POLYMET
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NorthMet Project

Geotechnical Data Package
Volume 2 - Hydrometallurgical Residue Facility

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This document was prepared for Poly Met Mining Inc. by
Barr Engineering Co.

Certification

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota

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Table of Contents

Acronyms, Abbreviations and Units

Acronym	Stands For
ESSA	Effective Stress Stability Analysis
GCL	geosynthetic clay liner
HDPE	high-density polyethylene
JTL	JTL Laboratories, Inc.
Lakefield	SGS Lakefield Research Laboratories
LLDPE	linear low-density polyethylene geomembranes
LTVSMC	LTV Steel Mining Company
MCC	Modified Cam-Clay
MDNR	Minnesota Department of Natural Resources
MGS	Minnesota Geological Survey
OCR	over-consolidation ratios
PolyMet	Poly Met Mining Inc.
PSHA	Probabilistic Seismic Hazard Analysis
QA/QC	quality assurance/quality control
tsf	tons per square foot
USGS	United States Geological Survey
WWTP	Waste Water Treatment Plant

1.0 Introduction

This Geotechnical Data Package – Volume 2 presents the geotechnical data used by the Residue Management Plan (Reference (1)). In this data package, Tailings Basin is the existing former LTV Steel Mining Company (LTVSMC) tailings basin, Emergency Basin is the existing former LTVSMC Emergency Basin, and Residue is the NorthMet combined hydrometallurgical residue. In addition, Hydrometallurgical Residue Facility is designated HRF and Flotation Tailings Basin is designated FTB. If changes in facility operating methods warrant HRF design updates, revisions will be made to this document if needed based on those HRF design updates.

The HRF will be a lined basin designed for storage of the Residue produced during the 20 years of ore processing at the Process Plant. The HRF will be located to the northwest of the Process Plant and will be constructed on top of the Emergency Basin (Large Figure 1). Portions of the South Dam of Tailings Basin Cell 2W (also referred to as the HRF North Dam in this data package) will be used as the northern side of the HRF. Natural high ground located to the southwest and southeast of the HRF will serve as HRF perimeter dams. New dams will be constructed in the lower areas between the natural high ground and HRF North Dam to complete the perimeter of the HRF. A more detailed description of the HRF is provided in Section 5.1. Overall HRF development, operations, monitoring and reclamation information is presented in the Residue Management Plan (Reference (1)).

The HRF must be configured to contain the stored Residue. The HRF design must include dam slopes capable of achieving the required slope stability factor of safety, and the HRF liner system must be designed and constructed in a manner that maintains hydraulic containment of the process water used to transport the Residue to the HRF for permanent storage. This document presents the site exploration information, the slope stability analysis and the settlement analysis on which the HRF design is based and on which the HRF foundation preparation procedures are based. In addition to the geotechnical analyses and associated design recommendations for the HRF, experience-based HRF design and construction considerations are also reflected in the proposed design of the HRF.

1.1 Outline

The outline of this document is as follows:

Section 2.0	Regulatory basis for HRF design.
Section 3.0	Description of existing facilities and site conditions.
Section 4.0	Data on physical properties of materials included in geotechnical analyses for the HRF.
Section 5.0	Description of geotechnical modeling performed for HRF design.
Section 6.0	Results of geotechnical modeling performed for HRF design.

This document may evolve through the environmental review, permitting, operating and closure phases of the Project. A Revision History is included at the end of the document.

2.0 Regulatory Basis

The requirements for the HRF geotechnical modeling are based on requirements of the Minnesota Department of Natural Resources (MDNR) Division of Ecological and Water Resources, Dam Safety Unit (hereinafter "Agency") and outlined in Attachment A (NorthMet Geotechnical Modeling Work Plan), which describes the required methods of geotechnical analysis and the required slope stability safety factor outcomes.

The HRF dams must be constructed in accordance with applicable requirements of Minnesota Administrative Rules, parts 6115.0300 through 6115.0520 – Dams. Portions of the rules are applied to dams universally, while applicability of some rule requirements is dependent on the hazard classification of the dams. The following rule excerpt aids in establishing the hazard classification of the HRF dams:

> 6115.0340 CLASSIFICATION OF DAMS
>
> All existing and proposed dams shall be classified by the MDNR Commissioner into the following three hazard classes: those dams where failure, misoperation, or other occurrences or conditions would probably result in:
>
> A. Class I: any loss of life or serious hazard, or damage to health, main highways, high-value industrial or commercial properties, major public utilities, or serious direct or indirect, economic loss to the public;
>
> B. Class II: possible health hazard or probable loss of high-value property, damage to secondary highways, railroads or other public utilities, or limited direct or indirect economic loss to the public other than that described in Class III; and
>
> C. Class III: property losses restricted mainly to rural buildings and local county and township roads that are an essential part of the rural transportation system serving the area involved.
>
> Any dam whose failure, misoperation, or other occurrences or conditions would result only in damages to the owner and would not otherwise affect public health, safety, and welfare as described in Classes I, II, and III, shall not be subject to this hazard classification. A dam that is not classified as a hazard Class I, II, or III dam, and those which are not included in the definition of dam in part 6115.0230, subpart 5, definition of dam, shall be subject to applicable provisions of parts 6115.0200 to 6115.0260, and shall not be subject to these dam safety rules. Changes in development in the vicinity of the dam may result in future reclassification.

There is a large, sparsely populated land area to the south and west of the proposed HRF. Poly Met Mining Inc. (PolyMet) property and infrastructure is located immediately to the north and east. As provided by the rules, the MDNR Commissioner must establish the hazard classification for the dams. The classification is subsequently used to define HRF dam permitting, inspection and reporting requirements, notwithstanding requirements of other rules, such as the MDNR Permit to Mine. In particular, the stability of the dams must be evaluated for liquefaction, shear failure, seepage failure, and overturning, sliding, overstressing and excessive deformation. The HRF dams have been evaluated for those factors that are applicable as agreed with the MDNR Division of Ecological and Water Resources, Dam Safety Unit, and outlined in Attachment A and the analysis and results are presented in this document.

Minnesota Rules do not explicitly prescribe allowable flow rates through liner systems. Maximum allowable permeabilities of equal to or less than 1 x 10^{-7} cm/sec are typically required by the Minnesota Pollution Control Agency for liner systems.

The State of Minnesota requires submittal, review, and state approval of a quality assurance/quality control (QA/QC) program for liner systems prior to construction. In addition, the State requires submittal of a construction documentation report that summarizes the details of the facility construction and presents the results of the quality assurance testing. The facility design engineer and a qualified independent testing laboratory most often perform quality assurance testing. Quality assurance for facilities like the HRF typically includes:

- density testing of compacted dam fill materials
- peel and shear strength testing of seams in the geomembrane liner systems
- electrical leak location surveys for liner systems, to the extent possible and extent applicable to the type of liner system installed
- overall confirmation of compliance of construction materials with specifications
- construction surveying to confirm facility line and grade compliance with specifications
- maintenance of construction observation records and a photographic record of construction activities

Permit issuance for the facility depends on compliance with the approved QA/QC plan. A template construction QA/QC plan is provided as an attachment to Reference (1).

3.0 Existing Facilities and Site Conditions

This section describes the Emergency Basin, historic seismic activity in Minnesota, and the geology and hydrogeology of the HRF site. Large Figure 1 shows the location of the Tailings Basin Cells 1E and 2W, and Plant Area, as well as the proposed HRF; located partially above the Emergency Basin. The former Emergency Basin Footprint is also evident as the gray-brown area within the HRF footprint on Large Figure 2.

3.1 Existing Former LTVSMC Emergency Basin (Emergency Basin)

The Emergency Basin is constructed in a topographic low area. Its southern tip initiates near the central portion of the proposed HRF, widening and deepening into a former ravine that trended to the north. The original purpose of the Emergency Basin was to contain taconite tailings discharge from the main LTVSMC Tailings Thickeners in the event of a power failure. Accidental overflows, spillage, and floor drainage from the former LTVSMC Concentrator Building also reached the Emergency Basin. These materials were deposited hydraulically through an underground Emergency Tunnel terminating at the southeast side of the Emergency Basin. Overflow from sumps in LTVSMC booster pump house Number 1 was also directed into the Emergency Basin. Material flowed by gravity into the Emergency Basin and was placed hydraulically. Material in the basin consists of slimes, fine tailings, coarse tailings, and concentrate (Reference (2)).

The starter dam of the Tailings Basin Cell 2W South Dam (same as proposed HRF North Dam) was constructed in 1970-1971. Prior to its construction, the Emergency Basin extended roughly 3,000 feet north into the current area of Cell 2W. Kaiser Engineering correspondence indicates the Cell 2W starter dam was constructed over the unconsolidated tailings in the Emergency Basin. A geotechnical drilling investigation during the winter of 1970 revealed approximately 24 to 32 feet of fine tailings and slimes in the deepest portions of the ravine along the alignment of the starter dam (Reference (3), Reference (4)).

The North Dam is approximately 160 feet in height from the surface of the Emergency Basin. It has an overall slope angle of 4 horizontal to 1 vertical (4H:1V) with mid-slope benches. An upstream construction method was used to construct the dam whereby the height of the dam was advanced by incrementally constructing a berm on the crest of the dam. The tailings basin was then filled nearly up to the crest of the new berm and the process was repeated. To maintain adequate width and stability, the base of the berm was extended onto weaker material in the basin. Upstream construction results in a shell of relatively strong material encapsulating weaker material. The North Dam is comprised of a shell of LTVSMC coarse tailings with occasional inclusions of LTVSMC fine tailings and LTVSMC slimes (Reference (5)).

A railroad track is located along the western perimeter of the area. The rail bed is visible on Large Figure 2. It extends from the south between the southwest and southeast high ground areas and runs along the base of the southwest high ground area (west of the Emergency Basin) before passing between the southwest high ground area and the HRF North Dam. This track is abandoned shortly beyond this area and now serves only industries located at the former LTVSMC site. A plan is being developed to revise the track serving these industries so that the portion impacted by the HRF can be removed.

Drainage of the Emergency Basin occurs to the northwest between Cell 2W and the railroad grade. A railroad embankment (Hinsdale Bridge Approach) is located to the southeast and east of the HRF at an elevation higher than the HRF. The track embankment consists of undisturbed granite outcropping to the south and blast rock derived from original plant construction activities. The HRF is located west and downhill from the rail embankment. There are no proposed changes to this rail line and the HRF is not anticipated to effect the rail embankment. Likewise, the use of this rail line is not anticipated to affect the performance of the HRF. The structural fill to be used for HRF dam construction, due to it being placed in thin lifts and compacted and being constructed to relatively flat slopes, will not be sensitive to nearby rail traffic.

Existing materials in the Emergency Basin, which will serve as the foundation materials for portions of the HRF, have experienced relatively small amounts of consolidation since cessation of LTVSMC operations in early 2001. This is due to the hydraulic placement of the material and hydrostatic pressures resulting from impounded water in the Emergency Basin. As a result, settlement is expected when the Emergency Basin is loaded by the HRF. As described in Section 5.4.1, to minimize the amount of strain on the HRF liner caused by deformation and differential settlement of the foundation materials, it is recommended that a preload (surcharge) be placed on the Emergency Basin to increase the pre-consolidation pressure of the material. Wick drains, discussed in Section 4.1, can be incorporated into the preload construction to reduce consolidation time but should be considered optional. Wick drains may not be of value if HRF construction can occur over several construction seasons, thereby allowing sufficient time for pre-consolidation of foundation materials to occur without wick drain addition.

3.2 Site Conditions

3.2.1 Bedrock Geology

The Emergency Basin is entirely underlain by quartz monzonite and monzodiorite of the Neoarchean Giant’s Range batholith (Reference (6)). These pink to dark-greenish gray, hornblende-bearing, coarse-grained rocks are referred to collectively as the “Giant’s Range granite”. The granite has been scoured by glaciers, creating local depressions, linear valleys, and neighboring hills and ridges that make up the highest topography in the area; such as the Embarrass Mountains, located due west of the emergency basin shown in Large Figure 3.

The location of linear valleys is sometimes interpreted to correspond with the location of faults in the bedrock. For example, the Minnesota Geological Survey (MGS) has inferred but not confirmed the presence of a north-south trending fault to underlie the proposed HRF (Reference (6)), Large Figure 4). A bedrock geological map compiled in 2003 by M.A. Jirsa and T.J. Boerboom of the MGS depicts the same area without an inferred fault (Reference (7)).

3.2.2 Surficial Geology

In general, the Quaternary geology of the region is a thin (0-30 feet, but locally thicker with a range of 0 to 150 feet) blanket of glacial deposits including till, lacustrine materials, and outwash (Reference (8)). Lehr and Hobbs mapped the area as part of the Wampus Lake Moraine (Reference (9)). Minnesota Geologic Survey Map 164 (Reference (10)) categorizes all glacial deposits in the area as Rainy Lobe till and resedimented glacial deposits, overlain locally by post-glacial peat. Test pits for preliminary NorthMet engineering studies and informal observations of sumps and other small excavations confirm the description above. Glacial deposits in most areas consist of unsorted sand, silt, and clay with cobbles and boulders. Boulders on the ground surface can be greater than 10 feet in size and there may be a boulder lag horizon (a surface with a high concentration of boulders) just below the ground surface in some areas. Based on borings completed by Braun in 1976, the till is described as heterogeneous fine-to-medium-grained clayey-to-silty sand with gravel and boulders (Reference (11)).

In the area of the proposed HRF, bedrock is generally within 25 feet of the existing ground surface, except where surface materials have been built up either to support the former LTVSMC facilities or where tailings or plant overflow materials have been deposited in the Emergency Basin, as shown in Large Figure 5.

A series of geological cross-sections have been established through the Emergency Basin. The locations of the geological cross-sections are shown in Large Figure 2. They are defined as follows:

- Cross-Section A-A’ and B-B’: Large Figure 6
- Cross-Section C-C’ and D-D’: Large Figure 7
- Cross-Section E-E’, F-F’, and G-G’: Large Figure 8
- Cross-Section H-H’: Large Figure 9

Native surficial deposits, which have been sampled and logged at boring locations in and around the emergency basin, have been limited to silty sands with interbedded coarser-grained alluvial deposits and peat, also referred to as muskeg. There is a thin layer of peat below the fill in the Emergency Basin and the toe of the Tailings Basin that was encountered at borings 70-ST -13, -14, -15 and -16, and DH96 -9, -10, -11, and -13. The underlying silty sand consists of brown to dark grayish brown silty sand with gravel (SM), gravelly sand with silt (SP-SM), and silty clay with gravel (CL-ML). At boring locations 10-04, and -05 and BH-B, -C, and -G, alluvial material is present and consists of tan to gray to brown medium- to coarse-grained sand with gravel (SP) or coarse-grained gravel with sand (GP) underlying the silty sand. Boring logs within the Emergency Basin are included in Attachment B. Boring locations are shown on Large Figure 2. Some borings are for environmental work conducted in the Emergency Basin and do not include standard penetration testing.

3.2.3 Hydrology and Hydrogeology

The Rainy Lobe glacial deposits form the major surficial aquifer in the region that encompasses the Emergency Basin. Underlying the glacial deposits is Precambrian crystalline and metamorphic bedrock. Neither the glacial deposits nor the bedrock is a reliable source of water and the ground-water potential is poor (Reference (12).

In some locations, discontinuous peat deposits have been encountered between the tailings and the glacial deposits. On top of the glacial deposits are numerous wetlands and minor surface-water drainages. Low spots are generally peat bog or open wetland. Topography is subdued and drainage is poor. These features generally represent surficial expressions of the water table.

Regionally, groundwater flows primarily northward, from the Embarrass Mountains to the Embarrass River. As the Tailings Basin was built over time, a groundwater mound formed beneath the basin due to seepage from the basin, altering local flow directions and rates. Active seeps have been identified along the South Dam. The number of active seeps has declined since the January 2001 termination of tailings deposition activities. In addition to the visible seeps, groundwater likely flows out from beneath the Tailings Basin into the surrounding glacial till (Reference (13)).

Groundwater elevations based on measurements and modeling results presented in Reference (13) are shown in Large Figure 10. These elevations are generalized based on modeling, can be expected to vary locally and seasonally, and have limited impact on HRF design other than for base grade selection and construction considerations.

3.2.4 Seismicity and Ground Motion

Northern Minnesota is not a highly active seismic zone. In fact, Minnesota has one of the lowest levels of earthquake occurrence in the United States. As of the initiation of work on this Data Package, only 20 small to moderate quakes had been reported in Minnesota since 1860. Table 3-1 summarizes this earthquake history. The earthquakes listed in Table 3-1 are associated with minor reactivation of ancient faults in response to stress changes. It can be seen that only 9 out of the 20 earthquakes have been recorded, whereas 11 are based on the magnitude intensity from felt reports.

Table 3-1 Historical Seismicity of Minnesota[1]

Epicenter (nearest town)	Mo/day/yr	Lat.	Long.	Felt area (km^2)	Maximum intensity	Magnitude (M)
1 Long Prairie	1860-61	46.1	94.9	-	VI-VII	5.0
2 New Prague	12/16/1860	44.6	93.5	-	VI	4.7
3 St. Vincent	12/28/1880	49.0	97.2	-	II-IV	3.6
4 New Ulm	2/5-2/12/1881	44.3	94.5	v.local	VI	3.0-4.0
5 Red Lake	2/6/1917	47.9	95.0	-	V	3.8
6 Staples	9/3/1917	46.34	94.63	48,000	VI-VII	4.3
7 Bowstring	12/23/1928	47.5	93.8	-	IV	3.8
8 Detroit Lakes	1/28/1939	46.9	96.0	8,000	IV	3.9-3
9 Alexandria	2/15/1950	46.1	95.2	3,000	V	3.6
10 Pipestone(1)	9/28/1964	44.0	96.4	-	-	3.4
11 Morris(1)	7/9/1975	45.50	96.10	82,000	VI	4.8-4.6
12 Milaca(1)	3/5/1979	45.85	93.75	-	-	1.0
13 Evergreen(1)	4/16/1979	46.78	95.55	-	-	3.1
14 Rush City(1)	5/14/1979	45.72	92.9	-	-	0.1
15 Nisswa(1)	7/26/1979	46.50	94.33	v.local	III	1.0
16 Cottage Grove	4/24/1981	44.84	92.93	v.local	III-IV	3.6
17 Walker	9/27/1982	47.10	97.6	v.local	II	2.0
18 Dumont(1)	6/4/1993	45.67	96.29	69,500	V-VI	4.1
19 Granite Falls(1)	2/9/1994	44.86	95.56	11,600	V	3.1
20 Alexandria(1)	4/29/2011	45.88	95.47	-	-	2.5

(1) Asterisks denote earthquakes that were recorded instrumentally. All others and their associated magnitudes are based solely on intensity data from felt reports.

See Reference (14) for Historical Seismicity of Minnesota – Events 1 through 19. Event 20 based on United Press International report; April 29, 2011.

Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location relative to the epicenter of the earthquake. Intensity is determined from effects on people, structures, and the natural environment. The abbreviated Modified Mercalli Intensity Scale is:

I. Not felt except by a very few under especially favorable conditions.
II. Felt only by a few persons at rest, especially on upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Vehicles may rock slightly. Vibrations similar to the passing of a truck.
IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Vehicles rocked noticeably.
V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Overall damage slight.
VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII. Damage slight in specially designed structures; considerable damage and/or partial collapse in ordinary substantial buildings. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed. Some rail lines bent.
XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Most rail lines bent substantially.
XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Per the data in Table 3-1, the strongest documented earthquakes were associated with the 1860 Long Prairie earthquake (M5.0) and the 1917 Staples earthquake (M4.3). Near their epicenters, these earthquakes caused objects to fall, cracked masonry, and damaged chimneys. A more recent, though less dramatic event was the 1993 Dumont earthquake. The magnitude of this earthquake was M4.1. It affected an area of approximately 27,000 square miles with associated intensity of V-VI near the epicenter. However, no injuries or serious damage occurred (Reference (14)).

For the HRF a seismic risk calculation of ground motion was prepared based on United States Geological Survey (USGS) web site data (http://earthquake.usgs.gov/research/hazmaps/interactive/index.php), which contains information about seismicity in the United States. The result of the USGS report is summarized in Table 3-2, which summarizes the ground motions for different probabilities of exceedance.

Table 3-2 Summary of Seismic Risk Calculation

Peak Ground Acceleration vs. Probability of Exceedance			
Peak Ground Acceleration - gravity [g]	0.006	0.012	0.024
Per Annum Probability of Occurrence	0.0021	0.0010	0.0004
Probability of Occurrence in 50 Years	10%	5%	2%
Return Period [years]	475	975	2,475

It can be seen from the data in Table 3-2 that the peak ground acceleration of 0.024g at the site occurs at a 2% probability of exceedance in 50 years. This corresponds to a 0.0004 probability of exceedance per year, or a return period of once every 2,475 years. In summary, the historical record indicates that a severe earthquake is highly unlikely in Minnesota. Weak to moderate earthquakes do occasionally occur, though the threat from such events is small.

4.0 Physical Properties of Materials

Physical properties for the LTVSMC coarse and fine tailings, LTVSMC slimes, LTVSMC bulk tailings, glacial till, and compressed peat have been updated several times, as additional geotechnical evaluations have been performed. Parameters used in this analysis combine recent in situ and laboratory testing and historic data to support the design parameters. The development of these parameters is discussed in Reference (15). Because the schedule of updates to Reference (15) is not exactly synchronized with updates to this Geotechnical Data Package, occasional discrepancies can be expected in the data used in the corresponding analyses. Discrepancies are small and will be reconciled only on an as-needed basis (i.e., when discrepancies are such that factors of safety would likely fall below design criteria upon reanalysis using updated design parameters).

This Geotechnical Data Package – Volume 2 – Version 5, does not incorporate results of the 2014 geotechnical investigations. Those results will be presented in the update to Geotechnical Data Package – Volume 1 (Reference (15)). The hydraulic conductivity findings for glacial till and for bedrock as updated in Geotechnical Data Package – Volume 1 – Version 5 (Reference (15)) have not been incorporated because they are expected to be largely inconsequential to the geotechnical modeling outcomes for HRF design. The hydraulic conductivity of the glacial till derived from recent slug testing differs by less than one-half order of magnitude from the hydraulic conductivity used in the analysis, and the hydraulic conductivity of the fractured bedrock is nearly 100 times lower than the hydraulic conductivity of the surficial deposits (Reference (16)). Given this disparity in hydraulic conductivity values, the majority of flow beneath the HRF will occur in the Glacial Till, consistent with the assumptions of the HRF design modeling. The updated hydraulic conductivities may have some effect on the time required for preload (Section 5.4.1). This will be addressed through preload monitoring.

Structural fill used to construct dams in lower areas between natural high ground may consist of blasted rock, sand, glacial till, LTVSMC coarse tailings, or other engineer specified and Agency approved fill. Geotechnical properties for the LTVSMC bulk tailings were used in modeling of regions of structural fill. The LTVSMC Bulk Tailings properties provide a reasonable basis on which to compute slope stability factor of safety. LTVSMC Bulk Tailings have a lower friction angle than the LTVSMC Coarse Tailings anticipated for use in dam construction and only a slightly higher friction angle than the Glacial Till that may be used in dam construction. Detailed specifications for structural fill that yield a fill having the geotechnical properties used for geotechnical modeling will be provided in construction specifications for Agency reference prior to construction. At minimum these specifications will define acceptable material types, overall material placement methodology requirements (e.g., structural fill shall be placed in thin lifts not to exceed an as-yet to be determined specified thickness), and density requirements (e.g., structural fill shall be compacted to equal or greater than 95-percent of the maximum dry density determined by ASTM Specification D-698, Standard Proctor Method).

As discussed in Sections 3.1 and 3.2.2, materials in the Emergency Basin range from LTVSMC coarse tailings to LTVSMC slimes. Materials discharged to the basin deposited based on particle size and weight, so that there are gradual trends of differing material composition. To account for this variability, the generalization was made that all materials in the Emergency Basin would be classified as LTVSMC slimes. For computation of foundation compressibility and wick drain design, this assumption is conservative because the LTVSMC slimes are the weakest and most compressible tailings in the Emergency Basin. The following section presents the parameters used specifically for HRF geotechnical modeling. Locations of recent field-testing completed within the proposed footprint of the HRF are shown in Large Figure 2.

In addition to Residue, the HRF may receive gypsum from the Waste Water Treatment Plant, lime for residue pH neutralization (if necessary), and materials from the former LTVSMC Coal Ash Landfill. These materials, if placed in the HRF, are estimated to represent up to approximately 5% to 10% of the facility solid volume. The chemical and physical properties of any non-residue materials proposed to be stored in the HRF will be tested prior to placement, to confirm they meet standards set for liner, leakage collection system, and drainage collection system compatibility and performance. Any materials not meeting these standards would not be placed in the HRF. Also, the volume of these additional materials will be compared to the remaining design capacity of the HRF prior to disposal, to ensure that the additional volume will not exceed the design capacity.

4.1 Permeability Parameters

Seepage analysis is required for the slope stability modeling and the stress-deformation analysis for the HRF. Permeability is the key parameter for the seepage analysis. The values of permeability for the various types of materials at the HRF were estimated through in-situ testing during geotechnical investigations (cone penetration test (CPTu) dissipation tests) and laboratory testing on bulk or undisturbed material samples. Laboratory material testing results and detailed explanations of the permeability values used in previous analyses and the process for choosing parameters can be found in Geotechnical Data Package – Volume 1 (Reference (15)). Permeability parameters reported in Reference (15) have been used for the geotechnical analysis of the HRF presented herein. For the bedrock underlying the site, the permeability used for this analysis was developed during the water-balance and geochemical modeling (Reference (13)). The values of permeability used in the seepage model are summarized in Table 4-1. The method used to derive permeability values for the LTVSMC slimes and compressed peat with wick drains installed is described following Table 4-1.

Table 4-1 Summary of Material Permeabilities

Material	Permeability (ft/sec)	Permeability (cm/sec)
LTVSMC Coarse Tailings	8.00E-05	2.44E-03
LTVSMC Fine Tailings	6.56E-07	2.00E-05
LTVSMC Slimes	3.15E-08	9.60E-07
LTVSMC Bulk Tailings	2.63E-06	8.02E-05
Glacial Till	1.65E-04	5.03E-03
Sand	3.28E-04	1.00E-02
Residue (used for rate of drainage computation – quantity vs. time)	1.12E-06	3.40E-05
Residue (used for computation of time for drainage to occur)	1.80E-07[(1)]	5.50E-06[(1)]
Compressed Peat	1.18E-07	3.60E-06
Bedrock	2.81E-09	8.56E-08
LTVSMC Slimes – Wick	7.69E-08	2.34E-06
Compressed Peat – Wick	2.87E-08	8.75E-07

(1) To account for anticipated consolidation (densification) of the residue within the cell and corresponding reduction in residue permeability, average permeability used to estimate time for drainage to occur is assumed.

The LTVSMC slimes and the compressed peat underlying the HRF location have the potential to develop excess pore water pressures and reduced strength as stresses are imposed on these materials by construction of the overlying HRF. Installation of wick drains is an option available to PolyMet to minimize the time required for pore water pressures to reach equilibrium as HRF development proceeds. Wick drains are advantageous because they reduce the drainage path distance excess pore water pressure must travel to reach equilibrium. The most common application of wick drains is to accelerate consolidation in areas where preload will be applied (Reference (17)) as proposed for the HRF.

Wick drains are long flexible rectangular plastic bands encased by a geotextile fabric. Wick drains are mechanically inserted vertically into soil strata to provide additional avenues for relief of excess soil pore-water pressure. The outer geotextile allows excess pore water pressure from surrounding materials to flux through it, but prevents the highly permeable inner plastic core from clogging with native material. Wick drains are most effective in saturated normally to slightly over-consolidated soils. Wick drains are designed to perform in the presence of vertical and lateral loads. Although the drains will bend in response to soil compression, they maintain a continuous flow path and conduit for relief of excess pore water pressure from the surrounding soil.

Because wick drains are manufactured of synthetic materials they have a long life, but for this Project, their benefit would be early in the life of the Project during the pre-loading process and foundation preparation. They would be installed throughout the Emergency Basin to account for potential material variability in the foundation soils.

Wick drains are delivered on reels and have lengths ranging from 450 to 1,000 feet. They are usually installed with static, vibratory, or combination static-vibratory force. A wide variety of field equipment can be adapted to accommodate wick drain installation. An excavator equipped with a sliding mandrel, capable of reaching the design depth, usually performs installation. Installation begins by attaching the lead end of the wick drain to the mandrel. The mandrel protects the lead end of the wick drain while it is forced into the soil. Once the design depth has been reached, the wick drain is anchored in place and the mandrel is retracted. The final step is to cut the wick drain from the reel leaving an ample length above the surface, which is then connected into a drainage collection system. The drainage collection system would accumulate water from the wick drain system and direct it away from the site (to northwest via current drainage paths). A typical drainage collection system consists of a highly permeable granular drainage blanket, horizontally placed wick drains, piping system, or some combination of these features.

Composite permeabilities were given to LTVSMC slimes and compressed peat in the Emergency Basin where wick drain installation could occur. The installation process tends to smear material around the perimeter of the wick drain decreasing permeability. However, because of wick drain installation the hydraulic gradient is greatly increased and this compensates for the diminished permeability. The increase of hydraulic gradient is due to the shortening of the excess pore water pressure drainage path. Equation 4-1 is a variation of Darcy's law, which is used to illustrate flow through a saturated soil.

$$\boldsymbol{v = ki} \qquad \text{Equation 4-1}$$

where: v = discharge velocity

k = permeability (also called hydraulic conductivity)

i = hydraulic gradient

Equation 4-2 illustrates computations for hydraulic gradient and shows that decreasing the drainage path length will result in an increase of hydraulic gradient.

$$\boldsymbol{i = \frac{\Delta h}{L}} \qquad \textbf{Equation 4-2}$$

where: Δh = head loss

L = drainage path length

The calculation used to determine composite permeabilities of the LTVSMC slimes and compressed peat with wick drains is described in the example Bangkok Field Study of Vertical Wick Drains on the GeoStudio website (http://www.geo-slope.com). The general steps to calculate a composite permeability are as follows:

- Calculate the equivalent drain thickness based on preliminary wick drain type and design parameters,
- Calculate the plane strain permeability,
- Establish the radius of the smear zone based on mandrel dimensions, and
- Calculate the governing permeability.

A wick drain spacing of approximately 5.0 feet in a triangular pattern was used to calculate the permeability. A typical wick drain size of 4 inches by 0.16 inches was used to calculate the equivalent drain thickness. The mandrel size was assumed to be 1.8 inches by 4.9 inches to calculate the smear zone.

As previously noted, use of wick drains as a means to accelerate consolidation of HRF foundation materials may not be warranted if construction of the first lift of the HRF can be extended over several construction seasons, thereby allowing sufficient time for pre-consolidation of foundation materials to occur by pre-loading without wick drain addition. If it is ultimately determined by PolyMet that HRF construction can be extended over multiple years, then any material properties described in this section, and analyses elsewhere in this Geotechnical Data Package that include wick drains will be reviewed and revised where necessary to confirm analysis outcomes.

4.2 Stress-Deformation Parameters

The HRF liner system must be designed to withstand the stresses and strains (deformation) due to differential settlement in the HRF foundation. The deformation of the foundation is a result of weaker material in the Emergency Basin consolidating under the load of the Residue being placed in the HRF. Stress-deformation parameters were assigned to each material used in the analysis. Two types of stress-deformation constitutive models were used: linear-elastic and Modified Cam-Clay (MCC). A constitutive model defines a stress-strain path for a material, such that each strain along the stress-strain path corresponds to a specific stress. The two constitutive models used in this analysis vary in stress-strain path shape and in the parameters used to define each stress-strain path. In general, the linear-elastic model is used for highly consolidated materials, and the MCC model is used for lightly to unconsolidated materials.

4.2.1 Linear-Elastic Materials

The linear-elastic constitutive model uses a direct proportion to relate stress and strain. Figure 4-1 illustrates the stress (σ) strain (ε) relationship in a linear-elastic material model.

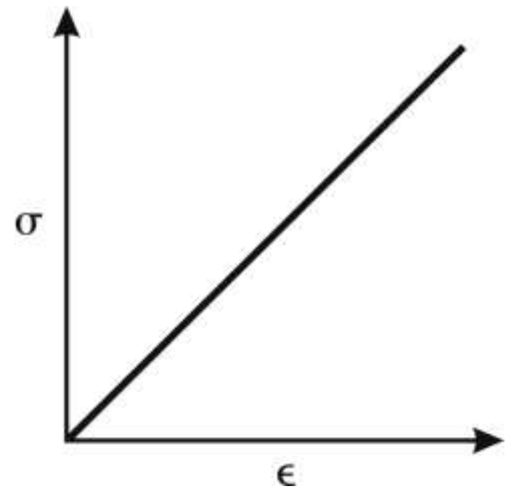

Figure 4-1 Linear-Elastic Stress-Strain Diagram

The linear-elastic material model is defined by the elastic modulus, E, and Poisson's Ratio, μ. The elastic modulus is the slope of the line shown in Figure 4-1. This slope is the stress-strain path for a given material. The second parameter needed to define a linear-elastic constitutive model is Poisson's Ratio. Poisson's Ratio is the relationship between horizontal and vertical strain. For typical soils, the horizontal to vertical strain is 0.30 (i.e., if a cube of soil is compressed vertically 1 inch, it will expand horizontally 0.3 inches).

Linear-elastic models are best suited for materials with large over-consolidation ratios (OCR) (Reference (18)). The term OCR refers to the relationship of a material's maximum past effective pressure, or pre-consolidation pressure, to its present effective pressure. Materials having an OCR greater than 1 are considered over-consolidated. Glacial till, LTVSMC coarse tailings (due to compaction during construction), Giant's Range granite, sand (due to compaction during construction), and LTVSMC bulk tailings (due to compaction during construction) are all considered over-consolidated and were defined using linear-elastic models.

Stress-deformation parameters for Giant's Range granite were estimated using Reference (19). Stress-deformation parameters for sand were estimated using Reference (20). Poisson's Ratio was assumed to be 0.30 for all linear-elastic materials, except for Giant's Range granite, which used a value of 0.18 presented in Reference (19). Giant's Range granite is relatively incompressible compared to other materials in the model. The elastic modulus for glacial till, LTVSMC coarse tailings, and LTVSMC bulk tailings were developed through an iterative process using triaxial test data and a finite element modeling program. The following steps present the first iteration:

1. Incremental strain-modulus plots were developed using laboratory results from triaxial testing.

2. Initial moduli seed values were selected from the incremental strain-modulus plots for the finite element modeling program.

3. Maximum strains were calculated for each material using results from the finite element modeling program.

4. New moduli were selected from the strain-modulus plots using the strains calculated from the finite element modeling program.

5. The new moduli were analyzed in the finite element model.

This process was repeated until the moduli used to calculate strain in the finite element model matched the moduli selected from the strain-modulus plots.

4.2.2 Modified Cam-Clay (MCC) Materials

The MCC constitutive model is an elasto-plastic strain hardening/softening model. The MCC constitutive model is most appropriately applied to saturated normally to slightly over-consolidated soils, which experience significant non-reversible volume changes when compressed (Reference (18)). Residue, LTVSMC fine tailings, LTVSMC slimes, LTVSMC slimes - wick, compressed peat, and compressed peat - wick were assigned MCC parameters. Figure 4-2 illustrates the stress (σ) strain (ε) relationship in a MCC material model.

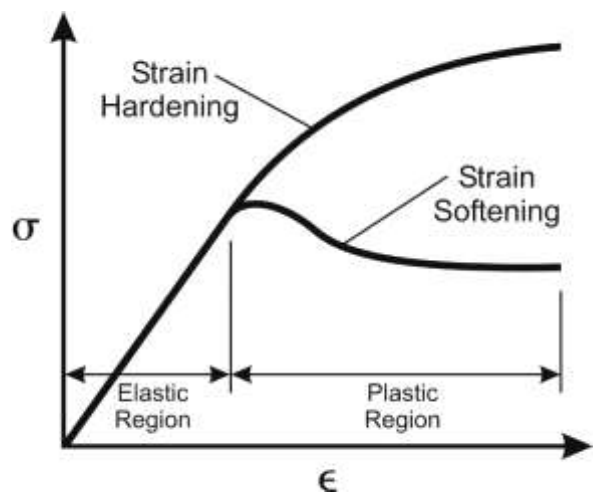

Figure 4-2 Modified Cam-Clay (MCC) Stress-Strain Diagram

There are two distinct regions of the MCC constitutive model: (1) an elastic region at lower strains and (2) a plastic region at higher strains. The term elastic relates to non-permanent deformation; a material will spring back to its initial shape. The plastic region of the stress-strain curve is the range of higher strain values that will cause permanent deformation in a material. The transition between these regions is termed the yield point. Moving to the right of the yield point, the additional strain will cause an increase in stress (strain hardening) or a decrease in stress (strain softening.) Strain hardening is typical for normally to slightly over-consolidated material. Strain softening is common in highly over-consolidated material.

There are three major curves that define consolidation shown in Figure 4-3: over-consolidation, normal consolidation, and rebound. It is common practice to approximate consolidation curves as lines to simplify calculations. The terms over-consolidation and normal consolidation are used to label the behavior of soils at the HRF. Over-consolidated materials can be defined by a single curve, represented as (1) in Figure 4-3, in a linear elastic model. These materials, if not stressed beyond their previously experienced highest effective stress, will not reach an effective stress sufficient to cause normal consolidation. Normally consolidated materials are materials that have not experienced an effective stress greater than their current effective stress. Consolidation for these materials begins along the normal consolidation line, illustrated as (2) and (5) in Figure 4-3.

Every material has a unique consolidation curve. For a given material, its normal consolidation curve always has a slope greater than its over-consolidation curve. When effective pressure (stress) is removed from a material, i.e. glacial retreat and removal of overburden, the void ratio will increase at a rate less than the rate at which it decreased during normal consolidation. The soil will retain a particle configuration similar to that at its past maximum effective pressure as it rebounds along portion (3) of the rebound curve in Figure 4-3. If the effective stress again increases on the material, it will compress again, following a curve similar to that of the rebound curve (4) in Figure 4-3. Once an effective stress similar to its maximum past effective stress is reached, consolidation will diverge to the normal consolidation curve illustrated as (5) in Figure 4-3. It is customary to define the over-consolidation curve (1) and portions (3) and (4) of the rebound curve as the same rate (Reference (21)).

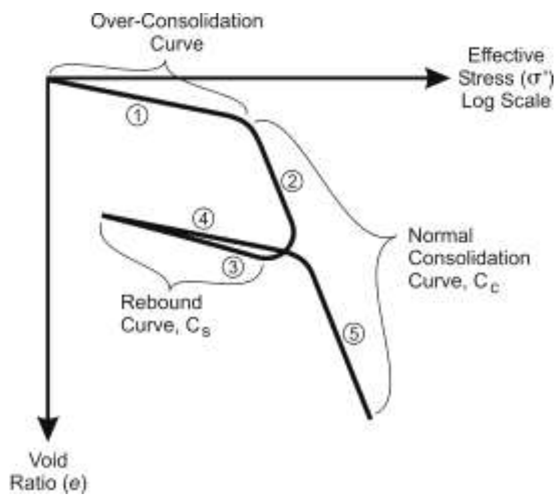

Figure 4-3 Consolidation Curve

Two key parameters that define a MCC constitutive model are the compression index and swell index, given the symbols λ (C_c) and κ (C_s), respectively. The compression index and swell index are shown in Figure 4-3. The compression index is the slope of the normal consolidation curve, which is similar to the strain path of the strain-hardening curve in the plastic region of Figure 4-2. The swell index is the slope of the rebound curve, which is comparable to the over-consolidation curve and linear-elastic portion of Figure 4-3 and Figure 4-2, respectively.

The difference between C_c-C_s and λ-κ values relates to the log-scale upon which effective stress is plotted. It is customary for soil testing laboratories to develop the C_c and C_s from an isotropic one-dimensional compression test in terms of an effective stress base 10 log-scale. However, it is typical for modeling programs to use the analogous terms λ and κ, upon which effective stress is plotted, on a natural log-scale.

4.2.3 Stress-Deformation Parameter Summary

Laboratory and field data obtained in 1996 (Reference (22)), and 2005 and 2007 (Reference (15)) geotechnical investigations were used to establish stress-deformation parameters. Seepage parameters discussed in Section 4.1 and shear strength parameters discussed later in Section 4.3 were also required for the stress-deformation analysis. Further information concerning the historical values and selection of the seepage and shear strength parameters used in the analysis can be found in Reference (15). Table 4-2 summarizes the stress-deformation properties used in the analyses.

Table 4-2 Summary of Stress-Deformation Parameters

Material	Model	Unit Weight (pcf)	Elasticity modulus, (psf)	ϕ, (deg)[1]	Poisson's ratio, μ	Normal Consol. line slope, λ	Swelling line slope, κ	Initial Void Ratio, e_o
Glacial Till	Linear Elastic	135	5.00E+05	-	0.30	-	-	-
LTVSMC Coarse Tailings	Linear Elastic	135	8.40E+05	-	0.30	-	-	-
LTVSMC Fine Tailings	Soft Clay (MCC)	130	-	33	0.30	0.05	0.01	1.07
LTVSMC Slimes	Soft Clay (MCC)	120	-	34	0.30	0.07	0.01	1.14
LTVSMC Slimes – Wick	Soft Clay (MCC)	120	-	34	0.30	0.07	0.01	1.14
Residue[2]	Soft Clay (MCC)	115	-	30	0.30	0.18	0.03	1.92

Material	Model	Unit Weight (pcf)	Elasticity modulus, (psf)	ϕ, (deg)(1)	Poisson's ratio, μ	Normal Consol. line slope, λ	Swelling line slope, κ	Initial Void Ratio, e_o
Giant's Range Granite	Linear Elastic	165	1.69E+09	-	0.18	-	-	-
Sand	Linear Elastic	120	6.00E+05	-	0.30	-	-	-
LTVSMC Bulk Tailings	Linear Elastic	130	1.00E+06	-	0.30	-	-	-
Bedrock – Blasted	Linear Elastic	135	1.00E+06	-	0.30	-	-	-
Compressed Peat	Soft Clay (MCC)	85	-	30	0.30	0.70	0.09	3.84
Compressed Peat - Wick	Soft Clay (MCC)	85	-	30	0.30	0.70	0.09	3.84

(1) The term M (the slope of the critical state line) can be defined by the equation: $M = \frac{6 \sin \phi'}{3 - \sin \phi'}$

(2) In stress-deformation models other than the Residue Settlement Column (Large Figure 15), Residue is modeled using placeholder linear elastic parameters. These models only require the thickness and unit weight of the Residue to be valid. Residue consolidation is considered in the Residue Settlement Column analysis (Section 5.4.2.)

All MCC materials were assumed to be normally consolidated and assigned an OCR of 1.0, allowing normal consolidation to begin immediately. This creates the greatest amount of deformation and produces the most conservative model. The initial void ratio was determined through laboratory testing. The drained angle of internal friction was used to define the transition from over-consolidation to normal consolidation (Reference (18)). Further information concerning the void ratio and drained angle of internal friction values can be found in Reference (15). Poisson’s Ratio was assumed to be 0.30 for all MCC materials.

The MCC parameters λ and κ were calculated using the compression index, C_c, and swell index, C_s. Triaxial tests, a 3-dimensional isotropic compression test, and 1-dimensional compression tests were performed to determine C_c and C_s for the LTVSMC fine tailings, LTVSMC slimes, and compressed peat. Wick drains were assumed not to affect the stress-deformation parameters.

Residue parameters were established based on material collected from the SGS Lakefield Research Laboratories (Lakefield) pilot plant testing (Section 4.4). Following Hydrometallurgical Plant start-up, a re-assessment of the Residue parameters will be conducted using Residue produced by the Hydrometallurgical Plant to determine any variations with the Lakefield pilot plant. If warranted, the geotechnical analysis of the HRF will be updated using the new Residue information.

4.3 Unit Weight and Shear Strength Parameters for Slope Stability Analysis

An Effective Stress Stability Analysis (ESSA) was performed to evaluate HRF dam slope stability. The ESSA condition uses the unit weights and long-term shear strengths of materials. Material shear strength properties used in the analyses were determined by interpreting data from subsurface explorations performed in the Tailing Basin and the Emergency Basin. The data include in situ testing conducted in 1996 (Reference (22)), 2005 and 2007 (Reference (15)), as well as recent and historical laboratory test results. Testing results, a detailed discussion of historical values, and selection of shear strength parameters used in this analysis can be found in Reference (15).

Residue density characteristics are described in Section 4.4. Residue shear strength parameters were not tested due to their limited role in determining dam stability for the HRF. However, to facilitate stability modeling, model input values for the Residue were selected using the Stark and Eid (Reference (23)) fully softened friction angle chart. Based on liquid limit, the minimum ESSA friction angle was determined to be 30 degrees as shown on Large Figure 11.

Sand shear strength parameters were estimated using Reference (20). LTVSMC slimes - wick and compressed peat - wick shear strength parameters were assumed to be similar to LTVSMC slimes and compressed peat, respectively. Table 4-3 summarizes the material properties used in the slope stability analyses.

Table 4-3 Unit Weight and Shear Strength Parameters for HRF Slope Stability Analysis

Material(1)	Unit Weight		ESSA	
	Saturated (pcf)	Moist (pcf)	c’ (psf)	φ’ (deg)
LTVSMC Coarse Tailings	135	130	-	39
LTVSMC Fine Tailings	130	125	-	33
LTVSMC Slimes/ LTVSMC Slimes - Wick	120	120	-	34
Compressed Peat/ Compressed Peat - Wick	85	80	500	30
Glacial Till	135	130	-	37
Sand	120	120	-	30
LTVSMC Bulk Tailings	130	125	-	37.5
Residue (for use in stability analysis)	115	110	-	30
Bedrock – Blasted	135	125	-	33
Bedrock	N/A		Impenetrable	

(1) Material parameters listed in Table 4-3 are consistent with material parameters used in NorthMet Geotechnical Data

Material[1]	Unit Weight		ESSA	
	Saturated (pcf)	Moist (pcf)	c' (psf)	φ' (deg)

Package - Volume 1- Version 3 (Reference (15). Variations from values reported in more recent versions of Geotechnical Data Package – Volume 1 may occur. As reported herein, computed slope stability safety factors are well above required values and minor increases or decreases in material friction angle (φ' (deg)) and/or unit weights would not have a substantive effect on computed slope stability safety factors relative to required values.

Structural fill for the HRF dams will be free draining (modeled as LTVSMC bulk tailings) and will be placed and compacted in a uniform manner; typically to 95% of Standard Proctor Maximum Dry Density (ASTM Method D-698). Because the compacted tailings can be expected to be densely packed and non-contractive it is appropriate to assume that liquefaction of the structural fill will not occur. Standard quality control and assurance, by means of field density measurements, will be implemented during construction to confirm that compaction specifications are achieved.

4.4 Density Parameters for HRF Sizing and Settlement Analysis

Pilot plant testing was done at Lakefield in Lakefield, Ontario. The Residue from the Lakefield pilot plant was visually classified using the Unified Soil Classification System (USCS). The USCS yields a general understanding of the Residue's physical characteristics, which in turn were used in evaluation of HRF liner and cover designs. Results of the Residue classification are presented in Attachment C. The visual classification of the Residue was confirmed by grain-size and hydrometer analysis (by ASTM Method D422) on a composite sample of the Residue (Attachment C). The analysis confirmed the predominance of silt-size particles and results are summarized as follows:

- Sand Content: 15% by weight
- Silt Content: 84% by weight
- Clay Content: 1% by weight

Additional laboratory testing, summarized below, was performed to supplement the visual classification and grain-size analysis of the material, and to understand the physical characteristics of the Residue. This supplemented the chemical characteristics data from the Lakefield pilot plant testing and the Residue characterization performed for groundwater flow modeling presented in Reference (13). Table 4-4 presents the general Residue characteristics, which is followed by a more detailed summary of testing results. The recommended design values shown in the right hand column of Table 4-4 were used in the HRF sizing and residue settlement analysis.

Table 4-4 Summary of Residue Characteristics for HRF Sizing and Settlement Analysis

Characteristic	Value Obtained in the Literature Search	Residue as Tested	Recommended Design Values
Specific Gravity	-	-	2.75 (see Table 4-5 for G_s approximation)
Assumed Beach Slope above the water line(1)	0.4 to 1 %	-	0.5%
Assumed Beach Slope below the water line(2)	2 to 4%	-	3%
In-place Dry Density vs. Confining Stress(3)	-	58.1 pcf @ 0.01 tsf	Design Values for Liner Strain and/or Slope Stability Analysis: Dry Unit Wt. = 80 pcf Sat. Unit Wt. = 115 pcf Design Values for Initial Cell Sizing: Dry Unit Wt. = 73 pcf
	-	61.5 @ 0.1 tsf	
	-	71.0 @ 1.0 tsf	
	-	76.5 @ 2.0 tsf	
	-	77.1 @ 3.0 tsf(4)	

(1) The term "Beach" refers to the surface of the deposited Residue, extending from the perimeter of the HRF to the interior of the facility. The Residue surface or beach can be described as being exposed in some areas (the Residue above the water line) and submerged in other areas (the Residue below the water line).
(2) The beach slope below water line was estimated from soundings performed on water-deposited flyash at ash pond facilities. The residue (primarily gypsum) is anticipated to have characteristics similar to flyash (for utilities where the flyash is primarily gypsum).
(3) Pounds per cubic foot are "pcf". Tons per square foot are "tsf".
(4) In-Place density at 3.0 tsf is estimated from projection of Void Ratio vs. Log of Pressure Curve to 3.0 tsf (Attachment C).

Table 4-5 Computed Specific Gravity of Hydrometallurgical Residue

Residue Component	Tons/Year (approximation)(1)	% of Total	Specific Gravity	Tons/Year x Specific Gravity
Gypsum	208,326	66.6%	2.33	485,400
Natrojarosite	67,158	21.5%	3.30	221,621
Hematite	18,548	5.9%	5.30	98,304
Plagioclase	6,183	2.0%	2.75	17,003
Talc	4,157	1.3%	2.75	11,432
Quartz	3,804	1.2%	2.65	10,081
Brucite	2,975	1.0%	2.40	7,140
Geothite	1,542	0.5%	3.80	5,860
Halite	107	0.0%	2.17	232
Subtotal	312,800			857,073
Hydrometallurgical Residue Weighted Average Specific Gravity =				**2.74**

(1) Reference (1)

As noted for Table 4-4, a consolidation test (ASTM Method D2435) was performed on a sample of the Residue to estimate the possible range in density of the Residue, under an assumption of in-pond disposal. A sample of the Residue was placed in a cylindrical load cell and pressure was applied incrementally to a maximum of 2 tons per square foot (tsf); a pressure estimated to be roughly two thirds the pressure that the Residue will experience at the bottom of the facility (roughly 80 feet in maximum depth). The 2-tsf maximum test pressure was selected and the consolidation test was performed at a time when a shallower HRF was contemplated.

The time-rate of consolidation curves show that the tested Residue sample consolidated slowly. This is somewhat counter to the typically rapid consolidation of non-cohesive silt-size materials. Had the testing time been extended and had the maximum test load been increased to 3-tsf, some additional densification of the sample would have occurred. For design purposes, an average dry density in the range of 70 to 80 pounds per cubic foot is recommended. Values near the low end of this range should be used for estimating cell-sizing requirements to accommodate the roughly 313,000 tons per year of Residue projected to be generated. A saturated unit weight calculated using dry density values near the upper end of this range should be used for stress-strain related evaluations (i.e., settlement and slope stability). Using the upper end of the dry density range of values yields a higher saturated unit weight. In this analysis, use of a higher unit weight will apply more downward pressure on the liner system, thus increasing the strain in the liner and creating a more conservative model for evaluation of liner stress-strain performance. The saturated unit weight value of 115 pounds per cubic foot (rounded up from 113 pounds per cubic foot) was calculated using Equation 4-3.

$$\gamma_{sat} = \left(1 - \frac{1}{G_s}\right) * \gamma_d + \gamma_w$$ **Equation 4-3**

where: γ_{sat} = saturated unit weight

G_s = specific gravity

γ_d = dry unit weight

γ_w = unit weight of water

Bateman Engineering has projected (by METSIM Model Version U3) an in-pond dry density of Residue solids of 66.5 percent solids by weight. On this basis, and using an average specific gravity of solids of 2.75, the average in–pond dry density of Residue solids is 72 pounds per cubic foot. This value is similar to the average dry density obtained from consolidation testing, thereby confirming the appropriateness of use of such values for sizing of the HRF. Use of higher values for specific gravity of solids would yield higher in-pond dry densities, which in turn would yield smaller estimates of cell size requirements.

The plasticity limits of the sample of the Residue were evaluated using the Atterberg Limits test (ASTM Method D4318). The resulting Plasticity Index (a measure of soil cohesion) was 2.3 percent, indicating that the Residue sample had low cohesion.

It is worth noting here that the geotechnical test methods used for Residue testing were developed and are applicable to natural soil materials that are physically and chemically unaltered by precipitation processes such as those from which the components of the Residue are derived. The Residue components consist of agglomerations of particles caused by chemical addition intended to force separation and settling of specific materials within a treatment process. The results of this testing are considered in initial sizing of the HRF, but subsequent in-situ experience gained from full-scale operations may lead to a need for future adjustments in HRF sizing. The HRF will be configured to accommodate minor sizing adjustments (facility footprint and dam height) without significant changes to the connected infrastructure (i.e., piping and pumping systems). For the HRF, with average east-west and north-south dimensions measuring over 1,000 feet, even noticeable changes in facility height (e.g., 5 feet) will have a small effect on overall facility footprint dimensions.

Additional HRF sizing considerations are the potential for water treatment plant solids (gypsum) to be disposed of within the HRF and for coal combustion residuals (coal ash) to be relocated to the HRF from an existing coal ash landfill near FTB Cell 1E. Water treatment plant design is ongoing but initial projections are that overall solids volume to be disposed of within the HRF will increase about 1% to 2% with the addition of water treatment plant solids. This small increase in HRF capacity requirement will be confirmed once water treatment plant design is being finalized. The coal ash landfill is estimated to contain a total of approximately 260,000 cubic yards of materials, of which approximately 250,000 cubic yards are coal ash that would be relocated to the HRF. This represents about 4% of the currently proposed HRF capacity. For purposes of this Geotechnical Data Package, a 5% to 6% increase in solids volume is negligible and does not affect the analysis or conclusions presented herein.

5.0 Geotechnical Models for HRF Design

The HRF must provide safe, long-term storage of Residue. Thus, the geotechnical design must encompass adequate storage for the proposed 20-year operating life of the Project (HRF operations begin after Mine Year 2, which results in an 18-year HRF life) and meet Project regulatory requirements. The analysis of the HRF includes seepage, stress-deformation and slope stability modeling. The 2007 GeoStudio software suite was used to perform the analyses. The critical cross-sections (the cross-sections anticipated to yield the lowest slope stability safety factor) of the HRF were analyzed. The following sections describe the cross-sections selected for analysis and the analysis in detail.

5.1 HRF Facility Configuration

The HRF is a single cell structure with an 18-year design capacity of approximately 6,400,000 cubic yards for Residue and an additional 3-foot minimum freeboard (14-foot maximum freeboard at a Residue surface slope of 0.5 percent). The HRF design and operating plans are presented in Reference (1). The perimeter will have an irregular shape consisting of the North Dam, natural high ground, and new dams. The dams will be constructed from natural soil and quarried bedrock obtained from the high ground on the southeast and southwest sides of the HRF. Some LTVSMC coarse tailings may also be utilized for dam construction. The HRF will be located on top of the Emergency Basin. New dams will be located beyond the extent of the emergency basin and will be founded on existing silty sand, gravel glacial till, and Giants Range granite. Foundation preparation for all new dams will consist of removal of surficial peat (if any) until bedrock or glacial till is encountered. Both materials provide a suitable dam foundation. With this construction process, further subsurface exploration at this time is not warranted. Such exploration may be warranted at a future date if it were determined that such information would aid construction contractors in preparation of bids for dam construction. An outline of the proposed HRF configuration is shown on each geological cross section (Large Figure 6 through Large Figure 9). Boring logs and locations in reference to the geological cross sections are discussed in Section 3.2.2.

The interior of the HRF dams will be sloped at 4 horizontal to 1 vertical (4H:1V). Thirty-foot horizontal benches will be placed at elevations of 1,600 and 1,630 feet. Dam construction material will be placed as needed to maintain the constant slope and bench widths around the inner perimeter of the facility, which will include some blasting of the natural high ground on the site perimeter. This geometry will allow for the placement of the geosynthetic liner in increments as HRF development progresses vertically and horizontally over the life of the facility.

HRF dams will be constructed using a downstream construction method. To advance in height using the downstream construction method, material is added to the crest and the downstream slope (exterior slope) of the dam. While the material is placed, it will be compacted to the design density. The maximum height of the proposed dams is approximately 85 feet with a crest elevation of 1650 feet. The exterior, downstream, face of the dams will be constructed at a slope of 4H:1V. Structural fill used to construct the dams is discussed in Section 4.0.

To contain the process water used to transport the Residue to the HRF, the HRF will use a multi-layered geosynthetic liner system to create hydraulic isolation between the Residue and surrounding material. The liner system components, listed in order from bottom to top, will consist of: (1) a geosynthetic clay liner (GCL), (2) lower geomembrane, (3) geocomposite (geonet), and (4) upper geomembrane. Leakage through the upper geomembrane will be collected via the geonet and routed to a leakage collection system for recycling. This system will limit the hydraulic head on the lower liner system, thereby substantially limiting liquid loss from the HRF.

During LTVSMC operations, active seeps were observed along the southern toe of Tailings Basin Cell 2W. The seeps have diminished since the termination of tailings deposition in the cell. Flotation Tailings will be deposited only in Cell 1E and 2E. Because tailings will not be added to Cell 2W, the active seepage along the toe of the south dam is expected to remain negligible. The design of the HRF requires additional LTVSMC coarse tailings and/or bulk tailings to be added to the toe of the south dam of Cell 2W. Similar to the existing tailings in the south dam, these additional fill materials will provide adequate drainage (Table 4-1 for permeability values) to dissipate pore water pressure in the event seeps reform. The tailings will be supplemented with a seepage collection pipe to aid in dissipation of any excess pore water pressure below the liner due to seeps. Collection pipe water will be managed in the same manner that FTB seepage is managed (Reference (24)). Pore water pressure dissipation, should any pore water pressures develop, will also be provided by the drainage layer proposed beneath the HRF pre-load fill. Finally, the contents of the HRF will act as a buttress and counterweight on the south side of Cell 2W, thereby further preventing any pore water pressure impacts on the HRF liner system should pore water pressures ever become temporally elevated in this area.

5.2 HRF Facility Cross-Sections for Geotechnical Modeling

HRF dams will be constructed of compacted structural fill placed to meet construction specification requirements. There will be little variability from one dam area to another; only the HRF subgrade conditions will vary. Due to the flat slope angles selected for the dams, each dam section is anticipated to yield similar slope stability factors of safety.

The choice of cross sections for geotechnical modeling considered the entirety of the HRF in combination with the surrounding features (hillsides, wetland areas, existing tailings basin, and emergency basin conditions). Two cross sections (A-A’ and C-C’) were selected for analysis, at locations where the combination of foundation conditions and dam height are expected to yield the lowest factor of safety in slope stability analysis. Numerous borings, CPT soundings, and aerial images were compiled to establish cross-section geometry.

Cross-section A-A’ begins south of the future southern dam and terminates near the crest of the HRF North Dam. It follows the same path as geological cross-section A-A’ shown in Large Figure 2, which approximates the base of the former ravine discussed in Section 3.2. This cross-section, shown in Large Figure 6, incorporates the thickest sections of low strength material. The material in this region includes a layer of LTVSMC slimes overlying a thin peat

layer. This cross-section also intersects the middle of the previous tailings disposal area through the thickest section of compacted tailings and silty sand. In addition, there are no Giant Range Granite extrusions that would provide additional support such as in most of the other geological cross-sections shown in Large Figure 2. This cross-section encompasses native materials and the existing Emergency Basin, existing Tailings Basin dams, and new dam construction.
Large Figure 12 and Large Figure 13 show the Existing Conditions Geometry and End of Operations (Year 20) Geometry, respectively at cross-section A-A'. Geotechnical modeling outcomes for the southern dam of cross-section A-A' for each lift (Lifts 1 through 3) of dam development are presented in Section 6.2 of this report.

Development of the HRF will buttress and improve slope stability safety factor for the existing southern dam of Cell 2W (the northern dam of the HRF). Slope stability will increase as development of the HRF proceeds through additional lifts to higher elevations. This is due to the continued buttressing and overall reduction in slope height and slope angle that will result in the southern dam of Cell 2W as HRF development proceeds. However, for cross-section A-A' the first lift of the northern dam of the HRF (the southern dam of Cell 2W) was included in the slope stability evaluation as a point of comparison to the factor of safety values being computed for the other HRF dams.

Although expected to yield similar modeling outcomes, to evaluate variability between cross-sections, the final lift (Lift 3) of the northwestern dam of cross-section C-C' was also modeled to evaluate slope stability (Large Figure 7). Cross-section C-C' begins northwest of the future northwest dam and terminates near the existing rail embankment to the southeast. It follows the same path as geological cross-section C-C' shown in Large Figure 2. The material underlying this cross-section is primarily silty sand with gravel and Giant's Range Granite, and these materials are incorporated into the geotechnical modeling for cross-section C-C'.

The coordinate system used in the models was based on vertical elevation and horizontal distances. Left and right distances, and lower bound elevations of -2800, 660, and 1,400 feet, respectively, were considered to be far enough from the areas of interest to not influence the HRF modeling results. Slope stability model results are presented in Section 6.2.1.

In summary, the following sections are modeled for evaluation of slope stability factor of safety:

- Cross-Section A-A'
    - Southern Dam – Lifts 1, 2 and 3
    - Northern Dam – Lift 1
- Cross-Section C-C'
    - Northwestern Dam – Lift 3

For cross-section A-A’ a finite element model was used to calculate stress-deformation effects during the life span of the HRF. The finite-element mesh for End of Operations (Year 20) is shown in Large Figure 14. The finite element mesh size was optimized, so it was fine enough to capture important soil behavior yet coarse enough to make the analysis computationally efficient. The majority of elements had a maximum mesh size of 17 feet, but mesh size in the Emergency Basin was reduced by roughly an order of magnitude to 1.7 feet to provide greater definition of flow and consolidation.

5.3 Seepage Analysis

The seepage analysis was conducted using SEEP/W, part of the GeoStudio 2007 Version 7.19 software package. SEEP/W uses the finite-element model to compute groundwater movement and pore water pressure distribution within porous materials, such as soil and rock. This program can analyze both simple and highly complex seepage problems, including saturated and unsaturated flow, steady state and transient conditions, and a variety of boundary conditions. Product integration allows the use of seepage files in stress-deformation and slope stability analyses.

The following assumptions were applied to the seepage analysis:

- The phreatic surface in the Emergency Basin is maintained at an elevation of 1,560 feet.
    - Currently, water in the deepest areas of the Emergency Basin is estimated to be 3 to 5 feet in depth. Surficial water will be pumped or drained away from the Emergency Basin before the sand drainage blanket is placed and the wick drains are installed.
    - The wick drains and sand, which act as a drainage blanket above the wick drains, will allow pore water pressures to reach equilibrium at an elevation of 1560 feet. Any seepage from Cell 2W seeps will be removed by high permeability structural fill and a seepage collection pipe as previously described in Section 5.1.
- An upstream phreatic surface was not included in the models.
    - A seepage collection system along the toe of the North Dam will maintain the phreatic surface at an elevation near 1560 feet.
- The liner system forms an impermeable boundary. The HRF is effectively hydraulically independent of the surrounding material and liquid within the HRF cannot seep through the liner system into the HRF dams.

In addition, effects of precipitation are negligible. Most precipitation is expected to run off from the exterior face of the HRF dams, will be diverted away from the HRF via drainage swales and/or will fall into the lined HRF and be incorporated with other process water contained within the HRF. The area tributary to the HRF is limited by the perimeter dam of the HRF so is small such that the impact of even a large rain event would result in a small increase in the already existing pond depth.

As discussed in Section 4.1, wick drains are long flexible plastic bands encased in geotextiles. Equation 4-2 shows that wick drains increase the hydraulic gradient by reducing the drainage path for dissipation of excess pore water pressure. Wick drains were incorporated into the analysis by assigning constant head parameters to line segments. Wick drain line segments were set at 5-foot horizontal intervals in a triangular arrangement. This pattern was selected because it is the average recommended configuration and will provide a quick response to alleviate excess pore water pressure (Reference (17)) in HRF foundation materials. The wick drain line segments extended from the surface of the Emergency Basin through the LTVSMC slimes and compressed peat, terminating in the glacial till. A constant head of 1560 feet was assigned to each line, as well as the base of the sand drainage blanket. LTVSMC slimes and compressed peat in the emergency basin were assigned new seepage parameters to account for the proposed installation of wick drains. The new seepage parameters were discussed in Section 4.1. Seepage parameters were not changed in the glacial till, because the wick drains do not extend fully through the unit, but rather only penetrate into the unit.

The installation of wick drains in a triangular 5-foot horizontal pattern reduces the maximum drainage path from approximately 60 feet to 2.5 feet thus increasing the hydraulic gradient as shown in Equation 4-2. If it is ultimately determined by PolyMet that HRF construction can be extended over multiple years, then any analyses described in this section and elsewhere in this Geotechnical Data Package that include wick drains will be reviewed and revised where necessary to confirm analysis outcomes.

5.4 Stress-Deformation Analysis

A design consideration for the HRF is the deformation occurring along the interface between the Emergency Basin materials (the HRF foundation materials) and the HRF. It is assumed that strain along this interface directly correlates to strain in the HRF liner system. The geomembrane and geosynthetic components of the liner system perform adequately within a manufacturer-specified range of strains. Using cross-section A-A’, analyses were completed to estimate the deformation of the Emergency Basin materials in their existing form due to the load applied by the HRF, and the strain that could result in the liner system. A coupled pore water pressure and deformation model was used for this analysis.

The stress-deformation analysis was conducted using SIGMA/W, part of the GeoStudio 2007 Version 7.19 software package. Pore water pressures computed in SEEP/W were imported into the SIGMA/W analysis to compute initial stress conditions in the model. SIGMA/W was then used to model pore water pressure generation and dissipation associated with external loading and/or unloading. A series of transient analyses were run consecutively to simulate changes in pore water pressure and deformation over time. This approach accounts for time-dependent settlement of materials, as it is related to seepage and deformation parameters of each material.

Time allotments were assigned to each step of the transient analysis. The transient analysis was divided into 10 steps. The preload was modeled in five steps or five lifts. Two additional steps were given to (1) the placement of a sand drainage layer before the preload steps and (2) the removal of the preload. Fourteen-day periods were assigned to the sand drainage blanket and to each preload lift; the minimum expected time to form each lift. The preload removal was assigned 28 days. Three steps were used for the fill time of the HRF. The three filling steps of the HRF correspond to bench elevations of 1600 feet and 1630 feet and the crest elevation of 1650 feet. The cumulative times to fill the HRF to elevations of 1600, 1630 and 1650 feet were modeled at 4, 13, and 20 years, respectively. Actual times will vary and be somewhat less than the 13 and 20 year increments modeled (i.e., HRF facility operating life is projected at 18 years total) but as illustrated by the model results subsequently described, stress-deformation response is relatively rapid and model outcomes are unaffected by the extended time frame utilized in the modeling. A final 100-year period was used to analyze the total amount and decaying rate of consolidation of the Residue.

The following assumptions were applied to simplify the stress-deformation analysis:

- The entire addition/removal of a preload/Residue lift takes place at the beginning of each step.
- The sand unit will be 3 feet thick, as recommended in Reference (17).
- Five preload lifts will be 10 feet thick. This will result in a 50-foot high preload embankment. The final height will be adjusted on the basis of the data gathered from settlement gauges and piezometers used to monitor settlement and pore water pressure during placement of the preload.
- Material used to construct the dams in lower areas between natural high ground will be specified to be placed and compacted in a uniform manner to achieve consistent density and strength.

5.4.1 Preload

A preload imparts increased stress on underlying material, causing consolidation to occur. Once the underlying material is adequately consolidated, an additional preload lift is added and the process is repeated or the preload is removed. Pre-consolidation has occurred when the preload is removed and the underlying material has a maximum past effective stress greater than the present effective stress, which results in an OCR greater than 1.0.

As described in Section 4.2.2, normally consolidated soils are materials in which the present effective stress is equal to the maximum past effective stress. An example of a normally consolidated soil is deposits of material in river deltas. Over-consolidated soils are materials in which the present effective stress is less than the past maximum effective stress. Soils once below glaciers are typically over-consolidated, due to the tremendous weight on soils imparted by the glacier. Normally consolidated materials experience greater compression (consolidation) when subjected to an increase in stress than over-consolidated materials.

Consolidation is also a function of a materials' void ratio and unit weight. Void ratio is the ratio of the volume of voids to the volume of solids in a unit volume. Normally consolidated materials generally have higher void ratios than similar over-consolidated materials. Increasing the effective stress on soil consolidates the underlying material by decreasing its void ratio and creating a denser particle configuration indicated by a higher unit weight. After a preload is removed, the underlying soil will rebound slightly. If additional weight is added to the soil, the new displacement will closely follow the rebound curve to the normal consolidation curve. Once the rebound curve is passed, further increases in effective stress will cause greater deformation.

Figure 4-3 shows a typical consolidation curve. As shown, effective stress increase on an over-consolidation curve causes a lesser change in the void ratio than a similar stress increase on the normal consolidation curve. A rebound curve is shown as a part of the consolidation curve. The numerical sequence shows: (1) over-consolidation curve, (2) normal consolidation curve, (3) unload curve, (4) rebound curve, and (5) normal consolidation curve.

The preload proposed for the HRF will pre-consolidate material in the Emergency Basin by creating an over-consolidated soil. Settling plates or strain gauges and piezometers will be installed on top of the Emergency Basin prior to placing the preload. Settlement and pore water pressure values will be compared to modeling results. Plots of settlement and pore water pressure versus time will be maintained to determine the time-rate of settlement and used as a guide to indicate when the next preload lift will be placed. If warranted, the initial modeling will be reviewed and updated. After the preload is removed a rebound curve will form, which must be followed upon the addition of future load. Because material in the Emergency Basin is normally consolidated, consolidation will begin along the portion of the curve shown as (2) in Figure 4-3. To achieve maximum consolidation, excess pore water pressure must dissipate from the Emergency Basin foundation before the preload is removed. The addition of wick drains in the Emergency Basin would reduce the time required to relieve all excess pore water pressure. Relief of excess pore water pressure can also be achieved by extending the time allowed for consolidation in response to placement of each preload load, prior to placement of the next load increment. After adequate consolidation has occurred, the preload will be removed, and consolidation will progress to (3) on Figure 4-3. At this point material in the Emergency Basin will be slightly over-consolidated. It is expected that the majority of the material used for the preload can be used in the new perimeter dams for the HRF. Some preload material will be required for the foundation of the HRF to be leveled to the design elevation. As Residue is added to the HRF, the consolidation path will follow the rebound curve shown as (4) in Figure 4-3. Eventually, the weight of the Residue will create an effective stress equal to the maximum past effective stress caused by the preload. At this point the consolidation will begin following the normal consolidation curve path, identified as (5) in Figure 4-3.

Modeled consolidation results of the LTVSMC slimes within the Emergency Basin were corroborated using Equation 5-1 and Equation 5-2 to approximate the settlement of the LTVSMC slimes in the Emergency Basin due to the preload before it is removed. Equation 5-1 is illustrated in Figure 4-3 as line segment (2). A second equation is required to calculate additional settlement due to the stress induced by the HRF. Equation 5-2 approximates the settlement of the LTVSMC slimes in the Emergency Basin due to the HRF after the preload has been removed. This equation is represented in Figure 4-3 as line segments (4) and (5). The primary consolidation results, S_c, are additive due to the principle of superposition with the conservative assumption that no net loss of settlement due to the removal of the preload occurred, such that segment (3) in Figure 4-3 is ignored. Because the LTVSMC slimes are normally consolidated, line segment (1) in Figure 4-3 is not a portion of the settlement path. Settlements estimated from placement of the preload are discussed in Section 6.1.

$$S_c = \frac{C_c * H}{1 + e_o} * \log \frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}$$ **Equation 5-1**

Where:
S_c = consolidation settlement
C_c = compression index (Figure 4-3)
H = thickness of LTVSMC slimes
e_o = initial void ratio
σ'_o = effective overburden pressure at H/2
$\Delta\sigma'$ = effective uniform distributed load applied at the ground surface

$$S_c = \frac{C_s * H}{1 + e_o} * \log \frac{\sigma'_c}{\sigma'_o} + \frac{C_c * H}{1 + e_o} * \log \frac{\sigma'_o + \Delta\sigma'}{\sigma'_c}$$ **Equation 5-2**

Where:
C_s = swell index (Figure 4-3)
σ'_c = pre-consolidation effective pressure at H/2

5.4.2 Residue Consolidation Model

Following the termination of Residue placement, a dewatering program will begin to remove and treat water from the HRF (Reference (25)). At this point, the Residue is expected to be fully saturated to an elevation of 1650 feet. As water migrates to the dewatering outlet, pore water pressures will reduce and the effective stress on the Residue will increase, as shown in Equation 5-3.

$$\sigma = \sigma' + u$$ **Equation 5-3**

Where: σ = total stress
σ' = effective stress
u = pore water pressure

Because water is incompressible relative to the compressibility of soil, settlement is expected within a soil stratum as pore water pressure is removed and the effective stress on the soil increases.

Consolidation (settlement) is based on effective stress and void ratio (Figure 4-3.) In a geotechnically homogeneous material, which the Residue is taken to be for purposes of this evaluation, the amount of consolidation will coincide with the depth of material. In the HRF, the greatest depth of Residue is approximately 80 feet. To reduce computational effort and time, the Residue settlement model was truncated to a 5-foot wide by 80-foot tall column. The column is shown in Large Figure 15.

The following assumptions were applied to the stress-deformation analysis:

- Infiltration due to precipitation was not included. Temporary cover and then final cover will be placed over the HRF to minimize infiltration due to precipitation.

- Potential future variations in climate were not included in this analysis and are not warranted for the short 20-year duration of the project.

- All foundation settlement in the Emergency Basin is expected to be complete at the termination of Residue placement.

- Residue consolidation is expected to occur throughout the operating life of the facility but for this analysis was assumed to begin at the End of Operations (Mine Year 20). This simplifying assumption yields a conservatively high estimate of the residue consolidation and HRF surface settlement that will occur after cessation of HRF operations.

- Pore water pressure will approach zero pounds per square foot during Residue dewatering. This assumption yields a conservatively high estimate of the residue consolidation and HRF surface settlement that will occur after cessation of HRF operations.

The consolidation is comprised of three modeling events: 1) a steady state seepage analysis corresponding to the point in time at which residue discharge into the HRF is completed, 2) an instantaneous stress evaluation in which gravity is applied to the model and initial stresses are determined, and 3) a transient coupled stress/pore water pressure analysis in which results from the first and second modeling events are coupled together and allowed to change with time. The third event incorporates a zero pressure-head boundary condition at the base of the facility, thereby allowing pore water pressures greater than zero to dissipate from the base of the residue column, which reduces the pore water pressure in the system and therefore changes effective stress. A detailed explanation of this modeling approach can be found in the SIGMA/W user manual (Reference (18)). Estimations can be updated as residue samples are obtained from full-scale operations. Closure planning can correspondingly be updated in conjunction with required periodic updates to reclamation plans.

Residue consolidation modeling reflects End of Operations (Mine Year 20) conditions. During operations, pond depth soundings will occasionally be taken to compute facility capacity consumption rates and for confirming the timing of construction of the next vertical lift of the facility. Further, during operations, newly generated Residue is placed over existing Residue, creating capacity by consolidation of the underlying Residue. The Residue discharge location into the facility will be relocated as needed throughout the life of the facility to fill the facility to as uniform a Residue depth as possible, while also creating a final Residue surface that matches desired final contours to the extent possible.

Several factors could extend the time necessary to achieve zero pore water pressure, including lower than expected hydraulic conductivity of the consolidated residue, or drainage system malfunction. If malfunctions of the drainage system could not be repaired, then alternate dewatering techniques would be explored and/or alternate cover system designs would be considered. For example, an alternate dewatering technique may include installation of wick drains into the residue to aid consolidation and dewatering. Alternate cover system designs may include thicker geogrid reinforced or geotextile reinforced cover soil layer components to facilitate equipment access, and incorporation of a drainage layer immediately below the cover to facilitate collection and removal of residue consolidation water. HRF functionality would not be affected but final design details may change and timing of final cover placement could be delayed.

