Minnesota Department of Natural Resources

Division of Ecological & Water Resources

MNDNR PERMITTING AND REPORTING SYSTEM

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REVISION 04132015 **APP ID** 6463

Public Waters/Dam Permit Application

Reference Number: 2016-1383

Date Submitted to DNR: July 20, 2016 at 7:42 AM

Application Reference Name: Poly Met Mining, Inc.

DNR Lead Hydrologist: **Kirstin Stutzman**
Area: Eveleth
Email: kirstin.stutzman@state.mn.us
Phone: 218-302-3246

DNR Region: Northeast Region 2
Address: MN DNR EWR
525 Lake Avenue Suite #415
Duluth, MN 55802

Parties (*Individuals and Organizations associated with the permit application*)

Poly Met Mining, Inc. - Landowner or Government Unit

Address: 6500 Co Rd 666, PO Box 475, Hoyt Lakes, MN 55750
Phone: 218-471-2150

Christie Kearney - Contact (*representing Poly Met Mining, Inc.*) (*submitted application*)

Address: 6500 County Road 666, Hoyt Lakes, MN 55750
Phone: 218-471-2163
Email: ckearney@polymetmining.com

Proposed Activity

Dam Safety - Construction

Location and Water Resources

Site Name: Hydrometallurgical Residue Facility
(Dam Safety - Construction)
Counties: St. Louis
Watersheds: St. Louis River
PLS: T59N-R14W-S8 NESW, T59N-R14W-S8 NWSE
UTM: X:563868 Y:5273032
Water Resources: Lake: (Null), Dug Pit/Holding Pond

Public Waters/Dam Overview

1	Please assign a reference/project name to this application.	Poly Met Mining, Inc.
2	What is the main type of work you are proposing to do?	Work in or near a lake, wetland, or river/stream (e.g., excavate, place fill, install a structure in a waterbody, modify a dam)
3	When is the anticipated start date for the project?	08/01/2017
4	When is the anticipated bid date for the project, if applicable? (optional)	06/01/2017
5	When is the expected completion date for the entire project?	08/01/2039
6	Briefly describe the overall project purpose and need.	The NorthMet Project is a copper-nickel-platinum group elements mine and associated processing facilities. This dam safety permit application is for construction of the Hydrometallurgical Residue Facility to store hydrometallurgical residue associated with the 20 years of ore processing.
7	Has any portion of the proposed work in wetlands or water areas already started?	No
8	Is this a transportation project sponsored by a government unit?	No
9	Will the project require any dewatering (the deliberate removal of water through the use of a pump, ditch, etc. to lower water levels to allow work to be accomplished)?	Yes
10	Will the removed water remain within its original source at all times (e.g., only pumped over the side of a coffer dam and never pumped off site to a holding pond)?	No
11	Has an Environmental Assessment Worksheet (EAW) or Environmental Impact Statement (EIS) been completed for the project, or will it be required?	Yes
12	Has the project gone through a Natural Heritage (endangered species) review?	Yes

Activity Detail

Activity: Dam Safety - Construction

How many different sites will have dam/weir construction work (i.e., the number of individual stream/river, ditch, lake, pond, pit, and/or wetland crossings or impact areas)? 1

Site Name: Hydrometallurgical Residue Facility

1	Provide the name for the owner of the dam.	Poly Met Mining, Inc.
2	Provide the mailing address for the owner of the dam.	PO Box 475 (6500 Co Rd 666), Hoyt Lakes, MN 55750
3	Provide the phone number for the owner of the dam.	(218) 471-2150
4	Provide the email address for the owner of the dam.	ckearney@polymetmining.com
5	Provide the name for the entity that maintains and/or operates the dam.	Poly Met Mining, Inc.
6	Provide the phone number for the entity that maintains and/or operates the dam.	(218) 471-2150
7	Provide the email address for the entity that maintains and/or operates the dam.	ckearney@polymetmining.com
8	Provide the name of the professional engineer.	Thomas Radue

Activity Detail (*Continued*)

9	Provide the company name for the professional engineer.	Barr Engineering Company
10	Provide the mailing address for the professional engineer.	4300 MarketPointe Drive, Suite 200, Minneapolis, MN 55435
11	Provide the phone number for the professional engineer.	(952) 832-2871
12	Provide the email address for the professional engineer.	tradue@barr.com
13	What is the primary purpose of the dam?	Water supply
14	Indicate the type of the dam.	Other
15	If Other, please specify:	mine tailings, earthen materials (granular filter, rock)
16	What is the estimated cost of the project in whole dollars?	$9,140,000.00
17	What is the watershed area in square miles? (include one decimal point)	0.14 square miles
18	What is the elevation datum for the dam?	NAVD 1988
19	What is the elevation at the top of the dam in feet? (include one decimal point)	1,650 feet
20	What is the elevation at the principal spillway inlet/runout in feet? (include one decimal point)	1,539 feet
21	What is the elevation at the natural streambed at the downstream toe in feet? (include one decimal point)	1,560 feet
22	What is the reservoir area at the top of the dam in acres? (whole number only)	97 acres
23	What is the reservoir area at the principal spillway inlet/runout in acres? (whole number only)	97 acres
24	What is the storage volume at the top of the dam in acre-feet? (whole number only)	4,653 acre-feet
25	What is the storage volume at the principal spillway inlet/runout in acre-feet? (whole number only)	4,653 acre-feet
26	Do you have the financial capabilities to maintain and repair the dam?	Yes
27	Do you have all impoundment flowage easements to the top of the dam?	Yes
28	Do you have all access rights and easements to construct and maintain the dam?	Yes
29	Select the resource(s) below that describes the type of water bodies that could be impacted at this site.	lake, dug pit/holding pond
30	Counties	St. Louis
31	Watersheds	St. Louis River
32	PLS	T59N-R14W-S8 NESW, T59N-R14W-S8 NWSE
33	UTMXY	X:563868 Y:5273032
34	Water resources	Lake: (Null), Dug Pit/Holding Pond

Acknowledgment (***By the party who submitted the permit application***)

Acknowledgement (*Continued*)

☑ **I attest that:**

·I own or control (by lease, license, or other permission) the land that I propose to alter, AND

·There are no easements or other restrictions on the land that would prohibit the proposed activities from being authorized under a permit, AND

·I possess the authority to undertake the work described, or I am acting as a duly authorized agent, AND

·The information submitted and the statements made concerning this application are true and correct to the best of my knowledge.

PRINTED: 07/20/2016 at 7:42 AM

NorthMet Dam Safety Permit Application

Hydrometallurgical Residue Facility

Prepared for
Poly Met Mining, Inc.

May 2017

4300 MarketPointe Drive
Minneapolis, MN 55435
952.832.2600
www.barr.com

NorthMet Dam Safety Permit Application: Hydrometallurgical Residue Facility

May 2017

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Certifications

I hereby certify that this plan, specification, or 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.

Thomas J. Radue

Thomas J. Radue

PE #: 20951

May 15, 2017

Date

1.0 Introduction

This document constitutes an application for a Dam Safety Permit in the state of Minnesota for the NorthMet Project Hydrometallurgical Residue Facility (HRF). It provides the information required by Minnesota Rules, part 6115.0410 and the Minnesota Permitting and Reporting System (MPARS).

1.1 Project Description

Poly Met Mining, Inc. (PolyMet) is proposing to develop the NorthMet Project (Project) copper-nickel-platinum group elements mine and associated processing facilities. The Project is described in Section 1.1 of the NorthMet Mining Project and Land Exchange Final Environmental Impact Statement (FEIS) (Reference (1)). The Project is located south of the city of Babbitt and north of the city of Hoyt Lakes in St. Louis County, Minnesota, as shown on Large Figure 1. Existing infrastructure in the vicinity of the HRF is shown on Large Figure 2.

1.2 Hydrometallurgical Residue Management

The Hydrometallurgical Plant, which will begin operations several years after mining commences, will generate up to approximately 313,000 tons of Residue annually and up to a total of 6,170,000 tons, if the plant processes all the nickel flotation concentrate streams produced by the flotation process. The hydrometallurgical process would generate residues from five sources:

- autoclave residue from the leach residue filter
- high-purity gypsum from the solution-neutralizing filter (depending on the market, this could become a saleable product, but is currently planned to be managed as a waste)
- gypsum, iron, and aluminum hydroxide from the iron and aluminum filter
- magnesium hydroxide precipitate from the magnesium removal tank
- other minor plant spillage sources

These wastes would be combined and disposed of in the HRF that would be located at the existing LTVSMC Emergency Basin, adjacent to the southern edge of the existing tailings basin Cell 2W. Residue management is described in the Residue Management Plan (Appendix A).

In addition to the above-listed sources, solid wastes from the Waste Water Treatment System (WWTS) would be recycled directly into the Hydrometallurgical Plant to recover metals, creating additional waste. The WWTS solids would be similar to the hydrometallurgical residue, consisting primarily of gypsum, metal hydroxides, and calcite.

During LTVSMC operations, fly ash, dredging spoil, and coal pile cleanup material were placed in a solid waste storage site (Coal Ash Landfill) to the east of Tailings Basin Cell 1E. The location of this landfill would be inundated by tailings in approximately year 7 of Tailings Basin operation. Therefore, the contents would be analyzed and relocated to the HRF, or other approved facility, prior to that time.

The Residue will be a slurry of fine sand, silt, and clay-size particles, with individual particle diameter on the order of 0.5 millimeters or less. The slurry will be pumped from the Hydrometallurgical Plant to the HRF. A pond would be maintained within the HRF so that the solids in the slurry would settle out, while the majority of the liquid would be recovered by a pump system and returned to the plant for reuse. The slurry discharge will be configured such that the discharge point into the cell periodically can be adjusted (vertically and horizontally) to distribute Residue uniformly within the cell. Water will be lost from this closed loop system to evaporation from the cell surface and entrapment within the Residue's pore space. No leakage through the HRF double liner system is expected. Precipitation falling within the HRF will be retained. The perimeter dams of the HRF will be configured to prevent precipitation run-on from adjacent land areas.

The HRF will be one double-lined cell with geomembrane and geosynthetic clay liners, developed incrementally as needed, expanding vertically and horizontally from the initial construction. The first increment would be constructed over two to three construction seasons. Most of the site-preparation activities and major earthwork would occur in the first two construction seasons. Placing the geosynthetic clay liner would occur in the third year of construction. The remaining earthwork and completion of the geomembrane liner installation for the upper elevations of the facility would occur as needed to maintain adequate capacity. An HRF Construction and Operation Timeline is provided on Figure 1. The HRF liner and dams will be constructed in increments (stages) to allow for Residue deposition for the life of the cell (approximately 17 to 18 years) after which the cell will be closed with a temporary and then a final cover system.

A temporary cover system is proposed for initial HRF closure to preclude future infiltration of precipitation during residue dewatering, while accommodating differential settlement that may occur as residue is dewatered at closure. Once residue dewatering is complete and settlement has concluded, the surface of the residue facility will be graded as needed to facilitate surface water runoff from the final cover system. Temporary and final cover systems will utilize geosynthetic hydraulic barrier materials, with final cover overlain by additional soil cover layers to facilitate establishment of a vegetated, erosion resistant final cover.

This permit application covers all planned increments of HRF construction; from site preparation, through incremental cell development and final cover. For further description of HRF staging, see Section 2.2.1 of the Appendix A).

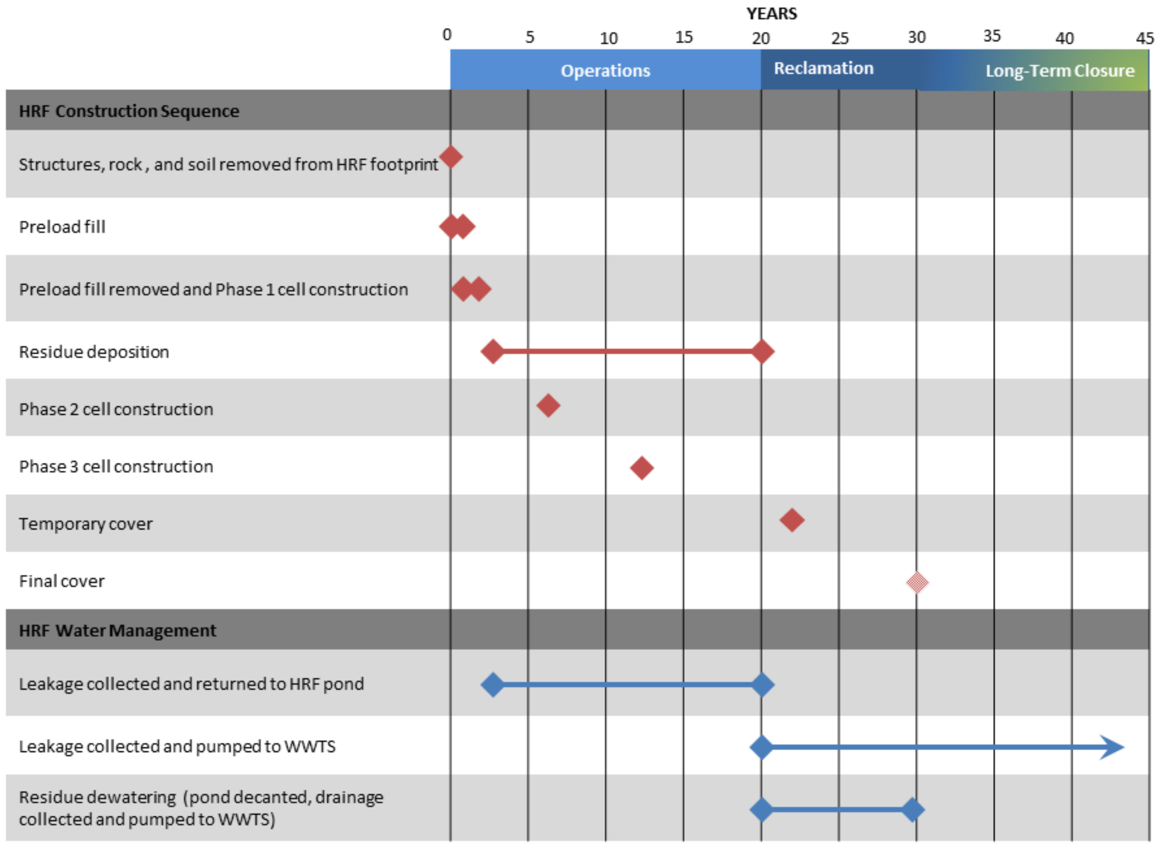


Figure 1 HRF Construction and Operation Timeline

1.3 Definitions and Terms

In this document, the Hydrometallurgical Residue Facility (HRF) refers to the proposed NorthMet HRF impoundment. Residue is the slurry of fine sand, silt, and clay-sized particles left over after nickel flotation concentrate streams are processed at the Hydrometallurgical Plant.

1.4 Dam Safety Permit Application Structure

The content requirements for this HRF Dam Safety Permit Application are summarized in Large Table 1, which is described further in Section 2.0. Portions of the required HRF Dam Safety Permit Application documentation and information was prepared to support the Project EIS and Permit to Mine (PTM) process, has undergone extensive DNR review and peer review, and is therefore already in the DNR files and the public record. So as not to re-produce existing information, the approach for this application is to communicate where required application information can be found; requirements that are already met in other documentation are referenced in Large Table 1, as further described in Section 2.0. Any components not previously developed are presented in the subsequent sections of this application, or in the documents referenced in Large Table 1.

2.0 Permit Application Requirements

The requirements for Dam Safety Permit applications in Minnesota are laid out in Minnesota Rules, part 6115.0410 and the Minnesota Permitting and Reporting System (MPARS) application. Large Table 1 summarizes each requirement, provides the regulatory citation, and identifies the document which contains the information. Table 2-1 describes the configuration of Large Table 1.

Table 2-1 Dam Safety Permit Application Correlation Table (Large Table 1) Format Summary

Section	Citation	Requirement	Document	Section and Page Number
Large Table 1 is divided into the five primary permit application content sections required by Minnesota Rules, part 6115.0410: • General Permit Application • Preliminary Design Report • Final Design Report • Plans and Specifications • Permit Standards	Provides the citation for the Minnesota Rules in which the permit application content requirement is stated.	Provides a synopsis of required permit application content.	Identifies the document currently on file with the DNR and in the public record in which the required permit application content is presented.	Identifies the Section and Page Number of the document in which the required permit application content is presented.

Note: This HRF Dam Safety Permit Application consists of the content provided within this written document, and in the sections and on the pages of the documents referenced in Large Table 1

The MPARS has been submitted on-line at www.dnr.state.mn.us/mpars as part of this Dam Safety Permit Application.

3.0 Permit Application Supporting Content

The sections and pages of the documents referenced in Large Table 1 in aggregate constitute the majority of the HRF Dam Safety Permit Application. Additional application content not previously submitted to the DNR is presented in the following subsections.

3.1 General Permit Application

The items required under the General Permit Application have been previously submitted to the DNR and are referenced in Large Table 1.

3.2 Preliminary Design Report

Most items required under the Preliminary Design Report have been previously submitted to the DNR and are referenced in Large Table 1. The following subsections present additional application information not previously submitted to the DNR.

3.2.1 Preliminary Cost Estimate

Per Minnesota Rules, part 6115.0520, DNR Dam Inspection Fees paid by PolyMet will be based on estimated costs of dam construction. At the end of each stage of construction, and in any case at intervals not exceeding five years in duration, PolyMet will file an affidavit of actual costs for each stage of construction. In cases where actual construction costs exceed estimates, PolyMet will pay the associated Inspection Fee difference. The initial Inspection Fee shall be based on the estimated initial year cost of dam construction, provided as Large Table 2.

The dam construction reflected by the estimated costs presented in Large Table 2 will be initiated a year or more following initiation of HRF site preparation activities, consisting of area preload construction for HRF foundation improvement. It is anticipated that the Dam Inspection Fee will not apply during the years of area preload construction, and that PolyMet will first be subject to Dam Inspection Fees in the year in which the initial phase of HRF dam and liner construction is initiated, because that will be the point in time at which the dams are constructed and first have the capability to retain water. Portions of the HRF construction costs unrelated to Residue containment and dam stability are excluded from the computation of Dam Inspection Fees and are noted as such on Large Table 2 and/or excluded from Large Table 2 in their entirety (e.g., preload and Residue discharge pipeline).

3.2.2 Ancillary Features

Some features that will be co-located with the HRF do not serve a Residue containment function and therefore are ancillary to overall dam safety permitting. Ancillary features and their general function and location are summarized in Table 3-1. Ancillary features are shown on the Permit Application Support Drawings provided with the Residue Management Plan (Appendix A).

Table 3-1 Hydrometallurgical Residue Facility Ancillary Features

Item	Location	Function
Seepage Collection Drain	Along Toe of Slope of Interface of Cell 2W South Dam with HRF	Collection of Cell 2W Toe-of-Slope Seepage to Prevent Hydraulic Head Build-Up and Potential Uplift of HRF Liner Prior to Filling HRF for Initial Operations
Preload Lifts 1 through 5	Former LTV Steel Mining Company (LTVSMC) Emergency Basin Area	Preconsolidation of Existing LTVSMC Tailings to Improve HRF Foundation Prior to HRF Liner Construction; To Minimize Future HRF Liner Differential Settlement and Liner Strain
Residue Discharge Pipeline	North Side of HRF	Transport of Residue Slurry from Hydrometallurgical Plant to HRF
Process Water Transfer Pump Raft and Return Pipeline	North Side of HRF	Return of Process Water from HRF to Hydrometallurgical Plant
Residue Discharge Pipeline	Interior Side of HRF Perimeter Dam	Transport of Residue to Discharge on Perimeter of HRF
Access Roads	Crest of HRF Dam	Provide Vehicle Access onto Crest of HRF Dams

Note: Items noted in the table above are shown in the Permit Application Support Drawings (Attachment A of Appendix A).

3.3 Final Design Report

Most items required under the Final Design Report are provided as an attachment to this permit application or have been previously submitted to the DNR and are referenced in Large Table 1. The following subsections present additional application information not previously submitted to the DNR.

3.3.1 Borrow and Aggregate Locations and Volumes

The borrow materials and aggregates required for HRF construction and closure are listed in Table 3-2, including estimated quantities and planned borrow locations.

Table 3-2 Borrow and Aggregate Locations and Volumes

Borrow Type and Use	Estimated Quantity	When Used	Planned Borrow Locations
Granular Filter Material for Preload Subgrade	121,000 Cubic Yards	HRF Site Preparation	PolyMet Discretion
Granular Drainage Material for Drainage Collection System	312,000 Cubic Yards	HRF Construction	PolyMet Discretion
Blast Rock for Preload	329,000 Cubic Yards	HRF Site Preparation	On-Site Bedrock Removal for HRF Construction
18" Minus Rock for Drainage Collection System	96,000 Cubic Yards	HRF Construction	PolyMet Discretion
1" Minus Rock for Drainage Collection System	315,000 Cubic Yards	HRF Construction	PolyMet Discretion
Bulk Tailings Borrow for HRF Perimeter Dams	1,647,000 Cubic Yards	HRF Construction	Tailings Basin Cell 1E/2E Dam, Cell 2W Dam,
Import Borrow for HRF Perimeter Dams and HRF Cover System	2,727,000 Cubic Yards	HRF Construction and Closure	PolyMet Discretion
Topsoil for HRF Perimeter Dams and HRF Cover System	264,000 Cubic Yards	HRF Construction and Closure	HRF Footprint Area Salvage and PolyMet Discretion
Class II Riprap for HRF Cover System	800 Cubic Yards	HRF Closure	PolyMet Discretion

Note: Material quantities listed above are approximate based on designs presented in the Permit Application Support Drawings (Attachment A of Appendix A). Planned borrow locations listed are for cost estimate purposes; borrow locations will be refined based on additional data collected prior to construction.

3.3.2 Detailed Cost Estimate

A detailed cost estimate for the initial year of HRF liner construction is provided as Large Table 2. The cost estimate provides:

- a listing of each of the construction materials required for the initial year of HRF liner construction
- the unit of measure and quantity for each construction material
- an estimate of unit price for each construction material, based on evaluation of unit pricing provided by independent construction contractors
- the cost estimate extension
- comments providing additional context for the cost estimates

The detailed estimate is expected to serve as the basis for the first annual Dam Inspection Fee due from PolyMet to the DNR. As noted in Section 3.2.1, it is anticipated that DNR annual Inspection Fees for the HRF will initiate upon construction of the HRF liner system, which in turn is anticipated to begin the year following completion of preload construction. Estimates will subsequently be replaced by actual costs incurred at the time of construction. Some material types are included in Large Table 2 with quantities of zero, because they will be used in future years but not the initial year of HRF construction. Quantities for these materials will be added at the time of the applicable cost estimate update.

3.4 Plans and Specifications

As previously noted, HRF Permit Application Support Drawings are provided with the Residue Management Plan (Attachment A of Appendix A). Construction specifications for HRF construction are also provided with the Residue Management Plan (Attachment G of Appendix A). The construction specifications have been prepared absent a final decision by PolyMet on project implementation approach (e.g., Design-Bid-Build, Engineer-Procure-Construct). Construction specifications will be updated as deemed appropriate by PolyMet once project permits are received and a project implementation approach selected.

3.5 Classification of Dams and Dam Break Analysis

Per Minnesota Rules, part 6115.0340, all existing and proposed dams shall be classified by the commissioner into one of three hazard classes – those dams where failure, misoperation, or other occurrences or conditions would probably result in:

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;

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

Class III: property losses restricted mainly to rural buildings and local county and township roads which are an essential part of the rural transportation system serving the area involved.

A dam break analysis was completed to fulfill dam safety permitting requirements (Attachment L to Appendix A). No plausible HRF dam failure scenarios were identified. PolyMet has prepared a Contingency Action Plan for the HRF (Attachment K of Appendix A) which supports the safe operation of the HRF dams by defining responsibilities and providing procedures for identifying and responding to unexpected and potentially hazardous conditions threatening the integrity and performance of the HRF.

The Minnesota Department of Natural Resources (DNR) has not yet classified the proposed Hydrometallurgical Residue Facility dams, but it is anticipated that they will be classified as Class II dams. The HRF dams have been designed to achieve necessary factors of safety (Geotechnical Data Package – Volume 2, (Reference (2)), so a dam break is unlikely. However, if an HRF dam failure were to occur, consequences will be primarily environmental. The site is generally remotely located from any public roadways or utilities, it is separated from Project infrastructure by natural high ground, and its design is such that even if a failure occurred, nearby rail embankments would likely be unaffected due to their location and configuration relative to proposed HRF dams.

3.6 Permit Standards

The items required under Permit Standards have been previously submitted to the DNR and are referenced in Large Table 1.

4.0 References

1. **Minnesota Department of Natural Resources, U.S. Army Corps of Engineers and United States Forest Service.** Final Environmental Impact Statement: NorthMet Mining Project and Land Exchange. November 2015.

2. **Poly Met Mining Inc.** NorthMet Project Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (v6). July 2016.

3. —. NorthMet Project Wetland Data Package (v11). April 2015.

4. —. NorthMet Project Water Modeling Data Package Volume 2 - Plant Site (v11). March 2015.

5. —. NorthMet Project Waste Characterization Data Package (v12). February 2015.

6. —. NorthMet Project Air Quality Management Plan - Plant (v7). December 2014.

7. **Barr Engineering Co.** Permit to Mine Application. Prepared for Poly Met Mining, Inc. NorthMet Project. June 2017.

