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INVESTIGATION OF THE POROUS ENVELOPE EFFECT AT THE FAULT LAKE TAILINGS SITE

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INVESTIGATION OF THE POROUS ENVELOPE

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FINAL REPORT

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Executive Summary

In 1992, Noranda Technology Centre undertook a hydrogeological investigation of the Fault Lake tailings site. The tailings have been deposited in a kettle lake formed within glacial outwash sand and gravel. The site is unique in that, theoretically, a “porous envelope effect” may occur. If this is the case, flow through the tailings mass is low enough, relative to the surrounding, more permeable till, that impact to the ground water by tailings oxidation is insignificant at the regional scale. The specific objectives of the investigation were to analyze the chemical and physical hydrogeology of the site, to delineate areas affected by acid mine drainage generated from the tailings, and to verify the presence of the porous envelope effect.

The hydraulic conductivity (**K**) of the Fault Lake tailings measured 1.2×10^{-5} cm/s at a mid-level depth in the tailings and 3.6×10^{-6} cm/s in the deepest part of the tailings. Comparatively, the measurements of **K** for the glacial sediments averaged 1.6×10^{-3} cm/s. This is a two order of magnitude contrast in hydraulic conductivity. Flow modelling indicated that this is sufficient to route most regionally flowing groundwater around the tailings.

During the spring and fall, ponding occurs at the north dam, south dam and various berms. The water slowly infiltrates into the tailings and evaporates from the ponds. During the summer months, extensive ponding has not been observed. The water level in the tailings is perched higher and fluctuates greater than the regional water level. Regional groundwater flows to the northeast from the tailings dam at a velocity of about 2 m/yr. Groundwater flowing from the southerly dam goes south. Because the groundwater velocity is controlled by the hydraulic gradient, the velocities could have been higher during tailings disposal.

The tailings are characterized by two layers due to the disposal of different types of tailings: Layer 1 is pyrrhotite rich and Layer 2 is pyrrhotite poor. Layer 1 is centrally located on the tailings and in close proximity of the northerly spigot position. In the centre of Layer 1 pyrrhotite was identified to a maximum depth of 9 m, but was at highest composition in the upper 3 m where it is near 50%. Layer 2 is below Layer 1 in the centre of the tailings. In the southerly portion of the tailings Layer 1 pinches out.

Mineralogical analysis and acid-base accounting of the tailings indicated that carbonate mineral reserves are available for short-term neutralization of acid during the first stage of oxidation when rates are high, and silicate mineral reserves are abundant for long-term buffering. The neutralization potential of the tailings plays an important role for the attenuation of acidity and metals

from sulphide oxidation, which were detected but have been attenuating in the tailings deposit.

Sulphide oxidation has been at its highest rate since deposition discontinued in 1978, yet little impact of sulphide oxidation was observed in the groundwater of the surrounding till. Sulphide oxidation products leaching from the tailings appear to be alleviated by the porous envelope effect. Several favourable factors contribute to create the porous envelope effect and to limit the observed metal concentrations downgradient of the tailings:

(1) the hydraulic conductivity contrast between the tailings and the surrounding sediments;

(2) the limited infiltration through the surface of the tailings;

(3) the dilution of metals flushed from the tailings by water flowing around and below the tailings; and

(4) the chemical attenuation of metals, which likely plays a large role both inside the tailings mass and in the surrounding sediments.

The porous envelope effect could probably be present at other locations near mine sites. Tailings deposition could possibly be done at these sites with little effect on groundwater quality, pending that thorough site evaluations are performed and that appropriate control is done at the time of deposition.

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1. INTRODUCTION

In 1992, Noranda Technology Centre (NTC) undertook a hydrogeological investigation of the Fault Lake tailings site. The site is unique in that, theoretically, a "porous envelope effect" may occur. If this is the case, flow through the tailings mass is slower than the surrounding, more permeable till, so that impact to the regional groundwater by tailings oxidation is insignificant.

The specific objectives of the investigation were to analyze the physical and chemical hydrogeology of the site, to delineate areas affected by acid mine drainage generated from the tailings, and to verify the presence of the porous envelope effect. A report documenting part 1 of the investigation was issued in September 1993 (NTC 1993). The current report documents part 2 of the investigation. Portions of the part 1 report are summarized in this report.

1.1 Background

The Fault Lake tailings site is located northwest of the Falconbridge Sudbury operations, approximately 3 km north of Falconbridge and 0.5 km east of the Sudbury Airport (**Fig. 1**). The tailings were deposited between 1965 and 1978 and were produced from the milling of nickel ore in the Sudbury area. **Figure 2** is an aerial photograph of the site in 1946, showing the site before tailings disposal activities. The region was characterized by several small depressions (kettles) in which many contained lakes (kettle lakes). Approximately 6.45 million tonnes of tailings containing as much as 50% pyrrhotite were deposited in a kettle lake depression. Tailings were discharged at two spigot locations on the west and were contained by dams to the north and south of the site (**Fig. 3**). The deposit has an approximate volume of 3.36 x 10^6 m^3 and a surface area of 22.2 ha (55 acre). It sits in a 55 ha (136 acre) closed watershed.

In 1971, while deposition was active, the analysis of groundwater in one well located 2 km downgradient (northeast) of the Fault Lake tailings site indicated above-background sulphate levels of 382 mg/L, suggesting influence from tailings oxidation (International Water Supply, 1971). Groundwater and surface water monitoring and analysis done at later dates showed improvements in water quality.

1.2 Surficial Geology

Kettles, fluvial terraces, discontinuous crevasse fillings, and eskers within the Fault Lake tailings area are evidence of a glacial meltwater channel, partly choked with stranded ice blocks. The small round kettle lake depressions were formed after melting of stranded ice blocks which were caught among the mass of glacial sediments. The sediments are assembled in longitudinal formations which follow a southeasterly meltwater flow direction, leading from Bowlands Bay, part of Lake Wanipitie. **Figure 4** shows the main overburden materials and their orientation in the area of the site. Overburden beneath the tailings and surrounding the site mainly consists of coarse to fine glacial outwash sands and gravels with some large boulders and silt lenses. Overburden thickness varies within the studied area, from 36 m to more than 60 m.

1.3 Summary of part 1 of the investigation

The draft report (NTC 1993, Appendix E) documented the field activities and computer flow modelling conducted in 1992 and 1993. The activities included the following:

1 Installation of 14 groundwater monitoring stations, consisting of 1 to 3 piezometers each,

2 Grain-size distribution analysis on recovered core samples,

3. Measurement of overburden hydraulic conductivities in the piezometers using a falling head test.

4. Measurement of water levels in the piezometers in December 1992 and March 1993,

5. Sampling and water quality analyses of groundwater taken from the piezometers in December 1992 and March 1993,

6. Two-dimensional saturated-unsaturated steady-state flow modelling of the site using SEEP/W computer software.

The report concluded that conditions for porous envelope containment may be occurring at the Falconbridge Fault Lake tailings site. Water quality sampling did not show any evidence of above background metal concentrations, which suggests minimal leaching of metals from the tailings. Flow modelling supported the porous envelope hypothesis, which corroborates the inference that impact to the regional groundwater by tailings oxidation is insignificant. Factors which contribute to low metal concentrations downgradient of the Fault Lake tailings are listed, as follows:

1. High hydraulic conductivity contrast between the tailings and the surrounding overburden sediments,

2. Low position of the water table relative to the tailings bottom,

3. Limited infiltration through the surface of the tailings,

4. Dilution of metals flushed from the tailings by groundwater flowing through the overburden, around and below the tailings,

5. Chemical attenuation of metals in the tailings and overburden.

1.4 Objectives of part 2 of the investigation

The specific objectives of the investigation were to complete the analysis of the physical and undertake the chemical hydrogeology of the site, to delineate areas affected by acid mine drainage generated from the tailings, and to verify the presence of the porous envelope effect. In part 1 of the investigation, groundwater monitoring stations were located outside of the original lake-shore boundary. A principal objective of part 2 of the investigation was to core into the deepest part of the tailings deposit, recover tailings samples for geochemical evaluation, install piezometers in the tailings and sample tailings porewater. With piezometers located in the tailings and below the watertable it was also possible to conduct field measurements of hydraulic conductivity of the tailings. The results were compared with estimates of hydraulic conductivity calculated in part 1 of the investigation using the grain-size distribution D_{50} and the modified Kozeny-Carman equation.

In part 1 of the investigation, using water level measurements in the piezometers and lake level elevations from the topography map, the regional flow direction was shown to be to the northeast, through the esker sediments and at an average flow velocity of 30 cm/yr. These findings were used to define the boundary conditions of the flow modelling. To support these findings, in part 2 of the investigation, surface water monitoring stations were established to monitor the water levels of the kettle lakes to the northeast and southwest.

Groundwater sampling from the piezometers and water quality analysis was continued in part 2 of the investigation, as well as sampling and analyses of surface waters at the monitoring stations.

2. METHODOLOGY

2.1 Field work

2.1.1 Coring and installation of groundwater monitoring stations FS15

Groundwater monitoring station FS15 was approximately located in the deepest part of the tailings, between FS5 and FS12 (**Fig. 5**). Prior to the drilling campaign, piezocone testing was conducted at the coring site by the University of British Colombia, Department of Civil Engineering, in-situ testing group (Davies 1994). Results not only showed the presence of layered tailings and a 9 m unsaturated zone but also indicated that the maximum depth to refusal was 41.1 m. This evidence confirmed the location of FS15. The plotted piezocone data can be found in Appendix D.

Drilling of the groundwater monitoring station FS15 was conducted on Dec 11-12, 1993 using a 15 cm ID hollow stem auger mounted on a Acker 82 drill rig. Two holes were drilled and one piezometer was installed in each. Piezometer FS15-A was installed at 35 m and FS15-B, at 24 m. The piezometers were constructed of 2.4 cm (15/16 inch) ID, schedule 80 PVC pipe with a 0.3 m (1 ft) PVC screened tip. They were installed by placing the pipe inside the hollow stem auger at the required depth. The auger was raised approximately 1.5 m and clean silica sand was packed around the PVC screen. A bentonite seal was placed above the sand to insure hydraulic isolation of the well. The auger was then pulled up which allowed saturated tailings to close in around the piezometer pipe. A second bentonite seal was placed above the tailings and the open hole was backfilled with sand. Bentonite seals and steel casings equipped with locking covers were also installed at the surface to protect the piezometers and prevent infiltration of water from surface. The elevation of the uncapped piezometer and ground surface were surveyed by Falconbridge Ltd. Exploration. Water level measurements were conducted on May 27, July 16 and August 27 of 1994. The borehole and piezometer installation logs and water level data are located in Appendix A.

While coring FS15-A, continuous vertical sampling of tailings was conducted in 5-ft intervals using a 5-ft (split spoon) sampling barrel. Upon retrieval, the samples were split into approximately 45 cm lengths and stored with minimal atmospheric contact to preserve in-situ conditions. Laboratory analyses performed on the recovered samples are described in Section 2.2.2.

2.1.2 Hydraulic conductivity measurement at FS15

Measurements of *in-situ* hydraulic conductivity were conducted at FS15-A and FS15-B using the "rising head test". The test is performed below the water table. The piezometer is pumped dry, simulating an instantaneous water level decline in the piezometer, and water level recovery is recorded with time. Water level recovery was monitored manually using a watch and water level indicator.

Interpretation of the water level versus time data was conducted using the Hvorslev (1951) method for point piezometers. As described in Freeze and Cherry (1979), the hydraulic conductivity (K) is determined using the following equation:

$$K = \frac{r^2 \ln\frac{L}{R}}{2LT_o} \qquad \textbf{(1)}$$

where, $\mathbf{T_o}$ is the time lag or time that would be required for the complete equalization of the head differences if the original rate of inflow were maintained, **L** is the length and **R** is the radius of the piezometer intake or screen, and **r** is the inside radius of the piezometer pipe.

2.1.3 Trenching

The purpose of the trenching activity was to aerially characterize the near-surface tailings. Three trenches were dug with a backhoe to a maximum depth of 2.5 m. Locations of the trenches are shown in **Figure 6**. The trench walls were logged in detail, noting visible grain-size and color changes as indicators of composition and sulphide oxidation. Tailings samples were recovered for moisture content determination and geochemical analysis as described in Section 2.2.3.

2.1.4 Installation of surface-water monitoring stations

At each station a 1-inch diameter steel bar was driven in the lake to which a "2x4" wood was attached. The 1 m staff plate was attached to the "2x4" with screws so that approximately half of the staff plate was submerged. Zero level on each staff plate was surveyed by Falconbridge Ltd. Exploration. The staff plates were installed in the kettle lakes to the northeast and southwest of the site in order to determine the regional water level elevations and longitudinal gradients. The location of the monitoring stations at Lakes 1-5 are shown in **Figure 5**. Monitoring stations were also installed in two lakes further to the southwest, shown in **Figure 1**. These two lakes were not referred to in part 1 of the investigation (Appendix E) and were therefore identified as Lakes A and B. Water level readings were conducted on May 27, July 16 and August 27 of 1994. Survey coordinates and water level data are documented in Appendix B.

2.1.5 Water quality sampling

Water from the surface-water and groundwater monitoring stations was sampled in December 1993, May 1994 and August 1994. Before sampling, the depth to water level was measured and at least three well volumes were purged to remove standing water. After the water had been sufficiently recovered, depth to water level was re-measured and water samples collected.

The samples were collected using a peristaltic pump, a nitrogen-driven positive displacement pump, or the Waterra system. The groundwater samples were filtered using a 0.45 µm (ACRO 50A) disposable in-line filter. Field measurements of pH, temperature, oxidation reduction-potential (ORP), and electrical specific conductance (EC) were recorded. Half of each sample was acidified in the field using reagent grade (2% v/v) hydrochloric acid (HCl) for metal preservation prior to analysis. All electrodes were calibrated before use and between samples. All sampling equipment was rinsed with distilled water before each sample was collected.

Water samples were transported to a field laboratory within six hours from collection. In the laboratory, measurements of pH were repeated on the non-acidified portion of the samples along with titration for acidity and alkalinity.

2.1.6 Measurement of near-surface pore-gas oxygen concentrations

The dominant method of oxygen transport in tailings has been shown to result from diffusion through partially gas-filled pores and is described by Fick's first law:

$$J = -D_e \frac{\partial C}{\partial Z} \qquad \textbf{(2)}$$

where	J	=	diffusive flux of oxygen (moles m^{-2} s^{-1})
	D_e	=	effective diffusion coefficient (m^2 s^{-1})
	C	=	concentration (moles m^{-3})
	Z	=	depth in the tailings (m)

The concentration gradient required for diffusion in tailings results from differences between gas concentrations in the pore spaces and the atmosphere. In pore spaces of reactive tailings, gaseous oxygen concentrations are lower than atmospheric values largely due to consumption by geochemical reactions related to the oxidation of sulphide minerals. The resulting gradient drives gaseous oxygen into the tailings at a rate which is governed by the diffusion coefficient. An oxidized front generally develops in tailings where un-oxidized tailings are actively oxidized and oxygen is readily consumed. As reactive tailings age, the oxidized front generally migrates deeper into the tailings which decrease the gradient. Many factors control the oxidation process and the character of the oxidation front but in general as oxidation progresses, the concentration gradient decreases.

On the surface of the Fault Lake tailings, a hard pan has developed which may retard the flux of oxygen to the sulphide tailings and limit oxidation of the tailings. An estimate of the flux may be calculated from Fick's first law by knowing the diffusion coefficient of the surface hard pan and the concentration gradient across the surface hard pan. As a reconnaissance to oxygen flux determination, pore-gas sampling probes were installed at several depths below the surface hard pan. Oxygen concentrations were measured and concentration gradients calculated. **Figure 7** shows the probe installation and sampling procedure. Each probe was installed in a 2-inch diameter hole, which was drilled to depth with a hand auger. Coarse sand was place around the probe tip and the hole was backfilled with bentonite. The probes were measured for gaseous oxygen concentration on December 13, 1993 and May 27, 1994. The gas was sampled by extraction of 5 cm^3 volume with a hypodermic needle, and measured with a Teledyne portable oxygen analyzer.

2.2 Laboratory work

2.2.1 Analysis of water

Chemical analysis was conducted on groundwater samples taken from piezometers. Samples were split in the field and one portion promptly preserved by the addition of HCl to a concentration of 2% by volume. In the NTC analytical laboratory, the acidified portion of each water sample taken from the piezometers was analyzed for dissolved metal and major ions and the non-acidified portion was analyzed for chloride. Potassium (K) was analyzed using flame atomic emission, ferric iron (Fe^{3+}) by colorimetry/volumetry, chloride (Cl^-) by turbidimetry, and all other elements by inductively coupled plasma spectrophotometry (ICP). All certificates of analysis appear in Appendix C.

The kettle lakes were sampled at the staff plate gauges. Grab samples were taken, filtered and analyzed using the same procedure as for the groundwater samples.

Quality assurance and quality control (QA/QC) testing for all sample batches was performed using replicate and standard samples. The samples were collected to evaluate reproducibility and accuracy of the analytical procedure and to assess the cleanliness of the equipment during sampling. The results of the quality assurance testing are included in Appendix C.

2.2.2 Solids and porewater analysis of FS15 core samples and trenching samples

Selected tailings samples recovered from the coring of borehole FS15-A and trenching activities were analyzed for mineralogy and porewater quality. Porewater was obtained by squeezing tailings samples at 0.8 MPa in a stainless steel loading cell using a pneumatic squeeze apparatus. The extracted porewater was promptly preserved by the addition of HCl to a concentration of 2% by volume. The samples were analyzed using ICP methods to determine major metal and ion concentrations. A second and non-acidified aliquot of porewater was used for pH, redox potential, and electrical specific conductivity measurements, and for Cl^- determination.

After squeezing, the remaining solids were oven-dried and analyzed at NTC for selected elemental composition using acid digestion procedures and ICP methods. An non-squeezed tailings sample of approximately 100 g was also oven dried and sent to Lakefield Research Laboratories for x-ray diffraction (XRD) testing using a Co target and Fe filter. Results of the XRD analysis provide qualitative mineralogical composition of the samples. Six core samples were selected for XRD-pattern interpretation and free silica quantification by Lakefield Research Laboratories.

2.2.3 Acid-base accounting of FS15 core samples

Acid-base accounting (ABA) was conducted on selected tailings samples recovered from cores of the FS15-A borehole. ABA is a static test which examines the acid-generating and acid-neutralizing capacity of a sample. ABA cannot reveal whether a sample will become acidic, it only measures the theoretical acid-base balance of a sample. Kinetic testing (e.g., humidity cells) is required to determine if/when and to what extent the acidity may be generated.

The maximum potential for acid production (AP) was calculated from the total S analysis using stoichiometric equation 3 of pyrrhotite oxidation. A factor of 31.25 was applied to the percent S, which assumes 1 mole FeS is neutralized by 1 mole $CaCO_3$. Units are given in kg of $CaCO_3$ equivalent per tonne of tailings.

$$FeS + CaCO_3 + \frac{9}{4}O_2 + \frac{1}{2}H_2O \rightarrow FeOOH + SO_4^{2-} + CO_2 + Ca^{2+} \quad \textbf{(3)}$$

The acid-neutralizing potential (NP) was evaluated using the B.C. Research Initial Test method (Duncan and Bruynesteyn 1979). A 10 g sample was suspended in 100 mL of distilled water and stirred for approximately 15 minutes. The natural pH was recorded, and the sample was titrated to pH 3.5 with 1.0 N sulphuric acid using an automatic titrator. The test was continued until less than 0.1 ml of acid was added over a 4 hour period. The total volume of acid added was recorded and converted to kg of H_2SO_4 per tonne of sample. The choice of end point of pH 3.5 was based on an assumption that this represents the limit above which iron and sulphide oxidizing bacteria such as *Thiobacillus ferrooxidans* are not active. Therefore, if the theoretical acid production is less than that determined by the B.C. Research Test (i.e., the amount of acid required to titrate the solid to an end pH of 3.5), then biochemical oxidation can not be maintained. The test gave results in kg H_2SO_4 per tonne of material. Units were converted to kg of $CaCO_3$ per tonne tailings using stoichiometric equation 4, where 1 mole H_2SO_4 is neutralized by 1 moles $CaCO_3$.

$$CaCO_3 + H_2SO_4 \rightarrow Ca^{2+} + CO_2 + SO_4^{2-} + H_2O \quad \textbf{(4)}$$

The AP and NP are evaluated in the ABA method by two approaches: (1) the net neutralization potential (NNP) which is calculated by substraction of AP from NP, and (2) the ratio of NP to AP. In general, if the NNP is negative then the sample is declared "potentially acid generating", and if NP/AP > 2.5 then the sample is declared "net acid neutralizing". Paste pH was also conducted on the tailings samples which can sometimes indicate whether net acid generation has already developed.

2.2.4 Application of MINTEQA2 to trench and borehole sample analyses

Geochemical data for tailings porewater was interpreted with an equilibrium speciation computer model called MINTEQA2 (USEPA, Aug 1990). The program has a extensive thermodynamic database and utilizes thermodynamic principals to solve multiple-component chemical equilibrium reactions for gaseous, aqueous and solid phase interactions, including adsorption.

For each porewater sample analysis, temperature, pH, redox potential and aqueous components were inputed into the model. The model determines the mass distribution of possible aqueous ion species and the saturation indices (SI) of possible mineral solid phases. Saturation indices were calculated using the following equation:

$$SI = \log \left(\frac{IAP}{K}\right) \quad (5)$$

where,	SI	=	saturation index (unitless),
	IAP	=	ion activity product (mol/L),
	K	=	solubility product (mol/L).

SI values equal to zero indicate equilibrium with respect to a mineral phase. SI values less than zero indicate undersatuation and SI values greater than zero indicate supersaturation. Such information provide a basis for determining the probability of solids that may form in the tailings or that may be present and reacting with resident porewater.

3. RESULTS

3.1 Physical hydrogeology

3.1.1 Groundwater

Measurements of water level elevation in the piezometers were conducted in November of 1992, March and December of 1993, and May, July and Aug of 1994. All data were tabulated and plotted against time, and appear in Appendix A. Water level elevations in the kettle lakes were measured in May, July and August of 1994. These data appear in Appendix B.

A generalized watertable contour map (**Fig. 8**) was developed for the Fault Lake tailings area by using the water level data and the topographic contours taken from the survey map (Falconbridge Exploration survey, May 1984). Because shallow groundwater flow in hummocky unconsolidated terrain tends to be controlled by topography, the watertable contours were generally drawn to reflect the topographic contours. The galciofluvial sand and gravel deposits form the upland area, on which the Sudbury Airport and Fault Lake tailings were placed, and the glaciolacustrine deposits to the northwest and southeast form the lowlands (see **Fig. 4**). The shallow groundwater flow, indicated by the arrows on **Figure 8**, travels from the uplands to the lowlands. The flow direction is perpendicular to the watertable (head) contours, and where the contours are closely grouped, the flow gradient is large. South of the tailings the flow is to the west with a gradient of 0.02. North of the tailings, the flow is towards the northeast with a much smaller gradient. The flow gradient is commonly used to calculate the velocity of flow which is explained later in this section.

A cross-sectional representation of the data illustrates the longitudinal position of the watertable. The water level elevation in the shallowest piezometer was used as a close approximation of the watertable elevation which is acceptable where vertical head gradients are small, as they were in the regional overburden aquifer (Appendix A). Two cross sections were plotted (**Fig. 9**). Section A-A' extends southwest-northeast and illustrates the regional watertable position. Section B-B' extends southeast-northwest and illustrates the watertable position across the tailings.

Section A-A' is represented in **Figure 10**. The lakes located south of the tailings had a watertable elevation in the vicinity of 308 m and showed no south-southwesterly gradient. This indicates that the lakes are alined along a watertable contour. Golder Associates Ltd. in a hydrogeological investigation of the Falconbridge smelter area (1993), show the lakes to be located at the groundwater divide. The watertable below the northern portion of the tailings and extending to the northeast was at 299 m and showed a gradient of 0.0002.

Section B-B' is represented in **Figure 11**. The figure shows the deepest part of the tailings below the regional watertable level of 299 m, and the watertable in the tailings perched above this level. The perched watertable also shows large changes in elevation. These large fluctuations typically occur in tailings (Woyshner and St-Arnaud 1994), a process which has been described by Abdul and Gillham (1984). It is related to the fact that the watertable can rapidly rise through the capillary fringe after a minor recharge event of very little volume. Vertical head gradients are also larger in the tailings (Appendix A), which are necessary to push water through finer grained material. At FS15 (located in the centre of the tailings), the gradient is downward when the water level is high and upward when the water level is low. Measured gradients were 0.55, -0.05 and -0.35, respectively in May, July and Aug of 1994.

Table 1 shows the results of the hydraulic conductivity tests for each piezometer. Measured hydraulic conductivities in the natural overburden units were highly variable, ranging between 8 x 10^{-1} cm/s (at FS10) and 2.5 x 10^{-5} cm/s (at FS4). The large variations in hydraulic conductivity are explained by the variability in soil types typical of ice-contact deposits which include silts, sands, gravels, and boulders. The higher values of hydraulic conductivity (such as at FS10 and FS14) would occur where fast meltwater flows would have formed accumulations of well-sorted sands and gravels. The lower hydraulic conductivities occur where glacial abrasion and slow meltwater flows would have left silts. The hydraulic conductivity values also suggest that silts may be present within void spaces between boulders (at FS4, for example).

The geometric average of all hydraulic conductivity measurements is 1.6 x 10^{-3} cm/s. This value would be representative of a clean to silty medium sand, and is considered to be representative of the overall effective hydraulic conductivity of the ice-contact deposits in which the tailings lie.

The hydraulic conductivities were measured in the tailings at FS15-A and at FS15-B. In FS15-A, at a 35 m depth, the hydraulic conductivity was 3.6 x 10^{-6} cm/s, and in FS15-B, at 24 m, it was 1.2 x 10^{-5} cm/s. The results are similar to those calculated in part 1 of the investigation (NTC 1993) using the grain-size distribution D_{50} and the modified Kozeny-Carman equation (Bear 1972). The resulting estimates averaged 1.2 x 10^{-5} cm/s which is identical to the measurement at FS15-B. The lower conductivity at FS15-A supports the inference that the tailings are more consolidated at a deeper depth.

The average linear groundwater flow velocity (***v***) in the overburden and tailings can be estimated by the Darcy equation.

$$v = K\, i \,/\, n \qquad (6)$$

Using the average hydraulic conductivity (***K***) , hydraulic gradient (***i***), and an estimated porosity (***n***), the calculated velocity for various portions of the site were estimated.

Calculated groundwater velocity.

Flow Location	Hydraulic Gradient	Hydraulic Conductivity (cm/s)	Porosity	Velocity (cm/day)
Maximum vertical flow through the saturated tailings	0.55	1×10^{-5}	0.45	1.1
Westerly lateral flow through the overburden south of the tailings	0.02	1×10^{-3}	0.30	5.8
Northeasterly lateral flow through the overburden north of the tailings	0.0002	1×10^{-2}	0.30	0.6

3.1.2 Unsaturated zone

Table 2 shows the measured water content of the tailings samples recovered from borehole FS15-A in December 1993. The watertable level in the tailings was approximately 15 m below the surface, and above the watertable, alternating wet and dry layers were present. The alternating wet and dry layers are also present in the trench samples taken in May 1994 (**Table 3**), particularly in Trenches 2 and 3. In Trench 1 the water content ranged between 28 and 39% which is similar to the water content in the wetter layers of Trenches 2 and 3. Results show that the tailings are unsaturated, and therefore not inhibiting oxidation.

Dry densities were measure on samples taken from the trenches. **Table 4** shows the results and the calculated volumetric water contents. The dry density of the samples taken from Trench 1 were lower than those from Trenches 2 and 3. Volumetric water content was also higher in samples taken from Trench 1 than those from Trenches 2 and 3.

3.2 Chemical hydrogeology

This section presents the results of the chemical analyses performed on the water samples collected from the piezometers and kettle lakes. Sampling was conducted in December 1992, March and December 1993, and May and August 1994. The results of the December 1992 and March 1993 analyses were presented in the report documenting part 1 of the investigation (NTC 1993) but are also summarized in this section. Results from the December

1993, May and August 1994 analyses are shown in **Tables 5 through 11** and discussed in this section. Concentrations of nickel, iron and sulphate characterized the general water quality found at the site and are discussed in most detail. Other metal and ion concentrations and physico-chemical parameters were determined and are listed in the tables.

3.2.1 Composition of regional waters

The background groundwater monitoring station FS2 showed a near neutral pH, owing to the alkalinity in the water. The alkalinity in the groundwater taken from the deeper piezometer was around 80 mg/L as $CaCO_3$. The shallower piezometer showed 20 mg/L of alkalinity as $CaCO_3$. This suggests that alkalinity is being consumed by water percolating through the vadose zone. Acidity was less than 10 mg/L as $CaCO_3$. Nickel concentrations were generally less than 0.025 mg/L. Analysis for iron showed a maximum concentration of 0.5 mg/L as Fe^{3+} but were commonly less than the 0.025 mg/L detection limit. Sulphate concentrations ranged between 30 and 43 mg/L.

Background groundwater monitoring station FS2 analytical data.

Date	Piezometer	Ni mg/L	Fe_T mg/L	Fe^{3+} mg/L	S mg/L	SO_4^{2-} mg/L
Dec 92	FS2-A FS2-B	0.012 0.010	0.027 0.018	-- --	12.2 12.2	34 32
Mar 93	FS2-A FS2-B	< 0.005 < 0.005	< 0.005 0.033	-- --	11.0 11.1	-- --
Dec 93	FS2-A FS2-B	< 0.025 < 0.025	0.43 < 0.025	0.50 < 0.05	14.6 11.9	-- --
May 94	FS2-A FS2-B	< 0.025 < 0.025	< 0.025 < 0.025	< 0.05 < 0.05	12.5 8.7	41 30
Aug 94	FS2-A FS2-B	< 0.025 < 0.025	< 0.025 < 0.025	< 0.15 < 0.15	15.4 10.9	43 30

Grab samples taken at the surface water monitoring stations near the tailings site and downgradient further to the northeast (Lakes 1-5) generally resembled the groundwater taken from the background monitoring station (FS2). The pH was above 6 and the alkalinity ranged between 25 and 70 mg/L as $CaCO_3$. Nickel and iron concentrations were below the 0.025 mg/L detection limit and sulphur ranged between 2 and 8 mg/L (6-24 mg/L SO_4^{2-}).

Further to the southwest, at stations Lake A and Lake B, grab samples showed a different composition. The pH was lower, ranging between 4 and 5, and the alkalinity was depleted. Nickel concentrations were 0.1-0.3 mg/L at Lake A and 0.03-0.08 mg/L at Lake B. Iron was detectable at 0.06 mg/L in a sample from Lake A and 0.2 mg/L in a sample from Lake B. Sulphur concentrations resembled those measured in the other lakes. These values show how regional surface waters can vary owing to such factors as atmospheric deposition or production of organic acids.

3.2.2 pH, alkalinity and acidity

Groundwater sampled from the overburden aquifer generally had pH values above 6, owing to the alkalinity in the water. Alkalinity measurements averaged 75 mg/L as $CaCO_3$ and had a sample standard deviation of 42 mg/L as $CaCO_3$. Highest alkalinities in the overburden aquifer, ranging from 105 to 170 mg/L as $CaCO_3$, were observed beneath the tailings at FS3, FS5 and FS13. In the saturated zone of the tailings, the alkalinity was higher that any observations in the overburden aquifer; values ranged from 246 to 270 mg/L as $CaCO_3$ for samples taken from station FS15. This may suggest that portions of the tailings are currently a source for alkalinity, increasing the alkalinity in the overburden aquifer above background levels.

In the piezometers northeast of the site, pH values fell below 5 for samples collected in May and August 1994. Alkalinities were also depleted. Because these data were lower than those of background waters in close proximity to the tailings, this suggests that acidity may be migrating from the tailings at the northerly dam. The values, however, were not lower than those of Lakes A and B, further to the southwest. Measurements of acidity at the stations northeast of the dam were low, generally less than 10 mg/L as $CaCO_3$ but showed maximum levels of 26, 16 and 38 mg/L as $CaCO_3$, respectively at FS8, FS9 and FS10. Downgradient of the southerly dam, at FS1, the pH, acidity and alkalinity resembled background levels.

Field pH and alkalinity in groundwater samples taken from stations northeast of the site.

Station	Dec 93	May 94		Aug 94	
	pH	pH	Alkalinity mg/L $CaCO_3$	pH	Alkalinity mg/L $CaCO_3$
FS8-A	6.2	**4.1**	**8**	--	--
FS9-A	5.5	6.3	62	5.9	70
FS9-B	6.7	6.0	66	6.1	100
FS9-C	6.4	**4.6**	**6**	--	--
FS10-A	6.6	6.2	22	5.3	30
FS10-B	6.0	**3.1**	**6**	**4.3**	**10**

3.2.3 Iron concentrations

Above-background levels of iron were consistently observed in samples taken from the stations to the northeast of the site (FS8, FS9 and FS10). The highest observed concentration was 23.5 mg/L at FS8 in December 1993 but in May 1994 it had reduced to 8 mg/L. This trend was also observed in samples taken from FS9. The source of the iron may likely be the tailings at the dam where water commonly ponds and flushes that portion of the tailings. However, because sulphate levels are not elevated (section 3.2.5), it may also be caused by the dissolution of siderite ($FeCO_3$) in the aquifer, a precipitate remnant of tailings discharge.

Observed above-background iron concentrations (mg/L) in overburden aquifer.

Station	Dec 92	Mar 93	Dec 93	May 94	Aug 94
FS8-A	**1.31**	0.019	**23.5**	**7.95**	--
FS9-A	0.023	0.091	0.204	< 0.025	< 0.025
FS9-B	0.042	0.139	0.119	< 0.025	< 0.025
FS9-C	0.055	**0.746**	**1.87**	**0.794**	--
FS10-A	0.034	0.002	**0.807**	**0.783**	0.343
FS10-B	**0.710**	0.003	**0.856**	**0.686**	0.168

3.2.4 Nickel concentrations

Above-background concentrations of nickel were measured at the stations to northeast of the site (FS8, FS9, and FS10) and below the southerly portion of the tailings (FS3 and FS13). Samples taken from the shallow piezometer at FS10 consistently showed values above 0.5 mg/L, ranging between 0.5 and 1.2 mg/L. At FS9, 0.4 mg/L was measured twice. The highest concentration of nickel in the saturated zone of the tailings (at FS15) was 1.2 mg/L. Therefore, the source of nickel in the overburden aquifer may likely be the ponded area at the northerly dam, and possibly other ponded areas in the southerly portion of the tailings. Alternatively, because nickel coprecipitates with iron, it may have been released with the dissolution of siderite.

Observed above-background nickel concentrations (mg/L) in overburden aquifer.

Station	Dec 92	Mar 93	Dec 93	May 94	Aug 94
FS3-A	0.014	**0.138**	--	--	< 0.025
FS3-B	--	0.039	< 0.025	< 0.025	**1.428**
FS3-C	--	--	--	--	--
FS8-A	0.007	< 0.005	< 0.025	**0.544**	--

FS9-A FS9-B FS9-C	0.010 < 0.005 --	< 0.005 < 0.005 0.046	0.079 < 0.025 **0.418**	0.066 < 0.025 **0.407**	0.077 0.084 --
FS10-A FS10-B	0.006 0.009	0.019 **0.532**	0.055 **0.853**	< 0.025 **1.200**	0.041 **0.739**
FS13-A	--	--	--	0.059	**0.116**

3.2.5 Sulphur concentrations

Above-background sulphur concentrations (as SO_4^{2-}) were encountered in samples taken from stations below the tailings (FS3, FS4, FS5 and FS13). Highest concentrations were measured below the southerly portion of the tailings, in FS3 and FS13. Nickel concentrations were also above background levels at FS3 and FS13. The presence of the tracer-labelled drilling water was encountered in all samples taken from station FS3. Samples should therefore be obtained from this station at a later date to confirm the elevated concentrations, after all the drill water evacuates.

Above background levels of sulphur were observed in samples taken from FS1, the monitoring station below the southerly dam (but nickel was not detected). This suggest that sulphate is likely migrating from the tailings and to the south, towards the New tailings area. The New tailings area is an active site of high pyrrhotite composition.

Below the northerly portions of the tailings, at FS4 and FS5, sulphur concentrations were above background levels but not greatly elevated (32-66 mg/L). At the stations located downgradient, northeast of the site where nickel and iron were detected, pH was depressed and alkalinity was depleted (at FS8, FS9 and FS10), sulphate concentrations were at background levels. This suggests little impact from tailings oxidation.

Observed above-background sulphur concentrations (mg/L) in overburden aquifer.

Station	Dec 92	Mar 93	Dec 93	May 94		Aug 94	
	S	S	S	S	SO_4^{2-}	S	SO_4^{2-}
FS1-A	**73.7**	**72.5**	**75.2**	**71.3**	***210.***	**78.9**	***216.***
FS1-B	**85.7**	**113.**	**135.**	**122.**	***318.***	**118.**	***319.***
FS1-C	11.8	11.2	22.4	9.5	*32.4*	--	--
FS3-A	4.63	**49.5**	--	--	--	**192.**	***534.***
FS3-B	--	**82.2**	**187.**	**188.**	***412.***	--	--
FS3-C	--	--	--	--	--	**111.**	***303.***
FS4-A	--	**35.4**	--	**58.3**	***166.***	**62.8**	***190.***
FS4-B	--	**34.8**	--	16.6	*50.6*	18.3	*57.2*
FS4-C	--	8.49	--	10.3	*49.8*	11.5	*35.6*
FS5-A	--	**33.8**	--	**33.8**	***97.7***	**37.0**	***112.***
FS5-B	--	**33.6**	--	**35.7**	***104.***	**39.8**	***120.***
FS5-C	--	**32.1**	--	**64.2**	***187.***	**65.9**	***191.***

FS13-A	--	--	--	--	--	--	***276.***

3.2.6 Site manganese concentrations

Manganese was below the 0.005 mg/L detection limit in samples taken from the background monitoring station (FS2) and the surface water monitoring stations (Lakes 1-5). Above background concentrations of manganese were observed in samples taken from all of the other stations except FS1, the station below the southerly dam. Highest concentrations were 94.5 mg/L at FS3, 36.2 mg/L at FS4 and 69.1 mg/L at FS5.

3.3 Tailings mineralogy

3.3.1 Borehole FS15-A samples

Results of the x-ray diffraction (XRD) analysis on the tailings samples recovered from borehole FS15-A are shown in **Table 12**. Diffraction peaks were qualitatively identified and categorized as major, minor or trace. The upper 4 m were dominated by pyrrhotite and quartz with minor occurrences of chlorite and plagioclase. Below this, chlorite and quartz were dominant with small amounts of pyrrhotite. The amount of pyrrhotite decreased with depth until it was not detectable at a depth of 10 m. At these deeper depths, the mineralogy can be characterized as a complex assemblage with major chlorite and quartz, and minor mica, plagioclase, amphibole and calcite.

The percentage of quartz was determined on six samples **(Table 13)**. Results show that quartz is more plentiful at depth, in the tailings void of pyrrhotite. About twice the amount of quartz appeared in the four samples selected from 17, 21, 32, and 35 m (14-19%), as compared to the two samples selected from 0.5 and 1.5 m (7-8%).

Table 14 shows the results of the chemical analysis performed on the tailings solid samples recovered from borehole FS15-A. Most notable is the difference between the 2 samples taken from the upper 2 m and the other samples at depth. Near the surface, the composition of Fe and S were higher, while concentrations of Al, Ca, K, Mg and Mn were lower. These results corroborate the results from the XRD analysis, specifically, the decrease in the amount of pyrrhotite with depth. This finding indicates two layers which is illustrated in **Figure 12a** where the measured S concentrations were converted to FeS equivalent.

3.3.2 Trench samples

Detailed sampling of the upper 2.5 m of the tailings was conducted at three locations, Trenches 1-3, shown in **Figure 6**. Analytical data and field observations of color show that the tailings are layered. The layering also appears to extend the entire depth of the tailings, based on the piezocone test (Appendix D).

A 5-10 cm thick hard pan has formed on the surface of the tailings owing to sulphide oxidation. Unlike hard pans that precipitate below the depth of oxidation, the hard pan at Fault Lake has formed at the surface. Hard pans that form at or near the depth of oxidation are typically characterized by cementation of tailings by Fe(III) mineral. MINTEQA2 modelling, described later in this section, indicates that the porewaters are supersaturated with respect to these minerals, suggesting precipitation. Because the hard pan has formed at the surface, evaporative fluxes of water and solutes may have contributed to its formation. Hard pans precipitating in tailings may play a significant role to restrict the flux of oxygen into the tailings and limit sulphide oxidation (Blowes et al. 1991). Where desiccation and weathering cracks have developed at the surface, the hard pan has apparently been lifted by ice heaving and sulphide oxidation appears to have been advanced at these spots. In areas where the hard pan has not been lifted, the depth to unoxidized tailings was approximate 20 cm.

Results from the ICP analyses on the tailings solid samples are shown in **Table 15**. Samples collected from Trench 1, located at the southerly portion of the tailings near FS13, were different in composition than those collected from Trench 2, Trench 3 and FS15-A. Most notably, iron and sulphur concentrations in Trenches 2 and 3 showed layering with low values in the range of those observed in Trench 1 (12-14% Fe and 0.8- 2.0% S) (**Fig. 13**). This indicates that the pyrrhotitic tailings are distributed at the surface in the central and northerly portions of the site. By subtracting the percent sulphate from the total sulphur composition (**Table 16**), results indicate that the sulphur at Trench 1 is primarily sulphate, while in Trenches 2 and 3 it is layered unoxidized sulphide (pyrrhotite).

Composition of other elements show that Al, Ca, K, Mg and Mn were lower in Trenches 2 and 3 than in Trench 1. In general the tailings at Trench 1 appear to resemble the composition of the pyrrhotite poor tailings found at depth at FS15.

3.4 Tailings porewater analyses

3.4.1 Borehole FS15-A samples

Table 17 shows the results of the chemical analysis conducted on porewater pneumatically extracted from the tailings samples. Concentrations of Fe, Ni, Zn and S were elevated in the upper two samples (1 & 2), and decreased with depth. **Figure 12b** shows the depth profile of Fe and S concentrations. The values measured in samples 1 and 2 are typical of sulphide oxidation. Lower values at depth may be controlled by secondary mineral precipitation/dissolution.

Porewater samples were also measured for pH, redox potential and electrical conductivity (**Table 18**). Results from samples 1 and 2 indicate sulphide oxidation. At depth, porewaters appear to be buffered by calcite (detected with XRD), which corroborates secondary mineral precipitation. For example, in the presences of calcite, Al^{3+} and Fe^{3+} precipitate as hydroxide minerals and Fe^{2+} and Mn^{2+} precipitate as a carbonate minerals. Ni^{2+} is generally soluble in the presence of calcite but may co-precipitate with iron minerals or with gypsum.

MINTEQA2 modelling (**Table 22**) of the porewater extracted from samples recovered from borehole FS15-A indicate supersaturation with respect to iron hydroxide minerals and jarosite in the 2 m of the tailings. This suggest that these minerals are precipitating. The porewaters are slightly supersaturated with respect to gypsum, which is interpreted as gypsum being at equilibrium with calcium and sulphate. The porewaters are also near saturation (slightly undersaturated) with respect to melanterite.

3.4.2 Trench samples

ICP analysis of porewaters pneumatically extracted from samples taken from the trenches show variable results (**Table 19**). Trenches 2 and 3 showed the highest concentrations of $Fe_{(T)}$, Ni, and S and showed distinctive layering (**Fig. 14**). As with the borehole FS15-A samples, the values measured are typical of sulphide oxidation. The concentrations declined with depth which suggest secondary mineral precipitation. Trench 1 generally showed lower values indicating little sulphide oxidation.

As with the borehole samples, the physico-chemical parameters measured on the extracted porewater from Trenches 2 and 3 indicated tailings oxidation (**Table 20**). The lowest measured pH was 2.1 from Trench 2, at a depth of 15 cm. The pH increased with depth. The highest measured value was 4.8. Trench 3 showed similar values but having a pH of 6.1 at the bottom of the trench. This indicates neutralization of porewaters. Trench 1 showed pH values greater than 6 below a depth of 1 m and not less than 4.4 above 1 m. Values of electrical conductivity were also less at Trench 1.

MINTEQA2 modelling of the porewater extracted from samples taken from the trenches indicates supersaturation with respect to iron hydroxide minerals and jarosite (**Table 22**). This suggest that these minerals are likely precipitating. Melanterite is near saturation and gypsum is at equilibrium with calcium and sulphate.

3.5 Acid-base accounting

A comparison of the acid potential (AP) and neutralization potential (NP) versus depth is illustrated in **Figure 12c** and data is found in **Table 21**. The AP of the upper samples clearly dominates the acid-base balance. The negative net neutralization potential (NNP) of the upper 7 m (5 samples) shows a potential of acid generation. The AP was calculated for the trench samples (**Table 16**) and show a high potential for acid generation at Trenches 2 and 3. At depth, below 14 m, the tailings are net acid neutralizing, owing to the NP/AP being greater than 2.5.

Overall, AP exceeded NP. An average of all 23 samples gave an AP of 95 kg $CaCO_3$/t and an NP 52 kg $CaCO_3$/t. Because the average NNP is -43 kg $CaCO_3$/t, the tailings show a potential for acid generation. The paste pH measurements of the samples (**Figure 12d**) indicate that acid generation products are present in the upper 4 meters of the tailings. Silicate minerals were also depleted in the upper 1.5-3 m of the tailings, where elsewhere they are abundant. Silicate minerals have a NP but not measured in the B.C. research test because the kinetics are slower than the length of the test. In slow moving tailings porewaters silicate mineral NP may be significant.

3.6 Pore-gas oxygen measurements

Pore-gas oxygen measurements were conducted at two depth profiles, near FS5 and FS15. The probes were installed in December 1993. At each site the probes were positioned at four depths below the hard pan. Measurements were conducted in December 1993 and May 1994 and are shown in **Table 23**. The data indicates that in December, when the surface was frozen, gaseous oxygen concentrations were near zero at the oxidized front (20 cm depth), owing to the oxidation of pyrrhotite. In May, after spring thaw, gaseous oxygen concentrations were 4-7% at the oxidation front and near zero 40-100 cm below the oxidized front.

4. DISCUSSION

Based on the x-ray diffraction analysis and elemental analysis, the Fault Lake tailings can be characterized by two distinct layers. Layer 1 is rich in pyrrhotite, and is centrally located on the tailings and in close proximity of the northerly spigot positions. Layer 1 pinches out at distal locations from the spigot positions. In the centre of the tailings Layer 1 extends from the surface to about a 9 m depth. The upper 3 m of Layer 1 is substantially sulphide rich. The sulphide composition of Layer 1 progressively decreasing with depth. Layer 2 is sulphide poor and is located below Layer 1. In the southerly portion of the tailings, where Layer 1 pinches out, Layer 2 appears to extend to the surface.

Acid-base accounting indicates substantial reserves of acid potential (AP) in Layer 1 and little in Layer 2. Neutralization potential (NP) is generally constant throughout the tailings but is depleted in the upper part of Layer 1. The net neutralization potential (NNP=NP-AP) of Layer 1 shows a potential for acid generation. Considering the extreme of the negative NNP and field observations, the upper part of Layer 1 is clearly acid generating. In fact, measurements of paste pH and extracted porewater pH indicate that net acid generation has already developed in the upper part of Layer 1. Layer 1 is unsaturated and water is not appreciably limiting oxygen availability. The observed gaseous oxygen concentrations in the surface tailings indicate active oxidation.

In Layer 2, the tailings are generally net acid neutralizing. Below a depth of 14 m in the centre of the tailings (at FS15) the NP/AP ratio ranged between 2.1 and 5.7 kg $CaCO_3$/tonne of tailings. The NP/AP value that indicates whether a sample can be considered acid generating is not well defined. A value less than 2.5 kg $CaCO_3$/tonne of tailings is often used, but kinetic test data by Morin et al. (1995) suggests the threshold could be lower.

The potential capacity of the tailings to neutralize sulphide oxidation from Layer 1 can be estimated by averaging the NNP measurements, giving a value of -43 kg $CaCO_3$/t. This suggests that the tailings, overall, have a theoretical potential for acid generation. However, since the duration of the B.C. Initial Test was generally 24-48 hrs, the test evaluated short-term NP (e.g., carbonate NP). Long-term NP from silicate minerals was not evaluated but is significant because silicate minerals are abundant and porewater flow velocities are low. Chlorite, mica and plagioclase are abundant in the Fault Lake tailings. At other sites (e.g., Waite Amulet), silicate minerals have been shown to be effective buffers. In addition, as the oxidation front extends into the tailings (with time), the concentration gradient of O_2 will decrease which will also decrease the flux and availability of oxygen for sulphide oxidation (St-

Arnaud 1994). A surface hard pan has also formed owing to pyrrhotite oxidation which may additionally limit oxidation, and as the hard pan develops further, the rate of oxidation may continue to decrease. In short, tailings oxidation is greatest immediately following exposure to the atmosphere and decreases with time. During the decades following deposition, carbonate minerals are highly utilized for neutralization, when ample carbonate reserves are present. As the oxidation rate decreases, long-term neutralization is available by silicate minerals.

Potential concerns include: (1) preferential flow paths through the tailings which may deplete the NP along the flow path and provide a conduit for acidity and metals mobility, though no clear evidence of this is seen; and (2) sulphide oxidation along the perimeter of the tailings where the thickness of Layer 2 may be minimal.

Sulphide oxidation in the upper part of Layer 1 has released Fe, Ni, Si, Zn and S (as SO_4), as seen in the elevated porewater concentrations. Below this, porewater concentrations of Fe, Ni, Si, Zn and S are low and pH values are near neutral. Neutral pH values suggest buffering of acidic porewaters by carbonate minerals (Blowes 1984). Trace amounts of calcite and the elevated Ca concentrations in the porewater of sample 3 support this explanation. The low concentrations of Fe, Ni, Si, Zn and S suggest precipitation, as trace amounts of gypsum have precipitated in the upper part of Layer 1.

Currently, groundwater sampled from piezometers located directly northeast of the tailings show slightly depressed pH values and depleted alkalinities, but not less than those observed in lakes to the southwest (Lakes A and B). Concentrations of nickel and iron were also marginally above-background levels, but show acidities and sulphate concentrations similar to background levels. Groundwater samples taken from other piezometers located beneath the tailings (upgradient) and from the kettle lakes located further downgradient, however, show background levels. This may suggest that the source of these oxidation products may be behind the tailings dam where ponded water has been observed. The fact that levels of pH, alkalinity and nickel improve downgradient of the tailings and are at background levels in the lakes further downgradient suggests thatmetals are effectively attenuated.

Levels of sulphate marginally above-background levels were detected below the northwesterly portion of the tailings (at FS4 and FS5). Elevated levels of sulphate were not detected in other stations to the northeast. This may be owing to the porous envelope effect and/or the flow path may be further towards the west.

In the southerly portion of the tailings, limited sulphide minerals were observed. As a result, tailings porewaters generally indicated limited sulphide oxidation products. In the overburden groundwaters below the southerly portion of the tailings, above background levels of sulphate were detected. Directly downgradient of the southerly dam, above background levels of sulphate were also detected. This indicates that sulphate is leaching from the tailings and migrating south towards the New tailings area. This is not seen as being problematic because the maximum concentration detected at the downgradient station (FS1) was low (319 mg/L), and the New tailings area has its own containment.

5. CONCLUSIONS

1) The piezometric elevations throughout the Fault Lake site, combined with lake elevations and topographic contours, indicates that the regional groundwater flow direction south of the tailings is toward the east. North of the tailings, it is towards the northeast.

2) The water level in the tailings is perched higher than and fluctuates larger than the regional watertable.

3) The average bulk hydraulic conductivity of the glacial outwash soil material surrounding the tailings is estimated at 1.6×10^{-3} cm/s. The hydraulic conductivity of the Fault Lake tailings measured 1.2×10^{-5} cm/s at a mid-level depth in the tailings, and 3.6×10^{-6} cm/s in the deepest part of the tailings.

4) Two-dimensional groundwater flow models conducted in part 1 of the investigation (NTC 1993) showed that groundwater flow is diverted around the tailings mass due to the hydraulic conductivity contrast between the tailings and the surrounding sediments. The models also showed that flushing of the tailings mass by groundwater should not contribute significantly to the regional groundwater flow system under present water table conditions, as well as under conditions of moderate rise in water table level.

5) Sulphide minerals were identified in the upper 9 m of the tailings deposit and concentrated in the upper 3 m. Aerially they were concentrated in the central and northerly portions of the tailings, in proximity of the northerly spigot location.

6) Sulphide oxidation was detected but geochemical processes have been attenuating acidity and metals in the tailings deposit. Analysis of tailings porewater showed elevated levels of nickel, iron, and sulphate indicating the presence of sulphide oxidation products within portions of the tailings deposit near the surface. Metal concentrations are attenuated in the deeper parts of the tailings. Apparent high variability in measured metal concentrations could be caused by variations in the intensity of oxidation across the surface of the tailings due to surface effects such as drying and cracking.

7) Acid-base accounting indicated a net deficit in short-term neutralization potential (NP) and a potential for acid generation. Long-term NP was not evaluated but may be a significant part of total NP since porewater velocities are low and silicate minerals are abundant. In addition, as

tailings oxidation progresses (and as NP is depleted), the rate of oxidation and the release of oxidized products should decrease, owing to increased depth to unoxidized tailings. Therefore, reserves of short-term NP are available during the early period of high oxidation rates, and reserves of silicate minerals are abundant for long-term buffering.

8) Sulphide oxidation has been at its highest rate since deposition discontinued in 1978, yet little impact of sulphide oxidation was observed in the groundwater of the surrounding till. The largest offsite impact is directly northeast of the tailings, where pH values are slightly depressed and alkalinities are depleted, but not less that Lakes A and B further to the southwest. Concentrations of nickel and iron are marginally above background levels. The source of the sulphide oxidation products may likely be at the tailings dam where ponding of water has been observed. Alternatively, siderite dissolution in the aquifer, precipitated during tailings deposition, may be a source for nickel and iron (Walter et al. 1994). Nevertheless, the values improve with distance, and further downgradient, the kettle lakes show background levels. This suggests qualities owing to the porous envelope effect.

9) Factors which contribute to limit metal concentrations downgradient of the Fault Lake tailings are:

- the large hydraulic conductivity contrast between the tailings and the surrounding sediments,
- the limited infiltration through the surface of the tailings,
- the dilution of metals flushed from the tailings by water flowing around and below the tailings, and
- chemical attenuation of metals in the tailings and overburden.

These factors could probably be present at other locations near mine sites. Tailings deposition could be done at these sites with little effect on groundwater quality pending that thorough site evaluations are performed and that appropriate control is done at the time of deposition.

6. RECOMMENDATIONS

1) Two years of water quality monitoring have been conducted. Additional sampling of the groundwater and surface-water monitoring stations should be continued to confirm the observed trends.

2) The acid-base accounting on tailings samples recovered from borehole FS15-A suggest that the Layer 2 tailings will not be acid generating. Kinetic testing should be conducted to determine if/when and to what extent acidity may be generated from Layer 2 tailings. Samples are presently sealed, frozen and stored at NTC.

3) Avoid disturbing the tailings and exposing fresh unoxidized pyrrhotite to the atmosphere. Avoid large ponds or water covers that will dissolve secondary minerals and increase flushing to the overburden groundwater.

7. CLOSURE

Field work and preliminary data analyses for the work were performed by P. Tibble and S. Aiken. N. Michelutti assisted in field work during the summer of 1994. Numerical modelling in part 1 of the investigation was done by B. Aubé. M. Li reviewed the manuscript. L. St-Arnaud coordinated the project and reviewed the final report. M. Woyshner was the principal investigator of part 2 of the investigation. Project management from Falconbridge was provided by M. Wiseman.

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Table 1. Measured hydraulic conductivity

Piezometer Number	Material	K (cm/s)
FS1-A	Overburden	--
FS1-B	Overburden	2.5E-03
FS1-C	Overburden	--
FS2-A	Overburden	2.9E-03
FS2-B	Overburden	2.9E-03
FS3-A	Overburden	1.0E-02
FS3-B	Overburden	8.6E-03
FS3-C	Tailings	--
FS4-A	Overburden	2.5E-05
FS4-B	Overburden	5.1E-05
FS4-C	Overburden	3.0E-05
FS5-A	Overburden	1.9E-04
FS5-B	Overburden	9.3E-05
FS5-C	Overburden	3.1E-04
FS6-A	Overburden	1.2E-04
FS6-B	Overburden	1.5E-04
FS6-C	Overburden	4.0E-04
FS7-A	Overburden	--
FS8-A	Overburden	6.1E-03
FS9-A	Overburden	8.9E-05
FS9-B	Overburden	7.6E-05
FS9-C	Overburden	8.1E-04
FS10-A	Overburden	8.0E-01
FS10-B	Overburden	8.0E-01
FS11-A	Overburden	--
FS12-A	Overburden	--
FS13-A	Overburden	--
FS14-A	Overburden	4.0E-02
FS14-B	Overburden	4.0E-02
FS15-A	Tailings	3.6E-06
FS15-B	Tailings	1.2E-05

Table 2. Measured water content of tailings samples taken from borehole FS15-A.

Sample	Sample Interval (m)	Average Depth (m)	Water Content (%)
1 A	0.25-0.40	0.33	19
1 B	0.40-0.60	0.50	22
1 C	0.60-0.80	0.70	11
2 A	0.80-0.95	0.88	11
2 B	0.95-1.25	1.10	10
2 C	1.25-1.41	1.33	12
Tube 3 0-20	3.40-3.60	3.50	14
Tube 3 20-40	3.60-3.80	3.70	14
Tube 3 40-60	3.80-4.00	3.90	11
Tube 3 60-80	4.00-4.20	4.10	14
Tube 3 80-100	4.20-4.40	4.30	24
Tube 3 100-120	4.40-4.60	4.50	26
4 30-55	5.35-5.50	5.43	16
4 55-85	5.50-5.80	5.70	36
4 85-136	5.80-6.01	5.91	46
7 50-90	10.50-10.95	10.72	32
13 0-40	19.81-20.21	20.01	37
13 40-80	20.21-20.61	20.41	34
18 B	27.79-28.19	27.99	32
21 C	33.05-33.40	33.23	39
23 C	35.60-35.80	35.70	29

Table 3. Measured water content of tailings samples taken from trenches.

Sample	Sample interval (m)	Gravimetric Water Content (%)
Trench 1		
T 1-A	0.00-0.10	39
T 1-B	0.45-0.55	30
T 1-C	0.95-1.05	32
T 1-D	1.45-1.55	29
T 1-E	1.95-2.05	32
T 1-F	2.45-2.55	28
Trench 2		
T 2-A	0.00-0.05	8
T 2-B	0.05-0.25	34
T 2-C	0.25-0.45	13
T 2-D	0.45-0.50	24
T 2-E	0.50-0.80	17
T 2-F	0.80-1.00	14
T 2-G	1.00-1.20	13
T 2-J	1.25-1.45	9
T 2-H	1.20-1.75	8
T 2-I	2.10	29
T 2-K	2.40	22
T 2-L	2.50	9
Trench 3		
T 3-A	0.00-0.05	13
T 3-B	0.05-0.25	10
T 3-C	0.30-0.50	10
T 3-D	0.55-0.70	13
T 3-E	0.80-1.00	21
T 3-F	1.00-1.30	13
T 3-G	1.35-1.60	13
T 3-H	2.00-2.20	33

Table 4. Measured water content and dry density of tailings taken from trenches.

Sample	Depth (m)	Dry Density	Gravimetric Moisture Content %	Volumetric Moisture Content %
Trench 1				
T1D1	0.50	1.45	19	28
T1D2	1.00	1.51	35	53
T1D3	1.50	1.39	18	26
T1D4	2.00	1.44	29	42
T1D5	2.50	1.83	17	31
Trench 2				
T2D1	0.50	2.51	10	25
T2D2	1.00	2.58	10	26
T2D3	1.50	2.62	7	18
T2D4	2.00	2.73	6	15
T2D5	2.50	2.66	7	17
Trench 3				
T3D1	0.50	2.11	7	14
T3D2	1.00	2.15	6	13
T3D3	1.50	2.61	3	8
T3D4	2.00	2.42	5	12

Table 5. Physico-chemical parameter values for groundwater samples taken from piezometers at Fault Lake, December 1993.

Sample	Field Temperature (C)	Field REDOX Potential (mV)	Field Electrical Conductivity (mS/cm)	Field pH	Lab pH	Lab Acidity (mg/L CaCO3)
FS1-A	3.2	231	0.519	7.40	8.17	8
FS1-B	3.4	230	0.804	7.40	6.20	< 4
FS1-C	3.5	229	0.207	7.40	8.15	8
FS2-A	4.3	250	0.280	7.30	8.17	8
FS2-B	6.3	251	0.127	7.40	7.77	8
FS3-B	7.0	220	0.980	7.10	7.94	8
FS8-A	4.6	200	0.200	6.20	7.17	12
FS9-A	5.2	240	0.230	5.50	7.95	8
FS9-B	3.8	-40	0.228	6.70	8.16	6
FS9-C	3.2	110	0.098	6.40	7.55	8
FS10-A	5.3	20	0.077	6.60	7.93	8
FS10-B	5.3	160	0.110	6.00	6.68	14

Table 6. Physico-chemical parameter values for water samples taken from monitoring stations at Fault Lake, May 1994.

Sample	Field measurements					Lab measurements					
	Temperature (C)	REDOX Potential (mV)	Electrical Conductivity (mS/cm)	pH	Alkalinity * (mg CaCO3/L)	Temperature (C)	REDOX Potential (mV)	Electrical Conductivity (mS/cm)	pH	Alkalinity (mg CaCO3/L)	Acidity (mg/L CaCO3)
FS1-A	10.5	234	0.404	7.42	64	16.4	236	0.522	7.88	78	< 2
FS1-B	9.6	246	0.386	7.30	--	15.8	224	0.748	8.01	80	< 2
FS1-C	11.0	231	0.366	6.89	--	16.3	224	0.197	5.98	52	< 2
FS2-A	--	355	0.287	7.48	80	19.0	282	0.289	8.18	84	< 2
FS2-B	--	269	0.122	6.51	--	19.3	270	0.114	6.74	20	< 2
FS3-B	--	180	0.984	7.60	--	19.0	248	1.061	7.92	74	< 2
FS4-A	--	644	0.541	7.04	84	18.0	202	0.527	7.85	90	6
FS4-B	--	175	0.342	6.96	--	17.8	242	0.346	7.72	58	8
FS4-C	--	221	0.290	7.21	--	18.0	228	0.292	8.18	66	< 2
FS5-A	--	218	0.420	7.27	97	19.0	269	0.404	8.30	104	< 2
FS5-B	--	178	0.434	7.40	--	19.0	257	0.437	8.01	132	10
FS5-C	--	51	0.569	6.94	--	19.3	270	0.546	7.69	134	10
FS6-A	--	207	0.328	6.81	63	19.5	262	0.350	7.92	80	4
FS8-A	9.2	173	0.143	4.13	--	16.3	157	0.138	5.90	8	26
FS9-A	11.8	221	0.227	6.29	54	19.2	273	0.229	7.71	62	8
FS9-B	12.6	262	0.227	6.03	46	19.0	160	0.235	7.69	66	8
FS9-C	11.1	243	0.080	4.56	--	19.0	180	0.079	5.34	6	16
FS10-A	9.2	165	0.071	6.15	19	18.7	254	0.074	6.97	22	8
FS10-B	12.8	335	0.134	3.09	--	18.9	367	0.133	4.72	6	38
FS13-A	--	160	2.31	6.61	--	15.4	187	2.29	6.94	170	38
FS15-A	--	254	1.913	7.2	--	16.6	247	1.938	8.01	246	28
FS15-B	--	166	3.33	7.23	--	16.0	241	3.38	7.88	268	12
Lake A	--	375	0.078	4.54	--	20	361	0.075	4.58	< 2.0	14
Lake B	--	282	0.039	5.08	--	20.3	317	0.038	5.11	4	< 2
Lake 1	--	199	0.194	7.8	--	20.5	262	0.203	7.8	70	< 2
Lake 2	18	247	0.099	6.75	--	20	251	0.094	7.07	32	6
Lake 3	19	211	0.177	7.92	--	20	236	0.185	8.13	64	< 2
Lake 4	19.1	181	0.235	8.05	--	20	250	0.245	8.08	64	< 2

Field alkalinities were measured with a HACH hand-held digital titator.

Table 7. Physico-chemical parameter values for water samples taken from monitoring stations at Fault Lake, August 1994.

Sample	Field Temperature (C)	Field REDOX Potential (mV)	Field Electrical Conductivity (mS/cm)	Field pH	Lab Acidity (mg/L CaCO3)	Lab Alkalinity (mg/L CaCO3)
FS1-A	15	201	0.615	6.83	< 2	70
FS1-B	17.4	211	0.857	7.01	< 2	75
FS1-C	--	--	--	--	--	--
FS2-A	19.7	180	0.298	6.89	2	75
FS2-B	18	186	0.132	6.97	--	20
FS3-A	16.6	171	1.17	7.51	5	90
FS3-B	--	--	--	--	--	--
FS3-C	20.2	171	0.84	6.86	6	155
FS4-A	16.7	165	0.595	6.14	10	85
FS4-B	17.4	168	0.375	6.08	5	50
FS4-C	15	174	0.331	6.7	3	70
FS5-A	15.5	159	0.445	6.35	10	130
FS5-B	15.5	158	0.463	6.57	< 2	120
FS5-C	17.5	158	0.62	6.55	< 2	150
FS6-A	14.1	154	0.366	6.88	2	80
FS6-B	--	--	--	--	--	--
FS6-C	--	--	--	--	--	--
FS7-A	--	--	--	--	--	--
FS8-A	--	--	--	--	--	--
FS9-A	18.7	163	0.254	5.93	< 2	70
FS9-B	19.8	164	0.274	6.11	3	100
FS9-C	--	--	--	--	--	--
FS10-A	19.7	167	0.084	5.32	< 2	30
FS10-B	19	171	0.111	4.32	8	10
FS11-A	--	--	--	--	--	--
FS12-A	--	--	--	--	--	--
FS13-A	16.7	182	1.87	7.2	29	105
FS14-A	18.4	178	0.129	6.31	< 2	40
FS14-B	--	--	--	--	--	--
FS15-A	--	--	--	--	--	--
FS15-B	18.4	197	4.2	6.4	27	270
Lake-A	20.8	167	0.069	4.05	< 2	5
Lake-B	23	237	0.037	4.06	< 2	5
Lake-1	24	228	0.181	5.77	2	35
Lake-2	20.7	156	0.184	6.35	5	55
Lake-3	21.2	152	0.087	6.21	< 2	25
Lake-4	21	161	0.241	6.45	3	60
Lake-5	20.7	156	0.218	6.47	< 2	40

Table 8. Major metal and ion concentrations in groundwater samples taken from piezometers at Fault Lake, December 1993.

Sample	Sample Number	Al (mg/L)	As (mg/L)	Ca (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Na (mg/L)	Ni (mg/L)	Pb (mg/L)	S (mg/L)	Se (mg/L)	Zn (mg/L)	Fe+3 (mg/L)	Cl (mg/L)
FS1-A	93227	0.306	< 0.250	83.792	< 0.025	< 0.025	< 0.025	< 5.000	21.392	< 0.005	20.704	< 0.025	< 0.250	75.242	< 0.500	< 0.025	< 0.050	5.980
FS1-B	93229	0.300	< 0.250	130.617	< 0.025	< 0.025	< 0.025	< 5.000	31.026	< 0.005	42.731	< 0.025	< 0.250	134.753	< 0.500	< 0.025	< 0.050	12.100
FS1-C	93231	0.460	< 0.250	38.565	< 0.025	< 0.025	< 0.025	< 5.000	7.086	< 0.005	18.504	< 0.025	< 0.250	22.447	< 0.500	< 0.025	< 0.050	3.600
FS2-A	93233	0.324	< 0.250	38.651	< 0.025	< 0.025	0.428	6.974	9.469	< 0.005	13.743	< 0.025	< 0.250	14.625	< 0.500	< 0.025	0.500	18.200
FS2-B	93235	0.300	< 0.250	15.778	< 0.025	< 0.025	< 0.025	< 5.000	3.957	< 0.005	9.702	< 0.025	< 0.250	11.904	< 0.500	< 0.025	< 0.050	4.040
FS3-B	93237	0.294	< 0.250	198.437	< 0.025	< 0.025	0.031	6.065	23.891	0.282	33.508	< 0.025	< 0.250	187.115	< 0.500	< 0.025	< 0.050	16.900
FS8-A	93239	0.315	< 0.250	13.625	< 0.025	< 0.025	23.541	< 5.000	3.178	4.770	12.350	< 0.025	< 0.250	15.027	< 0.500	< 0.025	1.150	2.020
FS9-A	93241	0.258	< 0.250	31.883	< 0.025	< 0.025	0.204	< 5.000	5.618	0.471	13.394	0.079	< 0.250	10.827	< 0.500	0.049	< 0.050	12.800
FS9-B	93243	0.350	< 0.250	34.260	< 0.025	< 0.025	0.119	< 5.000	5.239	0.071	17.633	< 0.025	< 0.250	9.825	< 0.500	< 0.025	< 0.050	10.700
FS9-C	93245	0.406	< 0.250	7.807	0.128	0.102	1.870	< 5.000	1.377	0.874	13.797	0.418	< 0.250	9.406	< 0.500	< 0.025	< 0.050	2.240
FS10-A	93247	< 0.250	< 0.250	9.343	< 0.025	< 0.025	0.807	< 5.000	1.582	1.165	10.428	0.055	< 0.250	2.076	< 0.500	< 0.025	< 0.050	2.270
FS10-B	93249	0.471	< 0.250	7.647	< 0.025	< 0.025	0.856	< 5.000	1.402	2.576	14.538	0.853	< 0.250	11.981	< 0.500	< 0.025	< 0.050	2.320

Table 9. Major metal and ion concentrations in samples taken from surface and ground water monitoring stations at Fault Lake, May 1994.

Sample	Sample Number	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L
FS1-A	94747	< 0.250	< 0.250	82.180	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	20.855	< 0.005
FS1-B	94748	< 0.250	< 0.250	123.194	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	30.174	< 0.005
FS1-C	94749	< 0.250	< 0.250	22.344	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	4.407	< 0.005
FS2-A	94750	< 0.250	< 0.250	36.874	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	9.318	< 0.005
FS2-B	94751	< 0.250	< 0.250	11.847	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	3.502	< 0.005
FS3-B	94752	< 0.250	< 0.250	201.518	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	31.425	94.470
FS4-A	94753	< 0.250	< 0.250	81.060	< 0.025	< 0.025	< 0.025	< 0.025	1.527	7.673	18.956	0.444
FS4-B	94754	< 0.250	< 0.250	42.702	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	7.197	9.550	0.201
FS4-C	94755	< 0.250	< 0.250	33.927	< 0.025	26.070	< 0.025	< 0.025	< 0.025	< 5.000	6.761	36.220
FS5-A	94756	< 0.250	< 0.250	68.931	< 0.025	< 0.025	< 0.025	< 0.025	0.068	5.478	10.158	69.150
FS5-B	94757	< 0.250	< 0.250	58.314	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	9.357	0.276
FS5-C	94758	< 0.250	< 0.250	101.736	< 0.025	< 0.025	< 0.025	< 0.025	1.381	8.216	15.750	0.195
FS6-A	94759	< 0.250	< 0.250	40.739	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	8.342	0.128
FS8-A	94760	< 0.250	< 0.250	8.114	< 0.025	61.560	< 0.025	< 0.025	7.946	< 5.000	1.867	2.688
FS9-A	94761	< 0.250	< 0.250	29.000	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	5.868	0.113
FS9-B	94762	< 0.250	< 0.250	29.245	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	5.923	0.400
FS9-C	94763	0.275	< 0.250	4.218	< 0.025	< 0.025	< 0.025	< 0.025	0.794	< 5.000	1.299	0.437
FS10-A	94764	< 0.250	< 0.250	5.281	< 0.025	28.970	< 0.025	< 0.025	0.783	< 5.000	1.445	0.865
FS10-B	94765	2.889	< 0.250	3.146	< 0.025	0.104	< 0.025	74.460	0.686	< 5.000	1.219	1.682
FS13-A	94766	< 0.250	< 0.250	466.454	< 0.025	< 0.025	< 0.025	< 0.025	0.307	72.296	193.768	1.191
FS15-A	94767	< 0.250	< 0.250	155.217	< 0.025	< 0.025	< 0.025	< 0.025	0.271	95.339	136.439	0.301
FS15-B	94768	< 0.250	< 0.250	334.953	< 0.025	< 0.025	< 0.025	< 0.025	3.678	148.746	291.771	0.337
Lake A	94741	0.274	< 0.250	2.806	< 0.025	< 0.025	< 0.025	81.580	0.057	< 5.000	1.726	0.083
Lake B	94742	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	0.932	0.056
Lake 1	94743	< 0.250	< 0.250	22.729	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	6.133	< 0.005
Lake 2	94744	< 0.250	< 0.250	9.011	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	3.021	< 0.005
Lake 3	94745	< 0.250	< 0.250	24.177	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	4.220	< 0.005
Lake 4	94746	< 0.250	< 0.250	30.107	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	5.606	< 0.005

Sample	Sample Number	Na mg/L	Ni mg/L	Pb mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Te mg/L	Tl mg/L	Zn mg/L	Fe+3 mg/L	Cl mg/L	SO4 mg/L
FS1-A	94747	15.577	< 0.025	< 0.250	71.293	< 0.250	< 0.500	8.978	< 0.100	< 0.250	< 0.025	< 0.050	6.310	210.000
FS1-B	94748	27.891	< 0.025	< 0.250	122.466	< 0.250	< 0.500	8.926	< 0.100	< 0.250	< 0.025	< 0.050	10.500	318.000
FS1-C	94749	9.729	< 0.025	< 0.250	9.490	< 0.250	< 0.500	5.447	< 0.100	< 0.250	< 0.025	< 0.050	2.150	32.400
FS2-A	94750	10.780	< 0.025	< 0.250	12.519	< 0.250	< 0.500	6.336	< 0.100	< 0.250	< 0.025	< 0.050	14.700	41.000
FS2-B	94751	5.366	< 0.025	< 0.250	8.715	< 0.250	< 0.500	6.614	< 0.100	< 0.250	< 0.025	< 0.050	1.770	29.600
FS3-B	94752	32.671	< 0.025	< 0.250	188.403	< 0.250	< 0.500	5.992	< 0.100	< 0.250	< 0.025	< 0.050	23.600	412.000
FS4-A	94753	15.002	< 0.025	< 0.250	58.286	< 0.250	< 0.500	6.505	< 0.100	< 0.250	< 0.025	0.440	19.900	166.000
FS4-B	94754	13.223	< 0.025	< 0.250	16.573	< 0.250	< 0.500	6.716	< 0.100	< 0.250	< 0.025	< 0.050	42.900	50.600
FS4-C	94755	16.444	< 0.025	< 0.250	10.335	< 0.250	< 0.500	3.260	0.133	< 0.250	0.029	< 0.050	53.700	49.800
FS5-A	94756	11.799	0.042	< 0.250	33.826	< 0.250	< 0.500	6.621	< 0.100	< 0.250	0.051	< 0.050	6.620	97.700
FS5-B	94757	33.082	0.038	< 0.250	35.712	< 0.250	< 0.500	6.571	< 0.100	< 0.250	< 0.025	< 0.050	4.760	104.000
FS5-C	94758	12.516	0.068	< 0.250	64.199	< 0.250	< 0.500	5.472	< 0.100	< 0.250	< 0.025	1.160	5.530	187.000
FS6-A	94759	20.404	< 0.025	< 0.250	12.462	< 0.250	< 0.500	4.711	< 0.100	< 0.250	< 0.025	< 0.050	35.600	35.600
FS8-A	94760	7.766	0.544	< 0.250	9.656	< 0.250	< 0.500	10.428	0.114	< 0.250	0.151	0.543	< 0.200	27.000
FS9-A	94761	11.168	0.066	< 0.250	9.770	< 0.250	< 0.500	6.577	< 0.100	< 0.250	0.089	< 0.050	11.400	27.800
FS9-B	94762	11.031	< 0.025	< 0.250	9.959	< 0.250	< 0.500	6.433	< 0.100	< 0.250	< 0.025	< 0.050	11.400	28.100
FS9-C	94763	8.437	0.407	< 0.250	8.846	< 0.250	< 0.500	7.097	< 0.100	< 0.250	0.055	< 0.050	< 0.200	25.600
FS10-A	94764	7.397	< 0.025	< 0.250	2.978	< 0.250	< 0.500	4.276	< 0.100	< 0.250	< 0.025	0.617	1.910	9.430
FS10-B	94765	11.205	1.200	< 0.250	9.235	< 0.250	< 0.500	8.747	< 0.100	< 0.250	0.271	0.558	1.800	27.600
FS13-A	94766	28.177	0.059	< 0.250	616.943	0.252	< 0.500	4.476	< 0.100	< 0.250	< 0.025	< 0.050	2.710	--
FS15-A	94767	159.479	0.078	< 0.250	365.951	< 0.250	< 0.500	4.994	0.135	< 0.250	< 0.025	< 0.050	38.200	--
FS15-B	94768	331.551	0.139	< 0.250	859.588	0.308	< 0.500	6.897	0.157	< 0.250	< 0.025	< 0.050	40.600	--
Lake A	94741	3.867	0.273	< 0.250	9.985	< 0.250	< 0.500	0.314	< 0.100	< 0.250	0.051	< 0.050	--	--
Lake B	94742	3.580	0.083	< 0.250	4.139	< 0.250	< 0.500	0.406	< 0.100	< 0.250	< 0.025	< 0.050	--	--
Lake 1	94743	8.539	< 0.025	< 0.250	7.874	< 0.250	< 0.500	0.171	< 0.100	< 0.250	< 0.025	< 0.050	--	--
Lake 2	94744	4.662	< 0.025	< 0.250	5.116	< 0.250	< 0.500	0.252	< 0.100	< 0.250	< 0.025	< 0.050	--	--
Lake 3	94745	6.912	< 0.025	< 0.250	7.472	< 0.250	< 0.500	0.071	< 0.100	< 0.250	< 0.025	< 0.050	--	--
Lake 4	94746	11.192	< 0.025	< 0.250	8.014	< 0.250	< 0.500	0.457	< 0.100	< 0.250	< 0.025	< 0.050	--	--

Table 10. Major metal and ion concentrations in samples taken from surface and ground water monitoring stations at Fault Lake, August 1994.

