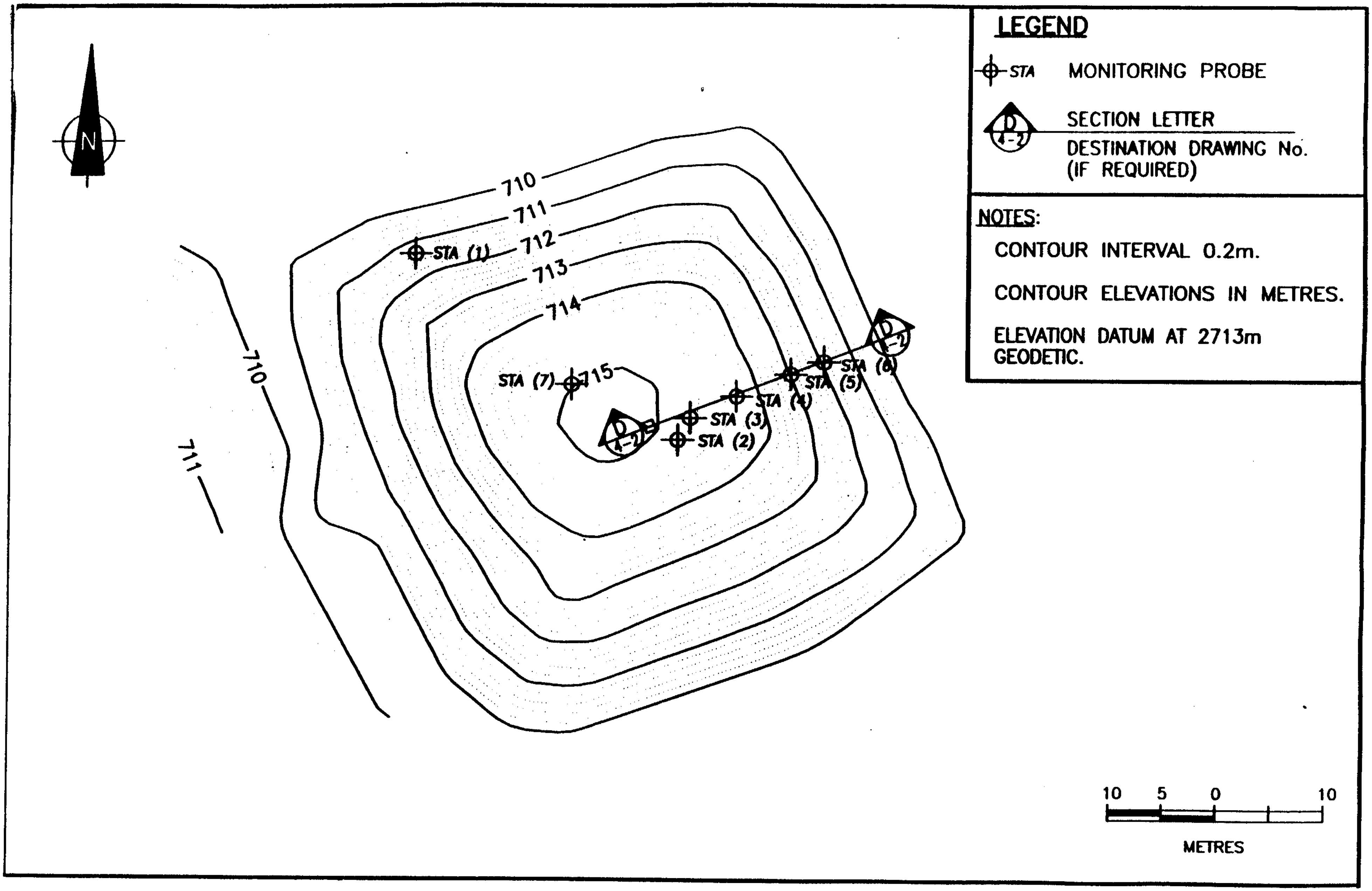

Figure 7. Site plan and instrument cluster locations at Pile 7/12.

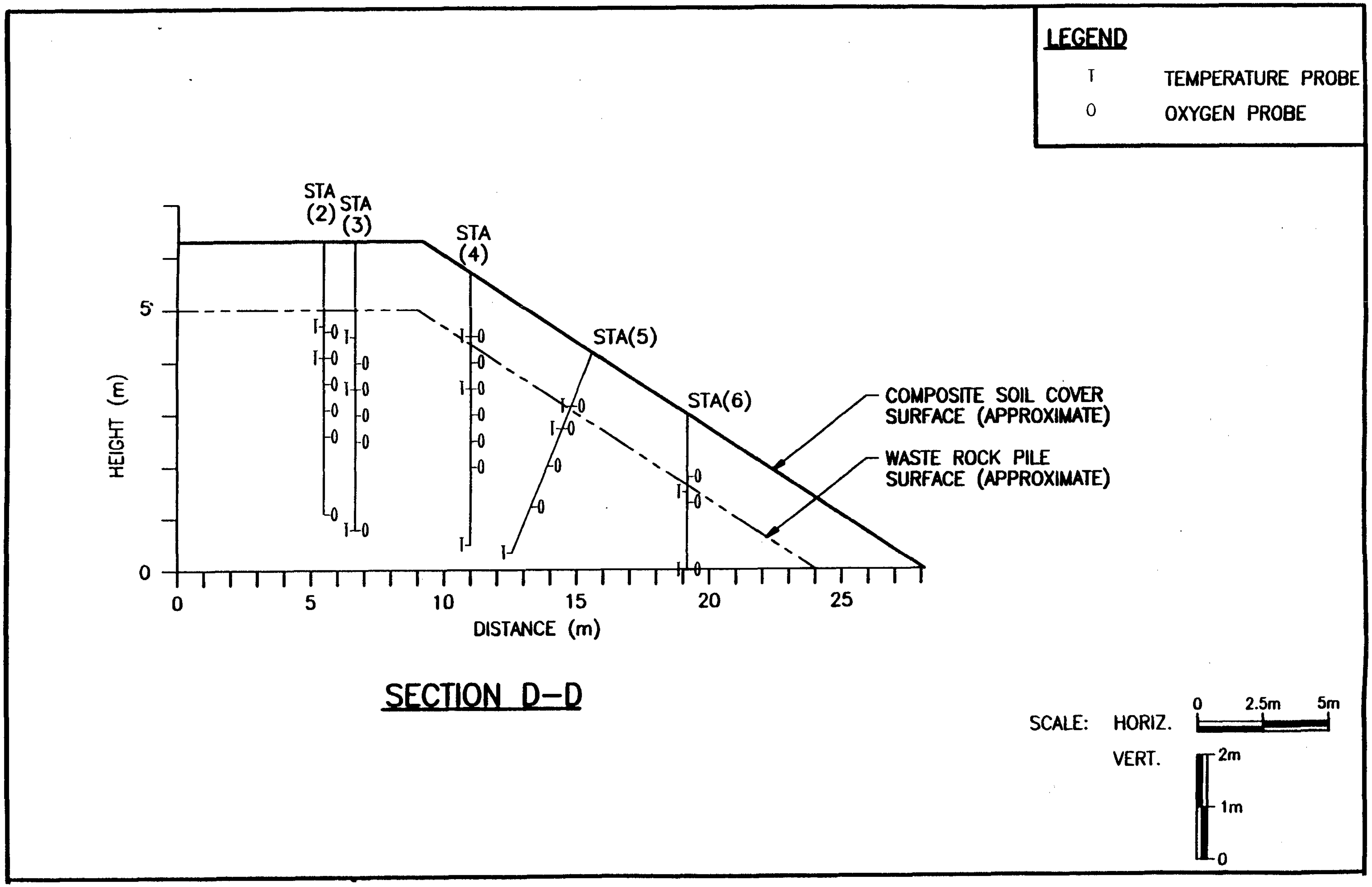

Figure 8. Cross section at Pile 7/12.

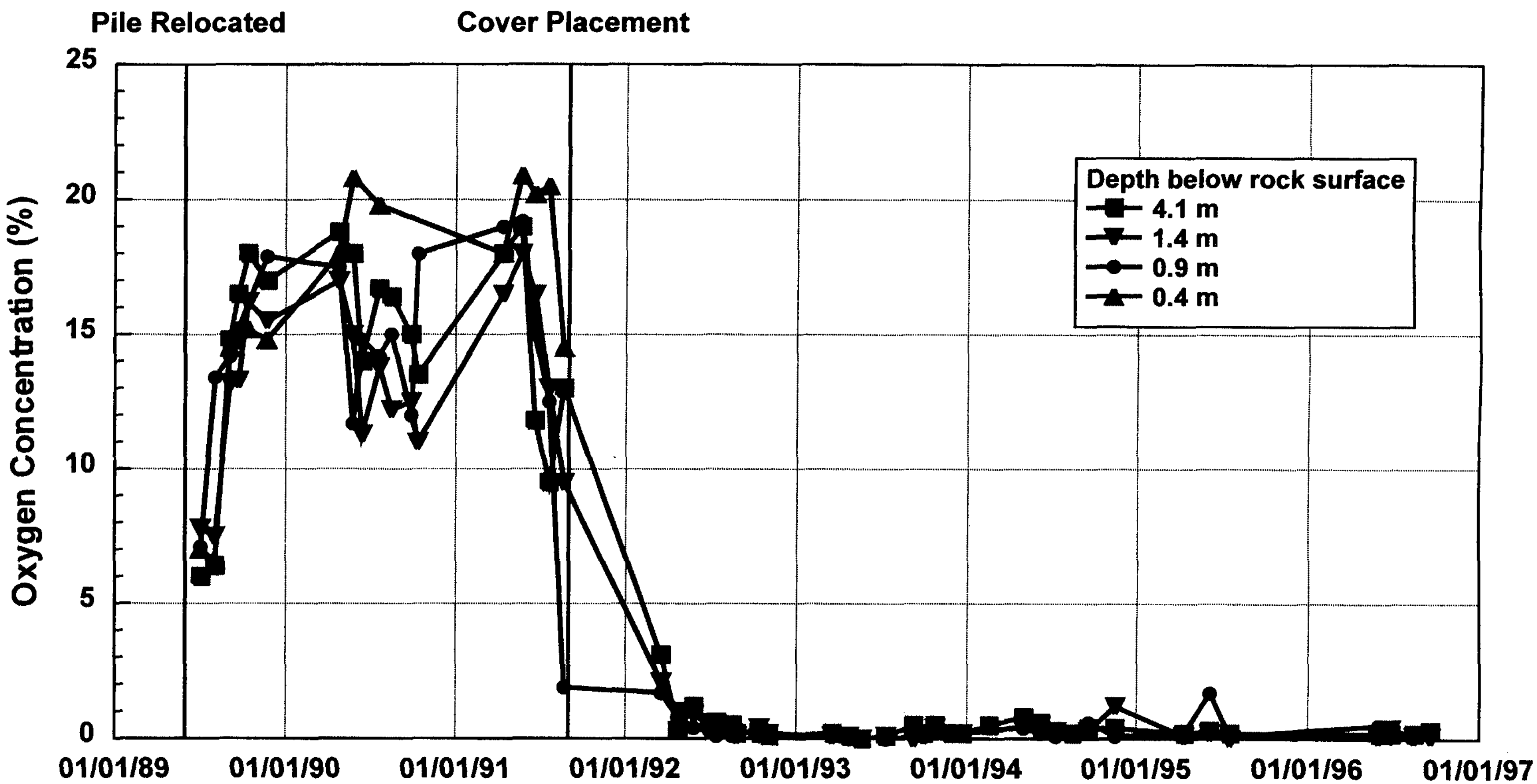

Figure 9. Pore-gas oxygen concentrations at Station 3 of Pile 7/12.

data found in Table A-5 (Appendix A), show little deviation between manual and automated data.

Figure 10 shows the manual measurements and the datalogger monthly averages at Station 3. After the relocation of the waste rock in 1989, temperatures were at their highest; relocation remixes and fractures the material, exposing new surface areas, and causing higher oxidation rates that elevate pile temperatures. Temperatures dropped following relocation, and by the summer of 1991, pile temperatures resembled those observed at Pile 18B (**Figure 6**). Temperatures were further reduced following the cover placement in the fall of 1991, and have stayed in a similar range through 1996. The annual variation in temperature, owing to changes in ambient air temperature, is shown to be largest near the surface of the site and decreasing with depth. Temperature peaks appear to be less that those observed at Pile 18B (**Figure 6**), which could be explained by reduced oxidation rates imposed by the cover. Another factor might be the insulating effect of the cover. The implication from the temperature data that the cover has contributed to lower sulphide oxidation rates is further discussed in Section 4 when temperature data at Pile 7/12 are compared to those taken at Pile 18B.

3.1.3 Leachate

Water samples were collected for metal analyses from the centre drain, the perimeter drain, and the drains of the east and west lysimeters. Sampling was conducted on June 7 and October 8 of 1995, and on May 31, June 27, July 30, September 10 and October 10 of 1996. Detailed data can be found in Tables B-1, B-2, B-3 and B-4 (Appendix B) along with all previously reported data in MEND Report 2.31.1b (1996). A more complete analysis for samples taken in the five sampling campaigns in 1996 can be found in Tables B-5 and B-6 (Appendix B).

Figure 11 shows pH and concentrations of Fe, SO_4, Cu and Zn at the centre drain, collected at the base of the pile. During 1995 and 1996 values of pH ranged from 2.7 to 3.2, Zn ranged from 60 to 870 mg/L, Fe ranged from 377 to 20,700 mg/L, and SO_4 ranged from 1,090 to 32,500 mg/L. Concentrations in the leachate showed an annual fluctuation that generally had highest concentrations in the summer. Overall, results from 1995 and 1996 suggest slight improvement in concentrations from those measured in preceding years.

The improvement in leachate water quality is better seen in a plot of annual average concentrations and loadings (**Figure 12**). The reduction in component loadings were primarily influenced by the reduction in infiltration. An infiltration of 50% of precipitation was assumed for loading calculations before cover placement (which was conservative), and 2% after cover placement (confirmed by lysimeter data in MEND Report 2.31.1b (1996).

Infiltration into the waste rock pile was measured during 1995 and 1996. The amounts of water collected by both lysimeters during 1996 are shown in **Table 1**. During the winter, infiltration is very low because the water is frozen above the lysimeters, which are located

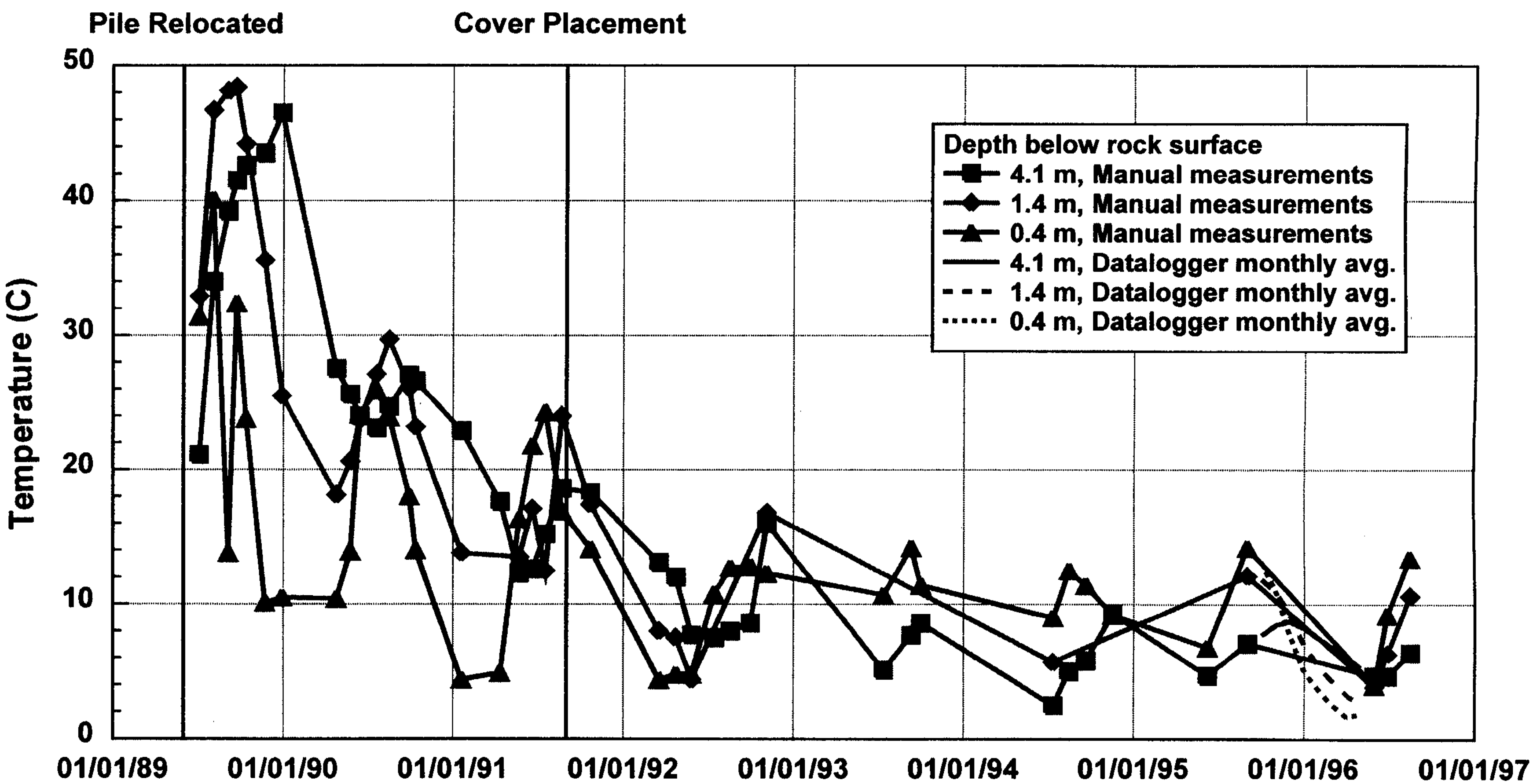

Figure 10. Temperature measurements at Station 3 of Pile 7/12.

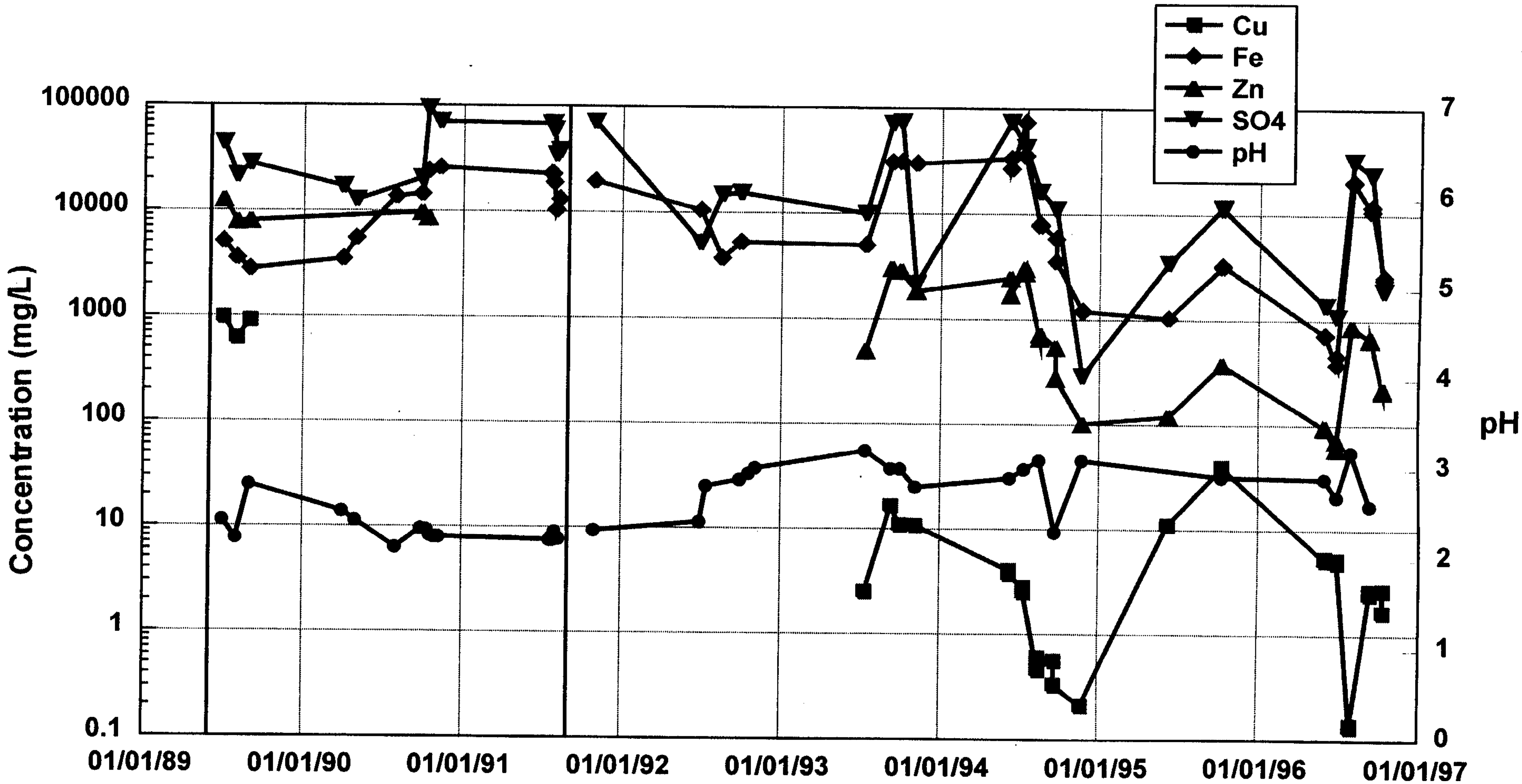

Figure 11. Water quality of leachate from centre drain of Pile 7/12.

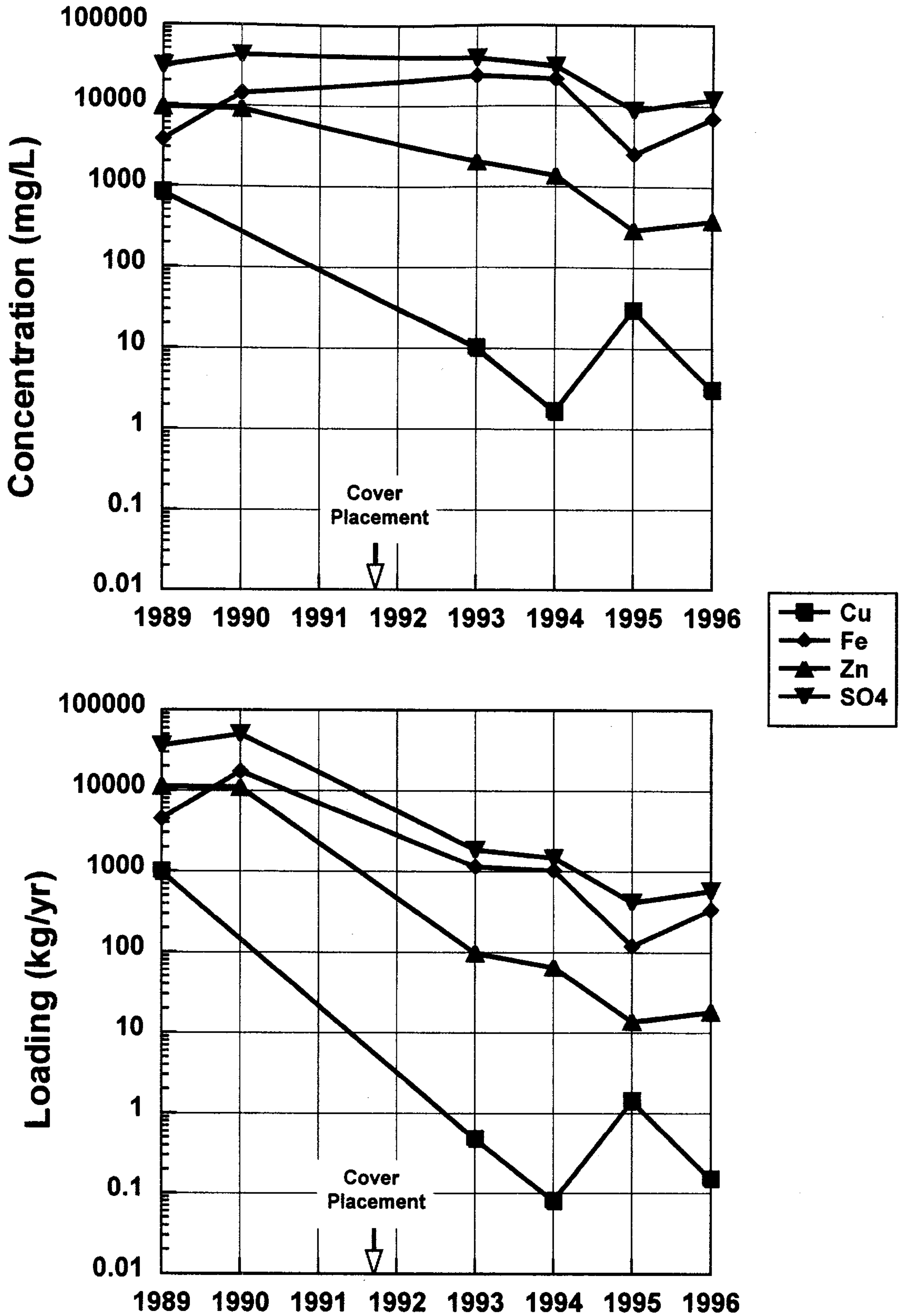

Figure 12. Average annual concentrations and loadings at the centre drain of Pile 7/12.

Table 1. Calculation of infiltration into Pile 7/12 during 1996 as a percent of precipitation.