Large Tables

Large Table 1 Hydrometallurgical Residue Facility Dam Safety Permit Requirements: Correlation Table

Subsection of Minnesota Rules Part 6115.0410[(1)]	Rule Citation[(2)]	Rule Requirement[(3)]	Source Document[(4)]	Section and Page Number in Source Document[(5)]
General Permit Application	6115.0410 (2)(B)	Purpose	Residue Management Plan - Hydrometallurgical Residue Facility (Appendix A)	Section 1.0, pages 2-3
	MPARS Application	Project purpose and need.	Final Environmental Impact Statement (Reference (1))	Section 1.3 (Overall Project), pages 11-13 of Section 1
			Residue Management Plan - Hydrometallurgical Residue Facility (Appendix A)	Section 1.0, pages 2-3
	6115.0410 (2)(C)	Location, type, size, and height of the dam.	Residue Management Plan - Hydrometallurgical Residue Facility (Appendix A)	Section 2.2, pages 7-8
	6115.0410 (2)(D)	Storage capacity of impoundment.	Residue Management Plan - Hydrometallurgical Residue Facility (Appendix A)	Table 2-2, page 8
	MPARS Application	Project description, including a description of all project elements that effect aquatic resources (wetlands, streams, etc.).	Final Environmental Impact Statement (Reference (1))	Sections 3.0 through 6.0
		Plans and cross-section or profile drawings showing the location, character, and dimensions of all proposed activities and aquatic resource impacts.	Dam Safety Permit Application for HRF	Attachment A of Appendix A
			Wetland Data Package (Reference (3))	Large Figure 10 and Large Figure 25
		Description of direct or indirect impacts to aquatic resources.	Wetland Data Package (Reference (3))	Sections 5.1.6 and 5.2.2, pages 21, 48-56
Preliminary Design Report	6115.0410 (3)(A)	A general statement setting forth the effect on the environment.	Final Environmental Impact Statement (Reference (1))	Section 4.0, page 1 of Section 4
	6115.0410 (3)(B)	Maps showing the location of county, township, and section lines; the outline of the impoundments; the location of state, county, and township roads; the locations of utilities, e.g., pipelines, transmission, telegraph, and telephone lines; the topography; and other structure or facilities including dwellings affected by the proposed dam.	Dam Safety Permit Application for HRF	Large Figure 1, Large Figure 2
	6115.0410 (3)(C)	A report of surface conditions, i.e., geology, topography.	Water Modeling Data Package - Plant Site (Reference (4))	Section 4.3, pages 14-16
	6115.0410 (3)(D)	Typical cross-sections of the dam accurately showing elevations, proposed impoundment levels and top width.	Dam Safety Permit Application – HRF Permit Application Support Drawings	Attachment A of Appendix A
	6115.0410 (3)(E)	Logs of borings in the foundation and in the borrow areas.	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2))	Attachment B
		Results of seismic and resistivity subsurface investigations, when they are readily available.	Reports are not readily available, therefore this requirements is not applicable.	
	6115.0410 (3)(F)	Preliminary design assumptions, operational aspects, tentative conclusions, and references. The design assumptions shall pertain to such hydrologic features as drainage area, rainfall data, runoff, inflow, area-capacity-elevation data, and flood routing, in addition to structural, geologic, and geotechnical assumptions.	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2))	Sections 4.0 through 6.0
	6115.0410 (3)(G)	A preliminary cost estimate.	Dam Safety Permit Application for HRF	Large Table 2
	6115.0410 (3)(H)	Future plans on ultimate project size including dams and impoundments.	Dam Safety Permit Application – HRF Permit Application Support Drawings	Attachment A of Appendix A
	6115.0410 (3)(I)	A general description of all other activities and elements related to and part of the total dam project, such as operational plans and details of smaller dams, dikes, diversions, reclaim water facilities, and other facility and utility lines including pipelines, roads, and railroads. The report shall identify each element or activity of the total dam project which would require a permit under the provisions of parts 6115.0150 to 6115.0260.	Dam Safety Permit Application for HRF	Table 3-1

Subsection of Minnesota Rules Part 6115.0410[1]	Rule Citation[2]	Rule Requirement[3]	Source Document[4]	Section and Page Number in Source Document[5]
Final Design Report	6115.0410 (6)(A)	General description of the project, such as its service life, production rates, required storage and area(s).	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 1.0, pages 2-3
		Geological considerations such as physiography, topography, geology, seismicity, and groundwater conditions.	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2)	Section 3.2, pages 6-11
		Hydrologic Studies such as:		
		physical features, climatology	Water Modeling Data Package - Plant Site (Reference (4))	Sections 4.1 and 4.2, pages 13-14
		design storm and design flood characteristics, flood routing	Dam Safety Permit Application	Section 3.5, page 5
		water-material balance	Water Modeling Data Package - Plant Site (Reference (4))	Section 6.1.3, page 135
		free-board requirements	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 4.1, pages 20-21
		dam-break flood	Dam Safety Permit Application for HRF	Section 3.5, page 11
		geotechnical information, such as rock-soil sampling and logging, geophysical investigations, field and lab testing, instrumentation data	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2)	Attachments
		considerations of construction materials and their properties, such as quantities required, borrow and aggregate locations and volumes, field and lab work and investigations, concrete, waste materials generation and placement techniques	Dam Safety Permit Application for HRF	Table 3-2 (Construction Material Quantities and Borrow Locations), and Attachment G of Appendix A(Construction Specifications)
		investigation of the stored waste materials such as generation, transportation, mechanical/chemical/special testing, disposal practice	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2)	Section 4.0, pages 12-13
			Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 2.1, pages 4-7
			Waste Characterization Data Package (Reference (5))	Section 6.0, pages 42-46
	6115.0410 (6)(B)	Seepage analysis	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2)	Section 5.3, pages 31-32
		Stability, deformation, and settlement analysis.	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2)	Section 6, pages 41-57
		Design details of facilities, such as dam, foundation, impoundment, abutments, spillways or decant facilities, diversions, outlet works, and instrumentation.	Dam Safety Permit Application – HRF Permit Application Support Drawings	Attachment A of Appendix A
			Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 5.5 (Instrumentation), pages 27-31
		Operational aspects, such as impoundment operating criteria, initial filling criteria, responsibility and coordination, emergency procedures, and warning systems.	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 4.4 (Operational Plan), pages 20-23
			Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Attachment K (Contingency Action Plan)
		Air, water, and solid pollution controls, sedimentation, and erosion controls.	Air Quality Management Plan – Plant (Reference (6))	Attachment A (Fugitive Emissions Control Plan)
			Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Sections 2.2.2 and 4.3 (Double liner and leakage system), pages 8-15, and page 22
			Dam Safety Permit Application – HRF Permit Application Support Drawings	Attachment A of Appendix A
			Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Sections 5.0 and 7.0 (Erosion), pages 24-31, and 33-36
		Operational and post-operational maintenance and abandonment considerations.	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Sections 4.0 and 7.0, pages 20-23, and pages 33-36
		Surveillance and inspection programs.	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 5.0 and Attachment J, pages 24-31, and pages 1-6 of Attachment J
	6115.0410(6)(C)	Detailed cost estimate.	Dam Safety Permit Application for HRF	Large Table 2
Plans and Specifications	6115.0410 (7)(A-C)	Plans	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Attachment A
		General Provisions	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Attachment G
		Technical Specifications	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Attachment G

Subsection of Minnesota Rules Part 6115.0410[1]	Rule Citation[2]	Rule Requirement[3]	Source Document[4]	Section and Page Number in Source Document[5]
Permit Standards	6115.0410 (8)(B)	Lack of other suitable feasible and practical alternative sites and that the dam will benefit the population or socioeconomic base of the area involved.	Final Environmental Impact Statement (Reference (1))	Section 3
	6115.0410 (8)(C)	The need in terms of quantifiable benefits.	Final Environmental Impact Statement (Reference (1))	Section 1.3.2.1, page 11 of Section 1
	6115.0410 (8)(D)	The stability of the dam, foundation, abutments, and impoundment under all conditions of construction and operation, including consideration of liquefaction, shear, or seepage failure, overturning, sliding, overstressing and excessive deformation, under all loading conditions including earthquake. This determination must be based on current, prudent engineering practice, and the degree of conservatism employed must depend on hazards.	Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (Reference (2)	Section 6.0, page 41-57
	6115.0410 (8)(E)	Discharge and/or storage capacity capable of handling the design flood based on current, prudent engineering practice and the hazard classification.	Residue Management Plan - Hydrometallurgical Residue Facility Appendix A)	Section 2.5, pages 17-18
	None. Information requested by DNR on 10/31/13.	Financial Assurance.	Permit to Mine Application (Reference (7))	Section 16

(1) Section – Denotes the primary sub-sections of Minnesota Rules, part 6115.0410 for Dam Safety Permitting.
(2) Rule Citation – Denotes the sub-section of the Rule that the Permit Application content addresses.
(3) Rule Requirement – Provides a summary statement of the content requirement of each sub-section of the Rule.
(4) Document – Lists the document containing the content/information required by the cited Rule.
(5) Section and Page Number – Lists the document's section and page number on which the content/information required by the Rule is located.

Large Table 2 Hydrometallurgical Residue Facility Phase 1 Construction Cost Estimate

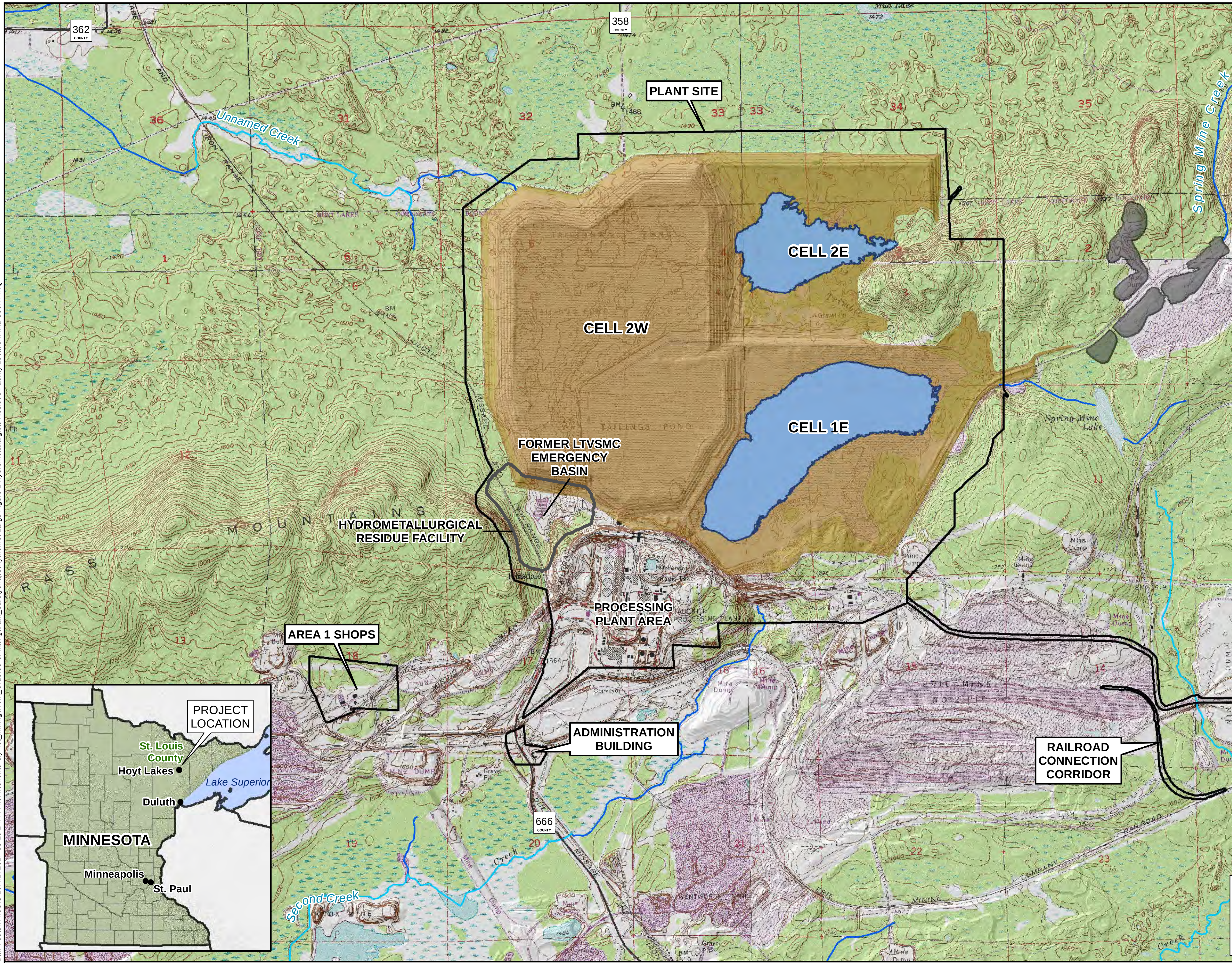
Item	Description	Unit	Phase 1 Quantity	Contractor Estimate	Cost Extension[1]	Comments
1	**Mobilization and Demobilization**	LS	1	$448,000.00	$448,000	Project Setup, Equipment Mob. and Demob., Routine Project Admin., Health and Safety, Etc.
2	**Ancillary Activities**				$0	See Below
2.a.	Environmental Protection Measures	LS	1	$4,800.00	$5,000	Environmental Protection Requirements - Inspect and Repair Prior Year Installations
2.b.	Temporary Dewatering and Pumping	LS			$0	None
3	**Strip Vegetation**	Acre	0		$0	None
4	**Fine Grading and Surface Compaction - Liner Subgrade**	SY	0		$0	None
5	**Bulk Earthwork**				$0	See Below
5.a.	Topsoil Excavation and Stockpile	CY	0		$0	In-Place Cubic Yards
5.b.	Coarse Tailings Borrow	CY	0		$0	In-Place Cubic Yards
5.c.	Common Borrow	CY	0		$0	In-Place Cubic Yards
5.d.	Common Excavation and Stockpile	CY	0		$0	In-Place Cubic Yards
6	**Geosynthetics**				$0	See Below
6.a.	Geosynthetic Clay Liner	SF	2,169,900	$0.66	$1,423,000	CETCO CN or Engineer Approved Equal
6.b.	80 mil White LLDPE Geomembrane - Textured (Smooth on Base of HRF)	SF	2,169,900	$0.72	$1,562,000	GSE or Engineer Approved Equal White Textured LLDPE
6.c.	60 mil White LLDPE Geomembrane - Textured (Smooth on Base of HRF)	SF	2,169,900	$0.60	$1,302,000	GSE or Engineer Approved Equal White Textured LLDPE
6.d.	Non-woven Geotextile	SY	171,300	$1.60	$274,000	Between Granular Drainage Material and Geomembrane
7	**Drainage Collection System**				$0	See Below
7.a.	Drainage Collection Trench	LF	0		$0	Grading of Trench, Furnish and Install Granular Material and Geotextile
7.b.	Geocomposite Drainage Layer	SY	0		$0	GSE 10 oz./sq. yd. Fabrinet HF or Engineer Approved Equal
7.c.	20" Dia. DR 160 HDPE Sidewall Riser Pipe	LF	0		$0	Includes Pipe, Geotextile, and Embedment
7.d.	Furnish and Install Surepump	EA	0		$0	Includes Pump, Sensors, Hose, and all Pipe and Fittings up to Connection with 4" diam. Dewatering
7.e.	Geocomposite	SY	32,600	$6.00	$196,000	None
7.f.	Granular Drainage Material (geocomposite cover and miscellaneous)	CY	110,600	$9.60	$1,062,000	Assumed 2' Cover Over Basin Bottom
7.g.	20" Dia. HDPE SDR 11 Sidewall Riser Pipe	LF	340	$88.00	$30,000	None
7.h.	12" Dia. HDPE SDR 11 Perforated Sump Pipe	LF	50	$88.00	$4,000	None
7.i.	12" Dia. HDPE SDR 11 14° Bend	EA	2	$720.00	$1,000	None
7.j.	Corrugated Metal Pipe Over Riser	LF	40	$24.00	$1,000	None
7.k.	Furnish and Install Pump and Skid Assembly	EA	2	$18,754.00	$38,000	None
7.l.	20"x12" HDPE SDR 11 Reducer	EA	2	$960.00	$2,000	None
8	**Return Water System**				$0	See Below
8.a.	Furnish and Install Return Water Pumps [1]	LS	1	$650,816.00	$651,000	Incl. Pumps, Pump Raft, Floating Walkway Access (200'), Fittings, Flexible Hose
8.b.	Furnish and Install 6-inch Diameter DR17 HDPE Pipe	LF	350	$18.40	$6,000	Pipe from Return Water Pump to Flow Meter. Assumed 150' on Float and 200' to Flow Meter
8.c.	Furnish and Install Return Water Flow Meter	EA	1	$12,800.00	$13,000	Fittings, Meter, Valve, 6" 8'x10' Concrete Slab, and all Pipe up to 90 Bend Connection with 8" HDPE
8.d.	Furnish and Install 8-inch Diameter DR17 HDPE Pipe	LF	3,700	$24.00	$89,000	Pipe from Flow Meter to Booster Pumphouse
9	**Various Mechanical**				$0	See Below
9.a.	Furnish and Install 6-inch Diameter DR11 HDPE Pipe	LF	6,900	$20.00	$138,000	Discharge Pipe and Auxiliary Pipe
9.b.	Furnish and Install Discharge Point	EA	6	$4,800.00	$29,000	Tee, Valve, 12" Casing, Valve Cover, 4" Compressor Pipe, Flexible Hose Connect and Necessary Fittings
9.c.	Furnish and Install 6-foot Diameter Manhole	LF	24	$600.00	$14,000	None
9.d.	Furnish and Install 8-foot Diameter Manhole	LF	10	$960.00	$10,000	3 x 8'-Deep MH
9.e.	Furnish and Install Cleanout Valve	EA	6	$4,800.00	$29,000	None
9.f.	Furnish and Install Pig Launch Valve	EA	5	$17,600.00	$88,000	None
10	**Exterior Dike Slope Erosion Control - Topsoil, Seed, Mulch and**	Acre	0		$0	4" Topsoil, Shallow Rooted Grasses, Fertilizer, and Spray Applied Mulch
11	**Site Restoration**	Acre	0		$0	Seed, Fertilize and Mulch Disturbed Areas Including Stockpiles (See Item Above for Dike Slopes)
12	**System Start-up and Trouble Shooting**	LS	1	$7,200.00	$7,000	None

Item	Description	Unit	Phase 1 Quantity	Contractor Estimate	Cost Extension[1]	Comments
13	**Leakage Detection System**				$0	See Below
13.a.	Geocomposite	SY	241,100	$6.00	$1,447,000	None
13.b.	Granular Drainage Material	CY	2,400	$20.00	$48,000	None
13.c.	20" Dia. HDPE SDR 11 Sidewall Riser Pipe	LF	370	$88.00	$33,000	None
13.d.	12" Dia. HDPE SDR 11 Perforated Sump Pipe	LF	200	$88.00	$18,000	None
13.e.	12" Dia. HDPE SDR 11 14° Bend	EA	2	$720.00	$1,000	None
13.f.	Corrugated Metal Pipe Over Riser	LF	40	$60.00	$2,000	None
13.g.	Furnish and Install Pump and Skid Assembly	EA	2	$69,754.00	$140,000	None
13.h.	20"x12" HDPE SDR 11 Reducer	EA	2	$960.00	$2,000	None
14	**Pipe Trench**	LF	1,200	$20.00	$24,000	Trench for Discharge, Auxiliary and Return Pipe
Construction Cost Estimate - Hydrometallurgical Residue Facility Phase 1					**$9,140,000**	

Note: Mine Year 5 is the first year of liner construction, the first year in which the HRF can retain water, and anticipated to be the first year in which DNR dam safety inspections are expected to occur.

(1) Cost extensions rounded to nearest $1,000.

Large Figures



[1] These are provisional representations of PWI watercourses found on the current paper regulatory maps. Due to previous disturbance, data sources may show watercourses that no longer exist.
[2] The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD features are created from DNR 24K Streams and 1:24,000 USGS quadrangle maps. Due to previous disturbance, data sources may show watercourses that no longer exist.

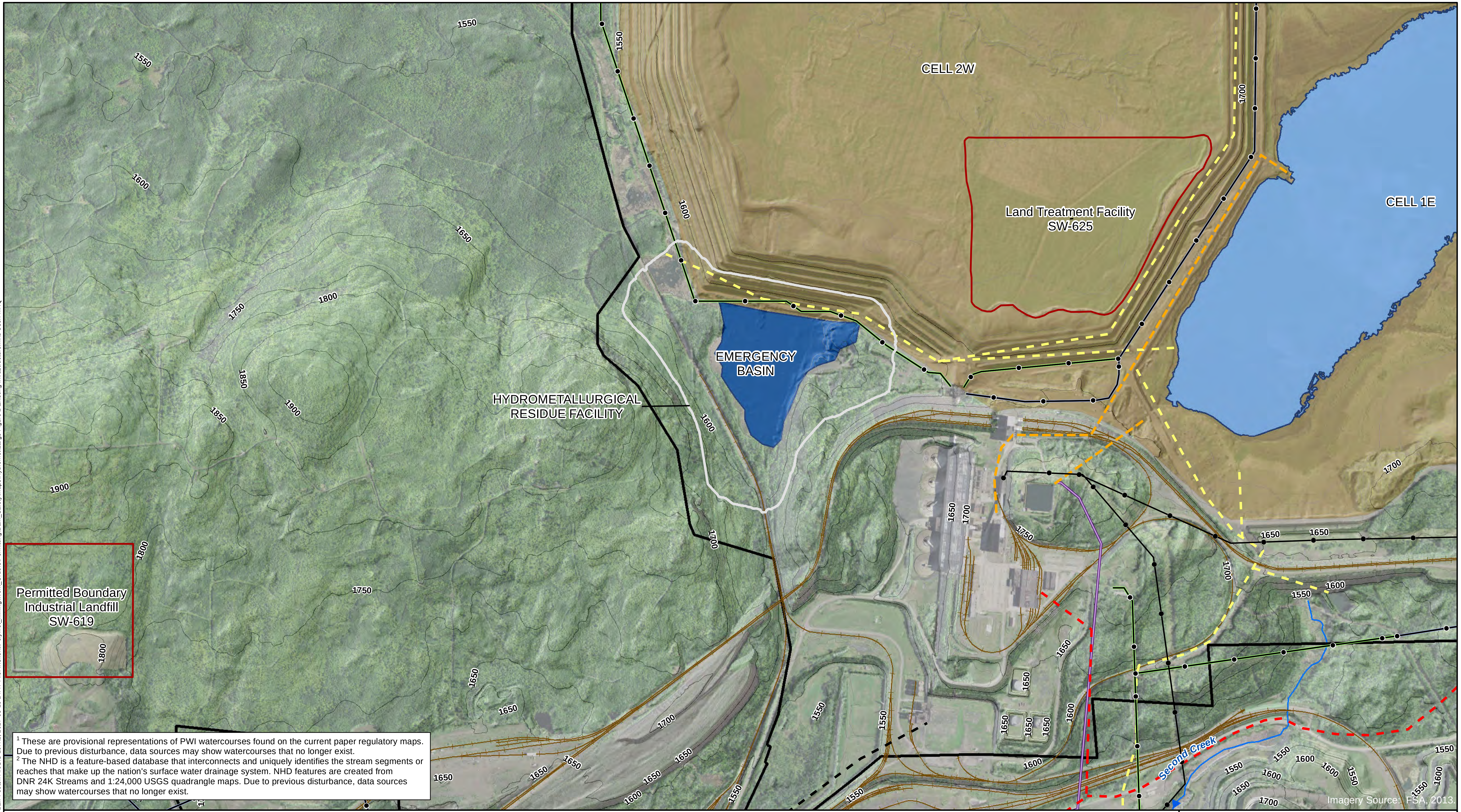
- EIS Project Areas
- Existing Tailings Basin
- Tailings Ponds
- Area 5 Stockpile Footprints
- Public Waters Inventory (PWI) Watercourses[1]
- National Hydrography Dataset (NHD) Rivers & Streams[2]

0 1,500 3,000 6,000
Feet

BARR

HYDROMETALLURGICAL RESIDUE FACILITY LOCATION
NorthMet Project
Poly Met Mining, Inc.

Large Figure 1
Dam Safety Permit Application



[1] These are provisional representations of PWI watercourses found on the current paper regulatory maps. Due to previous disturbance, data sources may show watercourses that no longer exist.
[2] The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD features are created from DNR 24K Streams and 1:24,000 USGS quadrangle maps. Due to previous disturbance, data sources may show watercourses that no longer exist.

- EIS Project Areas
- Existing Tailings Basin
- Tailings Ponds
- Area 5 Stockpile Footprints
- Solid Waste Facilities - Approximate Boundaries
- Existing Private Railroad
- Colby Lake Pipeline
- Existing Pipelines
  - Tailings Water Management (Suface)
  - Tailings Water Management (Underground)
  - Inter-Pit Pipeline for Shop Water Supply (Underground)
  - Natural Gas Line (Underground)
- Power Lines In Use
- Power Lines Not In Use
- Public Waters Inventory (PWI) Watercourses[1]
- National Hydrography Dataset (NHD) Rivers & Streams[2]

0 500 1,000 2,000
Feet

BARR

HYDROMETALLURGICAL RESIDUE FACILITY AREA
EXISTING INFRASTRUCTURE
NorthMet Project
Poly Met Mining, Inc.

Large Figure 2
Dam Safety Permit Application

Appendices

Appendix A

Residue Management Plan

POLYMET
MINING

NorthMet Project

Residue Management Plan

Version 6

Issue Date: May 15, 2017

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

Certifications

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.