Sample	Sample Number	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	Ni mg/L	Pb mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Te mg/L	Tl mg/L	Zn mg/L	Fe+3 mg/L	Cl mg/L	SO4 mg/L
FS1-A	941804	0.753	< 0.250	89.665	< 0.025	< 0.025	< 0.025	< 0.025	0.040	< 5.000	21.289	< 0.005	18.737	< 0.025	< 0.250	78.855	< 0.250	< 0.500	9.254	< 0.100	< 0.250	< 0.025	< 0.150	6.200	216.000
FS1-B	941805	0.653	< 0.250	127.567	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	31.143	< 0.005	27.318	< 0.025	< 0.250	118.323	< 0.250	< 0.500	9.246	< 0.100	< 0.250	< 0.025	0.150	9.600	319.000
FS2-A	941806	0.659	< 0.250	40.235	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	9.746	< 0.005	13.246	< 0.025	< 0.250	15.447	< 0.250	< 0.500	6.403	< 0.100	< 0.250	< 0.025	< 0.150	14.700	42.600
FS2-B	941807	0.617	< 0.250	15.681	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	3.501	0.005	8.449	< 0.025	< 0.250	10.903	< 0.250	< 0.500	6.559	< 0.100	< 0.250	< 0.025	< 0.150	2.220	30.300
FS3-A	941808	0.755	< 0.250	201.772	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	6.149	32.081	0.132	34.732	< 0.025	< 0.250	192.051	< 0.250	< 0.500	6.062	< 0.100	< 0.250	< 0.025	0.240	24.100	534.000
FS3-C	941809	0.755	< 0.250	171.705	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	15.346	12.390	0.159	12.367	1.428	< 0.250	111.429	< 0.250	< 0.500	4.700	< 0.100	< 0.250	< 0.025	< 0.150	2.810	303.000
FS4-A	941810	0.533	< 0.250	82.214	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	8.757	19.253	0.479	15.766	< 0.025	< 0.250	62.824	< 0.250	< 0.500	6.196	< 0.100	< 0.250	< 0.025	< 0.150	20.400	190.000
FS4-B	941811	0.662	< 0.250	42.334	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	9.189	9.923	0.253	14.817	< 0.025	< 0.250	18.331	< 0.250	< 0.500	7.367	< 0.100	< 0.250	< 0.025	0.160	44.200	57.200
FS4-C	941812	0.771	< 0.250	40.038	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	5.740	7.625	0.016	16.897	< 0.025	< 0.250	11.499	< 0.250	< 0.500	3.252	< 0.100	< 0.250	< 0.025	< 0.150	39.800	35.600
FS5-A	941813	0.779	< 0.250	74.302	< 0.025	< 0.025	< 0.025	< 0.025	0.274	6.361	10.017	0.088	9.973	< 0.025	< 0.250	37.006	< 0.250	< 0.500	6.609	< 0.100	< 0.250	< 0.025	0.380	5.710	112.000
FS5-B	941814	0.622	< 0.250	69.935	< 0.025	< 0.025	< 0.025	< 0.025	0.474	6.106	10.558	0.376	25.042	< 0.025	< 0.250	39.779	< 0.250	< 0.500	6.839	< 0.100	< 0.250	< 0.025	0.470	4.950	120.000
FS5-C	941815	0.619	< 0.250	106.146	< 0.025	< 0.025	< 0.025	< 0.025	0.052	9.028	15.439	0.222	14.377	< 0.025	< 0.250	65.883	< 0.250	< 0.500	5.434	< 0.100	< 0.250	< 0.025	0.210	6.920	191.000
FS6-A	941816	0.597	< 0.250	46.945	< 0.025	< 0.025	< 0.025	< 0.025	0.107	< 5.000	8.962	0.133	21.689	< 0.025	< 0.250	14.418	< 0.250	< 0.500	4.839	< 0.100	< 0.250	< 0.025	0.280	36.900	37.100
FS9-A	941817	0.687	< 0.250	39.322	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	6.057	0.067	12.693	0.077	< 0.250	10.637	< 0.250	< 0.500	6.631	< 0.100	< 0.250	0.031	< 0.150	11.800	28.400
FS9-B	941818	0.741	< 0.250	40.210	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	6.387	0.526	14.628	0.084	< 0.250	11.773	< 0.250	< 0.500	6.007	< 0.100	< 0.250	< 0.025	< 0.150	11.700	29.500
FS10-A	941819	0.647	< 0.250	11.289	< 0.025	< 0.025	< 0.025	< 0.025	0.343	< 5.000	1.803	0.869	8.520	0.041	< 0.250	4.204	< 0.250	< 0.500	4.108	< 0.100	< 0.250	< 0.025	0.360	2.470	12.300
FS10-B	941820	1.844	< 0.250	9.009	< 0.025	0.031	< 0.025	0.028	0.168	< 5.000	1.323	1.158	9.969	0.739	< 0.250	7.122	< 0.250	< 0.500	6.967	< 0.100	< 0.250	0.177	0.280	1.970	19.300
FS13-A	941821	0.743	< 0.250	433.734	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	68.121	168.250	1.061	26.772	0.116	< 0.250	558.560	< 0.250	< 0.500	4.368	< 0.100	< 0.250	< 0.025	< 0.150	3.570	276.000
FS14-A	941822	0.562	< 0.250	19.894	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	3.947	0.015	7.314	< 0.025	< 0.250	6.105	< 0.250	< 0.500	0.968	< 0.100	< 0.250	< 0.025	< 0.150	2.410	17.500
FS15-B	941823	0.510	< 0.250	174.047	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	15.208	12.488	0.167	12.590	1.278	< 0.250	114.374	< 0.250	< 0.500	4.612	< 0.100	< 0.250	< 0.025	< 0.150	39.900	550.000
Lake-A	941645	0.300	< 0.250	5.297	< 0.025	< 0.025	< 0.025	0.065	< 0.025	< 5.000	1.975	0.035	5.420	0.196	< 0.250	7.235	< 0.250	< 0.500	0.142	< 0.100	< 0.250	< 0.025	< 0.150	2.580	22.400
Lake-B	941646	< 0.250	< 0.250	1.560	< 0.025	< 0.025	< 0.025	< 0.025	0.217	< 5.000	0.816	0.012	5.134	0.028	< 0.250	2.367	< 0.250	< 0.500	0.635	< 0.100	< 0.250	< 0.025	< 0.150	2.690	9.960
Lake-1	941647	< 0.250	< 0.250	16.376	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	5.776	< 0.005	9.952	< 0.025	< 0.250	6.872	< 0.250	< 0.500	0.177	< 0.100	< 0.250	< 0.025	< 0.150	15.200	21.600
Lake-2	941648	< 0.250	< 0.250	24.186	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	3.948	< 0.005	8.513	< 0.025	< 0.250	7.116	< 0.250	< 0.500	0.493	< 0.100	< 0.250	< 0.025	< 0.150	8.850	22.500
Lake-3	941649	< 0.250	< 0.250	10.073	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	2.863	< 0.005	6.006	< 0.025	< 0.250	4.740	< 0.250	< 0.500	0.179	< 0.100	< 0.250	< 0.025	< 0.150	2.900	16.000
Lake-4	941650	< 0.250	< 0.250	28.878	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	5.231	< 0.005	12.444	< 0.025	< 0.250	7.643	< 0.250	< 0.500	0.401	< 0.100	< 0.250	< 0.025	< 0.150	15.700	23.300
Lake-5	941651	< 0.250	< 0.250	24.277	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	6.771	< 0.005	10.079	< 0.025	< 0.250	17.833	< 0.250	< 0.500	0.126	< 0.100	< 0.250	< 0.025	< 0.150	5.640	53.300

Table 11. Quality assurance and quality control of Fault Lake monitoring station water sampling.

Sample	Sample Number	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	Ni mg/L	Pb mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Te mg/L	Tl mg/L	Zn mg/L	Fe+3 mg/L	Cl mg/L	SO4 mg/L
December 1993																									
Prepared spike	--	5.000	2.000	20.000	2.000	--	--	5.000	20.000	5.000	20.000	5.000	5.000	5.000	5.000	--	--	0.000	--	--	--	20.000	20.000	--	--
Analysis of spike	93253	5.465	1.958	21.375	2.127	--	--	5.476	21.879	5.751	19.900	5.069	12.421	5.630	5.469	965.970	--	< 0.500	--	--	--	22.092	19.600	394.000	--
	93254	5.445	1.976	21.353	2.121	--	--	5.484	21.845	< 5.000	19.907	5.055	12.201	5.590	5.528	961.480	--	< 0.500	--	--	--	22.077	14.600	419.000	--
	93255	5.335	1.905	21.405	2.134	--	--	5.472	21.845	5.880	19.871	5.067	12.427	5.570	5.460	963.840	--	< 0.500	--	--	--	22.127	14.500	421.000	--
Analysis of field blanks	93250	< 0.250	< 0.250	0.689	< 0.025	--	--	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	8.004	< 0.025	< 0.250	< 0.250	--	< 0.500	--	--	--	< 0.025	< 0.050	1.690	--
	93251	< 0.250	< 0.250	0.572	< 0.025	--	--	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	7.249	< 0.025	< 0.250	< 0.250	--	< 0.500	--	--	--	< 0.025	< 0.050	1.740	--
	93252	< 0.250	< 0.250	0.528	< 0.025	--	--	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	7.186	< 0.025	< 0.250	< 0.250	--	< 0.500	--	--	--	< 0.025	< 0.050	1.760	--
May 1994																									
Prepared spike	--	5.000	2.000	20.000	2.000	0.000	0.000	5.000	20.000	5.000	20.000	5.000	5.000	5.000	5.000	--	0.000	0.000	0.000	0.000	0.000	20.000	20.000	--	--
Analysis of spike	94784	4.865	2.030	18.811	2.203	< 0.025	< 0.025	5.189	21.082	< 5.000	19.243	5.035	10.566	5.646	5.768	927.585	< 0.250	< 0.500	7.471	< 0.100	< 0.250	23.760	19.100	--	--
	94785	4.861	1.960	19.153	2.214	< 0.025	< 0.025	5.288	21.453	< 5.000	19.411	5.098	10.467	5.750	5.796	939.676	< 0.250	< 0.500	7.587	< 0.100	< 0.250	23.996	18.800	--	--
	94786	4.931	2.034	19.040	2.211	< 0.025	< 0.025	5.224	21.288	6.400	19.339	5.124	10.374	5.738	5.805	944.439	< 0.250	< 0.500	7.550	< 0.100	< 0.250	24.086	19.100	--	--
Analysis of field blanks	94781	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	5.769	< 0.025	< 0.250	< 0.250	< 0.250	< 0.500	0.215	< 0.100	< 0.250	< 0.025	< 0.050	--	--
	94782	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	5.536	< 0.025	< 0.250	< 0.250	< 0.250	< 0.500	0.243	0.124	< 0.250	< 0.025	< 0.050	--	--
	94783	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	5.578	< 0.025	< 0.250	< 0.250	< 0.250	< 0.500	0.214	< 0.100	< 0.250	< 0.025	< 0.050	--	--
August 1994																									
Prepared spike	--	5.000	0.000	0.000	0.000	0.000	0.000	0.000	20.000	0.000	0.000	5.000	--	2.000	0.000	--	0.000	0.000	0.000	0.000	0.000	7.000	20.000	--	--
Analysis of spike	941655	4.863	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	20.239	< 5.000	< 0.500	4.883	4.364	2.003	< 0.250	20.616	< 0.250	< 0.500	< 0.050	< 0.100	< 0.250	6.997	19.100	--	--
	941656	4.880	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	20.213	< 5.000	< 0.500	4.873	4.354	2.007	< 0.250	20.466	< 0.250	< 0.500	< 0.050	< 0.100	< 0.250	6.964	19.200	--	--
Equip. blank	941652	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	4.241	< 0.025	< 0.250	< 0.250	< 0.250	< 0.500	< 0.050	< 0.100	< 0.250	< 0.025	--	2.330	2.740
Equip. blank	641653	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	4.483	< 0.025	< 0.250	< 0.250	< 0.250	< 0.500	0.073	< 0.100	< 0.250	< 0.025	--	2.390	2.660
Travel blank	941654	< 0.250	< 0.250	< 0.050	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 5.000	< 0.500	< 0.005	4.417	< 0.025	< 0.250	< 0.250	< 0.250	< 0.500	0.059	< 0.100	< 0.250	< 0.025	--	2.300	2.610

Table 12. Interpretation of x-ray diffraction patterns on tailings samples recovered from borehole FS15-A.

Sample	Depth (m)	Pyrrhotite	Chlorite	Mica	Plagioclase	Amphibole	Quartz	Calcite	Gypsum
1	0.5	**major**	minor	nd	minor	nd	**major**	nd	trace
2	1.5	**major**	minor	nd	minor	nd	**major**	nd	trace
3	3.0	**major**	minor	minor	minor	minor	**major**	trace	trace
4	4.6	minor	**major**	minor	minor	minor	**major**	minor	nd
5	6.2	minor	**major**	minor	minor	minor	**major**	minor	nd
6	7.8	trace	**major**	minor	minor	minor	**major**	minor	nd
7	9.4	trace	**major**	minor	minor	minor	**major**	minor	nd
8	11.0	minor	**major**	minor	minor	minor	**major**	minor	nd
9	12.6	minor	**major**	minor	minor	minor	**major**	minor	nd
10	14.2	minor	**major**	minor	minor	minor	**major**	minor	nd
11	15.8	minor	**major**	minor	minor	minor	**major**	minor	nd
12	17.4	minor	**major**	minor	minor	minor	**major**	minor	nd
13	19.0	minor	**major**	minor	minor	minor	**major**	minor	nd
14	20.6	minor	**major**	minor	minor	minor	**major**	minor	nd
15	22.2	minor	**major**	minor	minor	minor	**major**	minor	nd
16	23.8	minor	**major**	minor	minor	minor	**major**	minor	nd
17	25.4	minor	**major**	minor	minor	minor	**major**	minor	nd
18	27.0	minor	**major**	minor	minor	minor	**major**	minor	nd
19	28.6	minor	**major**	minor	minor	minor	**major**	minor	nd
20	30.2	minor	**major**	minor	minor	minor	**major**	minor	nd
21	31.8	minor	**major**	minor	minor	minor	**major**	minor	nd
22	33.4	minor	**major**	minor	minor	minor	**major**	minor	nd
23	35.0	minor	**major**	minor	minor	minor	**major**	minor	nd

nd = not detected

Table 13. Interpretation by Lakefield Research Laboratories of x-ray diffraction patterns on FS15-A tailings samples.

Sample	1	2	12	14	21	23
Depth (m)	0.5	1.5	17.4	20.6	31.8	35.0
Pyrrhotite, $Fe_{(1-x)}S$	**major**	**major**	-	-	-	-
Chlorite, $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$	minor	minor	**major**	**major**	**major**	**major**
Mica, $(K,Na)(Al,Mg,Fe)_2(Si,Al)O_{10}(OH)_2$	-	-	minor	minor	minor	minor
Plagioclase, $(Na,Ca)(Si,Al)_{O8}$	minor	minor	minor	minor	minor	minor
Amphibole, $(Na,K),Ca_2(Fe,Mg)_5(Al,Si)_8O_{22}(OH)_2$	-	-	minor	minor	minor	minor
Quartz, SiO_2 (free silica determination)	minor (6.8%)	minor (7.9%)	minor (13.9%)	minor (14.0%)	minor (18.6%)	minor (15.3%)
Calcite, $CaCO_3$	-	-	minor	minor	minor	minor
Gypsum, $CaSO_4$•$2H_2O$	trace	trace	-	-	-	-

Table 14. Selected elemental composition of tailings samples taken from borehole FS15-A, December 1993.

Sample	Depth (m)	Al (%)	As (ug/g)	Ca (%)	Cd (ug/g)	Cu (ug/g)	Fe (%)	K (%)	Mg (%)	Mn (%)	Na (%)	Ni (%)	Pb (ug/g)	S (%)	Se (ug/g)	Zn (ug/g)	Cl (ug/g)
1	0.50	2.05	537.82	0.65	< 2.00	965.55	40.28	0.12	1.04	0.04	0.34	0.87	90.68	18.26	106.37	120.23	< 40.00
2	1.50	2.10	410.09	0.98	< 2.00	574.16	37.61	0.17	1.30	0.05	0.51	0.65	108.29	17.32	117.43	85.02	< 40.00
3	4.00	3.11	460.52	1.70	< 2.00	670.11	30.82	0.29	1.97	0.08	0.49	0.56	< 20.00	12.58	80.28	90.33	< 40.00
4	5.50	4.88	572.88	2.72	< 2.00	520.06	17.34	0.45	3.07	0.12	0.57	0.29	< 20.00	3.65	41.59	90.56	< 40.00
5	7.50	4.22	487.32	2.05	< 2.00	442.83	19.17	0.36	2.67	0.10	0.50	0.31	< 20.00	4.69	45.79	72.57	< 40.00
6	9.65	5.18	544.42	2.79	< 2.00	660.66	13.89	0.42	3.38	0.13	0.53	0.43	< 20.00	1.35	< 40.00	99.39	< 40.00
7	10.70	4.57	531.10	2.91	< 2.00	430.41	13.98	0.38	2.92	0.12	3.26	0.26	296.66	1.92	< 40.00	87.54	< 40.00
8	12.00	5.59	610.75	2.92	< 2.00	398.94	13.95	0.48	3.68	0.14	0.54	0.38	< 20.00	1.05	< 40.00	107.54	< 40.00
9	13.70	5.39	554.14	2.91	< 2.00	424.93	13.24	0.42	3.62	0.14	0.52	0.29	< 20.00	0.81	< 40.00	94.87	< 40.00
10	15.20	5.35	522.45	2.80	< 2.00	238.17	12.46	0.43	3.59	0.14	0.50	0.17	< 20.00	0.41	41.41	82.32	< 40.00
11	16.00	4.67	442.58	3.04	< 2.00	250.05	11.08	0.36	3.05	0.12	0.52	0.17	< 20.00	0.45	< 40.00	179.99	< 40.00
12	18.00	5.72	571.25	3.14	< 2.00	354.90	13.94	0.49	3.80	0.14	0.53	0.30	< 20.00	0.86	< 40.00	110.32	< 40.00
13	20.00	4.73	488.64	3.10	< 2.00	249.90	11.35	0.41	3.13	0.12	0.49	0.15	< 20.00	0.61	< 40.00	64.68	< 40.00
14	22.00	4.85	463.35	2.83	< 2.00	277.30	11.24	0.43	3.15	0.13	0.51	0.15	< 20.00	0.48	< 40.00	103.30	< 40.00
15	23.30	4.83	479.20	2.78	< 2.00	255.84	10.85	0.39	3.32	0.12	0.52	0.18	< 20.00	0.56	< 40.00	74.78	< 40.00
16	24.30	5.11	444.03	2.91	< 2.00	200.03	11.50	0.44	3.40	0.13	0.51	0.14	< 20.00	0.35	< 40.00	74.13	< 40.00
17	26.30	5.56	569.12	3.55	< 2.00	297.49	13.08	0.43	3.73	0.15	0.52	0.23	< 20.00	0.66	< 40.00	99.26	230.00
18	28.40	5.42	603.52	2.90	< 2.00	326.75	12.74	0.44	3.64	0.14	0.54	0.29	54.80	0.72	55.24	94.19	< 40.00
19	29.30	5.65	644.58	2.57	< 2.00	412.55	12.95	0.50	3.67	0.14	0.55	0.34	< 20.00	0.76	< 40.00	100.77	< 40.00
20	31.00	5.48	616.29	2.80	< 2.00	358.66	12.25	0.43	3.65	0.13	0.50	0.26	< 20.00	0.68	< 40.00	91.27	241.00
21	33.50	5.60	576.13	2.88	< 2.00	318.56	12.83	0.45	3.71	0.14	0.51	0.30	< 20.00	0.69	< 40.00	111.38	379.00
22	34.00	5.53	579.49	3.11	< 2.00	202.79	12.91	0.40	3.63	0.14	0.58	0.22	< 20.00	0.49	< 40.00	89.56	221.00
23	36.80	5.45	574.19	3.04	< 2.00	302.39	13.01	0.42	3.62	0.14	0.50	0.31	< 20.00	0.70	< 40.00	97.25	252.00

Table 15. Selected elemental composition of tailings samples taken from trenches, May 1994.

Sample	Depth (m)	Al %	As ug/g	Ca %	Cd ug/g	Co ug/g	Cr ug/g	Cu ug/g	Fe %	K %	Mg %	Mn %	Na %	Ni %	Pb ug/g	S %	Sb ug/g	Se ug/g	Te ug/g	Tl ug/g	Zn ug/g	Cl %	HPO4 ug/g	SO4 %
Trench 1																								
T 1-A	0.05	4.894	582	2.081	< 3	59	330	263	14.340	0.427	2.927	0.104	0.136	0.142	< 25	1.759	178	< 50	19	< 25	157	4.75	< 40	6.68
T 1-B	0.50	4.741	558	2.452	< 3	195	262	861	15.420	0.416	3.020	0.128	0.130	0.475	< 25	2.084	199	< 50	19	< 25	229	4.59	< 40	6.32
T 1-C	1.00	5.167	571	2.854	< 3	177	390	845	14.130	0.504	3.277	0.141	0.164	0.445	< 25	1.156	165	< 50	21	< 25	204	4.84	< 40	3.30
T 1-D	1.50	5.261	595	2.930	< 3	162	299	970	13.390	0.483	3.394	0.136	0.163	0.377	< 25	0.848	200	< 50	21	< 25	199	3.75	< 40	3.33
T 1-E	2.00	4.825	525	2.585	< 3	104	228	433	12.320	0.426	3.118	0.128	0.109	0.238	< 25	0.994	151	< 50	20	< 25	162	4.99	< 40	2.96
T 1-F	2.50	4.457	500	2.493	< 3	129	324	660	15.760	0.400	2.936	0.120	0.117	0.326	< 25	2.015	227	< 50	13	< 25	180	4.77	< 40	3.24
Trench 2																								
T 2-A	0.03	0.448	337	0.082	< 3	34	33	172	32.930	0.075	0.218	0.007	0.051	0.101	< 25	13.460	277	< 50	31	< 25	79	4.14	< 40	4.22
T 2-B	0.15	0.866	345	0.111	< 3	38	52	131	33.570	0.189	0.478	0.020	0.065	0.116	< 25	7.823	253	< 50	27	< 25	186	3.91	< 40	13.40
T 2-C	0.35	0.684	397	0.177	< 3	188	53	511	43.450	< 0.050	0.289	0.007	0.065	0.576	< 25	20.630	325	< 50	41	< 25	139	4.86	< 40	6.79
T 2-D	0.48	2.458	441	0.763	< 3	83	138	464	30.860	0.228	1.366	0.047	0.067	0.207	< 25	3.986	228	< 50	21	< 25	99	5.26	< 40	17.90
T 2-E	0.65	1.115	438	0.309	< 3	197	55	558	48.250	0.076	0.618	0.016	0.068	0.727	< 25	20.629	365	< 50	35	< 25	138	4.80	< 40	6.68
T 2-F	0.90	2.614	473	0.832	< 3	191	135	1139	29.570	0.225	1.609	0.064	0.066	0.757	< 25	9.089	251	< 50	25	< 25	204	4.51	< 40	6.71
T 2-G	1.10	1.380	442	0.308	< 3	201	86	733	43.210	0.164	0.877	0.032	0.060	0.700	< 25	21.109	344	< 50	38	< 25	133	5.07	< 40	4.12
T 2-J	1.30	0.709	436	0.379	< 3	203	35	611	48.930	0.083	0.436	0.015	0.069	0.766	< 25	28.210	359	< 50	34	< 25	122	4.44	< 40	5.16
T 2-H	1.48	4.039	444	1.539	< 3	113	251	593	15.670	0.334	2.612	0.012	0.062	0.260	< 25	2.870	166	< 50	< 10	< 25	164	4.65	< 40	5.52
T 2-I	2.10	0.775	399	0.349	< 3	216	44	638	46.800	0.078	0.483	0.104	0.082	0.816	< 25	26.970	368	< 50	43	< 25	122	4.84	< 40	4.34
T 2-K	2.40	3.511	478	1.592	< 3	129	184	497	22.340	0.300	2.267	0.094	0.087	0.359	< 25	8.306	225	< 50	11	< 25	147	4.40	< 40	6.84
T 2-L	2.50	1.057	461	0.233	< 3	184	56	490	46.650	0.085	0.667	0.022	0.063	0.731	< 25	21.029	373	< 50	46	< 25	113	4.67	< 40	4.24
Trench 3																								
T 3-A	0.03	3.830	435	0.559	< 3	47	260	150	14.650	0.331	2.385	0.089	0.091	0.068	< 25	0.740	166	< 50	< 10	< 25	120	4.79	< 40	4.12
T 3-B	0.15	1.127	409	0.386	< 3	357	123	4729	38.430	0.051	0.434	0.011	0.056	0.618	< 25	9.385	281	< 50	23	< 25	121	4.97	< 40	8.63
T 3-C	0.40	1.346	434	0.571	< 3	184	70	512	40.900	0.134	0.750	0.023	0.069	0.654	< 25	14.726	300	< 50	23	< 25	127	4.31	< 40	12.00
T 3-D	0.63	2.022	422	0.897	< 3	179	94	531	31.900	0.196	1.249	0.050	0.077	0.579	< 25	11.595	247	< 50	23	< 25	145	4.60	< 40	7.03
T 3-E	0.90	3.209	445	1.083	< 3	140	158	439	20.620	0.308	1.987	0.081	0.074	0.424	< 25	5.917	190	< 50	< 10	< 25	151	4.45	< 40	6.57
T 3-F	1.15	0.612	460	0.165	4	226	42	649	47.890	0.066	0.381	0.012	0.057	0.847	< 25	21.637	336	< 50	48	< 25	132	4.70	< 40	4.94
T 3-G	1.48	1.891	409	0.668	< 3	160	126	630	32.050	0.173	1.248	0.048	0.065	0.557	< 25	14.948	256	< 50	25	< 25	161	4.18	< 40	6.77
T 3-H	2.10	4.381	541	2.002	< 3	156	212	760	13.520	0.374	2.818	0.114	0.098	0.361	< 25	1.088	135	< 50	< 10	< 25	180	4.65	< 40	5.53

Table 16. Sulphate and sulphide composition in tailings and stoichiometric estimate of acid potential.

Sample	Depth (m)	S(total) %	SO4 %	SO4 as S (SO4)/3 %	Sulphide as S [S(total)]-[SO4 as S] %	Acid Potential (Sulphide as S)x(31.25) (kg CaCO3/tonne)
Trench 1						
T 1-A	0.05	1.759	6.680	2.23	-0.47	0
T 1-B	0.50	2.084	6.320	2.11	-0.02	0
T 1-C	1.00	1.156	3.300	1.10	0.06	2
T 1-D	1.50	0.848	3.330	1.11	-0.26	0
T 1-E	2.00	0.994	2.960	0.99	0.01	0
T 1-F	2.50	2.015	3.240	1.08	0.93	29
Trench 2						
T 2-A	0.03	13.460	4.220	1.41	12.05	377
T 2-B	0.15	7.823	13.400	4.47	3.36	105
T 2-C	0.35	20.630	6.790	2.26	18.37	574
T 2-D	0.48	3.986	17.900	5.97	-1.98	0
T 2-E	0.65	20.629	6.680	2.23	18.40	575
T 2-F	0.90	9.089	6.710	2.24	6.85	214
T 2-G	1.10	21.109	4.120	1.37	19.74	617
T 2-J	1.30	26.970	4.340	1.45	25.52	798
T 2-H	1.48	28.210	5.160	1.72	26.49	828
T 2-I	2.10	2.870	5.520	1.84	1.03	32
T 2-K	2.40	8.306	6.840	2.28	6.03	188
T 2-L	2.50	21.029	4.240	1.41	19.62	613
Trench 3						
T 3-A	0.03	0.740	4.120	1.37	-0.63	0
T 3-B	0.15	9.385	8.630	2.88	6.51	203
T 3-C	0.40	14.726	12.000	4.00	10.73	335
T 3-D	0.63	11.595	7.030	2.34	9.25	289
T 3-E	0.90	5.917	6.570	2.19	3.73	116
T 3-F	1.15	21.637	4.940	1.65	19.99	625
T 3-G	1.48	14.948	6.770	2.26	12.69	397
T 3-H	2.10	1.088	5.530	1.84	-0.76	0

Table 17. Major metal and ion concentrations in exracted porewater from borehole FS15-A tailings samples, December 1993.

Sample	Depth (m)	Depth (m)	Ag (mg/L)	Al (mg/L)	As (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Ca (mg/L)	Cd (mg/L)	Cl (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe Total (mg/L)	Fe+3 (mg/L)	K (mg/L)	Li (mg/L)
1	0.40-0.60	0.50	< 0.05	235.89	6.97	4.43	< 0.05	0.89	423.26	0.88	--	75.46	0.17	< 0.025	8008.00	320.00	52.78	0.84
2	0.95-1.25	1.10	< 0.05	6.49	5.29	60.72	< 0.05	1.32	441.08	< 0.02	30.80	2.16	< 0.02	< 0.025	12500.00	890.00	290.97	< 0.25
3	3.80-4.00	3.90	< 0.05	0.52	< 0.25	0.30	0.18	< 0.05	1380.00	< 0.02	--	0.31	< 0.02	0.026	20.19	< 0.05	209.82	< 0.25
4	5.50-5.80	5.70	< 0.05	0.29	< 0.25	0.48	< 0.05	< 0.05	550.41	< 0.02	21.10	< 0.02	< 0.02	< 0.025	16.12	< 0.05	148.88	< 0.25
5	7.15-7.45	7.30	< 0.05	0.26	< 0.25	0.38	< 0.05	< 0.05	596.93	< 0.02	7.13	< 0.02	< 0.02	< 0.025	0.23	< 0.05	170.02	< 0.25
6	8.75-9.15	8.95	< 0.05	0.60	< 0.25	0.36	< 0.05	< 0.05	523.38	< 0.02	8.74	< 0.02	< 0.02	< 0.025	1.82	< 0.05	175.75	< 0.25
7	10.50-10.95	10.72	< 0.05	0.31	< 0.25	0.41	< 0.05	< 0.05	496.26	< 0.02	29.30	< 0.02	< 0.02	< 0.025	10.00	< 0.05	182.35	< 0.25
8	12.05-12.43	12.24	< 0.05	< 0.25	< 0.25	0.28	< 0.05	< 0.05	525.54	< 0.02	15.00	< 0.02	< 0.02	< 0.025	2.13	< 0.10	180.75	< 0.25
9	13.57-13.97	13.77	< 0.05	0.26	< 0.25	0.34	< 0.05	< 0.05	559.95	< 0.02	17.80	< 0.02	< 0.02	< 0.025	1.47	< 0.05	178.58	< 0.25
10	15.09-15.49	15.29	< 0.05	0.34	< 0.25	0.33	< 0.05	< 0.05	493.35	< 0.02	61.90	< 0.02	< 0.02	< 0.025	5.78	< 0.05	146.73	< 0.25
11	16.61-16.91	16.76	< 0.05	2.01	< 0.25	0.47	0.22	< 0.05	1940.00	< 0.02	53.60	0.11	< 0.02	0.040	66.25	47.90	173.97	< 0.25
12	18.08-18.43	18.25	< 0.05	0.44	< 0.25	0.44	< 0.05	< 0.05	552.68	< 0.02	50.50	< 0.02	< 0.02	< 0.025	3.07	< 0.05	177.23	< 0.25
13	20.21-20.61	20.41	< 0.05	0.51	< 0.25	0.44	< 0.05	< 0.05	577.35	< 0.02	69.40	< 0.02	< 0.02	< 0.025	2.64	< 0.05	181.66	< 0.25
14	21.74-22.14	21.94	< 0.05	0.38	< 0.25	0.34	< 0.05	< 0.05	432.92	< 0.02	--	< 0.02	< 0.02	< 0.025	0.07	< 0.05	144.41	< 0.25
15	23.17-23.47	23.32	< 0.05	0.69	< 0.25	0.37	< 0.05	< 0.05	480.85	< 0.02	66.60	< 0.02	< 0.02	< 0.025	0.57	< 0.05	153.61	< 0.25
16	24.70-25.00	24.35	< 0.05	0.59	< 0.25	0.35	< 0.05	< 0.05	348.97	< 0.02	64.60	< 0.02	< 0.02	< 0.025	0.30	< 0.05	144.59	< 0.25
17	26.21-26.51	26.36	< 0.05	< 0.25	< 0.25	< 0.25	< 0.05	< 0.05	355.54	< 0.02	57.50	< 0.02	< 0.02	< 0.025	0.46	< 0.05	125.14	< 0.25
18	27.79-28.19	27.99	< 0.05	0.35	< 0.25	< 0.25	< 0.05	< 0.05	456.33	< 0.02	58.70	< 0.02	< 0.02	< 0.025	0.82	< 0.05	137.07	< 0.25
19	29.31-29.66	29.49	< 0.05	0.39	< 0.25	0.44	< 0.05	< 0.05	279.36	< 0.02	56.40	< 0.02	< 0.02	0.087	0.17	< 0.05	120.98	< 0.25
20	30.88-31.28	31.08	< 0.05	10.73	< 0.25	0.29	0.08	< 0.05	239.54	< 0.02	44.80	0.03	0.07	0.070	23.99	1.70	100.32	< 0.25
21	33.05-33.40	33.23	< 0.05	0.45	< 0.25	0.32	< 0.05	< 0.05	313.38	< 0.02	60.60	< 0.02	< 0.02	0.027	1.75	< 0.05	115.57	< 0.25
22	33.84-34.14	34.00	< 0.05	0.49	< 0.25	0.32	< 0.05	< 0.05	284.61	< 0.02	46.60	< 0.02	< 0.02	< 0.025	1.14	< 0.05	103.08	< 0.25
23	36.18-36.58	36.38	< 0.05	< 0.25	< 0.25	0.36	0.05	< 0.05	393.19	< 0.02	51.70	0.03	< 0.02	< 0.025	0.38	< 0.05	119.38	< 0.25

Sample	Depth (m)	Depth (m)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Ni (mg/L)	Pb (mg/L)	S (mg/L)	Sb (mg/L)	Se (mg/L)	Si (mg/L)	Sn (mg/L)	Sr (mg/L)	Te (mg/L)	Ti (mg/L)	Tl (mg/L)	Zn (mg/L)
1	0.40-0.60	0.50	388.04	19.21	< 0.25	12.16	3200.00	< 0.25	12200.00	0.35	< 0.25	34.18	< 0.25	< 2.50	1.10	< 0.50	< 0.25	19.766
2	0.95-1.25	1.10	794.77	101.94	< 0.25	13.61	200.73	< 0.25	9280.00	9.25	< 0.25	19.27	3.27	< 2.50	1.88	< 0.50	< 0.25	4.648
3	3.80-4.00	3.90	521.35	4.03	< 0.25	11.45	84.23	< 0.25	5710.00	0.84	< 0.25	0.84	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	0.254
4	5.50-5.80	5.70	457.52	0.78	< 0.25	14.25	0.93	< 0.25	1100.00	0.81	< 0.25	6.25	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
5	7.15-7.45	7.30	313.74	0.57	< 0.25	19.51	2.48	< 0.25	1240.00	0.49	< 0.25	2.22	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
6	8.75-9.15	8.95	409.77	0.68	< 0.25	23.94	2.91	< 0.25	1020.00	0.83	< 0.25	5.50	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
7	10.50-10.95	10.72	443.10	1.15	< 0.25	34.82	0.90	< 0.25	1070.00	0.74	< 0.25	6.28	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
8	12.05-12.43	12.24	174.89	0.90	< 0.25	66.22	1.84	< 0.25	761.83	0.44	< 0.25	6.18	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
9	13.57-13.97	13.77	146.55	0.55	< 0.25	90.68	2.25	< 0.25	768.18	0.54	< 0.25	5.31	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
10	15.09-15.49	15.29	136.88	0.48	< 0.25	114.63	2.14	< 0.25	688.88	0.56	0.43	6.37	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
11	16.61-16.91	16.76	102.38	10.64	< 0.25	111.18	6.70	< 0.25	620.82	0.54	< 0.25	7.71	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
12	18.08-18.43	18.25	149.26	0.53	< 0.25	140.54	1.22	< 0.25	769.46	0.37	< 0.25	5.95	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
13	20.21-20.61	20.41	204.27	0.82	< 0.25	173.11	1.07	< 0.25	863.41	0.37	< 0.25	6.53	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
14	21.74-22.14	21.94	205.08	0.35	< 0.25	302.93	3.09	< 0.25	935.15	0.42	< 0.25	4.77	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
15	23.17-23.47	23.32	246.18	0.47	< 0.25	342.91	2.58	< 0.25	1020.00	0.59	< 0.25	4.50	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
16	24.70-25.00	24.35	208.97	0.31	< 0.25	280.86	1.88	< 0.25	810.85	0.52	< 0.25	3.67	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
17	26.21-26.51	26.36	210.32	0.30	< 0.25	302.62	2.96	< 0.25	850.55	0.42	< 0.25	2.83	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
18	27.79-28.19	27.99	194.22	0.39	< 0.25	309.21	0.76	< 0.25	924.85	< 0.25	< 0.25	5.23	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
19	29.31-29.66	29.49	119.29	0.25	< 0.25	194.17	2.93	< 0.25	530.55	< 0.25	0.41	3.36	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
20	30.88-31.28	31.08	111.28	0.48	< 0.25	160.27	2.26	< 0.25	467.22	< 0.25	0.46	14.67	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
21	33.05-33.40	33.23	137.85	0.46	< 0.25	177.11	0.59	< 0.25	568.05	< 0.25	0.70	6.05	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
22	33.84-34.14	34.00	131.50	0.27	< 0.25	171.92	3.18	< 0.25	530.66	< 0.25	0.32	4.48	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025
23	36.18-36.58	36.38	125.63	0.33	< 0.25	148.38	3.00	< 0.25	776.31	< 0.25	0.29	4.22	< 0.25	< 2.50	< 0.25	< 0.50	< 0.25	< 0.025

Table 18. Extracted porewater physico-chemical parameter values for borehole FS15-A tailings samples, December 1993

Sample	Depth (m)	pH	REDOX Potential (mV)	Electrical Conductivity (mS/cm)
1.00	0.50	3.91	189.60	10.27
2.00	1.10	3.89	185.40	5.04
3.00	3.90	6.27	75.80	3.73
4.00	5.70	6.50	-45.20	2.80
5.00	7.30	7.27	---	4.30
6.00	8.95	7.06	---	2.97
7.00	10.72	6.55	-37.90	3.11
8.00	12.24	6.41	---	2.49
9.00	13.77	6.43	---	2.52
10.00	15.29	6.88	---	2.85
11.00	16.76	6.48	---	2.56
12.00	18.25	6.42	-8.00	2.48
13.00	20.41	6.48	-3.00	2.82
14.00	21.94	6.51	---	3.28
15.00	23.32	6.88	---	3.75
16.00	24.35	7.70	---	3.34
17.00	26.36	7.55	---	3.53
18.00	27.99	6.54	---	3.02
19.00	29.49	7.89	---	2.05
20.00	31.08	7.51	---	2.11
21.00	33.23	6.53	-13.90	2.29
22.00	34.00	7.59	---	2.36
23.00	36.38	6.58	-17.30	1.80

Table 19. Major metal and ion concentrations in extracted porewater from trench tailngs samples, May 1994.

Sample	Sample interval (m)	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	Ni mg/L	Pb mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Te mg/L	Tl mg/L	Zn mg/L	Fe+3 mg/L	Cl mg/L	SO4 mg/L
Trench 1																									
T 1-A	0.00-0.10	5.43	< 0.25	564.04	< 0.03	2.32	< 0.03	1.34	17.03	50.53	27.70	7.06	8.00	57.15	0.43	539.84	< 0.25	< 0.50	30.85	0.16	< 0.25	1.02	5.50	4.33	1530.00
T 1-B	0.45-0.55	1.89	1.06	464.12	< 0.03	15.51	< 0.03	< 0.03	1421.00	234.23	951.08	240.46	16.81	730.95	0.64	3042.00	1.04	< 0.50	14.81	0.20	0.30	5.77	18.30	12.30	10100.00
T 1-C	0.95-1.05	0.29	< 0.25	562.88	< 0.03	0.09	< 0.03	< 0.03	2.37	166.64	533.09	2.21	11.63	22.26	< 0.25	1140.39	0.96	< 0.50	6.65	0.10	< 0.25	0.12	0.08	10.60	3500.00
T 1-D	1.45-1.55	0.29	< 0.25	500.24	< 0.03	< 0.03	< 0.03	< 0.03	0.32	240.81	845.53	0.82	15.74	4.51	< 0.25	1513.94	1.43	< 0.50	7.22	0.13	< 0.25	0.03	< 0.05	10.20	4900.00
T 1-E	1.95-2.05	< 0.25	< 0.25	577.88	< 0.03	0.11	< 0.03	< 0.03	15.49	223.04	1022.75	2.32	13.34	19.63	< 0.25	1907.02	1.86	< 0.50	2.09	0.11	< 0.25	0.09	0.24	13.40	5890.00
T 1-F	2.45-2.55	0.27	< 0.25	691.00	< 0.03	< 0.03	< 0.03	< 0.03	0.37	183.20	1311.09	0.72	23.20	2.17	< 0.25	2337.96	2.13	< 0.50	4.79	< 0.10	< 0.25	< 0.03	< 0.05	19.30	5190.00
Trench 2																									
T 2-A	0.00-0.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T 2-B	0.05-0.25	290.51	5.35	272.72	0.04	1.82	2.02	7.48	3635.00	8.41	168.14	6.82	9.07	60.94	< 0.25	4379.00	2.94	< 0.50	112.53	0.39	< 0.25	2.29	3040.00	6.10	11300.00
T 2-C	0.25-0.45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T 2-D	0.45-0.50	958.66	13.94	466.25	0.33	35.23	1.41	152.47	7345.00	27.56	288.43	12.61	26.97	947.09	< 0.25	7340.00	3.79	< 0.50	124.93	0.77	0.81	12.13	1530.00	2.33	16300.00
T 2-E	0.50-0.80	67.73	6.51	449.86	0.24	3.70	< 0.03	< 0.03	6452.00	8.54	205.63	9.45	7.95	574.88	< 0.25	4566.00	3.83	< 0.50	19.73	0.70	0.52	5.43	157.00	< 0.50	12300.00
T 2-F	0.80-1.00	35.13	8.29	443.14	< 0.03	8.94	< 0.03	< 0.03	7285.00	216.44	966.32	140.99	12.20	3612.00	1.74	7768.00	0.62	< 0.50	41.08	0.78	0.68	23.09	219.00	< 0.50	17100.00
T 2-G	1.00-1.20	1.34	4.84	448.14	0.09	2.76	< 0.03	< 0.03	6129.00	151.15	549.90	93.50	9.71	293.10	0.40	4996.00	4.64	< 0.50	15.09	0.61	0.59	11.41	136.00	6.16	10800.00
T 2-J	1.25-1.45	1.17	2.58	426.04	0.14	2.97	< 0.03	< 0.03	2938.00	149.99	441.36	71.47	9.52	281.26	0.34	3259.00	2.52	< 0.50	13.22	0.35	0.34	4.80	15.30	5.42	9000.00
T 2-H	1.20-1.75	1.14	< 0.25	494.77	< 0.03	2.29	< 0.03	0.07	299.19	191.63	1021.25	135.40	12.60	174.52	< 0.25	2423.00	1.46	< 0.50	12.81	0.11	< 0.25	1.26	2.61	14.10	5790.00
T 2-I	2.10	0.47	3.73	553.60	0.14	8.51	< 0.03	< 0.03	4119.00	203.97	795.59	120.18	12.87	757.09	0.54	6956.00	2.72	< 0.50	7.91	0.46	0.51	4.92	31.50	7.96	10900.00
T 2-K	2.40	4.27	3.64	444.98	0.08	5.01	< 0.03	< 0.03	4750.00	284.42	1134.37	151.73	13.04	367.02	0.65	5534.00	4.52	< 0.50	17.20	0.46	0.44	5.15	61.90	10.30	13400.00
T 2-L	2.50	0.77	6.41	439.72	0.07	6.14	< 0.03	< 0.03	7507.00	207.48	629.76	78.63	10.28	663.79	0.56	7307.00	4.57	< 0.50	9.41	0.73	0.48	6.29	120.00	< 0.50	14200.00
Trench 3																									
T 3-A	0.00-0.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T 3-B	0.05-0.25	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T 3-C	0.30-0.50	60.10	13.68	443.93	0.49	38.82	< 0.03	< 0.03	14530.00	122.62	556.87	52.50	8.86	2832.00	2.01	13590.00	5.71	< 0.50	16.29	1.41	1.39	15.45	294.00	52.50	17500.00
T 3-D	0.55-0.70	7.70	12.81	440.48	0.11	10.80	< 0.03	< 0.03	15340.00	320.23	1089.96	213.55	12.86	2329.00	1.27	15370.00	7.64	< 0.50	18.77	1.31	1.71	11.39	355.00	86.50	16700.00
T 3-E	0.80-1.00	9.70	11.87	457.21	0.11	7.50	< 0.03	< 0.03	14000.00	312.66	1488.44	213.16	11.96	1697.00	0.95	12490.00	8.40	< 0.50	23.15	1.13	1.38	15.31	304.00	158.00	17100.00
T 3-F	1.00-1.30	5.34	6.38	461.37	1.90	7.42	< 0.03	< 0.03	5926.00	259.61	760.48	262.93	10.88	2679.00	2.08	6992.00	0.62	< 0.50	18.32	0.54	1.04	20.06	87.10	33.50	16800.00
T 3-G	1.35-1.60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T 3-H	2.00-2.20	< 0.25	< 0.25	704.89	< 0.03	0.06	< 0.03	0.05	42.80	240.31	469.57	1.99	11.57	8.12	< 0.25	2316.31	0.91	< 0.50	2.63	< 0.10	< 0.25	0.09	0.20	14.00	3880.00

Table 20. Extracted porewater physico-chemical parameter values for trench tailings samples, May 1994

Sample	Depth (m)	pH	REDOX Potential (mV)	Electrical Conductivity (mS/cm)
Trench 1				
T 1-A	0.05	4.40	301.00	2.24
T 1-B	0.50	4.68	177.00	7.78
T 1-C	1.00	6.60	60.00	3.90
T 1-D	1.50	6.67	165.00	5.37
T 1-E	2.00	6.23	58.00	6.16
T 1-F	2.50	6.84	121.00	7.25
Trench 2				
T 2-A	0.03	*	*	*
T 2-B	0.15	2.13	522.00	12.44
T 2-C	0.35	*	*	*
T 2-D	0.48	2.75	380.00	14.52
T 2-E	0.65	4.17	191.00	11.09
T 2-F	0.90	3.73	222.00	16.86
T 2-G	1.10	4.35	176.00	11.79
T 2-J	1.30	4.52	167.00	11.35
T 2-H	1.48	4.32	189.00	7.93
T 2-I	2.10	4.78	169.00	6.56
T 2-K	2.40	4.16	205.00	11.72
T 2-L	2.50	4.19	185.00	13.01
Trench 3				
T 3-A	0.03	*	*	*
T 3-B	0.15	*	*	*
T 3-C	0.40	4.05	207.00	18.98
T 3-D	0.63	4.10	206.00	20.20
T 3-E	0.90	4.07	198.00	17.75
T 3-F	1.15	4.12	214.00	12.13
T 3-G	1.48	*	*	*
T 3-H	2.10	6.12	-72.00	5.72

* No porewater extractable or sample was hardpan

Table 21. Acid-base accounting of samples recovered from borehole FS15-A.

Sample		B.C. Research Initial Test of neutralization potential (NP)				Stoichiometric estimate of acid potential (AP)		Acid-base accounting	
Number	Depth (m)	Paste pH	1N H2SO4 Counsumed (ml/10g)	Acid-consuming Ability (kg H2SO4/tonne)	NP (kg CaCO3/tonne)	Total S (%)	AP (kg CaCO3/tonne)	NNP (NP-AP) (kg CaCO3/tonne)	NP/AP
1	0.50	3.3	0.0	0	0	18.26	571	-571	0.00
2	1.10	3.3	0.0	0	0	17.32	541	-541	0.00
3	3.90	5.5	3.6	18	18	12.58	393	-375	0.05
4	5.70	7.2	11.2	55	56	3.65	114	-58	0.49
5	7.30	6.2	7.6	37	38	4.69	147	-109	0.26
6	8.95	7.3	11.3	55	57	1.35	42	14	1.34
7	10.72	7.5	11.9	58	60	1.92	60	0	0.99
8	12.24	7.2	11.0	54	55	1.05	33	22	1.68
9	13.77	7.4	11.6	57	58	0.81	25	33	2.31
10	15.29	7.3	11.6	57	58	0.41	13	45	4.49
11	16.76	7.7	11.4	56	57	0.45	14	43	4.07
12	18.25	7.4	13.0	64	65	0.86	27	38	2.42
13	20.41	7.6	12.7	62	64	0.61	19	44	3.32
14	21.94	7.6	13.0	64	65	0.48	15	50	4.34
15	23.32	7.6	12.0	59	60	0.56	17	43	3.45
16	24.35	7.8	12.5	61	63	0.35	11	51	5.68
17	26.36	7.5	16.4	80	82	0.66	21	61	3.99
18	27.99	7.2	12.7	62	64	0.72	23	41	2.81
19	29.49	7.3	10.0	49	50	0.76	24	26	2.11
20	31.08	7.4	11.3	55	57	0.68	21	35	2.68
21	33.23	7.5	11.6	57	58	0.69	22	36	2.68
22	34.00	7.4	12.5	61	63	0.49	15	47	4.07
23	36.38	7.4	11.5	56	58	0.70	22	36	2.62
Average	--	--	--	--	52	--	95	-43	0.55

(1) Acid potential was calculated by multiplying the total S% by 31.25 which assums 1 mole pyrrhotite is neutralized by 1 mole CaCO3.
(2) Neutralization potential is converted from acid-consuming ability by assuming 1 mole H2SO4 is neutralized by 1 mole CaCO3.

Table 22. MINTEQA2 saturation indicies of secondary minerals occuring in sulphide rich tailings.

Sample	Depth (m)	Ferrihydrite Fe(OH)3	Goethite FeOOH	Hematite Fe2O3	Jarosite KFe3(SO4)2(OH)6	Melanterite FeSO4 7H2O	Gypsum CaSO4 2H2O
Borehole FS15-1							
1	0.50	1.29	5.32	15.60	15.26	-0.62	0.53
2	1.10	1.72	5.74	16.45	16.93	-0.52	0.47
3	3.90	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-3.27	0.96
4	5.70	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-3.65	0.30
5	7.30	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.45	0.39
6	8.95	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.61	0.27
7	10.7	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-3.86	0.26
8	12.2	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.56	0.25
9	13.8	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.72	0.28
10	15.3	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.14	0.21
11	16.8	4.09	8.11	21.18	14.04	-3.93	0.54
12	18.3	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.40	0.28
13	20.4	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.46	0.30
14	21.9	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-6.00	0.22
15	23.3	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.09	0.26
16	24.4	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.39	0.10
17	26.4	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.20	0.12
18	28.0	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.94	0.23
19	29.5	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.70	-0.05
20	31.1	3.53	7.55	20.06	9.52	-3.60	-1.40
21	33.2	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.68	0.00
22	34.0	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-4.87	-0.05
23	36.4	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.27	0.16
Trench 1							
T 1-A	0.05	1.04	5.06	15.08	11.34	-3.76	-1.65
T 1-B	0.50	1.79	5.81	16.59	14.13	-1.58	0.36
T 1-C	1.00	1.41	5.44	15.83	6.50	-4.50	0.31
T 1-D	1.50	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.31	0.30
T 1-E	2.00	1.52	5.54	16.04	8.33	-3.61	0.38
T 1-F	2.50	Fe3+ nd	Fe3+ nd	Fe3+ nd	Fe3+ nd	-5.31	0.39
Trench 2							
T 2-A	0.03	--	--	--	--	--	--
T 2-B	0.15	-1.90	2.12	9.21	8.80	-2.10	-0.01
T 2-C	0.35	--	--	--	--	--	--
T 2-D	0.48	-0.57	3.46	11.88	11.73	-1.06	0.28
T 2-E	0.65	1.88	5.90	16.76	14.48	-0.95	0.33
T 2-F	0.90	1.11	5.13	15.23	14.95	-0.89	0.34
T 2-G	1.10	2.13	6.16	17.27	15.82	-1.01	0.29
T 2-J	1.30	1.53	5.55	16.06	13.56	-1.28	0.30
T 2-H	1.48	0.53	4.56	14.07	10.98	-2.35	0.29
T 2-I	2.10	2.13	6.16	17.28	14.71	-1.16	0.40
T 2-K	2.40	1.54	5.57	16.10	15.10	-1.05	0.35
T 2-L	2.50	1.81	5.84	16.64	15.66	-0.87	0.33
Trench 3							
T 3-A	0.03	--	--	--	--	--	--
T 3-B	0.15	--	--	--	--	--	--
T 3-C	0.40	1.81	5.84	16.64	15.69	-0.63	0.30
T 3-D	0.63	1.95	5.98	16.91	16.28	-0.65	0.27
T 3-E	0.90	1.86	5.88	16.73	16.14	-0.67	0.30
T 3-F	1.15	1.57	5.59	16.15	15.36	-0.94	0.38
T 3-G	1.48	--	--	--	--	--	--
T 3-H	2.10	1.34	5.36	15.68	7.95	-3.21	0.43

Fe3+ np = Fe3+ ion not detected in porewater

Table 23 Pore-gas oxygen concentration measurements.

Depth (m)	Dec 1993 (%)	May 1993 (%)
Station 1, near FS15		
0.20	0.40	6.6
0.25	0.40	5.8
0.55	0.45	1.05
1.05	0.40	0.9
Station 2, near FS5		
0.23	0.65	3.8
0.30	0.35	1.2
0.65	0.35	0.8
1.10	0.35	0.75

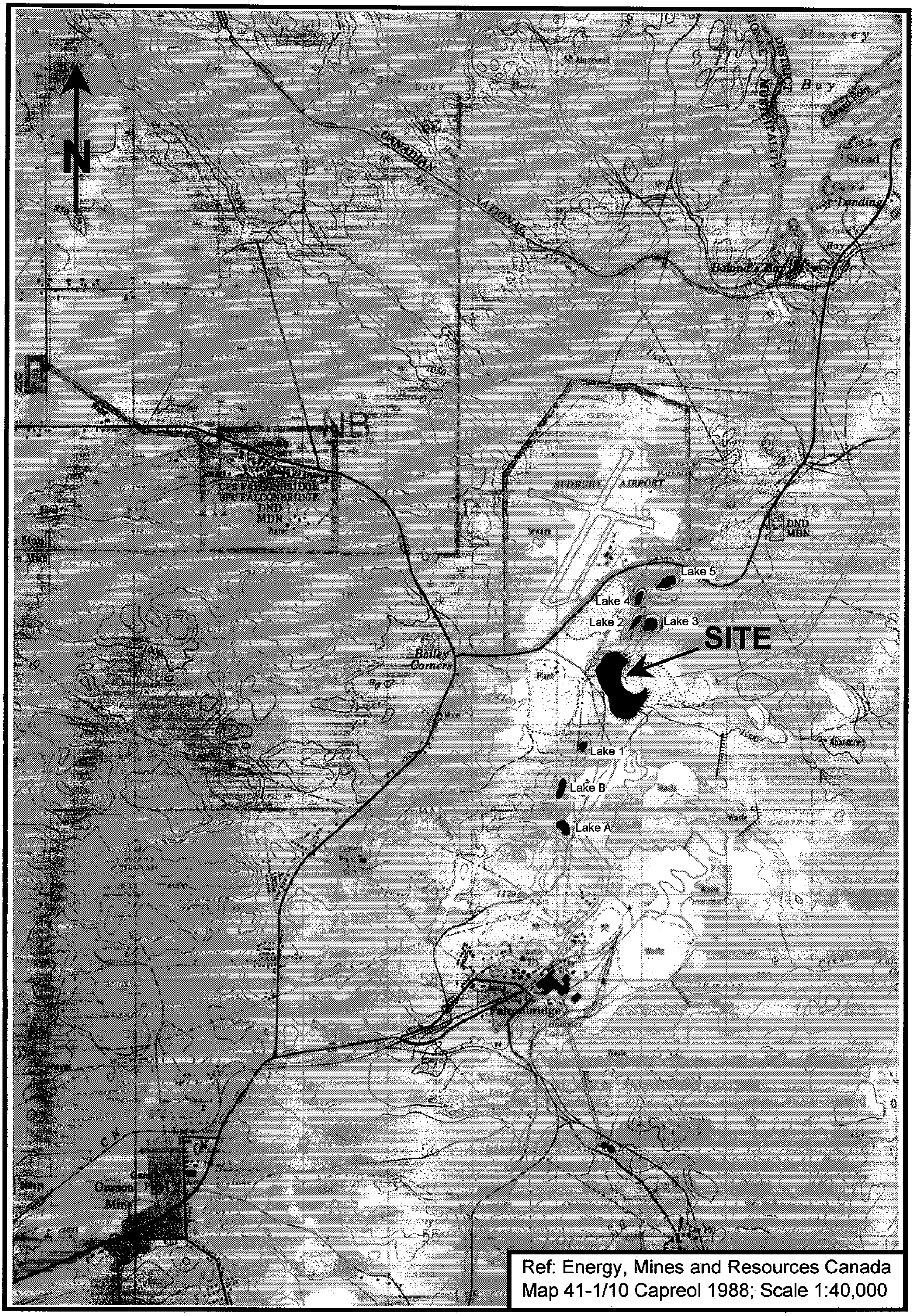


Figure 1. Site location plan.

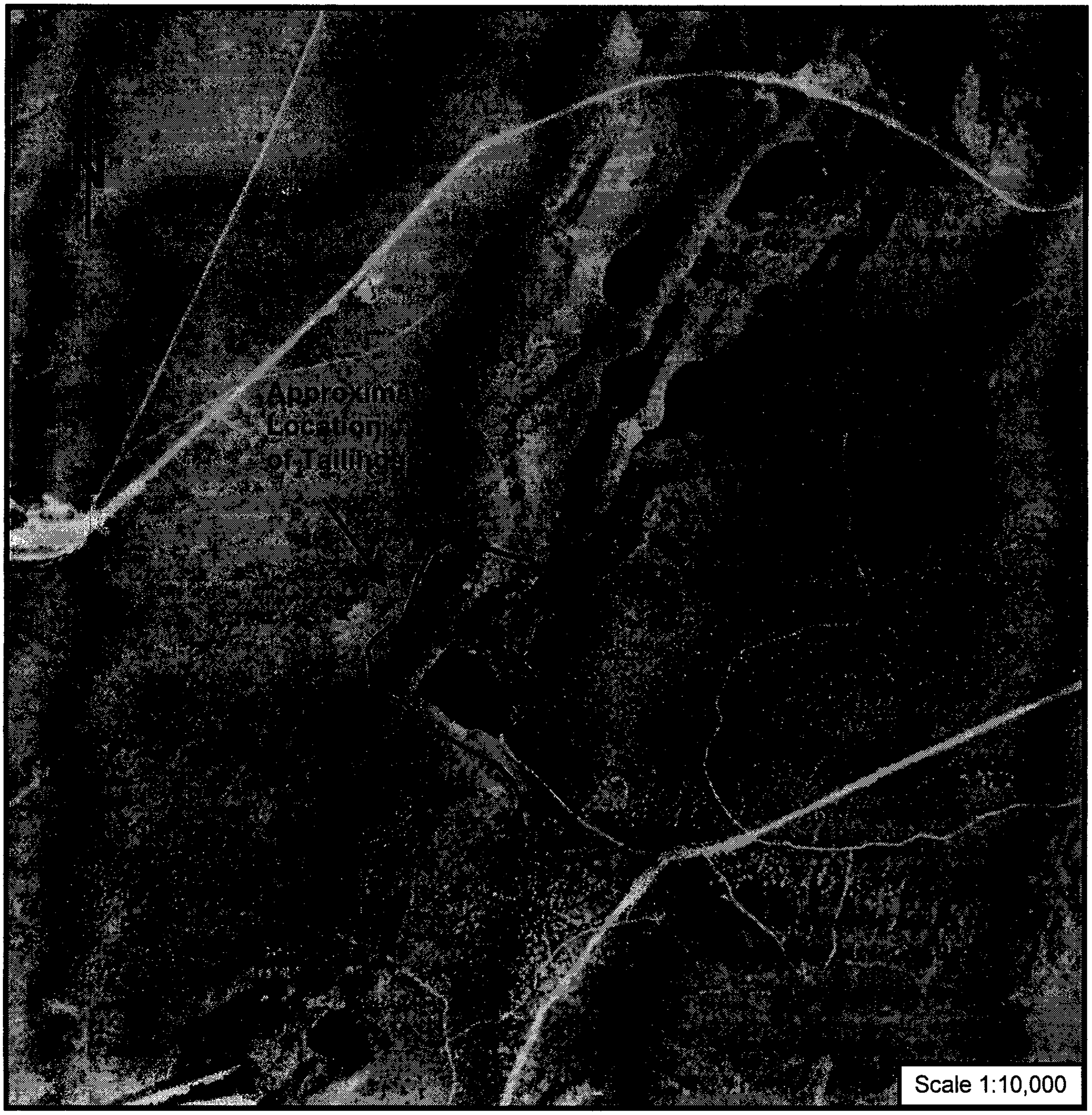


Figure 2. Aerial photograph of site in 1946, prior to tailings disposal.

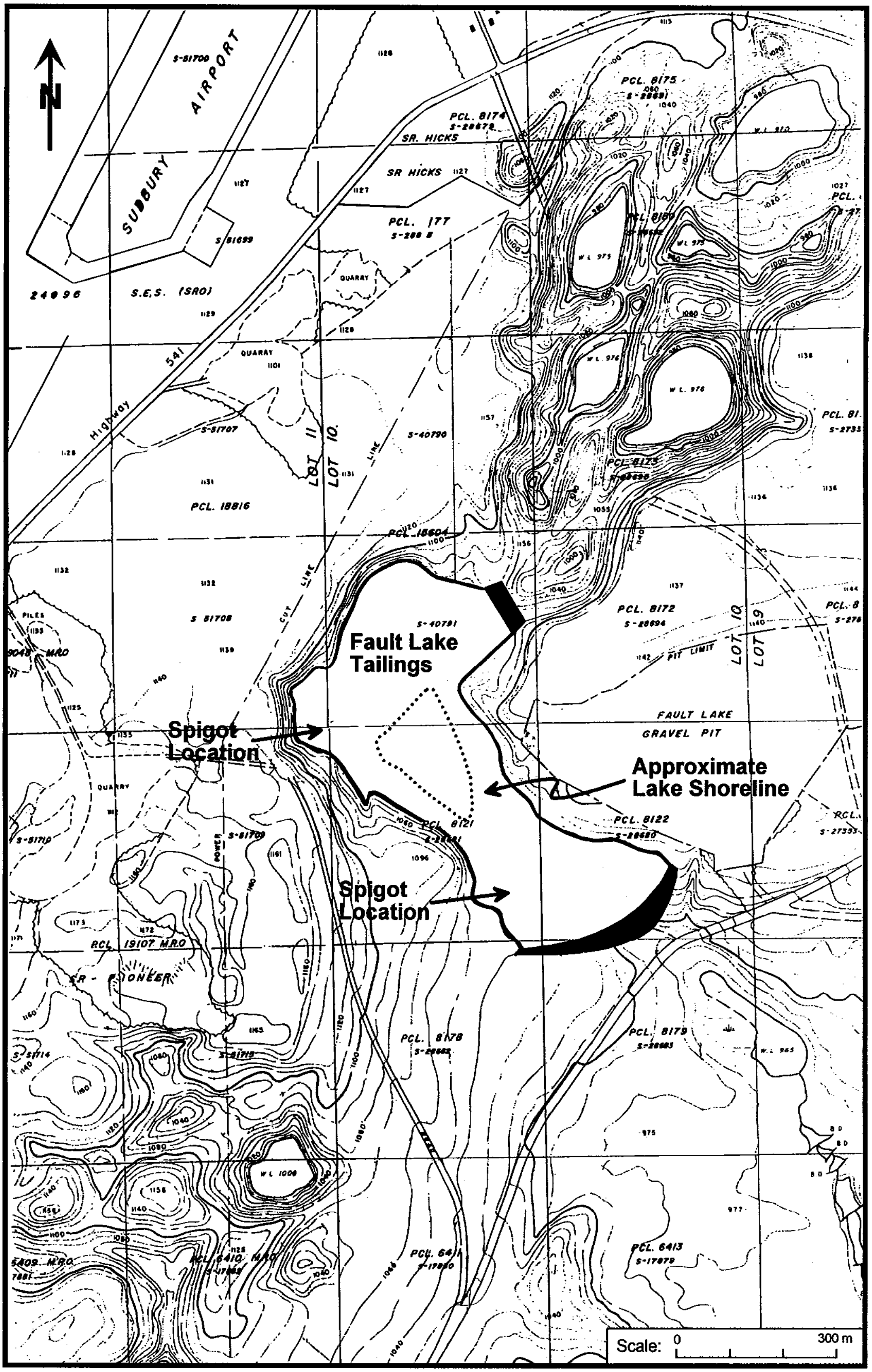
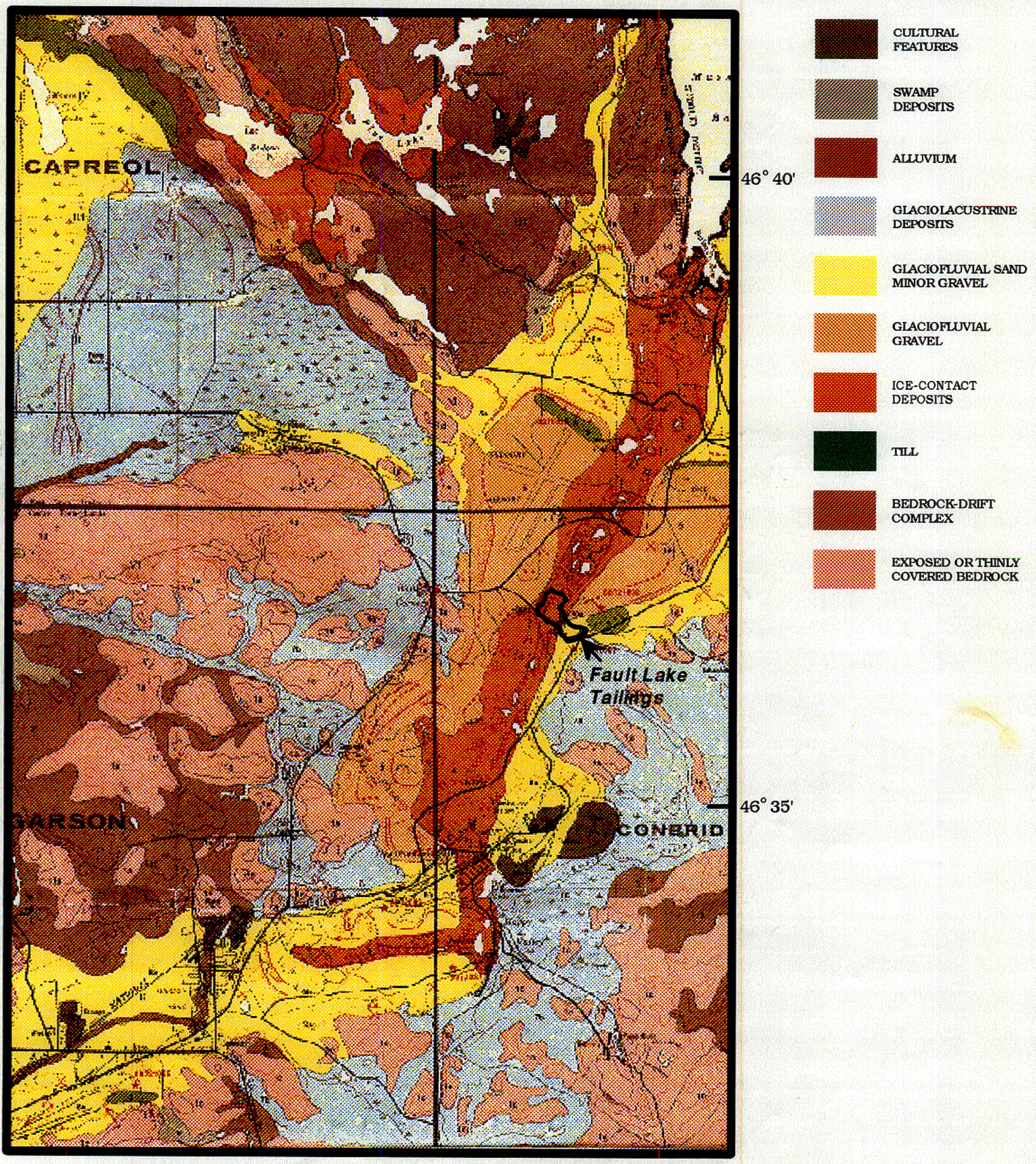


Figure 3. Site plan and topography.

GEOMAP.DRW



Noranda Technology Centre Mineral Sciences Environment	Figure 2. Overburden Geology Falconbridge Sudbury SCALE: 1:50,000 — 1000 0 1000 Metres	SOURCE: Ontario ministry of natural resources, Ontario geological survey map 2397

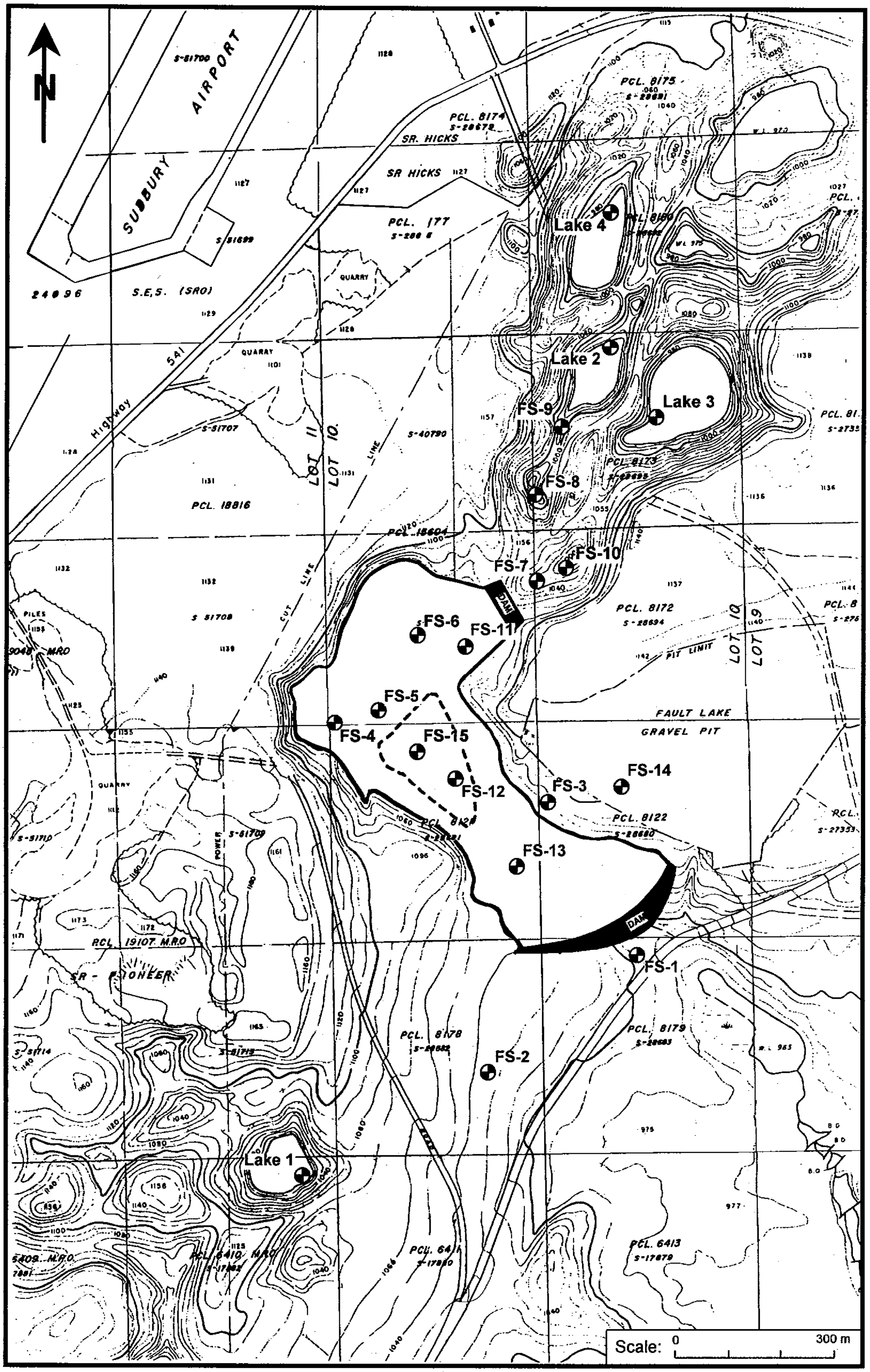


Figure 5. Monitoring station location plan.

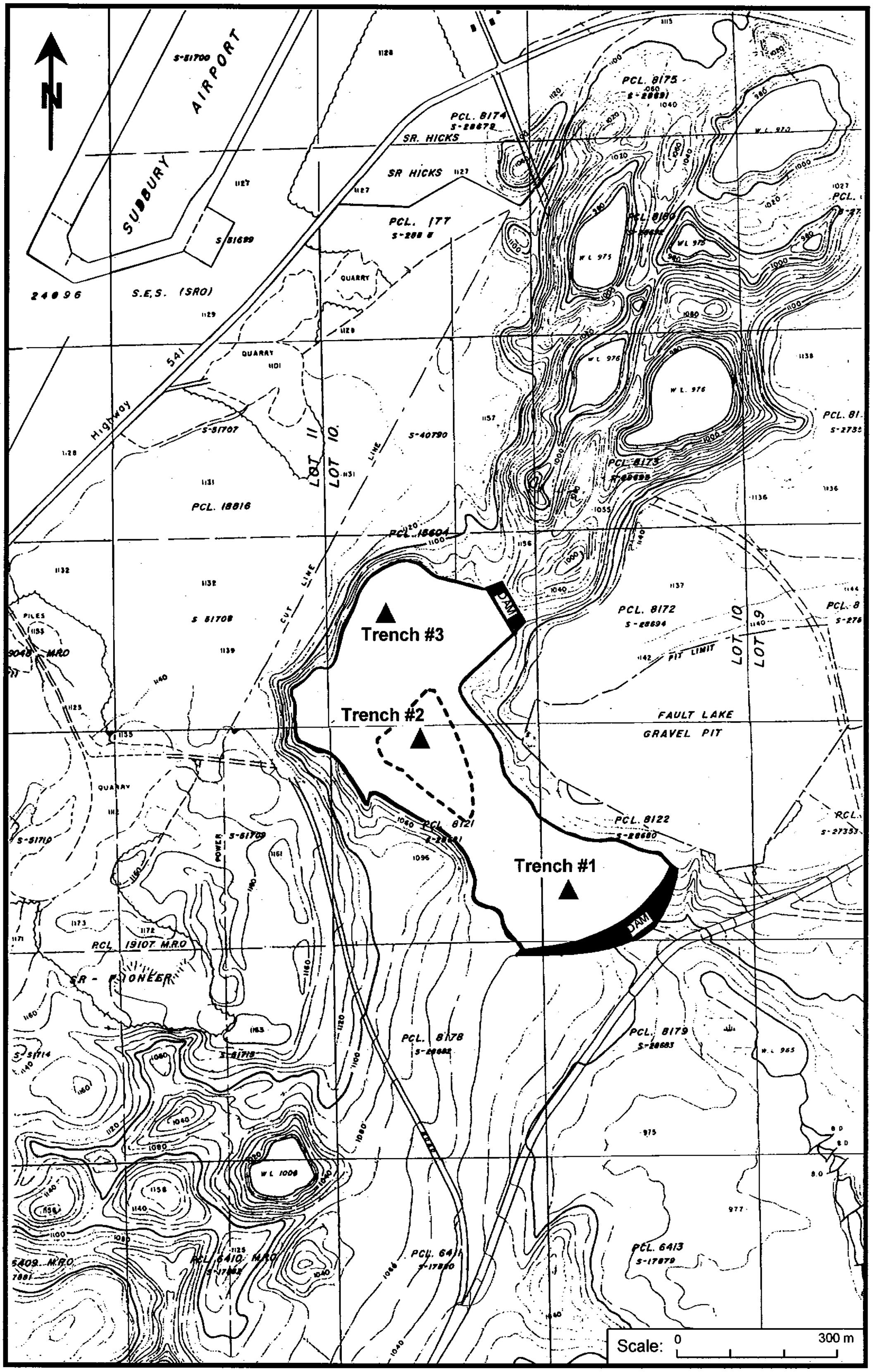


Figure 6. Trench location plan.