Date	Rainfall for Period (mm)	Cumulative Rainfall (mm)	West Lysimeter (L)	West Lysimeter (mm)	West Lysimeter Cumulative (mm)	West Lysimeter Percent of Rainfall	East Lysimeter (L)	East Lysimeter (mm)	East Lysimeter Cumulative (mm)	East Lysimeter Percent of Ranfall
10/08/95	--	--	3	0.48	--	--	10	1.61	--	--
05/31/96	378.5	--	10.0	1.61	--	--	0.0	0.00	--	--
06/27/96	72.7	72.7	10.3	1.66	1.66	2.29%	10.2	1.65	1.65	2.26%
07/30/96	150.1	222.8	11.4	1.84	3.50	1.57%	10.9	1.76	3.40	1.53%
09/10/96	63.2	286.0	0.0	0.00	3.50	1.22%	18.0	2.90	6.31	2.21%
10/10/96	81.3	367.3	9.4	1.52	5.02	**1.37%**	10.2	1.65	7.95	**2.16%**

Notes:

(1) Rainfall was used rather than total precipitation because snow blows off the top of the pile where the lysimeters are located.

(2) Percent calculations were conducted on cumulative amounts after the covers thawed.

(3) Area of lysimeter is 6.2 m2.

on top of the pile where snow accumulation is greatly reduced. Therefore, the majority of infiltration collected by the lysimeters comes from rainfall during the summer and fall. The average infiltration of the two lysimeters was found to be 1.8% of rainfall from June through October, 1996.

3.2 Cover Data

Data collected in the cover at Pile 7/12 include hydraulic properties (moisture content, conductivity and suction), pore-gas oxygen concentrations, and temperatures.

3.2.1 Moisture Content

Moisture content of the cover was determined by the time-domain reflectometry (TDR) method. Measurements were conducted on July 28 and August 31 of 1995, and June 6, June 28 and July 30 of 1996. These data can be found in Table A-6 (Appendix A) along with all previous measurements.

Figure 13 shows the moisture content measurements plotted against time. In general, the till is at a high degree of saturation, and the sand below the till is at a low (residual) degree of saturation, indicating that the capillary barrier is effective in retarding drainage from the till. The moisture drainage curve showed saturated conditions of the till to be 35 to 36 %vol (Figure 3 in Yanful et al. 1993a). The highest levels obtained in-situ when the cover was placed ranged from 31 to 37 %vol (Figure 4 in Yanful et al. 1993b); the maximum moisture content (i.e., water saturated conditions) varied with the degree of compaction. Residual saturation of the sand was shown in the moisture drainage curve to be about 10 %vol (Figure 3 in Yanful et al. 1993a).

The high degree of saturation of the till indicates that the cover is effective in retarding the ingress of oxygen. The upper most lift of the west profile, however, showed some dewatering, which suggests local variation in cover effectiveness. This was also observed in the water content profile taken with the air-entry permeameter measurements (Appendix D). The significance of surface dewatering is quantified by calculating the oxygen flux through the cover.

Based on water content measurements taken during 1996, gaseous oxygen fluxes through

$$F = D_e \frac{dc}{dz}$$

the cover were calculated using Fick's first law (Equation 1),
where $\mathbf{D_e}$ is the effective diffusion coefficient, **dc/dz** is the oxygen concentration gradient, and **F** is the oxygen flux. $\mathbf{D_e}$ was calculated using an empirical equation which relates the water saturation of the soil to $\mathbf{D_e}$. The relation is described in Elberling (1994). The highest possible gradient was used (given atmospheric levels at the top of the till and zero at the bottom); lower gradients were observed when the concentration of oxygen did not reach

Welcome Screen | Search | Report List

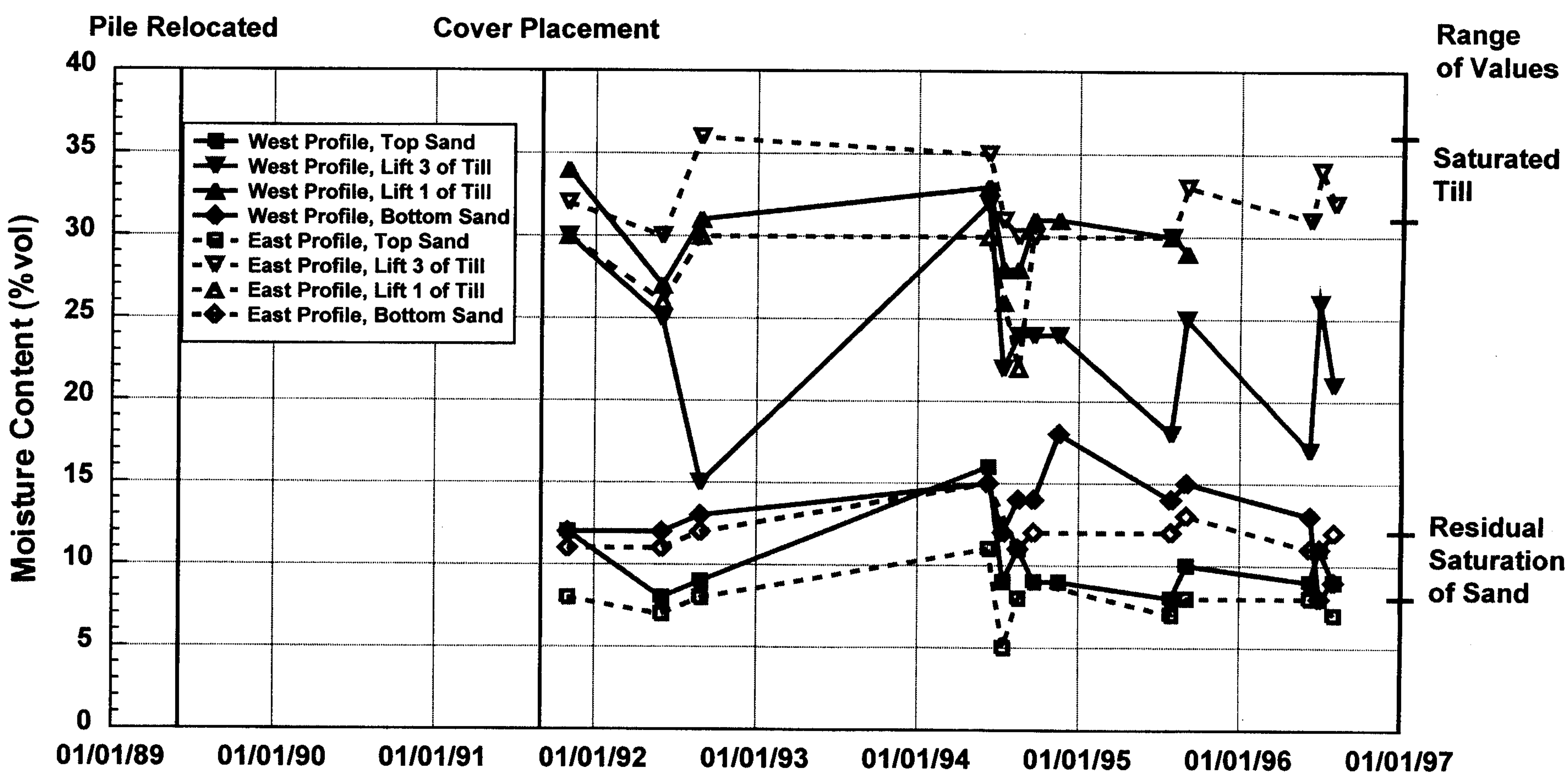

Figure 13. Water content of cover on Pile 7/12 by TDR method.

zero. The calculated values are considered to be a high estimate of flux because the highest concentration gradient was used, but also because water content measurements were taken from the top lift of the till, which reflects the driest portion of the cover; higher water contents in the lower lifts would further limit oxygen diffusion.

Oxygen flux was calculated for the two TDR profiles located at the top of the pile (**Table 2**). Results from the east profile show that the cover is effective in limiting flux to very low values; a maximum value was calculated at 0.15 mol/m^2/yr. Results from the west profile, however, show higher levels, somewhere in the range of 11 to 37 mol/m^2/yr, that indicate a less effective control of sulphide mineral oxidation. For comparison, estimated fluxes of gaseous oxygen in uncovered tailings at Waite Amulet ranged 35 to 193 mol/m^2/yr, and in covered tailings, 0.13 mol/m^2/yr (Yanful 1993). These findings indicate that the cover varies in its effectiveness to control oxidation.

Since sustained dewatering was observed only at the upper most lift of the west profile (located at the top of the pile), a likely explanation would be evaporation. Westerly exposures are subject to higher evaporation because they receive sunshine and wind when the air temperature has warmed, when dew and fog have dissipated. Additional moisture content measurements at various locations on the cover may clarify this observation.

The oxygen concentration profiles through the cover (**Figure 16**) may also indicate more influx of O_2 at the west profile. A cover with a high moisture content would limit diffusion of O_2 and result in a large concentration gradient, as shown at the east profile. However, if the moisture content of the cover was lower, then diffusion would not be limited as much and the concentration gradient would be smaller, as at the west profile. This would assume all other parameter were equal (eg, quantity and reactivity of the sulphide minerals, and composition of cover). This observation is a matter of concern and is discussed in Section 4 and recommendations made in Section 6.

3.2.2 Hydraulic Conductivity

Hydraulic conductivity (**K**) measurements of the till were conducted in October 1995. The method and results are detailed in Appendix D. The average of the two tests taken in 1995 is shown in **Figure 14** along with previous measurements taken in 1993 and 1991. **K** of the till was shown to vary between 10^{-6} and 10^{-5} cm/s, but did not show defined effects from freeze and thaw. Damage to the till from freeze and thaw would have been observed as an increase in **K** of at least 1 order of magnitude. The average of all the **K** measurements was 3.3×10^{-6} cm/s.

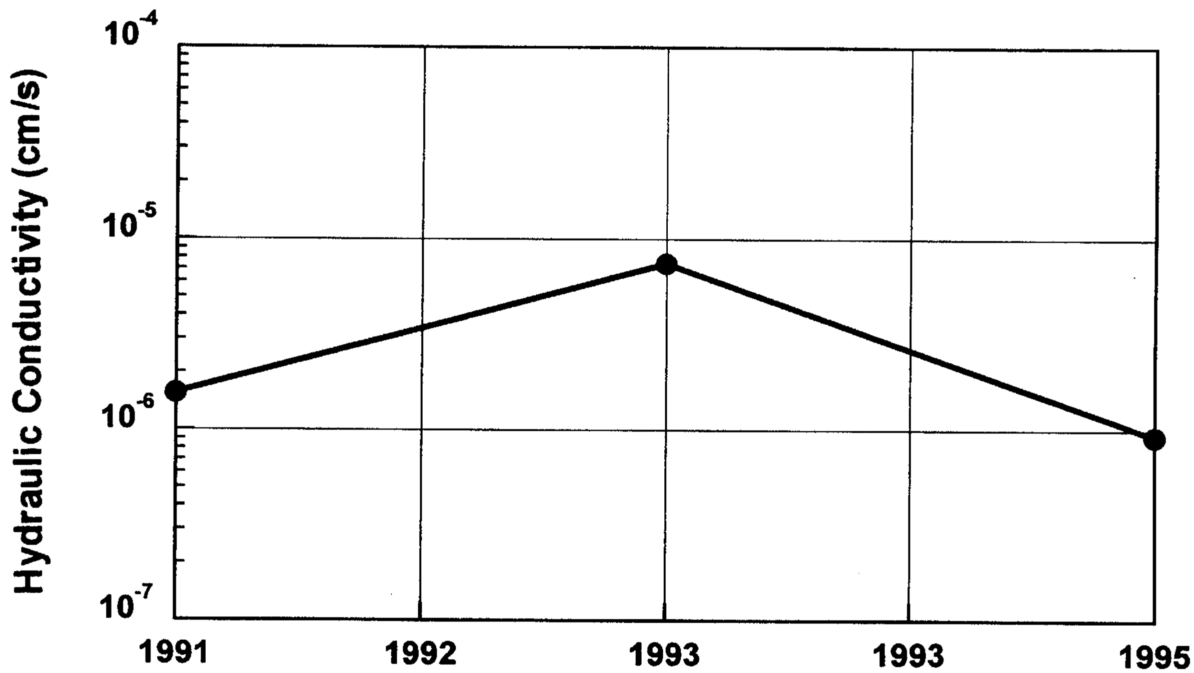

Figure 14. Air Entry Permeameter measurements on the till at Pile 7/12.

Table 2. Calculation of gaseous oxygen flux through the till layer of the cover during 1996.

TDR Measurement Site	Porosity	Water Content (1996 average, %vol)	Saturation	De (m2/s)	dC (mol/m3)	dZ (m)	dC/dZ (mol/m4)	Flux of O2 (mol/m2/yr)
Top lift of west profile	Avg 32.3	21	0.66	1.5E-07	8.841	0.60	5.30	24.471
	Max 34.7	21	0.61	2.2E-07	8.841	0.60	5.30	37.077
	Min 29.1	21	0.73	6.8E-08	8.841	0.60	5.30	11.358
Top lift of east profile	Avg 32.3	32	1.00	1.9E-11	8.841	0.60	5.30	0.003
	Max 34.7	32	0.93	9.2E-10	8.841	0.60	5.30	0.155
	Min 29.1	32	1.11	1.9E-11	8.841	0.60	5.30	0.003

Notes:

1) The top lift represents the driest portion of the cover;
higher water contents in the lower portions of the till would further limit diffusion of oxygen.
2) The range in porosity of the till was taken from Yanful et al. 1993, Can. Geotech. J. 30:588-599.
3) Diffusion coefficient (De) was calculated using a relation to saturation as described in Elberling 1994, Nordic Hydrology 24:323-338.
4) Oxygen flux was calculated with Fick's first law for the diffusion of gas, F = De dC/dZ;
the change in O2 concentration (dC) from atmospheric to zero is 8.841 moles/m3.
5) A dC of 8.841 is the highest possible value;
lower values were present when O2 concentration in the sand below the till did not reach zero.
6) Given notes 1 and 5, flux calculations are a high estimate.
7) For comparison, estimated gaseous oxygen flux at Waite Amulet ranged from 35 to 193 mol/m2/yr for uncovered tailings,
and 0.13 mol/m2/yr for covered tailings (Yanful 1993, J. Geotech. Eng. 119(8):1207-1228).

3.2.3 Soil Suction

Monthly averages of the cover suction data, collected by the datalogger, are found in Table C-1 for 1995 and Table C-2 for 1996 (Appendix C). Soil suction is the energy state of water in soil. It represents the ability of soil to retain water, and is expressed numerically as a positive number, which corresponds to the negative pressure. The unit used in this report is ?metres of water? to coincide with the unit commonly used to express hydraulic head. The suction value is subtracted from the elevation of the sensor to obtain the hydraulic head. Water flows from a high head to a low head.

Figure 15 is a plot of the monthly average hydraulic heads versus depth and shows the vertical hydraulic gradients across the cover during September through December 1995. The September data were used to calculate the vertical gradient because the sensors progressively froze with depth as the fall and winter progressed, giving rise to erroneous readings. Only the data from non-frozen sensors are presented in Figure 15. A linear regression of the data from the east and west profiles (indicated by circles around the September symbols) gives slope of 0.079 with a 90% confidence level (r^2=0.90). These data indicate that unsaturated flow through the cover was downward during September through December 1995, with an average gradient (i) of 0.079. According to reported information from the soil cover projects at Waite Amulet (MEND Report 2.21.2 1993) and Kidd Creek (MEND Report 2.23.2ab 1993), a similar flow pattern is also likely during the spring and summer, but alternating with upward gradients during summer dry periods. However, the sampling frequency at Heath Steele was not sufficiently detailed to show this pattern.

3.2.4 Oxygen

Pore-gas oxygen measurements in the cover were conducted on August 31, 1995 (Table A-7 in Appendix A). The data were plotted with the oxygen data collected in the pile during 1995 (**Figure 16**). Figure 16 compares oxygen data from Pile 7/12 to data from Pile 18B. These data are discussed in Section 4.

3.2.5 Temperature

Temperatures in the cover were measured with thermocouples using the datalogger. The thermocouples are located in the thermoconductivity sensors (?Agua blocks?), that were originally designed to measure suction. These sensors were not functional for the measurement of soil suction, but some of the thermocouples continue to function for temperature measurement. Monthly averages of the cover temperature data are located in Table C-1 for 1995 and Table C-2 for 1996 (Appendix C). These data are discussed in Section 4.

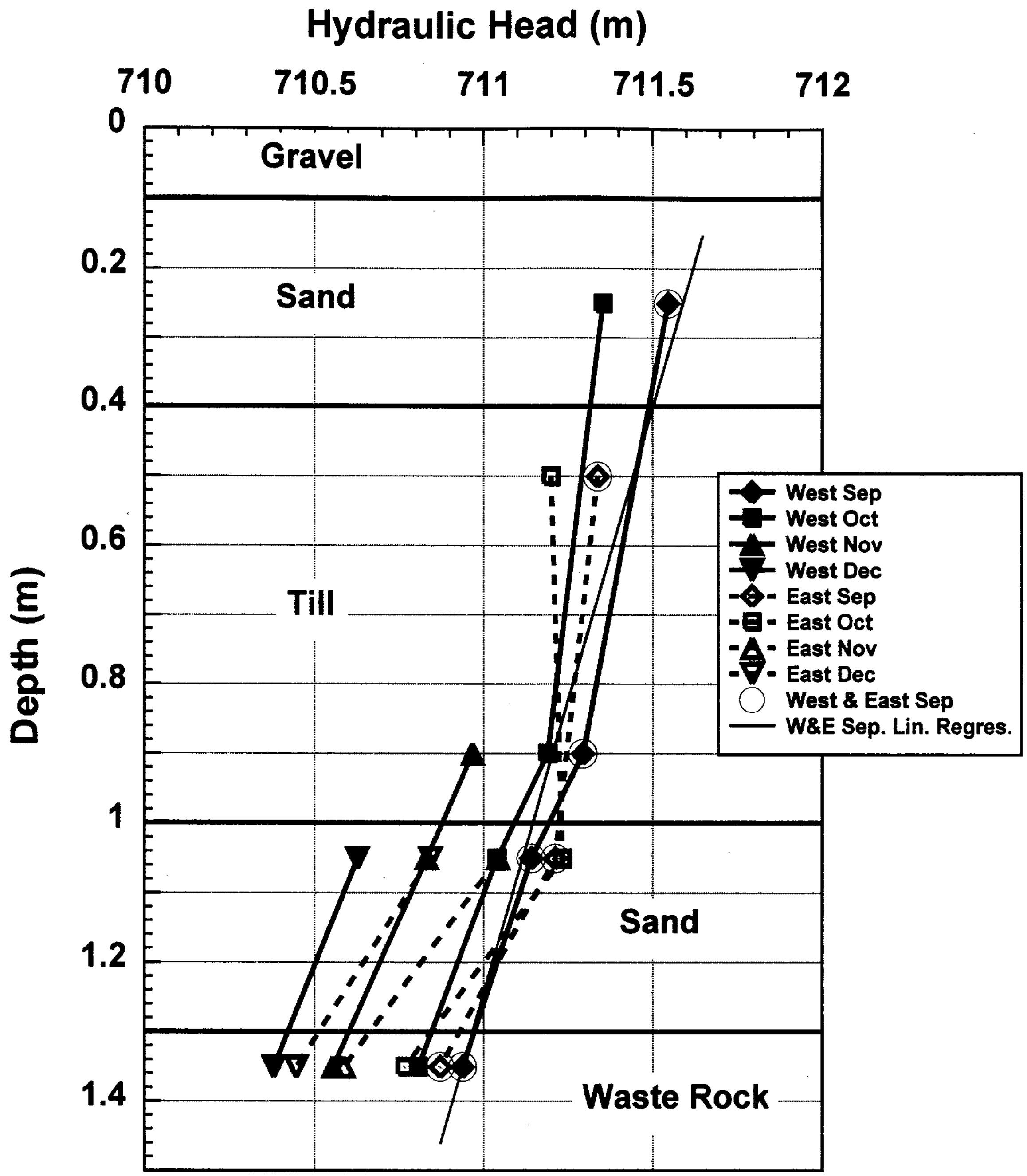

Figure 15. Hydraulic gradients across the cover at Pile 7/12.

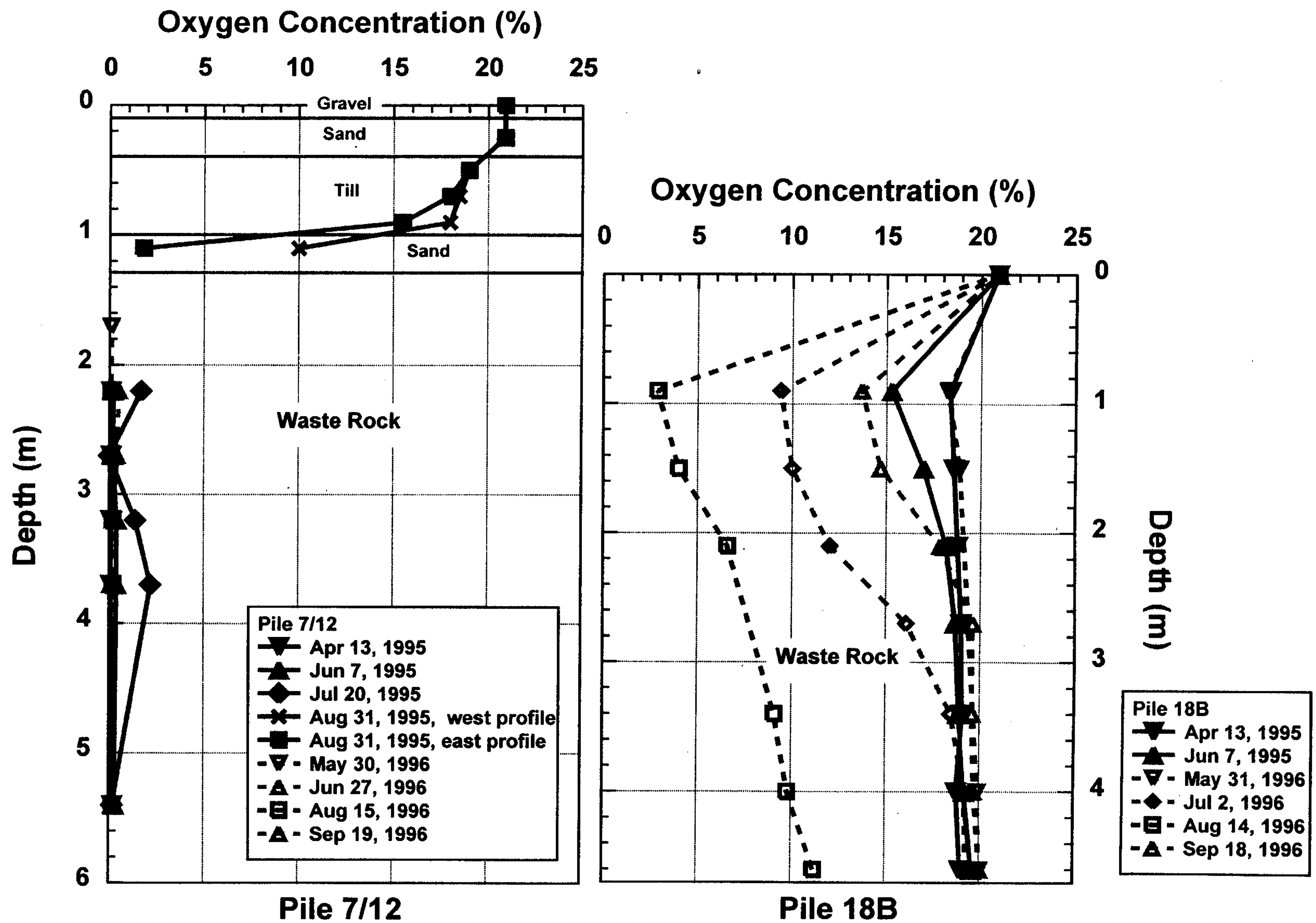

Figure 16. Pore-gas oxygen concentrations taken at Station 3, Piles 7/12 and 18B.

3.3 Meteorological Data

Meteorological data collected at Pile 7/12 are located in Table C-1 for 1995 and Table C-2 for 1996 (Appendix C). The rain gauge and evaporation pan was not functional during 1995 due to wind damage. Precipitation data for 1994-1997 and station normals for Little River Mine (i.e., the Heath Steele site) are located in Appendix E.

4. DISCUSSION

4.1 Cover Saturation, Oxygen Flux and Temperature

Data collected in 1995 and 1996 indicated that the composite soil cover on Pile 7/12 continues to minimize the influx of oxygen to the waste rock pile. This was evidenced by three findings: (1) water content of the covers indicated that the capillary barrier was functional to curtail oxidation, although losses at one station need further study; (2) pore-gas oxygen concentrations were low; and (3) temperature data suggested a reduction in oxidation rate.

1) The water content of the till layer was found to have a high degree of saturation, and the underlying sand a low degree of saturation (**Figure 13**). This indicates that the capillary barrier concept was functional to retard drainage of the till. The high degree of saturation in the till is fundamental to minimize the influx of oxygen. Rates of oxygen flux were calculated from water content measurements (**Table 2**) and showed that flux was retarded to low levels at one of the two stations; while at the other station, flux was only partially retarded. This suggests that only portions of the cover may prove to be effective in the long term as an oxygen barrier, while other areas may not be quite as satisfactory. As discussed in Section 3.2.1, these areas may be on the side of a hill that receives the most sunshine (the adret), owing to dewatering from higher evaporation. It is recommended to assess the cause(s) of the apparent problem (Section 6).