Thomas J. Radue

Thomas J. Radue, P.E.
PE #20951
Senior Geotechnical Engineer

05/15/2017

Date

Table of Contents

Acronyms, Abbreviations and Units

Acronym	Stands For
ASTM	American Society for Testing and Materials
DSI	Dam Safety Inspection
DSR	Dam Safety Review
CAP	Contingency Action Plan
GCL	Geosynthetic Clay Liner
HDPE	High Density Polyethylene
HRF	Hydrometallurgical Residue Facility
LTVSMC	LTV Steel Mining Company
FTB	Flotation Tailings Basin
DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
QA/QC	Quality Assurance and Quality Control
SDS	State Disposal System
WWTS	Waste Water Treatment System

1.0 Introduction

This document describes the Residue Management Plan for Poly Met Mining Inc.'s (PolyMet) NorthMet Project (Project). The Project is described in the Final Environmental Impact Statement (Reference (1)). The Project will utilize hydrometallurgical processing to recover metals from flotation concentrate and the combined hydrometallurgical residue (Residue) will be placed in the Hydrometallurgical Residue Facility (HRF). The HRF will be a lined facility constructed on top of the Emergency Basin located to the northwest of the Process Plant near the southwest corner of the Tailings Basin.

In this document Tailings Basin is the existing former LTV Steel Mining Company (LTVSMC) tailings basin, Flotation Tailings Basin (FTB) refers to the Tailings Basin with PolyMet's Flotation Tailings impounded atop, and Emergency Basin is the existing former LTVSMC Emergency Basin.

The Hydrometallurgical Plant, which will begin operations several years after mining commences, will generate up to approximately 313,000 tons of Residue annually, if the plant processes all the nickel flotation concentrate streams produced by the flotation process. Some nickel flotation concentrates may be sold directly, depending on customer requirements and project economics, in which case less Residue would be generated. The Residue will be a slurry of fine sand, silt and clay-size particles, with individual particle diameter on the order of 0.5 millimeters or less. The slurry will be pumped from the Hydrometallurgical Plant to the HRF. The HRF will be one double-lined cell with geomembrane and geosynthetic clay liners. The Residue will settle out within the HRF and the remaining process water will be pumped from the HRF back to the Hydrometallurgical Plant. Water will be lost from this closed loop system to evaporation from the cell surface and entrapment within the Residue's pore space. The HRF liner system will limit leakage from the cell bottom. Precipitation falling within the HRF will be retained. Perimeter dams of the HRF will be configured to prevent surface water run-on into the HRF. The slurry discharge will be configured such that the discharge point into the cell can periodically be adjusted (vertically and horizontally) to distribute Residue uniformly within the cell. The HRF liner and dams will be raised to allow for Residue deposition for the life of the cell (approximately 17 to 18 years) after which the cell will be closed with a temporary and then a final cover system. The layout of the HRF is shown in Hydrometallurgical Residue Facility Permit Application Support Drawings HRF-001 through HRF-024 (Attachment A).

Personnel who will be responsible for HRF management are:

- *Operations Contact* - Beneficiation Division Manager or designee - Responsible for overall HRF design, planning, operations, maintenance, and monitoring.

- *Design Engineer* (an independent consultant and Minnesota-registered Engineer retained specifically for dam safety expertise) - Responsible for performance monitoring, data analysis and interpretation, dam safety inspection and reporting assistance, HRF dam planning and design assistance, and permitting assistance.

1.1 Outline

The outline of this document is:

Section 1.0 Introduction and description of existing conditions

Section 2.0 HRF Design

Section 3.0 Summary of HRF geotechnical analysis outcomes

Section 4.0 Description of operational plans including Residue Transport and Deposition System, Return Water System, Leakage Collection System and General Maintenance

Section 5.0 Description of HRF monitoring activities including monitoring of dams, Residue Transport and Deposition System, Return Water System, Leakage Collection System and Stormwater Management System

Section 6.0 Description of annual reporting requirements including compliance to plan and waste characterization update

Section 7.0 Description of the reclamation and postclosure plan for the HRF

This document is intended to evolve through the environmental review, permitting [Minnesota Pollution Control Agency (MPCA) State Disposal System (SDS), Minnesota Department of Natural Resources (DNR) Division of Ecological and Water Resources, Dam Safety Unit, and DNR Permit to Mine], operating, reclamation and postclosure phases of the Project. It will be reviewed and updated as necessary in conjunction with changes that occur in facility operating and maintenance methods or requirements. A Revision History is included at the end of the document.

1.2 Existing Conditions

The HRF will be located on top of the Emergency Basin which is near the southwest corner of the Tailings Basin as show on Drawing HRF-003 of Attachment A. It will be constructed on mostly disturbed ground and will take advantage of existing topographic features to reduce the material needed for dam construction. A railroad grade will be abandoned and removed to facilitate HRF construction. This area and its history are further described in Section 3.0 of Geotechnical Data Package - Volume 2 (Reference (2)).

2.0 HRF Design

The design of the HRF is based on a number of factors including State of Minnesota Rule requirements, expected Residue generation rates, hydrology within the HRF, geotechnical considerations (slope stability, strain in liner system, and leakage), and HRF operating plans. The timing for start-up of the Hydrometallurgical Plant and the HRF will depend primarily on commodity prices. The HRF has been designed with capacity for approximately 17 to 18 years of operations (life depends primarily on final in-place Residue density).

Based on a review of historical data, a study of the Residue properties, and geotechnical evaluations, it is feasible to construct the HRF on the Emergency Basin site. To manage water resource impacts, the HRF will have a double liner and a Leakage Collection System. Leakage is water that leaks through the upper layer of the liner system. The HRF will also have a Drainage Collection System that will be used during reclamation to speed Residue dewatering. Drainage is water that flows through the Residue and is collected above the upper layer of the liner system.

Additional HRF design 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 the FTB. These materials represent a 5% to 6% addition to solids volume and are not expected to require significant alterations in the HRF design (Sections 6.1.1 and 6.3.1 of Reference (2)), especially considering the currently anticipated operating life for the HRF of 17 to 18 years.

The following paragraphs provide an overview of the HRF design. Development plans are presented on Drawings HRF-001 through HRF-024.

2.1 Residue Characterization

The hydrometallurgical process generates several types of residues. During the pilot-plant processing, samples of each type of residue and the combined Residue were collected for laboratory testing to determine geochemical and geotechnical parameters. The results are used in HRF sizing, slope stability analyses, and design of the Drainage and Leakage Collection Systems. The pilot-plant residue sample and grain-size distribution are believed to be representative of that expected from the commercial plant. Once operations start, Residue samples will be collected and analyzed for chemical and physical properties to confirm data used in HRF design. Because the HRF design will utilize a downstream configuration for dams, slope stability will not be sensitive to the physical properties of the Residue. Because the Residue contains a large percentage of gypsum (calcium sulfate - CaSO4) and minerals shown in Table 2-1, the primary polyethylene liner system will not be sensitive to the chemical properties of the Residue. The geosynthetic clay liner (GCL) component of the HRF liner system will be somewhat sensitive to chemical properties of the Residue and testing to confirm GCL performance is discussed in Section 2.2.

2.1.1 Geochemical Characterization

The results of initial chemical testing and long-term kinetic testing of the Residue are presented in Section 6 of the Waste Characterization Data Package (Reference (3)).

The Residue is made up of precipitates from the sources shown in Table 2-1.

Table 2-1 Hydrometallurgical Residue Streams

Residue	Tons/Hour	Tons/Year	Mineralogy
Leach Residue	13.52	106,600	63% natrojarosite [$NaFe^{3+}_3(SO_4)_2(OH)_6$] 17.4% hematite [$Fe_2O_3$] 6.9% gypsum [$CaSO_4 \cdot H_2O$] 5.8% plagioclase [$Na_{0.5}Ca_{0.5}Si_3AlO_8$] 3.9% talc [$Mg_3Si_4O_{10}(OH)_2$] 3% quartz [$SiO_2$]
Iron and Aluminum	24.45	192,800	98.9% gypsum 0.8% goethite 0.3% quartz
Magnesium Residue	1.695	13,400	76.8% gypsum 22.2% brucite [$Mg(OH)_2$] 0.8% halite [NaCl] 0.2% quartz
Total Residue Flow (Solids)	39.67	312,800	N/A
Total Residue Flow Repulped to 45% Solids (Solution)	47.79	376,800	N/A

Note: Tons/Year is on the basis of 7,884 Hydrometallurgical Plant operating hours per year.

Humidity cell tests on residues showed an initial rapid flush of acidity and metals as process water was rinsed from the residues. As the tests proceeded, the individual leachates remained acidic but leaching of metals and acidity decreased, reflecting dissolution of the residues. Sulfate concentrations remained elevated due to ongoing dissolution of gypsum.

Individual and combined samples of the NorthMet hydrometallurgical residues were used to develop an overall understanding of the residues. Results indicate that:

- leach residue is acidic
- magnesium removal residue contains significant neutralizing material
- there is potential for acid generation to be greater than neutralizing capacity in the long term, therefore lime or limestone will be blended with the Residue prior to disposal in the lined HRF

Individual residues and the combined Residue are not hazardous wastes. All of the residues that were produced during continuous pilot-plant testing (2005 bulk hydrometallurgical and 2009 nickel hydrometallurgical) represent the Residues that will be contained in the HRF if the project is approved. All residues produced were analytically tested, both as separate residue samples and as a combined residue, and all results were below the RCRA hazardous waste thresholds, indicating that for the parameters analyzed (metals), the hydrometallurgical residue is not characteristically hazardous. The results of this analytical test work is summarized in detail in Attachment B and Attachment C.

In addition to the above-listed sources, solid wastes from the Waste Water Treatment System (WWTS) would be recycled directly into the Hydrometallurgical Plant to recover metals, creating additional waste. The WWTS solids would be similar to the hydrometallurgical residue, consisting primarily of gypsum, metal hydroxides, and calcite.

During LTVSMC operations, fly ash, dredging spoil, and coal pile cleanup material were placed in a solid waste storage site (Coal Ash Landfill) to the east of Tailings Basin Cell 1E. The location of this landfill would be inundated by tailings in approximately Mine Year 7 of Tailings Basin operation. Therefore, the contents would be analyzed and relocated to the HRF, or other approved facility, prior to that time.

The water treatment plant solids will be primarily gypsum. Coal ash from air quality control systems frequently contains a large percentage of gypsum, depending on design and operating characteristics of the power plant boiler and air quality control systems. The proposed HRF liner system is suitable for acceptance of gypsum. Water treatment plant solids and coal ash are a minor component of the overall waste stream to be disposed of in the HRF. The treatment plant solids will be characterized as part of any future treatment plant pilot-testing and the coal ash will be characterized prior to removal. If it is determined that these materials are for any reason not compatible with co-disposal with the Residue, then alternate management plans will be developed.

2.1.2 Geotechnical Parameters

Geotechnical parameters of the Residue are presented in Section 4.4 of Reference (2). In summary:

- Grain-size and hydrometer analysis (by ASTM Method D422) on a composite sample of the Residue is summarized as follows:
  - Sand Content: 15% by weight
  - Silt Content: 84% by weight
  - Clay Content: 1% by weight
- Recommended Specific Gravity for Design
  - 2.75
- Recommended In-Place Density for Design
  - 80 Pounds/Cubic Foot Dry
  - 115Pounds/Cubic Foot Saturated
- Recommended Effective Shear Strength Friction Angle
  - 30 Degrees

2.2 Dam and Liner Design

2.2.1 Dams

Design of the HRF dams is based on field and laboratory testing of Residue and the Emergency Basin as described in Reference (2). Dams will be constructed using downstream construction methods wherein the interior segments of the dam are constructed first, then the dam is raised upward and outward from the center of the cell as additional HRF capacity is needed. Dam development is shown in plan view and cross-section on Drawings HRF-008 through HRF-012. The dams will be constructed using soil borrow and possibly quarried rock from the hills adjoining the HRF to the southeast and southwest as shown on Drawing HRF-005. LTVSMC coarse tailings may also be utilized if needed to supplement the other borrow sources. Southeast and southwest segments of the HRF dam will abut existing high ground. The north HRF dam will abut Tailings Basin Cell 2W.

Prior to construction of the primary stand-alone dam segment for the HRF, consisting of the dam segment on the northwest corner of the facility, any unsuitable foundation materials will be improved through pre-load application described later, or by excavation and replacement of unsuitable foundation materials. Dam construction material will be placed in thin lifts of approximately 12 to 15 inches in loose lift thickness. Each lift will be compacted to a specified density in order to achieve the desired dam construction material shear strength. This construction procedure enhances long-term stability of the dams and alleviates concern for slope stability failure mechanisms that could develop if dam construction material were not adequately compacted.

Exterior dam slopes will be 3H:1V to achieve adequate slope stability and to facilitate long-term maintenance. Interior dam slopes will be 4H:1V to facilitate cell liner construction and to achieve adequate liner stability. The dams will be raised in three primary construction phases as presented in Table 2-2. This is to accommodate phased liner installation. Because the dams of the cell are constructed in major increments prior to and during operations, Residue discharge points into the cell will be relocated as frequently as needed to utilize the full capacity of the cell, thereby extending the time between dam rises.

Table 2-2 HRF Development

Approx. Year Available	Phase	Crest Elevation	Approximate Cumulative Residue Capacity (Cubic Yards)
3	1	1600	1,090,000
6	2	1630	3,760,000
13	3	1650	6,170,000
Total	N/A	N/A	6,170,000

Note: Approximate Cumulative Capacity is cubic yards for Residue, water treatment plant solids, and coal ash combined. Capacity for water clarification and freeboard is above and beyond the Residue capacity presented.

2.2.2 Liner and Leakage Collection System

2.2.2.1 Liner and Leakage Collection System Design

The HRF liner system will be a double liner system; two barrier layers separated by a leakage collection layer, or liner system of performance equivalent to that of a double liner. The liner cross-section, shown on Figure 2-1 and Drawing HRF-016, will consist of:

- Upper Liner – 80-mil Linear Low Density Polyethylene (LLDPE) Geomembrane
- Leakage Collection Layer – continuous layer of Geocomposite Drainage Net (Geocomposite)
- Lower Liner – 60-mil Linear Low Density (LLDPE) or High Density Polyethylene (HDPE) above a Geosynthetic Clay Liner (GCL). The lower liner, with two barrier layer components (geomembrane liner and GCL) is commonly referred to as a composite liner.

Double liner systems (Figure 2-1) historically have provided built-in redundancy and improved performance compared to that of a single liner or composite liner and perform well when installed with industry-standard attention to quality control to minimize installation defects. The function of each component of this double liner system follows:

- Upper Liner – the upper liner serves as the primary barrier to leakage from the HRF. Its thickness is selected for durability and to resist ice impacts in the event of any temporary shutdowns of the hydrometallurgical process in winter months.

- Leakage Collection Layer – The leakage collection layer will collect any leakage that passes through defects in the upper liner. The leakage collection layer is included in the liner system because typically, even with application of industry-standard quality control procedures during installation of the upper liner, some installation defects can remain. The leakage collection layer directs leakage to a sump from which it will be pumped back to the HRF pond. Together, the leakage collection layer and the associated sump, pumps and piping comprise the Leakage Collection System.

- Lower Liner – the lower composite liner provides a virtually leak free barrier to prevent leakage that may pass through the upper liner from leaving the HRF. Leakage retained above the lower liner will be collected by the Leakage Collection System.

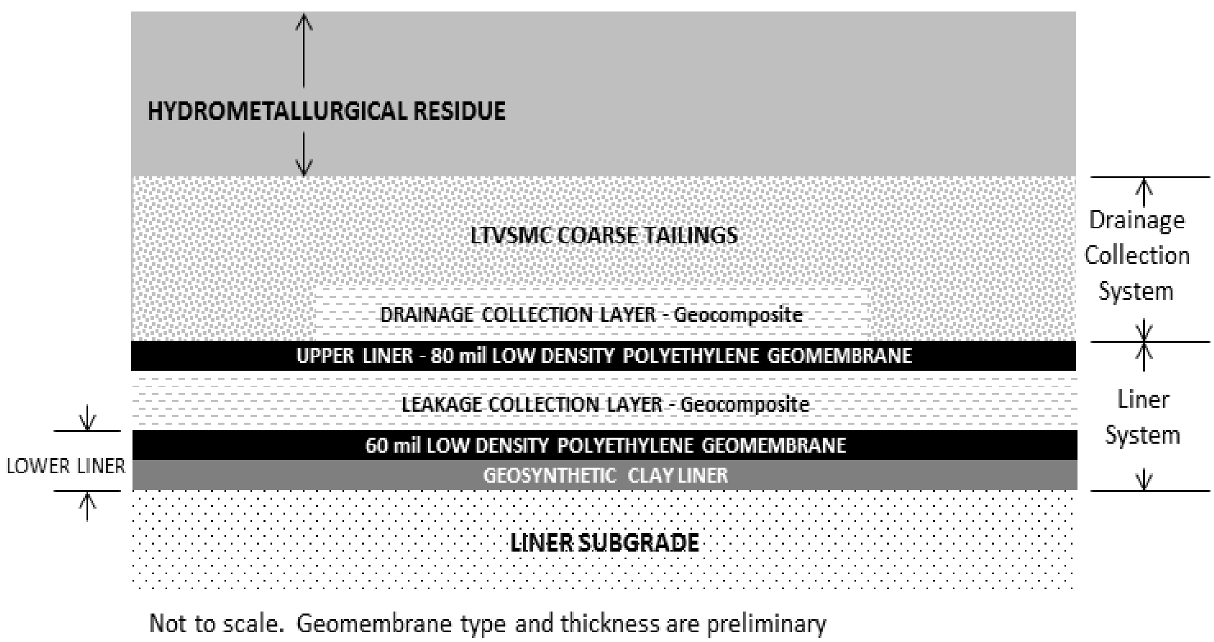


Figure 2-1 HRF Liner System and Drainage Collection System

During operations the Leakage Collection System will recycle leakage back into the HRF pond. During reclamation and postclosure, the Leakage Collection System will continue to operate, but leakage will be routed to the WWTS as described in Section 7.3.1.

The proposed double liner acknowledges that historically, even with extensive quality control during geomembrane liner installation, a very limited number of installation defects may remain undetected and unrepaired during liner installation. However, recent research shows that advances in geomembrane design and installation produce defect free installations such that a double liner system may no longer be required. As environmental review and permitting proceeds PolyMet will consider the relative benefits of alternate liner configurations and if any changes are proposed, will update this Residue Management Plan and supporting documents for agency review. Any liner design changes will be required to and will be on the basis of achieving environmental protection equal to that provided by the proposed double liner system. Further, any liner design changes will require agency review and approval prior to construction.

2.2.2.2 Liner System Strain Management

Adequate long-term performance of the HRF liner system will depend in part on its ability to tolerate the strain that it will undergo during the life of the facility. Strain is a measure of the change in length of a segment of liner relative to its original length; it is most often presented in terms of percent change in length relative to original length. Evaluation of strain is important because the containment ability of a liner system will diminish significantly if integrity of the liner system is compromised as a result of excess strain.

The majority of strain on the liner system will be due to settlement of the foundation materials. To minimize strain due to settlement, a preload will be placed to consolidate sediments in the Emergency Basin prior to construction of the HRF liner system and the dams. Wick drains 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. The design and modeling of the preload are presented in Sections 5 and 6 of Reference (2). The preload will be removed once materials in the Emergency Basin have been adequately consolidated. As presented in Section 6 of Reference (2), after placement and removal of the preload, estimated strains imposed on the liner system are well below allowable strains and will not affect liner integrity.

2.2.2.3 Liner System Leakage Management

In addition to tolerating strain induced in the liner system, the liner system must provide the level of containment required for environmental protection. In this context containment refers to the rate of flow (leakage) through the liner system, measured in terms of gallons per acre per day. Flow is a function of the hydraulic conductivity of the liner system, the hydraulic conductivity of soils underlying the liner system, the specific design details of the liner (i.e., single liner, composite liner, double liner, thickness of the liner, other), quality of the installation, and the hydraulic head on the liner.

Leakage through the upper liner is intercepted by the Leakage Collection System; hence any leakage from the HRF would be through the lower composite liner. Attachment D describes the computation of flow through a composite liner system such as the geomembrane overlying the geosynthetic clay (the lower liner).

Flow through the liner is a function of the quality of the contact between the geomembrane and the underlying soil, the hydraulic head on the liner, the frequency and size of defects in the geomembrane liner, and the thickness and hydraulic conductivity of the soil underlying the geomembrane. The equation for composite liners is used to estimate leakage rate through defect areas in the geomembrane component of the composite liner, with leakage through the remainder of the composite liner area being negligible. Therefore, some estimation of number of defects per acre and the size of a typical defect in the geomembrane component of a composite liner is required in order to estimate leakage through the lower liner of the HRF. Schroeder et al., (Reference (4)) reviewed literature and case studies regarding liner installation defects and as a result recommends a defect size of one square centimeter and the defect frequencies presented in Table 2-3. “Frequency” denotes percentage of installed liners falling within installation quality range.

Table 2-3 Geomembrane Defect Density and Frequency

Installation Quality	Defect Density (number per acre)	Frequency (%)
Excellent	Up to 1	10
Good	1 to 4	40
Fair	4 to 10	40
Poor	10 to 20(1)	10

(1) Schroeder notes that higher defect densities have been reported for old facilities with poor materials, installation, operations; however, high densities are not characteristic of modern practice.

Table 2-4 presents estimated flow rates through the lower liner of the HRF as a function of the hydraulic conductivity of the GCL underlying the lower geomembrane.

Table 2-4 Composite Liner – Flow Rate vs. Hydraulic Head

Material Thickness and Material Type Below Geomembrane	Hydraulic Conductivity (K) of Material Below Geomembrane (cm/sec)	Flow Through Composite Liner (gallons/acre/day) (1) Hydraulic Head (feet)				
		1	20	40	60	80
0.021' Geosynthetic Clay Liner (GCL) (2)	5.0×10^{-9}	0	46	170	364	625
0.021' Geosynthetic Clay Liner (GCL) – CETCO R-101 Polymer-Treated GCL (3)	1.5×10^{-9}	0	19	69	147	253
0.021' Geosynthetic Clay Liner (GCL) – GSE Polymer-Treated GCL (K at 176 Days) (4)	7.2×10^{-10}	0	11	40	85	146

(1) Attachment D – Liner Leakage Rate Computations. Values presented above are average leakage rate for circular, square, and rectangular defects.
(2) The hydraulic conductivity of 5 x 10-9 cm/sec is the manufacturer reported value (for GSE Bentoliner CAR GCL and for CETCO Resistex GCL) for polymer-treated GCLs for use in moderate to high ionic strength environments.
(3) The hydraulic conductivity of 1.5 x 10-9 cm/sec is the CETCO-recommended design value for their polymer-treated GCL when tested with PolyMet synthetic HRF leachate Attachment F
(4) The hydraulic conductivity of 7.2 x 10-10 cm/sec is the 176 day test value for GSE polymer-treated GCL when tested with PolyMet synthetic HRF Attachment F

The normal operating condition for the HRF will be with 1 foot or less of hydraulic head on the lower composite liner, because the Leakage Collection System will remove leakage that passes through the upper liner. 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.

The expected chemical characteristics of the Residue are summarized in Table 2-1. The data was used in evaluation of liner options and the data is thought to be a good representation of Residue and leachate composition. The physical and hydraulic performance of the liner types proposed (geomembranes and geosynthetic clay) vary depending on the chemical characteristics of the liquid being contained. Geomembrane performance can diminish when in contact with high-concentration petrochemicals, whereas dissolved metals and salts in contained liquid will have little or no effect on geomembrane performance. A chemical resistance chart for polyethylene geomembranes is provided in Attachment E. Of primary interest in the context of the HRF are liquids containing sodium, chlorides, magnesium, and sulfates. Comparison of previously referenced leachate quality data to chemical resistance of the polyethylene geomembrane indicate that polyethylene geomembranes can be expected to perform well. For sodium bentonite clays used in the GCL, performance can diminish when in contact with high-concentration petrochemicals or high-concentration dissolved metals and salts, particularly calcium and sodium, which can replace ions within the clay, resulting in microscopic level changes in clay structure and measurable changes in physical performance.

As evidenced by the chemical characteristics data for the Residue, petroleum compounds will not exist at concentrations of concern for the liner types proposed and are not expected to be components of flow to the HRF. Concentrations of calcium and sodium in the Residue placed in the HRF will be on the order of 530 to approximately 600 mg/l for calcium and 13 to approximately 580 mg/l for sodium. This wide range of sodium concentrations is based on the sodium concentrations of the individual residue types that will make up the combined Residue, as discussed in Section 2.1.1. Ion concentrations at the expected levels can have a detrimental effect on GCL performance, typically seen as increases in liner hydraulic conductivity. As reported by Daniel (Reference (5)), hydraulic conductivity of a geosynthetic clay liner increased nearly three orders of magnitude (from 1 x 10^{-9} centimeters per second to 1 x 10^{-6} centimeters per second) when permeated with a fluid having a high concentration of calcium chloride (13,700 mg/l). However, hydraulic conductivity was also closely correlated with confining stress. The hydraulic conductivity decreased as confining stress increased from roughly 10 pounds per square inch (psi) to 60 psi, at which point there was no further increase in hydraulic conductivity. Daniel (Reference (5)) reported the values presented in Table 2-5 for hydraulic conductivity of the geosynthetic clay liner when permeated with the calcium chloride.

Table 2-5 Hydraulic Conductivity vs. Confining Stress(1)

Approximate Confining Stress (psi)	Equivalent Residue Cell Depth (feet, at Residue Saturated Unit Weight of 113 pcf)	Hydraulic Conductivity (cm/s)
10	12.7	1 x 10^{-6}
20	25.5	2 x 10^{-6}
30	38.2	1 x 10^{-7}
40	50.0	5 x 10^{-9}
50	63.7	1 x 10^{-9}
60	76.5	5 x 10^{-10}

Note: As reported in Reference (2)

In light of the research by Daniel (Reference (5)), CETCO Lining International was contacted and requested to demonstrate adequacy of performance of a geosynthetic clay liner permeated by synthetic leachate produced to simulate the liquid to be contained by the HRF. CETCO produced three test specimens of their GCL, with proprietary treatments applied to each specimen prior to initiation of hydraulic conductivity testing. The GCL's were polymer-treated in an effort to create a GCL liner that performs well even when in contact with liquids of elevated calcium, magnesium and sodium content at relatively low confining stress; a condition expected to exist early in the operation of the HRF. A synthetic leachate was prepared to yield a solution with elevated ion concentration. For the volume of synthetic leachate prepared, the leachate was determined to be ion-saturated after addition of the following compounds.