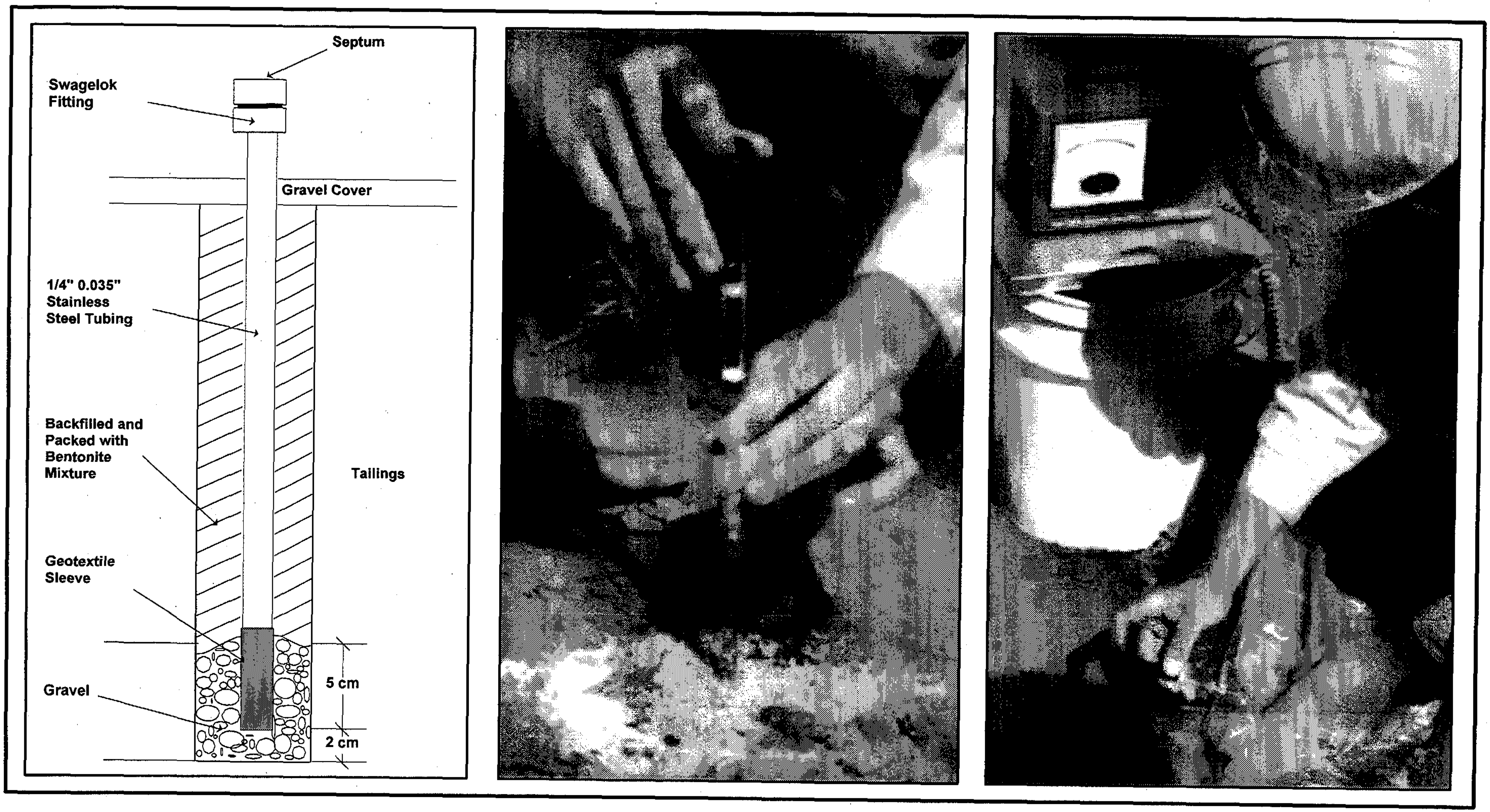


Figure 7. Measurement of pore-gas oxygen concentration..

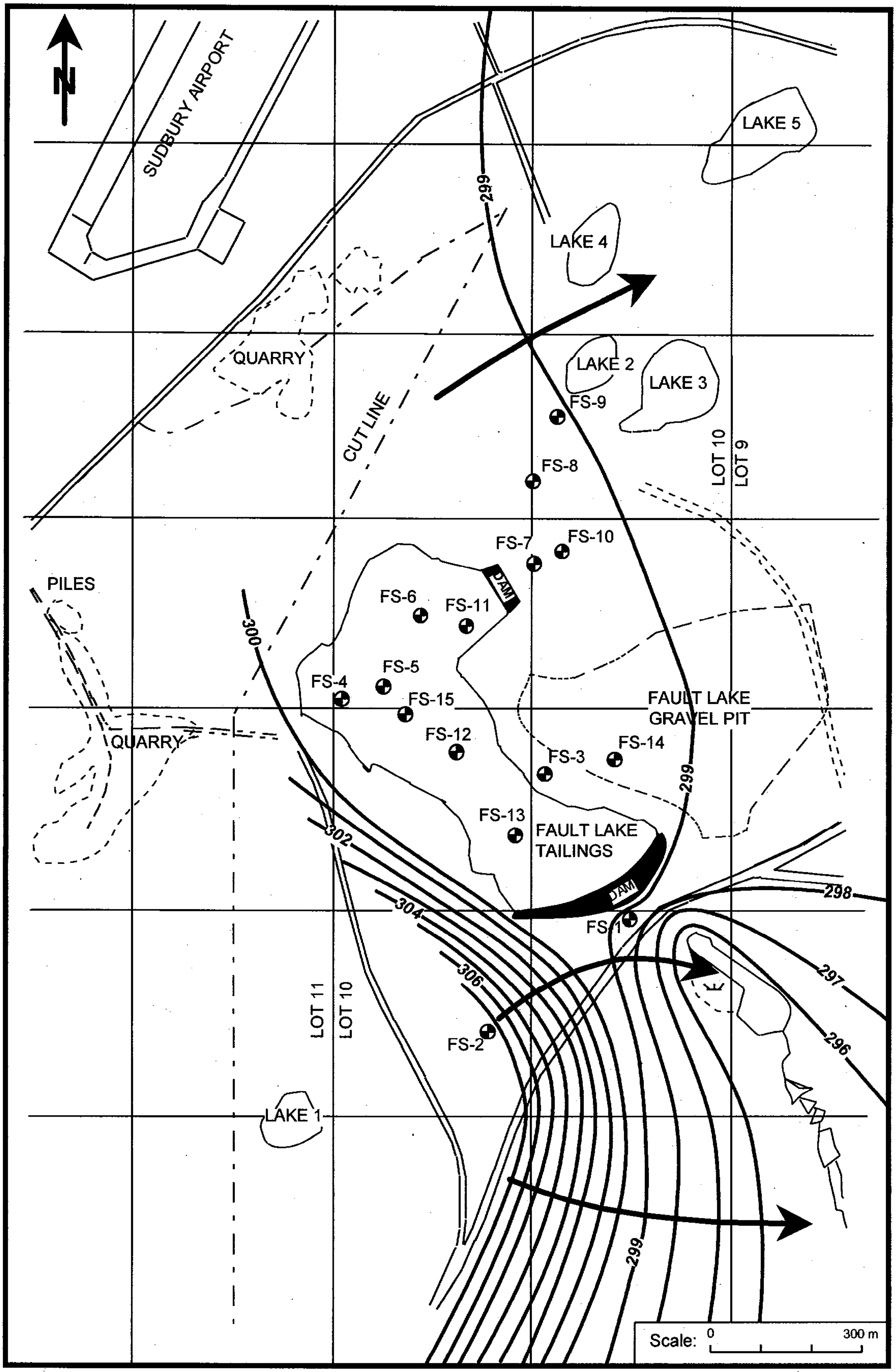


Figure 8. Generalized watertable contour plan.

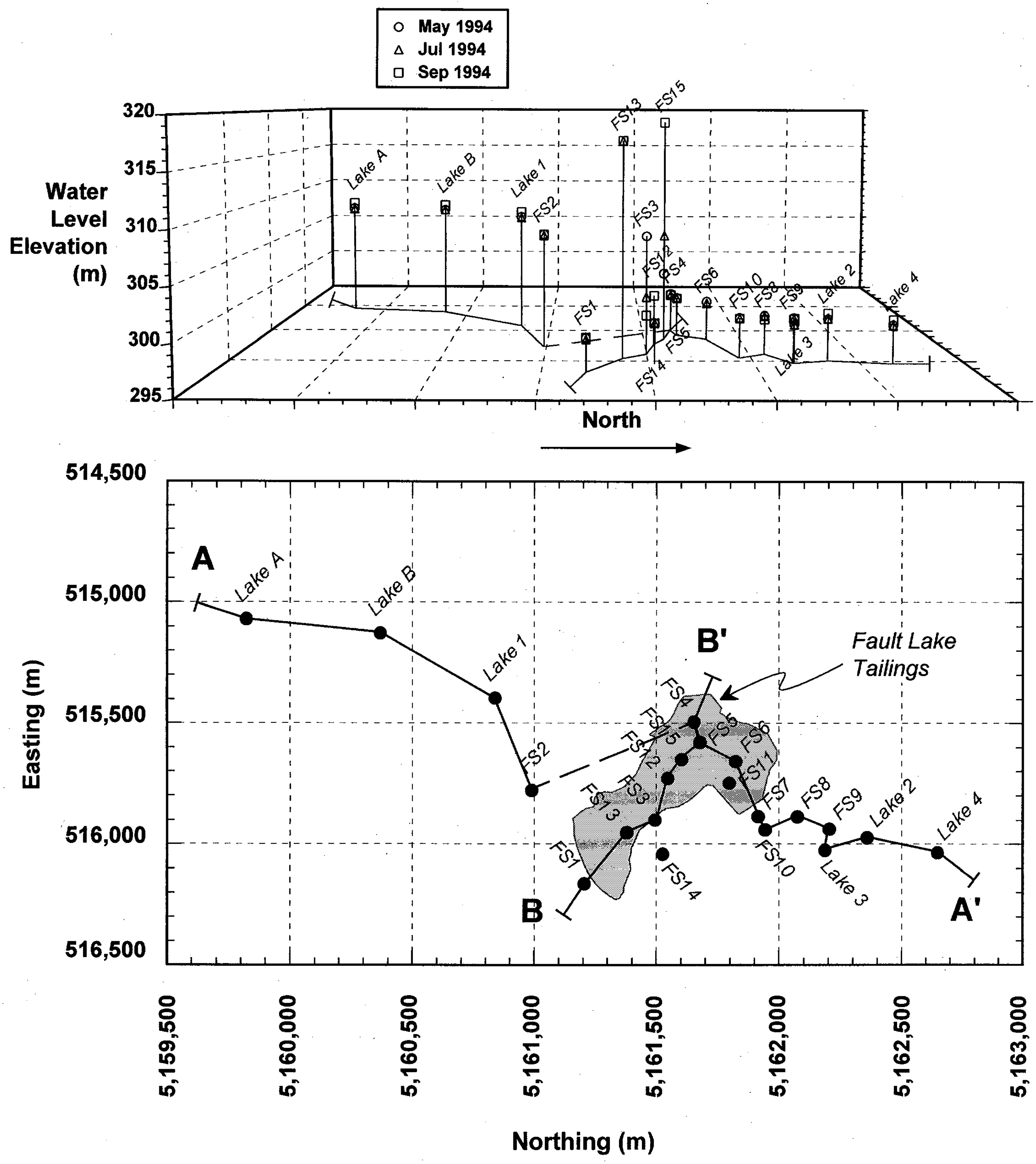


Figure 9. Cross sectional location plan and water level elevations.

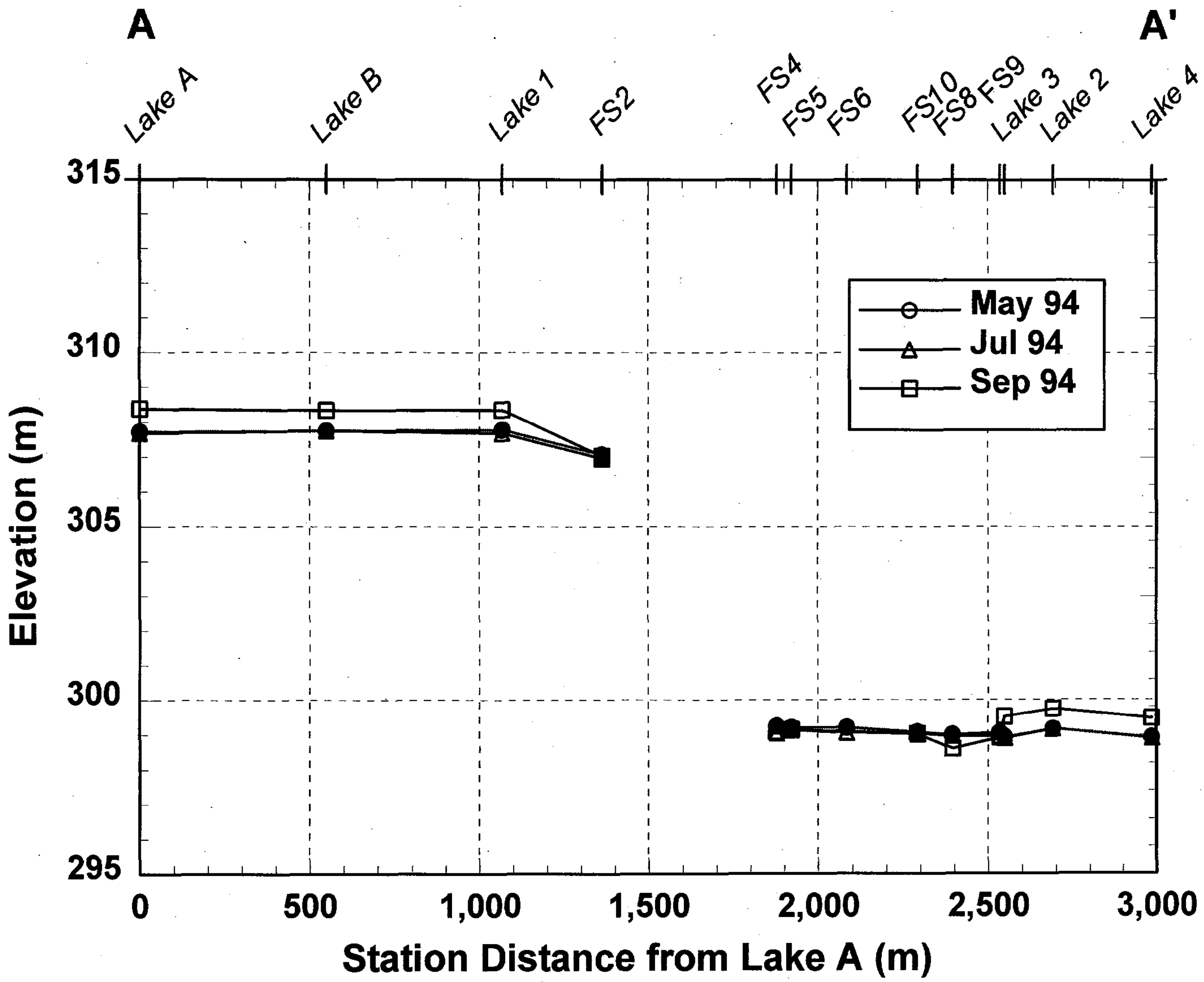


Figure 10. Regional water level elevations along section A-A'.

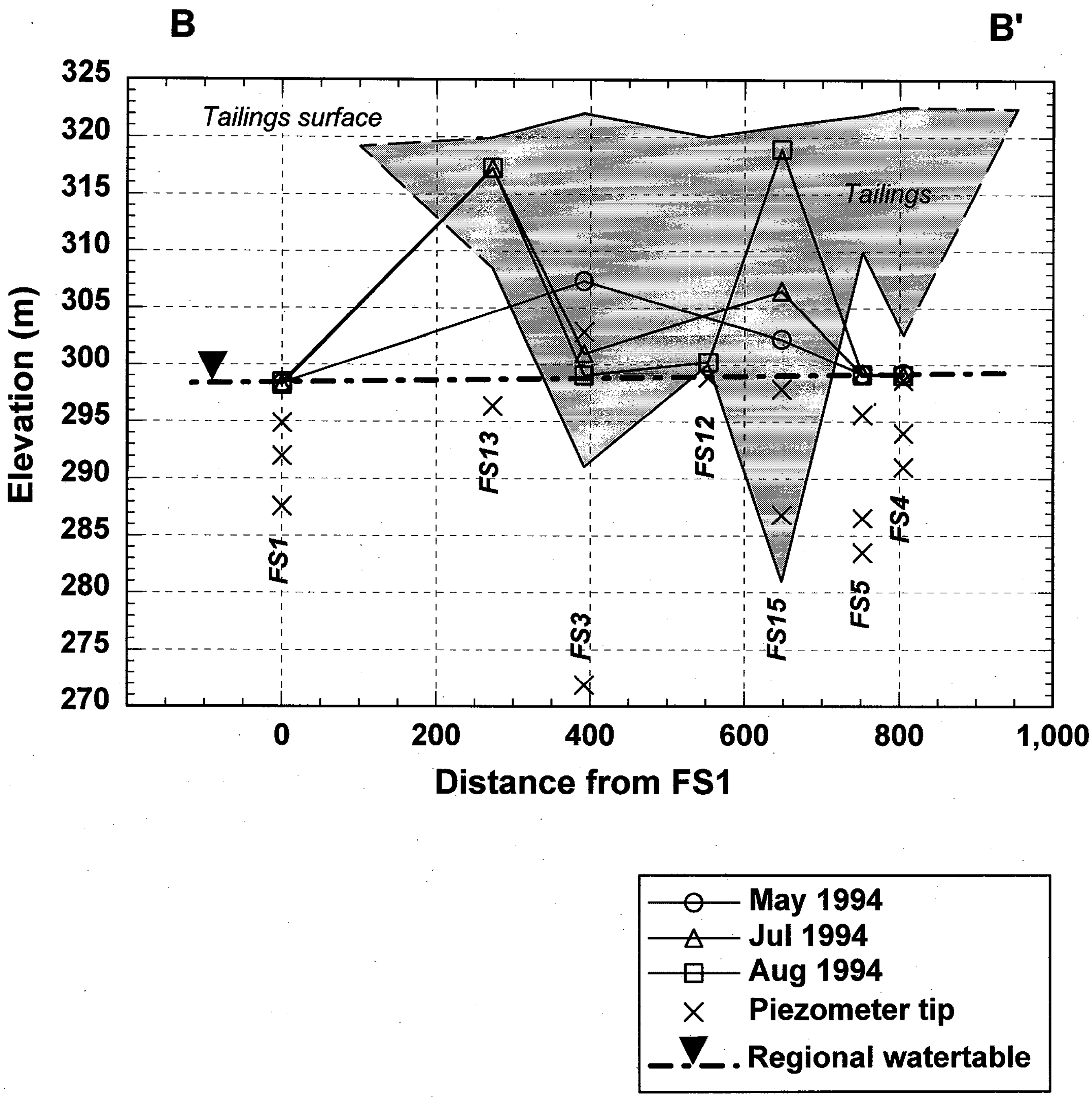


Figure 11. Water level elevations in the shallowest piezometers along section B-B'.

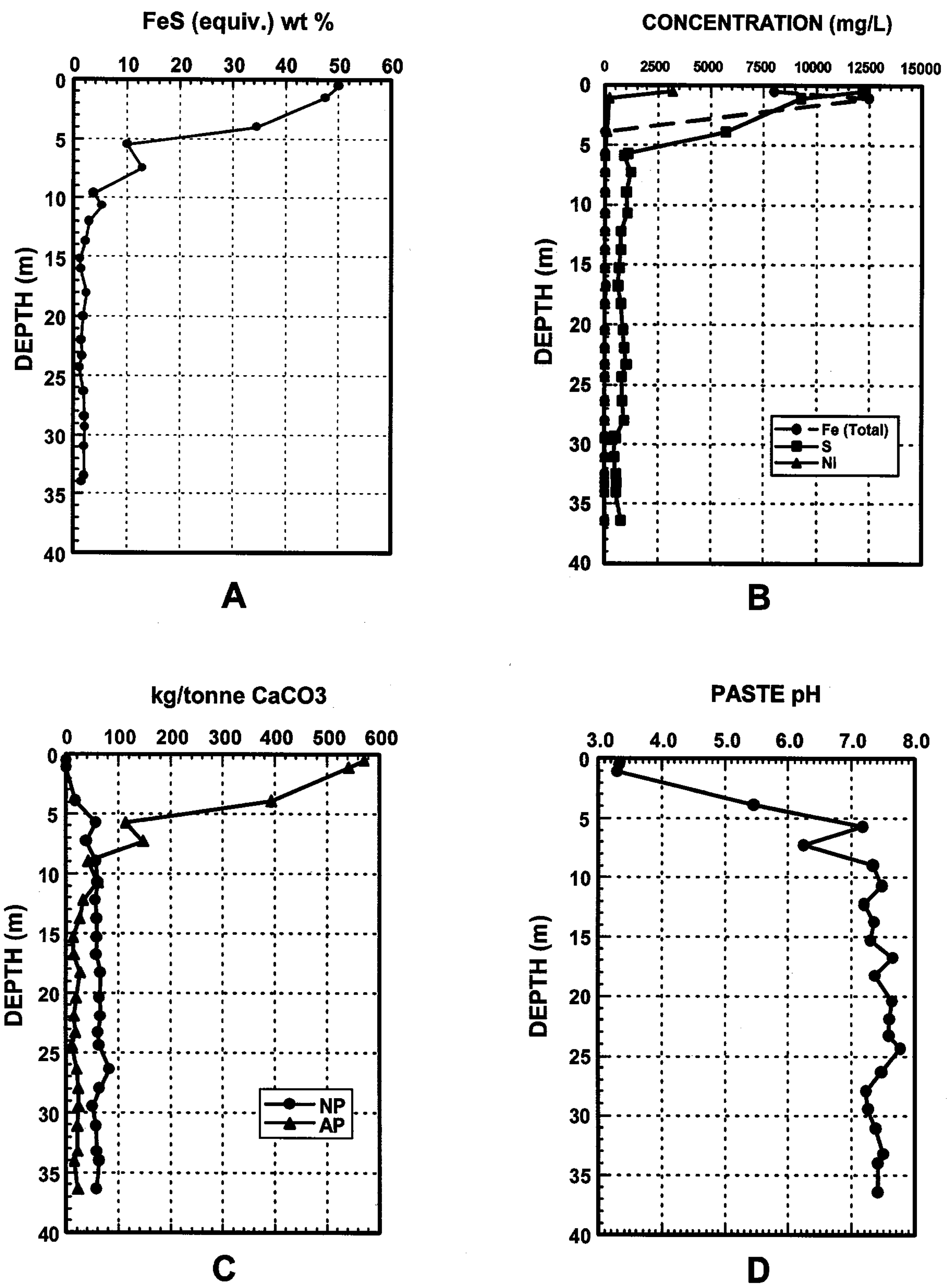


Figure 12. Equivalent FeS composition, porewater chemistry, acid and neutralization potential, and paste pH distribution by depth at borehole FS15-A.

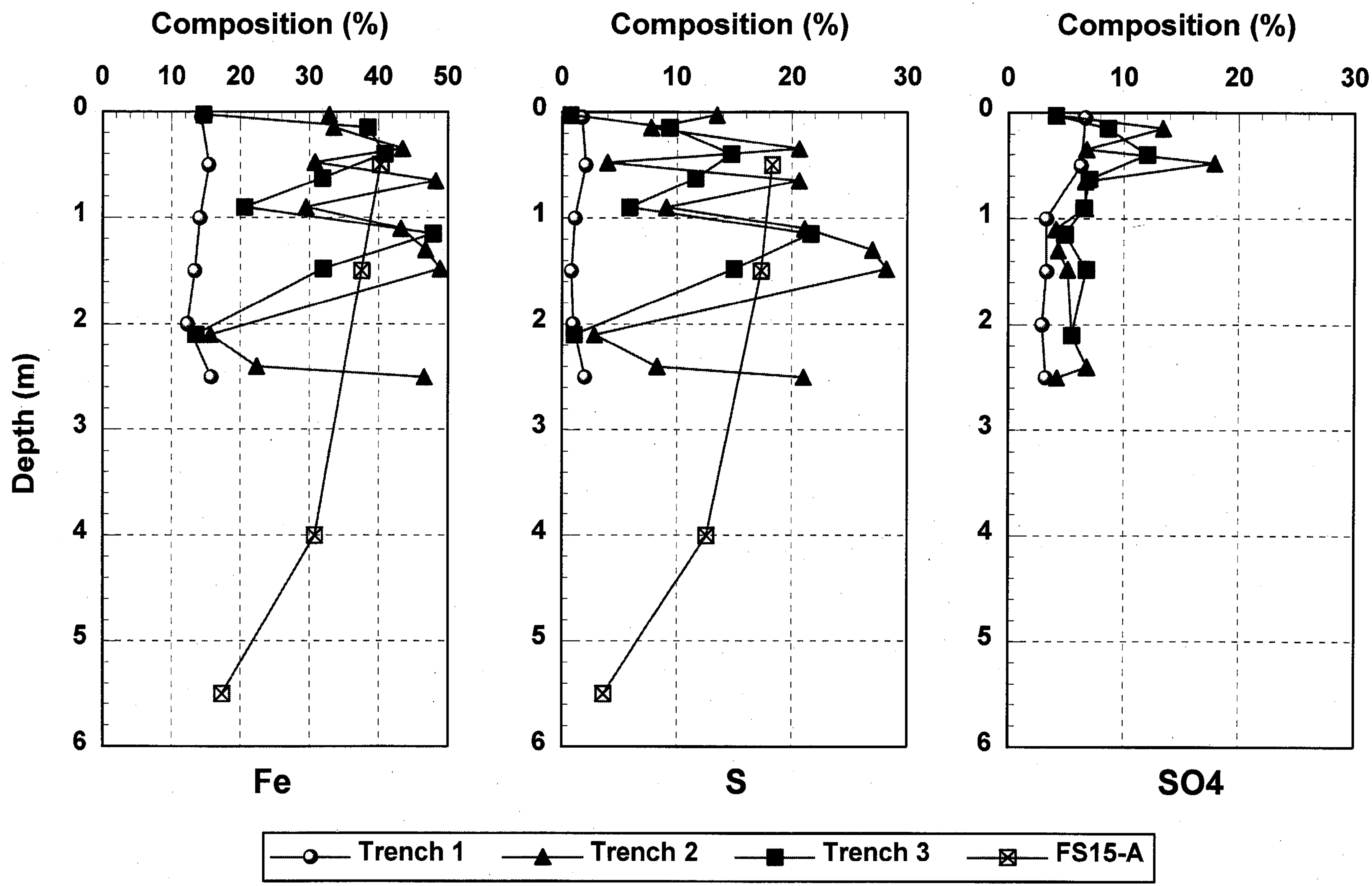


Figure 13. Iron and sulphur composition of tailings samples taken from the three trenches and borehole FS15-A.

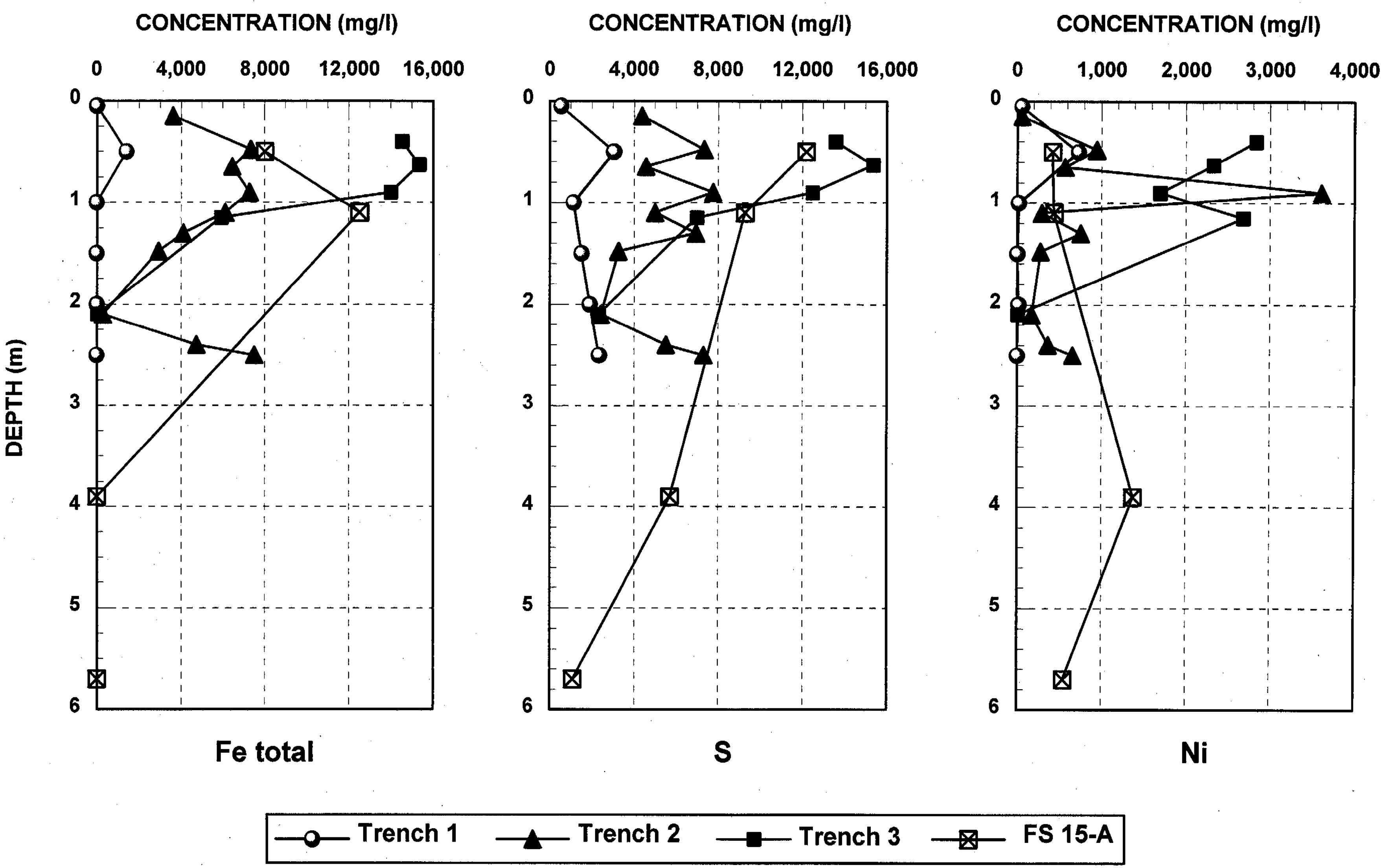


Figure 14. Porewater chemistry for tailings samples taken from the three trenches and borehole FS15-A.

APPENDIX A

Groundwater monitoring station data

NORANDA TECHNOLOGY CENTRE - BOREHOLE AND PIEZOMETER INSTALLATION LOG

PROJECT: **Fault Lake Tailings, Falconbridge**

BOREHOLE ID: **FS15-A**

PIEZO. INSIDE RADIUS (r): **12 mm**

COORDINATES: N **5161600.09 m**

E **515650.20 m**

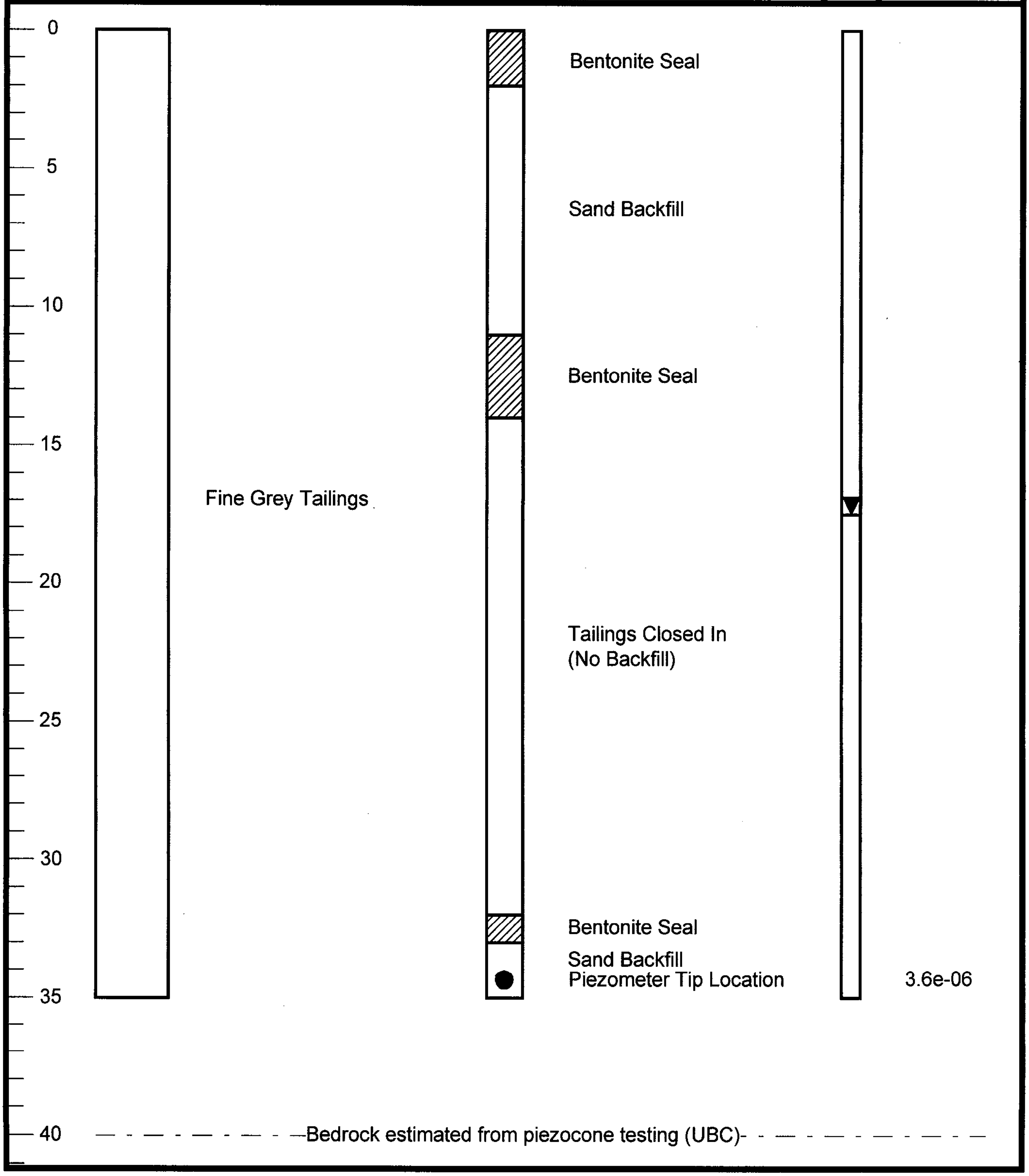
GROUND ELEVATION: **321.00 m**

CORE SIZE: **0.15 m**

PIEZO. TIP RADIUS (R): **8 mm**

PIEZO. TIP LENGTH (l): **26 cm**

DEPTH (m)	CORE DESCRIPTION	BOREHOLE FILL DESCRIPTION	WATER LEVELS	HYDRAULIC CONDUCTIVITY (cm/s)



NORANDA TECHNOLOGY CENTRE - BOREHOLE AND PIEZOMETER INSTALLATION LOG

PROJECT: **Fault Lake Tailings, Falconbridge**
BOREHOLE ID: **FS15-B**
PIEZO. INSIDE RADIUS (r): **12 mm**

COORDINATES: N **5161604.97 m**
GROUND ELEVATION: **321.00 m**
PIEZO. TIP RADIUS (R): **8 mm**

E **515649.59 m**
CORE SIZE: **0.15 m**
PIEZO. TIP LENGTH (l): **26 cm**

DEPTH (m)	CORE DESCRIPTION	BOREHOLE FILL DESCRIPTION	WATER LEVELS	HYDRAULIC CONDUCTIVITY (cm/s)

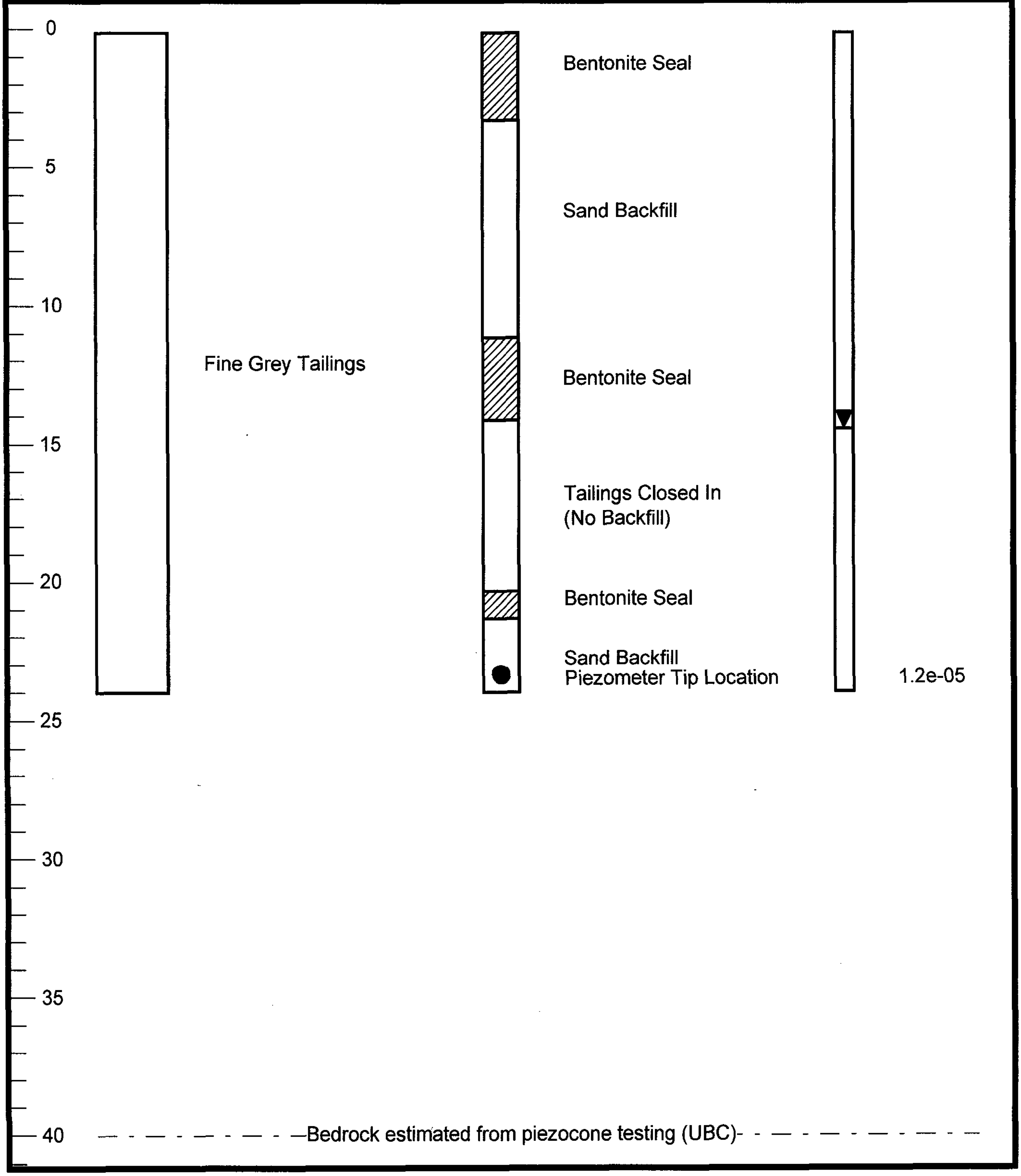


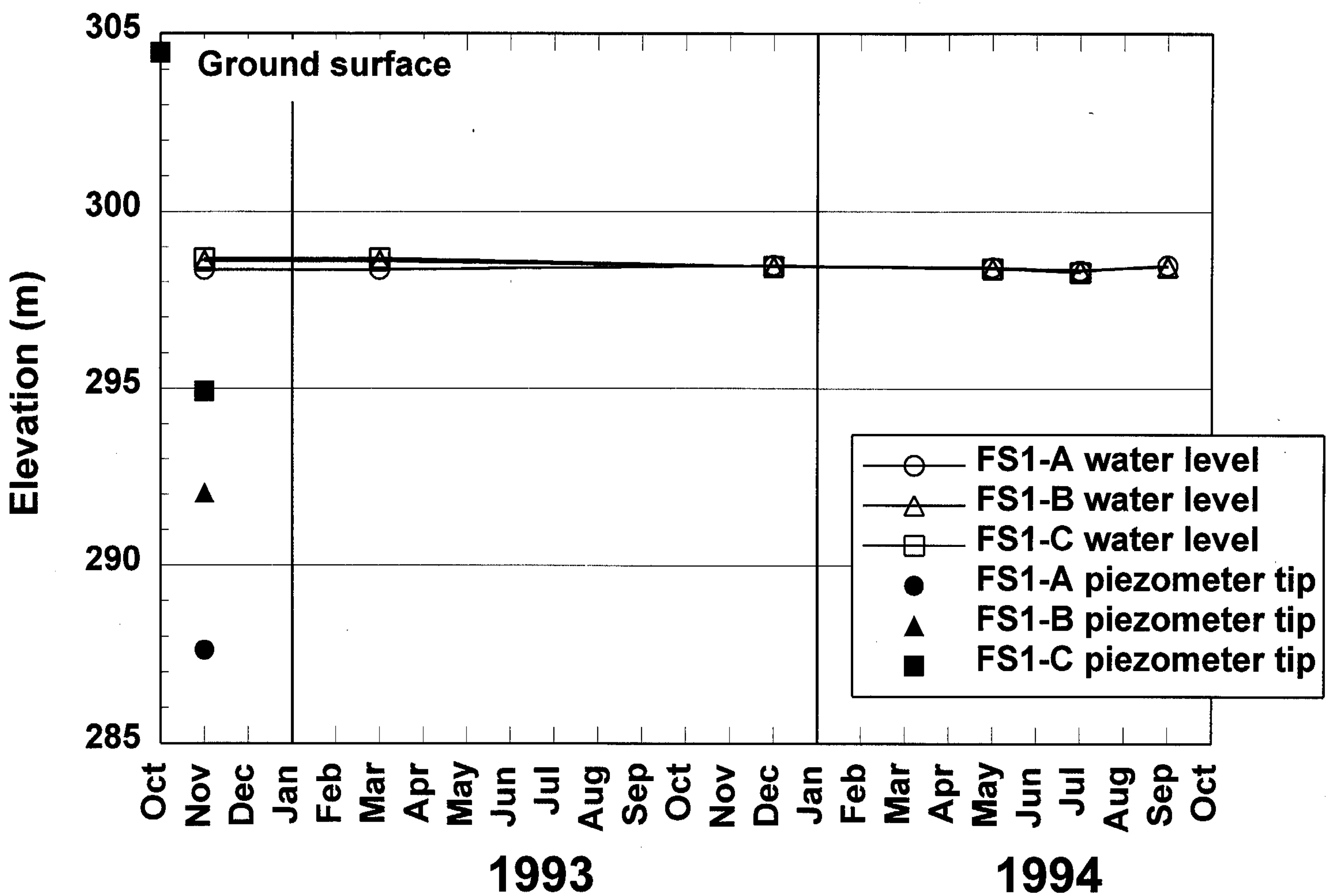
Table A1. Location of groundwater monitoring stations.

Station	Northing (m)	Easting (m)
FS1	5161204.9	516163.5
FS2	5160988.2	515777.6
FS3	5161495.7	515900.7
FS4	5161653.3	515495.0
FS5	5161677.0	515577.9
FS6	5161823.3	515659.0
FS7	5161914.8	515885.8
FS8	5162074.8	515886.4
FS9	5162204.6	515937.6
FS10	5161943.7	515941.2
FS11	5161797.4	515748.6
FS12	5161546.0	515727.9
FS13	5161378.6	515952.5
FS14	5161526.2	516041.2
FS15	5161280.1	515649.9

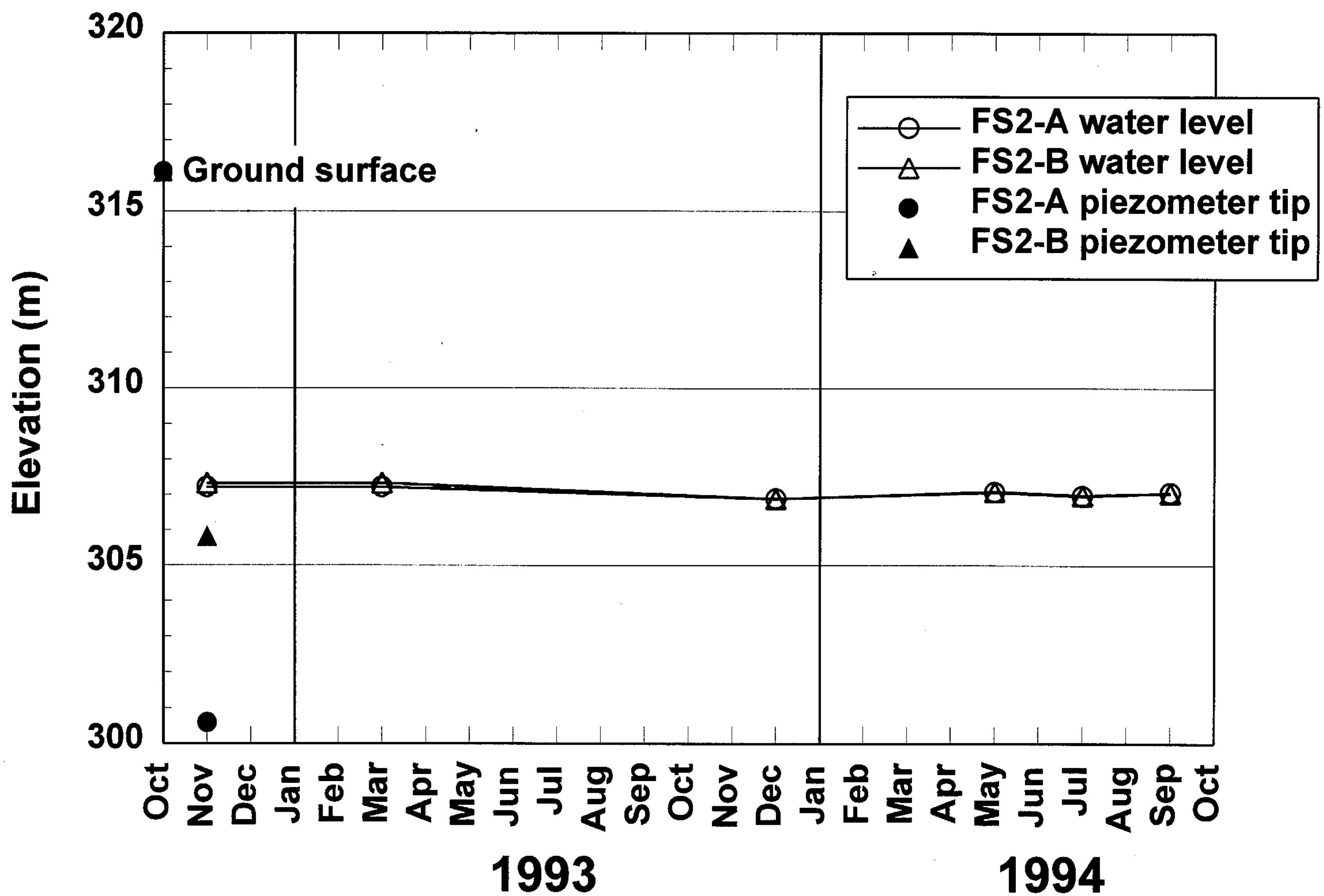
Table A2: Water level elevations in piezometers at Fault Lake tailngs site.

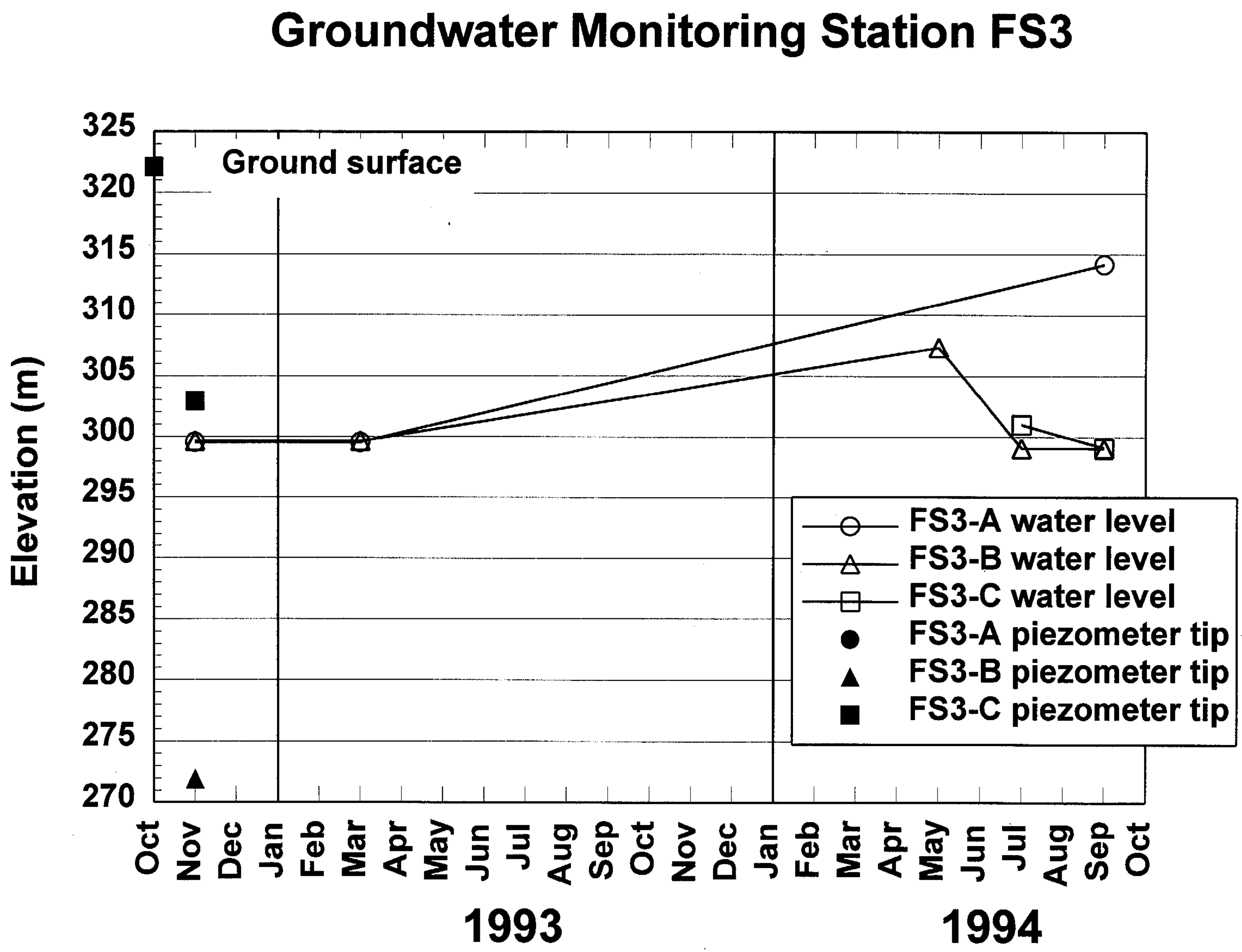
Piezometer	Elevations									
	Ground (m)	Top of Piezometer (m)	Tip of Piezometer (m)	Depth of tip below ground (m)	Nov 24, 92 Water (m)	Mar 26, 93 Water (m)	Dec 8, 93 Water (m)	May 21, 94 Water (m)	Jul 16, 94 Water (m)	Sep 3, 94 Water (m)
FS1-A	304.468	305.270	287.620	16.848	298.360	298.353	298.470	298.440	298.320	298.470
FS1-B		305.237	292.047	12.422	298.652	298.603	298.447	298.420	298.337	298.447
FS1-C		305.240	294.920	9.549	298.695	298.673	298.450	298.420	298.280	dry
FS2-A	316.112	316.843	300.593	15.518	307.233	307.208	306.873	307.063	306.953	307.043
FS2-B		316.843	305.823	10.288	307.248	307.318	306.873	307.083	306.973	307.043
FS3-A	322.117	322.988	262.988	60.000	299.528	299.525	--	--	--	314.168
FS3-B		322.918	271.903	50.213	299.888	299.630	--	307.358	299.068	299.048
FS3-C		322.943	302.920	19.197	dry	dry	--	--	301.023	299.093
FS4-A	322.635	323.357	291.017	31.618	299.507	291.910	--	299.097	298.927	299.157
FS4-B		323.394	294.004	28.631	299.454	299.460	--	299.174	299.004	299.174
FS4-C		323.464	298.654	23.981	299.584	299.510	--	299.249	299.064	299.084
FS5-A	321.934	322.802	283.522	38.411	299.582	299.582	--	299.322	299.082	299.152
FS5-B		322.741	286.541	35.392	301.766	301.766	--	299.666	299.101	--
FS5-C		322.845	295.645	26.289	299.565	299.565	--	299.205	299.145	--
FS6-A	320.897	321.711	287.541	33.356	300.301	300.301	--	299.211	299.066	--
FS6-B		321.419	298.949	21.949	299.519	299.519	--	dry	dry	dry
FS6-C		321.440	311.720	9.177	311.740	311.740	--	dry	dry	dry
FS7-A	309.894	310.653	301.703	8.191	dry	dry	dry	dry	dry	dry
FS8-A	302.762	303.508	298.408	4.353	299.288	--	299.098	298.998	298.968	298.608
FS9-A	302.579	303.325	291.025	11.553	299.325	--	299.125	298.815	298.975	298.935
FS9-B		303.414	292.214	10.365	299.264	--	299.074	298.969	298.964	298.924
FS9-C		303.469	298.669	3.910	299.369	--	299.169	299.049	dry	dry
FS10-A	304.194	304.953	294.133	10.061	299.313	--	299.133	299.053	299.018	299.003
FS10-B		304.959	296.699	7.495	299.349	--	299.159	299.079	299.039	299.019
FS11-A	320.379	320.602	299.172	21.207	299.352	299.309	--	--	dry	dry
FS12-A	320.044	320.044	298.894	21.150	299.054	299.124	--	--	dry	300.244
FS13-A	319.282	319.946	296.396	22.886	299.446	299.460	--	--	317.251	317.296
FS14-A	322.970	323.193	292.843	30.127	299.243	296.820	--	298.403	298.963	299.593
FS14-B		324.015	297.365	25.605	299.460	299.280	--	299.165	299.105	299.145
FS15-A	321.000	321.826	286.826	35.000	--	--	--	306.136	307.096	312.926
FS15-B		321.865	297.865	24.000	--	--	--	302.265	306.505	318.965

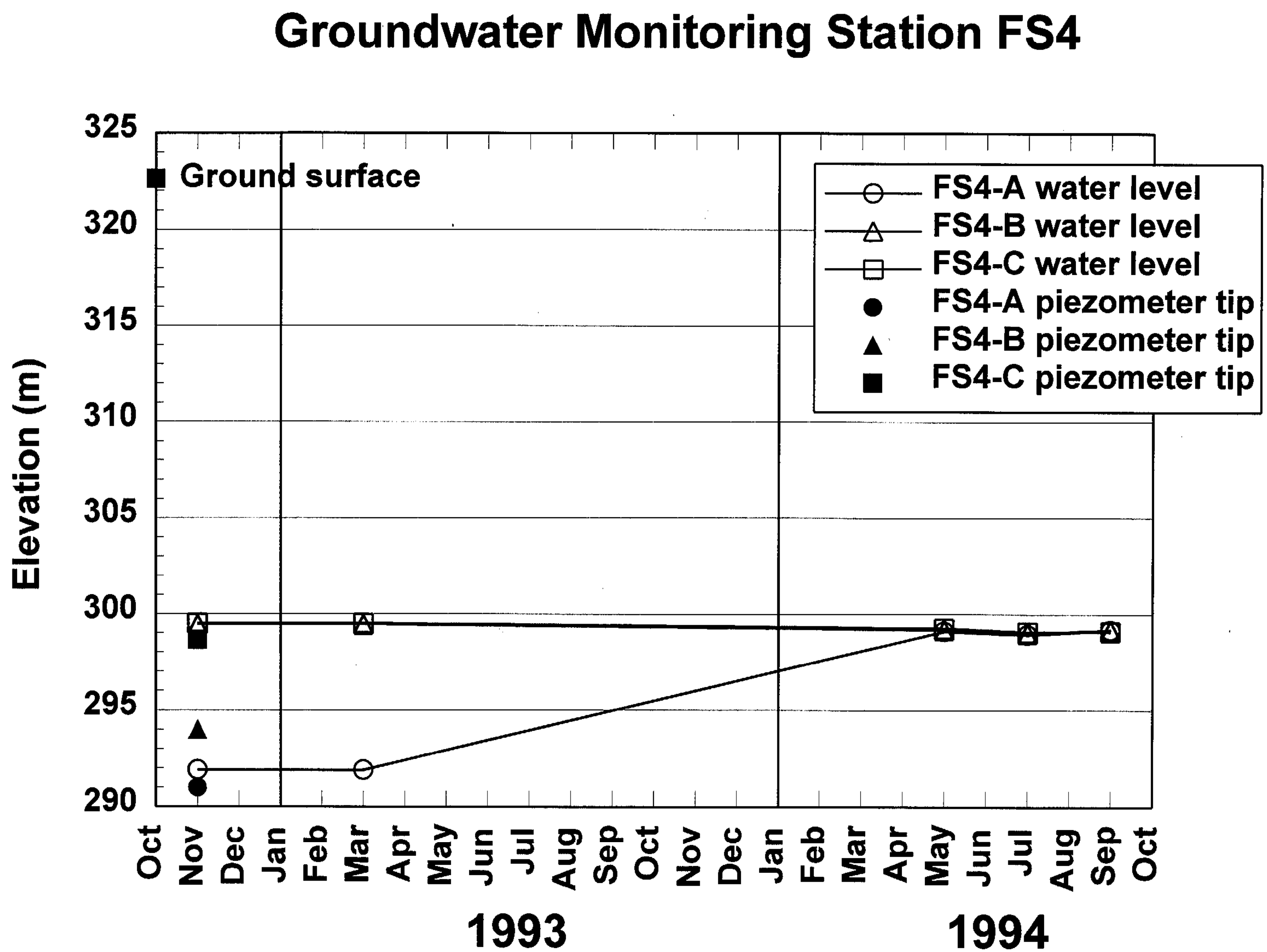
Groundwater Monitoring Station FS1

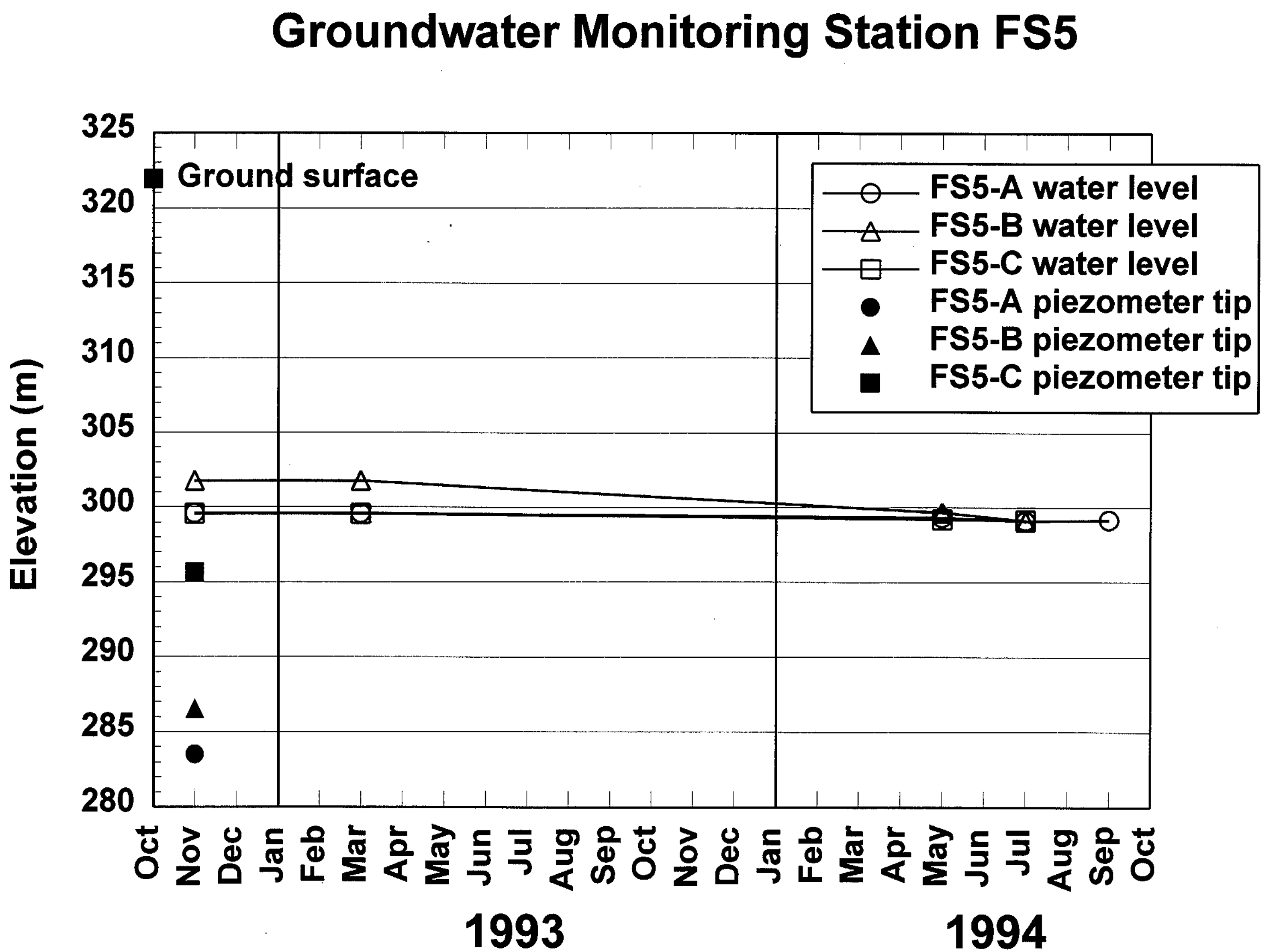


Groundwater Monitoring Station FS2

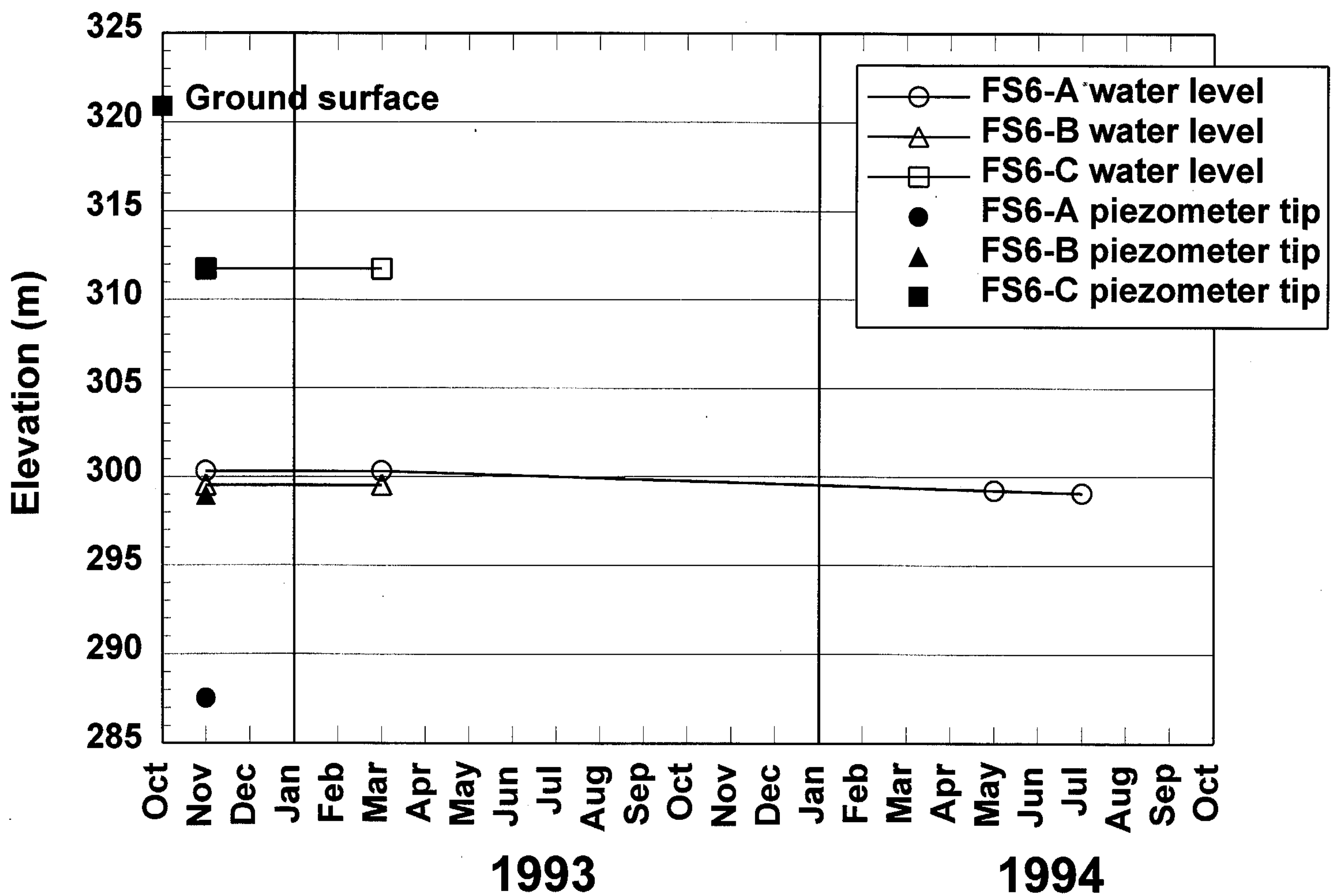


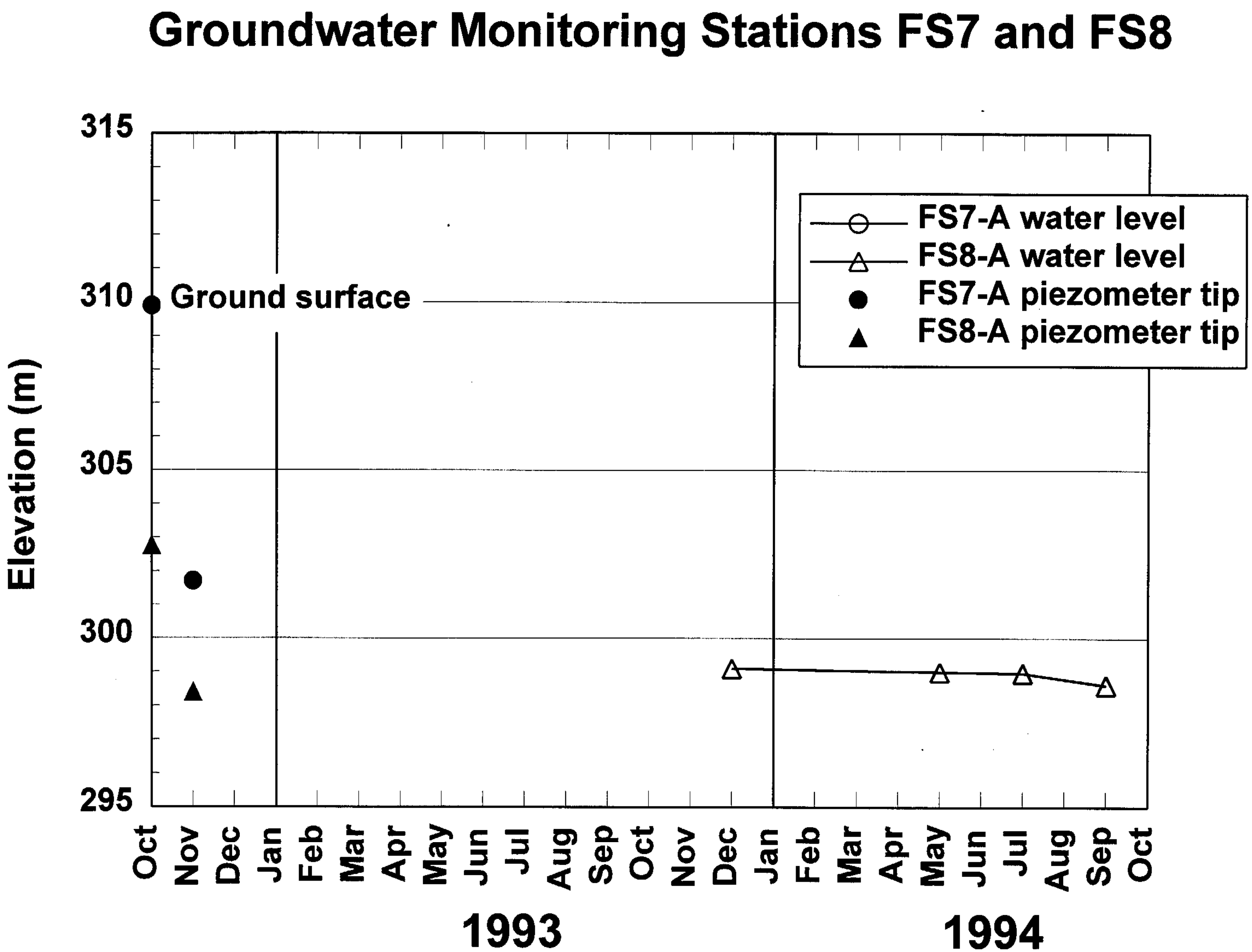

Groundwater Monitoring Station FS3
Ground surface
Elevation (m)
325
320
315
310
305
300
295
290
285
280
275
270
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1993
1994
FS3-A water level
FS3-B water level
FS3-C water level
FS3-A piezometer tip
FS3-B piezometer tip
FS3-C piezometer tip


Groundwater Monitoring Station FS4
Elevation (m)
325
320
315
310
305
300
295
290
Ground surface
FS4-A water level
FS4-B water level
FS4-C water level
FS4-A piezometer tip
FS4-B piezometer tip
FS4-C piezometer tip
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
1993
1994

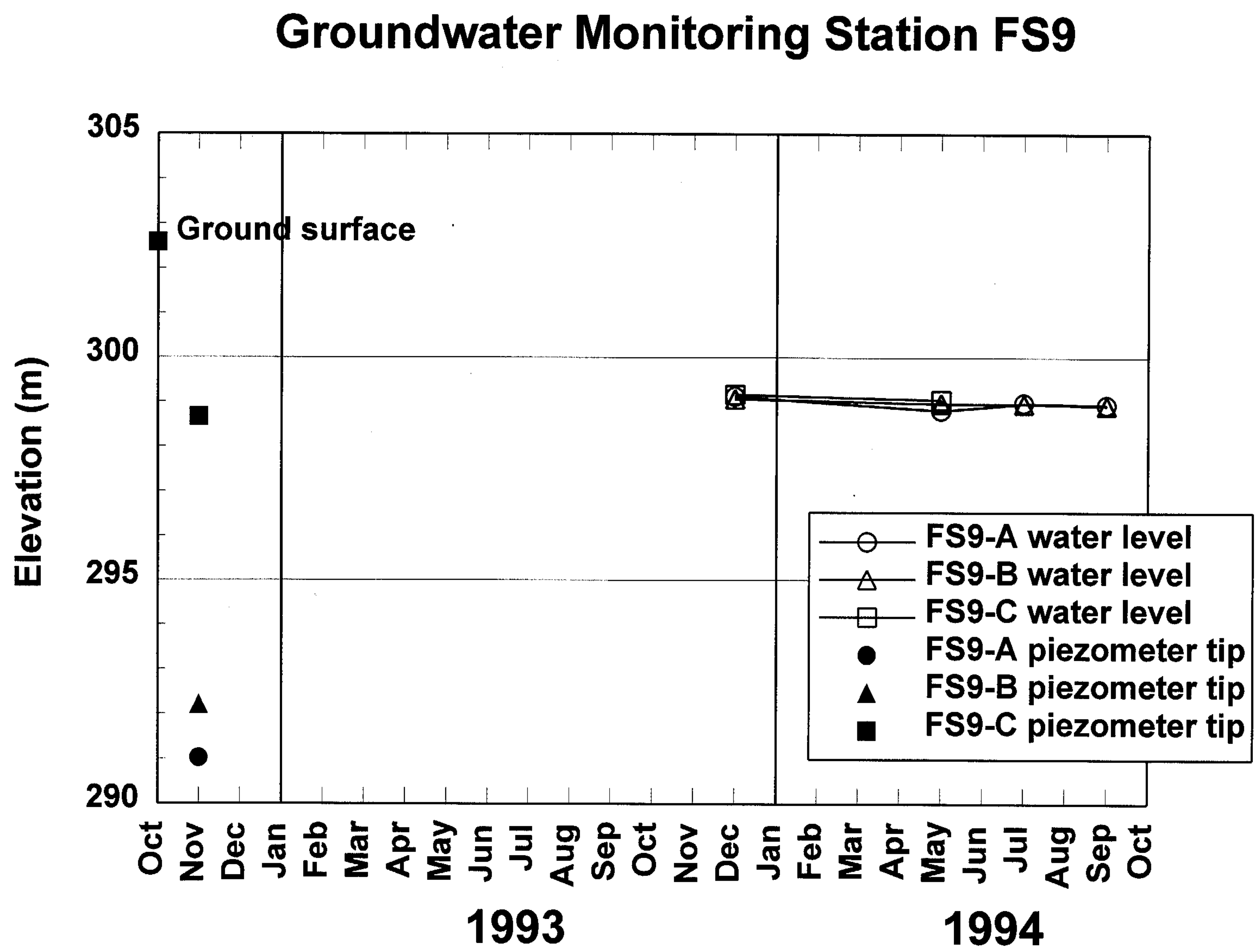

Groundwater Monitoring Station FS5
Elevation (m)
325
320
315
310
305
300
295
290
285
280
Ground surface
FS5-A water level
FS5-B water level
FS5-C water level
FS5-A piezometer tip
FS5-B piezometer tip
FS5-C piezometer tip
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
1993
1994