5.5 Slope Stability Analysis

The slope stability analysis was conducted using SLOPE/W, part of the GeoStudio 2007 Version software package. SLOPE/W uses the limit equilibrium theory to compute the factor of safety of earth and rock slopes. In the limit equilibrium approach, material is assumed to be at the state of limiting equilibrium and a factor of safety is computed. The state of limit equilibrium occurs when the soil and reinforcement strengths are reduced by the factor of safety (i.e., the system is at the verge of failure), meaning at this state the soil and reinforcement mobilize their respective strengths simultaneously. SLOPE/W is capable of using a variety of methods to compute the factor of safety of a slope while analyzing complex geometry, stratigraphy, and loading conditions.

Spencer’s method was used as the search technique to determine the factor of safety in the stability analysis. Spencer’s method is considered an adequate search technique because it satisfies all conditions of static equilibrium and provides a factor of safety based on both force and moment equilibrium. In addition, the analysis searches for the presence of tension cracks, and if found, incorporates them into the calculations. A minimum slip surface depth of 5 feet was used in the analysis. For the HRF, slope instabilities (failure surfaces) less than 5 feet in depth are considered superficial, and maintenance issues only.

In SLOPE/W, the critical failure surface was analyzed using the grid-and-radius circular searching technique where the grid of the center of slip circles (or center of blocks) and radii (or ends of blocks) are established by the user. Once the critical slip surface was found, the technique optimizes the solution of the circular surface, yielding the lowest factor of safety.

5.5.1 Slope Stability Analysis Methods

In accordance with the MDNR-approved Geotechnical Modeling Work Plan (Attachment A), the HRF perimeter dams were designed to meet a minimum factor of safety of 1.5 for ESSA. The ESSA is performed to analyze slopes in which slow loading or unloading, or no external loading is in progress. In these instances, the drained shear strength of the materials is mobilized and no shear-induced pore water pressures are developed.

The slope stability analysis was performed for the intermediate lifts of the HRF development and for the End of Operations (Mine Year 20) configuration of the HRF. As agreed by the MDNR and PolyMet during development of Attachment A, slope stability with respect to excess pore water pressure in the South Dam of Cell 2W (north side of the HRF) was not analyzed and such analysis was deemed unnecessary due to a number of factors including:

- the slow filling rate of the HRF occurring over an 18-year time-frame and the resulting slow rate of stress increase in the underlying soils,
- the creation of a buttress on the South Dam of Cell 2W via construction of the HRF and the resulting increase in slope stability,
- the planned borrow of coarse tailings from the crest of the slope on the south dam of Cell 2W which will further reduce driving forces within the slope, and
- the hydraulic separation of the HRF and associated liquids and precipitation from the surrounding soils via the HRF liner system, thereby further limiting the potential for increases in the phreatic surface.

Evaluation of stability for liquefied soil strength conditions also was excluded from requirements in Attachment A due to the planned foundation preparation and dam construction techniques described herein, that remove the potential for soil liquefaction to occur.

5.5.2 Probabilistic Seismic Hazard Analysis

The seismic risks associated with the site were evaluated by performing a Probabilistic Seismic Hazard Analysis (PSHA). This is a site-specific seismic analysis that assesses the potential local and regional seismic sources that could affect the site, models their attenuation to the site, and provides a probabilistic response for conditions at the site. Seismicity at the site is likely to be governed by one of two conditions: (1) nearfield events, which are low-level earthquakes with epicenters in the Midwest, and (2) farfield events, which are higher magnitude earthquakes caused by the New Madrid Seismic Zone. The New Madrid Seismic Zone contains the nearest active fault and is approximately 920 miles south of the site near New Madrid, Missouri.

Evaluation of the nearfield, farfield, and combined (combination of the nearfield and farfield events) seismically induced forces on the FTB geo-structures revealed negligible effects on the stability of FTB dams (Reference (15)). The constructed HRF with its relatively flat slopes and compacted structural fill for embankments is inherently even more stable than the FTB. Therefore, a PSHA was not conducted for the HRF.

The configuration of the HRF will use the South Dam of Cell 2W, natural high ground (bedrock) located to the southwest and southeast, and new downstream constructed dams in the lower areas between the natural high ground to complete its perimeter. The HRF will form a buttress on the South Dam of Cell 2W. Buttressing this slope will increase the effective stress on the Emergency Basin and the toe of the South Dam of Cell 2W. The natural high ground (bedrock) is not prone to seismic hazards due to its massive crystalline structure. The newly constructed dams in the low areas between the natural high ground are less susceptible to seismic hazards due to their coarse permeable nature, which will encourage drainage. The HRF is hydraulically separated from the surrounding soils due to its liner system, which will prevent an elevated phreatic surface from forming in the surrounding soils. Structural fill material will be placed in thin lifts and will be mechanically compacted to a high percentage of Standard Proctor maximum dry density. The new dams will be constructed in a downstream construction configuration (Section 5.1) with relatively flat slopes (4H:1V) historically accepted by the Agency for mine slopes in northern Minnesota. As shown in Large Figure 4, there is an inferred (by the MGS) fault underlying the HRF. Though this may be a potential source of excess pore water pressure, the fault's existence has not been confirmed and as previously noted in Section 3.2.1, is not depicted in recent geologic mapping of the area. Further, the HRF will be underlain by a granular drainage layer with ductile pipes, constructed as part of the pre-load fill. The drainage system will suffice in relieving any excess pore water pressure that could develop along this inferred fault. In addition, the proposed foundation preparation activities and dam construction will effectively fill any surface voids in the inferred fault zone. In summary, seismic hazards are improbable considering the following:

- PSHA evaluation of the FTB geo-structures revealing negligible effects on the stability of FTB dams,
- buttress addition increasing the effective stress applied on the Emergency Basin and toe of the South Dam of Cell 2W,
- removal of material from the crest of the South Dam of Cell 2W, reducing driving forces acting to destabilize the slope,
- lack of saturated soils surrounding the HRF,

- a granular drainage layer underlying the HRF to expedite the transfer of excess pore water pressure in a controlled manner, and
- construction methodology planned for new dam construction, including:
  - Removal of unsuitable foundation materials,
  - Fill being placed in thin lifts and mechanically compacted to a high percentage of Standard Proctor maximum dry density,
  - Downstream construction, and
  - Relatively flat dam side slopes (4H:1V).

6.0 Geotechnical Modeling Results for HRF Design

The results of the seepage, stress-deformation, and slope stability analyses for the HRF are presented in the following sections. Also included is geotechnical-related design information for the HRF drainage and leakage collection system and chemical compatibility information related to the residue and geosynthetic clay component of the HRF liner system.

6.1 Stress-Deformation

As shown in Large Figure 16, the greatest amount of deformation in the liner system foundation occurs at a node 280 feet away from the toe of the South Dam. This point will be referred to as "Node A" for the remainder of this document. Fine tailings and slimes in this area are the thickest at approximately 50 feet and yield the greatest vertical displacement in the foundation after the HRF is filled.

Due to their quantity, it is potentially impractical to excavate and replace the foundation materials with structural fill to support the HRF. Further, excavation of the materials to significant depth may lead to instability of the Tailings Basin South Dam, which relies on the material in the Emergency Basin for foundation support. Any excavation and replacement plan for existing foundation materials would require further analysis and design. For the scenario of leaving the Emergency Basin materials in place, to reduce the deformation potential of the foundation materials before the liner system is installed, the design of the HRF proposes that a preload be applied to the Emergency Basin. This will pre-consolidate material in the Emergency Basin, thereby limiting the potential future strains as discussed in Section 5.4.1. Model solutions after the removal of the preload are shown in Large Figure 16 to Large Figure 20. They are defined as follows:

- Vertical displacement: Large Figure 16
- Pore water pressure: Large Figure 17
- Total head pressure: Large Figure 18
- Total vertical stress: Large Figure 19
- Effective vertical stress: Large Figure 20

Node A, the point of greatest vertical displacement along the interface between the Emergency Basin and the HRF, was tracked throughout the analysis. Both vertical displacement and pore water pressure were monitored. Large Figure 21 and Large Figure 22 show the vertical displacement and pore water pressure change during the preload (surcharge) loading and removal, respectively. Because of the assumption that the preload was applied all at once in the model, but in actuality will take time to construct, the displacement response and pore water pressure magnitudes in Large Figure 21 and Large Figure 22, respectively, are exaggerated.

Vertical displacement will generally occur at a slower rate and spikes in pore water pressure will have smaller magnitudes during actual construction. Lateral displacement was minimal and only considered during liner strain calculations, discussed in Section 6.1.2.

The initial displacement shown in Large Figure 21 relates to the placement of the sand drainage blanket associated with preparation for preload construction. The next five steps indicate displacement due to preload lifts. The first lift has the greatest impact on displacement. Change in displacement diminishes with each subsequent preload lift as expected because change in stress will be less as fill height increases. When the preload lift is removed, Node A rebounds up an estimated nine percent. The aggregate settlement of Node A during pre-loading is estimated at 3.9 feet.

Large Figure 22 illustrates the variations in pore water pressure due to the preload. Similar to Large Figure 21, the first spike in pore water pressure relates to the placement of the sand layer. Subsequent spikes in pore water pressure correlate to the additions and removal of the preload. As noted previously, pore water pressure magnitudes are exaggerated by the geotechnical model and in the resulting figures due to the modeled instantaneous placement of the preload lifts.

Model solutions for End of Operations (Mine Year 20) are shown in Large Figure 23 to Large Figure 27. They are defined as follows:

- Pore water pressure: Large Figure 23
- Total head pressure: Large Figure 24
- Total vertical stress: Large Figure 25
- Effective vertical stress: Large Figure 26
- Vertical displacement: Large Figure 27

Node A, which experienced the greatest variation in displacement and pore water pressure during the pre-loading, was tracked again during the filling operation of the HRF. The cumulative vertical displacement and pore water pressure variations are shown in Large Figure 28 and Large Figure 29, respectively. The time interval shown for Large Figure 28 and Large Figure 29 begins after the removal of the preload and ends at End of Operations (Mine Year 20).

As shown in Large Figure 28, the vertical displacement at Node A begins at -3.9 feet, after the rebound caused by the removal of the preload, and ends with a final displacement of -5.3 feet. The aggregate additional displacement is -1.4 feet after the liner system has been installed. Because of the assumption that the load was applied all at once in the model, but in actuality will take time to construct, the displacement response and pore water pressure magnitudes in Large Figure 28 and Large Figure 29, respectively, are exaggerated. Vertical displacement will occur at a slower rate and spikes in pore water pressure will have smaller magnitudes.

Large Figure 30 and Large Figure 31 illustrate the change in vertical displacement with respect to effective stress for Node A. Initially, vertical displacement is shown to increase steadily as the effective stress (preload) increases. Once the preload is removed, the displacement follows the rebound curve. As Residue is added to the HRF, the consolidation path follows the rebound curve. Once the in situ effective stress in the Emergency Basin exceeds the maximum past effective stress, at an approximate elevation of 1600 feet, an increase in vertical displacement occurs. The vertical displacement path for Node A is similar to the effective stress versus void ratio plot shown in Figure 4-3. Without a preload, an estimated displacement of -5.3 feet would be expected. As a result of applying a preload to the Emergency Basin, the maximum vertical settlement estimated for the HRF is reduced to -1.4 feet.

Modeled settlement values were corroborated with settlement calculations based on Equation 5-1 and Equation 5-2. Settlement calculations were based on stress acting at Node A. The estimated settlement of the LTVSMC slimes before removal of the preload is 2.7 feet, compared to the modeled value of 4.1 feet. Equation 5-2, used to model additional settlement due to the increased weight of the HRF, estimates a settlement of 1.2 feet. Using the principle of superposition and assuming no rebound, the settlement equations calculate a total displacement of 3.9 feet compared to the aggregate modeled value of 5.3 feet. Because the saturated unit weight of Residue was used for this analysis, incorporation of precipitation into this analysis would have no effect on the outcomes.

6.1.1 Residue Consolidation

Residue consolidation will occur after cessation of Residue discharge to the HRF, as cell dewatering occurs. Over time, the rate of consolidation will reduce. Once pore-water pressure has reached equilibrium (when drainage is complete after approximately 10 years – ref. Section 6.3.1), primary consolidation will be complete and further consolidation will be negligible. Large Figure 31 illustrates the decaying trend of consolidation modeled in the HRF. Total settlement of the Residue surface in areas with the greatest depth of Residue is estimated via modeling to be 9.6 feet. As a check on model results, based on the change in void ratio correlating to the change in effective stress, the settlement was also calculated to be approximately 9.6 feet (Attachment D). As the depth of Residue decreases near the edge of the HRF, less settlement will occur. The resulting deformed surface of the HRF will be concave with the greatest deformation in areas of greatest Residue thickness.

Residue consolidation and settlement values presented above are estimates based on the assumptions that:

- The entire residue column is placed instantaneously, at which point settlement of the residue begins. In reality, residue will be placed in the HRF continuously and as it settles, newly placed residue will fill space vacated due to settlement.

- The residue column is homogeneous and settles uniformly. In reality, some components of the residue may settle faster than others, leading to a somewhat non-homogeneous residue mix with some zones that settle more than other zones.

On similar large, deep disposal facilities of this type (consisting primarily of coal ash and gypsum disposal facilities), it is Barr's experience that material settles quickly (a predominance of immediate settlement and limited consolidation settlement).

Final HRF capacity will be selected to provide adequate capacity for storage of all Residue produced by the Hydrometallurgical Plant during operations and for the small quantity of water treatment plant residue and coal ash expected to be disposed of within the HRF. Additional storage capacity can be achieved by increasing construction lifts from 3 to 4 feet if needed based on experience gained from full-scale operations. The increased heights will not adversely affect the stability of the facility due to the relatively flat slope angles being used and the downstream dam configuration being utilized.

The current design/management plan for the HRF utilizes an in-cell pond for sedimentation of the residue solids for clarification of the residue transport water prior return of the water to the hydrometallurgical plant for recycling. The plan does not include recirculating liquid to the surface of the HRF, via the drainage collection system, during plant operation and the placement of Residue. Due to the size and depth of the HRF, it is assumed that drainage recovery and recirculation at a rate required to generate a sizeable downward gradient and increased effective stress in the residue to affect additional residue consolidation would be impractical (large pumping and piping systems) and cost prohibitive. However, following the end of plant operation, pumps installed in the drainage collection sump will begin dewatering the HRF and any resulting densification of the residue due to progressively increasing effective stress will occur as drainage collection and removal progresses. Precipitation falling on the Residue is unlikely to have a significant impact on pore water pressure within the Residue; the annual depth of precipitation is small relative to the total depth of the HRF. Therefore, precipitation is unlikely to affect the overall settlement of the Residue.

6.1.2 Strain in Liner System

Strain in the HRF liner system will be the result of differential settlement between points along the liner interface with the HRF foundation materials. Strain along this interface is considered to correlate to the strain that will be induced in the HRF liner system. Large Figure 32 shows the estimated percent strain in the liner as a function of horizontal distance in the model. Positive strain values indicate axial extension, and negative strain values indicate axial compression. Axial extension, or stretching of the liner system, is of importance whereas axial compression is not. The maximum strain in the liner system is estimated to be 0.20 percent. This value is well within tolerable limits of most geosynthetics. In several areas of the liner, the model calculated a non-intuitive axial compression. However, considering the strains in a complex discretized stress-deformation model, node movement may not be as expected. A general cumulative elongation is expected to occur in the liner system.

Strain capacity will remain relatively constant in the liner system. Any fluctuation in strain capacity will be most noticeable along the seams between geomembrane sheets. Manufacturers typically do not report maximum allowable strain for geomembrane seams. Rather, lengths of welds made in the field are tested in a laboratory to determine an index of expected minimum tensile strength. Liner systems are designed so that the critical failure is not due to peeling or shearing of the seams. Typically, laboratory tests result in a large amount of sheet elongation near the seam being tested, but not a rupture of the seam itself. Laboratory strain capacity results are used by the engineer to assess the need to replace inferior seams during construction. The testing method that addresses the evaluation of geomembrane seams is described in ASTM D6392-08.

The structural fill underlying the liner will be compacted to achieve uniform density. Consolidation and settlement of the structural fill underlying the liner can be expected to be negligible. On the south side of Cell 2W (north side of the HRF), placement of structural fill below the liner system is expected to result in uniformly distributed downward settlement, causing compression in the liner system rather than extension. Therefore, no excess strain is anticipated in the liner system along the south side of Cell 2W.

Table 6-1 lists the allowable strain and elongation at break percentages for several GSE Lining Technology, LLC high-density polyethylene (HDPE) and linear low-density polyethylene geomembranes (LLDPE). The allowable strain in the HDPE geomembrane is 12 percent. Because LLDPE is more ductile than HDPE and the LLDPE has an elongation at break strain value greater than 500 percent, the allowable strain for LLDPE can be assumed to be at least 12 percent or greater. The allowable strain in the GCL portion of the HRF liner is in the range of 1 to 19 percent, depending on the GCL type and installation procedures.

Table 6-1 Typical Strain Values for Geosynthetic Components

Name[3]	Allowable Strain, %	Elongation at Break, %	Tensile Strength at Break lb/in
GSE HD Textured Geomembrane (60 mil)	12	100	115
GSE HD Textured Geomembrane (80 mil)	12	100	155
GSE Ultra Flex (LLDPE) Textured Geomembrane (60 mil)	N/A	500	168
GSE Ultra Flex (LLDPE) Textured Geomembrane (80 mil)	N/A	500	224
Geosynthetic Clay Liner	1 to 19 [1],[2]	N/A	25 to > 50 [2]

(1) Allowable strain in GCL liner depends on GCL type and installation procedures.
(2) GCL Tensile Strength at Break depends on GCL type (Reference (26)).
(3) GSE geomembrane data used for reference; actual geomembrane supplier may vary.

6.2 Slope Stability

A slope stability analysis was performed for new dams proposed for the HRF perimeter, in the areas not bounded by the existing hillsides to the east and south. The analyses were performed on the south dam for each development lift, and on the south and northwest dam at their completion height for End of Operations (Mine Year 20) when the dams are at their greatest height and therefore yield their lowest slope stability safety factor. Analysis on the north dam was on the first development lift when this dam should yield its lowest slope stability safety factor. These conditions are anticipated to be the most critical conditions throughout the life of the facility.

6.2.1 Global Slope Stability

As required by Attachment A, the dams require ESSA and must achieve a safety factor of ≥ 1.5. Stability analyses were performed for intermediate lifts 1 and 2 of the south dam of cross-section A-A' as well as the End of Operations (Lift 3) conditions for this dam and for the northwest dam in cross-section C-C'. Stability analysis was performed for lift 1 of the north dam in cross-section A-A'. Results of the ESSA stability analyses are presented in Table 6-2. The model solution outputs are shown in Large Figure 33 through Large Figure 37.

Table 6-2 Global Slope Stability Analysis Results

Analysis	Cross-Section A-A' ESSA (South Dam)	Cross-Section A-A' ESSA (North Dam)	Cross-Section C-C' ESSA (Northwest Dam)
Target Factor of Safety (FOS)	~1.5	~1.5	~1.5
Lift 1 – Computed FOS	2.34	2.72	N/A
Lift 2 – Computed FOS	2.32	N/A	N/A
Lift 3 - End of Operations (Year 20) – Computed FOS	2.32	N/A	2.27

As shown in Table 6-2, the factor of safety for the ESSA stability analysis is greater than the target factor of safety. This indicates that the dams will be stable during all lifts. As shown in Large Figure 33 through Large Figure 37, the critical failure surfaces begin at the crest and daylight at or above the toe of the dam. The minimum slip surface depth for these analyses was set at 5 feet. Because the angle of repose for the dam fill material (approximately 30 degrees) is greater than the proposed dam downstream slope angle (18 degrees), surficial slope failures are not expected. The gap between the End of Operations factor of safety and the target factor of safety indicate that dam height could be increased further and still achieve an acceptable slope stability factor of safety.

As agreed with the MDNR, because the material in the constructed dams will be well compacted and because the HRF liner system will preclude leakage through the dams, Undrained Shear Strength Analysis and Liquefaction Analyses were not applicable and were not performed.

6.2.2 Infinite Slope Stability

As described in Section 5.1, the HRF geosynthetic liner system will consist of the following components, listed in order from bottom to top: (1) a GCL, (2) lower geomembrane, (3) geocomposite (geonet), and (4) upper geomembrane. Textured upper and lower geomembranes will likely be used for increased interface friction. The geocomposite between the upper and lower geomembranes will be a geonet encased on both sides by geotextiles. A GCL will be located below the lower geomembrane.

The interior slope angle for the HRF and the geosynthetic materials of the liner that will directly contact the underlying soils used for dam construction must be selected to produce a stable liner system – a system that will not slide down-slope as the HRF is filled with Residue. Equation 6-1 was used to calculate the factors of safety against down-slope sliding between successive liner components. In addition, each successive layer of the liner system must have an adequate interface friction angle with the underlying layer to prevent down-slope movement of any layer of the liner system, and the GCL must be internally reinforced to prevent internal shear failure of the GCL. Infinite slope stability for the liner system layer interfaces are shown in Table 6-3.

$$FS = \frac{\tan(\delta)}{\tan(\beta)}$$

Equation 6-1

Where: δ = interface friction angle (degree)

β = slope angle (degree)

Table 6-3 Infinite Slope Stability Analysis Results

Interface Number	Material Types	Slope Angle, β (deg)	Interface Friction Angle, δ (deg)	Target FS	Computed FS
4	Textured Geomembrane above Geocomposite Drainage Net	15.95	28	~1.5	1.86
3	Geocomposite Drainage Net above Textured Geomembrane	15.95	28	~1.5	1.86
2	Textured Geomembrane above Geosynthetic Clay Liner	15.95	28	~1.5	1.86
1	Geosynthetic Clay Liner above Granular Soil	15.95	24	~1.5	1.56

Computed factor of safety values shown in Table 6-3 are based on commonly reported interface friction angles between the materials anticipated to be used for the HRF liner (Reference (27)). Any variation from the anticipated material types warrants project-specific interface shear testing to confirm that the friction angles produce slope stability safety factors that are greater than the target factor of safety.

Per Fox and Ross (Reference (28)), shear failure in GCL-Geomembrane liner systems will occur at the interface with the lowest peak shear strength. Peak shear strengths for internally reinforced GCLs vary by normal stress and GCL type. For the GCL type to be specified for this Project (a woven-to-nonwoven needle-punched GCL), per Zornberg et.al. (Reference (29)) typical peak shear strengths (internal friction angle $Ø_p$ degrees) are approximately 40 degrees with additional strength provided by cohesion. Based on Equation 6.1, for an internal friction angle of 40 degrees and a slope angle of 15.95 degrees, the computed factor of safety against internal shear failure is 2.94, which is greater than the Target FS. This is without consideration of the added benefit the cohesive strength in the GCL provides.

6.2.3 Blast Induced Vibrations and Slope Stability

Natural high ground to the southwestern and southeastern edge of the emergency basin consists of rock outcroppings, which will need to be reshaped to achieve a minimum interior slope angle of 4H:1V for the HRF. Blasting will be required to loosen and break apart the rock outcroppings into manageable sizes that can be removed from the slope. Blasting has the potential to cause pore water pressure spikes and permanent deformation. Vibration, movement, and spikes in pore water pressure of the north side of the HRF, Emergency Basin, and any new construction should be closely monitored during blasting. Small test blasts should be conducted with long delays to determine the effects of blasting. Because permanent deformation is cumulative, tension cracks in the north side of the HRF, Emergency Basin, and any new construction must be examined and repaired before any additional blasting can take place.

The value for allowable permanent deformation of a slope due to earthquake-induced movement varies greatly. Movement increases exponentially after initiating, so monitoring movement will be vital to the safety of the area. As reported in Reference (30), slopes with less than 0.5 feet of ground movement should be considered safe, while slopes moving more than 1.0 foot will be considered unsafe and/or require further evaluation. The safety of any slope movement beyond 0.5 feet will be determined by the engineer.

The potential blasting configuration for the construction of the HRF and its effect on the inferred fault is beyond the scope of this document. Consistent with generally accepted construction procedures, visual observation of the HRF foundation conditions below the specified pre-load area will be made in conjunction with construction. Any areas where foundation conditions must be improved will be identified and resolved prior to proceeding with overlying construction.

6.3 Drainage and Leakage Collection Systems

Drainage typically refers to liquid that drains from a waste deposit and is collected by the drainage collection system. The HRF will act as a sedimentation basin, and will remain full or partially full of water during routine operations. In this context, drainage is liquid that drains from the deposited Residue and is collected during or after cessation of Residue disposal activities.

6.3.1 Drainage Collection System

Drainage collection will be achieved by placing strips of geocomposite across the base of the HRF. The geocomposite is comprised of a geonet with a geotextile heat-laminated to one or both sides of the geonet. The geocomposite strips subsequently discharge into a dewatering sump from where the collected drainage will be pumped to the HRF during operations and to the Waste Water Treatment Plant (WWTP) in closure.

Design of a drainage collection system is based primarily on structural performance and hydraulic performance. Structural considerations of the geocomposite include compression and creep resistance of the geonet. With regard to the hydraulic performance, the key factors for the HRF drainage collection system are the transmissivity of the geonet, the filtration properties of the associated geotextile (Reference (31)) and the time for Residue dewatering as controlled largely by the rate of liquid drainage from the Residue.

A model was developed to determine the drainage area (the summation of the lengths times the widths of the geocomposite drains) required at the base of the HRF to sufficiently reduce the hydraulic head in the HRF to facilitate reclamation. For this analysis the 3-dimensional modeling code MODFLOW was used (Reference (32)). The version used for this work was MODFLOW-2000 (Reference (33)). The graphical user interface, Groundwater Vistas (Version 5.09 Build 16), was used for the construction of the MODFLOW model (Reference (34)).

Results of the model (Figure 6-1) indicate that, in order to achieve sufficient dewatering to facilitate temporary cover placement over the Residue surface once Residue discharge into the HRF is complete, the geocomposite drains should be spaced not greater than125 feet apart across the base of the cell. With this spacing and a pumping rate of 300 gpm, the hydraulic head should be lowered approximately 10 to 17 feet within approximately 1.5 years following cessation of Residue discharge into the HRF. This drained surface layer of Residue should provide a sufficiently stable construction base to facilitate placement of a temporary cover system in advance of completing permanent reclamation once cell dewatering is completed and Residue settlement has diminished. In the event that it is impractical to access the low density residue for temporary cover construction during the regular construction season, then construction of the temporary cover (which will remain in place and serve as a foundation for final cover) can occur in the winter on the frozen residue surface; a technique used to cover paper sludge and other low strength waste materials. Alternatively, material strength modifiers such as Calciment (off-spec cement) could be used to improve strength of the residue surface, or a thick geotextile or geogrid reinforced soil layer could be placed to facilitate access.

With this configuration and based on a maximum Residue depth of approximately 80 feet, the cells should be effectively dewatered within approximately 10 years of the cessation of Residue discharge into the HRF. A check of this time estimate can be made using Darcy’s Law for velocity using Equation 4-1. Based on a permeability of 5.5 x 10^{-6} cm/sec (Table 4-1) and an 80 foot flow path, the estimated time for drainage to occur through the 80 foot column of residue is approximately 14 years (5113 days); a value commensurate with the 10 year (3652 day) estimate from the MODFLOW model. These dewatering calculations assume drainage only through the geocomposite drainage collection layer. The calculations ignore drainage through the overlying layer of LTVSMC Coarse Tailings. This means that drawdown may be more rapid than modeled for an 80-foot column of residue.

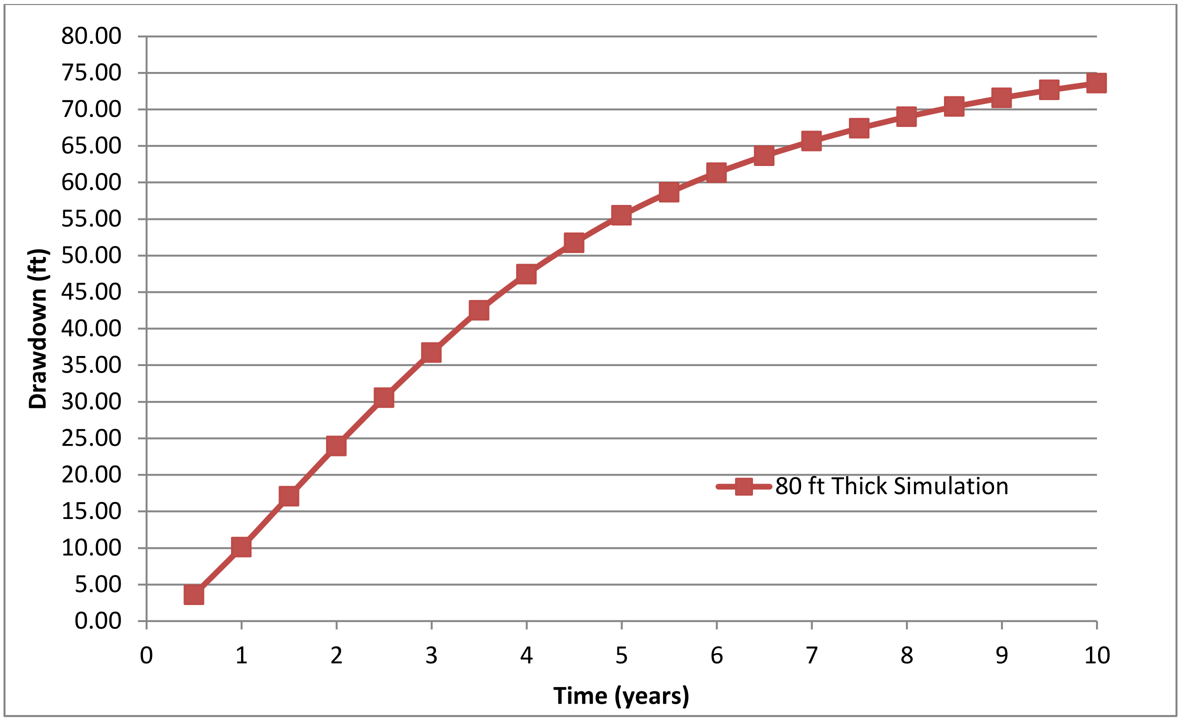

Figure 6-1 HRF Dewatering: Hydraulic Head Drawdown vs. Time at 125 Foot Drain Spacing

The estimates of drawdown time and consolidation are for facility design and permitting. The Project design includes flexible features such as the availability of the WWTP during reclamation and long-term closure to treat HRF leachate for as long as it is generated. Residue generated during full-scale operations will be tested to update estimates of drawdown time, and these updates will be included in annual reporting as described in the Residue Management Plan (Reference (1)), along with any planned changes in operations based on monitoring data and operational experience.

Prior to Residue deposition within the HRF, coarse tailings will be placed as a granular filter over the strips of geocomposite to prevent migration of the Residue into the geocomposite. The fly ash component of any relocated coal ash is anticipated to have a particle size distribution and hydraulic conductivity similar to that of the Residue, so it is anticipated that the coarse tailings will also separate any relocated coal ash from the geocomposite drainage layer. Prior to coal ash relocation, ash samples will be collected and evaluated for gradation to confirm that the drainage layer design remains adequate. Design equations used to determine granular filter gradation requirements are (Reference (20)):

$$\frac{D_{15(Filter\ Soil)}}{D_{85\ (Soil\ to\ Protect)}} \leq 4$$ **Equation 6-2**

$$\frac{D_{15(Filter\ Soil)}}{D_{15\ (Soil\ to\ Protect)}} \geq 4$$ **Equation 6-3**

Where, for a design based on characteristics of the Residue:

> $D_{15(Filter\ Soil)}$ = nominal diameter of which 15% by weight of the protective filter material (coarse tailings) is finer
>
> $D_{15(Soil\ to\ Protect)}$ = nominal diameter of which 15% by weight of the material to be protected (Residue) is finer
>
> $D_{85(Soil\ to\ Protect)}$ = nominal diameter of which 85% by weight of the material to be protected (Residue) is finer

These equations provide a range of acceptable D_{15} particle sizes for a filter material. This range is between 0.06 mm and 0.30 mm for the $D_{15\ (Filter\ Soil)}$; LTVSMC coarse tailings. The average D_{15} particle size for LTVSMC coarse tailings is 0.075 mm. Filter criteria for a geotextile states the apparent opening size of the geotextile must be less than or equal to twice the D_{85} particle size of the filtered material. D_{85} particle size doubled is 2.5 mm. Thus, a geotextile with apparent opening size of 0.212 mm would be appropriate for this filter configuration. If erosion of the coarse tailings appears to be a problem at the onset of impounding Residue in the HRF, sand bags or similar means can be used to secure the geocomposite.

A number of design features are included to reduce the potential for clogging the geocomposite strips. The LTVSMC Coarse Tailings cover over the geocomposite strips is selected to prevent migration of residue into the geocomposite strips. The design of the geocomposite includes a performance reduction factor (thereby requiring a higher performing geocomposite) to account for chemical precipitation within the geocomposite. Further, the LTVSMC Coarse Tailings cover provides a continuous drainage layer through which drainage to the Drainage Collection Sump for subsequent removal will also occur.

The geocomposite must have sufficient compression strength to withstand the overburden pressure induced by the Residue. Geonets are selected to have a compressive strength twice the stress that they are expected to resist (Reference (32)). Assuming a complete saturated column of Residue at the expected deepest area in the HRF (worst-case scenario), the applied total stress is approximately 9,200 psf. Considering this criteria, a geonet approximately 270 mm thick with a nonwoven geotextile heat-bonded to both sides with a compressive strength greater than 18,000 psf is recommended. Detailed specification of the selected geocomposite will be provided in construction specifications for Agency reference prior to construction.

Settlement due to consolidation of materials within the Emergency Basin (underlying the HRF) is expected to have negligible impact on the performance of the drainage collection system. The system is designed to move liquid to the drainage collection sump in the northwest corner of the HRF utilizing a 1% slope. Assuming settlement occurs within the Emergency Basin material at a uniform rate, equivalent settlements can be determined for various locations in the Emergency Basin based on the material depth and End of Operations settlement at Node A. The 1% slope of the drainage collection system will decrease the most between areas experiencing greater settlement than for areas experiencing less settlement. Settlements were calculated at Node A and along cross-sections H-H' (Large Figure 9) at borings 70-ST13-A (deep area of Emergency Basin) and 70-ST-12 (shallow area of Emergency Basin) and added to the change in elevation due to the 1% grade to preliminarily estimate the reduction in slope at the bottom of the HRF. The estimated total changes in elevation due to settlement at Node A, 70-ST-13A and 70-ST-12 are 1.4 feet, 3.85 feet, and 6.13 feet, respectively. These settlements correlate to a slope of 0.75% between 70-ST-12 and 70-ST-13A; and a slope of 0.96% between 70-ST-13A and Node A. Slope change is depicted in Large Figure 38.

The minimum design slope suggested for the drainage collection system is 1% to facilitate drainage of virtually all free liquid from the HRF as part of reclamation activities. Based on the preliminary estimates of settlement summarized above, the slope of the base of the HRF may fall below the minimum recommended value, depending on actual settlements that occur. Rather than overbuilding the liner slopes based on the modeling performed to date, the settlement of the HRF subgrade will be monitored during pre-load fill placement to gather additional data on which final settlement estimates will be based. Slope adjustments will then be made based on these final settlement estimates.

6.3.2 Leakage Collection System

The upper liner of the HRF liner system will consist of a single geomembrane liner. Any defects in this liner that go undetected and unrepaired during construction will yield leakage of HRF pond water to the geocomposite drainage layer underlying the upper geomembrane and overlying the lower composite geomembrane and geosynthetic clay liner system. The geocomposite must be selected and configured with sufficient transmissivity and cross-sectional flow area to transmit any leakage through the upper geomembrane liner to the leakage collection sump without building excessive hydraulic head (typically ≤ 1 foot) on the lower composite liner system. Maintenance of a low hydraulic head on the lower composite liner is the means by which virtually all leakage through the lower composite liner is prevented. Computation of the leakage rate through the upper layer of the HRF liner system is necessary so that the rate at which water is captured, treated, and pumped to the HRF during operations and to the FTB (or water treatment plant) in closure is properly accounted for in the FTB water balance. The following assumptions are used to calculate the leakage rate through the upper layer of the double liner system.

- Leakage through the upper liner, consisting of a single geomembrane, occurs entirely through potential defects in the upper liner.

- For the liner leakage calculations, the defects in the single geomembrane are assumed circular with a diameter of 1 centimeter and a frequency of 2.5 defects per acre.
- Flow through a defect is calculated using the orifice equation. Because there is a pond present in the design of the HRF, the head on the defect is simply the elevation difference between the pond water surface and the liner.
- Flow through the Residue is calculated using Darcy's Law for saturated porous media.
- Both the size and number of defects in the liner, or the conductivity of the Residue above the liner may limit flow through the upper liner.

The flow per unit area, q, based on the orifice equation is shown in Equation 6-4, where n is the number of defects per acre [$1/L^2$], a is the area of the defect [L^2], H is the depth of the Residue over the liner [L], and d is the distance between the water surface and the Residue surface (negative if the water drops below the Residue, positive if there is a standing pond) [L].

$$q = 0.6na\sqrt{2g(H + d)}$$ **Equation 6-4**

When a standing pond is present in the HRF, the flow per unit area, q, based on Darcy's Law is shown in Equation 6-5, where K is the saturated permeability of the Residue. When the water surface drops below the Residue while it is draining in closure, the flow per unit area is simply equal to the saturated hydraulic conductivity; in other words, d equals zero.

$$q = K\left(\frac{H + d}{H}\right)$$ **Equation 6-5**

Leakage flow is constrained by the limitations on flow through liner defects (the orifice equation) and by the hydraulic conductivity of the Residue (Darcy's law). Figure 6-2 is an example plot of leakage flow based on the orifice equation and Darcy's Law at different Residue depths. When Residue is shallower, flow is constrained by the inability of liner defects to transmit an unlimited amount of flow, so the controlling flow line (the dark blue line) follows the orifice equation (purple line). However, as the Residue depth increases, a point is reached where flow becomes constrained by the hydraulic conductivity of the Residue, which controls the rate at which liquid can move through and drain from the Residue (the orange line). From that point, the controlling flow line follows Darcy's Law (the orange line). The Drainage Collection System is designed to collect the leakage flow as shown by the dark blue controlling flow line.

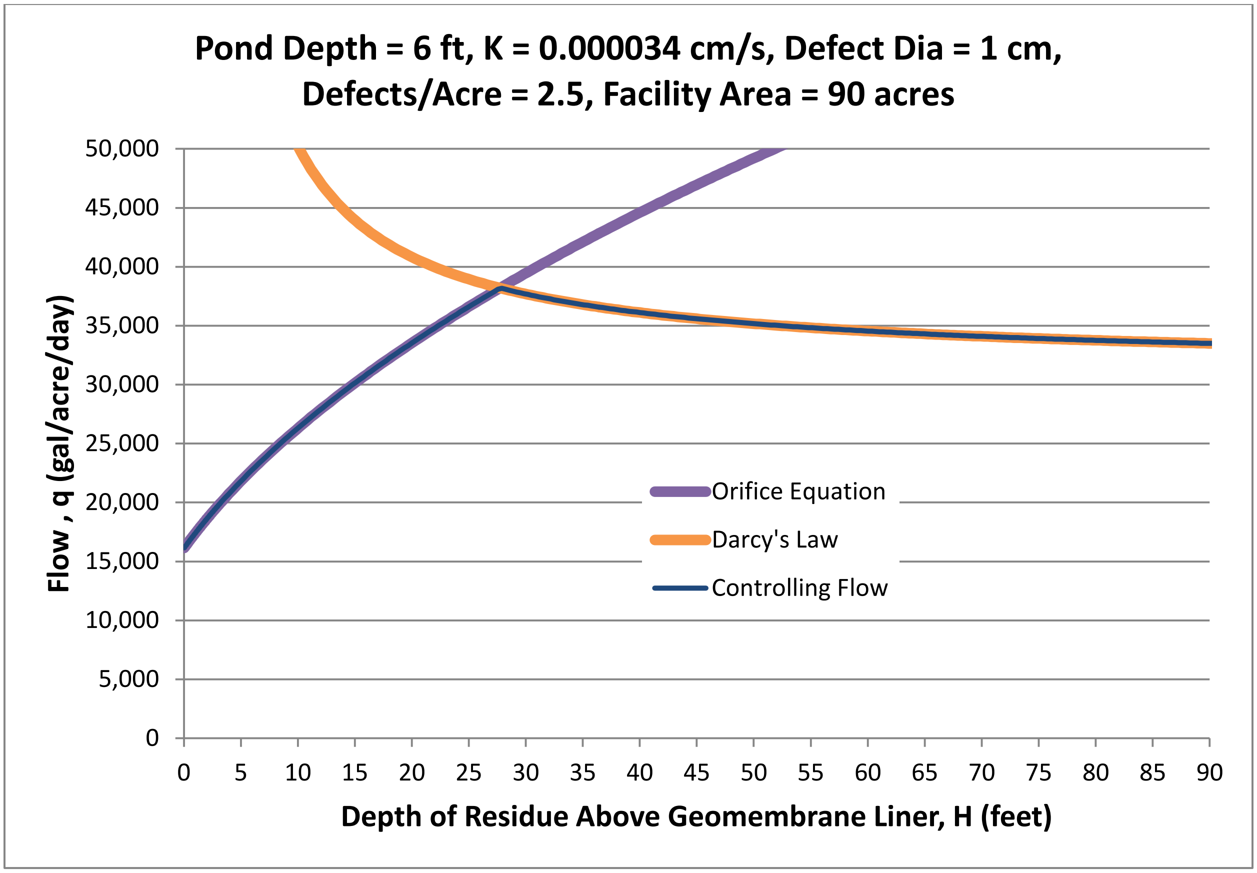

Figure 6-2 HRF Dewatering: Hydraulic Head Drawdown vs. Time

The estimated flow presented in Figure 6-2 represents that flow that the geocomposite drainage layer, underlying the upper liner, must be designed to collect in order to maintain less than or equal to one foot of hydraulic head on the lower composite (geomembrane over geosynthetic clay) liner system. It is the geocomposite drainage layer in combination with the configuration of the underlying composite liner and leakage collection system that produce an overall HRF liner system yielding virtually no leakage from the HRF.

The geocomposite in the HRF leakage collection system will be a continuous layer. This is a change from earlier HRF leakage collection system designs that envisioned strips of geocomposite at a 130-foot spacing between the upper and lower geomembrane components of the liner system. Design calculations for the HRF Leakage Collection System geocomposite layer, presented in Attachment E, assume strips of geocomposite, rather than a continuous layer. Attachment E calculations, which show that the configuration with strips of geocomposite could provide adequate capacity to collect the calculated leakage flow, have not been updated for this document. The continuous layer of geocomposite will be equal to or improve on the capacity of the leakage collection system shown in Appendix E, and thus provide adequate capacity to transmit the leakage occurring through the upper geomembrane into the Leakage Collection

System, limiting hydraulic head on the lower geomembrane and achieving practically zero leakage from the HRF. Since the geocomposite layer is now continuous, geocomposite transmissivity requirements might be reduced from those assumed in Attachment E. These requirements will be determined during final design.

The Leakage Collection Sump is sized to accommodate the maximum leakage flow, which will take place during the first lift of the HRF. The Leakage Collection Sump is designed to handle a flow of approximately 8,000 gallons/minute (the transmissivity of a geocomposite such as the GSE PermaNet SL, with design safety factors applied, is approximately 4 gallons/minute/foot; multiplied by the 2,000-foot sump perimeter). The maximum estimated leakage is approximately 2,340 gallons/minute (the maximum leakage rate of 38,000 gallons/acre/day multiplied by the ultimate HRF footprint of roughly 90 acres), well below the 8,000 gallon/minute capacity of the geocomposite and the Leakage Collection Sump. Leakage collection system design computations and HRF leakage rate computations are provided as Attachment E.

The HRF liner design assumes that post-construction liner leak location surveys are imperfect and that some defects in the upper geomembrane component of the liner system remain undetected and unrepaired following liner construction. Recently developed geomembranes facilitate post-construction leak location surveys that are proven capable of detecting all liner defects. The defects can then be repaired prior to placing the lined facility into service. At the point in time when the HRF proceeds to permitting, PolyMet will evaluate recently developed geomembranes as an alternate to the proposed geomembranes, as means by which overall liner configuration can potentially be simplified while still achieving the objective of a virtually leak free HRF.

6.4 Chemical Compatibility of GCL with Leakage from Hydrometallurgical Residue

The GCL selected for the HRF must be able to meet performance standards under the chemical and climatic conditions expected at the HRF. This topic is fully addressed in Section 2.2.2.3 of the Residue Management Plan (Reference (1)). In brief, ions such as those of calcium and sodium are known to have potentially detrimental effects on the long-term permeability of GCLs; the GCL permeability has the potential to increase in the presence of such ions, particularly when these ions are present in high concentrations. Therefore, two GCL suppliers (CETCO and GSE) were requested to evaluate the potential for any leakage that occurs through the geomembrane liner of the HRF to have a detrimental effect on the permeability of their GCLs.

CETCO and GSE utilized the services of JTL Laboratories, Inc. (JTL) to perform permeability tests on a number of GCL samples permeated with a synthetic leachate. The leachate was manufactured by GSE and CETCO and supplied to JTL as described in the test reports provided in Attachment F. As described in the May 13, 2008 test report provided by CETCO (Attachment F), three GCLs were manufactured by CETCO for permeability testing using the synthetic leachate as the permeant. The test on one GCL containing a plastic membrane component was terminated early-on due to impracticalities associated with manufacturing of the product. The two other CETCO GCLs were prepared by adding two different proprietary high molecular weight polymers to the sodium bentonite used in the GCL. Based on the tests performed by JTL for CETCO, the GCL utilizing the “R-101” polymer formulation was most successful and is expected to have a long-term permeability of 1.5 x 10^{-9} cm/sec when permeated with leakage, should it occur through the geomembrane liner of the HRF.

In the testing, the CETCO R-101 GCL was directly hydrated with the synthetic leachate. Research indicates that prehydration with clean water prior to exposure to high ionic strength liquids is beneficial to GCL performance (Attachment F). Freshwater prehydration, which is expected to occur at the HRF as the GCL absorbs moisture from the facility subgrade soil, would improve GCL performance above the laboratory test results.

Testing of the CETCO R-101 GCL showed slight variability in permeability over the 500-day test. Measured permeability, which was initially approximately 6 x 10^{-10} cm/sec, increased to approximately 1.5 x 10^{-9} cm/sec. The noted hydraulic conductivity increase is less than one order of magnitude, and computations provided in Attachment E demonstrate that the computed leakage rate through the GCL remains near zero even if the hydraulic conductivity of the GCL increases by two orders of magnitude.

Based on the June 16, 2010 data reported by JTL Laboratories to GSE, the GCL provided by GSE for testing using synthetic leachate as a permeant is expected to have a long-term permeability of about 7.2 x 10^{-10} cm/sec when permeated with leakage, should it occur through the geomembrane liner of the HRF.

The potential effects of climatic conditions on GCL performance, particularly effects of freeze-thaw cycles, have been studied by numerous researchers (Reference (27)). Findings indicate that GCL performance is minimally affected by freeze-thaw cycles. Further, the majority of the GCL component of the hydrometallurgical residue facility liner system will be below the water elevation, and therefore not exposed to freeze-thaw cycles. The portions of the GCL that are above the water elevation will only undergo freeze-thaw cycles for a limited amount of time; i.e., only for a few years until the hydrometallurgical residue facility is raised vertically. Available evidence indicates that the GCL’s limited exposure to freeze-thaw cycles is not expected to significantly affect its performance.

Based on the laboratory testing reported herein, specifications for the GCL component of the HRF should require use of polymer-treated GCL manufactured specifically in anticipation of the chemical characteristics of the liquid and the pore water that will be contained within the HRF.

7.0 Revision History

Date	Version	Description
9/29/2011	1	Initial Release
5/31/2012	2	Version 2 incorporates edits and updates made in response to Version 1 review comments received from the MDNR, USACE, EPA, ERM and Knight Piesold.
10/12/2012	3	Version 3 incorporates edits and updates made in response to Version 2 review comments received from the MDNR, USACE, EPA, ERM and Knight Piesold.
10/31/2014	4	Version 4 incorporates edits to address unresolved Co-lead agency comments as communicated to PolyMet by the MDNR on 08/22/2014. Additional changes to this document address the proposed relocation of coal ash to the HRF, and the option of preload placement over multiple construction seasons as an alternate to wick drain installation.
11/26/2014	5	Version 5 resolves MDNR and Knight Piesold comments on Version 4, and integrates response to comments on Version 3 requested by the MDNR to be incorporated into Version 5.
7/11/2016	6	Updated to include signed PE certification

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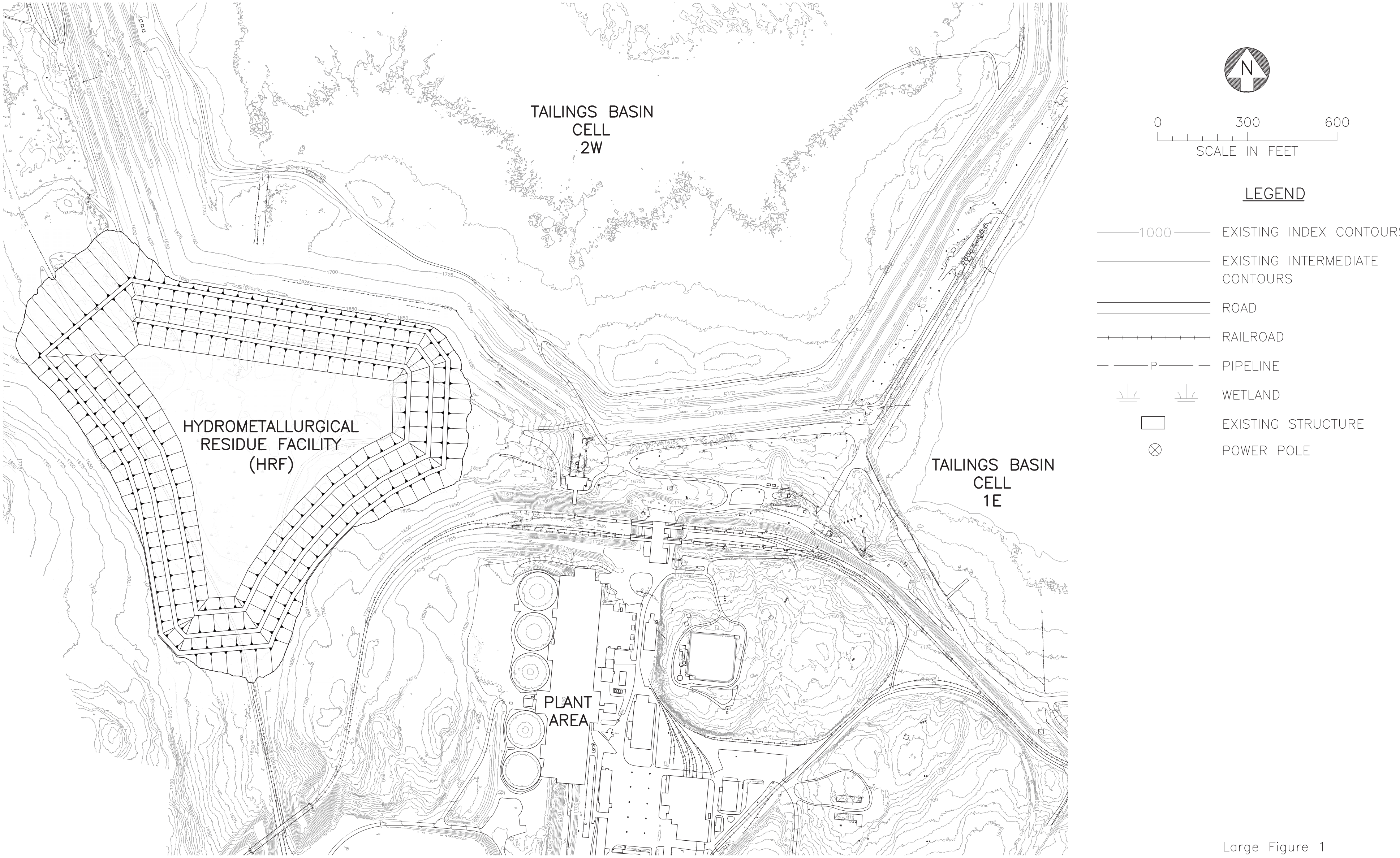
List of Tables

List of Figures

List of Large Figures

List of Attachments

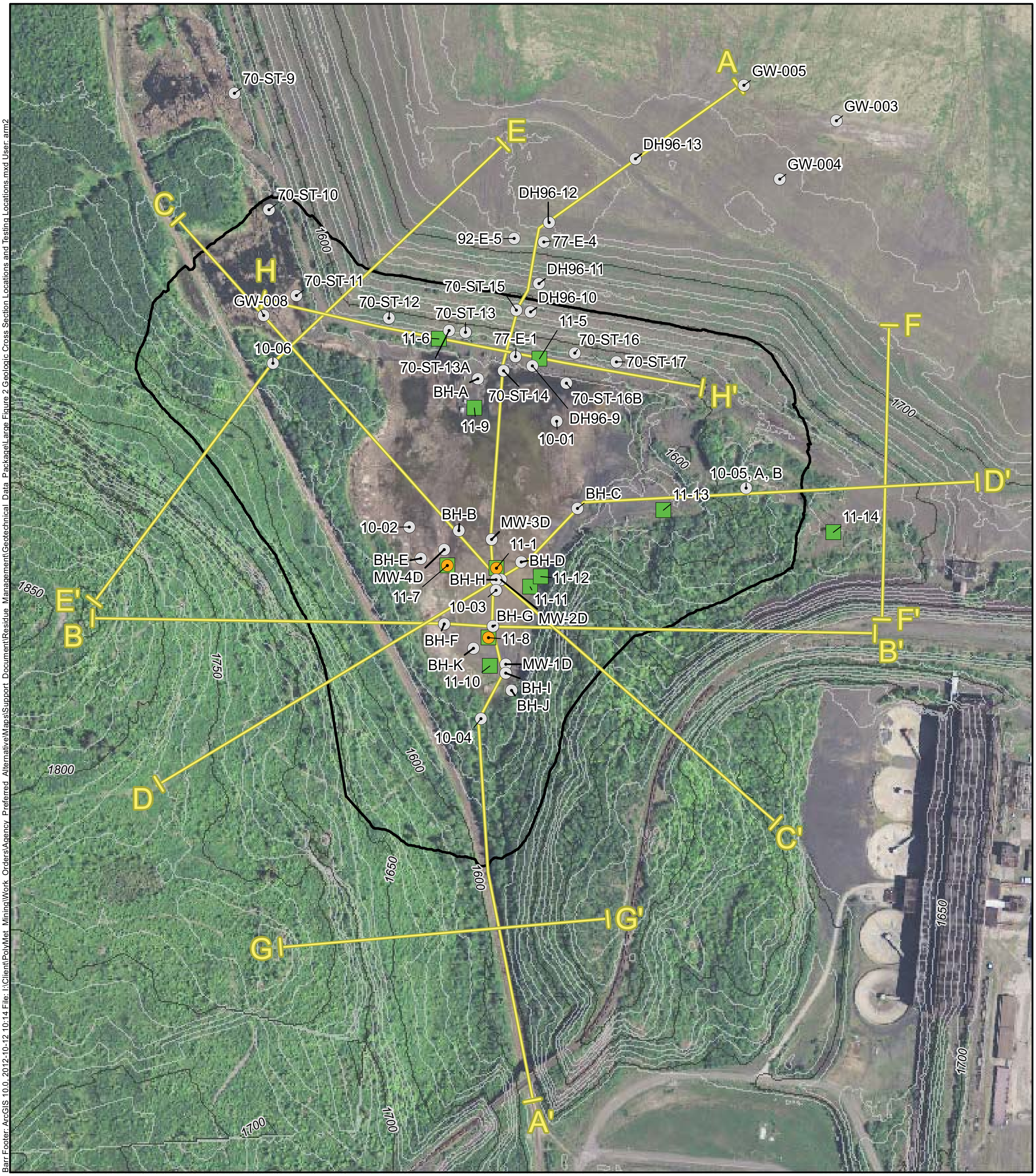
Large Figures



Large Figure 1

HRF LOCATION DIAGRAM

PolyMet Mining Company
Hoyt Lakes, MN



Historic Boring

DMT Testing

CPT Testing

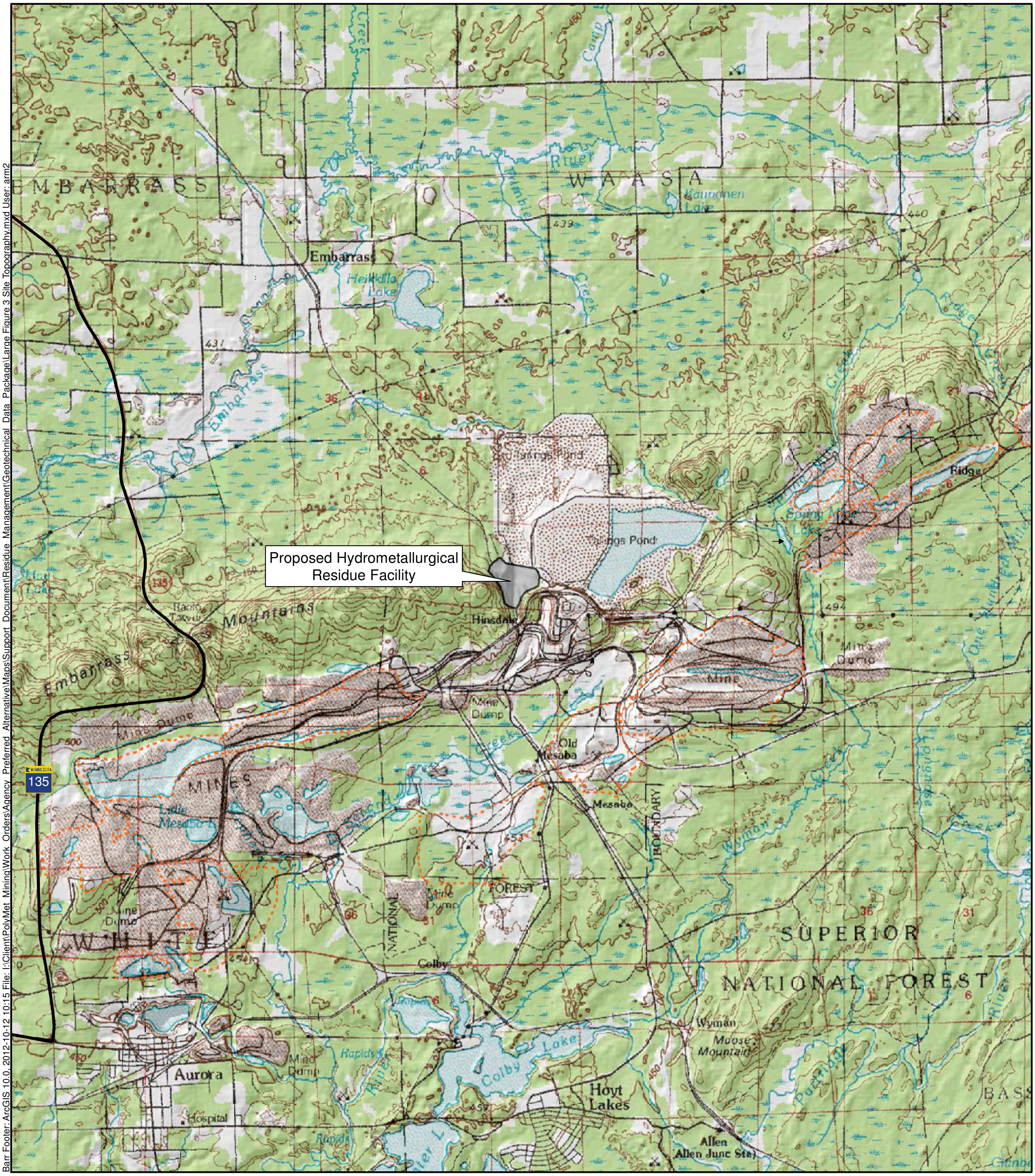
Cross Section Line

HRF Footprint

0 300 600 1,200

Feet

Large Figure 2
HRF GEOLOGIC CROSS SECTION LOCATIONS AND TESTING LOCATIONS
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

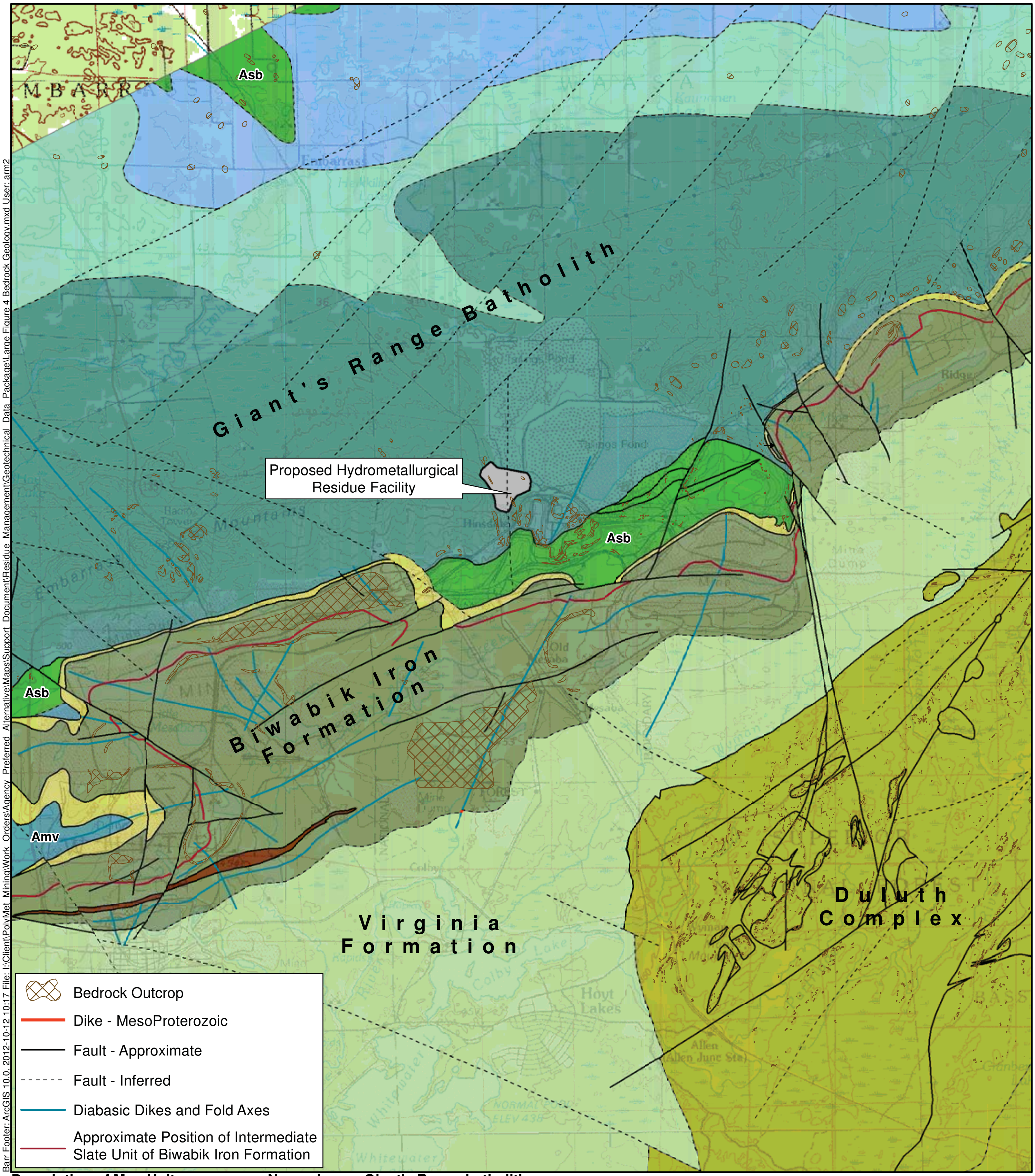


Taconite Pits

Sources:
USGS Lake Vermillion 100:000 Quadrangle
Taconite Pits: DNR Mining Features, 2009.

0 0.75 1.5 3
Miles

Large Figure 3
HRF AREA SITE TOPOGRAPHY
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



Description of Map Units

- Miscellaneous mafic intrusions

Mesoproterozoic

- Duluth Complex and associated intrusive rocks and North Shore volcanic rocks

Paleoproterozoic

- Virginia Formation
- Biwabik Iron Formation
- Pokegama Quartzite

Neoarchean - Giant's Range batholith

- Quartz monzonite and monzodiorite
- Quartz monzonite, monzodiorite, and monzogranite
- Tonalite to granodiorite

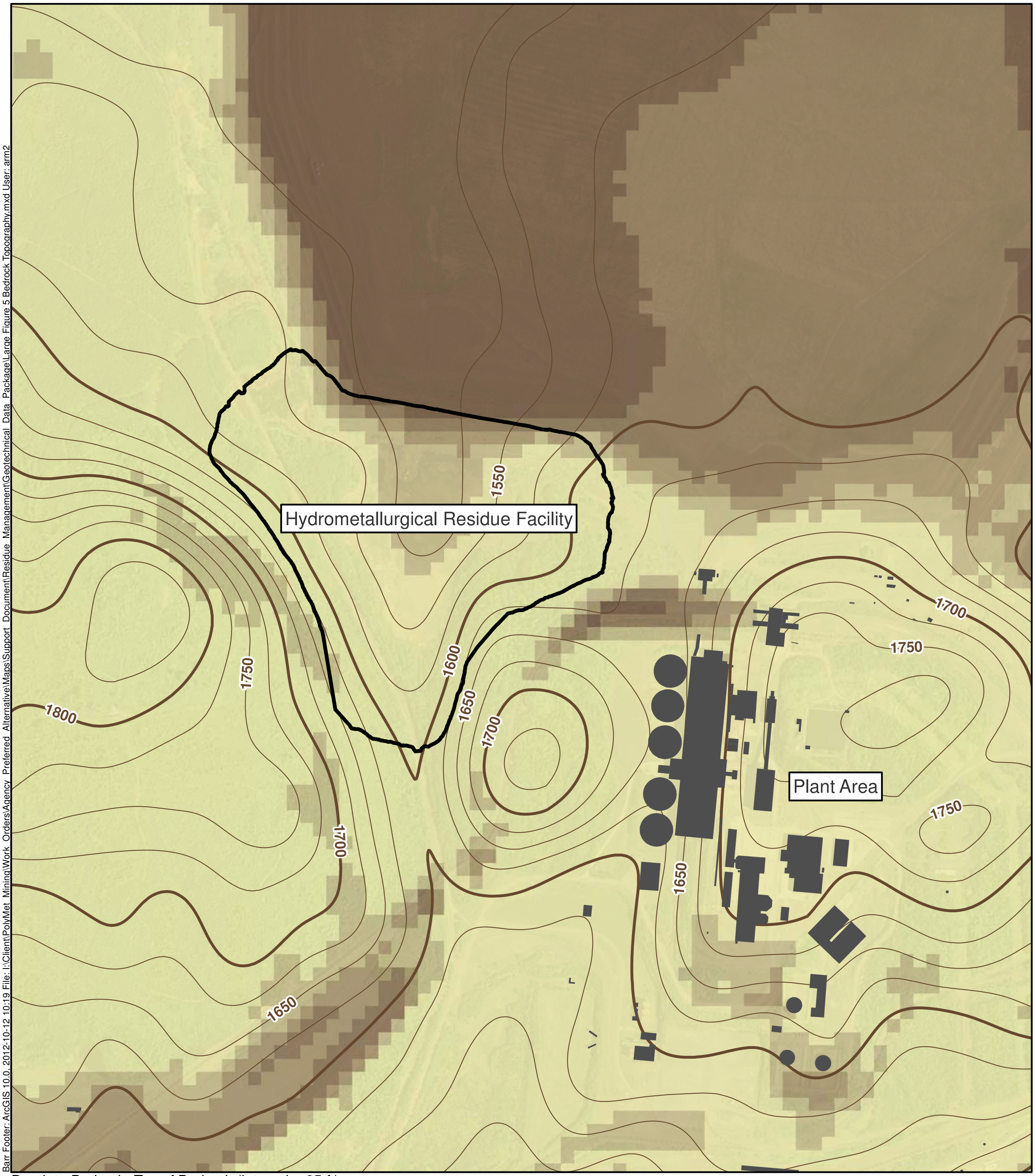
Neoarchean - Supracrustal and hypabyssal intrusive rocks

- Mud Lake sequence rocks
- Minntac sequence and inferred equivalent rocks

Sources: Geology: MGS M-163; Outcrop information: MGS M-141

0 0.75 1.5 3
Miles

Large Figure 4
HRF AREA
BEDROCK GEOLOGY
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



Depth to Bedrock

- < 25
- 25-50
- 50-75
- 75-100
- > 100

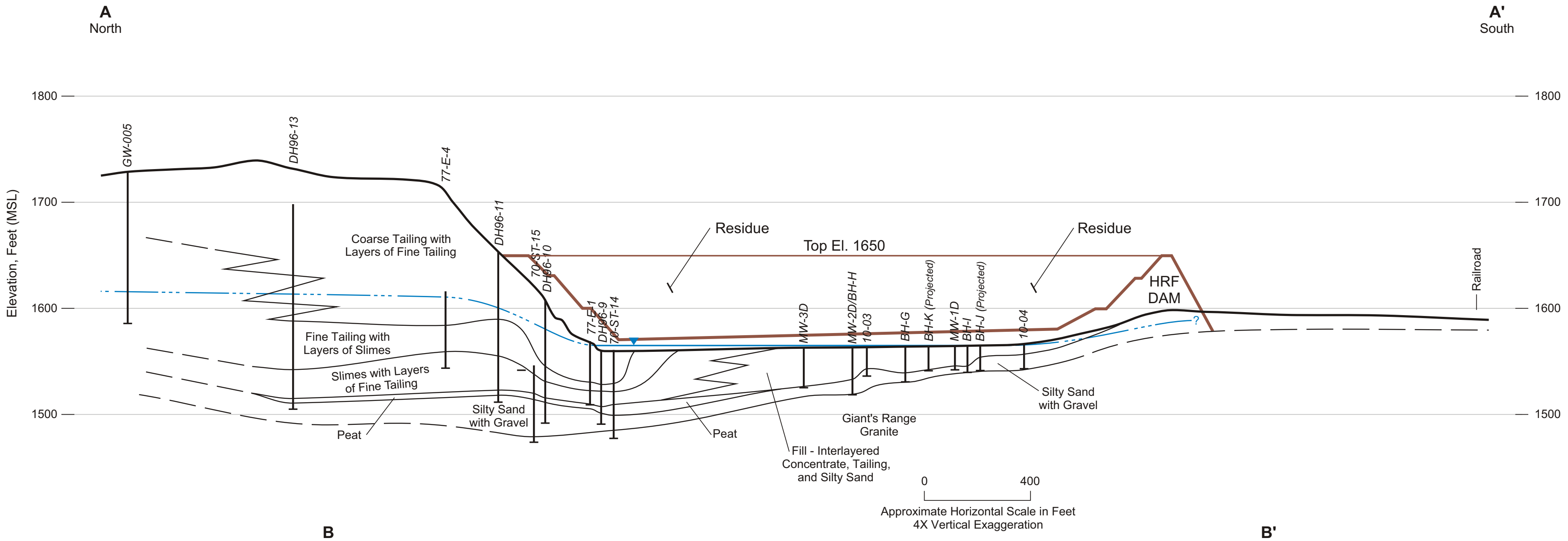
Top of Bedrock (interval = 25 ft)

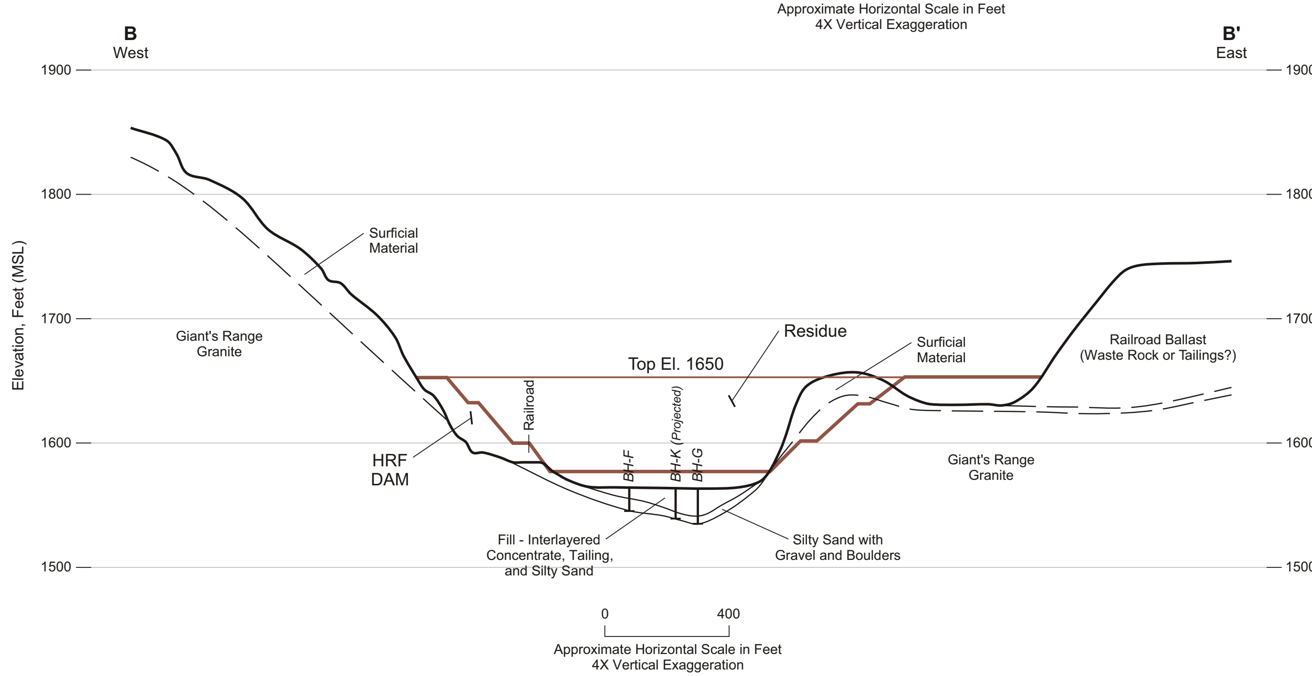
- 100 Ft Contour
- 25 Ft Contour

0 500 1,000 2,000
Feet

Large Figure 5
HRF AREA
BEDROCK TOPOGRAPHY
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

Sources: Top of bedrock: DNR Hydrogeologic database 2006
Depth to bedrock: MGS M-158





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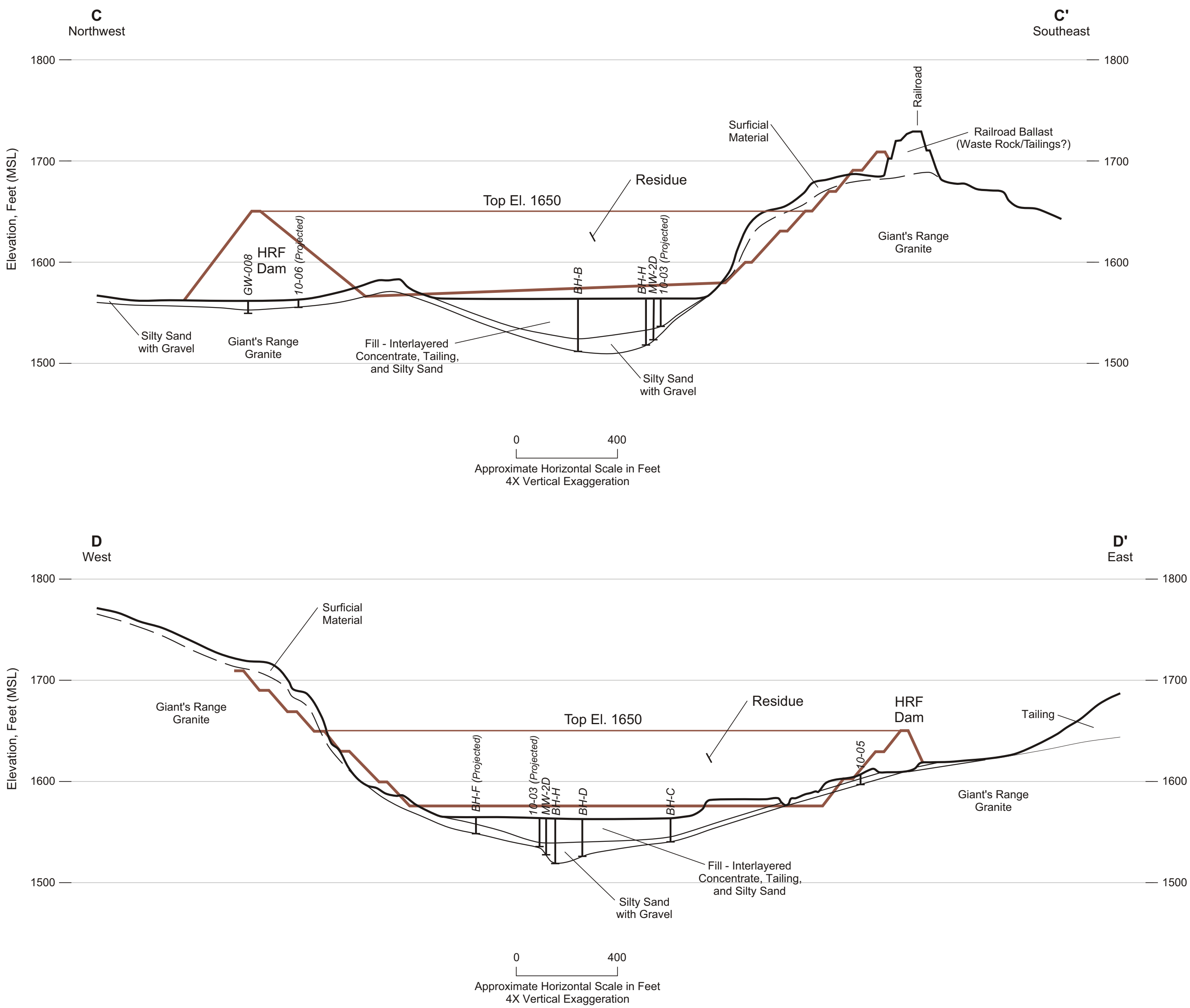
Large Figure 6