1.72g CaCl2	3.02g MgSO4	0.02g H2SO4
0.31g CaSO4	0.20g NaCl	0.21g K2SO4

Three modified GCLs were tested:

- R101 – polymer treated sodium bentonite GCL
- R102 – sodium bentonite GCL with internal geofilm
- R103 – polymer and biocide treated sodium bentonite GCL

GCL testing was subcontracted to JTL Laboratories, Inc. of Canonsburg, PA. The GCLs were set up in 4 inch-diameter flexible wall permeameters. The permeameter inflow and outflow pressures were set to maximum 5 psi effective confining pressure as outlined in ASTM D6766 and D7100. The GCLs were then each permeated with the synthetic leachate. The effluent bladders were emptied once they contained enough fluid to run an electrical conductivity test. The tubing and porous stones were flushed periodically to prevent blockage.

Final results of the hydraulic conductivity testing on Sample R-101 are presented in Attachment F as are preliminary test results on Sample R-102 and R-103, which were subsequently removed from further consideration due to manufacturing challenges and some diminished performance relative to R-101. As indicated by the test results, the R-101 GCL performed well, with hydraulic conductivities remaining at or below approximately 1.5 x 10-9 cm/sec for the duration of the period of testing.

GSE also performed project-specific tests on polymer-treated GCL. Their test reports are provided in Attachment F and show GCL hydraulic conductivity performance at acceptable levels and in fact improving with time.

The research conducted by Daniel (Reference (5)) as described previously was limited to testing of the GCL materials available over 12 years ago at the time that the research was performed. Within the last one to two years, both GSE and CETCO (two major manufacturers and suppliers of GCL) have developed and now produce polymer-treated GCLs suitable for use in the presence of medium to high ionic strength liquids as expected at the HRF and the referenced research by Daniel no longer applies.

For the HRF a polymer-treated GCL (GSE's Bentoliner CAR, CETCO's Resistex, or approved equals) will be specified to achieve the desired GCL performance. As the HRF is filled with Residue, the confining stress will increase on the GCL, thereby further enhancing the overall GCL performance.

2.2.3 Drainage Collection System

During reclamation the HRF will be dewatered, as described in Section 7.2.1. A Drainage Collection System installed above the liner system will speed dewatering of the Residue. The Drainage Collection System is illustrated in Figure 2-1 and detailed on Drawings HRF-008 and HRF-013 through HRF-016. The Drainage Collection System consists of strips of geocomposite drainage net placed on the bottom of the cell above the liner system. Geocomposite drainage strips will be used for the drainage collection system, rather than collection pipes in trenches, in order to speed installation and simplify the construction of the double liner system. The geocomposite drainage strips will be covered by a 2-foot thick layer of coarse tailings to provide a continuous drainage collection layer. The drainage collection layer will discharge to a sump and pump system on the northwest side of the cell. The Drainage Collection System will be installed during construction of the cell and activated at the time of cell closure.

2.2.4 Construction

The construction requirements for the HRF are presented in Drawings HRF-001 through HRF-024 and in the Construction Specifications provided as Attachment G. The primary HRF construction activities and sequence are:

- removal of structures from HRF footprint
- removal of rock and soil as needed
- installation of wick drains, if used, over Emergency Basin, including a granular drainage layer and geogrid reinforcement as needed
- placement and monitoring of Emergency Basin preload fill
- discharge of the preload fill water to the FTB Groundwater Containment System
- removal of preload fill and construction of dams to the Phase1 elevation

- installation of double liner and Leakage Collection System
- installation of Drainage Collection System
- installation of pumping and piping systems, power supply and controls
- performance of electrical leak location surveys as specified
- completion of construction documentation report
- HRF facility start-up.

The design and construction procedures for the HRF are consistent with the design used for double-lined facilities; there are no aspects of the design that are unique.

Construction quality control and assurance (QA/QC) will occur throughout HRF construction. Construction QA/QC will begin with regulatory agency review and approval of the construction QA/QC plan. A Construction Quality Assurance Manual template for the installation of the soil and geosynthetic components of liner and cover systems is included as Attachment H. This manual addresses QA/QC procedures for earthwork, geomembrane and geosynthetic clay liner installation, and piping components of the HRF double liner and leakage collection system, drainage collection system, and cover system.

Upon completion of construction, a construction documentation report will be prepared to document that construction of the HRF was completed in general conformance with regulatory agency permit requirements.

2.3 Residue Transport and Deposition System

Residue slurry from the Hydrometallurgical Plant will be pumped to the HRF through an HDPE pipe with discharge points as shown on Drawings HRF-008 through HRF-010. Proposed pipeline location is shown on Drawing HRF-017 and discharge point details are shown on Drawing HRF-018. The pipe will have a shut-off valve at the edge of the cell upstream of the ports to protect personnel working in and around the cell from inadvertent supply pump operation. Each of the ports will have valves to allow for distribution of flow to control the solids deposition in the cell. An exposed hose connector will be fitted to each port, from which flexible hose can be extended to change the discharge configuration as the water and Residue levels rise in the cell.

The water treatment plant solids transport and deposition system, which is not shown on the current plan set, will consist of a small diameter pipeline from the water treatment plant to either a nearby tie-in to the Residue transport pipe or via a dedicated pipe to the HRF. The treatment plant solids will be transported in slurry form for co-disposal with the Residue. This will be detailed during final design.

The coal ash placement into the HRF, which is of limited duration, can be accomplished by at least two methods. One method is to place the ash in the base of the HRF, prior to placement of Residue into the HRF. This would be accomplished by transporting the ash by truck down a soil ramp to the base of the HRF where the ash would be spread and compacted. This is the approach routinely used by electric power utility companies on any dry ash landfill. An alternate approach is by placing the ash into the HRF several years after the HRF is placed into operation. The HRF would be configured (minor HRF liner/embankment modifications) for dumping of the ash into the HRF by constructing designated dumping locations on the perimeter crest of the HRF dam, and by constructing the appropriate liner protections at these dumping locations. This is similar to the approach used at typical coal ash disposal facilities that accept both slurried and dry coal ash.

The coal ash and water treatment plant solids represent a small component of the overall waste stream to be placed in the HRF. Minor adjustments to facility design can be made as needed to accommodate these small quantities of material. Emphasis in this document hereafter is on the facility design and operating requirements for Residue management.

2.4 Return Water System

As the solids settle out in the cell, clear water from the cell will be pumped to the Hydrometallurgical Plant for reuse. A floating pump system will be constructed of double pumps supported on pontoons (Drawing HRF-019). A water return pipe will be quick-coupled in sections so that the pipe can be shortened as the water level rises in the pond. At the top of the dam of the HRF, the water return pipe will be connected to the pipe that runs to the Hydrometallurgical Plant.

2.5 Stormwater Management

The tributary area to the HRF is well understood and relatively small. The tributary area is limited by the system of HRF dams and by the high ground areas to the west and south. Potential surface water run-on into the HRF pond will be diverted by configuration of the perimeter dams, and the presence of the railroad embankment (Hinsdale Bridge Approach). Diversion swales will be installed in these areas to redirect surface water away from the HRF pond. During initial phases of cell development, a land-locked area may develop immediately east of the cell. Surface water runoff in this area will be diverted area away from the HRF. This is shown on Drawings HRF-008 through HRF-010.

Precipitation falling inside the dams will flow to the pond and form part of the make-up water for the Hydrometallurgical Plant. The HRF is designed as a closed system without release of water. Precipitation falling on the exterior of the dams will mainly run off or infiltrate through the material that forms the dams. Based on past experience at the facility, stormwater runoff is not expected to cause significant erosion of the dams. Vegetation will be established on dams as part of construction to minimize erosion and fugitive dust. Dam erosion will be corrected and re-vegetated. If areas of excess or repetitive erosion emerge, channels and/or outfall structures can be designed for those locations.

3.0 Geotechnical Modeling Outcomes

Geotechnical analysis requirements for the HRF were determined by PolyMet in consultation and agreement with the Dam Safety Unit of the DNR Division of Ecological and Water Resources and the Division's subcontracted geotechnical consulting engineers. Geotechnical analysis requirements for the HRF are defined in Attachment A of Geotechnical Data Package Volume 2 (Reference (2)). Geotechnical modeling methods and results for the HRF design are presented in Sections 5 and 6 of Reference (2).

Stability of the dams was analyzed for effective stress strength conditions. The target global slope stability safety factor from this analysis is > 1.5. The proposed HRF design achieves a computed safety factor of 2.27.

Deformation of the HRF liner system must be limited to that allowed by the least strain-tolerant component of the double liner system; the geosynthetic clay liner (GCL). The allowable strain in the GCL ranges from 1 to 19% (depending on GCL type and installation procedures). The computed strain on the liner system for the proposed HRF design is 0.20%, so is acceptable.

The components of the liner system are designed to act as hydraulic barriers to leakage; not as structural members of the dam system. Therefore, the liner layers must not be allowed to slide relative to one-another. Evaluation of this potential for sliding was performed using infinite slope stability analyses. The target infinite slope stability safety factor for all HRF liner system components is > 1.5. On the basis of the interface friction angles used in the analysis, the design proposed for the HRF achieves a computed safety factor of 1.86 or greater for all HRF liner system components. Therefore the design is acceptable. Interface friction angles will require confirmation upon bidding of HRF construction and corresponding selection of material suppliers.

The conclusion of the geotechnical evaluation is that the proposed dams can be constructed on top of the Emergency Basin and industry standard factors of safety can be achieved or exceeded.

4.0 Operational Plan

Residue deposition in the HRF will commence when the Hydrometallurgical Plant begins operation in approximately Mine Year 3. Figure 4-1 shows the overall timeline for HRF construction and operation. The following paragraphs describe the HRF operation.

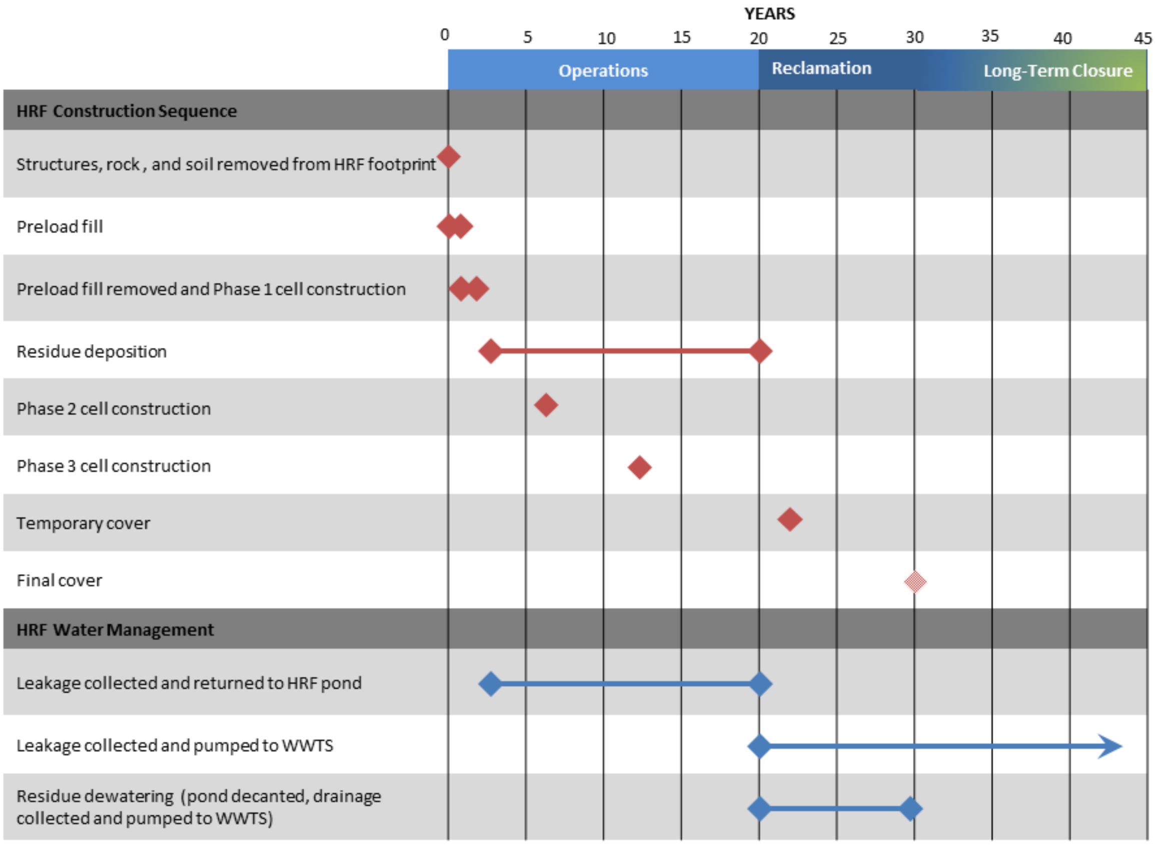


Figure 4-1 HRF Construction and Operation Timeline

4.1 Residue Transport and Deposition System

The HRF will function as a large-scale sedimentation basin. A pond will be maintained within the cell such that the solid fraction of the slurry (the Residue) settles out within the cell, while the majority of the liquid fraction is recovered and returned to the Hydrometallurgical Plant for reuse. The levels of both the solids and liquid within the cell will increase incrementally over time. A benefit of the wet placement approach for the Residue is the substantial reduction in fugitive dust emissions compared to a dry placement approach.

With a wet placement approach, operations must guard against dam overtopping. Overtopping could potentially occur if the Return Water System were to fail or be accidentally shutdown while the Residue Transport and Deposition System continued to operate. Typical instrumentation and control system interlocks will be employed to avoid this situation. Motor electrical load and pipeline pressure monitors will be installed on the Return Water System such that unplanned system shutdowns trigger signals for system operators. The system will be interlocked with and programmed to shut down the Residue Transport and Deposition System within a specified timeframe if system operators either do not respond to the signal and/or are unable to resolve the Return Water System operations issues within a pre-determined timeframe. Even in the event of a failed system shutdown, many days of continued Residue deposition would be required to raise pond level to overtopping. The lack of water return, which will be necessary for plant operations, would be discovered well in advance of water levels in the HRF becoming problematic.

Stormwater input is another potential source of overtopping. Overtopping will be avoided by operating the HRF pond with sufficient freeboard to accommodate pond water level bounce due to a severe precipitation event. Water level bounce within the cell from precipitation events is expected to be minimal, because the dams of the HRF are configured to minimize surface water run-on to the extent practical (Section 2.5). The cell is sized to accommodate up to 3 feet of freeboard so that some wave run-up and water level bounce can safely occur. Initial operations will be used to refine the minimum freeboard requirements.

4.2 Return Water System

The Return Water System will be automated to balance water return from the HRF with the water demand at the Hydrometallurgical Plant. Any fluctuation in demand will be accommodated by temporary water level changes in the HRF and in the process water tank at the Hydrometallurgical Plant. Water level in the HRF will also be managed as needed to facilitate Residue deposition at the desired locations within the HRF and to achieve the desired water clarity for process water at the Hydrometallurgical Plant.

The accumulation of solids in the return water pumping system will require continual monitoring and maintenance. The pump intake will be placed as close as possible to the water surface to draw the cleanest water, but some solids may remain in suspension and be pulled into the pumping system. Those solids will be deposited wherever flow is not straight and smooth, such as in the pump volute or at valves. Flow into the Hydrometallurgical Plant process water tank and pump power usage will be monitored so that decreasing performance trends can be detected before a pump is entirely plugged. Redundant pumps and pipelines are provided to maintain operations if one pump or pipeline is out of service for cleaning or repair. As the water level rises over the life of the HRF, pump discharge rates will increase as the static hydraulic head decreases. Because the latter trend may mask the former, routine visual inspection will be performed in order to monitor the rate of solids deposition in the pumping system. This will be especially important at the beginning of operations to establish a baseline of performance.

4.3 Leakage Collection System

The Leakage Collection System described in Section 2.2.2 will continuously return any leakage to the HRF pond. Recirculation will occur at the rate required to draw down leachate levels, allow uninhibited discharge of leachate into the collection system, and limit the hydraulic head on the lower composite layer of the liner system.

4.4 General Maintenance

Typical maintenance of the HRF may include:

- snow removal from the dam crest to allow access during winter months
- repair of eroded dam crest, slope or toe
- seeding and mulching to facilitate the growth of vegetation and control fugitive dust (Attachment A of Reference (6))
- grading of the dam crest and replacement of surface material
- Return Water System maintenance (i.e., flow rate monitoring and system cleaning)
- Residue Transport and Deposition System maintenance
- Leakage Collection System maintenance (i.e., flow rate monitoring and system cleaning)
- Repair and/or replacement of damaged geotechnical instrumentation and monitoring devices.

The majority of the non-mechanical maintenance work at the HRF will be carried out on an as-required basis, rather than on a scheduled basis because it is driven by weather events rather than hours of operation. Mechanical components will be incorporated into a planned inspection and maintenance program.

4.5 Winter Operation

The Residue will be discharged from the Hydrometallurgical Plant at elevated temperature, typically in the range of 85 to 105° F. As a result, Residue Transport pipeline operations will be consistent year-long. However, in the event of a prolonged system shutdown during freezing conditions, exposed sections of the Residue Transport pipeline will be drained by gravity flow to the HRF.

With the elevated temperature of the Residue slurry, freeze-up of the HRF pond at the point of discharge will not occur. Freeze-up, if it does occur, would occur at locations more distant from the discharge location. Although temporarily exposed and idle Residue surfaces may freeze, newly deposited Residue will thaw frozen surfaces and Residue will generally deposit in a consistent manner within the HRF year-round.

The Return Water System operation procedures will be consistent throughout the year with the exception that, should pond freeze-up occur within portions of the HRF, then the location of the Return Water System will require periodic relocation to maintain operations in an unfrozen portion of the HRF pond.

Winter operations are not expected to significantly affect Residue compaction/consolidation. If ice does form in the HRF, the ice thickness will be limited; underlying Residue and water will remain unfrozen and will consolidate/compact as it does year-round. Further, any ice formation would be a seasonal, short-term phenomenon that could have short term effects on Residue consolidation at shallow depths, but no effect at greater depth within the HRF.

The transition from winter to spring operations is not expected to result in high water issues in the HRF pond, because pond water level will be controlled by operations personnel. If the water level trends higher than planned, operations personnel will lower the operating water levels by reducing make-up water additions from the Plant Reservoir, and increasing the amount of process water withdrawn from the HRF pond.

Leakage Collection System operation procedures will be consistent throughout the year, because the system will be below the frost line. The leakage collection sump will initially be covered by 8 feet of coarse aggregate and 2 feet of LTVSMC coarse tailings (refer to Detail 2 of Dwg. No. HRF-015 of HRF Permit Application Support Drawings - Version 5), followed shortly thereafter by additional water and Residue. This cover thickness is sufficient to prevent freezing of liquid in the sump, thereby accommodating year-round sump operations and leakage extraction.

5.0 Monitoring

Proper performance of the HRF will depend in part on systematic inspection, monitoring and maintenance of the facility components throughout the life of the facility.

5.1 Semi-Annual Dam Safety Inspections

The purpose of a Dam Safety Inspection (DSI) is to evaluate, on a regular basis, the current and past performance of the HRF dams and to observe potential deficiencies in their condition, performance and/or operation. DSIs will consist of detailed observations made by the *Design Engineer* and an evaluation of information on dam performance, operating and other relevant conditions obtained from routine monitoring.

The *Design Engineer* conducting the DSI must be qualified (qualified geotechnical engineer registered in the State of Minnesota) to conduct dam safety evaluations and be familiar with the designs and other site-specific conditions and requirements pertaining to the dam. It is the responsibility of the *Operations Contact* to retain a qualified and experienced *Design Engineer*.

DSIs will initially be conducted semi-annually. The *Operations Contact* will accompany the *Design Engineer* for all or part of the DSI. The DSI frequency should be reviewed at the time of each annual Dam Safety Review. A non-routine DSI may be required as a follow up to the reporting of an unusual event or observation.

Each DSI will incorporate a routine review, in addition to direct evaluation of dam safety, of the following:

- the operations and maintenance record
- the availability at the site of all documents pertaining to dam safety
- change in relevant regulatory requirements since the last DSI

The *Design Engineer* will issue a report following the DSI. The report will include conclusions and any necessary recommendations in clear and explicit statements. The *Operations Contact* will review each DSI report. The *Operations Contact* will be responsible for preparing and executing an appropriate action plan to confirm that all recommendations made in a DSI report are followed. Copies of the reports will be available at the office of the *Operations Contact* and in the office of the *Design Engineer*.

5.2 Weekly/Daily Dam Inspections

Routine dam inspection activities will occur on an ongoing basis and will supplement the more detailed DSIs. The purpose of weekly/daily dam inspection is to observe the conditions and performance of the HRF dams and associated facilities so that any changes to dam conditions or performance can be identified and potentially hazardous conditions can be promptly addressed. The *Operations Contact* will confirm that dam inspections are conducted per the guidance provided in this document.

Dam inspection will primarily involve routine and event driven observations of the dam and associated facilities. When documenting dam inspections, a standard form (Attachment I) will be used. Digital images will be taken from a reference location with Latitude and Longitude imbedded in the electronic meta-data for comparing photos for conditions that may vary with time (e.g., deformation of the dam structure, or progressive erosion).

Observations of suspected irregularities of the dam structure will be immediately reported to the *Operations Contact* and *Design Engineer*. Additional reporting will be performed as required by facility permits.

Observations to be made during the daily dam inspections will include:

- condition of piping (Residue Transport and Deposition System, Return Water System, Leakage Collection System)
- evidence of subsidence or sinkholes in the Residue
- confirmation that no physical damage has occurred to the HRF as a result of factors such as weather, vandalism, or malfunction of components

Weekly observations will be conducted on a specific day of the week to promote consistency. Observations to be made during the weekly inspections will include:

- the daily observations listed above,
- evidence of dam structure deformation (e.g., slope bulging or crest settlement)
- evidence of leakage, overland runoff or erosion
- possible evidence of piping/subsurface erosion downstream of the dam
- any/other unusual conditions in the dam area

All dam inspection reports will be reviewed by the *Operations Contact*, circulated to management personnel as appropriate, and filed.

5.3 Inspections after Unusual Events/Observations

Unusual events/observations must be immediately brought to the attention of the *Operations Contact* who will document the event/observation, record the immediate action taken, initiate a special inspection and, if necessary, contact the *Design Engineer*. Examples of unusual events/observations that would require attention with respect to dam safety are listed in Table 5-1.

Table 5-1 HRF Unusual Events/Observations That Warrant a Non-Routine Inspection

Event/Observation	Possible Immediate Action
Extreme runoff event.	Inspect the slopes and the crest of the dam looking for areas of concentrated runoff or erosion. Make a note of saturated ground or soft ground conditions at dam slopes and toes. Examine dam slopes for indications of localized slumping/instability. Inspect Residue transport/return water pipeline route. Check water levels in the pond relative to critical levels and continue monitoring until the pond inflows subside. Initiate findings review by *Design Engineer*.
Rupture of pipeline at dam structure.	Stop the pump. Check for dam erosion. Initiate findings review by *Design Engineer*.
Significant, relatively rapid erosion (any cause) of dam slope or sudden leakage break at dam slope or downstream of dam in form of continuous leakage or boils. Deformation at dam crest, slope or toe area, including development of a continually saturated area at ground surface.	Measure size of erosion and/or estimate leakage area and flow Rate. Consult with *Design Engineer*.
Significant change in the piezometer level/levels.	Check piezometer readings again to confirm findings. Initiate findings review by *Design Engineer*.
Other events/observations.	Consult *Operations Contact*

5.4 Dam Safety Review

Routine Dam Safety Reviews (DSRs) at the HRF will be carried out every five years after initial operation. This scheduling requirement should be confirmed or revised at the time of each DSI. The principal objective of a DSR is to ascertain that a dam has an adequate margin of safety, based on the current engineering practice and updated operations and design input data. A DSR may also be carried out to address a specific problem. The team conducting a DSR will be qualified to conduct safety evaluations and be familiar with the designs and other site-specific conditions and requirements pertaining to operations of the HRF.

A detailed scope of work for each DSR will be defined by the leader of the DSR team prior to conducting the DSR, and be consistent with engineering practice at the time it is conducted. Each DSR will incorporate, in addition to direct evaluation of dam safety, a detailed review of the following:

- adequacy of past DSI practice, the DSI recommendations, and their implementation
- Operations, Maintenance and Inspection Plan
- timing for the next regular DSR

Each DSR report will include conclusions and, if necessary, recommendations pertaining to the safety of the dam. As in the case of DSI reports, an action plan will be prepared by the *Operations Contact* to address the DSR recommendations. A copy of each report will be available at the office of the *Operations Contact*.

5.5 Geotechnical Instrumentation

Geotechnical instrumentation will provide data for dam safety monitoring, and link actual dam performance with stability and leakage modeling completed as part of Dam Safety permitting. Instrumentation is described below, detailed in the Instrumentation and Monitoring Plan (Attachment J), and shown on Drawings HRF-009, HRF-010, HRF-012, and HRF-024.

The dams of the HRF will be constructed as described in Section 2.2.1 and the HRF will be lined as described in Section 2.2.2. Because the proposed exterior dam slopes, at 3H:1V are relatively flat and because the potential for leakage through the dams is minimized by the liner system, deformation or instability of the dams is not anticipated. The geotechnical instrumentation for the HRF will be designed accordingly, with a limited number of piezometers and inclinometers installed after Phase 2 is constructed. These instruments will then be relocated or replaced when Phase 3 is constructed.