Groundwater Monitoring Station FS6

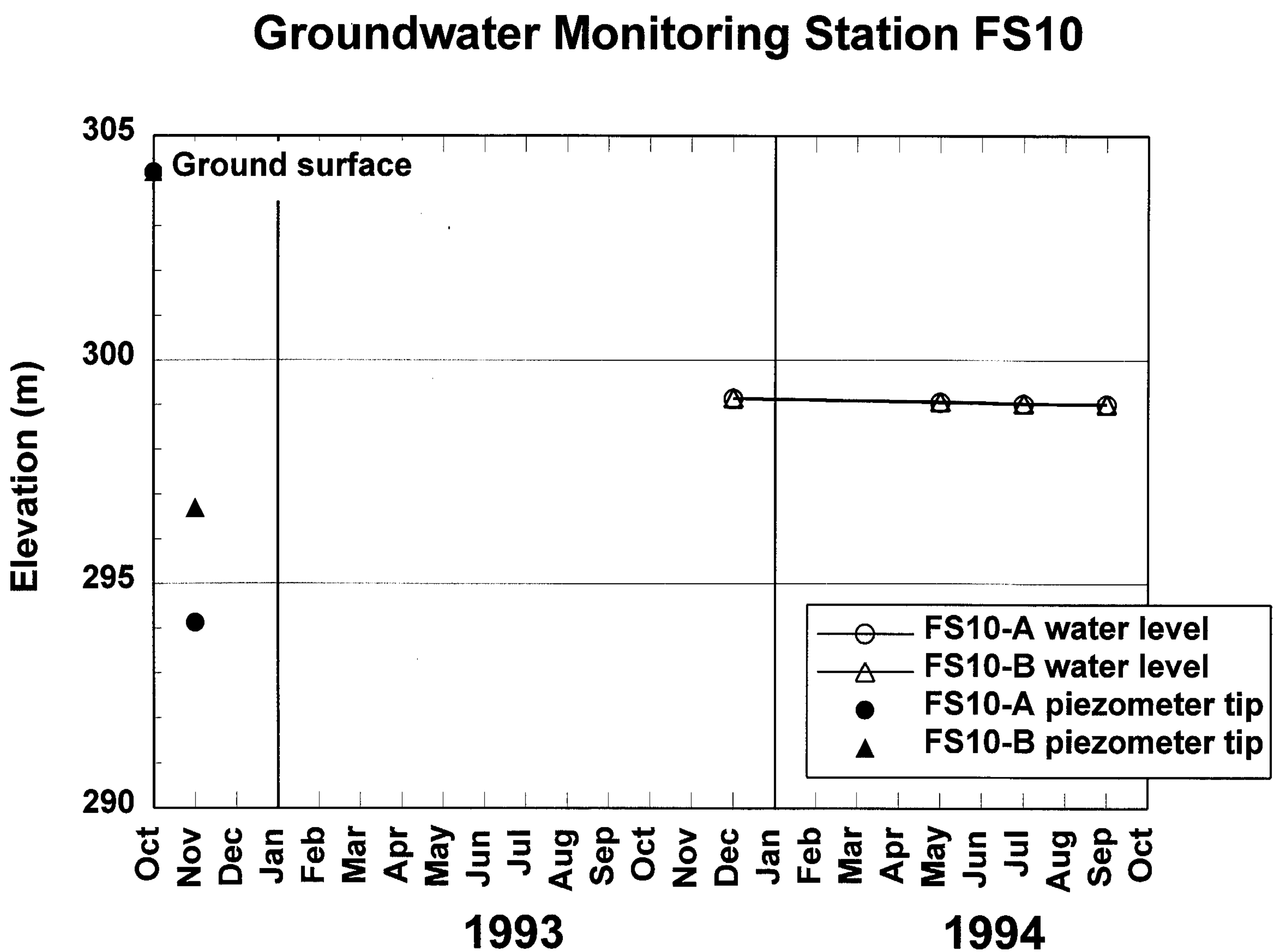


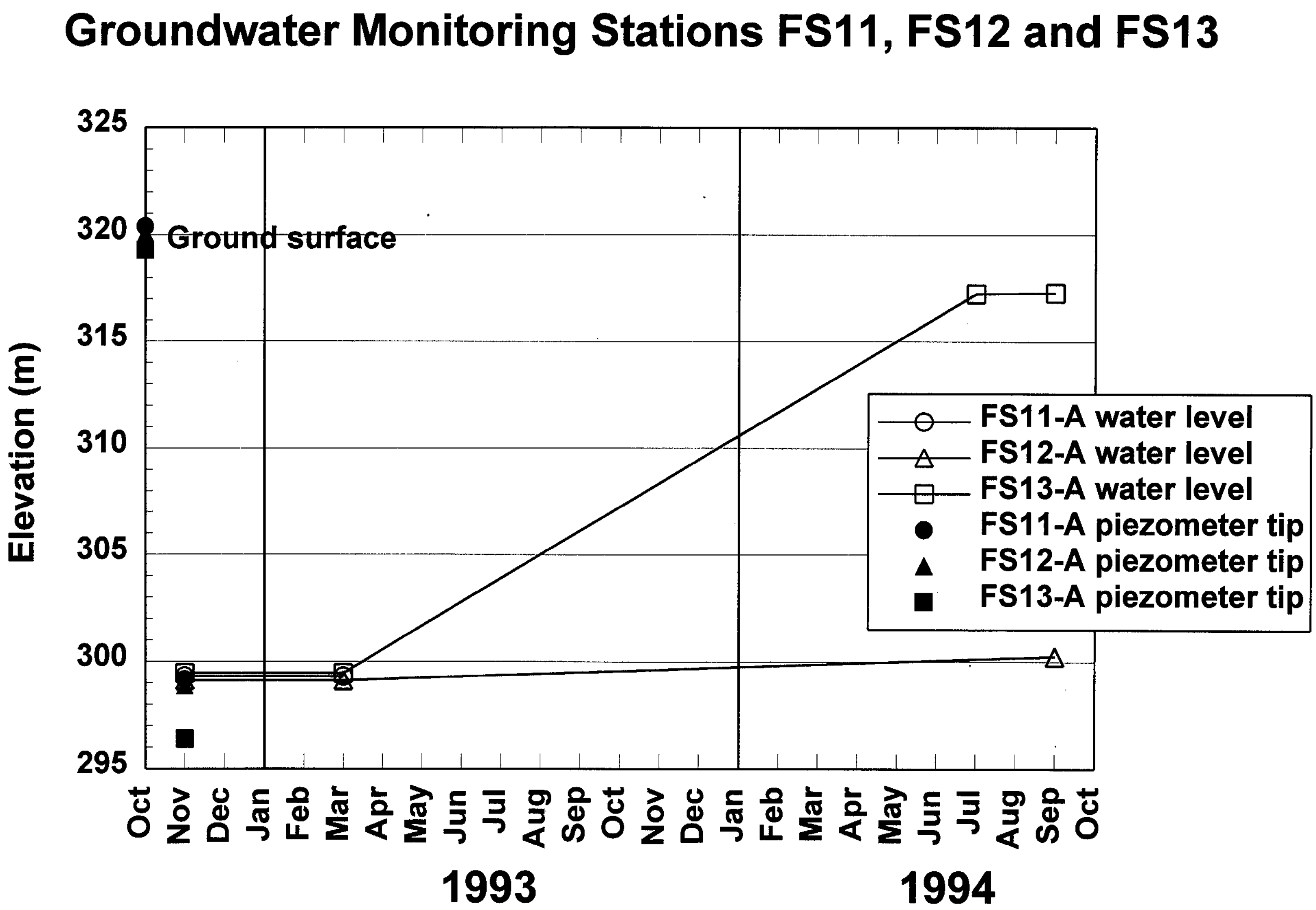


Groundwater Monitoring Stations FS7 and FS8
Elevation (m)
315
310
305
300
295
Ground surface
FS7-A water level
FS8-A water level
FS7-A piezometer tip
FS8-A piezometer tip
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1993
1994



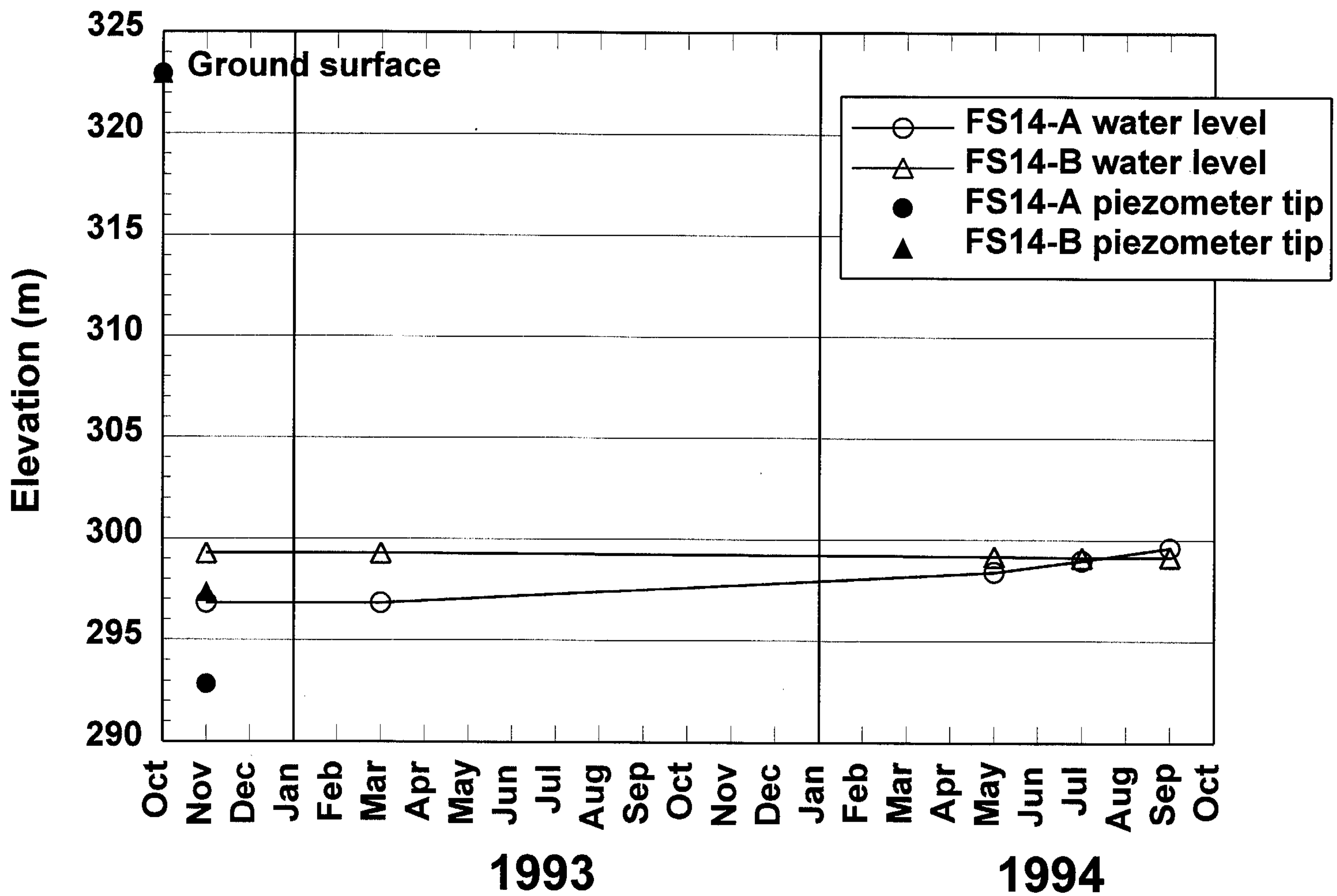
Groundwater Monitoring Station FS9
305
300
295
290
Elevation (m)
Ground surface
FS9-A water level
FS9-B water level
FS9-C water level
FS9-A piezometer tip
FS9-B piezometer tip
FS9-C piezometer tip
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1993
1994

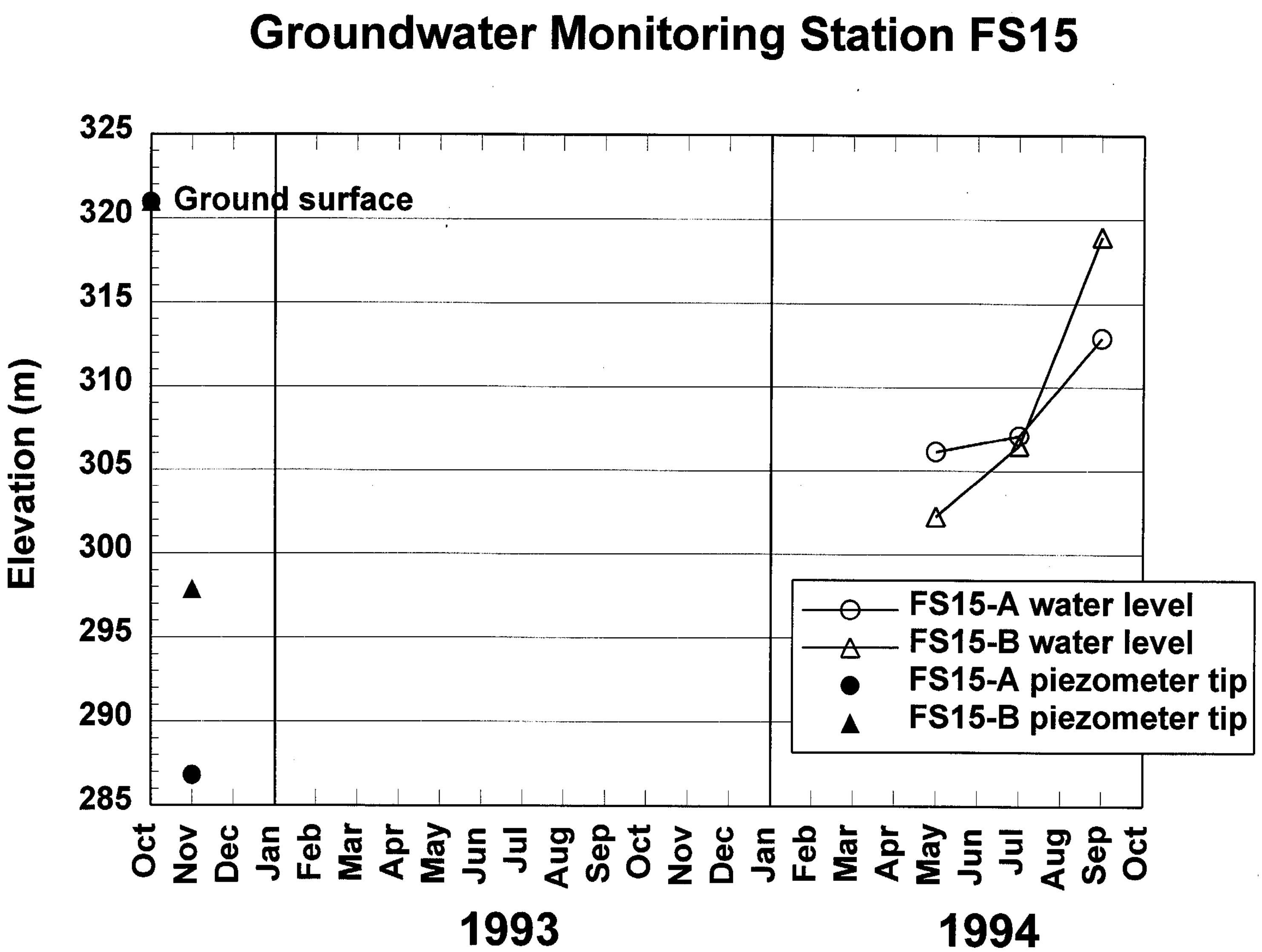

Groundwater Monitoring Station FS10
305
300
295
290
Elevation (m)
Ground surface
FS10-A water level
FS10-B water level
FS10-A piezometer tip
FS10-B piezometer tip
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1993
1994



Groundwater Monitoring Stations FS11, FS12 and FS13
Elevation (m)
325
320
315
310
305
300
295
Ground surface
FS11-A water level
FS12-A water level
FS13-A water level
FS11-A piezometer tip
FS12-A piezometer tip
FS13-A piezometer tip
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1993
1994

Groundwater Monitoring Station FS14





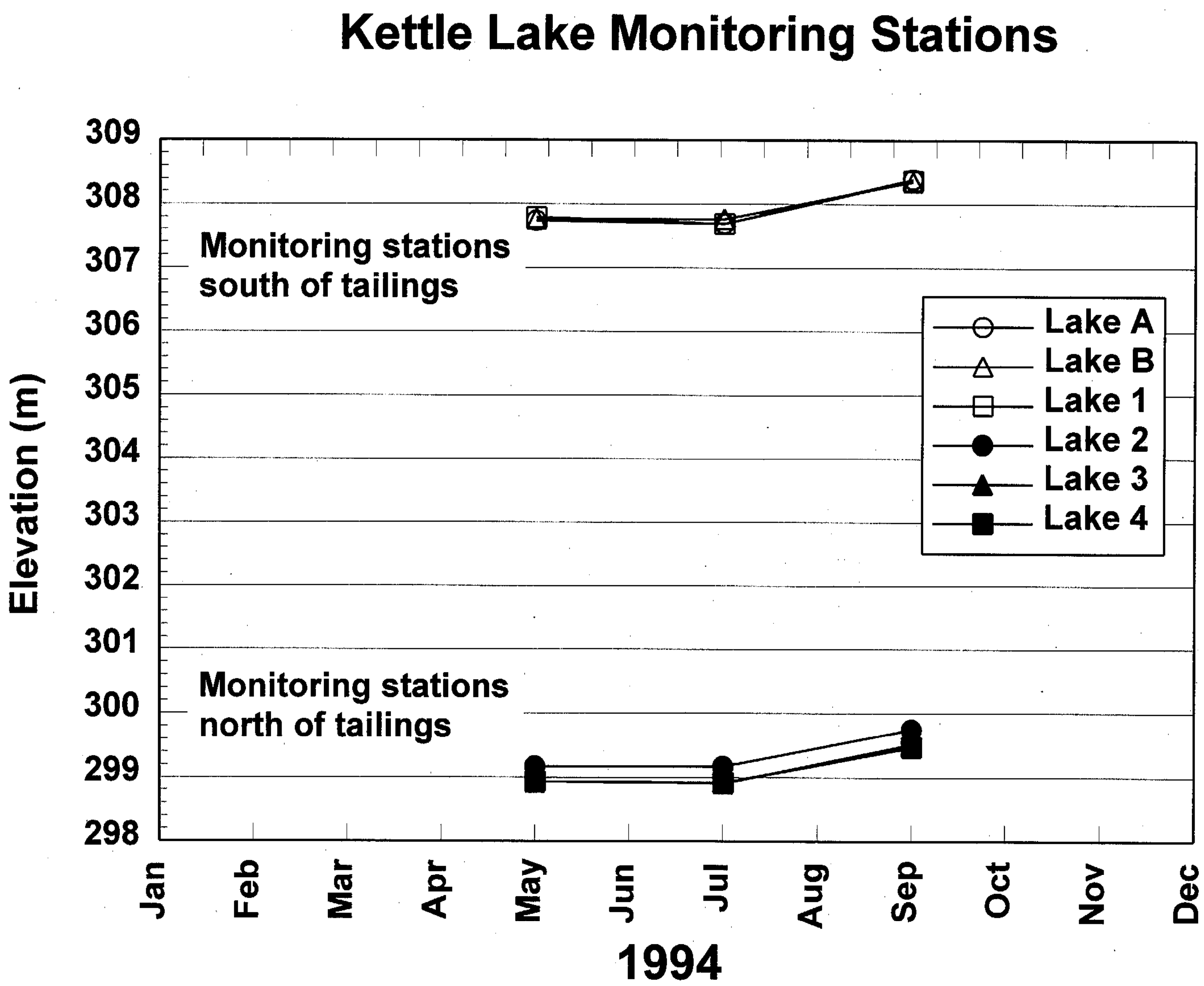
Groundwater Monitoring Station FS15
Elevation (m)
325
320
315
310
305
300
295
290
285
Ground surface
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
1993
1994
FS15-A water level
FS15-B water level
FS15-A piezometer tip
FS15-B piezometer tip

APPENDIX B

Surface water monitoring station data

Table B1. Location and water level elevations of kettle lakes.

Lake	Location of gauge UTM Co-ordinates (m)		Elevation				
	Northing (m)	Easting (m)	Zero reading on Staff Plate (m)	May 27, 94 Water Level (m)	Jul 16, 94 Water Level (m)	Sep 3, 94 Water Level (m)	May 1984 Topo map Water Level (m)
A	5159502.9	515068.4	307.126	307.736	307.690	308.386	307.540
B	5160048.8	515126.3	307.220	307.760	307.763	308.350	307.240
1	5160519.0	515396.0	307.254	307.789	307.690	308.369	307.240
2	5162039.0	515973.3	298.545	299.165	299.165	299.745	297.480
3	5161866.2	516025.1	298.298	298.924	298.903	299.514	297.480
4	5162328.9	516035.4	298.343	298.931	298.917	299.471	297.180


Kettle Lake Monitoring Stations
Elevation (m)
309
308
307
306
305
304
303
302
301
300
299
298
Monitoring stations south of tailings
Monitoring stations north of tailings
Lake A
Lake B
Lake 1
Lake 2
Lake 3
Lake 4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1994

APPENDIX C

Laboratory Certificates of Analysis

Table C1. ICP detection limits in clean aqueous solutions.

Element	mg/L	Element	mg/L
Ag	0.01	Mn	0.001
Al	0.05	Mo	0.05
As	0.05	Na	0.05
B	0.05	Ni	0.005
Ba	0.01	Pb	0.05
Be	0.01	S	0.05
Ca	0.01	Sb	0.05
Cd	0.005	Se	0.05
Co	0.005	Si	0.01
Cr	0.005	Sn	0.05
Cu	0.005	Sr	0.05
Fe	0.005	Te	0.05
K	1	Tl	0.05
Li	0.05	Ti	0.1
Mg	0.1	Zn	0.005

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-102-13-56
Date: 1/11/94

A/To : P.Tibble M.Woyshner PROJET / PROJECT: V2-1 T03

Lab #	I.D.	Description	Al	As	Ca	Cd	Cu
327	93226	Water					
328	93227	Water	.31 mg/L	< .25 mg/L	83.79 mg/L	< .02 mg/L	< .02 mg/L
329	93228	Water					
330	93229	Water	.30 mg/L	< .25 mg/L	130.62 mg/L	< .02 mg/L	< .02 mg/L
331	93230	Water					
332	93231	Water	.46 mg/L	< .25 mg/L	38.56 mg/L	< .02 mg/L	< .02 mg/L
333	93232	Water					
334	93233	Water	.32 mg/L	< .25 mg/L	38.65 mg/L	< .02 mg/L	< .02 mg/L
335	93234	Water					
336	93235	Water	.30 mg/L	< .25 mg/L	15.78 mg/L	< .02 mg/L	< .02 mg/L
337	93236	Water					
338	93237	Water	.29 mg/L	< .25 mg/L	198.44 mg/L	< .02 mg/L	< .02 mg/L
339	93238	Water					
340	93239	Water	.31 mg/L	< .25 mg/L	13.62 mg/L	< .02 mg/L	< .02 mg/L
341	93240	Water					
342	93241	Water	.26 mg/L	< .25 mg/L	31.88 mg/L	< .02 mg/L	< .02 mg/L
343	93242	Water					
344	93243	Water	.35 mg/L	< .25 mg/L	34.26 mg/L	< .02 mg/L	< .02 mg/L
345	93244	Water					
346	93245	Water	.41 mg/L	< .25 mg/L	7.81 mg/L	.13 mg/L	.10 mg/L
347	93246	Water					
348	93247	Water	< .25 mg/L	< .25 mg/L	9.34 mg/L	< .02 mg/L	< .02 mg/L
349	93248	Water					
350	93249	Water	.47 mg/L	< .25 mg/L	7.65 mg/L	< .02 mg/L	< .02 mg/L
351	93250	Water	< .25 mg/L	< .25 mg/L	.69 mg/L	< .02 mg/L	< .02 mg/L
352	93251	Water	< .25 mg/L	< .25 mg/L	.57 mg/L	< .02 mg/L	< .02 mg/L
353	93252	Water	< .25 mg/L	< .25 mg/L	.53 mg/L	< .02 mg/L	< .02 mg/L
354	93253	Water	5.47 mg/L	1.96 mg/L	21.37 mg/L	2.13 mg/L	5.48 mg/L
355	93254	Water	5.45 mg/L	1.98 mg/L	21.35 mg/L	2.12 mg/L	5.48 mg/L
356	93255	Water	5.34 mg/L	1.91 mg/L	21.41 mg/L	2.13 mg/L	5.47 mg/L

Commentaires/ Comments: par ICP. Cl : par IC. Fe+3 : par colorimétrie.

Effectué par/ Work by : J. Groleau B. Legault
D. Thériault R. Pelletier

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-102-13-56
Date: 1/11/94

A/To : P.Tibble M.Woyshner PROJET / PROJECT: V2-1 T03

Lab #	I.D.	Description	Fe	K	Mg	Mn	Na
327	93226	Water					
328	93227	Water	< .02 mg/L	< 5.00 mg/L	21.39 mg/L	< 5.00 ug/L	20.70 mg/L
329	93228	Water					
330	93229	Water	< .02 mg/L	< 5.00 mg/L	31.03 mg/L	< 5.00 ug/L	42.73 mg/L
331	93230	Water					
332	93231	Water	< .02 mg/L	< 5.00 mg/L	7.09 mg/L	< 5.00 ug/L	18.50 mg/L
333	93232	Water					
334	93233	Water	.43 mg/L	6.97 mg/L	9.47 mg/L	< 5.00 ug/L	13.74 mg/L
335	93234	Water					
336	93235	Water	< .02 mg/L	< 5.00 mg/L	3.96 mg/L	< 5.00 ug/L	9.70 mg/L
337	93236	Water					
338	93237	Water	.03 mg/L	6.06 mg/L	23.89 mg/L	.28 mg/L	33.51 mg/L
339	93238	Water					
340	93239	Water	23.54 mg/L	< 5.00 mg/L	3.18 mg/L	4.77 mg/L	12.35 mg/L
341	93240	Water					
342	93241	Water	.20 mg/L	< 5.00 mg/L	5.62 mg/L	.47 mg/L	13.39 mg/L
343	93242	Water					
344	93243	Water	.12 mg/L	< 5.00 mg/L	5.24 mg/L	.07 mg/L	17.63 mg/L
345	93244	Water					
346	93245	Water	1.87 mg/L	< 5.00 mg/L	1.38 mg/L	.87 mg/L	13.80 mg/L
347	93246	Water					
348	93247	Water	.81 mg/L	< 5.00 mg/L	1.58 mg/L	1.17 mg/L	10.43 mg/L
349	93248	Water					
350	93249	Water	.86 mg/L	< 5.00 mg/L	1.40 mg/L	2.58 mg/L	14.54 mg/L
351	93250	Water	< .02 mg/L	< 5.00 mg/L	< .50 mg/L	< 5.00 ug/L	8.00 mg/L
352	93251	Water	< .02 mg/L	< 5.00 mg/L	< .50 mg/L	< 5.00 ug/L	7.25 mg/L
353	93252	Water	< .02 mg/L	< 5.00 mg/L	< .50 mg/L	< 5.00 ug/L	7.19 mg/L
354	93253	Water	21.88 mg/L	5.75 mg/L	19.90 mg/L	5.07 mg/L	12.42 mg/L
355	93254	Water	21.85 mg/L	< 5.00 mg/L	19.91 mg/L	5.06 mg/L	12.20 mg/L
356	93255	Water	21.85 mg/L	5.88 mg/L	19.87 mg/L	5.07 mg/L	12.43 mg/L

Commentaires/ Comments: par ICP. Cl : par IC. Fe^{+3} : par colorimétrie.

Effectué par/ Work by : J. Groleau B. Legault
D. Thériault R. Pelletier

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-102-13-56
Date: 1/11/94

A/To : P.Tibble M.Woyshner PROJET / PROJECT: V2-1 T03

Lab #	I.D.	Description		Fe+3		Cl	
327	93226	Water				5.98	mg/L
328	93227	Water	<	.05	mg/L		
329	93228	Water				12.10	mg/L
330	93229	Water	<	.05	mg/L		
331	93230	Water				3.60	mg/L
332	93231	Water	<	.05	mg/L		
333	93232	Water				18.20	mg/L
334	93233	Water		.50	mg/L		
335	93234	Water				4.04	mg/L
336	93235	Water	<	.05	mg/L		
337	93236	Water				16.90	mg/L
338	93237	Water	<	.05	mg/L		
339	93238	Water				2.02	mg/L
340	93239	Water		1.15	mg/L		
341	93240	Water				12.80	mg/L
342	93241	Water	<	.05	mg/L		
343	93242	Water				10.70	mg/L
344	93243	Water	<	.05	mg/L		
345	93244	Water				2.24	mg/L
346	93245	Water	<	.05	mg/L		
347	93246	Water				2.27	mg/L
348	93247	Water	<	.05	mg/L		
349	93248	Water				2.32	mg/L
350	93249	Water	<	.05	mg/L		
351	93250	Water	<	.05	mg/L	1.69	mg/L
352	93251	Water	<	.05	mg/L	1.74	mg/L
353	93252	Water	<	.05	mg/L	1.76	mg/L
354	93253	Water		19.60	mg/L	394.00	mg/L
355	93254	Water		14.60	mg/L	419.00	mg/L
356	93255	Water		14.50	mg/L	421.00	mg/L

Commentaires/ Comments: par ICP. Cl : par IC. Fe+3 : par colorimétrie.

Effectué par/ Work by : J. Groleau B. Legault
D. Thériault R. Pelletier

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CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Al	As	Ca	Cd	Co
8090	94741	Water	.27 mg/L	< .25 mg/L	2.81 mg/L	< .03 mg/L	< .03 mg/L
8091	94742	Water	< .25 mg/L	< .25 mg/L	< .05 mg/L	< .03 mg/L	< .03 mg/L
8092	94743	Water	< .25 mg/L	< .25 mg/L	22.73 mg/L	< .03 mg/L	< .03 mg/L
8093	94744	Water	< .25 mg/L	< .25 mg/L	9.01 mg/L	< .03 mg/L	< .03 mg/L
8094	94745	Water	< .25 mg/L	< .25 mg/L	24.18 mg/L	< .03 mg/L	< .03 mg/L
8095	94746	Water	< .25 mg/L	< .25 mg/L	30.11 mg/L	< .03 mg/L	< .03 mg/L
8096	94747	Water	< .25 mg/L	< .25 mg/L	82.18 mg/L	< .03 mg/L	< .03 mg/L
8097	94748	Water	< .25 mg/L	< .25 mg/L	123.19 mg/L	< .03 mg/L	< .03 mg/L
8098	94749	Water	< .25 mg/L	< .25 mg/L	22.34 mg/L	< .03 mg/L	< .03 mg/L
8099	94750	Water	< .25 mg/L	< .25 mg/L	36.87 mg/L	< .03 mg/L	< .03 mg/L
8100	94751	Water	< .25 mg/L	< .25 mg/L	11.85 mg/L	< .03 mg/L	< .03 mg/L
8101	94752	Water	< .25 mg/L	< .25 mg/L	201.52 mg/L	< .03 mg/L	< .03 mg/L
8102	94753	Water	< .25 mg/L	< .25 mg/L	81.06 mg/L	< .03 mg/L	< .03 mg/L
8103	94754	Water	< .25 mg/L	< .25 mg/L	42.70 mg/L	< .03 mg/L	< .03 mg/L
8104	94755	Water	< .25 mg/L	< .25 mg/L	33.93 mg/L	< .03 mg/L	26.07 ug/L
8105	94756	Water	< .25 mg/L	< .25 mg/L	68.93 mg/L	< .03 mg/L	< .03 mg/L
8106	94757	Water	< .25 mg/L	< .25 mg/L	58.31 mg/L	< .03 mg/L	< .03 mg/L
8107	94758	Water	< .25 mg/L	< .25 mg/L	101.74 mg/L	< .03 mg/L	< .03 mg/L
8108	94759	Water	< .25 mg/L	< .25 mg/L	40.74 mg/L	< .03 mg/L	< .03 mg/L
8109	94760	Water	< .25 mg/L	< .25 mg/L	8.11 mg/L	< .03 mg/L	61.56 ug/L
8110	94761	Water	< .25 mg/L	< .25 mg/L	29.00 mg/L	< .03 mg/L	< .03 mg/L
8111	94762	Water	< .25 mg/L	< .25 mg/L	29.25 mg/L	< .03 mg/L	< .03 mg/L
8112	94763	Water	.28 mg/L	< .25 mg/L	4.22 mg/L	< .03 mg/L	< .03 mg/L
8113	94764	Water	< .25 mg/L	< .25 mg/L	5.28 mg/L	< .03 mg/L	28.97 ug/L
8114	94765	Water	2.89 mg/L	< .25 mg/L	3.15 mg/L	< .03 mg/L	.10 mg/L
8115	94766	Water	< .25 mg/L	< .25 mg/L	466.45 mg/L	< .03 mg/L	< .03 mg/L
8116	94767	Water	< .25 mg/L	< .25 mg/L	155.22 mg/L	< .03 mg/L	< .03 mg/L
8117	94768	Water	< .25 mg/L	< .25 mg/L	334.95 mg/L	< .03 mg/L	< .03 mg/L
8118	94775	Water	< .25 mg/L	< .25 mg/L	81.14 mg/L	< .03 mg/L	< .03 mg/L
8119	94776	Water	< .25 mg/L	< .25 mg/L	81.51 mg/L	< .03 mg/L	< .03 mg/L
8120	94777	Water	< .25 mg/L	< .25 mg/L	81.26 mg/L	< .03 mg/L	< .03 mg/L
8121	94778	Water	< .25 mg/L	< .25 mg/L	79.56 mg/L	< .03 mg/L	< .03 mg/L
8122	94779	Water	< .25 mg/L	< .25 mg/L	79.87 mg/L	< .03 mg/L	< .03 mg/L
8123	94780	Water	< .25 mg/L	< .25 mg/L	80.85 mg/L	< .03 mg/L	< .03 mg/L
8124	94781	Water	< .25 mg/L	< .25 mg/L	< .05 mg/L	< .03 mg/L	< .03 mg/L
8125	94782	Water	< .25 mg/L	< .25 mg/L	< .05 mg/L	< .03 mg/L	< .03 mg/L
8126	94783	Water	< .25 mg/L	< .25 mg/L	< .05 mg/L	< .03 mg/L	< .03 mg/L
8127	94784	Water	4.87 mg/L	2.03 mg/L	18.81 mg/L	2.20 mg/L	< .03 mg/L
8128	94785	Water	4.86 mg/L	1.96 mg/L	19.15 mg/L	2.21 mg/L	< .03 mg/L
8129	94786	Water	4.93 mg/L	2.03 mg/L	19.04 mg/L	2.21 mg/L	< .03 mg/L
8130	94719	Water					
8131	94720	Water					
8132	94721	Water					
8133	94722	Water					
8134	94723	Water					
8135	94724	Water					
8136	94725	Water					
8137	94726	Water					
8138	94727	Water					
8139	94728	Water					
8140	94729	Water					
8141	94730	Water					
8142	94731	Water					
8143	94732	Water					
8144	94733	Water					
8145	94734	Water					
8146	94735	Water					
8147	94736	Water					
8148	94737	Water					
8149	94738	Water					
8150	94739	Water					

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault A. Bouchard
R. Pelletier J. Groleau

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CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Al	As	Ca	Cd	Co
8151	94740	Water					

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe^{+3} par colorimétrie.

Effectué par/ Work by : D. Thériault, A. Bouchard, R. Pelletier, J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Ref.: V2-105-12-56
Date: 6/28/94

Lab #	I.D.	Description	Cr	Cu	Fe	K	Mg
8151	94740	Water					

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault A. Bouchard
R. Pelletier J. Groleau

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CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Mn		Na		Ni		Pb		S	
8090	94741	Water	83.09	ug/L	3.87	mg/L	.27	mg/L	< .25	mg/L	9.98	mg/L
8091	94742	Water	55.77	ug/L	3.58	mg/L	82.76	ug/L	< .25	mg/L	4.14	mg/L
8092	94743	Water	< .01	mg/L	8.54	mg/L	< .03	mg/L	< .25	mg/L	7.87	mg/L
8093	94744	Water	< .01	mg/L	4.66	mg/L	< .03	mg/L	< .25	mg/L	5.12	mg/L
8094	94745	Water	< .01	mg/L	6.91	mg/L	< .03	mg/L	< .25	mg/L	7.47	mg/L
8095	94746	Water	< .01	mg/L	11.19	mg/L	< .03	mg/L	< .25	mg/L	8.01	mg/L
8096	94747	Water	< .01	mg/L	15.58	mg/L	< .03	mg/L	< .25	mg/L	71.29	mg/L
8097	94748	Water	< .01	mg/L	27.89	mg/L	< .03	mg/L	< .25	mg/L	122.47	mg/L
8098	94749	Water	< .01	mg/L	9.73	mg/L	< .03	mg/L	< .25	mg/L	9.49	mg/L
8099	94750	Water	< .01	mg/L	10.78	mg/L	< .03	mg/L	< .25	mg/L	12.52	mg/L
8100	94751	Water	< .01	mg/L	5.37	mg/L	< .03	mg/L	< .25	mg/L	8.71	mg/L
8101	94752	Water	94.47	ug/L	32.67	mg/L	< .03	mg/L	< .25	mg/L	188.40	mg/L
8102	94753	Water	.44	mg/L	15.00	mg/L	< .03	mg/L	< .25	mg/L	58.29	mg/L
8103	94754	Water	.20	mg/L	13.22	mg/L	< .03	mg/L	< .25	mg/L	16.57	mg/L
8104	94755	Water	36.22	ug/L	16.44	mg/L	< .03	mg/L	< .25	mg/L	10.33	mg/L
8105	94756	Water	69.15	ug/L	11.80	mg/L	42.21	ug/L	< .25	mg/L	33.83	mg/L
8106	94757	Water	.28	mg/L	33.08	mg/L	37.86	ug/L	< .25	mg/L	35.71	mg/L
8107	94758	Water	.20	mg/L	12.52	mg/L	67.89	ug/L	< .25	mg/L	64.20	mg/L
8108	94759	Water	.13	mg/L	20.40	mg/L	< .03	mg/L	< .25	mg/L	12.46	mg/L
8109	94760	Water	2.69	mg/L	7.77	mg/L	.54	mg/L	< .25	mg/L	9.66	mg/L
8110	94761	Water	.11	mg/L	11.17	mg/L	65.72	ug/L	< .25	mg/L	9.77	mg/L
8111	94762	Water	.40	mg/L	11.03	mg/L	< .03	mg/L	< .25	mg/L	9.96	mg/L
8112	94763	Water	.44	mg/L	8.44	mg/L	.41	mg/L	< .25	mg/L	8.85	mg/L
8113	94764	Water	.86	mg/L	7.40	mg/L	< .03	mg/L	< .25	mg/L	2.98	mg/L
8114	94765	Water	1.68	mg/L	11.20	mg/L	1.20	mg/L	< .25	mg/L	9.23	mg/L
8115	94766	Water	1.19	mg/L	28.18	mg/L	58.75	ug/L	< .25	mg/L	616.94	mg/L
8116	94767	Water	.30	mg/L	159.48	mg/L	77.90	ug/L	< .25	mg/L	365.95	mg/L
8117	94768	Water	.34	mg/L	331.55	mg/L	.14	mg/L	< .25	mg/L	859.59	mg/L
8118	94775	Water	< .01	mg/L	18.41	mg/L	< .03	mg/L	< .25	mg/L	73.21	mg/L
8119	94776	Water	< .01	mg/L	18.67	mg/L	< .03	mg/L	< .25	mg/L	72.39	mg/L
8120	94777	Water	< .01	mg/L	18.73	mg/L	< .03	mg/L	< .25	mg/L	72.87	mg/L
8121	94778	Water	< .01	mg/L	17.89	mg/L	< .03	mg/L	< .25	mg/L	71.83	mg/L
8122	94779	Water	6.58	ug/L	17.97	mg/L	< .03	mg/L	< .25	mg/L	70.59	mg/L
8123	94780	Water	< .01	mg/L	18.29	mg/L	< .03	mg/L	< .25	mg/L	72.35	mg/L
8124	94781	Water	< .01	mg/L	5.77	mg/L	< .03	mg/L	< .25	mg/L	< .25	mg/L
8125	94782	Water	< .01	mg/L	5.54	mg/L	< .03	mg/L	< .25	mg/L	< .25	mg/L
8126	94783	Water	< .01	mg/L	5.58	mg/L	< .03	mg/L	< .25	mg/L	< .25	mg/L
8127	94784	Water	5.03	mg/L	10.57	mg/L	5.65	mg/L	5.77	mg/L	927.59	mg/L
8128	94785	Water	5.10	mg/L	10.47	mg/L	5.75	mg/L	5.80	mg/L	939.68	mg/L
8129	94786	Water	5.12	mg/L	10.37	mg/L	5.74	mg/L	5.80	mg/L	944.44	mg/L
8130	94719	Water										
8131	94720	Water										
8132	94721	Water										
8133	94722	Water										
8134	94723	Water										
8135	94724	Water										
8136	94725	Water										
8137	94726	Water										
8138	94727	Water										
8139	94728	Water										
8140	94729	Water										
8141	94730	Water										
8142	94731	Water										
8143	94732	Water										
8144	94733	Water										
8145	94734	Water										
8146	94735	Water										
8147	94736	Water										
8148	94737	Water										
8149	94738	Water										
8150	94739	Water										

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault, R. Pelletier, A. Bouchard, J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Mn	Na	Ni	Pb	S
8151	94740	Water					

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault, R. Pelletier, A. Bouchard, J. Groleau

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CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Sb	Se	Si	Te	Tl
8090	94741	Water	< .25 mg/L	< .50 mg/L	.31 mg/L	< .10 mg/L	< .25 mg/L
8091	94742	Water	< .25 mg/L	< .50 mg/L	.41 mg/L	< .10 mg/L	< .25 mg/L
8092	94743	Water	< .25 mg/L	< .50 mg/L	.17 mg/L	< .10 mg/L	< .25 mg/L
8093	94744	Water	< .25 mg/L	< .50 mg/L	.25 mg/L	< .10 mg/L	< .25 mg/L
8094	94745	Water	< .25 mg/L	< .50 mg/L	70.52 ug/L	< .10 mg/L	< .25 mg/L
8095	94746	Water	< .25 mg/L	< .50 mg/L	.46 mg/L	< .10 mg/L	< .25 mg/L
8096	94747	Water	< .25 mg/L	< .50 mg/L	8.98 mg/L	< .10 mg/L	< .25 mg/L
8097	94748	Water	< .25 mg/L	< .50 mg/L	8.93 mg/L	< .10 mg/L	< .25 mg/L
8098	94749	Water	< .25 mg/L	< .50 mg/L	5.45 mg/L	< .10 mg/L	< .25 mg/L
8099	94750	Water	< .25 mg/L	< .50 mg/L	6.34 mg/L	< .10 mg/L	< .25 mg/L
8100	94751	Water	< .25 mg/L	< .50 mg/L	6.61 mg/L	< .10 mg/L	< .25 mg/L
8101	94752	Water	< .25 mg/L	< .50 mg/L	5.99 mg/L	< .10 mg/L	< .25 mg/L
8102	94753	Water	< .25 mg/L	< .50 mg/L	6.50 mg/L	< .10 mg/L	< .25 mg/L
8103	94754	Water	< .25 mg/L	< .50 mg/L	6.72 mg/L	< .10 mg/L	< .25 mg/L
8104	94755	Water	< .25 mg/L	< .50 mg/L	3.26 mg/L	.13 mg/L	< .25 mg/L
8105	94756	Water	< .25 mg/L	< .50 mg/L	6.62 mg/L	< .10 mg/L	< .25 mg/L
8106	94757	Water	< .25 mg/L	< .50 mg/L	6.57 mg/L	< .10 mg/L	< .25 mg/L
8107	94758	Water	< .25 mg/L	< .50 mg/L	5.47 mg/L	< .10 mg/L	< .25 mg/L
8108	94759	Water	< .25 mg/L	< .50 mg/L	4.71 mg/L	< .10 mg/L	< .25 mg/L
8109	94760	Water	< .25 mg/L	< .50 mg/L	10.43 mg/L	.11 mg/L	< .25 mg/L
8110	94761	Water	< .25 mg/L	< .50 mg/L	6.58 mg/L	< .10 mg/L	< .25 mg/L
8111	94762	Water	< .25 mg/L	< .50 mg/L	6.43 mg/L	< .10 mg/L	< .25 mg/L
8112	94763	Water	< .25 mg/L	< .50 mg/L	7.10 mg/L	< .10 mg/L	< .25 mg/L
8113	94764	Water	< .25 mg/L	< .50 mg/L	4.28 mg/L	< .10 mg/L	< .25 mg/L
8114	94765	Water	< .25 mg/L	< .50 mg/L	8.75 mg/L	< .10 mg/L	< .25 mg/L
8115	94766	Water	.25 mg/L	< .50 mg/L	4.48 mg/L	< .10 mg/L	< .25 mg/L
8116	94767	Water	< .25 mg/L	< .50 mg/L	4.99 mg/L	.14 mg/L	< .25 mg/L
8117	94768	Water	.31 mg/L	< .50 mg/L	6.90 mg/L	.16 mg/L	< .25 mg/L
8118	94775	Water	< .25 mg/L	< .50 mg/L	8.93 mg/L	< .10 mg/L	< .25 mg/L
8119	94776	Water	< .25 mg/L	< .50 mg/L	9.07 mg/L	< .10 mg/L	< .25 mg/L
8120	94777	Water	< .25 mg/L	< .50 mg/L	9.04 mg/L	< .10 mg/L	< .25 mg/L
8121	94778	Water	< .25 mg/L	< .50 mg/L	8.83 mg/L	< .10 mg/L	< .25 mg/L
8122	94779	Water	< .25 mg/L	< .50 mg/L	8.88 mg/L	< .10 mg/L	< .25 mg/L
8123	94780	Water	< .25 mg/L	< .50 mg/L	8.95 mg/L	< .10 mg/L	< .25 mg/L
8124	94781	Water	< .25 mg/L	< .50 mg/L	.21 mg/L	< .10 mg/L	< .25 mg/L
8125	94782	Water	< .25 mg/L	< .50 mg/L	.24 mg/L	.12 mg/L	< .25 mg/L
8126	94783	Water	< .25 mg/L	< .50 mg/L	.21 mg/L	< .10 mg/L	< .25 mg/L
8127	94784	Water	< .25 mg/L	< .50 mg/L	7.47 mg/L	< .10 mg/L	< .25 mg/L
8128	94785	Water	< .25 mg/L	< .50 mg/L	7.59 mg/L	< .10 mg/L	< .25 mg/L
8129	94786	Water	< .25 mg/L	< .50 mg/L	7.55 mg/L	< .10 mg/L	< .25 mg/L
8130	94719	Water					
8131	94720	Water					
8132	94721	Water					
8133	94722	Water					
8134	94723	Water					
8135	94724	Water					
8136	94725	Water					
8137	94726	Water					
8138	94727	Water					
8139	94728	Water					
8140	94729	Water					
8141	94730	Water					
8142	94731	Water					
8143	94732	Water					
8144	94733	Water					
8145	94734	Water					
8146	94735	Water					
8147	94736	Water					
8148	94737	Water					
8149	94738	Water					
8150	94739	Water					

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault A. Bouchard
R. Pelletier J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Sb	Se	Si	Te	Tl
8151	94740	Water					

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault A. Bouchard
R. Pelletier J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Ref.: V2-105-12-56
Date: 6/28/94

Lab #	I.D.	Description	Zn	Cl	SO4	Fe+3
8090	94741	Water	50.67 ug/L			< .05 mg/L
8091	94742	Water	< .03 mg/L			< .05 mg/L
8092	94743	Water	< .03 mg/L			< .05 mg/L
8093	94744	Water	< .03 mg/L			< .05 mg/L
8094	94745	Water	< .03 mg/L			< .05 mg/L
8095	94746	Water	< .03 mg/L			< .05 mg/L
8096	94747	Water	< .03 mg/L			< .05 mg/L
8097	94748	Water	< .03 mg/L			< .05 mg/L
8098	94749	Water	< .03 mg/L			< .05 mg/L
8099	94750	Water	< .03 mg/L			< .05 mg/L
8100	94751	Water	< .03 mg/L			< .05 mg/L
8101	94752	Water	< .03 mg/L			< .05 mg/L
8102	94753	Water	< .03 mg/L			440.00 ug/L
8103	94754	Water	< .03 mg/L			< .05 mg/L
8104	94755	Water	28.77 ug/L			< .05 mg/L
8105	94756	Water	51.29 ug/L			< .05 mg/L
8106	94757	Water	< .03 mg/L			< .05 mg/L
8107	94758	Water	< .03 mg/L			1.16 mg/L
						1.18 mg/L
8108	94759	Water	< .03 mg/L			< .05 mg/L
8109	94760	Water	.15 mg/L			543.00
8110	94761	Water	88.83 ug/L			< .05 mg/L
8111	94762	Water	< .03 mg/L			< .05 mg/L
8112	94763	Water	55.05 ug/L			< .05 mg/L
8113	94764	Water	< .03 mg/L			617.00 ug/L
8114	94765	Water	.27 mg/L			558.00 ug/L
8115	94766	Water	< .03 mg/L			< .05 mg/L
8116	94767	Water	< .03 mg/L			< .05 mg/L
8117	94768	Water	< .03 mg/L			< .05 mg/L
8118	94775	Water	< .03 mg/L			< .05 mg/L
8119	94776	Water	< .03 mg/L			< .05 mg/L
8120	94777	Water	< .03 mg/L			< .05 mg/L
8121	94778	Water	< .03 mg/L			< .05 mg/L
8122	94779	Water	< .03 mg/L			< .05 mg/L
8123	94780	Water	< .03 mg/L			< .05 mg/L
8124	94781	Water	< .03 mg/L			< .05 mg/L
8125	94782	Water	< .03 mg/L			< .05 mg/L
8126	94783	Water	< .03 mg/L			< .05 mg/L
8127	94784	Water	23.76 mg/L			19.10 mg/L
8128	94785	Water	24.00 mg/L			18.80 mg/L
8129	94786	Water	24.09 mg/L			19.10 mg/L
8130	94719	Water		6.31 mg/L	210.00 mg/L	
8131	94720	Water		10.50 mg/L	318.00 mg/L	
8132	94721	Water		2.15 mg/L	32.40 mg/L	
8133	94722	Water		14.70 mg/L	41.00 mg/L	
8134	94723	Water		1.77 mg/L	29.60 mg/L	
8135	94724	Water		23.60 mg/L	412.00 mg/L	
8136	94725	Water		19.90 mg/L	166.00 mg/L	
8137	94726	Water		42.90 mg/L	50.60 mg/L	
8138	94727	Water		53.70 mg/L	49.80 mg/L	
8139	94728	Water		6.62 mg/L	97.70 mg/L	
8140	94729	Water		4.76 mg/L	104.00 mg/L	
8141	94730	Water		5.53 mg/L	187.00 mg/L	
8142	94731	Water		35.60 mg/L	35.60 mg/L	
8143	94732	Water		< .20 mg/L	27.00 mg/L	
8144	94733	Water		11.40 mg/L	27.80 mg/L	
8145	94734	Water		11.40 mg/L	28.10 mg/L	
8146	94735	Water		< .20 mg/L	25.60 mg/L	
8147	94736	Water		1.91 mg/L	9.43 mg/L	
8148	94737	Water		1.80 mg/L	27.60 mg/L	
8149	94738	Water		2.71 mg/L		

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault A. Bouchard
R. Pelletier J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: V2-105-12-56
Date: 6/28/94

A/To : P.Tibble

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Zn	Cl	SO4	Fe+3
8150	94739	Water		38.20 mg/L		
8151	94740	Water		40.60 mg/L		

Commentaires/ Comments: par ICP. Cl et SO4 par IC. Fe+3 par colorimétrie.

Effectué par/ Work by : D. Thériault, R. Pelletier, A. Bouchard, J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: T03001-5-53
Date: 10/03/94

A/To : M.Woyshner

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Al	As	Ca	Cd	Co
13960	941784	Fault Lake					
13961	941785	Fault Lake					
13962	941786	Fault Lake					
13963	941787	Fault Lake					
13964	941788	Fault Lake					
13965	941789	Fault Lake					
13966	941790	Fault Lake					
13967	941791	Fault Lake					
13968	941792	Fault Lake					
13969	941793	Fault Lake					
13970	941794	Fault Lake					
13971	941795	Fault Lake					
13972	941796	Fault Lake					
13973	941797	Fault Lake					
13974	941798	Fault Lake					
13975	941799	Fault Lake					
13976	941800	Fault Lake					
13977	941801	Fault Lake					
13978	941802	Fault Lake					
13979	941803	Fault Lake					
13980	941804	Fault Lake	.75 mg/L	< .25 mg/L	89.67 mg/L	< .03 mg/L	< .03 mg/L
13981	941805	Fault Lake	.65 mg/L	< .25 mg/L	127.57 mg/L	< .03 mg/L	< .03 mg/L
13982	941806	Fault Lake	.66 mg/L	< .25 mg/L	40.24 mg/L	< .03 mg/L	< .03 mg/L
13983	941807	Fault Lake	.62 mg/L	< .25 mg/L	15.68 mg/L	< .03 mg/L	< .03 mg/L
13984	941808	Fault Lake	.76 mg/L	< .25 mg/L	201.77 mg/L	< .03 mg/L	< .03 mg/L
13985	941809	Fault Lake	.76 mg/L	< .25 mg/L	171.70 mg/L	< .03 mg/L	< .03 mg/L
13986	941810	Fault Lake	.53 mg/L	< .25 mg/L	82.21 mg/L	< .03 mg/L	< .03 mg/L
13987	941811	Fault Lake	.66 mg/L	< .25 mg/L	42.33 mg/L	< .03 mg/L	< .03 mg/L
13988	941812	Fault Lake	.77 mg/L	< .25 mg/L	40.04 mg/L	< .03 mg/L	< .03 mg/L
13989	941813	Fault Lake	.78 mg/L	< .25 mg/L	74.30 mg/L	< .03 mg/L	< .03 mg/L
13990	941814	Fault Lake	.62 mg/L	< .25 mg/L	69.93 mg/L	< .03 mg/L	< .03 mg/L
13991	941815	Fault Lake	.62 mg/L	< .25 mg/L	106.15 mg/L	< .03 mg/L	< .03 mg/L
13992	941816	Fault Lake	.60 mg/L	< .25 mg/L	46.95 mg/L	< .03 mg/L	< .03 mg/L
13993	941817	Fault Lake	.69 mg/L	< .25 mg/L	39.32 mg/L	< .03 mg/L	< .03 mg/L
13994	941818	Fault Lake	.74 mg/L	< .25 mg/L	40.21 mg/L	< .03 mg/L	< .03 mg/L
13995	941819	Fault Lake	.65 mg/L	< .25 mg/L	11.29 mg/L	< .03 mg/L	< .03 mg/L
13996	941820	Fault Lake	1.84 mg/L	< .25 mg/L	9.01 mg/L	< .03 mg/L	30.56 ug/L
13997	941821	Fault Lake	.74 mg/L	< .25 mg/L	433.73 mg/L	< .03 mg/L	< .03 mg/L
13998	941822	Fault Lake	.56 mg/L	< .25 mg/L	19.89 mg/L	< .03 mg/L	< .03 mg/L
13999	941823	Fault Lake	.51 mg/L	< .25 mg/L	174.05 mg/L	< .03 mg/L	< .03 mg/L

Commentaires/ Comments: By ICP , except Fe+3: by colorimetry. Anions by IC.

Effectué par/ Work by : L. Lavoie, B. Legault, J. Groleau, D. Thériault

N.D. for M.M.H.

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: T03001-5-53
Date: 10/03/94

A/To : M.Woyshner

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Cr	Cu	Fe	K	Mg
13960	941784	Fault Lake					
13961	941785	Fault Lake					
13962	941786	Fault Lake					
13963	941787	Fault Lake					
13964	941788	Fault Lake					
13965	941789	Fault Lake					
13966	941790	Fault Lake					
13967	941791	Fault Lake					
13968	941792	Fault Lake					
13969	941793	Fault Lake					
13970	941794	Fault Lake					
13971	941795	Fault Lake					
13972	941796	Fault Lake					
13973	941797	Fault Lake					
13974	941798	Fault Lake					
13975	941799	Fault Lake					
13976	941800	Fault Lake					
13977	941801	Fault Lake					
13978	941802	Fault Lake					
13979	941803	Fault Lake					
13980	941804	Fault Lake	< .03 mg/L	< .03 mg/L	40.33 ug/L	< 5.00 mg/L	21.29 mg/L
13981	941805	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	< 5.00 mg/L	31.14 mg/L
13982	941806	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	< 5.00 mg/L	9.75 mg/L
13983	941807	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	< 5.00 mg/L	3.50 mg/L
13984	941808	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	6.15 mg/L	32.08 mg/L
13985	941809	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	15.35 mg/L	12.39 mg/L
13986	941810	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	8.76 mg/L	19.25 mg/L
13987	941811	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	9.19 mg/L	9.92 mg/L
13988	941812	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	5.74 mg/L	7.63 mg/L
13989	941813	Fault Lake	< .03 mg/L	< .03 mg/L	.27 mg/L	6.36 mg/L	10.02 mg/L
13990	941814	Fault Lake	< .03 mg/L	< .03 mg/L	.47 mg/L	6.11 mg/L	10.56 mg/L
13991	941815	Fault Lake	< .03 mg/L	< .03 mg/L	52.01 ug/L	9.03 mg/L	15.44 mg/L
13992	941816	Fault Lake	< .03 mg/L	< .03 mg/L	.11 mg/L	< 5.00 mg/L	8.96 mg/L
13993	941817	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	< 5.00 mg/L	6.06 mg/L
13994	941818	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	< 5.00 mg/L	6.39 mg/L
13995	941819	Fault Lake	< .03 mg/L	< .03 mg/L	.34 mg/L	< 5.00 mg/L	1.80 mg/L
13996	941820	Fault Lake	< .03 mg/L	28.25 ug/L	.17 mg/L	< 5.00 mg/L	1.32 mg/L
13997	941821	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	68.12 mg/L	168.25 mg/L
13998	941822	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	< 5.00 mg/L	3.95 mg/L
13999	941823	Fault Lake	< .03 mg/L	< .03 mg/L	< .03 mg/L	15.21 mg/L	12.49 mg/L

Commentaires/ Comments: By ICP , except Fe+3: by colorimetry. Anions by IC.

Effectué par/ Work by : L. Lavoie J. Groleau
B. Legault D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: T03001-5-53
Date: 10/03/94

A/To : M.Woyshner

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Mn	Na	Ni	Pb	S
13960	941784	Fault Lake					
13961	941785	Fault Lake					
13962	941786	Fault Lake					
13963	941787	Fault Lake					
13964	941788	Fault Lake					
13965	941789	Fault Lake					
13966	941790	Fault Lake					
13967	941791	Fault Lake					
13968	941792	Fault Lake					
13969	941793	Fault Lake					
13970	941794	Fault Lake					
13971	941795	Fault Lake					
13972	941796	Fault Lake					
13973	941797	Fault Lake					
13974	941798	Fault Lake					
13975	941799	Fault Lake					
13976	941800	Fault Lake					
13977	941801	Fault Lake					
13978	941802	Fault Lake					
13979	941803	Fault Lake					
13980	941804	Fault Lake	< .01 mg/L	18.74 mg/L	< .03 mg/L	< .25 mg/L	78.86 mg/L
13981	941805	Fault Lake	< .01 mg/L	27.32 mg/L	< .03 mg/L	< .25 mg/L	118.32 mg/L
13982	941806	Fault Lake	< .01 mg/L	13.25 mg/L	< .03 mg/L	< .25 mg/L	15.45 mg/L
13983	941807	Fault Lake	5.44 ug/L	8.45 mg/L	< .03 mg/L	< .25 mg/L	10.90 mg/L
13984	941808	Fault Lake	.13 mg/L	34.73 mg/L	< .03 mg/L	< .25 mg/L	192.05 mg/L
13985	941809	Fault Lake	.16 mg/L	12.37 mg/L	1.43 mg/L	< .25 mg/L	111.43 mg/L
13986	941810	Fault Lake	.48 mg/L	15.77 mg/L	< .03 mg/L	< .25 mg/L	62.82 mg/L
13987	941811	Fault Lake	.25 mg/L	14.82 mg/L	< .03 mg/L	< .25 mg/L	18.33 mg/L
13988	941812	Fault Lake	16.32 ug/L	16.90 mg/L	< .03 mg/L	< .25 mg/L	11.50 mg/L
13989	941813	Fault Lake	88.44 ug/L	9.97 mg/L	< .03 mg/L	< .25 mg/L	37.01 mg/L
13990	941814	Fault Lake	.38 mg/L	25.04 mg/L	< .03 mg/L	< .25 mg/L	39.78 mg/L
13991	941815	Fault Lake	.22 mg/L	14.38 mg/L	< .03 mg/L	< .25 mg/L	65.88 mg/L
13992	941816	Fault Lake	.13 mg/L	21.69 mg/L	< .03 mg/L	< .25 mg/L	14.42 mg/L
13993	941817	Fault Lake	66.65 ug/L	12.69 mg/L	77.01 ug/L	< .25 mg/L	10.64 mg/L
13994	941818	Fault Lake	.53 mg/L	14.63 mg/L	83.61 ug/L	< .25 mg/L	11.77 mg/L
13995	941819	Fault Lake	.87 mg/L	8.52 mg/L	40.92 ug/L	< .25 mg/L	4.20 mg/L
13996	941820	Fault Lake	1.16 mg/L	9.97 mg/L	.74 mg/L	< .25 mg/L	7.12 mg/L
13997	941821	Fault Lake	1.06 mg/L	26.77 mg/L	.12 mg/L	< .25 mg/L	558.56 mg/L
13998	941822	Fault Lake	15.27 ug/L	7.31 mg/L	< .03 mg/L	< .25 mg/L	6.10 mg/L
13999	941823	Fault Lake	.17 mg/L	12.59 mg/L	1.28 mg/L	< .25 mg/L	114.37 mg/L

Commentaires/ Comments: By ICP , except Fe+3: by colorimetry. Anions by IC.

Effectué par/ Work by : L. Lavoie J. Groleau
B. Legault D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE/ CERTIFICATE OF ANALYSIS

Ref.: T03001-5-53
Date: 10/03/94

A/To : M.Woyshner

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Sb	Se	Si	Te	Tl
13960	941784	Fault Lake					
13961	941785	Fault Lake					
13962	941786	Fault Lake					
13963	941787	Fault Lake					
13964	941788	Fault Lake					
13965	941789	Fault Lake					
13966	941790	Fault Lake					
13967	941791	Fault Lake					
13968	941792	Fault Lake					
13969	941793	Fault Lake					
13970	941794	Fault Lake					
13971	941795	Fault Lake					
13972	941796	Fault Lake					
13973	941797	Fault Lake					
13974	941798	Fault Lake					
13975	941799	Fault Lake					
13976	941800	Fault Lake					
13977	941801	Fault Lake					
13978	941802	Fault Lake					
13979	941803	Fault Lake					
13980	941804	Fault Lake	< .25 mg/L	< .50 mg/L	9.25 mg/L	< .10 mg/L	< .25 mg/L
13981	941805	Fault Lake	< .25 mg/L	< .50 mg/L	9.25 mg/L	< .10 mg/L	< .25 mg/L
13982	941806	Fault Lake	< .25 mg/L	< .50 mg/L	6.40 mg/L	< .10 mg/L	< .25 mg/L
13983	941807	Fault Lake	< .25 mg/L	< .50 mg/L	6.56 mg/L	< .10 mg/L	< .25 mg/L
13984	941808	Fault Lake	< .25 mg/L	< .50 mg/L	6.06 mg/L	< .10 mg/L	< .25 mg/L
13985	941809	Fault Lake	< .25 mg/L	< .50 mg/L	4.70 mg/L	< .10 mg/L	< .25 mg/L
13986	941810	Fault Lake	< .25 mg/L	< .50 mg/L	6.20 mg/L	< .10 mg/L	< .25 mg/L
13987	941811	Fault Lake	< .25 mg/L	< .50 mg/L	7.37 mg/L	< .10 mg/L	< .25 mg/L
13988	941812	Fault Lake	< .25 mg/L	< .50 mg/L	3.25 mg/L	< .10 mg/L	< .25 mg/L
13989	941813	Fault Lake	< .25 mg/L	< .50 mg/L	6.61 mg/L	< .10 mg/L	< .25 mg/L
13990	941814	Fault Lake	< .25 mg/L	< .50 mg/L	6.84 mg/L	< .10 mg/L	< .25 mg/L
13991	941815	Fault Lake	< .25 mg/L	< .50 mg/L	5.43 mg/L	< .10 mg/L	< .25 mg/L
13992	941816	Fault Lake	< .25 mg/L	< .50 mg/L	4.84 mg/L	< .10 mg/L	< .25 mg/L
13993	941817	Fault Lake	< .25 mg/L	< .50 mg/L	6.63 mg/L	< .10 mg/L	< .25 mg/L
13994	941818	Fault Lake	< .25 mg/L	< .50 mg/L	6.01 mg/L	< .10 mg/L	< .25 mg/L
13995	941819	Fault Lake	< .25 mg/L	< .50 mg/L	4.11 mg/L	< .10 mg/L	< .25 mg/L
13996	941820	Fault Lake	< .25 mg/L	< .50 mg/L	6.97 mg/L	< .10 mg/L	< .25 mg/L
13997	941821	Fault Lake	< .25 mg/L	< .50 mg/L	4.37 mg/L	< .10 mg/L	< .25 mg/L
13998	941822	Fault Lake	< .25 mg/L	< .50 mg/L	.97 mg/L	< .10 mg/L	< .25 mg/L
13999	941823	Fault Lake	< .25 mg/L	< .50 mg/L	4.61 mg/L	< .10 mg/L	< .25 mg/L

Commentaires/ Comments: By ICP , except Fe+3: by colorimetry. Anions by IC.

Effectué par/ Work by : L. Lavoie, J. Groleau, B. Legault, D. Thériault

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Ref.: T03001-5-53
Date: 10/03/94

A/To : M.Woyshner

PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Zn	Cl	N(NO2)	N(NO3)	SO4
13960	941784	Fault Lake		6.20 mg/L	< .12 mg/L	2.74 mg/L	216.00 mg/L
13961	941785	Fault Lake		9.60 mg/L	< .12 mg/L	5.26 mg/L	319.00 mg/L
13962	941786	Fault Lake		14.70 mg/L	< .12 mg/L	1.75 mg/L	42.60 mg/L
13963	941787	Fault Lake		2.22 mg/L	< .12 mg/L	1.20 mg/L	30.30 mg/L
13964	941788	Fault Lake		24.10 mg/L	< .12 mg/L	< .05 mg/L	534.00 mg/L
13965	941789	Fault Lake		2.81 mg/L	< .12 mg/L	1.26 mg/L	303.00 mg/L
13966	941790	Fault Lake		20.40 mg/L	< .12 mg/L	< .05 mg/L	190.00 mg/L
13967	941791	Fault Lake		44.20 mg/L	< .12 mg/L	< .05 mg/L	57.20 mg/L
13968	941792	Fault Lake		39.80 mg/L	< .12 mg/L	< .05 mg/L	35.60 mg/L
13969	941793	Fault Lake		5.71 mg/L	< .12 mg/L	.99 mg/L	112.00 mg/L
13970	941794	Fault Lake		4.95 mg/L	< .12 mg/L	< .05 mg/L	120.00 mg/L
13971	941795	Fault Lake		6.92 mg/L	< .12 mg/L	1.34 mg/L	191.00 mg/L
13972	941796	Fault Lake		36.90 mg/L	< .12 mg/L	2.99 mg/L	37.10 mg/L
13973	941797	Fault Lake		11.80 mg/L	< .12 mg/L	2.97 mg/L	28.40 mg/L
13974	941798	Fault Lake		11.70 mg/L	< .12 mg/L	2.06 mg/L	29.50 mg/L
13975	941799	Fault Lake		2.47 mg/L	< .12 mg/L	< .05 mg/L	12.30 mg/L
13976	941800	Fault Lake		1.97 mg/L	< .12 mg/L	3.25 mg/L	19.30 mg/L
13977	941801	Fault Lake		3.57 mg/L	< .12 mg/L	.24 mg/L	276.00 mg/L
13978	941802	Fault Lake		2.41 mg/L	< .12 mg/L	.75 mg/L	17.50 mg/L
13979	941803	Fault Lake		39.90 mg/L	< .12 mg/L	< .05 mg/L	550.00 mg/L
13980	941804	Fault Lake	< .03 mg/L				
13981	941805	Fault Lake	< .03 mg/L				
13982	941806	Fault Lake	< .03 mg/L				
13983	941807	Fault Lake	< .03 mg/L				
13984	941808	Fault Lake	< .03 mg/L				
13985	941809	Fault Lake	< .03 mg/L				
13986	941810	Fault Lake	< .03 mg/L				
13987	941811	Fault Lake	< .03 mg/L				
13988	941812	Fault Lake	< .03 mg/L				
13989	941813	Fault Lake	< .03 mg/L				
13990	941814	Fault Lake	< .03 mg/L				
13991	941815	Fault Lake	< .03 mg/L				
13992	941816	Fault Lake	< .03 mg/L				
13993	941817	Fault Lake	31.13 ug/L				
13994	941818	Fault Lake	< .03 mg/L				
13995	941819	Fault Lake	< .03 mg/L				
13996	941820	Fault Lake	.18 mg/L				
13997	941821	Fault Lake	< .03 mg/L				
13998	941822	Fault Lake	< .03 mg/L				
13999	941823	Fault Lake	< .03 mg/L				

Commentaires/ Comments: By ICP , except Fe+3: by colorimetry. Anions by IC.

Effectué par/ Work by : L. Lavoie, B. Legault, J. Groleau, D. Thériault

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Ref.: T03001-5-53
Date: 10/03/94

A/To : M.Woyshner PROJET / PROJECT: V21 T03 100

Lab #	I.D.	Description	Fe+3	F
13960	941784	Fault Lake		< .20 mg/L
13961	941785	Fault Lake		< .20 mg/L
13962	941786	Fault Lake		< .20 mg/L
13963	941787	Fault Lake		< .20 mg/L
13964	941788	Fault Lake		< .20 mg/L
13965	941789	Fault Lake		< .20 mg/L
13966	941790	Fault Lake		< .20 mg/L
13967	941791	Fault Lake		< .20 mg/L
13968	941792	Fault Lake		< .20 mg/L
13969	941793	Fault Lake		< .20 mg/L
13970	941794	Fault Lake		< .20 mg/L
13971	941795	Fault Lake		< .20 mg/L
13972	941796	Fault Lake		< .20 mg/L
13973	941797	Fault Lake		< .20 mg/L
13974	941798	Fault Lake		< .20 mg/L
13975	941799	Fault Lake		< .20 mg/L
13976	941800	Fault Lake		< .20 mg/L
13977	941801	Fault Lake		< .20 mg/L
13978	941802	Fault Lake		< .20 mg/L
13979	941803	Fault Lake		< .20 mg/L
13980	941804	Fault Lake	< .15 mg/L	
13981	941805	Fault Lake	.15 mg/L	
13982	941806	Fault Lake	< .15 mg/L	
13983	941807	Fault Lake	< .15 mg/L	
13984	941808	Fault Lake	.24 mg/L	
13985	941809	Fault Lake	< .15 mg/L	
13986	941810	Fault Lake	< .15 mg/L	
13987	941811	Fault Lake	.16 mg/L	
13988	941812	Fault Lake	< .15 mg/L	
13989	941813	Fault Lake	.38 mg/L	
13990	941814	Fault Lake	.47 mg/L	
13991	941815	Fault Lake	.21 mg/L	
13992	941816	Fault Lake	.28 mg/L	
13993	941817	Fault Lake	< .15 mg/L	
13994	941818	Fault Lake	< .15 mg/L	
13995	941819	Fault Lake	.36 mg/L	
13996	941820	Fault Lake	.28 mg/L	
13997	941821	Fault Lake	< .15 mg/L	
13998	941822	Fault Lake	< .15 mg/L	
13999	941823	Fault Lake	< .15 mg/L	

Commentaires/ Comments: By ICP , except Fe+3: by colorimetry. Anions by IC.

Effectué par/ Work by : L. Lavoie, J. Groleau, B. Legault, D. Thériault

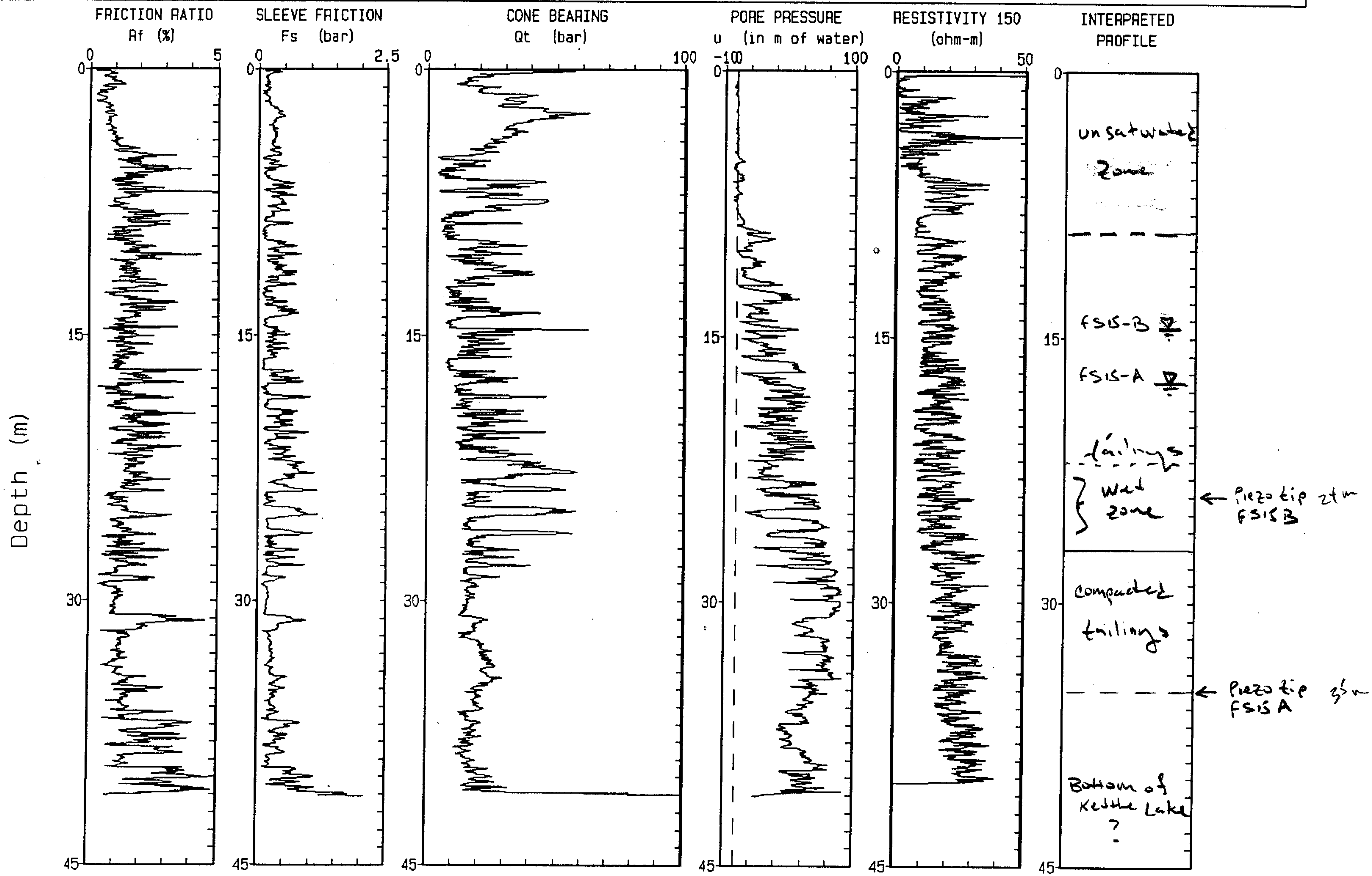
APPENDIX D

Piezocone data taken near monitoring station FS15 (UBC).

UBC IN-SITU TESTING

ENGINEER: MPD TJB DATE: 10-14-93 13:24 SOUNDING: f01-9333.dat

LOCATION: Falcon No. 1 CONE: Hog3 w/ Old Res JOB#: F01-9333 U2ppd



Depth Increment : .025 m Max Depth : 41.10 m

APPENDIX E

Investigation of the porous envelope effect at the Fault Lake tailing site, Part 1, draft report.

INVESTIGATION OF THE POROUS ENVELOPE EFFECT

AT THE FAULT LAKE TAILINGS SITE

PRELIMINARY DRAFT REPORT

submitted to:

Falconbridge Limited
Sudbury Operations

and

The Ontario Ministry of Northern Development and Mines

by

Noranda Technology Centre
Mineral Sciences Laboratory
Environmental Program

September 1993

Executive Summary

A porous envelope effect may occur in groundwater systems when mine tailings of low permeability are placed within high permeability soils. If the permeability contrast between the tailings and the natural soil is large, groundwater will flow around the tailings mass rather than through it, and metal leaching may be small.

The present hydrogeological study suggests that conditions for porous envelope containment may be occurring.at the Falconbridge Fault Lake tailings site. The tailings have been deposited in a kettle lake formed within glacial outwash sand and gravel.

Water quality sampling in monitoring wells outside the tailings did not show any evidence of above-background metal concentrations, which suggests that leaching of metals from the tailings would be minimal. This is also suggested by the results of water sampling in nearby lakes, and by groundwater flow models.

Factors which contribute to limit metal concentrations downgradient of the Fault Lake tailings are:

- high hydraulic conductivity contrast between the tailings and the surrounding sediments,
- low position of the water table relative to the tailings bottom,
- limited infiltration through the surface of the tailings,
- dilution of metals flushed from the tailings by water flowing around and below the tailings,
- chemical attenuation of metals in the tailings and overburden

These factors could probably be present at other locations near mine sites. Tailings deposition could be done at these sites with little effect on groundwater quality pending that thorough site evaluations are performed and that appropriate control is done at the time of deposition.