HRF GEOLOGIC CROSS SECTIONS
A-A' AND B-B'



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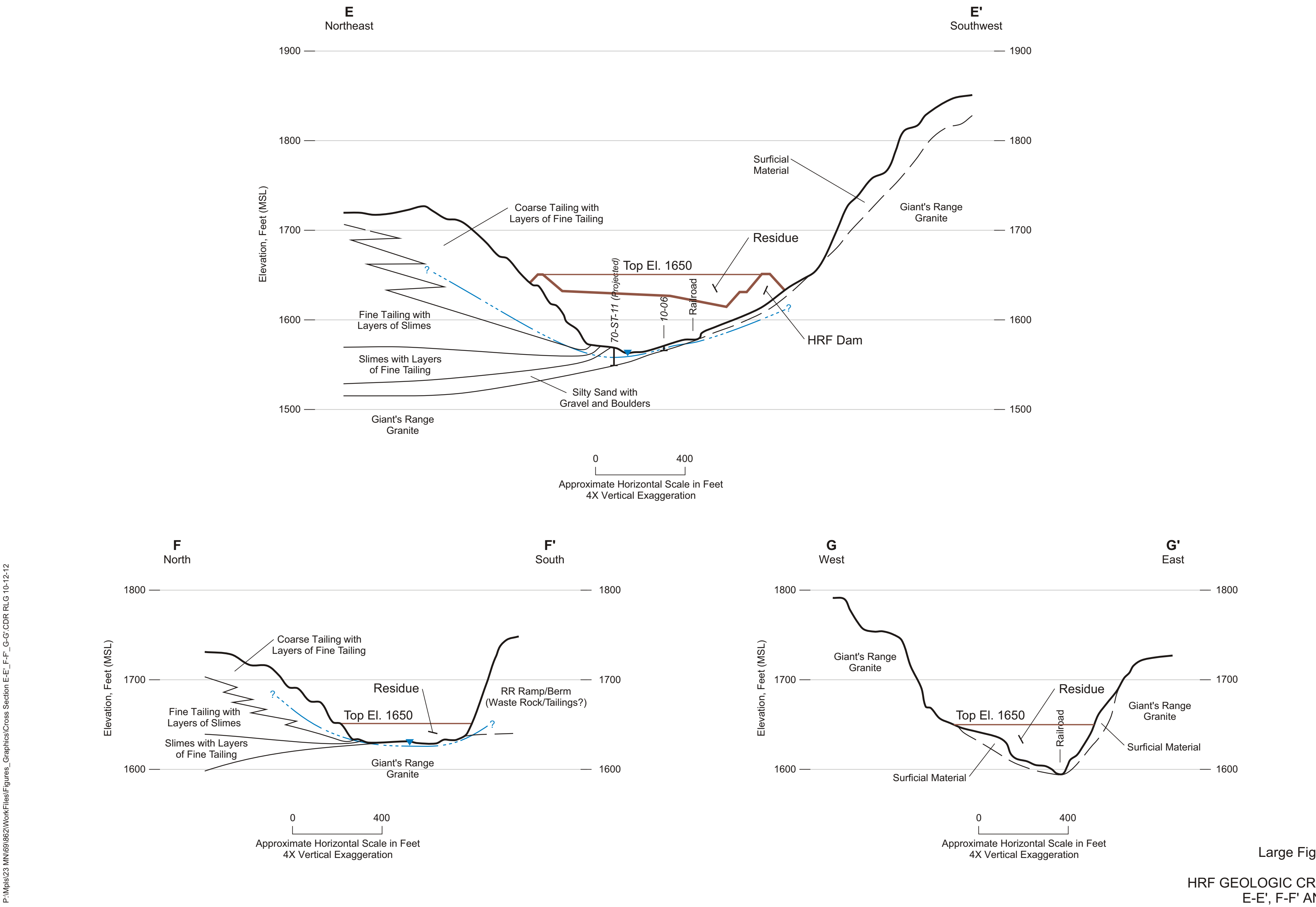
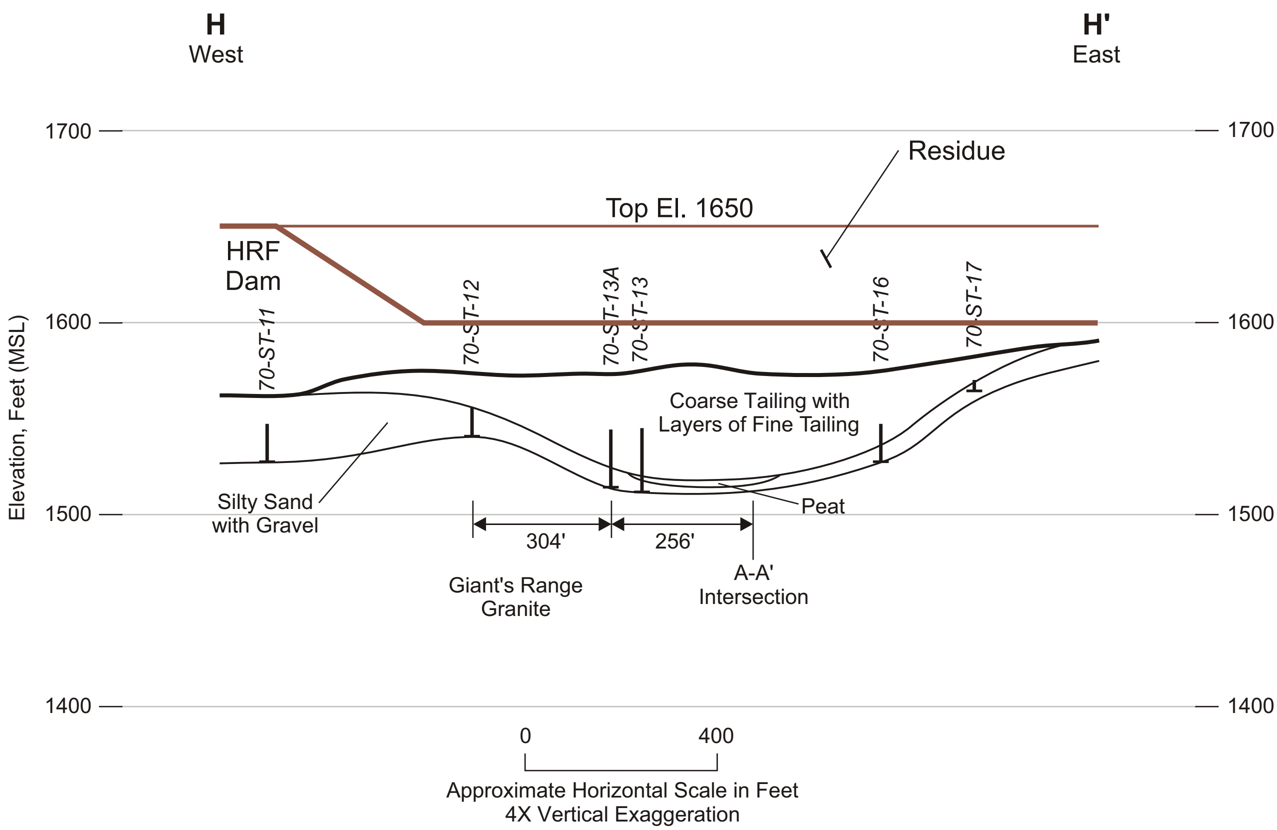
Large Figure 7

HRF GEOLOGIC CROSS SECTIONS
C-C' AND D-D'



Large Figure 8

HRF GEOLOGIC CROSS SECTIONS
E-E', F-F' AND G-G'



Large Figure 9

HRF GEOLOGIC CROSS SECTION H-H'

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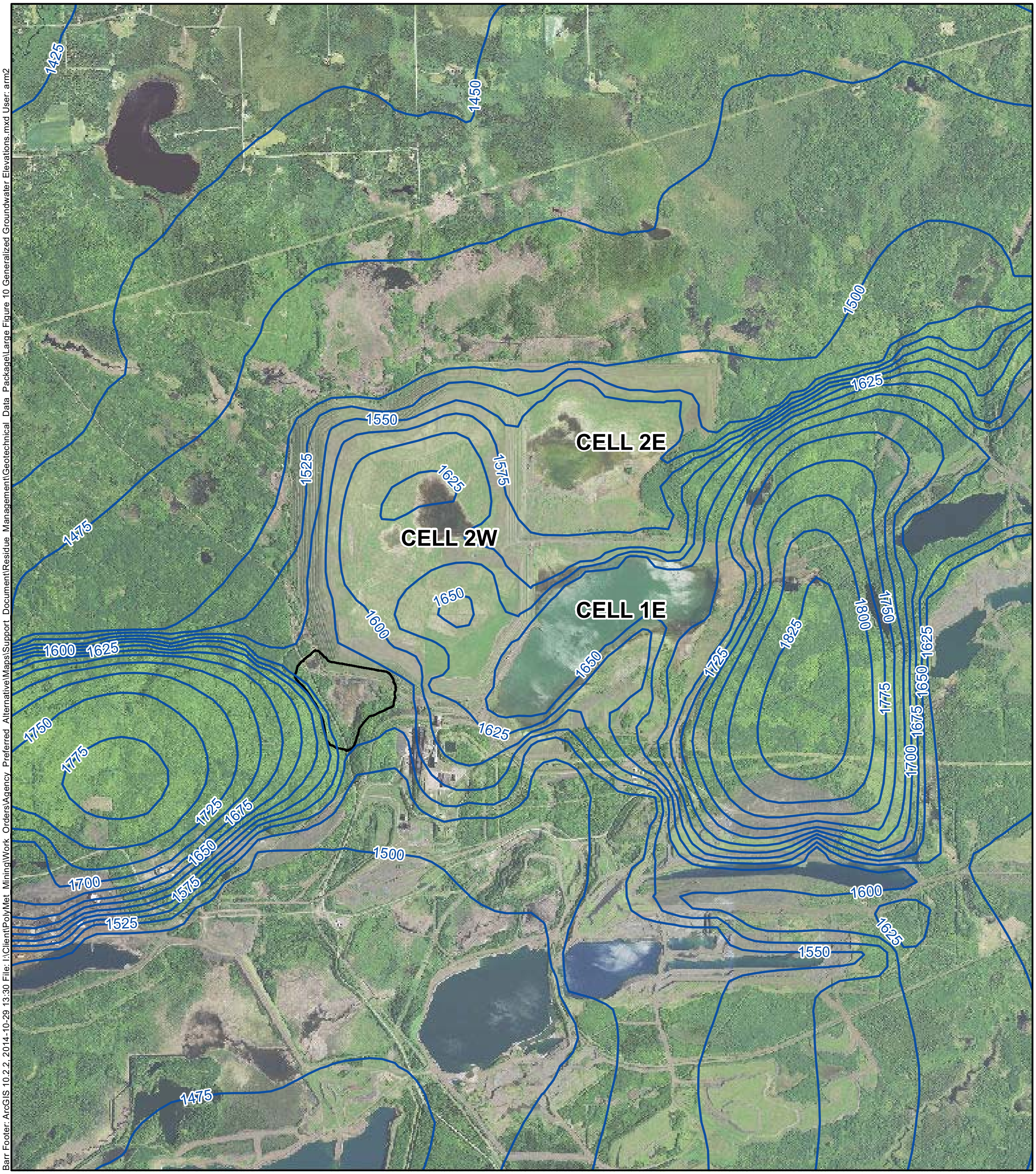


Surficial Aquifer Groundwater Contours[1]

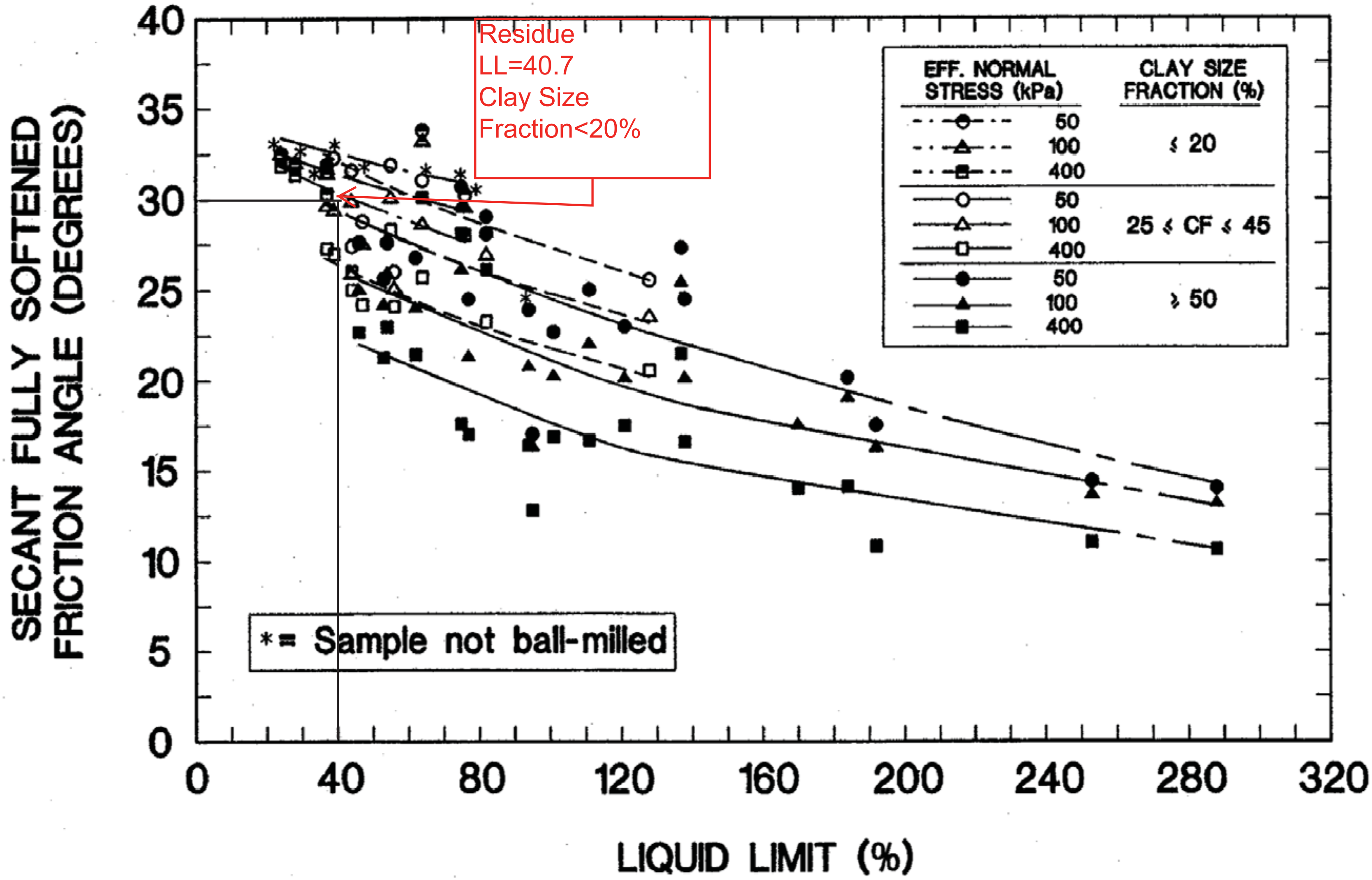
HRF Footprint

[1]Inferred water table contours were developed using a combination of measured groundwater elevations in site monitoring wells and contours from the Plant Site MODFLOW model.

0 2,000 4,000 8,000

Feet

Large Figure 10
HRF AREA GENERALIZED
GROUNDWATER ELEVATIONS
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN



Large Figure 11. Revised Fully Softened Friction Angle Relationships with Liquid Limit, Clay-Size Fraction, and Effective Normal Stress (Stark and Eid, 1997).

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Critical Cross Section A-A'
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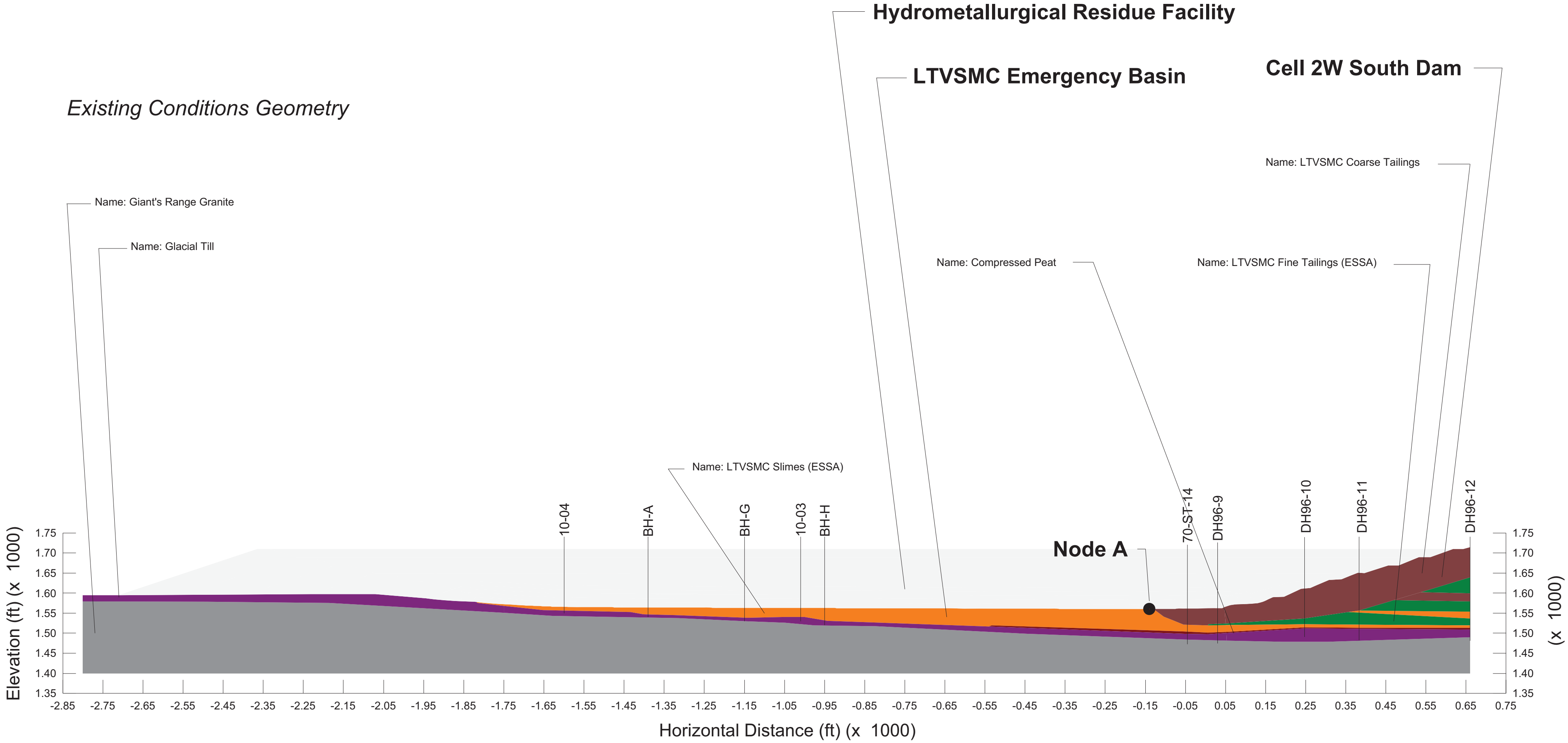
SEEP/W Analysis, Steady-State Method

Large Figure 12
Existing Conditions Geometry



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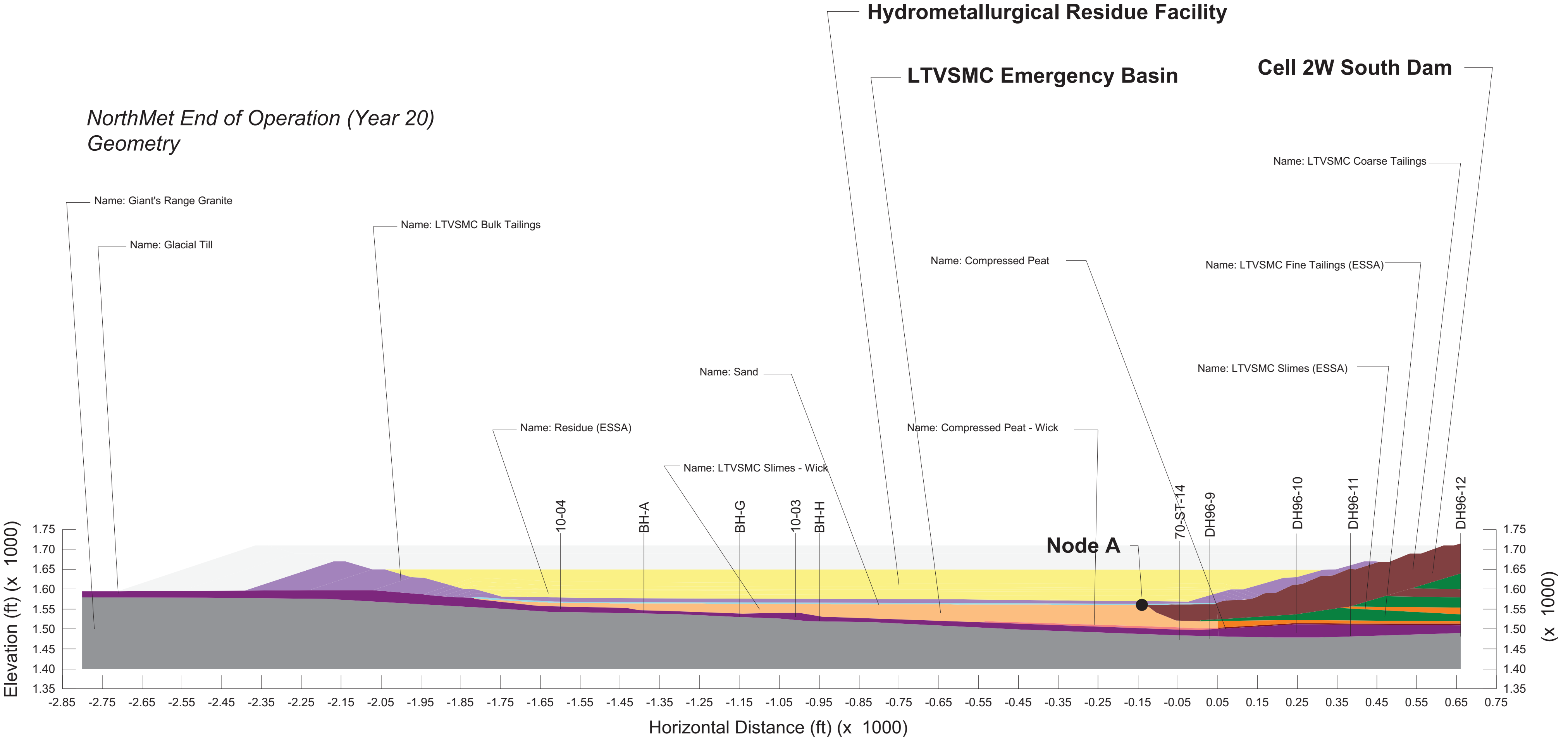
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/11/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 13
HRF End of Operation (Year 20)
Geometry A-A'



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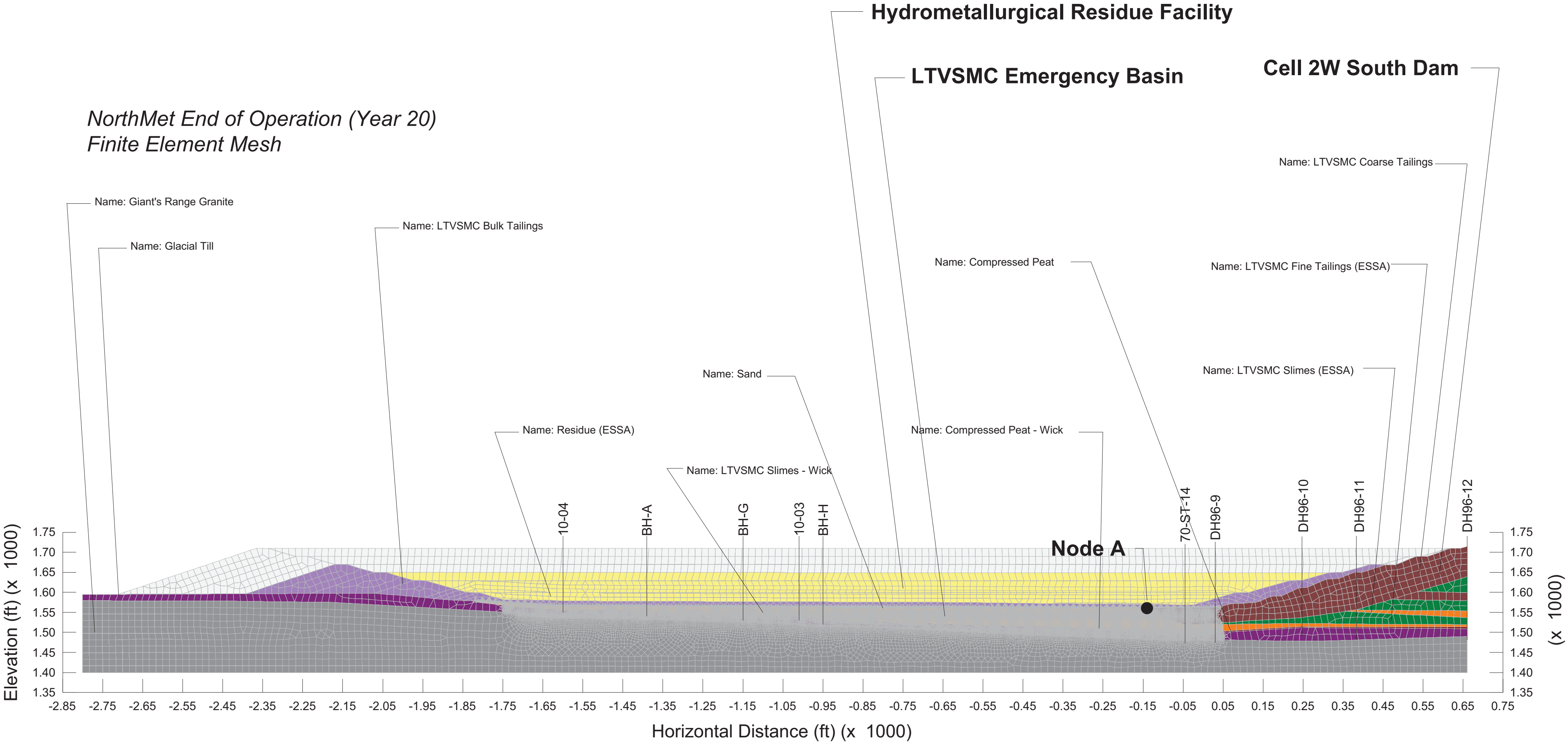
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/11/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 14
HRF End of Operation (Year 20)
Finite Element Mesh A-A'



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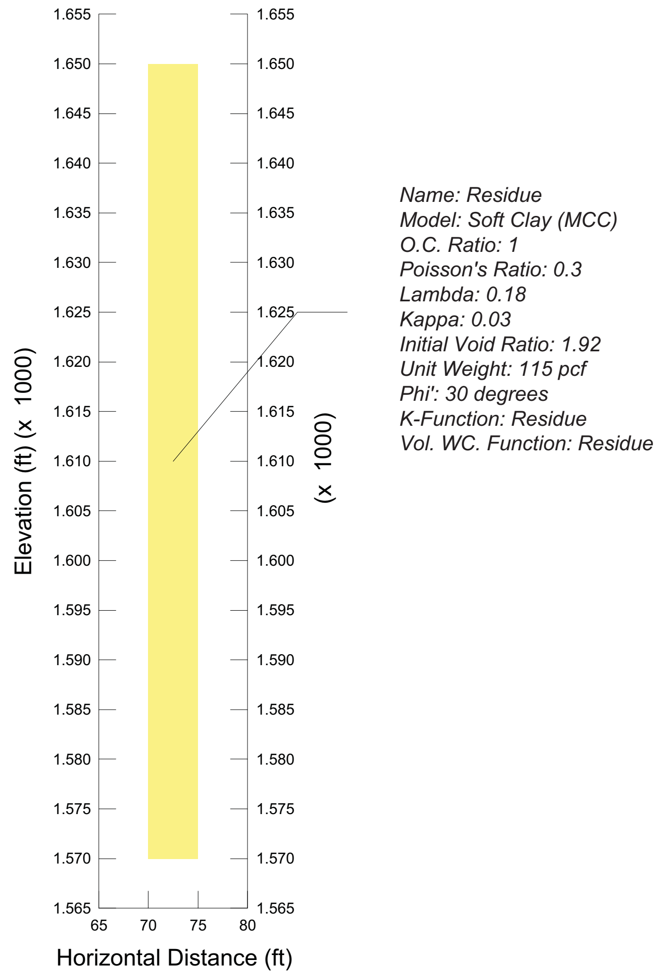
Large Figure 15
Residue Settlement Column

PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section
File Name: Residue Column.gsz
Date: 2/13/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Residue Settlement Column



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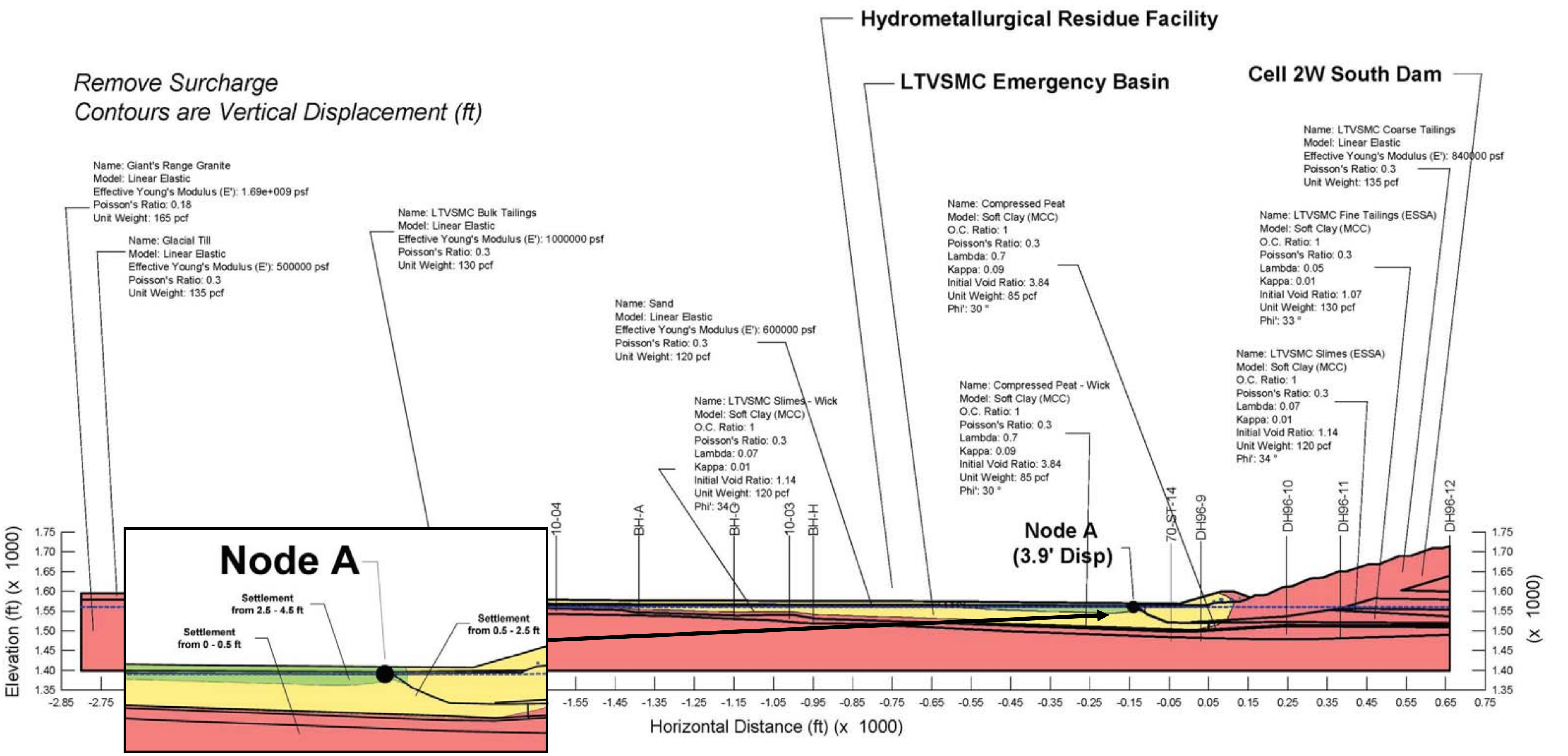
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 16
Total Vertical Displacement at Removal of Preload



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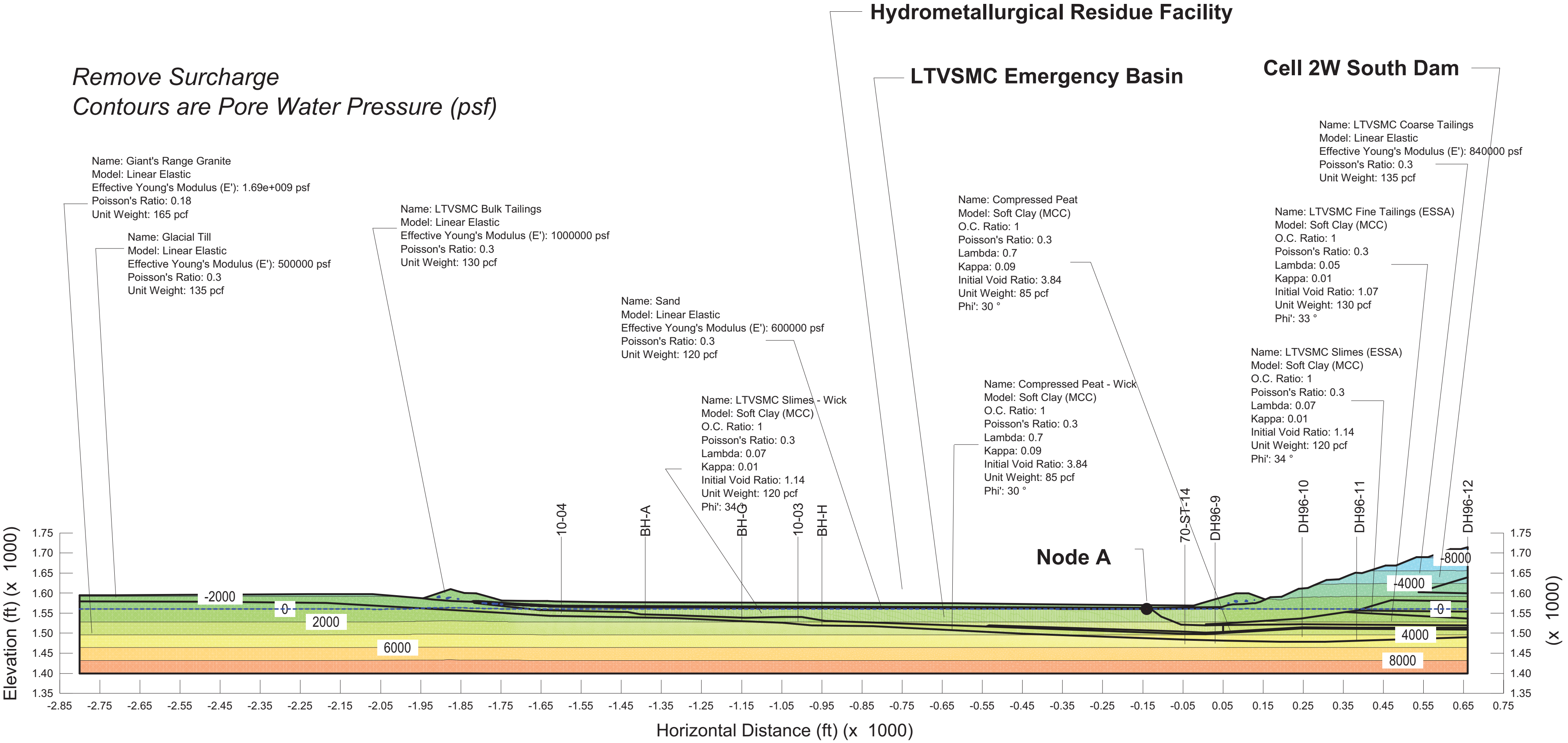
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 17
Pore-Water Pressure at Removal of Preload



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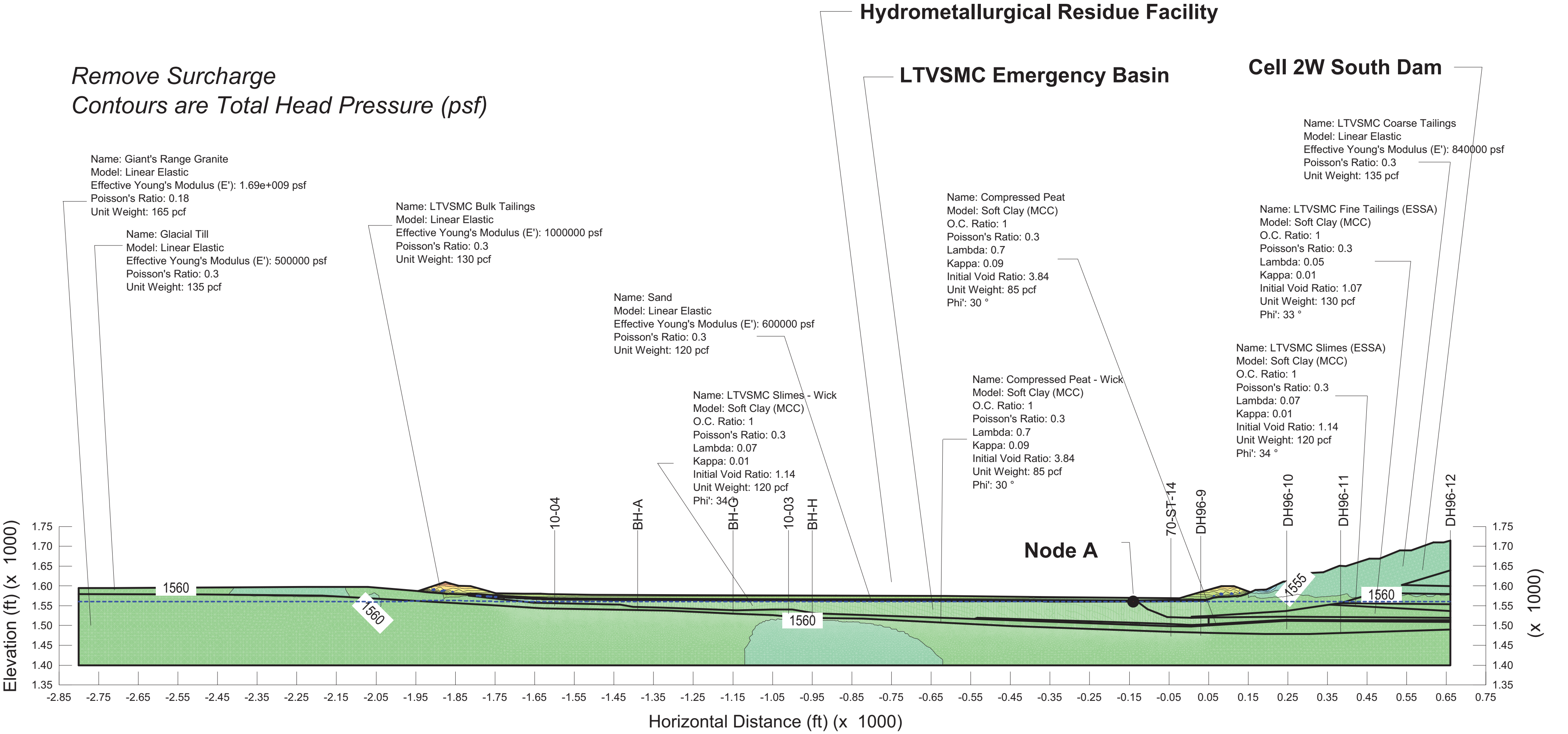
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 18
Total Head Pressure at Removal of Preload



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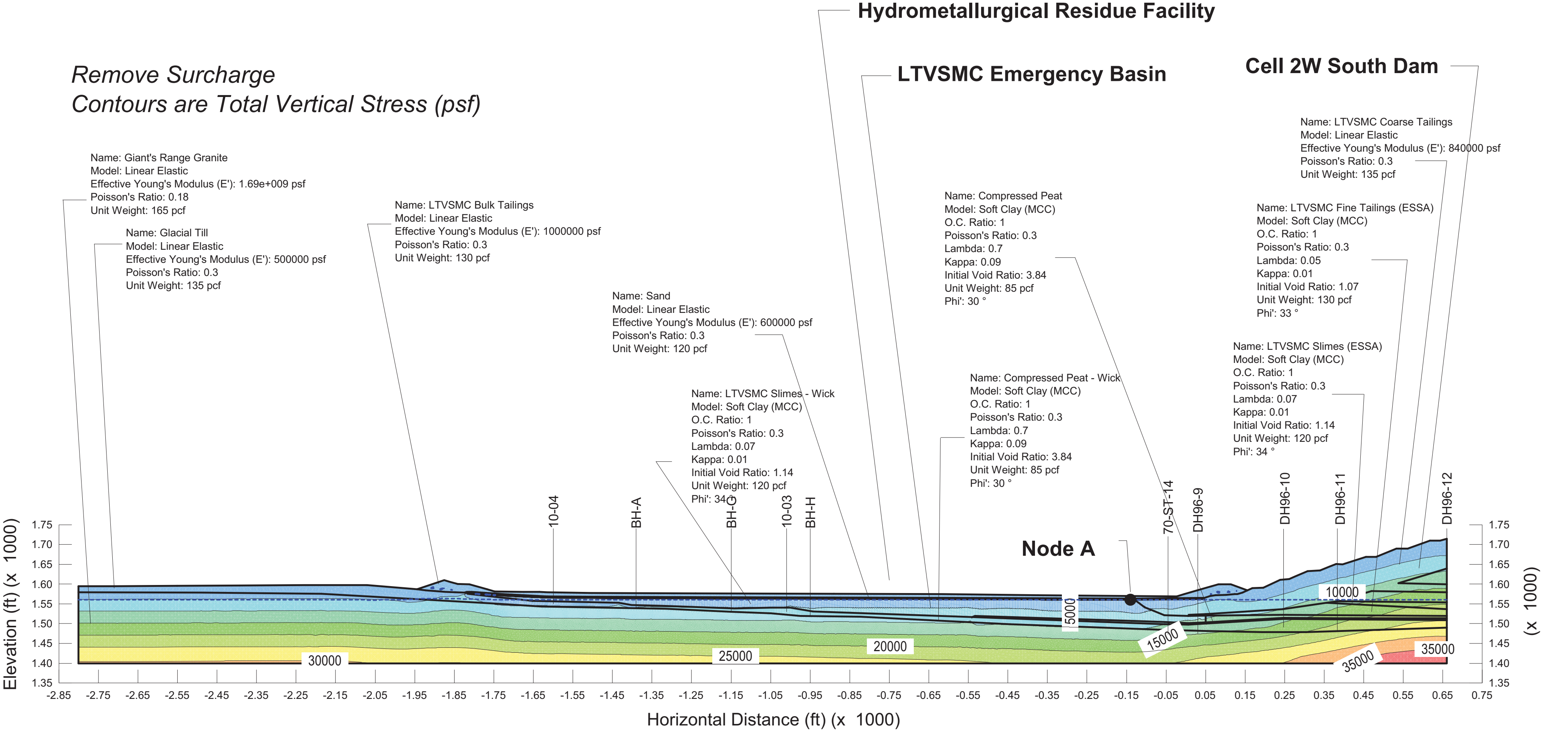
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 19
Total Vertical Stress at Removal of Preload



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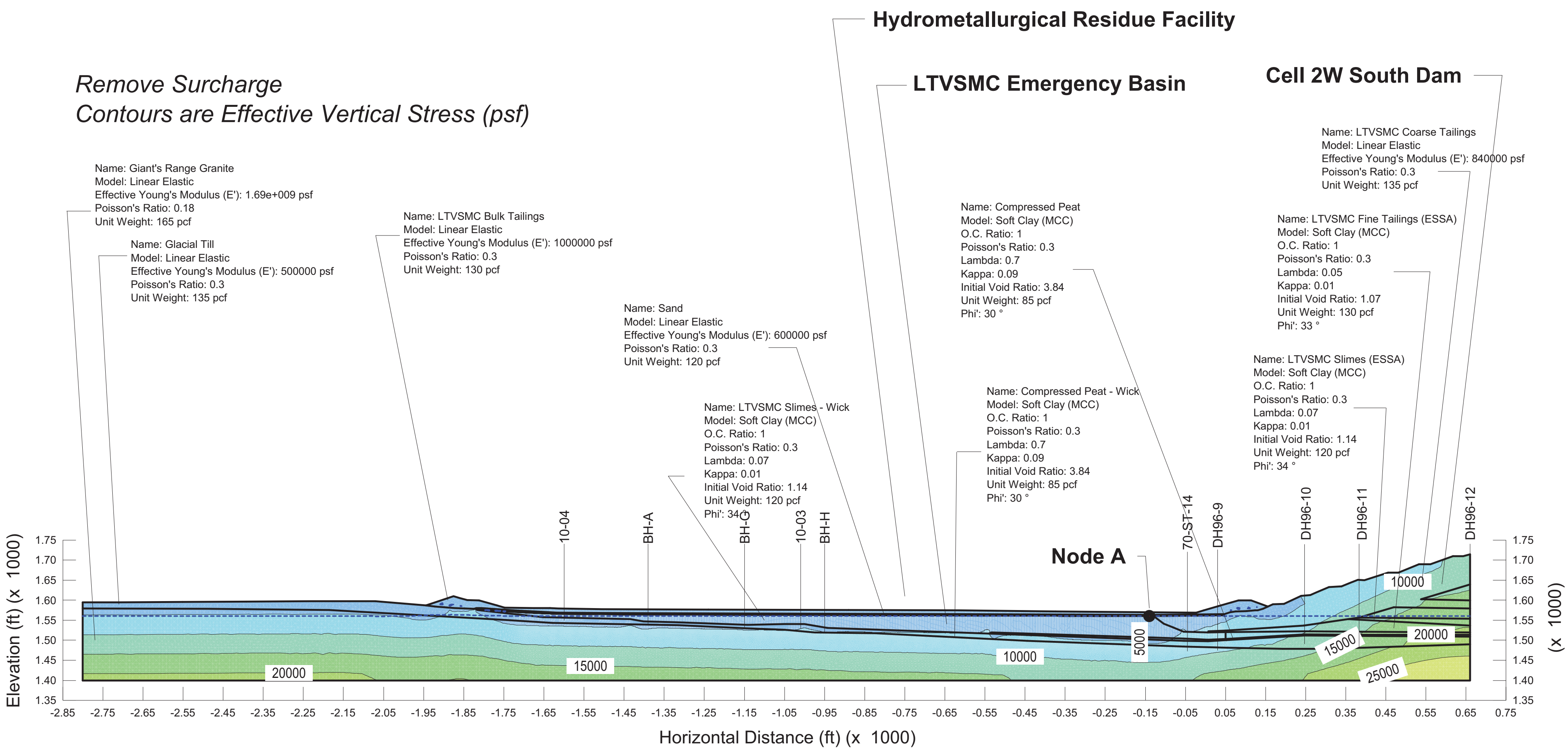
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 20
Effective Vertical Stress at Removal of Preload



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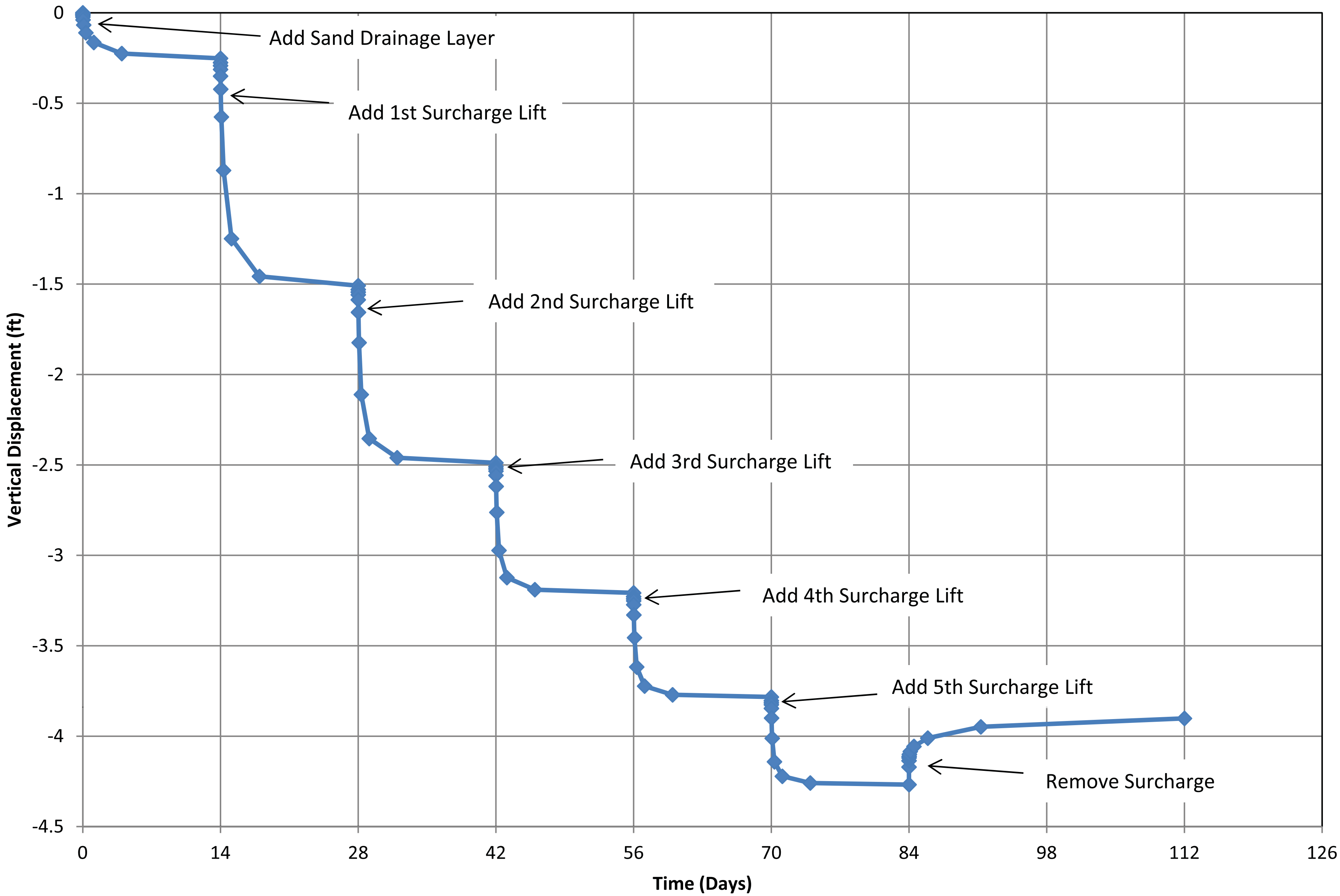
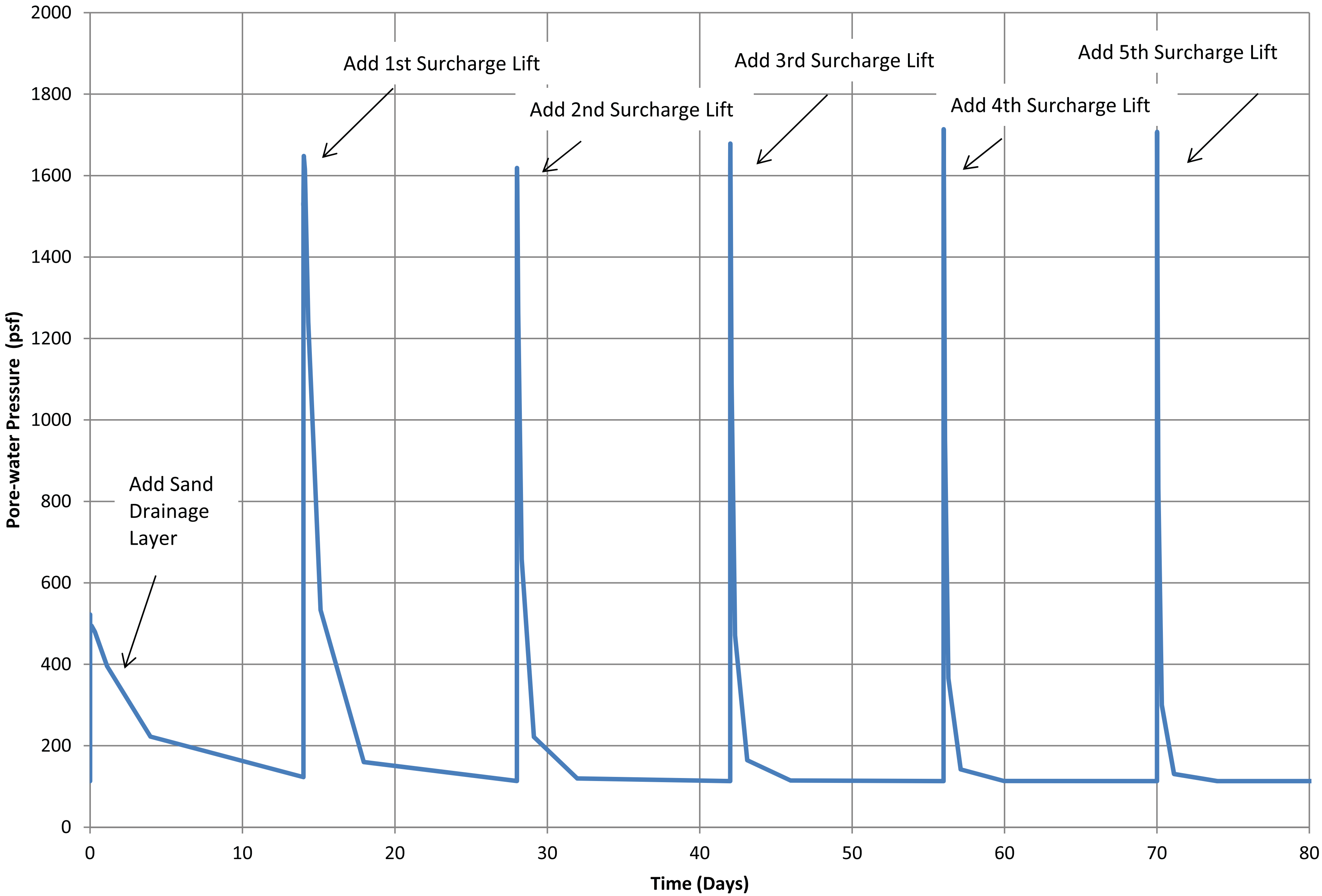


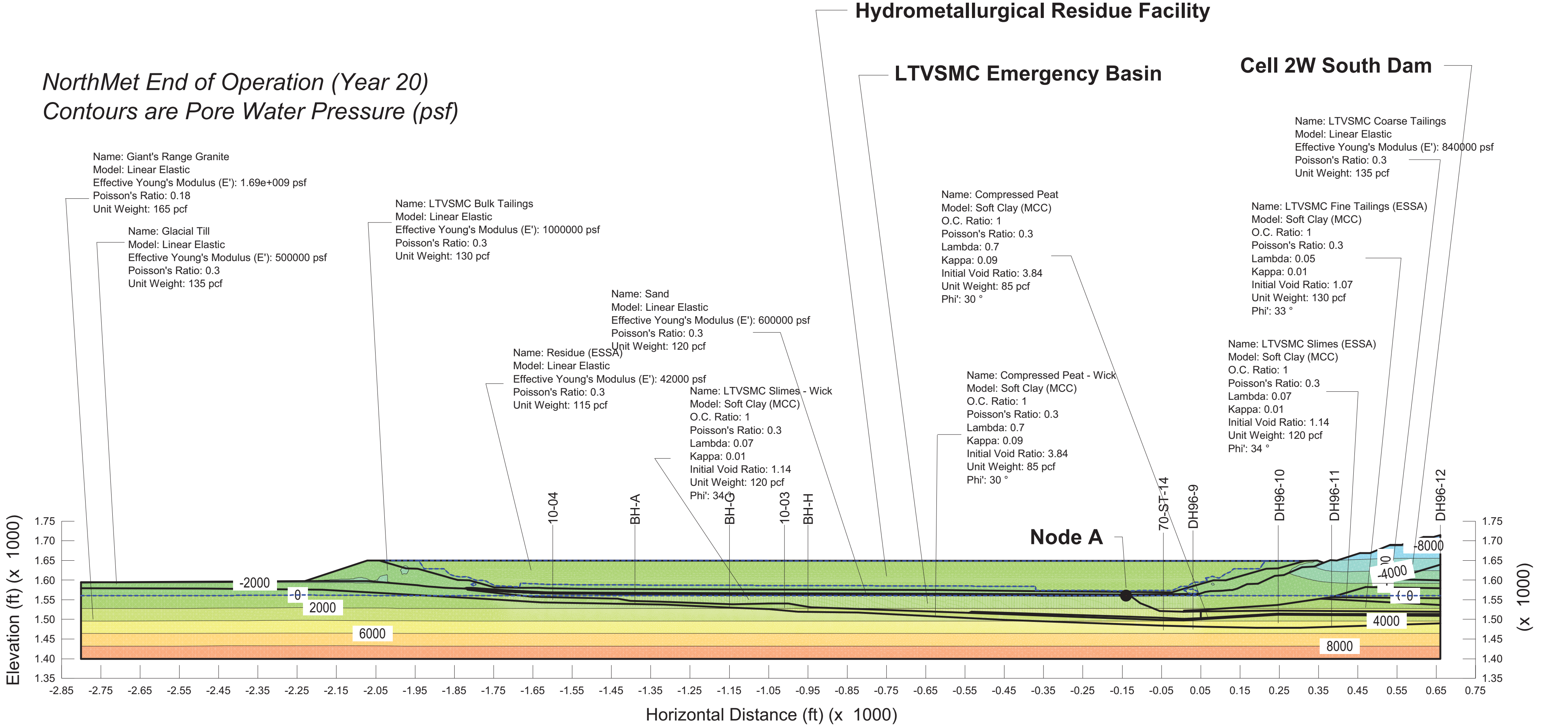
Large Figure 21. Vertical Displacement at Node A after Removal of Surcharge
NorthMet Hydrometallurgical Residue Facility



Large Figure 22. Pore-Water Pressure at Node A after Removal of Surcharge
NorthMet Hydrometallurgical Residue Facility

PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

Large Figure 23
Pore-Water Pressure at End of Operation (Year 20)



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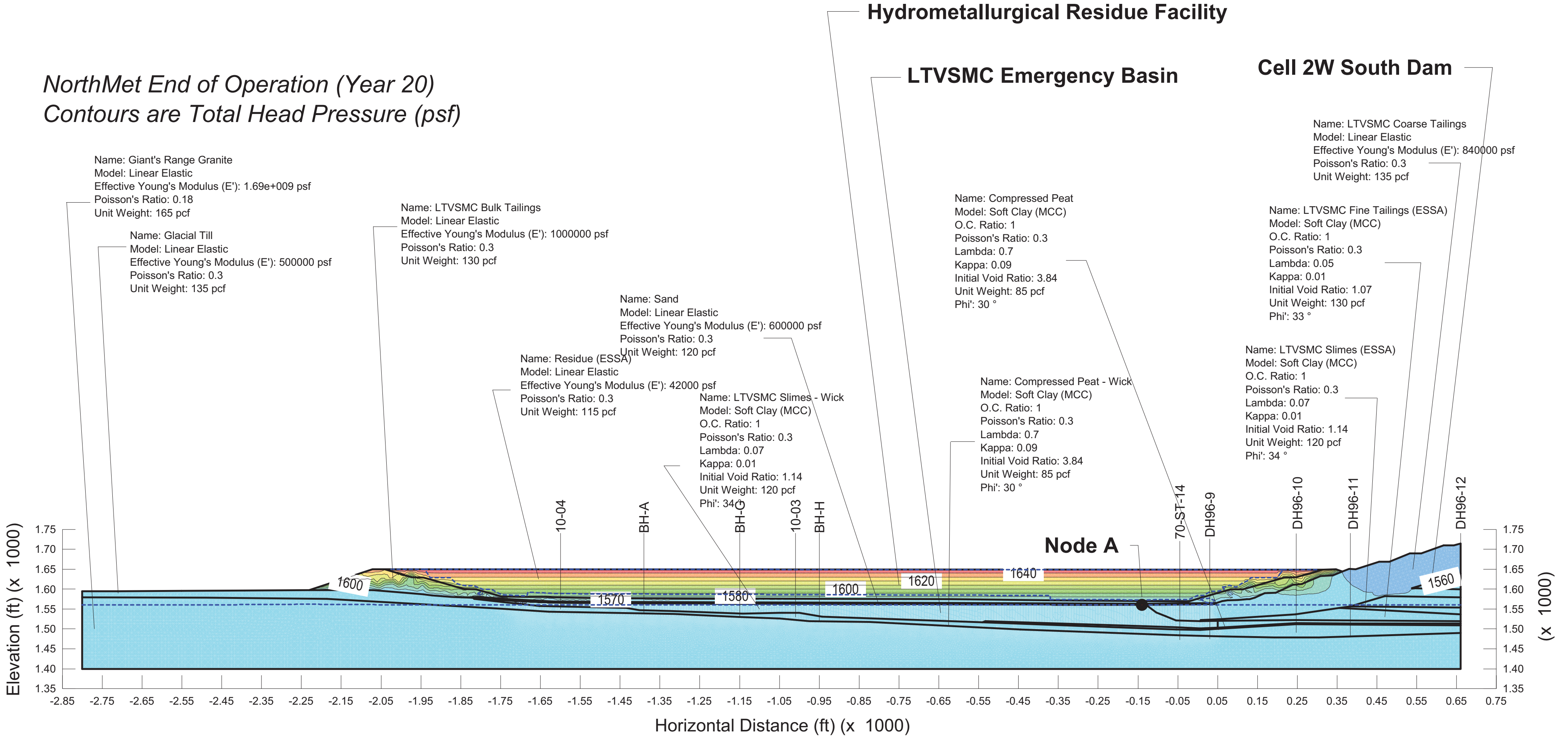
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

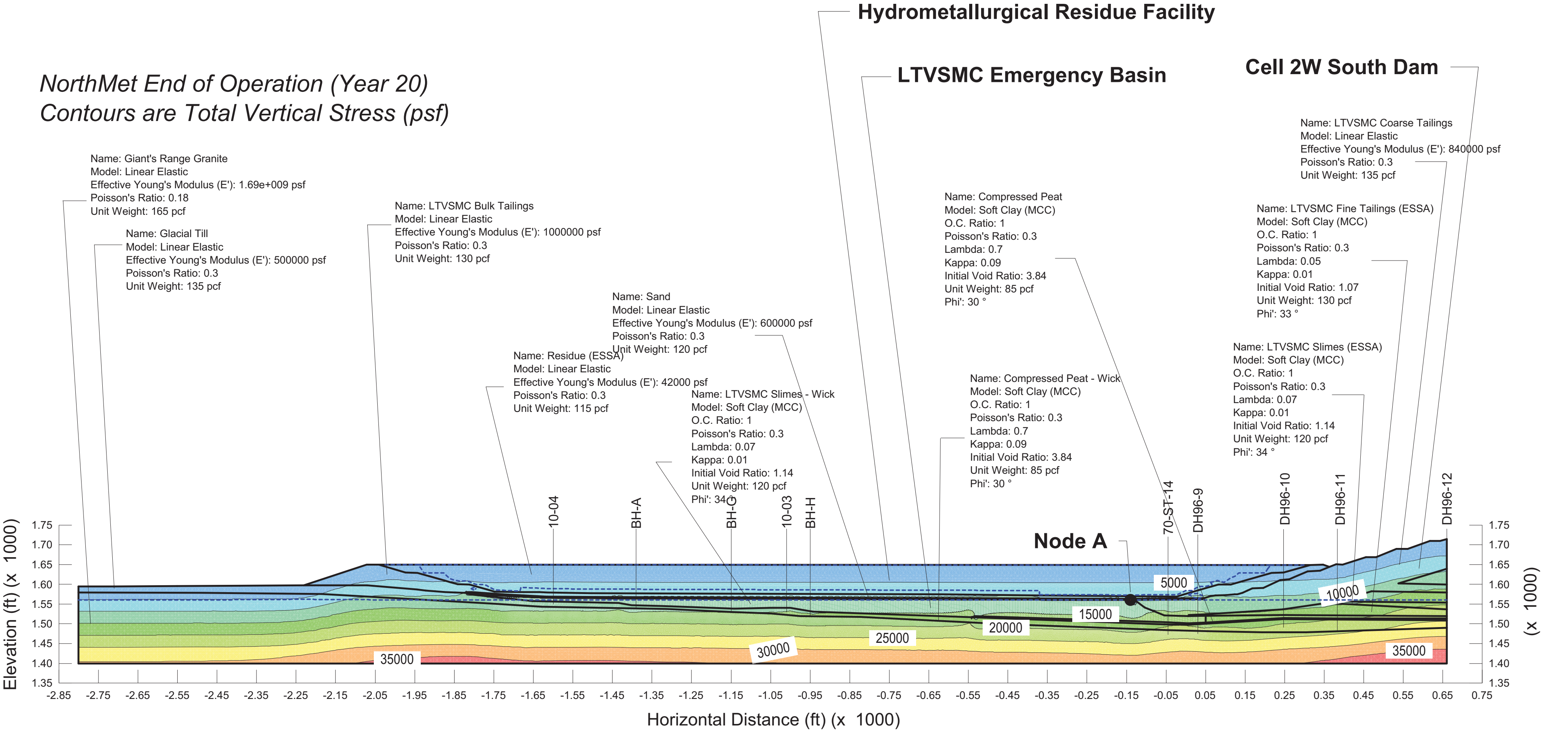
Large Figure 24
Total Head Pressure at End of Operation (Year 20)



P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz

PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

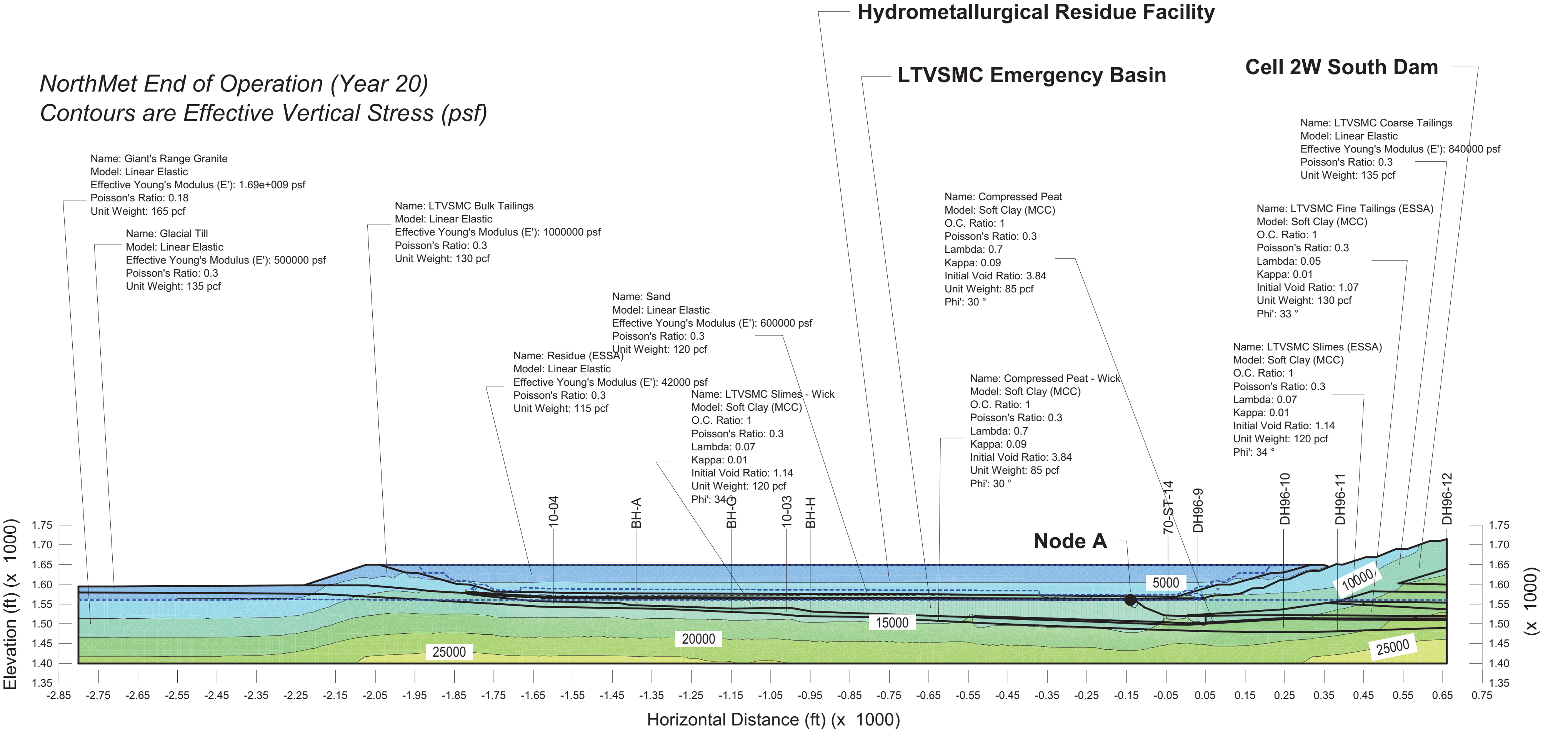
Large Figure 25
Total Vertical Stress at End of Operation (Year 20)



P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz

PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

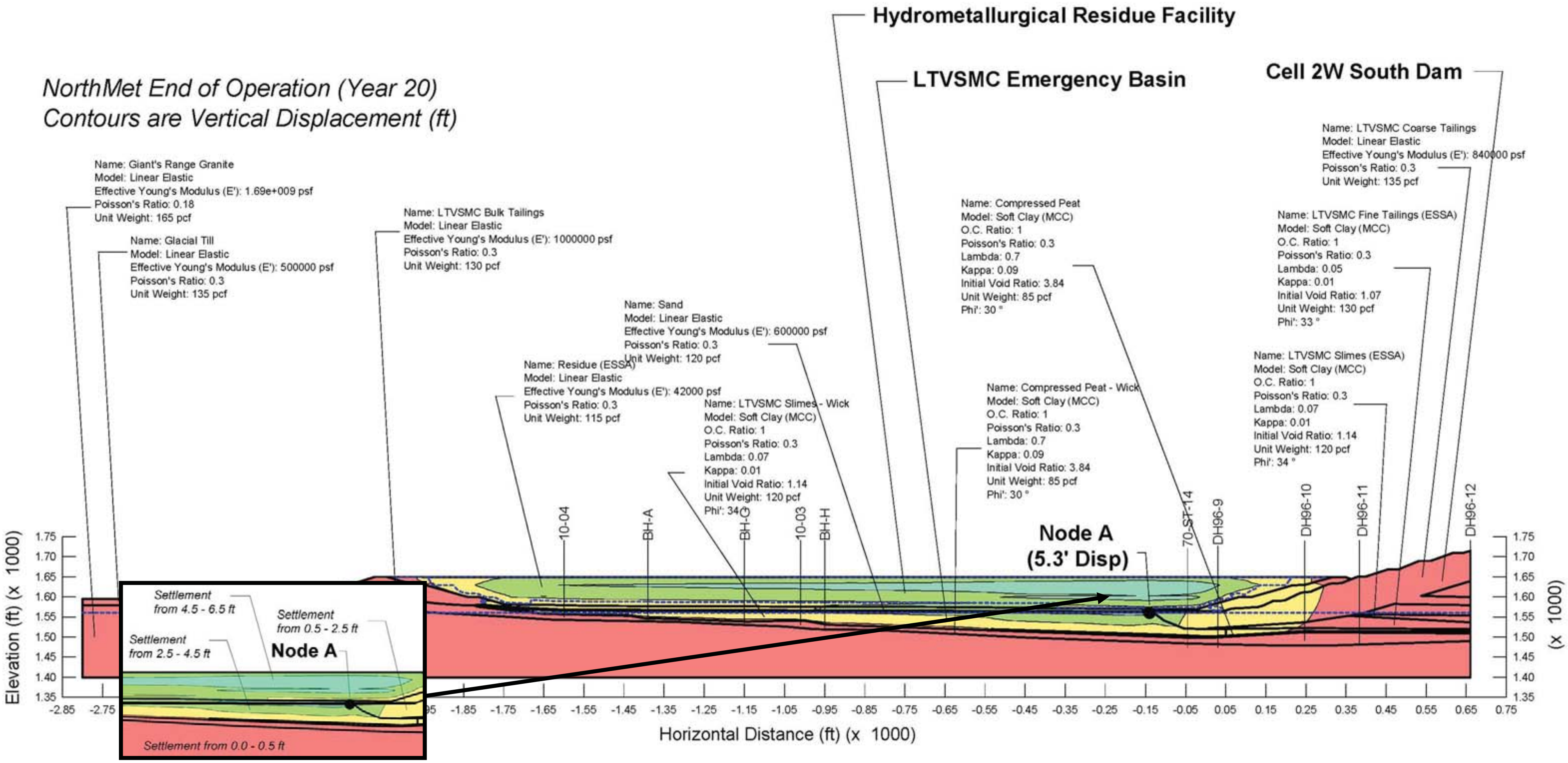
Large Figure 26
Effective Vertical Stress at End of Operation (Year 20)