5.5.1 Piezometers

Piezometers will be installed during Phase 2 and Phase 3 of HRF construction to monitor the phreatic surface within the HRF dams. The location of the phreatic surface has a significant impact on slope stability, and actual location as recorded from piezometers will periodically be compared to phreatic surface location determined by slope stability and seepage modeling to confirm that its location is within acceptable limits. Standpipe piezometers will be read twice per year at a minimum. Piezometer readings will be plotted against time and sent to the *Design Engineer* for review and analysis.

5.5.2 Inclinometers

Inclinometers will be installed during HRF Phase 2 and Phase 3 to monitor the movement of the HRF dams. Manual inclinometer readings will be taken twice per year (minimum), plotted, and sent to the *Design Engineer* for review and analysis.

5.5.3 Survey Monitoring Points

Survey monitoring points will be established to facilitate the monitoring of horizontal and vertical deformation of the HRF dams. The survey monitoring points will be surveyed twice per year. The readings will be recorded on a standard form, plotted against time, and sent to the *Design Engineer* for review and analysis.

5.6 Monitoring of Other Systems

The following monitoring procedures are required for the HRF and associated systems.

- Water quality monitoring - The water in the HRF and at leakage collection points will be routinely sampled, analyzed and reported as defined in the SDS permit. Water quality monitoring is further described in Reference (7). HRF Pond and HRF Leachate (collected from the Drainage Collection System) waters are expected to be sampled and analyzed for metals at least quarterly. Water quality near the HRF will be monitored using a system of surface water sampling points and groundwater quality monitoring wells as defined in the SDS permit.

- Transport and Deposition System monitoring - The pipes that carry Residue from the Hydrometallurgical Plant to the HRF and associated pipeline connections will be inspected to confirm that the components are in good condition at all times and leaks do not occur. Inspections will be performed on a regular basis and if damaged or worn out components are observed or if leaks are detected, the affected parts will be repaired or replaced. The amount of Residue and water delivered to the HRF will be recorded (manually or via automated mass flow instrumentation) daily.

- Drainage Collection System monitoring – During the reclamation phase, the amount of water collected will be recorded (manually or via automated systems) daily. The components of the Drainage Collection System including pipes, connections, sumps, pumps, etc. will be inspected on a regular basis to confirm that the components are in good condition at all times. Damaged or worn out components will be repaired or replaced.

- Leakage Collection System monitoring - The amount of water collected will be recorded (manually or via automated systems) daily. The components of the Leakage Collection System including pipes, connections, sumps, pumps, etc. will be inspected on a regular basis to confirm that the components are in good condition at all times. Damaged or worn out components will be repaired or replaced.

- Pond monitoring - The HRF pond level will be recorded daily (manually or via automated systems) to confirm water containment within the HRF dams and sufficient freeboard. The dams will be regularly inspected for signs of instability such as cracking, material sliding, erosion features, and leakage. Such items will be brought to the attention of the *Operations Contact* and promptly repaired.

- Return Water System monitoring - The amount of water returned to the Hydrometallurgical Plant will be recorded (manually or via automated systems) daily. The components of the Return Water System including pipes, connections, sumps, pumps, barges, etc. will be inspected on a regular basis to confirm that the components are in good condition at all times. Damaged or worn out components will be repaired or replaced.

- Residue monitoring - Once Residues are being produced, individual and combined residue samples will be taken to confirm the physical and chemical characteristics of the individual and combined residues for purposes of:

  - Aiding the optimization of beneficiation processes,

  - Confirming the hydrometallurgical residue is not characteristically hazardous (and therefore not subject to RCRA)

  - Confirming residue physical characteristics and generation rates, and

  - Confirming hydrometallurgical residue facility (HRF) capacity consumption rates.

  The samples will be collected and analyzed as follows:

  - Individual and combined residue samples will be analyzed for specific gravity of solids, particle size distribution, total metals, and TCLP as a part of equipment and operational process performance review and optimization.

  - Initially sampling will be weekly until routine equipment and operational process troubleshooting is complete and the process is optimized, then monthly.

Analytical results from Residue physical and chemical characterization and HRF pond and leachate water chemistry are expected to be included as part of DNR Permit to Mine and MPCA NPDES/SDS permit reporting requirements.

Table 5-2 summarizes the geotechnical inspection and maintenance plan. For each inspection event listed in Table 5-2 the following information will be recorded and retained by the *Operations Contact*:

- date and time of the inspection
- name of inspector
- summary list of observations made
- date and nature of any repairs or other actions taken

Table 5-2 Inspection and Maintenance Plan

Item	Operation	Frequency
Operational Components: Residue slurry pipeline Residue slurry discharge Return water pump Return water pipeline	Inspect/Record	Daily
	Repair/Record	Daily, as soon as possible
Residue slurry flow rate	Observe/Record	Continuous
Pond Water Level	Observe/Record	Observe daily, record weekly.
Dams	Inspect/Record	Weekly
	Repair/Record	When damage is observed
Turf Areas	Mow/Record	Once per year or as needed
	Inspect/Record	Monthly, non-winter months
	Fertilize/Record	When poor vegetation growth is observed.
	Repair/Record	Within four weeks of observation of necessary repair, season permitting.

Item	Operation	Frequency
Diversion Berms/ Runoff Water Swales	Inspect for sediment accumulation and/or erosion/record	Weekly and after each rainfall event of 0.5 inches or more.
	Remove excess sediment/record	When sediment depth is greater than design depth.
	Reestablish vegetation/Record	Within four weeks of observation of necessary repair, season permitting.
Riprap	Inspect/Record	Weekly and after each rainfall event of 0.5 inches or more.
	Repair/Record	Within four weeks of observation of necessary repair, season permitting.
Leakage Collection System	Visually Inspect/Record	Twice per year
	Clean/Record	As needed to maintain proper operation

5.7 Contingency Action Plan

A Contingency Action Plan (CAP) has been prepared (Attachment K) to provide initial guidance to on-site personnel and emergency responders in the case of unplanned occurrences at the HRF. The CAP identifies and specifies initial actions in response to a variety of occurrences representing differing levels of severity and complexity. Content of the CAP is based in part on outcomes of the dam break analysis for the HRF (Attachment L), which indicates a low probability of occurrence for an HRF dam break. In most cases initial responses will be followed up with review by the *Design Engineer* to confirm that initial responses are adequate and to identify any further actions that may be required. In severe situations time of response is of the essence and the *Design Engineer* should be notified immediately of the conditions on site so that additional recommendations can be identified and established immediately.

6.0 Reporting

The SDS permit will require and define routine water quality reporting which is described in Section 6 of Reference (7). The Permit to Mine and Dam Safety Permit will also require that annual reports be submitted. The content requirements for those reports will be defined in those permits. The Annual Dam Safety Report to be submitted to the DNR is anticipated to include:

- a summary of DSIs and DSRs conducted during the year
- a summary of all routine inspections that occurred during the past year
- a summary of all unusual events/observations that occurred during the past year
- identification of any planned changes in operations that could impact dam stability
- a discussion of the past years construction and the proposed next year's construction
- description of scheduled and unscheduled maintenance
- instrumentation readings including recent data and period of record graphs
- a brief discussion or interpretation of the monitoring data

The Annual Permit to Mine Report to be submitted to the DNR is anticipated to include:

- current chemical characterization of the Residue
- the total tons of Residue placed in the HRF from the start of operations through the past year and remaining planned capacity
- a map showing where Residue was placed and where vegetation was established for dust control or reclamation during the past year
- a map showing where Residue is planned to be placed and where vegetation is planned to be established for dust control or reclamation during the coming year
- identification of any planned changes in operations that could impact reclamation and postclosure

7.0 Hydrometallurgical Residue Facility Reclamation and Postclosure

7.1 Incremental Reclamation

As dams are constructed, exterior slopes will be stabilized and vegetated in accordance with Minnesota Rules, part 6132.3200 and in accordance with requirements of the Fugitive Emissions Control Plan (Attachment A to Reference (6)).

7.2 Final Reclamation

7.2.1 Residue Dewatering

Reclamation preparation will commence within the year after the last year of operations. Ponded water will be decanted and pumped to the WWTS for treatment and discharge as described in the Water Management Plan – Plant (Reference (7)).

At closure, the void spaces in the Residue will be full of water. A portion of this water will be retained in the Residue while a portion will drain. The volume of water that will drain from the Residue is somewhat uncertain. It will depend on the final hydraulic conductivity of the deposited Residue and the quantity of moisture that is permanently retained by the Residue. The Drainage Collection System (Section 2.2.3) will be activated at closure, and operate until drainage ceases. Drainage will be pumped to the WWTS for treatment and discharged (Section 4.2 of Reference (8). The rate of drainage will decrease over time as the pore water within the Residue is collected and removed.

7.2.2 Cover System

A multi-layer cover system will be placed over the Residue. Cover placement will be staged.

Early in the Residue dewatering process, access to the Residue surface may be somewhat difficult, due to the fine-grained characteristics of the Residue. A temporary cover will be placed to limit infiltration of precipitation while dewatering progresses and the Residue consolidates and settles. The barrier layer of the temporary cover, in addition to covering the deposited Residue, will be extended over the dams to exclude rainwater infiltration back into the Residue while also accommodating settlement of the temporary cover system. The settlement of the temporary cover will be monitored, and when the rate and magnitude of settlement has diminished, the final cover will be placed.

The cover system is designed to have a relatively flat slope. The Residue will be a water-deposited material that will naturally deposit at a relatively flat slope - currently estimated at a 1% slope. The Residue, consisting of saturated silt-size particles, would be difficult to regrade to steeper slopes as part of closure. Placement of the temporary cover will accommodate differential settlement, and positive drainage will be re-established when the final cover is placed over the temporary cover. This cover construction sequence of temporary cover placement followed by final cover placement is depicted on Drawing HRF-020 and planned final cover grades are shown on Drawing HRF-021.

In ascending order, the cover system will consist of:

- a layer of LTVSMC tailings or common borrow immediately above the Residue with geotextile or geogrid reinforcing placed between the Residue and tailings/borrow if needed to create a working surface (Drawing HRF-020)
- a barrier layer consisting of a geosynthetic clay liner (GCL) overlain by a 40-mil low density polyethylene or similar MPCA-approved geomembrane barrier layer
- additional LTVSMC coarse tailings and/or common borrow and cover soils will be placed on top of the barrier layer to create a covered surface capable of sustaining a vegetated cover
- vegetation will be established as described in Attachment A of Reference (6)

During HRF reclamation and cover construction the following will be removed:

- Residue Transport and Deposition System
- Return Water System (after completion of facility dewatering)
- Power lines (once facility dewatering and water treatment are complete)
- Power substations (once facility dewatering and water treatment are complete.

7.3 Postclosure

Once reclamation activities described in Section 7.2 are complete, a postclosure period will begin. The following paragraphs describe the postclosure activities.

7.3.1 Leakage Collection System

The Leakage Collection System described in Section 4.3 will continue to operate during reclamation and postclosure although at greatly reduced rates. Collected leakage will be treated at the WWTS (or subsequently, non-mechanical treatment systems) then discharged as described in Section 4.2 of Reference (8). Leakage water quality will be monitored. Potentially, leakage water quality could reach a point where it could be released directly without treatment while maintaining compliance with applicable water quality standards. It is expected that leakage will stop at some point. When leakage stops, Leakage Collection System pumps and pipes and supporting electric power systems will be removed.

7.3.2 Surface Runoff Management

In order to achieve a reclamation system that is largely maintenance-free (stipulated as a goal in the NDR nonferrous rules), an open-meadow closure approach will be used, with estimated contours as depicted in Drawings HRF-021 and HRF-022. This approach will yield a gently sloping closure surface that readily sheds surface water runoff, accommodates future differential settlement of the underlying Residue, and minimizes ponding of water on the closed HRF surface. To control surface water runoff, the cover will slope gently toward the site perimeter to promote natural drainage. Final cover slopes on the cell interior will be relatively shallow (on the order of 1.0%) to minimize surface water runoff flow velocity and erosion. Runoff that becomes channelized along the cell perimeter will be routed through plug-resistant inlet structures and piping systems (Drawing HRF-023). These piping systems, which are commonly used at closed solid waste management facilities, will be used to safely transmit runoff down-slope, particularly after the transition of the relatively flat top slope to the steeper slope of the dam of the facility (at slopes on the order of 15%).

7.3.3 Facility Inspection

Detailed inspection of the facility after reclamation will initially be conducted three to four times annually to identify any areas requiring maintenance, with inspection frequency decreasing to a semi-annual basis after reclamation systems/features have become well established. A written log will be maintained to document findings and response requirements for each inspection event. The detailed inspections will include:

- evaluation of the reclaimed systems for settlement, erosion and vegetation quality,
- inspection of Leakage Collection System for damage or degradation,
- inspection of surface water runoff control facilities for erosion or accumulation of sediment, and
- evaluation of site security features

7.3.4 Facility Maintenance

Any problems identified during a routine inspection will be corrected. This includes, but is not limited to, repair of the Leakage Collection System, security systems, cover materials, berms, culverts, riprap, vegetation, dams, or other infrastructure. For example, in the event that excessive erosion occurs soil would be placed and compacted, and measures taken to prevent recurrence of the problem. If riprap were displaced, it would be replaced and measures taken to prevent a recurrence of the problem. If there are any areas where cover vegetation were poorly established or otherwise stressed, reseeding or other measures would be instituted and an adequate turf established.

In addition to corrective measures, routine surface care maintenance will be performed, such as mowing to prevent tree growth if needed and maintenance of stormwater drainage channel flow capacity.

Consistent with requirements of Minnesota Rules, part 6115.0390 Termination of Operations and Perpetual Maintenance, the HRF dams and appurtenances will be perpetually maintained so as to maintain their integrity.

7.3.5 Dam Safety Monitoring

Piezometer and inclinometer monitoring will continue during reclamation and postclosure. The location and details of the piezometers can be found in Attachment J. The frequency of monitoring will decrease and monitoring will eventually cease once the cover system has been completed, once vegetation has become established, and once it is confirmed that there are no areas where surface runoff is becoming channelized and causing erosion of the facility dams.

7.3.6 Reporting

Reports will be prepared describing the inspections, conditions observed, corrective actions, maintenance activities, and monitoring activities performed in connection with the HRF.

7.4 Reclamation Cost Estimates

For information on reclamation and the associated cost estimates, see the Reclamation Plan and Contingency Reclamation Estimates that will be part of the Permit to Mine application. The Contingency Reclamation Estimate will be the basis for financial assurance required by Minnesota Rules, part 6132.1200. This plan and estimate will be updated annually to include contingency reclamation for the site conditions representative of the end of the upcoming year of operation.

Revision History

Date	Version	Description
10/31/2011	1	Initial release
12/14/2012	2	Updated Permit Application Support Drawings, added Dam Stability Instrumentation and Monitoring Plan and Emergency Action Plan. Minor edits for clarity and to drawing number references to coincide with updated drawings
11/7/2014	3	Minor edits to address agency comments to Version 2 and placement of material relocated from Coal Ash Landfill in the HRF. Emergency Action Plan retitled Contingency Action Plan. Addition of Construction QA Manual template.
12/12/2014	4	Minor edits to address agency comments to Version 3.
07/11/2016	5	Version 5 adds signed PE certification, and HRF Dam Failure Notification Flowchart within HRF Contingency Action Plan in response to DNR comment on Version 4.
05/15/2017	6	Minor edits to incorporate updated Contingency Action Plan and to update References.

References

1. **Minnesota Department of Natural Resources, U.S. Army Corps of Engineers and U.S. Forest Service.** Final Environmental Impact Statement: NorthMet Mining Project and Land Exchange. November 2015.

2. **Poly Met Mining Inc.** NorthMet Project Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (v6). July 2016.

3. —. NorthMet Project Waste Characterization Data Package (v12). February 2015.

4. **Schroeder, P. R., Aziz, N. M., Lloyd, C. M. and Zappi, P. A.** The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3. *U.S. Environmental Protection Agency Office of Research and Development.* Washington, D.C. : s.n., September 1994. Vols. EPA/600/R-94/168a.

5. *Hydraulic Durability of Geosynthetic Clay Liners.* **Daniel, D.E.** s.l. : Geosynthetic Research Institute, Folsom, PA, 2000. Proceedings of the 14th Annual GRI Conference, Las Vegas, NV. pp. 118-135.

6. **Poly Met Mining Inc.** NorthMet Project Air Quality Management Plan - Plant (v7). December 2014.

7. —. NorthMet Project Water Management Plan - Plant (v6). May 2017.

8. —. NorthMet Project Adaptive Water Management Plan (v11). May 2017.

List of Tables

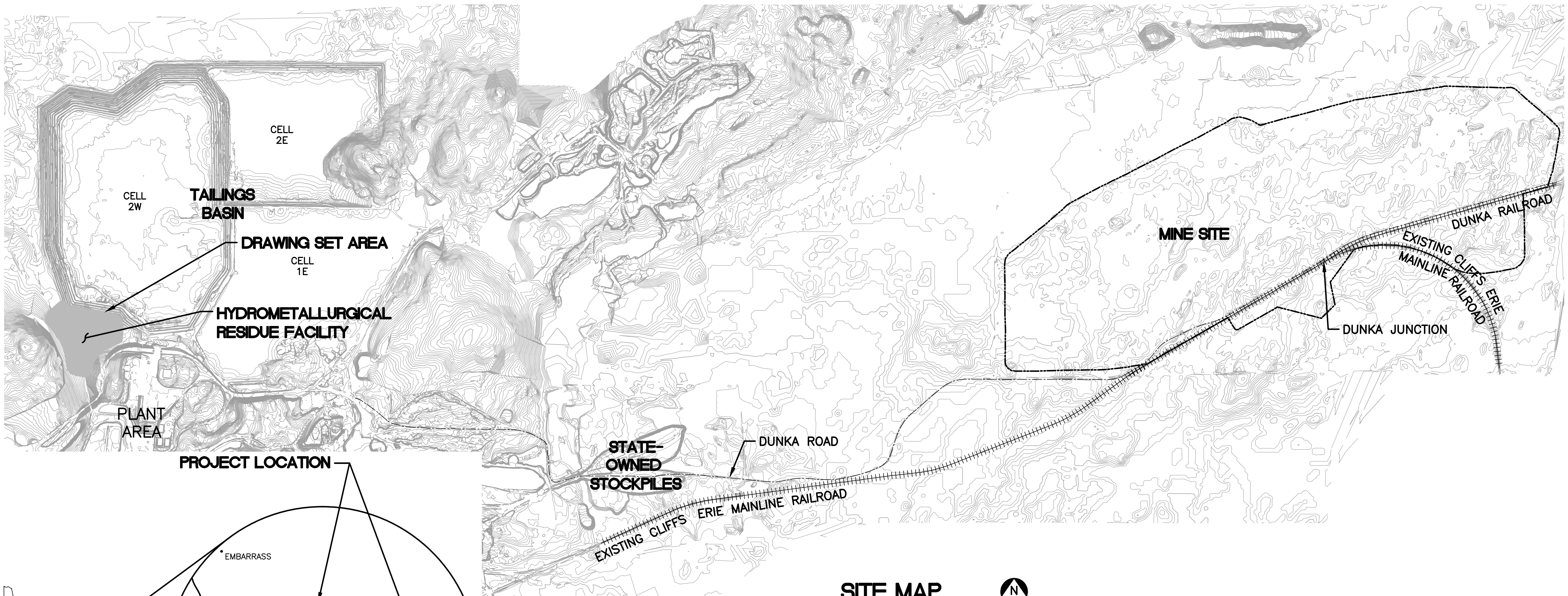
List of Attachments

Attachments

Attachment A

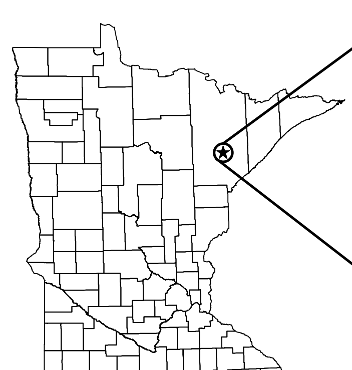
Hydrometallurgical Residue Facility Permit Application Support Drawings

POLY MET MINING, INC. NORTHMET PROJECT
PERMIT APPLICATION SUPPORT DRAWINGS
HYDROMETALLURGICAL RESIDUE FACILITY
HOYT LAKES, MINNESOTA



SITE MAP

0 2000 4000
SCALE IN FEET



LOCATION MAP
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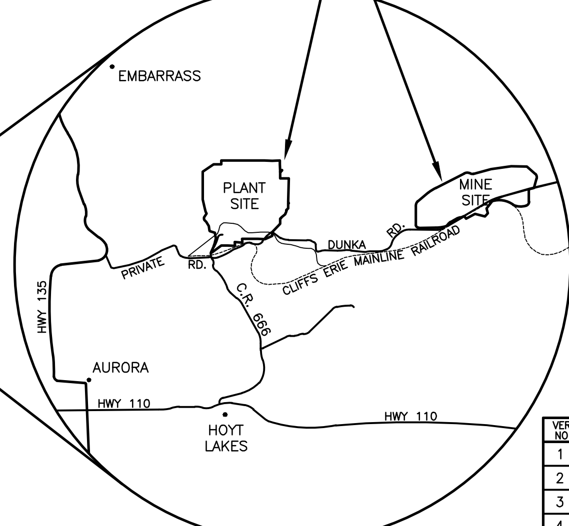


VICINITY MAP
NOT TO SCALE

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
3	12/14/12	RESIDUE MANAGEMENT PLAN – VERSION 2 – ATTACHMENT A
4	05/19/15	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS
5	05/15/17	PERMIT APPLICATION UPDATES

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	5	5/15/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION		

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR 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.

PRINTED NAME THOMAS J. RADUE
SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
LOCATION MAP AND SITE MAP

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

POLYMET MINING

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-001
REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-001.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:22 PM

INCHES 1 2

GENERAL LEGEND

- EXISTING CONTOUR – MAJOR (1000)
- EXISTING CONTOUR – MINOR
- PROPOSED CONTOUR – MAJOR (1000)
- PROPOSED CONTOUR – MINOR
- EXISTING POWER POLE
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL
- EXISTING STRUCTURES
- TREE LINE
- WETLAND BOUNDARY
- EXISTING CULVERT
- EXISTING PIPELINE (P)
- OVERHEAD ELECTRIC (OE)
- DISCHARGE POINT
- DEWATERING OUTLET POINT
- RETURN PUMP PAD
- DEWATERING PUMP
- SURFACE DRAINAGE
- DRAINAGE COLLECTION STRUCTURE AND PIPE
- DRAINAGE AREA BOUNDARY
- PROPOSED DAMS
- PROPOSED DEWATERING PIPE (DW)
- PROPOSED DISCHARGE PIPELINE (D)
- PROPOSED RETURN PIPELINE (R)
- PROPOSED CULVERT (NON–MINE WATER)
- PROPOSED SEEPAGE COLLECTION DRAIN
- PROPOSED STORMWATER DRAIN
- PROPOSED MANHOLE
- PROPOSED WICK DRAIN LATERAL PIPE
- PROPOSED RIP RAP
- FILL SLOPE
- CUT SLOPE

ABBREVIATIONS

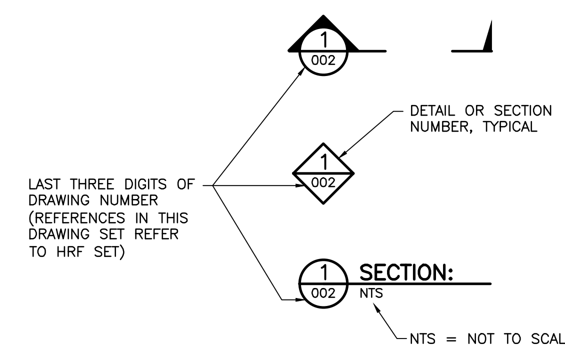
APPROX.	–	APPROXIMATE
CMP	–	CORRUGATED METAL PIPE
CPEP	–	CORRUGATED POLYETHYLENE PIPE
CY	–	CUBIC YARD
DR	–	DIMENSION RATIO
DWG	–	DRAWING
EL.	–	ELEVATION
F	–	DIAMETER
FTB	–	FLOTATION TAILINGS BASIN
GCL	–	GEOSYNTHETIC CLAY LINER
HDPE	–	HIGH DENSITY POLYETHYLENE
HRF	–	HYDROMETALLURGICAL RESIDUE FACILITY
LDPE	–	LOW DENSITY POLYETHYLENE
LF	–	LINEAR FEET
LTVSMC	–	LTV STEEL MINING COMPANY
MCY	–	MILLION CUBIC YARDS
mil	–	ONE THOUSANDTH OF AN INCH
MIN	–	MINIMUM
MSL	–	MEAN SEA LEVEL
NTS	–	NOT TO SCALE
SCH.	–	SCHEDULE
SDR	–	STANDARD DIMENSION RATIO
TYP.	–	TYPICAL

SHEET INDEX

SHEET NO. TITLE

GENERAL DRAWINGS

DRAWING NUMBERING



NOTES

1. COORDINATE SYSTEM IS MINNESOTA STATE PLANE NORTH ZONE, NAD83.
2. ELEVATIONS ARE MEAN SEA LEVEL (MSL), NAVD88.
3. EXISTING TOPOGRAPHIC INFORMATION SHOWN ON THE DRAWINGS WAS PREPARED BY AEROMETRIC, INC. FROM LIDAR DATA COLLECTED ON MARCH 17, 2010.