2) Pore-gas oxygen concentration measurements indicated that less oxygen was reaching the waste rock; concentrations decreased across the cover, and were near zero in the waste rock, which was contrary to those observed in the control, Pile 18B (**Figure 16**). In Pile 18B, oxygen concentrations were near atmospheric levels at depth, as they were in Pile 7/12 before the placement of the cover. The low oxygen concentrations observed in Pile 7/12 result from the cover controlling the flux; **Figure 9** demonstrated this.

3) The temperature data for 1998 through 1996, plotted in **Figure 10**, show that, after the cover was installed on Pile 7/12 in 1991, the internal temperatures of the pile were significantly reduced from about 25 ^{o}C to about 10 ^{o}C on the average, indicating a significant reduction in the exothermic oxidation reactions. Also, at depth in Pile 7/12, temperatures varied between 6 and 10 ^{o}C for averaged data taken by the datalogger (**Figure 17**) and between 1 and 10 ^{o}C for instantaneous manual measurements **(Figure 18**). A comparison to measurements taken at in Pile 18B suggests that higher temperatures found in Pile 18B, varying between 8 and 13 ^{o}C (**Figure 19**), were caused by higher rates of sulphide oxidation, since the reaction is exothermic. For both piles, it was found that the temperature variations were primarily seasonal.

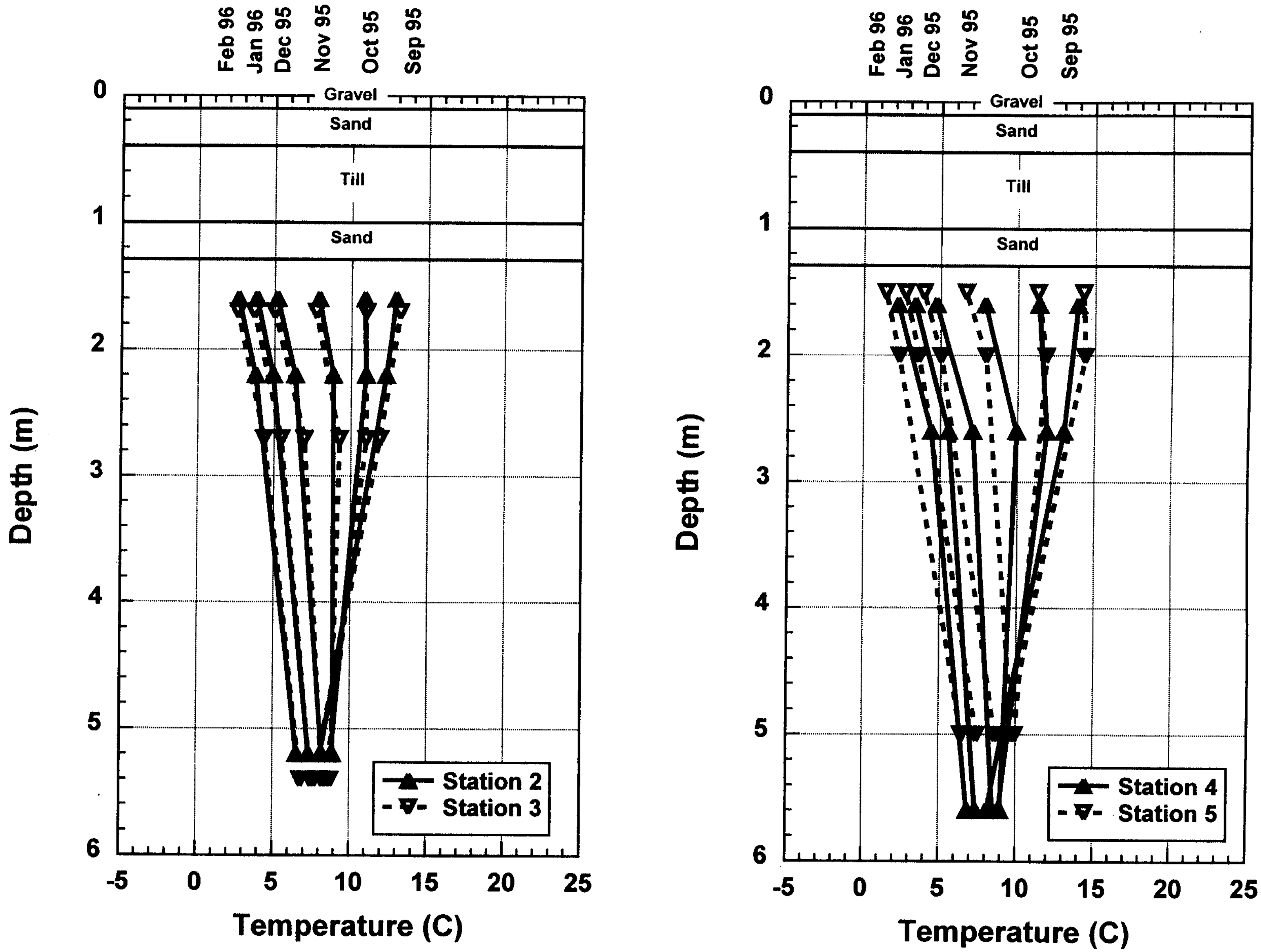

Figure 17. Monthly average temperature measurements at Pile 7/12 (taken by datalogger).

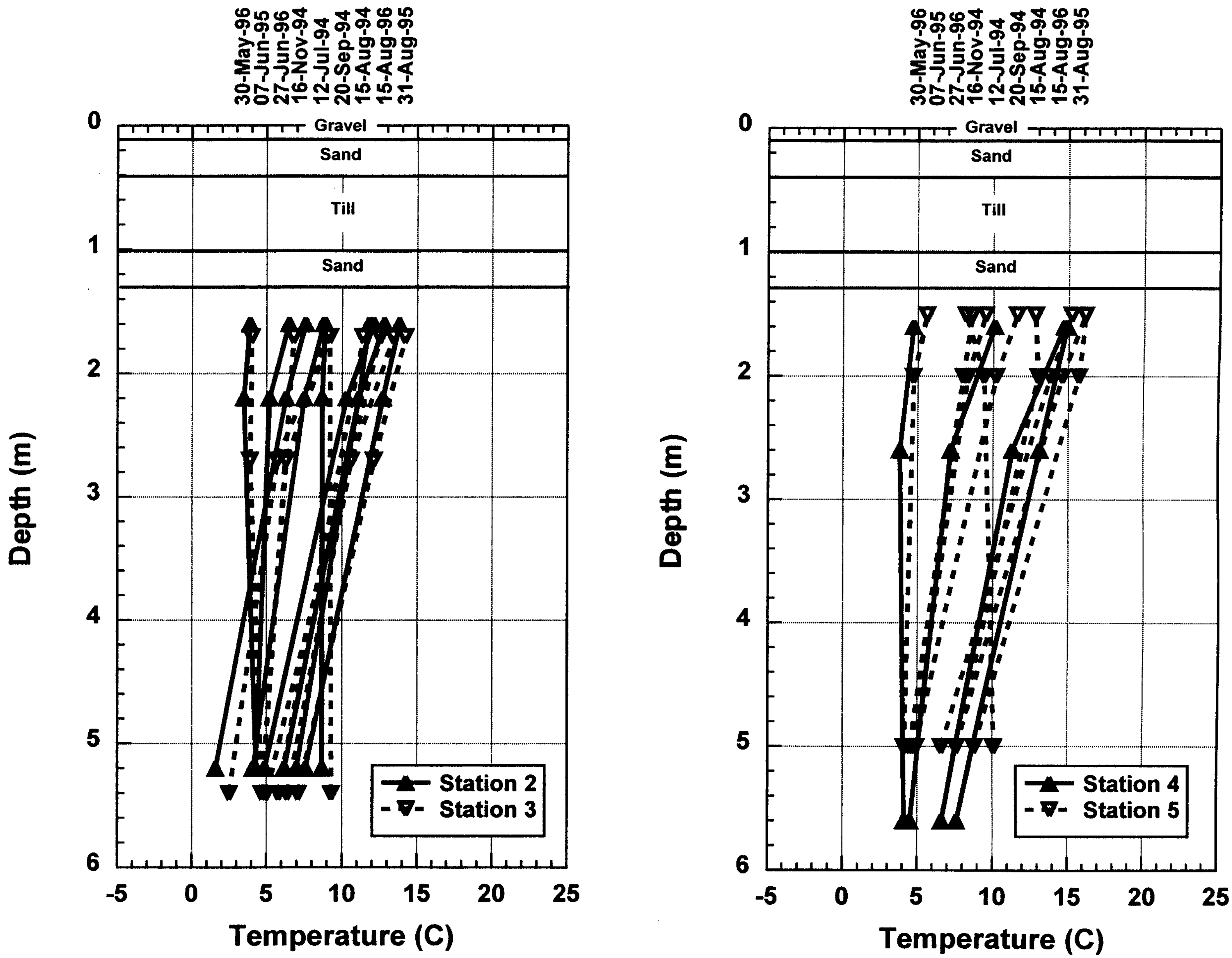

Figure 18. Manual measurements of temperature at Pile 7/12.

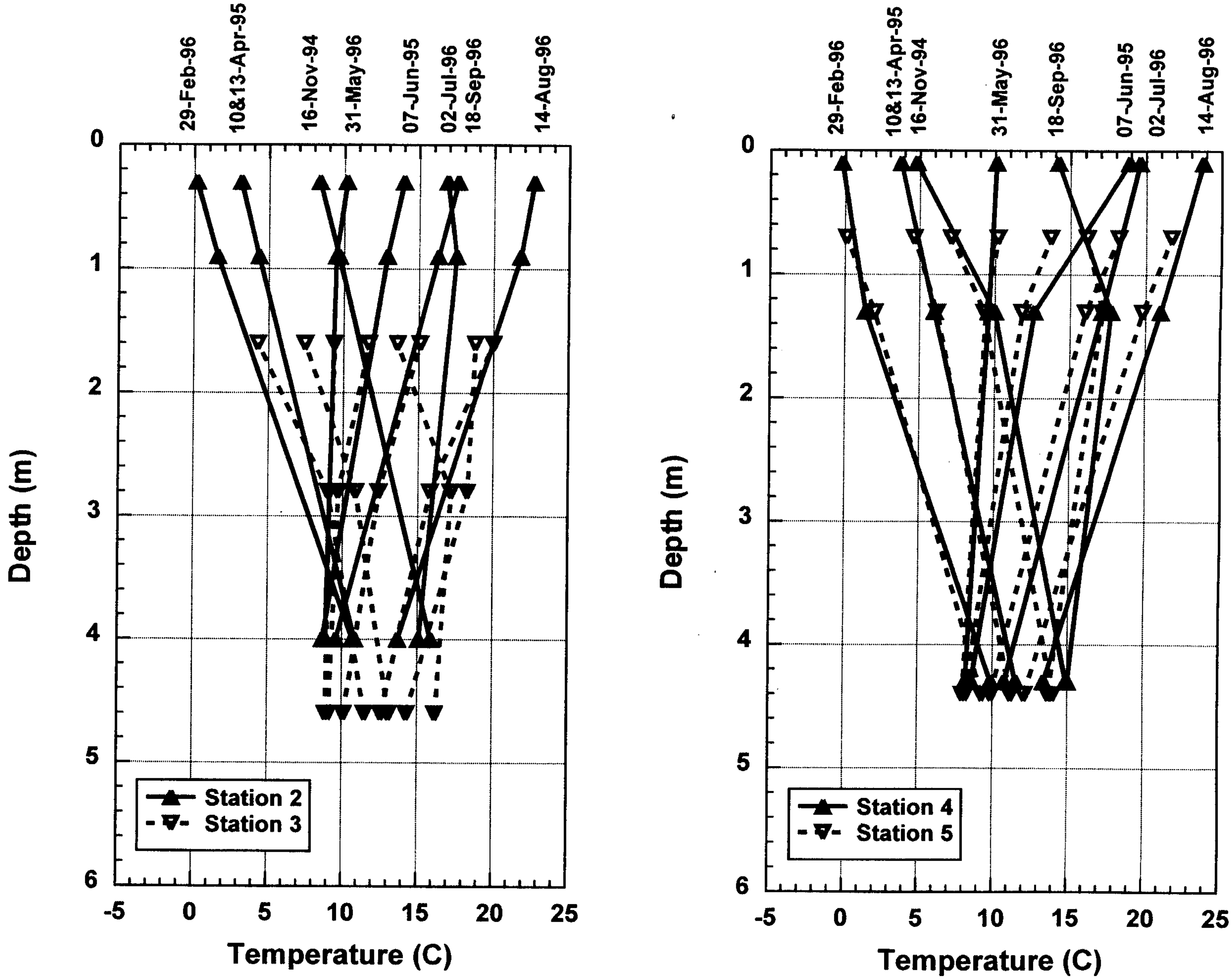

Figure 19. Manual measurements of temperature at Pile 18B.

4.2 Infiltration and Seepage Quality

Data collected in 1995 and 1996 also indicate that the cover continues to retard the infiltration of water to the waste rock. The saturated hydraulic conductivity (K) of the till was measured in 1995 to be $1x10^{-6}$ cm/s (**Figure 14**), and the hydraulic gradient (i) across the cover was measured at 0.079 (**Figure 15**). The specific discharge (q) from Darcy?s law (q=Ki) is calculated at 25 mm/yr. This value is the theoretical infiltration (precipitation less evaporation and runoff), which is 2% of normal precipitation (1,100 mm/yr). The infiltration measured by the lysimeters was 2% of rainfall (**Table 1**). This reduced infiltration results in benefits of a 98% reduction in seepage volumes and a corresponding reduction in contaminant loadings, as seen in **Figure 12**.

Given a 25 mm/yr rate of infiltration, an estimated flushing rate for one pore volume of Pile 7/12 is 30 years (**Table 3**). Many pore volumes are needed to dissolve and flush the secondary minerals that have accumulated following sulphide mineral oxidation prior to the placement of the cover. Assuming reduced oxidation of the sulphides by the presence of the cover, further improvement to porewater concentration of metals and sulphate should occur once secondary minerals are flushed and pH rises. However, the time required for a major improvement in porewater quality is dependent on many factors including flow pathways and the volume and location of the oxidation products within the pile, and is likely to be many decades. This is one of the limitations of applying a soil cover to already oxidized sulphide minerals.

Loadings of metals and sulphate in the leachate from the base of Pile 7/12 was found to slightly improve with the passing years (**Figure 12**). The initial reduction of loadings followed the placement of the cover and was caused by reduced infiltration. Continued monitoring since placement of the cover has shown decreased loadings owing to decreased porewater concentrations. However, the high contaminant concentrations, due to previous oxidation, mask any reduction in oxidation attributable to the cover.

4.3 Effect on Water Treatment Costs

Reduced loadings from a covered waste rock pile will have beneficial outcomes for treatment: (1) a lower volume of flow to be treated, and (2) the concentrations of metals and sulphate will be at a more consistent level. Less effluent from reduced infiltration, however, implies that runoff has increased, which would require appropriate stormwater management. Runoff water, due to adjacent sources of contaminants, may also require treatment until porewater quality improves. For example, the analyses of the runoff water at Pile 7/12 indicates that treatment could be required prior to release (Table B-2 in Appendix B).

Monetary benefits from savings in lime consumption are shown in **Table 4**. Three conditions are shown: (1) no cover, (2) improvement to acidity load by reduced infiltration, and (3) improvement to acidity load by reduced infiltration and porewater concentrations. The largest savings is from reduced infiltration ($187/yr per 1000 tonnes of waste rock) and an additional savings ($8.70/yr per 1000 tonnes of waste rock) is attributed to the reduced concentrations observed in 1995 and 1996, for a total treatment cost savings of $196/yr per 1000 tonnes of waste rock. This indicates that, for a pre-oxidised waste rock, savings in lime costs would be achieved shortly after construction, with a modest additional savings as porewater quality improves.

Table 3. Calculation of flushing rate of Pile 7/12.

Pile hydrology		
Hydraulic gradient (i)	0.079	
Hydraulic conductivity (K)	1E-06	cm/s
Specific discharge (q = K x i)	24.8	mm/yr
Normal precipitation	1100	mm/yr
Infiltration (% of precip.)	2.3%	
Pile geometry		
Height	5	m
Surface area	2000	m2
Volume	6200	m3
Pile saturation		
Core coverage	50%	
Surface area	1000	m2
Porosity	0.3	
Pore volume of pile	1500	m3
Degree of saturation	0.5	
Water volume (pore volume x saturation)	750	m3
Flushing rate		
Infiltration	24.8	m3/yr
Percent of water volume flushed each year	3.3	%
Number of years to flush water volume of pile	30	years

Table 4. Calculation of lime required for treating Pile 7/12 seepage.

Effluent condition	Years	Cu+Fe+Zn Load			Lime required			
		kg/yr	mol/yr	reduction	mol/yr	tonne/yr	$/yr	$/yr per 1000 tonnes of waste rock
Pre-cover base case	1989 and 1990	22601	374484	--	374484	27.74	$2,774.18	$198.16
Improvement less infiltration	1993 and 1994	1174	20816	94.4%	20816	1.54	$154.21	$11.01
Additional improvement less oxidation	1995 and 1996	246	4364	98.8%	4364	0.32	$32.33	$2.31

Notes:

1) The H+ produced from one mole of Cu 2+, Fe 2+, or Zn 2+ hydroxide precipitation is neutralized by 1 mole of lime.
2) The cost of lime was assumed to be $100 per tonne.
3) The mass Pile 712 is about 14,000 tonnes.
4) Cu, Fe and Zn load for precover conditions may have been inflated due to elevated oxidation rates from the pile relocation activities, which would have an effect of inflating the "% improvement" values and noncovered pile lime requirements.
5) Actual lime requirements for bench tests are typically 10-20% higher than those calculated using analytical data.

5. CONCLUSIONS

The design objectives for the Heath Steele soil cover system were to provide a low hydraulic conductivity barrier to minimize the influx of water, and provide an oxygen diffusion barrier to minimize the influx of oxygen. The design of the cover system utilized the capillary barrier concept. At the conclusion of Phase IV of the Heath Steele Waste Rock Study (MEND Report 2.31.1b 1996), it was found that additional monitoring of the waste rock pile was needed to confirm the benefits of the soil cover. For Phase V, the contaminant concentrations and loadings in the seepage were evaluated, in addition to continuing the monitoring of oxygen and temperature in the piles and moisture in the cover for a further two years (1995-96).

The following conclusions result from the Phase V monitoring:

i) The composite soil cover continues to minimize the influx of oxygen to the pile; levels are typically well below 1%.

ii) The cover is limiting water infiltration to about 2% of rainfall.

iii) The loadings of metals and sulphate have decrease about 99%, primarily due to the decreased volume, and to a limited extent, due to reduced porewater concentration.

iv) The potential cost of lime for treatment was reduced by $187/yr per 1000 tonnes of waste rock due to reduced seepage volume shortly after the cover was installed, and a further $8.70/yr per 1000 tonnes of waste rock due to gradual seepage quality improvement.

v) Further improvement in water quality is likely to be very slow, as it will take many decades to flush out the previously-generated oxidation products.

vi) The results to date indicate that this design of composite soil cover has been effective for over five years in controlling the influx of both oxygen and water into reactive waste rock.

vii) Long term effectiveness of the cover is still a concern; there is some evidence of dewatering of part of the cover, which requires further assessment.

viii) Composite soil covers should be considered for sulphidic waste disposal situations, particularly where the treatment cost savings are likely to exceed the cost of installing and maintaining the cover system. The long term stability of the covers and waste piles require further study.

6. RECOMMENDATIONS

The five year evaluation of the composite soil cover on Pile 7/12 (oxidized sulphidic waste rock) has confirmed that the design is effective in limiting influx of both oxygen and water. Due to the high level of contamination of the pre-oxidized rock, the effect on oxidation rate cannot be directly measured, but some improvement in water quality has been observed. A potential lime treatment cost savings of $187/yr per 1000 tonnes of waste rock has been calculated. The overall results to date indicate that a composite soil cover can be an effective means of controlling AMD generation and release. Some further cooperative research appears warranted, both to monitor the continuing effectiveness of the cover, and to examine the apparent dewatering of part of the saturated layer.

Specific recommendations are as follow, the first two being critical.

i) A long term program should be implemented to continue monitoring the effectiveness of the cover on Pile 7/12. To minimize cost this could be a triennial program for the period May to October, and include collecting monthly leachate samples, and measurement of temperature, oxygen profiles and cover moisture content.

ii) A detailed assessment of moisture content of the cover should be conducted, in view of the apparent dewatering of part of the cover. This study should be designed to identify the cause(s) and degree of such dewatering, as retention of moisture is critical to the long term performance of composite soil covers. Evaporation from sun and wind exposed areas or lateral drainage are two possibilities to consider.

iii) A tracer test might be considered to determine flow rates and improve the water balance. Similarly, a core sampling campaign might be undertaken to assess the distribution of secondary minerals. These studies would be helpful in predicting improvements in water quality.

iv) There could also be assessments of the effect of vegetation on overall performance.

The study has found that composite soil covers offer a potential tool for cases of sulphidic waste disposal situations, where the treatment cost savings exceed the cost of installing and maintaining the cover system. Provisions must be made to ensure long term stability. It should be emphasized that careful design and field installation is essential.

7. ACKNOWLEDGEMENTS

B. Walker, M. Noël and K. Godfrey of the Heath Steele Division (HSD) conducted the performance monitoring. K. Shikatani of Noranda Technology Centre (NTC) conducted the air entry permeameter measurements. M. Woyshner (consultant to NTC) authored the report. M. Patterson was the project manager for HSD and Gilles Tremblay for MEND. L. St-Arnaud provided management at NTC. K. Wheeland (consultant to NTC) reviewed the final draft.

8. REFERENCES

Elberling, B., Nicholson, R.V., Reardon, E.J., and Tibble, P. 1994. Evaluation of Sulphide Oxidation Rates: A Laboratory Study Comparing Oxygen Fluxes and Rates of Oxidation Product Release. Can. Geotech. J. 31: 375-383.

MEND Report 1.22.1a (1994) by ADI Nolan Davis Inc., in association with Australian Nuclear Science and Technology Organization. Field Procedures Manual: Gas Transfer Measurements Waste Rock Piles Heath Steele Mines New Brunswick. Available from MEND. Ottawa, Ontario, Canada.

MEND Report 2.21.2 (1993) by Noranda Technology Centre. Field Evaluation of the Effectiveness of Engineered Soil Covers for Reactive Tailings: Volume 1 - Laboratory and Field Tests. Volume 2 - University Contracts. Available from MEND. Ottawa, Ontario, Canada.

MEND Report 2.23.2ab (1993) by Noranda Technology Centre. Hydrologic and Hydrogeologic Evaluation of the Thickened Tailings Disposal System at Kidd Division, Falconbridge Limited. Available from MEND. Ottawa, Ontario, Canada.

MEND Report 2.31.1a (1992) by ADI Nolan Davis Inc. Heath Steele Waste Rock Study, Phases 1 to 3. Available from MEND. Ottawa, Ontario, Canada.

MEND Report 2.31.1b (1994) by ADI Nolan Davis Inc. Engineering Design and Construction Phase IV - Composite Soil Cover Acids Waste Rock Study Heath Steele Mines. Available from MEND. Ottawa, Ontario, Canada.

MEND Report 2.31.1b (1996) by ADI Nolan Davis Inc. Monitoring Report Phase IV - Composite Soil Cover Acid Waste Rock Study Heath Steele Mines. Available from MEND. Ottawa, Ontario, Canada.

Yanful, E.K. (1993). Oxygen Diffusion through Soil Covers on Sulphidic Mine Tailings. J. Geotech. Eng. 119(8):1207-1228.

Yanful, E.K., Bell, A.V., and Woyshner, M.R. (1993a). Design of a Composite Soil Cover for an Experimental Waste Rock Pile near Newcastle, New Brunswick, Canada. Can. Geotech. J. 30, 578-587.

Yanful, E.K., Riley, M.D., Woyshner, M.R., and Duncan, J. (1993b). Construction and Monitoring of a Composite Soil Cover on an Experimental Waste Rock Pile near Newcastle, New Brunswick, Canada. Can. Geotech. J. 30, 588-599.

9. APPENDICES

9.1 Appendix A: Oxygen, Temperature, and Moisture Content Data

Table A-1. Pore-gas oxygen concentration measurements at Pile 18B.