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1. INTRODUCTION

In 1992, Noranda Technology Centre (NTC) undertook a hydrogeological investigation of the Fault Lake tailings site. The site is unique in that, theoretically, a "porous envelope effect" may occur. If this is the case, flow through the tailings mass is low enough, relative to the surrounding more permeable till, that impact to the groundwater by tailings oxidation is insignificant at the regional scale.

The specific objectives of the investigation were to analyze the chemical and physical hydrogeology of the site, to delineate areas affected by acid mine drainage (AMD) generated from the tailings, and to verify the presence of the porous envelope effect.

1.1 Background

The Fault Lake tailings site is located northwest of the Falconbridge Sudbury operations, approximately 3 km north of Falconbridge and 0.5 km east of the Sudbury Airport (Fig. 1). The tailings were deposited between 1965 and 1978 and were produced from the milling of nickel ore in the Sudbury area. Approximately 6.45 million tonnes of tailings containing as much as 50% pyrrhotite were deposited in a depression of a maximum depth of approximately 30 m. The tailings were contained by dams to the north and south of the site. The deposit has an approximate volume of 3.36×10^6 m^3 and a surface area of 22.2 ha (55 acre). It sits in a 55 ha (136 acre) closed watershed (Fig. 1a).

During the spring and fall, ponding occurs at the north dam, south dam and various berms. The water slowly infiltrates into the tailings and evaporates from the ponds. During the summer months, extensive ponding has not been observed. Tailings in areas where ponding has occurred are soft and grey, while the rest of the tailings are hard and crusty, showing orange traces of oxidation.

In 1971, while deposition was active, the analysis of groundwater in one well located 2 km downgradient (northeast) of the Fault Lake tailings site indicated above-background sulphate levels of 382 mg/L, suggesting influence from tailings oxidation International Water Supply, 1971). Groundwater and surface water monitoring and analysis done at later dates, though, showed improvements in water quality and suggested that impact to groundwater by tailings oxidation would have stopped.

1.2 Surficial Geology

Overburden thickness varies within the studied area, from 36 m to more than 60 m. Overburden mainly consists of coarse to fine glacial outwash sands and gravels with some large boulders and silt lenses.

Kettles, fluvial terraces, discontinuous crevasse fillings, and eskers within the Fault Lake tailings area are evidence of a glacial meltwater channel, partly choked with stranded ice blocks. The small round kettle lakes were formed after the late melting of the stranded ice blocks which were caught among the mass of glacial sediments. The sediment are assembled in longitudinal formations which follow a northeasterly direction, eventually leading into Bowlands Bay, part of Lake Wanipitie. Figure 2 shows the main overburden materials and their orientation in the area of the site.

2. INVESTIGATIVE METHODOLOGY

2.1 Installation of Groundwater Monitoring Stations

The routes by which acid water could be transported from the Fault Lake tailings site were identified by field observations and supported by geophysical data prior to the drilling of the monitoring wells (Geomar, 1991, 1992). Probable seepage routes were identified leaving the tailings site at the base of the north and south dams.

Thirteen groundwater monitoring stations were located to sample the groundwater in the sediments directly below the tailings deposit and along the seepage routes. In addition, one station (FS-2) was located upgradient of the tailings to characterize background conditions. Figure 3 shows the locations of all the stations and also shows the outline of the original kettle lake as determined from aerial photographs taken prior to tailings deposition. Bedrock in the vicinity of the tailings site was not instrumented as it was not believed to have an important influence on groundwater flow in the area.

Drilling of the groundwater monitoring stations at the Fault Lake tailings site was conducted using a 15 cm ID hollow stem auger. A total of 14 holes were drilled in the overburden between September 15 and November 8, 1992. Diamond core attachments were required where boulders were encountered. At stations where the water table was deep below the surface, water injection was required in order to prevent excess friction on the drill stem. The water served as a lubricant and coolant, as a means for removing drill cuttings, and as a way to clean the holes after drilling was completed. The water was supplied from the Falconbridge mill, and was modified by the addition of rhodamine-D, a non-adsorbing photo-degradable tracer. This enabled the possibility of recognizing the presence of drilling water which could have remained in the boreholes at the time of groundwater sampling. Samples of the overburden and tailings were obtained using a split spoon sampler. Grain size analysis was conducted on most of the samples collected and the results are displayed in Appendix A.

Piezometers / monitoring wells installed at all the stations of the Fault Lake Tailings site are 1.9 cm (0.75 inch) ID, schedule 80 PVC pipe with a 0.3 m (1 ft) PVC screened tip. These were installed by placing the pipe inside the hollow stem auger at the required depth. The auger was then raised approximately 1.5 m at which time clean silica sand was packed around the PVC screen. A bentonite seal was placed above the sand to insure hydraulic isolation of the well. Bentonite seals and steel casings equipped with locking covers were also installed at the surface to protect the wells and prevent infiltration of water from surface.

After installation, all monitoring wells were labelled and surveyed. The labels were numbered according to station location and depth (e.g., at location FS-1, well FS-1-A is deeper than well FS-1-B). Boreholes logs and corresponding well tip locations and station coordinates appear in Appendix B.

Each monitoring well was purged of initial drilling water. Water in the well was allowed to re-equilibrate and level readings were then obtained using an electrical water level meter. Water level data is also included in Appendix B.

2.2 Water Sampling and Analysis

Groundwater was sampled from monitoring wells in December 1992 and in March 1993. Before sampling, the depth to water level was measured and three well volumes were purged to eliminate standing water and drill water. After the water had been sufficiently recovered, depth to water level was re-measured and water samples collected.

The samples were collected using a peristaltic pump, a nitrogen-driven positive displacement pump, or the Waterra system. The groundwater samples were filtered using a 0.45 µm (ACRO 50A) disposable in-line filter. Field measurements of pH, temperature, oxidation reduction potential (Eh), and electrical conductance were recorded. Half of each sample was acidified in the field using reagent grade (2% v/v) hydrochloric acid (HCl) for metal preservation prior to analysis. All electrodes were calibrated before use and between samples. All sampling equipment was rinsed with distilled water before each sample was collected.

Water samples were transported to a field laboratory within six hours from collection. In the laboratory, measurements of pH were repeated on the non-acidified portion of the samples along with titration for acidity and alkalinity.

In the NTC analytical laboratory, the acidified portion of each sample was analyzed for dissolved metal and major ions and the non-acidified portion was analyzed for chloride. Potassium (K) was analyzed using flame atomic emission, ferrous iron (Fe^{2+}) by colorimetry/volumetry, chloride (Cl^{-}) by turbidimetry, and all other elements by inductively coupled plasma spectrophotometry (ICP). All certificates of analysis appear in Appendix C.

Tailings pore water was sampled by squeezing tailings samples using a pneumatic squeeze apparatus at 0.8 MPa in a stainless steel loading cell. Due to the low water contents of the samples, it was required to saturate the samples with distilled water in order to retrieve enough volume for analysis (saturatlon extract procedure). Initial and final moisture contents were determined to calculate a dilution factor, which was used to correct the metal concentrations determined on the extract solution by the same analytical methods as described above.

Quality testing for all sample batches was performed using replicate and standard samples. The samples were collected to evaluate reproducibility and accuracy of the analytical procedure and to assess the cleanliness of the equipment during sampling. Coefficient of variation and relative error for the samples selected were low, indicating good quality data. The results of the quality assurance testing are included in Appendix C.

Five kettle lakes in the Fault Lake tailings area (Fig. 3) were sampled in October 1992 by Falconbridge personnel. Samples were collected at selected depths from each of the ponds and analyzed using the same procedure as for the groundwater samples. The five ponds were numbered according to Fig.3.

2.3 Hydraulic Conductivity Measurements

Measurements of *in-situ* hydraulic conductivity were conducted at most of the monitoring stations using the "falling head test". The test is performed below the water table. An instantaneous water level rise in the piezometer is induced with a slug and water level recovery is recorded with time. Water level recovery was monitored either manually, using a watch and water level indicator, or automatically, using a Shape SH3500 submersible pressure transducer (which also served as a slug) and a Lakewood meter/logger.

Interpretation of the water level versus time data was conducted using the Hvorslev (1951) method for point piezometers. As described in Freeze and Cherry (1979), hydraulic conductivity (K) is determined using the following equation:

$$K = \frac{r^2 \ln\frac{L}{R}}{2LT_o} \quad (1)$$

where, $\mathbf{T_o}$ is the time lag or time that would be required for the complete equalization of the head differences if the original rate of inflow were maintained, **L** is the length of the piezometer intake or screen, and **R** is the radius of the piezometer, and **r** is the radius of the borehole.

3. RESULTS

3.1 Physical Hydrogeology

Measurements indicated that, in general, the water table is 0 to 2 m below the base of the tailings, except at station FS-6 where the water table is within the tailings (about 8 m above the base of the tailings). At that station, the water level may be high due to surface ponding or perched on fine-grained material. At station FS-12, which is the closest to the centre of the original kettle lake, the measured water level was approximately at the same level as the base of the tailings, or approximately 20 m below the tailings surface. The base of the tailings may be slightly deeper than the water table in the small area of the tailings between stations FS-12 and FS-5. The fact that most of the tailings are above the water table is surprising because water was visible in the kettle lake before tailings deposition. Reasons for this apparent water level change are discussed further.

A water table contour map (Fig. 4) was constructed for the Fault Lake tailings area by using the data collected in November 1992 and March 1993 to show average groundwater conditions. Since groundwater flow in hummocky terrain is generally controlled by topography, the water table contours reflect topographic contours. Regional groundwater flow from the tailings watershed is northeast toward the small kettle lakes and southeast toward the new tailings area, as illustrated by the arrows on Fig.4.

Hydraulic gradients were calculated for both vertical and horizontal directions. Vertical gradients were near zero at most of the monitoring stations surrounding the tailings deposit. Beneath the tailings deposit, vertical gradients were significant and indicate vertical percolation. At stations FS-4, FS-5 and FS-6 vertical gradients were respectively 2.5, 0.7 and 1.0. At FS-5, an upward gradient also appears, which, when coupled with the high (>1) gradient at FS-4, suggests partially confined conditions and/or localized flow paths below the tailings (likely from the region around FS-6). Horizontal gradients were very small. At the north dam, between stations FS-6 and FS-8 the horizontal gradient was 0.0002. The horizontal gradient at the south dam, between monitoring station FS-1 and FS-13, was 0.007.

Table 1 shows the results of the hydraulic conductivity tests for each piezometer. Measured hydraulic conductivities in the natural overburden units were highly variable, ranging between $8x10^{-1}$ cm/s (at FS-10) and $2.5x10^{-5}$ cm/s (at FS-4). The large variations in hydraulic conductivity are explained by the variability in soil types typical of ice-contact deposits which include silts, sands, gravels, and boulders. The higher values of hydraulic conductivity (such as at FS-10 and FS-14) would occur where fast meltwater flows would have formed accumulations of well-sorted sands and gravels. The lower hydraulic conductivities occur where glacial abrasion and slow meltwater flows would have left finer silts. The hydraulic conductivity values also suggest that silts may be present within void spaces between boulders (at FS-4, for example).

The geometric average of all hydraulic conductivity measurements is 1.6×10^{-3} cm/s. This value would be representative of a clean to silty medium sand, and is considered to be representative of the overall effective hydraulic conductivity of the ice-contact deposits in which lie the tailings.

The average linear groundwater velocity (***v***) in the overburden north of the tailings can be estimated by the Darcy equation:

$$v = K\, i \,/\, n \qquad \textbf{(2)}$$

Using the average hydraulic conductivity (***K***) of $1.6x10^{-3}$ cm/s, a hydraulic gradient (***i***) of 0.0002, and an estimated porosity (***n***) of 0.30, the calculated velocity north of the tailings is approximately 30 cm/year. With a horizontal gradient of 0.007, the calculated average darcy velocity south of the tailings is 6 m/year. This velocity is only approximate, and actual local velocities may vary by a factor of 10.

The hydraulic conductivity of the tailings could not be measured with the same field techniques used for measurements in the natural overburden because the tailings were above the water-table. The hydraulic conductivity of the tailings was therefore estimated using the *Kozeny-Carman* equation (Bear, 1972):

$$K = \frac{d_m^2}{180} \frac{n^3}{(1-n)^2} \qquad (3)$$

where d_m is a representative particle diameter and n is the soil porosity. Table 2 shows the results of these calculations using an estimated porosity of 0.45 and the median particle diameter, or d_{50}. The resulting estimated tailings hydraulic conductivities averaged 1.2×10^{-5} cm/s, which is consistent with measurements at other sites (Yanful and St-Arnaud, 1991, for example). For comparative purposes, calculations of tailings hydraulic conductivities using various porosities and particle diameters are presented in Appendix D . The measured hydraulic conductivities of tailings and overburden materials also agree with previous estimates done by Geocon (1985).

3.2 Chemical Hydrogeology

Results of the analysis of tailings pore water, groundwater, and water from surface bodies are shown in Tables 3 through 8. Concentrations of nickel, sulphate, and total iron characterize the general water quality found at the site and are discussed in most detail. Other physico-chemical parameters and chemical concentrations were determined and are listed in the Tables.

Water extractions were performed on 6 selected samples collected in November 1992 at each of the monitoring stations located on the tailings (Table 3). Nickel concentrations varied from 4 mg/L (FS-11 at 6.1 m depth) to 644 mg/L (FS-4 at 6.1 m depth). Sulphate concentrations varied from 3041 mg/L (FS-11 at 6.1 m depth) to more than 84 g/L (84,600 mg/L at FS-4). Total iron concentrations were between 0.5 mg/L to 466 mg/L. These values indicate the presence of high metal concentrations due to sulphide oxidation within portions of the tailings deposit. Metal concentrations in the pore water are strongly influenced by downward water movement and chemical precipitation and dissolution reactions which occur in the tailings mass. These effects seem to have attenuated nickel in the deeper parts of the tailings to concentrations of 5 to 8 mg/L (FS-12, depth 16 m; FS 13, depth 9 m in Table 3). Thermodynamic calculations done on porewater quality data from FS-4 and FS-6 using the MINTEQ program (Felmy et. al, 1984) suggested that the pore water could be near saturation with respect to nickel sulphate mineral species.

Variability in measured metal concentrations could also be caused by variations in the intensity of oxidation across the surface of the tailings. Visual inspection of the tailings shows the development of cracks and crusty layers at the surface which could locally influence water and oxygen entry and the resulting production of acid. Thorough investigations of the geochemical sources and evolution of metal concentrations have been investigated for other sulphide tailings sites (Blowes et. al, 1988, for example) and for the Falconbridge main pyrrhotite tailings site adjacent to the Fault Lake site (Nicholson and David, 1991). The investigation of the geochemistry of the Fault Lake tailings was not part of the objectives of the present study, and was therefore not pursued further than described above.

Background groundwater monitoring station FS-2 showed a pH near 7 and nickel concentrations near 0.01 mg/L, iron near 0.03 mg/L, and sulphate near 30 mg/L (Tables 4 to 7). Although nickel levels at FS-2 were slightly lower in the second sampling round (<0.005 mg/L), iron and sulphate values were the same as in the first round. The metal concentrations measured in the first sampling round at FS-2 can thus be accepted as background concentrations for groundwater at the site.

Background pH could be lower than that measured at FS-2 (as low as 6) due, for example, to the infiltration of acidic rainwater.

Groundwater sampled around the tailings site in December 1992 and March 1993 had pH values above 6 (Tables 4 to 7). Above-background concentrations of nickel were measured in wells FS-3A, FS-3B, FS-9C, and FS-10B; the highest of these concentrations was 0.5 mg/L (at FS-10), and was measured during only one of the sampling rounds. Only at FS-3 were the higher nickel levels associated with above-background sulphate concentrations of near 240 mg/L. Above-background sulphate concentrations were also encountered at station FS-1 (max 339 mg/L), but were not associated with any above-background metal concentrations.

Sampling results suggest that metal concentrations are not high enough to affect groundwater quality. This is also suggested by the results of surface water quality sampling (Table 8), which do not show the presence of any metal above background concentrations.

The presence of the tracer-labelled drilling water was encountered during both of the sampling rounds at some of the monitoring stations. Wells FS-3C, -6B, -6C, -14A, -14B were therefore not sampled. Samples should be obtained from these stations at a later date, after all the drill water evacuates. Monitoring at all stations should also be pursued.

4.0 GROUNDWATER FLOW MODELLING

4.1 Modelling Procedure

Groundwater flow around the tailings was simulated using the saturated-unsaturated flow modelling program SEEP/W (GEO-SLOPE International, 1992). SEEP/W requires the definition of a domain (finite-element grid), of soil hydraulic conductivities, and of boundary conditions to determine the flownet.

Two models were defined in order to obtain a quasi-3-dimensional perspective of the groundwater flows in the Fault Lake tailings area. Model 1 was a plan model, and was defined as a rectangle with the long edges parallel to the main flow direction inferred from the equipotential map of Fig.4. Model 1 was conceptual and represented the flow of water directly beneath the soil surface as affected by the hydraulic conductivity contrast between the tailings and the surrounding sediments. Model 1 did not incorporate the effect of hydraulic potential variations due to topographical effects.

Model 2 was a cross-section across stations FS-4 to FS-9 (**A-A'** in Fig 3). The model domain started 305 m (1000 ft) southwest of FS-4, extended 105 m (344 ft) northeast of FS-9 and passed through FS-6 and FS-8. Surface elevations were taken from the monitoring well data where possible; otherwise, the topographic map was used. Tailings and bedrock depths were determined using drilling data. Model 2 was extended 5 m into the bedrock by assuming that the top part of the bedrock was fractured and was not hydraulically isolated from the overburden.

Representative hydraulic conductivities (K) for the soils and tailings were derived from the geometric mean of the field measurements, as described in section 3.1. The modelling also required the input of soil characteristic functions describing the decrease in hydraulic conductivity with water content in the unsaturated zone. These characteristic functions were not specifically determined for the Fault Lake soils. Instead, functions for soils similar to those at the Fault Lake site reported in Yanful at. al (1993) were used and were considered accurate enough for the present study.

Boundary Conditions

Constant head boundary conditions were defined at both ends of the model domains. In Model 1, the constant heads were set equal to the elevation of the nearest lakes: lake #1 (306.7 m) in the south and lake #3 (297.6 m) in the north. The elevations of these lakes are marked on the topographic map (Fig 1) and the numbering of the lakes is marked in Figure 3. Since Model 1 simulated horizontal flow only, precipitation and evaporation effects were not considered.

In Model 2, a water table elevation slightly higher than that measured at FS-4 was used at **A** (300 m), and for **A'**, the elevation of lake #2 was taken off the topographic map (297.6 m). Two top boundary conditions were used: with infiltration (Model 2A) and without infiltration (Model 2B). In Model 2A, the infiltration flux across the top boundary was determined using previous estimates from Yanful et. al (1993) obtained using the HELP (Hydrologic Evaluation of Landfill Performance) computer program of Shroeder et. al (1984). HELP is a deterministic water balance program which uses climatic, soil and design data to calculate infiltration. Different fluxes were used in the SEEP/W modelling depending on the slope and nature of the ground surface. The tailings surface infiltration was set to 200 mm/year, sloped till 250 mm/year and flat till 350 mm/year. It was determined that infiltration into the till would be higher than that into the tailings since the hydraulic conductivity is higher and the water table is low. This would cause precipitation to be absorbed by the till and transferred away from the surface (to the water table), thereby limiting evaporation. On the tailings, evaporation is enhanced by surface ponding and infiltration is reduced compared to the till.

4.2 Modelling Results

Flow vectors for Model 1 describing groundwater flow without topographical effects are shown in Figure 5(A). The flow vectors represent the direction of flow, with their length being proportional to the flow quantities. Figure 5(A) clearly demonstrates that the water flows mainly in the till and around the tailings because of the higher hydraulic conductivity of the till. The hydraulic gradients (in m of water) are illustrated in Figure 5(B). Higher gradients (closer contours) developed across the tailings, as opposed to around the tailings, because of the restriction to flow.

Figure 6 depicts the flow characteristics for Model 2A (section with infiltration). The figure indicates that the horizontal flow is predominantly in the till and does not enter the tailings. In addition, all water that infiltrates the surface of the tailings flows vertically through the tailings and to the right (northeast). Therefore, water that flows through the tailings is only that water which infiltrates into the tailings from precipitation. The model also shows that the water infiltrating into the till left of the tailings flows to the left (west). In this case where the hydraulic gradient and flow velocities are low, the direction of flow in the west side of the section may be an artifact of the model. In any case, the hydraulic gradient and flow velocities generally agree with the water table contour map (Fig. 4), and suggest that flow from the west is not likely to enter the tailings.

Figure 7 displays the results of Model 2B (without infiltration). As in Model 1 (plan view), water flow bypasses the tailings. Essentially, no water flows into or out of the tailings; the calculated fraction of water flowing through the tailings, as opposed to around it, is less than 0.4%. The head contours below the tailings show that an increased gradient exists in that part of the flow section. This is simply due to the smaller cross-sectional area available in the flow domain. A dilution of contaminated water leaking from the tailings proportional to the groundwater discharge rate is expected to occur in that part of the flow section. Higher gradients are also evident at the right of the grid where the cross-sectional area of the till is again reduced.

To simulate conditions that would occur if the water table was to rise into the tailings and saturate the bottom portion of the impoundment, the constant head boundary functions at either end of the section were modified (Model 2C). The results of the simulation, which includes infiltration, are displayed in Figure 8. Although the bottom 5 metres of the tailings are saturated, the flow vectors within the saturated tailings are insignificantly small, as in Model 2A. The result shows that the flow is predominantly below the impoundment and suggests that the increase in metal loading in the groundwater due to the water table rise could not be significant.

The use of a 2-D flow model to assess the conditions on the Fault Lake site has inherent limitations. In particular, any quantification of flow volumes is affected by the fact that all the water is forced to move within the 2-D reference plane, while, in reality, water also moves across the plane. This would reduce the porous envelope effect in the model compared to reality. Another limitation is that, in reality, metal velocities usually slower than water velocities, and metal concentrations usually decrease as the water moves through the tailings and soils. This chemical attenuation is not taken into account by the model, so model predictions based only on groundwater flow can lead to overestimation of chemical loadings. The flow model is however very useful for predicting the worse-case scenario where no chemical attenuation would take place. Predictions which account for chemical attenuation are complex and are not part of the objectives of the present study.

5. DISCUSSION

The glacial sediments surrounding the Fault Lake tailings site are characterized by their elongated formation and relatively high bulk hydraulic conductivities. This creates a flow system with a relatively flat and deep water table. Several favourable factors contribute to limit the observed metal concentrations downgradient of the tailings: (1) the hydraulic conductivity contrast between the tailings and the surrounding sediments, as described conceptually by Model 1 in the previous section; (2) the low position of the water table relative to the tailings bottom, which has the effect of limiting the volume of tailings in saturated conditions, as described in Model 2; (3) the limited infiltration through the surface of the tailings, (4) the dilution of metals flushed from the tailings by water flowing around and below the tailings; (5) chemical attenuation of metals, which probably plays a large role both inside the tailings mass and in the surrounding sediments.

All the factors outlined above have a chance to occur simultaneously at other sites. The probability of occurrence for each of the factors are as follows:

(1) hydraulic conductivity contrast:

Sediments of high hydraulic conductivities such as sands and gravels do occur commonly in Canada. The ice-contact deposits surrounding the Fault Lake area possess a high average hydraulic conductivity, but are also characterized by a high variability due to the process by which they were deposited which produced a mix of particle sizes. Other sand and gravel units may be more uniform and have less variability in hydraulic properties; bulk hydraulic conductivities may be higher (near 10^{-2} cm/s, for example).

As for tailings, measurements at several sites (for example by Blowes et. al, 1988; Yanful and St-Arnaud, 1992) have yielded values close to 10^{-5} cm/s, as measured at the Fault Lake tailings. Large hydraulic conductivity contrasts between tailings and surrounding sediments are therefore commonly possible.

(2) Deep water table

The water table in well-drained sand and gravel formations in temperate climates will usually be deep below the ground surface. The depth to water table is also largely affected by topographical features. The hummocky terrain surrounding the Fault Lake site is largely controlled by the occurrence of the kettle lakes. In other similar glacial outwash areas, kettle lakes may not occur; however, depending on bedrock topography, the coarse glacial deposits are commonly elevated and produce deep water tables.

At the Fault Lake site, the water table was expected to be within the tailings because the area of deposition was once a kettle lake. The observed water table, however, was lower, probably because of man-made changes in the watershed. One hypothesis is that the tailings deposit may divert hillside runoff which had once entered the lake, to the edges of the tailings where it infiltrates into the till. Once within the till, the water is less likely to flow into the tailings. Therefore, as illustrated in Model 2 in the previous section, only the precipitation that infiltrates into the tailings surface will reach the water table below the tailings. This has the effect of reducing the watershed supplying the water table below the tailings (or the original lake) from 55 ha to 22 ha (the surface area of the tailings). Other changes to watersheds due to quarry excavation may also contribute to the change in water level.

(3) limited infiltration

Infiltration of water through the surface of the tailings surfaces is usually less than through most natural soils. This is due to the relatively low bulk hydraulic conductivity of the tailings, the high potential for evaporation at the tailings surface, and the formation of dense crusts at the tailings surface which can further reduce the tailings conductivity. Infiltration is promoted by water ponding on the tailings surface. At the Fault Lake tailings site, infiltration could be reduced compared to present conditions by preventing the ponding of water along the dams.

(4) dilution by regional groundwater flow

Large glacial outwash sediment formations are propitious to high groundwater discharges which are less susceptible to degradation by point contamination sources. In the case of the Fault Lake site, results from Model 2 suggest that flow upgradient of the tailings site would not be very large. The occurrence of much larger regional flow systems at other sites is possible.

(5) chemical attenuation

Some amount of chemical attenuation in the form of precipitation and adsorption reactions occur in most tailings. The degree at which these reactions take place depends on geochemical and mineralogical factors, in particular those which influence the neutralisation potential of the tailings. Chemical attenuation in the Fault Lake tailings is suggested by the tailings pore water data, and could also occur within the natural overburden deposits.

All five of the factors outlined above would contribute to create the porous envelope effect; these factors could probably be present at other locations near mine sites. Tailings deposition in these types of environments could be done with little effect on groundwater quality, pending that thorough site evaluations are performed and that appropriate control is done at the time of deposition.

5. CONCLUSIONS

1) The piezometric elevations throughout the Fault Lake site, combined with lake elevations, suggest that the regional direction of subsurface flow is toward the northeast, along with the alignment of kettle lakes. Some sub-regional flow systems could be moving groundwater in other directions.

2) The base of the tailings are at the same level or higher than the water table across most of the site. This is surprising because water was visible in the kettle lake before tailings deposition. Low water infiltration in the tailings and changes in watershed configurations due to nearby quarry excavation are suggested as causes for the apparent water level change.

3) The average bulk hydraulic conductivity of the glacial outwash soil material surrounding the tailings is estimated at 1.6×10^{-3} cm/s. The hydraulic conductivity of the tailings was estimated using grain size correlations at 1×10^{-5} cm/s. These values agree with previous estimates.

4) Analysis of tailings pore water showed elevated values of nickel, iron, and sulphate indicating the presence of sulphide oxidation products within portions of the tailings deposit. Metal concentrations are attenuated in the deeper parts of the tailings. Apparent high variability in measured metal concentrations could

be caused by variations in the intensity of oxidation across the surface of the tailings due to surface effects such as drying and cracking.

5) Water quality sampling in monitoring wells outside the tailings did not show any evidence of above-background metal concentrations, which suggests that leaching of metals from the tailings would be minimal. This is also suggested by the results of water sampling in nearby lakes.

6) Two-dimensional groundwater flow models showed that groundwater flow is diverted around the tailings mass due to the hydraulic conductivity contrast between the tailings and the surrounding sediments. The models also showed that flushing of the tailings mass by groundwater should not contribute significantly to the regional groundwater flow system under present water table conditions, as well as under conditions of moderate rise in water table level.

7) Factors which contribute to limit metal concentrations downgradient of the Fault Lake tailings are:

- the large hydraulic conductivity contrast between the tailings and the surrounding sediments,
- the low position of the water table relative to the tailings bottom,
- the limited infiltration through the surface of the tailings,
- the dilution of metals flushed from the tailings by water flowing around and below the tailings
- chemical attenuation of metals in the tailings and overburden

These factors could probably be present at other locations near mine sites. Tailings deposition could be done at these sites with little effect on groundwater quality pending that thorough site evaluations are performed and that appropriate control is done at the time of deposition.

CLOSURE

Field work and preliminary data analysis for this work were performed by S. Aiken. Numerical modelling was done by B. Aubé. M. Woyshner and P. Tibble assisted in the review and preparation of the final report. L. St-Arnaud coordinated the project and reviewed the final report.

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Table 1. Hydraulic Conductivity of Natural Soils

Piezometer No.	K (cm/s)
FS-1-A	No Test
FS-1-B	2.5E-03
FS-1-C	No Test
FS-2-A	2.9E-03
FS-2-B	2.9E-03
FS-3-A	1.0E-02
FS-3-B	8.6E-03
FS-3-C	No Water
FS-4-A	2.5E-05
FS-4-B	5.1E-05
FS-4-C	3.0E-05
FS-5-A	1.9E-04
FS-5-B	9.3E-05
FS-5-C	3.1E-04
FS-6-A	1.2E-04
FS-6-B	1.5E-04
FS-6-C	4.0E-04
FS-7	No Water
FS-8	6.1E-03
FS-9-A	8.9E-05
FS-9-B	7.6E-05
FS-9-C	8.1E-04
FS-10-A	8.0E-01
FS-10-B	8.0E-01
FS-11	3.6E-03 *
FS-12	1.0E-04 *
FS-13	2.0E-02 *
FS-14-A	4.0E-02
FS-14-B	4.0E-02

* Estimate - From Grain Size Data

Table 2. Estimated Tailings Conductivities Using Modified Kozeny-Carman

Sample	Depth (m)	d50 (mm)	K (cm/s)
FS-4	Surface	0.0185	5.73E-07
FS-4	6.10 - 6.70	0.044	3.24E-06
FS-4	7.6 - 8.2	0.017	4.84E-07
FS-5	Surface	0.058	5.63E-06
FS-5	3.05 - 3.65	0.071	8.44E-06
FS-5	4.57 - 5.18	0.0245	1.00E-06
FS-5	7.6 - 8.2	0.011	2.03E-07
FS-6	Surface	0.017	4.84E-07
FS-6	3.05 - 3.65	0.024	9.64E-07
FS-6	4.5 - 5.2	0.0082	1.13E-07
FS-6	6.1 - 6.71	0.16	4.28E-05
FS-6	7.62 - 8.07	0.21	7.38E-05
FS-8	1.5 - 2.1	0.051	4.35E-06
FS-11	1.5 - 2.1	0.04	2.68E-06
FS-11	6.1 - 6.71	0.12	2.41E-05
FS-11	7.6 - 8.2	0.021	7.38E-07
FS-11	9.1 - 9.8	10	1.67E-01
FS-11	15.2 - 15.8	6.4	6.85E-02
FS-11	16.8 - 17.4	0.91	1.39E-03
FS-11	18.3 - 18.9	0.48	3.86E-04
FS-11	19.8 - 20.4	0.18	5.42E-05
FS-12	16.76 - 17.37	0.12	2.41E-05
FS-12	19.81 - 20.42	0.18	5.42E-05
FS-13	3.1 - 3.7	0.0195	6.36E-07

Table 3. Metal concentrations in tailings pore water

Sample	Depth (m)	Al (mg/L)	As (mg/L)	Ca (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)
FS-4	6.1 - 6.7	3.88	<0.25	8536.00	<0.02	0.15	465.60	1188.25	3773.30
FS-6	6.1 - 6.7	0.95	<0.25	3197.70	0.09	0.11	109.77	319.77	602.14
FS-11	6.1 - 6.7	<0.25	<0.25	890.50	<0.02	<0.02	0.79	143.85	173.99
FS-12a	16.8 - 17.4	<0.25	<0.25	1056.00	<0.02	0.04	0.42	211.20	226.80
FS-12b	19.8 - 20.4	<0.25	<0.25	1316.00	<0.02	<0.02	0.41	291.40	248.16
FS-13	9.1 - 9.8	<0.25	<0.25	1395.00	<0.02	<0.02	0.52	281.25	879.75

Sample	Depth (m)	Mn (mg/L)	Na (mg/L)	Ni (mg/L)	Pb (mg/L)	SO4 (mg/L)	Se (mg/L)	Zn (mg/L)
FS-4	6.1 - 6.7	96.03	81.48	645.05	<0.25	84681.00	<0.50	3.69
FS-6	6.1 - 6.7	4.30	153.34	30.48	<0.25	29340.30	<0.50	3.22
FS-11	6.1 - 6.7	0.79	87.68	4.00	<0.25	3041.40	<0.50	0.10
FS-12a	16.8 - 17.4	1.37	79.56	5.63	<0.25	7200.00	<0.50	0.11
FS-12b	19.8 - 20.4	1.00	141.38	4.79	<0.25	4230.00	<0.50	0.38
FS-13	9.1 - 9.8	2.45	97.88	8.21	<0.25	6750.00	<0.50	0.27

Table 4. Physico-Chemical Parameter Values Fault Lake, December 1992

Sample	Temp. C	pH (field)	pH (lab)	Eh (mv)	Conductivity (uS/cm)	Acidity (mg/L CaCO3)	Alkalinity (mg/L CaCO3)
FS-1-A	8.1	7.15	7.10	542	470	<50	50
FS-1-B	8.7	8.12	7.95	526	580	<50	150
FS-1-C	6.6	7.96	7.90	521	212	<50	100
FS-2-A	4.5	7.94	7.90	432	188	<50	100
FS-2-B	5.5	7.12	7.01	413	209	<50	<50
FS-3-A	7.4	6.36	6.40	370	90	<50	<50
FS-3-B	<------------			Tracer in Water		------------>	
FS-3-C	<------------			Tracer in Water		------------>	
FS-4-A	<------------			Tracer in Water		------------>	
FS-4-B	<------------			Tracer in Water		------------>	
FS-4-C	<------------			Tracer in Water		------------>	
FS-5-A	<------------			Tracer in Water		------------>	
FS-5-B	<------------			Tracer in Water		------------>	
FS-5-C	<------------			Tracer in Water		------------>	
FS-6-A	<------------			Tracer in Water		------------>	
FS-6-B	<------------			Tracer in Water		------------>	
FS-6-C	<------------			Tracer in Water		------------>	
FS-7	<------------			No Water		------------>	
FS-8	7.3	6.02	5.91	486	150	<50	<50
FS-9-A	6.8	6.82	6.80	455	175	<50	<50
FS-9-B	7.8	6.75	6.70	472	254	<50	<50
FS-9-C	7.5	6.39	6.51	419	158	<50	<50
FS-10-A	6.3	6.52	6.40	409	149	<50	<50
FS-10-B	6.7	5.87	6.10	390	123	<50	<50
FS-11	<------------			No Water		------------>	
FS-12	<------------			No Water		------------>	
FS-13	<------------			No Water		------------>	
FS-14-A	<------------			Tracer in Water		------------>	
FS-14-B	<------------			Tracer in Water		------------>	

Table 5. Metal and Major Ion Concentrations in Groundwater Sampled
Fault Lake Tailings, December 1992

Sample	Al (mg/L)	As (mg/L)	Ca (mg/L)	Cd (ug/L)	Co (ug/L)	Cr (ug/L)	Cu (ug/L)	Fe (ug/L)	K (mg/L)	Mg (mg/L)	Mn (ug/L)	Na (mg/L)	Ni (ug/L)	Pb (mg/L)	S (mg/L)	Se (mg/L)	Sn (mg/L)	Zn (ug/L)	Cl (mg/L)	NO3 (mg/L)	SO4 (mg/L)	Fe2+ (mg/L)
FS-1-A	0.07	<0.05	84.44	<5.00	<5.00	<5.00	<5.00	10.9	2.39	21.68	21.7	14.48	<5.00	<5.00	73.74	<0.05	<0.05	<5.00	4.02	12.9	210	-
FS-1-B	0.05	<0.05	84.86	<5.00	<5.00	<5.00	<5.00	13.9	1.65	21.02	6.6	37.44	<5.00	<5.00	85.69	<0.05	<0.05	<5.00	6.47	24.9	239	-
FS-1-C	0.07	<0.05	18.42	<5.00	<5.00	<5.00	5.04	49.4	1.30	3.35	3.86	23.68	<5.00	0.07	11.82	<0.05	<0.05	<5.00	3.97	8.37	31.9	-
FS-2-A	<0.05	<0.05	33.68	<5.00	<5.00	<5.00	<5.00	27.2	1.09	8.17	22.7	6.49	11.9	<5.00	12.2	<0.05	<0.05	<5.00	13.5	8.22	33.5	-
FS-2-B	<0.05	<0.05	21.54	<5.00	<5.00	<5.00	7.16	17.7	1.73	3.64	95.4	7.89	9.75	<5.00	12.2	<0.05	<0.05	<5.00	3.70	5.25	32.4	-
FS-3-A	0.08	<0.05	9.52	<5.00	<5.00	<5.00	0.08	140	<1.00	2.42	16.6	2.84	14.1	<5.00	4.63	<0.05	<0.05	150	2.07	2.08	11.2	-
FS-3-B		--		------>																		
FS-3-C		--		------>																		
FS-4-A		--		------>																		
FS-4-B		--		------>																		
FS-4-C		--		------>																		
FS-5-A		--		------>																		
FS-5-B		--		------>																		
FS-5-C		--		------>																		
FS-6-A		--		------>																		
FS-6-B		--		------>																		
FS-6-C		--		------>																		
FS-7	No Water			------>																		
FS-8	0.07	<0.05	11.66	<5.00	<5.00	<5.00	<5.00	1310	1.92	2.58	6310	6.95	6.68	<5.00	12.89	<0.05	<0.05	15.4	1.56	6.75	27.4	1.05
FS-9-A	0.08	<0.05	28.71	<5.00	<5.00	<5.00	<5.00	23.2	1.84	3.83	73.9	5.15	9.75	<5.00	7.93	<0.05	<0.05	<5.00	5.20	2.30	16.6	-
FS-9-B	0.08	<0.05	22.81	<5.00	<5.00	<5.00	<5.00	42.5	2.45	3.33	120	22.33	<5.00	<5.00	7.80	<0.05	<0.05	<5.00	9.51	2.38	20.7	-
FS-9-C	0.08	<0.05	6.18	<5.00	7.23	<5.00	<5.00	55.4	1.20	1.11	1510	11.83	110	<5.00	10.03	<0.05	<0.05	<5.00	3.06	2.61	29.3	-
FS-10-A	0.08	<0.05	12.07	<5.00	<5.00	<5.00	<5.00	34.2	1.59	2.04	1.51	8.29	5.78	<5.00	3.14	<0.05	<0.05	<5.00	1.74	1.32	17.4	-
FS-10-B	<0.05	<0.05	6.17	<5.00	24.00	<5.00	<5.00	710	1.00	1.28	5.56	6.85	9.03	<5.00	6.65	<0.05	<0.05	<5.00	1.74	<0.20	17.3	0.68
FS-11	No Water			------>																		
FS-12	No Water			------>																		
FS-13	No Water			------>																		
FS-14-A		--		------>																		
FS-14-B		--		------>																		

-- Not Sampled

Table 6. Physico-Chemical Parameter Values Fault Lake Tailings, March 1993

Sample	Temp. C	Eh (mv)	Conductivity (uS/cm)	Acidity (mg/L CaCO3)	Alkalinity (mg/L CaCO3)
FS-1-A	6.2	495	660	< 0.05	< 0.05
FS-1-B	6.8	491	943	< 0.05	< 0.05
FS-1-C	6.3	493	205	< 0.05	< 0.05
FS-2-A	6.3	492	310	< 0.05	< 0.05
FS-2-B	6.1	492	176	< 0.05	< 0.05
FS-3-A	7.6	498	730	< 0.05	< 0.05
FS-3-B	7.6	483	996	< 0.05	< 0.05
FS-4-A	8	452	523	< 0.05	< 0.05
FS-4-B	9.9	458	507	< 0.05	< 0.05
FS-4-C	10.9	464	365	< 0.05	< 0.05
FS-5-A	9.4	379	515	< 0.05	< 0.05
FS-5-B	10.3	371	591	< 0.05	< 0.05
FS-5-C	11.7	365	554	< 0.05	< 0.05
FS-6-A	9.8	366	401	< 0.05	< 0.05
FS-6-B	<---------	No water	----------------------------------->		
FS-6-C	<---------	No water	----------------------------------->		
FS-7	<---------	No water	----------------------------------->		
FS-8	8.9	236	221	< 0.05	< 0.05
FS-9-A	10.3	247	261	< 0.05	< 0.05
FS-9-B	11.7	255	263	< 0.05	< 0.05
FS-9-C	12.1	307	126	< 0.05	< 0.05
FS-10-A	7.3	281	155	< 0.05	< 0.05
FS-10-B	9.2	292	111	< 0.05	< 0.05
FS-11	<---------	No water	----------------------------------->		
FS-12	<---------	No water	----------------------------------->		
FS-13	<---------	No water	----------------------------------->		
FS-14-A	<---------	No water	----------------------------------->		
FS-14-B	<---------	No water	----------------------------------->		

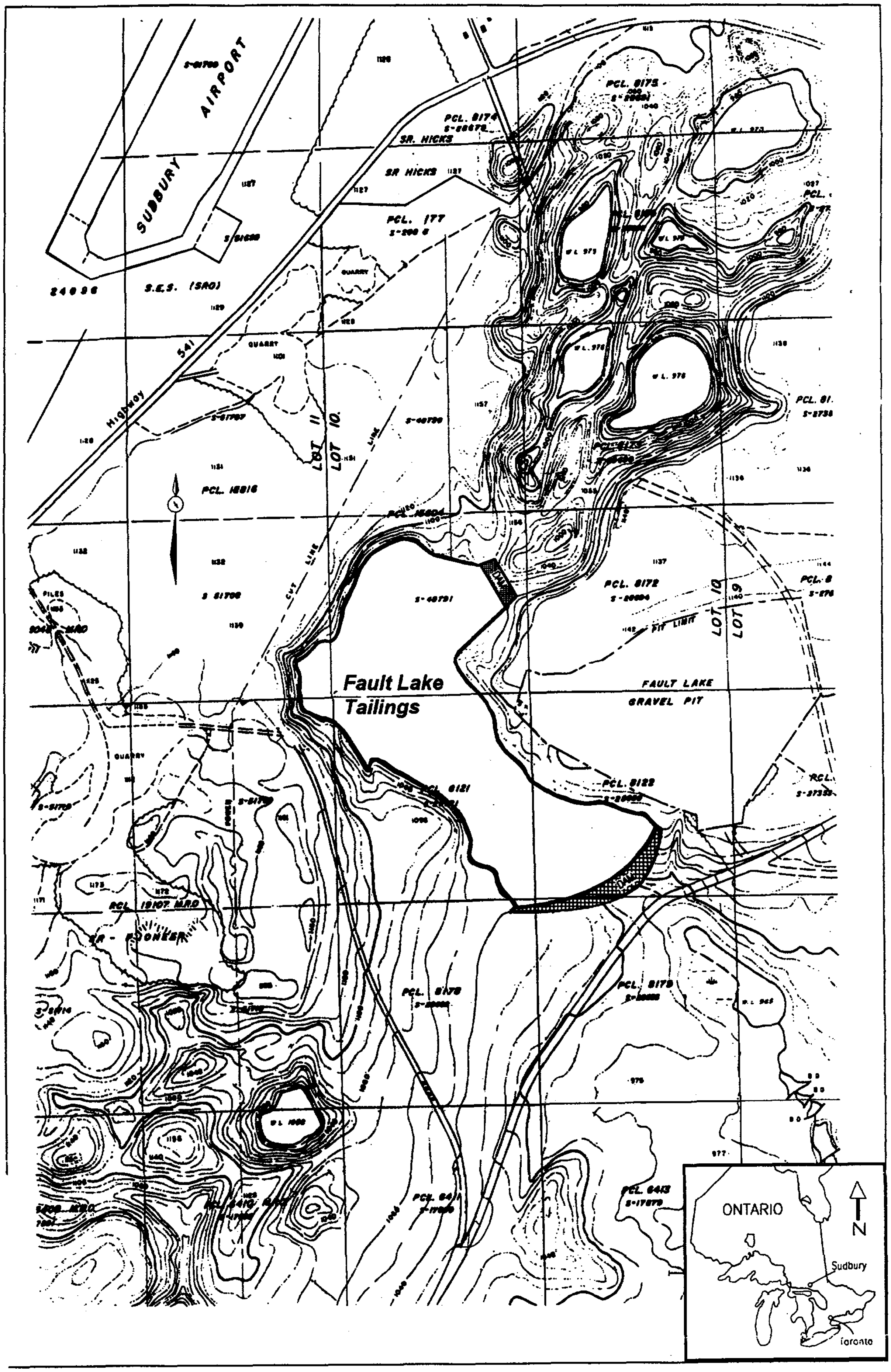
Table 7. Metal and Major Ion Concentrations in Groundwater Sampled
Fault Lake Tailings, March 1993

Sample	Al (mg/L)	As (mg/L)	Ca (mg/L)	Cd (ug/L)	Co (ug/L)	Cr (ug/L)	Cu (ug/L)	Fe (ug/L)	K (mg/L)	Mg (mg/L)	Mn (ug/L)	Na (mg/L)	Ni (ug/L)	Pb (mg/L)	S (mg/L)	Se (mg/L)	Sn (mg/L)	Zn (ug/L)
FS-1A	0.06	<0.05	80.94	<5.00	<5.00	<5.00	<5.00	<5.00	2.19	21.16	13.40	15.34	<5.00	<0.05	72.48	<0.05	<0.05	<5.00
FS-1B	<0.05	<0.05	95.42	<5.00	<5.00	<5.00	<5.00	<5.00	1.29	24.18	2.12	53.95	<5.00	<0.05	113.43	0.07	<0.05	<5.00
FS-1C	0.08	<0.05	16.55	<5.00	<5.00	<5.00	<5.00	<5.00	<1	3.20	<1	14.72	<5.00	<0.05	11.16	<0.05	<0.05	<5.00
FS-2A	0.08	<0.05	28.60	<5.00	<5.00	<5.00	5.19	<5.00	1.22	7.11	1.91	6.36	<5.00	<0.05	11.01	<0.05	<0.05	<5.00
FS-2B	0.12	<0.05	18.36	<5.00	<5.00	<5.00	<5.00	33.10	1.01	4.01	47.20	3.99	<5.00	<0.05	11.11	<0.05	0.06	<5.00
FS-3A	0.08	<0.05	73.76	<5.00	<5.00	<5.00	<5.00	<5.00	3.18	16.33	76.00	25.33	138.00	<0.05	49.52	<0.05	<0.05	<5.00
FS-3B	0.08	<0.05	101.29	<5.00	<5.00	<5.00	<5.00	<5.00	3.34	18.37	318.00	27.81	38.80	<0.05	82.23	<0.05	<0.05	<5.00
FS-3C		--		------------------------------>														
FS-4A	0.07	<0.05	52.60	<5.00	<5.00	<5.00	<5.00	1.34	5.88	11.89	248.00	18.42	<5.00	<0.05	35.45	<0.05	<0.05	<5.00
FS-4B	0.10	<0.05	62.05	<5.00	<5.00	<5.00	<5.00	14.10	6.52	12.17	176.00	20.43	11.70	<0.05	34.84	<0.05	<0.05	<5.00
FS-4C	0.18	<0.05	18.25	<5.00	<5.00	<5.00	<5.00	56.80	3.37	2.89	24.70	48.16	<5.00	<0.05	8.49	<0.05	<0.05	<5.00
FS-5A	0.17	<0.05	63.02	<5.00	<5.00	<5.00	5.29	192.00	5.64	10.86	274.00	13.95	<5.00	<0.05	33.78	<0.05	<0.05	<5.00
FS-5B	0.17	<0.05	47.01	<5.00	<5.00	<5.00	6.95	356.00	3.03	9.09	265.00	42.64	<5.00	<0.05	33.58	<0.05	<0.05	<5.00
FS-5C	0.23	<0.05	53.37	<5.00	<5.00	<5.00	6.02	514.00	8.04	8.50	146.00	31.79	6.01	<0.05	32.07	<0.05	<0.05	<5.00
FS-6A	0.26	<0.05	41.37	<5.00	<5.00	<5.00	6.95	<5.00	3.82	9.15	64.70	17.62	<5.00	<0.05	14.66	<0.05	<0.05	<5.00
FS-6B		--		------------------------------>														
FS-6C		--		------------------------------>														
FS-7		--		------------------------------>														
FS-8A	0.09	<0.05	11.38	<5.00	5.29	<5.00	<5.00	19.32	2.05	2.39	5.44	4.84	<5.00	<0.05	12.54	<0.05	<0.05	<5.00
FS-9A	0.07	<0.05	29.03	<5.00	<5	<5.00	<5.00	91.00	1.91	4.64	156.00	6.16	<5.00	<0.05	8.79	<0.05	<0.05	<5.00
FS-9B	0.12	<0.05	26.81	<5.00	<5	<5.00	<5.00	139.00	2.15	4.35	110.00	11.01	<5.00	<0.05	8.61	<0.05	<0.05	<5.00
FS-9C	0.31	<0.05	6.38	<5.00	8.30	<5.00	<5.00	746.00	<1	1.13	1.12	11.87	46.30	<0.05	8.54	<0.05	<0.05	<5.00
FS-10A	0.41	<0.05	15.37	<5.00	7.03	<5.00	5.30	1.68	1.62	2.09	1.58	8.24	19.40	<0.05	3.79	<0.05	<0.05	7.50
FS-10B	0.16	<0.05	6.13	<5.00	84.80	<5.00	13.40	2.54	<1	1.16	1.92	2.87	532.00	<0.05	8.37	<0.05	<0.05	0.14
FS-11		--		------------------------------>														
FS-12		--		------------------------------>														
FS-13		--		------------------------------>														
FS-14-A		--		------------------------------>														
FS-14-B		--		------------------------------>														

-- Not Sampled

Table 8. Chemical Quality of Surface Water
Fault Lake Tailings, October 1992

Sample	Depth (m)	As (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe(T) (mg/L)	Mn (mg/L)	Na (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)	SO4 (mg/L)	pH
Pond #1	0.00	0.003	0.0003	<0.02	0.07	0.01	7.3	0.03	0.003	0.007	27	7.20
Pond #1	2.74	0.003	0.0002	<0.02	0.08	0.01	7.3	0.02	0.003	<0.005	28	7.40
Pond #1	4.57	0.003	0.0005	<0.02	0.06	0.01	7.3	0.02	0.002	0.009	28	7.60
Pond #2	0.00	0.007	0.0002	<0.02	0.05	0.01	5.3	<0.02	0.003	<0.005	26	7.60
Pond #2	4.57	0.006	0.0002	<0.02	0.06	0.01	4.9	<0.02	0.004	<0.005	25	7.60
Pond #2	7.62	0.010	0.0002	<0.02	0.17	0.03	5.0	<0.02	0.002	<0.005	24	7.20
Pond #3	0.00	<0.003	0.0002	<0.02	0.05	0.01	1.8	0.02	0.001	<0.005	18	7.40
Pond #3	9.14	<0.003	0.0002	<0.02	0.05	0.01	2.0	0.02	0.002	0.011	18	7.00
Pond #3	15.24	0.007	0.0002	<0.02	0.60	0.36	2.0	0.03	0.002	0.006	15	6.70
Pond #4	0.00	0.006	0.0002	<0.02	0.03	0.01	.9	<0.02	<0.002	0.013	25	7.40
Pond #4	4.57	0.006	0.0002	<0.02	0.04	0.01	9	<0.02	0.003	<0.005	25	7.80
Pond #4	8.23	0.005	0.0003	<0.02	0.05	0.01	8.9	<0.02	0.003	0.007	25	7.80
Pond #5	0.00	0.003	0.0002	<0.02	0.02	0.01	7.2	0.02	0.001	<0.005	67	7.80
Pond #5	9.14	0.002	0.0002	<0.02	0.02	0.01	7.2	0.02	0.003	0.009	65	7.80
Pond #5	15.24	0.007	0.0003	<0.02	0.28	0.57	7.8	0.02	0.002	0.007	69	7.00



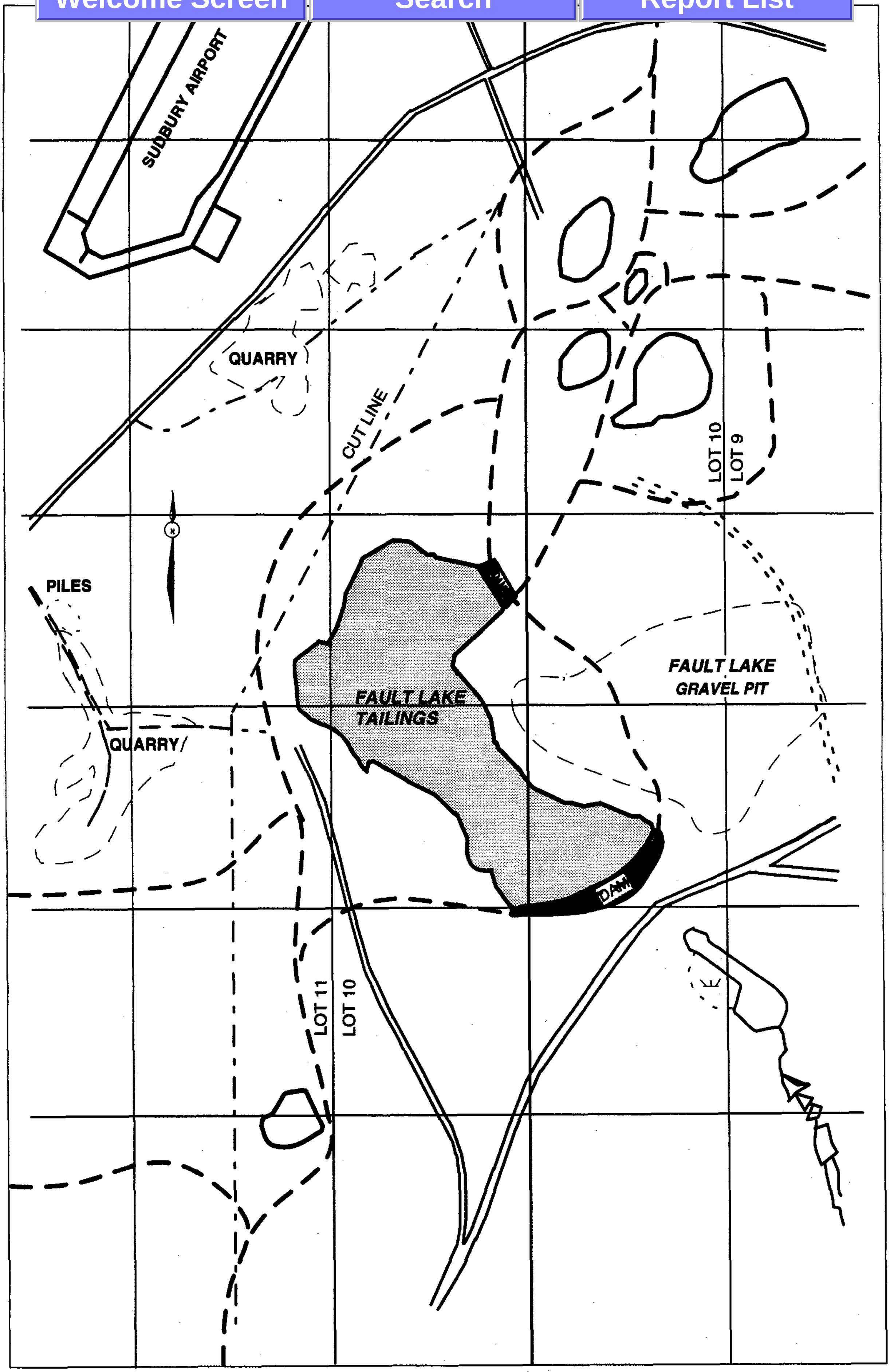
CENTRE DE TECHNOLOGIE NORANDA
ENVIRONMENTAL PROGRAM

Figure 1: Site plan and Topography

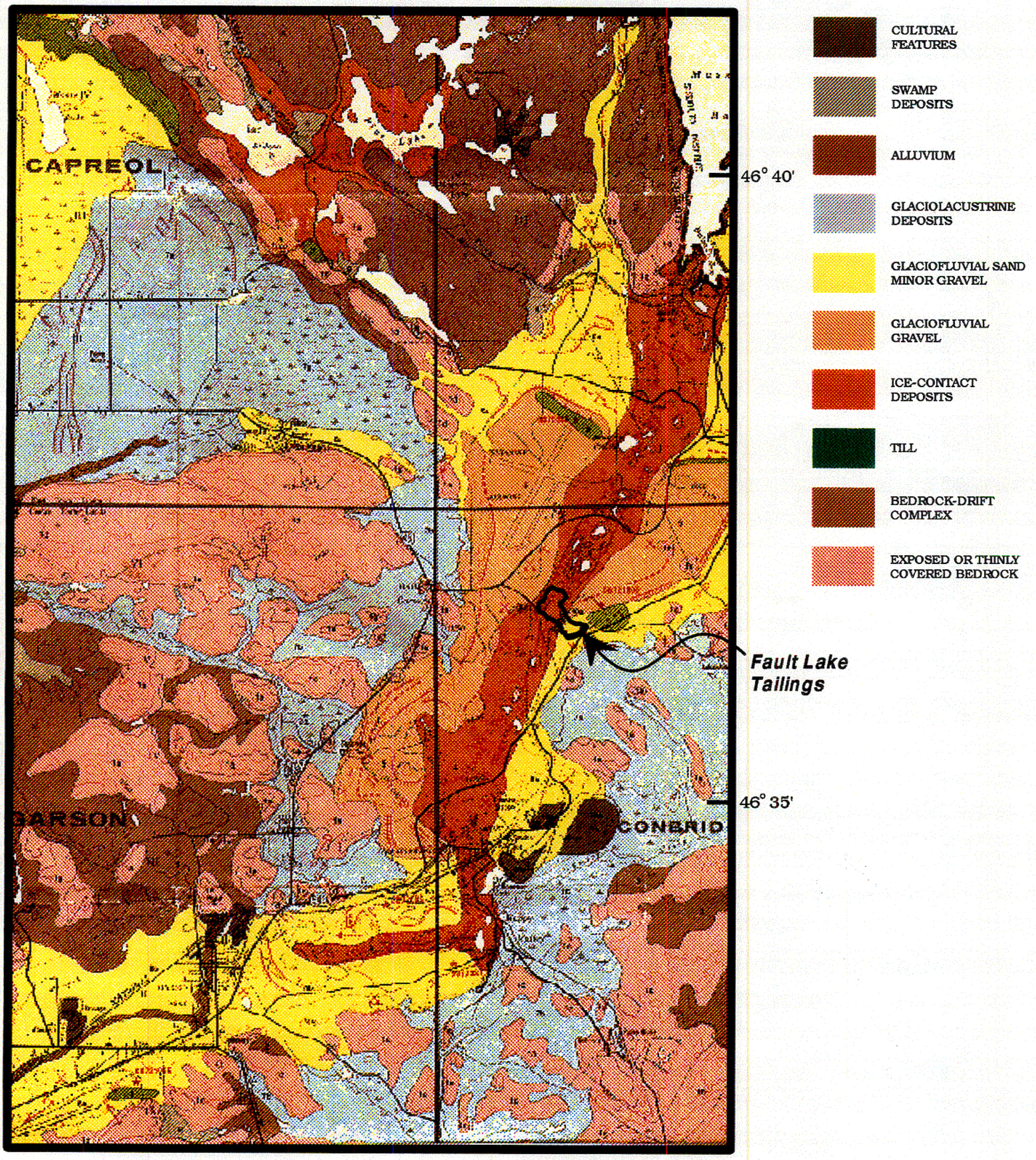
Prepared by: BA
DATE: APR 1993

Scale: 0 500 ft 1000 ft

Fault Lake Tailings Site
Porous Envelope Concept



CENTRE DE TECHNOLOGIE NORANDA ENVIRONMENTAL PROGRAM	Figure 1a. Watershed limits MAY 1993 / SHED1A.DRW — Scale: 0 500 ft 1000 ft	Fault Lake Tailings Site Porous Envelope Concept Prepared by: S.A., R.F., P.T



Noranda Technology Centre Mineral Sciences Environment	Figure 2. Overburden Geology Falconbridge Sudbury SCALE: 1:50,000 — 1000 0 1000 Metres	SOURCE: Ontario ministry of natural resources, Ontario geological survey map 2397

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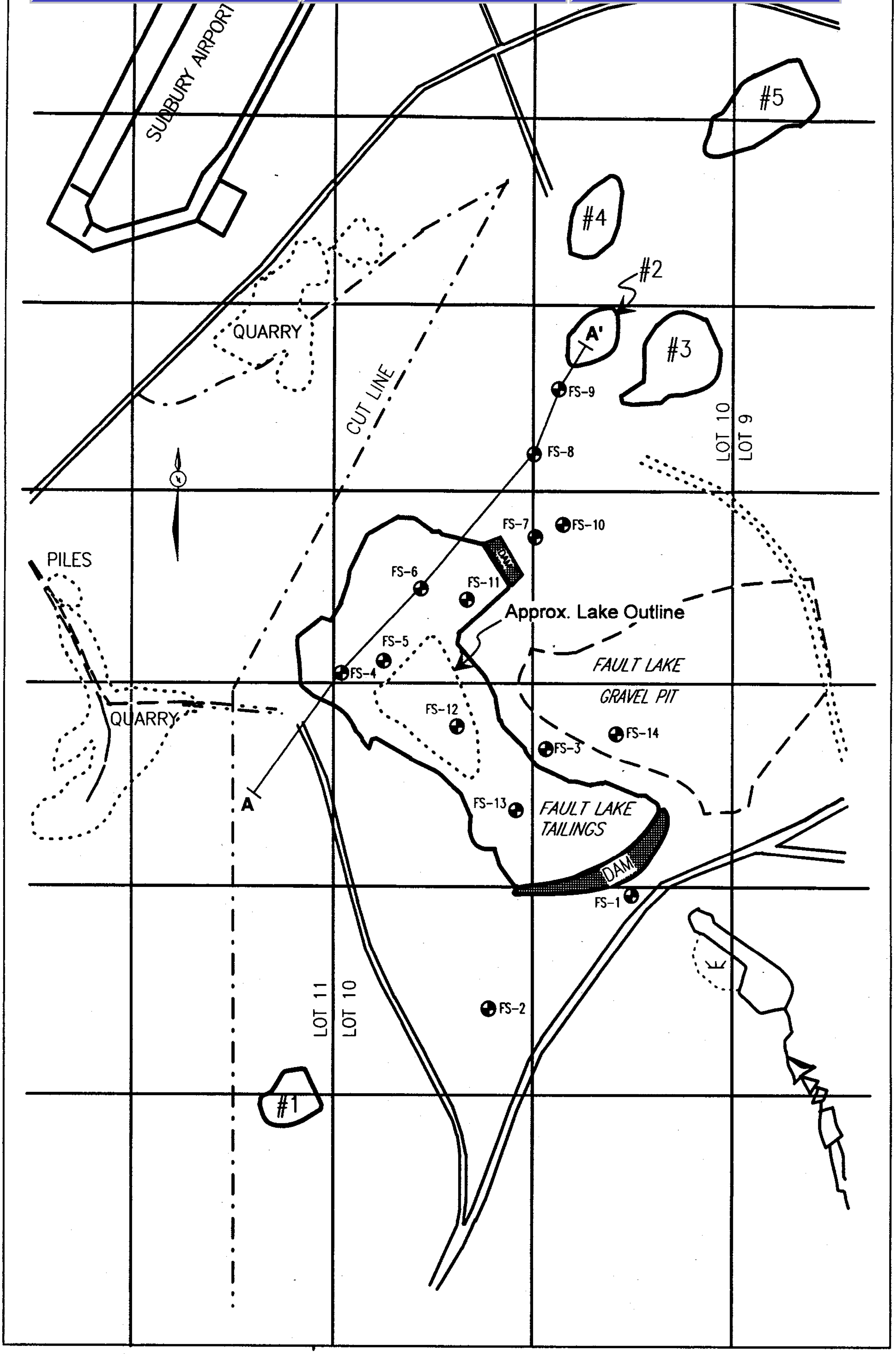


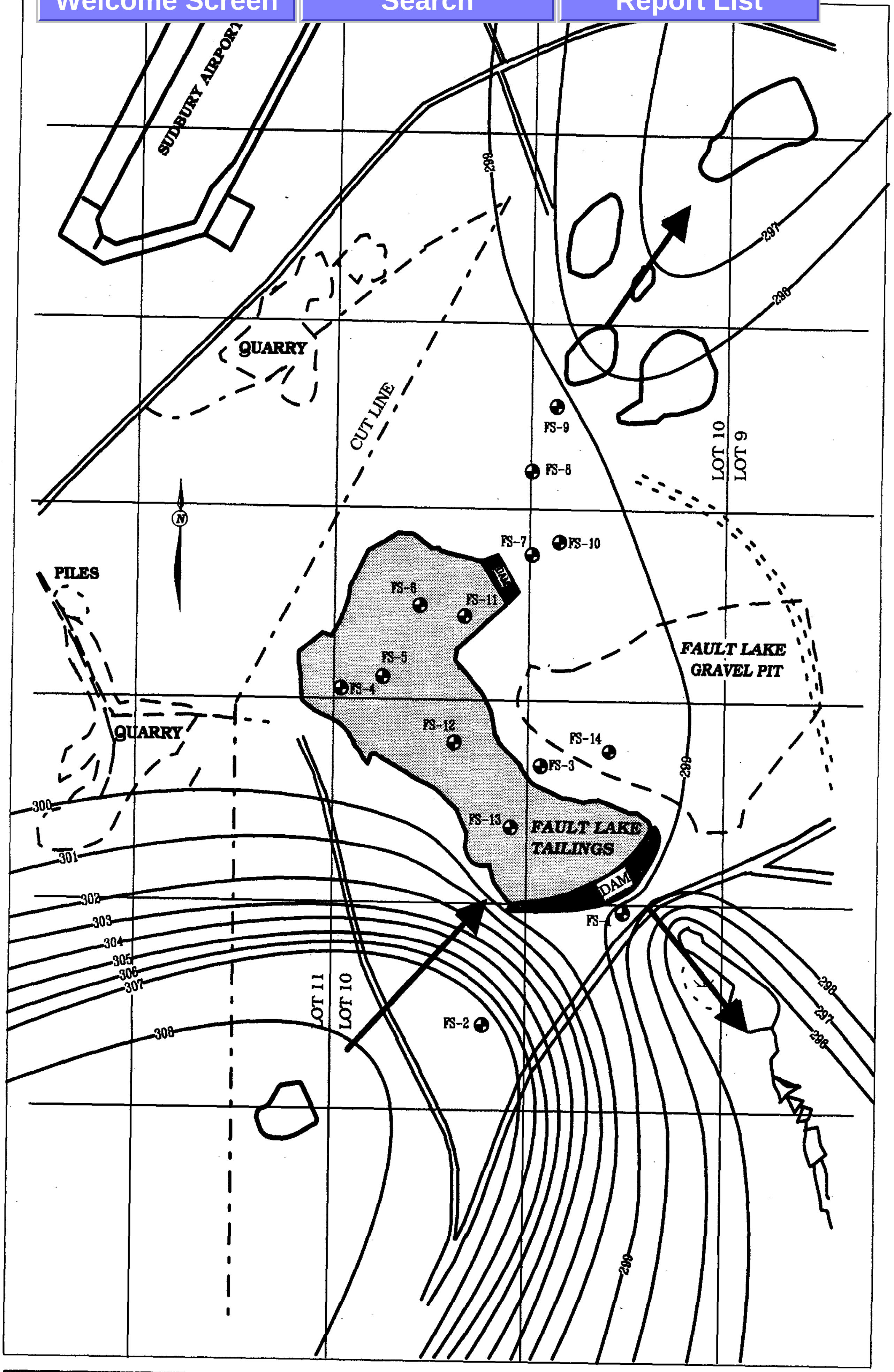
CENTRE DE TECHNOLOGIE NORANDA
ENVIRONMENTAL PROGRAM

Figure 3. Piezometer Locations

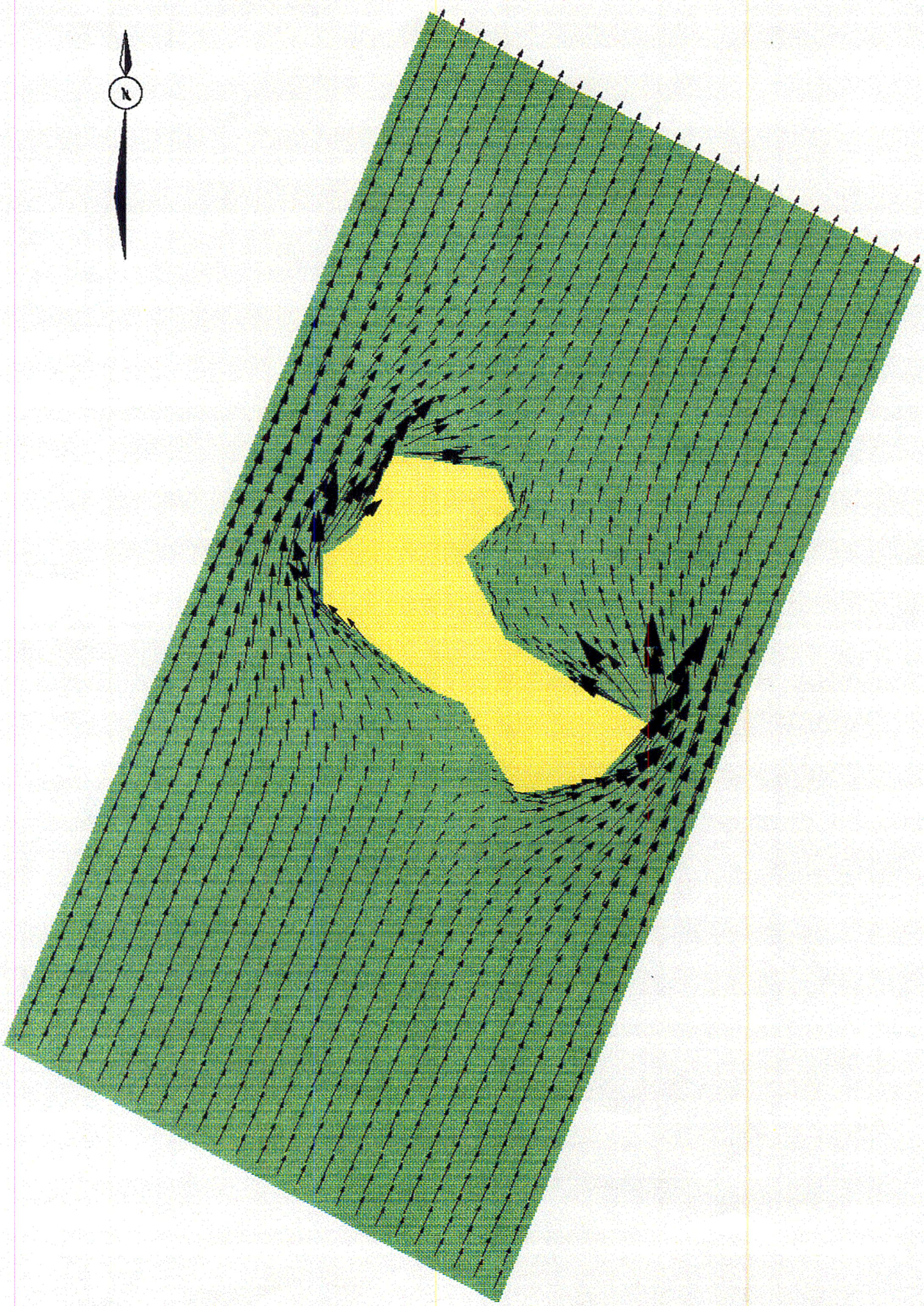
Prepared by: BA, RF
APR 1993

Scale: 0 500 ft 1000 ft

Fault Lake Tailings Site
Porous Envelope Concept



CENTRE DE TECHNOLOGIE NORANDA ENVIRONMENTAL PROGRAM	Figure 4. Water Elevation Contours	Fault Lake Tailings Site Porous Envelope Concept
SEPT 1993	Scale: 0 500 ft 1000 ft	Prepared by: B.A., R.F., P.T
H2O_CONT.DRW		



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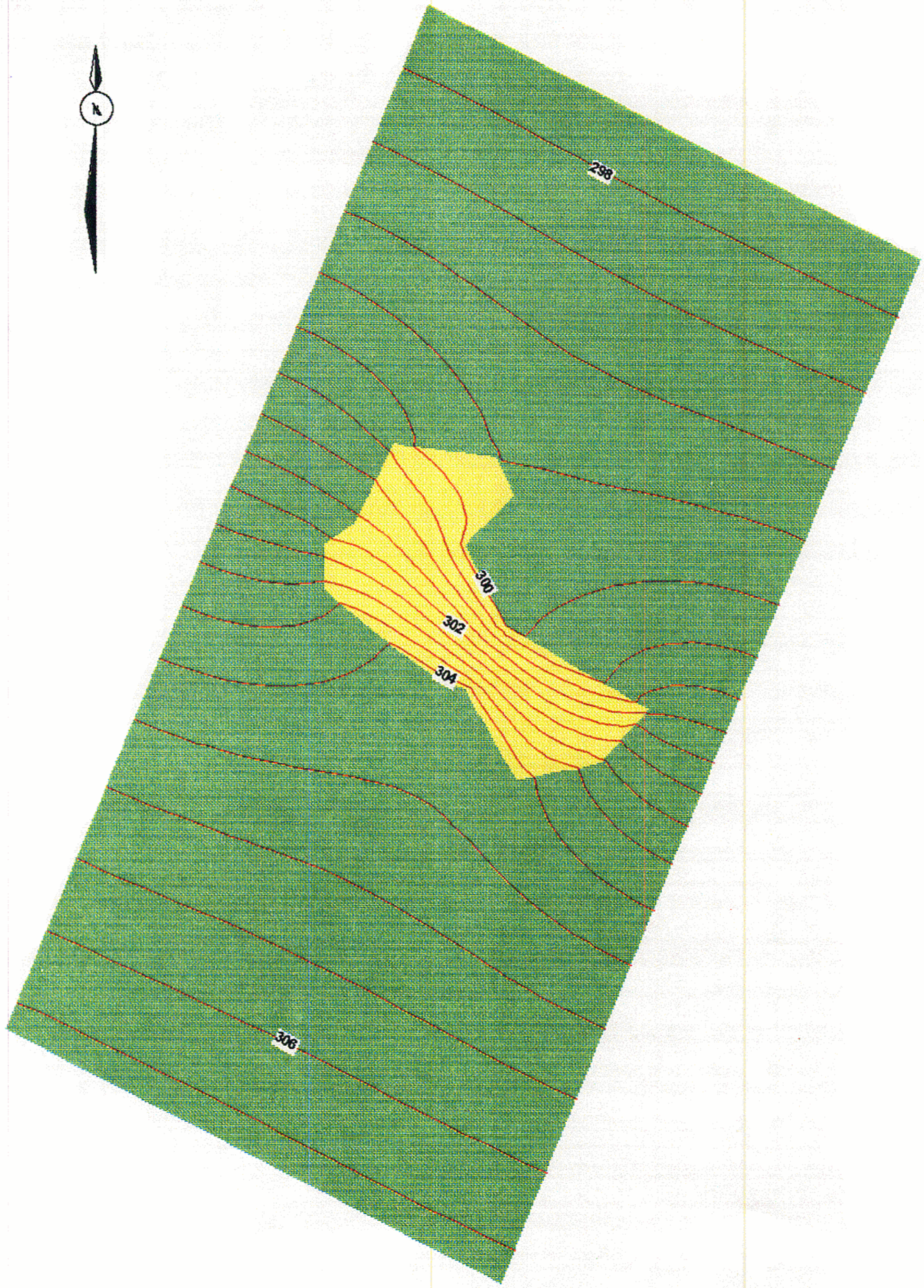
ENVIRONMENTAL PROGRAM