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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DRAWN: CAD
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SCALE: AS SHOWN

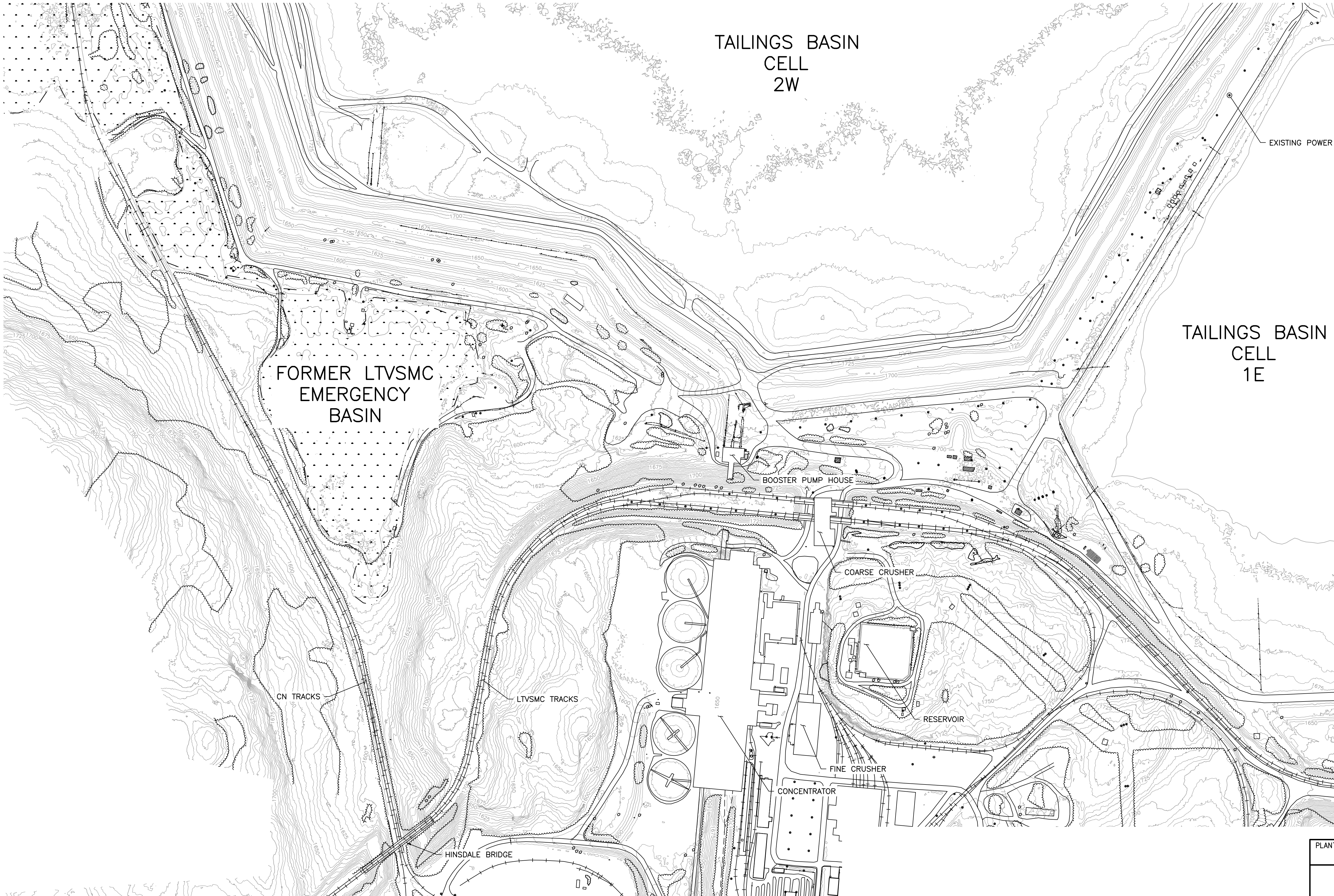
PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
LEGEND AND SHEET INDEX

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1–800–632–2277

DWG. NO. HRF–002
REV A



1 PLAN: EXISTING CONDITIONS

0 300 600
SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
3	12/14/12	RESIDUE MANAGEMENT PLAN – VERSION 2 – ATTACHMENT A
4	05/19/15	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS
5	05/15/17	PERMIT APPLICATION UPDATES

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	5	5/15/17
FOR CONSTRUCTION		

NOT APPROVED FOR CONSTRUCTION.

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PRINTED NAME THOMAS J. RADUE
SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
EXISTING CONDITIONS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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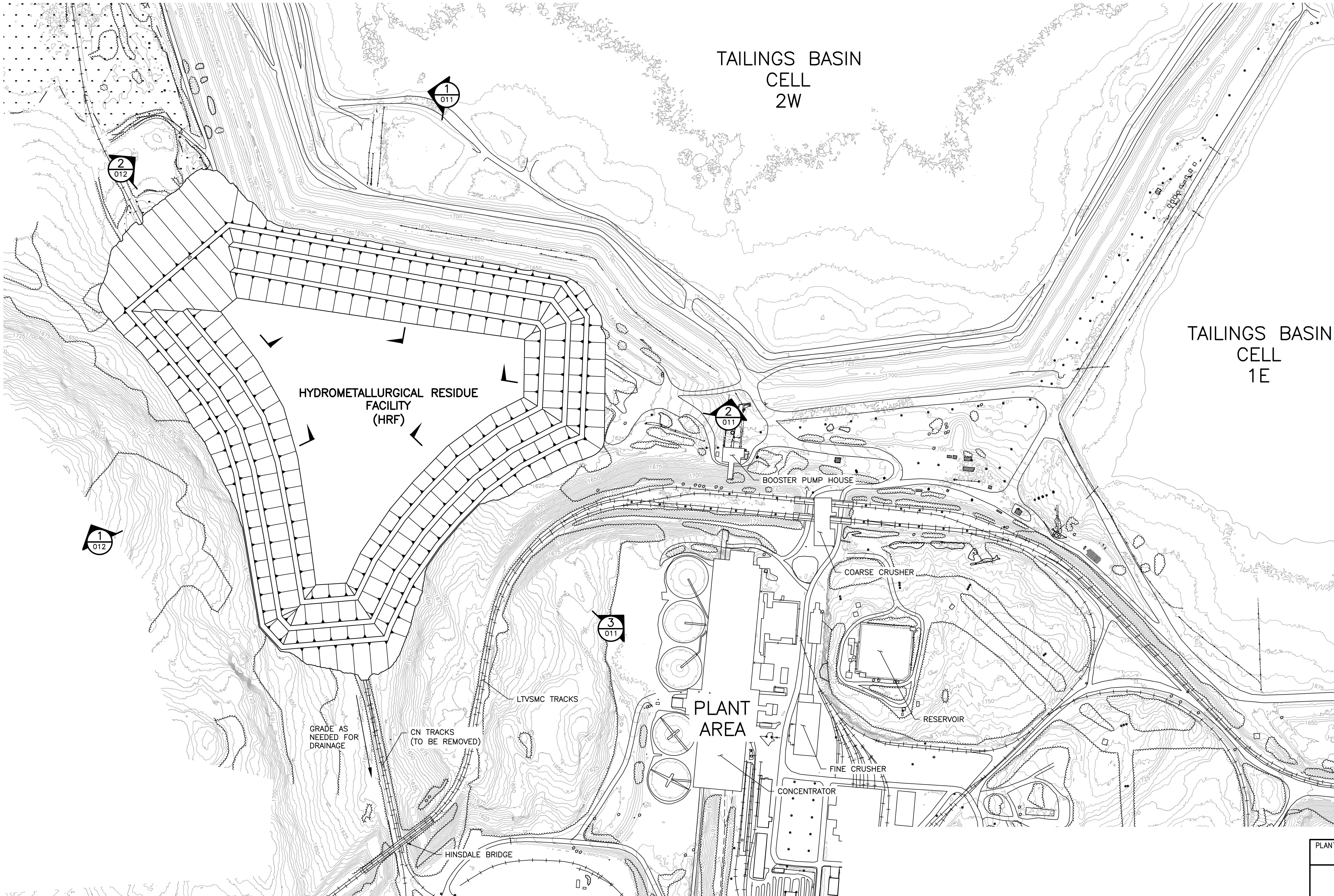
DWG. NO. HRF-003
REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-003.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:26 PM

INCHES 1 2



1 PLAN: RESIDUE FACILITY LAYOUT

0 300 600 SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
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SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
RESIDUE FACILITY LAYOUT
MINE YEAR 20

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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DWG. NO. HRF-004

REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-004.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:29 PM

INCHES 1 2

NOTES:

1. APPROXIMATE SOIL AND ROCK REMOVAL VOLUME = 329,000 CY

1 PLAN: EMERGENCY BASIN REMOVALS

0 200 400
SCALE IN FEET

VER NO	DATE	DESCRIPTION
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SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
EMERGENCY BASIN EXCAVATIONS
AND REMOVALS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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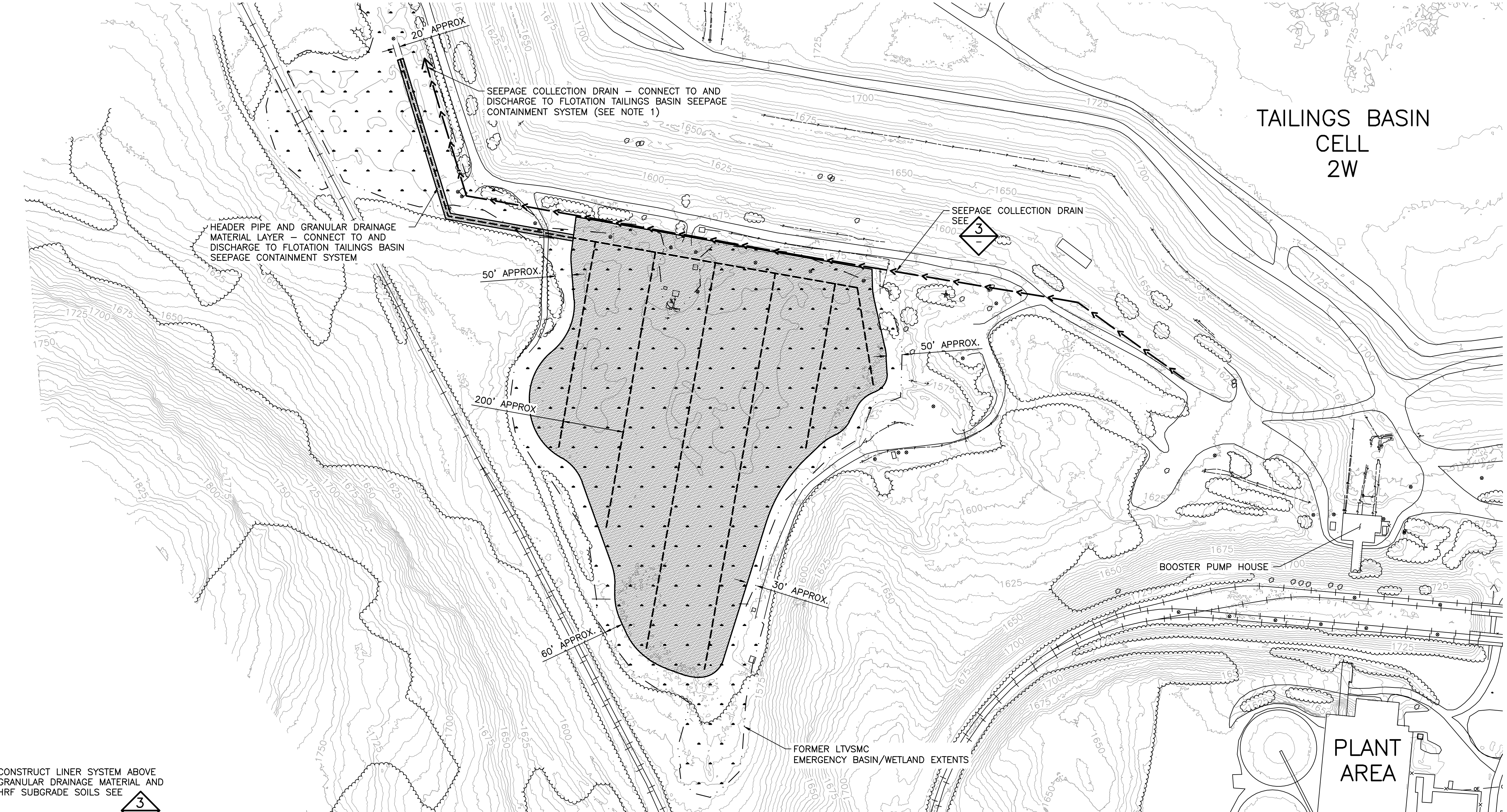
DWG. NO. HRF-005

REV A

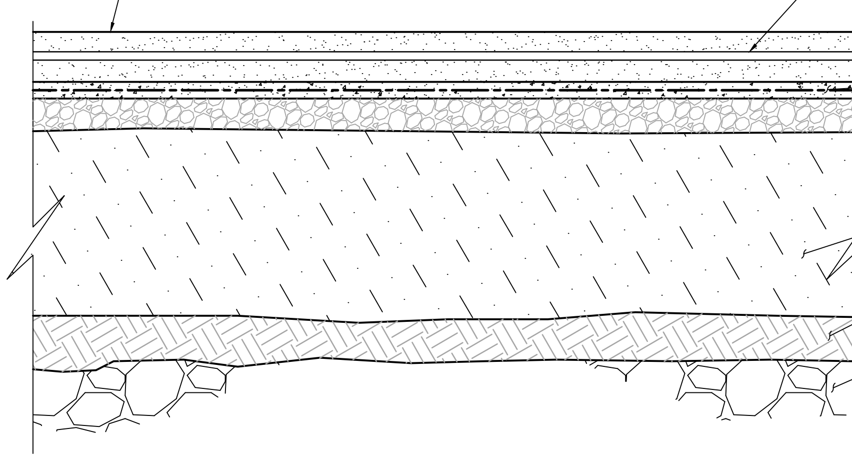
CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-005.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:32 PM

INCHES 1 2

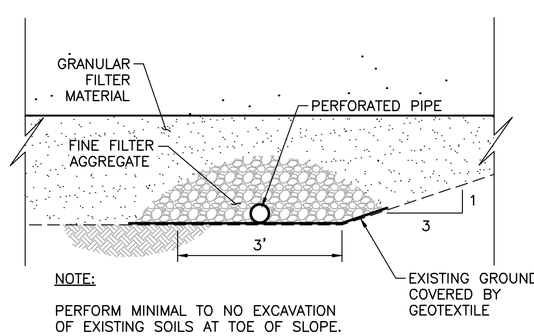


1 PLAN: SEEPAGE COLLECTION LAYOUT

0 200 400
SCALE IN FEET



2 DETAIL: DRAIN INSTALLATION
NTS



NOTE:

PERFORM MINIMAL TO NO EXCAVATION OF EXISTING SOILS AT TOE OF SLOPE.

3 DETAIL: SEEPAGE COLLECTION DRAIN
NTS

NOTES:

1. SEE FLOTATION TAILINGS BASIN SEEPAGE CONTAINMENT SYSTEM DRAWINGS FOR CONTAINMENT SYSTEM LOCATION AND DESIGN.

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY SUBGRADE IMPROVEMENT AND SEEPAGE COLLECTION DRAIN LAYOUT

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING CO.
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SUITE 200
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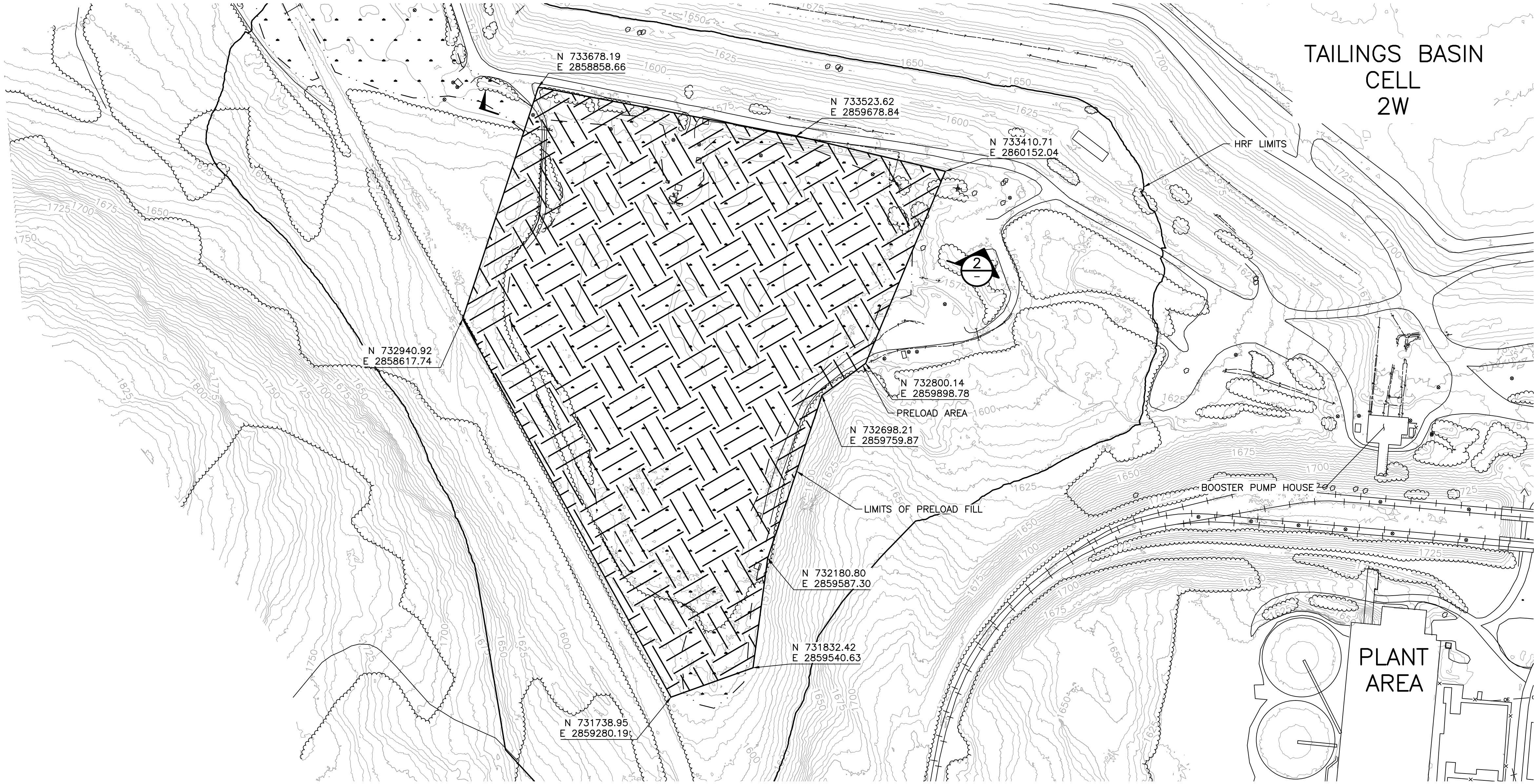
Ph: 1-800-632-2277

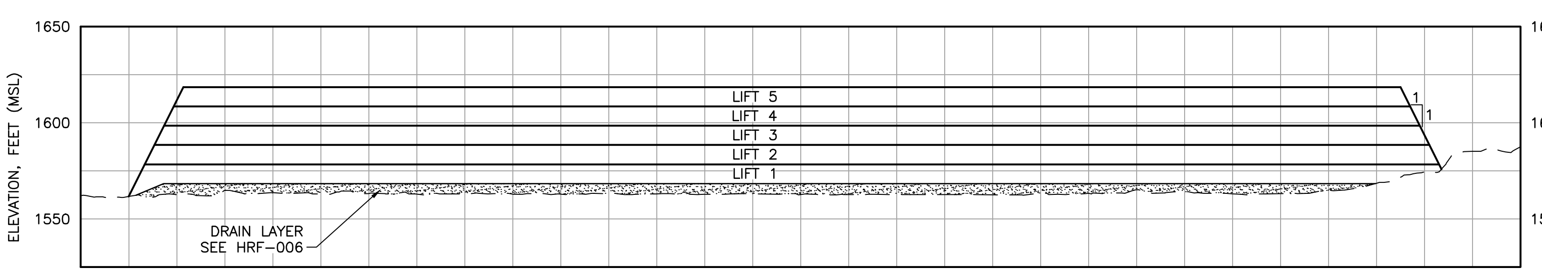
DWG. NO. HRF-006
REV A

INCHES 1 2



1 PLAN: PRELOAD LAYOUT

0 200 400
SCALE IN FEET



2 SECTION: PRELOAD LIFTS

0 100 200
HORIZONTAL SCALE IN FEET

NOTES:

1. PRELOAD AREA USING SOIL AND ROCK REMOVED FOR HRF (SEE DWG. HRF-005).

2. SOIL AND ROCK PRELOAD MATERIAL TO BE REMOVED TO HRF LINER GRADE AND UTILIZED FOR HRF DAM CONSTRUCTION.

3. NUMBER OF PRELOAD LIFTS IS PRELIMINARY.

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1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
EMERGENCY BASIN PRELOAD

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
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MINNEAPOLIS, MN.
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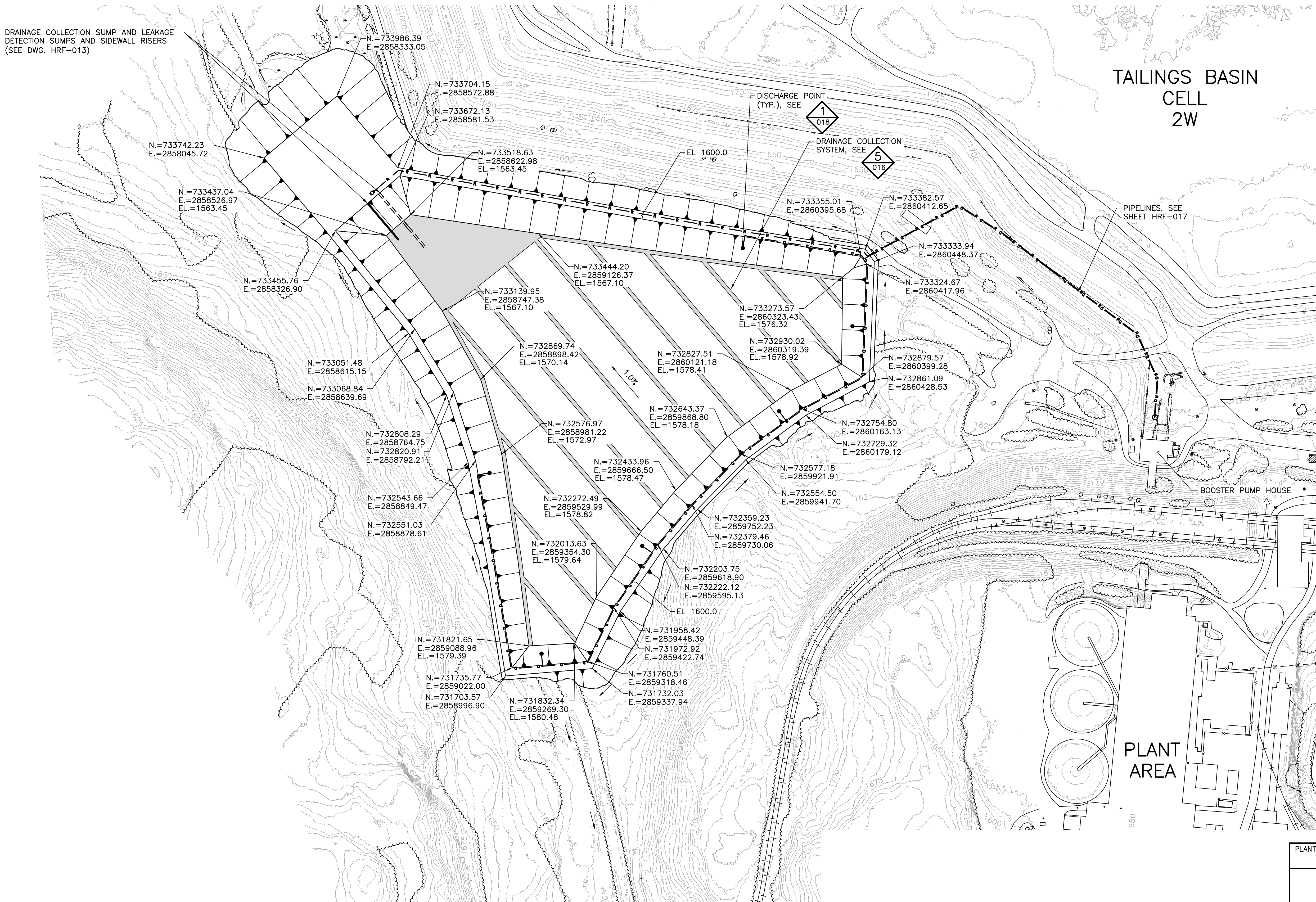
DWG. NO. HRF-007
REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-007.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:37 PM

INCHES 1 2

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-008.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:40 PM



NOTES:

1. UPPER LINER SURFACE SHOWN.
2. DRAINAGE COLLECTION GEOCOMPOSITE SHOWN (SHADED AREA).
3. PLACE HRF LINER OVER BASE AND INTERIOR SLOPES OF CELL. SEE DWG. HRF-016.