Stn	Port	Depth (m)	Elevation (m)	10-Dec-1988	14-Jan-1989	17-Feb-1989	30-Apr-1989	15-May-1989	04-Jul-1989	03-Aug-1989	04-Sep-1989	22-Sep-1989	13-Oct-1989	22-Nov-1989	25-Apr-1990	25-May-1990	14-Jun-1990	20-Jul-1990	16-Aug-1990	28-Sep-1990	12-Oct-1990	11-Apr-1991	22-May-1991	19-Jun-1991	19-Jul-1991	21-Aug-1991	22-Oct-1991
1	1	3.2	18.0	19.8		20.5		19.2	18.8				19.0	19.5					19.8	20.5	20.7		21.0		20.8		
	2	2.6	18.6	19.8	19.8	19.9	19.8	19.6	20.0	19.5	20.0	19.2	19.8		20.5	20.5	19.8	19.0	18.6	19.5	20	20.0	19.5	20.0		20.0	21.8
	3	2.0	19.2	19.4	19.6	19.6	19.5	19.6	20.4	19.0	20.0	19.5	20.0	20.5	20.5	20.5	19.8	19.4	18.5	19.3	20	20.0	19.5	20.2	20.0	20.0	21.8
	4	1.4	19.8	19.4	19.6	19.2	19.7	19.6	20.5	19.5	20.2	19.5	20.2		20.6	20.5	19.8	19.4	18.6	19.5	20	20.0	19.5	11.0	20.0	20.0	21.8
	5	0.8	20.4	19.6	19.6	19.6	20.0	19.8	20.4	19.5	20.1	19.5	20.4		20.7	20.8	19.8	19.2	18.5	19.3	20		20.0	11.0	20.0	20.0	21.8
	6	0.2	21.0	19.6	20.2	19.4	20.0		20.3	19.5	20.5	20.0	20.6	20.8	20.7	20.8	20.0	19.0	18.5	19.3	20.2	20.5	20.0		20.5	20.0	21.8
2	1	4.6	19.2	18.6	18.6	19.6		18.8	17.1	12.0	13.5	11.7	15.5	18.0	20.0	20.5	19.6	17.2	11.5	17.5	18.7	19.5	18.5	19.5	18.0	17.5	20.0
	2	4.0	19.8	18.4	18.6	18.7	18.0	19.0	16.4	11.5	13.3	11.2	15.5		20.0	20.2	19.2	16.0	12.0	17.7	18.5	19.5	18.5	19.0	14.5	17.0	10.0
	3	3.4	20.4	18.4	19.2	18.7	18.0	18.8	16.6	9.5	13.5	10.5	18.7	18.0	20.0	20.0	19.0	14.1	10.3	17.7	18.5	19.0	19.0	19.5	11.5	16.5	20.0
	4	2.7	21.1	18.5	19.4	18.6	19.2	18.8	16.6	9.4	14.5	11.0	18.5		20.3	20.2	19.3	15.0	10.5	17.5	18.5	19.0	19.0	19.5	10.5	17.0	20.0
	5	2.1	21.7	18.5	17.8	18.5	18.5	18.5	13.6	7.6	14.5	10.0	18.2		20.0	20.1	17.5	11.7	9.7	16.5	18	19.0	19.0	17.0	7.0	17.0	20.0
	6	1.5	22.3	18.4	16.5	17.5	17.0	17.6	7.7	4.2	12.5	7.0	17.4	15.8	19.9	19.9	14.0	7.9	8.5	15.5	17	19.0	18.5	13.5	4.7	17.0	20.0
	7	0.9	22.9						5.9	2.8	15.9	7.0	17.4		19.6	19.0	9.8	4.0	6.7	14.0	16	15.0	17.5	13.0	11.5	16.5	19.5
3	1	4.6	19.2	18.5			19.6	19.0	19.5	14.0	17.1	14.5	14.5	17.0	20.0	20.5	20.0	17.5	11.0	13.0	16.2		17.5	20.2	17.5	18.0	20.0
	2	4.0	19.8	18.5		19.6		19.3	18.7	11.5	12.0	12.7	13.5		20.1	20.5	19.8	17.4	10.9	13.0	18	20.0	17.5	20.0	16.0	16.5	20.0
	3	3.4	20.4	18.3	19.0	19.4	19.2	19.0	18.2	9.0	12.0	15.0	12.7	11.8	20.0	20.5	19.8	16.2	10.0	17.0	18	19.5	17.5	20.0	14.0	15.5	20.0
	4	2.7	21.1	17.8	17.6	18.3	18.5	18.5	16.0	8.0	11.0	10.7	12.7		19.9	20.0	19.0	15.5	9.0	11.0	17	19.0	18.0	15.5	10.5	14.0	19.5
	5	2.1	21.7	17.6		16.5	17.6	17.1	10.2	4.9	9.0	6.6	11.2	10.5	19.7	19.5	17.7	16.0	7.0	10.5	16.5	18.0	17.5	8.4	3.8	13.0	19.0
	6	1.5	22.3	15.4	11.2	11.5	16.7	15.8	5.5	0.9	6.7	3.1	7.5		19.3	19.0	13.5	7.1	4.2	10.7	15.5	18.5	16.5	6.8	1.4	10.5	18.5
	7	0.9	22.9	15.5	9.8	8.0		13.9	5.2	0.2		2.6	4.5	7.7	18.9	18.5	9.0	2.8	1.9	11.0	15	17.5	14.0	10.0	3.3	8.6	17.0
4	1	4.6	19.2	1.5			16.6	17.6	9.6	5.1	10.1	6.6	15.2	13.0	18.5	19.3	13.2	9.0	8.2	10.5	14	18.0	14.5	11.5	11.2	12.0	14.0
	2	4.0	19.8	14.4			18.0	18.0	12.8	5.1	10.4	6.3	15.2		19.0	19.1	13.3	9.0	7.3	9.8	13.5	18.0	14.0	11.2	8.8	10.5	14.0
	3	3.4	20.4	16.5			18.6	18.3	8.0	4.8	9.9	6.3	15.0	15.5	19.8	19.0	10.8	6.0	6.2	9.4	12.5	19.0	13.5	10.0	6.0	8.8	14.0
	4	2.7	21.1	17.5	16.6		18.5	18.2	6.8	3.6	8.8	4.8	13.5		19.7	17.0	9.5	6.5	6.5	8.4	12	19.0	11.0	8.6	4.3	7.1	14.5
	5	2.1	21.7	16.5	16.4		17.5	17.5	5.1		6.0	3.0	13.5	14.5	19.2	15.0	9.3	2.5	1.8	6.4	10.5	18.0	7.5	6.2	2.0	4.3	13.5
	6	1.5	22.3	16.4			14.6	13.8	1.1	0.1	1.0	0.2	14.5	11.3	17.1	13.0	5.5	1.0	2.1	1.2	5.3	13.5	5.0	3.0	0.7	0.2	8.8
	7	0.6	23.2																			11.5		3.0	1.4	0.1	6.5
5	1	3.7	18.6	1.1	0.9			3.9	1.7	0.5	1.3	0.3	1.0	1.0	7.4	5.0	16.5	4.0	10.5	1.7	2.9	15.0	8.5	2.8	3.8		6.5
	2	3.1	19.2	1.9			7.8	8.7	4.1	2.0	2.8	2.3	3.0	2.5	9.7	7.0	8.5	4.0	4.3	3.8	4.5	7.2	7.5	4.4	4.0	5.2	4.9
	3	2.5	19.8	3.2	6.8		7.0	6.6	3.1	1.2	2.5	0.6	2.5		9.9	10.0	10.1	3.7	4.2	4.2	4.5	7.8	9.0	5.5	4.5	5.8	6.1
	4	1.9	20.4	3.4	11.5		8.6	8.8	1.5	0.1	1.4	2.0	6.0	5.0	12.2	15.2	11.5	5.5	3.6	7.2	7.1	8.0	11.5	9.2	21.5	8.1	9.7
	5	1.2	21.1	10.2	15.0		12.0	11.5	4.6	3.2	8.0	4.2	10.5		14.1	15.8	11.5	6.3	6.5	10.5	9.2	11.5	14.0	14.5	7.0	9.8	12.5
	6	0.6	21.7	11.5	15.0		14.0	15.7	2.7	2.4	8.3	3.8	10.2	11.5	14.0	18.0	10.0	6.0	5.4	9.6	8.9	11.5	16.0	17.5	6.8	8.2	12.5
	7	0.1	22.2	11.5	20.0		20.5	20.8	20.5	17.0	19.4	15.2	19.0	20.0	20.5	20.5	20.8	20.8	20.0	19.7	19.5	20.0		21.0	21.7	20.5	21.8
6	1	4.3	16.7	2.7	7.7		4.1	8.0	3.2	1.0	2.7	1.5	4.2	5.0		5.0	9.8	5.2	1.5	13.7	4.4			18.0	20.0	9.6	
	2	3.7	17.3	3.7	8.8		5.0	9.9	5.5	3.0	5.0	1.9	4.5		7.5	6.0	10.5	5.6	3.4	7.6	4.3	6.0		12.5	9.3	9.6	5.2
	3	3.0	18.0	6.0	11.8		5.6	11.8	7.6	4.1	9.0	5.4	9.5	8.0	9.6	11.2	9.8	6.6	3.7	12.0	8.1	5.3		13.5	7.1	4.7	1.5
	4	2.4	18.6	17.0	18.2		10.0	12.0	8.0	4.8	11.0	4.0	15.0		12.6	15.5	10.0	7.5	4.5	13.5	12	13.5		13.0	7.2	8.6	
	5	1.8	19.2	16.0	18.6		13.0	15.5	12.0	4.5	11.0	7.6	14.5	15.5	13.5	16.5	10.5	7.4	8.7	14.0	11.5	20.8		14.0	7.0		21.8
	6	1.2	19.8	16.8	18.6		14.0	15.8	15.0	7.1	13.0	9.5	15.5		15.0	17.5	17.5	10.0	5.0	14.7	13.5			16.0	10.5	11.5	21.8
	7	0.6	20.4	16.5	18.8		15.0	15.5	13.9	9.5	14.9	14.2	16.5	16.8	16.0	17.8	14.5	10.0			14	14.5		14.5	7.3	12.0	17.5

Stn	Port	Depth (m)	Elevation (m)	17-Mar-1992	22-Apr-1992	26-May-1992	29-Jun-1992	15-Jul-1992	17-Aug-1992	29-Sep-1992	19-Oct-1992	03-Nov-1992	19-Mar-1993	24-Apr-1993	21-May-1993	13-Jul-1993	10-Sep-1993	01-Oct-1993	26-Oct-1993	29-Nov-1993	22-Dec-1993	18-Feb-1994	30-Mar-1994	03-May-1994	08-Jun-1994	12-Jul-1994	15-Aug-1994	20-Sep-1994	16-Nov-1994	13-Apr-1995	07-Jun-1995	31-May-1996	02-Jul-1996	14-Aug-1996	18-Sep-1996
1	1	3.2	18.0	21.0																															
	2	2.6	18.6			20.0	20.2	19.6	20.5	20.5	20.4	20.3	17.5	20.5	19.2	19.5	19.5	20.8	20.5	21.4	20.3	18.7	12.2	20.4	20.1	19.0	19.5	19.9	19.8	19.9	20.7	20.5	19.8	18.7	19.8
	3	2.0	19.2	17.5		18.0	20.2	19.3	20.5	20.6	20.5	20.4	17.8	20.5	19.7	19.5	19.7	20.8	20.3	21.4	20.3	18.7	12.1	20.2	20.1	19.0	19.7	19.9	20.1	19.9	20.8	20.7	19.8	19	19.9
	4	1.4	19.8			19.2	20.3	19.2	20.2	20.8	20.5	20.5	17.8	20.6	19.6	19.5	19.7	20.8	20.6	21.3	20.4	18.8	12.4	20.0	20.2	19.0	19.7	19.9	20.0	19.8	20.7	20.4	19.8	18.8	19.9
	5	0.8	20.4			19.0	20.5	19.3	20.2	20.8	20.3	20.5		20.6	19.8	19.6	19.6	20.8	20.6	21.4	20.5	18.9	12.0	19.8	20.3	19.0	19.6	20.0	20.3	19.6	20.9		19.4	18.5	20
	6	0.2	21.0	16.5		19.0	20.8	20.5	20.8	20.8	20.7	20.6		20.8	20.6	20.8	20.8	21.5	20.7	21.6				19.7	20.5	20.2	20.6	21.0	20.8						20.9
2	1	4.6	19.2			20.0	16.2	16.0	15.2	19.2	19.7	20.0	17.4	20.0	19.3	17.9	18.2	19.6	19.7	21.6	19.6	18.1		17.3	18.9	15.5	13.5	16.8	18.2	18.6	20.0	20.7	18.1		20.9
	2	4.0	19.8			20.0	16.0	15.3	16.1	19.1	19.6	19.9	17.5	20.4	19.4	17.0	17.9	19.7	19.6	20.7	19.6	18.5		19.3	18.8	14.3	12.2	16.5	18.3	19.1	19.9	20.8	17.9	12.4	19.1
	3	3.4	20.4			20.0	14.8	13.9	13.8	18.7	19.3	19.8	17.0	20.4	19.4	16.1		20.1	19.9	20.9	19.7	19.0		19.9	17.9	12.1	10.7	17.2	18.3	19.4	20.0	20.7	17	11.5	18.7
	4	2.7	21.1			20.0	14.0	15.5	14.4	18.7	19.9	19.9	17.0	20.5	19.3	16.9	19.8	20.3	18.5	20.8	19.9	18.8		20.2	17.9	11.3	11.1	16.4	18.7	19.5	20.2	19.9	17.1	11.7	19.4
	5	2.1	21.7			20.0	13.0	13.1	12.8	18.4	20.1	19.9	15.9	20.7	19.1	15.6	17.7	20.1	18.6	20.6	19.9			20.0	17.5	10.1	9.9	17.0	18.2	20.1	19.5			10.9	19.5
	6	1.5	22.3			20.0	12.0	12.5	11.4	17.7	19.9	19.8	13.7	20.8	18.9	13.2	17.0	20.0	19.4	20.4	19.7	17.3		19.7	17.0	8.5	9.2	17.2	18.3	19.9	19.2	19.8	13.4	8.9	18.6
	7	0.9	22.9			20.0	16.5	14.4	18.0	18.9	19.3	19.6	10.0	20.8	18.1	10.5	15.9	19.3	19.6	20.1	19.0				16.3	13.1	9.3	15.8	18.4	20.4	17.5	19.4	12.4	8.2	17.5
3	1	4.6	19.2				17.5	15.7	15.7	19.9	19.9	20.3	16.9	20.4	19.9	16.7	18.0	16.8	18.0	18.3	19.1	15.4		16.8	18.5	15.9	11.2	13.3	17.7	19.0	19.6	20	19.3	11.2	20
	2	4.0	19.8			20.5	17.1	14.1	14.7	19.6	19.9	20.2	17.2	20.4	19.8	17.1	17.2	15.7	17.2	18.7	19.1	15.7		17.0	18.7	14.5	10.6	13.7	17.5	18.8	19.2	19.9	19.2	9.8	19.7
	3	3.4	20.4			20.5	16.0	12.2	13.7	19.5	19.8	20.2	17.2	20.4	19.7	16.8	15.4	16.0	15.4	18.9	19.3			17.3	18.8	13.1	10.7	13.5	17.7	19.1	18.9		18.5	9.1	19.6
	4	2.7	21.1			20.5	15.5	11.3	12.9	19.3	19.6	20.0	15.6	20.3	19.3	15.7	14.0	15.8	14.0	18.0	19.5			17.2	18.5	12.1	10.6	12.9	17.8	19.0	18.7		16.1		19.6
	5	2.1	21.7			19.5	13.5	9.6	11.5	19.2	19.2	19.6	10.6	20.0	18.1	12.3	13.3	15.2	13.3	18.4	19.2			16.9	18.3	9.8	8.8	12.9	17.5	18.8	18.2		12	6.6	17.9
	6	1.5	22.3			18.5	8.6	7.0	6.8	18.5	19.0	19.0	5.2	18.3	16.1	7.0	10.3	15.8	10.3	17.9				16.7	16.8	6.0	7.0	12.3	17.1	8.6	17.0	18.9	10	4	14.7
	7	0.9	22.9			17.0	5.1	4.2	4.7	17.0	17.7	18.4		19.0	14.7	3.6	7.7	16.3	7.7	15.8	18.8		2.3	17.3	14.9	4.0	6.3	13.7	17.1	18.4	15.3	18.3	9.4	2.9	13.7
4	1	4.6	19.2		20.0	18.5	11.6	9.1	9.9	18.0	16.1	16.3	11.4	18.7	16.9	10.2	9.8	12.9	9.8	17.4	18.3	15.3	11.3	16.7	14.3	8.9	7.1	11.3	16.5	17.6	13.7				20.9
	2	4.0	19.8		20.0	18.0	10.4	7.3	7.9	17.9	15.4	17.1	12.6	19.2	17.4	9.4	8.5	12.7	8.5	17.5	18.5	15.1	11.6	16.5	14.0	8.2	7.0	11.6	16.8	17.7	12.9	18.9	12.1	6.4	13.3
	3	3.4	20.4		19.5	17.5	8.1	5.9	9.6	17.7	14.7	17.7	13.6	19.7	16.8	7.6	6.9	12.4	6.9	17.4	18.9	14.8	12.1	16.4	12.7	6.7	5.9	11.3	16.7		11.8	18.4	11.2	4.8	11.3
	4	2.7	21.1		20.0	15.5	6.0	5.2	4.6	17.6	12.3	16.9	14.8	19.8	14.7	5.8	5.3	11.5	5.3	17.1	18.9			16.3	10.8	5.3	4.5	10.4	16.6	17.8	10.8	17.1	9.9	3.5	9.8
	5	2.1	21.7		19.5	14.5	3.9	2.8	4.5	16.8	10.2	15.2		19.1	12.4	3.4	3.4	9.7	3.4	16.2			11.0	15.9	8.5	3.5	3.3	8.3	15.9	17.2	9.5	15.3	7.5	1.8	8.1
	6	1.5	22.3		19.0	11.5	0.5	0.9	3.0	15.6	6.4	12.3	9.7	16.6	8.6	0.5	0.7	4.8	0.7	14.8	19.1	14.0	6.8	13.9	4.7	0.6	0.4	3.1	13.5	14.9	6.2	12.3	2.4	0.2	3.3
	7	0.6	23.2	17.5	18.0	8.1	0.1	0.2	5.2	15.3	3.7	11.2	5.4	15.4	5.2	0.0	0.5	1.2	0.5	13.4		13.7	4.0	13.0	2.0	0.2	0.6	0.4	12.6	13.7	2.6	10.4	3	0.4	0.7
5	1	3.7	18.6	9.8		6.0	2.9	1.2	1.5	16.6	3.0	1.5	1.8	7.8	6.6	1.6	2.4	3.0	2.4	2.5	2.7	2.0	0.6	3.7		2.0	6.0	3.5	3.4	6.4				3	4.5
	2	3.1	19.2	6.0	19.5	8.8	5.0	3.7	3.8	17.4	4.9	4.2		9.9	7.9	4.0	4.6	6.3	4.6	5.3	5.0	5.6	1.4	6.1	8.4	4.3	5.4	6.2	7.3	6.7	8.6	10.1	10.2	6	7.2
	3	2.5	19.8	8.2	19.5	10.5	4.6	4.1	7.2	17.5	7.9	6.6	6.7	10.3	8.8	4.8	5.3	7.9	5.3	9.0	7.8	9.4	2.0	7.8	9.2	4.8	7.0	8.6	12.6	8.9	10.2	11	12.4	7.3	8.5
	4	1.9	20.4	12.5	19.5	12.5	6.0	6.6	6.1	17.9	12.4	10.8	8.2	11.5	10.4	6.6	7.3	11.3	7.3	12.4	10.7	11.9	2.6	10.9	10.9	5.9	9.2	12.5	16.4	12.5	12.3	12.2	14.5	8.8	10.7
	5	1.2	21.1	8.5	19.5	14.5	6.9	6.6	7.2	18.3	14.6	13.6	7.6	12.7	11.3	7.2	8.1	14.2	8.1	13.8	11.5	11.2	2.7	12.7	11.7	6.3	9.8	14.6	17.2	14.3	13.1	13.1	15	8.9	11.4
	6	0.6	21.7	7.4	19.5	13.5	5.8	5.4	6.0	18.0	14.3	13.6		12.8	11.0	4.6	7.1	14.1	7.1	13.1	10.8			14.1	10.8	5.2	7.9	14.0	16.8	14.8	13.8	13.8	15.7	9.6	11.7
	7	0.1	22.2	20.0		20.8	20.8																												
6	1	4.3	16.7	20.0				3.5	4.7	18.4	5.2	3.9		9.6	9.7	4.9	1.7	4.5	1.7	4.4	2.8	16.2	12.7		8.9				15.5	19.5		16.1	14.3		9.6
	2	3.7	17.3	18.5	21.8	12.5	5.1	7.4	6.5	18.5	6.0	4.3		9.8	9.9	5.4	1.8	5.0	1.8	8.0	3.1	17.4	12.2	9.0	8.9	8.3	5.8	12.1	15.7	19.2	13.4				11.6
	3	3.0	18.0		21.8	15.5	5.5	4.2	7.0	18.4	6.5	8.1	18.1	10.9	10.8	5.3	3.0	8.9	3.0	14.9	5.9	18.8	13.3	9.6	9.0	8.3	7.3	13.7	16.1	18.6	13.3	15.2	12.9	9.8	8.7
	4	2.4	18.6	19.0	21.8	13.5	5.0	4.8	9.5	19.1	10.8	16.0	16.9	11.5	11.8	5.1	6.3	12.8	6.3	17.5	15.1	18.9	15.2	10.1	11.0	8.4	7.1	14.6	16.5	17.2	13.4	14.2	12.8	10	8.5
	5	1.8	19.2	20.0	21.8	14.5	8.4	6.7	10.3	19.4	13.6	15.9		15.8	NA	5.8	6.2	12.7	6.2	17.5	14.9	18.9	15.2	13.1	11.0	9.4	8.0	14.6	16.7	17.3	13.5	14.8	13.5	10	8.5
	6	1.2	19.8	19.0	21.8	16.0	13.7	11.6	11.3	19.7	15.8	16.7		17.3	14.2	7.8	8.0	15.1	8.0	17.9	14.7	18.4	9.4	17.1	11.7	10.9	12.6	16.8	17.9	17.6	15.4	15.7	14	11.4	10.6
	7	0.6	20.4	15.0	21.8		11.9	12.2	11.0	20.1	16.7	18.2			14.2	7.1	9.1	17.8	9.1	18.2	14.6	17.4	5.3	19.2	11.8	10.6	15.9	19.8	20.3	18.4	17.8	15.6	16.2	14.1	12.6

Table A-2. Temperature measurements at Pile 18B.

Stn	Port	Depth (m)	Elevation (m)	1988 10-Nov	1988 10-Dec	1989 14-Jan	1989 17-Feb	1989 30-Apr	1989 15-May	1989 04-Jul	1989 03-Aug	1989 04-Sep	1989 22-Sep	1989 12-Oct	1989 22-Nov	1989 29-Dec	1990 25-Apr	1990 25-May	1990 14-Jun	1990 20-Jul	1990 16-Aug	1990 28-Sep	1990 12-Oct	1991 16-Jan	1991 11-Apr	1991 22-May	1991 19-Jun	1991 17-Jul	1991 21-Aug	1991 22-Oct
1	Red	1.8	19.4	6.8	6.8	7.0	8.0	5.4	4.7	9.7	12.4	15.2	13.5	12.1	10.0	10.3	5.7	6.7	7.3	10.4	14.5	12.8	12.7	7.5	7.9	7.6	6.2	19.1	14.2	11.9
	Blue	0.6	20.6	6.0	2.5	2.5	4.9	1.8	6.9	16.6	19.2	17.2	15.7	8.9	4.9	5.1	3.2	5.1	12.8	18.7	20.7	11.8	10.4	3.1	4.1	8.3	12.2	16.6	19.4	9.0
	Surface	0.0	21.2	3.2	-7.2	-12.9	-20.1	7.7	17.7	26.7	26.3	19.9	18.1	9.5	-4.0	-14.5	10.5	19.6	22.3	23.0	26.4	23.6	16.6	-3.1		28.7	32.5	33.4	16.5	3.0
2	Red	4.0	19.8	16.2	13.4	12.4	13.0	8.4	6.9	9.7	12.4	18.5	16.2	16.4	16.4	16.9	10.2	9.5	9.8	11.6	14.7	16.6	17	13.1	12.6	8.5	8.2	11.4	15.5	18.2
	Blue	0.9	22.9	9.1	3.9	0.7	2.7	-0.2	6.2	19.2	22.0	19.9	19.3	12.8	8.1	7.0	5.9	7.0	15.3	21.1	22.5	16.2	13.8	3.1	5.3	9.7	14.4	19.7	22.2	13.4
	Black	0.3	23.5	7.7	2.1	-0.7	1.4	-0.6	6.9	19.8	23.3	19.8	19.1	10.7	5.8	5.1	6.1	6.5	17.5	22.8	22.5	15.3	12	1.1	4.1	12.2	16.1	20.6	21.1	11.1
	Surface	0.0	23.8	3.2	-7.2	-12.9	-20.0	7.7	17.7	26.7	28.7	25.1	24.9	10.7	-3.4	-14.5	13.3	19.9	27.3	26.3	31.0	22.9	16.5	-3.1		28.4	30.5	32.3	17.8	3.8
3	Red	4.6	19.2	16.9	15.1	13.8	14.4	9.5	8.0	10.0	12.7	17.7	15.7	15.7	16.6	17.0	10.4	9.0	9.6	11.4	14.2	15.5	16.2	14.2		9.5	8.0	11.0	14.0	17.9
	Blue	2.8	21.0	16.1	12.8	10.0	11.5	6.6	6.9	13.0	16.8	20.1	19.5	18.6	16.6	8.2	8.4	8.7	10.2	14.3	17.8	18.9	18.6	12.3		11.0	9.8	14.3	18.2	19.0
	Black	1.6	22.2	11.5	6.4	5.0	6.5	2.7	7.4	17.3	20.1	20.3	19.8	16.2	12.2		6.1	7.4	12.3	18.0	21.0	17.8	16.3	7.6		15.1	12.6	17.3	21.1	16.1
	Surface	0.0	23.8	3.2	-7.3	-12.9	-20.0	7.7	17.7	27.3	28.5	25.1	22.7	10.4	-4.1	-14.5	11.5	19.6	25.3	21.9	26.5	24.4	16.6	-3.1		27.2	34.9	31.6	18.0	4.8
4	Red	4.3	19.5	15.1	13.5	11.8		7.7	7.4	10.2	12.9	18.8	15.0	15.5	15.0	16.8	9.2	9.3	10.0	11.7	14.9	15.9	15.5	13.9	11.7	9.5	8.4	11.2	14.9	17.0
	Blue	1.3	22.5	9.5	4.7	1.2		0.2	8.0	18.3	21.0	19.9	17.9	12.8	8.3	8.1	5.7	7.6	14.4	19.6	21.9	15.7	13.4	5.2	5.7	9.2	14.1	17.8	21.5	13.8
	Black	0.1	23.7	5.3	-5.2	-3.1		0.0	9.9	23.8	24.7	20.8	18.1	9.9	1.5	3.8	5.8	7.8	20.2	23.8	21.5	14.2	11.3	0.4	3.6	9.7	20.5	21.9	17.0	7.2
	Surface	0.0	23.8	3.2	-7.2	-12.9		7.7	17.7	27.3	28.2	20.9	27.9	10.7	-5.1	-14.8	15.2	20.9	29.8	28.2	26.6	26.1	16.9	-3.1		21.9	30.6	40.1	15.6	3.6
5	Red	4.4	17.9	14.6	12.5	10.9		8.0	7.2	9.6	11.8	17.9	14.1	14.2	14.1	13.1	8.4	8.8	10.0	10.7	13.3	14.7	14.3	13.3	11.2	9.5	7.7	10.0	13.7	15.7
	Blue	1.3	21.0	9.9	4.5	1.9		0.5	7.8	17.7	20.4	18.7	18.0	12.9	8.4	8.4	5.1	7.3	14.0	18.8	21.3	15.8	12.9	6.6	5.4	10.9	13.2	17.8	21.2	12.9
	Black	0.7	21.6	8.3	1.1	-1.5		-0.2	8.6	19.1	22.2	18.3	17.8	9.8	5.2	5.7	5.6	6.3	16.9	21.6	21.5	14.7	10.7	4.4	4.6	12.0	16.0	20.4	19.9	10.6
	Surface	0.0	22.3	3.2	-7.2	-12.9		7.7	17.7	28.6	27.3	20.9	29.3	9.9	-5.0	-	11.6	28.8	31.2	28.7	31.5	23.8	16.7	-3.1		25.5	36.0	39.7	17.0	3.8
6	Red	4.2	16.8	12.4	8.7	7.0		4.1	6.5	8.1	10.2	15.5	12.5	12.4	12.1	13.0	7.2	7.4	8.0	9.1	11.4	12.8	11.6	11.1	10.8	5.4	6.5	8.6	12.1	13.9
	Blue	1.1	19.9	10.1	5.2	0.8		-0.5	5.7	14.4	17.8	19.0	17.3	13.9	9.4	8.0	3.1	7.1	10.7	15.1	18.5	16.1	13.4	7.5	7.4	8.6	10.8	15.3	19.2	13.7
	Black	0.2	20.8	9.4	1.5	-3.3		-0.8	7.7	17.8	20.6	19.2	17.3	10.6	5.8	4.1	3.6	5.8	13.7	19.7	20.7	14.5	10.7	4.7	5.2		13.7	18.9	20.7	11.3
	Surface	0.0	21.0	3.2	-7.2	-12.9		7.7	17.7	28.6	27.3	20.9	25.1	10.0	-5.0	-	12.4	25.1	27.6	24.9	30.0	24.5	16.5	-3.1	NA	23.5	32.3	37.9	18.0	4.7