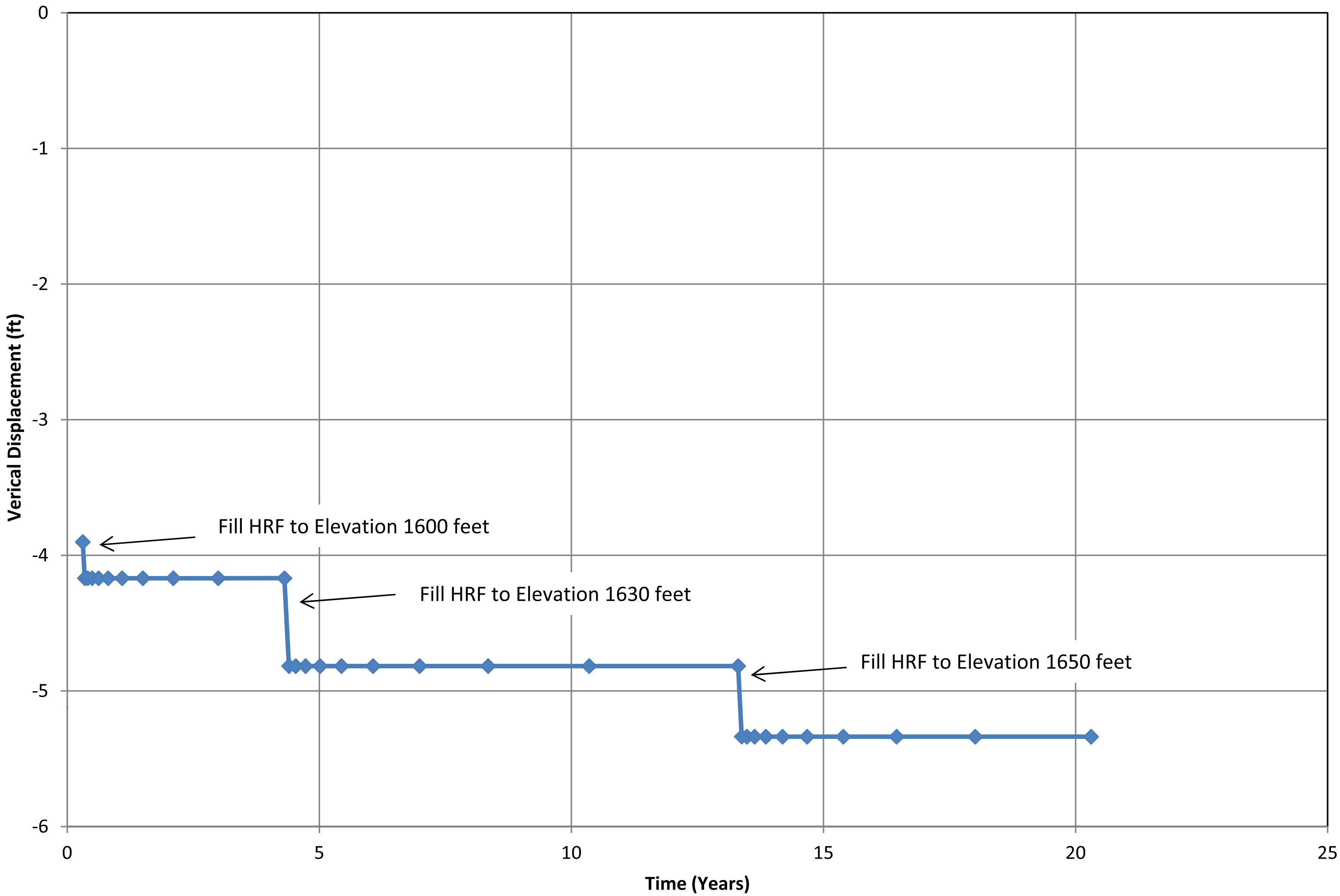
P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz

PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SIGMA/W Analysis, Coupled Stress/PWP Method

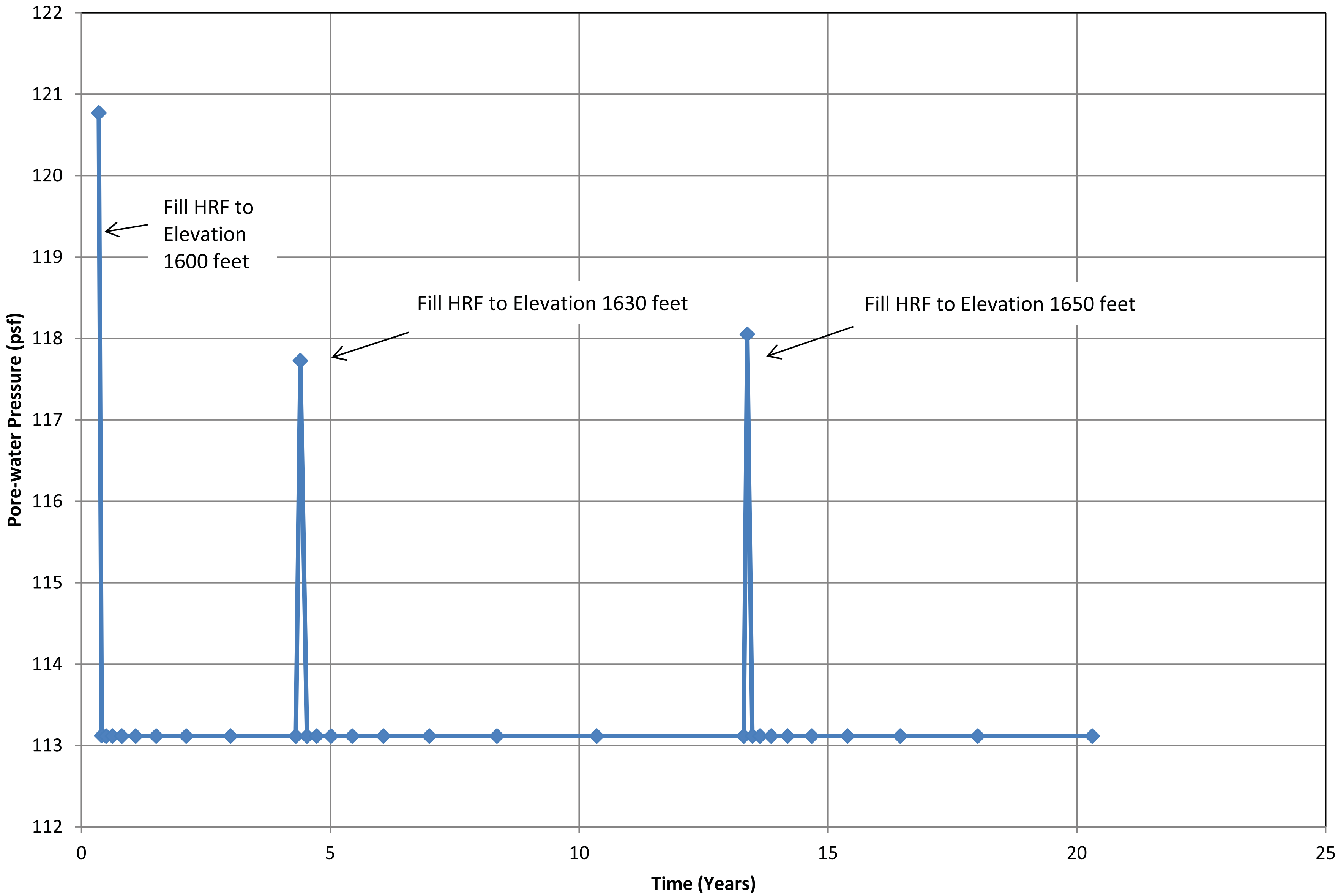
Large Figure 27
Total Vertical Displacement at End of Operation (Year 20)



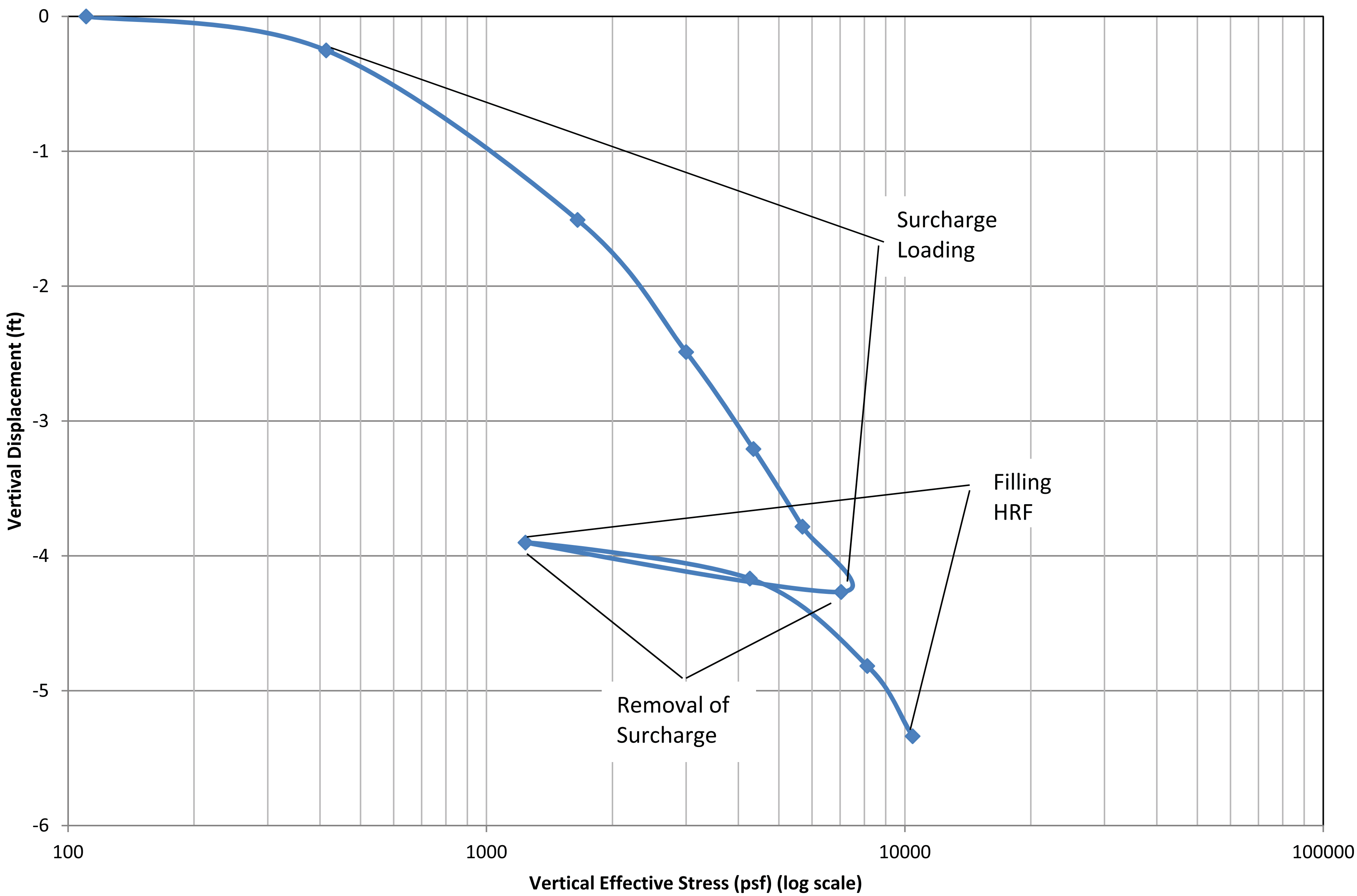
P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz



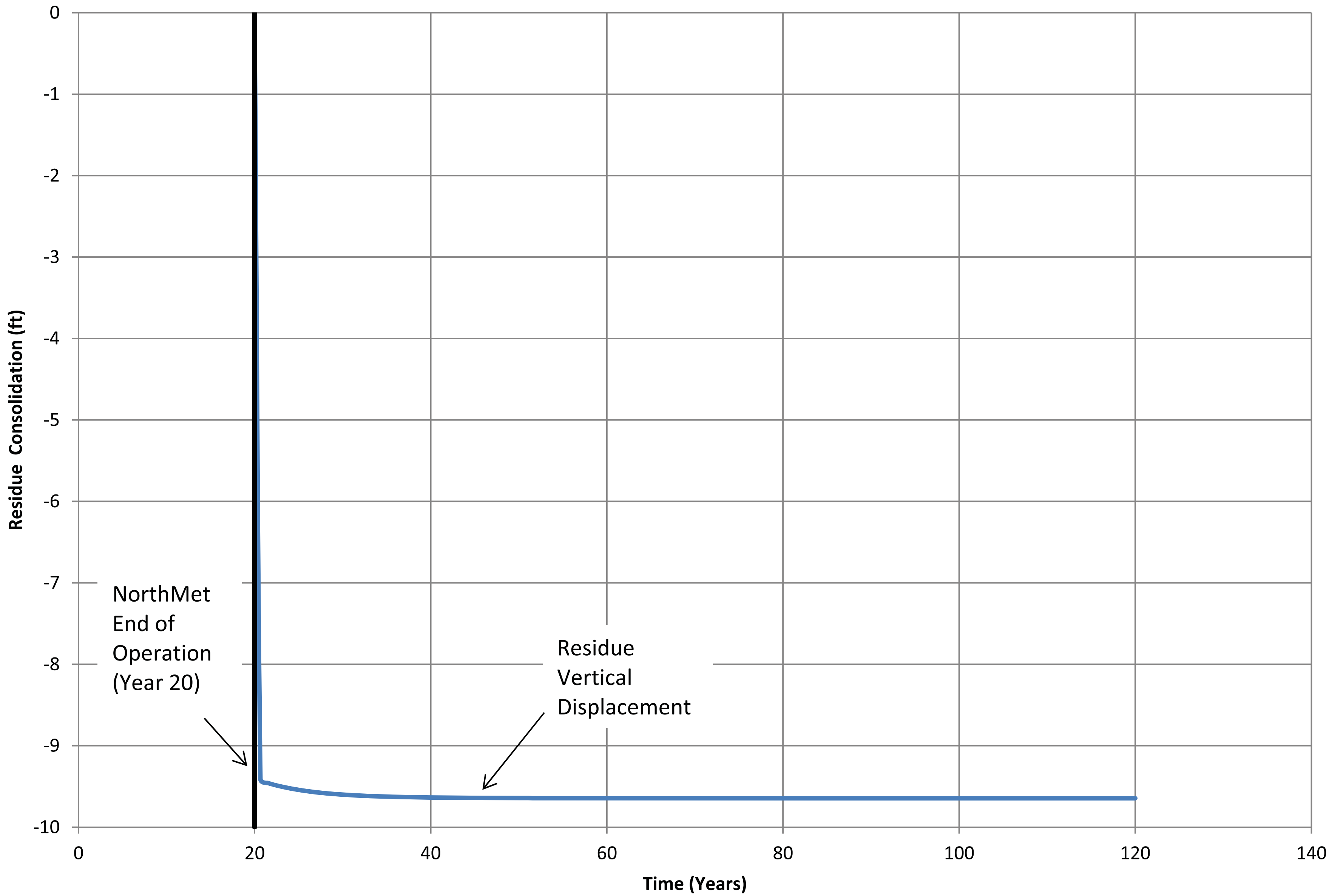
Large Figure 28. Vertical Displacement at Node A at End of Operation (Year 20)
NorthMet Hydrometallurgical Residue Facility



Large Figure 29. Pore-Water Pressure at Node A at End of Operation (Year 20)
NorthMet Hydrometallurgical Residue Facility

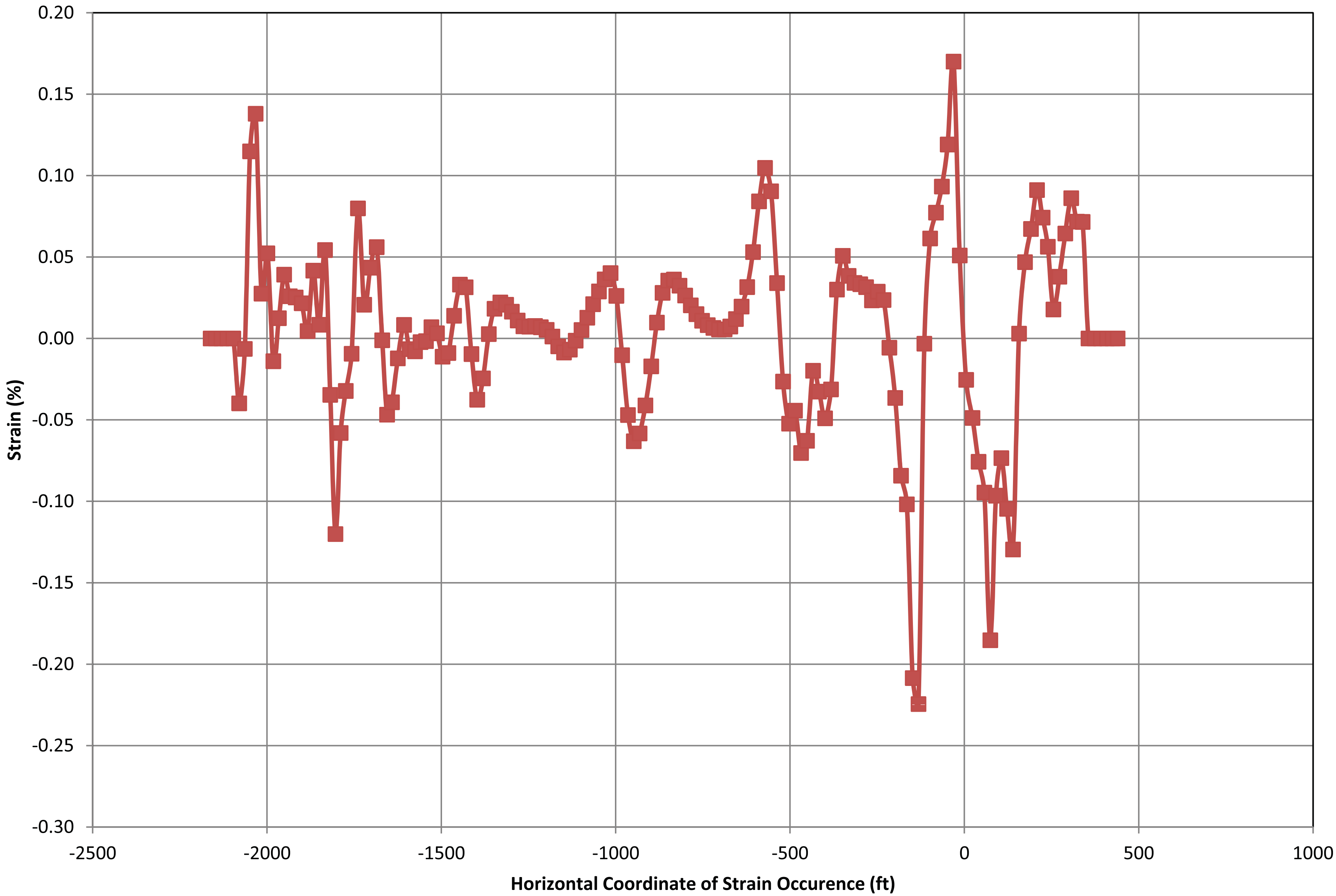


Large Figure 30. Displacement due to Effective Stress at Node A
NorthMet Hydrometallurgical Residue Facility



Large Figure 31. Residue Consolidation at Node A NorthMet Hydrometallurgical Residue Facility

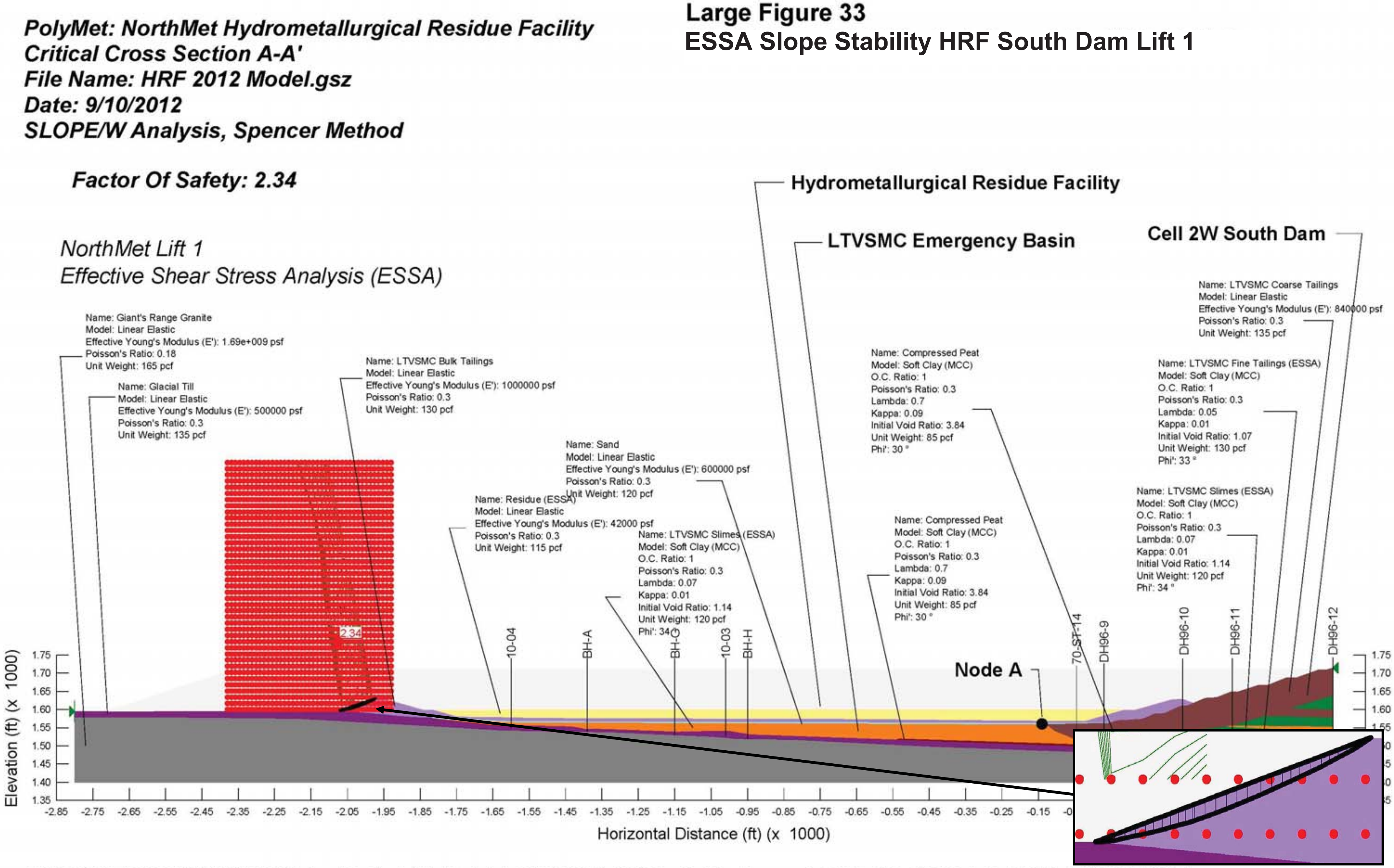
P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Results\Residue column.xls



Large Figure 32. Strain in Geosynthetic Liner at NorthMet End of Operation (Year 20)
NorthMet Hydrometallurgical Residue Facility

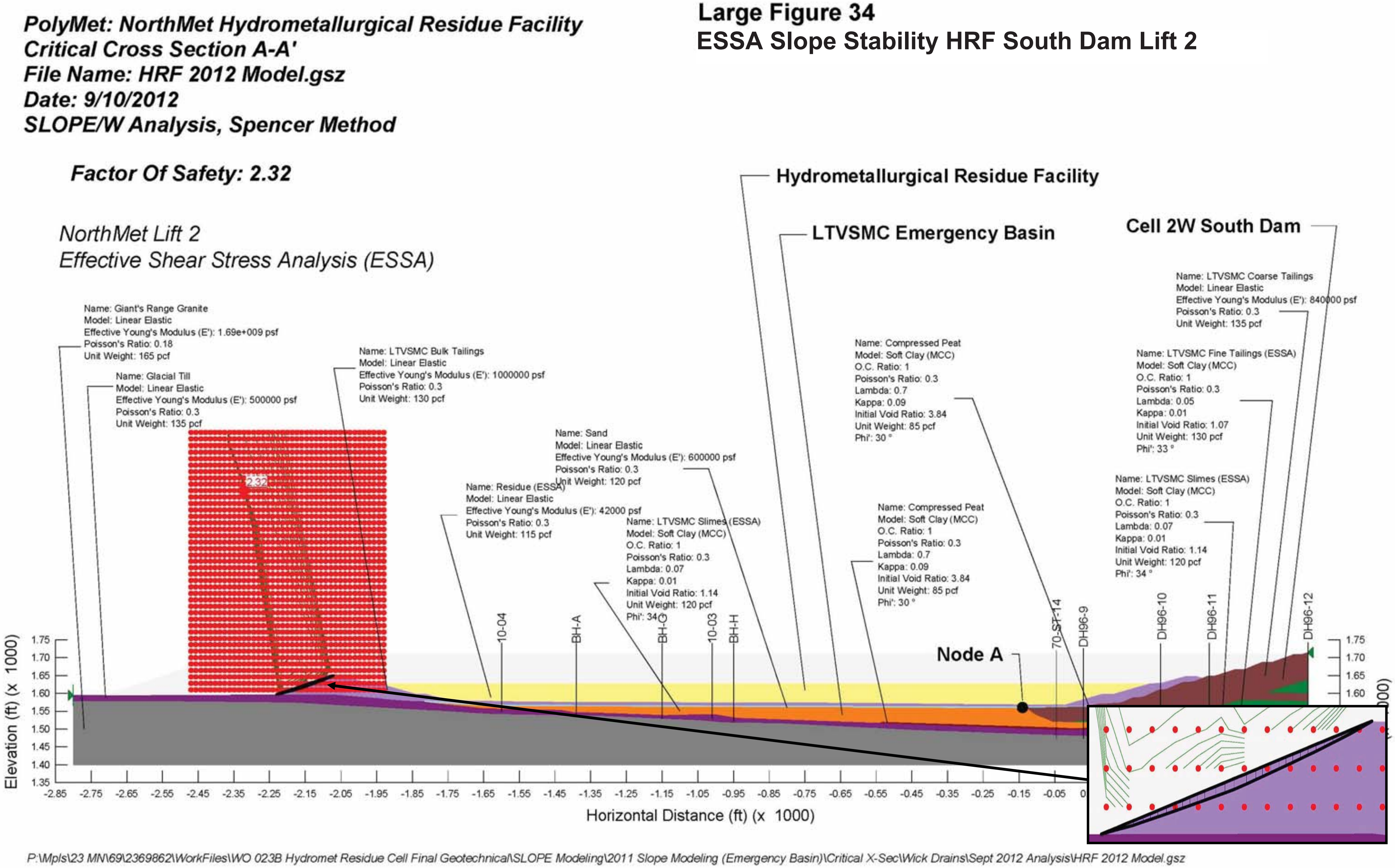
P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Results\Strain.xls

Large Figure 33
ESSA Slope Stability HRF South Dam Lift 1



P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz

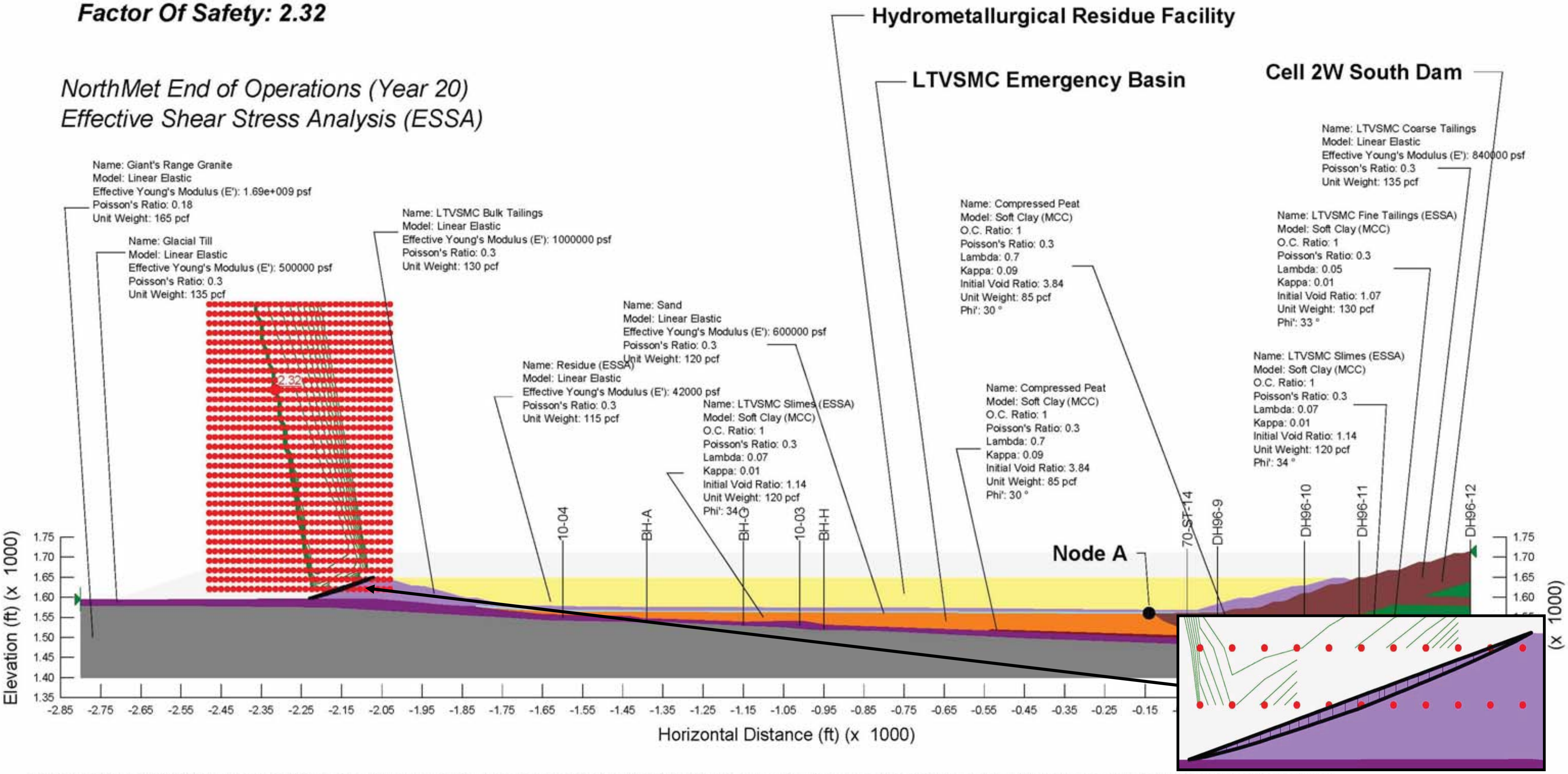
Large Figure 34
ESSA Slope Stability HRF South Dam Lift 2



PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 9/10/2012
SLOPE/W Analysis, Spencer Method

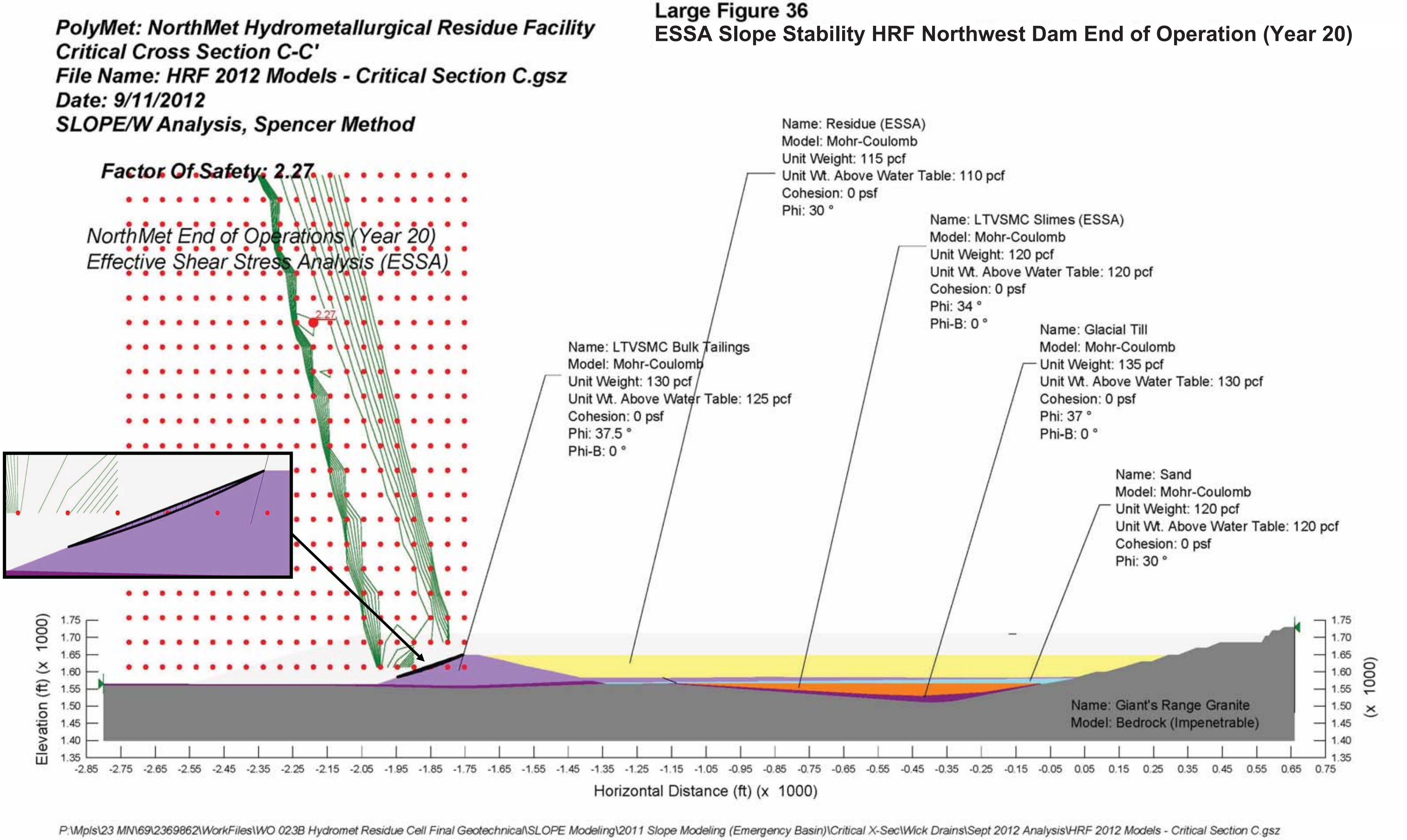
Large Figure 35
ESSA Slope Stability HRF South Dam End of Operation (Year 20)

Factor Of Safety: 2.32



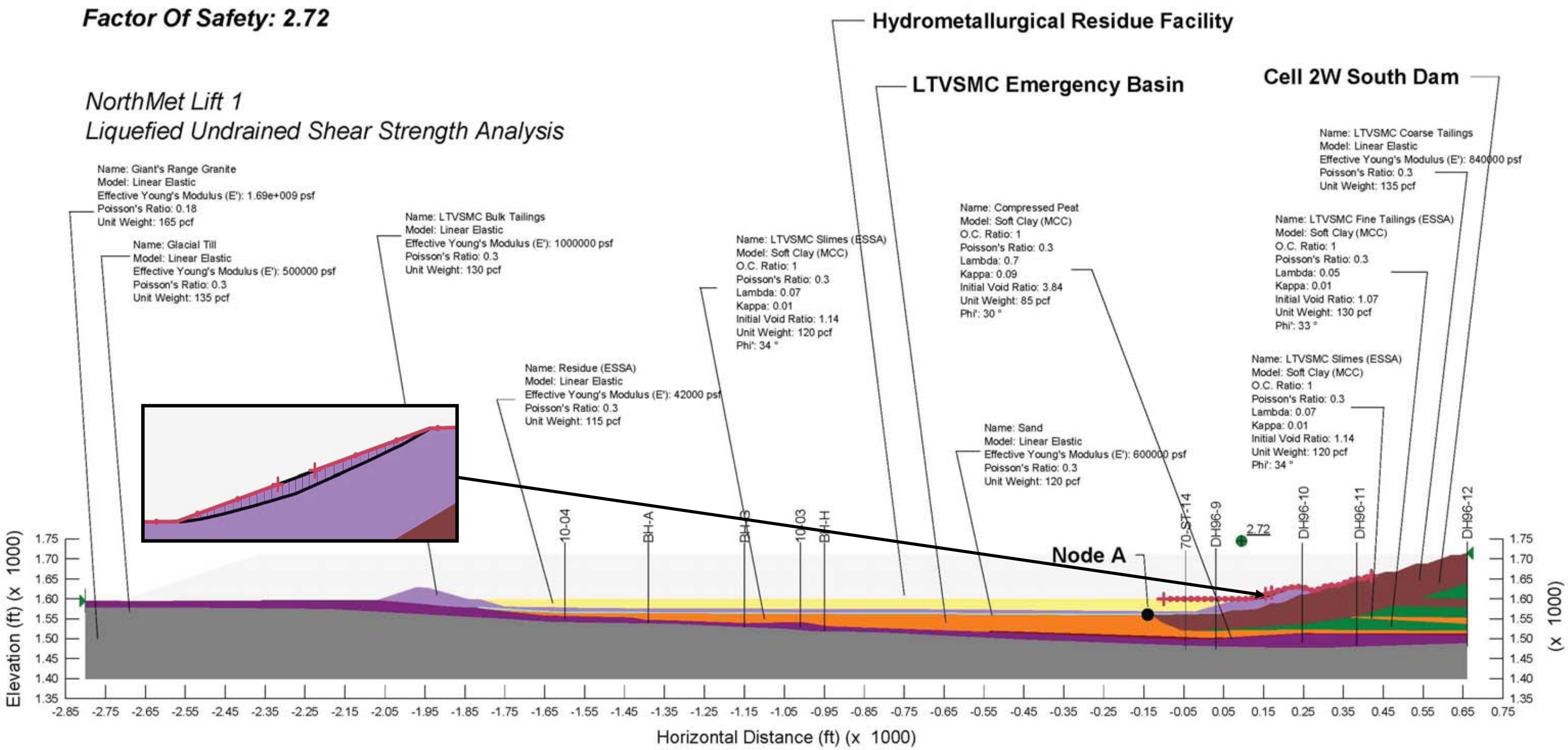
P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz

Large Figure 36
ESSA Slope Stability HRF Northwest Dam End of Operation (Year 20)

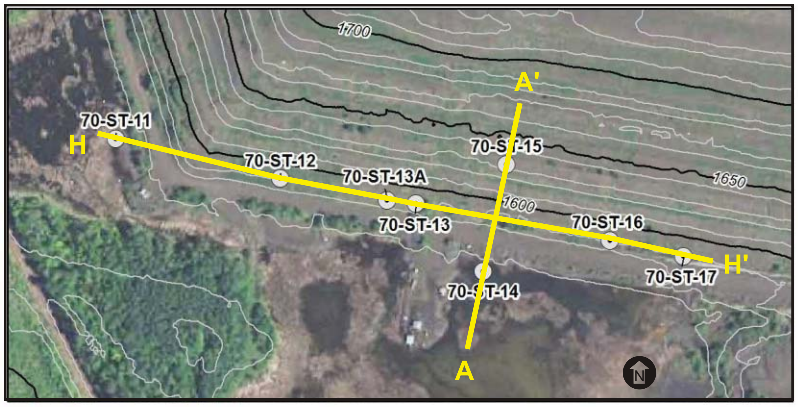


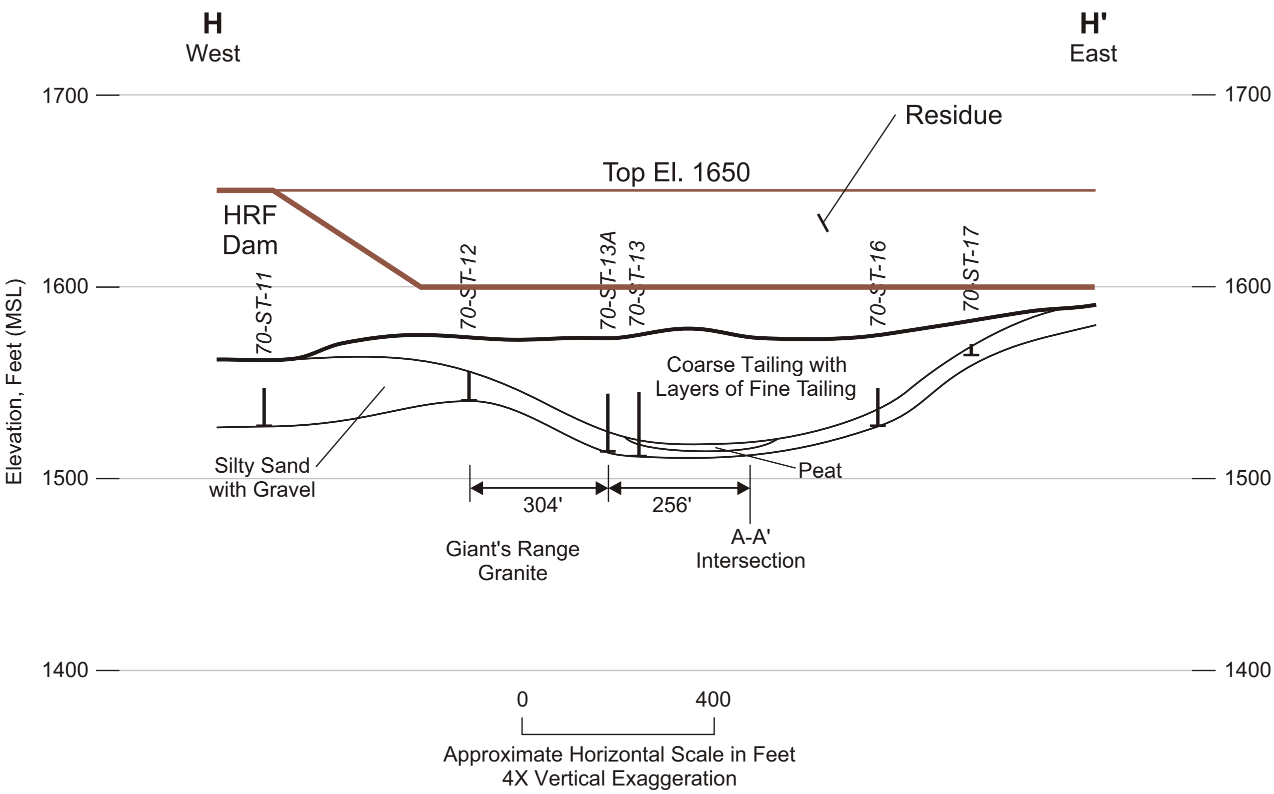
Large Figure 37
ESSA Slope Stability HRF North Dam Lift 1

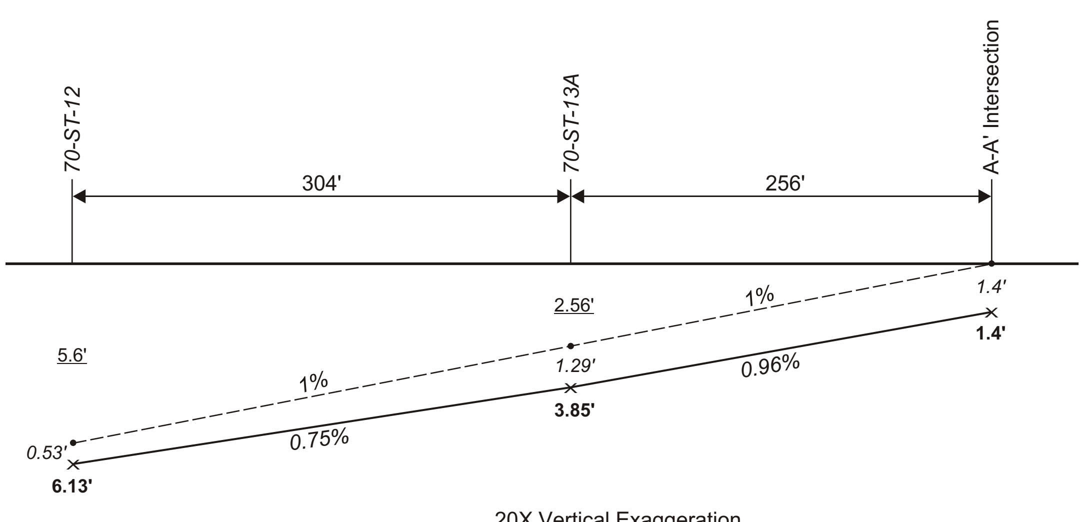
PolyMet: NorthMet Hydrometallurgical Residue Facility
Critical Cross Section A-A'
File Name: HRF 2012 Model.gsz
Date: 10/9/2012
SLOPE/W Analysis, Spencer Method



P:\Mpls\23 MN\69\2369862\WorkFiles\WO 023B Hydromet Residue Cell Final Geotechnical\SLOPE Modeling\2011 Slope Modeling (Emergency Basin)\Critical X-Sec\Wick Drains\Sept 2012 Analysis\HRF 2012 Model.gsz







5.6' Change in Depth due to 1% Slope

0.53' Change in Depth due to Expected Settlement

6.13' Total Change in Depth

Large Figure 38

CHANGE IN HRF LINER SLOPE DUE TO SETTLEMENT

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Attachments

Attachment A

NorthMet Geotechnical Modeling Work Plan

NorthMet Geotechnical Modeling Work Plan
Version 1 - Submitted by PolyMet on 06/16/2011

This document is the Work Plan for geotechnical modeling of the NorthMet Project as requested by the Geotechnical Stability Impact Assessment Planning Summary Memo, NorthMet Project EIS, dated May 18, 2011. The findings from the geotechnical modeling will be incorporated into a 3-Volume Geotechnical Data Package – and summarized and referenced as needed. NorthMet Project Geotechnical Data Package Volumes 1 through 3 will consist of:

- Volume 1 – Flotation Tailings Basin
- Volume 2 – Hydrometallurgical Residue Facility
- Volume 3 – Stockpiles

Project:

The project that will be evaluated is the project described in the Lead Agency Draft Alternative Summary as amended 03/04/11. This Work Plan will be reviewed and amended as necessary in response to project changes in the event such changes require substantive changes to previously analyzed facility designs.

Background:

The NorthMet Project includes two material disposal facilities that include dams, consisting of the Flotation Tailings Basin for final deposition of flotation tailings, and the Hydrometallurgical Residue Facility for final deposition of the hydrometallurgical residue. The Flotation Tailings Basin and Hydrometallurgical Residue Facility are designed using an iterative process whereby facility capacity requirements and geotechnical requirements are utilized to determine the facility geometry and overall sizing requirements to contain the tailings and residue expected to be generated through the life of the project. A third type of material disposal facility, which does not require dams but does entail foundation and slope construction, is the waste rock stockpiles at the Mine Site (a.k.a. Stockpiles).

An important input parameter to the facility designs are the slope stability safety factors. Acceptable slope stability safety factors are selected and then the facilities (Flotation Tailings Basin and Hydrometallurgical Residue Facility) are configured to achieve these safety factors as computed by modeling performed during facility design. In the case of Stockpiles, MDNR-mandated design requirements have been developed that result in acceptable safety factors.

The slope stability analysis methods that are used to compute slope stability safety factors are not required universally. In other words, some types of analysis are appropriate to some facility configurations while not applicable to other configurations. For example, undrained strength stability analysis (USSA) for slope stability is appropriate for the upstream construction approach planned for the Flotation Tailings Basin. It is not necessary for the Hydrometallurgical Residue Facility which will utilize downstream construction with a liner system. With this context the geotechnical work plans for the Flotation Tailings Basin, Hydrometallurgical Residue Facility, and Stockpiles are outlined below.

Flotation Tailings Basin Geotechnical Model for SDEIS, FEIS and Permitting:

The objective of the Tailings Basin Geotechnical Modeling for the SDEIS, FEIS and Permitting is to demonstrate the ability of the Critical Cross-Section (i.e., Cross-Section F; that cross-section anticipated to yield the lowest slope stability safety factor as indicated in the Preliminary Geotechnical Evaluation – March 2009) to comply with the required global slope stability safety factors. The information content of the March 2009 Preliminary Geotechnical Evaluation will be updated and formatted to accommodate the 3-Volume Geotechnical Data Package format, with content further amended as necessary to both reflect the Draft Alternative (March 4, 2009, and as amended) and to incorporate the specific guidance provided below. The following is a step-by-step summary of the planned Flotation Tailings Basin geotechnical modeling process.

1. Gather existing conditions data (i.e. basin topography, stratigraphy, soil and tailings strength and hydraulic characteristics, and other data as needed to support geotechnical modeling and Flotation Tailings Basin design). Note – this data has previously been compiled and presented in the Preliminary Geotechnical Evaluation – March 2009. This information will be incorporated into the Geotechnical Data Package – Volume 1, which will present the analyses outlined in this Work Plan. Results of in-laboratory testing of liquefied shear strength of NorthMet flotation tailings, completed subsequent the March 2009 evaluation, will be incorporated into the work prescribed in this Geotechnical Modeling Work Plan.

2. Develop tailings basin slope cross-sections (i.e., geometry and stratigraphy for existing and planned conditions) for the Flotation Tailings Basin for seepage and stability modeling. Models presented in the Preliminary Geotechnical Evaluation – March 2009 utilized surveyed cross-sections of the existing basin and proposed cross-sections of future dam raises; existing models will be reconfigured as needed to accommodate the modeling approach outlined in this Work Plan. This information will then be incorporated into the Geotechnical Data Package – Volume 1.

3. Develop seepage and stability models of the Flotation Tailings Basin using Geo-Slope International, Inc. modeling software (i.e., SLOPE/W, SEEP/W, SIGMA/W and QUAKE/W as necessary) for the following conditions:

   a. Normal operating condition with lowest design Safety Factor (will model for normal pool elevation with steady-state seepage conditions and including bentonite amended exterior face of new dams).
   b. Maximum dam height and increased pond elevation to account for pond bounce predicted to occur during a Probable Maximum Precipitation [PMP] event. Transient seepage analysis will be utilized as needed to account for the temporarily elevated pond condition produced by a PMP event.
   c. Post closure with cover effective (bentonite amended exterior face of new dams, beaches, and pond bottom) and with pond at design elevation (after closure, fail-safe water level controls will be implemented to limit pond bounce during a PMP event to at or near the pond design elevation).

4. Configure geotechnical data for model input. Model input parameters for hydraulic conductivity are anticipated to remain as utilized for the Preliminary Geotechnical Evaluation – March 2009. .For the March 2009 Preliminary Geotechnical Evaluation, all LTVSMC fine tailings and slimes and all saturated NorthMet tailings were assumed to be liquefiable; updated analysis will establish stress-strain criteria for which materials will transition from non-liquefied strengths to liquefied (steady state) strengths. This is to accommodate triggering analysis by which materials will be modeled as non-liquefied if stress-strain criteria are not exceeded, and modeled as liquefied if stress-strain criteria are exceeded. Data inputs that by mutual MDNR—PolyMet agreement remain poorly defined will be analyzed via sensitivity analysis to characterize their impact on model results.

5. Design slopes to achieve the following:

    a. Effective Stress Stability Analysis (ESSA) – Factor of Safety $\geq$ 1.5 for effective shear strength conditions.
    b. Undrained Strength Stability Analysis (USSA) – Factor of Safety $\geq$ 1.3 for undrained shear strength conditions for non-statically liquefiable soils (i.e., end of construction case per dam raise).
    c. Liquefaction Analysis ($USSA_{liq}$)
        i. Contractive/Dilative Material Behavior Analysis – Identify materials having the potential to liquefy by classifying materials as contractive or dilative based on published correlations compared to site-specific field data (i.e., SPT blowcounts, CPT tip resistance, and shear wave velocities).
        ii. Static Liquefaction (i.e., induced by embankment construction or non-seismic event)
            1. For static liquefaction slope stability analyses, determine if liquefaction can be triggered. Use published triggering relationships and model results to determine areas along the slip surface where liquefaction will be triggered (Olson & Stark, 2003, Yield Strength Ratios and Liquefaction Analysis of Slopes and Embankments). If the safety factor against triggering static liquefaction is $\geq$ 1.5, no further liquefaction analysis is needed.
            2. If the safety factor against triggering is < 1.5, perform static liquefaction slope stability analysis. .If the resulting slope stability analysis safety factor is < 1.2, then modify the slope design until safety factor criteria are met.
        iii. Seismic Liquefaction (i.e., induced by seismic event)
            1. Develop material damping coefficients for LTVSMC and NorthMet tailings.
            2. Use Geo-Slope software to compute initial stresses and steady-state pore-water pressure distribution.
            3. Apply earthquake loads via QUAKE/W (earthquake loads to be obtained from probabilistic seismic hazard analysis [PSHA]) and compare results to a SLOPE/W yield undrained model to identify

the elements within the model that liquefy as a result of the seismic loading.

4. Use published triggering relationships and model results to determine areas along the slip surface where liquefaction will be triggered (Olson & Stark, 2003, Yield Strength Ratios and Liquefaction Analysis of Slopes and Embankments).
5. Perform slope stability analysis in SLOPE/W (using liquefied shear strengths applied to elements shown to liquefy).
6. Perform deformation modeling in SIGMA/W to predict magnitude of deformation.

6. Report final design and operating requirements necessary to maintain required slope stability safety factors and deformation requirements for the critical slope cross-section (assumed to be Cross-Section F for SDEIS modeling).

7. Following MDNR Dam Safety review and approval of Critical Cross-Section modeling process/procedures and outcomes, proceed with modeling cross-sections G (north side of Cell 2E) and N (south side of Cell 1E) for final Flotation Tailings Basin design (for input to SDEIS, FEIS and/or Permitting as timing accommodates).

8. Within two years of basin start-up, complete analysis of one additional cross-section located at the mid-1980s piping failure location near the southwest corner of Cell 1E.

Reporting – the Geotechnical Data Package Volume 1 will present the background/supporting information and results of the Flotation Tailings Basin geotechnical analyses described in this Work Plan. Geotechnical Data Package – Volume 1 will contain the pertinent content previously presented in the Preliminary Geotechnical Evaluation – March 2009; reconfigured in response to MDNR Dam Safety requests to group all geotechnical data by material type (i.e., LTVSMC coarse tailings, fine tailings and slimes, NorthMet bulk tailings, etc.) rather than by data type (i.e., hydraulic conductivity, liquefied shear strength, undrained shear strength, etc.). Furthermore, analysis methods required by this Work Plan and the associated results will be presented in Geotechnical Data Package – Volume 1 to the extent that analysis methods and results supersede contents of the Preliminary Geotechnical Evaluation – March 2009. Included will be descriptions and drawings depicting existing conditions and what will be built, results of geotechnical analyses for operating and post-closure conditions, and presentation of all model input parameters and model outputs. Where model input parameters are derived from multiple data points, the approach utilized for input parameter selection will be described. Included will be a description of how stability is anticipated to vary over time following tailings basin closure.

Hydrometallurgical Residue Facility Geotechnical Models for SDEIS, FEIS and Permitting:

The objective of the Hydrometallurgical Residue Facility Geotechnical Modeling for the SDEIS, FEIS and Permitting is to:

- demonstrate the ability of the most sensitive slope cross-section to comply with the required slope stability safety factors for global stability,
- demonstrate the ability of the composite liner system to comply with infinite slope stability safety factor requirements, and to
- demonstrate the capability of the composite liner system to withstand the strain anticipated due to differential settlement that may occur in the facility foundation materials.

The following is a step-by-step summary of the planned Hydrometallurgical Residue Facility geotechnical modeling process.

1. Gather existing conditions data (i.e. facility foundation material stratigraphy and strength data, hydrogeologic data and other data as needed to support geotechnical modeling of the Hydrometallurgical Residue Facility). Note – portions of this data have previously been compiled and presented in the Preliminary Geotechnical Evaluation – March 2009. This information will be incorporated into the Geotechnical Data Package Volume 2 and will be supplemented with additional facility location-specific data. Data on existing baseline water sources at the site, including surface discharges from the surrounding highlands, will be gathered for consideration during hydrometallurgical residue facility design. The facility will be designed to accommodate any such surface discharges and hence these discharges will not impact geotechnical modeling of the hydrometallurgical residue facility.

2. Gather additional residue strength and hydraulic conductivity data and/or representative published data for use in facility design. This information will be incorporated into the Geotechnical Data Package Volume 2 to the extent needed to facilitate the modeling outlined herein.

3. Develop residue facility layout and slope cross-sections (i.e., geometry and stratigraphy for existing and planned conditions) for proposed residue facility stability and deformation modeling. Note – seepage through the residue facility embankments will be inhibited by the composite liner system and seepage modeling will be an unnecessary component of this analysis.

4. Develop global and infinite slope stability models and deformation models of the facility using Geo-Slope International, Inc. modeling software (i.e., SLOPE/W, SEEP/W and SIGMA/W as necessary). Model the following:

   a. Deformation of hydromet residue facility foundation and liner system.
   b. Infinite slope stability of hydromet residue facility liner system (if necessary/applicable).
   c. Global stability of hydromet residue facility embankments.

   Model maximum residue facility dam height with minimum and maximum pond elevation, and post closure – cover effective with minimum pond elevation. Model for effective shear stress conditions. Modeling for undrained shear strength conditions will not be necessary due to lined facility design with imported and mechanically placed dam fill and lack of seepage through the dam.

5. Configure geotechnical data for model input. Model input parameters will be based on data collected for and presented in the Preliminary Geotechnical Evaluation – March 2009. For materials to be imported for construction, engineering judgment will be used to select conservative shear strength parameters for input to the slope stability analysis and liner deformation analysis.

6. Use SLOPE/W to calculate the Global Safety Factor for the following conditions:

    a. Effective Stress Stability Analysis (ESSA) – Safety Factor $\geq$ 1.5
    b. Slope failures on external face and internal face of residue facility embankments.

7. Perform infinite slope stability analysis to confirm that load from residue deposition will be transferred to facility foundation soils and will not induce excess strain in facility liner materials.

8. Perform deformation modeling to predict magnitude of deformation and resulting strain in the facility liner system for comparison to allowable strain in liner system. Allowable strains are material-specific and will be determined from manufacturers specifications for the materials selected for the facility liner.

9. Report final basin design and operating requirements necessary to maintain required slope stability safety factors and deformation requirements.

9. Reporting – the Geotechnical Data Package Volume 2 will present the background/supporting information and results of the Hydrometallurgical Residue Facility geotechnical analyses described in this Work Plan. Included will be descriptions and drawings depicting existing conditions and what will be built, results of geotechnical analyses for operating and post-closure conditions, and presentation of all model input parameters and model outputs. Where model input parameters are derived from multiple data points, the approach utilized for input parameter selection will be described. Included will be a description of how stability is anticipated to vary over time.

Stockpile Geotechnical Models for SDEIS, FEIS and Permitting:

The objective of the Stockpile Geotechnical Modeling for the SDEIS, FEIS and Permitting is to comply with Mn Rule 6132.2400 (stockpile slopes will be as required by 6132.2400 Subp. 2. B. and stockpile foundations will be as required by 6132.2400 Subp. 2. A. (1)). These are design requirements that have been established to insure acceptable slope stability safety factors for global stability and acceptable foundation stability, the latter of which relates to the capability of the geomembrane liner system to withstand the strain anticipated due to differential settlement that may occur in the stockpile foundation materials.

The following is a step-by-step summary of the planned Stockpile geotechnical modeling process.

1. Gather existing conditions data (i.e. facility foundation material stratigraphy and strength data and other data as needed to support foundation design). Existing site information will be utilized for analysis performed in support of the SDEIS and FEIS, with additional data gathered and designs updated as needed for final design in conjunction with permitting. Existing information will be incorporated into the Geotechnical Data Package Volume 3

2. Configure stockpile slopes to meet or exceed minimum dimensional requirements established by Mn Rule 6132.2400.

3. Perform stockpile subgrade settlement analysis to predict magnitude of deformation and resulting strain in the stockpile liners for comparison to allowable strain in the liner system. Allowable strains are material-specific and will be determined from manufacturers specifications for the materials selected for the stockpile liners.

4. Report final stockpile design and operating requirements necessary to maintain required slope stability safety factors and liner performance requirements.

5. Reporting – the Geotechnical Data Package Volume 3 will present the background/supporting information and results of the Stockpile geotechnical analyses described in this Work Plan. Included will be descriptions and drawings depicting existing conditions and what will be built, results of geotechnical analyses for operating and post-closure conditions, and presentation of all model input parameters and model outputs. Where model input parameters are derived from multiple data points, the approach utilized for input parameter selection will be described. Included will be a description of how stability is anticipated to vary over time.

Attachment B

Hydrometallurgical Residue Facility Boring Logs

LOG OF BORING

PROJECT: 70-50 Basin #2 Expansion Erie Mining Co. Hoyt Lakes, Minn.	BORING: ST-9 LOCATION: Sta. 44+25
	DATE: 3/2/70 — SCALE: 1" = 6'

Elev. 1547.6	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
1543.6	4'	Fine to Medium Loamy Sand, with granite fragments, dark brown to grey brown, moist (very dense)	80		89
		Refusal at 4.0'			
		Boring attempted again at station 44+00 with refusal at 1.5'			

SOIL ENGINEERING SERVICES, INC.

LOG OF BORING

PROJECT: 70-50
Basin #2 Expansion
Erie Mining Co.
Hoyt Lakes, Minn.

BORING: ST-10
LOCATION: Sta. 50+00

DATE: 3/2/70 SCALE: 1" = 6'

Elev. 1543.0	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
		Fine to Medium Sandy Loam to Loamy Sand, grey mottled with reddish brown and dark brown, wet (medium dense)	21		90
1539.0	4'				
		Fine to Medium Sandy Loam to Loamy Sand and granite fragments, greyish brown, wet (medium dense to dense)	32		91
				▼	
			21		92
			33		93
1532.5	10.5				
		Refusal at 10.5'			

No water encountered at 10.0' when measured immediately after completion
Water level at 7.0' when measured 2 hours later

SOIL ENGINEERING SERVICES, INC.

LOG OF BORING

PROJECT: 70-50 Basin #2 Expansion Erie Mining Co. Hoyt Lakes, Minn.	BORING: ST-11 LOCATION: Sta. 54+00, Centerline
	DATE: 3/2/70 — SCALE: 1" = 6'

Elev. 1547.3	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
		Fine to Medium Sandy Loam to Loamy Sand, grey mottled with reddish brown and brown, frozen to wet (dense)	35		94 γdry = 109.7 pcf mc = 18.8%
1545.3	2'				
		Fine to Medium Sandy Loam, non plastic, with Gravel and boulders, greyish brown, wet (very dense)	34		95
			45		96
			100/1"	▼	
			60		
1528.3	19'				

Water level at 10' when measured immediately after completion

LOG OF BORING

PROJECT: 70-50 Erie Mining Co. Basin #2 Expansion Hoyt Lakes, Minn.	BORING: ST-12 LOCATION: Sta. 58+50
	DATE: 3/2/70 SCALE: 1" = 6'

Elev. 1550.9	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
		Fine to Medium Sandy Loam, with Coarse Gravel and lenses of Sand, brown, moist (very dense)	65		58 LL = 12 PL = 11
			70		59
1541.9	9'		100/2"		60
1540.9	10'	Fine Sand, brown, with pieces of weathered*	120		61
		Refusal			

No water encountered in probing boring immediately after completion

Boring attempted at stations 58+75 (elevation 1554.0) and 58+25 with refusal at 1.5'

*Charcoal colored schist

LOG OF BORING

PROJECT: 70-50 Basin #2 Expansion Erie Mining Co. Hoyt Lakes, Minn.	BORING: ST-13 LOCATION: Sta. 62+00 DATE: 2/27/70 SCALE: 1" = 6'

Elev. 1542.4	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
		Ice			
1540.4	2'			▼	
		Fine to Medium Sand to Fine Sand, dark grey, (very loose) (tailings)	1		47
			4		48
			2		49
			2		50
1518.4	24'				
		Fibrous Peat with wood, dark brown, wet	6		51
1516.4	26'				
		Fine Loamy Sand to Sandy Loam with granite fragments and lenses of Medium Sand grey, wet (dense)	40		52
1510.4	32'				
		Refusal			

Water level at 3' when measured immediately after completion and at 2' when rechecked 5 days later

LOG OF BORING

PROJECT: 70-50
Basin #2 Expansion
Erie Mining Co.
Hoyt Lakes, Minnesota

BORING: ST-13A

LOCATION:

Sta. 61+50

DATE: 2/27/70

SCALE: 1" = 6'

Elev. 1542	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
1541	1'	Ice			
		Fine Sand, dark grey, (loose) (tailings)		▼	
			5		53 Specific Gravity = 3.03
1533	9'				
		Fine Loamy Sand, grey (very loose) (tailings)	2		54
			3		55
1523	19'				
		Fine Sand, dark grey (loose) (tailings)	6		56
1519	23'				
		Fine to Medium Sandy Loam with layers of Clay and Sand, dark brown and brown, wet	15		57
		Granite fragments (medium dense)			
1513	29'				
		Refusal			

Water level at 2.0' when measured immediately after completion and at 2.0' when measured 5 days later

LOG OF BORING

SOIL ENGINEERING SERVICES, INC. 40.

PROJECT: 70-50 Basin #2 Expansion Erie Mining Co. Hoyt Lakes, Minn.	BORING: ST-14 LOCATION: Sta. 64+00 DATE: 2/24/70 SCALE: 1" = 6'

Elev. 1544.8	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
		Fine Sand, grey, frozen to wet (loose) (tailings)	2		1
			3		2
			5		3 Specific Gravity = 2.88
			5		4
1530.8	14'				
		Fine Sand with layers of Silt Loam and Very Fine Sand, grey, wet (loose) (tailings)	7		5
			4		6
1520.8	24'				
		Silt Loam, non plastic, with layers of Sand, greyish brown, wet (loose) (tailings)	5		7 Specific Gravity = 2.85
1515.8	29'				
		Fine to Medium Sand, grey (tailings) (medium dense)	15		8
1510.8	34'				
		Fibrous Peat with wood, dark brown, moist to wet (soft)	4		9
			3		10 mc = 417%
1500.3	44.5'				
		Muck, olive, wet (soft)	3		11 mc = 216%
1495.3	49.5'				
		Medium to Loose Sand and Gravel, brownish grey, wet (loose)	1		12
1491.8	53'				
		Fine Sand with a little Gravel, dark grey, layers of brown Medium Sand and a few pieces of wood, wet (medium dense)	18		13
1487.8	57'				
		Medium to Coarse Sand with granite fragments, brown, wet (very dense)	52		14
1482.3	62.5'				
		Refusal			

Water level at 2' when measured immediately after completion and at surface when rechecked 8 days later

LOG OF BORING

41.

PROJECT: 70-50 Basin #2 Expansion Erie Mining Co. Hoyt Lakes, Minn.	BORING: ST-15 LOCATION: Sta. 64+00
	DATE: 2/25/70 — SCALE: 1" = 6'

Elev.	Depth	Description of Materials	BPF	WL	Sample #	Tests or Notes
1543.5	0'	Fine Sand, grey, frozen to wet (loose) (tailings)		▼		
			3		15	
1533.5	10'		2		16	
		Very Fine Loamy Sand with layers of brown Silt Loam, grey, wet (loose) (tailings)	3		17	
1524.5	19'					
		Fine Sand, grey, (loose) (tailings)	2		18	
			3		19	
			9		20	
1511.5	32'					
		Very Fibrous Peat with wood, dark brown, moist (soft)	4		21	
1505.8	38'					
		Muck, olive, wet (soft)	3		22	γ dry = 38.3 pcf m.c = 91.5%
1501.5	42'					
		Fine to Medium Sandy Loam with Gravel, slightly plastic to plastic, brownish grey, wet (medium dense)	15		23	LL = 11 PL = 11
			15		24	γ dry = 142.7 pcf mc = 6.6%
1489.5	54'					
		Fine to Medium Loamy Sand, with Gravel, brown, wet (very dense)	116		25	
			46		26	
1479.5	64'					
		Granite fragments	37		27	
1472.5	71'		120/5"		28	

Water level at 3' when measured immediately after completion and again 7 days later

LOG OF BORING

PROJECT: 70-50
Basin #2 Expansion
Erie Mining Co.
Hoyt Lakes, Minn.

BORING: ST-16
LOCATION:
Sta. 67+00

DATE: 2/26/70
SCALE: 1" = 6'

Elev. 1547.4	Depth 0'	Description of Materials	BPF	WL	Tests or Notes Sample #
1545.9	1.5'	Ice			
		Fine to Medium Sand, dark grey, lenses of brown Silt Loam below 7', moist to wet (loose) (tailings)	3	▼	31
			3		32
			4		33
			6		34
1534.4	13'				
1532.4	15'	Silt Loam, brown, mixed with Peat & Wood (loose)	2		35
1529.4	18'	Fine to Medium Loamy Sand, with granite fragments, brown, wet			
		Refusal			

Water level at 3.0' when measured immediately after completion and again 6 days later

LOG OF BORING

PROJECT: 70-50 Basin #2 Expansion, Erie Mining Co., Hoyt Lakes, Minn.	BORING: ST-16B
	LOCATION: Sta. 67+00
	DATE: 2/27/70 — SCALE: 1" = 6'

Elev. 1546.8	Depth 0'	Description of Materials	BPF	WL	Tests or Notes / Sample #
1545.3	1.5'	Ice			
		Very Fine Sand to Fine Sandy Loam with lenses of Silt Loam, grey, frozen to wet (loose) (tailings)	5		40
			5		41
			9		42
			4		43
			7		44
1519.8	27'				
		Granite fragments with Fine to Medium Sandy Loam, (primarily reddish granite)	65		45
1511.8	35'		120/2"		46
		Refusal			

Water level at 4.0' when measured immediately after completion and at 2' when measured 5 days later

LOG OF BORING

PROJECT: 70-50 Basin #2 Expansion Erie Mining Co. Hoyt Lakes, Minn.	BORING: ST-17 LOCATION: Sta. 69+00 DATE: 2/27/70 SCALE: 1" = 6'

Elev. 1567.4	Depth 0'	Description of Materials	BPF	WL	Tests or Notes / Sample #
		Fine to Medium Sandy Loam, a little Fine Gravel, brown, (very dense)	62		29 30 γdry = 134.3 pcf m.c = 8.0% LL = 13 PL = 11
1563.4	4.0				
		Refusal Boring attempted at stations 69+45 (1569.3) and 69+50 (1561.7) with refusal at 7.5' and 2.5', respectively			

EBASCO SERVICES INCORPORATED

LOG OF BORING

PROJECT Erie Mining Company - E-Series Borings

ORDER NO. ______

ELEVATION ______ GWL 0 HRS. ______

—— HRS. ______

BORING NO. E-1

DATE START 7/22/77 DATE COMPLETE 7/22/77 FIELD ENGINEER Richard C Miller - EBASCO

DEPTH FEET	BLOWS PER SIX INCHES	SAMPLE NO. AND TYPE	RECOVERY	PROFILE	SOIL STRATA DEPTH	COLOR	MATERIAL CLASSIFICATION	REMARKS
						dk grey	Silty fine to coarse Sand, loose - (Tailing)	
5	6 / 4 / 4	1	18"					
10	4 / 6 / 12	2	18"			dk grey	Silty fine to coarse Sand, loose - (Tailing)	
15								
	18 / 17 / 14	3	18"			dk grey	Silty fine to medium Sand, trace coarse Sand, medium dense - (Tailing)	
20								
	7 / 7 / 9	4	18"			dk grey	Silty coarse Sand, trace medium Sand, loose - (Tailing)	
25								
	12 / 10 / 8	5	18"			dk grey	Silty medium Sand, trace fine Sand, medium dense - (Tailing)	
30								

REMARKS ______

BORING NO. E-1

EBASCO SERVICES INCORPORATED

LOG OF BORING

PROJECT Erie Mining Company - E-Series Borings
ORDER NO.
ELEVATION
GWL 0 HRS.
HRS.
BORING NO. E-1

DATE START 7/22/77 DATE COMPLETE 7/22/77 FIELD ENGINEER Richard C Miller - EBASCO

DEPTH FEET	BLOWS PER SIX INCHES	SAMPLE NO. AND TYPE	RECOVERY	PROFILE	SOIL STRATA DEPTH	COLOR	MATERIAL CLASSIFICATION	REMARKS
31	11 9 8	6	12"			dk grey	Silty medium Sand, trace coarse Sand, medium dense - (Tailing)	
35	7 6 6	7	18"			dk grey	Silty fine to medium Sand, loose - (Tailing)	
40	4 5 4	8	18"			dk grey	Silty very fine Sand to Silt with stringers of Clayey Silt, light brown, loose - (Tailing)	
45	4 3 2	9	18"				same as above	
50	6 2 2	10	18"			dk grey	Silt, some Clayey Silt to silty very fine Sand, loose - (Tailing)	
55	4 4 5	11	18"				Black very fine Sand to lenses of light brown Clayey Silt and grey Silt, loose - (Tailing)	
					58½'	brown	Muskeg	
60								

REMARKS

BORING NO. E-1

EBASCO SERVICES INCORPORATED

LOG OF BORING

SHEET 3 OF 3

PROJECT Erie Mining Company - E-Series Borings

ORDER NO.

ELEVATION GWL 0 HRS.

HRS.

BORING NO. E-1

DATE START 7/22/77 DATE COMPLETE 7/22/77 FIELD ENGINEER Richard C Miller - EBASCO

DEPTH FEET	BLOWS PER SIX INCHES	SAMPLE NO. AND TYPE	RECOVERY	PROFILE	SOIL STRATA DEPTH	COLOR	MATERIAL CLASSIFICATION	REMARKS
61	4 8 9	12	18"			brown	Muskeg	
					62'			
							depth of hole: 62'	
							piezometer installed	

REMARKS

BORING NO. E-1

EBASCO SERVICES INCORPORATED

LOG OF BORING

SHEET 1 OF 3

PROJECT Erie Mining Company - E-Series Borings

ORDER NO.

ELEVATION

GWL 0 HRS.

BORING NO. E-4

HRS.

DATE START 7/22/77 DATE COMPLETE 7/22/77 FIELD ENGINEER Richard C Miller - EBASCO

DEPTH FEET	BLOWS PER SIX INCHES	SAMPLE NO. AND TYPE	RECOVERY	PROFILE	SOIL STRATA DEPTH	COLOR	MATERIAL CLASSIFICATION	REMARKS
						dk grey	Silty fine Sand, trace medium Sand, loose - (Tailing)	
5	10 9 8	1	18"					
10	5 3 4	2	18"			dk grey	Silty fine Sand, some medium Sand, loose - (Tailing)	
15	6 6 5	3	18"			dk grey	Silty fine to medium Sand, trace coarse Sand, loose - (Tailing)	
20	5 4 5	4	18"			dk grey	Silty fine Sand, some medium Sand, loose - (Tailing)	
25	5 5 5	5	18"				same as above	

REMARKS

BORING NO. E-4

EBASCO SERVICES INCORPORATED

LOG OF BORING

PROJECT Erie Mining Company - E-Series Borings

ORDER NO.

ELEVATION ______ GWL 0 HRS. ______

BORING NO. E-4

___ HRS. ______

DATE START 7/22/77 DATE COMPLETE 7/22/77 FIELD ENGINEER Richard C Miller - EBASCO

DEPTH FEET	BLOWS PER SIX INCHES	SAMPLE NO. AND TYPE	RECOVERY	DESCRIPTION: PROFILE	DESCRIPTION: SOIL STRATA DEPTH	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	REMARKS
31	5 2 2	6	18"			dk grey	Silty very fine Sand, trace fine and medium Sand, loose - (Tailing)	
35								
	4 4 5	7	18"			dk grey	Silty very fine Sand, lenses of light brown Clayey Silt, loose - (Tailing)	
40								
	4 2 1	8	18"				same as above	
45								
	6 5 6	9	18"			dk grey	Silty fine Sand, loose - (Tailing)	
50								
	7 4 7	10	18"			dk grey	Silty very fine Sand, loose - (Tailing)	
55								
	1 1 2	11	18"			lt grey	Silt with lenses light brown Clayey Silt - 14" - Clayey Silt - 4", very loose - (Tailing)	
60								

REMARKS

BORING NO. E-4

EBASCO SERVICES INCORPORATED

LOG OF BORING

PROJECT Erie Mining Company - E-Series Borings

ORDER NO.

ELEVATION

GWL 0 HRS.

HRS.

BORING NO. E-4

DATE START 7/22/77

DATE COMPLETE 7/22/77

FIELD ENGINEER Richard C Miller - EBASCO

DEPTH FEET	BLOWS PER SIX INCHES	SAMPLE NO. AND TYPE	RECOVERY	PROFILE	SOIL STRATA DEPTH	COLOR	MATERIAL CLASSIFICATION	REMARKS
61	11 10 7	12	18"			dk grey	Silty very fine Sand, loose - (Tailing)	
65								
	1 1 2	13	18"			lt brown	Clayey Silt, very loose - (Tailing)	
					69½'		Boulder at 69½' - natural ground	
							depth of hole: 71' piezometer installed	

REMARKS

BORING NO. E-4

BORING LOG

PROJECT: LTV- Area 2W Tailing Basin
DATE STARTED: 10-16-92
DATE COMPLETED: 10-20-92
FIELD INSPECTOR: K. Mann (BEC)
CREW CHIEF: Larry Anderson (AEC)

BORING NO.: E-5

RISER PIPE ELEVATION: 1685.5 ft.

GROUND SURFACE ELEVATION: 1683.6 ft.