Figure 5(A). Flow Vectors in Plan View

Prepared by. BA
MAR 1993

Scale: 0 200 m 400 m

Fault Lake Tailings Site
Porous Envelope Conceptual Modelling Results



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ENVIRONMENTAL PROGRAM

Figure 5(B). Pressure Head Contours in Plan View

Prepared by. BA
MAR 1993

Scale: 0 200 m 400 m

Fault Lake Tailings Site
Porous Envelope Conceptual Modelling Results

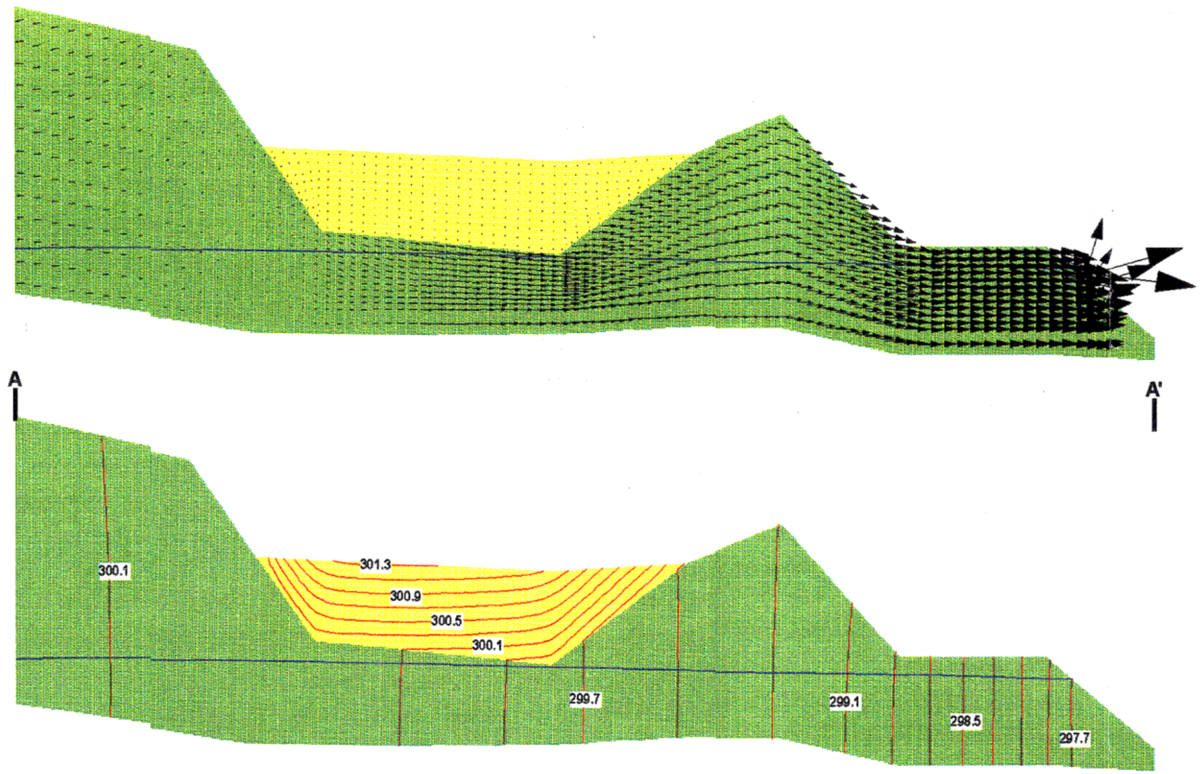

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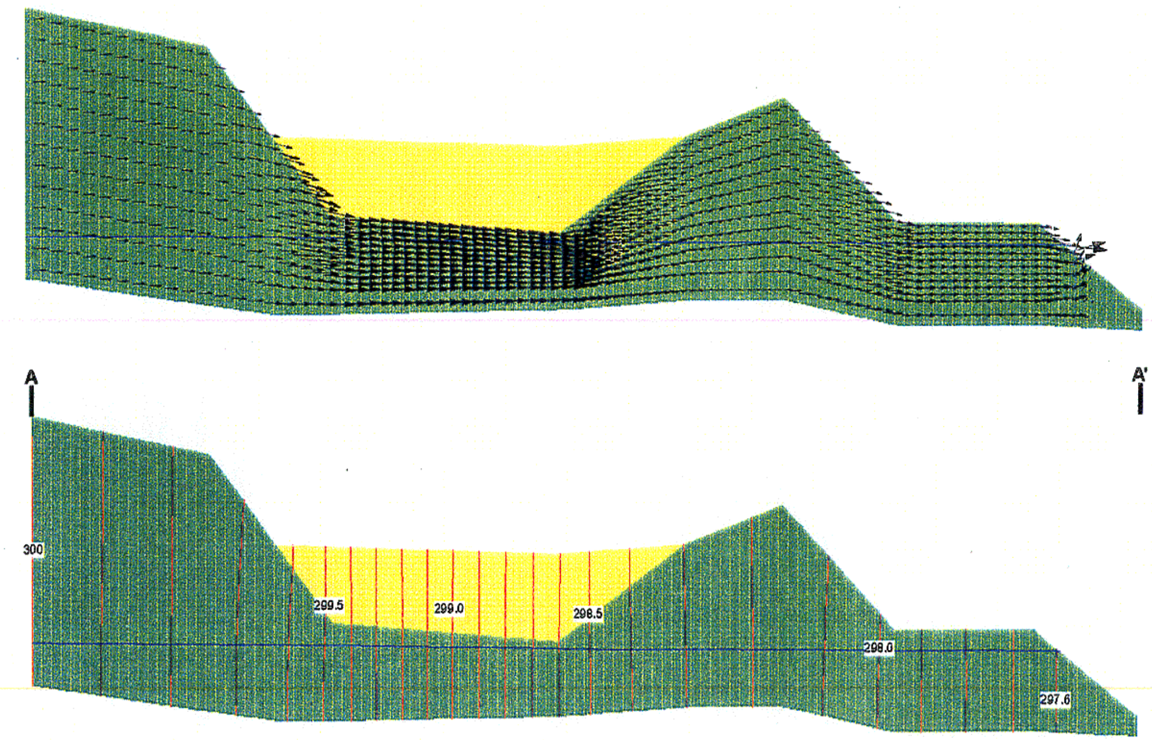
Figure 6. Flow Vectors and Head Contours With Infiltration

Prepared by: BA

MAR 1993

X Scale: 0 100 m Y Scale: 0 20 m

Fault Lake Tailings Site
Porous Envelope Conceptual Modelling Results



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ENVIRONMENTAL PROGRAM

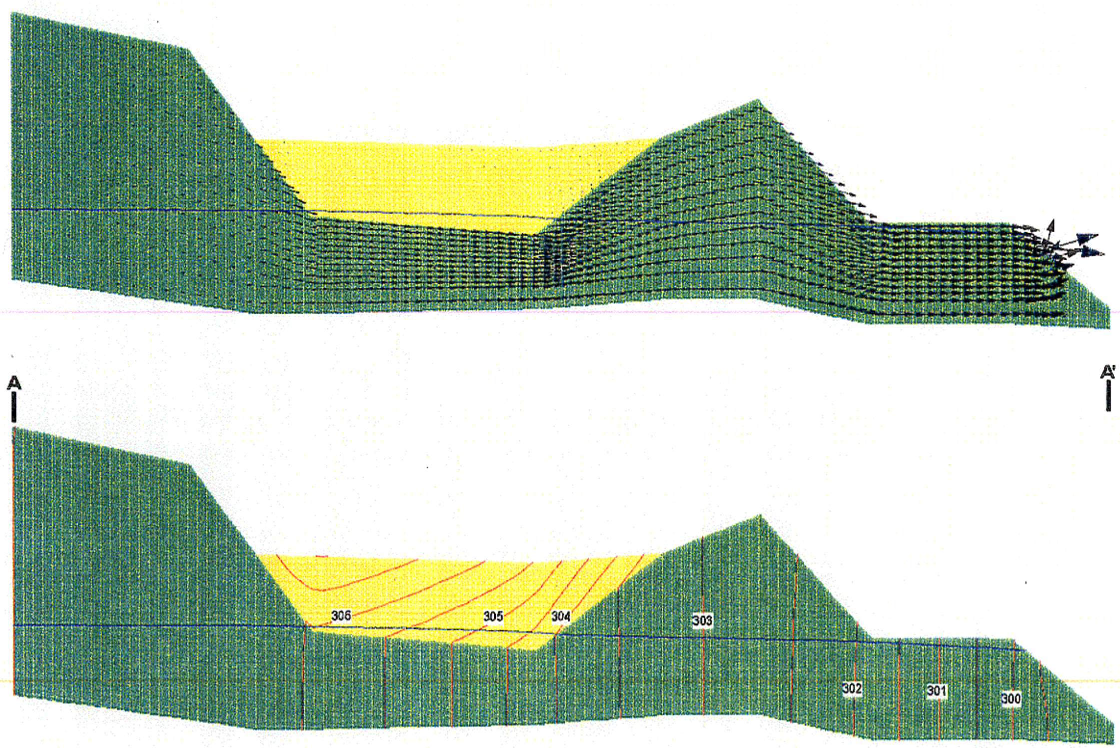
Figure 7. Flow Vectors and Head Contours Without Infiltration

Prepared by: BA

MAR 1993

X Scale: 0 100 m Y Scale: 0 20 m

Fault Lake Tailings Site
Porous Envelope Conceptual Modelling Results



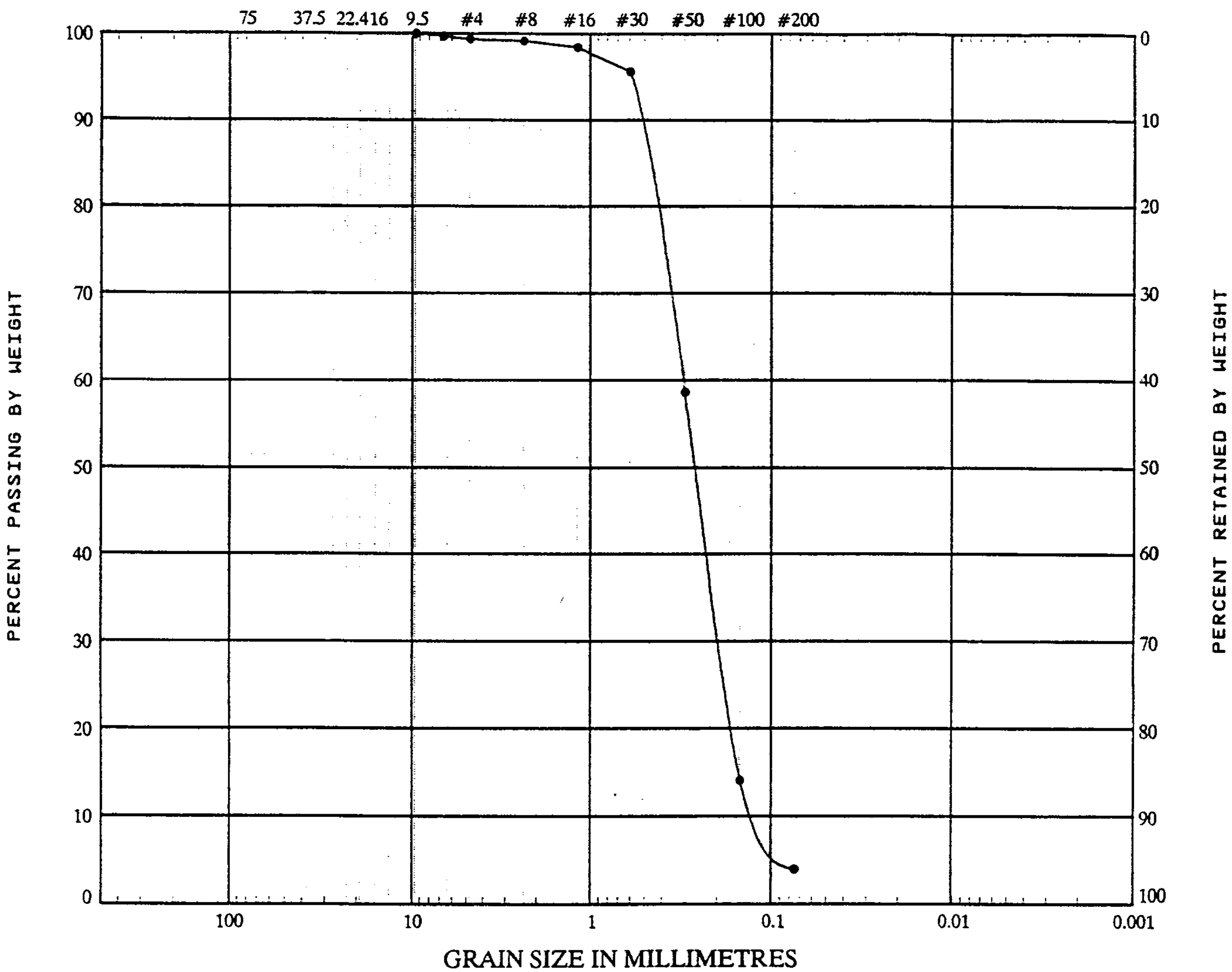
CENTRE DE TECHNOLOGIE NORANDA ENVIRONMENTAL PROGRAM	Figure 8. Flow Vectors and Head Contours With High Water Table Prepared by: BA MAR 1993 X Scale: 0 100 m Y Scale: 0 20 m	Fault Lake Tailings Site Porous Envelope Conceptual Modelling Results

APPENDIX E.1

Grain Size Distribution Curves

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-5		12.19-12.80	Fine sand

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
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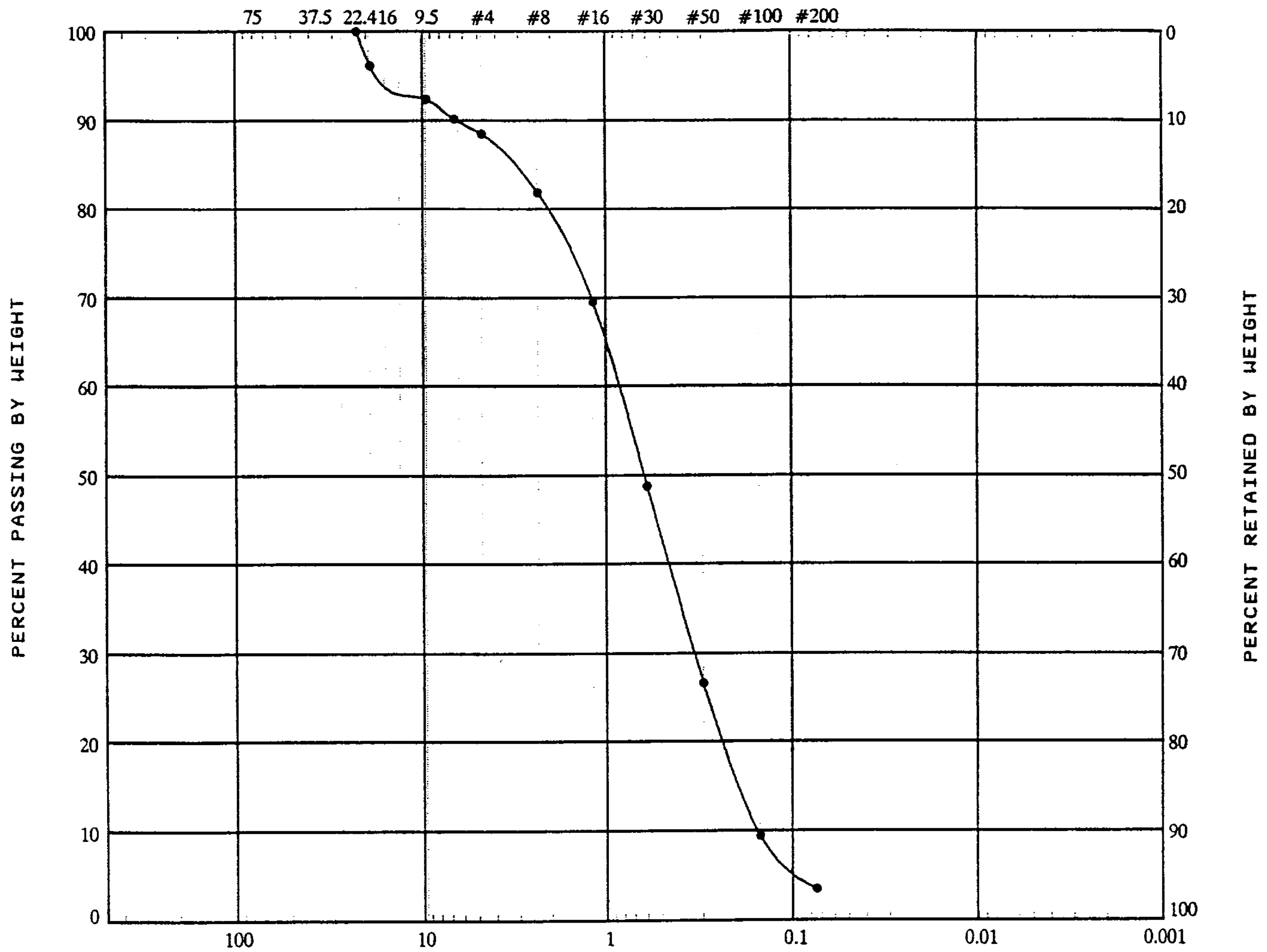
Figure No. 1

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-6		16.76-17.37	Fine to medium sand, trace gravel

REMARKS

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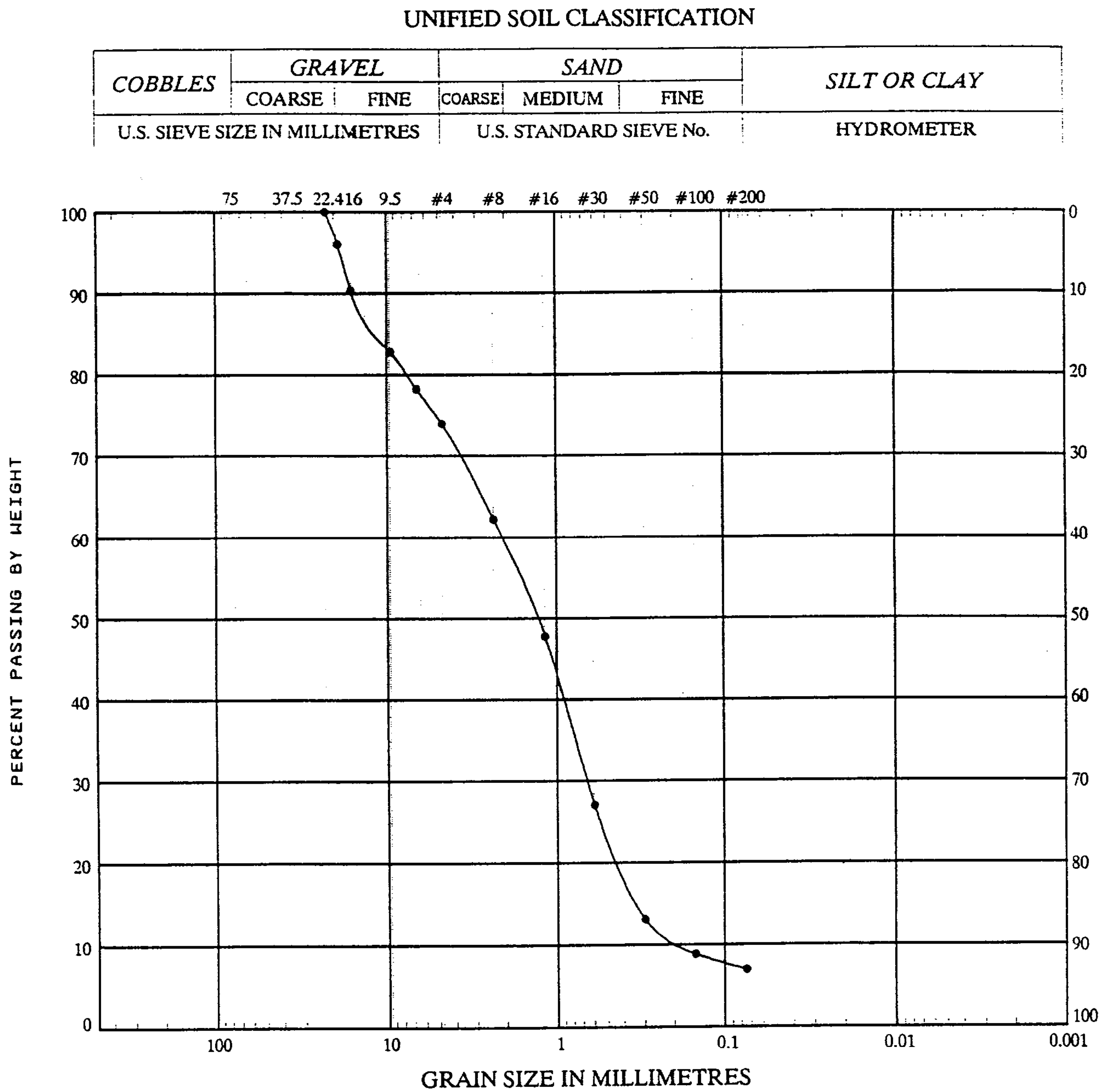
Figure No. 2



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-3		1.52-2.13	Gravelly sand

REMARKS

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Figure No. 3

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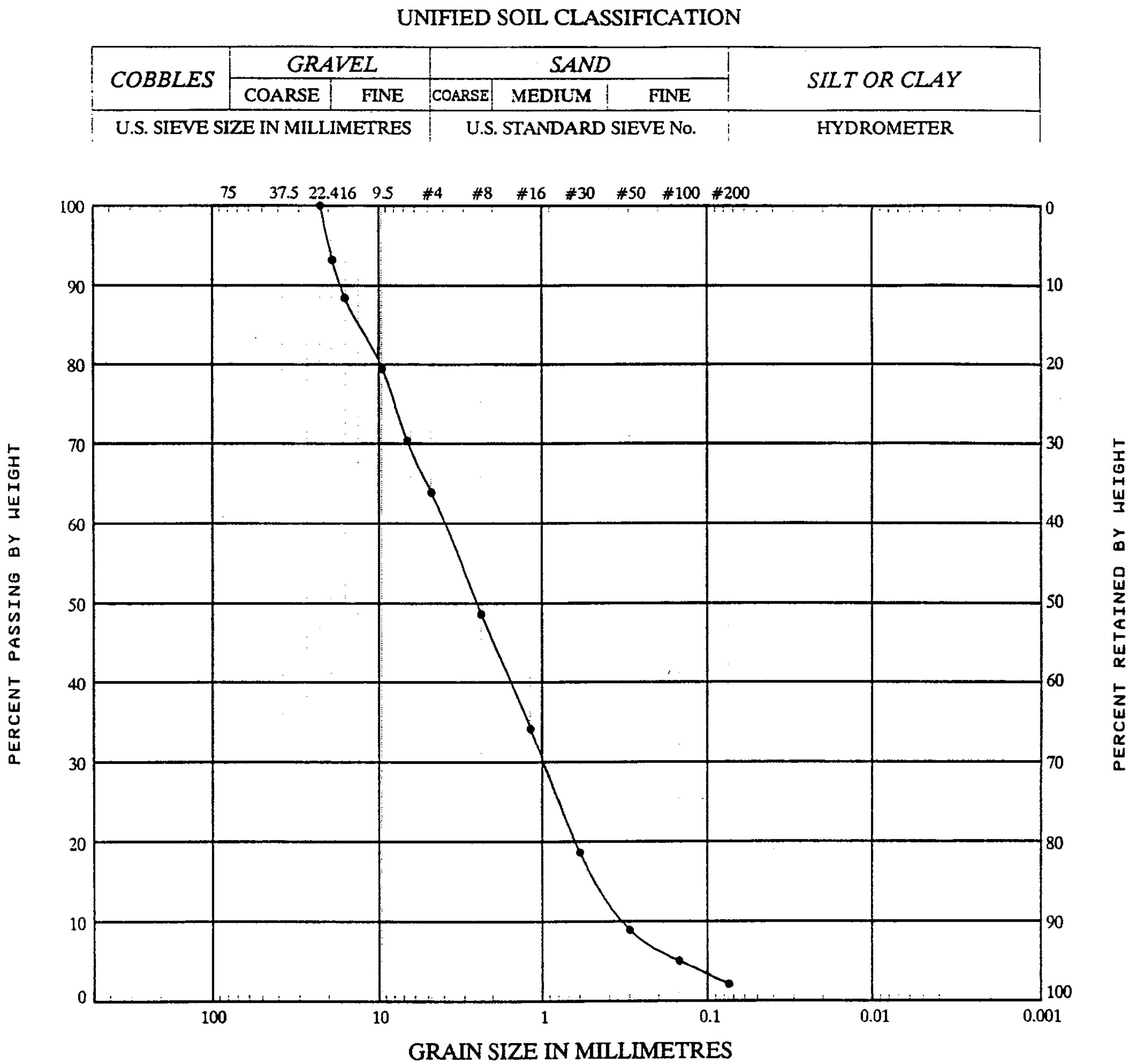

PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-3		3.05-3.65	Gravelly sand

REMARKS

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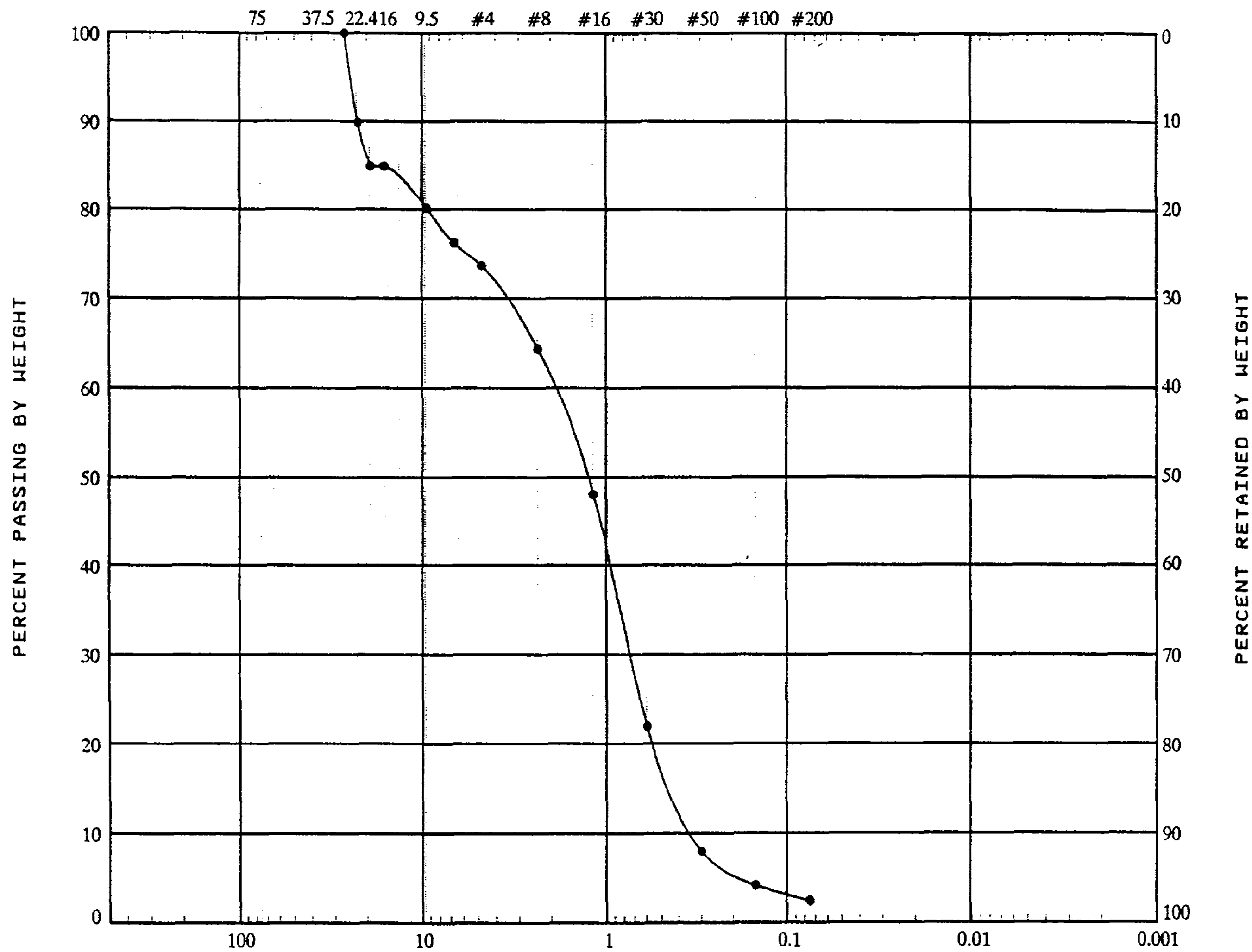
Figure No. 4

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



GRAIN SIZE IN MILLIMETRES

PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-3		4.57-5.18	Gravelly sand

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
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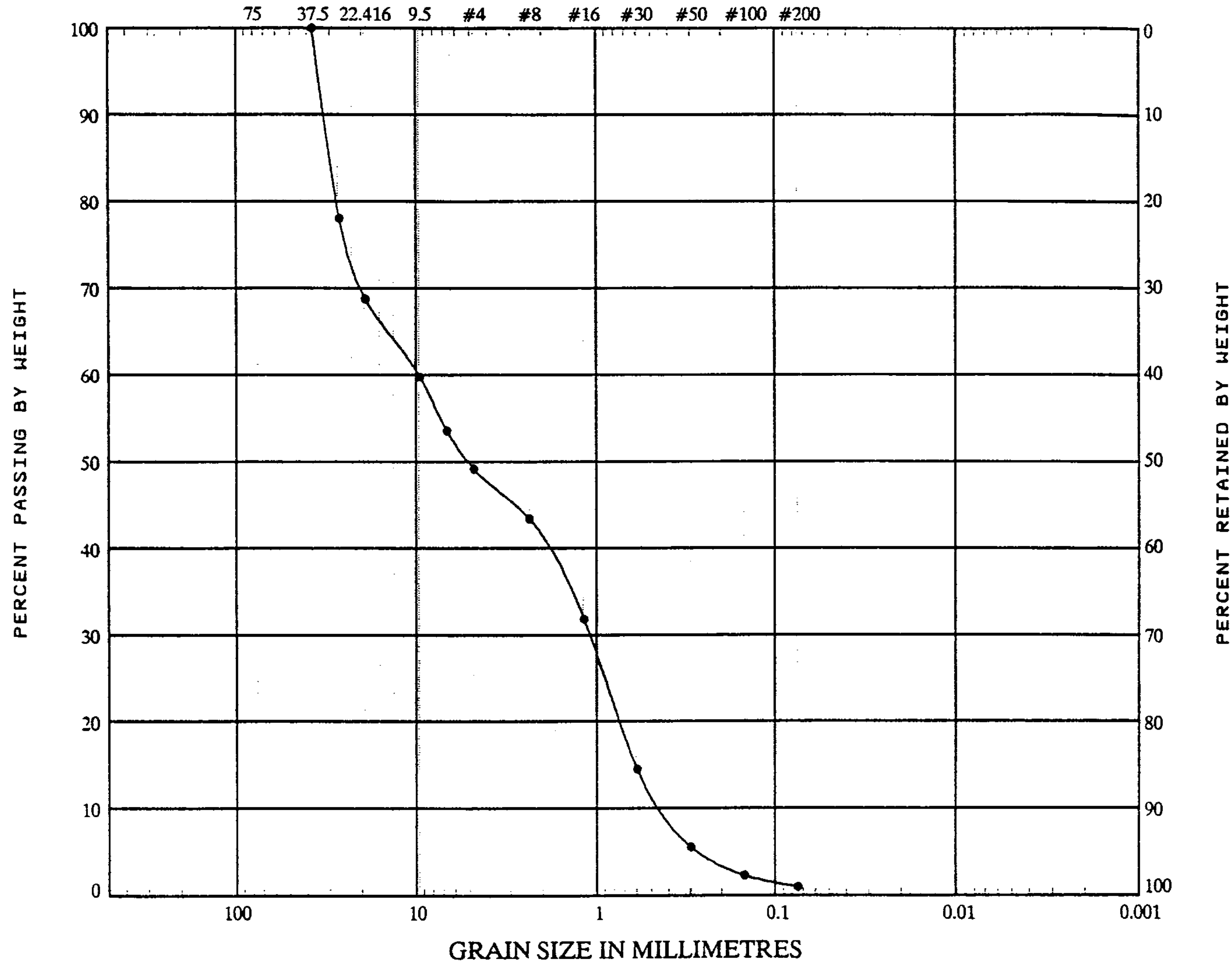
Figure No. 5

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-3		6.10-6.70	Sand and gravel

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
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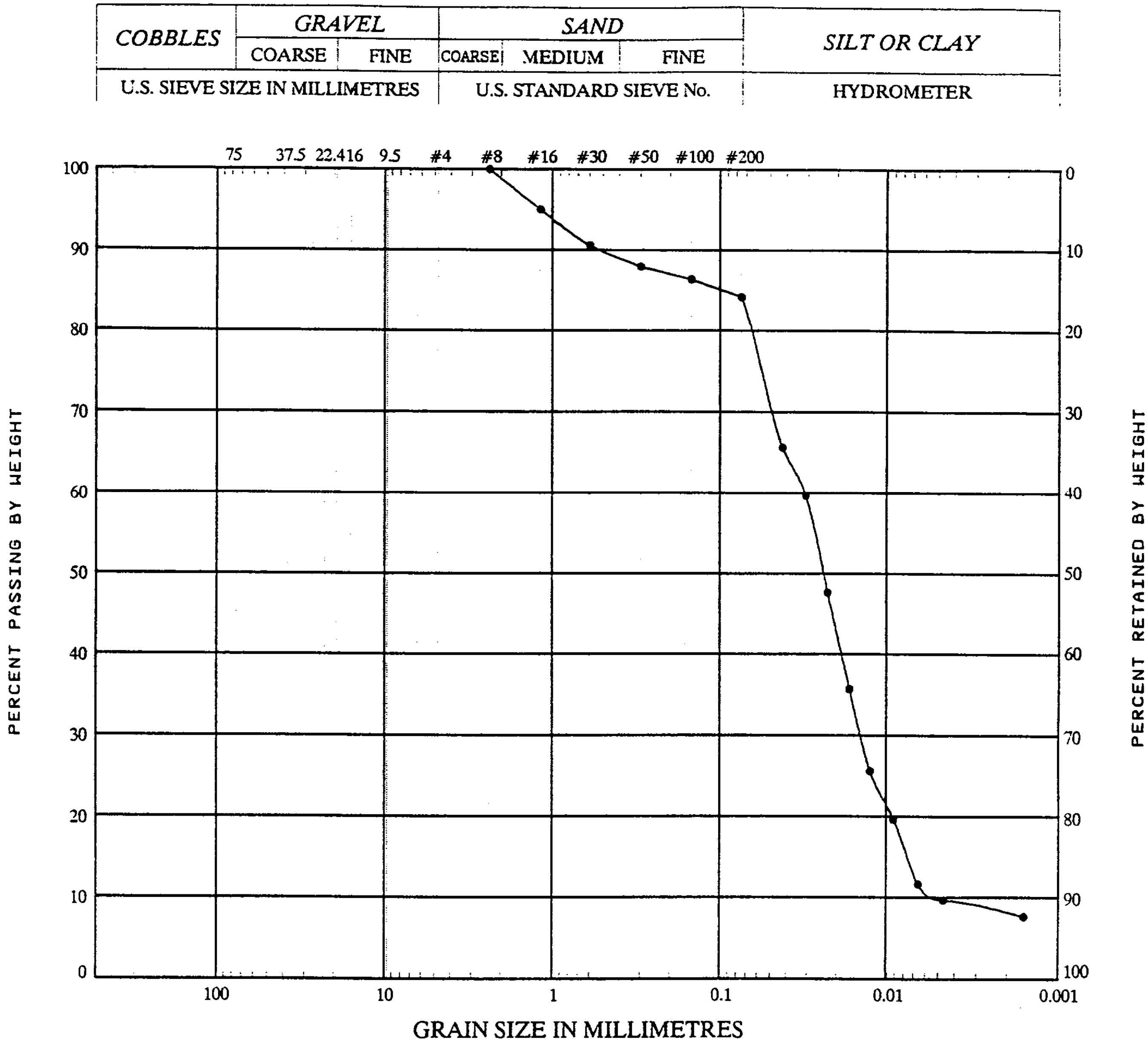
Figure No. 6

UNIFIED SOIL CLASSIFICATION



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

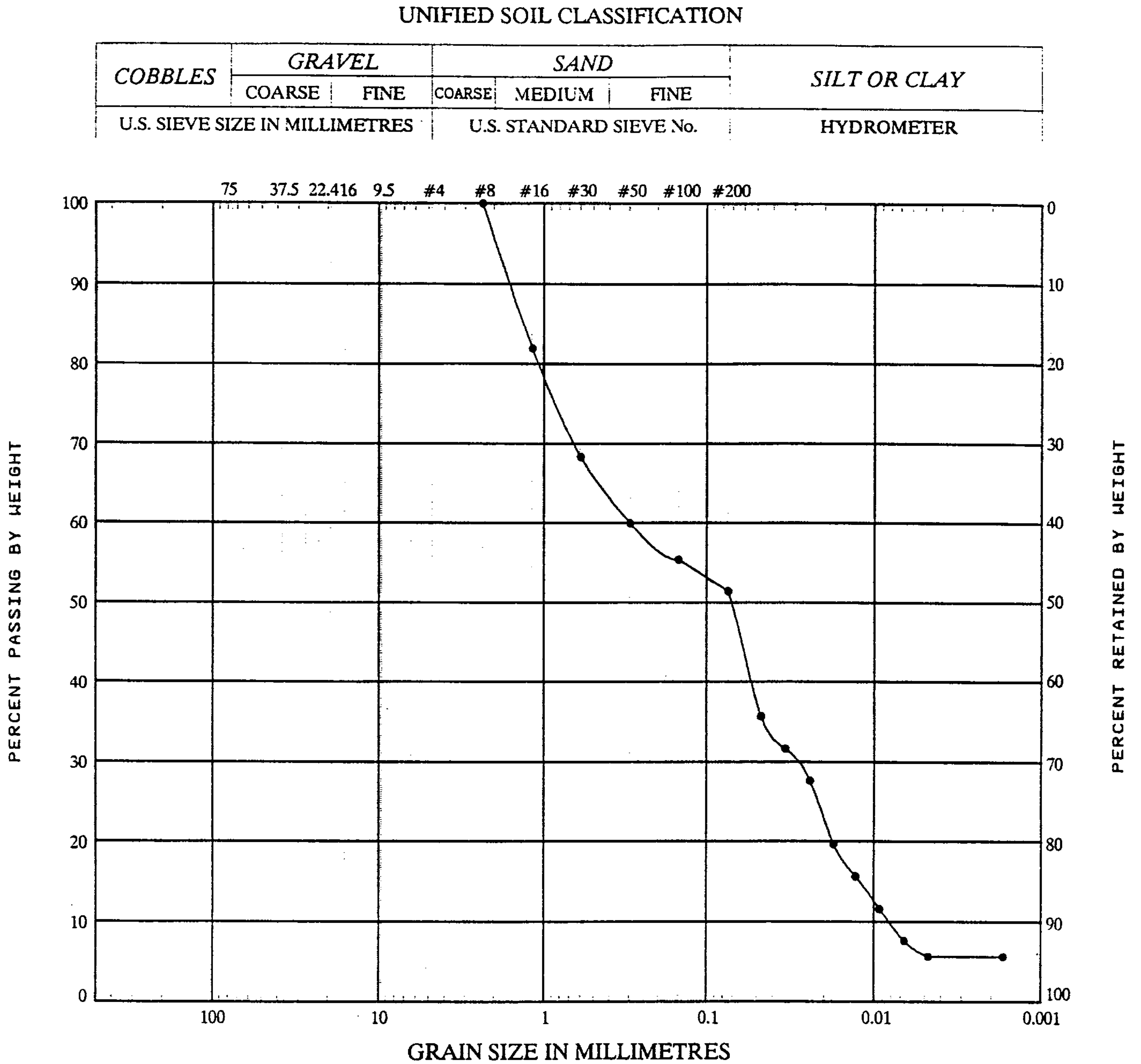
LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-6		3.05-3.65	Silt, some sand, trace clay

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 7



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

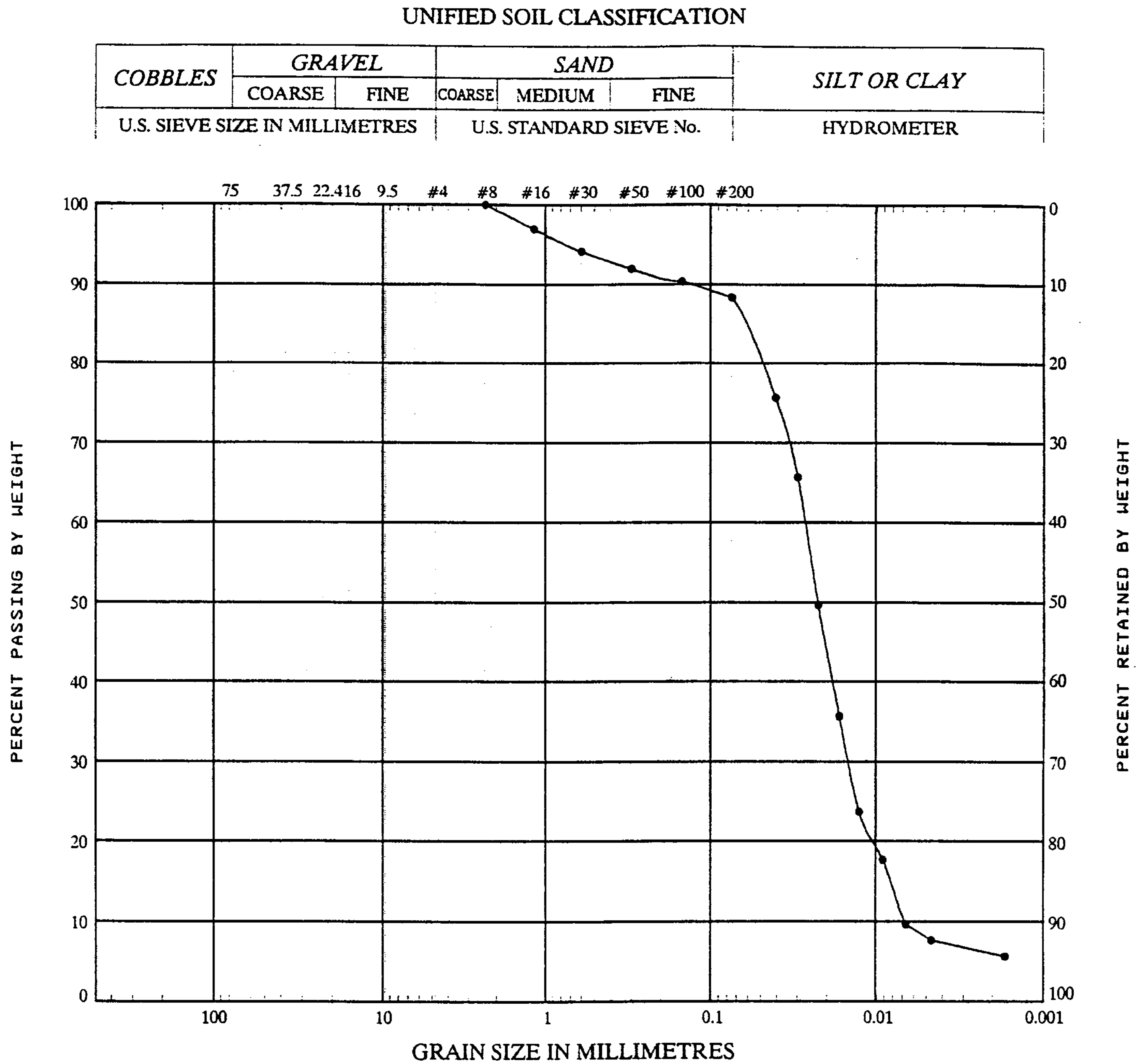
LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-5		3.05-3.65	Silt and sand, trace clay

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 8



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-5		4.57-5.18	Silt, trace sand and clay

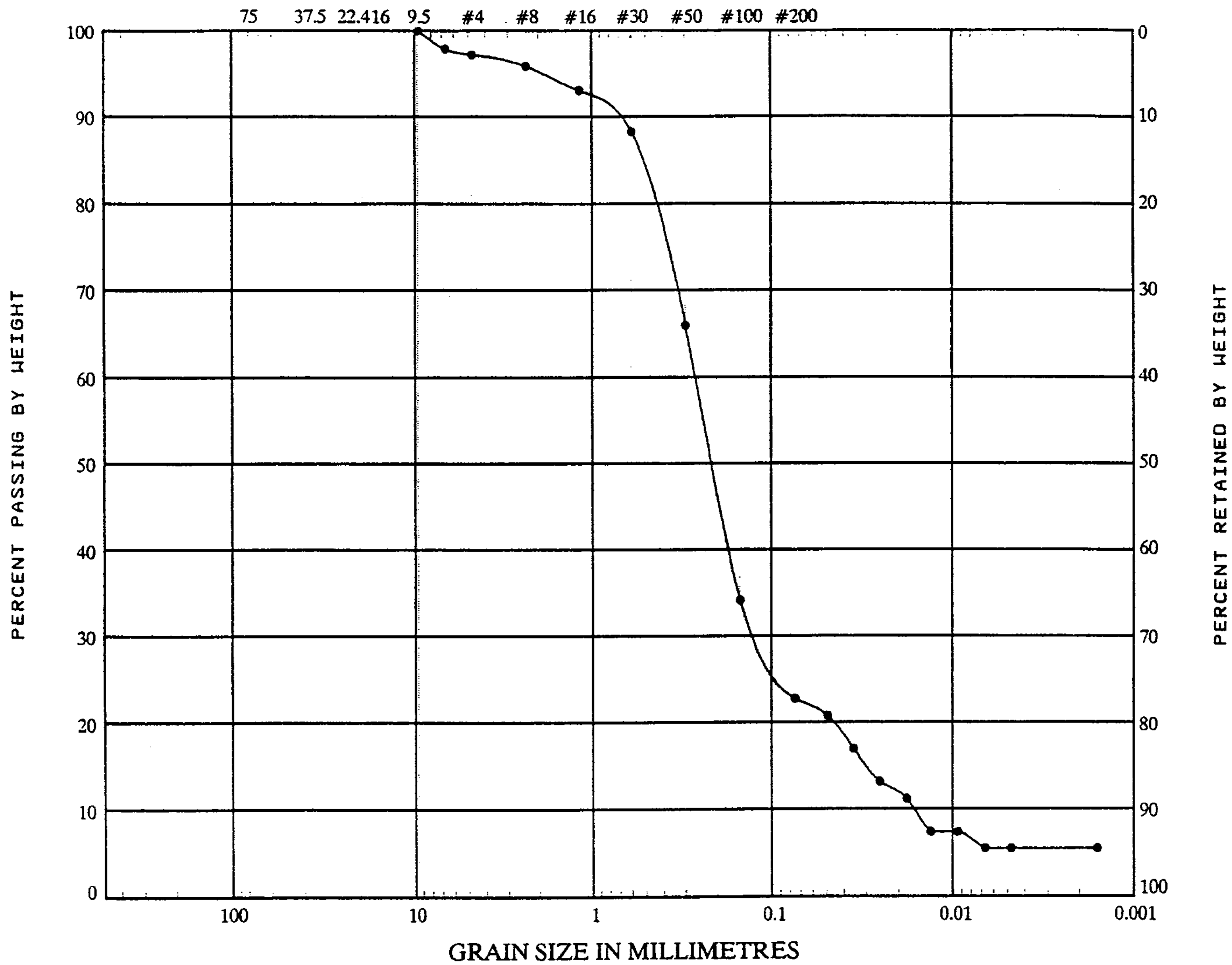
REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 9

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION Fault Lake Tailings, Falconbridge JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-6		7.62-8.07	Silty fine sand

REMARKS

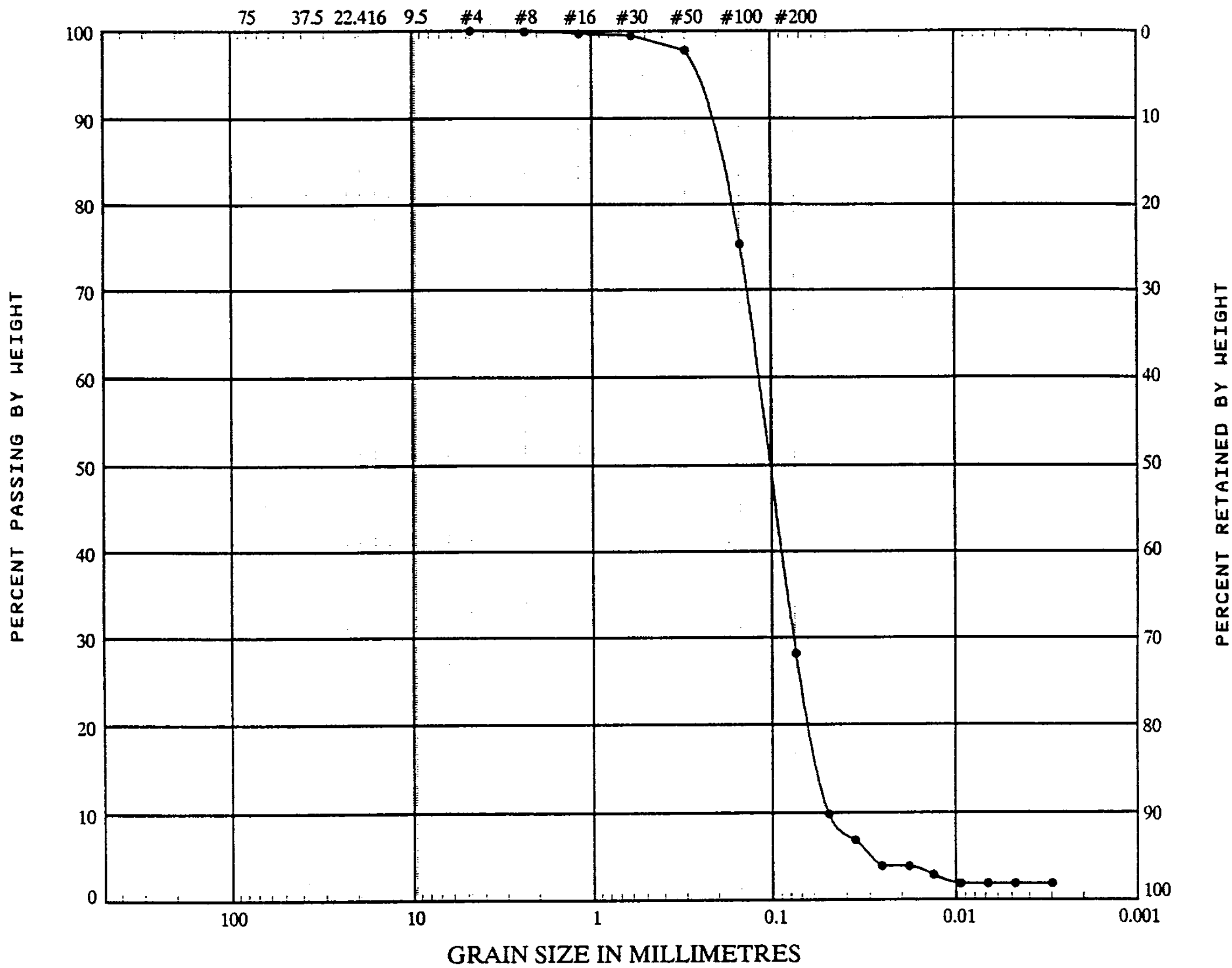
ENGLAND NAYLOR ENGINEERING LTD.

CONSULTING ENGINEERS

Figure No. 10

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

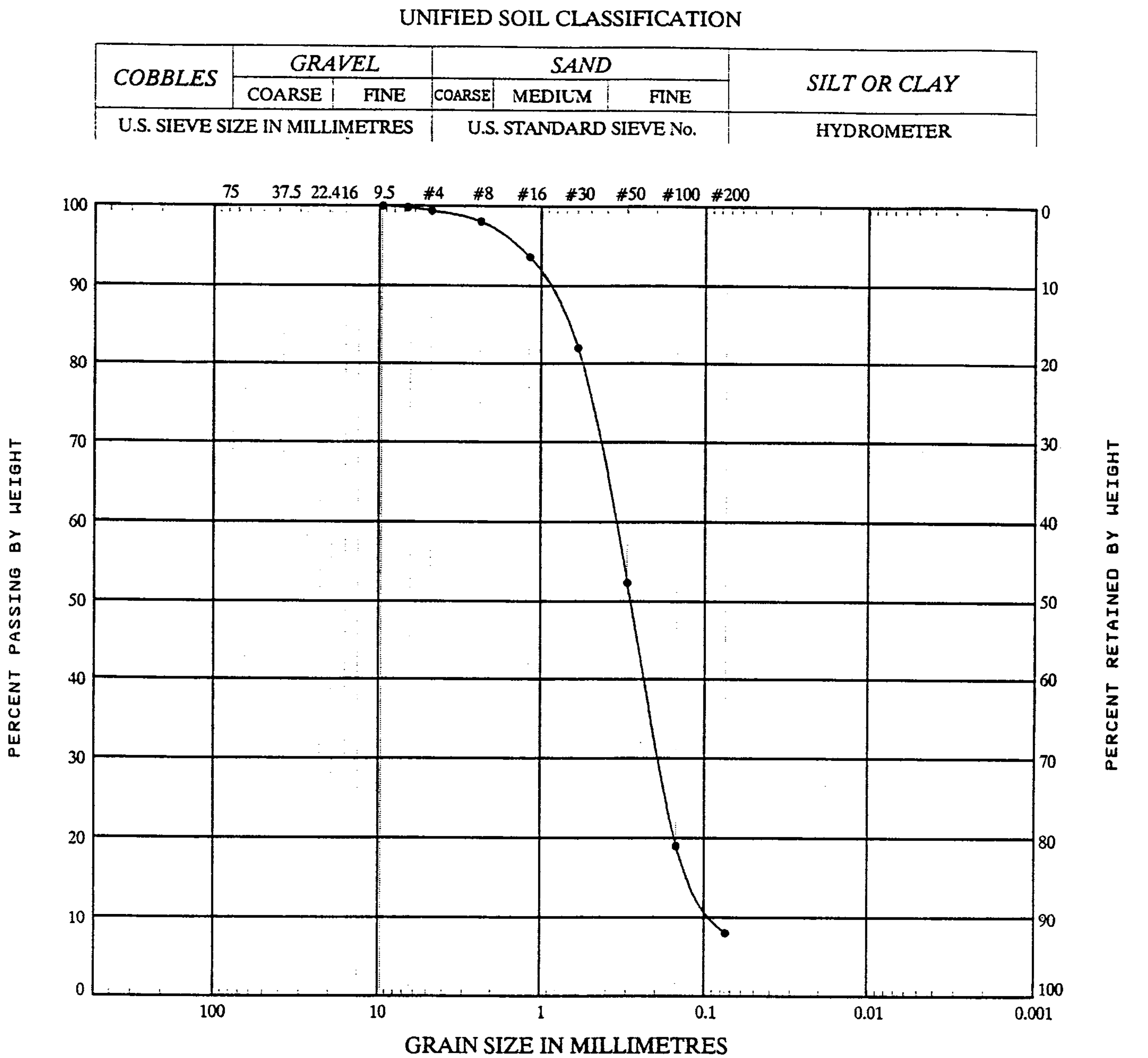
LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-1		Variable	SILT and fine SAND

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 1



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-3		59.4 - 60.1	Fine SAND

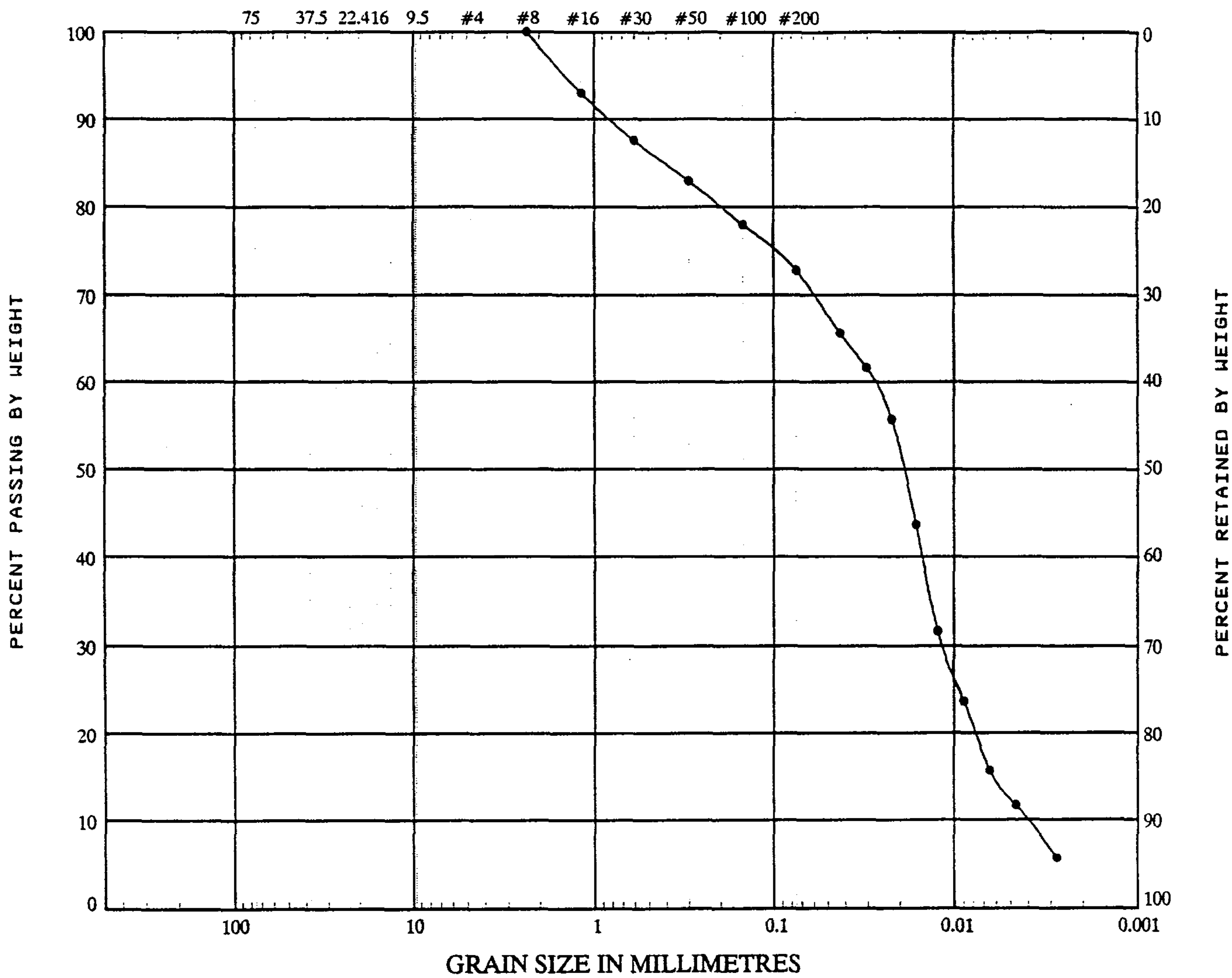
REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 2

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

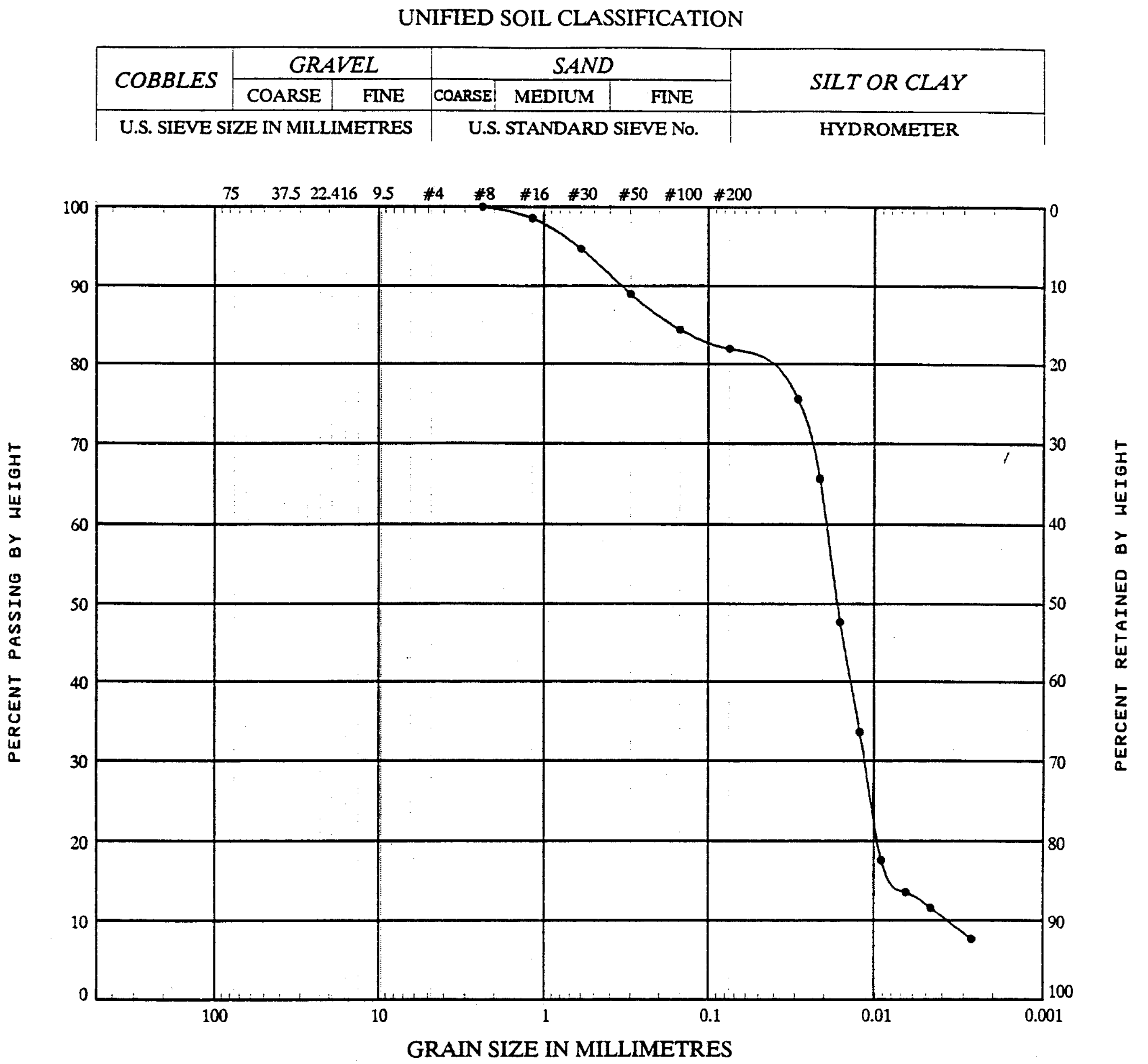
LOCATION ________ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-4		Surface	Sandy SILT, some clay

REMARKS ________

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 3



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ____ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-4		7.6 - 8.2	Sandy SILT, some clay

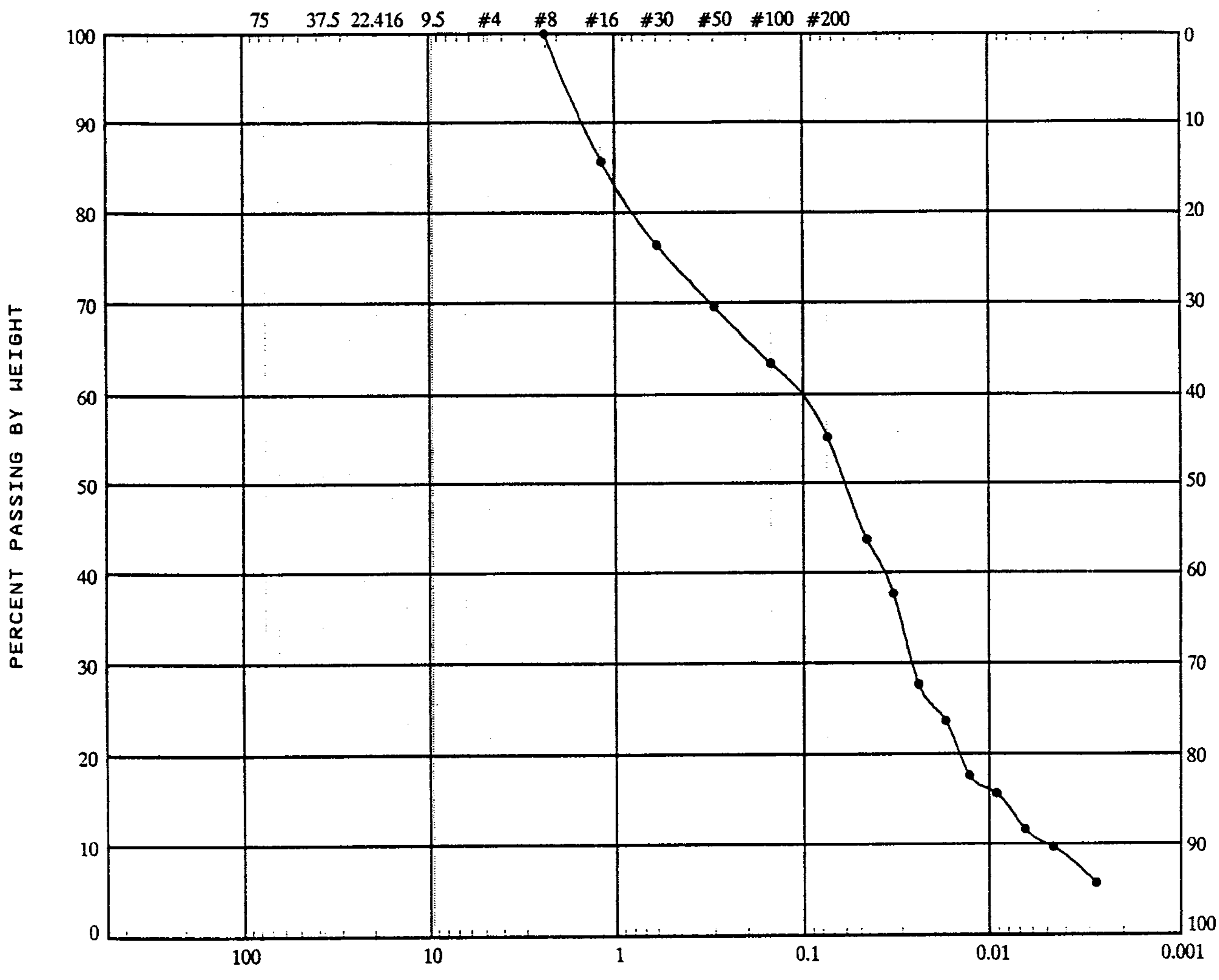
REMARKS ____

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 4

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
	U.S. SIEVE SIZE IN MILLIMETRES		U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

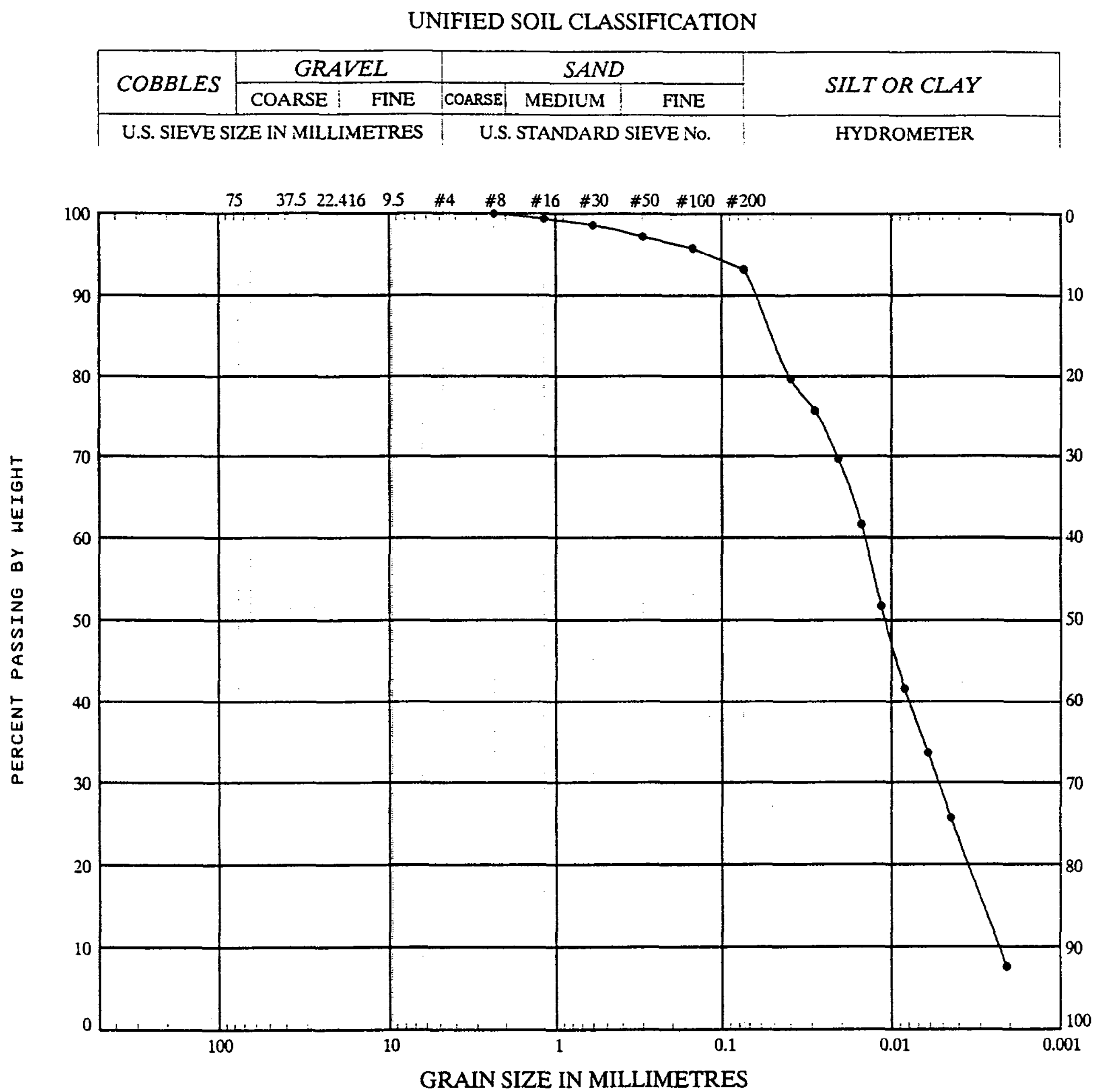
LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-5		Surface	Sandy SILT, some clay

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 5



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

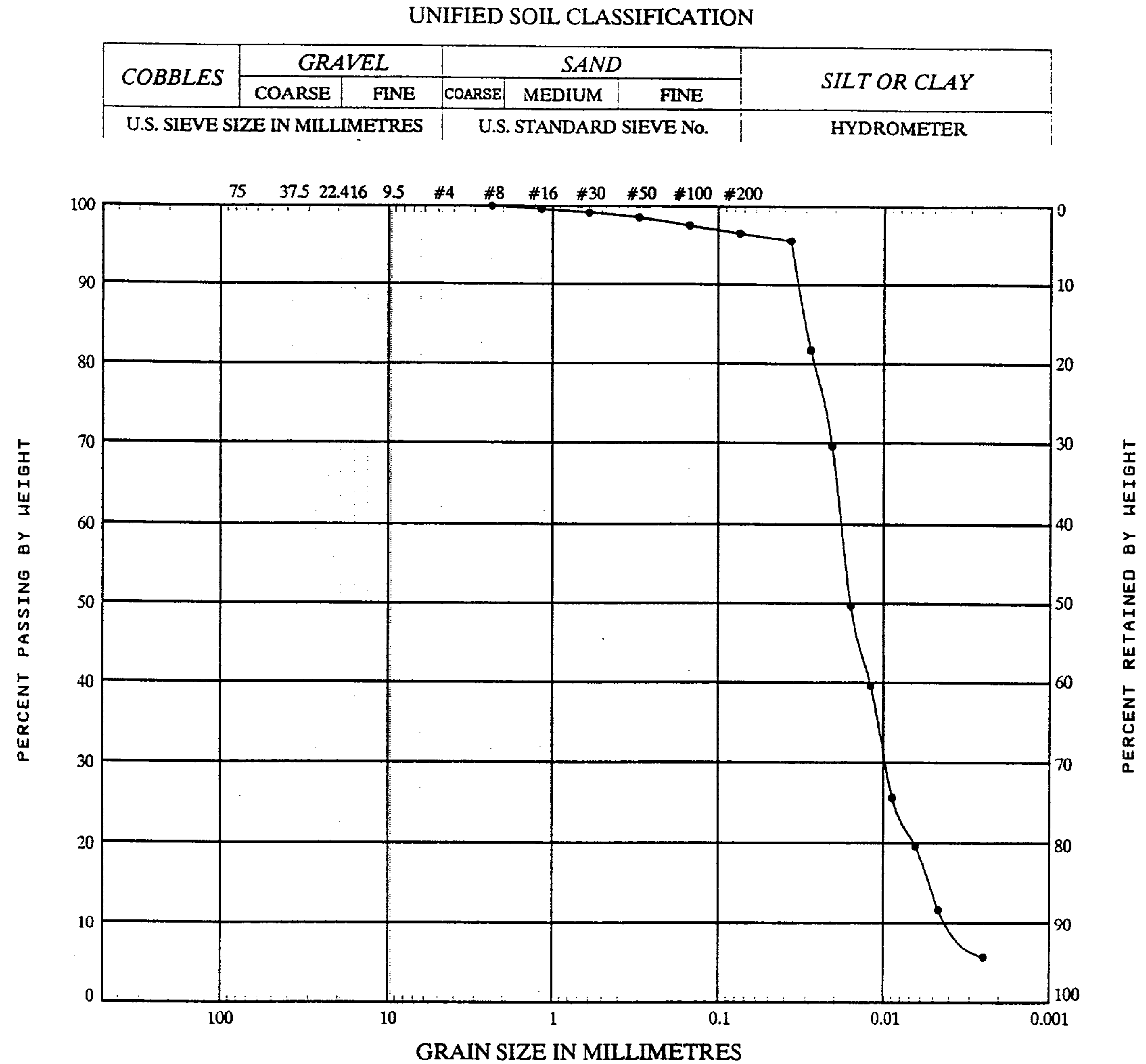
LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-5		7.6 - 8.2	SILT, some clay

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 6



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ____________ JOB NO. 0372L1

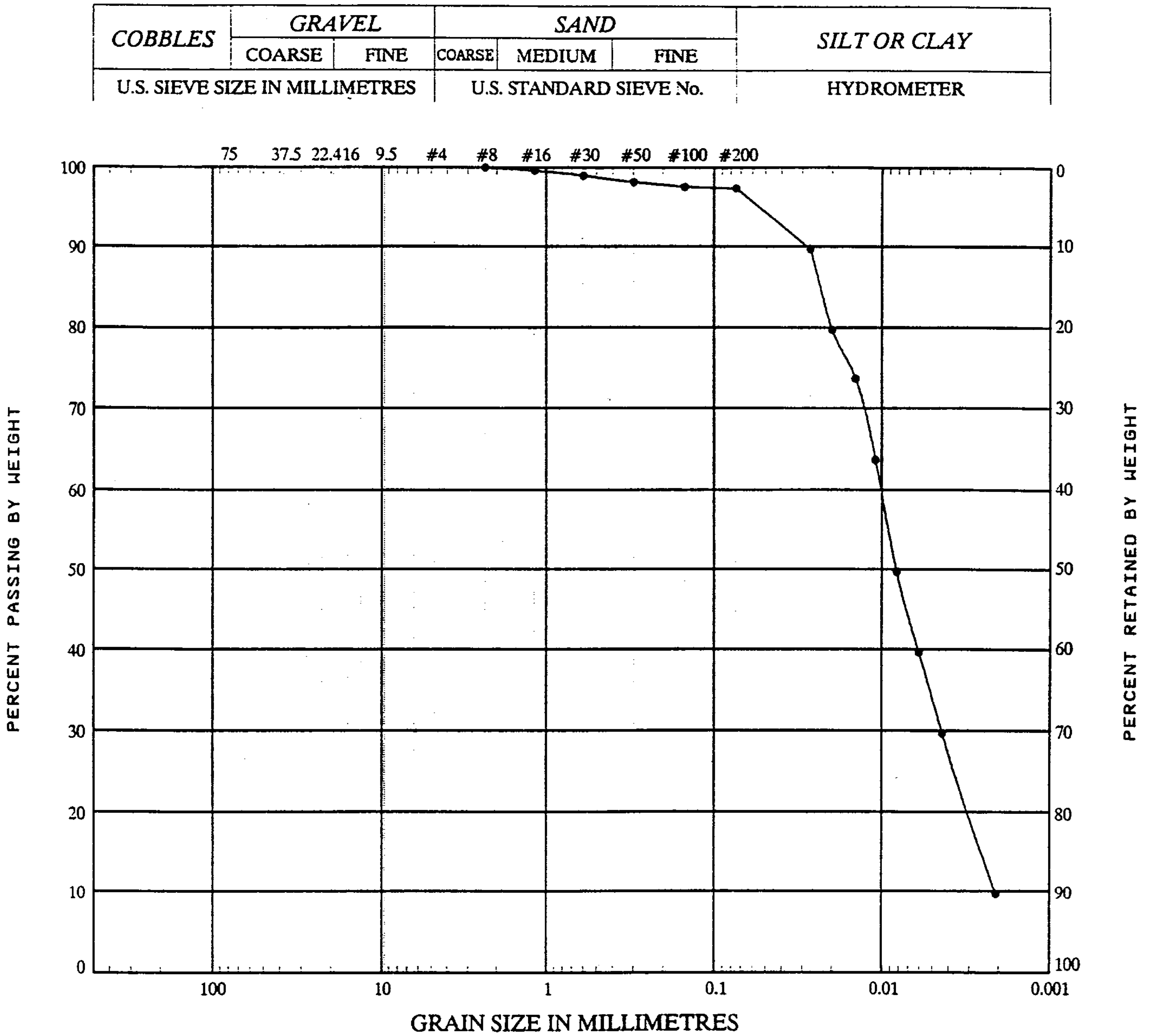
CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-6		Surface	SILT, some clay