Stn	Port	Depth (m)	Elevation (m)	1992 17-Mar	1992 22-Apr	1992 26-May	1992 24-Jun	1992 14-Jul	1992 17-Aug	1992 29-Sep	1992 03-Nov	1993 19-Mar	1993 24-Apr	1993 21-May	1993 13-Jul	1993 10-Sep	1993 01-Oct	1993 21-Oct	1993 25-Oct	1993 26-Oct	1993 29-Nov	1993 22-Dec	1994 18-Feb	1994 30-Mar	1994 03-May	1994 08-Jun	1994 12-Jul	1994 15-Aug	1994 20-Sep	1994 16-Nov	1995 10-Apr	1995 13-Apr	1995 07-Jun	1996 29-Feb	1996 31-May	1996 02-Jul	1996 14-Aug	1996 18-Sep
1	Red	1.8	19.4	5.4	6.1	4.9	9.1	9.8	10.9	11.8	10.9	5.6	5.7	4.8	10.7	13.5	12.2	0.5	6.5	12.1	6.7	8.1	5.3	3.6	4.4	6.8	7.0	11.4	11.1	10.8	3.3	4.8	6.4	5.4	5.5	8.8	12.9	13.9
	Blue	0.6	20.6	1.0	2.5	11.6	15.8	14.2	15.1	13.0	5.8	1.3	3.0	8.0	18.3	16.9	12.1	8.7	10.9	8.3	0.4	3.5	-0.3	0.4	1.7	12.8	15.2	18.1	12.1	6.5	-0.3	3.3	12.8	1.7	9.6	16.2	20.3	14.9
	Surface	0.0	21.2	-3.0	3.1	15.5	20.6	24.0	22.4	13.7			14.5			15.0		1.5	-2.9	-6.7	1.0				18.5	19.6	27.8	19.3	16.0	4.8	NA	NA				22.0		
2	Red	4.0	19.8	11.0	10.7	9.3	9.4	11.0	12.8	14.9	16.0	10.2	10.3	9.2	11.1	14.8	16.1	16.9	15.4	17.6	13.7	13.5	10.7	8.1	7.8	8.4	8.7	11.9	13.8	15.9	9.6	12.1	8.7	10.7	8.9	9.6	13.7	15.1
	Blue	0.9	22.9	0.1	2.1	13.7	17.2	15.2	18.8	17.6	8.9	0.4	5.3	10.2	19.6	19.6	16.8	11.8	9.4	12.2	4.4	5.3	0.5	0.9	3.4	12.5	17.1	20.8	16.1	9.7	3.1	5.6	12.9	1.6	9.5	16.3	21.8	17.5
	Black	0.3	23.5	-1.7	2.2	15.1	17.5	15.2	19.3	17.3	6.1	-0.1	5.2	11.0	21.0	19.7	15.5	10.2	7.3	10.6	1.8	4.3	-1.0	-0.7	3.9	14.1	18.7	21.6	15.1	8.4	2.1	4.2	14.0	0.2	10.2	17.6	22.7	16.9
	Surface	0.0	23.8	-3.0	4.6	16.4	24.1	27.5	27.5	15.2			14.8			14.7		1.5	-2.9	-6.7	1.0				12.1	17.4	27.5	20.1	16.9							22.0		
3	Red	4.6	19.2	11.7	11.0	9.5	9.5	8.4	12.5	14.5	16.0		10.4	9.6	11.2	14.2	15.6	11.9	15.9		13.8	14.9			7.7	8.1	8.6	11.6	13.5	16.2	13.1	13.1	9.1	11.5	8.9	10.1	12.6	14.3
	Blue	2.8	21.0	8.3	8.0	8.8	11.7	11.7	15.9	17.6	16.8		8.5	9.3	13.7	17.9	18.5	18.3	17.0	19.6	12.4	13.2			4.0	8.7	11.9	16.1	17.0	17.2	10.6	11.1	9.7	9.0	9.1	12.4	15.8	18.3
	Black	1.6	22.2	3.5	4.4	11.1	15.3	13.7	17.9	18.2	12.3		7.0	9.9	17.5	19.4	17.9	14.9	13.6		6.1	8.0	3.0		4.1	10.6	15.5	19.5	17.4	13.6	7.3	7.6	11.7	4.3	9.4	15.1	20.0	18.8
	Surface	0.0	23.8	-3.0	5.3	17.7	23.6	26.4	27.0	13.9			14.4			14.8		1.5	-1.5	-6.7	1.0				16.1	19.4	31.2	22.1	17.7	7.6						22.0		
4	Red	4.3	19.5	10.2	9.5	9.5	9.7	11.4	13.4	14.5	14.9	8.2	9.3	8.0	11.2	14.1	13.1	5.6	13.7		12.3	12.9		8.2	7.8	8.2	9.4	12.6	13.0	14.9	11.2	11.9	8.6	9.9	8.2	10.8	13.4	15.0
	Blue	1.3	22.5	0.6	3.5	13.7	16.5	15.5	19.0	17.0	9.5	-0.5	5.8	9.7	18.9	18.7	16.4	11.7	10.2		3.2	3.3		0.6	6.1	11.6	17.2	20.6	16.5	10.0	5.8	6.2	12.6	1.4	9.6	17.1	21.0	17.7
	Black	0.1	23.7	-4.3	6.6	15.0	16.9	16.2	22.8	14.7	1.1	-2.4	5.0	10.7	23.9	17.4	15.6	15.4	2.8		0.0	2.2		0.2	4.6	14.4	20.6	19.7	13.7	4.8	3.3	4.2	18.9	-0.2	10.1	19.6	23.8	14.2
	Surface	0.0	23.8	-3.0	5.4	21.0	19.0	30.5	28.8	14.3			14.4			13.7		1.4	-1.7		1.0				15.8	18.7	28.0	24.2	17.8							22.0		
5	Red	4.4	17.9	10.2	9.4	8.1	9.4	11.0	12.5	13.4	14.2	6.1	9.9	7.0	10.7	12.0	15.1	14.6	14.4		11.8	13.5		8.5	7.3	7.6	8.7	11.2	13.4	14.0	10.9	11.5	8.2	9.3	8.0	9.9	12.1	13.7
	Blue	1.3	21.0	0.8	2.6	11.8	16.3	15.4	18.3	16.4	8.9	1.1	6.5	8.8	18.1	18.0	16.4	10.7	10.2		3.0	6.0		0.9	4.1	11.2	16.3	19.9	15.6	9.3	5.9	6.4	11.8	2.0	9.4	16.0	19.8	17.1
	Black	0.7	21.6	-1.6	1.1	14.0	17.1	16.0	19.5	15.9	5.1	-0.2	5.9	10.5	20.1	17.8	14.6	8.3	7.3		0.1	3.0		0.3	7.5	13.4	19.1	21.2	14.2	7.1	4.5	4.8	13.7	0.1	10.2	18.2	21.7	16.1
	Surface	0.0	22.3	-3.0	4.4	21.7	21.8	23.9	28.0	16.1			14.5			15.0		1.6	-1.5		1.0				12.3	18.7	30.2	23.4	18.0							22.0		
6	Red	4.2	16.8	7.8	6.0	7.5	7.6	9.2	10.5	11.7	12.4	6.4	9.2	6.0	9.1	11.8	13.7	13.0	13.3		10.2	10.0		6.6	6.2	6.1	7.6	20.4	11.0	12.1	8.5	9.3	6.9	6.6	7.1	8.3	9.9	12.3
	Blue	1.1	19.9	2.5	1.3	8.6	13.0	13.5	16.2	16.0	10.9	2.0	5.6	6.5	14.9	17.1	16.7	12.3	12.6		5.3	5.9		1.2	1.6	8.0	14.0	17.7	15.8	10.1	5.6	6.3	9.3	3.4	7.8	13.4	17.1	17.1
	Black	0.2	20.8	0.8	-0.6	12.5	16.2	15.3	18.0	15.6	7.3	-0.2	5.4	6.4	18.3	17.7	15.6	10.0	8.3		0.6	3.5		-0.6	1.9	11.5	17.1	10.0	14.8	7.5	4.0	4.6	12.4	0.3	9.4	16.5	20.2	16.3
	Surface	0.0	21.0	-3.0	2.2	19.0	23.6	20.0	28.2	14.6			14.4			14.6		1.5	-1.0		1.0				12.5	17.6	30.1	22.2	16.7	5.4						22.0		

Table A-3a. Pore-gas oxygen concentration measurements at Pile 7/12 before placement of cover.

Stn	Port	Depth below Rock Surface (m)	Elevation (m)	1989 04-Jul	1989 03-Aug	1989 04-Sep	1989 22-Sep	1989 13-Oct	1989 22-Nov	1990 25-Apr	1990 25-May	1990 14-Jun	1990 20-Jul	1990 16-Aug	1990 28-Sep	1990 12-Oct	1991 11-Apr	1991 22-May	1991 19-Jun	1991 19-Jul	1991 21-Aug
1	1	1.4	708.70	18.4	19.0	20.4	20.3	20.8	19.9	20.8	20.5	15.2	17.7	19.5	19.5	18.0	20.0	21.0	19.0	15.5	20.5
	2	0.5	709.60	17.8	19.0	20.1	20.3	20.8	19.0	19.6	20.5	14.3	17.5	19.0	19.5	18.0	20.0	21.0	18.5	15.0	20.0
	3	0.4	709.70	18.0	18.5	20.4	19.8	20.6	20.0	20.6	20.5	14.5	17.5	18.5	19.2	17.5	20.8	21.0	18.2	15.0	19.5
2	1	3.9	709.60	0.5	0.5	16.6	17.6	14.1		17.9	15.0	12.7	11.0	17.2	13.5	11.5	19.5	19.5	11.0	9.0	11.5
	2	2.4	711.10	5.0	5.4	12.5	14.8	14.5	15.3	17.5	15.2	11.6	9.1	14.0	10.5	10.5	15.5	18.5	13.5	10.0	9.4
	3	1.9	711.60	5.0	5.2	10.3	13.3	13.0		15.9	14.0	11.3	9.0	12.6	11.5	9.2	14.5	17.0	17.5	14.0	9.6
	4	1.4	712.10	5.0	4.7	12.0	12.5	12.5	11.0	16.2	16.8	10.0	9.5	13.5	10.5	9.3	15.5	18.5	20.3	12.0	13.5
	5	0.9	712.60	6.3	3.9	10.5	11.0	13.5		16.6	20.5	8.5	15.5	13.5	15.5	9.3	16.5	20.5	20.8	18.5	13.5
	6	0.4	713.10	5.8	3.2	12.5	10.7	18.7	15.8	15.5	20.9	13.0	19.8	19.5	19.0	8.5	18.0	20.5	20.8	20.0	12.0
3	1	4.1	709.40	6.0	6.4	14.8	16.5	18.0	17.0	18.8	18.0	14.0	16.7	16.4	15.0	13.5	18.0	19.0	11.8	9.5	13.0
	2	2.9	710.60	7.3	7.1	14.0	16.0	17.5		20.4	20.0	14.2	16.0	16.6	14.0	13.0		19.0	10.0	13.2	
	3	2.4	711.10	7.3	7.2	13.5	14.8	17.7	15.0	18.9	18.0	13.5	15.6	16.0	14.5	13.0	18.0	19.0	8.1	6.7	11.5
	4	1.9	711.60	7.0	6.5	11.5	12.3	18.0		16.6	13.5	10.5	10.4	10.3	10.0	8.4	15.5	18.5	11.0	5.0	8.2
	5	1.4	712.10	7.8	7.5	13.2	13.3	16.2	15.5	17.0	15.0	11.3	13.8	12.2	12.5	11.0	16.5	18.0	16.5	13.0	9.5
	6	0.9	712.60	7.5	7.1	13.4	14.2	15.2		17.9	17.5	11.7	14.8	14.2	15.0	12.0	18.0	19.0	19.2	15.0	12.5
	7	0.4	713.10	7.0	6.6	14.5		15.2	14.8	18.0	20.8		19.8				18.0	20.9	20.2	20.5	14.5
4	1	4.3	708.80	9.0	8.6	15.5	17.5	19.0	17.8	19.5	18.0	15.5	17.5	20.5	16.2	15.5		20.5	20.2		
	2	2.8	710.30	11.0	10.5	17.8	19.5	19.5		19.5	18.0	16.1	18.4	16.2	18.5	16.5	19.0	19.0	14.0	11.5	15.0
	3	2.3	710.80	11.0	10.5	17.6	19.3	19.8	19.0	19.9	17.5	16.0	18.5	16.4	18.2	16.2	19.0	17.5	13.0	10.5	14.5
	4	1.8	711.30	11.2	10.2	17.6	19.3	19.6		19.4	17.1	15.6	18.5	16.0	18.0	16.5	19.0	19.0	13.5	10.5	14.5
	5	1.3	711.80	10.5	10.0	17.5	18.9	19.5	19.5	19.4	17.2	15.4	18.2	15.5	17.5	16.0	19.0	18.0	13.5	10.5	13.5
	6	0.8	712.30	10.5	10.0	17.0	17.6	19.4		19.1	17.2	15.0	18.2	15.5	17.5	15.2	18.5	18.0	13.0	10.0	12.5
	7	0.3	712.80	10.0	9.8	17.0	17.5	19.5	19.0	19.1	18.0	16.0	18.2	15.7	17.5	15.5	19.0	20.0	15.5		12.5
5	1	3.7	708.00	19.5	19.5	20.8	20.5	20.0	20.0	20.5	17.7	16.6	19.5	13.6	19.5	18.5	20.0	18.5	16.0	12.0	16.0
	2	2.3	709.40	20.0	20.0	20.8	20.5	20.7		20.5	12.5	17.0	20.2	16.6	20.0	20.0	20.5	18.5	17.0	12.5	18.0
	3	1.7	710.00	20.5	20.0	20.8	20.4	20.0	19.5	20.5	19.0	17.0	20.0	16.7	18.0	17.5	20.5	20.0	19.5		
	4	1.2	710.50	20.0	20.0	20.7	20.3	20.7		20.5	16.8	16.9	19.8	15.9	18.2	17.7	19.0	17.5	18.5	10.5	15.5
	5	0.7	711.00	20.8	20.0	20.5	20.2	20.5	20.5	20.5	18.5	16.8	19.8	15.9	18.5	17.5	19.0	19.5	19.0	11.0	16.0
	6	0.2	711.50	20.8	19.0	20.8	18.8	20.1	19.5	20.4	16.5	16.2	19.1	15.5	18.0	17.5	18.5	20.5	19.0	12.5	17.5
6	1	2.1	708.60	20.8	20.8	20.8	20.8	20.8	20.8	20.8	18.0	20.8	20.5	20.6	20.5	20.5		18.5	18.0	19.0	20.5
	2	0.6	710.10	20.8	20.5	20.5	20.3	20.7	20.8	20.5	17.3	20.4	20.5	20.4	20.2	20.2		18.0	17.5	18.0	20.5
	3	0.1	710.60	20.8	20.5	20.5	20.0	20.7	20.8	20.4	20.8	20.0	20.8	19.7	20.2	20.0		18.0	17.5	18.0	19.0

Table A-3b. Pore-gas oxygen concentration measurements at Pile 7/12 after placement of cover.

Stn	Port	Depth below Cover Surface (m)	Elevation (m)	1992 17-Mar	1992 22-Apr	1992 26-May	1992 29-Jun	1992 14-Jul	1992 17-Aug	1992 26-Aug	1992 14-Oct	1992 03-Nov	1993 19-Mar	1993 24-Apr	1993 21-May	1993 13-Jul	1993 10-Sep	1993 01-Oct	1993 26-Oct	1993 29-Nov	1993 22-Dec
1	1	2.7	708.70	6.8	0.6	0.6	0.5	0.5	0.8	0.2	0.2	0.2		0.4	0.4	0.1	0.1	0.1	0.4	0.2	0.1
	2	1.8	709.60	6.7	0.3	0.5	0.3	0.4	0.9	0.1	0.2	0.1		0.3	0.3	0.1	0.1	0.1	0.8	0.4	0.2
	3	1.7	709.70	11.5	1.6	0.6	2.5	0.3	1.2	0.1	0.1	0.1									
2	1	5.2	709.60			1.9	0.5	0.3	0.2	0.3	0.4	0.3	0.4	0.2	0.1	0.1	0.0	0.2	0.4	1.0	0.2
	2	3.7	711.10			1.6	1.1	0.4	0.6	0.3	0.3	0.3	0.2	0.3	0.1	0.1	0.0	0.1	0.4	0.6	0.2
	3	3.2	711.60		0.6	1.4	0.8	0.3	0.6	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.8	0.6	0.2	0.2
	4	2.7	712.10		0.8	1.5	0.9	0.3	1.5	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.3	0.2	0.3
	5	2.2	712.60		1.1	1.3	0.7	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.0	0.1	0.3	0.3	0.2
	6	1.7	713.10		0.6	1.2	0.5	0.2	0.5	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.3	0.2	0.2
3	1	5.4	709.40	3.1	0.3	1.2	0.6	0.6	0.5	0.2	0.2	0.1	0.2	0.1	0.0	0.1	0.5	0.2	0.5	0.2	0.2
	2	4.2	710.60																		
	3	3.7	711.10	7.0	0.6	1.1	0.8	0.5		0.1	0.3	0.1	0.4	0.1	0.0	0.1	0.0	0.1	0.7	0.2	0.2
	4	3.2	711.60	4.2	0.6	1.0	0.9	0.4	0.3	0.1	0.3	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.6	0.3	0.3
	5	2.7	712.10	2.1	1.0	0.9	0.5	0.3	0.2	0.1	0.4	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.4	0.2	0.2
	6	2.2	712.60	1.9	1.7	0.8	0.4	0.3	0.1	0.1	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.3
	7	1.7	713.10																		
4	1	5.6	708.80																		
	2	4.1	710.30	2.0	0.6	0.9	0.2	0.4	0.2	0.1	0.2	0.1	0.3	0.1	0.1	0.1	0.0	0.2	0.5	0.2	0.3
	3	3.6	710.80		0.2	0.6	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.2	0.4	0.2	0.2
	4	3.1	711.30	1.9	4.4	0.7	0.1	0.1	0.2	0.1	0.2	0.1		0.1	0.0	0.1	0.0	0.2	0.5	0.2	0.2
	5	2.6	711.80	2.2	4.8	0.7	0.1	0.3	0.1	0.1	0.1	0.1		0.1	0.0	0.2		0.2	0.6	0.2	0.3
	6	2.1	712.30		4.8	0.6	2.5	0.4	0.2	1.7	0.1	0.1		3.2	0.2	2.9	0.0	0.3	6.1	0.2	0.3
	7	1.6	712.80		3.3	0.6	2.4	0.2	0.1	1.3	0.1	0.0		3.2	0.1	1.4	0.0	0.4	6.3	0.2	0.3
5	1	5	708.00																		
	2	3.6	709.40		1.0	0.9	0.5	0.3	0.1	0.1	0.1	0.1		0.1	0.0	0.1	0.0	0.1	0.5	0.2	0.2
	3	3	710.00																		
	4	2.5	710.50				6.8	5.2	0.6	0.5	0.3	0.1		0.2	0.2	2.3	0.0	0.7	1.6	7.2	2.3
	5	2	711.00		9.0	0.8	4.1	1.2	2.9	3.2	0.1	0.2		3.6	1.4	7.0	0.0	4.1	7.6	14.0	8.6
	6	1.5	711.50		8.1	1.4	13.0	1.6	13.3	12.7	0.1	0.8		8.7	4.8	17.8	0.0	11.7	12.9	19.7	18.2
6	1	3.4	708.60			0.7	0.1	0.1	0.2	0.1	0.1	0.1		0.1	0.0	0.1	0.0	0.1	0.4	0.2	0.3
	2	1.9	710.10			0.7	0.1	0.4	0.2	0.1	0.1	0.0		0.1	0.0	0.0	0.0	0.1	0.3	0.2	0.4
	3	1.4	710.60		5.4	0.5	0.1	0.1	0.2	0.2	0.1	0.0		0.1	0.0	0.0	0.0	0.1	0.2	1.8	0.5

Stn	Port	1994 18-Feb	1994 30-Mar	1994 03-May	1994 08-Jun	1994 12-Jul	1994 15-Aug	1994 20-Sep	1994 16-Nov	1995 13-Apr	1995 07-Jun	1995 20-Jul	1996 30-May	1996 27-Jun	1996 15-Aug	1996 19-Sep
1	1	0.2	0.5	0.6	0.4	0.3	0.2	0.3	0.4							
	2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	4.1	0.2	0.4	0.3				
	3				1.2	0.3	0.7	0.4								
2	1			0.5	0.3	0.3	0.1	0.3	0.4	0.2	0.2	2.5	0.1	0.7	0.3	0.1
	2	0.2		0.3	0.4	0.3	0.1	0.3	0.3	0.1	0.2	2.0	0.1	0.4	0.1	0.1
	3			0.4	0.4	0.2	0.1	0.3	0.4	0.1	0.2	1.5	0.1	0.3	0.2	0.1
	4	0.2	0.2	0.3	0.4	0.3	0.1	0.3	0.4	0.1	0.2	0.8	0.2	0.6	0.1	0.1
	5	0.2		0.3	0.3	0.2	0.1	0.2	0.3	0.1	0.2	1.2	0.1	0.2	0.1	0.1
	6	0.2		0.4	0.3	0.2	0.1	0.4	0.3	0.1	0.1	0.5	0.1	0.3	0.1	0.1
3	1	0.5		0.8	0.6	0.3	0.2	0.4	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.3
	2															
	3	0.3		0.6	0.5	0.4	0.1	0.3	0.3	0.1	0.4	2.2	0.1	0.4	0.2	0.1
	4	0.3		0.8	0.5	0.2	0.2	0.4	0.9	0.1	0.4	1.4	0.2	0.2	0.2	0.2
	5				0.5	0.3	0.2	0.3	1.2	0.1	0.2	0.0	0.1	0.4	0.1	0.1
	6				0.4	0.2	0.1	0.2	0.6	0.1	0.2	1.7	0.1	0.5	0.1	0.1
	7												0.1			
4	1															0.1
	2	0.3		0.3	0.4	0.6	0.1	0.4	0.6		1.3	2.0	0.1	0.1	1.9	0.1
	3	0.2	0.2	0.3	0.4	0.6	0.1	0.3	1.6		1.6	1.9	0.1	0.1	1.4	0.1
	4	0.2	0.2	0.9	0.5	0.7	0.1	0.3	4.2	0.1	1.8	1.7	0.1	0.1	1.5	0.1
	5	0.2		0.6	0.4	0.6	0.2	0.3	3.6		1.3	1.6	0.1	0.1	2	0.1
	6	0.2	0.2	0.5	0.5	1.1	1.1	0.7	3.4		0.6	1.4	0.1	0.8	1.4	0.1
	7	0.1	0.2	0.5	0.6	0.6	0.5		1.3	0.1	0.2	0.7	0.1	0.5	0.5	0.1
5	1	0.5			2.8	5.0	1.7	3.6	5.1	4.1						
	2	0.3	0.2	0.5	0.4	0.3	0.2	0.1	0.4	0.2	0.6		0.2	0.2	0.1	0.1
	3															
	4	0.2	0.1	0.6	0.4	1.8	2.7	0.6	5.3	0.1	6.3		1.6	2	0.7	0.1
	5	1.2	0.1	0.4	1.0	3.9	5.3	3.0		0.1	6.8		3.1	5.8	2.9	0.5
	6	5.1	0.2	0.4	2.8	11.5	15.3	8.7		0.1	13.8		6.8	13	8.7	2.1
6	1	0.2	0.2	1.1	1.0	0.6	0.2	0.2			1.0		0.2	0.2	0.1	0.1
	2	0.2	0.3	0.8	1.8	0.6	0.1	0.1			1.0		0.1	0.1	0.2	0.1
	3	0.2		0.6	0.8	0.2	0.1	0.1			4.4		0.1	0.1	0.1	0.1

Welcome Screen | Search | Report List

Table A-4a. Temperature measurements at Pile 7/12 before placement of cover.