Depth (Feet)	Blows Per 6"	Sample Type	N Value	Recovery (Feet)	Profile	DESCRIPTION OF MATERIALS AND REMARKS
0						POORLY GRADED SAND (SP)-About 5% coarse sand; about 95% fine to medium sand; loose; dry; grey.
5	5 8 10 13	SS	18	1.8		6.0'
						POORLY GRADED SAND (SP)- Trace gravel; about 85% medium to coarse sand; about 15% fine sand; loose to medium dense; grey; dry.
10	4 4 5 5	SS	9	1.9		11.0'
						POORLY GRADED SAND (SP)- Trace gravel; about 10% coarse sand; about 85% fine to medium sand about 5% silt; loose to medium dense; black; dry.
						14.0'
15	5 5 7 9	SS	12	1.9		POORLY GRADED SAND (SP)- Trace gravel; about 85% medium to coarse sand; about 15% fine sand; medium dense; dark grey; dry.
						19.0'
20	5 6 6 6	SS	12	2.0		POORLY GRADED SAND- Black, as above.
						24.0'
25	8 10 17 21	SS	27	2.0		POORLY GRADED SAND WITH SILT (SP-SM)- About 80% fine sand; about 20% silt; black; medium dense; dry.
30	9 10	SS				▢ - Coarse Tailings

COMMENT: Soil boring was completed using a CME 550 rubber tire-mounted drilling rig with a 4 1/4-inch (ID) hollow stem auger by American Engineering Co. (AEC), and was observed by a geotechnical engineer from Barr Engineering Co. (BEC). Soil samples were collected according to ASTM Method D1586 using a 1 3/8-inch (ID) split barrel sampler (SS) and are described according to ASTM Method D2488.

BORING LOG

PROJECT: LTV- Area 2W Tailing Basin
DATE STARTED: 10-12-92
DATE COMPLETED: 10-20-92
FIELD INSPECTOR: K. Mann (BEC)
CREW CHIEF: Larry Anderson (AEC)

BORING NO.: E-5

GROUND SURFACE ELEVATION: 1683.6 ft.

Depth (Feet)	Blows Per 6"	Sample Type	N Value	Recovery (Feet)	Profile	DESCRIPTION OF MATERIALS AND REMARKS
30	12 10	SS	22	1.9		POORLY GRADED SAND WITH SILT (SP-SM)- About 90% fine sand; about 10% silt; black; medium dense; dry.
35	12 25 31 27	SS	56	1.9		
						39.0'
40	9 13 12 11	SS	25	2.0		POORLY GRADED SAND (SP)- About 95% fine to medium sand; about 5% silt; grey; medium dense to dense; dry.
						44.0'
45	11 15 26 26	SS	41	1.8		POORLY GRADED SAND (SP)- Trace gravel; about 5% coarse sand; about 90% fine to medium sand; about 5% silt; grey; dense; dry to moist. Layer or lense of silt and silty sand between 44 and 44.5 ft.
50	11 16 16 17	SS	32	1.9		
						54.0'
55	9 7 5 10	SS	12	1.9		POORLY GRADED SAND- As above, with silt layer. Silt is grey to black, slow dilatancy, low plasticity.
60						

▒ - Coarse Tailings

COMMENT: Soil boring continued at 54 feet using a 3 7/8-inch diameter tricone bit and drilling mud.

BORING LOG

PROJECT: LTV- Area 2W Tailing Basin
DATE STARTED: 10-16-92
DATE COMPLETED: 10-20-92
FIELD INSPECTOR: K. Mann (BEC)
CREW CHIEF: Larry Anderson (AEC)

BORING NO.: E-5

GROUND SURFACE ELEVATION: 1683.6 ft.

Depth (Feet)	Blows Per 6"	Sample Type	N Value	Recovery (Feet)	Profile	DESCRIPTION OF MATERIALS AND REMARKS
60	8 10 15 18	SS	25	1.9	Coarse Tailings	POORLY GRADED SAND (SP)- Trace gravel; about 5% coarse sand; about 90% fine to medium sand; about 5% silt; grey to black; dense; moist.
65	10 15 20 18	3T	35	1.3	Coarse Tailings	
70	10 12 12 16	SS	24	1.3	Coarse Tailings	
75	13 12 14 14	SS	26	1.7	Fine Tailings	75.0' INTERBEDDED SILTY SAND (SM) AND POORLY GRADED SAND (SP)- Silty sand consists of about 70% very fine to fine sand; about 30% silt; dense; grey to brown; laminated. Sand is as above, wet.
80	13 16 16 17	SS	32	1.5	Coarse Tailings; water level symbol	80.0' POORLY GRADED SAND (SP)- Trace gravel; about 80% medium to coarse sand, about 20% fine sand; dense, grey. Water level is approximately 81 ft.
85	15 13 18 16	SS	31	1.6	Coarse Tailings	
90						

Legend: - Coarse Tailings; - Fine Tailings

COMMENT:

BORING LOG

PROJECT: LTV- Area 2W Tailing Basin
DATE STARTED: 10-16-92
DATE COMPLETED: 10-20-92
FIELD INSPECTOR: K. Mann (BEC)
CREW CHIEF: Larry Anderson (AEC)

BORING NO.: E-5

GROUND SURFACE ELEVATION: 1683.6 ft.

Depth (Feet)	Blows Per 6"	Sample Type	N Value	Recovery (Feet)	Profile	DESCRIPTION OF MATERIALS AND REMARKS
90	10 11 16 16	SS	27	1.5	Coarse Tailings	POORLY GRADED SAND (SP)-Trace gravel; about 80% medium to coarse sand; about 20% fine sand; dense; grey.
95	17 15 13 16	SS	28	1.5	Coarse Tailings	
100					Coarse Tailings	
105						105.0'
105	12 11 18 18	SS	29	1.8	Coarse Tailings	POORLY GRADED SAND (SP)- About 5% coarse sand; about 90% fine to medium sand; about 5% silt; dense; grey to black.
110						110.0'
110	13 14 14 19	SS	28	¯1.7	Coarse Tailings	SILTY SAND (SM)- About 70% fine sand; about 30% silt; dense; grey.
						112.0' E.O.B.
115						Bottom of borehole.
120						

▒ - Coarse Tailings

COMMENT:

BORING LOG

PROJECT: LTV- Area 2W Tailing Basin
DATE STARTED: 10-16-92
DATE COMPLETED: 10-20-92
FIELD INSPECTOR: K. Mann (BEC)
CREW CHIEF: Larry Anderson (AEC)

BORING NO.: E-5

GROUND SURFACE ELEVATION: 1683.6 ft.

Depth (Feet)	Blows Per 6"	Sample Type	N Value	Recovery (Feet)	Profile	DESCRIPTION OF MATERIALS AND REMARKS
						Notes: Borehole E-5 was completed as a piezometer on 10/19/92 and 10/20/92 by American Engineering Company (AEC) using a CME 550 rubber tire-mounted drilling rig with a 4 1/4-inch (I.D.) hollow stem auger. Piezometer construction consists of a 2-inch (O.D.) schedule 80 PVC riser and screen forming an assembly 110.2 feet long. The screen, placed between 90.2 and 110.2 feet, is #10 slot and 20 feet long. The screen annulus was backfilled with coarse tailings to 82.5 feet, and a bentonite plug was placed to 80.5 feet. The remainder of the annulus was grouted, and a schedule 40 steel protective casing was installed over the riser pipe. The piezometer was developed by bailing.

COMMENT:

SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1559.6
Date drilled:	August 25, 1996	Coords (ft):	405,433N, 2,234,935E

Plot legend: ◆ % Passing #200 (scale 10, 30, 50, 70, 90); Plastic Limit ×, Water Content o, Liquid Limit × (scale 20%, 40%, 60%, 80%)

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
0				SAND (SM/SP-SM), fine to coarse, some silt, compact, angular, dark brownish gray, wet, (COARSE TAILINGS)	
5	16	1	SPT		
10	1	2	SPT	As above, very loose	
15	16	3	SPT	As above, compact	
20	17	4	SPT		
25	19	5	SPT		
30	12	6	SPT	As above, 2 inches fine tailings	
35					

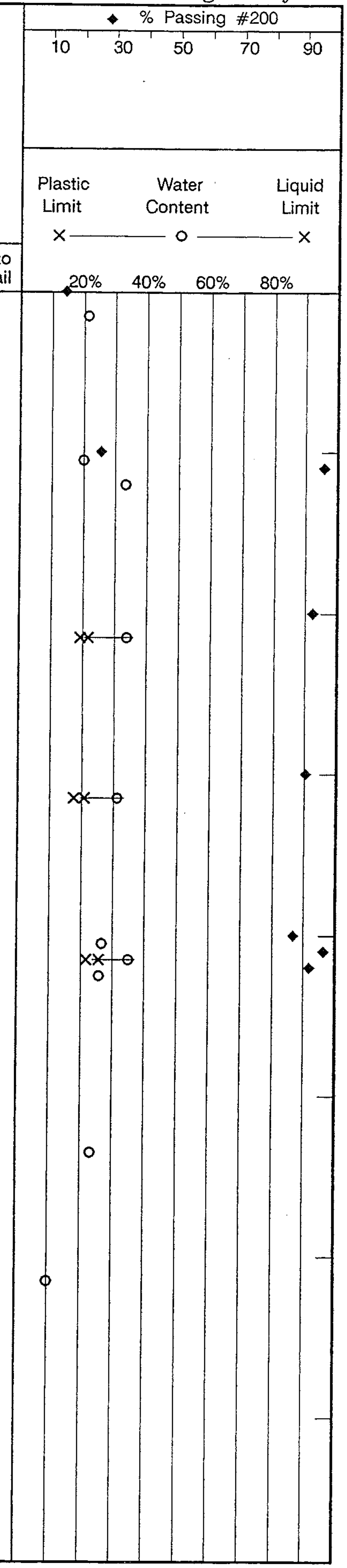
(Continued)

SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1559.6
Date drilled:	August 25, 1996	Coords (ft):	405,433N, 2,234,935E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	9	7	SPT		
				SAND (SM), fine, silty, loose, angular, gray, wet, (FINE TAILINGS)	
40	9	8A	SPT		
		8B		SILT (ML), trace fine sand, low plasticity, soft to firm, angular, brownish gray, wet, (SLIMES)	
45	4	9	SPT	As above, layers of fine tailings	
50	4	10	SPT	As above, black slime layers	
				SILT (ML), some fine sand, loose, angular, black, slime layers, wet, (FINE TAILINGS)	
55	7	11A	SPT		
		11B			
		11C		SILT & CLAY (ML/CL-ML), low plasticity, firm, angular, light gray, wet, black fine tailings layers, (SLIMES)	
				PEAT (PT), compact, black, brown & brownish red, moist	
60	15	12A	SPT		
		12B		SAND (SM/SC-SM), silty, clayey, fine, dense to very dense, angular, dark brownish gray, wet, (TILL)	
65	33	13	SPT	As above, trace gravel	
70				End of hole at 70.0 feet	



Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1610.3
Date drilled:	July 12,1996	Coords (ft):	405,676N, 2,234,927E

◆ % Passing #200: 10, 30, 50, 70, 90

Plastic Limit ×——— Water Content o ——— Liquid Limit ×: 20%, 40%, 60%, 80%

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
				SAND (SP), fine to coarse, trace to some silt, compact to dense, angular, brownish gray, damp, (COARSE TAILINGS)
5	16	1	SPT	
10	20	2	SPT	
				As above, medium to coarse, dense, wet
15	28	3	SPT	
20	14	4	SPT	
25	29	5	SPT	
30	27	6	SPT	
35				

(Continued)

SITKA CORP
Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1610.3
Date drilled:	July 12,1996	Coords (ft):	405,676N, 2,234,927E

◆ % Passing #200 (10, 30, 50, 70, 90)

Plastic Limit ×—— Water Content o —— Liquid Limit × (20%, 40%, 60%, 80%)

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
	32	7	SPT	SAND (SP), medium to coarse, trace to some silt, compact to dense, angular, brownish gray, damp, (COARSE TAILINGS)
40	36	8	SPT	
45	26	9	SPT	
50	25	10	SPT	
55	38	11	SPT	
60	36	12	SPT	
65	36	13	SPT	
70				

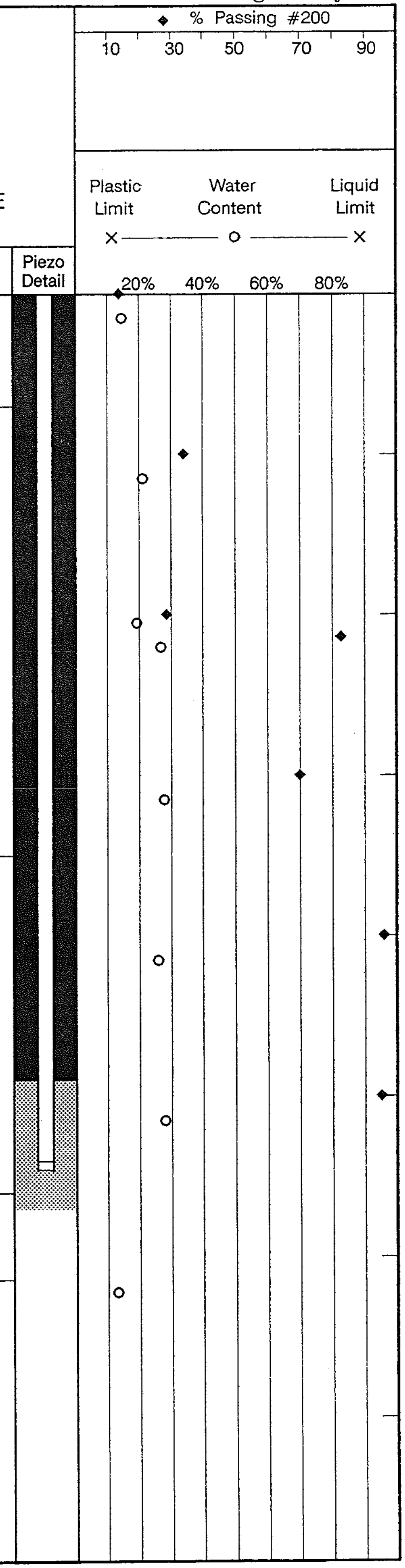
(Continued)

SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1610.3
Date drilled:	July 12,1996	Coords (ft):	405,676N, 2,234,927E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
	40	14	SPT	
				SAND (SP-SM), fine to medium, silty, compact, angular, gray, moist, (FINE TAILINGS)
75	25	15	SPT	
80	27	16A	SPT	
		16B		As above, fine sandy silt
85	29	17	SPT	
				SILT (ML), trace fine sand, very stiff, angular, gray to dark gray, wet, (SLIMES)
90	29	18	SPT	
95	27	19	SPT	
				ORGANIC SILT & PEAT (OL/PT), organic, dense, dark brown & dark black, moist (PEAT)
100	42	20A	SPT	
		20B		SAND (SC/SC-SM), clayey & silty, some gravel, very dense, angular & rounded, brownish gray, moist, (TILL)
105				



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SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1610.3
Date drilled:	July 12,1996	Coords (ft):	405,676N, 2,234,927E

◆ % Passing #200: 10, 30, 50, 70, 90

Plastic Limit ×——○—— × Liquid Limit; Water Content: 20%, 40%, 60%, 80%

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	72	21	SPT		
110	74	22	SPT		
115	29	23	SPT		
120				End of hole at 119.5 feet. Inclinometer installed at 119.5 feet, 2.6 foot stick up. Pneumatic piezometer installed in adjacent hole drilled with hollow-stem auger. Water Level @ 43.7 feet on 9/10/96.	
125					
130					
135					
140					

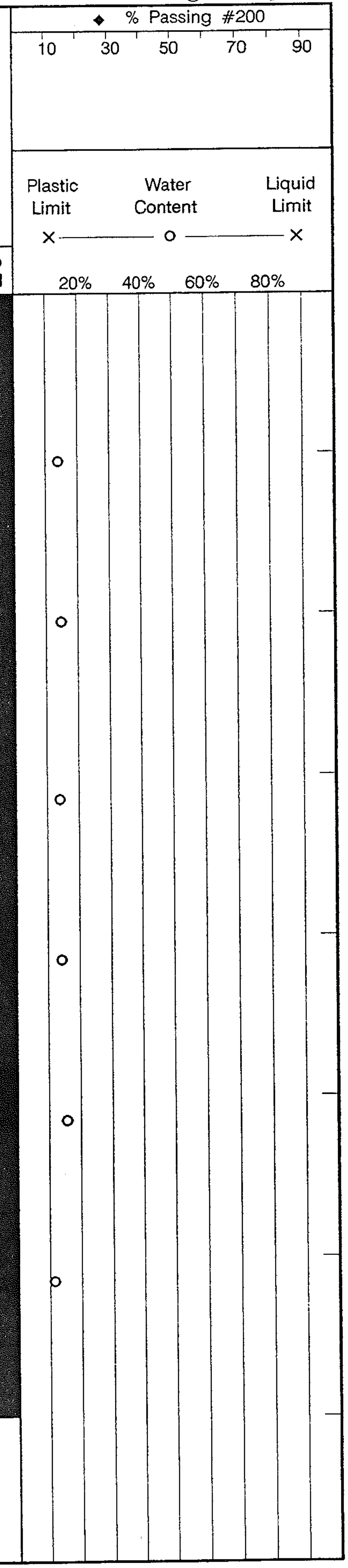
SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1649.3
Date drilled:	August 13 - 14, 1996	Coords (ft):	405,809N, 2,234,963E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
				SAND (SM), fine to medium, some silt, compact to dense, angular, brownish gray, damp, (COARSE TAILINGS)
5	14	1	SPT	
10	22	2	SPT	As above, trace to some silt (SM/SP-SM)
15	9	3	SPT	As above, moist
20	38	4	SPT	
25	29	5	SPT	As above, medium to coarse
30	50	6	SPT	As above, dense to very dense
35				

Piezo Detail



(Continued)

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1649.3
Date drilled:	August 13 - 14, 1996	Coords (ft):	405,809N, 2,234,963E

◆ % Passing #200: 10, 30, 50, 70, 90

Plastic Limit ×—— Water Content o —— × Liquid Limit: 20%, 40%, 60%, 80%

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
	77	7	SPT	
40	60	8	SPT	
45	44	9	SPT	
50	47	10	SPT	As above, some sandy silt (ML)
55	55	11	SPT	
60	31	12	SPT	As above, fine to coarse, compact to dense
				As above, some fine tailings layers
65	29	13	SPT	
70				

(Continued)

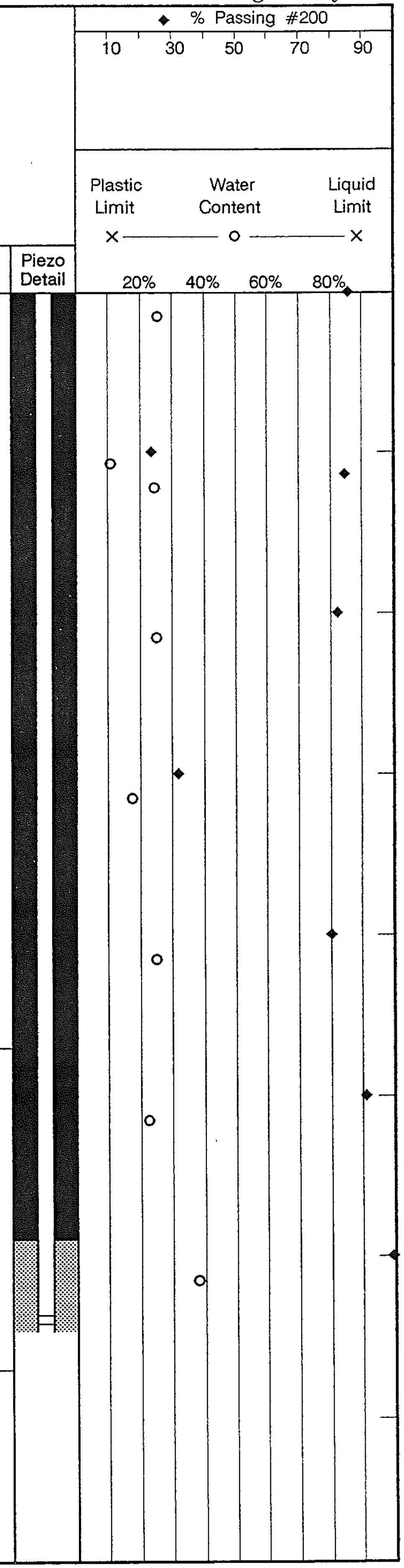
Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1649.3
Date drilled:	August 13 - 14, 1996	Coords (ft):	405,809N, 2,234,963E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
	32	14	SPT	
75	35	15	SPT	
80	23	16	SPT	
85	34	17	SPT	As above, some fine tailings layers
90	32	18	SPT	
95	8	19	SPT	SILT (ML), trace fine sand, firm, angular, brownish gray, wet, some fine tailings layers, (SLIMES)
100	24	20	SPT	SILT (ML), some sand to sandy, compact to dense, angular, gray, wet (FINE TAILINGS)
105				

(Continued)

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1649.3
Date drilled:	August 13 - 14, 1996	Coords (ft):	405,809N, 2,234,963E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
	13	21	SPT	
110	33	22A / 22B	SPT	As above, silty sand
115	37	23	SPT	
				As above, medium to coarse sand, silty
120	36	24	SPT	
				As above, silt, some medium to coarse sand
125	35	25	SPT	
				SILT (ML), trace medium to coarse sand, very stiff, angular, dark gray, wet, some fine tailings layers, (SLIMES)
130	27	26	SPT	
135	11	27	SPT	As above, clayey (CL-ML/ML), brownish gray
				SAND (SC-SM), silty, clayey, trace gravel, angular &
140				



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SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1649.3
Date drilled:	August 13 - 14, 1996	Coords (ft):	405,809N, 2,234,963E

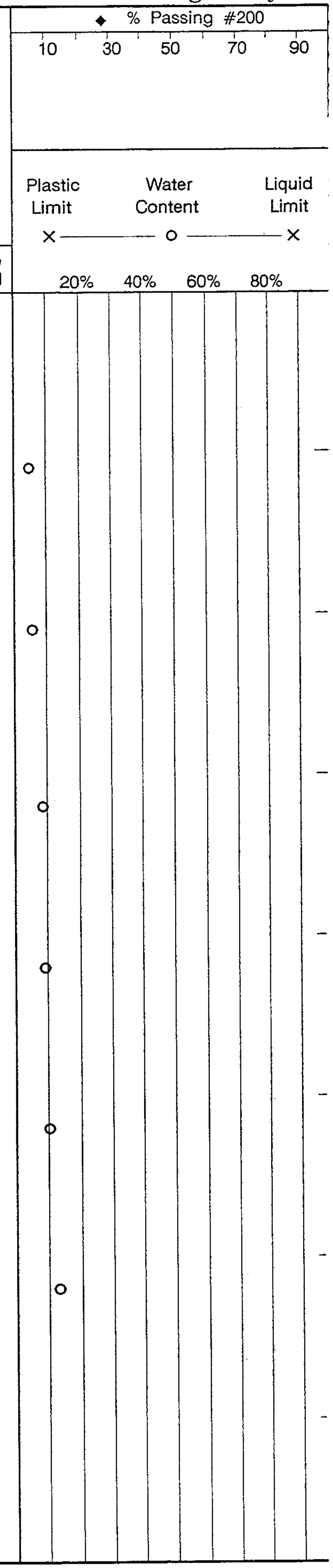
◆ % Passing #200: 10 30 50 70 90

Plastic Limit ×——— Water Content ○ ———× Liquid Limit (20% 40% 60% 80%)

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	31	28	SPT	rounded, brown, tan & red, wet (TILL)	
				End of Hole at 142.0 feet. Pneumatic piezometer installed. Water Level @ 76.5 feet on 9/10/96.	
145					
150					
155					
160					
165					
170					
175					

Project:	LTV Tailings Assessment
Project No:	L78.5.7
Location:	Hoyt Lakes, MN
Date drilled:	August 10 - 12, 1996
Equipment:	CME 750 mud rotary
Ground El (ft):	1712.4
Coords (ft):	406,082N, 2,235,010E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
0				SAND (SM/SP-SM), fine to coarse, some silt, compact, angular, brownish gray, damp, (COARSE TAILINGS)	
5	11	1	SPT		
10	15	2	SPT		
				As above, medium to coarse	
15	14	3	SPT		
20	25	4	SPT		
25	27	5	SPT		
30	26	6	SPT		
35					



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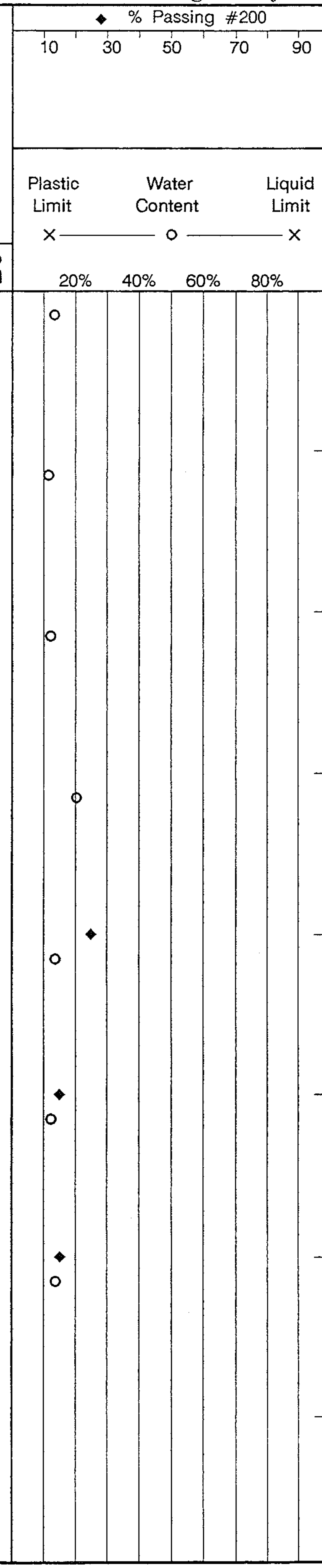
Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1712.4
Date drilled:	August 10 - 12, 1996	Coords (ft):	406,082N, 2,235,010E

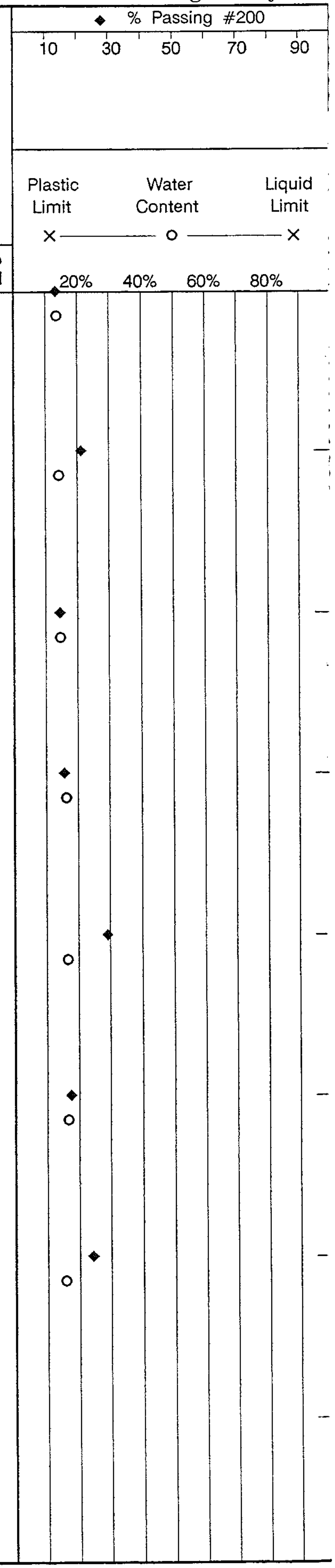


Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	63	7	SPT	As above, very dense	
40	31	8	SPT	As above, dense	
45	48	9	SPT		
				SAND (SM), fine, silty, dense, angular, gray, moist, (FINE TAILINGS)	
50	30	10	SPT		
55	46	11	SPT	As above, brown slime layers	
				SAND (SM/SP-SM), fine to medium, some silt, dense to very dense, angular, gray, (COARSE TAILINGS)	
60	41	12	SPT		
65	85	13	SPT		
70					

(Continued)

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1712.4
Date drilled:	August 10 - 12, 1996	Coords (ft):	406,082N, 2,235,010E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	44	14	SPT		
75	40	15	SPT	SAND (SM), fine to medium, silty, dense, angular, gray, moist, (FINE TAILINGS)	
80	33	16	SPT	SAND (SM/SP-SM), fine to medium, some silt to silty, dense, angular, gray, wet, (COARSE TAILINGS)	
85	32	17	SPT		
90	42	18	SPT	SAND (SM), fine to medium, silty, dense, angular, gray, wet, (FINE TAILINGS)	
95	42	19	SPT	SAND (SM), fine to medium, some silt, dense, angular, gray, wet, (COARSE TAILINGS)	
100	36	20	SPT	SAND (SM), fine to medium, some silt, dense, angular, gray, wet, (FINE TAILINGS)	
105					



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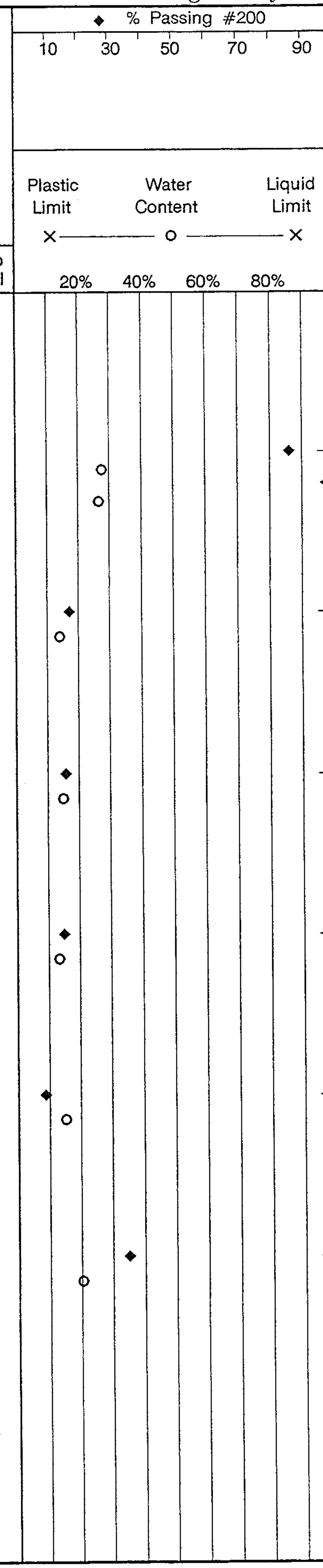
Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1712.4
Date drilled:	August 10 - 12, 1996	Coords (ft):	406,082N, 2,235,010E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	42	21	SPT	As above, silt, some fine sand	
110	17	22A	SPT		
		22B		SILT (ML), trace fine sand, very stiff, angular, gray, wet, (SLIMES)	
				SAND (SM/SP-SM), fine to medium, some silt, dense to very dense, angular, gray, wet, (COARSE TAILINGS)	
115	60	23	SPT		
120	47	24	SPT	As above, medium to coarse	
125	51	25	SPT		
130	34	26	SPT	As above, layers fine tailings	
				SAND (SM), fine, silty, dense, angular, gray, wet, 1.5 inch slime layer, (FINE TAILINGS)	
135	47	27	SPT		
				SAND (SM), fine, some silt, dense, angular, gray,	
140					



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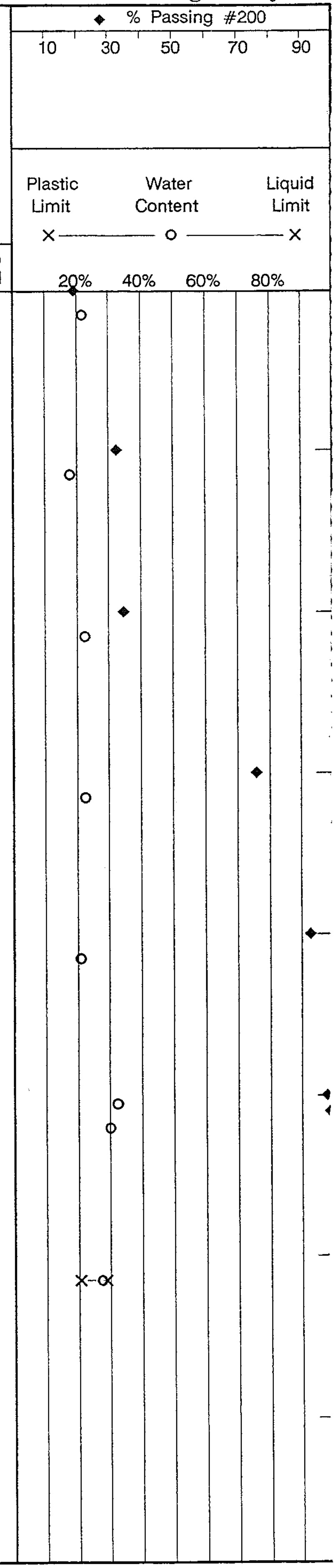
Project:	LTV Tailings Assessment
Project No:	L78.5.7
Location:	Hoyt Lakes, MN
Date drilled:	August 10 - 12, 1996
Equipment:	CME 750 mud rotary
Ground El (ft):	1712.4
Coords (ft):	406,082N, 2,235,010E

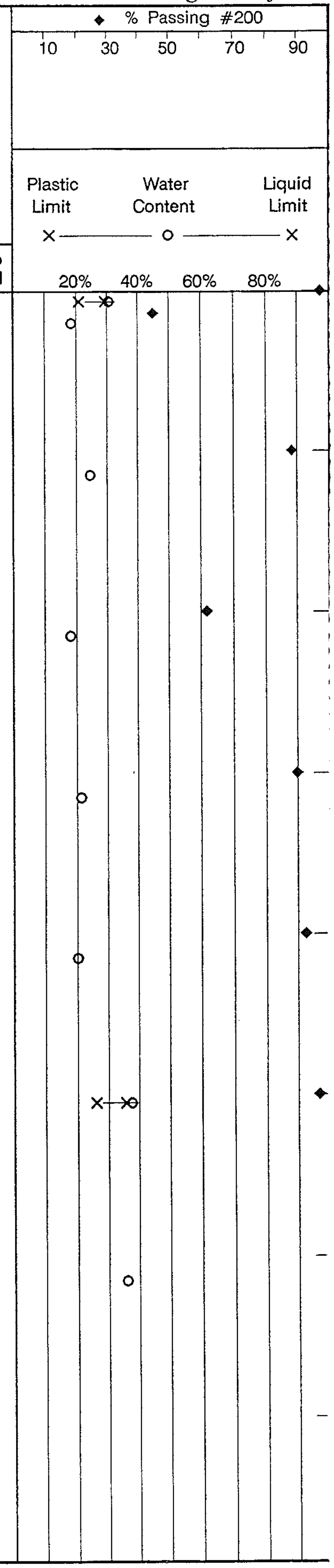


Depth (ft)	Blow Count	Sample No	Sample Type	Material Description
	41	28	SPT	wet, (COARSE TAILINGS)
				SAND (SM), fine, silty, dense, angular, brownish gray, wet, (FINE TAILINGS)
145	41	29	SPT	
150	37	30	SPT	
				As above, fine sandy silt
155	38	31	SPT	
				CLAY & SILT (CL/CL-ML), trace fine sand, low plasticity, firm to very stiff, angular, gray to brownish gray, wet, (SLIMES)
160	19	32	SPT	
165	17	33A / 33B	SPT	
170	7	34	SPT	
175				

(Continued)

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1712.4
Date drilled:	August 10 - 12, 1996	Coords (ft):	406,082N, 2,235,010E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	51	35A	SPT		
		35B		SILT & SAND (ML/SM), fine to medium, dense to very dense, angular, gray, wet, (FINE TAILINGS)	
				As above, silt, some sand	
180	47	36	SPT		
185	50	37	SPT	As above, silt and sand	
190	53	38	SPT	As above, silt, some sand	
				SILT (ML), trace fine sand, low plasticity, hard, angular, dark gray, wet, (SLIMES)	
195	74	39	SPT		
200	42	40A	SPT		
		40B		PEAT (PT/OH/OL), dense, dark brown & black, moist, organic	
205	17	41	SPT		
				SAND (SM/SC-SM), silty, clayey, trace gravels, very dense, angular & rounded, brown, gray & red, moist (TILL)	
210					



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Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1712.4
Date drilled:	August 10 - 12, 1996	Coords (ft):	406,082N, 2,235,010E

◆ % Passing #200: 10 30 50 70 90

Plastic Limit ×——— Water Content o ——— × Liquid Limit: 20% 40% 60% 80%

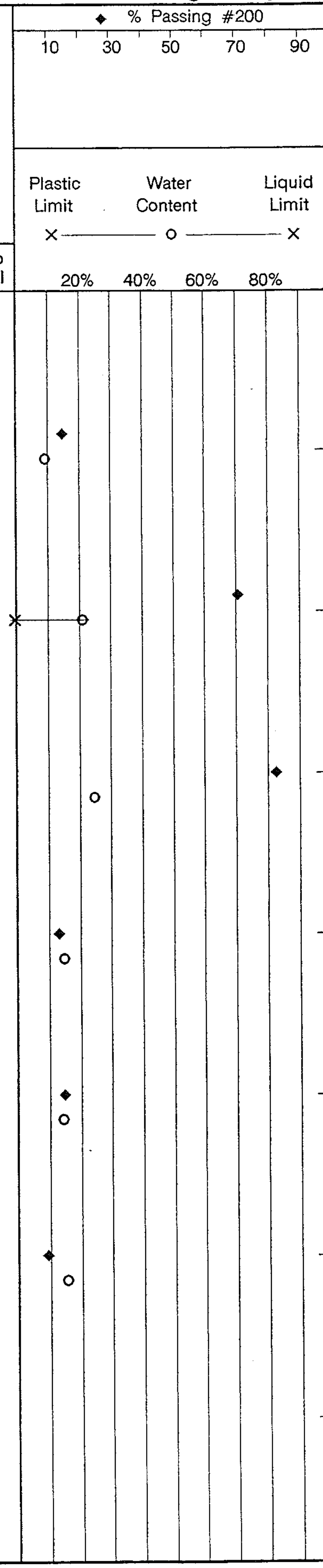
Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	54/ 0.3'	42	SPT		
215					
				End of hole at 218.0 feet Inclinometer installed at 218.0 feet, 1.8 foot stick up	
220					
225					
230					
235					
240					
245					

SITKA CORP

Test Hole Log

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1695.1
Date drilled:	August 19 - 20, 1996	Coords (ft):	406,370N, 2,235,398E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
0				SAND (SM/SP-SM), medium to coarse, some silt, compact, angular, gray, damp, (COARSE TAILINGS)	
5	17	1	SPT		
~8.5				SILT (ML), some fine sand to sandy, loose to very loose, angular, brownish gray, wet, (FINE TAILINGS)	
10	6	2	SPT		
15	2	3	SPT		
~18.5				SAND (SM/SP-SM), medium to coarse, trace to some silt, compact, angular, gray, moist, (COARSE TAILINGS)	
20	23	4	SPT		
25	16	5	SPT	As above, fine to medium	
30	29	6	SPT		
~33.5				SILT (ML), fine sandy, compact, angular, dark gray,	
35					



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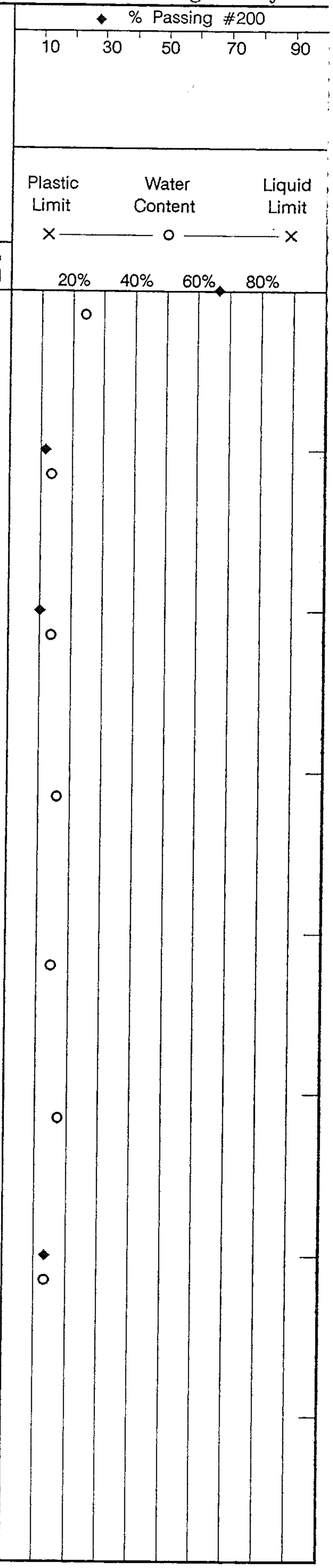
Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1695.1
Date drilled:	August 19 - 20, 1996	Coords (ft):	406,370N, 2,235,398E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	12	7	SPT	moist, some slime layers, (FINE TAILINGS)	
				SAND (SM/SP-SM), fine to medium, some silt, compact to dense, angular, brownish gray, moist, (COARSE TAILINGS)	
40	18	8	SPT		
45	29	9	SPT		
50	38	10	SPT		
55	18	11	SPT		
60	23	12	SPT		
65	31	13	SPT		
				SAND (SM), fine, silty, compact, angular, wet,	
70					



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Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1695.1
Date drilled:	August 19 - 20, 1996	Coords (ft):	406,370N, 2,235,398E

◆ % Passing #200 (10, 30, 50, 70, 90)

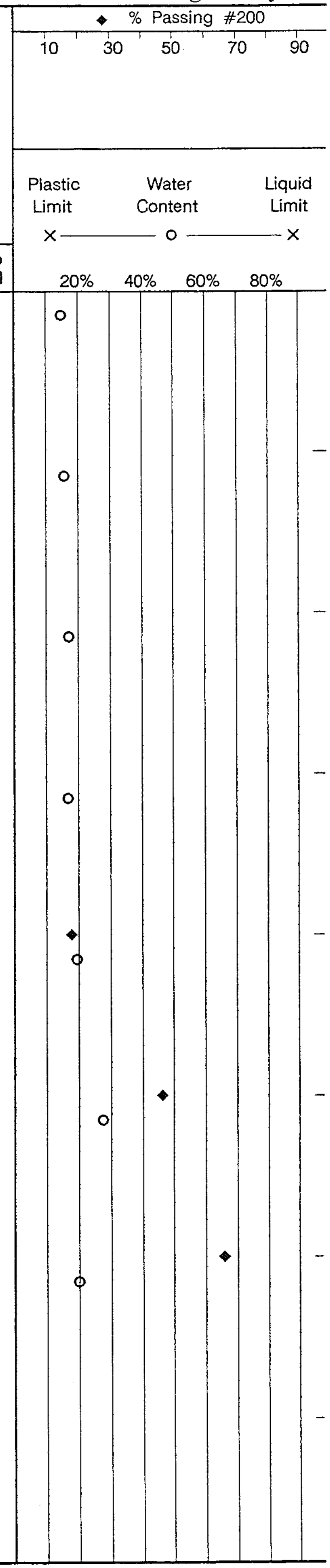
Plastic Limit × — Water Content ○ — Liquid Limit × (20%, 40%, 60%, 80%)

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	24	14	SPT	some coarse tailings layers, (FINE TAILINGS)	
75	22	15	SPT		
				SAND (SM), fine to medium, some silt, compact, angular, gray, wet (COARSE TAILINGS)	
80	29	16	SPT		
				SAND & SILT (SM/ML), fine to medium, compact to dense, angular, gray, wet, (FINE TAILINGS)	
85	28	17	SPT		
90	31	18	SPT		
				SAND (SM/SP-SM), fine to medium, some silt, dense, angular, gray, wet, (COARSE TAILINGS)	
95	41	19	SPT		
100	32	20	SPT	As above, becoming silty sand (SM)	
105					

(Continued)

Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1695.1
Date drilled:	August 19 - 20, 1996	Coords (ft):	406,370N, 2,235,398E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	37	21	SPT		
110	34	22	SPT		
115	39	23	SPT	As above, fine tailings & slime layers	
120	31	24	SPT		
125	37	25	SPT		
130	33	26	SPT	SAND & SILT (SM/ML), fine, compact to dense, angular, brownish gray, wet, (FINE TAILINGS)	
135	29	27	SPT	As above, fine sandy silt	
140					



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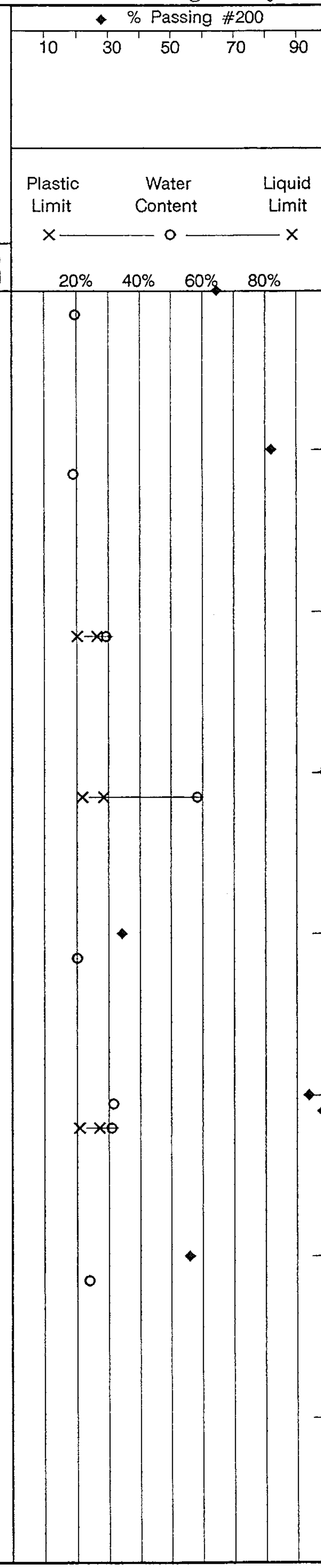
Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1695.1
Date drilled:	August 19 - 20, 1996	Coords (ft):	406,370N, 2,235,398E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	30	28	SPT		
145					
	19	29	SPT		
				SILT & CLAY (CL-ML), low plasticity, stiff, angular, brownish gray, wet, (SLIMES)	
150					
	13	30	SPT		
155					
	10	31	SPT		
				SAND (SM), fine, silty, dense, angular, brownish gray, wet, (FINE TAILINGS)	
160					
	44	32	SPT		
				SILT (ML), low plasticity, very stiff, angular, brownish gray, wet, (SLIMES)	
165	19	33A	SPT		
		33B			
				SILT & SAND (ML/SM), fine, dense, angular, dark gray, wet, (FINE TAILINGS)	
170					
	43	34	SPT		
				SILT (ML), low plasticity, very stiff to hard, angular,	
175					



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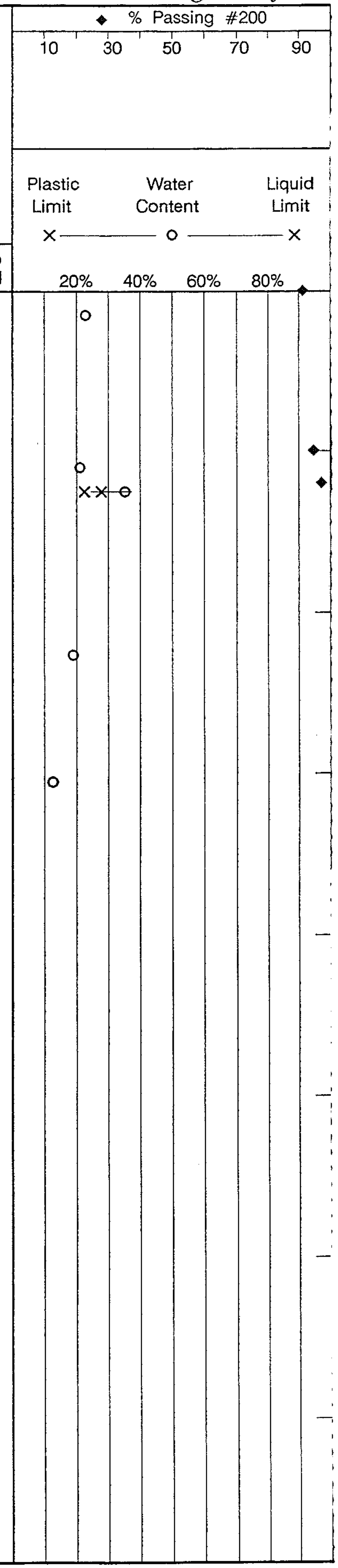
Project:	LTV Tailings Assessment	Equipment:	CME 750 mud rotary
Project No:	L78.5.7		
Location:	Hoyt Lakes, MN	Ground El (ft):	1695.1
Date drilled:	August 19 - 20, 1996	Coords (ft):	406,370N, 2,235,398E

Depth (ft)	Blow Count	Sample No	Sample Type	Material Description	Piezo Detail
	38	35	SPT	dark gray, wet, (SLIMES)	
180	29	36A 36B	SPT		
185	48	37A 37B	SPT	PEAT (PT/OH), dense, angular, dark brown & black, moist SAND (SM), fine, and silt, dense, angular, brown, moist	
190	71/ 0.5'	38	SPT	SAND (SC), fine, clayey, trace gravel, very dense, angular & rounded, brown, gray & red, (TILL)	
				End of Hole at 193.0 feet	
195					
200					
205					
210					



BORING NUMBER BH-A

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/21/09 **COMPLETED** 4/21/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING 0.50 ft
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG (depth)	MATERIAL DESCRIPTION	PID (ppm)
0	SS 1	67	SP	1.5	(SP) Brown to black, TAILINGS, no odor, wet	*
	SS 2	42	SP	3.5	(SP) Black, TAILINGS, no odor, wet	*
			GP		(GP) COARSE GRAVEL	
	SS 3	42	SP	6.0	(SP) Dark-brown to black, TAILINGS AND GRAVEL, no odor, wet	*
	SS 4	46	SP	8.5	(SP) Brown, SAND	*
10	SS 5	58	SP	11.0	(SP) Brown-gray, FINE-MEDIUM GRAINED SAND (last 8 inches is brown)	*
	SS 6	50	SP	13.5	(SP) As Above	*
	SS 7	50	SP	16.0	(SP) As Above	*
	SS 8	25	SP	18.5	(SP) As Above	*
20	SS 9	21	SP	21.0	(SP) As Above	*

PVC Temp well set 16-21 feet bgs
* = No PID readings obtained

Bottom of borehole at 21.0 feet.

BORING NUMBER BH-B

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet **PROJECT NAME** Emergency Basin Phase II
PROJECT NUMBER 7157FA.08 **PROJECT LOCATION** Hoyt Lakes, Minnesota
DATE STARTED 4/8/09 **COMPLETED** 4/10/09 **GROUND ELEVATION** ______ **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun **GROUND WATER LEVELS:**
DRILLING METHOD 4 1 4" HSA **AT TIME OF DRILLING** --- 6" Standing water at surface, drilled through water
LOGGED BY B. Flaada **CHECKED BY** D. Fossell **AT END OF DRILLING** ---
NOTES ______ **AFTER DRILLING** ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	PID (ppm)
0						Skipped interval	
	SS 1	21	SP-SM		3.5	(SP-SM) Black-drak gray, TAILINGS, saturated	<1
						Skipped interval	
	SS 2	42	SP-SM		6.0	(SP-SM) As Above	<1
						Skipped interval	
	SS 3	58	SP-SM			(SP-SM) As Above (4 inches)	<1
			SM		8.5	(SM) Tailings with concentrate, saturated	
10						Skipped interval	
	SS 4	100	SM		11.0	(SM) Dark gray, mottled, CONCENTRATE, saturated	<1
						Skipped interval	
	SS 5	100	SM		13.5	(SM) As Above	<1
						Skipped interval	
	SS 6	100	SM		16.0	(SM) As Above	<1
20					21.0	Water sample BH-B (H2O:1) interval	
						Skipped interval	
	SS 7	92	SP-SM		23.5	(SP-SM) Dark-gray to black, TAILINGS, some concentrate, saturated	<1
						Skipped interval	
	SS 8	83	SP-SM		26.0	(SP-SM) As Above	<1
						Skipped interval	
	SS 9	83	SP-SM		28.5	(SP-SM) As Above	<1
30						Skipped interval	
	SS 10	100	SP-SM		31.0	(SP-SM) Black, TAILINGS, coarser than above though	<1
						Skipped interval	
	SS 11	75	SP-SM		36.0	(SP-SM) As Above	<1
						Skipped interval	
	SS 12	58	SP-SM			(SP-SM) As Above (12 inches)	<1
			CL-ML		38.5	(CL-ML) Grayish-brown, SILTY CLAY with organic pieces, swamp smell	
40						Skipped interval	
	SS 13	25	CL-ML		41.0	(CL-ML) Brownish-gray to dark gray, SILTY CLAY with gravel and small granite fragments	<1
						Skipped interval	
	SS 14	83	CL-ML			(CL-ML) As Above (2 inches)	<1
			SP		43.5	(SP) Brown to grayish-brown, FINE-MEDIUM SAND	
						Skipped interval	
	SS 15	83	SP		46.0	(SP) Tan-brown, FINE-MEDIUM SAND, some silt	<1
						Water sample BH-B (H2O:2) interval	
50					50.0		

Bottom of borehole at 50.0 feet.

BORING NUMBER BH-C

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/17/09 **COMPLETED** 4/17/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING ---
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	PID (ppm)
0						Skipped interval	
	SS 1	38	SP-SM		3.5	(SP-SM) Dark gray, TAILINGS, saturated, some brick fragments on surface in this area	3.8
						Skipped interval	
	SS 2	33	SP-SM		6.0	(SP-SM) As Above	2.0
						Skipped interval	
	SS 3	42	SP-SM		8.5	(SP-SM) As Above	3.4
						Skipped interval	
10	SS 4	33	SP-SM		11.0	(SP-SM) As Above	3.7
						Skipped interval	
	SS 5	42	SP-SM		13.5	(SP-SM) As Above	4.0
						Skipped interval	
	SS 6	50	SP-SM		16.0	(SP-SM) As Above	2.5
						Skipped interval	
	SS 7	58	SP-SM		18.5	(SP-SM) As Above	3.0
20					20.5	16.5-18.5 feet water sample BH-C (H2O:1) interval	
						Skipped interval	
	SS 8	67	SP-SM SP		23.5	(SP-SM) As Above (5 inches) (SP) Tan-gray, MEDIUM-COARSE SAND WITH GRAVEL, wet (11 inches)	6.5
						Auger refusal at 23.5 feet	

Refusal at 23.0 feet.
Bottom of borehole at 23.0 feet.

BORING NUMBER BH-D

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/14/09 **COMPLETED** 4/14/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING --- 4 inches standing water at surface
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	Depth	MATERIAL DESCRIPTION	PID (ppm)
0						Skipped interval	
	SS 1	0			3.5	No recovery	
	SS 2	29	ML		6.0	Skipped interval (ML) Brown to dark gray, CONCENTRATE, saturated	6.5
	SS 3	75	ML		8.5	Skipped interval (ML) Dark gray to black, CONCENTRATE, saturated	8.2
10	SS 4	100	SP-SM ML		11.0	Skipped interval (SP-SM) Black-gray, TAILINGS, saturated (ML) Light-gray, CONCENTRATE, saturated	6.2
	SS 5	83	ML		13.5	Skipped interval (ML) As Above	5.1
	SS 6	83	ML		16.0	Skipped interval (ML) As Above	3.9
	SS 7	100	ML		18.5	Skipped interval (ML) Dark-gray, CONCENTRATE, saturated	4.5
20					23.0	Water sample BH-D (H2O:1) interval	
	SS 8	75	SP-SM		26.0	Skipped interval (SP-SM) Brown-tan, FINE-SILTY SAND, some gravel	2.0
	SS 9	25	SP-SM		28.5	Skipped interval (SP-SM) As Above	2.4
30	SS 10	21	SP-SM		31.0	Skipped interval (SP-SM) As Above	1.3
	SS 11	25	SP-SM		33.5	Skipped interal (SP-SM) As Above	1.6
					34.0	31.5-34 feet water sample BH-D (H2O:2) interval	

Bottom of borehole at 34.0 feet.

BORING NUMBER BH-E

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/16/09 **COMPLETED** 4/16/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING --- 8-10 inches of standing water at surface while drilling
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	PID (ppm)
0					Skipped interval	
	SS 1	0	ML	3.5	(ML) No recovery	
	SS 2	29	ML	6.0	Skipped interal (ML) Gray, CONCENTRATE, saturated	3.9
	SS 3	4	ML	8.5	Skipped interval (ML) As Above	5.1
10	SS 4	0	ML	11.0	Skipped interval (ML) No recovery	
	SS 5	25	ML	13.5	Skipped interval (ML) Gray, CONCENTRATE, saturated, slimy, soft	2.3
	SS 6	100	ML	16.0	Skipped interval (ML) As Above	1.0
	SS 7	50	ML	18.5	Skipped interval (ML) Dark-gray, CONCENTRATE	1.8
20				20.0	16-20 feet water sample BH-E (H2O:1) interval	
					Skipped interval	
	SS 8	58	ML SP-SM	23.5	(ML) As Above (12 inches) (SP-SM) Tailings (2 inches)	2.1
	SS 9	67	SP-SM SP-SM	26.0	Skipped interval (SP-SM) Black, TAILINGS (12 inches) (SP-SM) Brown, FINE-SILTY SAND	2.1
	SS 10	75	SP-SM	28.5	Skipped interval (SP-SM) As Above, sparse gravel	1.5
30	SS 11	75	SP-SM	31.0	Skipped interval (SP-SM) As Above	1.3
	SS 12	42	SP-SM	33.5	Skipped interval (SP-SM) As Above, more gravel, harder drilling	1.4
					31.5-33.5 feet water sample BH-E (H2O:2) interval Bottom of borehole at 33.5 feet.	

BORING NUMBER BH-F

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/10/09 **COMPLETED** 4/10/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING ---
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG		MATERIAL DESCRIPTION	PID (ppm)
0	SS 1	0			1.5	Skipped Interval	
	SS 2	58	SP-SM		3.5	(SP-SM) Dark gray - black, TAILINGS; 1st 2 inches had wood chips; last 3 inches coarser (like medium sand) tailings	<1
	SS 3	42	SP-SM		4.0	Skipped Interval	
					6.0	(SP-SM) As Above (like fine-medium sand) tailings	<1
	SS 4	33	SM		6.5	Skipped Interval	
					8.5	(SM) Gray, SILT; 1st 2 inches had small roots; last 3 inches was wood Soil Sampled for VOC, DRO, SVOC, and RCRA Metals @ 1240	<1
10	SS 5	33	SP-SM		9.0	Skipped Interval	
					11.0	(SP-SM) 3 inches gray SILT with gravel and roots; 5 inches brown, FINE-MEDIUM SAND; sparse gravel	<1
	SS 6	0	SP		11.5	Skipped Interval	
					13.5	(SP) No Recovery; looked like signs of wet sand on/in soil sample though	<1
	SS 7	83	SP		14.0	Skipped Interval	
					16.0	(SP) Brown-tan, FINE-MEDIUM SAND; some silt Soil Sampled for VOC, DRO, SVOC, and RCRA Metals @ 1250	<1
	SS 8	25	SP		17.5	(SP) As Above; rock @ 17.5 feet prevented drilling deeper Auger Refusal @ 17.5	<1

Refusal at 17.5 feet.
Bottom of borehole at 17.5 feet.

Northeast Technical Services Inc
Virginia, MN

BORING NUMBER BH-G

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/15/09 **COMPLETED** 4/15/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING --- SWL at surface while drilling
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	PID (ppm)
0					Skipped interval	
	SS 1	21	ML		(ML) Dark-gray to black, CONCENTRATE, saturated	2.6
3.5					Skipped inteval	
	SS 2	79	ML		(ML) Light-gray, CONCNTRATE, slimy, soft	9.2
6.0					Skipped interval	
	SS 3	100	ML		(ML) As Above	4.7
8.5					Skipped interval	
10	SS 4	100	ML		(ML) As Above (4 inches)	4.5
11.0			SP-SM		(SP-SM) DArk-gray to black, TAILINGS, saturated	
					Skipped interval	
	SS 5	79	SP-SM		(SP-SM) Dark-gray to black, TAILINGS, saturated	3.3
13.5					Skipped interval	
	SS 6	63	ML		(ML) Dark-gray, CONCENTRATE, saturated	3.5
16.0					Skipped interval	
	SS 7	50	ML		(ML) As Above	2.8
18.5					16-20 feet water sample BH-G (H2O:1) interal	
20.0					Skipped interval	
	SS 8	29	ML		(ML) Dark-gray, CONCENTRATE, saturated	3.2
23.5					Skipped interval	
	SS 9	13	SP		(SP) Brown to gray, MEDIUM-COARSE SAND WITH GRAVEL	8.0
26.0					Skipped interval	
	SS 10	17	GP		(GP) Dark-gray to black, COARSE GRAVEL with sand	3.7
28.5					Skipped interval	
30	SS 11	58	SP-SM		(SP-SM) Brown, FINE-SILTY SAND, sparse gravel	1.2
31.0					Skipped interval	
	SS 12	83	SP-SM		(SP-SM) As Above	1.3
33.5					26-31 feet water sample BH-G (H2O:2) interval	
					Bottom of borehole at 33.5 feet.	

BORING NUMBER BH-H

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/15/09 **COMPLETED** 4/15/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING ---
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	Bottom depth	MATERIAL DESCRIPTION	PID (ppm)
0						Skipped interval	
	SS 1	29	ML		3.5	(ML) Gray to brown, CONCENTRATE, saturated	2.8
	SS 2	54	ML		6.0	Skipped interval (ML) Light-brown, CONCENTRATE, saturated, slimy, soft	2.2
	SS 3	42	ML		8.5	Skipped interval (ML) Brown-gray, As above	3.5
10	SS 4	75	ML		11.0	Skipped interval (ML) As Above	2.2
	SS 5	54	ML		13.5	Skipped interval (ML) Dark-gray, As above	2.5
	SS 6	42	ML		16.0	Skipped interval (ML) As Above	2.1
20					20.5	Water sample BH-H (H2O:1) interval	
	SS 7	67	ML		23.5	Skipped interval (ML) Brown-gray, CONCENTRATE, slimy soft	<1
	SS 8	42	SP-SM		26.0	Skipped interval (SP-SM) Dark-gray TAILINGS	2.2
	SS 9	46	SP-SM		28.5	Skipped interval (SP-SM) As Above	2.2
30	SS 10	0			31.0	Skipped interval No recovery	
	SS 11	58	SP-SM		33.5	Skipped interval (SP-SM) Brown, FINE-SILTY SAND, no gravel	1.6
	SS 12	0			36.0	Skipped interval No recovery	
	SPT 13	63	SP		38.5	Skipped interval (SP) Gray to brown, FINE-MEDIUM SAND, saturated	1.6
40	SS 14	63	SP		41.0	Skipped interval (SP) As Above, not much gravel, saturated	1.3
					43.0	39-43 feet water sample BH-H (H2O:2) interval	

Bottom of borehole at 43.0 feet.

BORING NUMBER BH-I

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet

PROJECT NAME Emergency Basin Phase II

PROJECT NUMBER 7157FA.08

PROJECT LOCATION Hoyt Lakes, Minnesota

DATE STARTED 4/7/09 **COMPLETED** 4/8/09

GROUND ELEVATION **HOLE SIZE** 8 Inch

DRILLING CONTRACTOR Braun

GROUND WATER LEVELS:

DRILLING METHOD 4 1 4" HSA

AT TIME OF DRILLING ---

LOGGED BY B. Flaada **CHECKED BY** D. Fossell

AT END OF DRILLING ---

NOTES

AFTER DRILLING ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	PID (ppm)
0	SS 1	0			Skipped Interval (2.0)	
	SS 2	100	ML		(ML) Gray, silt; wet (4.0)	<1
	SS 3	0			No Recovery; wet (6.0)	
					6.5 Skipped Interval	
	SS 4	100	SP-SM		(SP-SM) Black sand with silt; moist (8.5)	<1
					9.0 Skipped Interval	
10	SS 5	100			Same As Above (11.0)	1.9
					11.5 Skipped Interval	
	SS 6	58			Same As Above (13.5)	1.2
					14.0 Skipped Interval	
	SS 7	100	SP-SM		(SP-SM) Black sand with silt; gravel at bottom (16.0)	1
	SS 8	100	SP		(SP) Black gravel to 17 feet; brown coarse sand to 18.5 feet; moist (18.5)	<1
					19.0 Skipped Interval	
20	SS 9	90			No Recovery (21.0)	
					21.5 Skipped Interval	
	SS 10	94	SP		(SP) Brown coarse sand; moist (24.0)	
	SS 11	38	SP		(SP) Grayish brown, medium sand with sparse gravel; moist (26.0)	<1

Refusal at 26.5 feet.
Bottom of borehole at 26.5 feet.

Northeast Technical Services Inc
Virginia, MN

BORING NUMBER BH-J

CLIENT PolyMet **PROJECT NAME** Emergency Basin Phase II
PROJECT NUMBER 7157FA.08 **PROJECT LOCATION** Hoyt Lakes, Minnesota
DATE STARTED 4/13/09 **COMPLETED** 4/14/09 **GROUND ELEVATION** **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun **GROUND WATER LEVELS:**
DRILLING METHOD 4 1 4" HSA **AT TIME OF DRILLING** ---
LOGGED BY B. Flaada **CHECKED BY** D. Fossell **AT END OF DRILLING** ---
NOTES **AFTER DRILLING** ---

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION	PID (ppm)
0					Skipped interval	
	SS 1	29	ML SP-SM	3.5	(ML) Black, CONCENTRATE (3 inches) (SP-SM) Black, TAILINGS, saturated (4 inches)	<1
					Skipped interval	
	SS 2	58	ML	6.0	(ML) Dark-gray to black, CONCENTRATE, saturated	3.8
					Skipped interval	
	SS 3	50	ML SP-SM	8.5	(ML) As Above (3 inches) (SP-SM) Gray, FINE-SILTY SAND, sparse gravel, last 4 inches brown, saturated	2.4
10					Skipped interval	
	SS 4	67	SP-SM	11.0	(SP-SM) Tan-brown, FINE-SILTY SAND, sparse gravel, saturated	2.9
					Skipped interval	
	SS 5	100	SP-SM	13.5	(SP-SM) As Above, more gravel now	2.2
					Skipped interval	
	SS 6	83	SP-SM	16.0	(SP-SM) As Above	2.7
					Skipped interval	
	SS 7	83	SP-SM	18.5	(SP-SM) As Above	1.0
					Skipped interval	
20	SS 8	100	SP-SM	21.0	(SP-SM) As Above	2.4
				25.0	Water sample BH-J interval	
					Bottom of borehole at 25.0 feet.	

BORING NUMBER BH-K

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/8/09 **COMPLETED** 4/8/09
GROUND ELEVATION **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING ---
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING 2.50 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	RECOVERY %	U.S.C.S.	GRAPHIC LOG	Depth	MATERIAL DESCRIPTION	PID (ppm)
0	SS 1	0			1.5	Skipped Interval	
	SS 2	25	SP-SM		3.5	(SP-SM) Dark gray, tailings; wet Water sampled for VOC, DRO, SVOC, and RCRA Metals @ 1240	<1
	SS 3	42	SP-SM		4.0 6.0	Skipped Interval (SP-SM) Lighter gray, tailings; wet	<1
	SS 4	50	SP-SM		6.5 8.5	Skipped Interval (SP-SM) Dary gray; tailings; 2 inches of gray silt @ bottom; wet	<1
10	SS 5	50	SP-SM		9.0 11.0	Skipped Interval (SP-SM) Dark gray; tailings; 5 inches of gray silt @ top; wood fragments; wet Soil Sampled for VOC, DRO, SVOC, and RCRA Metals @ 1330	<1
	SS 6	50	SP-SM		11.5 13.5	Skipped Interval (SP-SM) Gray, FINE-SILTY SAND (6 inches); orangish brown; FINE-MEDIUM SAND; wet	<1
	SS 7	42	SP		14.0 16.0	Skipped Interval (SP) Orangish brown to brown; FINE-MEDIUM SAND; wet; rock @ tip	<1
	SS 8	50	SP-SM		16.5 18.5	Skipped Interval (SP-SM) As Above; some silt; sparse gravel	<1
20	SS 9	50	SP-SM		19.0 21.0	Skipped Interval (SP-SM) As Above	<1
	SS 10	42	SP-SM		23.0	(SP-SM) As Above; coarser sand last 4 inches Soil Sampled for VOC, DRO, SVOC, and RCRA Metals @ 1345	<1

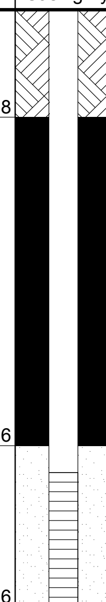
Refusal at 23.0 feet.
Bottom of borehole at 23.0 feet.

Northeast Technical Services Inc
Virginia, MN

WELL NUMBER MW-1D

CLIENT PolyMet
PROJECT NAME Emergency Basin Phase II
PROJECT NUMBER 7157FA.08
PROJECT LOCATION Hoyt Lakes, Minnesota
DATE STARTED 4/21/09 **COMPLETED** 4/21/09
GROUND ELEVATION 97.84 ft **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun
GROUND WATER LEVELS:
DRILLING METHOD 4 1 4" HSA
AT TIME OF DRILLING ---
LOGGED BY B. Flaada **CHECKED BY** D. Fossell
AT END OF DRILLING ---
NOTES
AFTER DRILLING 3.30 ft / Elev 94.54 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.	WELL DIAGRAM (Casing Top Elev: 100.53 (ft); Casing Type: PVC)
0–4.0			Concrete	93.8	
4.0–16.2			Bentonite	81.6	
16.2–22.2			Red Flint Sand 2 Inch PVC Screen	75.6	
			Bottom of borehole at 22.2 feet.		



Northeast Technical Services Inc
Virginia, MN

WELL NUMBER MW-2D

CLIENT	PolyMet	**PROJECT NAME**	Emergency Basin Phase II
PROJECT NUMBER	7157FA.08	**PROJECT LOCATION**	Hoyt Lakes, Minnesota

DATE STARTED 4/22/09 **COMPLETED** 4/22/09

GROUND ELEVATION 96.04 ft **HOLE SIZE** 8 Inch

DRILLING CONTRACTOR Braun

GROUND WATER LEVELS:

DRILLING METHOD 4 1 4" HSA

AT TIME OF DRILLING ---

LOGGED BY B. Flaada **CHECKED BY** D. Fossell

AT END OF DRILLING ---

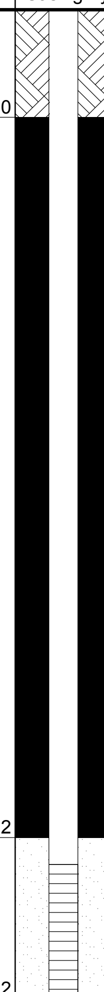
NOTES

AFTER DRILLING 1.85 ft / Elev 94.19 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.
0			Concrete	
4.0			Bentonite	92.0
30.8			Red Flint Sand 2 Inch PVC Screen	65.2
36.8			Bottom of borehole at 36.8 feet.	59.2

WELL DIAGRAM

Casing Top Elev: 98.44 (ft)
Casing Type: PVC



WELL NUMBER MW-3D

Northeast Technical Services Inc
Virginia, MN

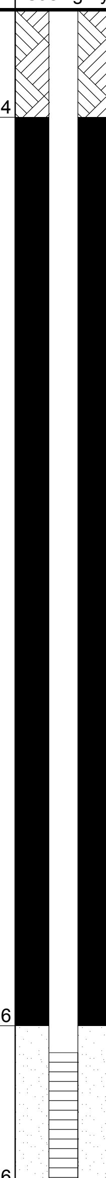
CLIENT PolyMet	**PROJECT NAME** Emergency Basin Phase II
PROJECT NUMBER 7157FA.08	**PROJECT LOCATION** Hoyt Lakes, Minnesota
DATE STARTED 4/23/09 **COMPLETED** 4/23/09	**GROUND ELEVATION** 95.36 ft **HOLE SIZE** 8 Inch
DRILLING CONTRACTOR Braun	**GROUND WATER LEVELS:**
DRILLING METHOD 4 1 4" HSA	**AT TIME OF DRILLING** ---
LOGGED BY M. Lucas **CHECKED BY** D. Fossell	**AT END OF DRILLING** ---
NOTES	**AFTER DRILLING** 1.50 ft / Elev 93.86 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.
0			Concrete	
4.0			Bentonite	91.4
37.8			Red Flint Sand 2 Inch PVC Screen	57.6
43.8			Bottom of borehole at 43.8 feet.	51.6

Depth scale: 0, 10, 20, 30, 40

WELL DIAGRAM

Casing Top Elev: 97.95 (ft)
Casing Type: PVC



WELL NUMBER MW-4D

Northeast Technical Services Inc
Virginia, MN

CLIENT PolyMet

PROJECT NAME Emergency Basin Phase II

PROJECT NUMBER 7157FA.08

PROJECT LOCATION Hoyt Lakes, Minnesota

DATE STARTED 4/23/09 **COMPLETED** 4/23/09

GROUND ELEVATION 95.19 ft **HOLE SIZE** 8 Inch

DRILLING CONTRACTOR Braun

GROUND WATER LEVELS:

DRILLING METHOD 4 1 4" HSA

AT TIME OF DRILLING ---

LOGGED BY M. Lucas **CHECKED BY** D. Fossell

AT END OF DRILLING ---

NOTES

AFTER DRILLING 1.50 ft / Elev 93.69 ft

DEPTH (ft)	SAMPLE TYPE NUMBER	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.	WELL DIAGRAM (Casing Top Elev: 97.69 (ft); Casing Type: PVC)
0 – 4.0			Concrete	91.2	
4.0 – 24.5			Bentonite	70.7	
24.5 – 30.5			Red Flint Sand 2 Inch PVC Screen	64.7	

Bottom of borehole at 30.5 feet.