1 — PLAN: LIFT 1 LAYOUT

0 200 400

SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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DATE 5/15/17 LICENSE# 20951

DRAWN: CAD

CHECKED: TJR

BARR PROJECT NO.: 23/69-0C29

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY LIFT 1 LAYOUT

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NORTHMET PROJECT
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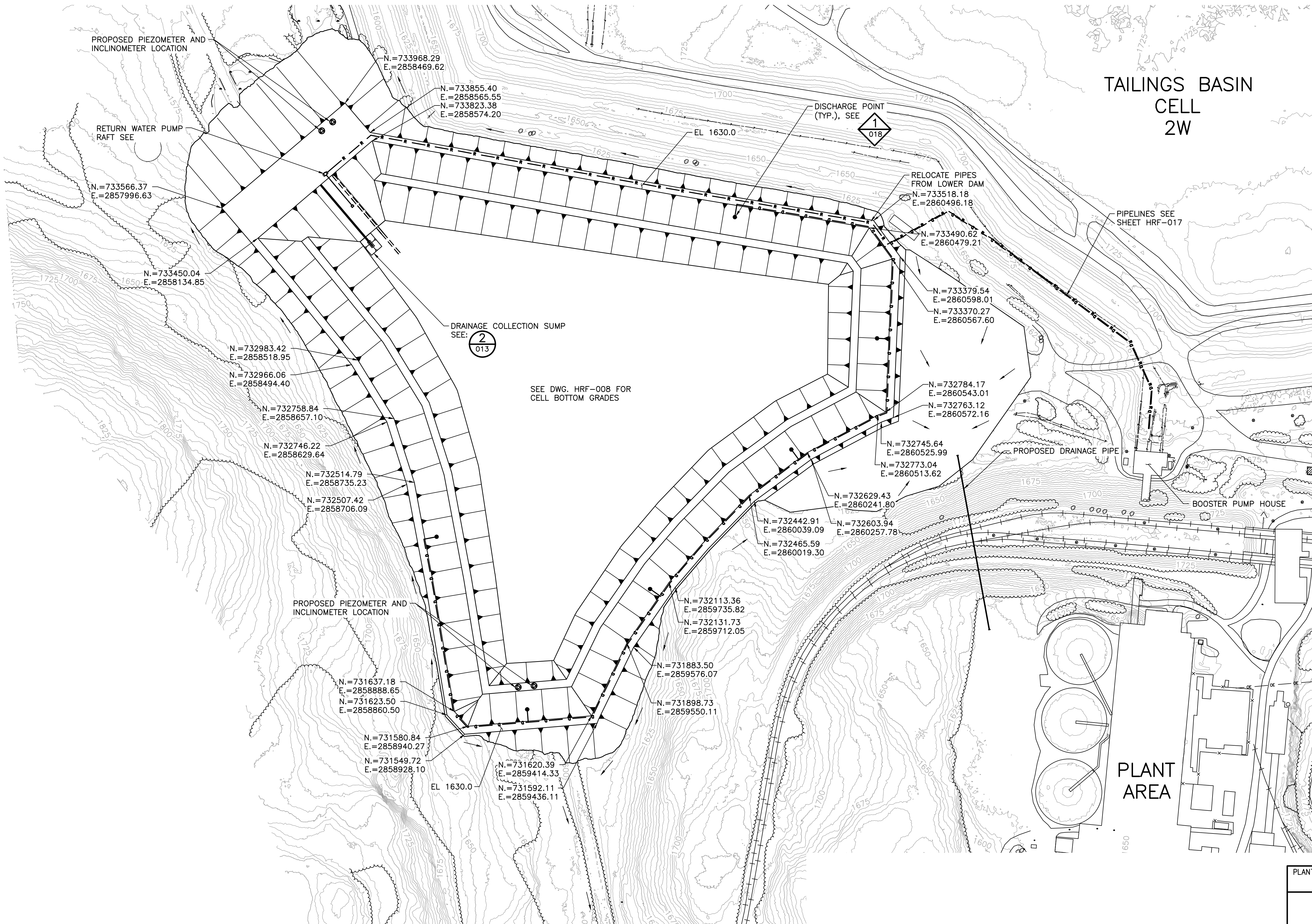
DWG. NO. HRF-008

REV A

INCHES 1 2

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-009.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:43 PM



NOTES:

1. LIFT 2 CONSTRUCTION YEAR TO BE BASED ON HRF CAPACITY CONSUMPTION RATE.
2. UPPER LINER SURFACE SHOWN.
3. FOR LEAKAGE DETECTION SUMP SEE 1/013
4. PLACE HRF LINER OVER BASE AND INTERIOR SLOPES OF CELL. SEE DWG. HRF-016.

1 PLAN: LIFT 2 LAYOUT

0 200 400
SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
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CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
LIFT 2 LAYOUT

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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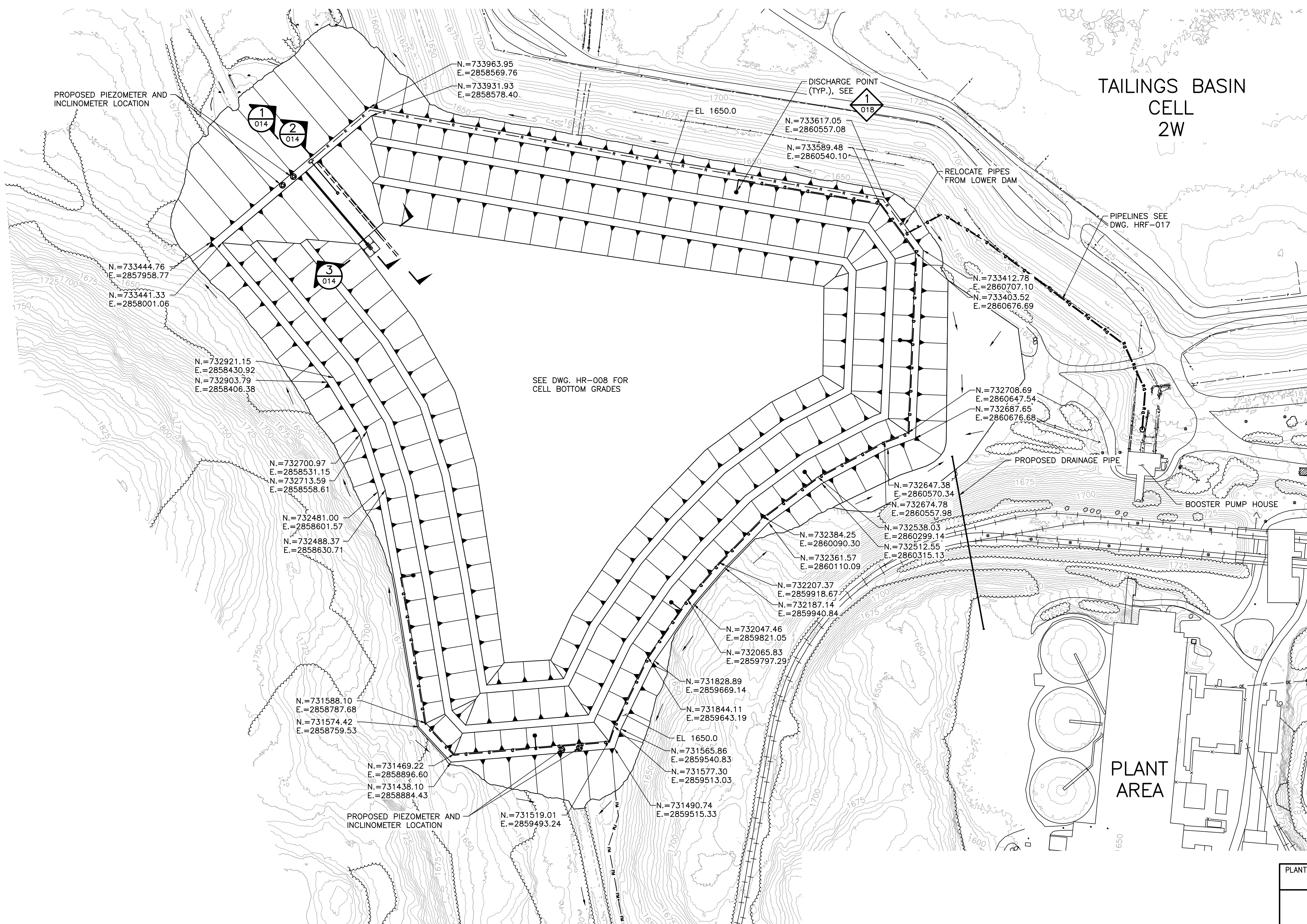
DWG. NO. HRF-009 REV A

INCHES 1 2



NOTES:

1. LIFT 3 CONSTRUCTION YEAR TO BE BASED ON HRF CAPACITY CONSUMPTION RATE.
2. UPPER LINER SURFACE SHOWN.
3. PLACE HRF LINER OVER BASE AND INTERIOR SLOPES OF CELL. SEE DWG. HRF-016.

1 PLAN: LIFT 3 LAYOUT

0 200 400
SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN - VERSION 1 - ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN - VERSION 1 - RESPONSE TO COMMENTS
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BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
LIFT 3 LAYOUT

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

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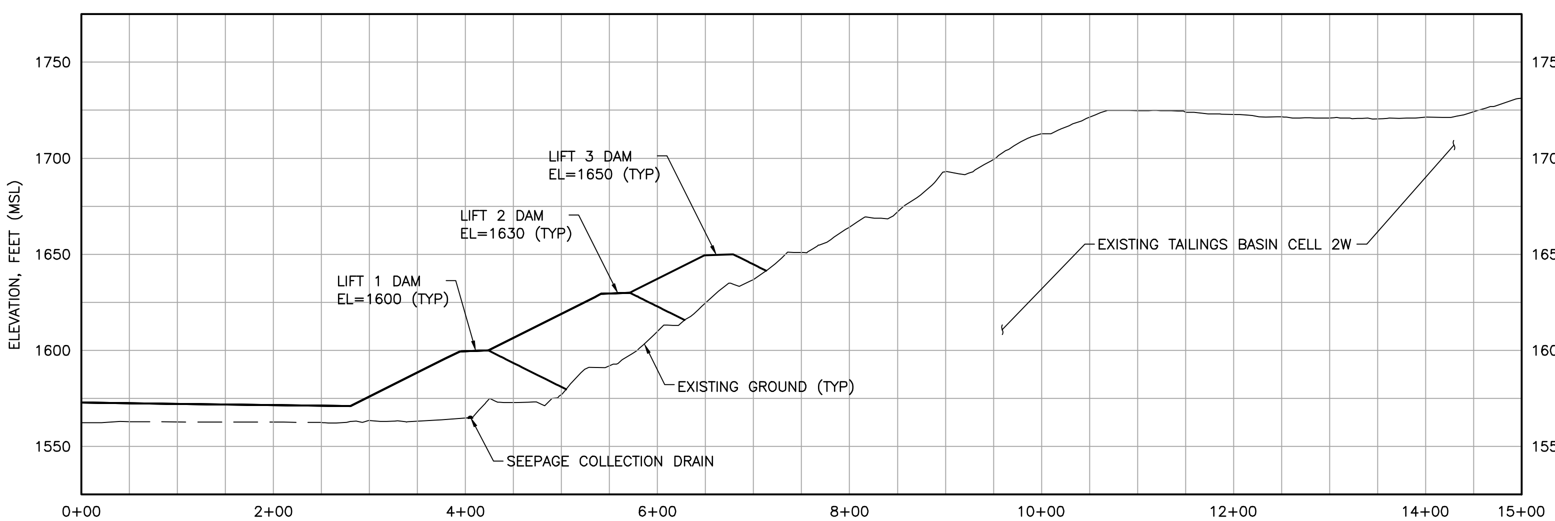
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-010

REV A

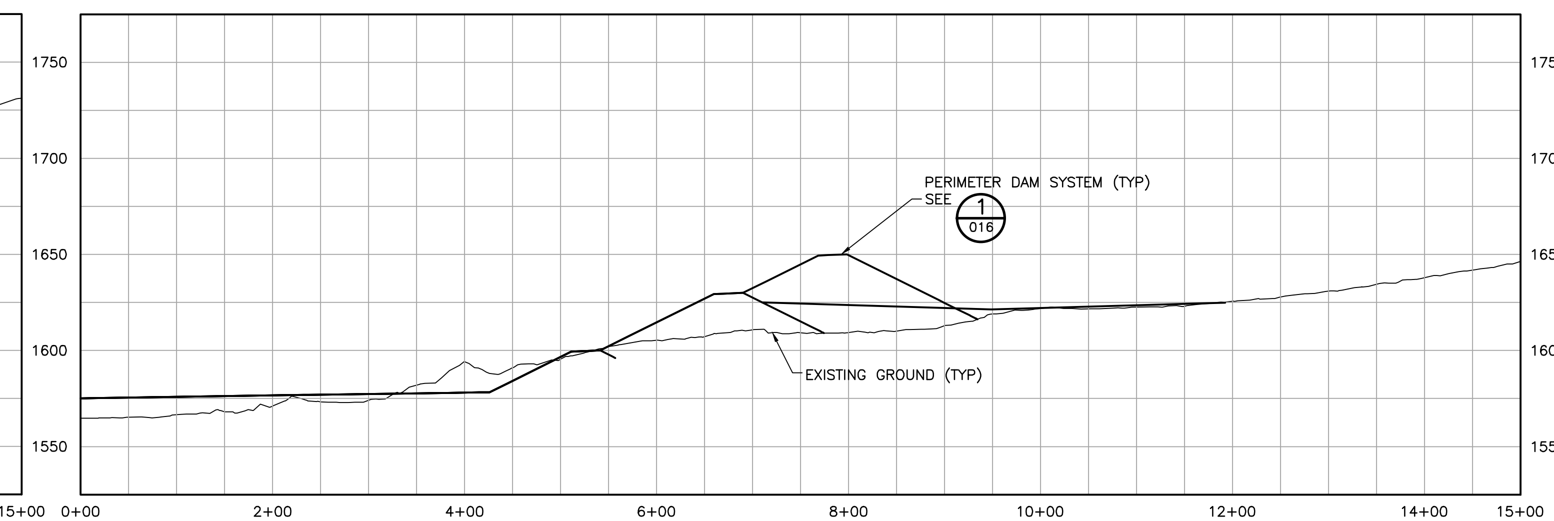
CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-010.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:45 PM

INCHES 1 2



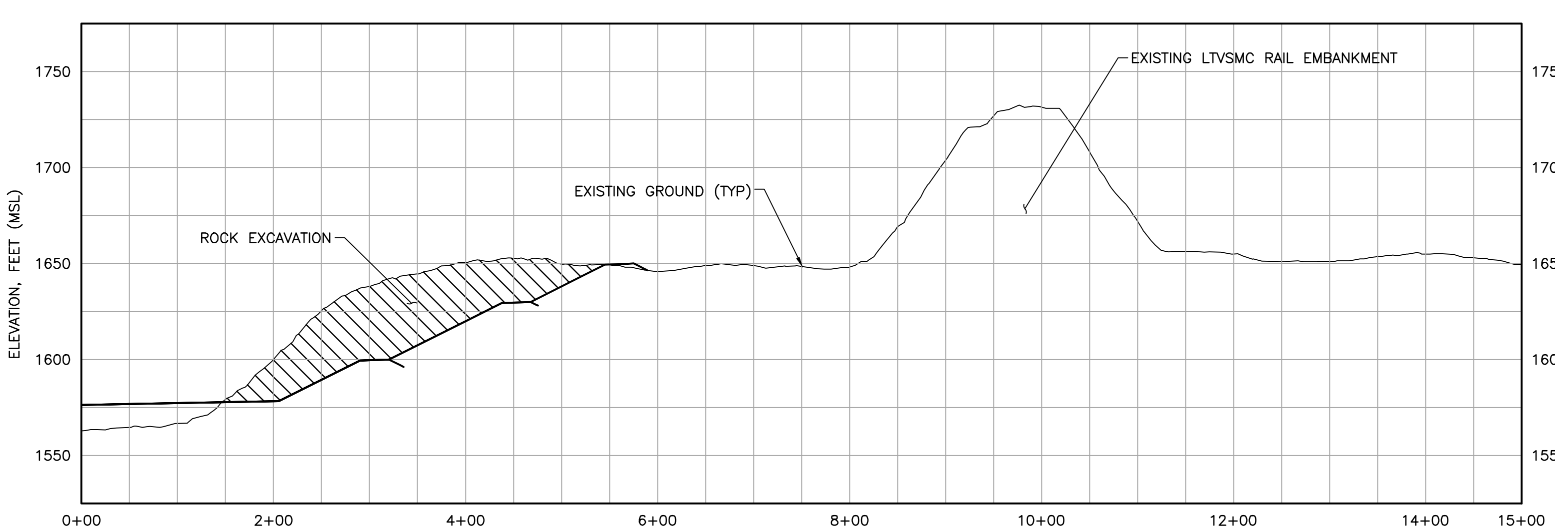
1 SECTION: HRF NORTH DAM

0 100 200
HORIZONTAL SCALE IN FEET



2 SECTION: HRF EAST DAM

0 100 200
HORIZONTAL SCALE IN FEET



3 SECTION: HRF SOUTH EAST DAM

0 100 200
HORIZONTAL SCALE IN FEET

NOTES:

1. SEE DWG. HRF-004 FOR SECTION LOCATIONS.

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
CROSS SECTIONS

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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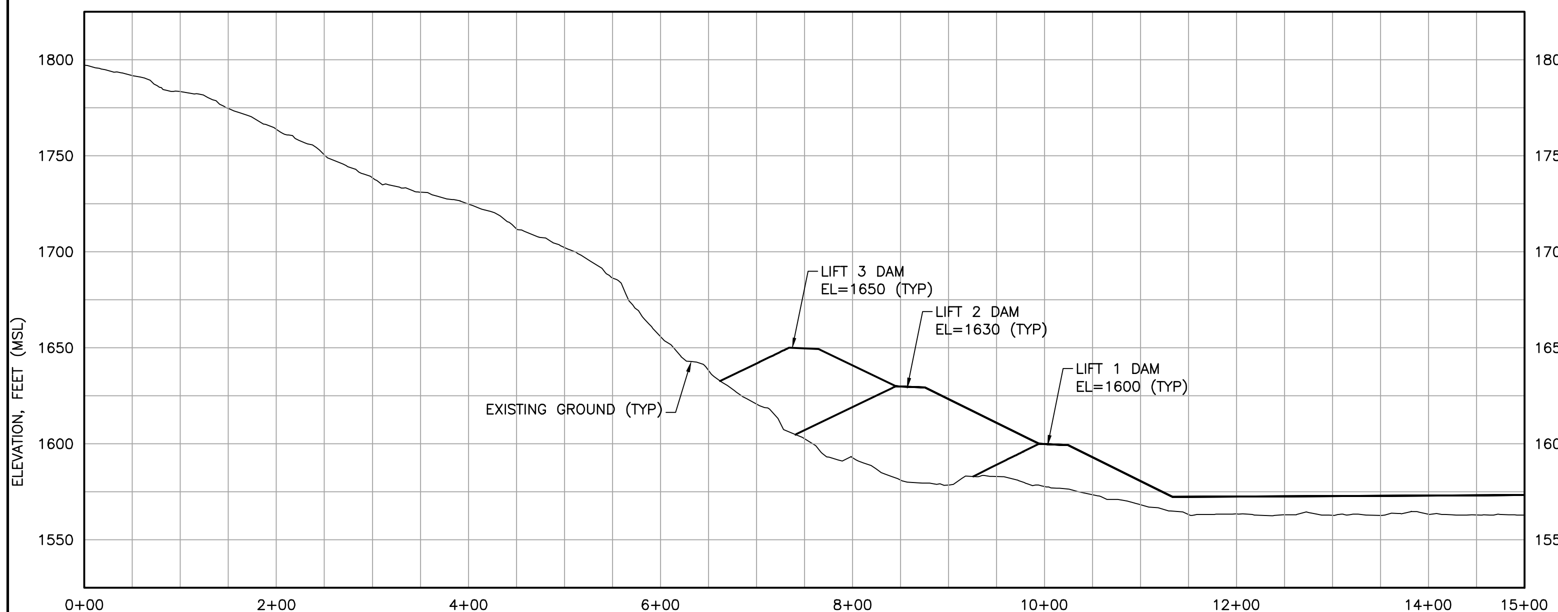
DWG. NO. HRF-011

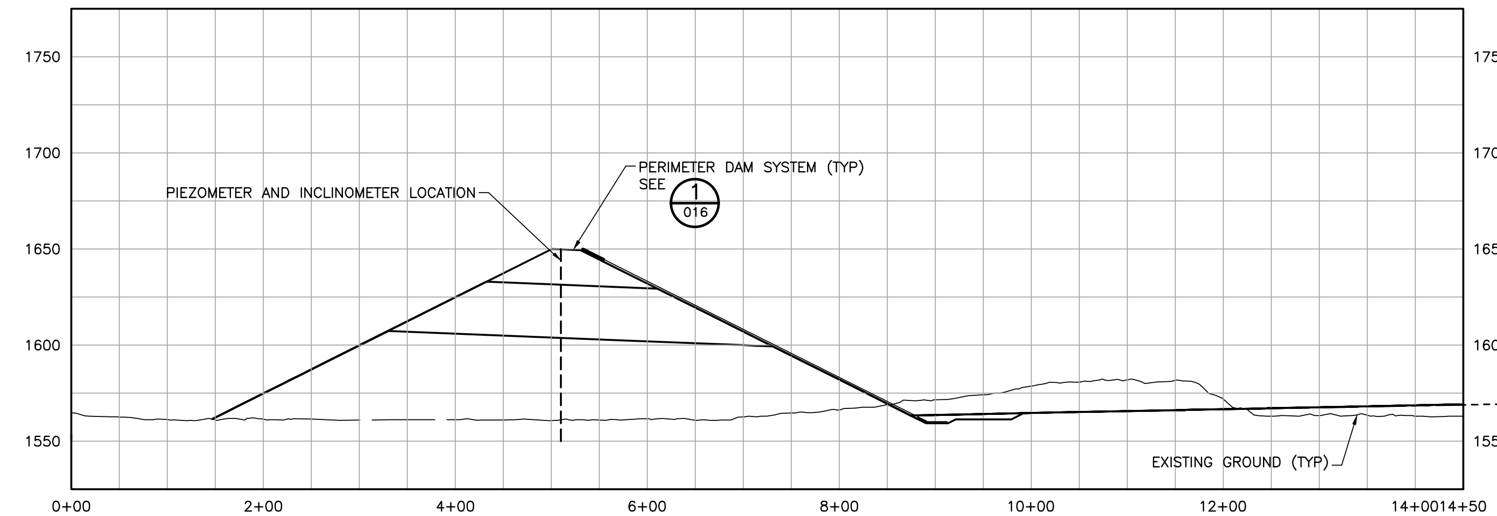
REV A

INCHES 1 2



1 SECTION: HRF SOUTH WEST DAM

0 100 200
SCALE IN FEET
HORIZONTAL



2 SECTION: HRF NORTH WEST DAM

0 100 200
SCALE IN FEET
HORIZONTAL

NOTES:

1. SEE DWG. HRF-004 FOR SECTION LOCATIONS.

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
CROSS SECTIONS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
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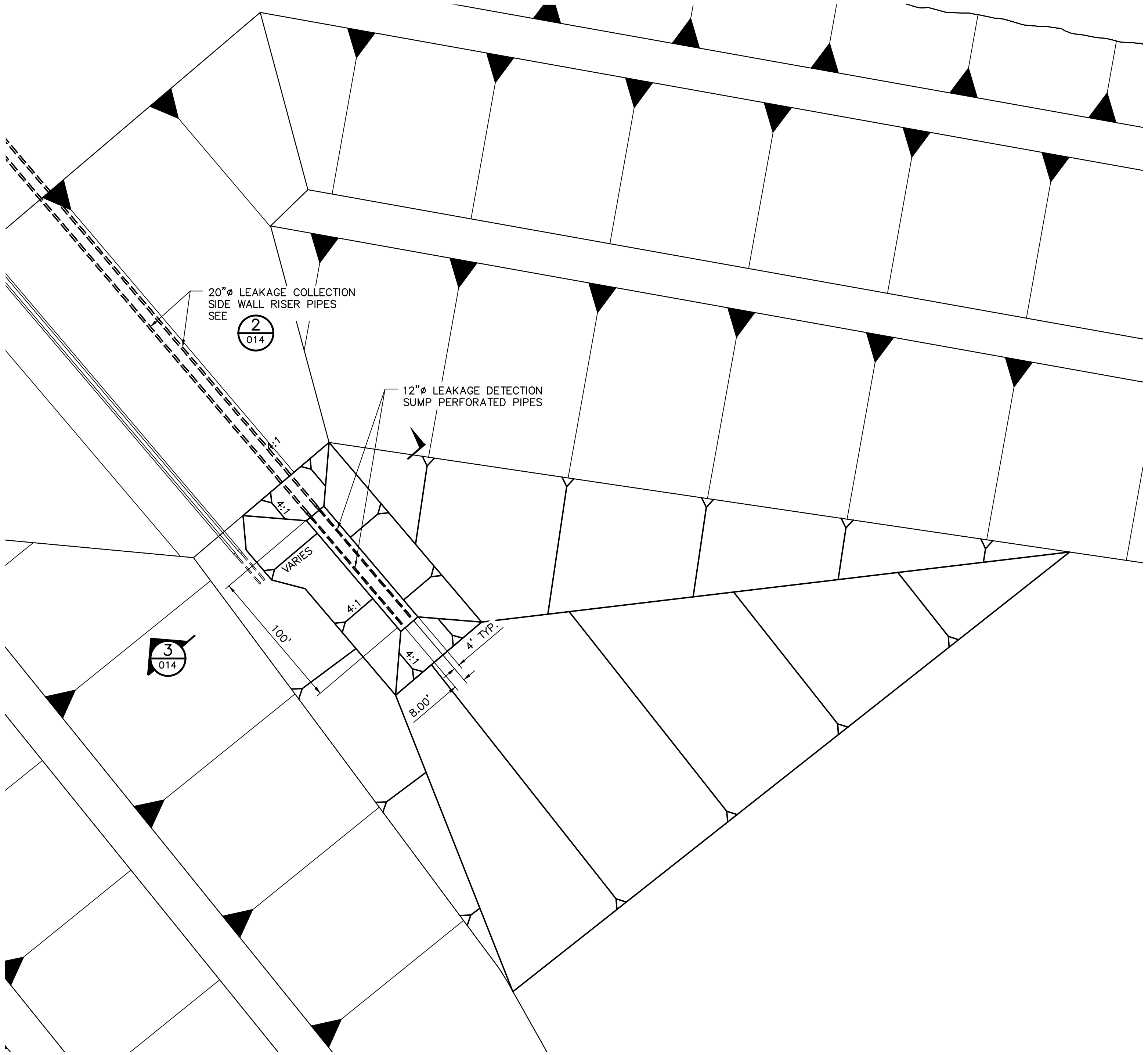
DWG. NO. HRF-012 REV A