Stn	Port	Depth below Rock Surface (m)	Elevation (m)	1989 04-Jul	03-Aug	04-Sep	22-Sep	12-Oct	22-Nov	29-Dec	1990 25-Apr	25-May	14-Jun	20-Jul	16-Aug	28-Sep	12-Oct	1991 18-Jan	11-Apr	22-May	19-Jun	17-Jul	21-Aug	22-Oct
1	Red	1.4	708.70	26.2	32.3	28.6	25.2	17.0	10.9	6.1	5.2	8.3	13.9	21.9	27.4	20.0	15.7	6.3	4.8	8.6	13.5			
	Blue	0.1	710.00	35.2	34.6	20.3	21.8	10.0	-0.9	-5.4	6.4	8.9	22.6	26.9	26.6	16.9	11.8	-0.7	1.8	14.2	18.4		17.7	11.9
	Surface	0.0	711.40	38.3	43.9	21.8	22.6	11.0	-4.7	-14.0	12.8	29.0	30.3	24.6	33.5	19.6	15.3			24.3	30.2	40.7	17.3	
2	Red	3.9	709.60	23.2	38.3	44.1	44.6	45.0	44.5	45.6	27.1	24.8	23.8	23.7	27.7	27.3	26.8	22.9	16.9	12.9	13.7	16.2	21.3	19.0
	Blue	0.9	712.60	27.3	42.1	42.1	41.9	37.0	26.7	25.6	14.5	14.9	21.9	26.4	28.6	22.1	18.7	13.8	9.1	13.5	17.5	9.3	22.8	17.3
	Black	0.3	713.20	28.9	37.5	30.9	33.2	26.9	14.5	15.5	10.3	10.9	22.1	25.7	24.3	18.1	14.2	4.4	5.1	14.6	19.2	23.3	15.3	15.5
	Surface	0.0	714.80	39.3	43.8	24.2	25.5	13.5	-4.7	-14.2	13.7	32.2	34.7	24.8	36.3	23.1	15.6			33.1	32.0	39.4	15.7	
3	Red	4.1	709.40	21.1	34.0	39.2	41.5	42.6	43.5	46.5	27.5	25.6	24.0	23.1	24.7	27.0	26.6	22.9	17.6	12.3	12.6	15.2	18.6	18.3
	Blue	1.4	712.10	32.9	46.7	48.1	48.4	44.2	35.6	25.5	18.1	20.6	23.7	27.1	29.7	26.1	23.2	13.8		13.5	17.1	12.5	24.0	17.4
	Black	0.4	713.10	31.4	40.1	13.8	32.4	23.8	10.1	10.5	10.4	13.9	24.1	25.9	23.9	18.0	14.0	4.4	4.9	16.3	21.8	24.3	16.9	14.1
	Surface	0.0	714.80	39.3	43.8	24.2	25.9	11.8	-5.1	-13.1	13.7	24.7	34.7	22.8	30.8	23.1	16.3			23.2	32.0	37.1	17.1	
4	Red	4.3	708.80	25.8	35.1	36.9	42.2	43.1	42.7	42.8	25.8	24.0	25.2	24.1	27.3	29.2	29.3	23.1	17.7	13.5	13.7	16.4	20.6	19.8
	Blue	1.3	711.80	35.2	42.9	39.4	45.4	43.0	40.5	38.2	19.5	21.0	25.2	28.6	31.9	30.0	28.3	17.6	12.9	14.2	17.6	22.7	25.5	18.3
	Black	0.3	712.80	33.5	38.4		32.7	25.1	14.1	15.8	11.5	14.6	26.4	27.5	27.3	20.5	16.3	3.0	4.9	17.5	24.4	26.7	17.5	14.2
	Surface	0.0	714.40	37.8	43.0	24.1	25.4	14.1	-5.0	-12.3	13.7	25.4	36.0	24.1	33.8	22.0	16.3			22.7	39.0	40.1	17.2	
5	Red	3.7	708.00	29.7	40.7	39.2	40.6	38.2	33.7	33.8	21.0	23.0	25.1	28.7	32.5	38.6	36.6	23.5	17.6	15.6	16.8	20.7	26.1	21.2
	Blue	0.7	711.00	34.9	42.5	35.4	37.8	29.5	22.8	26.4	13.8	15.3	26.6	33.3	36.9	31.4	26.3	9.0	8.5	15.7	20.9	27.2	24.4	16.2
	Black	0.2	711.50	33.6	40.2	27.9	31.9	22.0	10.5	11.2	10.0	13.0	26.3	30.4	31.4	25.0	18.8	3.3	5.0	16.6	23.8	27.7	17.7	14.1
	Surface	0.0	713.00	38.0	43.0	21.8	23.8	14.9	-0.1	-11.0	13.1	23.6	33.5	21.8	36.6	23.3	17.8	6.5		24.7	35.0	47.0	15.6	
6	Red	2.0	708.70	21.1	27.4	24.8	26.3	20.0	13.9	12.5	9.3	14.0	20.3	27.1	32.8	26.3	23.3	11.1	10.3	13.5	17.6	22.1	24.8	18.1
	Blue	0.4	710.30	27.4	35.9	27.2	28.1	17.6	9.0	9.7	7.4	11.0	23.8	31.4	33.4	24.8	20.2	6.3	5.9	15.2	20.8	26.1	21.7	16.5
	Surface	0.0	712.00	38.3	43.8	21.8	22.8	10.7	-0.4	-15.5	11.3	22.5	38.3	25.4	25.4	21.3	17.4			21.8	36.0	44.7	17.7	
7	Black	0.7	713.00	30.8	44.5	48.0	49.2	46.2	39.3	33.1								17.3	12.1		18.0	23.1	25.6	16.7
	Surface	0.0	715.00	39.3	43.9	24.2	29.9	14.6	-2.9	-10.5											42.0	45.5	17.2	

Table A-4b. Temperature measurements at Pile 7/12 after placement of cover.

Stn	Port	Depth below Cover Surface (m)	Elevation (m)	1992 17-Mar	22-Apr	26-May	14-Jul	17-Aug	29-Sep	03-Nov	1993 13-Jul	10-Sep	01-Oct	1994 12-Jul	15-Aug	20-Sep	16-Nov	1995 07-Jun	31-Aug	1996 30-May	27-Jun	15-Aug
1	Red	2.7	708.70							10.9									12.7	4.7	12.4	16.4
	Blue	1.4	710.00	-0.2	2.1	5.7	10.8	13.6	13.4	5.8	13.9	15.3		10.0	14.1	10.9	9.1	9.0	15.6	6.4	7.9	11.7
	Surface	0.0	711.40		5.0	12.2		26.7	13.8			15.3	10.1	24.8	20.2	20.5	4.3					
2	Red	5.2	709.60	11.9	11.5	6.8		8.1	9.8	16.0	4.2	8.1	7.5	1.6	4.9	7.0	8.7	4.3	7.6	4.3	4.1	6.2
	Blue	2.2	712.60	6.4	6.5	4.2	8.9	11.1	12.8	8.9	8.5	12.4	11.5	6.3	10.3	11.1	8.7	5.2	12.7	3.5	7.5	11.1
	Black	1.6	713.20	4.4	4.8	4.5	9.7	12.1	13.3	6.1	10.1	13.7	10.7	7.6	12.1	11.8	8.9	6.5	13.8	3.9	8.8	12.8
	Surface	0.0	714.80		5.5	14.1		24.2	14.0			15.3	10.1	24.8	20.2	20.5	4.3					
3	Red	5.4	709.40	13.1	12.0	7.7	7.5	8.0	8.6	16.0	5.1	7.7	8.6	2.5	5.0	5.8	9.3	4.7	7.1	4.7	4.7	6.4
	Blue	2.7	712.10	8.0	7.5	4.4				16.8				5.7					12.1	3.9	6.3	10.6
	Black	1.7	713.10	4.4	4.8	4.8	10.8	12.7	12.8	12.3	10.7	14.2	11.4	9.0	12.5	11.4	9.2	6.8	14.2	4	9.2	13.4
	Surface	0.0	714.80		4.8	14.1			14.0			15.3	10.1	24.8	20.2	20.5	4.3					
4	Red	5.6	708.80	12.4	12.1	8.3				14.9									7.6	4.1	4.5	6.6
	Blue	2.6	711.80	7.1	6.7	5.3				9.5									13.1	3.8	7.2	11.3
	Black	1.6	712.80	3.5	3.6	6.5				1.1									14.9	4.7	10.1	14.7
	Surface	0.0	714.40		4.7	17.2			14.0					24.8	20.2	20.5	4.3					
5	Red	5.0	708.00	12.3	10.0	7.6	8.6	9.2	11.0	14.2	6.5	9.9	9.8	4.5	6.6	7.6	10.1	4.8	8.8	4.1	4.9	7.6
	Blue	2.0	711.00	5.9	5.5	7.7	13.1	14.8	14.9	8.9	12.8	15.9	13.3	8.0	13.8	13.0	9.4	8.3	15.7	4.7	10.2	14.6
	Black	1.5	711.50	4.5		9.3	13.8	15.5	14.9	5.1	14.7	16.2	13.2	12.6	15.2	12.8	8.2	9.5	16.1	5.6	11.6	16.1
	Surface	0.0	713.00		3.8	16.8			13.9			15.3	10.1	24.8	20.2	20.5	4.3					
6	Red	3.3	708.70		7.8	6.3	9.7	10.7	11.8	12.4	8.1	12.0	10.7	6.6	9.1	10.1	10.5	5.8	11.7	4	6.2	9.8
	Blue	1.7	710.30		6.2	6.5	11.4	12.8	13.4	10.9	11.1	20.4	12.8	10.0	11.9	12.0	10.1		14.8	4.3	8.4	12.8
	Surface	0.0	712.00		3.5	14.4			13.8			15.3	10.1	24.8	20.2	20.5	3.9					
7	Black	2.0	713.00	6.5	6.5	6.5	8.4	10.5	12.4		7.5	11.9	10.2	4.5	9.4	10.7		4.8	12.7	2.8	6.9	11.3
	Surface	0.0	715.00		4.4	4.4			13.6			15.3		24.8	20.2	20.5		7.5				

Table A-5. Temperature measurement calibration at Pile 7/12 on August 31, 1995.

Stn	Port	Depth below Rock Surface (m)	Elevation (m)	Manual Measurement (C)	Datalogger Measurement (C)	Difference (C)
1	Red	1.4	708.70	12.7	12.6	0.1
	Blue	0.1	710.00	15.6	15.5	0.1
	Surface	0.0	711.40	15.8	--	--
2	Red	3.9	709.60	7.6	7.3	0.3
	Blue	0.9	712.60	12.7	12.5	0.2
	Black	0.3	713.20	13.8	13.7	0.1
	Surface	0.0	714.80	15.8	--	--
3	Red	4.1	709.40	7.1	6.9	0.2
	Blue	1.4	712.10	12.1	11.9	0.2
	Black	0.4	713.10	14.2	14.1	0.1
	Surface	0.0	714.80	15.8	--	--
4	Red	4.3	708.80	7.6	7.5	0.1
	Blue	1.3	711.80	13.1	13.2	-0.1
	Black	0.3	712.80	14.9	15.2	-0.3
	Surface	0.0	714.40	15.8	--	--
5	Red	3.7	708.00	8.8	8.7	0.1
	Blue	0.7	711.00	15.7	15.5	0.2
	Black	0.2	711.50	16.1	15.8	0.3
	Surface	0.0	713.00	15.8	--	--
6	Red	2.0	708.70	11.7	11.3	0.4
	Blue	0.4	710.30	14.8	14.5	0.3
	Surface	0.0	712.00	15.8	--	--
7	Black	0.7	713.00	12.4	12.3	0.1
	Surface	0.0	715.00	15.8	--	--

Table A-6. Water content by TDR of composite cover on Pile 7/12.

Date	West Profile				East Profile			
	Top Sand	Lift 3 of Till	Lift 1 of Till	Bottom Sand	Top Sand	Lift 3 of Till	Lift 1 of Till	Bottom Sand
31-Oct-91	12	30	34	12	8	32	30	11
31-May-92	8	25	27	12	7	30	26	11
26-Aug-92	9	15	31	13	8	36	30	12
08-Jun-94	16	32	33	15	11	35	30	15
12-Jul-94	9	22	28	12	5	31	26	--
15-Aug-94	11	24	28	14	8	30	22	11
20-Sep-94	9	24	31	14	9	30	31	12
16-Nov-94	9	24	31	18	--	--	--	--
28-Jul-95	8	18	30	14	7	30	--	12
31-Aug-95	10	25	29	15	8	33	--	13
06-Jun-96	9	17	--	13	8	31	--	11
28-Jun-96	11	26	--	8	8	34	--	11
30-Jul-96	9	21	--	9	7	32	--	12

Table A-7. Pore-gas oxygen measurements taken in cover on Pile 7/12 on August 31, 1995.

Profile	Port	Material	Depth (m)	O2 (%)
West	A	Top sand	0.25	21.9
	B	Lift 3 of till	0.50	19.0
	C	Lift 2 of till	0.70	18.5
	D	Lift 1 of till	0.90	18.0
	E	Bottom sand	1.10	10.0
East	A	Top sand	0.25	21.9
	B	Lift 3 of till	0.50	19.0
	C	Lift 2 of till	0.70	18.0
	D	Lift 1 of till	0.90	15.5
	E	Bottom sand	1.10	1.8

9.2 Appendix B: Waste Rock Effluent Water Chemistry

Table B-1. Water quality of samples taken from the centre drain of Pile 7/12.

Date (YY-MM-DD)	Comment	Quantity (L)	Al (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	S (mg/L)	Zn (mg/L)	Cl (mg/L)	SO4 (mg/L)	Temperature (C)	Conductivity (µS/cm)	pH	Acidity (mg/L)	Alkalinity (mg/L)
91-10-30	Total					19590								71042			2.3	54450	
92-06-24	Total					12.7								428			3.1	401	
92-06-24	Total					2								201				3.3	162
92-06-29	Total					10500								5140			2.4	35000	
92-07-14	Total																2.8		
92-08-17	Total					3720								14800				14400	
92-09-29	Total					5250								15400			2.9	15800	
92-10-19	Total																2.9		
92-11-03	Total																3.0		
93-07-13	Total		89.8	98.8	2.5	5000	24.6	128	51.6	9.8	3300	496	4.1	9970		8400	3.2		
93-09-10	Total		681	503	16.5	30600	19.7	1044	331	<0.01	23800	3015	4.6	71440		35000	3.0		
93-10-01	Total		806	555	10.9	30844	592	589	278	<0.01		2860	5.3	73854		29000	3.0		
93-11-05	Total		416	496	10.78	29840	0.28	693	<0.01	4.87		1835	5.4	2184		25000	2.8		
94-06-09	Total		983	376	4.07	33600	1	707	163	<5	24700	2470	29	74100		74700	2.9	63500	<0.4
94-06-09	Soluble		940	139	3.73	26900	1	286	47.3	<5	24500	1700		73600					
94-07-12	Total		633	459	2.78	73600	5.52	614	141	3.4	19500	3060	<0.5	43400		44400	3.0	28900	<0.4
94-07-12	Soluble		581	429	2.51	35800	4.48	577	122	2.1	16000	2790							
94-08-15	Total		141	164	0.46	7750	40	146	69	<1	6930	660	<0.5	16300		34000	3.1	13200	<0.5
94-08-15	Soluble		229	203	0.6	8050	<2	159	68	0.5	7115	722	<0.5			38200	3.1	14700	<0.5
94-09-21	Total		88.5	184	0.56	5850	0.2	136	47.8	0.8	3730	544	2.1	11200		8450	2.3	5750	<0.4
94-09-21	Soluble		32.9	107	0.33	3560	0.1	71.3	31.1	0.8	1790	276							
94-11-22	Total		17.7	59	0.21	1208	6.3	36.4	12.9	4.8	96.6	102	2.3	290		3070	3.1		<0.5
95-06-07			82.6	84	11.1	1040	0.05	31.4	12.2	3.88		120	16	3450				3090	
95-10-08	Soluble	3.0	312	166	38.8	3220	0.12	74.3	30.3	3.33		371	6	11700	11		2.9		
95-10-08	Total	3.0			39.7	3320						377		11300	11				
96-05-31	Soluble	7.0	32.8	38.0	5.20	723	<0.02	26.7	7.98	2.40		94.0			15		2.9		
96-05-31	Total	7.0	34.1	39.2	5.40	712	<0.02	27.8	8.44	2.43		96.7	35	1380	15	3570	2.9		<25
96-06-27	Soluble	8.9	24.6	31.6	4.92	377	<0.02	17.9	4.87	2.80		59.3			10		2.7		
96-06-27	Total	8.9	28.8	32.4	5.25	457	<0.02	19.4	5.52	2.78		70.7	3.7	1090	10	1820	2.7		<1
96-07-30	Soluble	108	95.4	263	0.135	20700	0.82	159	99.3	5.50		862			22		3.2		
96-07-30	Total	108	97.1	283	0.140	20300	0.75	164	98.6	5.25		870	6.0	32500	22	51700	3.2		<1
96-09-10	Soluble	7.3	119	242	2.45	10800	<0.2	170	78.7	2.62		653			8		2.6		
96-09-10	Total	7.3	129	265	2.64	11950	<0.2	172	86.5	2.85		674	13	24100	8	28600	2.6		<1
96-10-10	Soluble	7.0	85.2	97.1	2.67	2440	0.861	73.3	24.0	4.96		212			5		3.1		
96-10-10	Total	7.0	89.4	97.1	1.65	2600	0.950	64.4	25.6	4.78		221	4.5	1910	5	2750	3.1		<1

Table B-2. Water quality of samples taken from the perimeter drain of Pile 7/12.

Date (YY-MM-DD)	Comment	Quantity (L)	Al (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	S (mg/L)	Zn (mg/L)	Cl (mg/L)	SO4 (mg/L)	Temperature (C)	Conductivity (µS/cm)	pH	Acidity (mg/L)	Alkalinity (mg/L)
91-10-30	Total					651								2706			2.5	1980	
92-06-24	Total					2								201			3.3	162	
92-07-14	Total																3.76		
92-08-17	Total					1250								4300				3950	
92-09-29	Total					1600								3880			3.25	4200	
92-10-19	Total																3.29		
92-11-03	Total																3.63		
93-05-21	Total			65.8	10.5	3690	0.3	117	51.3	18.1		753	3.9	8380		29200	3		<1
93-07-13	Total		107	98.6	2.3	5300	18.9	148	56.5	5	3800	573	3.4	11490		9600	3.2		
93-09-10	Total		255	256	2.8	12600	5.5	390	139	4.9	9000	1479	3.7	27100		20000	3.3		
93-10-01	Total		11.7	34.7	<0.01	726	62.1	18.7	23.2	1.8		84.3	1.06	1710		2500	3.6		
93-11-05	Total		7.28	13.19	0.1	317	2.22	16.24	1.82	2.35		40.11	1.6	708		1440	2.9		
94-05-17	Total		307	263	1.4	10147	0.72	307	59.1	3.4		1401	30	22200		30600	3.1	17146	
94-06-09	Soluble		171	46.4	3.85	747	0.31	61.8	18.6	<5	1660	239		4990					
94-06-09	Total		173	116	3.89	1100	1.3	67.0	26.9	<5	1850	239	18.5	5850		9450	2.8	4070	<0.4
94-07-12	Soluble		187	205	2.1	12200	5.57	204	51	2.7	5920	1070							
94-07-12	Total		221	231	2.22	28900	7.22	234	53.2	2.8	6010	2500	1.1	14500		21000	3.0	10800	<0.4
94-08-15	Soluble		58.5	61	0.37	1500	10	41.9	21	4.7	1850	195	<0.5			4880	3.2	3080	<0.5
94-08-15	Total		53	36	0.53	1310	7	35	19	3	997	171	<0.5	3450		4660	3.1	2910	<0.5
94-09-21	Soluble		63	66.3	1.2	587	0.9	52.3	24.4	2.7	822	149							
94-09-21	Total		65	75.3	1.2	787	1	52.3	24.2	2.9	1091	196	2.4	3273		2260	2.4	2086	<0.4
94-11-22	Total		53.2	48	<0.01	558	5.8	36.4	14	5	573	88.2	8	1720		2700	2.6	1865	<0.5
95-06-07			26	30.2	1.09	68.4	2.9	18.2	13.4	5.53		3.06	4	550				396	
95-10-08	Sample 1, Soluble	50	47.2	58.9	1.56	654	0.81	26.4	13.9	5.59		60.4	7	2240	11		2.7		
95-10-08	Sample 3, Soluble	50	13.9	18	0.626	37.8	1.38	8.08	1.83	2.78		10.8	15	325	11		3.08		
95-10-08	Sample 5, Soluble	50	12.1	17.6	0.609	25.3	1.41	7.92	1.76	2.71		10	15	250	11		3.09		
95-10-08	Sample 2, Total	50			1.59	598						62.3		2120	11				
95-10-08	Sample 4, Total	50			0.618	27.6						10.2		270	11				
95-10-08	Sample 6, Total	50			0.612	26.3						10.2		270	11				
96-05-31	Soluble	14	25.2	33.5	1.07	81.1	1.28	19.4	5.02	3.93		38.1			20		2.75		
96-05-31	Total	14	26.9	36.6	1.09	112	1.26	20.4	5.32	3.99		40.4	3.5	590	20	1740	2.75		<0.5
96-06-27	Soluble	53.5	6.58	15.5	0.517	41.8	2.42	9.35	3.65	3.36		14.4			10		3.07		
96-06-27	Total	53.5	6.26	15	0.504	35.4	2.42	9.11	3.56	3.36		13.7	3.6	180	10	559	3.07		<1
96-07-30	Soluble	22.6	114	123	2.81	4850	1.24	89.2	4.05	4.2		331			24		3.11		
96-07-30	Total	22.6	124	123	2.95	4870	1.2	87.8	4.34	4.02		353	8	9950	24	20200	3.11		<1
96-09-10	Soluble	24.2	11.94	242	2.42	10600	<200	182	80.6	2.65		681			20		2.95		
96-09-10	Total	24.2	11.7	269	2.6	12000	<200	188	63.6	2.98		659	4.9	5300	20	6750	2.95		<1
96-10-10	Soluble	67.7	4.55	14.9	0.207	52.2	3.17	6.66	2.21	2.7		8.91			3		3.09		
96-10-10	Total	67.7	4.3	16.1	0.174	55.8	3.33	6.85	2.35	2.95		9.18	7	185	3	685	3.09		<1

Table B-3. Water quality of samples taken from the west lysimeter of Pile 7/12.

Date (YY-MM-DD)	Comment	Quantity (L)	Al (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	S (mg/L)	Zn (mg/L)	Cl (mg/L)	SO4 (mg/L)	Temperature (C)	Conductivity (µS/cm)	pH	Acidity (mg/L)	Alkalinity (mg/L)
92-04-22	Total																7.36		
92-07-14	Total																6.55		
92-09-29	Total																6.21		
92-11-03	Total																		
93-05-21	Total			45.3	<0.01	0.5	4.8	6.2	9.8	13		0.43	7.1	32		369	6.5		14.5
93-10-01	Total		0.1	28.3	<0.01	0.1	7.8	22	17.6	15		<0.01	3.88	59.4		280	6		
93-11-05	Total		<0.01	19.31	<0.01	<0.01	3.8	7.58	2.94	18.68		0.1	3.9	65.58		330	6		
94-06-09	Soluble		0.08	37.6	0.01	<0.01	2.7	12	19.6	8.0	75.9	1.03							
94-06-09	Total		0.24	41.6	0.06	1.1	2.8	12.9	22.1	9.0	76.3	1.55	2.7	229		660	5.9		59
94-07-12	Soluble		0.21	78.3	0.01	3.65	3.5	24.6	20.0	8.5	97	3.6							
94-07-12	Total		0.23	124	0.01	3.71	3.63	27.2	21.7	8.5	99.3	4.2	2.9	290		635	6.0		43.5
94-09-21	Soluble		0	60.4	<0.01	0.05	3.9	16.7	35.5	12.6	145	0.94							
94-09-21	Total		0.6	59	0.01	0.1	3.9	16.6	37.4	12.6	165	0	2.1	495		574	6.1		48
94-11-22	Total		1	67.3	<0.01	0.1	7.8	22	17.6	15	90	0.9	1.9	270		587	6.1		49.9
95-06-07			0.05	38.4	0.004	0.082	7.99	16.7	48.1	8.51		1.35	5	200				39	
95-10-08	Soluble	3	0.048	81.5	0.015	0.038	4.57	25.3	21.9	14.7		1.94	6	260	12		5.41		
95-10-08	Total	3			0.012	0.095						1.92		255	12				
96-05-31	Soluble	10	0.07	25.5	0.023	0.04	9.96	12.5	17.3	5.55		2.9			20		5.39		
96-05-31	Total	10	0.077	31.4	0.01	0.09	12	15.6	20.7	6.83		3.56	4.3	179	20	458	5.39		25
96-06-27	Soluble	10.3	0.124	60.6	0.02	<0.02	4.27	20.2	14.9	10.2		4.15			9		5.33		
96-06-27	Total	10.3	0.124	60	0.018	<0.02	4.2	20.3	15.1	10.4		4.24	2.2	240	9	555	5.33		31
96-07-30	Soluble	11.4	0.286	49.2	0.028	<0.1	6.79	16.7	12	9.13		5.46			22		5.27		
96-07-30	Total	11.4	0.292	4.92	0.022	<0.1	6.54	16.5	11.6	8.7		4.89	4	237	22	532	5.27		21
96-09-10	Soluble	0																	
96-09-10	Total	0																	
96-10-10	Soluble	9.4	0.242	48.1	0.031	<0.02	6.19	16.9	12.5	9.44		4.72			2		5.31		
96-10-10	Total	9.4	0.249	48.1	0.02	<0.02	6.25	16.3	11.9	9.44		5.25	3.2	230	2	550	5.31		21

Table B-4. Water quality of samples taken from the east lysimeter of Pile 7/12.