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-01 (p. 1 of 2)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
0–0.3	ICE - 4" thickness	ICE									
0.3–1.5	WATER - 14" deep	WATER		F/W	SU						
1.5–4	FILL, silt, trace roots, dark gray (slimes)	FILL/ TAILINGS	4		SS	0					
4–15	FILL, silt, dark gray (slimes)		1	M	SS	18					
			<1	M	SS	18					
			<1	M (water level ▼ at 10 ft)	SS	18					
			<1	M	SS	18					
15–24	FILL, silt with sand, dark gray and black, trace roots below about 17 feet, possible petroleum odor (slimes)		3	M	SS	9					
			<1	M	SS	7					
			6	M	SS	11					
			3	M	SS	16					
24–27	FILL, sandy silt, black (fine tailings)		15	M	SS	12					
27–29	FILL, silty clay, dark brown, laminations of dark gray silt (slimes)		5	M	SS	15					
29–30+	FILL, silty sand, black (fine tailings)		5	M	SS	12					

DEPTH:	DRILLING METHOD
0-49½'	3.25" HSA

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
3/4/10	11:15	51.0	49.5	48.0	---	10.0

BORING COMPLETED: 3/4/10

DR: LA LG: TDD Rig: 27C

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-01 (p. 2 of 2)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
32–34	FILL, sand, fine to medium grained, dark gray, laminations of silt (coarse tailings)	FILL/ TAILINGS	4	M	SS	9					
34–38	FILL, sand with silt, dark gray (coarse tailings)		9	M	SS	15					
			7	M	SS	11					
38–48	SILTY SAND, a little gravel, brown, wet, dense to medium dense (SM)	TILL	40	M	SS	10					
			29	M	SS	15					
48–51	GRAVELLY SAND WITH SILT, brown, wet, very dense (SP-SM)		58	M	SS	7					
51	**END OF BORING AT 51.0 FEET** Borehole backfilled with auger cuttings										

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-02 (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
	ICE - 6" thickness	ICE									
1	PEAT, fibric, dark brown, frozen (PT)	SWAMP DEPOSIT		F/W	SU						
2	FILL, silt, a little wood, dark gray (slimes)	FILL/ TAILINGS									
3			15	M	SS	13					
4											
5	FILL, wood										
6	FILL, sand with silt, dark gray (coarse tailings)		9	M	SS	8					
7	SILTY SAND, brown and dark grayish brown, moist (SM)	TILL									
8			4/0.5' 7/0.5' 50/0.3'	M	SS						
	AUGER REFUSAL AT 8.3 FEET Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-8.3'	**3.25" HSA**	**3/4/10**						**Surface**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **3/4/10**

DR: **LA** LG: **TDD** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-03 (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: ___ MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
1	FILL, sandy silt, dark gray, frozen (fine tailings)			F	SU						
3			3	F/W	SS	2					
4	FILL, silt, dark gray and black, possible petroleum odor (slimes)										
5			<1	W	SS	18					
7	FILL, silt, gray to dark gray (slimes)										
8			<1	W	SS	18					
10			<1	W	SS	6					
11		FILL/ TAILINGS									
13			<1	W	SS	6					
13	FILL, silty sand, fine grained, black to dark gray, lenses of sandy silt (fine tailings)										
15			7	W	SS	12					
17	FILL, silty sand, fine to medium grained, dark gray and black (coarse tailings)										
18			7	W	SS	12					
19	FILL, silt, dark gray and black (slimes)										
20			5	W	SS	12					
22	FILL, a mixture of black silty sand (coarse tailings) with brown gravel										
23			36/0.5' 50/0.3'	W	SS	6					
24	FILL, silty sand with gravel, grayish brown										
26		FILL	17	W	SS	6					
28	SLIGHTLY ORGANIC SILT, trace roots, dark brown (OL) (may be original topsoil)	TOPSOIL OR FINE ALLUVIUM	30	W	SS	3					
	GRAVELLY SILTY SAND WITH COBBLES AND BOULDERS (SM)	TILL	135/0.0'		SS	0.1					

AUGER REFUSAL AT 28.5 FEET
Borehole backfilled with auger cuttings

DEPTH:	DRILLING METHOD	WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
0-28½'	**3.25" HSA**	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
		3/5/10						**Surface**	
BORING COMPLETED: **3/5/10**									
DR: **LA** LG: **TDD** Rig: **27C**									

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-04 (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: ______ MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
0–2	ICE - 24" thickness	ICE		F							
2–4	FILL, silty sand, fine to medium grained, trace roots, dark gray (coarse tailings)	FILL/ TAILINGS	1	W	SS	3					
4–7.5	FILL, sand with silt, fine to medium grained, dark gray (coarse tailings)	FILL/ TAILINGS	13	W	SS	8					
			6/0.5' 50/0.5'	W	SS	4					
7.5–9	SILTY SAND WITH GRAVEL, trace roots, dark brown and dark gray, wet (SM)	TILL									
9–12	SILTY SAND WITH GRAVEL, brown, wet, medium dense (SM)	TILL	15	W	SS	6					
12–18.5	SILTY CLAYEY SAND WITH GRAVEL, apparent cobbles, brown, wet (SC-SM)	TILL	5/0.5' 10/0.5' 50/0.2'	W	SS	8					
18.5–21	SAND WITH GRAVEL, medium to coarse grained, brown, wet, very dense (SP)	COARSE ALLUVIUM	80	W	SS	8					
21	**END OF BORING AT 21.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-19½'	**3.25" HSA**	**3/5/10**						**Surface**
BORING COMPLETED: **3/5/10**								
DR: **LA** LG: **TDD** Rig: **27C**								

WATER LEVEL MEASUREMENTS

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-05 (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
0–2	FILL, organic silty sand with roots, dark brown	FILL		M	SU						
2–5	SILTY SAND WITH GRAVEL, brown, moist, medium dense (SM)	TILL	29	M	SS	12					
5–6.5	GRAVEL WITH SAND, brown, wet, dense (GP)	COARSE ALLUVIUM	42	W	SS	12					
6.5–7.5	SAND, fine to medium grained, brown, wet, very dense (SP)		50/0.3'	W	SS	3					

AUGER REFUSAL AT 7.5 FEET
Borehole backfilled with auger cuttings

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-7½'	**3.25" HSA**	**3/8/10**	**13:00**	**7.5**	**7.5**	**7.5**	**---**	**None**

BORING COMPLETED: **3/8/10**

DR: **LA** LG: **TM** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-05A (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
0–7	*No samples taken, see test boring 10-05*										
7	**AUGER REFUSAL AT 7.0 FEET** Borehole backfilled with auger cuttings *Boring performed 5' east of 10-05*										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-7'	**3.25" HSA**	**3/8/10**	**13:30**	**7.0**	**7.0**	**7.0**	**---**	**None**

BORING COMPLETED: **3/8/10**

DR: **LA** LG: **TM** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2** LOG OF BORING NO. **10-05B (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
1–7	*No samples taken, see test borings 10-05 and 10-05A*										
	AUGER REFUSAL AT 7.5 FEET Borehole backfilled with auger cuttings *Boring performed 10' south of 10-05A*		50/0.0'		SS	0					

DEPTH:	DRILLING METHOD
0-7½'	3.25" HSA

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
3/8/10	14:00	7.5	7.5	7.5	---	None

BORING COMPLETED: **3/8/10**

DR: **LA** LG: **TM** Rig: **27C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

BARR PROJECT NO: 23/69-0862-023

AET JOB NO: **07-04509.2**

LOG OF BORING NO. **10-06 (p. 1 of 1)**

PROJECT: **PolyMet Emergency Basin Investigation; Hoyt Lakes, MN**

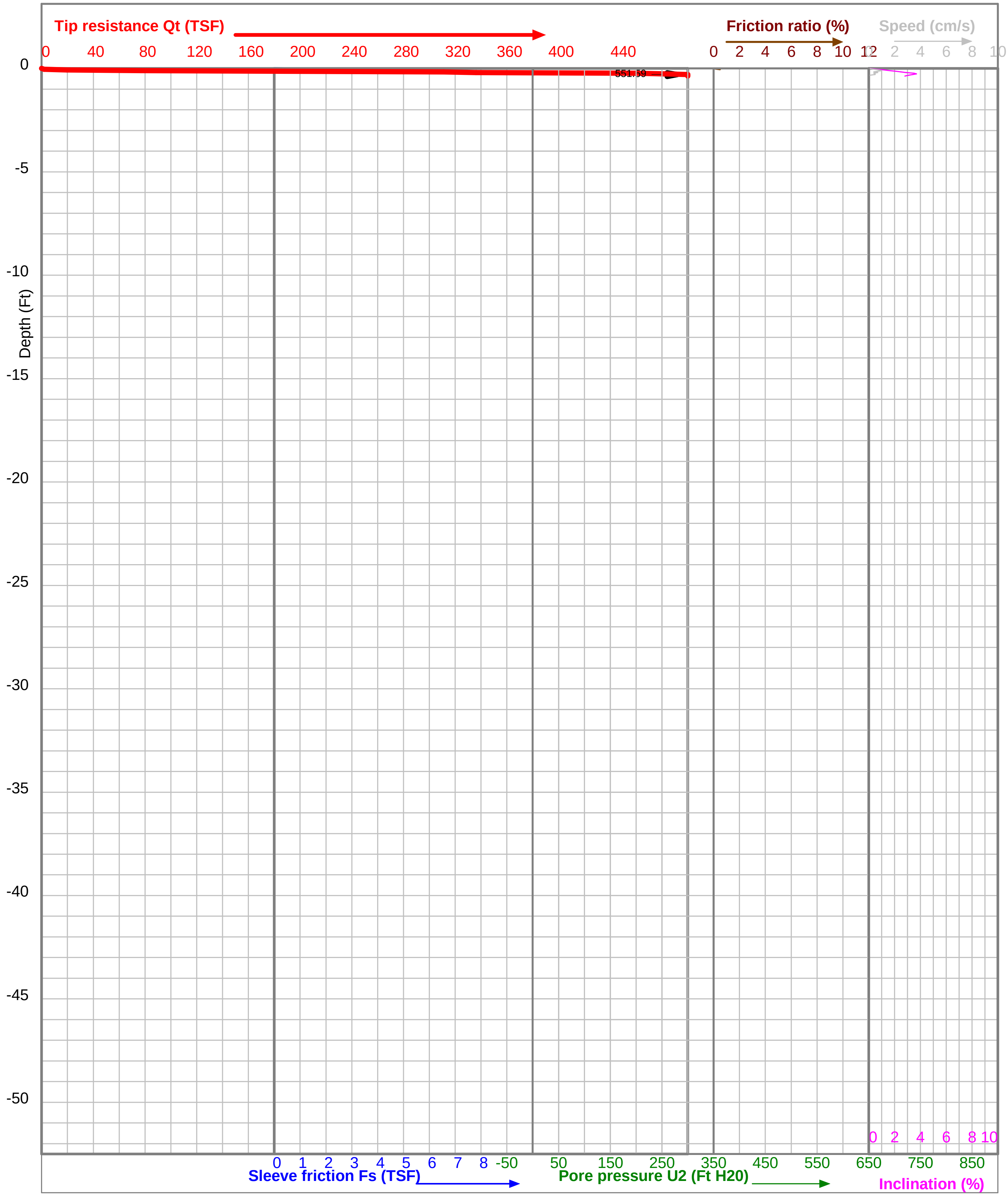
DEPTH IN FEET	SURFACE ELEVATION: ___ MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	FIELD & LABORATORY TESTS WC	DD	LL	PL	%-#200
	ORGANIC SILT WITH ROOTS, dark brown, frozen	TOPSOIL		F	HA						
1	SILTY SAND, brown, frozen (SM)										
2		TILL		F/M	HA						
3	**AUGER REFUSAL AT 3.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	WATER LEVEL MEASUREMENTS DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-3'	**Hand Auger**	**3/8/10**	**11:20**	**3.0**	**---**	**3.0**	**---**	**None**

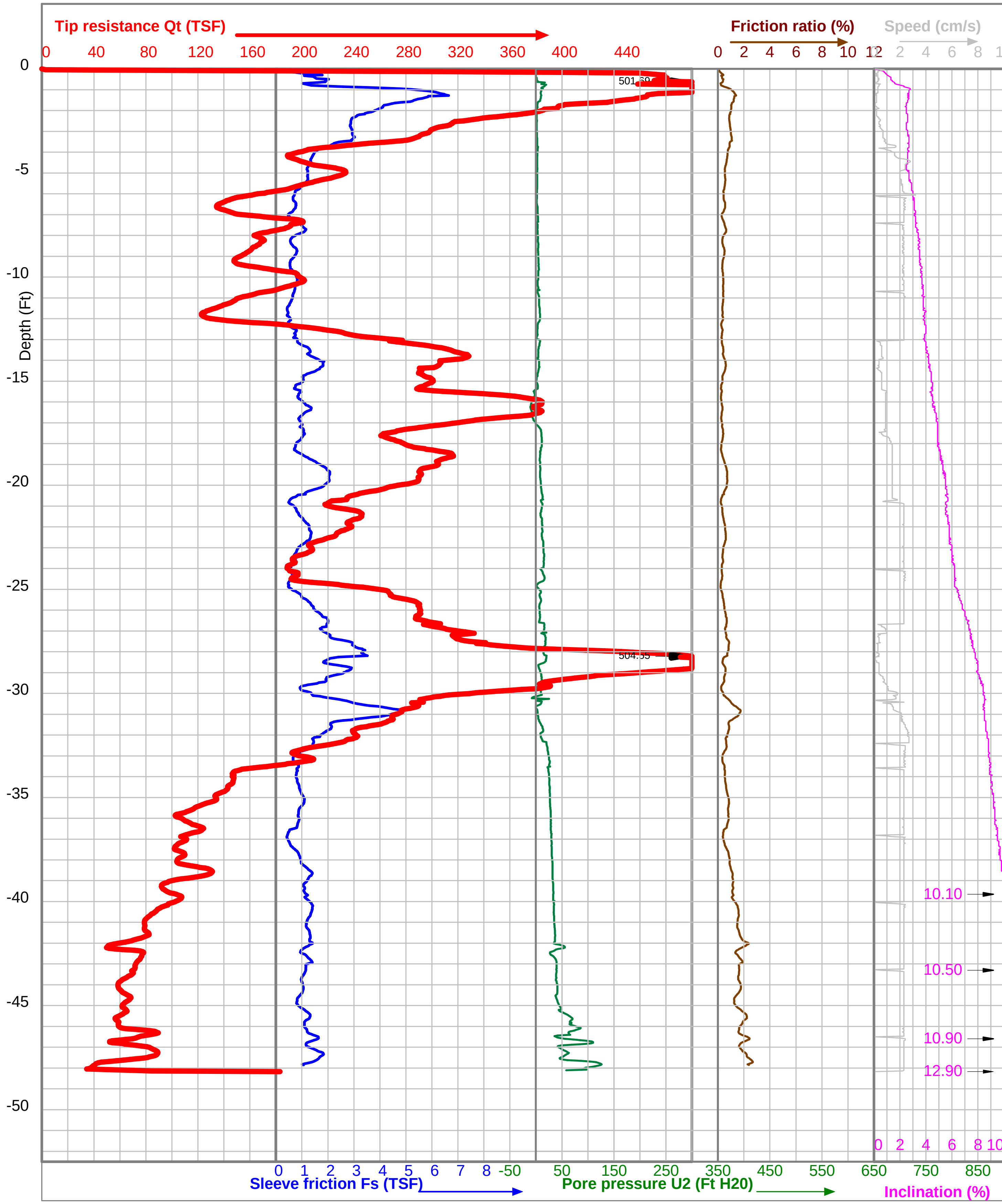
BORING COMPLETED: **3/8/10**

DR: **LA** LG: **TM** Rig:

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

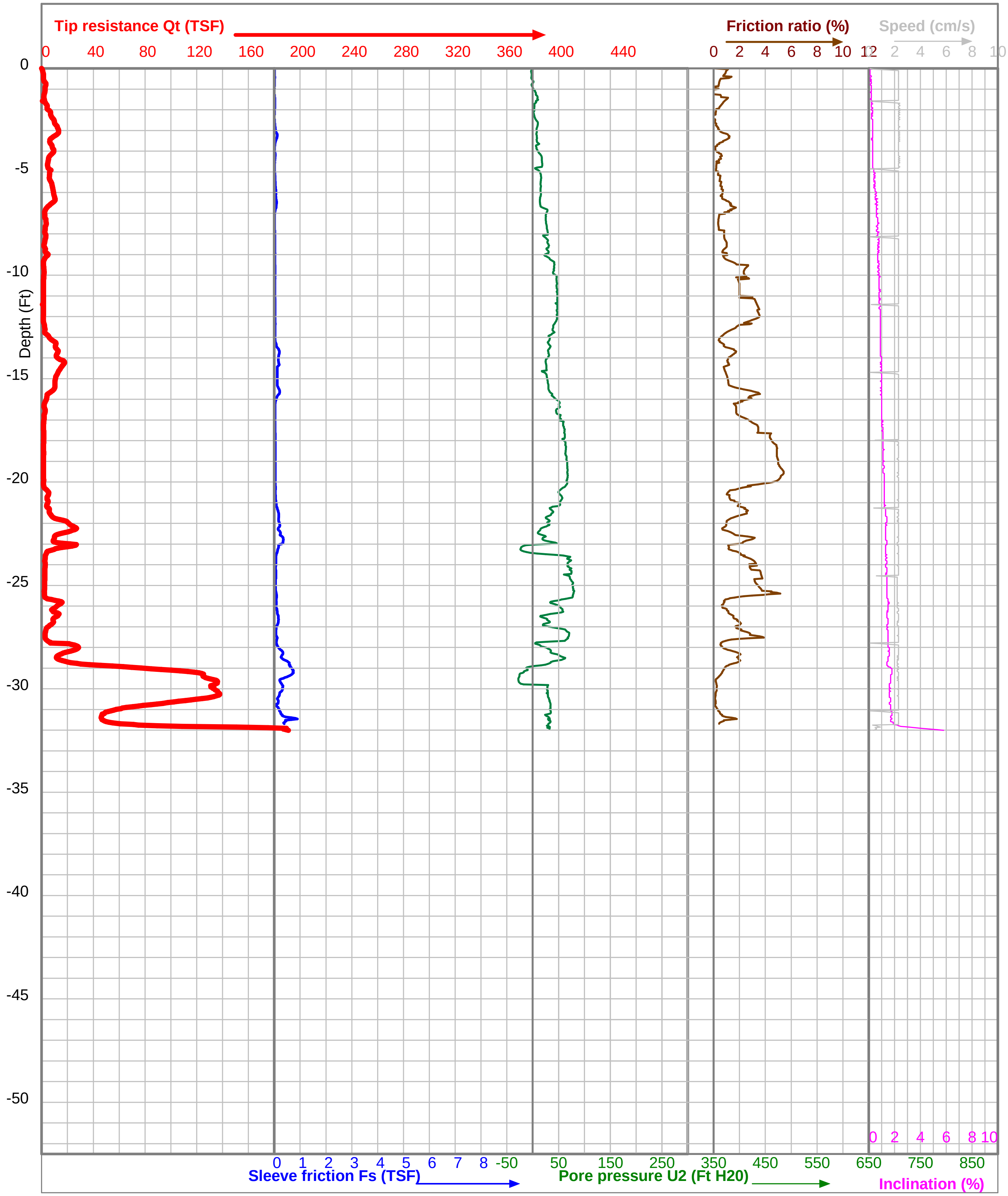


Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-05	Cone Type	I-CFXYP20-15		
Test Number	5	Cone ID	080903	X-Coord	47.60769
Client	Barr Engineering Co., Inc.	Start Time	11:36	Y-Coord	-92.14742
Boring Type	CPTU Sounding	Date	12-2-2011	Elev. Datum: WGS 84	



Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-06	Cone Type	I-CFXYP20-15		
Test Number	6	Cone ID	090710	X-Coord	47.60795
Client	Barr Engineering Co., Inc.	Start Time	9:59	Y-Coord	-92.14926
Boring Type	CPTU Sounding	Date	12-2-2011	Elev. Datum: WGS 84	

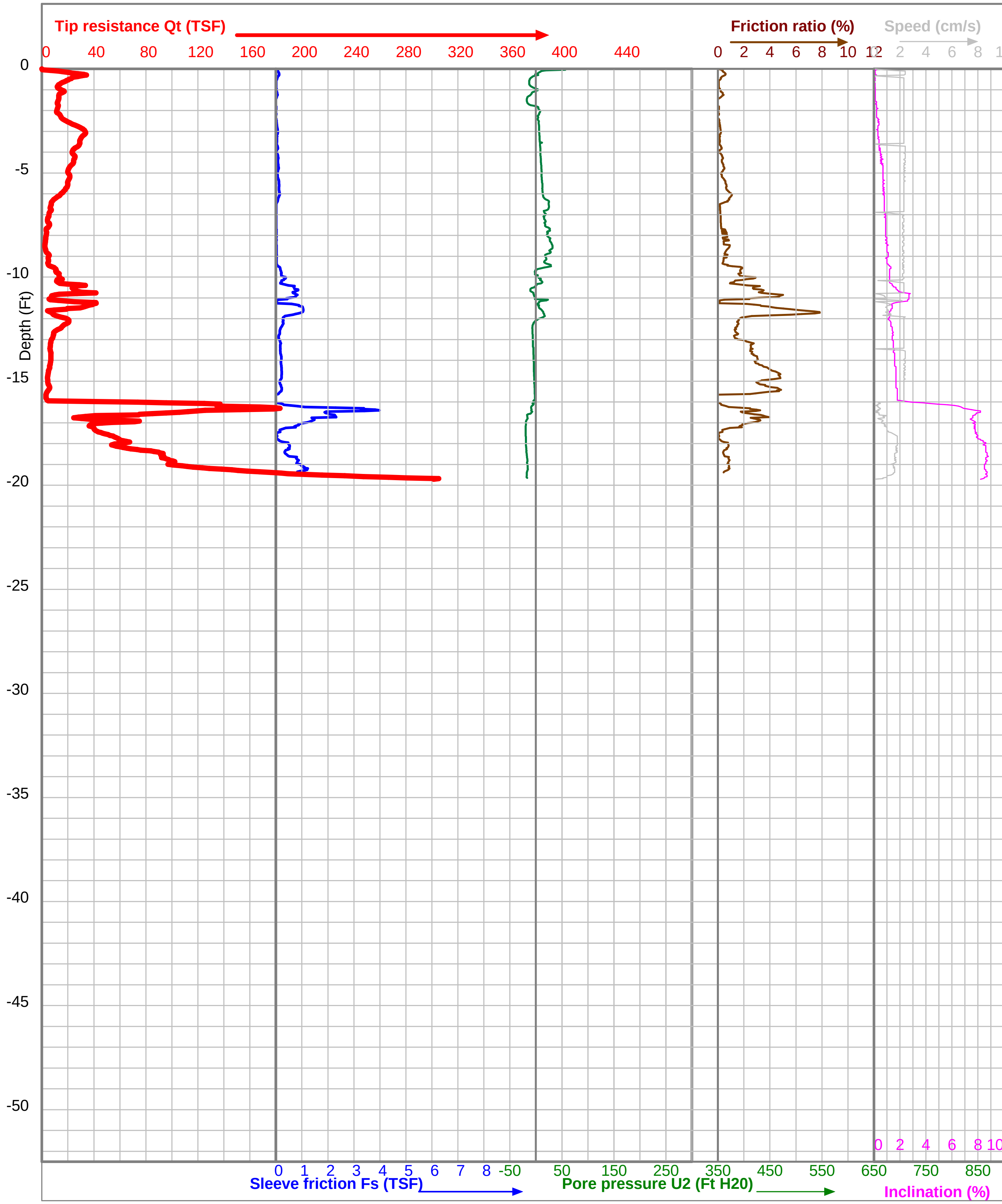
Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-07	Cone Type	I-CFXYP20-15		
Test Number	7	Cone ID	090709	X-Coord	47.60514
Client	Barr Engineering Co., Inc.	Start Time	14:30	Y-Coord	-92.14915
Boring Type	CPTU Sounding	Date	12-2-2011	Elev. Datum: WGS 84	



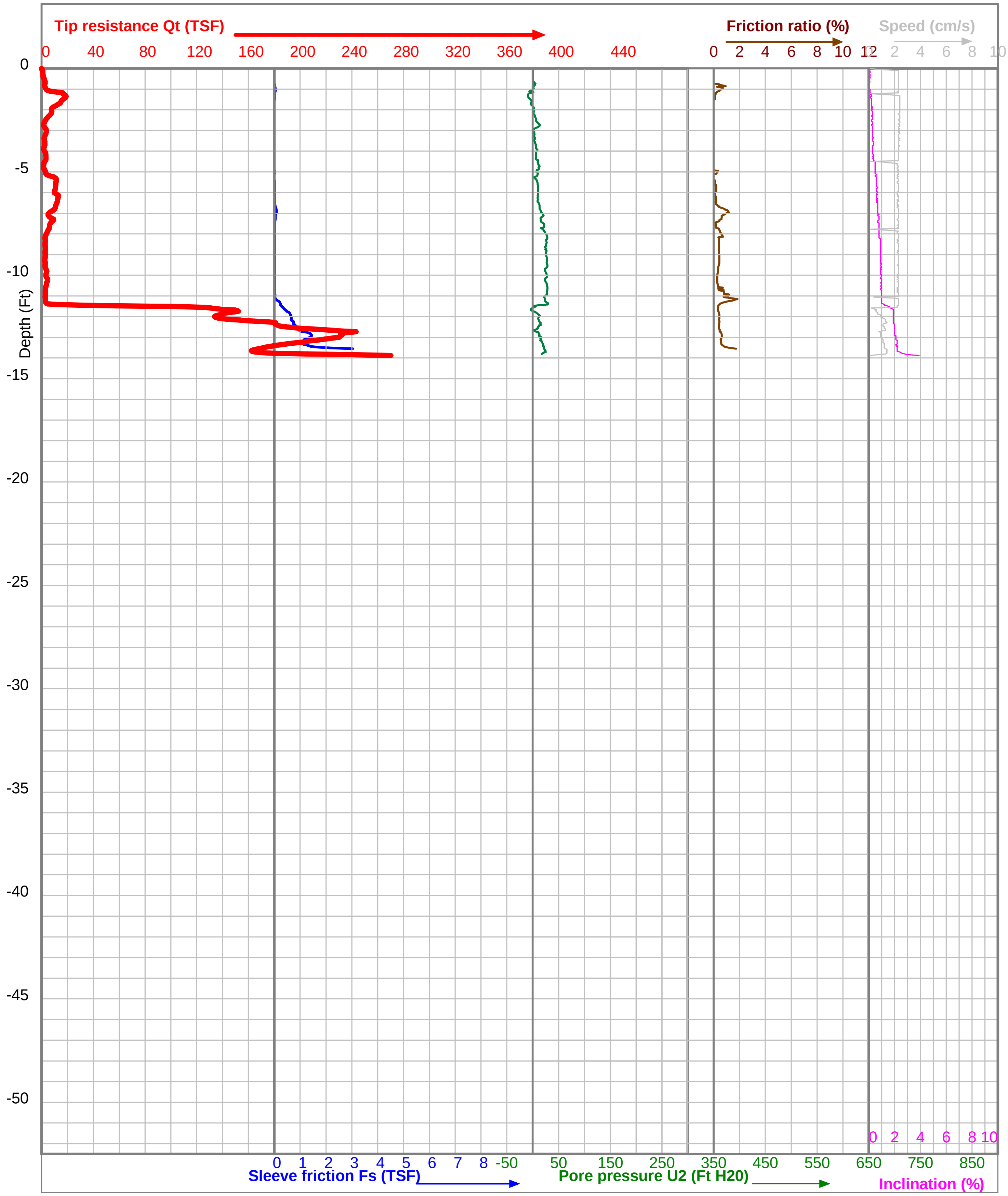
Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-01	Cone Type	I-CFXYP20-15		
Test Number	1	Cone ID	080903	X-Coord	47.60510
Client	Barr Engineering Co., Inc.	Start Time	8:37	Y-Coord	-92.14825
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	

Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-08	Cone Type	I-CFXYP20-15		
Test Number	8	Cone ID	090710	X-Coord	47.60424
Client	Barr Engineering Co., Inc.	Start Time	13:30	Y-Coord	-92.14841
Boring Type	CPTU Sounding	Date	12-2-2011	Elev. Datum: WGS 84	

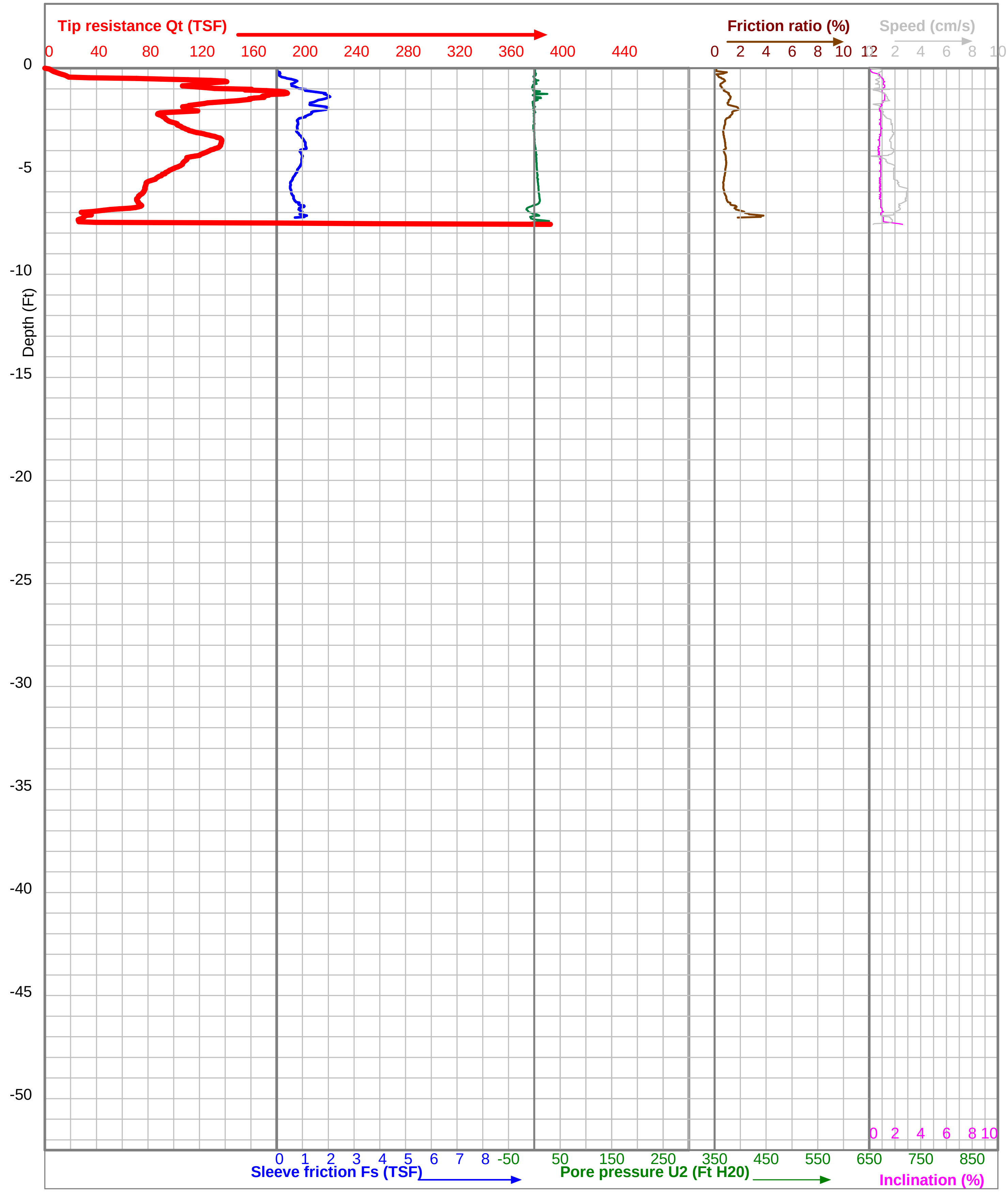
Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-09	Cone Type	I-CFXYP20-15		
Test Number	9	Cone ID	090710	X-Coord	47.60709
Client	Barr Engineering Co., Inc.	Start Time	11:14	Y-Coord	-92.14862
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	



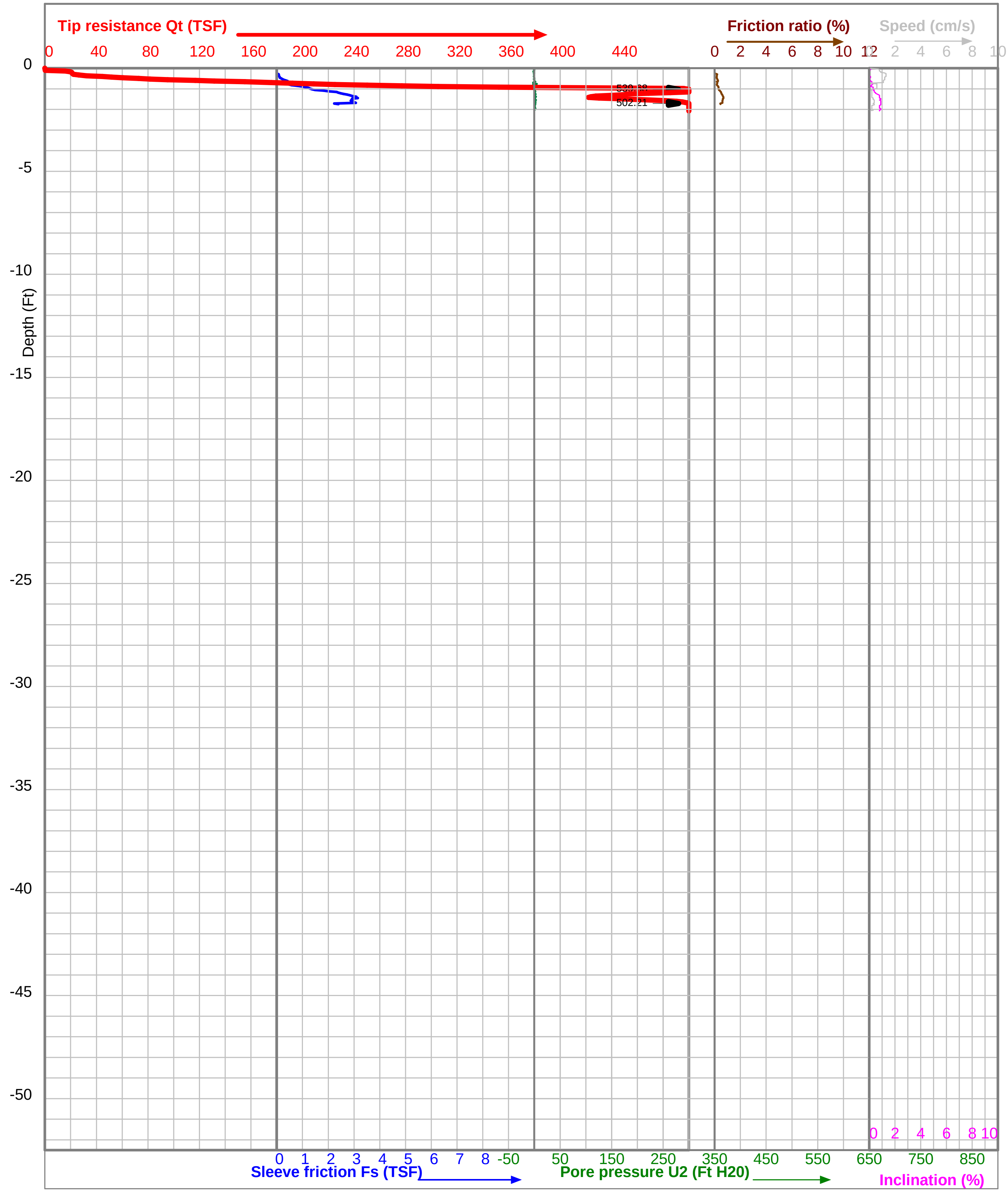
Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-10	Cone Type	I-CFXYP20-15		
Test Number	10	Cone ID	090709	X-Coord	47.60389
Client	Barr Engineering Co., Inc.	Start Time	14:22	Y-Coord	-92.14839
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	



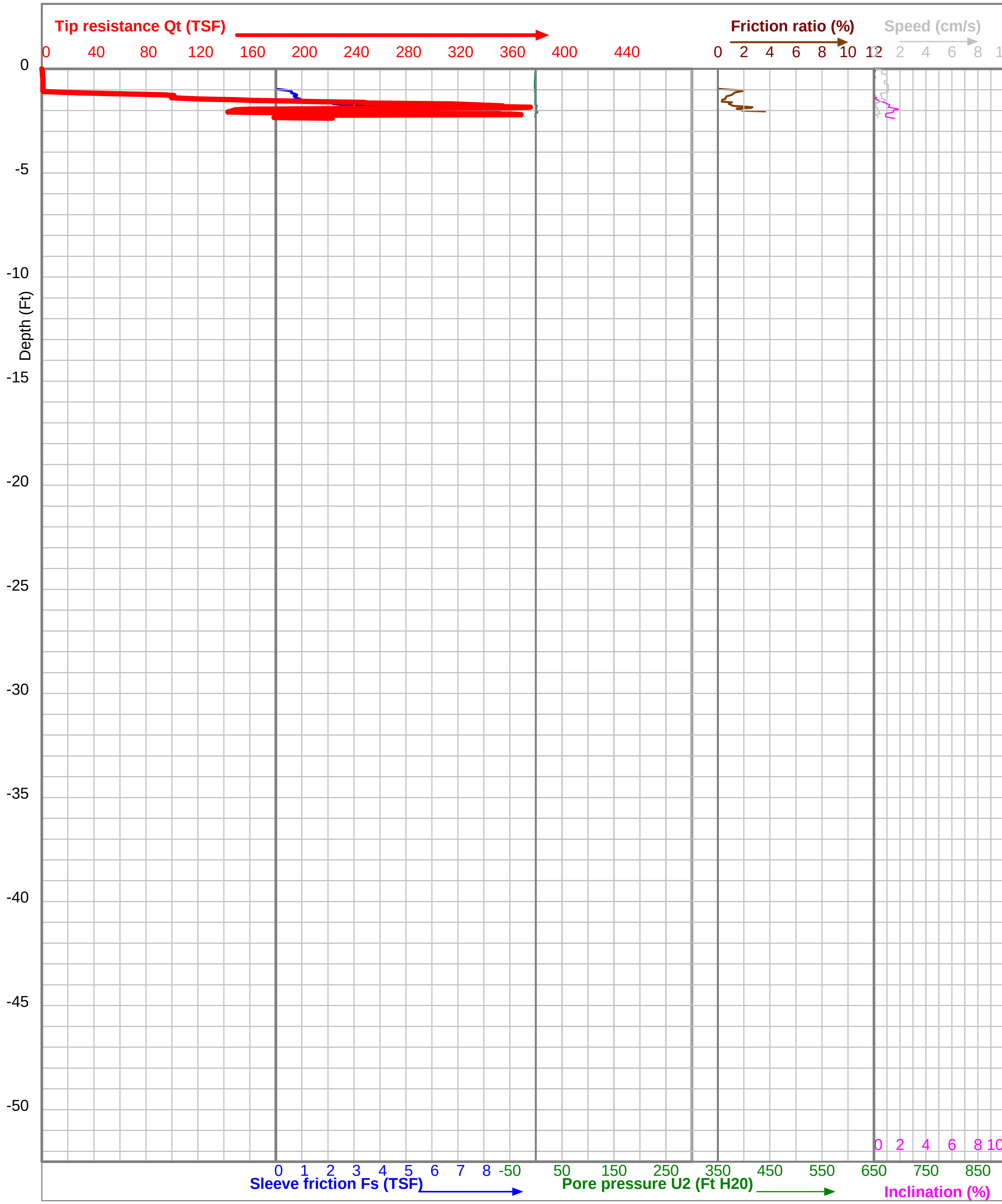
Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-11	Cone Type	I-CFXYP20-15		
Test Number	11	Cone ID	090710	X-Coord	47.60487
Client	Barr Engineering Co., Inc.	Start Time	14:59	Y-Coord	-92.14764
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	



Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-12	Cone Type	I-CFXYP20-15		
Test Number	12	Cone ID	080903	X-Coord	47.60499
Client	Barr Engineering Co., Inc.	Start Time	15:43	Y-Coord	-92.14744
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	



Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-13	Cone Type	I-CFXYP20-15		
Test Number	13	Cone ID	090710	X-Coord	47.60580
Client	Barr Engineering Co., Inc.	Start Time	16:15	Y-Coord	-92.14518
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	



Project	PolyMet 2011 CPT Investigation	CPT Operator	M. Brassington	Elevation (Ft MSL)	
Location	11-14	Cone Type	I-CFXYP20-15		
Test Number	14	Cone ID	090710	X-Coord	47.60550
Client	Barr Engineering Co., Inc.	Start Time	17:02	Y-Coord	-92.14207
Boring Type	CPTU Sounding	Date	13-2-2011	Elev. Datum: WGS 84	

New

GW-003

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

MINNESOTA UNIQUE WELL NO. 597383

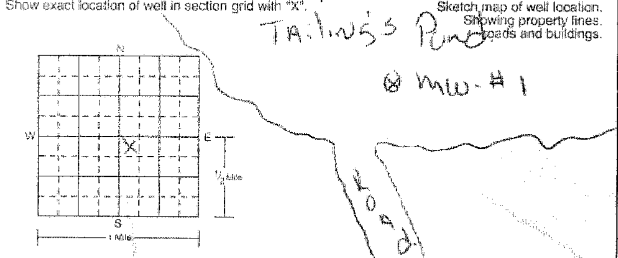
WELL LOCATION

County Name: ST. LOUIS

Township Name	Township No.	Range No.	Section No.	Fraction
Hoyt Lakes	59N	14W	8	NE-NW-SE

House Number, Street Name, City, and Zip Code of Well Location: LTV Steel Mine. Hoyt Lakes
or Fire Number:

Show exact location of well in section grid with "X". Sketch map of well location. Showing property lines, roads and buildings.



PROPERTY OWNER'S NAME: LTV Steel Mining Company

Property owner's mailing address if different than well location address indicated above.
P.O. Box 847
Hoyt Lake MN. 55750

WELL OWNER'S NAME: Same

Well owner's mailing address if different than property owner's address indicated above.

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
Fine To coarse			0	
Tailings	Gray			126.0

Use a second sheet, if needed

REMARKS, ELEVATION, SOURCE OF DATA, etc.

AET Job # 700204
Top of Riser Elv. 1717.10
Ground Surface Elv. 1714.10

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY

597383

WELL DEPTH (completed): 113.0 ft.
Date Work Completed: 7-7-98

DRILLING METHOD
☐ Cable Tool ☐ Driven ☐ Dug
☑ Auger ☐ Rotary ☐ Jetted
☐

DRILLING FLUID: Quick Gel Mud.
WELL HYDROFRACTURED? ☐ YES ☑ NO
FROM ______ ft. to ______ ft.

USE
☐ Domestic ☑ Monitoring ☐ Heating/Cooling
☐ Irrigation ☐ Community PWS ☐ Industry/Commercial
☐ Test Well ☐ Noncommunity PWS ☐ Remedial
☐ Dewatering ☐

CASING Drive Shoe? ☐ Yes ☑ No
☑ Steel ☑ Threaded ☐ Welded
☐ Plastic ☐

HOLE DIAM.

CASING DIAMETER		WEIGHT	HOLE DIAM.
4 in. to 93.0 ft.		lbs./ft.	7¾ in. to 125 ft.
in. to ft.		lbs./ft.	in. to ft.
in. to ft.		lbs./ft.	in. to ft.

SCREEN
Make: Johnson
Type: Stainless Steel
Slot/Gauze: .012
Length: 20
Set between 113.0 ft. and 93.0 ft.
FITTINGS: Flush coupling

OPEN HOLE
from ______ ft. to ______ ft.
Diam. 4"

STATIC WATER LEVEL: 89.5 ft. ☑ below ☐ above land surface Date measured ______

PUMPING LEVEL (below land surface): ______ ft. after ______ hrs. pumping ______ g.p.m.

WELL HEAD COMPLETION
☐ Pitless adapter manufacturer ______ Model ______
☑ Casing Protection 8" x 10" ☐ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

GROUTING INFORMATION
Well grouted? ☑ Yes ☐ No
Grout Material ☑ Neat cement ☐ Bentonite ☐ Concrete ☐ High Solids Bentonite
from 88.0 to 0 ft. ______ ☐ yds. ☐ bags
from ______ to ______ ft. ______ ☐ yds. ☐ bags
from ______ to ______ ft. ______ ☐ yds. ☐ bags

NEAREST KNOWN SOURCE OF CONTAMINATION
______ feet ______ direction ______ type
Well disinfected upon completion? ☐ Yes ☐ No

PUMP
☑ Not installed Date installed ______
Manufacturer's name ______
Model number ______ HP ______ Volts ______
Length of drop pipe ______ ft. Capacity ______ g.p.m.
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐

ABANDONED WELLS
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No unknown

VARIANCE
Was a variance granted from the MDH for this well? ☐ Yes ☐ No

WELL CONTRACTOR CERTIFICATION
This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

American Engineering Testing
Licensee Business Name

M663
Lic. or Reg. No.

[signature] 8-7-98
Authorized Representative Signature — Date

Larry Anderson
Name of Driller — Date

HE-01205-06 (Rev. 9/96)

GW 004

MINNESOTA DEPARTMENT OF HEALTH
WELL RECORD
Minnesota Statutes Chapter 103I

MINNESOTA UNIQUE WELL NO. 551772

WELL LOCATION

County Name: ST LOUIS

Township Name	Township No.	Range No.	Section No.	Fraction
Hoyt Lakes	59N	14W	8	SW NW NW SE

Numerical Street Address and City of Well Location or Fire Number: Hwy 666 No.

Show exact location of well in section grid with "X". Sketch map of well location. Showing property lines, roads and buildings.

N / W / E / S — ½ mi. — 1 mile

monitoring well #2

WELL DEPTH (completed): 104 ft

Date Work Completed: 10-26-94

DRILLING METHOD: ☐ Cable Tool ☒ Driven ☐ Dug ☐ Auger ☐ Rotary ☐ Jetted ☐

DRILLING FLUID: Water

USE: ☐ Domestic ☒ Monitoring ☐ Heating/Cooling ☐ Irrigation ☐ Public ☐ Industry/Commercial ☐ Test Well ☐ Dewatering ☐ Remedial ☐

CASING: ☒ Steel ☐ Plastic ☐ — Drive Shoe? ☒ Yes ☐ No — ☒ Threaded ☐ Welded

CASING DIAMETER: 4 in. to 82'6" ft. WEIGHT 10.5 lbs./ft.

HOLE DIAM.: 4 in. to 104 ft.

PROPERTY OWNER'S NAME: LTV Steel Mining Co.

Mailing address if different than property address indicated above.

SCREEN: S/S — Make: Cook — Type: 4" tele — Slot/Gauze: .012 — Set between 82'6 ft. and 104 ft. FITTINGS: K packer

OPEN HOLE: from — ft. to — ft. Diam. 3" Length 21'6"

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
Taconite				
Tailings	Gray	loose	0	104

Use a second sheet, if needed

STATIC WATER LEVEL: 75' 6" ft. ☒ below ☐ above land surface — Date measured 10/26/94

PUMPING LEVEL (below land surface): — ft. after ___ hrs. pumping ___ g.p.m.

WELL HEAD COMPLETION: ☐ Pitless adapter manufacturer ___ Model ___ ☐ Casing Protection ___ ☒ 12 in. above grade

GROUTING INFORMATION: Well grouted? ☒ Yes ☐ No — slurry around casing

Grout Material ☐ Neat cement ☒ Bentonite — from 0 to 80 ft. 3 ☐ yds. ☑ bags

NEAREST KNOWN SOURCE OF CONTAMINATION: 1000 feet ___ direction ___ type

Well disinfected upon completion? ☐ Yes ☒ No

PUMP: ☒ Not installed — Date installed ___ Manufacturer's name ___ Model number ___ HP ___ Volts ___ Length of drop pipe ___ ft. Capacity ___ g.p.m. Pressure Tank Capacity ___ Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐

ABANDONED WELLS: Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

REMARKS, ELEVATION, SOURCE OF DATA, etc.

WELL CONTRACTOR CERTIFICATION

This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Petersen Drlg Inc — Licensee Business Name — Lic. or Reg. No. 65183

[signature] — Authorized Representative Signature — Date 11/8/94

Dennis Petersen — Name of Driller — Date

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY

551772

HE-01205-04 (Rev. 5/92)

GW 004

MINNESOTA UNIQUE WELL NO. 551772

MINNESOTA DEPARTMENT OF HEALTH
WELL RECORD
Minnesota Statutes Chapter 103I

WELL LOCATION

County Name: ST LOUIS

Township Name	Township No.	Range No.	Section No.	Fraction
Hoyt Lakes	59N	14W	8	SW NW NWSE

Numerical Street Address and City of Well Location: Hwy 666 No.

or Fire Number:

Show exact location of well in section grid with "X". Sketch map of well location. Showing property lines, roads and buildings.

N, W, E, S, ½ mi., 1 mile

monitoring well #2

WELL DEPTH (completed): 104 ft

Date Work Completed: 10-26-94

DRILLING METHOD: ☐ Cable Tool ☒ Driven ☐ Dug ☐ Auger ☐ Rotary ☐ Jetted ☐

DRILLING FLUID: Water

USE: ☐ Domestic ☒ Monitoring ☐ Heating/Cooling ☐ Irrigation ☐ Public ☐ Industry/Commercial ☐ Test Well ☐ Dewatering ☐ Remedial ☐

CASING: ☒ Steel ☐ Plastic — Drive Shoe? ☒ Yes ☐ No — ☒ Threaded ☐ Welded ☐

HOLE DIAM.

CASING DIAMETER	WEIGHT	HOLE DIAM.
4 in. to 82'6" ft.	10.5 lbs./ft.	4 in. to 104 ft.
in. to ft.	lbs./ft.	in. to ft.
in. to ft.	lbs./ft.	in. to ft.

PROPERTY OWNER'S NAME: LTV Steel Mining Co.

Mailing address if different than property address indicated above.

SCREEN: S/S
Make: Cook
Type: 4" tele
Slot/Gauze: .012
Set between 82'6 ft. and 104 ft. FITTINGS: K packer

OPEN HOLE: from — ft. to — ft.
Diam. 3"
Length 21'6"

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
Taconite				
Tailings	Gray	loose	0	104

Use a second sheet, if needed

STATIC WATER LEVEL: 75' 6" ft. ☒ below ☐ above land surface Date measured 10/26/94

PUMPING LEVEL (below land surface): — ft. after hrs. pumping g.p.m.

WELL HEAD COMPLETION: ☐ Pitless adapter manufacturer Model ☐ Casing Protection ☒ 12 in. above grade

GROUTING INFORMATION: slurry around casing
Well grouted? ☒ Yes ☐ No
Grout Material ☐ Neat cement ☒ Bentonite
from 0 to 80 ft. 3 ☐ yds. ☒ bags
from to ft. ☐ yds. ☐ bags
from to ft. ☐ yds. ☐ bags

NEAREST KNOWN SOURCE OF CONTAMINATION: 1000 feet direction type
Well disinfected upon completion? ☐ Yes ☒ No

PUMP: ☒ Not installed Date installed
Manufacturer's name
Model number HP Volts
Length of drop pipe ft. Capacity g.p.m.
Pressure Tank Capacity
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐

ABANDONED WELLS
Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

REMARKS, ELEVATION, SOURCE OF DATA, etc.

WELL CONTRACTOR CERTIFICATION
This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Petersen Drlg Inc 69183
Licensee Business Name — Lic. or Reg. No.

[signature] 11/8/94
Authorized Representative Signature — Date

Dennis Petersen
Name of Driller — Date

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY

551772

HE-01205-04 (Rev. 5/92)

New

GW 005

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

MINNESOTA UNIQUE WELL NO. 597384

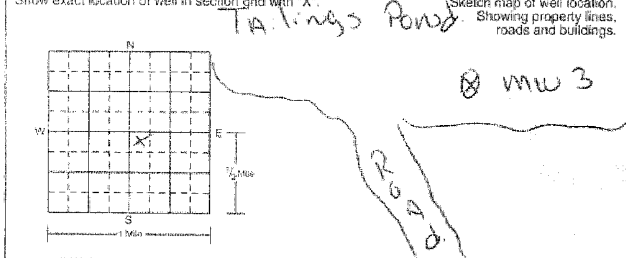
WELL LOCATION

County Name: ST. LOUIS

Township Name	Township No.	Range No.	Section No.	Fraction
HoyT LAKES	59N	14W	8	NW NW SE

House Number, Street Name, City, and Zip Code of Well Location / or Fire Number: LTV Steel Mine HoyT Lakes

Show exact location of well in section grid with "X". Sketch map of well location. Showing property lines, roads and buildings.



PROPERTY OWNER'S NAME
LTV Steel Mine Company

Property owner's mailing address if different than well location address indicated above.
P.O. Box 847
HoyT Lakes MN. 55750

WELL OWNER'S NAME
Same

Well owner's mailing address if different than property owner's address indicated above.

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
Fine TO Coarse			0	
TA.lings	Gray			125.0

Use a second sheet, if needed

REMARKS, ELEVATION, SOURCE OF DATA, etc.
AET Job # 700204
Top of Riser ElV. 1715.0
Ground surface ElV. 1712.50

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY

597384

WELL DEPTH (completed): 124.0 ft.
Date Work Completed: 7-9-98

DRILLING METHOD: ☐ Cable Tool ☐ Driven ☐ Dug ☐ Auger ☑ Rotary ☐ Jetted ☐

DRILLING FLUID: Quick Gel - Mud
WELL HYDROFRACTURED? ☐ YES ☑ NO
FROM ____ ft. to ____ ft.

USE: ☐ Domestic ☐ Irrigation ☐ Test Well ☑ Monitoring ☐ Community PWS ☐ Noncommunity PWS ☐ Dewatering ☐ Heating/Cooling ☐ Industry/Commercial ☐ Remedial ☐

CASING: ☑ Steel ☐ Plastic ☐ — Drive Shoe? ☐ Yes ☑ No — ☑ Threaded ☐ Welded

HOLE DIAM.: 7 7/8 in. to 125 ft.

CASING DIAMETER / WEIGHT:
4 in. to 104.0 ft. ____ lbs./ft.
____ in. to ____ ft. ____ lbs./ft.
____ in. to ____ ft. ____ lbs./ft.

SCREEN
Make: Johnson
Type: STAINLESS Steel
Diam.: 4
Slot/Gauze: .012
Length: 20'
Set between 124.0 ft. and 104.0 ft. FITTINGS: Flush couplings

OPEN HOLE: from ____ ft. to ____ ft.

STATIC WATER LEVEL: 90.9 ft. ☑ below ☐ above land surface Date measured ____

PUMPING LEVEL (below land surface): ____ ft. after ____ hrs. pumping ____ g.p.m.

WELL HEAD COMPLETION
☐ Pitless adapter manufacturer ____ Model ____
☑ Casing Protection 8" x 10' ☐ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

GROUTING INFORMATION
Well grouted? ☑ Yes ☐ No
Grout Material: ☑ Neat cement ☐ Bentonite ☐ Concrete ☐ High Solids Bentonite
from 92.0 to 0 ft. ☐ yds. ☐ bags
from ____ to ____ ft. ☐ yds. ☐ bags
from ____ to ____ ft. ☐ yds. ☐ bags

NEAREST KNOWN SOURCE OF CONTAMINATION
____ feet ____ direction ____ type
Well disinfected upon completion? ☐ Yes ☐ No

PUMP
☑ Not installed Date installed ____
Manufacturer's name ____
Model number ____ HP ____ Volts ____
Length of drop pipe ____ ft. Capacity ____ g.p.m.
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐

ABANDONED WELLS
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No unknown

VARIANCE
Was a variance granted from the MDH for this well? ☐ Yes ☑ No

WELL CONTRACTOR CERTIFICATION
This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

American Engineering Testing — MC063
Licensee Business Name — Lic. or Reg. No.

[signature] — 8-7-98
Authorized Representative Signature — Date

Larry Anderson
Name of Driller — Date

HE-01205-06 (Rev. 9/96)

Minnesota Unique Well No.

625044

County St. Louis
Quad
Quad ID

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 10/31/2001
Update Date 11/01/2001
Received Date

Well Name LTV STEEL MINING CO
Township Range Dir Section Subsections Elevation ft.
59 14 W 8 BCD **Elevation Method**

Well Depth 12 ft. **Depth Completed** 12 ft. **Date Well Completed** 04/09/2001

Drilling Method Auger (non-specified)

Drilling Fluid --

Well Hydrofractured? ☐ Yes ☑ No
From Ft. to Ft.

Use Monitor well

Casing Type Plastic **Joint** Unknown **Drive Shoe?** ☐ Yes ☐ No **Above/Below** ft.

Casing Diameter 1 in. to 4 ft. **Weight** lbs./ft. **Hole Diameter** 10 in. to 12 ft.

Well Address
P.O. BOX 847
HOYT LAKES MN 55750-0847

Geological Material	Color	Hardness	From	To
PEATY SOIL	BLACK	SOFT	0	0
FIRM SAND & PEAT	BROWN	SOFT	0	5
			0	
EXTRA DENSE ROCKS			5	12
			12	

Open Hole from ft. to ft.

Screen YES **Make** US FILTER **Type** steel (non-stainless)

Diameter 2 **Slot/Gauze** **Length** 8 **Set Between** 4 ft. and 12 ft.

Static Water Level
1.5 ft. from Land surface Date Measured 04/09/2001

PUMPING LEVEL (below land surface)
ft. after hrs. pumping g.p.m.

Well Head Completion
Pitless adapter manufacturer DOUBLE SEALE Model
☑ Casing Protection Y ☑ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

REMARKS
STS D10301
MW3
N47? 36.62' W92? 9.26'
DOUBLE SEALED PROTOP
OWNER'S MAILING ADDRESS: CO. RD. 666 P.O. BOX 847
HOYT LAKES, MN 55750-0847

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 4 ft. 2 bags

Nearest Known Source of Contamination
_feet _direction _type
Well disinfected upon completion? ☐ Yes ☑ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP _ Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☑ No

Variance Was a variance granted from the MDH for this well? ☐ Yes ☑ No

Well Contractor Certification
STS Consultants, Ltd. — License Business Name
M0150 — Lic. Or Reg. No.
ZEHNDA, D. — Name of Driller

First Bedrock
Last Strat
Aquifer
Depth to Bedrock ft.

County Well Index Online Report

625044

Printed 1/8/2009
HE-01205-07

near SE corner of basin

GW-008

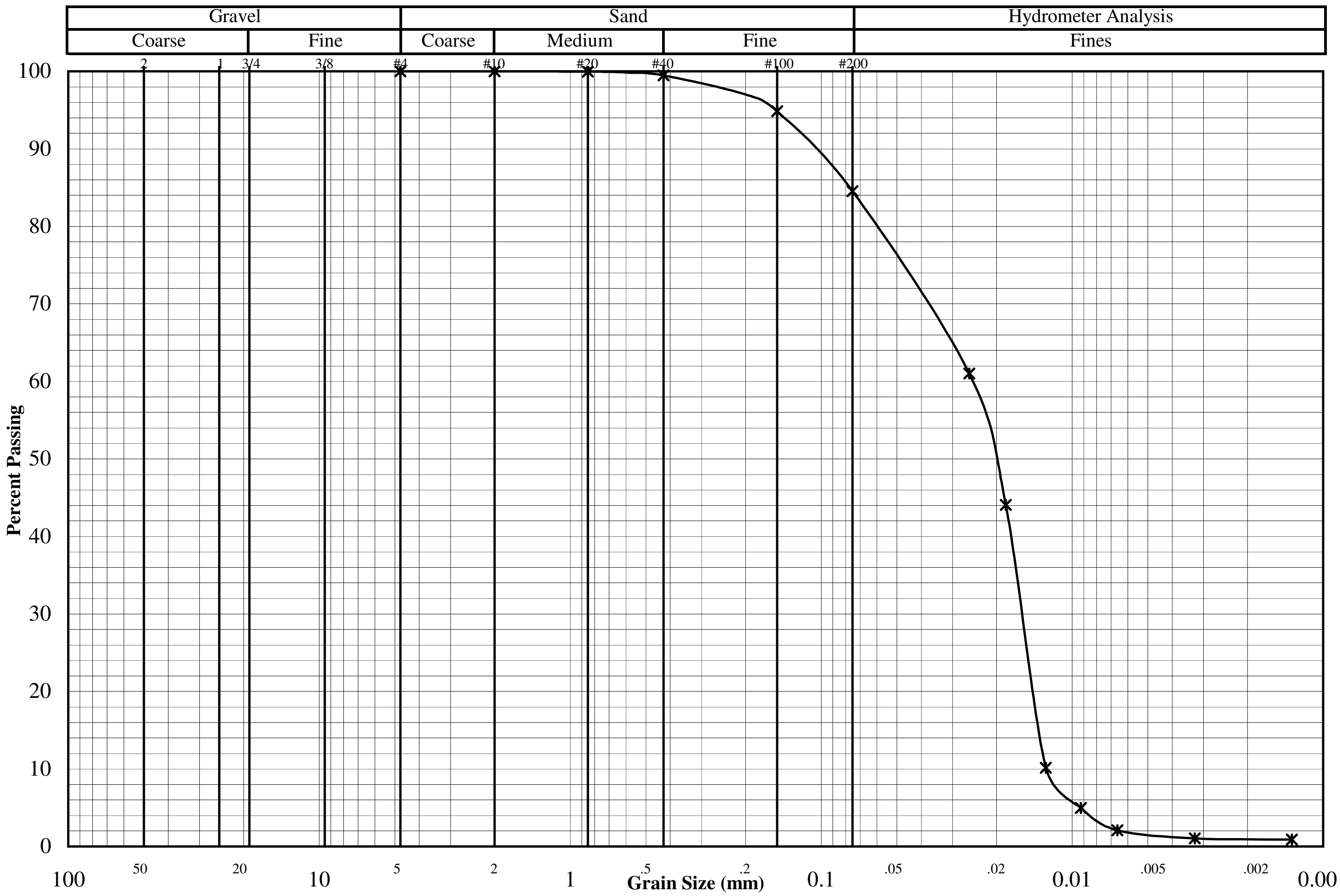
Attachment C

Residue Laboratory Test Results

Grain Size Distribution ASTM D422

Project:	Polymet Pilot Plant Combined Residue	**Job No. :**	**5628**
		Test Date:	3/30/06
Reported To:	Barr Engineering Company	**Report Date:**	9/4/12

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	Plant Residue	1		Bag	Tailings - Silt w/Sand (ML)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit	40.7		
Plastic Limit	38.4		
Plasticity Index	2.3		
Water Content	17.5		
Dry Density (pcf)			
Specific Gravity	2.75		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	450.1		
2"			
1.5"			
1"			
3/4"			
3/8"			
#4	100.0		
#10	100.0		
#20	99.9		
#40	99.5		
#100	94.9		
#200	84.5		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Thin film of material floated to the top of cylinder during hydrometer portion of test. This report was amended on 4-11-06 with a Specific Gravity based on average of tests and a consolidation test.

SOIL ENGINEERING TESTING, INC.

9301 Bryant Ave. South, Suite 107 Bloomington, Minnesota 55420-3436

Grain Size Distribution ASTM D422

Job No. : **5628**

Project:	Polymet Pilot Plant Combined Residue	Test Date:	3/30/06
Reported To:	Barr Engineering Company	Report Date:	9/4/12

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	Plant Residue	1		Bag	Tailings - Silt w/Sand (ML)
Spec 2					
Spec 3					

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.0257	61.02				
0.0184	44.07				
0.0128	10.17				
0.0092	4.96				
0.0066	2.09				
0.0032	1.05				
0.0013	0.88				

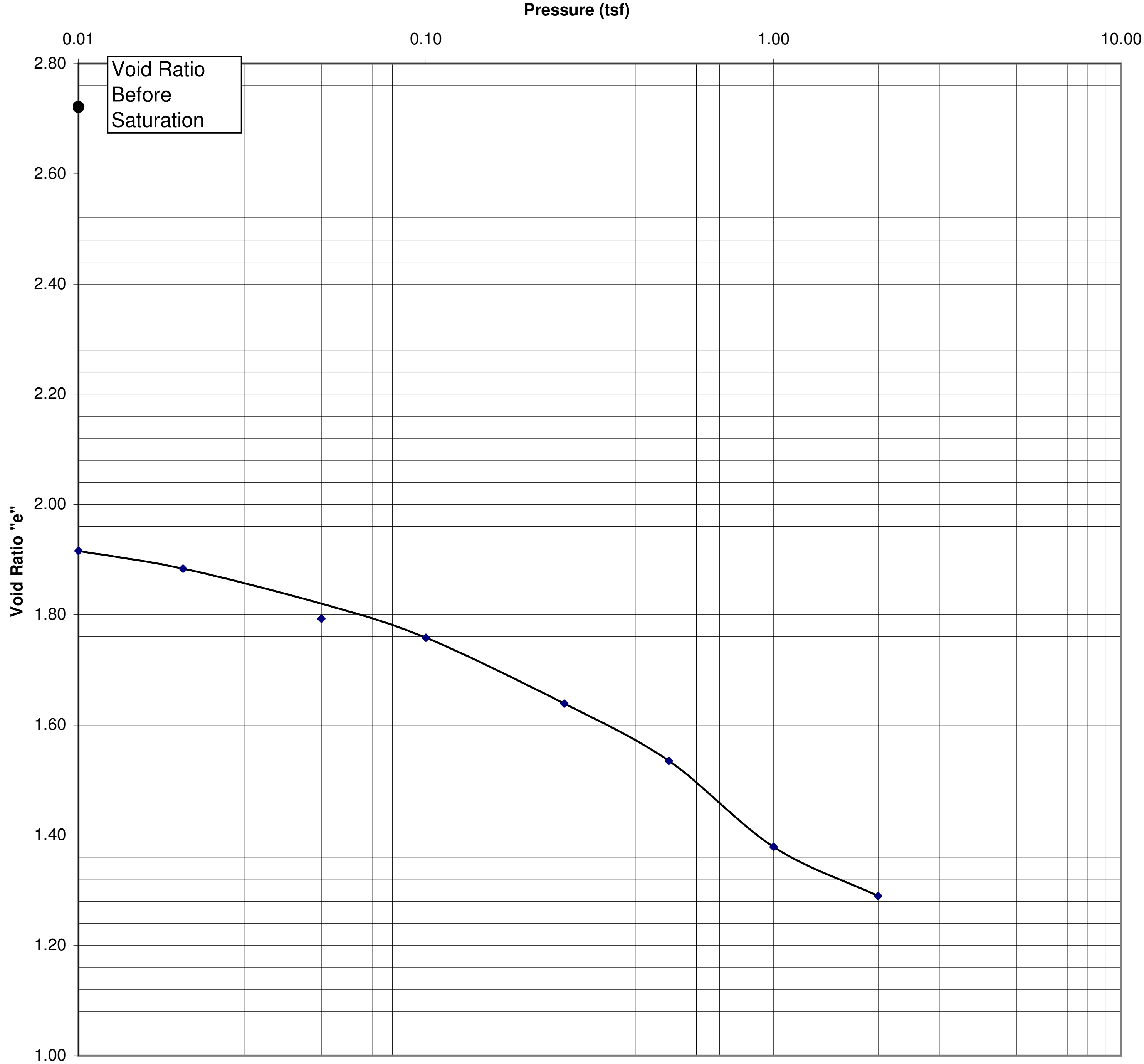
Permeability Test Data

Project: Polymet Pilot Plant Combined Residue — Date: 4/13/2006

Reported To: Barr Engineering Company — Job No.: 5628

Boring No.:							
Sample No.:	1						
Depth (ft)							
Location:							
Sample Type:	Bag						
Soil Type:	Tailings - Silt with Sand (ML)						
Atterberg Limits							
LL	40.7						
PL	38.4						
PI	2.3						
Permeability Test							
Before Test Conditions: Saturation %:	56.4%						
Porosity:	0.69						
Ht. (in):	2.99						
Dia. (in):	1.45						
Dry Density (pcf):	59.4						
Water Content:	41.2%						
Test Type:	Falling						
Max Head (ft):	4.0						
Confining press. (Effective-psi):	10.0						
Trial No.:	9-14						
Water Temp °C:	23.0						
% Compaction							
% Saturation (After Test)	97.0%						
Coefficient of Permeability							
K @ 20 °C (cm/sec)	**3.4×10^{-5}**						
K @ 20 °C (ft/min)	**6.8×10^{-5}**						
Notes:							

Void Ratio vs. Log of Pressure



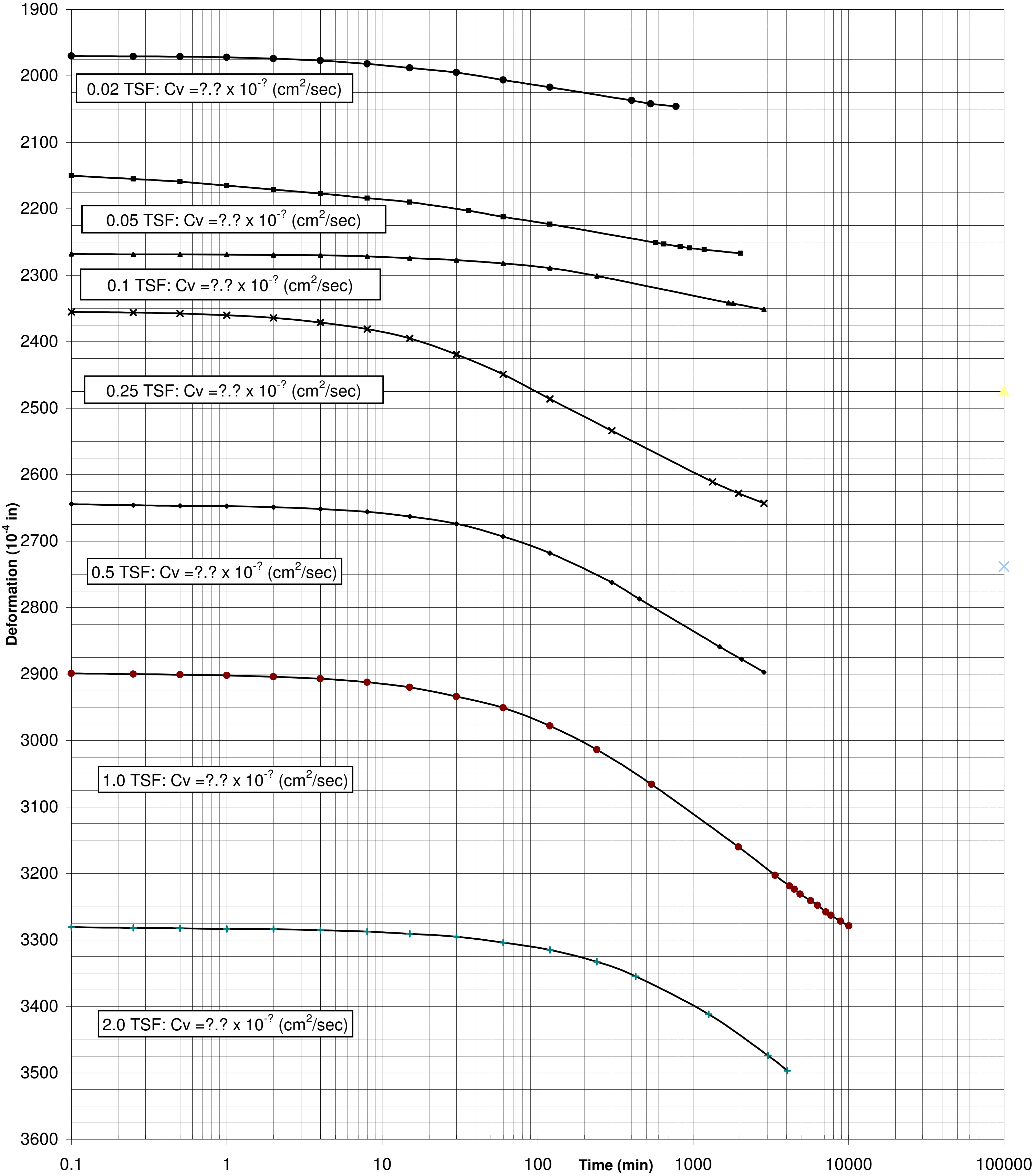
Project: Polymet Pilot Plant Combined Residue			Date: 5/15/06
Sample #: 1	Boring #:	Depth ft:	Job #: 5628
Soil Type: Tailings			
Initial W/C (%): 31.1	Dry Density (pcf): 45.6	LL: PL: PI:	Gs: 2.72 (Assumed)
Organic Content (%):	Initial Height (in.): 0.909	Diameter (in.): 2.505	e_o= 2.721
Preconsolidation Pressure (Pc):	Compression Index (Cc):	Recompression Index (Cr): ≅	
Remarks:			

9301 Bryant Ave. South, Suite 107

SOIL ENGINEERING TESTING, INC.

Bloomington, Minnesota 55420-3436

Consolidation Log of Time Curves



Project: Polymet Pilot Plant Combined Residue			Date: 5/15/06
Sample #: 1	Boring #:	Depth ft:	Job #: 5628

9301 Bryant Ave. South, Suite 107 — SOIL ENGINEERING TESTING, INC. — Bloomington, Minnesota 55420-3436

Table C-1 Hydrometallurgical Residue Composite Sample Consolidation Test Data Summary

Overburden Pressure (Tons/Square Foot)	Volume of Solids (cu. ft.)	Weight of Solids (lbs.)	Void Ratio (e)	Volume of Voids (V v, cu. ft.)	Total Volume (cu. ft.)	Dry Density (lbs./cu. ft.)	Dry Density (lbs./cu. ft.) (check)
0.01	6.95E-04	0.118	1.92	1.33E-03	2.03E-03	58.1	58.1
0.02	6.95E-04	0.118	1.88	1.31E-03	2.00E-03	59.0	58.9
0.05	6.95E-04	0.118	1.8	1.25E-03	1.95E-03	60.6	60.6
0.1	6.95E-04	0.118	1.76	1.22E-03	1.92E-03	61.5	61.5
0.25	6.95E-04	0.118	1.64	1.14E-03	1.83E-03	64.3	64.3
0.5	6.95E-04	0.118	1.54	1.07E-03	1.77E-03	66.8	66.8
1	6.95E-04	0.118	1.39	9.66E-04	1.66E-03	71.0	71.0
2	6.95E-04	0.118	1.22	8.48E-04	1.54E-03	76.5	76.5

Note:

1) Average overburden stress on hydrometallurgical residue in disposal cell is anticipated to be approximately 1.0 tons per square foot at closure.
2) Values based on specific gravity of solids of 2.72 as provided by Bateman Metals (May 2006), and weight of solids of: 0.118 pounds
3) Reference Soil Engineering Testing, Inc. May 10, 2006 Consolidation Test Data.
4) Data for the 2 tsf load is preliminary as of 5-15-2006.

Attachment D

Residue Settlement Calculations

PolyMet Hydrometallurgical Residue Cell: Residue Settlement - Model Outcomes Check

Updated 09/20/2011 EJB

Residue Settlement Estimation	Source
$S = \Delta e_{Mid\ Depth}/(1+e_o)*L_o$	(Terzaghi, Peck, Mesri Eq. 16.7)

S = Estimated Total Settlement

$\Delta e_{Mid\ Depth}$ = Change in Residue Void Ratio at Mid Depth of Facility

e_o = Initial Average Residue Void Ratio

L_o = Initial Residue Fill Depth (Approx. Elev 1650 ft to 1570 ft)

σ at L_o = (80ft x 73pcf)/2000 = 2.92 tsf

$e_{\sigma = 2.92\ tsf}$ = Residue Void Ratio at Confining Stress of 2.92 tsf (estimated full depth confining stress)

L_o =	80 ft	
e_o =	1.92	Attachment C (SET Job#5628)
$e_{\sigma=2.92\ tsf}$ =	1.22	Attachment C (SET Job#5628)
$\Delta e_{Full\ Depth}$ =	0.7	(1.92 - 1.22 = 0.7)
$\Delta e_{Mid\ Depth}$ =	0.35	(0.7 * 0.5 = 0.35)
Estimated Settlement =	9.6 ft	

Attachment E

Leakage Collection System Computations

Leakage Rate Computations for HRF Composite Liner System (Lower Liner)

Project Name: PolyMet
Project Number: 23/69-862-023

Updated by: TJR
Date: 9/4/2012

Design Objective: Based on design of the geocomposite to maintain geocomposite flow capacity greater than or equal to leakage rate into the geocomposite (from leakage through the overlying geomembrane liner); estimate the rate of leakage through the composite liner of the HRF.

Computation Approach: Giroud, J.P. (1997). "Equations for Calculating the Rate of Liquid Migration through Composite Liners Due to Geomembrane Defects," Geosynthetics International, Vol. 4, Nos. 3-4,

Liner Configuration	Contact Quality C_{qo}	Contact Quality C	Hydraulic Head h (feet)	Hydraulic Head h (meters)	Liner Thickness t_s (meters)	Defect Diameter (circular defects) d (meters)	Defect Area (circular defects) a (square meters)	Defect Width (rectangular and square defects) b (meters)	Defect Length (rectangular defects) B (meters)	Defects Per Acre n	Hydraulic Conductivity of Geomembrane Liner Subgrade K_s (centimeters/second)	Hydraulic Conductivity of Geomembrane Liner Subgrade K_s (meters/second)	Circular Defects Leakage Rate Q_{cir} (gallons/acre/day)	Square Defects Leakage Rate Q_{sqr} (gallons/acre/day)	Rectangular Defects Leakage Rate Q_{rec} (gallons/acre/day)	Average Leakage Rate from HRF Qavg (gallons/acre/day)
Geomembrane/ Geosynthetic Clay	0.21	0.52	2.75E-02	0.01	0.0065	0.01	0.000079	0.01	2	2.5	3.00E-09	3.00E-11	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
Sensitivity to Order of Magnitude Increase in Subgrade K_s	0.21	0.52	2.75E-02	0.01	0.0065	0.01	0.000079	0.01	2	2.5	3.00E-08	3.00E-10	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00
Sensitivity to Two Orders of Magnitude Increase in Subgrade K_s	0.21	0.52	2.75E-02	0.01	0.0065	0.01	0.000079	0.01	2	2.5	3.00E-07	3.00E-09	0.0.E+00	0.0.E+00	0.0.E+00	0.0.E+00

Leakage Rate Equations:

Circular Defects

$Q_{cir} = nC_{qo}\,[1 + 0.1\,(h/t_s)^{0.95}]\,a^{0.1}\,h^{0.9}\,k_s^{0.74}$

Square Defects

$Q_{sqr} = nC_{qo}\,[1 + 0.1\,(h/t_s)^{0.95}]\,b^{0.2}\,h^{0.9}\,k_s^{0.74}$

Rectangular Defect

$Q_{rec} = nC_{qo}\,[1 + 0.1\,(h/t_s)^{0.95}]\,b^{0.2}\,h^{0.9}\,k_s^{0.74} + nC_{q\infty}\,[1 + 0.2\,(h/t_s)^{0.95}]\,(B-b)\,b^{0.1}\,h^{0.45}\,k_s^{0.87}$

Reference Data (Input Data): GSE PermaNet SL Geocomposite

Geonet Core Thickness (mil):	3.30E+02
Geonet Core Thickness (ft):	2.75E-02

Summary: Due to low hydraulic head on composite liner system of HRF, computed and expected leakage rate through the HRF composite liner system is zero.

Project Name: PolyMet
Project Number: 23/69-862-023

Updated by: TJR
Date: 9/4/2012

Computations For: HRF Leakage Collection System - Geocomposite Design

Design Objective: Selection of Geocomposite Transmissivity and Flow Length to Achieve Saturated Flow Capacity of Geocomposite to Sump that is Equal to or Greater than Leakage Into the Geocomposite (from through the upper liner) so that Hydraulic Head on HRF Composite Liner Remains Within Geocomposite Drainage Layer.