REMARKS ____________

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 7

UNIFIED SOIL CLASSIFICATION



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

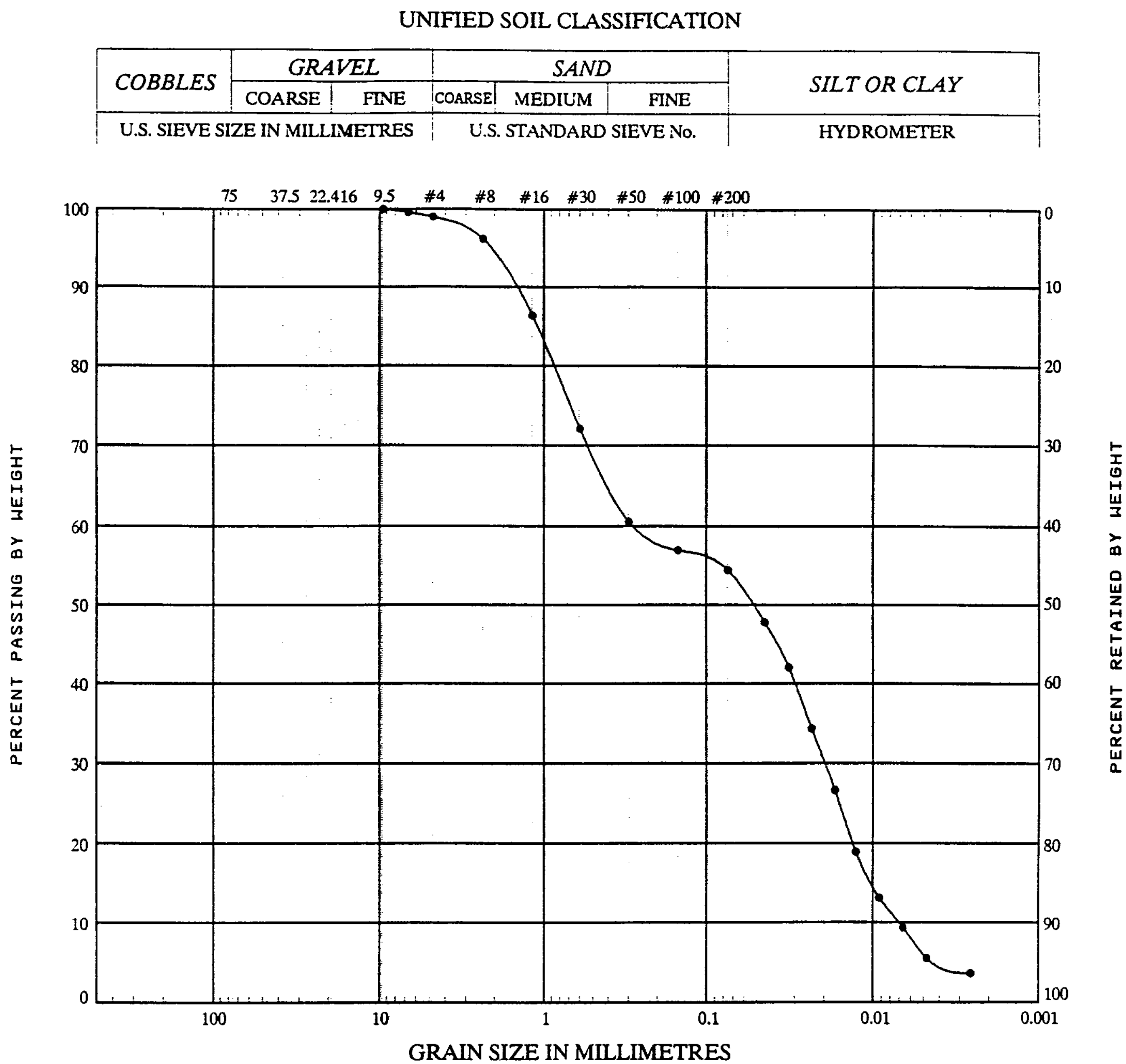
LOCATION ________ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-6		4.5 - 5.2	SILT, some clay

REMARKS ________

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 8



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION

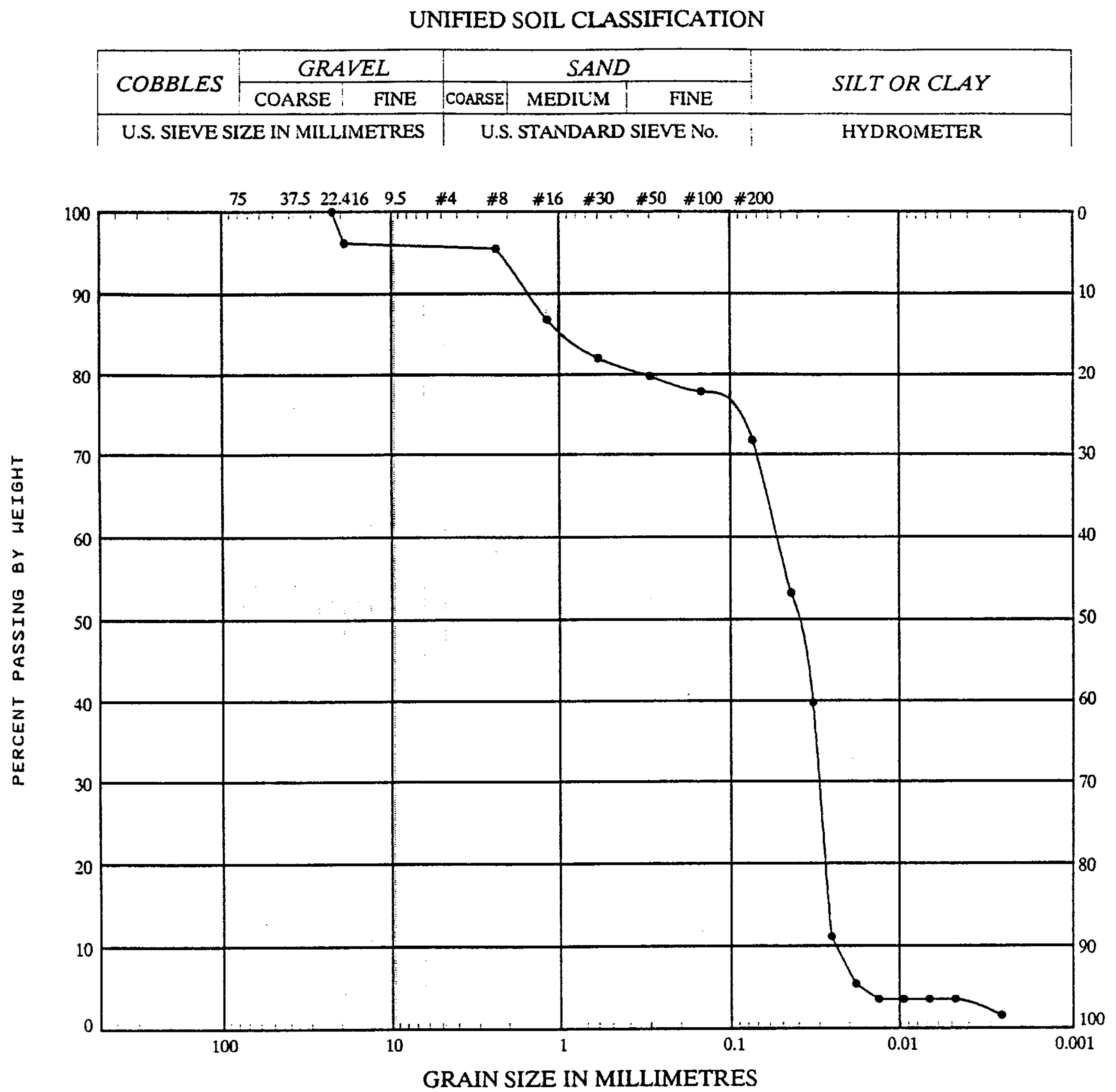
JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-8		1.5 - 2.1	SAND and SILT

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 9



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

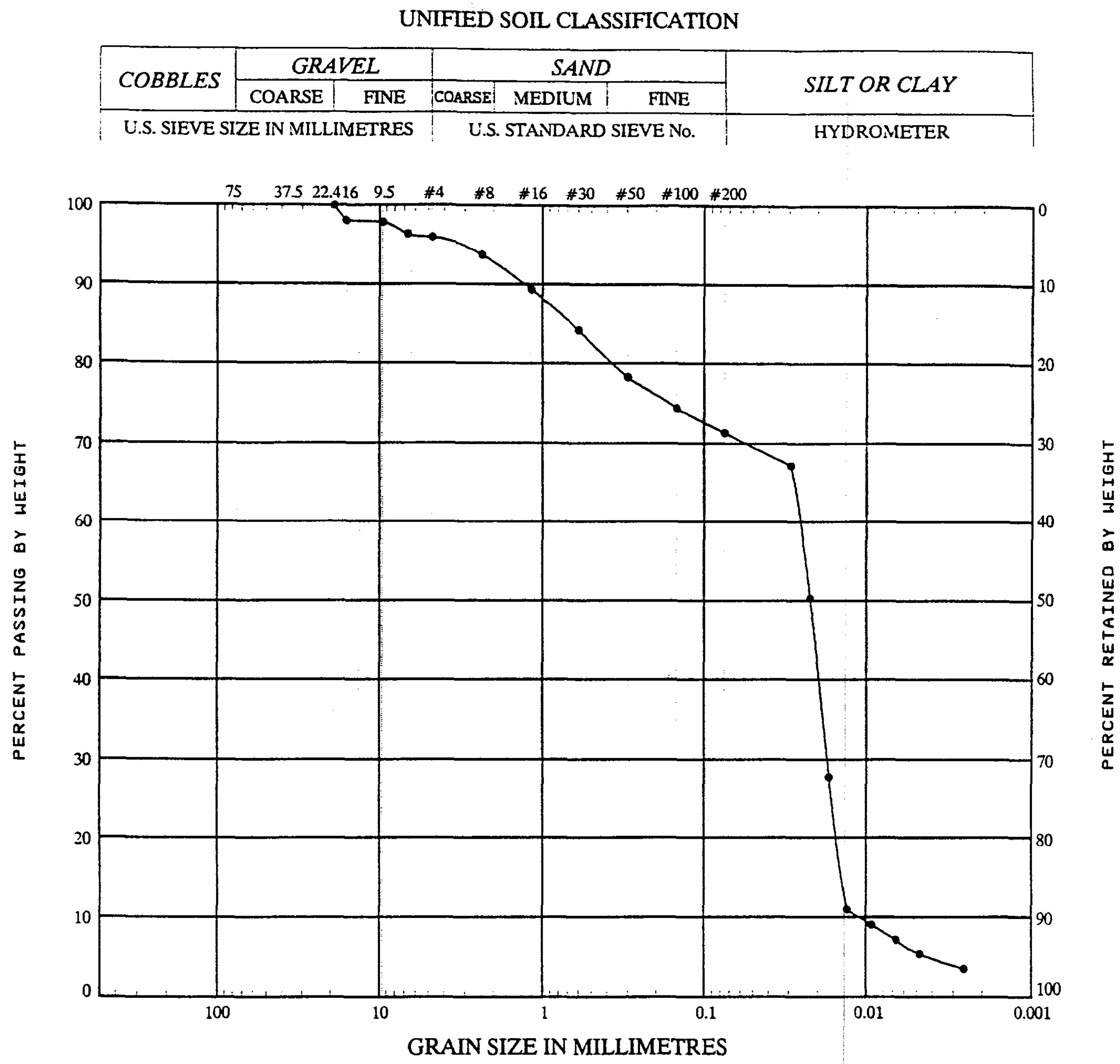
LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-11		1.5 - 2.1	Sandy SILT, some clay

REMARKS ______

ENGLAND-NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 10



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-11		7.6 - 8.2	Sandy SILT, some clay

REMARKS ______

ENGLAND NAYLOR ENGINEERING LTD.
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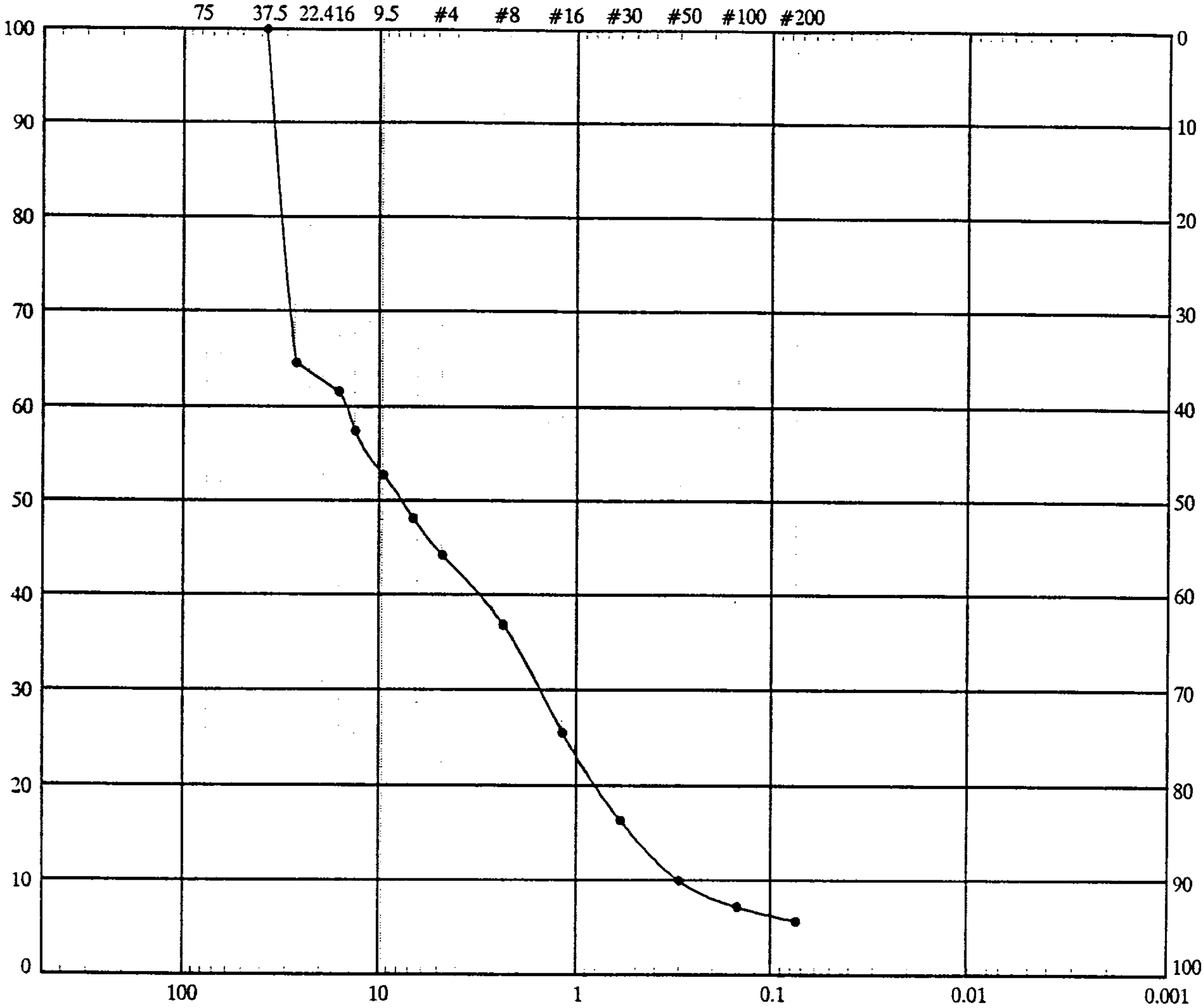
Figure No. 11

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
	U.S. SIEVE SIZE IN MILLIMETRES		U.S. STANDARD SIEVE No.			HYDROMETER



GRAIN SIZE IN MILLIMETRES

PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-11		9.1 - 9.8	SAND AND GRAVEL

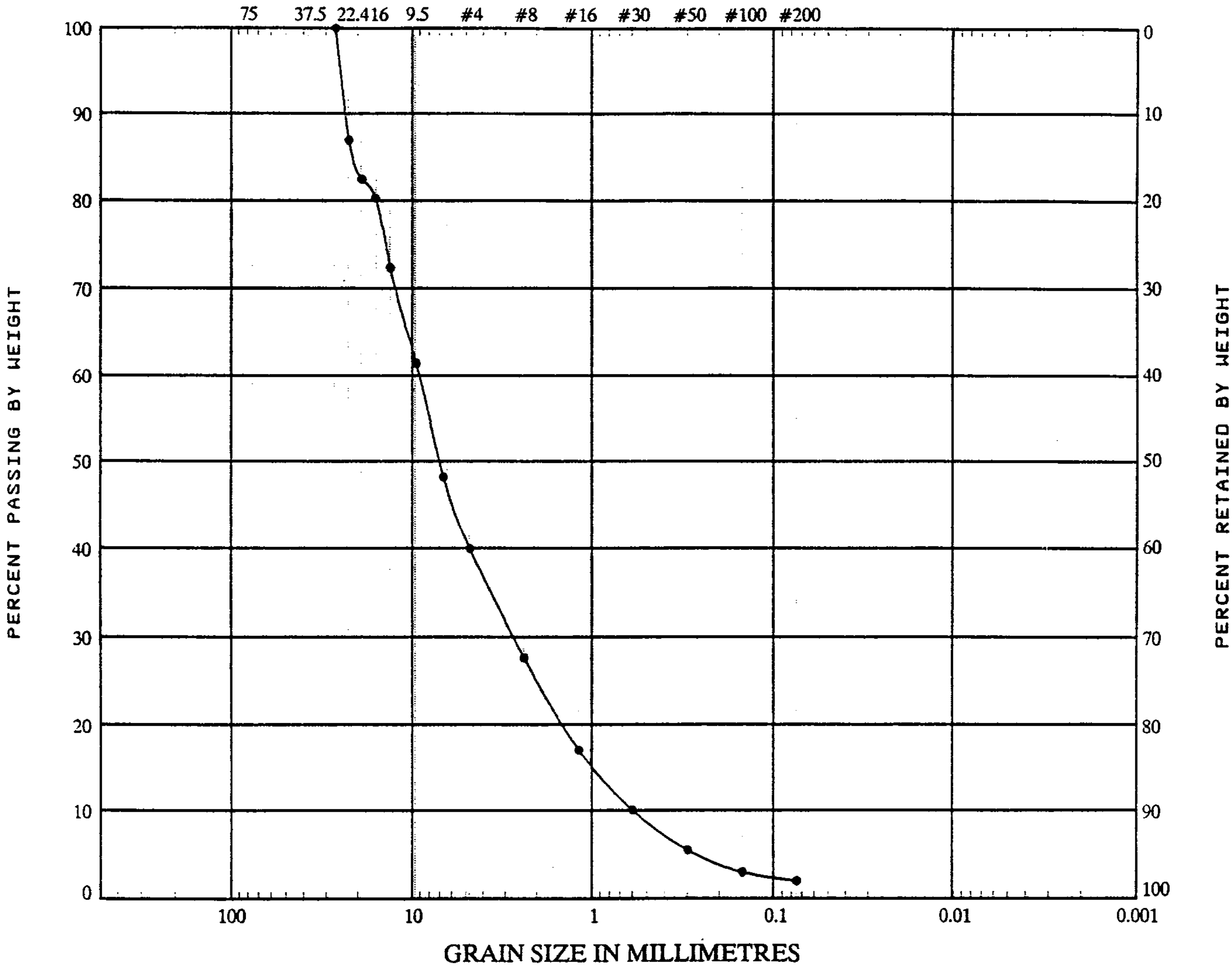
REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 12

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION

JOB NO. 0372L1

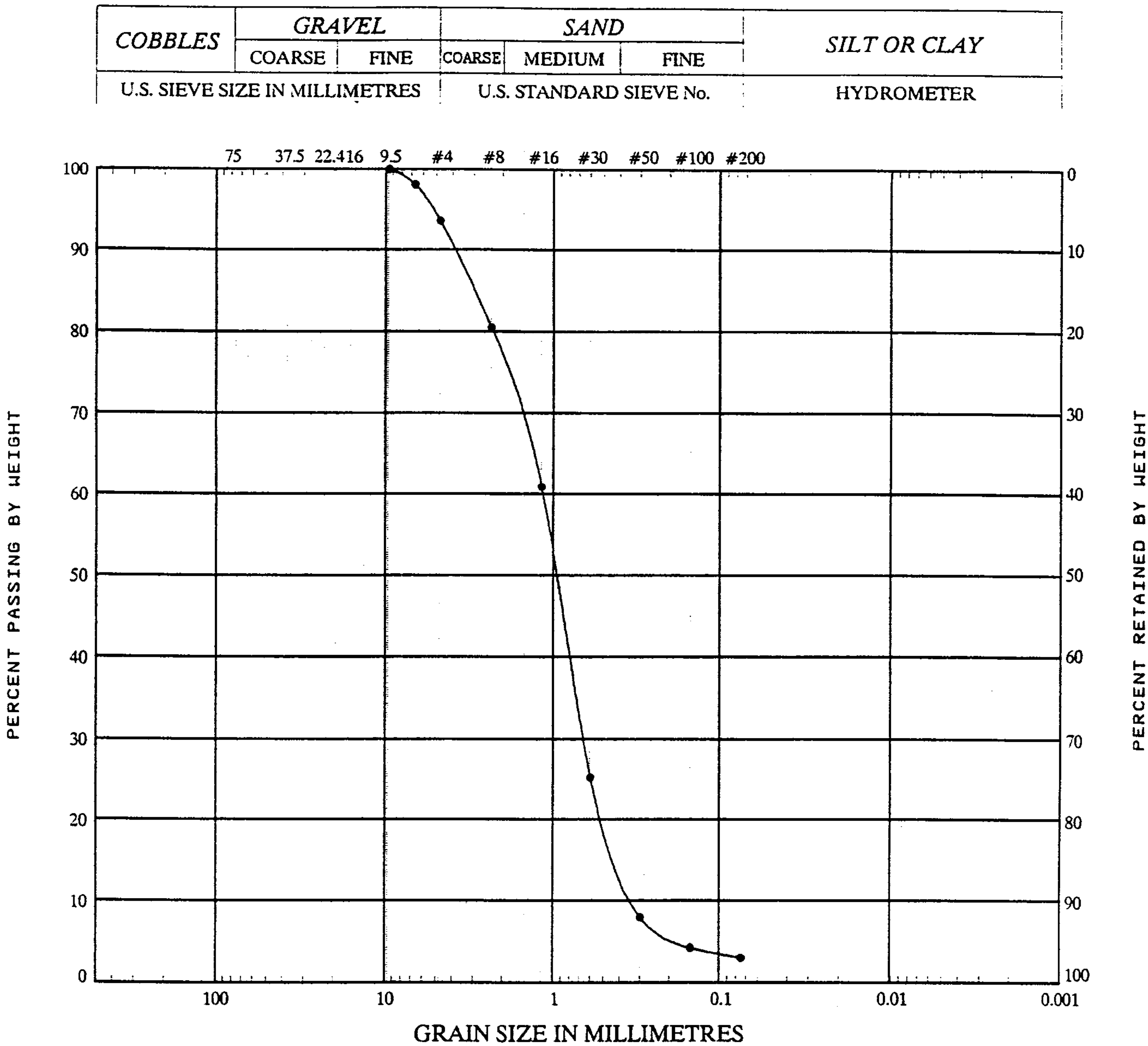
CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-11		15.2 - 15.8	SAND AND GRAVEL

REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 13

UNIFIED SOIL CLASSIFICATION



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-11		16.8 - 17.4	well graded SAND

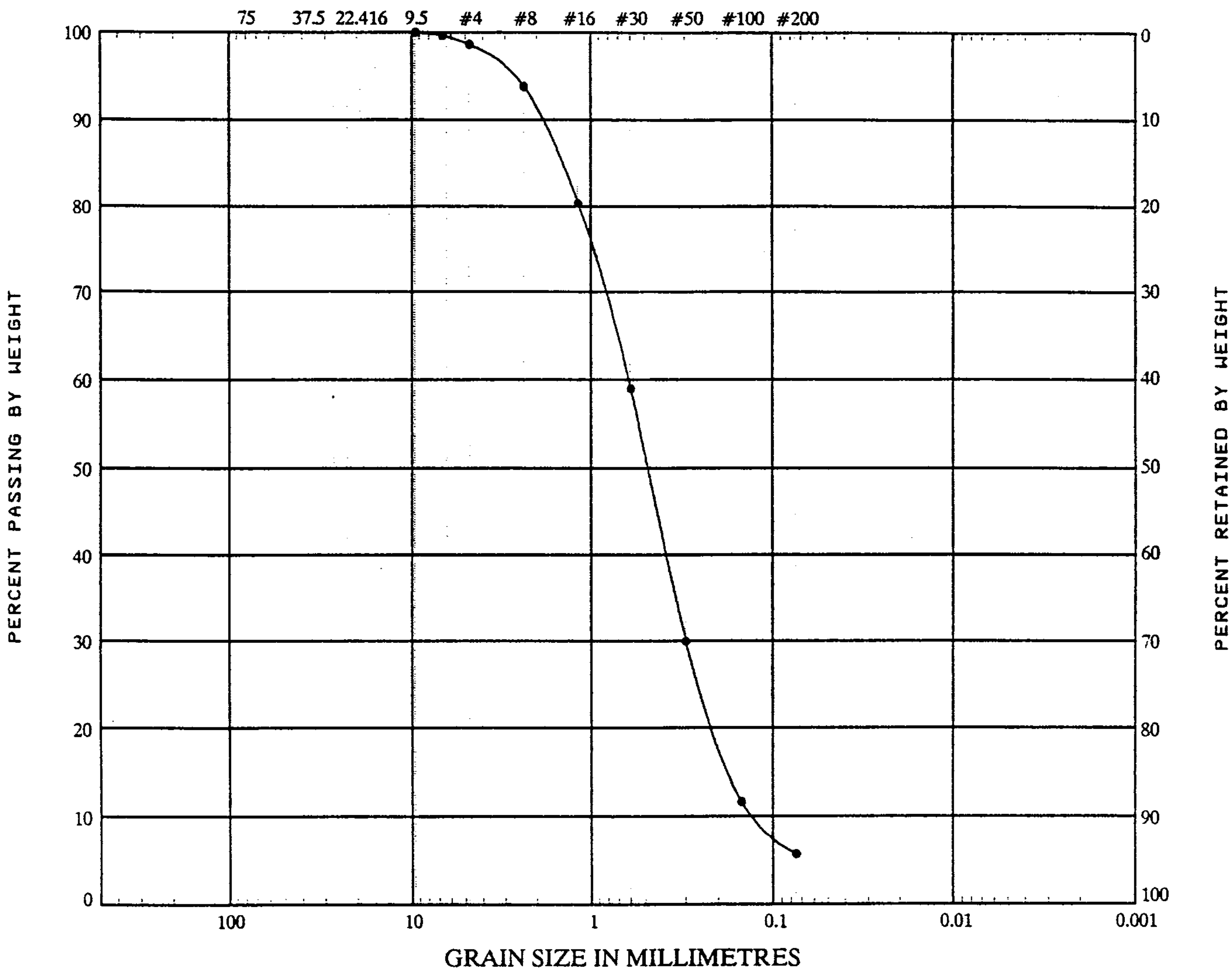
REMARKS ______

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 14

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

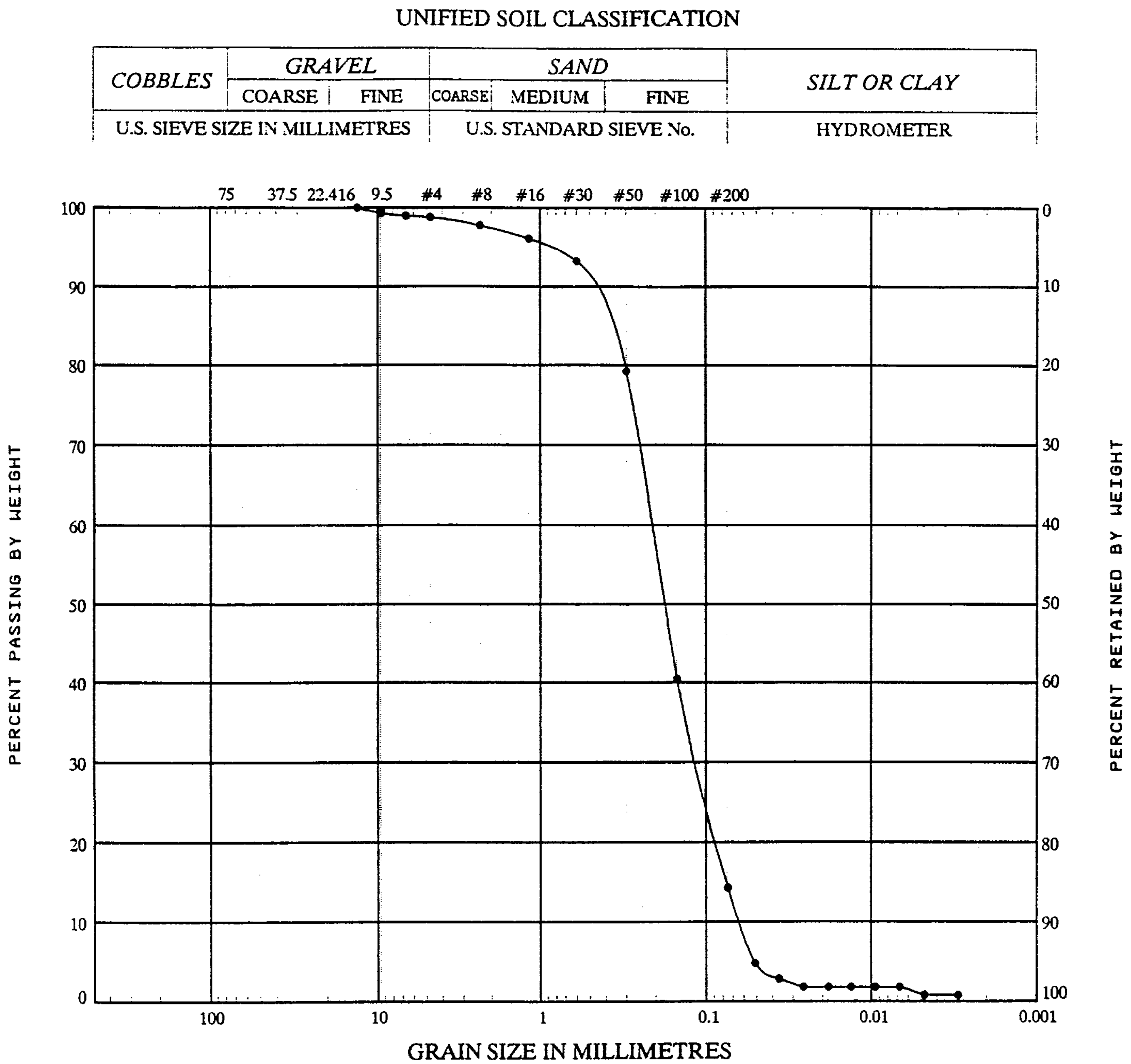
LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-11		18.3 - 18.9	fine to medium SAND

REMARKS ______

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 15



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ______ JOB NO. 0372L1

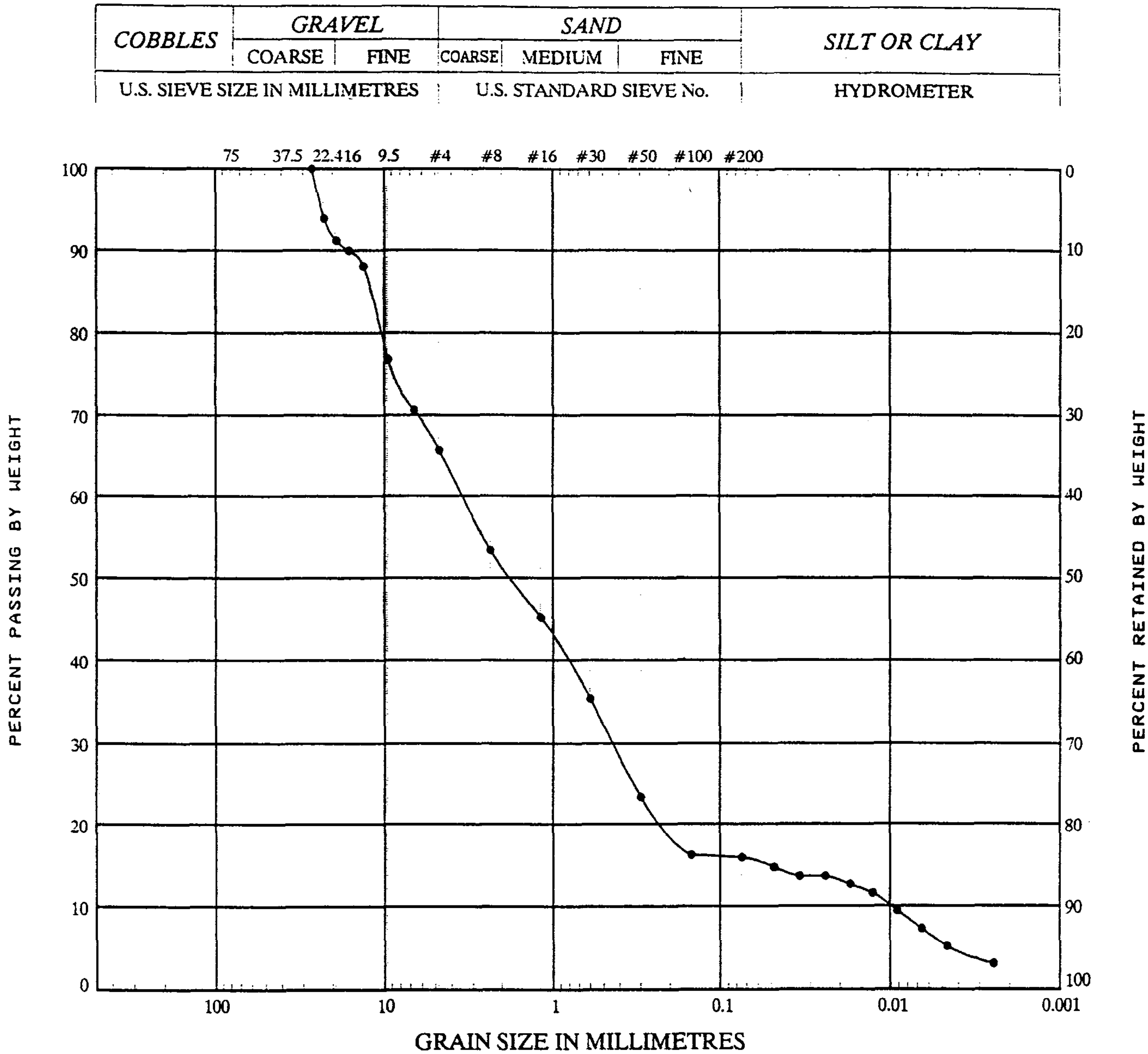
CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-11		19.8 - 20.4	Fine SAND, some SILT

REMARKS ______

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 16

UNIFIED SOIL CLASSIFICATION



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-12		21.3 - 21.9	Gravelly SAND, some SILT

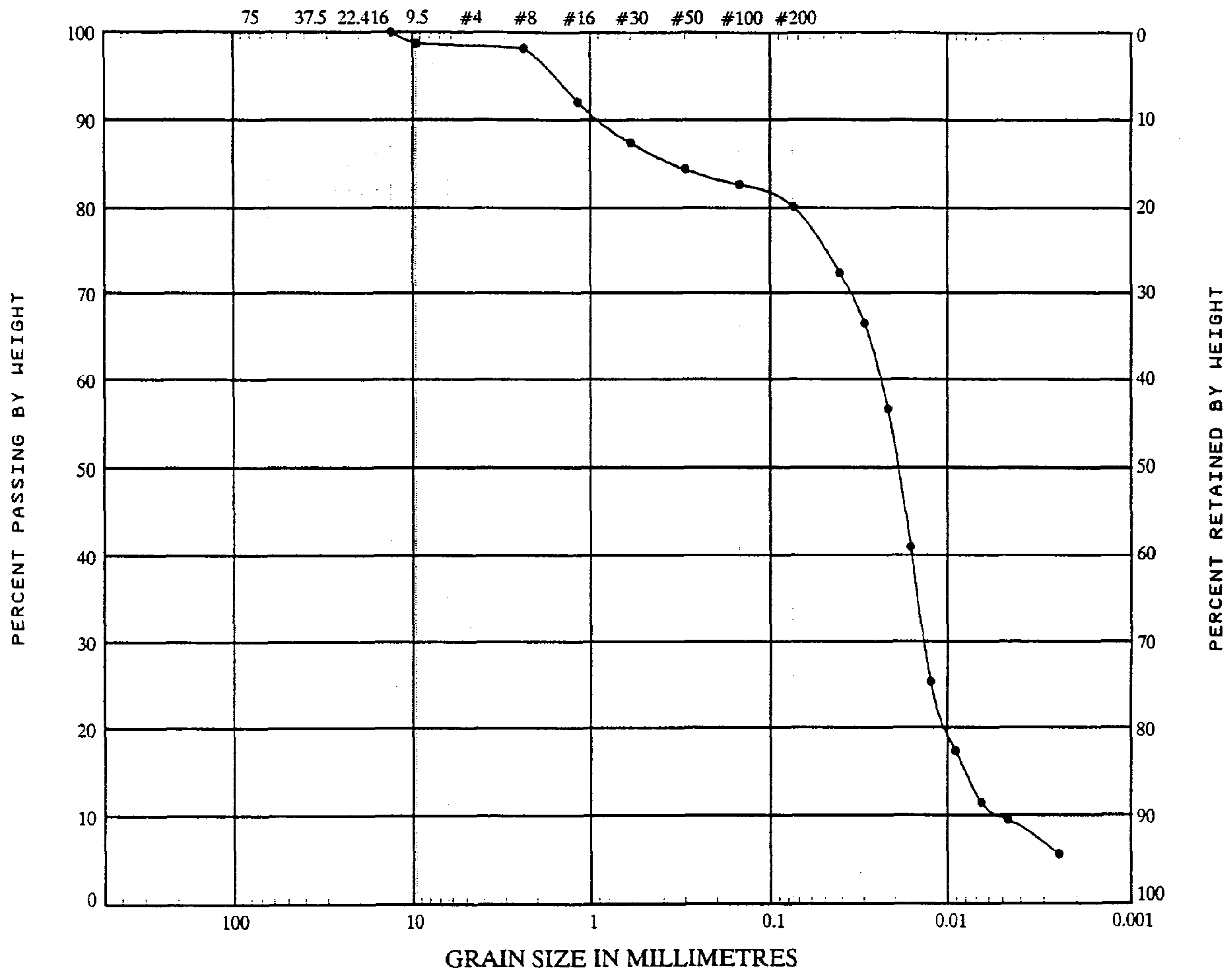
REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 17

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

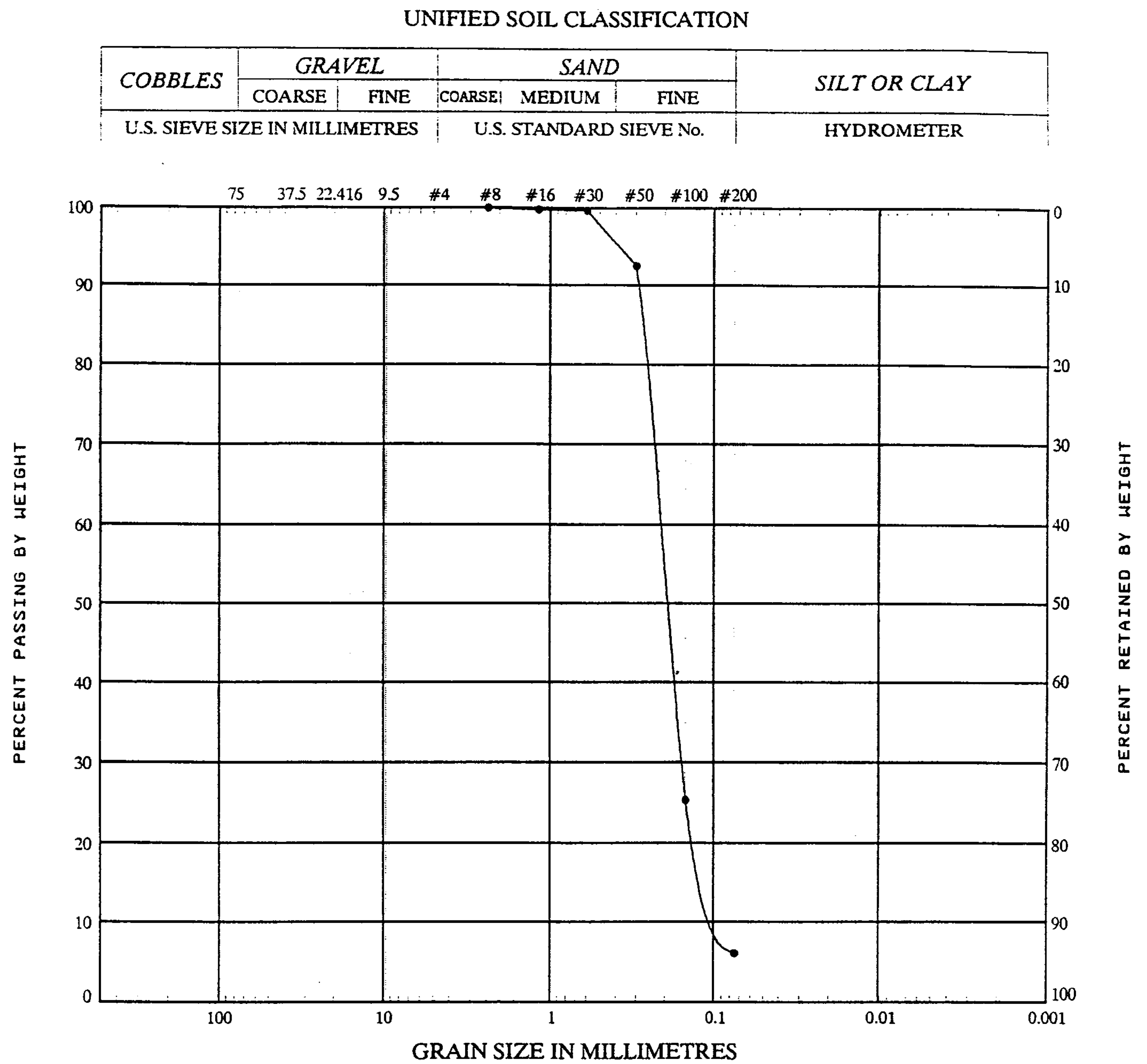
LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-13		3.1 - 3.7	Sandy SILT, some clay

REMARKS ______

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 18



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-13		15.2 - 15.9	Fine SAND

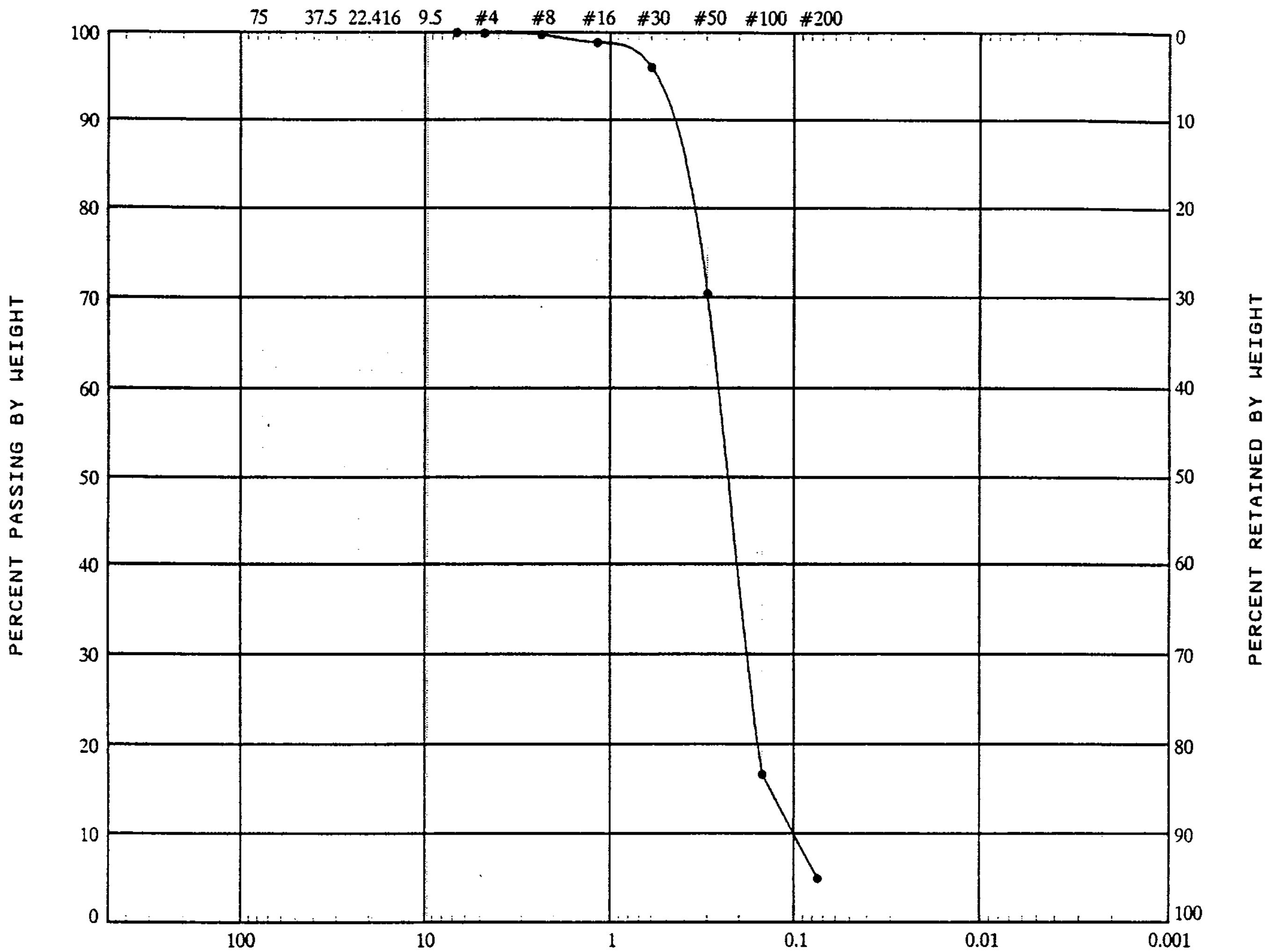
REMARKS

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 19

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	FS-13		12.2 - 12.8	Fine sand

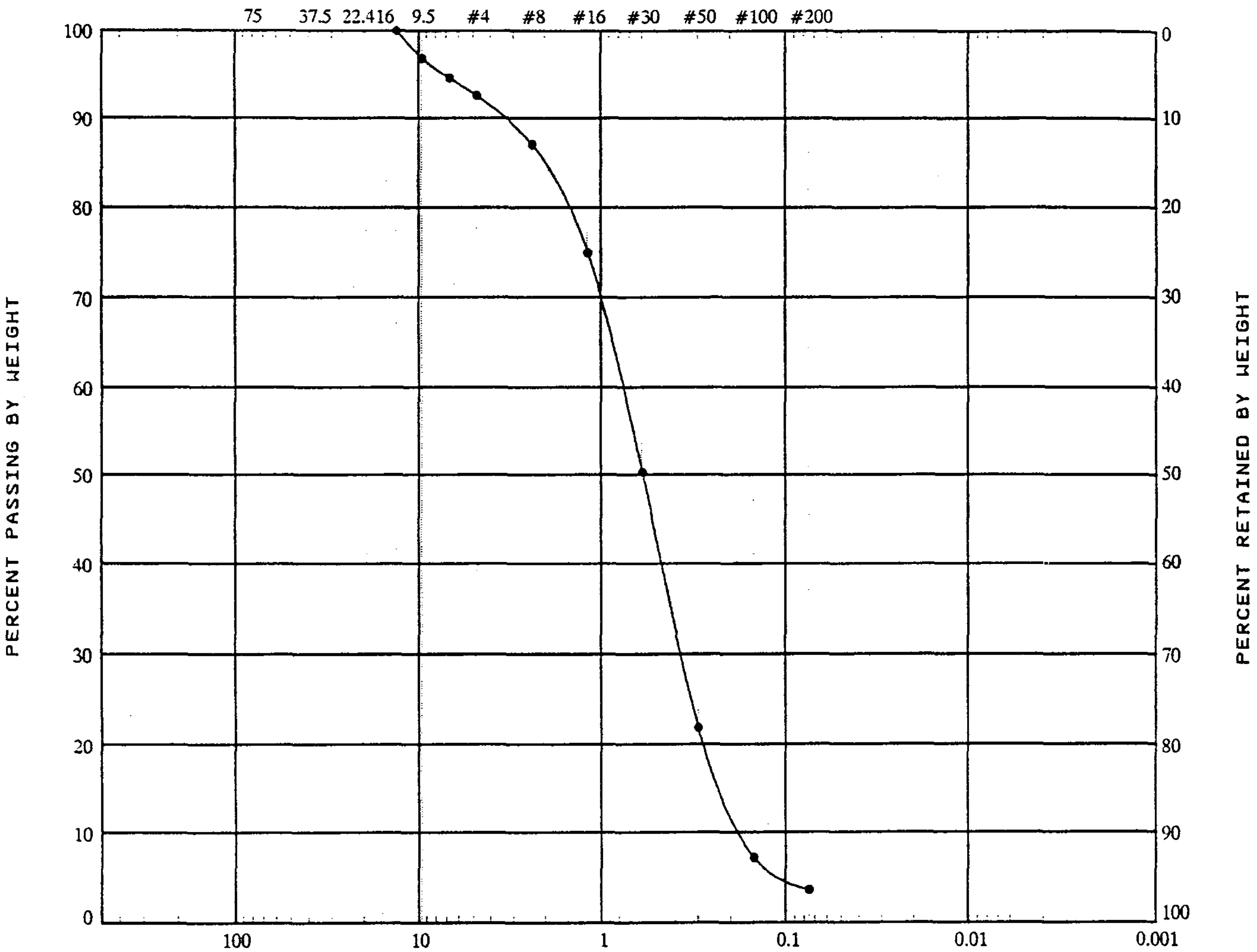
REMARKS ______

ENGLAND NAYLOR ENGINEERING LTD.
CONSULTING ENGINEERS

Figure No. 20

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



GRAIN SIZE IN MILLIMETRES

PROJECT Miscellaneous Lab Testing for Noranda Technology Centre

LOCATION ______ JOB NO. 0372L1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
•	FS-14		Variable	Fine to medium SAND

REMARKS ______

ENE ENGLAND NAYLOR ENGINEERING LTD. CONSULTING ENGINEERS

Figure No. 21

APPENDIX E.2

Monitoring well Data

Table B1. Locations of Monitoring Stations

Piezometer	Northing (m)	Easting (m)
FS-1	5161204.9	516063.5
FS-2	5160988.2	515777.6
FS-3	5161495.7	515900.7
FS-4	5161653.3	515495.0
FS-5	5161677.0	515577.9
FS-6	5161823.3	515659.0
FS-7	5161914.8	515885.8
FS-8	5162074.8	515886.4
FS-9	5162204.6	515937.6
FS-10	5161943.7	515941.2
FS-11	5161797.4	515748.6
FS-12	5161546.0	515727.9
FS-13	5161378.6	515952.5
FS-14	5161526.2	516041.2

Table B2. Fault Lake Piezometer Data

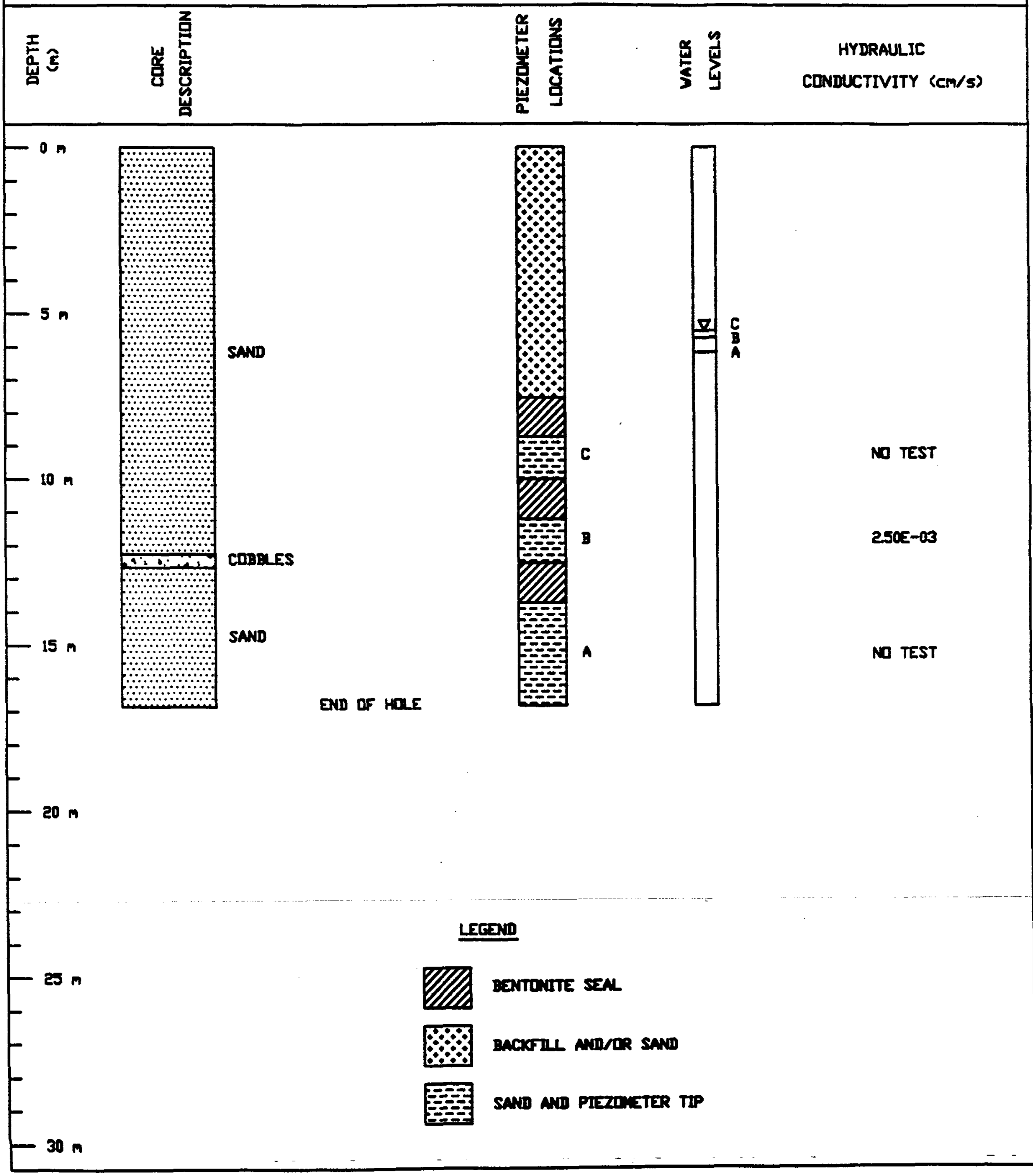
	Elevations (m)					
Piezometer	Ground	Top of Piezometer	Tip of Piezometer	Depth of tip below ground	Nov 24/92 Water	Mar 26/93 Water
FS-1-A	304.47	305.27	287.62	16.85	298.36	298.35
FS-1-B		305.24	292.05	12.42	298.65	298.60
FS-1-C		305.24	294.92	9.55	298.69	298.67
FS-2-A	316.11	316.84	300.59	15.52	307.23	307.21
FS-2-B		316.84	305.82	10.29	307.25	307.32
FS-3-A	322.12	322.99			299.53	299.52
FS-3-B		322.92	271.90	50.21	299.89	299.63
FS-3-C		322.94	302.92	19.20		
FS-4-A	322.63	323.36	291.02	31.62	299.51	291.91
FS-4-B		323.39	294.00	28.63	299.45	299.46
FS-4-C		323.46	298.65	23.98	299.58	299.51
FS-5-A	321.93	322.80	283.52	38.41	299.58	299.58
FS-5-B		322.74	286.54	35.39	301.77	301.77
FS-5-C		322.85	295.65	26.29	299.57	299.57
FS-6-A	320.90	321.71	287.54	33.36	300.30	300.30
FS-6-B		321.42	298.95	21.95	299.52	299.52
FS-6-C		321.44	311.72	9.18	311.74	311.74
FS-7	309.89	310.65	301.70	8.19		
FS-8	302.76	303.51	298.41	4.35	299.29	
FS-9-A	302.58	303.33	291.03	11.55	299.33	
FS-9-B		303.41	292.21	10.36	299.26	
FS-9-C		303.47	298.67	3.91	299.37	
FS-10-A	304.19	304.95	294.13	10.06	299.31	
FS-10-B		304.96	296.70	7.49	299.35	
FS-11	320.38	320.60	299.17	21.21	299.35	299.31
FS-12	320.04	320.04	298.89	21.15	299.05	299.12
FS-13	319.28	319.95	296.40	22.89	299.45	299.46
FS-14-A	322.97	323.19	292.84	30.13	299.24	296.82
FS-14-B		324.02	297.37	25.60	299.46	299.28

NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-1 | TOTAL DEPTH: 16.85 m

COORDINATES: N5161142.129,E516057.185 | ELEVATION: 304.465 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:



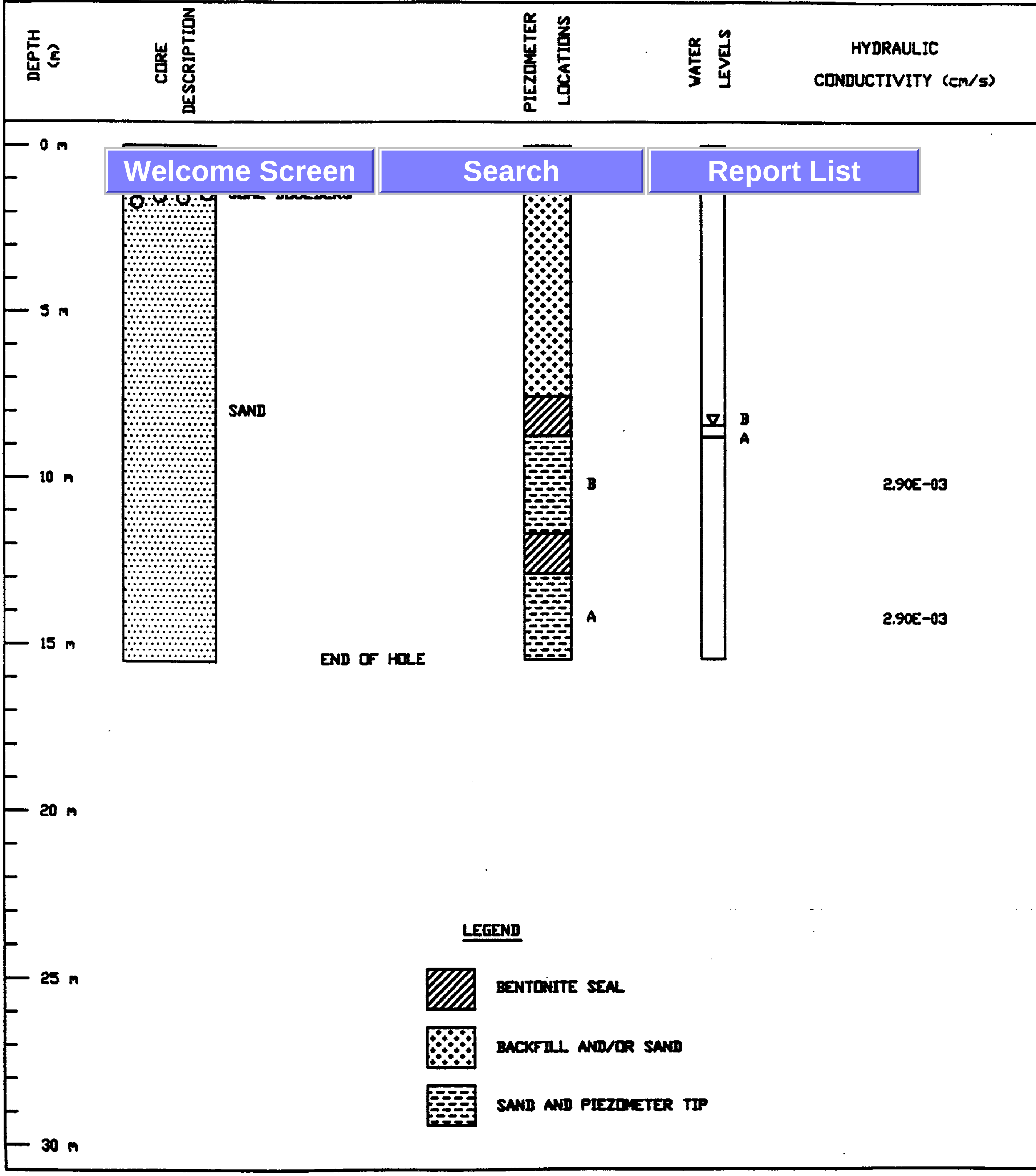
NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-2 | TOTAL DEPTH: 15.52 m

COORDINATES: N5160925.416,E515771.282 | ELEVATION: 316.108 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

Welcome Screen | Search | Report List



NORANDA TECHNOLOGY CENTRE – BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-3 | TOTAL DEPTH: 60.05 m

COORDINATES: N5160925.416,E515894.422 | ELEVATION: 322.113 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

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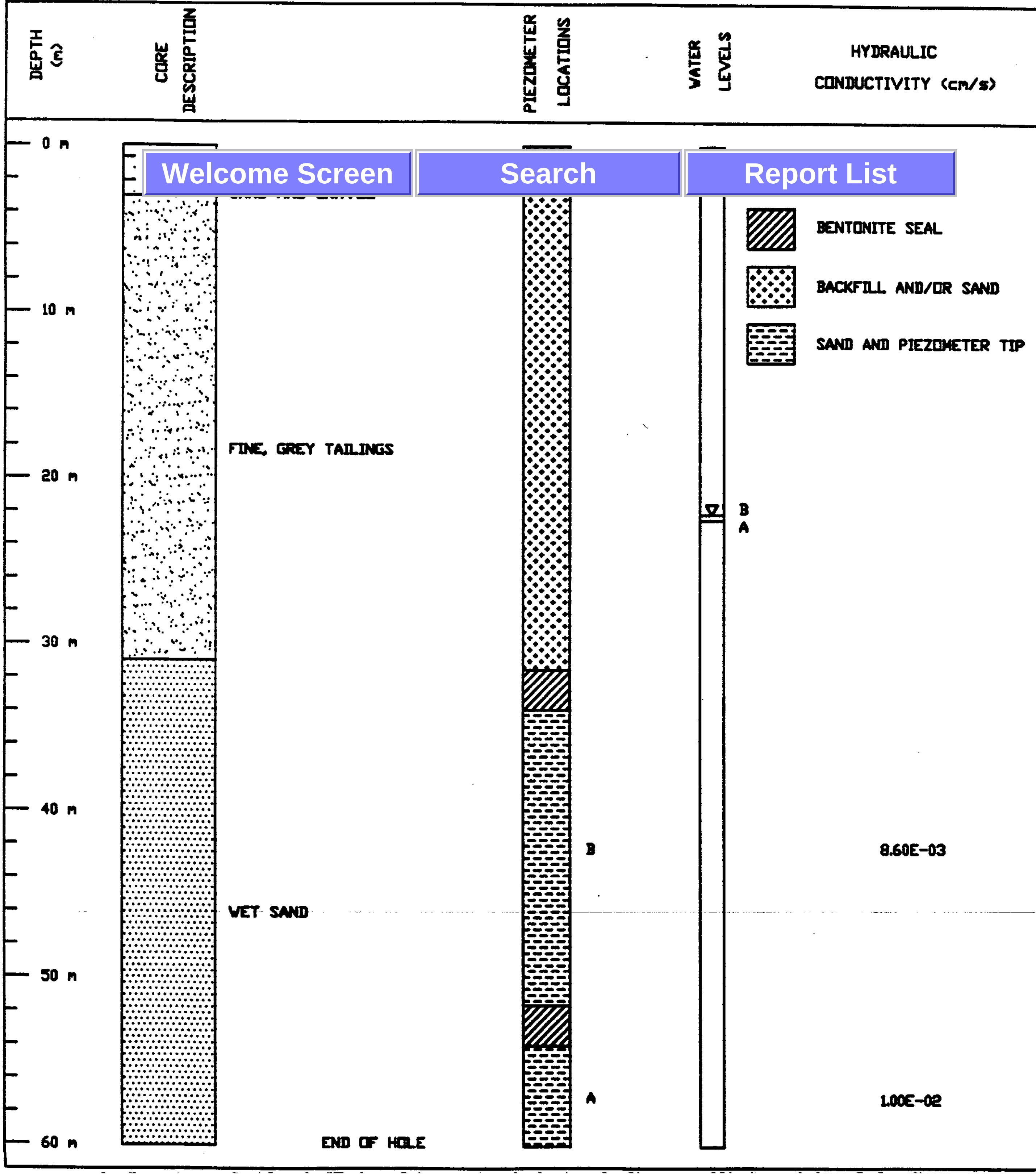
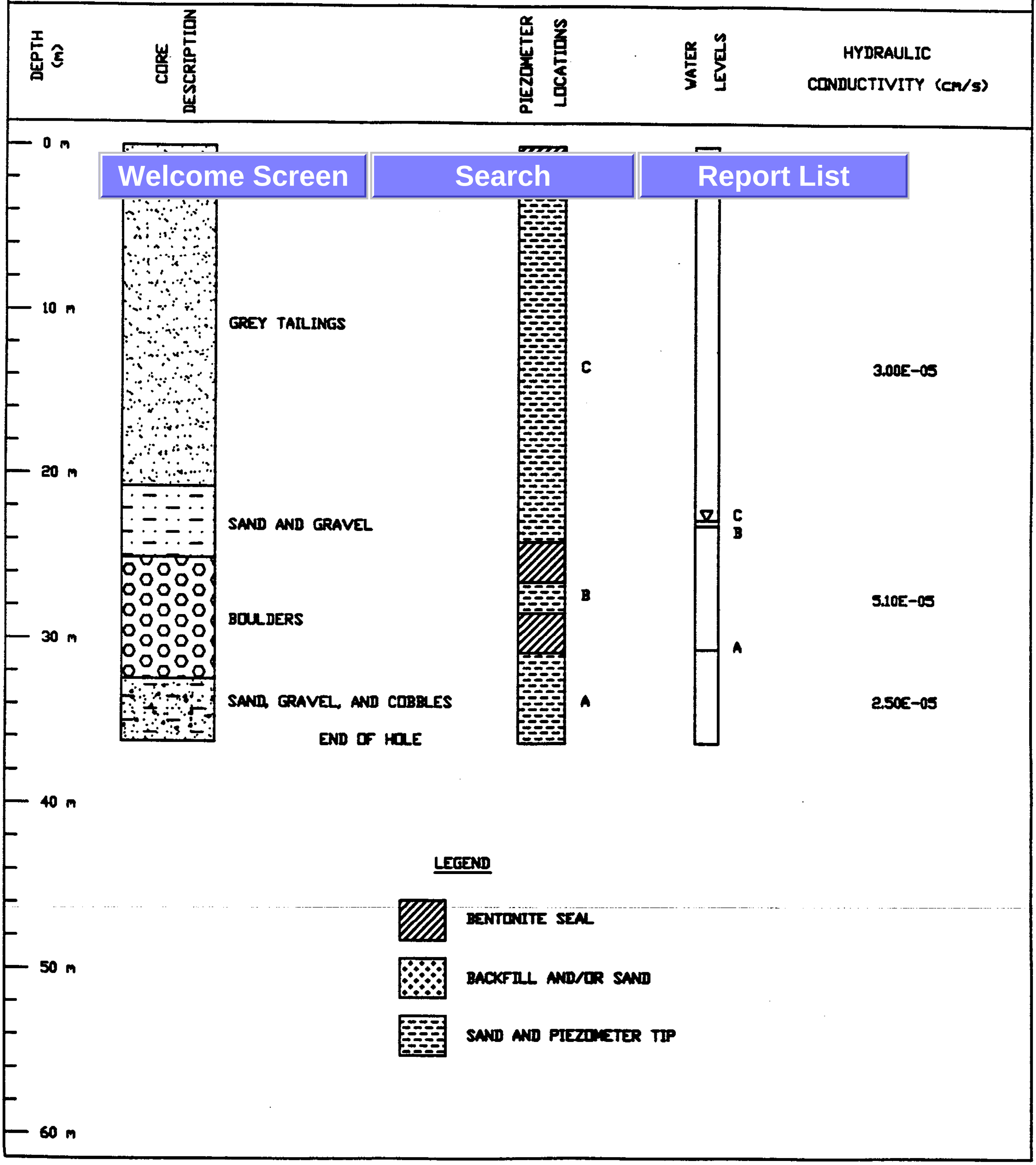


NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-4 | TOTAL DEPTH: 36.27 m

COORDINATES: N5161590.489,E515488.733 | ELEVATION: 322.631 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

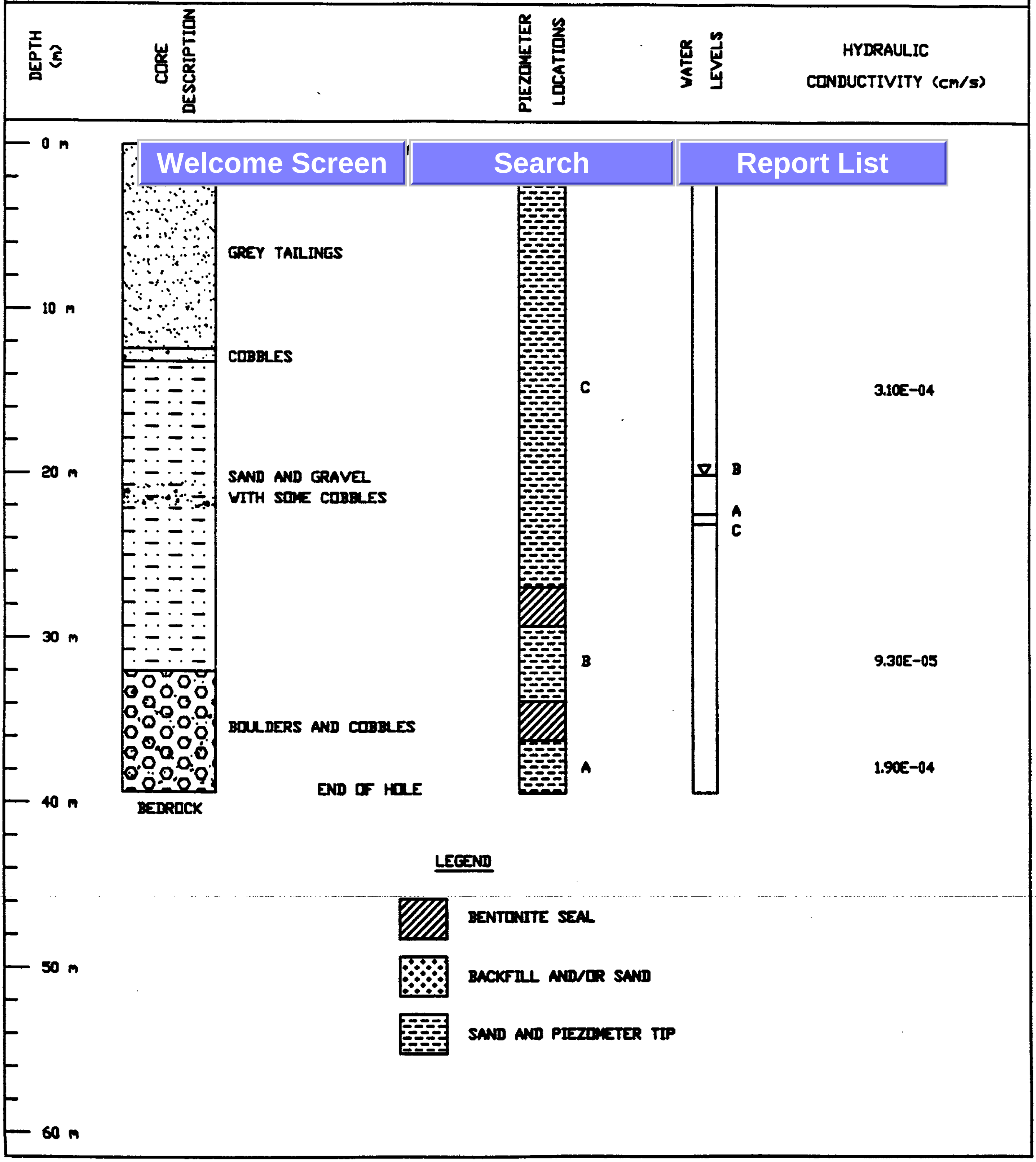


NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-5 | TOTAL DEPTH: 39.62 m

COORDINATES: N5161614.264,E157094.670 | ELEVATION: 321.930 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:



NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-6 | TOTAL DEPTH: 33.53 m

COORDINATES: N5161760.568,E515652.715 | ELEVATION: 320.893 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

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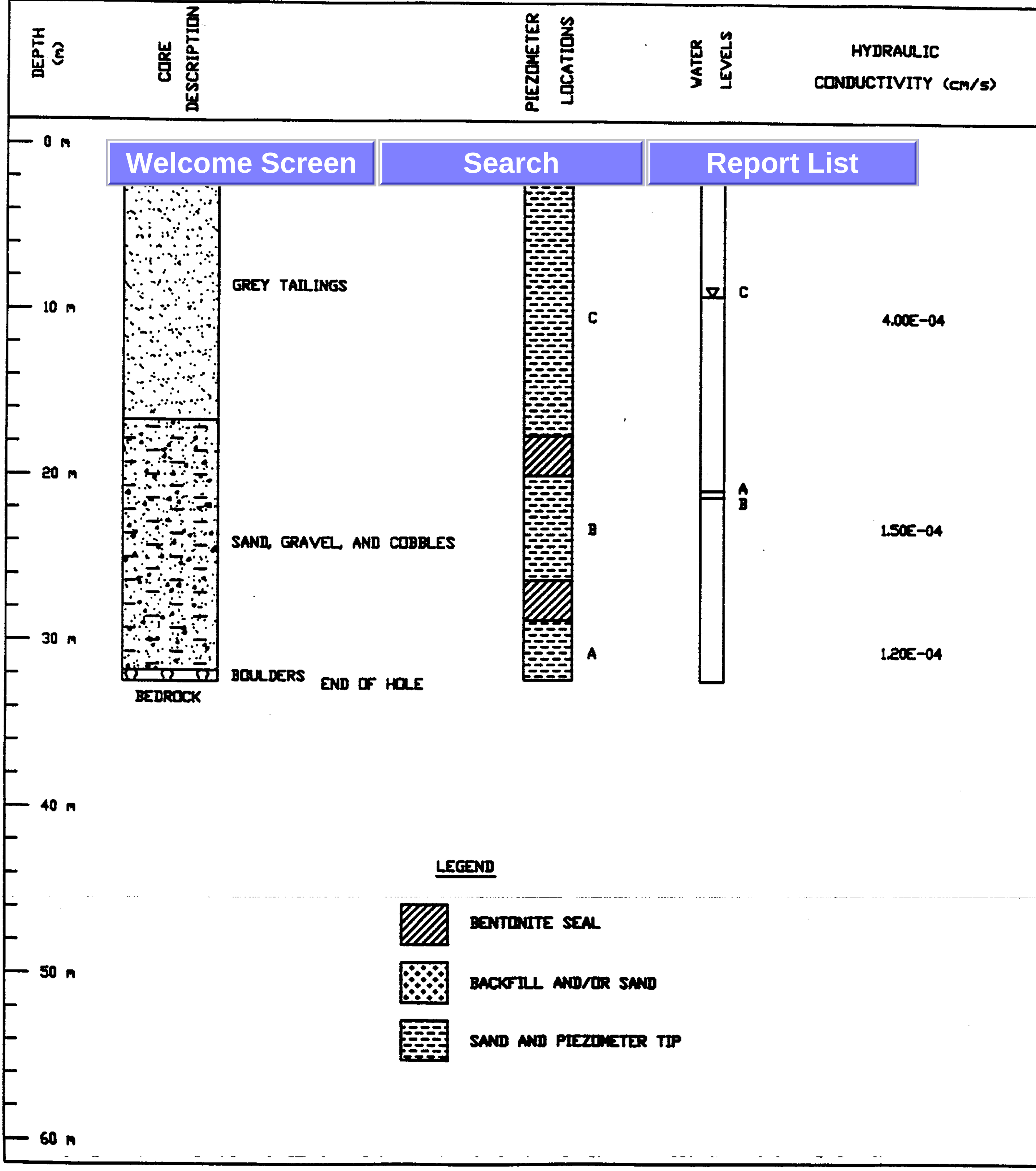

NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-7 | TOTAL DEPTH: 8.20 m

COORDINATES: N5161852.008,E515879.487 | ELEVATION: 309.890 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

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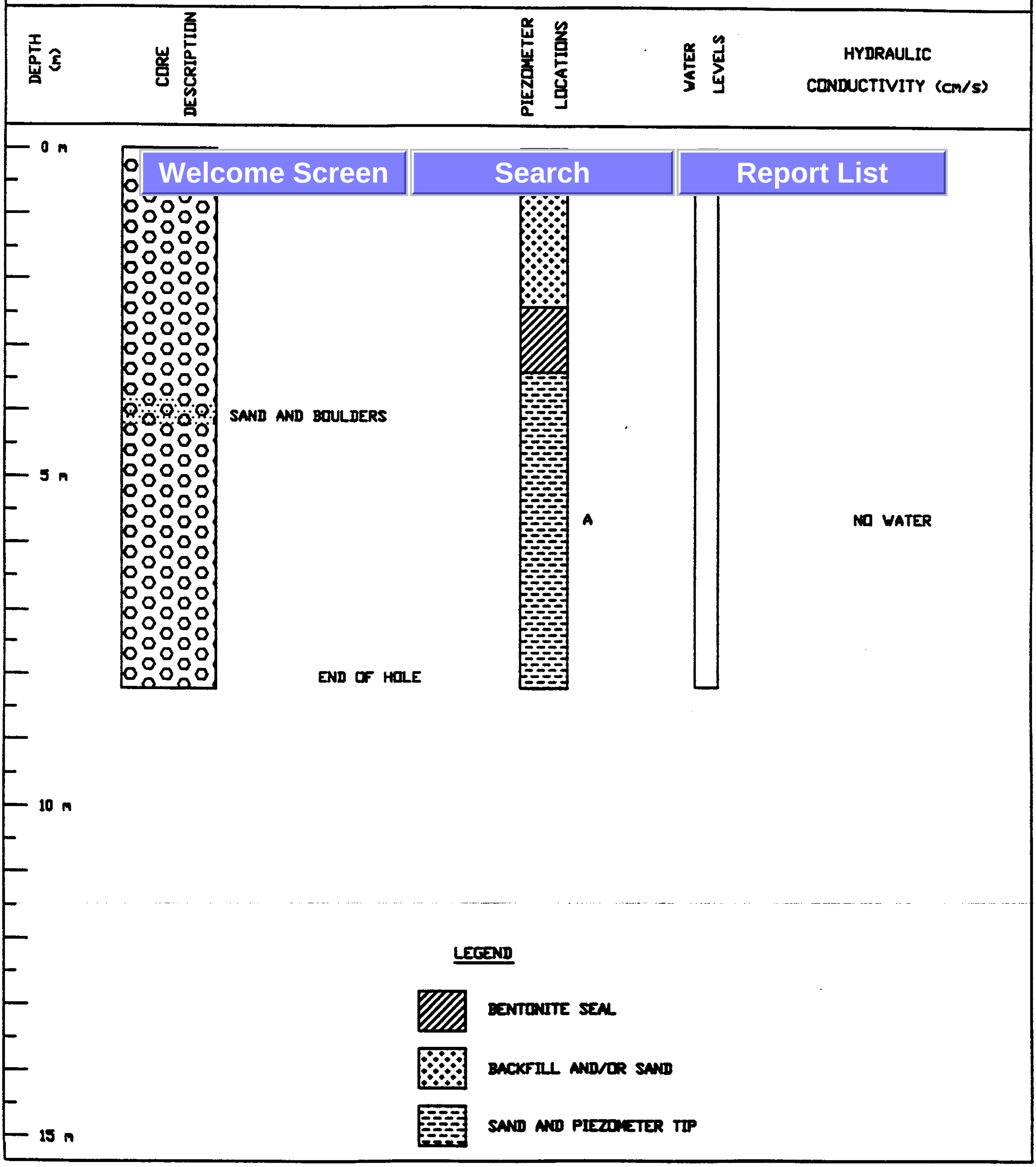
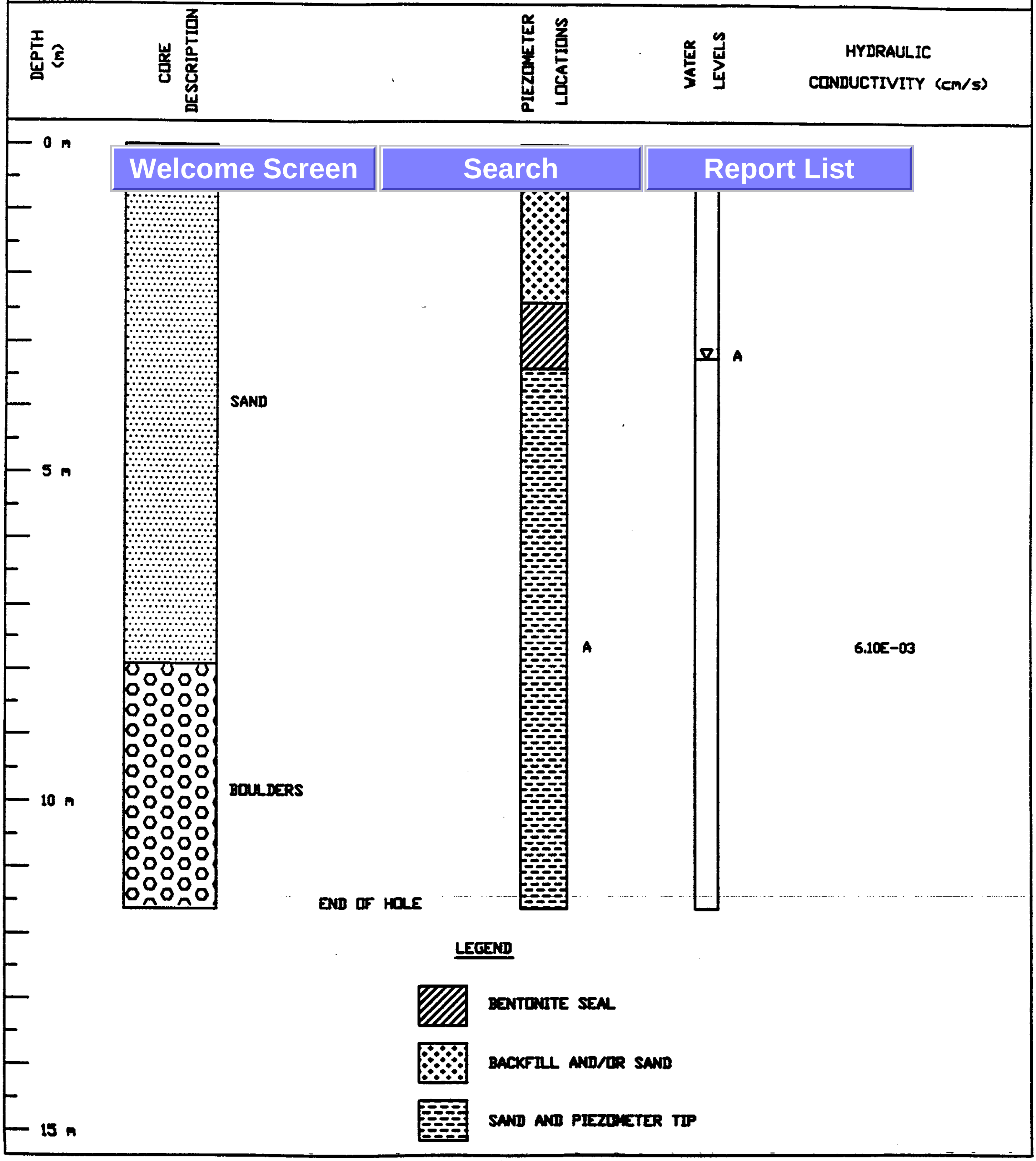


NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-8 | TOTAL DEPTH: 11.58 m

COORDINATES: N5162012.028,E515880.096 | ELEVATION: 302.758 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

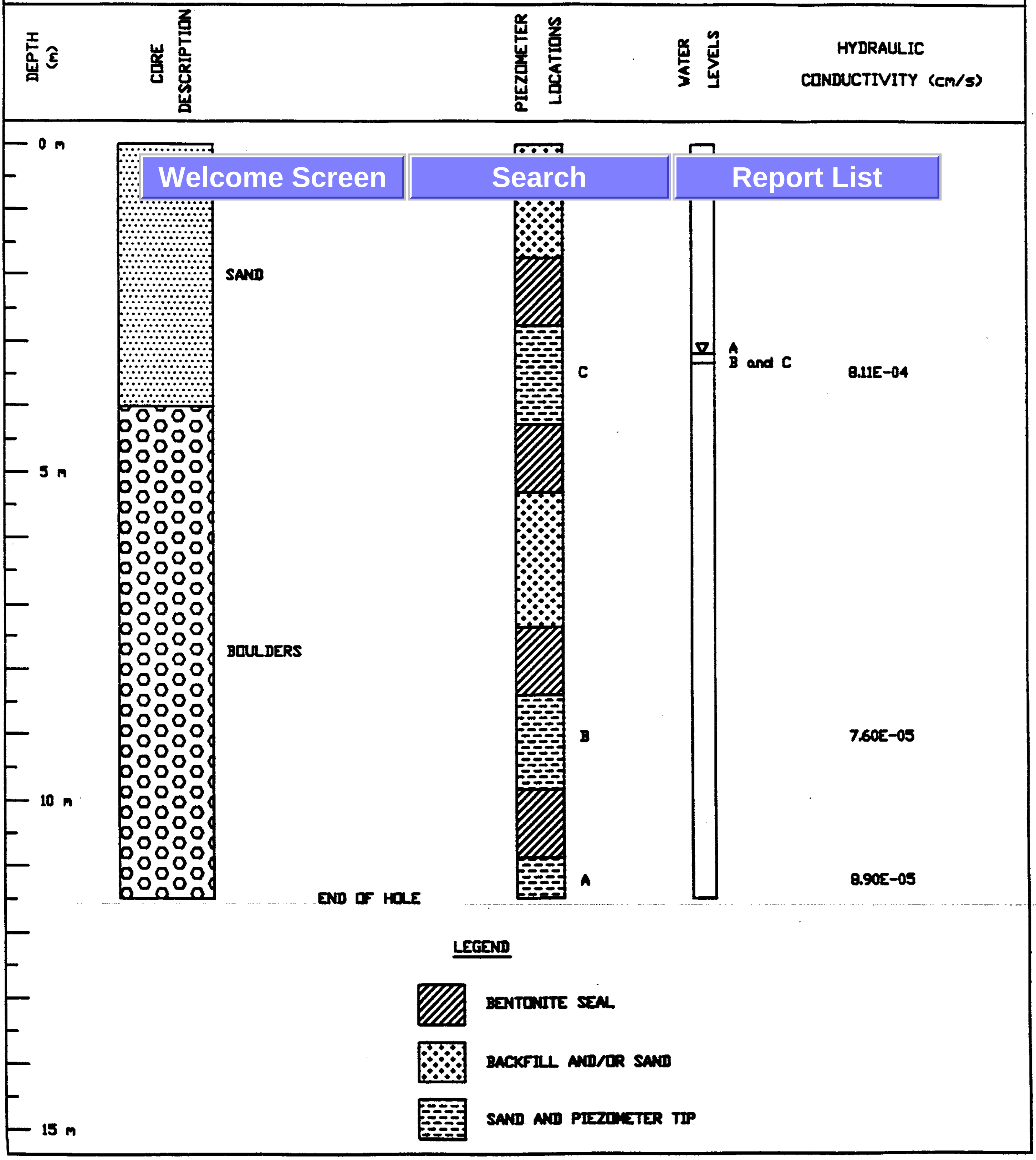


NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-9 | TOTAL DEPTH: 11.51 m

COORDINATES: N5162141.873,E515931.303 | ELEVATION: 302.575 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:



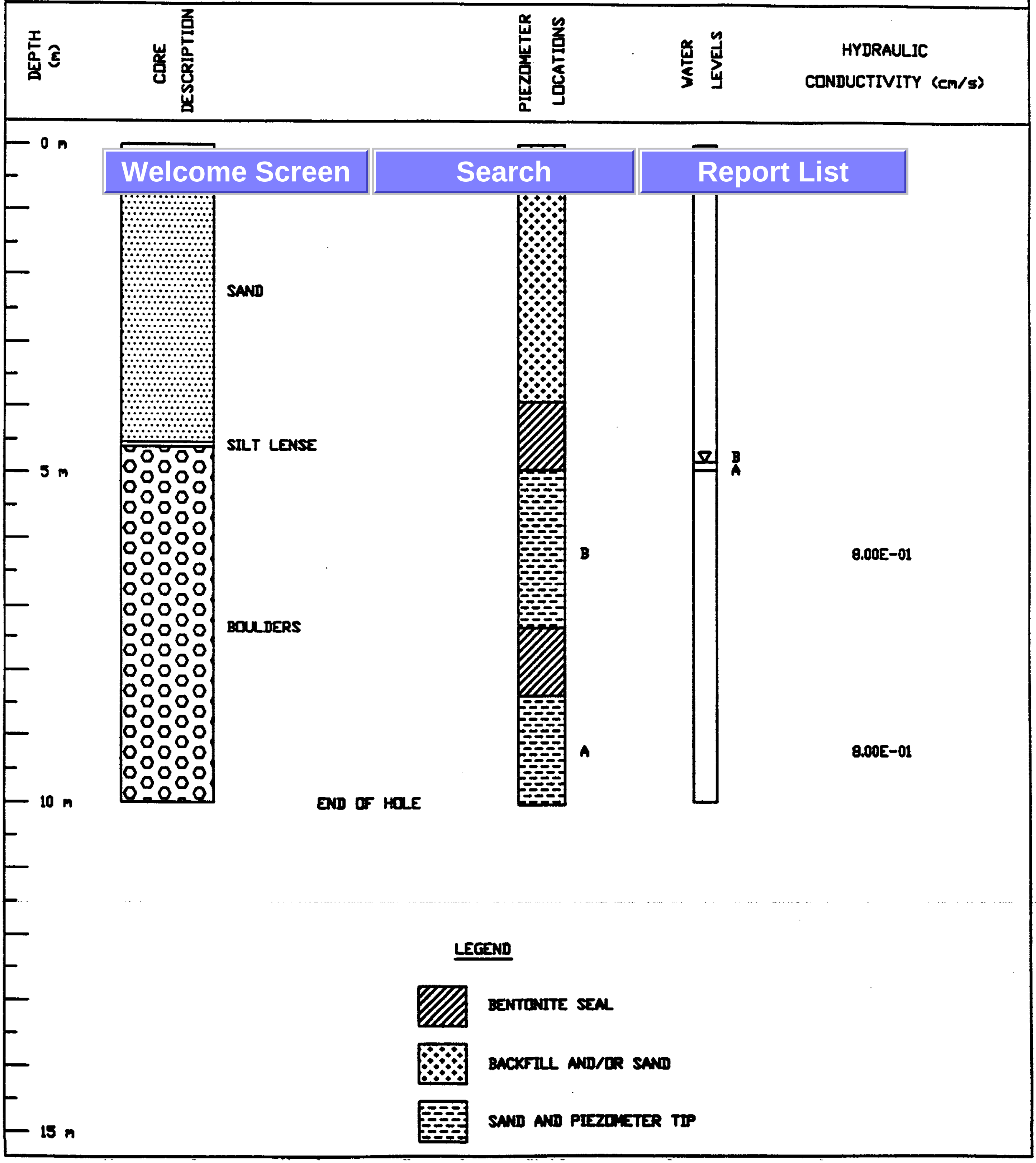
NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-10 | TOTAL DEPTH: 10.02 m

COORDINATES: N5161880.964,E515934.960 | ELEVATION: 304.191 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

Welcome Screen | Search | Report List

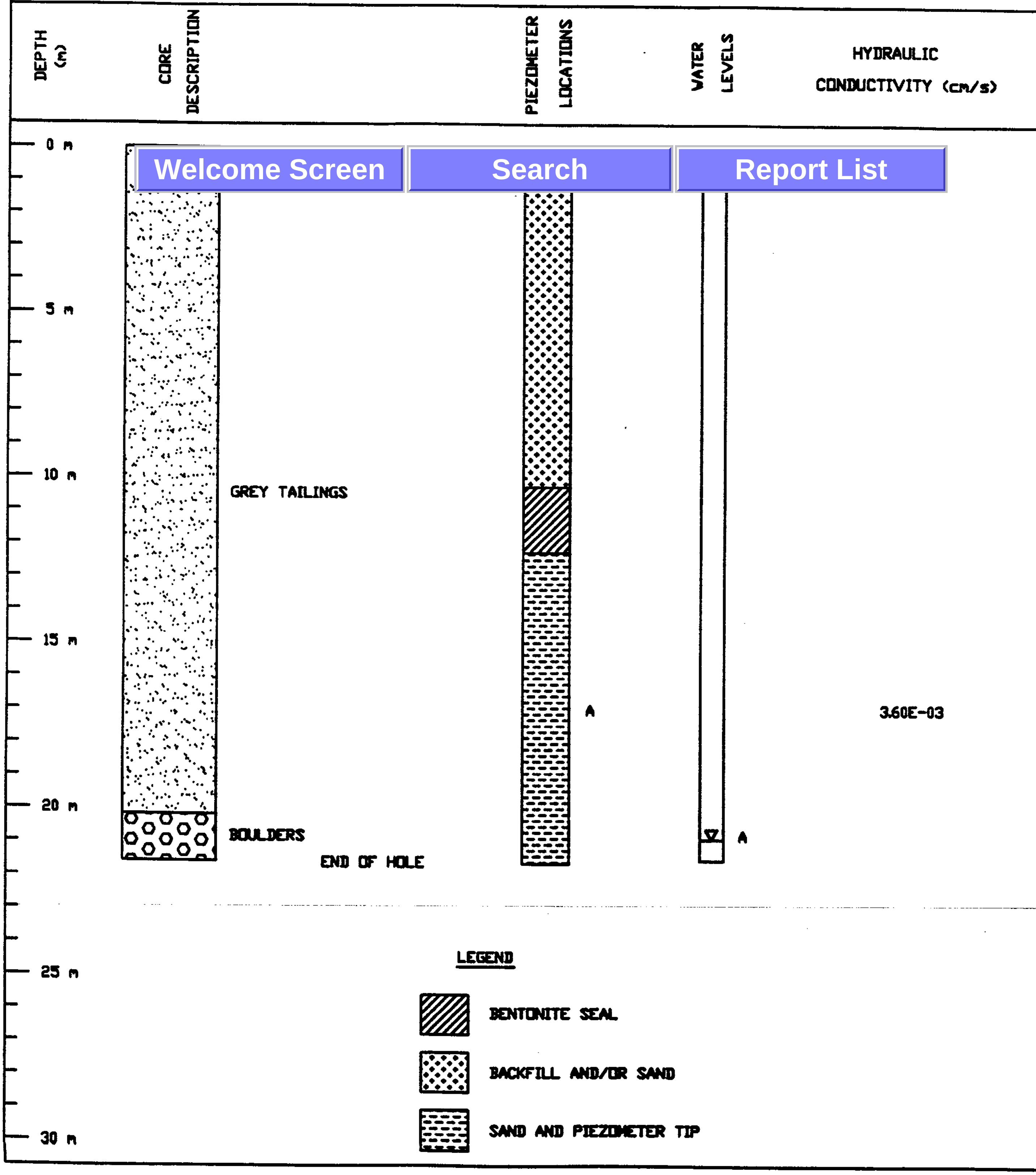


NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-11 | TOTAL DEPTH: 21.23 m

COORDINATES: N5161734.660,E515742.330 | ELEVATION: 320.375 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:



NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-12 | TOTAL DEPTH: 21.64 m

COORDINATES: N5161483.200,E515721.600 | ELEVATION: 320.040 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

DEPTH (m)	CORE DESCRIPTION	PIEZOMETER LOCATIONS	WATER LEVELS	HYDRAULIC CONDUCTIVITY (cm/s)

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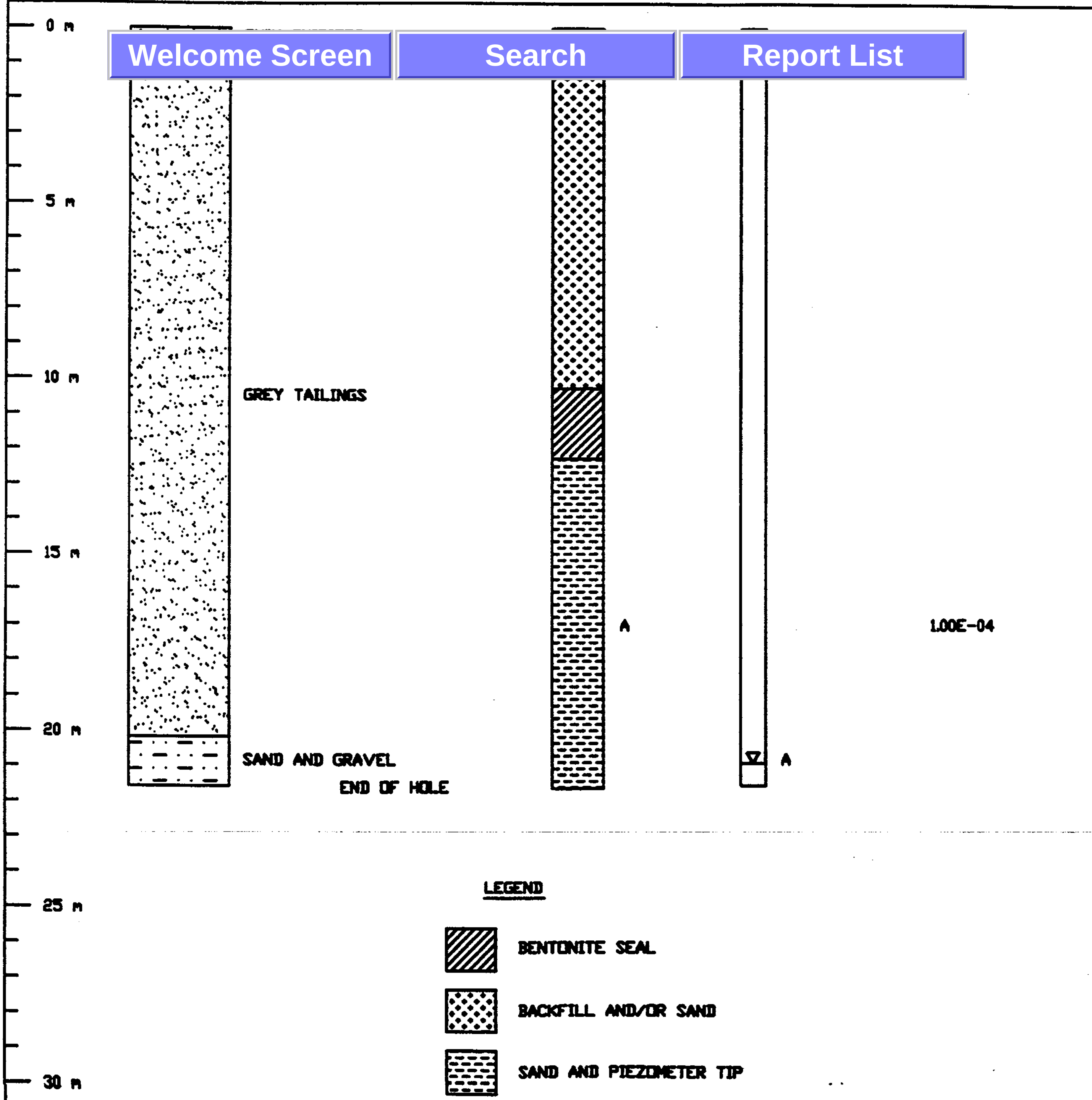


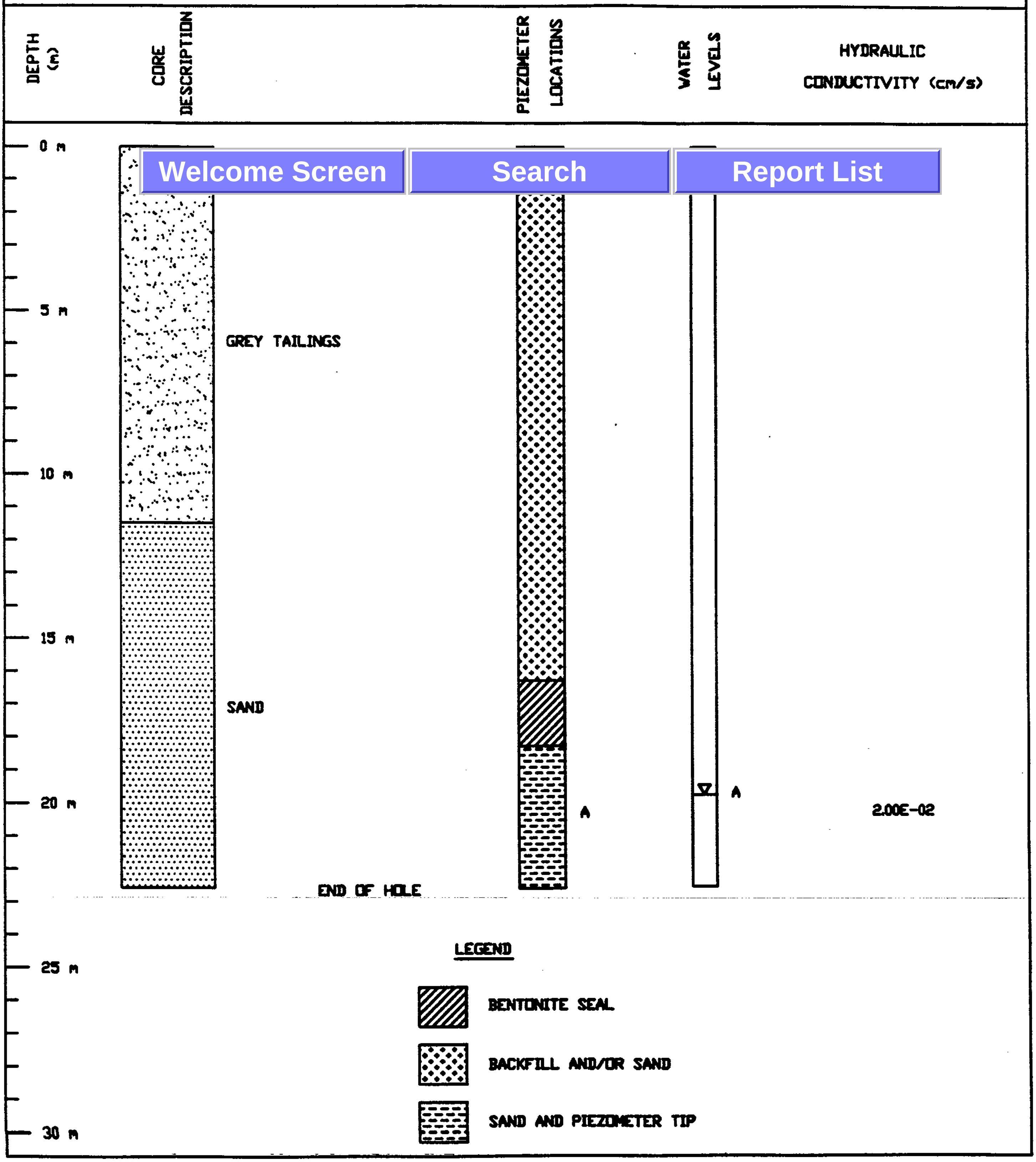
NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE | HOLE NO: FS-13 | TOTAL DEPTH: 22.84 m

COORDINATES: N5161315.865,E515946.238 | ELEVATION: 319.966 m | AZIMUTH:

DEPTH OF CASING: | DIAMETER: | DIP: | CORE SIZE:

Welcome Screen | Search | Report List



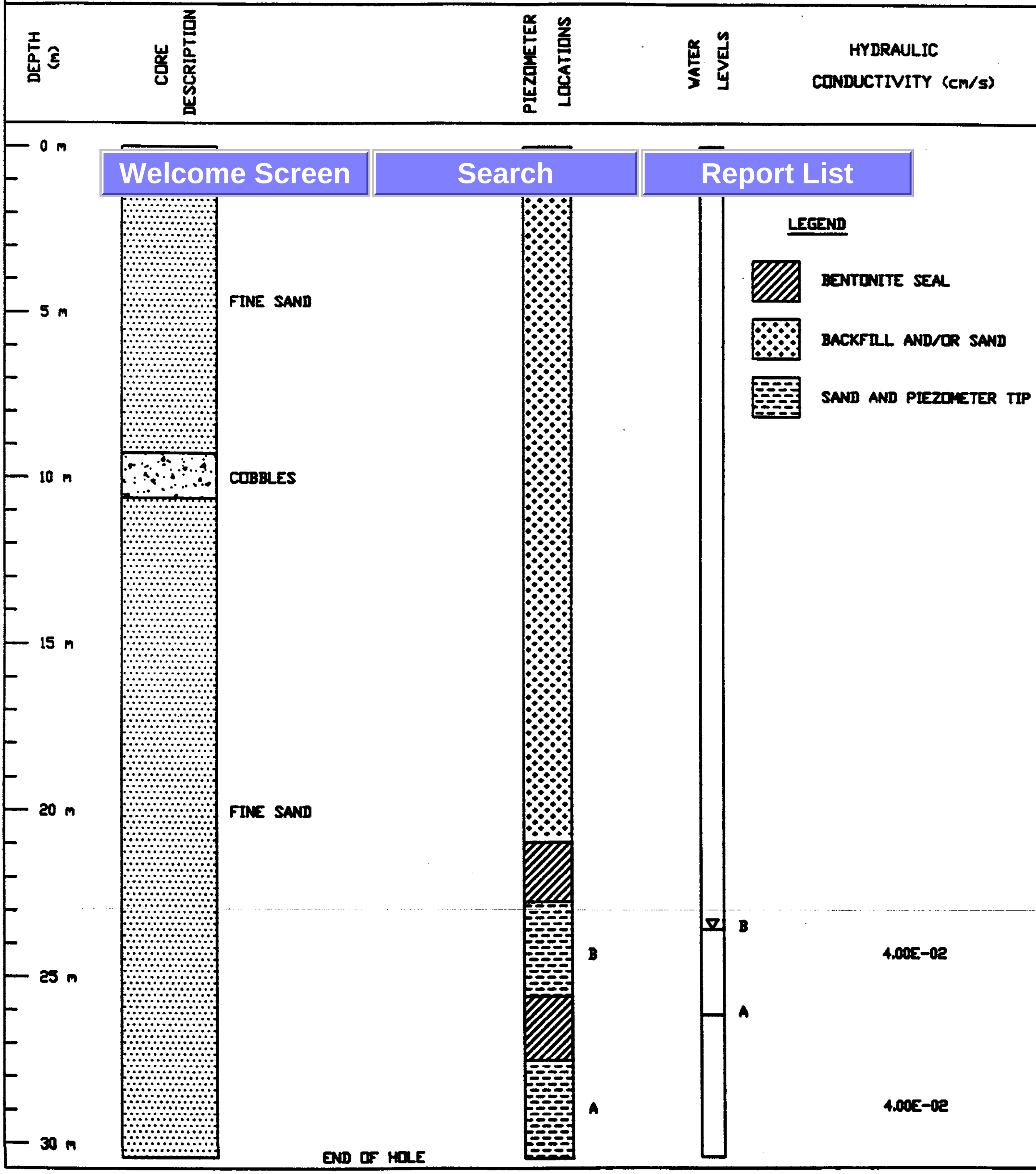
NORANDA TECHNOLOGY CENTRE - BOREHOLE LOG

PROJECT: FAULT LAKE TAILINGS, FALCONBRIDGE
HOLE NO: FS-14
TOTAL DEPTH: 30.15 m

COORDINATES: N5161463.388,E516034.935
ELEVATION: 322.966 m
AZIMUTH:

DEPTH OF CASING:
DIAMETER:
DIP:
CORE SIZE:

Welcome Screen | Search | Report List



APPENDIX E.3

Laboratory certificates of analyses

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud   PROJET / PROJECT: V2-1 T03   Date: 2/26/93

Lab #	I.D.	Description	Al	As	Ca	Cd	Co
2663	FS-1-A	EAU	.07 mg/L	< .05 mg/L	84.44 mg/L	< 5.00 µg/L	< 5.00 µg/L
2664	FS-1-B	EAU	.05 mg/L	< .05 mg/L	84.86 mg/L	< 5.00 µg/L	< 5.00 µg/L
2665	FS-1-C	EAU	.07 mg/L	< .05 mg/L	18.42 mg/L	< 5.00 µg/L	< 5.00 µg/L
2666	FS-2-A	EAU	< .05 mg/L	< .05 mg/L	33.68 mg/L	< 5.00 µg/L	< 5.00 µg/L
2667	FS-2-B	EAU	< .05 mg/L	< .05 mg/L	21.54 mg/L	< 5.00 µg/L	< 5.00 µg/L
2668	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] µg/L
2669	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] µg/L
2670	FS-9-A	EAU	.08 mg/L	< .05 mg/L	28.71 mg/L	< 5.00 µg/L	< 5.00 µg/L
2671	FS-9-B	EAU	.08 mg/L	< .05 mg/L	22.81 mg/L	< 5.00 µg/L	< 5.00 µg/L
2672	FS-9-C	EAU	.08 mg/L	< .05 mg/L	6.18 mg/L	< 5.00 µg/L	7.23 µg/L
2673	FS-9-S2	EAU	20.62 mg/L	1.04 mg/L	101.88 mg/L	1.02 mg/L	< 5.00 µg/L
2674	FS-10-A	EAU	.08 mg/L	< .05 mg/L	12.07 mg/L	< 5.00 µg/L	< 5.00 µg/L
2675	FS-10-B	EAU	< .05 mg/L	< .05 mg/L	6.17 mg/L	< 5.00 µg/L	24.00 µg/L
2676	FS-10-R1	EAU	.07 mg/L	< .05 mg/L	9.62 mg/L	< 5.00 µg/L	21.60 µg/L
2677	FS-10-R2	EAU	.07 mg/L	< .05 mg/L	9.64 mg/L	< 5.00 µg/L	22.70 µg/L
2678	FS-10-R3	EAU	.06 mg/L	< .05 mg/L	4.76 mg/L	< 5.00 µg/L	19.00 µg/L
2679	FS-10-S1	EAU	20.39 mg/L	1.02 mg/L	101.26 mg/L	1.01 mg/L	< 5.00 µg/L
2680	FS-15-D	EAU	.05 mg/L	< .05 mg/L	.15 mg/L	< 5.00 µg/L	< 5.00 µg/L
2681	FS-15-S3	EAU	20.85 mg/L	1.06 mg/L	103.14 mg/L	1.03 mg/L	< 5.00 µg/L

Commentaires/ Comments: Par ICP, sauf Cl, NO3, SO4: par IC. Fe(+2) et Fe(+3): par colorimétrie.

Effectué par/ Work by : R. Pelletier   D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1[illegible]03 Date: 2/26/93

Lab #	I.D.	Description	Cr	Cu	Fe	K	Mg
2663	FS-1-A	EAU	< 5.00 µg/L	< 5.00 µg/L	10.90 µg/L	2.39 mg/L	21.68 mg/L
2664	FS-1-B	EAU	< 5.00 µg/L	< 5.00 µg/L	13.90 µg/L	1.65 mg/L	21.02 mg/L
2665	FS-1-C	EAU	< 5.00 µg/L	5.04 µg/L	49.40 µg/L	1.30 mg/L	3.35 mg/L
2666	FS-2-A	EAU	< 5.00 µg/L	< 5.00 µg/L	27.20 µg/L	1.09 mg/L	8.17 mg/L
2667	FS-2-B	EAU	< 5.00 µg/L	7.16 µg/L	17.70 µg/L	1.73 mg/L	3.64 mg/L
2668							2.42 mg/L
2669							2.58 mg/L
2670	FS-9-A	EAU	< 5.00 µg/L	< 5.00 µg/L	23.20 µg/L	1.84 mg/L	3.83 mg/L
2671	FS-9-B	EAU	< 5.00 µg/L	< 5.00 µg/L	42.50 µg/L	2.45 mg/L	3.33 mg/L
2672	FS-9-C	EAU	< 5.00 µg/L	< 5.00 µg/L	55.40 µg/L	1.20 mg/L	1.11 mg/L
2673	FS-9-S2	EAU	< 5.00 µg/L	11.02 mg/L	30.32 mg/L	< 1.00 mg/L	< .10 mg/L
2674	FS-10-A	EAU	< 5.00 µg/L	< 5.00 µg/L	34.20 µg/L	1.59 mg/L	2.04 mg/L
2675	FS-10-B	EAU	< 5.00 µg/L	< 5.00 µg/L	.71 mg/L	< 1.00 mg/L	1.28 mg/L
2676	FS-10-R1	EAU	< 5.00 µg/L	< 5.00 µg/L	.56 mg/L	1.11 mg/L	1.14 mg/L
2677	FS-10-R2	EAU	< 5.00 µg/L	< 5.00 µg/L	.56 mg/L	1.09 mg/L	1.14 mg/L
2678	FS-10-R3	EAU	< 5.00 µg/L	< 5.00 µg/L	1.60 mg/L	< 1.00 mg/L	.79 mg/L
2679	FS-10-S1	EAU	< 5.00 µg/L	10.86 mg/L	30.04 mg/L	< 1.00 mg/L	< .10 mg/L
2680	FS-15-D	EAU	< 5.00 µg/L	< 5.00 µg/L	15.00 µg/L	< 1.00 mg/L	< .10 mg/L
2681	FS-15-S3	EAU	< 5.00 µg/L	11.15 mg/L	30.68 mg/L	< 1.00 mg/L	< .10 mg/L

Commentaires/ Comments: Par ICP, sauf Cl, NO3, SO4: par IC. Fe(+2) et Fe(+3): par colorimétrie.

Effectué par/ Work by : R. Pelletier D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1 T03 Date: 2/26/93

Lab #	I.D.	Description	Mn	Na	Ni	Pb	S
2663	FS-1-A	EAU	21.70 ug/L	14.48 mg/L	< 5.00 ug/L	< .05 mg/L	73.74 mg/L
2664	FS-1-B	EAU	6.60 ug/L	37.44 mg/L	< 5.00 ug/L	< .05 mg/L	85.69 mg/L
2665	FS-1-C	EAU	3.86 ug/L	23.68 mg/L	< 5.00 ug/L	.07 mg/L	11.82 mg/L
2666	FS-2-A	EAU	22.70 ug/L	6.49 mg/L	11.90 ug/L	< .05 mg/L	12.20 mg/L
2667	FS-2-B	EAU	95.40 ug/L	7.89 mg/L	9.75 ug/L	< .05 mg/L	12.20 mg/L
2668	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]63 mg/L
2669	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]99 mg/L
2670	FS-9-A	EAU	73.90 ug/L	5.15 mg/L	9.75 ug/L	< .05 mg/L	7.93 mg/L
2671	FS-9-B	EAU	.12 mg/L	22.33 mg/L	< 5.00 ug/L	< .05 mg/L	7.80 mg/L
2672	FS-9-C	EAU	1.51 mg/L	11.83 mg/L	.11 mg/L	< .05 mg/L	10.03 mg/L
2673	FS-9-S2	EAU	20.86 mg/L	1.04 mg/L	10.18 mg/L	< .05 mg/L	35.74 mg/L
2674	FS-10-A	EAU	1.51 mg/L	8.29 mg/L	5.78 ug/L	< .05 mg/L	3.14 mg/L
2675	FS-10-B	EAU	5.56 mg/L	6.85 mg/L	9.03 ug/L	< .05 mg/L	6.65 mg/L
2676	FS-10-R1	EAU	4.28 mg/L	6.94 mg/L	11.80 ug/L	< .05 mg/L	6.80 mg/L
2677	FS-10-R2	EAU	4.25 mg/L	6.86 mg/L	10.20 ug/L	< .05 mg/L	6.76 mg/L
2678	FS-10-R3	EAU	4.17 mg/L	4.41 mg/L	7.16 ug/L	< .05 mg/L	4.05 mg/L
2679	FS-10-S1	EAU	20.60 mg/L	1.02 mg/L	10.09 mg/L	< .05 mg/L	35.26 mg/L
2680	FS-15-D	EAU	1.44 ug/L	1.10 mg/L	< 5.00 ug/L	< .05 mg/L	.16 mg/L
2681	FS-15-S3	EAU	20.88 mg/L	1.03 mg/L	10.30 mg/L	< .05 mg/L	35.79 mg/L

Commentaires/ Comments: Par ICP, sauf Cl, NO3, SO4: par IC. Fe(+2) et Fe(+3): par colorimétrie.

Effectué par/ Work by : R. Pelletier D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1 T03 Date: 3/26/93

Lab #	I.D.	Description	Se		Sn		Zn	
2663	FS-1-A	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2664	FS-1-B	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2665	FS-1-C	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2666	FS-2-A	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2667	FS-2-B	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2668	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2669	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2670	FS-9-A	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2671	FS-9-B	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2672	FS-9-C	EAU	< .05	mg/L	< .05	mg/L	27.00	µg/L
2673	FS-9-S2	EAU	< .05	mg/L	< .05	mg/L	21.15	mg/L
2674	FS-10-A	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2675	FS-10-B	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2676	FS-10-R1	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2677	FS-10-R2	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2678	FS-10-R3	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2679	FS-10-S1	EAU	< .05	mg/L	< .05	mg/L	21.18	mg/L
2680	FS-15-D	EAU	< .05	mg/L	< .05	mg/L	< 5.00	µg/L
2681	FS-15-S3	EAU	< .05	mg/L	< .05	mg/L	21.39	mg/L

Commentaires/ Comments: Par ICP, sauf Cl, NO3, SO4: par IC. Fe(+2) et Fe(+3): par colorimétrie.

Effectué par/ Work by : R. Pelletier D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1 T03 Date: 2/26/93

Lab #	I.D.	Description	Cl	NO3	SO4	Fe(+2)	Fe(+3)
2663	FS-1-A	Water	4.02 mg/L	12.90 mg/L	210.00 mg/L		
2664	FS-1-B	Water	6.47 mg/L	24.90 mg/L	239.00 mg/L		
2665	FS-1-C	Water	3.97 mg/L	3.37 mg/L	31.90 mg/L		
2666	FS-2-A	Water	13.50 mg/L	8.22 mg/L	33.50 mg/L		
2667	FS-2-B	Water	3.70 mg/L	5.25 mg/L	32.40 mg/L		
2668	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
2669	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
2670	FS-9-A	Water	5.20 mg/L	2.30 mg/L	16.60 mg/L		
2671	FS-9-B	Water	9.51 mg/L	2.38 mg/L	20.70 mg/L		
2672	FS-9-C	Water	3.06 mg/L	2.61 mg/L	29.30 mg/L		
2673	FS-9-S2	Water	3.62 mg/L	< .20 mg/L	8.35 mg/L		
2674	FS-10-A	Water	1.74 mg/L	1.32 mg/L	17.40 mg/L		
2675	FS-10-B	Water	1.74 mg/L	< .20 mg/L	17.30 mg/L	.68 mg/L	
2676	FS-10-R1	Water			18.00 mg/L		
2677	FS-10-R2	Water			18.50 mg/L		
2678	FS-10-R3	Water			7.98 mg/L		
2679	FS-10-S1	Water			97.00 mg/L		29.10 mg/L
2680	FS-15-D	Water			2.57 mg/L		
2681	FS-15-S3	Water			96.80 mg/L		29.10 mg/L

Welcome Screen Search Report List

Commentaires/ Comments: Par ICP, sauf Cl, NO3, SO4: par IC. Fe(+2) et Fe(+3):par colorimétrie.

Effectué par/ Work by-: R. Pelletier D. Thériault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud B.Aubé PROJET / PROJECT: V2 1321 01 Date: 3/31/93

Lab #	I.D.	Description	Al	As	Ca	Cd	Cu
3350	MLW #1	Tailing H2O	12.30 mg/L	1.97 mg/L	.42 g/L	.21 mg/L	3.78 mg/L
3351	BLW #2	Tailing H2O	.39 mg/L	< .25 mg/L	4.05 g/L	< .02 mg/L	< .02 mg/L
3352	S #1	Lake water					
3353	S #2	Lake water					
3354	FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.03 mg/L
3355	FS-6	Tailing H2O	.51 mg/L	< .25 mg/L	1.71 g/L	.05 mg/L	.06 mg/L
3356	FS-11	Tailing H2O	< .25 mg/L	< .25 mg/L	.65 g/L	< .02 mg/L	< .02 mg/L
3357	FS-12a	Tailing H2O	< .25 mg/L	< .25 mg/L	.88 g/L	< .02 mg/L	.03 mg/L
3358	FS-12b	Tailing H2O	< .25 mg/L	< .25 mg/L	.70 g/L	< .02 mg/L	< .02 mg/L
3359	FS-13	Tailing H2O	< .25 mg/L	< .25 mg/L	.62 g/L	< .02 mg/L	< .02 mg/L

Commentaires/ Comments: par ICP.

Effectué par/ Work by : D. Thériault J. Groleau
B.Legault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud B.Aubé PROJET / PROJECT: V2 1321 01 Date: 3/31/93

Lab #	I.D.	Description	Fe	Mg	Mn	Na	Pb
3350	MLW #1	Tailing H2O	305.00 mg/L	176.00 mg/L	51.70 mg/L	69.70 mg/L	18.20 mg/L
3351	BLW #2	Tailing H2O	167.00 mg/L	40.60 mg/L	89.50 mg/L	72.90 mg/L	42.50 mg/L
3352	S #1	Lake water					
3353	S #2						
3354	FS-4	Tailing H2O	96.00 mg/L	778.00 mg/L	19.80 mg/L	16.80 mg/L	< .25 mg/L
3355	FS-6	Tailing H2O	58.70 mg/L	322.00 mg/L	2.30 mg/L	82.00 mg/L	< .25 mg/L
3356	FS-11	Tailing H2O	.58 mg/L	127.00 mg/L	.58 mg/L	64.00 mg/L	< .25 mg/L
3357	FS-12a	Tailing H2O	.35 mg/L	189.00 mg/L	1.14 mg/L	66.30 mg/L	< .25 mg/L
3358	FS-12b	Tailing H2O	.22 mg/L	132.00 mg/L	.53 mg/L	75.20 mg/L	< .25 mg/L
3359	FS-13	Tailing H2O	.23 mg/L	391.00 mg/L	1.09 mg/L	43.50 mg/L	< .25 mg/L

Welcome Screen Search Report List

Commentaires/ Comments: par ICP.

Effectué par/ Work by : D. Thériault J. Groleau

B.Lesault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud B.Aubé

PROJET / PROJECT: V2 1321 01

Date: 3/31/93

Lab #	I.D.	Description	S	Se	Zn	K	Cl
3350	MLW #1	Tailing H2O	.61 g/L	< .50 mg/L	317.00 mg/L	< 5.00 mg/L	
3351	BLW #2	Tailing H2O	.11 g/L	< .50 mg/L	133.00 mg/L	< 5.00 mg/L	
3352	S #1	Lake water			.95 g/L		1.22 g/L
3353	S [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.23 g/L
3354	FS-4	Tailing H2O	5.82 g/L	< .50 mg/L	.76 mg/L	245.00 mg/L	
3355	FS-6	Tailing H2O	5.23 g/L	< .50 mg/L	1.72 mg/L	171.00 mg/L	
3356	FS-11	Tailing H2O	.74 g/L	< .50 mg/L	.07 mg/L	105.00 mg/L	
3357	FS-12a	Tailing H2O	2.00 g/L	< .50 mg/L	.09 mg/L	176.00 mg/L	
3358	FS-12b	Tailing H2O	.75 g/L	< .50 mg/L	.20 mg/L	155.00 mg/L	
3359	FS-13	Tailing H2O	1.00 g/L	< .50 mg/L	.12 mg/L	125.00 mg/L	

Commentaires/ Comments: par ICP.

Effectué par/ Work by : D. Thériault J. Groleau
B.Legault

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud B.Aubé PROJET / PROJECT: V2 1321 01 Date: 3/31/93

Lab #	I.D.	Description	Ni	
3350	MLW #1	Tailing H20		
3351	BLW #2	Tailing H20		
3352	S #1			
3353	S #2			
3354	FS-4	Tailing H20	133.00	mg/L
3355	FS-6	Tailing H20	16.30	mg/L
3356	FS-11	Tailing H20	2.92	mg/L
3357	FS-12a	Tailing H20	4.69	mg/L
3358	FS-12b	Tailing H20	2.55	mg/L
3359	FS-13	Tailing H20	3.65	mg/L

Commentaires/ Comments: par ICP.

Effectué par/ Work by : D. Thériault J. Groleau

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud   PROJET / PROJECT: V2-1 T03   Date: 4/30/93

Lab #	I.D.	Description	Al	As	Ca	Cd	Co
6563	FS-1A	Water	.06 mg/L	< .05 mg/L	80.94 mg/L	< 5.00 µg/L	< 5.00 µg/L
6564	FS-1B	Water	< .05 mg/L	< .05 mg/L	95.42 mg/L	< 5.00 µg/L	< 5.00 µg/L
6565	FS-1C	Water	.08 mg/L	< .05 mg/L	16.55 mg/L	< 5.00 µg/L	< 5.00 µg/L
6566	FS-2A	Water	.08 mg/L	< .05 mg/L	28.60 mg/L	< 5.00 µg/L	< 5.00 µg/L
6567	FS-2B	Water	.12 mg/L	< .05 mg/L	18.36 mg/L	< 5.00 µg/L	< 5.00 µg/L
6568	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.00 µg/L
6569	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.00 µg/L
6570	FS-3B	Water	.08 mg/L	< .05 mg/L	101.29 mg/L	< 5.00 µg/L	< 5.00 µg/L
6571	FS-3C	Water	20.60 mg/L	1.01 mg/L	100.50 mg/L	1.02 mg/L	< 5.00 µg/L
6572	FS-4A	Water	.07 mg/L	< .05 mg/L	52.60 mg/L	< 5.00 µg/L	< 5.00 µg/L
6573	FS-4B	Water	.10 mg/L	< .05 mg/L	62.05 mg/L	< 5.00 µg/L	< 5.00 µg/L
6574	FS-4C	Water	.18 mg/L	< .05 mg/L	18.25 mg/L	< 5.00 µg/L	< 5.00 µg/L
6575	FS-5A	Water	.17 mg/L	< .05 mg/L	63.02 mg/L	< 5.00 µg/L	< 5.00 µg/L
6576	FS-5B	Water	.17 mg/L	< .05 mg/L	47.01 mg/L	< 5.00 µg/L	< 5.00 µg/L
6577	FS-5C	Water	.23 mg/L	< .05 mg/L	53.37 mg/L	< 5.00 µg/L	< 5.00 µg/L
6578	FS-6A	Water	.26 mg/L	< .05 mg/L	41.37 mg/L	< 5.00 µg/L	< 5.00 µg/L
6579	FS-6B	Water	21.04 mg/L	1.07 mg/L	101.23 mg/L	1.03 mg/L	< 5.00 µg/L
6580	FS-8A	Water	.09 mg/L	< .05 mg/L	11.38 mg/L	< 5.00 µg/L	5.29 µg/L
6581	FS-8B	Water	20.88 mg/L	1.07 mg/L	100.82 mg/L	1.03 mg/L	< 5.00 µg/L
6582	FS-9A	Water	.07 mg/L	< .05 mg/L	29.03 mg/L	< 5.00 µg/L	< 5.00 µg/L
6583	FS-9B	Water	.12 mg/L	< .05 mg/L	26.81 mg/L	< 5.00 µg/L	< 5.00 µg/L
6584	FS-9C	Water	.31 mg/L	< .05 mg/L	6.38 mg/L	< 5.00 µg/L	8.30 µg/L
6585	FS-10A	Water	.41 mg/L	< .05 mg/L	15.37 mg/L	< 5.00 µg/L	7.03 µg/L
6586	FS-10B	Water	.16 mg/L	< .05 mg/L	6.13 mg/L	< 5.00 µg/L	84.80 µg/L
6587	PREP.#1	Water	9.17 mg/L	.35 mg/L	253.30 mg/L	10.70 µg/L	48.40 µg/L
6588	SURF #1	Water	.47 mg/L	< .05 mg/L	71.49 mg/L	< 5.00 µg/L	7.60 µg/L
6589	SURF #2	Water	.47 mg/L	< .05 mg/L	70.16 mg/L	< 5.00 µg/L	7.18 µg/L

Commentaires/ Comments: Par ICP.

Effectué par/ Work by : R. Pelletier

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1 T03 Date: 4/30/93

Lab #	I.D.	Description	Cr	Cu	Fe	K	Mg
6563	FS-1A	Water	< 5.00 µg/L	< 5.00 µg/L	< 5.00 µg/L	2.19 mg/L	21.16 mg/L
6564	FS-1B	Water	< 5.00 µg/L	< 5.00 µg/L	< 5.00 µg/L	1.29 mg/L	24.18 mg/L
6565	FS-1C	Water	< 5.00 µg/L	< 5.00 µg/L	< 5.00 µg/L	< 1.00 mg/L	3.20 mg/L
6566	FS-2A	Water	< 5.00 µg/L	5.19 µg/L	< 5.00 µg/L	1.22 mg/L	7.11 mg/L
6567	FS-2B	Water	< 5.00 µg/L	< 5.00 µg/L	33.10 µg/L	1.01 mg/L	4.01 mg/L
6568	FS-2C	Water	< 5.00 µg/L	< 5.00 µg/L	< 5.00 µg/L	< 1.00 mg/L	< [illegible] mg/L
6569	FS-3A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] mg/L
6570	FS-3B	Water	< 5.00 µg/L	< 5.00 µg/L	< 5.00 µg/L	3.34 mg/L	18.37 mg/L
6571	FS-3C	Water	< 9.00 µg/L	11.08 mg/L	29.75 mg/L	< 1.00 mg/L	.11 mg/L
6572	FS-4A	Water	< 5.00 µg/L	< 5.00 µg/L	1.34 mg/L	5.88 mg/L	11.89 mg/L
6573	FS-4B	Water	< 5.00 µg/L	< 5.00 µg/L	14.10 µg/L	6.52 mg/L	12.17 mg/L
6574	FS-4C	Water	< 5.00 µg/L	< 5.00 µg/L	56.80 µg/L	3.37 mg/L	2.89 mg/L
6575	FS-5A	Water	< 5.00 µg/L	5.29 µg/L	192.00 µg/L	5.64 mg/L	10.86 mg/L
6576	FS-5B	Water	< 5.00 µg/L	6.95 µg/L	356.00 µg/L	3.03 mg/L	9.09 mg/L
6577	FS-5C	Water	< 5.00 µg/L	6.02 µg/L	514.00 µg/L	8.04 mg/L	8.50 mg/L
6578	FS-6A	Water	< 5.00 µg/L	6.95 µg/L	< 5.00 µg/L	3.82 mg/L	9.15 mg/L
6579	FS-6B	Water	< 5.00 µg/L	11.34 mg/L	30.21 mg/L	< 1.00 mg/L	.13 mg/L
6580	FS-8A	Water	< 5.00 µg/L	< 5.00 µg/L	19.32 mg/L	2.05 mg/L	2.39 mg/L
6581	FS-8B	Water	< 5.00 µg/L	11.26 mg/L	30.08 mg/L	< 1.00 mg/L	< .10 mg/L
6582	FS-9A	Water	< 5.00 µg/L	< 5.00 µg/L	91.00 µg/L	1.91 mg/L	4.64 mg/L
6583	FS-9B	Water	< 5.00 µg/L	< 5.00 µg/L	139.00 µg/L	2.15 mg/L	4.35 mg/L
6584	FS-9C	Water	< 5.00 µg/L	< 5.00 µg/L	746.00 µg/L	< 1.00 mg/L	1.13 mg/L
6585	FS-10A	Water	< 5.00 µg/L	5.30 µg/L	1.68 mg/L	1.62 mg/L	2.09 mg/L
6586	FS-10B	Water	< 5.00 µg/L	13.40 µg/L	2.54 mg/L	< 1.00 mg/L	1.16 mg/L
6587	PREP.#1	Water	< 5.00 µg/L	144.00 µg/L	908.70 mg/L	5.99 mg/L	238.66 mg/L
6588	SURF #1	Water	< 5.00 µg/L	6.44 µg/L	58.27 mg/L	2.39 mg/L	19.74 mg/L
6589	SURF #2	Water	< 5.00 µg/L	8.21 µg/L	57.19 mg/L	2.11 mg/L	19.24 mg/L

Welcome Screen Search Report List

Commentaires/ Comments: Par ICP.

Effectué par/ Work by : R. Pelletier

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1 T03 Date: 4/30/93

Lab #	I.D.	Description	Mn	Na	Ni	Pb	S
6563	FS-1A	Water	13.40 µg/L	15.34 mg/L	< 5.00 µg/L	< .05 mg/L	72.48 mg/L
6564	FS-1B	Water	2.12 µg/L	53.95 mg/L	< 5.00 µg/L	< .05 mg/L	113.43 mg/L
6565	FS-1C	Water	< 1.00 µg/L	14.72 mg/L	< 5.00 µg/L	< .05 mg/L	11.16 mg/L
6566	FS-2A	Water	1.91 µg/L	6.36 mg/L	< 5.00 µg/L	< .05 mg/L	11.01 mg/L
6567	FS-2B	Water	47.20 µg/L	3.99 mg/L	< 5.00 µg/L	< .05 mg/L	11.11 mg/L
6568	FS-2C	Water	< 1.00 µg/L	1.15 mg/L	< 5.00 µg/L	< .05 mg/L	.27 mg/L
6569	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49.52 mg/L
6570	FS-3B	Water	[illegible] µg/L	[illegible] mg/L	[illegible] µg/L	[illegible] mg/L	82.23 mg/L
6571	FS-3C	Water	20.22 mg/L	1.21 mg/L	9.90 mg/L	< .05 mg/L	36.00 mg/L
6572	FS-4A	Water	248.00 µg/L	18.42 mg/L	< 5.00 µg/L	< .05 mg/L	35.45 mg/L
6573	FS-4B	Water	176.00 µg/L	20.43 mg/L	11.70 µg/L	< .05 mg/L	34.84 mg/L
6574	FS-4C	Water	24.70 µg/L	48.16 mg/L	< 5.00 µg/L	< .05 mg/L	8.49 mg/L
6575	FS-5A	Water	274.00 µg/L	13.95 mg/L	< 5.00 µg/L	< .05 mg/L	33.78 mg/L
6576	FS-5B	Water	265.00 µg/L	42.64 mg/L	< 5.00 µg/L	< .05 mg/L	33.58 mg/L
6577	FS-5C	Water	146.00 µg/L	31.79 mg/L	6.01 µg/L	< .05 mg/L	32.07 mg/L
6578	FS-6A	Water	64.70 µg/L	17.62 mg/L	< 5.00 µg/L	< .05 mg/L	14.66 mg/L
6579	FS-6B	Water	20.50 mg/L	1.44 mg/L	10.03 mg/L	< .05 mg/L	36.29 mg/L
6580	FS-8A	Water	5.44 mg/L	4.84 mg/L	< 5.00 µg/L	< .05 mg/L	12.54 mg/L
6581	FS-8B	Water	20.47 mg/L	1.29 mg/L	10.00 mg/L	< .05 mg/L	35.72 mg/L
6582	FS-9A	Water	156.00 µg/L	6.16 mg/L	< 5.00 µg/L	< .05 mg/L	8.79 mg/L
6583	FS-9B	Water	110.00 µg/L	11.01 mg/L	< 5.00 µg/L	< .05 mg/L	8.61 mg/L
6584	FS-9C	Water	1.12 mg/L	11.87 mg/L	46.30 µg/L	< .05 mg/L	8.54 mg/L
6585	FS-10A	Water	1.58 mg/L	8.24 mg/L	19.40 µg/L	< .05 mg/L	3.79 mg/L
6586	FS-10B	Water	1.92 mg/L	2.87 mg/L	532.00 µg/L	< .05 mg/L	8.37 mg/L
6587	PREP.#1	Water	29.80 mg/L	7.94 mg/L	28.20 µg/L	< .05 mg/L	****** mg/L
6588	SURF #1	Water	2.19 mg/L	3.30 mg/L	< 5.00 µg/L	< .05 mg/L	118.67 mg/L
6589	SURF #2	Water	2.13 mg/L	3.25 mg/L	< 5.00 µg/L	< .05 mg/L	116.96 mg/L

Commentaires/ Comments: Par ICP.

Effectué par/ Work by : R. Pelletier

CENTRE DE TECHNOLOGIE NORANDA

CERTIFICAT D'ANALYSE / CERTIFICATE OF ANALYSIS

A/To : L.St-Arnaud PROJET / PROJECT: V2-1 T03 Date: 4/30/93

Lab #	I.D.	Description	Se	Sn	Zn
6563	FS-1A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6564	FS-1B	Water	.07 mg/L	< .05 mg/L	< 5.00 µg/L
6565	FS-1C	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6566	FS-2A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6567	FS-2B	Water	< .05 mg/L	.05 mg/L	< 5.00 µg/L
6568	FS-2C	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6569	FS-3 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6570	FS-3 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6571	FS-3C	Water	.05 mg/L	< .05 mg/L	21.08 mg/L
6572	FS-4A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6573	FS-4B	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6574	FS-4C	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6575	FS-5A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6576	FS-5B	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6577	FS-5C	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6578	FS-6A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6579	FS-6B	Water	< .05 mg/L	< .05 mg/L	21.33 mg/L
6580	FS-8A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6581	FS-8B	Water	< .05 mg/L	< .05 mg/L	21.16 mg/L
6582	FS-9A	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6583	FS-9B	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6584	FS-9C	Water	< .05 mg/L	< .05 mg/L	< 5.00 µg/L
6585	FS-10A	Water	< .05 mg/L	< .05 mg/L	7.50 µg/L
6586	FS-10B	Water	< .05 mg/L	< .05 mg/L	.14 mg/L
6587	PREP.#1	Water	.15 mg/L	.31 mg/L	13.17 mg/L
6588	SURF #1	Water	< .05 mg/L	< .05 mg/L	.39 mg/L
6589	SURF #2	Water	< .05 mg/L	< .05 mg/L	.40 mg/L

Commentaires/ Comments: Par ICP.

Effectué par/ Work by : R. Pelletier

certificate date: feb 26, 1993

	Al (mg/L)	As (mg/L)	Ca (mg/L)	Cd (ug/L)	Co (ug/L)	Cr (ug/L)	Cu (ug/L)	Fe (ug/L)	K (mg/L)	Mg (mg/L)	Mn (ug/L)	Na (mg/L)	Ni (ug/L)	Pb (mg/L)	S (mg/L)	Se (mg/L)	Sn (mg/L)	Zn (ug/L)
Standard sample	20.00	1.00	100.00	1.00	-	-	10.00	30.00	-	-	20.00	-	10.00	-	-	-	-	20.00
Laboratory Analysis	20.62	1.04	101.88	1.02	<5.00	<5.00	11.02	30.32	<1.00	<0.10	20.86	1.04	10.18	<0.05	35.74	<0.05	-	21.15
	20.39	1.02	101.26	1.01	<5.00	<5.00	10.86	30.04	<1.00	<0.10	20.60	1.02	10.09	<0.05	35.26	<0.05	-	21.18
	20.85	1.06	103.14	1.03	<5.00	<5.00	11.15	30.68	<1.00	<0.10	20.88	1.03	10.30	<0.05	35.79	<0.05	-	21.39
X (mg/L)	20.62	1.04	102.09	1.02	-	-	11.01	30.35	-	-	20.78	1.03	10.19	-	35.60	-	-	21.24
S.D. (mg/L)	0.19	0.02	0.78	0.01	-	-	0.12	0.26	-	-	0.13	0.01	0.09	-	0.24	-	-	0.11
C.V. (%)	0.91	1.57	0.77	0.80	-	-	1.08	0.86	-	-	0.61	0.79	0.84	-	0.67	-	-	0.50
Replicate	0.07	<0.05	9.62	<5.00	21.60	<5.00	<5.00	0.56	1.11	1.14	4.28	6.94	11.80	<0.05	6.80	<0.05	<0.05	<5.00
	0.07	<0.05	9.64	<5.00	22.70	<5.00	<5.00	0.56	1.09	1.14	4.25	6.86	10.20	<0.05	6.76	<0.05	<0.05	<5.00
	0.06	<0.05	4.76	<5.00	19.00	<5.00	<5.00	1.60	1.00	0.79	4.17	4.41	7.16	<0.05	4.05	<0.05	<0.05	<5.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	<5.00	0.91	1.07	1.02	4.23	6.07	9.72	<0.05	5.87	<0.05	<0.05	<5.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	0.49	0.05	0.16	0.05	1.17	1.92	0.00	1.29	<0.05	<0.05	<5.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	54.07	4.49	16.12	1.10	19.35	19.80	0.00	21.93	0.00	0.00	0.00
Lab Blank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laboratory Analysis	<0.05	<0.05	0.15	<5.00	<5.00	<5.00	<5.00	15	<1.00	<0.10	1.44	1.1	<5.00	<0.05	0.16	<0.05	<0.05	<5.00

X = Arithmetic mean
S.D. = Standard deviation
C.V. = Coefficient of variation

Fs2-26chem.wb1

certificate date: April 30, 1993

	Al (mg/L)	As (mg/L)	Ca (mg/L)	Cd (ug/L)	Co (ug/L)	Cr (ug/L)	Cu (ug/L)	Fe (ug/L)	K (mg/L)	Mg (mg/L)	Mn (ug/L)	Na (mg/L)	Ni (ug/L)	Pb (mg/L)	S (mg/L)	Se (mg/L)	Sn (mg/L)	Zn (ug/L)
Standard sample	20.00	1.00	100.00	1.00	-	-	10.00	30.00	-	-	20.00	-	10.00	-	-	-	-	20.00
Laboratory Analysis	20.60	1.01	100.50	1.02	<5.00	<5.00	11.08	29.75	<1.00	0.11	20.22	1.21	9.90	<0.05	36.00	0.05	<0.05	21.08
	21.04	1.07	101.23	1.03	<5.00	<5.00	11.34	30.21	<1.00	0.13	20.50	1.44	10.03	<0.05	36.29	<0.05	<0.05	21.30
	20.88	1.07	100.82	1.03	<5.00	<5.00	11.26	30.08	<1.00	0.10	20.47	1.29	10.00	<0.05	35.72	<0.05	<0.05	21.16
X (mg/L)	20.84	1.05	100.85	1.03	-	-	11.23	30.01	-	-	20.40	1.31	9.98	-	36.00	-	-	21.18
S.D. (mg/L)	0.18	0.03	0.30	0.00	-	-	0.11	0.19	-	-	0.13	0.10	0.06	-	0.23	-	-	0.09
C.V. (%)	0.87	2.69	0.30	0.46	-	-	0.97	0.65	-	-	0.62	7.26	0.56	-	0.65	-	-	0.43
Lab Blank	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Laboratory Analysis	<0.05	<0.05	0.11	<5.00	<5.00	<5.00	<5.00	<5.00	<1.00	<0.10	<1.00	1.15	<5.00	<0.05	0.27	<0.05	<0.05	<5.00

X = Arithmetic mean
S.D. = Standard deviation
C.V. = Coefficient of variation

Fs4-30chem.wb1

APPENDIX E.4

Calculations of tailings hydraulic conductivity.

Natural Soil Conductivities

Piezometer	Hole Depth (m)	Hydraulic Conductivity (cm/s)	Log K	
FS-4A	32.34	2.50E-05	-4.602	
FS-4B	29.39	5.10E-05	-4.292	
FS-9B	11.20	7.60E-05	-4.119	
FS-9A	12.30	8.90E-05	-4.051	
FS-5B	36.20	9.30E-05	-4.032	
FS-6A	34.17	1.20E-04	-3.921	
FS-5A	39.28	1.90E-04	-3.721	
FS-5C	27.20	3.10E-04	-3.509	
FS-9C	4.80	8.11E-04	-3.091	
FS-1B	13.19	2.50E-03	-2.602	<Median
FS-2B	11.02	2.90E-03	-2.538	
FS-3B	51.02	8.60E-03	-2.066	
FS-3A		1.00E-02	-2.000	
FS-14A	30.35	4.00E-02	-1.398	
FS-14B	26.65	4.00E-02	-1.398	
FS-10A	10.82	8.00E-01	-0.097	
FS-10B	8.26	8.00E-01	-0.097	
		Log Average:	**-2.752**	
		Average:	**1.77E-03**	
		Median:	**2.62E-03**	

Welcome Screen Search Report List

Estimated Tailings Conductivities Using Modified Kozeny-Carman

Sample #	Depth (m)	d50 (mm)	k50 (cm/s)	Log K	
FS-6	4.5 - 5.2	0.0082	1.13E-07	-6.949	
FS-5	7.6 - 8.2	0.011	2.03E-07	-6.694	
FS-6	Surface	0.017	4.84E-07	-6.315	
FS-4	7.6 - 8.2	0.017	4.84E-07	-6.315	
FS-4	Surface	0.0185	5.73E-07	-6.242	
FS-13	3.1 - 3.7	0.0195	6.36E-07	-6.196	
FS-11	7.6 - 8.2	0.021	7.38E-07	-6.132	
FS-6	3.05 - 3.65	0.024	9.64E-07	-6.016	
FS-5	4.57 - 5.18	0.0245	1.00E-06	-5.998	
FS-11	1.5 - 2.1	0.04	2.68E-06	-5.572	
FS-4	6.10 - 6.70	0.044	3.24E-06	-5.489	
FS-8	1.5 - 2.1	0.051	4.35E-06	-5.361	<Median
FS-5	Surface	0.058	5.63E-06	-5.250	
FS-5	3.05 - 3.65	0.071	8.44E-06	-5.074	
FS-12	16.76 - 17.37	0.12	2.41E-05	-4.618	
FS-11	6.1 - 6.71	0.12	2.41E-05	-4.618	
FS-6	6.1 - 6.71	0.16	4.28E-05	-4.368	
FS-11	19.8 - 20.4	0.18	5.42E-05	-4.266	
FS-12	19.81 - 20.42	0.18	5.42E-05	-4.266	
FS-6	7.62 - 8.07	0.21	7.38E-05	-4.132	
FS-11	18.3 - 18.9	0.48	3.86E-04	-3.414	
FS-11	16.8 - 17.4	0.91	1.39E-03	-2.858	
FS-11	15.2 - 15.8	6.4	6.85E-02	-1.164	
FS-11	9.1 - 9.8	10	1.67E-01	-0.776	
			Log Average:	**-4.920**	
			Average:	**1.20E-05**	
			Median:	**4.35E-06**	

Modified Kozeny-Carman

Sample #	Depth (m)	d50 (mm)	d10 (mm)	d30 (mm)	n	k50 (cm/s)	k10 (cm/s)	k30 (cm/s)
FS-4	Surface	0.0185	0.004	0.0125	0.45	5.73E-07	2.68E-08	2.61E-07
FS-4	6.10 - 6.70	0.044	0.013	0.022	0.45	3.24E-06	2.83E-07	8.10E-07
FS-4	7.6 - 8.2	0.017	0.0038	0.0115	0.45	4.84E-07	2.42E-08	2.21E-07
FS-5	Surface	0.058	0.005	0.027	0.45	5.63E-06	4.18E-08	1.22E-06
FS-5	3.05 - 3.65	0.071	0.0082	0.029	0.45	8.44E-06	1.13E-07	1.41E-06
FS-5	4.57 - 5.18	0.0245	0.0068	0.016	0.45	1.00E-06	7.74E-08	4.28E-07
FS-5	7.6 - 8.2	0.011	0.0024	0.0056	0.45	2.03E-07	9.64E-09	5.25E-08
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]7E-07
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.45	[illegible]	[illegible]	3.[illegible]7E-07
FS-6	4.5 - 5.2	0.0082	0.0021	0.0043	0.45	1.13E-07	7.38E-09	3.09E-08
FS-6	6.1 - 6.71	0.16	0.082	0.13	0.45	4.28E-05	1.13E-05	2.83E-05
FS-6	7.62 - 8.07	0.21	0.017	0.13	0.45	7.38E-05	4.84E-07	2.83E-05
FS-8	1.5 - 2.1	0.051	0.007	0.02	0.45	4.35E-06	8.20E-08	6.69E-07
FS-11	1.5 - 2.1	0.04	0.024	0.03	0.45	2.68E-06	9.64E-07	1.51E-06
FS-11	6.1 - 6.71	0.12			0.45	2.41E-05		
FS-11	7.6 - 8.2	0.021	0.0105	0.018	0.45	7.38E-07	1.85E-07	5.42E-07
FS-11	9.1 - 9.8	10	0.3	1.6	0.45	1.67E-01	1.51E-04	4.28E-03
FS-11	15.2 - 15.8	6.4	0.6	2.65	0.45	6.85E-02	6.02E-04	1.18E-02
FS-11	16.8 - 17.4	0.91	0.33	0.69	0.45	1.39E-03	1.82E-04	7.97E-04
FS-11	18.3 - 18.9	0.48	0.13	0.3	0.45	3.86E-04	2.83E-05	1.51E-04
FS-11	19.8 - 20.4	0.18	0.072	0.12	0.45	5.42E-05	8.68E-06	2.41E-05
FS-12	16.76 - 17.37	0.12	0.075	0.091	0.45	2.41E-05	9.41E-06	1.39E-05
FS-12	19.81 - 20.42	0.18	0.08	0.13	0.45	5.42E-05	1.07E-05	2.83E-05
FS-13	3.1 - 3.7	0.0195	0.0053	0.015	0.45	6.36E-07	4.70E-08	3.77E-07
				Average		9.92E-03	4.37E-05	7.44E-04

Sample #	Depth (m)	d50 (mm)	n 1	n 2	n 3	k1 (cm/s)	k2 (cm/s)	k3 (cm/s)
FS-4	Surface	0.0185	0.4	0.45	0.5	3.38E-07	5.73E-07	9.51E-07
FS-4	6.10 - 6.70	0.044	0.4	0.45	0.5	1.91E-06	3.24E-06	5.38E-06
FS-4	7.6 - 8.2	0.017	0.4	0.45	0.5	2.85E-07	4.84E-07	8.03E-07
FS-5	Surface	0.058	0.4	0.45	0.5	3.32E-06	5.63E-06	9.34E-06
FS-5	3.05 - 3.65	0.071	0.4	0.45	0.5	4.98E-06	8.44E-06	1.40E-05
FS-5	4.57 - 5.18	0.0245	0.4	0.45	0.5	5.93E-07	1.00E-06	1.67E-06
FS-5	7.6 - 8.2	0.011	0.4	0.45	0.5	1.20E-07	2.03E-07	3.36E-07
FS-6	Surface	0.017	0.4	0.45	0.5	2.85E-07	4.84E-07	8.03E-07
FS-6	3.05 - 3.65	0.024	0.4	0.45	0.5	5.69E-07	9.64E-07	1.60E-06
FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FS[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FS-6	7.62 - 8.07	0.21	0.4	0.45	0.5	4.36E-05	7.38E-05	1.23E-04
FS-8	1.5 - 2.1	0.051	0.4	0.45	0.5	2.57E-06	4.35E-06	7.23E-06
FS-11	1.5 - 2.1	0.04	0.4	0.45	0.5	1.58E-06	2.68E-06	4.44E-06
FS-11	6.1 - 6.71	0.12	0.4	0.45	0.5	1.42E-05	2.41E-05	4.00E-05
FS-11	7.6 - 8.2	0.021	0.4	0.45	0.5	4.36E-07	7.38E-07	1.23E-06
FS-11	9.1 - 9.8	10	0.4	0.45	0.5	9.88E-02	1.67E-01	2.78E-01
FS-11	15.2 - 15.8	6.4	0.4	0.45	0.5	4.05E-02	6.85E-02	1.14E-01
FS-11	16.8 - 17.4	0.91	0.4	0.45	0.5	8.18E-04	1.39E-03	2.30E-03
FS-11	18.3 - 18.9	0.48	0.4	0.45	0.5	2.28E-04	3.86E-04	6.40E-04
FS-11	19.8 - 20.4	0.18	0.4	0.45	0.5	3.20E-05	5.42E-05	9.00E-05
FS-12	16.76 - 17.37	0.12	0.4	0.45	0.5	1.42E-05	2.41E-05	4.00E-05
FS-12	19.81 - 20.42	0.18	0.4	0.45	0.5	3.20E-05	5.42E-05	9.00E-05
FS-13	3.1 - 3.7	0.0195	0.4	0.45	0.5	3.76E-07	6.36E-07	1.06E-06
				Average		5.85E-03	9.92E-03	1.65E-02

Note: Authors Sullivan and Hertel, 1942, prefer an average grain diameter (Bear 1972, p. 167)