Date (YY-MM-DD)	Comment	Quantity (L)	Al (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	S (mg/L)	Zn (mg/L)	Cl (mg/L)	SO4 (mg/L)	Temperature (C)	Conductivity (µS/cm)	pH	Acidity (mg/L)	Alkalinity (mg/L)
92-07-14	Total																5.9		
92-09-29	Total																6.16		
92-11-03	Total																6.78		
93-10-01	Total		0.19	22.8	<0.01	0.07	50.3	16.6	22.4	14.2		<0.01	2.45	305		680	5.8		
93-11-05	Total		<0.01	53.4	<0.01	<0.01	4.77	35.05	56.53	25.99		<0.01	2.80	256		7200	5.7		
94-06-09	Soluble		0.07	34.9	0.01	0.03	2.7	15	43	6.0	88	0.16		264					
94-06-09	Total		0.45	34.9	0.06	0.33	3.2	15.8	55.9	9.0	88.6	0.17	2.20	266		703	5.9	124	55.7
94-07-12	Soluble		0.23	58.8	0.01	<0.01	4.93	32.8	62.4	8.2	124	0.40							
94-07-12	Total		0.23	75.2	0.02	<0.01	5.89	43.3	75.2	12.7	165	0.50	3.20	398		794	6.3	47.9	54.2
94-08-15	Soluble		6.2	70	0.01	202	7	35.7	82	13.5	427	27.00	1.90			2740	4.5	552	9.4
94-08-15	Total		2	36	<0.01	<0.5	4	29	81	16	96	3.10	1.50	422		910	6.1	66.4	54.8
94-09-21	Soluble		0.1	87	0.01	0.06	5.4	33	94.6	13	254	0.03							
94-09-21	Total		0.2	110	0.2	0.1	5.4	37	95.4	13.1	266	0.10	2.30	798		894	6	90.1	53.8
94-11-22	Total		0.74	58	<0.01	0.91	7.4	29	69	13.5	122	0.36	2.00	366		755	6	217	47.7
95-06-07			0.134	82	0.022	0.801	4.35	26	25.8	12.9		2.44	7.00	310				54	
95-10-08	Soluble	10	0.059	45.3	0.007	0.085	10.67	20.3	43.8	11.7		1.6	6	195	12		5.27		
95-10-08	Total	10			0.005	0.129						1.60		205	12				
96-05-31	Soluble	0																	
96-05-31	Total	0																	
96-06-27	Soluble	10.2	0.175	24.3	0.012	<0.02	13.3	12.6	15.8	5.52		4.19			6		5.22		
96-06-27	Total	10.2	0.17	23.2	0.01	<0.02	12.3	12.7	15.9	5.67		4.24	3.90	130	6	364	5.22		28
96-07-30	Soluble	10.9	0.473	19.5	0.027	<0.1	20	10.6	9.02	4.6		6.13			24		5.18		
96-07-30	Total	10.9	0.514	20.2	0.015	<0.1	20.8	10.7	9.02	4.66		6.04	4.00	140	24	358	5.18		21
96-09-10	Soluble	18	546	21.7	0.023	0.022	23.2	12.4	10.5	5.84		6.19			18		5.08		
96-09-10	Total	18	545	22.3	0.018	<0.02	23.9	13.5	9.69	6.52		6.45	2.90	150	18	346	5.08		13
96-10-10	Soluble	10.2	0.786	20.1	0.042	<0.02	22.2	12.1	8.78	5.64		7.17			11		5.1		
96-10-10	Total	10.2	0.742	20.2	0.017	<0.02	21.9	11.6	9.28	5.52		7.18	3.00	150	11	405	5.1		11

Table B-5. Analytical results of water samples taken at Pile 7/12 during 1996, field parameters and general chemistry.

	May 31, 1996				June 27, 1996			
	Field Data				**Field Data**			
Date	May 31, 1996				June 27, 1996			
Location	Centre	Perimeter	E. Lysimeter	W. Lysimeter	Centre	Perimeter	E. Lysimeter	W. Lysimeter
Volume (L)	7	14	0	10	8.9	53.5	10.2	10.3
Temperature (C)	15	20		20	10	10	6	9
pH	2.88	2.75		5.39	2.7	3.07	5.22	5.33
	General Chemistry (nonfiltered)				**General Chemistry (nonfiltered)**			
Date	May 31, 1996				June 27, 1996			
Location	Center	Perimeter	E. Lysimeter	W. Lysimeter	Center	Perimeter	E. Lysimeter	W. Lysimeter
Concentration	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sodium	2.4	4.0		6.8	2.8	3.4	5.5	10.2
Potassium	< 0.02	1.26		12.0	< 0.02	2.42	13.3	4.27
Calcium	39.2	36.6		31.4	31.8	15.5	24.3	60.6
Magnesium	27.8	20.4		15.6	17.9	9.35	12.6	20.2
Iron	712	112		0.09	377	41.8	< 0.02	< 0.02
Manganese	8.44	5.32		20.7	4.87	3.65	15.8	14.9
Copper	5.40	1.09		0.010	4.92	0.517	0.012	0.020
Zinc	96.7	40.4		3.56	59.3	14.4	4.19	4.15
Ammonia (as N)	< 2.5	0.27		0.73	0.90	0.19	0.79	0.16
pH (units)	2.6	2.8		5.8	3.0	3.3	5.6	5.6
Alkalinity (as CaCO3)	< 25	< 0.5		25	< 1	< 1	28	31
Chloride	35.0	3.5		4.3	3.7	3.6	3.9	2.2
Sulfate	1380	590		179	1090	180	130	240
Nitrate + Nitrite (as N)	< 2.5	0.14		0.35	< 0.05	0.27	0.12	0.06
o-Phosphate (as P)	< 0.5	< 0.01		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
r-Silica (as SiO2)	55.0	55.0		19.7	3.5	33.0	23.5	19.6
Total Organic Carbon	36	2		3	1	< 1	2	2
Turbidity (NTU)	5.2	1.8		0.6	0.4	1.3	0.2	0.2
Conductivity (uS/cm)	3570	1740		458	1820	559	364	555
Calculated Parameters								
Bicarbonate as CaCO3	0.0	0.0		24.9	0.0	0.0	28.3	31.2
Carbonate as CaCO3	0.000	0.000		0.001	0.000	0.000	0.001	0.001
Hydroxide as CaCO3	0.000	0.000		0.000	0.000	0.000	0.000	0.000
Cation sum (meq/L)	33.281	11.210		4.373	25.635	4.600	3.590	5.921
Anion sum (meq/L)	29.719	12.393		4.371	22.798	3.868	3.391	5.687
% difference	5.65	-5.01		0.02	5.86	8.63	2.85	2.02
Theoretical Conductivity	1875.5	938.1		448.1	1484.5	350.1	358.3	596.1
Hardness (mg/L as CaCO3)	212.4	175.4		142.6	152.6	77.2	112.6	234.5
Ion Sum (mg/L)	2362.0	870.5		310.8	1596.7	309.0	251.9	395.6
Saturation pH (5oC)	14.20	14.15		8.75	13.57	13.73	8.79	8.40
Langelier Index (5oC)	-11.60	-11.35		-2.95	-10.57	-10.43	-3.19	-2.80

	July 30, 1996				September 10, 1996					
	Field Data				**Field Data**					
Date	July 30, 1996				September 10, 1996					
Location	Centre	Perimeter	E. Lysimeter	W. Lysimeter	Centre		Perimeter	E. Lysimeter	W. Lysimeter	Blank
Volume (L)	107.8	22.6	10.9	11.4	7.3		24.2	10.7	0	
Temperature (C)	22	24	24	22	8		20	18		
pH	3.24	3.11	5.18	5.27	2.61		2.95	5.08		
	General Chemistry				**General Chemistry**					
Date	July 30, 1996				September 10, 1996					
Location	Center	Perimeter	E. Lysimeter	W. Lysimeter	Center		Perimeter	E. Lysimeter	W. Lysimeter	Blank
Concentration	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sodium	5.5	4.2	4.6	9.1	2.6	2.7	3.7	5.8		11.9
Potassium	0.82	1.24	20.0	6.79	< 0.05	< 0.05	< 0.05	23.2		0.70
Calcium	263	123	19.5	49.2	241	242	39.7	21.7		2.7
Magnesium	159	89.2	10.60	16.70	158	182	24.0	12.4		0.55
Iron	20700	4850	< 0.1	< 0.1	11000	10600	1230	0.02		< 0.02
Manganese	99.3	4.05	9.02	12.0	76.7	80.6	10.8	10.5		< 0.001
Copper	0.135	2.81	0.027	0.028	2.47	2.42	0.443	0.023		0.002
Zinc	862	331	6.13	5.46	624	681	87.6	6.19		0.002
Ammonia (as N)	24.0	< 5	0.78	0.27	14.0	14.5	< 2.5	0.76		< 0.05
pH (units)	3.3	3.2	5.3	5.4	3.1	3.1	3.0	5.3		7.0
Alkalinity (as CaCO3)	< 1	< 1	21	21	< 1	< 1	< 1	13		24
Chloride	6.0	8.0	4.0	4.0	17.5	8.5	4.9	2.9		4.6
Sulfate	32500	9950	140	237	25000	23200	5300	150		2.6
Nitrate + Nitrite (as N)	< 5	< 5	< 0.5	< 0.5	< 0.05	< 0.05	< 0.05	0.75		0.20
o-Phosphate (as P)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.5	< 0.5	< 0.5	< 0.01		0.08
r-Silica (as SiO2)	< 5	< 5	30	24	< 25	< 25	< 25	29.0		10.7
Total Organic Carbon	< 1	< 1	2	2	79	38	22	2		< 1
Turbidity (NTU)	126	99.0	0.4	0.2	22.0	27.0	2.5	0.1		< 0.1
Conductivity (uS/cm)	51700	20200	358	532	29600	27600	8750	346		80
Calculated Parameters										
Bicarbonate as CaCO3	0.0	0.0	21.0	21.0	0.0	0.0	0.0	13.4		23.7
Carbonate as CaCO3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.022
Hydroxide as CaCO3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.005
Cation sum (meq/L)	1170.2	284.6	3.129	5.024	639.02	621.48	73.28	3.58		0.71
Anion sum (meq/L)	676.8	207.4	3.447	5.467	520.99	483.26	110.48	3.53		0.68
% difference	26.7	15.7	-4.83	-4.22	10.17	12.51	-20.25	0.74		2.61
Theoretical Conductivity	31716	9683	357.0	554.8	23659	21941	5484	384		69
Hardness (mg/L as CaCO3)	1311.5	674.5	92.3	191.6	1252.4	1353.8	198.0	105.2		8.9
Ion Sum (mg/L)	54625	15364	257.6	377.4	37139	35017	6701	274		49
Saturation pH (5oC)	13.12	13.83	9.01	8.65	13.31	13.34	14.32	9.17		9.73
Langelier Index (5oC)	-9.82	-10.63	-3.71	-3.25	-10.21	-10.24	-11.32	-3.87		-2.73

	October 10, 1996			
	Field Data			
Date	October 10, 1996			
Location	Centre	Perimeter	E. Lysimeter	W. Lysimeter
Volume (L)	7	67.7	10.2	9.4
Temperature (C)	5	3	11	2
pH	3.06	3.09	5.1	5.31
	General Chemistry			
Date	October 10, 1996			
Location	Center	Perimeter	E. Lysimeter	W. Lysimeter
Concentration	mg/L	mg/L	mg/L	mg/L
Sodium	5.0	2.7	5.6	9.4
Potassium	0.86	3.17	22.2	6.19
Calcium	97.1	14.9	20.1	48.1
Magnesium	73.3	6.66	12.1	16.9
Iron	2440	54.2	< 0.02	< 0.02
Manganese	24.0	2.21	8.78	12.5
Copper	2.67	0.207	0.042	0.031
Zinc	212	8.91	7.17	4.72
Ammonia (as N)	< 2.5	0.13	0.72	0.21
pH (units)	3.3	3.1	5.1	5.4
Alkalinity (as CaCO3)	< 1	< 1	11	21
Chloride	4.5	7.0	3.0	3.2
Sulfate	1910	185	150	230
Nitrate + Nitrite (as N)	< 0.05	0.47	0.76	0.81
o-Phosphate (as P)	< 0.01	< 0.5	< 0.01	< 0.01
r-Silica (as SiO2)	1.2	28.0	30.0	24.3
Total Organic Carbon	2	19	3	2
Turbidity (NTU)	0.5	31.0	0.1	< 0.1
Conductivity (uS/cm)	2750	685	405	550
Calculated Parameters				
Bicarbonate as CaCO3	0.0	0.0	11.2	20.9
Carbonate as CaCO3	0.000	0.000	0.000	0.000
Hydroxide as CaCO3	0.000	0.000	0.000	0.000
Cation sum (meq/L)	149.63	4.77	3.40	4.98
Anion sum (meq/L)	39.89	4.08	3.49	5.35
% difference	57.90	7.77	-1.19	-3.67
Theoretical Conductivity	2585	353	376	545
Hardness (mg/L as CaCO3)	544.3	64.6	100.0	189.7
Ion Sum (mg/L)	4771	315	270	372
Saturation pH (5oC)	13.86	14.45	9.27	8.66
Langelier Index (5oC)	-10.56	-11.35	-4.17	-3.26

Notes:

Calculated indicies and ion balance are designed for "normal" water samples. Samples with high organic carbon (i.e. #1-4) relative to the total ion sum do not include potential contribution from organic anions. Detection limits for some parameters are variable due to initial dilution to overcome interferences.

Calculations for samples with high transition metal concentrations (esp. Fe) do not account for variable oxidation states. (Fe2+ vs. Fe3+). Calculations are based upon the trivalent form although, Fe2+ may predominate. Sulfate is assumed to be SO42-, but HSO41- will predominate at low pH.

Table B-6. Analytical results of water samples taken at Pile 7/12 during 1996, trace metals.

Date	Dissolved Trace Metals (filtered) May 31, 1996				Dissolved Trace Metals (filtered) June 27, 1996				Dissolved Trace Metals (filtered) July 30, 1996			
Location	Centre	Perimeter	E. Lysimeter	W. Lysimeter	Centre	Perimeter	E. Lysimeter	W. Lysimeter	Centre	Perimeter	E. Lysimeter	W. Lysimeter
Concentration	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Aluminium	32800	25200		70	24600	6580	175	124	95400	114000	473	286
Antimony	0.3	0.1		0.2	0.9	0.3	0.3	0.4	< 1	< 1	1.0	< 1
Arsenic	3	< 1		2	21	< 1	2	1	17	12	< 10	< 10
Barium	< 1	7		38	1	12	54	34	< 5	< 5	72	49
Beryllium	2.0	2.4		< 0.1	2.4	1.2	0.1	0.3	2.7	4.9	< 1	< 1
Bismuth	< 0.1	< 0.1		< 0.1	2.6	0.2	0.2	< 0.1	< 10	< 10	< 10	< 10
Boron	< 5	< 5		6	3	3	7	5	< 10	< 10	< 10	< 10
Cadmium	67.7	29.2		4.9	69.0	15.7	3.8	3.3	46.3	95.7	3.0	3.3
Calcium	38000	33500		25500	31600	15500	24300	60600	263000	123000	19500	49200
Chromium	22	22		17	13	3	3	2	15	13	< 10	< 10
Cobalt	886	482		992	902	338	1130	290	219	1240	1030	284
Copper	5200	1070		23	4920	517	12	20	135	2810	27	28
Iron	723000	81100		40	377000	41800	< 20	< 20	20700000	4850000	< 100	< 100
Lead	4.9	3.4		2.7	1.3	1.7	0.9	2.7	< 1	4.8	1.3	15.5
Lithium	43.1	25.6		0.2	41.2	13.4	0.2	0.5	137.0	49.8	< 1	< 1
Magnesium	26700	19400		12500	17900	9350	12600	20200	159000	89200	10600	16700
Manganese	7980	5020		17300	4870	3850	15800	14900	99300	4050	9020	12000
Molybdenum	0.2	0.3		0.3	0.6	< 0.1	0.1	< 0.1	1.6	1.7	2.7	< 1
Nickel	82	138		93	100	69	121	76	44	170	147	74
Potassium	< 20	1280		9960	< 20	2420	13300	4270	820	1240	20000	6790
Rubidium	2.1	13.9		30.8	2.2	16.4	42.9	15.3	4.2	16.5	52.8	22.1
Selenium	1	1		1	7	2	2	3	< 10	< 10	< 10	< 10
Silver	0.3	0.2		< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 1	< 1	< 1	< 1
Sodium	2400	3930		5550	2800	3360	5520	10200	5500	4200	4600	9130
Strontium	38	57		89	40	50	98	212	107	117	100	187
Tellurium	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 1	< 1	< 1	< 1
Thallium	< 0.1	0.1		0.1	0.1	0.2	0.2	< 0.1	< 1	< 1	< 1	< 1
Tin	0.4	0.2		0.1	< 0.1	< 0.1	0.1	< 0.1	< 1	2	3	< 1
Uranium	4.2	2.9		< 0.1	6.0	1.5	< 0.1	< 0.1	11.9	16.2	< 1	< 1
Vanadium	< 1	< 1		< 1	3	< 1	< 1	< 1	< 10	20	< 10	< 10
Zinc	94000	38100		2900	59300	14400	4190	4150	862000	331000	6130	5460

Date	Dissolved Trace Metals (filtered) September 10, 1996						Dissolved Trace Metals (filtered) October 10, 1996			
Location	Centre		Perimeter	E. Lysimeter	W. Lysimeter	Blank	Centre	Perimeter	E. Lysimeter	W. Lysimeter
Concentration	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Aluminium	120000	118000	11940	546		6	85200	4550	786	242
Antimony	1	1	0.3	0.2		< 0.1	0.4	< 0.1	0.1	0.3
Arsenic	34	33	3	< 1		< 1	5	< 1	< 1	< 1
Barium	< 10	< 10	< 1	58		77	1	4	51	30
Beryllium	5	5	1.2	0.3		< 0.1	5.1	0.7	0.4	0.3
Bismuth	2	< 1	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	0.1
Boron	< 20	< 20	3	10		44	3	3	8	7
Cadmium	140	129	26.2	3.3		< 0.1	58.5	6.1	3.6	3.1
Calcium	241000	242000	39700	21700		2650	97100	14900	20100	48100
Chromium	26	28	6	9		4	15	4	3	8
Cobalt	1100	1060	310	1240		< 0.1	698	176	1240	300
Copper	2470	2420	443	23		2	2670	207	42	31
Iron	11000000	10600000	1230000	22		< 20	2440000	54200	< 20	< 20
Lead	2.2	2.7	26.3	1.4		0.7	0.8	106	35.4	16.0
Lithium	129	131	71.9	0.6		1.1	84.8	9.9	0.6	0.5
Magnesium	158000	182000	24000	12400		551	73300	6660	12100	16900
Manganese	76700	80600	10800	10500		< 1	24000	2210	8780	12500
Molybdenum	< 1	< 1	0.1	0.1		0.4	0.1	< 0.1	< 0.1	0.1
Nickel	109	112	44	188		1	156	45	177	71
Potassium	< 200	< 200	< 50	23200		703	861	3170	22200	6190
Rubidium	1.8	1.8	2.0	54.1		0.3	18.9	10.8	57.1	23.3
Selenium	18	19	2	5		1	10	2	5	7
Silver	< 1	< 1	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sodium	2590	2650	3690	5840		11900	4960	2700	5640	9440
Strontium	70	69	19	116		60	91	54	112	183
Tellurium	< 1	< 1	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Thallium	< 1	< 1	< 0.1	0.1		< 0.1	0.1	0.2	0.1	< 0.1
Tin	< 1	< 1	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	0.2
Uranium	14.1	13.5	2.5	< 0.1		< 0.1	8.9	1.6	< 0.1	< 0.1
Vanadium	81	90	7	< 1		3	24	< 1	< 1	< 1
Zinc	624000	681000	87600	6190		2	212000	8910	7170	4720

	Total Trace Metals (nonfiltered)				Total Trace Metals (nonfiltered)				Total Trace Metals (nonfiltered)			
Concentration	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Aluminium	34100	26900		77	28800	6260	170	124	97100	124000	514	292
Antimony	0.3	0.1		0.2	0.7	0.2	0.3	0.3	< 1	1.3	1.0	< 1
Arsenic	5	1		2	14	< 1	2	< 1	19	12	< 10	< 10
Barium	< 1	7		45	1	13	55	34	< 5	< 5	73	49
Beryllium	2.2	2.4		< 0.1	2.4	1.1	0.1	0.1	2.7	4.8	< 1	< 1
Bismuth	< 0.1	< 0.1		< 0.1	0.9	0.1	0.1	< 0.1	< 10	< 10	< 10	< 10
Boron	< 5	< 5		6	3	2	7	5	< 10	< 10	< 10	< 10
Cadmium	70.0	30.9		5.7	77.1	15.5	3.9	3.4	47.4	97.5	2.9	3.3
Calcium	39200	36600		31400	34200	15000	23200	60000	283000	123000	20200	4920
Chromium	26	20		19	13	3	3	2	17	13	10	< 10
Cobalt	924	502		1160	938	336	1130	293	231	1310	1030	287
Copper	5400	1090		10	5250	504	10	18	140	2950	15	22
Iron	712000	112000		90	457000	35400	< 20	< 20	20300000	4870000	< 100	< 100
Lead	1.0	0.2		0.8	0.3	0.2	0.8	2.7	< 1	< 1	13.7	8.8
Lithium	43.0	26.8		0.3	46.5	12.6	0.3	0.4	149.0	49.3	< 1	< 1
Magnesium	27800	20400		15600	19400	9110	12700	20300	164000	87800	10700	16500
Manganese	8440	5320		20700	5520	3560	15900	15100	98600	4340	9020	11600
Molybdenum	0.2	0.2		0.3	0.2	< 0.1	0.1	< 0.1	< 1	< 1	1.0	< 1
Nickel	84	107		113	99	68	124	76	46	171	154	75
Potassium	< 20	1260		12000	< 20	2420	12300	4200	750	1200	20800	6540
Rubidium	2.1	14.3		38.8	2.3	16.1	44.0	15.3	4.1	16.8	52.6	22.0
Selenium	1	< 1		2	7	1	2	4	< 10	< 10	< 10	< 10
Silver	0.4	0.1		< 0.1	0.3	< 0.1	< 0.1	< 0.1	< 1	< 1	< 1	< 1
Sodium	2430	3990		6830	2780	3360	5670	10400	5250	4020	4660	8700
Strontium	39	59		109	39	49	97	212	109	119	100	185
Tellurium	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 1	< 1	< 1	< 1
Thallium	< 0.1	0.1		0.1	< 0.1	0.3	0.2	< 0.1	< 1	< 1	< 1	< 1
Tin	0.5	0.2		0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 1	1	1.3	< 1
Uranium	4.4	3.0		< 0.1	6.3	1.4	< 0.1	< 0.1	12.0	16.2	< 1	< 1
Vanadium	< 1	< 1		< 1	3	< 1	< 1	< 1	< 10	19	< 10	< 10
Zinc	96700	40400		3560	70700	13700	4240	4240	870000	353000	6040	4890

	Total Trace Metals (nonfiltered)						Total Trace Metals (nonfiltered)			
Concentration	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Aluminium	119000	139000	11700	545		10	89400	4300	742	249
Antimony	1	1	0.3	0.2		< 0.1	0.4	< 0.1	0.1	0.3
Arsenic	33	31	3	< 1		< 1	5	< 1	< 1	< 1
Barium	< 10	< 10	< 1	63		74	1	5	52	31
Beryllium	4	5	1.0	0.3		< 0.1	5.3	0.8	0.4	0.3
Bismuth	4	< 1	0.1	< 0.1		< 0.1	< 0.1	0.5	< 0.1	< 0.1
Boron	< 20	< 20	3	10		39	3	4	8	7
Cadmium	142	135	26.4	3.3		< 0.1	58.5	5.7	3.1	2.9
Calcium	260000	269000	36500	22300		2440	97100	16100	20200	48100
Chromium	28	26	5	4		6	12	7	4	3
Cobalt	1060	1100	311	1250		< 0.1	654	172	1240	318
Copper	2670	2600	458	18		< 1	1650	174	17	20
Iron	11900000	12000000	1100000	< 20		< 20	2600000	55800	29	< 20
Lead	1.4	< 1	0.19	1.0		0.1	0.2	0.3	1.0	4.9
Lithium	134	136	74.0	0.7		1.1	81.7	10.5	0.5	0.5
Magnesium	156000	188000	22300	13500		486	64400	6850	11600	16300
Manganese	79400	93600	10100	9690		< 1	25600	2350	9280	11900
Molybdenum	< 1	< 1	0.1	< 0.1		0.4	< 0.1	0.2	< 0.1	0.1
Nickel	114	100	43	197		2	165	46	173	71
Potassium	< 200	< 200	< 20	23900		611	950	3330	21900	6250
Rubidium	2.4	2.1	2.0	59.3		0.3	18.6	11.4	56.7	23.2
Selenium	21	23	3	5		< 1	9	2	6	6
Silver	< 1	< 1	< 0.1	< 0.1		< 0.1	0.1	< 0.1	< 0.1	< 0.1
Sodium	2710	2980	3470	6520		11900	4780	2950	5520	9440
Strontium	85	80	18	130		55	86	51	108	186
Tellurium	< 1	< 1	< 0.1	< 0.1		< 0.1	< 0.1	0.2	< 0.1	< 0.1
Thallium	< 1	< 1	< 0.1	0.1		< 0.1	0.1	0.2	0.1	< 0.1
Tin	< 1	< 1	< 0.1	< 0.1		< 0.1	< 0.1	0.1	< 0.1	0.2
Uranium	14.8	14.7	2.7	< 0.1		< 0.1	8.9	1.6	< 0.1	< 0.1
Vanadium	90	92	7	< 1		4	23	< 1	< 1	< 1
Zinc	689000	659000	80400	6450		2	221000	9180	7180	5250

9.3 Appendix C: Data Collected by the Datalogger at Pile 7/12

Table C-1. 1995 monthly summary of data collected by datalogger at Pile 7/12.