Computation Approach: Reference Equation 139 in J.P. Giroud, J.G. Zornberg, and A. Zhao, *Hydraulic Design of Geosynthetic And Granular Liquid Collection Layers* , Geosynthetics International, 2000, Vol. 7. Nos. 4-6.

Equation 139: $\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta$

FS = Factor of Safety (Based on Designers Judgement) 1.5

$\theta_{measured-req}$ = required transmissivity of geocomposite to maintain hydraulic head within geocomposite

$\Pi\ (RF) = RF_{IMCO} \times RF_{IMIN} \times RF_{CR} \times RF_{IN} \times RF_{CD} \times RF_{PC} \times RF_{CC} \times RF_{BC}$

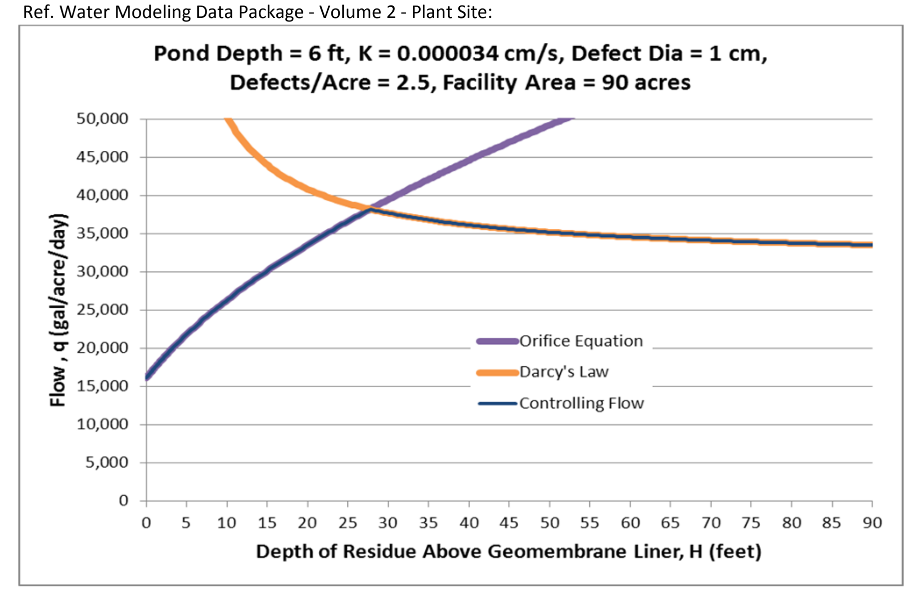
Reduction Factors		Reduction Factor Notes:
RF_{IMCO} = reduction factor for immediate compression	1.0	Accounted for in Manufactrers Published Transmissivity.
RF_{IMIN} = reduction factor for immediate intrusion	1.0	Accounted for in Manufactrers Published Transmissivity.
RF_{CR} = reduction factor for creep	1.1	Time-Dependent Hydraulic Transmissivity Reduction Due to Creep of Geocomposite Core.
RF_{IN} = reduction factor for delayed intrusion	1.2	Reduction Factor Due to Delayed Intrusion of Geotextile into Geocomposite Core.
RF_{CD} = reduction factor for chemical degredation	1.0	For Chemical Degredation of Polymeric Compounds During Service Life of Geocomposite.
RF_{PC} = reduction factor for particulate clogging	1.0	Hydraulic Transmissivity Reduction Due to Particles Migrating Into Geocomposite Core.
RF_{CC} = reduction factor for chemical clogging	1.2	Hydraulic Transmissivity Due to Chemical Precipitation in Geocomposite Core.
RF_{BC} = reduction factor for biological clogging	1.0	Hydraulic Transmissivity Reduction Due to Biological Growth in Geocomposite Core.

Π (RF) = 1.0 x 1.0 x 1.1 x 1.2 x 1.0 x 1.0 x 1.2 x 1.0 = 1.58

q_h = maximum leakage rate through upper geomembrane 38,000 gal/acre/day
1.35E-06 ft/sec

		Trial Geocomposite Transmissivity ≥ $\theta_{measured-req}$??
Trial 1: L=1,000 ft		
L = drainage length (feet)	1000 ft	
β = slope angle (degrees)	0.573 degrees	
sin β =	0.010	
Trial Geocomposite Transmissivity (GSE PermaNet SL)	2.15E-02 ft²/sec	
$\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta$ for L = 1000 ft		
$\boldsymbol{\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta}$		
= (1.5) (1.58) (1.35E-6) (1000) / (0.010)	**3.21E-01 ft²/sec**	No
Trial 2: L = 500 ft		
$\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta$ for L = 500 ft	**1.60E-01 ft²/sec**	No
Trial 3: L = 250 ft		
$\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta$ for L = 250 ft	**8.02E-02 ft²/sec**	No
Trial 4: L = 125 ft		
$\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta$ for L = 125 ft	**4.01E-02 ft²/sec**	No
Trial 5: L = 65 ft		
$\theta_{measured-req} = FS\ \Pi\ (RF)\ q_h\ L/\sin\beta$ for L = 65 ft	**2.08E-02 ft²/sec**	Yes

Ref. Water Modeling Data Package - Volume 2 - Plant Site:



Summary: Specify Geocomposite Drainage Layer to Have Transmissivity ≥ 2.08E-2 ft²/sec at Liner Slope of 1.0 Percent and Drain Pipe Spacing of 130 ft (= 2 x 65 ft). Modify Design as Needed to Account for Future Slope Changes, Drain Spacing Modifications and Alternate Geocomposite Transmissivity.

Attachment F

GSE and CETCO test reports

LINING TECHNOLOGIES
800.527.9948 www.cetco.com

May 13, 2008

Tom Radue
Vice President
Barr Engineering
4700 West 77th Street
Minneapolis, Minnesota 55435

Re: GCL Hydraulic Conductivity/Chemical Compatibility Test Results
Bentomat ST with Polymer-Treated Clay (R-101)
PolyMet Hydrometallurgical Residue Cells

Dear Mr. Radue:

In October 2006, CETCO contracted JLT Laboratories, in Canonsburg, Pennsylvania, to perform long-term compatibility tests of polymer-treated Bentomat GCL samples in contact with a synthetic PolyMet Hydrometallurgical Residue solution. The following sections describe the synthetic leachate solution used, the GCL samples tested, the compatibility/hydraulic conductivity test procedure, the test results and interpretation.

SYNTHETIC LEACHATE

The synthetic leachate solution used for this testing was prepared by CETCO using chemical concentrations and water quality data provided by Barr Engineering (please see Attachment A). We understand that the chemical concentrations were estimated using a process mass balance, and were intended to simulate the leachate expected at the PolyMet Hydrometallurgical Residue Cells at Hoyt Lakes. In preparing the synthetic solution, the laboratory discovered that many of the concentrations exceeded their respective solubility limits, resulting in significant precipitation of solids and likely much lower dissolved concentrations than given by the mass balance. Accordingly, the tests were performed using a 50% solution (the highest concentrations that would still remain in solution) to more closely simulate the dissolved chemical concentrations that may come in contact with the GCL in the field.

GCL SAMPLES

Three Bentomat ST samples were initially tested for this project: R-101 and R-103 (made with polymer-treated clay), and R-102 (made with an internal plastic membrane component). The R-102 test was terminated early-on, as it was an experimental product, determined to be impractical to manufacture on a large scale. The two remaining samples, R-101 and R-103, were prepared by adding two different proprietary, high-molecular weight polymers to the sodium bentonite. The polymers are intended to resist the potentially harmful effects of cations dissolved in the water in the following two ways: (1) the polymers bond to and encapsulate the clay particles, preventing harmful chemicals from intruding into the interlayer region where absorbed water is held; and (2) the polymers themselves expand when coming in contact with water, reducing the porosity of the overall system, helping to maintain a lower hydraulic conductivity. The laboratory procedure used to test these samples is discussed in the following section.

LABORATORY TEST PROCEDURE

Hydraulic conductivity/compatibility testing was performed in accordance with Scenario 2 of ASTM D6766, the Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Liquids. This method is recommended within the industry for conclusively evaluating GCL compatibility with site-specific leachates. The samples were hydrated with synthetic leachate for 48 hours under an effective stress of 5 psi, and then subjected to a hydraulic head of 2 psi to drive the flow of leachate through the samples. The method recommends that testing continue until the following termination criteria are met: (1) steady-state flow (defined as influent and effluent flow measurements within 25%); (2) at least two pore volumes of flow have passed through the specimen; and (3) chemical equilibrium (defined as electrical conductivity values within 10%) is established between the effluent and influent. To monitor these termination criteria during the testing period, flow measurements were collected daily, and chemical measurements were collected approximately once per month.

As mentioned previously, the test on sample R-102 was terminated in 2007. The test on sample R-103 was terminated in February 2008 due to excessive clogging of the porous stones and feed lines, driving the permeability to zero. The test on sample R-101 ran for 18 months, until all the required termination criteria were achieved. The compatibility test results for sample R-101 are presented in the following section.

COMPATIBILITY TEST RESULTS

The test on sample R-101 was run for 18 months (from October 26, 2006 to April 24, 2008), at which point all the ASTM D6766 Scenario 2 termination criteria were achieved. The flow and water quality measurements from JLT Laboratories for sample R-101 are presented in the attached test report (Attachment B). Apart from discrete spikes in measured flow corresponding to times when the porous plates and tubing were cleaned and flushed to remove chemical/biological precipitates, steady-state flow, the first termination criterion, was met almost immediately, on the fifth day of testing. The second termination criterion, two pore volumes of flow, was met after approximately 68 days. The third and final termination criterion, chemical equilibrium, was met after 546 days. The final measurements showed that the long-term, steady-state hydraulic conductivity of sample R-101 in contact with the synthetic site leachate is **1.51 x 10^{-9} cm/sec.**

In addition to testing the compatibility of R-101 with the synthetic site leachate, CETCO also evaluated the feasibility of manufacturing the R-101 product at full-scale. In March 2008, our Lovell facility performed a manufacturing trial on Bentomat with the R-101 formulation. The trial demonstrated that several hundred thousand square feet of material could be manufactured at the normal production rate, with minimal impact to standard operations. Accordingly, based on these trial findings, the R-101 product can readily be manufactured at the quantities required for the PolyMet project.

INTERPRETATION OF TEST RESULTS

Based on the laboratory testing results presented above, a GCL manufactured with the R-101 formulation would be expected to have a long-term hydraulic conductivity of 1.5 x 10^{-9} cm/sec, when hydrated and permeated with synthetic site leachate. These results indicate that the polymer-treated bentonite clay in R-101 was able to swell and maintain a low hydraulic conductivity even in the presence of the high ionic strength synthetic mine leachate. In is important to note that, since testing was performed in accordance with ASTM D6766, Scenario 2, it may actually yield a conservative representation of field conditions, for the following reasons:

- **Prehydration.** The R-101 sample was directly hydrated with the synthetic leachate at the beginning of the test. However, in the field, if the GCL is placed against a moist subgrade and then covered with a geomembrane, it will likely achieve hydration by pulling moisture from the subgrade soil long before it comes in contact with the site leachate. Several researchers, including Shackelford et. al. (2000) and Jo et al (2004), have shown that prehydration of a GCL with clean water prior to exposure to high strength liquids can significantly improve the GCL's hydraulic conductivity. Depending on the moisture of the subgrade at the PolyMet site, the GCL hydraulic conductivity may improve through prehydration with subgrade moisture or precipitation.

- **Confining Pressure.** The R-101 sample was tested at the standard recommended effective stress of 5 psi, which is roughly equivalent to the pressure exerted by 6 to 7 feet of soil. However, we understand that in the field, the liner system will be under several years' of tailings deposition, which is expected to reach an ultimate height of 60 to 80 feet. Therefore, the effective stress that will be acting on the tailings liner system will be much higher, perhaps 50 to 70 psi. Several researchers have shown that the hydraulic conductivity of bentonite is dictated by not only the pore water chemistry, but also by the confining pressure acting on the GCL. Daniel (2000) permeated GCLs with concentrated calcium chloride (5,000 mg/L) solutions at various confining pressures. At low compressive stress, the calcium solution had a dramatic effect on GCL performance. However, as the pressure increased to 400 kPa (approximately 58 psi), the hydraulic conductivity to distilled water and concentrated calcium solution was virtually identical. These results are consistent with the findings of Thiel and Criley (2005), who found that at effective stresses greater than 400 to 500 kPa (58 to 72 psi), the hydraulic conductivity of a GCL becomes virtually independent of the leachate chemistry.

CLOSING

Based on the ASTM D6766 long-term compatibility test results presented above, Bentomat manufactured with the R-101 polymer formulation is expected to have a long-term hydraulic conductivity of 1.5 x 10^{-9} cm/sec when hydrated and permeated with synthetic PolyMet site leachate. Additionally, the GCL hydraulic conductivity may improve considerably in the field, due to the potential benefits of prehydration from subgrade moisture and increased confining pressure. Based on the favorable results described above, CETCO recommends that the GCL product specified for the PolyMet Hydrometallurgical Residue Cells meets the following minimum requirements:

1. Polymer-enhanced product, with a manufacturer-demonstrated long-term laboratory hydraulic conductivity of 1.5 x 10^{-9} cm/sec, when tested in contact with the site leachate, per ASTM D6766, Scenario 2.

2. Manufacturer-demonstrated capability to manufacture and supply the large quantities required for the PolyMet project.

We appreciate the opportunity to provide this technical information. If you have any questions, please feel free to contact me at (847) 818-7945.

Sincerely,

Chris Athanassopoulos, P.E.
Technical Support Engineer

ATTACHMENT A
ESTIMATED CHEMICAL CONCENTRATIONS
POLYMET HYDROMETALLURGICAL RESIDUE CELLS
(PROVIDED BY BARR ENGINEERING)

CHLORIDE TAILINGS DECANT WATER - EXPECTED INORGANIC CONCENTRATIONS (mg/L)
Provided by Barr Engineering

	Al^{+3}	Ca^{+2}	Cl^{-}	Mg^{+2}	Na^{+}	SO_4^{-2}	S^{-2}
52 aAl2SO43 wt.%	0.8	0.0	0.0	0.0	0.0	4.2	0.0
53 aCaCl2 wt.%	0.0	4,151.2	7,343.2	0.0	0.0	0.0	0.0
54 aCaSO4 wt.%	0.0	615.1	0.0	0.0	0.0	1,474.4	0.0
55 aCoSO4 wt.%	0.0	0.0	0.0	0.0	0.0	3.4	0.0
56 aCuSO4 wt.%	0.0	0.0	0.0	0.0	0.0	19.2	0.0
57 aFeSO4 wt.%	0.0	0.0	0.0	0.0	0.0	0.3	0.0
58 aFe2SO43 wt.%	0.0	0.0	0.0	0.0	0.0	3.5	0.0
59 aHCl wt.%	0.0	0.0	0.9	0.0	0.0	0.0	0.0
61 aH2SO4 wt.%	0.0	0.0	0.0	0.0	0.0	119.2	0.0
62 aK2SO4 wt.%	0.0	0.0	0.0	0.0	0.0	759.2	0.0
63 aMgCl2 wt.%	0.0	0.0	0.2	0.1	0.0	0.0	0.0
64 aMgSO4 wt.%	0.0	0.0	0.0	4,065.2	0.0	16,065.3	0.0
65 aNaCl wt.%	0.0	0.0	800.1	0.0	518.9	0.0	0.0
66 aNaHS wt.%	0.0	0.0	0.0	0.0	77.8	0.0	108.5
67 aNa2SO4 wt.%	0.0	0.0	0.0	0.0	0.02	0.05	0.0
68 aNiSO4 wt.%	0.0	0.0	0.0	0.0	0.0	39.1	0.0
69 aZnSO4 wt.%	0.0	0.0	0.0	0.0	0.0	1.0	0.0
70 aNa3AuCl4 wt.%	0.0	0.0	0.00007	0.0	0.00004	0.0	0.0
71 aNa2PdCl4 wt.%	0.0	0.0	0.00033	0.0	0.00011	0.0	0.0
72 aNa2PtCl4 wt.%	0.0	0.0	0.00065	0.0	0.00021	0.0	0.0
73 aNa3RhCl6 wt.%	0.0	0.0	0.00014	0.0	0.00007	0.0	0.0
Total (mg/L)	**0.8**	**4,766.3**	**8,144.5**	**4,065.3**	**596.7**	**18,489.0**	**108.5**

ATTACHMENT B

JLT LABORATORIES, INC. FINAL TEST REPORT ON SAMPLE R-101

JLT LABORATORIES, INC.
GEOTECHNICAL, GEOSYNTHETIC AND MATERIALS TESTING AND RESEARCH

April 25, 2008
08LG951.01

CETCO
1500 West Shure Drive
Arlington Heights, IL 60004

Attn: Jim Olsta

**RE: FINAL COMPATIBILITY TEST RESULTS
BARR ENGINEERING SAMPLE R-101
WITH SYNTHETIC LEACHATE**

Dear Mr. Olsta:

Submitted herein are the final compatibility test results for sample R-101 using synthetic leachate. The sample was received on October 24, 2006 and set up to hydrate with leachate on October 25, 2006. The sample hydrated 48 hours from October 26, 2006 through October 27, 2006. On October 27, 2006 testing commenced with the first readings taken on October 28, 2006. Testing continued through April 24, 2008 for a total of 547 days.

Throughout this testing period, readings were taken every day at about 8:30AM, seven days a week for the duration of the test program.

Also throughout the test, the bladder accumulators were refilled with synthetic leachate on a regular basis. Typically, 100 to 150 cc's of leachate was used to refill the inflow bladder and the outflow bladder drained. After the 5th day of testing (November 1, 2006), inflow equaled outflow and continued for the duration of the test.

During the test, we regularly flushed the feed lines and the porous stones. You will note on the data sheets, that flow increased immediately after this flushing process.

After about 400 days of testing, we began to flush the inflow porous stones more aggressively using about 100 cc's of leachate. This did remove some sediment from the stones. We also passed the leachate through a 240 mesh Stainless Steel screen to ensure there were no suspended solids in the leachate. Thereafter, the flow did increase and essentially stabilized at about 475 days.

938 South Central Avenue • Canonsburg, Pennsylvania 15317 Tel: (724) 746-4441 Fax: (724) 745-4261

You will also note variations in the EC values throughout the test which is difficult to explain. The leachate definitely aged with time (1.5 years) and was exposed to air each time the container was opened to refill the bladders. We also stored the leachate in a refrigerator between uses. Thus, it was exposed to temperature excursions. Since we are not aware of its' constituents, any other explanation for these value differences would only be a guess.

We appreciate the opportunity to provide our services and look forward to working with you again. Should you have any questions, comments or require additional information, please do not hesitate to call.

Sincerely,

JLT LABORATORIES, INC.

John Boschuk, Jr., P.E.
President

cc: Report & Invoice
Chris Athanassopoulos

Enclosures
JB/mlb
\wp10\lettcr\08114
Inv # 3384

SUMMARY OF FLEX WALL PERMEABILITY TEST RESULTS
ASTM D-7100

Client	: CETCO		Date	:	04-25-08
Project Location	: Barr Engineering		Job No.	:	06LG951.01
Description	: R-101		Tested By	:	MLB/DB
	:		Checked By	:	JB
Permeant Fluid	: Syn Leachate		Spec. Gravity	:	2.74 Assumed

Physical Property Data

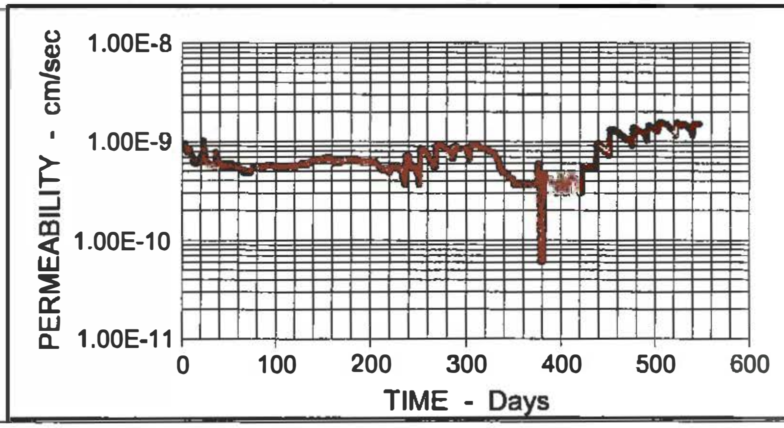
Initial Height (in)	:	0.17	Final Height (in)	:	0.24
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	4.00
Initial Wet Weight (g)	:	51.80	Final Wet Weight (g)	:	86.10
Wet Density (pcf)	:	92.29	Wet Density (pcf)	:	108.66
Moisture Content %	:	23.90	Moisture Content %	:	106.40
Dry Density (pcf)	:	74.49	Dry Density (pcf)	:	52.65

Test Parameters

Fluid	:	Syn Leachate	**Average Effective**		
Cell Pressure psi)	:	80.00	**Confining Pressure (psi)**	:	4.00
Head Water ɔsi)	:	77.00	Gradient	:	230.00
Tail Water ɔsi)	:	75.00	**Eff Stress at Base (psi)**	:	5

Permeability Input Data

Flow, Q	(cc)	:	2.50
Length, L	(in)	:	0.24
Area, A	(sqin)	:	12.57
Head, h	**(psi)**	**:**	**2.00**
Time, t	(min)	:	1442.00
Temp, T	(Deg C)	:	21.0



Computed Permeability

PERMEABILITY, K = 1.51E-009 (cm/sec) at 20 Degrees C

Day 547 **Total Inflow to Date : 657.8 cc**

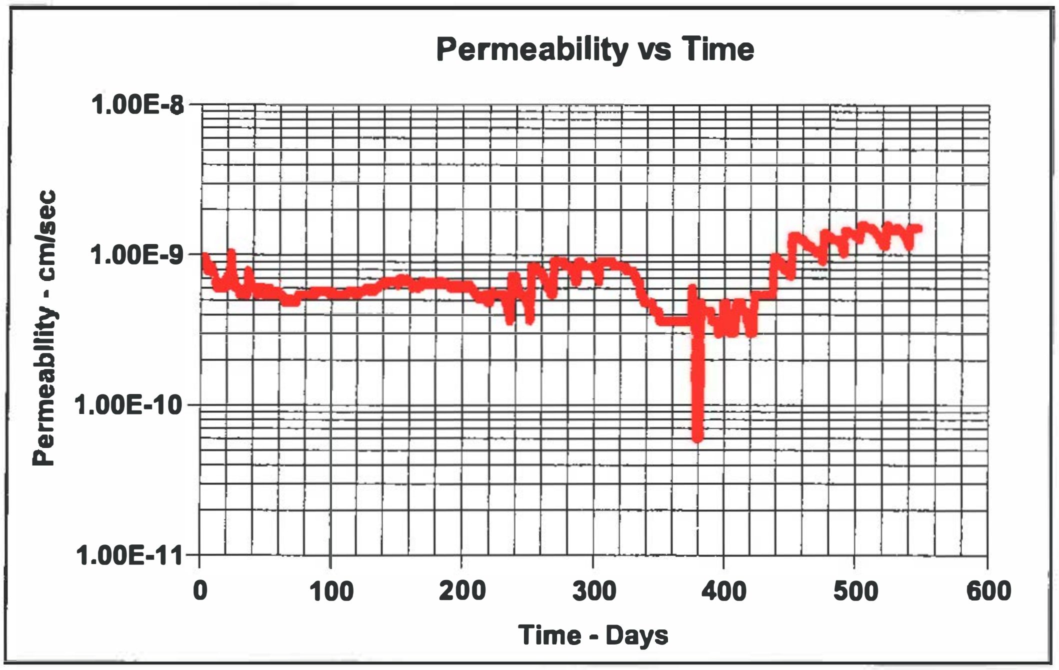
Description : R-101

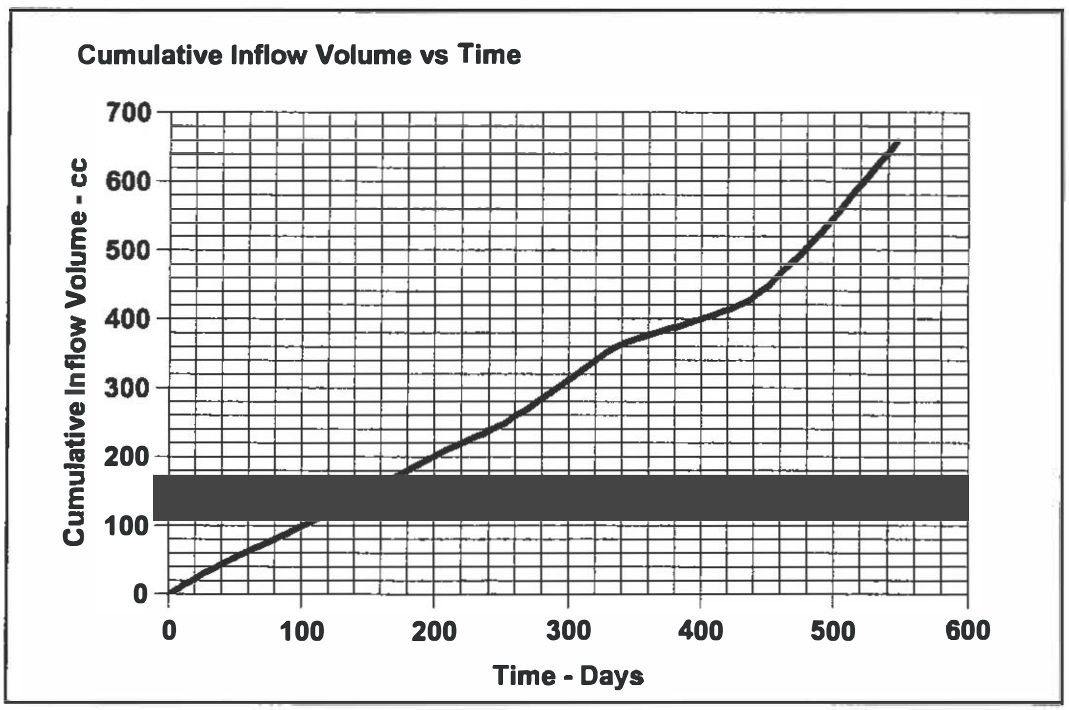
Date : 04-25-08

Estimated Pore Volume : 39 cc

Estimated Inflow Pore Volumes : 16.87

Permeant : Syn Leachate





JLT Laboratories, Inc.

Client : CETCO
Project Location : Barr Engineering
Description : R-101

Date : 04-25-08
Job No. : 06LG951.01
Tested By : MLB/DB
Checked By : JB

JLT

Sample ID : R-101

Estimated Poe Volume : 39 cc

Page 1

Elapsed Time Days	Permeability cm/sec	Inflow cc	Time minutes	Date	Total Cumulative Inflow Volume, cc	Pore Volumes	COMMENTS
1				10/26/2006	0.00	0.00	Synthetic Leachate
2				10/27/2006	0.00	0.00	
3	9.64E-010	1.6	1442	10/28/2006	1.60	0.04	
4	9.05E-010	1.5	1441	10/29/2006	3.10	0.08	
5	7.83E-010	1.3	1443	10/30/2006	4.40	0.11	Inflow: pH= 6.77 EC = 1.21 mS
6	7.95E-010	1.3	1421	10/31/2006	5.70	0.15	Outflow: pH = 6.55 EC = 3.05 mS
7	7.83E-010	1.3	1442	11/01/2006	7.00	0.18	
8	8.48E-010	1.4	1435	11/02/2006	8.40	0.22	
9	7.82E-010	1.3	1445	11/03/2006	9.70	0.25	
10	7.29E-010	1.2	1431	11/04/2006	10.90	0.28	Flushed Stones and Lines
11	7.14E-010	1.2	1461	11/05/2006	12.10	0.31	
12	6.03E-010	1.0	1442	11/06/2006	13.10	0.34	
13	6.02E-010	1.0	1444	11/07/2006	14.10	0.36	
14	6.03E-010	1.0	1442	11/08/2006	15.10	0.39	
15	6.03E-010	1.0	1441	11/09/2006	16.10	0.41	
16	6.03E-010	1.0	1442	11/10/2006	17.10	0.44	
17	6.64E-010	1.1	1440	11/11/2006	18.20	0.47	
18	6.63E-010	1.1	1442	11/12/2006	19.30	0.49	
19	6.03E-010	1.0	1441	11/13/2006	20.30	0.52	
20	7.23E-010	1.2	1442	11/14/2006	21.50	0.55	
21	7.23E-010	1.2	1442	11/15/2006	22.70	0.58	Inflow: pH= 7.04 EC = 1.61 mS
22	6.64E-010	1.1	1440	11/16/2006	23.80	0.61	Outflow: pH = 7.02 EC = 7.18 mS
23	1.03E-009	1.7	1437	11/17/2006	25.50	0.65	Flushed Stones and Lines
24	7.81E-010	1.3	1446	11/18/2006	26.80	0.69	
25	7.24E-010	1.2	1440	11/19/2006	28.00	0.72	
26	6.07E-010	1.0	1431	11/20/2006	29.00	0.74	
27	6.00E-010	1.0	1449	11/21/2006	30.00	0.77	
28	6.03E-010	1.0	1442	11/22/2006	31.00	0.79	
29	6.03E-010	1.0	1441	11/23/2006	32.00	0.82	
30	5.42E-010	0.9	1442	11/24/2006	32.90	0.84	
31	5.45E-010	0.9	1435	11/25/2006	33.80	0.87	
32	5.40E-010	0.9	1449	11/26/2006	34.70	0.89	
33	5.50E-010	0.9	1421	11/27/2006	35.60	0.91	
34	5.89E-010	1.0	1475	11/28/2006	36.60	0.94	
35	5.42E-010	0.9	1443	11/29/2006	37.50	0.96	
36	7.83E-010	1.3	1442	11/30/2006	36.60	0.99	Flushed Stones and Lines
37	7.22E-010	1.2	1444	12/01/2006	40.00	1.03	
38	6.64E-010	1.1	1440	12/02/2006	41.10	1.05	
39	6.02E-010	1.0	1443	12/03/2006	42.10	1.08	
40	6.03E-010	1.0	1442	12/04/2006	43.10	1.11	
41	6.06E-010	1.0	1434	12/05/2006	44.10	1.13	
42	6.04E-010	1.0	1439	12/06/2006	45.10	1.18	
43	5.42E-010	0.9	1442	12/07/2006	46.00	1.18	
44	6.02E-010	1.0	1444	12/08/2006	47.00	1.21	
45	6.07E-010	1.0	1431	12/09/2006	48.00	1.23	
46	5.97E-010	1.0	1456	12/10/2006	49.00	1.26	
47	6.00E-010	1.0	1448	12/11/2006	50.00	1.28	
48	5.43E-010	0.9	1439	12/12/2006	50.90	1.31	
49	6.02E-010	1.0	1444	12/13/2006	51.90	1.33	Inflow: pH= 8.57 EC = 2.31 mS
50	5.46E-010	0.9	1432	12/14/2006	52.80	1.35	Outflow: pH = 7.24 EC = 7.15 mS
51	5.97E-010	1.0	1456	12/15/2006	53.80	1.38	
52	5.43E-010	0.9	1439	12/16/2006	54.70	1.40	
53	6.02E-010	1.0	1443	12/17/2006	55.70	1.43	

54	5.47E-010	0.9	1431	12/18/2006	56.60	1.45	
55	5.43E-010	0.9	1439	12/19/2006	57.50	1.47	
56	5.46E-010	0.90	1433	12/20/2006	58.40	1.50	Page 2
57	5.42E-010	0.90	1442	12/21/2006	59.30	1.52	
58	5.42E-010	0.90	1442	12/22/2006	60.20	1.54	
59	5.73E-010	0.95	1440	12/23/2006	61.15	1.57	
60	5.76E-010	0.95	1433	12/24/2006	62.10	1.59	
61	5.41E-010	0.90	1448	12/25/2006	63.00	1.62	
62	5.40E-010	0.90	1447	12/26/2006	63.90	1.64	
63	5.12E-010	0.85	1442	12/27/2006	64.75	1.66	
64	5.16E-010	0.85	1431	12/28/2006	65.60	1.68	
65	4.82E-010	0.80	1442	12/29/2006	66.40	1.70	
66	5.11E-010	0.85	1444	12/30/2006	67.25	1.72	
67	5.12E-010	0.85	1442	12/31/2006	68.10	1.75	
68	5.13E-010	0.85	1440	01/01/2007	68.95	2.60	
69	4.83E-010	0.80	1439	01/02/2007	69.75	3.40	Flushed Stones and Lines
70	4.83E-010	0.80	1439	01/03/2007	70.55	4.20	
71	4.82E-010	0.80	1442	01/04/2007	71.35	5.00	
72	4.81E-010	0.80	1446	01/05/2007	72.15	5.80	
73	4.82E-010	0.80	1442	01/06/2007	72.95	6.60	
74	5.13E-010	0.85	1440	01/07/2007	73.80	7.45	
75	5.44E-010	0.90	1437	01/08/2007	74.70	8.35	
76	5.40E-010	0.90	1448	01/09/2007	75.60	9.25	
77	5.41E-010	0.90	1445	01/10/2007	76.50	10.15	
78	5.43E-010	0.90	1440	01/11/2007	77.40	11.05	
79	5.43E-010	0.90	1441	01/12/2007	78.30	11.95	
80	5.42E-010	0.90	1442	01/13/2007	79.20	12.85	
81	5.43E-010	0.90	1440	01/14/2007	80.10	13.75	
82	5.43E-010	0.90	1439	01/15/2007	81.00	14.65	
83	5.43E-010	0.90	1439	01/16/2007	81.90	15.55	
84	5.41E-010	0.90	1445	01/17/2007	82.80	16.45	
85	5.42E-010	0.90	1442	01/18/2007	83.70	17.35	
86	5.74E-010	0.95	1439	01/19/2007	84.65	18.30	
87	5.44E-010	0.90	1437	01/20/2007	85.55	19.20	
88	5.44E-010	0.90	1438	01/21/2007	86.45	20.10	
89	5.71E-010	0.95	1445	01/22/2007	87.40	21.05	
90	5.71E-010	0.95	1446	01/23/2007	88.35	22.00	
91	5.73E-010	0.95	1440	01/24/2007	89.30	22.95	
92	5.73E-010	0.95	1440	01/25/2007	90.25	23.90	
93	5.72E-010	0.95	1442	01/26/2007	91.20	24.85	
94	5.74E-010	0.95	1439	01/27/2007	92.15	25.80	
95	5.73E-010	0.95	1441	01/28/2007	93.10	26.75	
96	5.72E-010	0.95	1442	01/29/2007	94.05	27.70	EC Inflow: 1.84 mS Outflow 6.84 mS
97	5.73E-010	0.95	1440	01/30/2007	95.00	28.65	Flushed Stones and Lines
98	5.74E-010	0.95	1437	01/31/2007	95.95	29.60	
99	5.43E-010	0.90	1439	02/01/2007	96.85	30.50	
100	5.41E-010	0.90	1445	02/02/2007	97.75	31.40	
101	5.72E-010	0.95	1442	02/03/2007	98.70	32.35	
102	5.42E-010	0.90	1442	02/04/2007	99.60	33.25	
103	5.43E-010	0.90	1440	02/05/2007	100.50	34.15	
104	5.42E-010	0.90	1442	02/06/2007	101.40	35.05	
105	5.42E-010	0.90	1444	02/07/2007	102.30	35.95	EC inflow: 1.58 ms Outflow : 6.65 mS
106	5.42E-010	0.90	1442	02/08/2007	103.20	36.85	Flushed Stones and Lines
107	5.43E-010	0.90	1440	02/09/2007	104.10	37.75	
108	5.43E-010	0.90	1439	02/10/2007	105.00	38.85	
109	5.43E-010	0.90	1439	02/11/2007	105.90	39.55	
110	5.41E-010	0.90	1445	02/12/2007	106.80	40.45	
111	5.40E-010	0.90	1449	02/13/2007	107.70	41.35	
112	5.42E-010	0.90	1442	02/14/2007	108.60	42.25	
113	5.73E-010	0.95	1440	02/15/2007	109.55	43.20	
114	5.72E-010	0.95	1442	02/16/2007	110.50	44.15	
115	5.73E-010	0.95	1440	02/17/2007	111.45	45.10	
116	5.72E-010	0.95	1443	02/18/2007	112.40	46.05	
117	5.74E-010	0.95	1439	02/19/2007	113.35	47.00	
118	5.47E-010	0.90	1431	02/20/2007	114.25	47.90	
119	5.39E-010	0.90	1452	02/21/2007	115.15	48.80	
120	5.73E-010	0.95	1440	02/22/2007	116.10	49.75	

121	5.42E-010	0.90	1442	02/23/2007	117.00	50.65	
122	5.73E-010	0.95	1441	02/24/2007	117.95	51.60	Page 3
123	5.74E-010	0.95	1437	02/25/2007	118.90	52.55	
124	5.71E-010	0.95	1446	02/26/2007	119.85	53.50	
125	5.71E-010	0.95	1445	02/27/2007	120.80	54.45	
126	5.75E-010	0.95	1435	02/28/2007	121.75	55.40	
127	6.04E-010	1.00	1438	03/01/2007	122.75	56.40	Flushed Stones and Lines
128	6.04E-010	1.00	1438	03/02/2007	123.75	57.40	
129	6.03E-010	1.00	1442	03/03/2007	124.75	58.40	
130	5.72E-010	0.95	1443	03/04/2007	125.70	59.35	
131	6.03E-010	1.00	1440	03/05/2007	126.70	60.35	
132	6.03E-010	1.00	1440	03/06/2007	127.70	61.35	
133	5.73E-010	0.95	1441	03/07/2007	128.65	62.30	
134	6.04E-010	1.00	1439	03/08/2007	129.65	63.30	
135	6.03E-010	1.00	1441	03/09/2007	130.65	64.30	
136	6.03E-010	1.00	1442	03/10/2007	131.65	65.30	
137	6.32E-010	1.05	1443	03/11/2007	132.70	66.35	
138	6.34E-010	1.05	1440	03/12/2007	133.75	67.40	
139	6.35E-010	1.05	1437	03/13/2007	134.80	68.45	
140	6.65E-010	1.10	1438	03/14/2007	135.90	69.55	
141	6.64E-010	1.10	1439	03/15/2007	137.00	70.65	
142	6.34E-010	1.05	1440	03/16/2007	138.05	71.70	
143	6.63E-010	1.10	1442	03/17/2007	139.15	72.80	
144	6.63E-010	1.10	1441	03/18/2007	140.25	73.90	
145	6.63E-010	1.10	1442	03/19/2007	141.35	75.00	EC Inflow: 1.53 mS Outflow: 4.58 mS
146	6.62E-010	1.10	1444	03/20/2007	142.45	76.10	
147	6.65E-010	1.10	1438	03/21/2007	143.55	77.20	Flushed Stones and Lines
148	6.63E-010	1.10	1442	03/22/2007	144.65	78.30	
149	6.64E-010	1.10	1440	03/23/2007	145.75	79.40	
150	6.66E-010	1.10	1435	03/24/2007	146.85	80.50	
151	6.29E-010	1.05	1451	03/25/2007	147.90	81.55	
152	6.93E-010	1.15	1442	03/26/2007	149.05	82.70	
153	6.63E-010	1.10	1441	03/27/2007	150.15	83.80	
154	6.94E-010	1.15	1440	03/28/2007	151.30	84.95	
155	6.94E-010	1.15	1439	03/29/2007	152.45	86.10	
156	6.64E-010	1.10	1439	03/30/2007	153.55	87.20	
157	6.90E-010	1.15	1449	03/31/2007	154.70	88.35	
158	6.93E-010	1.15	1442	04/01/2007	155.85	89.50	
159	6.64E-010	1.10	1440	04/02/2007	156.95	90.60	
160	6.68E-010	1.10	1431	04/03/2007	158.05	91.70	
161	6.58E-010	1.10	1452	04/04/2007	159.15	92.80	
162	6.00E-010	1.00	1449	04/05/2007	160.15	93.80	
163	6.32E-010	1.05	1444	04/06/2007	161.20	94.85	
164	6.35E-010	1.05	1437	04/07/2007	162.25	95.90	
165	6.33E-010	1.05	1442	04/08/2007	163.30	96.95	
166	6.02E-010	1.00	1443	04/09/2007	164.30	97.95	
167	6.01E-010	1.00	1445	04/10/2007	165.30	98.95	
168	6.03E-010	1.00	1442	04/11/2007	166.30	99.95	
169	6.64E-010	1.10	1440	04/12/2007	167.40	101.05	
170	6.65E-010	1.10	1438	04/13/2007	168.50	102.15	
171	6.64E-010	1.10	1439	04/14/2007	169.60	103.25	
172	6.63E-010	1.10	1442	04/15/2007	170.70	104.35	
173	6.34E-010	1.05	1440	04/16/2007	171.75	105.40	
174	6.33E-010	1.05	1441	04/17/2007	172.80	106.45	
175	6.34E-010	1.05	1440	04/18/2007	173.85	107.50	
176	6.63E-010	1.10	1441	04/19/2007	174.95	108.60	Flushed Stones and Lines
177	6.63E-010	1.10	1442	04/20/2007	176.05	109.70	
178	6.35E-010	1.05	1437	04/21/2007	177.10	110.75	
179	6.34E-010	1.05	1439	04/22/2007	178.15	111.80	
180	6.61E-010	1.10	1445	04/23/2007	179.25	112.90	
181	6.34E-010	1.05	1439	04/24/2007	180.30	113.95	
182	6.62E-010	1.10	1444	04/25/2007	181.40	115.05	
183	6.35E-010	1.05	1437	04/26/2007	182.45	116.10	
184	6.62E-010	1.10	1444	04/27/2007	183.55	117.20	
185	6.37E-010	1.05	1432	04/28/2007	184.60	118.25	
186	6.63E-010	1.10	1442	04/29/2007	185.70	119.35	
187	6.56E-010	1.10	1456	04/30/2007	186.80	120.45	EC Inflow: 1.54 mS Outflow: 4.12 mS

188	6.43E-010	1.05	1420	05/01/2007	187.85	121.50	
189	6.33E-010	1.05	1442	05/02/2007	188.90	122.55	Page 4
190	6.31E-010	1.05	1445	05/03/2007	189.95	123.60	
191	6.03E-010	1.00	1442	05/04/2007	190.95	124.60	
192	6.03E-010	1.00	1440	05/05/2007	191.95	125.60	
193	6.04E-010	1.00	1439	05/06/2007	192.95	126.60	
194	6.34E-010	1.05	1438	05/07/2007	194.00	127.65	
195	6.02E-010	1.00	1444	05/08/2007	195.00	128.65	
196	6.33E-010	1.05	1442	05/09/2007	196.05	129.70	
197	6.32E-010	1.05	1443	05/10/2007	197.10	130.75	
198	6.03E-010	1.00	1440	05/11/2007	198.10	131.75	
199	6.03E-010	1.00	1440	05/12/2007	199.10	132.75	
200	6.03E-010	1.00	1442	05/13/2007	200.10	133.75	
201	6.32E-010	1.05	1444	05/14/2007	201.15	134.80	
202	6.02E-010	1.00	1443	05/15/2007	202.15	135.80	
203	6.31E-010	1.05	1446	05/16/2007	203.20	136.85	EC Inflow: 1.54 mS Outflow: 3.97 mS
204	6.34E-010	1.05	1440	05/17/2007	204.25	137.90	
205	6.33E-010	1.05	1442	05/18/2007	205.30	138.95	Flushed Stones and Lines
206	6.04E-010	1.00	1439	05/19/2007	206.30	139.95	
207	6.05E-010	1.00	1437	05/20/2007	207.30	140.95	
208	5.72E-010	0.95	1442	05/21/2007	208.25	141.90	
209	5.73E-010	0.95	1440	05/22/2007	209.20	142.85	
210	5.42E-010	0.90	1442	05/23/2007	210.10	143.75	
211	5.42E-010	0.90	1443	05/24/2007	211.00	144.65	
212	5.13E-010	0.85	1439	05/25/2007	211.85	145.50	
213	5.14E-010	0.85	1437	05/26/2007	212.70	146.35	
214	5.13E-010	0.85	1440	05/27/2007	213.55	147.20	
215	5.13E-010	0.85	1440	05/28/2007	214.40	148.05	
216	5.41E-010	0.90	1445	05/29/2007	215.30	148.95	
217	5.45E-010	0.90	1435	05/30/2007	216.20	149.85	
218	5.14E-010	0.85	1437	05/31/2007	217.05	150.70	
219	4.81E-010	0.80	1444	06/01/2007	217.85	151.50	
220	4.82E-010	0.80	1442	06/02/2007	218.65	152.30	
221	5.43E-010	0.90	1439	06/03/2007	219.55	153.20	
222	5.72E-010	0.95	1442	06/04/2007	220.50	154.15	
223	5.41E-010	0.90	1445	06/05/2007	221.40	155.05	
224	5.45E-010	0.90	1435	06/06/2007	222.30	155.95	
225	5.42E-010	0.9	1442	06/07/2007	223.20	156.85	
226	5.43E-010	0.9	1440	06/08/2007	224.10	157.75	
227	5.42E-010	0.9	1442	06/09/2007	225.00	158.65	
228	5.42E-010	0.9	1443	06/10/2007	225.90	159.55	
229	5.42E-010	0.9	1442	06/11/2007	226.80	160.45	
230	5.44E-010	0.9	1438	06/12/2007	227.70	161.35	
231	5.44E-010	0.9	1437	06/13/2007	228.60	162.25	
232	4.83E-010	0.8	1439	06/14/2007	229.40	163.05	
233	4.82E-010	0.8	1443	06/15/2007	230.20	163.85	
234	4.22E-010	0.7	1442	06/16/2007	230.90	164.55	
235	4.22E-010	0.7	1440	06/17/2007	231.60	165.25	
236	3.62E-010	0.6	1440	06/18/2007	232.20	165.85	Flushed Stones and Lines
237	7.23E-010	1.2	1442	06/19/2007	233.40	167.05	
238	7.25E-010	1.2	1439	06/20/2007	234.60	168.25	
239	7.25E-010	1.2	1439	06/21/2007	235.80	169.45	
240	7.23E-010	1.2	1443	06/22/2007	237.00	170.65	
241	6.03E-010	1.0	1440	06/23/2007	238.00	171.65	
242	6.03E-010	1.0	1442	06/24/2007	239.00	172.65	
243	5.43E-010	0.9	1441	06/25/2007	239.90	173.55	
244	5.43E-010	0.9	1440	06/26/2007	240.80	174.45	
245	5.43E-010	0.9	1440	06/27/2007	241.70	175.35	
246	5.42E-010	0.9	1442	06/28/2007	242.60	176.25	
247	5.42E-010	0.9	1443	06/29/2007	243.50	177.15	
248	4.84E-010	0.8	1437	06/30/2007	244.30	177.95	
249	4.83E-010	0.8	1439	07/01/2007	245.10	178.75	
250	4.22E-010	0.7	1440	07/02/2007	245.80	179.45	
251	3.62E-010	0.6	1442	07/03/2007	246.40	180.05	Flushed Stones and Lines
252	8.44E-010	1.4	1441	07/04/2007	247.80	181.45	
253	8.44E-010	1.4	1441	07/05/2007	249.20	182.85	
254	8.44E-010	1.4	1441	07/06/2007	250.60	184.25	

255	8.44E-010	1.4	1442	07/07/2007	252.00	185.65	
256	7.85E-010	1.3	1439	07/08/2007	253.30	186.95	
257	7.85E-010	1.3	1439	07/09/2007	254.60	188.25	Page 5
258	7.84E-010	1.3	1441	07/10/2007	255.90	189.55	
259	7.84E-010	1.3	1440	07/11/2007	257.20	190.85	In : 1.27 mS Out : 3.78mS
260	7.26E-010	1.2	1437	07/12/2007	258.40	192.05	
261	7.23E-010	1.2	1443	07/13/2007	259.60	193.25	
262	6.62E-010	1.1	1444	07/14/2007	260.70	194.35	
263	6.65E-010	1.1	1437	07/15/2007	261.80	195.45	
264	6.04E-010	1.0	1438	07/16/2007	262.80	196.45	
265	6.04E-010	1.0	1439	07/17/2007	263.80	197.45	
266	6.03E-010	1.0	1442	07/18/2007	264.80	198.45	
267	5.43E-010	0.9	1440	07/19/2007	265.70	199.35	
268	5.43E-010	0.9	1440	07/20/2007	266.60	200.25	Flushed Lines and Replaced Stones
269	9.04E-010	1.5	1442	07/21/2007	268.10	201.75	
270	9.05E-010	1.5	1441	07/22/2007	269.60	203.25	
271	9.03E-010	1.5	1443	07/23/2007	271.10	204.75	
272	9.05E-010	1.5	1440	07/24/2007	272.60	206.25	
273	9.06E-010	1.5	1439	07/25/2007	274.10	207.75	
274	9.06E-010	1.5	1438	07/26/2007	275.60	209.25	
275	9.06E-010	1.5	1439	07/27/2007	277.10	210.75	
276	9.04E-010	1.5	1442	07/28/2007	278.60	212.25	
277	8.44E-010	1.4	1441	07/29/2007	280.00	213.65	
278	8.45E-010	1.4	1440	07/30/2007	281.40	215.05	
279	8.44E-010	1.4	1442	07/31/2007	282.80	216.45	
280	8.43E-010	1.4	1443	08/01/2007	284.20	217.85	
281	8.45E-010	1.4	1440	08/02/2007	285.60	219.25	
282	7.83E-010	1.3	1442	08/03/2007	286.90	220.55	
283	7.84E-010	1.3	1441	08/04/2007	288.20	221.85	
284	7.85E-010	1.3	1439	08/05/2007	289.50	223.15	
285	6.64E-010	1.1	1439	08/06/2007	290.60	224.25	
286	6.65E-010	1.1	1437	08/07/2007	291.70	225.35	Flushed Stones and Lines
287	9.02E-010	1.5	1445	08/08/2007	293.20	226.85	
288	9.04E-010	1.5	1442	08/09/2007	294.70	228.35	
289	9.05E-010	1.5	1440	08/10/2007	296.20	229.85	
290	8.44E-010	1.4	1441	08/11/2007	297.60	231.25	
291	8.44E-010	1.4	1442	08/12/2007	299.00	232.65	
292	8.45E-010	1.4	1439	08/13/2007	300.40	234.05	
293	8.46E-010	1.4	1438	08/14/2007	301.80	235.45	
294	8.46E-010	1.4	1438	08/15/2007	303.20	236.85	
295	8.45E-010	1.4	1439	08/16/2007	304.60	238.25	
296	8.44E-010	1.4	1442	08/17/2007	306.00	239.65	
297	8.45E-010	1.4	1440	08/18/2007	307.40	241.05	
298	8.44E-010	1.4	1441	08/19/2007	308.80	242.45	
299	8.45E-010	1.4	1440	08/20/2007	310.20	243.85	
300	7.86E-010	1.3	1437	08/21/2007	311.50	245.15	
301	7.85E-010	1.3	1439	08/22/2007	312.80	246.45	
302	7.23E-010	1.2	1443	08/23/2007	314.00	247.65	
303	6.63E-010	1.1	1442	08/24/2007	315.10	248.75	Flushed Stones and Lines
304	9.05E-010	1.5	1440	08/25/2007	316.60	250.25	
305	9.04E-010	1.5	1442	08/26/2007	318.10	251.75	
306	9.06E-010	1.5	1438	08/27/2007	319.60	253.25	
307	9.04E-010	1.5	1442	08/28/2007	321.10	254.75	
308	9.05E-010	1.5	1440	08/29/2007	322.60	256.25	
309	9.05E-010	1.5	1441	08/30/2007	324.10	257.75	
310	9.04E-010	1.5	1442	08/31/2007	325.60	259.25	
311	9.03E-010	1.5	1443	09/01/2007	327.10	260.75	
312	9.03E-010	1.5	1444	09/02/2007	328.60	262.25	
313	9.06E-010	1.5	1438	09/03/2007	330.10	263.75	
314	8.46E-010	1.4	1438	09/04/2007	331.50	265.15	
315	8.44E-010	1.4	1442	09/05/2007	332.90	266.55	
316	8.43E-010	1.4	1443	09/06/2007	334.30	267.95	
317	8.44E-010	1.4	1442	09/07/2007	335.70	269.35	In : 1.67 mS Out : 3.35 mS
318	8.44E-010	1.4	1442	09/08/2007	337.10	270.75	
319	8.44E-010	1.4	1442	09/09/2007	338.50	272.15	
320	8.44E-010	1.4	1442	09/10/2007	339.90	273.55	
321	8.43E-010	1.4	1443	09/11/2007	341.30	274.95	

322	8.45E-010	1.4	1439	09/12/2007	342.70	276.35	
323	8.45E-010	1.4	1439	09/13/2007	344.10	277.75	
324	7.83E-010	1.3	1443	09/14/2007	345.40	279.05	Page 6
325	7.83E-010	1.3	1442	09/15/2007	346.70	280.35	
326	7.83E-010	1.3	1442	09/16/2007	348.00	281.85	
327	7.84E-010	1.3	1441	09/17/2007	349.30	282.95	
328	7.83E-010	1.3	1442	09/18/2007	350.60	284.25	
329	7.84E-010	1.3	1440	09/19/2007	351.90	285.55	
330	7.25E-010	1.2	1438	09/20/2007	353.10	286.75	
331	7.25E-010	1.2	1439	09/21/2007	354.30	287.95	
332	6.62E-010	1.1	1443	09/22/2007	355.40	289.05	
333	6.63E-010	1.1	1442	09/23/2007	356.50	290.15	
334	6.64E-010	1.1	1440	09/24/2007	357.60	291.25	
335	5.43E-010	0.9	1440	09/25/2007	358.50	292.15	
336	5.44E-010	0.9	1438	09/26/2007	359.40	293.05	
337	5.43E-010	0.9	1439	09/27/2007	360.30	293.95	
338	4.83E-010	0.8	1439	09/28/2007	361.10	294.75	
339	4.81E-010	0.8	1444	09/29/2007	361.90	295.55	
340	4.82E-010	0.8	1442	09/30/2007	362.70	296.35	
341	4.82E-010	0.8	1441	10/01/2007	363.50	297.15	
342	4.82E-010	0.8	1443	10/02/2007	364.30	297.95	
343	4.83E-010	0.8	1440	10/03/2007	365.10	298.75	
344	4.82E-010	0.8	1442	10/04/2007	365.90	299.55	
345	4.22E-010	0.7	1443	10/05/2007	386.60	300.25	
346	4.22E-010	0.7	1440	10/06/2007	367.30	300.95	
347	4.23E-010	0.7	1439	10/07/2007	368.00	301.65	
348	4.23E-010	0.7	1439	10/08/2007	368.70	302.35	
349	4.22E-010	0.7	1442	10/09/2007	369.40	303.05	
350	3.62E-010	0.6	1439	10/10/2007	370.00	303.65	
351	3.63E-010	0.6	1436	10/11/2007	370.60	304.25	
352	3.62E-010	0.6	1439	10/12/2007	371.20	304.85	
353	3.62E-010	0.6	1442	10/13/2007	371.80	305.45	
354	3.62E-010	0.6	1442	10/14/2007	372.40	306.05	
355	3.62E-010	0.6	1441	10/15/2007	373.00	306.65	
356	3.62E-010	0.6	1440	10/16/2007	373.60	307.25	
357	3.62E-010	0.6	1440	10/17/2007	374.20	307.85	
358	3.62E-010	0.6	1439	10/18/2007	374.80	308.45	In : 1.57 mS Out : 3.15 mS
359	3.62E-010	0.6	1442	10/19/2007	375.40	309.05	
360	3.62E-010	0.6	1441	10/20/2007	376.00	309.65	
361	3.62E-010	0.6	1442	10/21/2007	376.60	310.25	
362	3.62E-010	0.6	1440	10/22/2007	377.20	310.85	
363	3.63E-010	0.6	1438	10/23/2007	377.80	311.45	
364	3.62E-010	0.6	1439	10/24/2007	378.40	312.05	
365	3.61E-010	0.6	1443	10/25/2007	379.00	312.65	
366	3.62E-010	0.6	1442	10/26/2007	379.60	313.25	
367	3.62E-010	0.6	1440	10/27/2007	380.20	313.85	
368	3.62E-010	0.6	1440	10/28/2007	380.80	314.45	
369	3.63E-010	0.6	1438	10/29/2007	381.40	315.05	
370	3.62E-010	0.6	1439	10/30/2007	382.00	315.65	
371	3.62E-010	0.6	1439	10/31/2007	382.60	316.25	
372	3.61E-010	0.6	1444	11/01/2007	383.20	316.85	
373	3.62E-010	0.6	1442	11/02/2007	383.80	317.45	
374	3.62E-010	0.6	1441	11/03/2007	384.40	318.05	Flushed Inflow Lines and Stone
375	6.02E-010	1.0	1443	11/04/2007	385.40	319.05	
376	4.83E-010	0.8	1440	11/05/2007	386.20	319.85	In : 1.33 mS Out : 2.41 mS
377	2.41E-010	0.4	1442	11/06/2007	386.60	320.25	
378	6.02E-011	0.1	1443	11/07/2007	386.70	320.35	
379	6.03E-011	0.1	1440	11/08/2007	386.80	320.45	
380	6.04E-011	0.1	1439	11/09/2007	386.90	320.55	In: 1.55 mS Out :No Fluid
381	6.04E-011	0.1	1439	11/10/2007	387.00	320.65	
382	4.82E-010	0.8	1442	11/11/2007	387.80	321.45	Flushed Inflow Lines and Stone
383	4.23E-010	0.7	1439	11/12/2007	388.50	322.15	
384	4.23E-010	0.7	1438	11/13/2007	389.20	322.85	
385	4.23E-010	0.7	1439	11/14/2007	389.90	323.55	
386	4.22E-010	0.7	1442	11/15/2007	390.60	324.25	
387	4.22E-010	0.7	1442	11/16/2007	391.30	324.95	
388	4.22E-010	0.7	1441	11/17/2007	392.00	325.65	

389	4.22E-010	0.7	1440	11/18/2007	392.70	326.35	
390	3.62E-010	0.6	1440	11/19/2007	393.30	326.95	
391	3.62E-010	0.6	1441	11/20/2007	393.90	327.55	Page 7
392	3.62E-010	0.6	1440	11/21/2007	394.50	328.15	
393	3.62E-010	0.6	1439	11/22/2007	395.10	328.75	
394	3.62E-010	0.6	1439	11/23/2007	395.70	329.35	
395	3.00E-010	0.5	1449	11/24/2007	396.20	329.85	
396	3.01E-010	0.5	1442	11/25/2007	396.70	330.35	
397	3.02E-010	0.5	1440	11/26/2007	397.20	330.85	
398	3.04E-010	0.5	1431	11/27/2007	397.70	331.35	
399	4.79E-010	0.8	1452	11/28/2007	398.50	332.15	Flushed Inflow Lines and Stone
400	4.80E-010	0.8	1449	11/29/2007	399.30	332.95	
401	4.81E-010	0.8	1444	11/30/2007	400.10	333.75	
402	4.23E-010	0.7	1437	12/01/2007	400.80	334.45	
403	3.62E-010	0.6	1442	12/02/2007	401.40	335.05	
404	3.01E-010	0.5	1443	12/03/2007	401.90	335.55	
405	3.01E-010	0.5	1445	12/04/2007	402.40	336.05	
406	3.01E-010	0.5	1442	12/05/2007	402.90	336.55	
407	3.02E-010	0.5	1440	12/06/2007	403.40	337.05	
408	3.02E-010	0.5	1438	12/07/2007	403.90	337.55	
409	4.83E-010	0.8	1439	12/08/2007	404.70	338.35	Flushed Inflow Lines and Stone
410	4.82E-010	0.8	1442	12/09/2007	405.50	339.15	
411	4.83E-010	0.8	1440	12/10/2007	406.30	339.95	
412	4.82E-010	0.8	1441	12/11/2007	407.10	340.75	
413	4.83E-010	0.8	1440	12/12/2007	407.90	341.55	
414	4.22E-010	0.7	1441	12/13/2007	408.60	342.25	
415	4.22E-010	0.7	1442	12/14/2007	409.30	342.95	
416	4.23E-010	0.7	1437	12/15/2007	410.00	343.65	
417	3.62E-010	0.6	1439	12/16/2007	410.60	344.25	
418	3.62E-010	0.6	1442	12/17/2007	411.20	344.85	
419	3.01E-010	0.5	1443	12/18/2007	411.70	345.35	
420	3.01E-010	0.5	1445	12/19/2007	412.20	345.85	
421	3.01E-010	0.5	1442	12/20/2007	412.70	346.35	
422	3.02E-010	0.5	1440	12/21/2007	413.20	346.85	In : 1.62 mS Out : 2.57 mS
423	5.44E-010	0.9	1438	12/22/2007	414.10	347.75	Flushed Inflow Lines and Stone
424	5.43E-010	0.9	1439	12/23/2007	415.00	348.65	Backwashed Inflow Stone
425	5.42E-010	0.9	1442	12/24/2007	415.90	349.55	
426	5.43E-010	0.9	1440	12/25/2007	416.60	350.45	
427	5.43E-010	0.9	1441	12/26/2007	417.70	351.35	
428	5.43E-010	0.9	1440	12/27/2007	418.60	352.25	
429	5.43E-010	0.9	1440	12/28/2007	419.50	353.15	In : 1.60 mS Out : 2.55 mS
430	5.43E-010	0.9	1441	12/29/2007	420.40	354.05	
431	5.43E-010	0.9	1439	12/30/2007	421.30	354.95	
432	5.43E-010	0.9	1440	12/31/2007	422.20	355.85	In : 1.62 mS Out : 2.54 mS
433	5.43E-010	0.9	1439	01/01/2008	423.10	356.75	
434	5.43E-010	0.9	1439	01/02/2008	424.00	357.65	
435	5.42E-010	0.9	1442	01/03/2008	424.90	358.55	
436	5.43E-010	0.9	1440	01/04/2008	425.80	359.45	
437	5.43E-010	0.9	1441	01/05/2008	426.70	360.35	Flushed System and Backwashed
438	9.65E-010	1.6	1441	01/06/2008	428.30	361.95	Inflow Porous Stone
439	9.64E-010	1.6	1442	01/07/2008	429.90	363.55	
440	9.67E-010	1.6	1438	01/08/2008	431.50	365.15	
441	9.07E-010	1.5	1437	01/09/2008	433.00	366.65	
442	9.03E-010	1.5	1443	01/10/2008	434.50	368.15	
443	9.03E-010	1.5	1444	01/11/2008	436.00	369.65	
444	8.46E-010	1.4	1438	01/12/2008	437.40	371.05	
445	8.46E-010	1.4	1438	01/13/2008	438.80	372.45	
446	7.85E-010	1.3	1439	01/14/2008	440.10	373.75	
447	7.84E-010	1.3	1440	01/15/2008	441.40	375.05	
448	7.84E-010	1.3	1441	01/16/2008	442.70	376.35	
449	7.84E-010	1.3	1440	01/17/2008	444.00	377.65	
450	7.24E-010	1.2	1441	01/18/2008	445.20	378.85	
451	7.23E-010	1.2	1442	01/19/2008	446.40	380.05	Flushed System and Backwashed
452	1.33E-009	2.2	1438	01/20/2008	448.60	382.25	Inflow Porous Stone
453	1.33E-009	2.2	1438	01/21/2008	450.80	384.45	
454	1.33E-009	2.2	1439	01/22/2008	453.00	386.65	
455	1.33E-009	2.2	1442	01/23/2008	455.20	388.85	

456	1.33E-009	2.2	1440	01/24/2008	457.40	391.05	EC: In = 2.95 Out= 2.79 mS
457	1.27E-009	2.1	1440	01/25/2008	459.50	393.15	
458	1.27E-009	2.1	1439	01/26/2008	461.60	395.25	Page 8
459	1.27E-009	2.1	1439	01/27/2008	463.70	397.35	
460	1.27E-009	2.1	1442	01/28/2008	465.80	399.45	
461	1.21E-009	2.0	1440	01/29/2008	467.80	401.45	
462	1.21E-009	2.0	1441	01/30/2008	469.80	403.45	
463	1.14E-009	1.9	1442	01/31/2008	471.70	405.35	
464	1.15E-009	1.9	1438	02/01/2008	473.60	407.25	
465	1.15E-009	1.9	1437	02/02/2008	475.50	409.15	
466	1.14E-009	1.9	1442	02/03/2008	477.40	411.05	
467	1.09E-009	1.8	1435	02/04/2008	479.20	412.85	
468	1.08E-009	1.8	1447	02/05/2008	481.00	414.65	
469	1.08E-009	1.8	1442	02/06/2008	482.80	416.45	
470	1.03E-009	1.7	1440	02/07/2008	484.50	418.15	
471	1.03E-009	1.7	1441	02/08/2008	486.20	419.85	
472	1.02E-009	1.7	1442	02/09/2008	487.90	421.55	
473	1.03E-009	1.7	1439	02/10/2008	489.60	423.25	
474	9.66E-010	1.6	1439	02/11/2008	491.20	424.85	
475	9.04E-010	1.5	1442	02/12/2008	492.70	426.35	Flushed System and Stone
476	1.39E-009	2.3	1439	02/13/2008	495.00	428.65	
477	1.39E-009	2.3	1440	02/14/2008	497.30	430.95	
478	1.39E-009	2.3	1440	02/15/2008	499.60	433.25	
479	1.33E-009	2.2	1442	02/16/2008	501.80	435.45	
480	1.33E-009	2.2	1442	02/17/2006	504.00	437.65	
461	1.32E-009	2.2	1443	02/16/2008	506.20	439.65	
482	1.27E-009	2.1	1437	02/19/2008	506.30	441.95	EC: In=2.80 mS Out = 2.56 mS
483	1.27E-009	2.1	1438	02/20/2008	510.40	444.05	
484	1.27E-009	2.1	1439	02/21/2008	512.50	446.15	
485	1.27E-009	2.1	1442	02/22/2008	514.60	448.25	
486	1.27E-009	2.1	1441	02/23/2008	516.70	450.35	
487	1.21E-009	2.0	1434	02/24/2008	518.70	452.35	
488	1.20E-009	2.0	1446	02/25/2008	520.70	454.35	
489	1.14E-009	1.9	1442	02/26/2008	522.60	456.25	
490	1.09E-009	1.8	1440	02/27/2008	524.40	458.05	
491	1.03E-009	1.7	1441	02/28/2008	526.10	459.75	Flushed System and Stone
492	1.45E-009	2.4	1442	02/29/2008	528.50	462.15	
493	1.45E-009	2.4	1439	03/01/2008	530.90	464.55	
494	1.45E-009	2.4	1439	03/02/2008	533.30	466.95	
495	1.39E-009	2.3	1442	03/03/2008	535.60	469.25	
496	1.39E-009	2.3	1440	03/04/2008	537.90	471.55	
497	1.39E-009	2.3	1442	03/05/2008	540.20	473.85	
498	1.39E-009	2.3	1441	03/06/2008	542.50	476.15	
499	1.33E-009	2.2	1440	03/07/2008	544.70	478.35	
500	1.33E-009	2.2	1440	03/08/2008	546.90	480.55	
501	1.33E-009	2.2	1442	03/09/2006	549.10	482.75	
502	1.27E-009	2.1	1438	03/10/2008	551.20	484.85	EC: In = 2.81 mS Out = 2.75 mS
503	1.27E-009	2.1	1439	03/11/2008	553.30	486.95	Flushed System
504	1.57E-009	2.6	1441	03/12/2008	555.90	489.55	
505	1.57E-009	2.6	1440	03/13/2008	558.50	492.15	
506	1.57E-009	2.6	1442	03/14/2008	561.10	494.75	
507	1.57E-009	2.6	1439	03/15/2008	563.70	497.35	
508	1.51E-009	2.5	1440	03/16/2008	566.20	499.85	
509	1.51E-009	2.5	1440	03/17/2008	568.70	502.35	
510	1.51E-009	2.5	1441	03/18/2008	571.20	504.85	
511	1.51E-009	2.5	1443	03/19/2008	573.70	507.35	
512	1.51E-009	2.5	1438	03/20/2008	576.20	509.85	
513	1.45E-009	2.4	1437	03/21/2008	578.60	512.25	
514	1.45E-009	2.4	1443	03/22/2008	581.00	514.65	
515	1.39E-009	2.3	1442	03/23/2008	583.30	516.95	
518	1.39E-009	2.3	1441	03/24/2008	585.60	519.25	
517	1.33E-009	2.2	1440	03/25/2008	587.80	521.45	
518	1.27E-009	2.1	1440	03/26/2008	589.90	523.55	
519	1.27E-009	2.1	1439	03/27/2008	592.00	525.65	
520	1.21E-009	2.0	1438	03/28/2008	594.00	527.65	
521	1.14E-009	1.9	1442	03/29/2008	595.90	529.55	
522	1.15E-009	1.9	1441	03/30/2008	597.80	531.45	Flushed System

523	1.57E-009	2.6	1440	03/31/2008	600.40	534.05	
524	1.57E-009	2.6	1439	04/01/2008	603.00	536.65	
525	1.51E-009	2.5	1440	04/02/2008	605.50	539.15	Page 9
526	1.51E-009	2.5	1441	04/03/2008	608.00	541.65	
527	1.45E-009	2.4	1439	04/04/2008	610.40	544.05	
528	1.45E-009	2.4	1440	04/05/2008	612.80	546.45	
529	1.45E-009	2.4	1438	04/06/2008	615.20	548.85	
530	1.51E-009	2.5	1443	04/07/2008	617.70	551.35	Flushed System and Stone
531	1.51E-009	2.5	1441	04/08/2008	620.20	553.85	
532	1.51E-009	2.5	1440	04/09/2008	622.70	556.35	
533	1.45E-009	2.4	1442	04/10/2008	625.10	558.75	
534	1.45E-009	2.4	1438	04/11/2008	627.50	561.15	
535	1.39E-009	2.3	1441	04/12/2008	629.80	563.45	
536	1.39E-009	2.3	1442	04/13/2008	632.10	565.75	
537	1.33E-009	2.2	1442	04/14/2008	634.30	567.95	
538	1.27E-009	2.1	1441	04/15/2008	636.40	570.05	
539	1.20E-009	2.0	1443	04/16/2008	638.40	572.05	
540	1.15E-009	1.9	1437	04/17/2008	640.30	573.95	Flushed System and Stone
541	1.51E-009	2.5	1439	04/18/2008	642.80	576.45	
542	1.51E-009	2.5	1442	04/19/2008	645.30	578.95	
543	1.51E-009	2.5	1440	04/20/2008	647.80	581.45	
544	1.51E-009	2.5	1441	04/21/2008	650.30	583.95	
545	1.51E-009	2.5	1442	04/22/2008	652.80	586.45	
546	1.51E-009	2.5	1439	04/23/2008	655.30	588.95	EC: In = 2.81 mS Out = 2.75 mS
547	1.51E-009	2.5	1442	04/24/2008	657.80	591.45	Test Terminated

ATTACHMENT C
REFERENCES

REFERENCES

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2. Jo, H.Y., Benson, C.H., and T. Edil (2004) "Hydraulic Conductivity and Cation Exchange in Nonprehydrated and Prehydrated Bentonite Permeated with Weak Inorganic Salt Solutions," Clays and Clay Minerals, 52 (6), 661-679.

3. Shackelford, C.D, Benson, C.H., Katsumi, K., Edil, T., and L. Lin (2000) "Evaluating the Hydraulic Conductivity of GCLs Permeated with Non-Standard Liquids," Geotextiles and Geomembranes, 18, 133-161.

4. Thiel, R. and Criley, K. (2005) "Hydraulic Conductivity of a GCL Under Various High Effective Confining Stresses for Three Different Leachates." Presented at Geofrontiers 2005, Waste Containment and Remediation.

CETCO
LINING TECHNOLOGIES
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MEMO	**June 19, 2007**
To: Tom Radue Barr Engineering	From: Jim Olsta
cc:	
Subject: Hoyt Lake Mine Project	

Dear Mr. Radue:

We reviewed the GCL treat options with our manufacturing plants. R-101 can be produced at our normal production rates. There is a manufacturability issue with R-102 and it cannot be produced at this time. R-103 can be produced at a reduced production rate.

Please find attached the test data from JLT Laboratory regarding the synthetic mining leachate compatibility testing for R-101 and R-103. Both samples are still running well. R-101 has a hydraulic conductivity of 4.3×10^{-10} cm/s. Even though R-103 has recently taken an upward spike after the porous stones and the lines were flushed, it still has a low hydraulic conductivity of 1.6×10^{-9} cm/s.

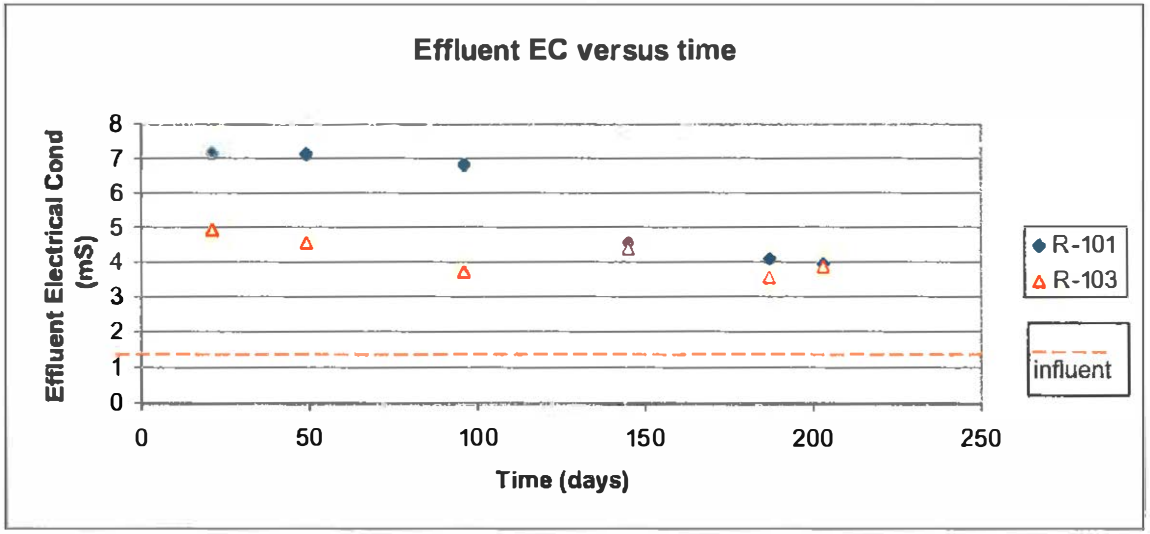
Also attached are the latest influent/effluent electrical conductivity (EC) results for the GCL compatibility testing with samples R-101 and R-103. The R-101 effluent EC has dropped from over 7.0 mS to less than 4.0 mS, but is still higher than the influent EC (1.5 mS). R-101 effluent EC has dropped significantly in the last four months and at the present rate should reach equilibrium in late August after ~300 days permeation. The R-103 effluent EC has dropped from ~5.0 mS to 3.6 mS and has been erratic. At its present trend it appears that it will not reach equilibrium until December after ~400 days permeation.

Right now the lab has to wait to collect several milliliters before testing EC. We are ordering a set of more sensitive meters which should allow them to measure closer to real time and determine EC equilibrium sooner.

If you have any questions, feel free to contact us.