Parameter	Depth (m)	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Air Temperature (C)															
Average			–	–	–	–	–	–	–	–	10.79	7.35	-2.65	-9.66	–
Maximum			–	–	–	–	–	–	–	–	25.73	25.17	14.16	0.31	–
Minimum			–	–	–	–	–	–	–	–	-1.72	-8.11	-19.75	-23.98	–
Relative Humidity (%)															
Average			–	–	–	–	–	–	–	–	72	86	85	86	–
Maximum			–	–	–	–	–	–	–	–	102	103	102	101	–
Minimum			–	–	–	–	–	–	–	–	17	18	43	43	–
Wind Speed (m/s)															
Average			–	–	–	–	–	–	–	–	3.227	3.287	3.353	3.864	–
Maximum			–	–	–	–	–	–	–	–	18.690	22.370	21.570	17.090	–
Rainfall (mm)			–	–	–	–	–	–	–	–	–	–	–	–	–
Pan Evaporation (mm)			–	–	–	–	–	–	–	–	–	–	–	–	–
Pile Temperature (C)															
Station 6	3.3	708.70	–	–	–	–	–	–	–	–	11.59	11.31	9.64	7.52	–
	1.7	710.30	–	–	–	–	–	–	–	–	14.10	12.33	8.60	5.86	–
Station 5	5	708.00	–	–	–	–	–	–	–	–	9.43	9.92	9.77	8.65	–
	2	711.00	–	–	–	–	–	–	–	–	14.36	11.85	7.95	5.04	–
	1.5	711.50	–	–	–	–	–	–	–	–	14.25	11.30	6.65	3.92	–
Station 4	5.6	708.80	–	–	–	–	–	–	–	–	8.15	8.91	9.01	8.52	–
	2.6	711.80	–	–	–	–	–	–	–	–	13.03	11.92	9.95	7.12	–
	1.6	712.80	–	–	–	–	–	–	–	–	13.90	11.38	7.90	4.73	–
Station 3	5.4	709.40	–	–	–	–	–	–	–	–	7.70	8.48	8.75	8.24	–
	2.7	712.10	–	–	–	–	–	–	–	–	11.88	11.00	9.26	6.97	–
	1.7	713.10	–	–	–	–	–	–	–	–	13.17	10.96	7.71	5.02	–
Station 2	5.2	709.60	–	–	–	–	–	–	–	–	8.13	8.81	8.91	8.19	–
	2.2	712.60	–	–	–	–	–	–	–	–	12.29	10.96	8.84	6.35	–
	1.6	713.20	–	–	–	–	–	–	–	–	12.89	10.88	7.90	5.17	–
Station 7	2	712.80	–	–	–	–	–	–	–	–	11.97	9.70	9.00	6.58	–
Station 1	2.7	708.70	–	–	–	–	–	–	–	–	12.20	10.71	8.43	6.29	–
	1.4	710.00	–	–	–	–	–	–	–	–	13.78	10.50	5.88	3.77	–
Cover Temperature (C)															
West Profile															
Top sand	0.25	714.75	–	–	–	–	–	–	–	–	12.72	8.91	1.86	-0.06	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.15	713.85	–	–	–	–	–	–	–	–	13.40	10.17	5.20	2.43	–
East Profile															
Top sand	0.25	714.75	–	–	–	–	–	–	–	–	12.68	8.93	1.86	-0.34	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	13.55	10.11	4.66	1.95	–
Bottom sand	1.15	713.85	–	–	–	–	–	–	–	–	13.60	10.42	5.57	2.79	–
Cover Suction (m of water)															
West Profile															
Top sand	0.25	714.75	–	–	–	–	–	–	–	–	3.203	3.396	3.785	8.365	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	2.805	2.910	3.132	3.646	–
Bottom sand	1.05	713.95	–	–	–	–	–	–	–	–	2.808	2.910	3.118	3.323	–
Waste rock	1.35	713.65	–	–	–	–	–	–	–	–	2.711	2.843	3.095	3.270	–
East Profile															
Top sand	0.25	714.75	–	–	–	–	–	–	–	–	5.756	6.090	7.191	16.413	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	3.161	3.300	3.709	7.280	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.05	713.95	–	–	–	–	–	–	–	–	2.737	2.716	2.906	3.107	–
Waste rock	1.35	713.65	–	–	–	–	–	–	–	–	2.778	2.882	3.063	3.203	–
Cover Porewater Head (m of water)															
West Profile															
Top sand	0.25	714.75	–	–	–	–	–	–	–	–	711.547	711.354	710.965	706.385	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	711.295	711.190	710.968	710.454	–
Bottom sand	1.05	713.95	–	–	–	–	–	–	–	–	711.142	711.040	710.832	710.627	–
Waste rock	1.35	713.65	–	–	–	–	–	–	–	–	710.939	710.807	710.555	710.380	–
East Profile															
Top sand	0.25	714.75	–	–	–	–	–	–	–	–	708.994	708.660	707.559	698.337	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	711.339	711.200	710.791	707.220	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.05	713.95	–	–	–	–	–	–	–	–	711.213	711.234	711.044	710.843	–
Waste rock	1.35	713.65	–	–	–	–	–	–	–	–	710.872	710.768	710.587	710.447	–

Notes:
(1) Pile temperature stations are listed in an east to west order.
(2) Elevation of cover top is 715.000 m, used to calculate porewater head.

Table C-2. 1996 monthly summary of data collected by datalogger at Pile 7/12.

Parameter	Depth (m)	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Air Temperature (C)															
Average			-11.92	-10.13	-5.60	1.80	–	–	–	–	–	–	–	–	–
Maximum			9.97	6.96	10.19	16.28	–	–	–	–	–	–	–	–	–
Minimum			-27.23	-31.15	-25.75	-7.59	–	–	–	–	–	–	–	–	–
Relative Humidity (%)															
Average			76	77	69	80	–	–	–	–	–	–	–	–	–
Maximum			99	99	98	98	–	–	–	–	–	–	–	–	–
Minimum			45	27	24	25	–	–	–	–	–	–	–	–	–
Wind Speed (m/s)															
Average			4.233	3.491	3.959	3.686	–	–	–	–	–	–	–	–	–
Maximum			21.090	15.970	21.730	20.610	–	–	–	–	–	–	–	–	–
Rainfall (mm)			0.3	1.8	0.2	3.0	–	–	–	–	–	–	–	–	–
Pan Evaporation (mm)			–	–	–	–	–	–	–	–	–	–	–	–	–
Pile Temperature (C)															
Station 6	3.3	708.70	5.85	4.85	4.02	3.47	–	–	–	–	–	–	–	–	–
	1.7	710.30	4.26	3.20	2.32	1.84	–	–	–	–	–	–	–	–	–
Station 5	5	708.00	7.44	6.45	5.45	4.58	–	–	–	–	–	–	–	–	–
	2	711.00	3.60	2.31	1.47	0.99	–	–	–	–	–	–	–	–	–
	1.5	711.50	2.71	1.43	0.72	0.38	–	–	–	–	–	–	–	–	–
Station 4	5.6	708.80	7.38	6.85	6.02	5.23	–	–	–	–	–	–	–	–	–
	2.6	711.80	5.53	4.43	3.13	2.42	–	–	–	–	–	–	–	–	–
	1.6	712.80	3.37	2.24	1.13	0.76	–	–	–	–	–	–	–	–	–
Station 3	5.4	709.40	7.49	6.80	6.10	5.31	–	–	–	–	–	–	–	–	–
	2.7	712.10	5.45	4.35	3.31	2.63	–	–	–	–	–	–	–	–	–
	1.7	713.10	3.68	2.61	1.69	1.88	–	–	–	–	–	–	–	–	–
Station 2	5.2	709.60	7.33	6.55	5.75	4.95	–	–	–	–	–	–	–	–	–
	2.2	712.60	4.91	3.78	2.75	2.07	–	–	–	–	–	–	–	–	–
	1.6	713.20	3.85	2.65	1.73	1.24	–	–	–	–	–	–	–	–	–
Station 7	2	712.80	4.45	–	–	1.18	–	–	–	–	–	–	–	–	–
Station 1	2.7	708.70	5.28	4.11	3.19	2.50	–	–	–	–	–	–	–	–	–
	1.4	710.00	2.98	1.48	0.71	0.35	–	–	–	–	–	–	–	–	–
Cover Temperature (C)															
West Profile															
Top sand	0.25	714.75	-0.68	-3.75	-2.57	0.33	–	–	–	–	–	–	–	–	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.15	713.85	1.61	-0.24	-0.81	-0.29	–	–	–	–	–	–	–	–	–
East Profile															
Top sand	0.25	714.75	-1.00	-3.62	-2.70	0.34	–	–	–	–	–	–	–	–	–
Lift 3 of till	0.50	714.50	–	–											
Lift 1 of till	0.90	714.10	1.09	-0.53	-0.98	-0.38	–	–	–	–	–	–	–	–	–
Bottom sand	1.15	713.85	1.83	0.34	-0.29	-0.12	–	–	–	–	–	–	–	–	–
Cover Suction (m of water)															
West Profile															
Top sand	0.25	714.75	2.956	–	–	–	–	–	–	–	–	–	–	–	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	3.822	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.05	713.95	3.481	–	–	–	–	–	–	–	–	–	–	–	–
Waste rock	1.35	713.65	3.324	46.266	–	119.613	–	–	–	–	–	–	–	–	–
East Profile															
Top sand	0.25	714.75	581.715	–	–	–	–	–	–	–	–	–	–	–	–
Lift 3 of till	0.50	714.50	91.096	–	–	–	–	–	–	–	–	–	–	–	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.05	713.95	2.506	35.791	–	–	–	–	–	–	–	–	–	–	–
Waste rock	1.35	713.65	3.314	6.521	27.827	23.290	–	–	–	–	–	–	–	–	–
Cover Porewater Head (m of water)															
West Profile															
Top sand	0.25	714.75	711.794	–	–	–	–	–	–	–	–	–	–	–	–
Lift 3 of till	0.50	714.50	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	710.278	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.05	713.95	710.469	–	–	–	–	–	–	–	–	–	–	–	–
Waste rock	1.35	713.65	710.326	667.384	–	594.037	–	–	–	–	–	–	–	–	–
East Profile															
Top sand	0.25	714.75	133.035	–	–	–	–	–	–	–	–	–	–	–	–
Lift 3 of till	0.50	714.50	623.404	–	–	–	–	–	–	–	–	–	–	–	–
Lift 2 of till	0.70	714.30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lift 1 of till	0.90	714.10	–	–	–	–	–	–	–	–	–	–	–	–	–
Bottom sand	1.05	713.95	711.444	678.159	–	–	–	–	–	–	–	–	–	–	–
Waste rock	1.35	713.65	710.336	707.129	685.823	690.360	–	–	–	–	–	–	–	–	–

Notes:
(1) Pile temperature stations are listed in an east to west order.
(2) Elevation of cover top is 715.000 m, used to calculate porewater head.

9.4 Appendix D: Air Entry Permeameter Measurements

Introduction

There were two AEP tests conducted on the Heath Steele waste rock cover on October 23rd and 24th 1995. The first test designated as "Site A" was performed in the south-west corner of the cover and the second test designated "Site B" was performed in the north-west corner. Both tests were performed on the horizontal surface of the cover, not on the slopes. Air temperature averaged 12 ^{o}C both days with cool temperatures in the morning (1-2^{o} C) and warming to 14 to 17^{o} C in the early afternoon. Skies were clear with cloudy periods with low to medium wind speeds.

Equipment and Methods

The AEP consists of a stainless steel cylindrical ring with a internal diameter of 25 cm, a height of 20 cm and with a top cover made of a clear acrylic plastic. The cylindrical ring is seated in a "trench" dug approximately 6 to 10 cm in depth which follows the circumference of the ring. The trench is then filled with a sodium bentonite paste and the cylindrical ring is slowly pushed into it creating a seal between the ring and the till. The theory is that the sodium bentonite has a lower hydraulic conductivity than the material being tested, therefore will not effect the results. Measurements are taken from the soil face and the area is calculated. The height from the soil face to the top of the cylindrical ring is also noted. An erosion layer of coarse sand or gravel is then placed on the sample face to prevent erosion during the filling of the AEP with water.

Once the erosion layer is in place, then the AEP cover is secured to the ring and tightened ensuring a water tight seal. Attached to the top cover are the mercury manometer, the graduated pipette and the various valves and piping required for the operation of the AEP. The graduated pipette is used to monitor the volume of water permeating into the material. The changes in height of water in the pipette are also used for calculating the gradients which are used in the hydraulic conductivity calculations. This is done by measuring the height of water above the material surface and the subsequent changes in height which are the changes in the head pressure. The mercury manometer is used at the termination of the test to determine the air entry value of the material being tested.

Once the cover was in place, surcharges (weights) were placed on rods which spanned across the cover. These surcharges were used to counteract the lifting forces produced by the head of water in the pipette and the AEP. Then the AEP was slowly filled with water. Checks for water leaks were constantly made. Once everything was verified, the valve which controlled the water flow from the pipette to the AEP was opened and the test started. Readings were taken as a function of time at regular intervals. More readings were taken early in the test while the gradients were high and less as the water level dropped and the gradient dropped.

Each test continued for five to six hours or until the level in the pipette was low. The low water level would produce a low gradient resulting in a reduced flow into the material. At this time, collection readings ceased, and the infiltration aspect of the test was considered terminated.

The final step was to determine the air entry value of the material. This was done by shutting off the valve to the pipette and effectively sealing off the AEP. Then, one side of the mercury manometer which was connected to a valve on the top cover was opened. The other side of the mercury manometer was then connected to a vacuum source, which in this case was a 50 cc syringe. Vacuum was applied to the manometer and subsequently to the AEP by pulling the plunger of the syringe. This procedure was repeated several times, each time increasing the vacuum within the AEP. When the vacuum applied reached the air entry value of the material, air bubbled up from the material face. This indicated that the air entry value was reached and the reading on the manometer was recorded.

Water Content Profile

Samples of the overlying sand layer and till material were taken and water contents determined. Sampling downwards through the till material was very difficult due to the high gravel content. Several attempts were made at each location. At Site A, a total depth (measured from the surface of the sand) of 74 cm (29") was sampled while only 56 cm (22") could be recovered from Site B.

Results

Hydraulic Conductivity

The final average 1995 hydraulic conductivity for sites A and B was 9.29 x 10^{-7} cm/s. This was lower than the 1993 K of 7.47 x 10^{-6} cm/s and slightly lower than the 1991 K of 1.56 x 10^{-6} cm/s. The difference in the measured K's can be explained by the variability in the physical cover (ie. materials and construction practices), the consolidation of the cover (till) and the effects of climatic conditions. It should be noted that each test required a different location on the cover, thereby increasing the likelihood that the discrepancy in the results were due to the variability of the cover in the locations where the tests are performed.

Water Content Profile

Although only the top 30 cm of the till material could be sampled at Site A and 15 cm at Site B), the profiles show that the till material has an average moisture content of 12%wt at the sand/till interface and increases with depth to approximately 16%wt at 25 mm depth. Both sites showed a similar profile above the sand/till interfaces and into the upper depths of the till material. The moisture content of the till at the sand/till interface represents only a 2%wt decrease in moisture content (12%wt from 14%wt) as compared to 1991's moisture content.

9.5 Appendix E: Meteorological Data

Table E-1. Little River Mine monthly precipitation summary.

MONTH	HISTORICAL DATA RAIN (mm)	SNOW (cm)	WATER EQUIV. (mm)	TOTAL PRECIP. (mm)	TOTAL ACCUM. (mm)	1994 DATA RAIN (mm)	SNOW (cm)	WATER EQUIV. (mm)	TOTAL PRECIP. (mm)	TOTAL ACCUM. (mm)
Jan	16.4	76.0	76.0	91.1	91.1	0.0	88.0	88.0	88.0	88.0
Feb	9.9	58.1	58.1	68.0	159.1	1.0	36.0	36.0	37.0	125.0
Mar	23.9	72.3	72.3	96.1	255.2	6.5	0.0	0.0	6.5	131.5
Apr	43.5	43.3	43.3	86.8	342.0	47.1	0.0	0.0	47.1	178.6
May	90.4	5.7	5.7	96.4	438.4	171.4	0.0	0.0	171.4	350.0
June	85.6	0.0	0.0	85.6	524.0	183.3	0.0	0.0	183.3	533.3
July	100.7	0.0	0.0	100.7	624.7	123.6	0.0	0.0	123.6	656.9
Aug	83.9	0.0	0.0	83.9	708.6	129.3	0.0	0.0	129.3	786.2
Sep	95.5	0.0	0.0	95.5	804.1	76.3	0.0	0.0	76.3	862.5
Oct	104.7	4.2	4.2	108.8	912.9	33.0	0.0	0.0	33.0	895.5
Nov	74.0	35.6	35.6	105.8	1018.7	45.5	12.0	12.0	57.5	953.0
Dec	33.8	81.0	81.0	115.6	1134.3	1.6	46.6	46.6	48.2	1001.2

MONTH	1995 DATA RAIN (mm)	SNOW (cm)	WATER EQUIV. (mm)	TOTAL PRECIP. (mm)	TOTAL ACCUM. (mm)	1996 DATA RAIN (mm)	SNOW (cm)	WATER EQUIV. (mm)	TOTAL PRECIP. (mm)	TOTAL ACCUM. (mm)
Jan	4.0	146.2	146.2	150.2	150.2	70.1	12.5	12.5	82.6	82.6
Feb	0.0	70.6	70.6	70.6	220.8	32.6	38.2	38.2	70.8	153.4
Mar	9.4	32.6	32.7	42.0	262.8	0.2	115.3	115.3	115.5	268.9
Apr	39.7	26.1	26.1	65.8	328.6	49.9	93.2	93.2	143.1	412
May	81.5	31.0	31.0	112.5	441.1	63.2	14.5	14.5	77.7	489.7
June	52.0	0.0	0.0	52.0	493.1	72.7	0.0	0.0	72.7	562.4
July	32.0	0.0	0.0	32.0	525.1	149.7	0.0	0.0	149.7	712.1
Aug	49.3	0.0	0.0	49.3	574.4	45.5	0.0	0.0	45.5	757.6
Sep	41.5	0.0	0.0	41.5	615.9	99.0	0.0	0.0	99.0	856.6
Oct	153.6	0.0	0.0	153.6	769.5	*104.7	*4.2	*4.2	*108.8	965.4
Nov	142.7	55.0	55.0	197.7	967.2	47.3	43.2	43.2	90.5	1055.9
Dec	0.0	244.0	244.0	244.0	1211.2	108.6	25.2	25.2	133.8	1189.7

NOTE: HISTORICAL DATA FROM NOLAN, DAVIS & ASSOCIATES (N.S.) LIMITED. DECEMBER 1990.

Note: Jan, Feb. readings incomplete.
October 1996 Readings are historical estimates, record sheet lost.

MONTH	1997 DATA RAIN (mm)	SNOW (cm)	WATER EQUIV. (mm)	TOTAL PRECIP. (mm)	TOTAL ACCUM. (mm)
Jan	25.4	103.8	103.8	129.2	129.2
Feb	0.0	111.6	111.6	111.6	240.8
Mar			0.0	0.0	240.8
Apr			0.0	0.0	240.8
May			0.0	0.0	240.8
June			0.0	0.0	240.8
July			0.0	0.0	240.8
Aug			0.0	0.0	240.8
Sep			0.0	0.0	240.8
Oct			0.0	0.0	240.8
Nov			0.0	0.0	240.8
Dec			0.0	0.0	240.8

Table E-2. Little River Mine station normals.

47°17'N 66°04'W/O, 341m, 1956 to/à 1990

	Jan janv	Feb févr	Mar mars	Apr avr	May mai	Jun juin	Jul juill	Aug août	Sep sept	Oct oct	Nov nov	Dec déc	Year année	
Temperature														**Température**
Daily Maximum (°C)	-7.1	-5.4	0.0	6.1	13.8	20.5	23.6	22.0	16.8	10.1	2.6	-4.2	8.2	Maximum quotidien (°C)
Daily Minimum (°C)	-17.2	-16.2	-10.2	-3.6	2.5	8.9	12.6	11.2	6.0	0.5	-5.2	-13.7	-2.0	Minimum quotidien (°C)
Daily Mean (°C)	-12.1	-10.6	-5.1	1.3	8.2	14.7	18.1	16.6	11.4	5.3	-1.2	-9.0	3.1	Moyenne quotidien (°C)
Extreme Maximum (°C)	13.0	13.5	20.0	26.0	31.7	33.3	34.0	35.0	30.5	25.0	19.4	13.3		Maximum extrême (°C)
Date	986/27	981/23	962/30	987/21	977/24+	969/13	983/04	975/02	983/06	983/01+	961/05	966/11		Date
Extreme Minimum (°C)	-37.2	-35.0	-29.4	-22.0	-15.0	-5.0	1.1	-1.1	-6.7	-10.6	-24.0	-40.0		Minimum extrême (°C)
Date	965/16	962/02	963/04	982/06	974/03+	956/09	976/01	973/26	975/15	965/29	989/28	989/30		Date
Degree-Days														**Degrés-jours**
Above 18 °C	0.0	0.0	0.0	0.0	1.9	17.3	43.0	27.5	4.1	0.1	0.0	N	N	Au-dessus 18°C
Below 18 °C	934.6	810.3	719.6	502.0	308.5	116.6	39.4	67.5	201.9	391.3	580.3	N	N	Au-dessous 18°C
Above 5 °C	0.0	0.3	1.2	12.5	114.4	290.7	406.6	363.0	193.8	57.5	8.9	N	N	Au-dessus 5°C
Below 0 °C	377.8	303.9	175.2	30.5	0.8	0.0	0.0	0.0	0.0	5.1	83.2	N	N	Au-dessous 0°C
Precipitation														**Précipitations**
Rainfall (mm)	16.1	10.5	23.7	48.8	88.9	89.0	101.6	89.6	97.7	95.0	71.7	32.5	765.1	Chutes de pluie (mm)
Snowfall (cm)	73.0	53.0	65.0	40.6	4.9	0.0T	0.0	0.0	0.0T	3.4	33.5	78.8	352.1	Chutes de neige (cm)
Precipitation (mm)	89.1	63.5	88.9	89.4	93.9	89.0	101.6	89.6	97.7	98.5	106.4	111.3	1118.9	Précipitations (mm)
Extreme Daily Rainfall (mm)	49.3	42.9	44.5	76.2	68.6	50.5	55.4	99.6	99.3	86.6	82.0	58.4		Extrême quot. de pluie (mm)
Date	978/09	970/03	970/26	973/28	956/28	977/07	976/12	962/07	969/09	958/24	985/06	958/16		Date
Extreme Daily Snowfall (cm)	50.0	34.8	35.6	50.8	20.3	0.0	0.0	0.0	0.0	17.8	64.0	48.3		Extrême quot. de neige (cm)
Date	987/11	958/19	971/04	975/04	967/09	987/30+	987/31+	987/31+	987/30+	962/26	986/21	978/25		Date
Extreme Daily Pcpn. (mm)	50.0	42.9	44.5	76.2	68.6	50.5	55.4	99.6	99.3	86.6	82.0	58.4		Extrême quot. de préc. (mm)
Date	987/11	970/03	970/26	973/28	956/28	977/07	976/12	962/07	969/09	958/24	985/06	958/16		Date
Month-end Snow Cover (cm)	82	98	86	27	0	0	0	0	0	0	N	55		Couver. de neige, fin de mois (cm)
Days With														**Journées avec**
Maximum Temperature >0°C	4	5	14	26	31	30	31	31	30	30	19	N	N	Température maximale >0°C
Measurable Rainfall	2	2	4	7	12	11	13	12	11	11	8	3	94	Hauteur de pluie mesurable
Measurable Snowfall	8	8	8	5	•	0	0	0	0	•	5	9	43	Hauteur de neige mesurable
Measurable Precipitation	9	9	11	11	13	11	13	12	11	11	11	11	132	Hauteur de préc. mesurable