Barr Engrg.

day	R-101	R-103
5	3.05	2.5
21	7.18	4.96
49	7.15	4.59
96	6.84	3.75
145	4.58	4.42
187	4.12	3.6
203	3.97	3.89



SUMMARY OF FLEX WALL PERMEABILITY TEST RESULTS
ASTM D-7100

JLT

Client	:	CETCO	Date	:	06-06-07
Project Location	:	Barr Engineering	Job No.	:	06LG951.01
Description	:	R-101	Tested By	:	MLB/DB
	:		Checked By	:	JB
Permeant Fluid	:	Syn Leachate	Spec. Gravity	:	2.74 Assumed

Physical Property Data

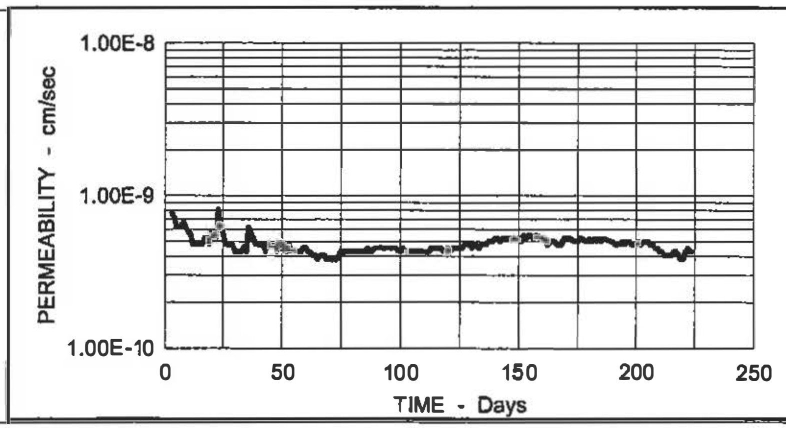
Initial Height (in)	:	0.17	Final Height (in)	:	[redacted]
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	
Initial Wet Weight (g)	:	51.80	Final Wet Weight (g)	:	
Wet Density (pcf)	:	92.29	Wet Density (pcf)	:	
Moisture Content %	:	22.00	Moisture Content %	:	
Dry Density (pcf)	:	75.65	Dry Density (pcf)	:	
Initial Void Ratio	:	1.2601	Final Void Ratio	:	
Saturation , %	:	47.8	Saturation , %	:	

Test Parameters

Fluid	:	Syn Leachate	**Effective**		
Cell Pressure psi)	:	80.00	**Confining Pressure (psi)**	**:**	4
Head Water ›si)	:	77.00	Gradient	:	290.53
Tail Water ›si)	:	75.00			

Permeability Input Data

Flow, Q	(cc)	:	0.90
Length, L	(in)	:	0.19
Area, A	(sqin)	:	12.57
Head, h	**(psi)**	**:**	**2.00**
Time, t	(min)	:	1435.00
Temp, T	(Deg C)	:	21.0



Computed Permeability

PERMEABILITY, K = 4.31E-010 (cm/sec) at 20 Degrees C

Day 224 Total Groundwater Inflow to Date : 222.3 cc

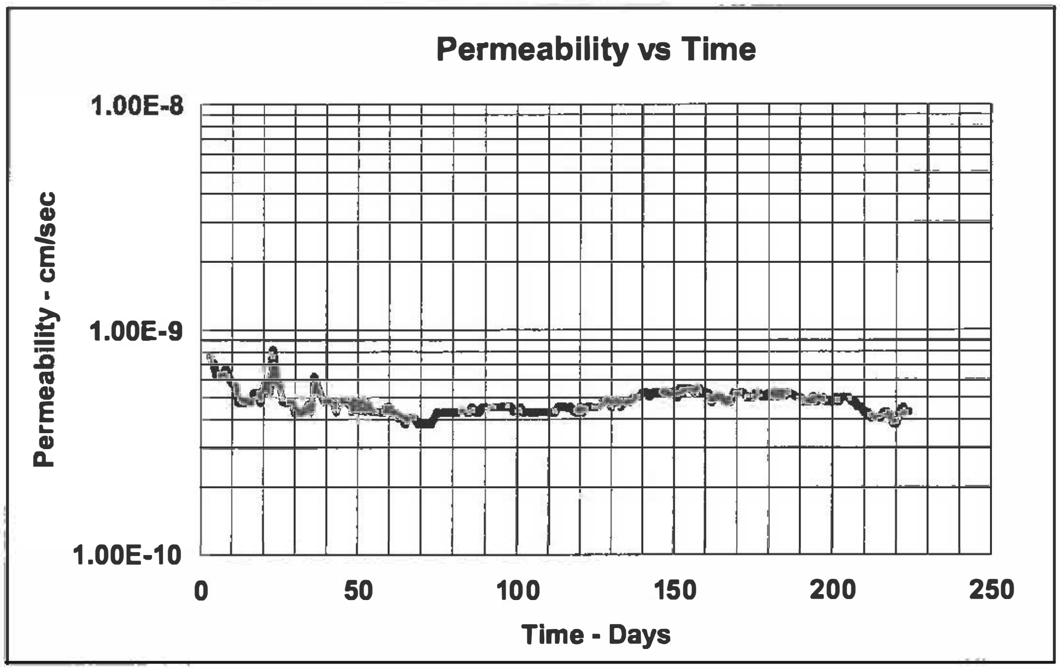
Description : R-101

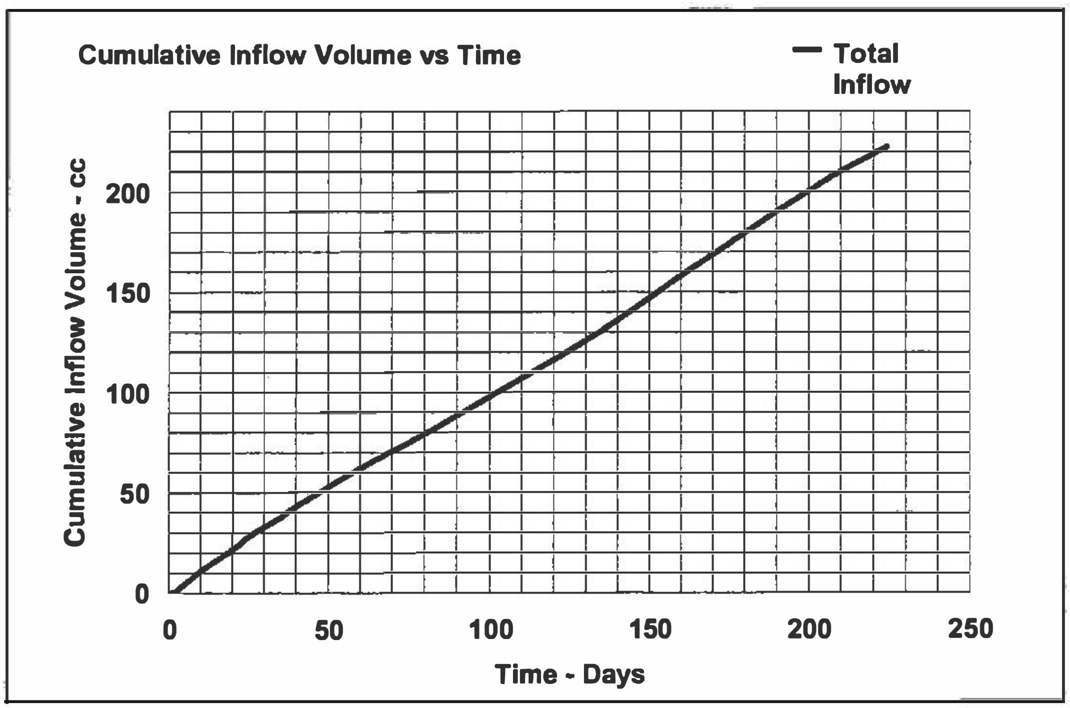
Date : 06-06-07

Estimated Pore Volume : 33 cc

Estimated Inflow Pore Volumes : 4.74

Permeant : Syn Leachate





JLT Laboratories, Inc.

Client :	CETCO	Date :	06-06-07
Project Location :	Barr Engineering	Job No. :	06LG951.01
Description :	R-101	Tested By :	MLB/DB
		Checked By :	JB

JLT

Sample ID : R-101

Estimated Poe Volume : 33 cc

Page 1

Elapsed Time Days	Permeability cm/sec	Inflow cc	Time minutes	Date	Total Cumulative Inflow Volume, cc	Pore Volumes	COMMENTS
1				10/26/2006	0.00	0.00	Synthetic Leachate
2				10/27/2006	0.00	0.00	
3	7.63E-010	1.6	1442	10/28/2006	1.60	0.05	
4	7.16E-010	1.5	1441	10/29/2006	3.10	0.09	
5	6.20E-010	1.3	1443	10/30/2006	4.40	0.13	Inflow: pH= 6.77 EC = 1.21 mS
6	6.29E-010	1.3	1421	10/31/2006	5.70	0.17	Outflow: pH = 6.55 EC = 3.05 mS
7	6.20E-010	1.3	1442	11/01/2006	7.00	0.21	
8	6.71E-010	1.4	1435	11/02/2006	8.40	0.25	
9	6.19E-010	1.3	1445	11/03/2006	9.70	0.29	
10	5.77E-010	1.2	1431	11/04/2006	10.90	0.33	Flushed Stones and Lines
11	5.65E-010	1.2	1461	11/05/2006	12.10	0.37	
12	4.77E-010	1.0	1442	11/06/2006	13.10	0.40	
13	4.76E-010	1.0	1444	11/07/2006	14.10	0.43	
14	4.77E-010	1.0	1442	11/08/2006	15.10	0.46	
15	4.77E-010	1.0	1441	11/09/2006	16.10	0.49	
16	4.77E-010	1.0	1442	11/10/2006	17.10	0.52	
17	5.25E-010	1.1	1440	11/11/2006	18.20	0.55	
18	5.25E-010	1.1	1442	11/12/2006	19.30	0.58	
19	4.77E-010	1.0	1441	11/13/2006	20.30	0.62	
20	5.72E-010	1.2	1442	11/14/2006	21.50	0.65	
21	5.72E-010	1.2	1442	11/15/2006	22.70	0.69	Inflow: pH= 7.04 EC = 1.61 mS
22	5.25E-010	1.1	1440	11/16/2006	23.80	0.72	Outflow: pH = 7.02 EC = 7.18 mS
23	8.14E-010	1.7	1437	11/17/2006	25.50	0.77	Flushed Stones and Lines
24	6.18E-010	1.3	1446	11/18/2006	26.80	0.81	
25	5.73E-010	1.2	1440	11/19/2006	28.00	0.85	
26	4.81E-010	1.0	1431	11/20/2006	29.00	0.88	
27	4.75E-010	1.0	1449	11/21/2006	30.00	0.91	
28	4.77E-010	1.0	1442	11/22/2006	31.00	0.94	
29	4.77E-010	1.0	1441	11/23/2006	32.00	0.97	
30	4.29E-010	0.9	1442	11/24/2006	32.90	1.00	
31	4.31E-010	0.9	1435	11/25/2006	33.80	1.02	
32	4.27E-010	0.9	1449	11/26/2006	34.70	1.05	
33	4.36E-010	0.9	1421	11/27/2006	35.60	1.08	
34	4.66E-010	1.0	1475	11/28/2006	36.60	1.11	
35	4.29E-010	0.9	1443	11/29/2006	37.50	1.14	
36	6.20E-010	1.3	1442	11/30/2006	38.80	1.18	Flushed Stones and Lines
37	5.72E-010	1.2	1444	12/01/2006	40.00	1.21	
38	5.25E-010	1.1	1440	12/02/2006	41.10	1.25	
39	4.77E-010	1.0	1443	12/03/2006	42.10	1.28	
40	4.77E-010	1.0	1442	12/04/2006	43.10	1.31	
41	4.80E-010	1.0	1434	12/05/2006	44.10	1.34	
42	4.78E-010	1.0	1439	12/06/2006	45.10	1.37	
43	4.29E-010	0.9	1442	12/07/2006	46.00	1.39	
44	4.76E-010	1.0	1444	12/08/2006	47.00	1.42	
45	4.81E-010	1.0	1431	12/09/2006	48.00	1.45	
46	4.72E-010	1.0	1456	12/10/2006	49.00	1.48	
47	4.75E-010	1.0	1448	12/11/2006	50.00	1.52	
48	4.30E-010	0.9	1439	12/12/2006	50.90	1.54	
49	4.76E-010	1.0	1444	12/13/2006	51.90	1.57	Inflow: pH= 6.57 EC = 2.31 mS
50	4.32E-010	0.9	1432	12/14/2006	52.80	1.60	Outflow: pH = 7.24 EC = 7.15 mS
51	4.72E-010	1.0	1456	12/15/2006	53.80	1.63	
52	4.30E-010	0.9	1439	12/16/2006	54.70	1.66	
53	4.77E-010	1.0	1443	12/17/2006	55.70	1.69	

54	4.33E-010	0.9	1431	12/18/2006	56.60	1.72	
55	4.30E-010	0.9	1439	12/19/2006	57.50	1.74	
56	4.32E-010	0.90	1433	12/20/2006	58.40	1.77	Page 2
57	4.29E-010	0.90	1442	12/21/2006	59.30	1.80	
58	4.29E-010	0.90	1442	12/22/2006	60.20	1.82	
59	4.54E-010	0.95	1440	12/23/2006	61.15	1.85	
60	4.56E-010	0.95	1433	12/24/2006	62.10	1.88	
61	4.28E-010	0.90	1446	12/25/2006	63.00	1.91	
62	4.28E-010	0.90	1447	12/26/2006	63.90	1.94	
63	4.05E-010	0.85	1442	12/27/2006	64.75	1.96	
64	4.09E-010	0.85	1431	12/28/2006	65.60	1.99	
65	3.82E-010	0.80	1442	12/29/2006	66.40	2.01	
66	4.05E-010	0.85	1444	12/30/2006	67.25	2.04	
67	4.05E-010	0.85	1442	12/31/2006	68.10	2.06	
68	4.06E-010	0.85	1440	01/01/2007	68.95	2.91	
69	3.82E-010	0.80	1439	01/02/2007	69.75	3.71	Flushed Stones and Lines
70	3.82E-010	0.80	1439	01/03/2007	70.55	4.51	
71	3.82E-010	0.80	1442	01/04/2007	71.35	5.31	
72	3.81E-010	0.80	1446	01/05/2007	72.15	6.11	
73	3.82E-010	0.80	1442	01/06/2007	72.95	6.91	
74	4.06E-010	0.85	1440	01/07/2007	73.80	7.76	
75	4.31E-010	0.90	1437	01/08/2007	74.70	8.66	
76	4.28E-010	0.90	1448	01/09/2007	75.60	9.56	
77	4.28E-010	0.90	1445	01/10/2007	76.50	10.46	
78	4.30E-010	0.90	1440	01/11/2007	77.40	11.36	
79	4.30E-010	0.90	1441	01/12/2007	78.30	12.26	
80	4.29E-010	0.90	1442	01/13/2007	79.20	13.16	
81	4.30E-010	0.90	1440	01/14/2007	80.10	14.06	
82	4.30E-010	0.90	1439	01/15/2007	81.00	14.96	
83	4.30E-010	0.90	1439	01/16/2007	81.90	15.86	
84	4.28E-010	0.90	1445	01/17/2007	82.80	16.76	
85	4.29E-010	0.90	1442	01/18/2007	83.70	17.66	
86	4.54E-010	0.95	1439	01/19/2007	84.65	18.61	
87	4.31E-010	0.90	1437	01/20/2007	85.55	19.51	
88	4.31E-010	0.90	1438	01/21/2007	86.45	20.41	
89	4.52E-010	0.95	1445	01/22/2007	87.40	21.36	
90	4.52E-010	0.95	1446	01/23/2007	88.35	22.31	
91	4.54E-010	0.95	1440	01/24/2007	89.30	23.26	
92	4.54E-010	0.95	1440	01/25/2007	90.25	24.21	
93	4.53E-010	0.95	1442	01/26/2007	91.20	25.16	
94	4.54E-010	0.95	1439	01/27/2007	92.15	26.11	
95	4.54E-010	0.95	1441	01/28/2007	93.10	27.06	
96	4.53E-010	0.95	1442	01/29/2007	94.05	28.01	EC Inflow: 1.84 mS Outflow 6.84 mS
97	4.54E-010	0.95	1440	01/30/2007	95.00	28.96	Flushed Stones and Lines
98	4.55E-010	0.95	1437	01/31/2007	95.95	29.91	
99	4.30E-010	0.90	1439	02/01/2007	96.85	30.81	
100	4.28E-010	0.90	1445	02/02/2007	97.75	31.71	
101	4.53B-010	0.95	1442	02/03/2007	98.70	32.66	
102	4.29E-010	0.90	1442	02/04/2007	99.60	33.56	
103	4.30E-010	0.90	1440	02/05/2007	100.50	34.46	
104	4.29E-010	0.90	1442	02/06/2007	101.40	35.36	
105	4.29E-010	0.90	1444	02/07/2007	102.30	36.26	EC Inflow: 1 58 ms Outflow : 6.65 mS
108	4.29B-010	0.90	1442	02/08/2007	103.20	37.16	Flushed Stones and Lines
107	4.30E-010	0.90	1440	02/09/2007	104.10	38.06	
108	4.30E-010	0.90	1439	02/10/2007	105.00	38.96	
109	4.30E-010	0.90	1439	02/11/2007	105.90	39.86	
110	4.28E-010	0.90	1445	02/12/2007	106.80	40.76	
111	4.27E-010	0.90	1449	02/13/2007	107.70	41.66	
112	4.29E-010	0.90	1442	02/14/2007	108.60	42.56	
113	4.54E-010	0.95	1440	02/15/2007	109.55	43.51	
114	4.53B-010	0.95	1442	02/16/2007	110.50	44.46	
115	4.54E-010	0.95	1440	02/17/2007	111.45	45.41	
116	4.53E-010	0.95	1443	02/18/2007	112.40	46.36	
117	4.54E-010	0.95	1439	02/19/2007	113.35	47.31	
118	4.33E-010	0.90	1431	02/20/2007	114.25	48.21	
119	4.26E-010	0.90	1452	02/21/2007	115.15	49.11	
120	4.54E-010	0.95	1440	02/22/2007	116.10	50.06	

121	4.29E-010	0.90	1442	02/23/2007	117.00	50.96	Page 3
122	4.54E-010	0.95	1441	02/24/2007	117.95	51.91	
123	4.55E-010	0.95	1437	02/25/2007	118.90	52.86	
124	4.52E-010	0.95	1446	02/26/2007	119.85	53.81	
125	4.52E-010	0.95	1445	02/27/2007	120.80	54.78	
126	4.55E-010	0.95	1435	02/28/2007	121.75	55.71	
127	4.78E-010	1.00	1438	03/01/2007	122.75	56.71	Flushed Stones and Lines
128	4.78E-010	1.00	1438	03/02/2007	123.75	57.71	
129	4.77E-010	1.00	1442	03/03/2007	124.75	58.71	
130	4.53E-010	0.95	1443	03/04/2007	125.70	59.66	
131	4.78E-010	1.00	1440	03/05/2007	126.70	60.66	
132	4.78E-010	1.00	1440	03/06/2007	127.70	61.66	
133	4.54E-010	0.95	1441	03/07/2007	128.65	62.61	
134	4.78E-010	1.00	1439	03/08/2007	129.65	63.61	
135	4.77E-010	1.00	1441	03/09/2007	130.65	64.61	
136	4.77E-010	1.00	1442	03/10/2007	131.65	65.61	
137	5.01E-010	1.05	1443	03/11/2007	132.70	66.66	
138	5.02E-010	1.05	1440	03/12/2007	133.75	67.71	
139	5.03E-010	1.05	1437	03/13/2007	134.80	68.76	
140	5.26E-010	1.10	1438	03/14/2007	135.90	69.86	
141	5.26E-010	1.10	1439	03/15/2007	137.00	70.96	
142	5.02E-010	1.05	1440	03/16/2007	138.05	72.01	
143	5.25E-010	1.10	1442	03/17/2007	139.15	73.11	
144	5.25E-010	1.10	1441	03/18/2007	140.25	74.21	
145	5.25E-010	1.10	1442	03/19/2007	141.35	75.31	EC Inflow: 1.53 mS Outflow: 4.58 mS
146	5.24E-010	1.10	1444	03/20/2007	142.45	76.41	
147	5.26E-010	1.10	1438	03/21/2007	143.55	77.51	Flushed Stones and Lines
148	5.25E-010	1.10	1442	03/22/2007	144.65	78.61	
149	5.25E-010	1.10	1440	03/23/2007	145.75	79.71	
150	5.27E-010	1.10	1435	03/24/2007	146.85	80.81	
151	4.98E-010	1.05	1451	03/25/2007	147.90	81.86	
152	5.49E-010	1.15	1442	03/26/2007	149.05	83.01	
153	5.25E-010	1.10	1441	03/27/2007	150.15	84.11	
154	5.49E-010	1.15	1440	03/28/2007	151.30	85.26	
155	5.50E-010	1.15	1439	03/29/2007	152.45	86.41	
156	5.26E-010	1.10	1439	03/30/2007	153.55	87.51	
157	5.46E-010	1.15	1449	03/31/2007	154.70	88.66	
158	5.49E-010	1.15	1442	04/01/2007	155.85	89.81	
159	5.25E-010	1.10	1440	04/02/2007	156.95	90.91	
160	5.29E-010	1.10	1431	04/03/2007	158.05	92.01	
161	5.21E-010	1.10	1452	04/04/2007	159.15	93.11	
162	4.75E-010	1.00	1449	04/05/2007	160.15	94.11	
163	5.00E-010	1.05	1444	04/06/2007	161.20	95.16	
164	5.03E-010	1.05	1437	04/07/2007	162.25	96.21	
165	5.01E-010	1.05	1442	04/08/2007	163.30	97.26	
166	4.77E-010	1.00	1443	04/09/2007	164.30	98.26	
167	4.76E-010	1.00	1445	04/10/2007	165.30	99.26	
168	4.77E-010	1.00	1442	04/11/2007	166.30	100.26	
169	5.25E-010	1.10	1440	04/12/2007	167.40	101.36	
170	5.26E-010	1.10	1438	04/13/2007	168.50	102.46	
171	5.26E-010	1.10	1439	04/14/2007	169.60	103.56	
172	5.25E-010	1.10	1442	04/15/2007	170.70	104.66	
173	5.02E-010	1.05	1440	04/16/2007	171.75	105.71	
174	5.01E-010	1.05	1441	04/17/2007	172.80	106.76	
175	5.02E-010	1.05	1440	04/18/2007	173.85	107.81	
176	5.25E-010	1.10	1441	04/19/2007	174.95	108.91	Flushed Stones and Lines
177	5.25E-010	1.10	1442	04/20/2007	176.05	110.01	
178	5.03E-010	1.05	1437	04/21/2007	177.10	111.06	
179	5.02E-010	1.05	1439	04/22/2007	178.15	112.11	
180	5.24E-010	1.10	1445	04/23/2007	179.25	113.21	
181	5.02E-010	1.05	1439	04/24/2007	180.30	114.26	
182	5.24E-010	1.10	1444	04/25/2007	181.40	115.36	
183	5.03E-010	1.05	1437	04/26/2007	182.45	116.41	
184	5.24E-010	1.10	1444	04/27/2007	183.55	117.51	
185	5.04E-010	1.05	1432	04/28/2007	184.60	118.56	
186	5.25E-010	1.10	1442	04/29/2007	185.70	119.66	
187	5.20E-010	1.10	1456	04/30/2007	186.80	120.76	EC Inflow: 1.54 mS Outflow: 4.12 mS

188	5.09E-010	1.05	1420	05/01/2007	187.85	121.81	
189	5.01E-010	1.05	1442	05/02/2007	188.90	122.86	Page 4
190	5.00E-010	1.05	1445	05/03/2007	189.95	123.91	
191	4.77E-010	1.00	1442	05/04/2007	190.95	124.91	
192	4.78E-010	1.00	1440	05/05/2007	191.95	125.91	
193	4.78E-010	1.00	1439	05/06/2007	192.95	126.91	
194	5.02E-010	1.05	1438	05/07/2007	194.00	127.96	
195	4.76E-010	1.00	1444	05/08/2007	195.00	128.96	
196	5.01E-010	1.05	1442	05/09/2007	196.05	130.01	
197	5.01E-010	1.05	1443	05/10/2007	197.10	131.06	
198	4.78E-010	1.00	1440	05/11/2007	198.10	132.06	
199	4.78E-010	1.00	1440	05/12/2007	199.10	133.06	
200	4.77E-010	1.00	1442	05/13/2007	200.10	134.06	
201	5.00E-010	1.05	1444	05/14/2007	201.15	135.11	
202	4.77E-010	1.00	1443	05/15/2007	202.15	136.11	
203	5.00E-010	1.05	1446	05/16/2007	203.20	137.16	EC Inflow: 1.54 mS Outflow: 3.97 mS
204	5.02E-010	1.05	1440	05/17/2007	204.25	138.21	
205	5.01E-010	1.05	1442	05/18/2007	205.30	139.26	Flushed Stones and Lines
206	4.78E-010	1.00	1439	05/19/2007	206.30	140.26	
207	4.79E-010	1.00	1437	05/20/2007	207.30	141.26	
208	4.53E-010	0.95	1442	05/21/2007	208.25	142.21	
209	4.54E-010	0.95	1440	05/22/2007	209.20	143.16	
210	4.29E-010	0.90	1442	05/23/2007	210.10	144.06	
211	4.29E-010	0.90	1443	05/24/2007	211.00	144.96	
212	4.06E-010	0.85	1439	05/25/2007	211.85	145.81	
213	4.07E-010	0.85	1437	05/26/2007	212.70	146.66	
214	4.06E-010	0.85	1440	05/27/2007	213.55	147.51	
215	4.06E-010	0.85	1440	05/28/2007	214.40	148.36	
216	4.28E-010	0.90	1445	05/29/2007	215.30	149.26	
217	4.31E-010	0.90	1435	05/30/2007	216.20	150.16	
218	4.07E-010	0.85	1437	05/31/2007	217.05	151.01	
219	3.81E-010	0.80	1444	06/01/2007	217.85	151.81	
220	3.82E-010	0.80	1442	06/02/2007	218.65	152.61	
221	4.30E-010	0.90	1439	06/03/2007	219.55	153.51	
222	4.53E-010	0.95	1442	06/04/2007	220.50	154.46	
223	4.28E-010	0.90	1445	06/05/2007	221.40	155.36	
224	4.31E-010	0.90	1435	06/06/2007	222.30	156.26	

SUMMARY OF FLEX WALL PERMEABILITY TEST RESULTS
ASTM D-7100

JLT

Client	:	CETCO	Date	:	06-06-07
Project Location	:	Barr Engineering	Job No.	:	06LG951.01
Description	:	R-103	Tested By	:	MLB/DB
	:		Checked By	:	JB
Permeant Fluid	:	Syn Leachate	Spec. Gravity	:	2.74 Assumed

Physical Property Data

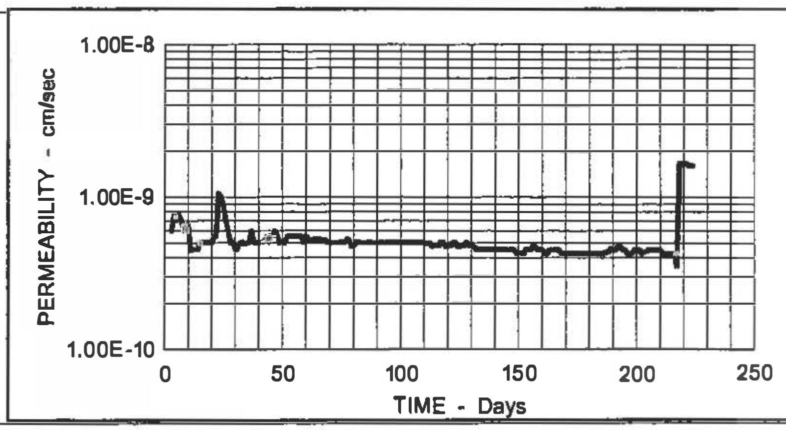
Initial Height (in)	:	0.18	Final Height (in)	:	[redacted]
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	[redacted]
Initial Wet Weight (g)	:	48.10	Final Wet Weight (g)	:	[redacted]
Wet Density (pcf)	:	80.94	Wet Density (pcf)	:	[redacted]
Moisture Content %	:	23.00	Moisture Content %	:	[redacted]
Dry Density (pcf)	:	65.80	Dry Density (pcf)	:	[redacted]
Initial Void Ratio	:	1.5983	Final Void Ratio	:	[redacted]
Saturation , %	:	39.4	Saturation , %	:	[redacted]

Test Parameters

Fluid	:	Syn Leachate	**Effective**		
Cell Pressure psi)	:	80.00	**Confining Pressure (psi)**	:	4
Head Water ɔsi)	:	77.00	Gradient	:	276.00
Tail Water ɔsi)	:	75.00			

Permeability Input Data

Flow, Q	(cc)	:	3.20
Length, L	(in)	:	0.20
Area, A	(sqin)	:	12.57
Head, h	**(psi)**	**:**	**2.00**
Time, t	(min)	:	1435.00
Temp, T	(Deg C)	:	21.0



Computed Permeability

PERMEABILITY, K = 1.61E-009 (cm/sec) at 20 Degrees C

Day 224 Total Groundwater Inflow to Date : 234.45 cc

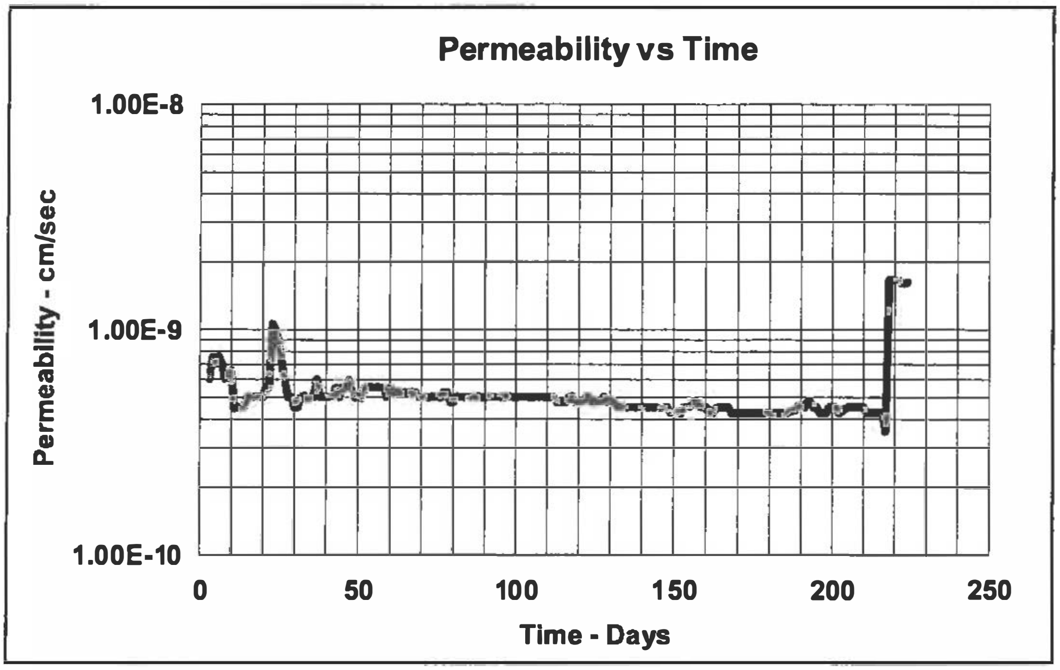
Description : R-103

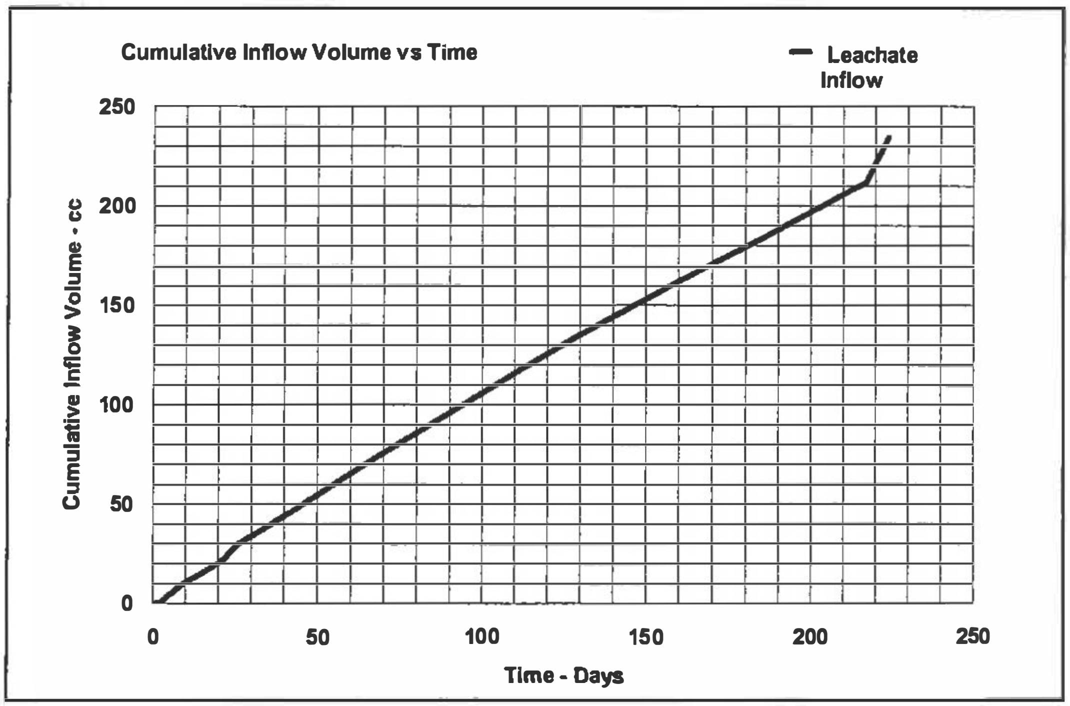
Date : 06-06-07

Estimated Pore Volume : 32 cc

Estimated Inflow Pore Volumes : 7.33

Permeant : Syn Leachate





JLT Laboratories, Inc.

Client : CETCO
Project Location : Barr Engineering
Description : R-103

Date : 06-06-07
Job No. : 06LG951.01
Tested By : MLB/DB
Checked By : JB

JLT

Sample ID : R-103

Estimated Poe Volume : 32 cc

Elapsed Time Days	Permeability cm/sec	Inflow cc	Time minutes	Date	Total Cumulative Inflow Volume, cc	Pore Volumes	COMMENTS
1				10/26/2006	0.0	0.00	Synthetic Leachate
2				10/27/2006	0.0	0.00	
3	6.03E-010	1.2	1442	10/28/2006	1.2	0.04	
4	7.54E-010	1.5	1441	10/29/2006	2.7	0.08	
5	7.03E-010	1.40	1443	10/30/2006	4.1	0.13	Inflow: pH= 6.51 EC = 1.54 mS
6	7.64E-010	1.50	1421	10/31/2006	5.6	0.18	Outflow: pH = 6.18 EC = 2.50 mS
7	7.03E-010	1.40	1442	11/01/2006	7.0	0.22	
8	6.06E-010	1.20	1435	11/02/2006	8.2	0.26	
9	6.01E-010	1.20	1445	11/03/2006	9.4	0.29	
10	6.58E-010	1.30	1431	11/04/2006	10.7	0.33	Flushed Stones and Lines
11	4.46E-010	0.90	1461	11/05/2006	11.6	0.36	
12	4.52E-010	0.90	1442	11/06/2006	12.5	0.39	
13	4.51E-010	0.90	1444	11/07/2006	13.4	0.42	
14	4.52E-010	0.90	1442	11/08/2006	14.3	0.45	
15	5.03E-010	1.00	1441	11/09/2006	15.3	0.48	
16	5.02E-010	1.00	1442	11/10/2006	16.3	0.51	
17	5.03E-010	1.00	1440	11/11/2006	17.3	0.54	
18	5.02E-010	1.00	1442	11/12/2006	18.3	0.57	
19	5.03E-010	1.00	1441	11/13/2006	19.3	0.60	
20	5.02E-010	1.00	1442	11/14/2006	20.3	0.63	
21	5.52E-010	1.10	1442	11/15/2006	21.4	0.67	Inflow: pH= 6.45 EC = 1.62 mS
22	5.53E-010	1.10	1440	11/16/2006	22.5	0.70	Outflow: pH = 6.13 EC = 4.96 mS
23	1.06E-009	2.10	1437	11/17/2006	24.6	0.77	Flushed Stones and Lines
24	1.00E-009	2.00	1446	11/18/2006	26.6	0.83	
25	9.05E-010	1.80	1440	11/19/2006	28.4	0.89	
26	7.08E-010	1.40	1431	11/20/2006	29.8	0.93	
27	6.00E-010	1.20	1449	11/21/2006	31.0	0.97	
28	5.02E-010	1.00	1442	11/22/2006	32.0	1.00	
29	5.03E-010	1.00	1441	11/23/2006	33.0	1.03	
30	4.52E-010	0.90	1442	11/24/2006	33.9	1.06	
31	4.54E-010	0.90	1435	11/25/2006	34.8	1.09	
32	5.00E-010	1.00	1449	11/26/2006	35.8	1.12	
33	5.10E-010	1.00	1421	11/27/2006	36.8	1.15	
34	4.91E-010	1.00	1475	11/28/2006	37.8	1.18	
35	5.02E-010	1.00	1443	11/29/2006	38.8	1.21	
36	5.02E-010	1.00	1442	11/30/2006	39.8	1.24	Flushed Stones and Lines
37	6.02E-010	1.20	1444	12/01/2006	41.0	1.28	
38	5.03E-010	1.00	1440	12/02/2006	42.0	1.31	
39	5.02E-010	1.00	1443	12/03/2006	43.0	1.34	
40	5.02E-010	1.00	1442	12/04/2006	44.0	1.38	
41	5.05E-010	1.00	1434	12/05/2006	45.0	1.41	
42	5.03E-010	1.00	1439	12/06/2006	46.0	1.44	
43	5.52E-010	1.10	1442	12/07/2006	47.1	1.47	
44	5.01E-010	1.00	1444	12/08/2006	48.1	1.50	
45	5.57E-010	1.10	1431	12/09/2006	49.2	1.54	
46	5.47E-010	1.10	1456	12/10/2006	50.3	1.57	
47	6.00E-010	1.20	1448	12/11/2006	51.5	1.61	
48	5.54E-010	1.10	1439	12/12/2006	52.6	1.64	
49	5.01E-010	1.00	1444	12/13/2006	53.6	1.68	Inflow: pH= 6.93 EC = 1.81 mS
50	5.06E-010	1.00	1432	12/14/2006	54.6	1.71	Outflow: pH = 6.38 EC = 4.59 mS
51	4.97E-010	1.00	1456	12/15/2006	55.6	1.74	
52	5.54E-010	1.10	1439	12/16/2006	56.7	1.77	
53	5.52E-010	1.10	1443	12/17/2006	57.8	1.81	
54	5.57E-010	1.10	1431	12/18/2006	58.9	1.84	

55	5.54E-010	1.10	1439	12/19/2006	60.0	1.88	
56	5.56E-010	1.10	1433	12/20/2006	61.1	1.91	Page 2
57	5.52E-010	1.10	1442	12/21/2006	62.2	1.94	
58	5.52E-010	1.10	1442	12/22/2006	63.3	1.98	
59	5.03E-010	1.00	1440	12/23/2006	64.3	2.01	
60	5.56E-010	1.10	1433	12/24/2006	65.4	2.04	
61	5.26E-010	1.05	1446	12/25/2006	66.5	2.08	
62	5.25E-010	1.05	1447	12/26/2006	67.5	2.11	
63	5.27E-010	1.05	1442	12/27/2006	68.6	2.14	
64	5.31E-010	1.05	1431	12/28/2006	69.6	2.18	
65	5.27E-010	1.05	1442	12/29/2006	70.7	2.21	
66	5.27E-010	1.05	1444	12/30/2006	71.7	2.24	
67	5.27E-010	1.05	1442	12/31/2006	72.8	2.27	
68	5.28E-010	1.05	1440	01/01/2007	73.8	2.31	
69	5.03E-010	1.00	1439	01/02/2007	74.8	2.34	
70	5.03E-010	1.00	1439	01/03/2007	75.8	2.37	
71	5.02E-010	1.00	1442	01/04/2007	76.8	2.40	
72	5.01E-010	1.00	1446	01/05/2007	77.8	2.43	
73	5.02E-010	1.00	1442	01/06/2007	78.8	2.46	
74	5.03E-010	1.00	1440	01/07/2007	79.8	2.49	
75	5.04E-010	1.00	1437	01/08/2007	80.8	2.53	
76	5.00E-010	1.00	1448	01/09/2007	81.8	2.56	
77	5.26E-010	1.05	1445	01/10/2007	82.9	2.59	
78	5.28E-010	1.05	1440	01/11/2007	83.9	2.62	
79	4.77E-010	0.95	1441	01/12/2007	84.9	2.65	
80	4.77E-010	0.95	1442	01/13/2007	85.8	2.68	
81	5.03E-010	1.00	1440	01/14/2007	86.8	2.71	
82	5.03E-010	1.00	1439	01/15/2007	87.8	2.74	
83	5.03E-010	1.00	1439	01/16/2007	88.8	2.78	
84	5.01E-010	1.00	1445	01/17/2007	89.8	2.61	
85	5.02E-010	1.00	1442	01/18/2007	90.8	2.84	
86	5.03E-010	1.00	1439	01/19/2007	91.8	2.87	
67	5.04E-010	1.00	1437	01/20/2007	92.8	2.90	
88	5.04E-010	1.00	1436	01/21/2007	93.8	2.93	
89	5.01E-010	1.00	1445	01/22/2007	94.8	2.96	
90	5.01E-010	1.00	1446	01/23/2007	95.8	2.99	
91	5.03E-010	1.00	1440	01/24/2007	96.8	3.03	
92	5.03E-010	1.00	1440	01/25/2007	97.8	3.06	
93	5.02E-010	1.00	1442	01/26/2007	98.8	3.09	
94	5.03E-010	1.00	1439	01/27/2007	99.8	3.12	
95	5.03E-010	1.00	1441	01/28/2007	100.8	3.15	
96	5.02E-010	1.00	1442	01/29/2007	101.8	3.18	EC Inflow: 1.85 mS Outflow : 3.75 mS
97	5.03E-010	1.00	1440	01/30/2007	102.8	3.21	
98	5.04E-010	1.00	1437	01/31/2007	103.8	3.24	
99	5.03E-010	1.00	1439	02/01/2007	104.8	3.28	
100	5.01E-010	1.00	1445	02/02/2007	105.8	3.31	
101	5.02E-010	1.00	1442	02/03/2007	106.8	3.34	
102	5.02E-010	1.00	1442	02/04/2007	107.8	3.37	
103	5.03E-010	1.00	1440	02/05/2007	108.8	3.40	
104	5.02E-010	1.00	1442	02/06/2007	109.8	3.43	
105	5.03E-010	1.00	1441	02/07/2007	110.8	3.46	EC Inflow: 1.76 mS Outflow : 3.60 mS
106	5.02E-010	1.00	1442	02/08/2007	111.8	3.49	
107	5.03E-010	1.00	1440	02/09/2007	112.8	3.53	
108	5.03E-010	1.00	1439	02/10/2007	113.8	3.56	
109	5.03E-010	1.00	1439	02/11/2007	114.8	3.59	
110	5.01E-010	1.00	1445	02/12/2007	115.8	3.62	
111	5.00E-010	1.00	1449	02/13/2007	116.8	3.65	
112	5.02E-010	1.00	1442	02/14/2007	117.8	3.68	
113	4.78E-010	0.95	1440	02/15/2007	118.8	3.71	
114	4.77E-010	0.95	1442	02/16/2007	119.7	3.74	
115	4.78E-010	0.95	1440	02/17/2007	120.7	3.77	
116	4.77E-010	0.95	1443	02/18/2007	121.6	3.80	
117	5.03E-010	1.00	1439	02/19/2007	122.6	3.83	
118	5.06E-010	1.00	1431	02/20/2007	123.6	3.86	
119	4.74E-010	0.95	1452	02/21/2007	124.6	3.89	
120	4.78E-010	0.95	1440	02/22/2007	125.5	3.92	
121	4.77E-010	0.95	1442	02/23/2007	126.5	3.95	

122	5.03E-010	1.00	1441	02/24/2007	127.5	3.98	
123	5.04E-010	1.00	1437	02/25/2007	128.5	4.01	Page 3
124	4.76E-010	0.95	1446	02/26/2007	129.4	4.04	
125	4.76E-010	0.95	1445	02/27/2007	130.4	4.07	
126	4.79E-010	0.95	1435	02/28/2007	131.3	4.10	
127	4.78E-010	0.95	1438	03/01/2007	132.25	4.13	
128	5.04E-010	1.00	1438	03/02/2007	133.25	4.16	
129	4.77E-010	0.95	1442	03/03/2007	134.2	4.19	
130	4.77E-010	0.95	1443	03/04/2007	135.15	4.22	
131	4.78E-010	0.95	1440	03/05/2007	136.1	4.25	
132	4.53E-010	0.90	1440	03/06/2007	137	4.28	
133	4.52E-010	0.90	1441	03/07/2007	137.9	4.31	
134	4.53E-010	0.90	1439	03/08/2007	138.8	4.34	
135	4.52E-010	0.90	1441	03/09/2007	139.7	4.37	
136	4.52E-010	0.90	1442	03/10/2007	140.6	4.39	
137	4.52E-010	0.90	1443	03/11/2007	141.5	4.42	
138	4.53E-010	0.90	1440	03/12/2007	142.4	4.45	
139	4.54E-010	0.90	1437	03/13/2007	143.3	4.48	
140	4.53E-010	0.90	1438	03/14/2007	144.2	4.51	
141	4.53E-010	0.90	1439	03/15/2007	145.1	4.53	
142	4.53E-010	0.90	1440	03/16/2007	146	4.56	
143	4.52E-010	0.90	1442	03/17/2007	146.9	4.59	
144	4.52E-010	0.90	1441	03/18/2007	147.8	4.62	
145	4.52E-010	0.90	1442	03/19/2007	148.7	4.65	EC Inflow: 1.58 mS Outflow : 4.42 mS
146	4.51E-010	0.90	1444	03/20/2007	149.6	4.68	
147	4.53E-010	0.90	1438	03/21/2007	150.5	4.70	
148	4.52E-010	0.90	1442	03/22/2007	151.4	4.73	
149	4.27E-010	0.85	1440	03/23/2007	152.25	4.76	
150	4.29E-010	0.85	1435	03/24/2007	153.1	4.78	
151	4.29E-010	0.85	1435	03/25/2007	153.95	4.81	
152	4.24E-010	0.85	1451	03/26/2007	154.8	4.84	
153	4.52E-010	0.90	1442	03/27/2007	155.7	4.87	
154	4.52E-010	0.90	1441	03/28/2007	156.6	4.89	
155	4.53E-010	0.90	1440	03/29/2007	157.5	4.92	
156	4.78E-010	0.95	1439	03/30/2007	158.45	4.95	
157	4.78E-010	0.95	1439	03/31/2007	159.4	4.98	
158	4.50E-010	0.90	1449	04/01/2007	160.3	5.01	
159	4.52E-010	0.90	1442	04/02/2007	161.2	5.04	
160	4.53E-010	0.90	1440	04/03/2007	162.1	5.07	
161	4.30E-010	0.85	1431	04/04/2007	162.95	5.09	
162	4.24E-010	0.85	1452	04/05/2007	163.8	5.12	
163	4.50E-010	0.90	1449	04/06/2007	164.7	5.15	
164	4.51E-010	0.90	1444	04/07/2007	165.6	5.18	
165	4.54E-010	0.90	1437	04/08/2007	166.5	5.20	
166	4.52E-010	0.90	1442	04/09/2007	167.4	5.23	
167	4.52E-010	0.90	1443	04/10/2007	168.3	5.26	
168	4.26E-010	0.85	1445	04/11/2007	169.15	5.29	
169	4.27E-010	0.85	1442	04/12/2007	170	5.31	
170	4.27E-010	0.85	1440	04/13/2007	170.85	5.34	
171	4.28E-010	0.85	1438	04/14/2007	171.7	5.37	
172	4.28E-010	0.85	1439	04/15/2007	172.55	5.39	
173	4.27E-010	0.85	1442	04/16/2007	173.4	5.42	
174	4.27E-010	0.85	1440	04/17/2007	174.25	5.45	
175	4.27E-010	0.85	1441	04/18/2007	175.1	5.47	
176	4.27E-010	0.85	1440	04/19/2007	175.95	5.50	
177	4.27E-010	0.85	1441	04/20/2007	176.8	5.53	
178	4.27E-010	0.85	1442	04/21/2007	177.65	5.55	
179	4.28E-010	0.85	1437	04/22/2007	178.5	5.58	
180	4.28E-010	0.85	1439	04/23/2007	179.35	5.60	
181	4.26E-010	0.85	1445	04/24/2007	180.2	5.63	
182	4.28E-010	0.85	1439	04/25/2007	181.05	5.66	
183	4.26E-010	0.85	1444	04/26/2007	181.9	5.68	
184	4.28E-010	0.85	1437	04/27/2007	182.75	5.71	
185	4.26E-010	0.85	1444	04/28/2007	183.6	5.74	
186	4.30E-010	0.85	1432	04/29/2007	184.45	5.76	
187	4.35E-010	0.85	1416	04/30/2007	185.3	5.79	EC Inflow: 1.57 mS Outflow : 3.60 mS
188	4.38E-010	0.90	1488	05/01/2007	186.2	5.82	

189	4.59E-010	0.90	1420	05/02/2007	187.1	5.85	
190	4.52E-010	0.90	1442	05/03/2007	188	5.88	Page 4
191	4.51E-010	0.90	1445	05/04/2007	188.9	5.90	
192	4.77E-010	0.95	1442	05/05/2007	189.85	5.93	
193	4.78E-010	0.95	1440	05/06/2007	190.8	5.96	
194	4.53E-010	0.90	1439	05/07/2007	191.7	5.99	
195	4.53E-010	0.90	1438	05/08/2007	192.6	6.02	
196	4.26E-010	0.85	1444	05/09/2007	193.45	6.05	
197	4.27E-010	0.85	1442	05/10/2007	194.3	6.07	
198	4.27E-010	0.85	1443	05/11/2007	195.15	6.10	
199	4.53E-010	0.90	1440	05/12/2007	196.05	6.13	
200	4.53E-010	0.90	1440	05/13/2007	196.95	6.15	
201	4.52E-010	0.90	1442	05/14/2007	197.85	6.18	
202	4.26E-010	0.85	1444	05/15/2007	198.7	6.21	
203	4.35E-010	0.90	1498	05/16/2007	199.60	6.24	EC Inflow: 1.59 mS Outflow : 3.89 mS
204	4.44E-010	0.85	1385	05/17/2007	200.45	6.26	
205	4.53E-010	0.90	1440	05/18/2007	201.35	6.29	
206	4.52E-010	0.90	1442	05/19/2007	202.25	6.32	
207	4.53E-010	0.90	1439	05/20/2007	203.15	6.35	
208	4.54E-010	0.90	1437	05/21/2007	204.05	6.38	
209	4.52E-010	0.90	1442	05/22/2007	204.95	6.40	
210	4.53E-010	0.90	1440	05/23/2007	205.85	6.43	
211	4.27E-010	0.85	1442	05/24/2007	206.70	6.46	
212	4.27E-010	0.85	1443	05/25/2007	207.55	6.49	
213	4.28E-010	0.85	1439	05/26/2007	208.40	6.51	
214	4.28E-010	0.85	1437	05/27/2007	209.25	6.54	
215	4.27E-010	0.85	1440	05/28/2007	210.10	6.57	
216	4.26E-010	0.65	1445	05/29/2007	210.95	7.42	
217	3.53E-010	0.70	1435	05/30/2007	211.65	8.12	Flushed Stones and Lines
218	1.66E-009	3.30	1437	05/31/2007	214.95	11.42	
219	1.65E-009	3.30	1444	06/01/2007	218.25	14.72	
220	1.66E-009	3.30	1442	06/02/2007	221.55	18.02	
221	1.66E-009	3.30	1439	06/03/2007	224.85	21.32	
222	1.61E-009	3.20	1442	06/04/2007	228.05	24.52	
223	1.60E-009	3.20	1445	06/05/2007	231.25	27.72	
224	1.61E-009	3.20	1435	06/06/2007	234.45	30.92	

JLT LABORATORIES, INC.
GEOTECHNICAL, GEOSYNTHETIC AND MATERIALS TESTING AND RESEARCH

June 16, 2010
10LR2044.01

GSE Lining Technology, Inc.
19103 Gundle Road
Houston, TX 77073

Attn: Jimmy Youngblood

RE: FINAL RESULTS - PANEL 16
POLYMET MOCK GCL
JLT PROPOSAL DATE: 7-30-2009
PO NO: 48942-000-OP

Dear Mr. Youngblood:

Submitted herein are the final results of Compatibility testing performed on the mock GCL described above. The test was performed for a total duration of 176 days. The test was terminated because we ran out of the synthetic leachate. In addition we could not obtain pH or EC readings on the inflow side because the leachate ran out. For the outflow side, the liquid in the accumulator bladder was crystalized and could not be tested. However, the pH and EC inflow and outflow readings taken on May 4^{th} were well within the guidance of the standard.

We appreciate the opportunity to provide our services and look forward to working with you again. Should you have any questions, comments or require additional information, please do not hesitate to call. Thank you.

Sincerely,

JLT LABORATORIES, INC.

John Boschuk, Jr., P.E.
President

cc: Accounts Payable - Invoice Only

Enclosures
JB:mlb

SUMMARY OF FLEX WALL PERMEABILITY
TEST RESULTS
ASTM D-6766

Client	:	GSE	Date	:	05/23/10
Project Location	:	Polymet	Job No.	:	09LR2044.01
Description	:	MOCK GCL As-Received MC	Tested By	:	MLB/DB
	:	6 oz and 6 oz Fabric	Checked By	:	JB
		0.8 lbs/sq ft 30 Cap Clay	Panel No	:	16
Permeant Fluid	:	Synthetic Leachate 1-gal Jug	Spec Gravity	:	2.74 Assumed

Physical Property Data

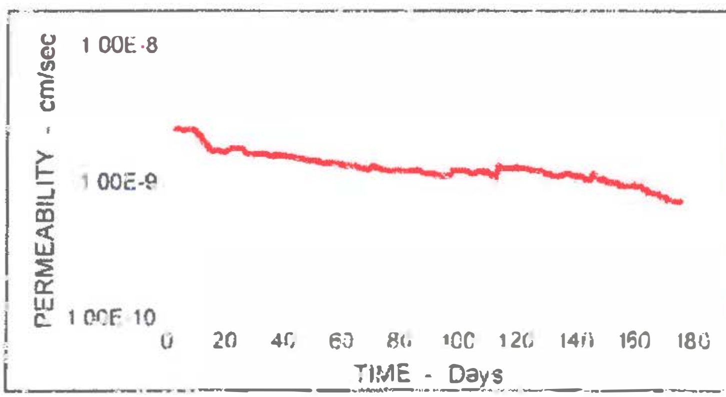
Initial Height (in)	:	0.19	Final Height (in)	:	0.22
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	4.00
Initial Wet Weight (g)	:	39.60	Final Wet Weight (g)	:	75.60
Wet Density (pcf)	:	63.13	Wet Density (pcf)	:	104.08
Moisture Content %	:	10.10	Moisture Content %	:	91.10
Dry Density (pcf)	:	57.34	Dry Density (pcf)	:	54.47

Test Parameters

Fluid	:	Synthetic Leachate	**Average Effective**		
Cell Pressure (psi)	:	80.00	**Confining Pressure (psi)**	:	4.00
Head Water (psi)	:	77.00	Gradient	:	250.91
Tail Water (psi)	:	75.00	**Eff Stress at Base (psi)**	:	5

Permeability Input Data
For Last Data Point

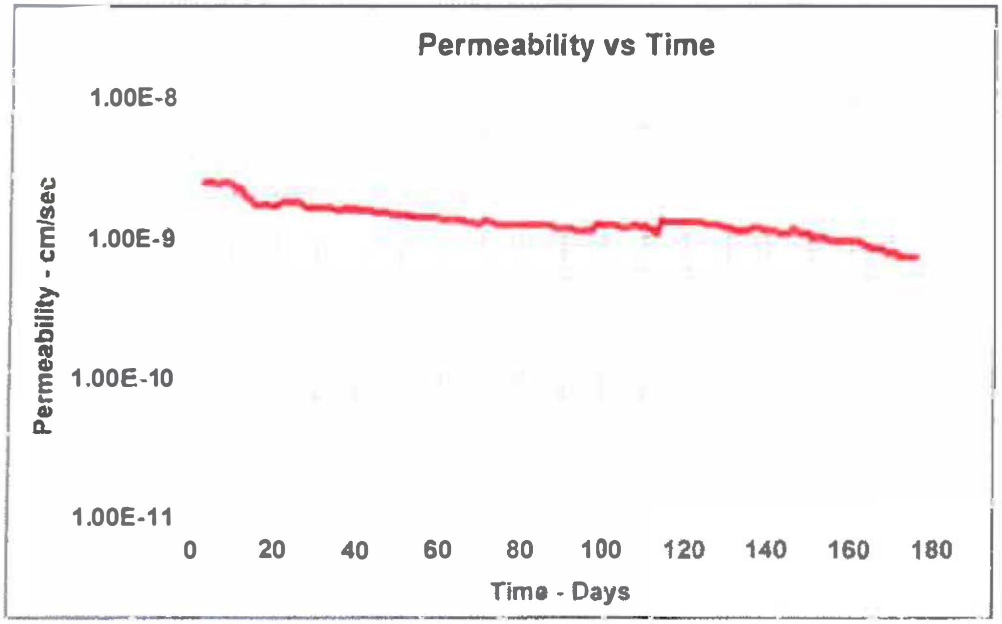
Flow, Q	(cc)	:	1.30
Length, L	(in)	:	0.22
Area, A	(sqin)	:	12.57
Head, h	**(psi)**	:	**2.00**
Time, t	(min)	:	1441.00
Temp, T	(Deg C)	:	21.0

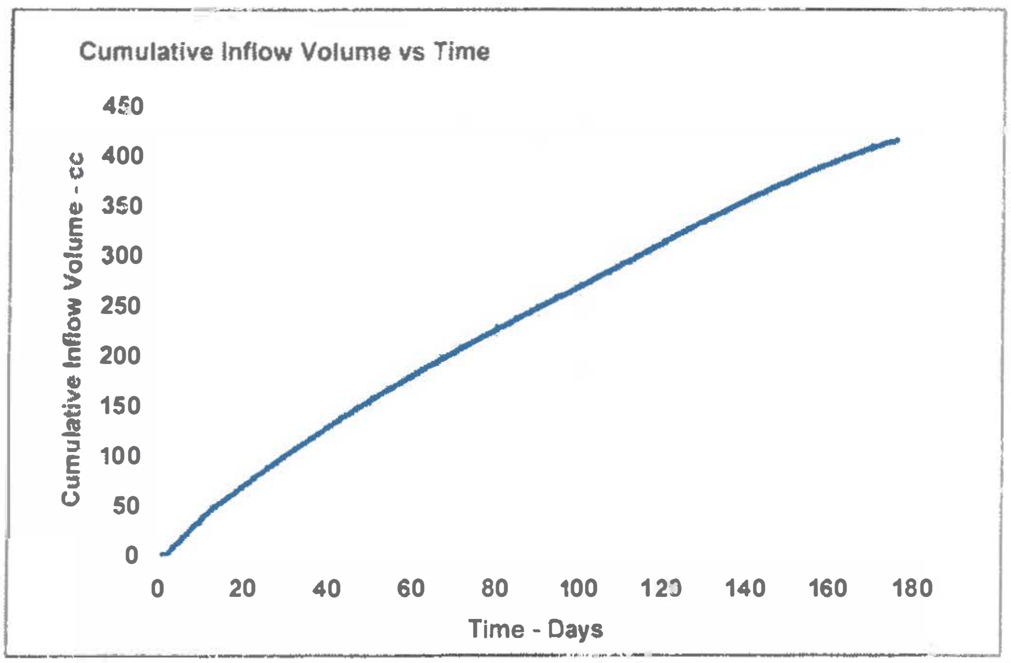


Computed Permeability

PERMEABILITY, K = 7.19E-010 (cm/sec) at 20 Degrees C
Day 176 **Inflow to Date : 414.6 cc**

Description	MOCK GCL As-Received MC	Date	05/23/10
	6 oz and 6 oz Fabric	Estimated Pore Volume	32 2 cc Revised
	0.8 lbs/sq ft	Estimated Inflow Pore Volumes	12 88
Permeant	Synthetic Leachate		





JLT Laboratories, Inc

Client	GSI	Date	05/23/10
Project Location	Polymer	Job No	09LR2644-01
Description	MOCK GCL As Received MC	Tested By	MLB/LE
	6 oz and 6 oz Fabric	Checked By	JB
	0.8 lbs/sq ft		

JLT

Sample ID GCL As Received MC
6 oz and 6 oz Fabric

Estimated Pore Volume 32.2 cc

Elapsed Time Days	Permeability cm/sec	Inflow cc	Time minutes	Date	Total Cumulative Inflow Volume cc	Pore Volumes	COMMENTS
1				11/27/2009	0.00	0.00	Start with Synthetic Leachate
2				11/28/2009	0.00	0.00	
3	2.43E-009	4.4	1441	11/29/2009	4.40	0.14	
4	2.49E-009	4.5	1441	11/30/2009	8.90	0.28	
5	2.43E-009	4.4	1443	12/01/2009	13.30	0.41	
6	2.38E-009	4.3	1441	12/02/2009	17.60	0.55	
7	2.43E-009	4.4	1442	12/03/2009	22.00	0.68	
8	2.44E-009	4.4	1435	12/04/2009	26.40	0.82	In 25.5 Out 26.1
9	2.43E-009	4.4	1442	12/05/2009	30.80	0.96	
10	2.32E-009	4.2	1442	12/06/2009	35.00	1.09	
11	2.23E-009	4.0	1439	12/07/2009	39.00	1.21	
12	2.21E-009	4.0	1442	12/08/2009	43.00	1.34	
13	1.93E-009	3.5	1444	12/09/2009	46.50	1.44	
14	1.88E-009	3.4	1442	12/10/2009	49.90	1.55	
15	1.71E-009	3.1	1441	12/11/2009	53.00	1.65	
16	1.66E-009	3.0	1442	12/12/2009	56.00	1.74	In 25.4 Out 26.1
17	1.71E-009	3.1	1440	12/13/2009	59.10	1.84	
18	1.71E-009	3.1	1442	12/14/2009	62.20	1.93	
19	1.66E-009	3.0	1441	12/15/2009	65.20	2.02	
20	1.66E-009	3.0	1442	12/16/2009	68.20	2.12	
21	1.71E-009	3.1	1442	12/17/2009	71.30	2.21	
22	1.77E-009	3.2	1440	12/18/2009	74.50	2.31	
23	1.77E-009	3.2	1437	12/19/2009	77.70	2.41	
24	1.76E-009	3.2	1446	12/20/2009	80.90	2.51	
25	1.77E-009	3.2	1440	12/21/2009	84.10	2.61	EC In 25 EC Out 23.4
26	1.77E-009	3.2	1440	12/22/2009	87.30	2.71	
27	1.66E-009	3.0	1442	12/23/2009	90.30	2.80	
28	1.60E-009	2.9	1441	12/24/2009	93.20	2.89	
29	1.61E-009	2.9	1442	12/25/2009	96.10	2.98	
30	1.61E-009	2.9	1439	12/26/2009	99.00	3.07	
31	1.61E-009	2.9	1438	12/27/2009	101.90	3.16	
32	1.61E-009	2.9	1441	12/28/2009	104.80	3.25	EC In 24.9 EC Out 23.9
33	1.63E-009	2.9	1421	12/29/2009	107.70	3.34	
34	1.59E-009	2.9	1452	12/30/2009	110.60	3.43	
35	1.55E-009	2.8	1443	12/31/2009	113.40	3.52	
36	1.55E-009	2.8	1442	01/01/2010	116.20	3.61	
37	1.60E-009	2.9	1440	01/02/2010	119.10	3.70	
38	1.55E-009	2.8	1439	01/03/2010	121.90	3.79	
39	1.61E-009	2.9	1440	01/04/2010	124.80	3.88	
40	1.55E-009	2.8	1441	01/05/2010	127.60	3.96	
41	1.55E-009	2.8	1441	01/06/2010	130.40	4.05	
42	1.55E-009	2.8	1439	01/07/2010	133.20	4.14	EC In 0.73 ppt pH In 7.22
43	1.55E-009	2.8	1441	01/08/2010	136.00	4.22	EC Out 0.75 ppt pH Out 7.27
44	1.49E-009	2.7	1442	01/09/2010	138.70	4.31	
45	1.50E-009	2.7	1438	01/10/2010	141.40	4.39	
46	1.49E-009	2.7	1439	01/11/2010	144.10	4.48	
47	1.49E-009	2.7	1439	01/12/2010	146.80	4.56	
48	1.44E-009	2.6	1441	01/13/2010	149.40	4.64	
49	1.43E-009	2.6	1444	01/14/2010	152.00	4.72	
50	1.43E-009	2.6	1432	01/15/2010	154.60	4.80	

51	1 44E-009	2 6	1442	01/16/2010	157 25	4 88	
52	1 44E-009	2 6	1441	01/17/2010	159 80	4 96	
53	1 38E-009	2 5	1442	01/18/2010	162 30	5 04	
54	1 38E-009	2 5	1440	01/19/2010	164 80	5 12	
55	1 38E-009	2 5	1439	01/20/2010	167 30	5 20	EC In 2 98 pH In 5 75
56	1 38E-009	2 5	1442	01/21/2010	169 80	5 27	EC Out 2 97 pH Out 5 78
57	1 38E-009	2 5	1441	01/22/2010	172 30	5 35	
58	1 38E-009	2 5	1442	01/23/2010	174 80	5 43	
59	1 38E-009	2 5	1442	01/24/2010	177 30	5 51	
60	1 33E-009	2 4	1433	01/25/2010	179 70	5 58	
61	1 32E-009	2 4	1446	01/26/2010	182 10	5 66	
62	1 32E-009	2 4	1447	01/27/2010	184 50	5 73	
63	1 33E-009	2 4	1442	01/28/2010	186 90	5 80	
64	1 34E-009	2 4	1431	01/29/2010	189 30	5 88	
65	1 33E-009	2 4	1442	01/30/2010	191 70	5 95	
66	1 27E-009	2 3	1444	01/31/2010	194 00	6 02	
67	1 27E-009	2 3	1442	02/01/2010	196 30	6 10	
68	1 27E-009	2 3	1440	02/02/2010	198 60	6 17	
69	1 22E-009	2 2	1439	02/03/2010	200 80	6 24	Backwashed Stones
70	1 27E-009	2 3	1439	02/04/2010	203 10	6 31	
71	1 33E-009	2 4	1442	02/05/2010	205 50	6 38	
72	1 27E-009	2 3	1446	02/06/2010	207 80	6 45	
73	1 27E-009	2 3	1442	02/07/2010	210 10	6 52	
74	1 22E-009	2 2	1440	02/08/2010	212 30	6 59	
75	1 22E-009	2 2	1437	02/09/2010	214 50	6 66	
76	1 21E-009	2 2	1448	02/10/2010	216 70	6 73	
77	1 21E-009	2 2	1445	02/11/2010	218 90	6 80	
78	1 22E-009	2 2	1440	02/12/2010	221 10	6 87	Backwashed Stones
79	1 22E-009	2 2	1441	02/13/2010	223 30	6 93	
80	1 22E-009	2 2	1442	02/14/2010	225 50	7 00	
81	1 22E-009	2 2	1440	02/15/2010	227 70	7 07	
82	1 22E-009	2 2	1439	02/16/2010	229 90	7 14	
83	1 21E-009	2 2	1444	02/17/2010	232 10	7 21	EC In 2 25 pH In 6 39
84	1 22E-009	2 2	1436	02/18/2010	234 30	7 28	EC Out 2 22 pH Out 6 42
85	1 22E-009	2 2	1437	02/19/2010	236 50	7 34	
86	1 21E-009	2 2	1444	02/20/2010	238 70	7 41	
87	1 22E-009	2 2	1437	02/21/2010	240 90	7 48	
88	1 16E-009	2 1	1438	02/22/2010	243 00	7 55	
89	1 16E-009	2 1	1445	02/23/2010	245 10	7 61	
90	1 16E-009	2 1	1446	02/24/2010	247 20	7 68	
91	1 16E-009	2 1	1440	02/25/2010	249 30	7 74	
92	1 16E-009	2 1	1440	02/26/2010	251 40	7 81	
93	1 10E-009	2 0	1442	02/27/2010	253 40	7 87	
94	1 11E-009	2 0	1439	02/28/2010	255 40	7 93	
95	1 11E-009	2 0	1441	03/01/2010	257 40	7 99	
96	1 10E-009	2 0	1442	03/02/2010	259 40	8 06	Backwashed Stones
97	1 11E-009	2 0	1440	03/03/2010	261 40	8 12	
98	1 22E-009	2 2	1437	03/04/2010	263 60	8 19	
99	1 22E-009	2 2	1439	03/05/2010	265 80	8 25	
100	1 21E-009	2 2	1445	03/06/2010	268 00	8 32	
101	1 22E-009	2 2	1442	03/07/2010	270 20	8 39	
102	1 22E-009	2 2	1443	03/08/2010	272 40	8 46	
103	1 22E-009	2 2	1440	03/09/2010	274 60	8 53	
104	1 16E-009	2 1	1442	03/10/2010	276 70	8 59	
105	1 16E-009	2 1	1444	03/11/2010	278 80	8 66	
106	1 15E-009	2 1	1442	03/12/2010	280 90	8 72	
107	1 22E-009	2 2	1440	03/13/2010	283 10	8 79	
108	1 22E-009	2 2	1439	03/14/2010	285 30	8 86	
109	1 16E-009	2 1	1439	03/15/2010	287 40	8 93	
110	1 21E-009	2 2	1445	03/16/2010	289 60	8 99	
111	1 15E-009	2 1	1449	03/17/2010	291 70	9 06	
112	1 10E-009	2 0	1442	03/18/2010	293 70	9 12	
113	1 05E-009	1 9	1440	03/19/2010	295 60	9 18	Backwashed Stones
114	1 33E-009	2 4	1442	03/20/2010	298 00	9 25	
115	1 27E-009	2 3	1441	03/21/2010	300 30	9 33	

116	1 27E 009	2 3	1443	03/22/2010	302 60	9 40	
117	1 27E 009	2 3	1439	03/23/2010	304 90	9 47	F
118	1 27E 009	2 3	1439	03/24/2010	307 20	9 54	EC In 2 35 pH In
119	1 27E 009	2 3	1441	03/25/2010	309 50	9 61	EC Out 2 31 pH Ou
120	1 30E 009	2 3	1443	03/26/2010	311 80	9 68	
121	1 27E 009	2 3	1442	03/27/2010	314 10	9 75	
122	1 27E 009	2 3	1441	03/28/2010	316 40	9 83	
123	1 27E 009	2 3	1437	03/29/2010	318 70	9 90	
124	1 27E 009	2 3	1446	03/30/2010	321 00	9 97	
125	1 21E 009	2 20	1445	03/31/2010	323 20	10 04	
126	1 22E 009	2 20	1435	04/01/2010	325 40	10 11	
127	1 22E 009	2 20	1438	04/02/2010	327 60	10 17	
128	1 22E 009	2 20	1438	04/03/2010	329 80	10 24	
129	1 16E 009	2 10	1442	04/04/2010	331 90	10 31	
130	1 16E 009	2 10	1443	04/05/2010	334 00	10 37	
131	1 16E 009	2 10	1440	04/06/2010	336 10	10 44	
132	1 11E 009	2 00	1440	04/07/2010	338 10	10 50	
133	1 11E 009	2 00	1441	04/08/2010	340 10	10 56	
134	1 11E 009	2 00	1439	04/09/2010	342 10	10 62	
135	1 11E 009	2 00	1441	04/10/2010	344 10	10 69	Flushed Stones and L
136	1 16E 009	2 10	1442	04/11/2010	346 20	10 75	
137	1 16E 009	2 10	1443	04/12/2010	348 30	10 82	
138	1 16E 009	2 10	1440	04/13/2010	350 40	10 88	
139	1 11E 009	2 00	1437	04/14/2010	352 40	10 94	
140	1 11E 009	2 00	1438	04/15/2010	354 40	11 01	
141	1 11E 009	2 00	1439	04/16/2010	356 40	11 07	
142	1 11E 009	2 00	1440	04/17/2010	358 40	11 13	
143	1 05E 009	1 90	1442	04/18/2010	360 30	11 19	
144	1 05E 009	1 90	1441	04/19/2010	362 20	11 25	
145	1 05E 009	1 90	1442	04/20/2010	364 10	11 31	Flushed Stones and Li
146	1 16E 009	2 10	1444	04/21/2010	366 20	11 37	
147	1 11E 009	2 00	1438	04/22/2010	368 20	11 43	
148	1 05E 009	1 90	1442	04/23/2010	370 10	11 49	
149	1 05E 009	1 90	1440	04/24/2010	372 00	11 55	
150	1 05E 009	1 90	1435	04/25/2010	373 90	11 61	
151	9 88E 010	1 80	1451	04/26/2010	375 70	11 67	
152	9 94E 010	1 80	1442	04/27/2010	377 50	11 72	
153	9 95E 010	1 80	1441	04/28/2010	379 30	11 78	
154	9 96E 010	1 80	1440	04/29/2010	381 10	11 84	
155	9 41E 010	1 70	1439	04/30/2010	382 80	11 89	
156	9 41E 010	1 70	1439	05/01/2010	384 50	11 94	
157	9 35E 010	1 70	1449	05/02/2010	386 20	11 99	
158	9 39E 010	1 70	1442	05/03/2010	387 90	12 05	
159	9 38E 010	1 70	1443	05/04/2010	389 60	12 10	EC In 2 41 pH In 8
160	9 40E 010	1 70	1441	05/05/2010	391 30	12 15	EC Out 2 39 pH Out
161	9 39E 010	1 70	1442	05/06/2010	393 00	12 20	
162	9 42E 010	1 70	1438	05/07/2010	394 70	12 26	
163	8 83E 010	1 60	1444	05/08/2010	396 30	12 31	
164	8 87E 010	1 60	1437	05/09/2010	397 90	12 36	
165	8 29E 010	1 50	1442	05/10/2010	399 40	12 40	
166	8 28E 010	1 50	1443	05/11/2010	400 90	12 45	
167	8 27E 010	1 50	1445	05/12/2010	402 40	12 50	
168	8 29E 010	1 50	1442	05/13/2010	403 90	12 54	
169	7 74E 010	1 40	1440	05/14/2010	405 30	12 59	
170	7 73E 010	1 40	1438	05/15/2010	406 70	12 63	
171	7 75E 010	1 40	1439	05/16/2010	408 10	12 67	
172	7 18E 010	1 30	1442	05/17/2010	409 40	12 71	
173	7 19E 010	1 30	1440	05/18/2010	410 70	12 75	
174	7 19E 010	1 30	1441	05/19/2010	412 00	12 80	
175	7 19E 010	1 30	1440	05/20/2010	413 30	12 84	
176	7 19E 010	1 30	1441	05/21/2010	414 60	12 88	Not enough for EC or pH

CHLORIDE TAILINGS DECANT WATER - EXPECTED INORGANIC CONCENTRATIONS (mg/L)
Provided by Barr Engineering

	Al^{+3}	Ca^{+2}	Cl^{-}	Mg^{+2}	Na^{+}	SO_4^{-2}	S^{-2}
52 aAl2SO43 wt.%	0.8	0.0	0.0	0.0	0.0	4.2	0.0
53 aCaCl2 wt.%	0.0	4,151.2	7,343.2	0.0	0.0	0.0	0.0
54 aCaSO4 wt.%	0.0	615.1	0.0	0.0	0.0	1,474.4	0.0
55 aCoSO4 wt.%	0.0	0.0	0.0	0.0	0.0	3.4	0.0
56 aCuSO4 wt.%	0.0	0.0	0.0	0.0	0.0	19.2	0.0
57 aFeSO4 wt.%	0.0	0.0	0.0	0.0	0.0	0.3	0.0
58 aFe2SO43 wt.%	0.0	0.0	0.0	0.0	0.0	3.5	0.0
59 aHCl wt.%	0.0	0.0	0.9	0.0	0.0	0.0	0.0
61 aH2SO4 wt.%	0.0	0.0	0.0	0.0	0.0	119.2	0.0
62 aK2SO4 wt.%	0.0	0.0	0.0	0.0	0.0	759.2	0.0
63 aMgCl2 wt.%	0.0	0.0	0.2	0.1	0.0	0.0	0.0
64 aMgSO4 wt.%	0.0	0.0	0.0	4,065.2	0.0	16,065.3	0.0
65 aNaCl wt.%	0.0	0.0	800.1	0.0	518.9	0.0	0.0
66 aNaHS wt.%	0.0	0.0	0.0	0.0	77.8	0.0	108.5
67 aNa2SO4 wt.%	0.0	0.0	0.0	0.0	0.02	0.05	0.0
68 aNiSO4 wt.%	0.0	0.0	0.0	0.0	0.0	39.1	0.0
69 aZnSO4 wt.%	0.0	0.0	0.0	0.0	0.0	1.0	0.0
70 aNa3AuCl4 wt.%	0.0	0.0	0.00007	0.0	0.00004	0.0	0.0
71 aNa2PdCl4 wt.%	0.0	0.0	0.00033	0.0	0.00011	0.0	0.0
72 aNa2PtCl4 wt.%	0.0	0.0	0.00065	0.0	0.00021	0.0	0.0
73 aNa3RhCl6 wt.%	0.0	0.0	0.00014	0.0	0.00007	0.0	0.0
Total (mg/L)	**0.8**	**4,766.3**	**8,144.5**	**4,065.3**	**596.7**	**18,489.0**	**108.5**