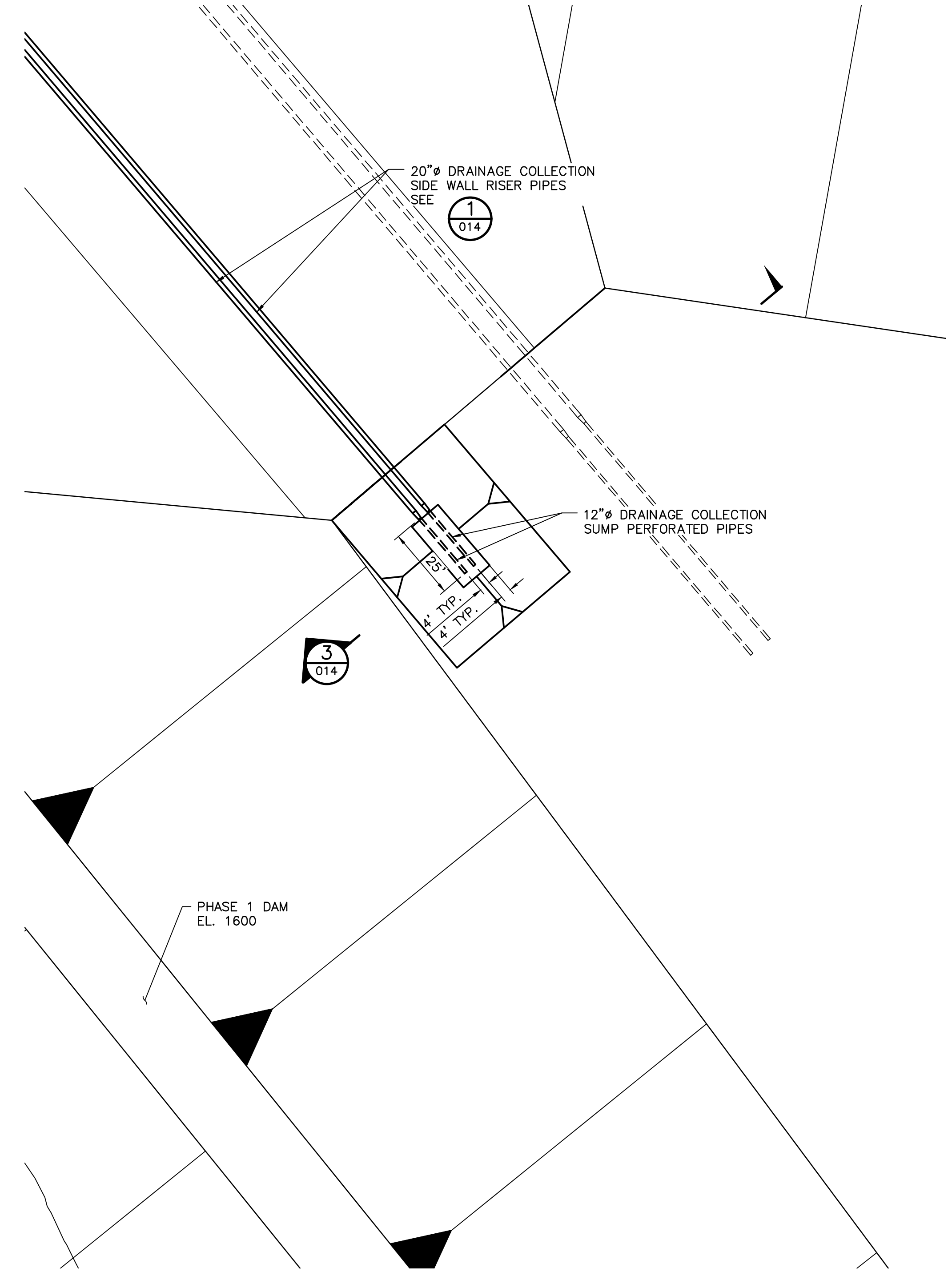
CADD USER: Cristion A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-012.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:48 PM

INCHES 1 2



1 PLAN: LEAKAGE DETECTION SUMP AND SIDEWALL RISER

0 50 100
SCALE IN FEET



2 PLAN: DRAINAGE COLLECTION SUMP AND SIDEWALL RISER

0 30 60
SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	5	5/15/17
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PRINTED NAME THOMAS J. RADUE
SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

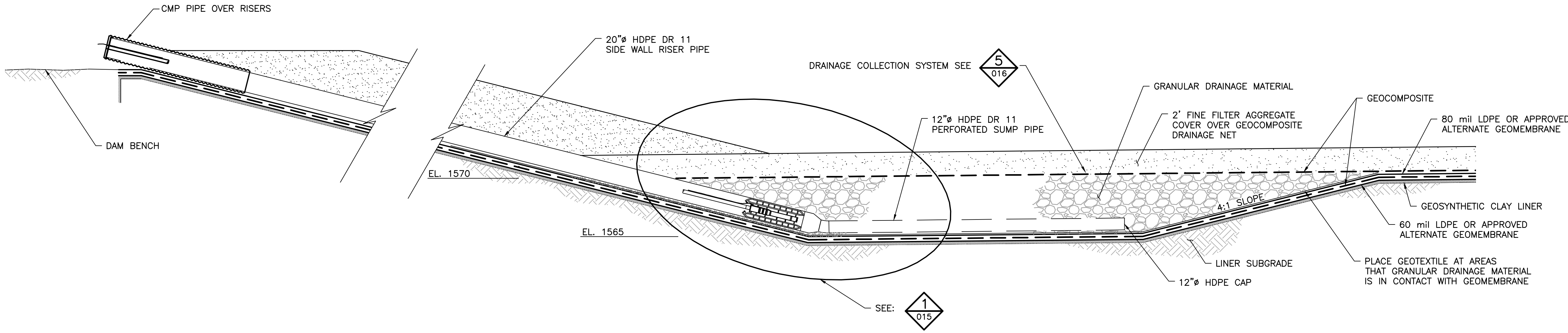
HYDROMETALLURGICAL RESIDUE FACILTY
SUMP AND SIDEWALL RISER PLAN LAYOUT

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

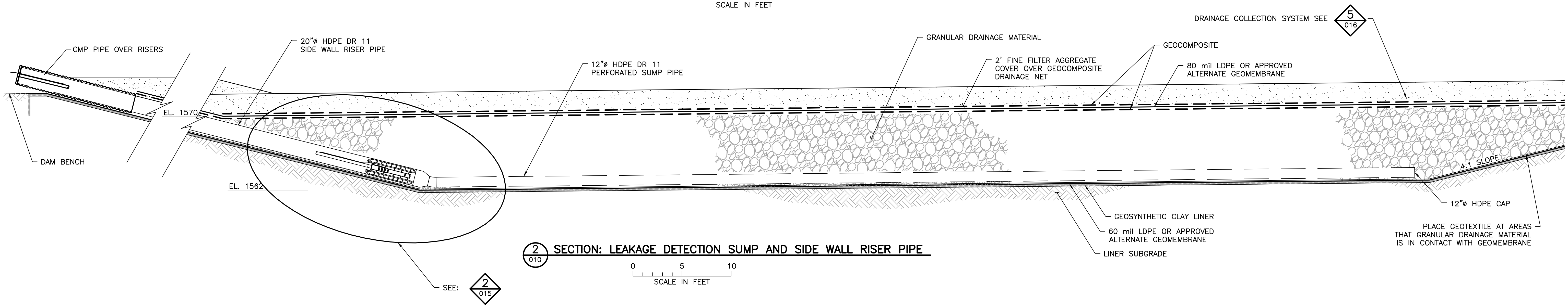
DWG. NO. HRF-013
REV A

INCHES 1 2



1/010 SECTION: DRAINAGE COLLECTION SUMP AND SIDE WALL RISER PIPE

0 5 10 SCALE IN FEET



2/010 SECTION: LEAKAGE DETECTION SUMP AND SIDE WALL RISER PIPE

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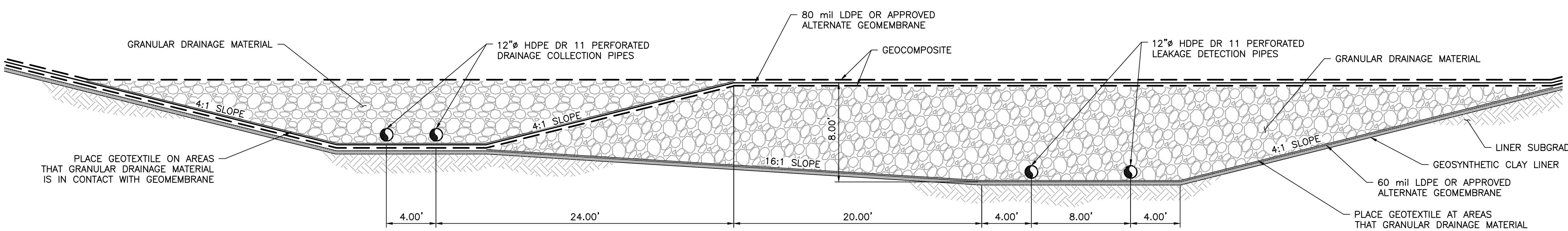

3/010 SECTION: DRAINAGE COLLECTION AND LEAKAGE DETECTION PIPES AND SUMPS

0 5 10 SCALE IN FEET

NOTES:

1. SEE DWG. HRF-010 FOR SECTION LOCATIONS.
2. DIFFERENCE IN GRANULAR DRAINAGE MATERIAL PATTERN SHOWN FOR VISUAL CLARITY PURPOSES ONLY. BOTH LEAKAGE DETECTION AND DRAINAGE COLLECTION AGGREGATES ARE THE SAME.
3. GEOMEMBRANE TYPE AND GEOCOMPOSITE TYPE REQUIRES APPROVAL BY DESIGN ENGINEER.
4. LINER SEPARATION NOT SHOWN TO SCALE FOR CLARITY.

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
SUMP AND SIDEWALL RISER SECTIONS

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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DWG. NO. HRF-014

REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-014.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:51 PM

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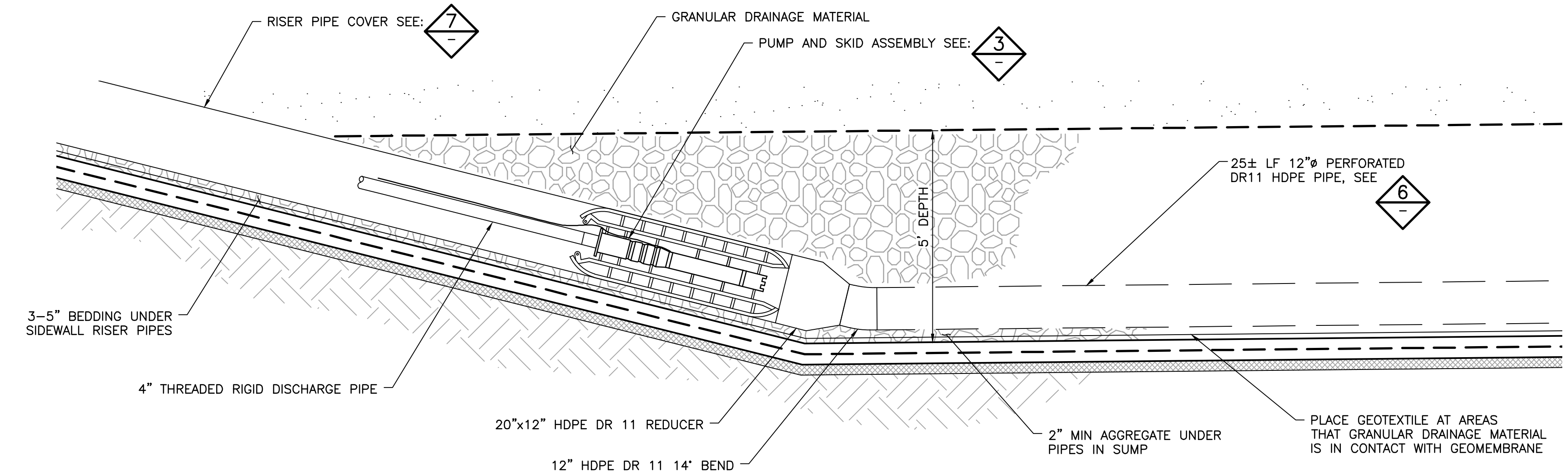
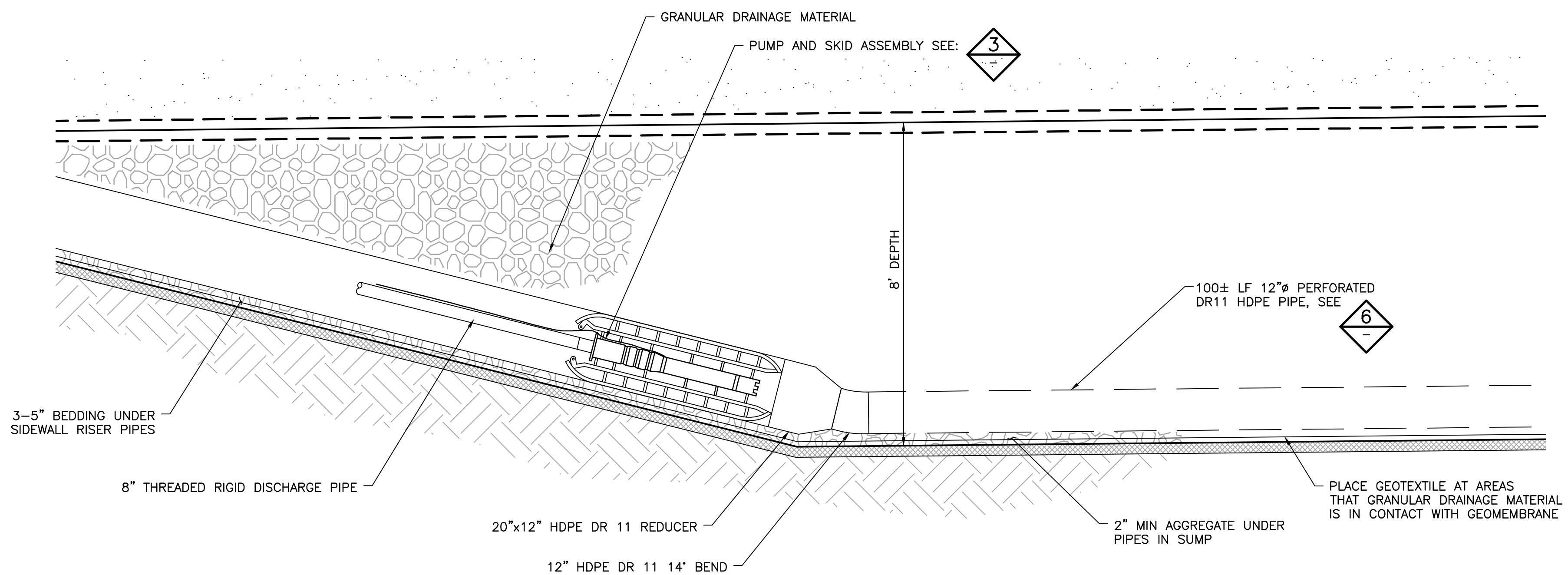
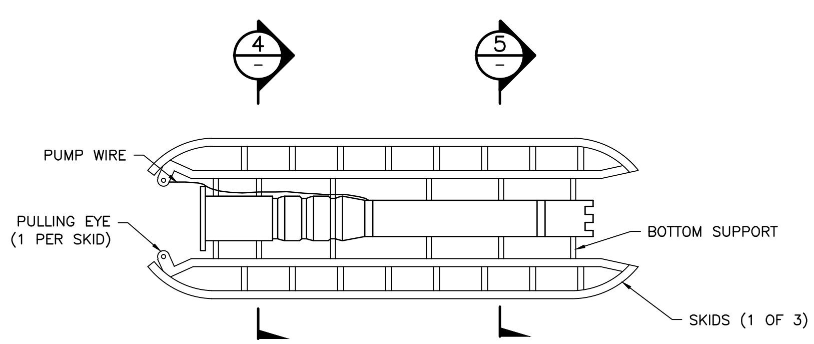


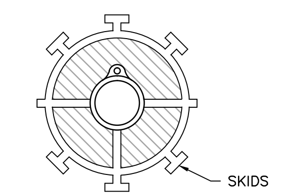
1 / 015 DETAIL: DRAINAGE COLLECTION SUMP
NTS



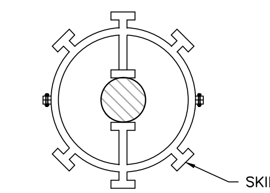
2 / 015 DETAIL: LEAKAGE DETECTION SUMP
NTS



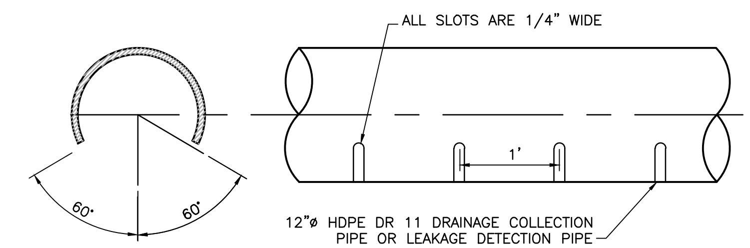
3 DETAIL: PUMP AND SKID ASSEMBLY
NTS



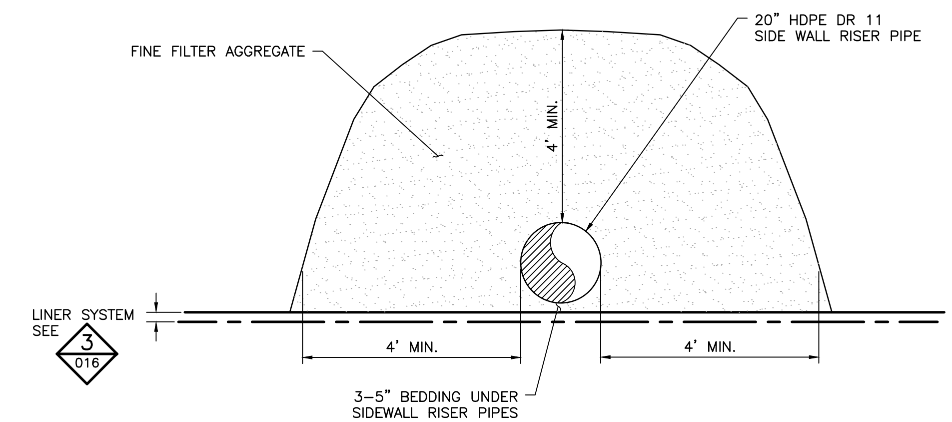
4 SECTION: PUMP AND SKID SECTION
NTS



5 SECTION: PUMP AND SKID SECTION
NTS



6 DETAIL: DRAINAGE COLLECTION AND LEAKAGE DETECTION PIPE PERFORATION
NTS



7 DETAIL: RISER PIPE COVER
NTS

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
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SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
SUMP AND PUMP DETAILS

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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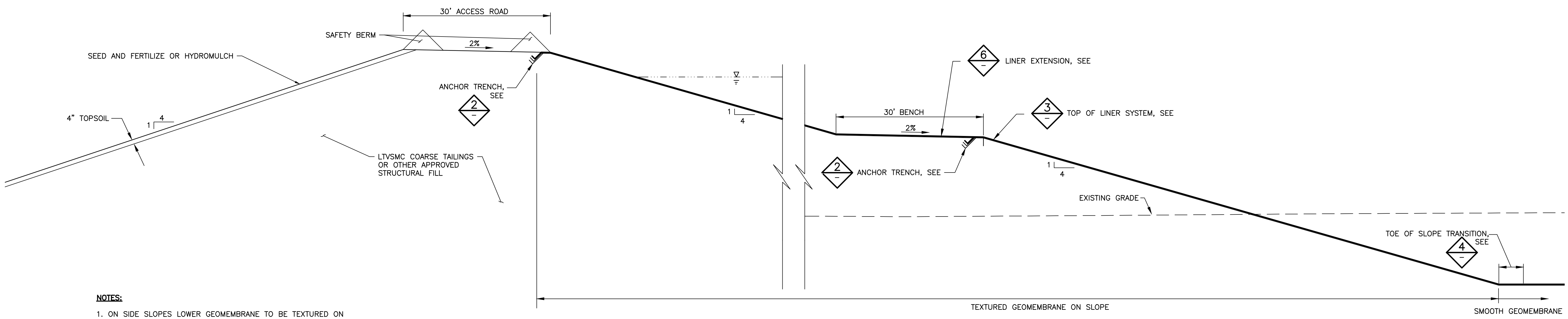
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-015
REV A

INCHES 1 2

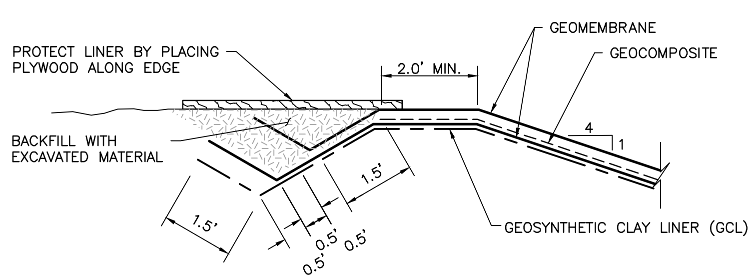


NOTES:

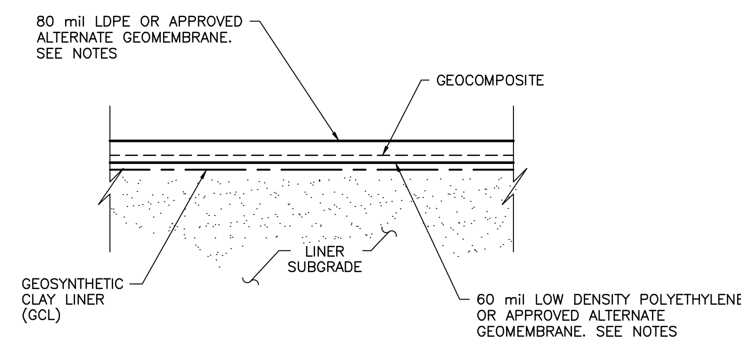
1. ON SIDE SLOPES LOWER GEOMEMBRANE TO BE TEXTURED ON BOTH SIDES. UPPER GEOMEMBRANE TO BE TEXTURED ON BOTTOM SIDE ONLY.

2. GEOMEMBRANE TYPE AND THICKNESS IS PRELIMINARY. TYPE AND THICKNESS MUST BE APPROVED BY DESIGN ENGINEER.

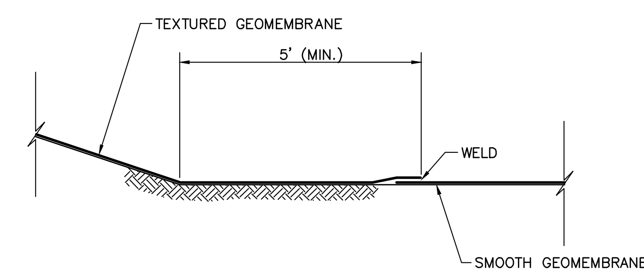
SECTION: PERIMETER DAM TYPICAL CROSS SECTION 1
NTS



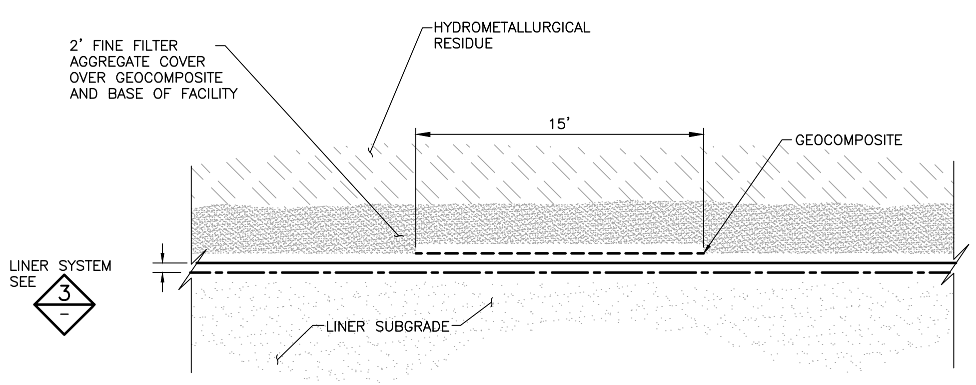
2 DETAIL: "V" ANCHOR TRENCH GCL/GEOMEMBRANE BARRIER LAYER
NTS



3 DETAIL: LINER SYSTEM
NTS

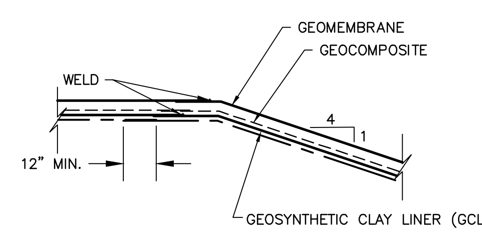


4 DETAIL: TOE OF SLOPE GEOMEMBRANE – TYPE TRANSITION
NTS



5 DETAIL: DRAINAGE COLLECTION SYSTEM

0 5 10
SCALE IN FEET



6 DETAIL: LINER SYSTEM EXTENSION
NTS

VER NO	DATE	DESCRIPTION
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DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
TYPICAL SECTIONS
AND DETAILS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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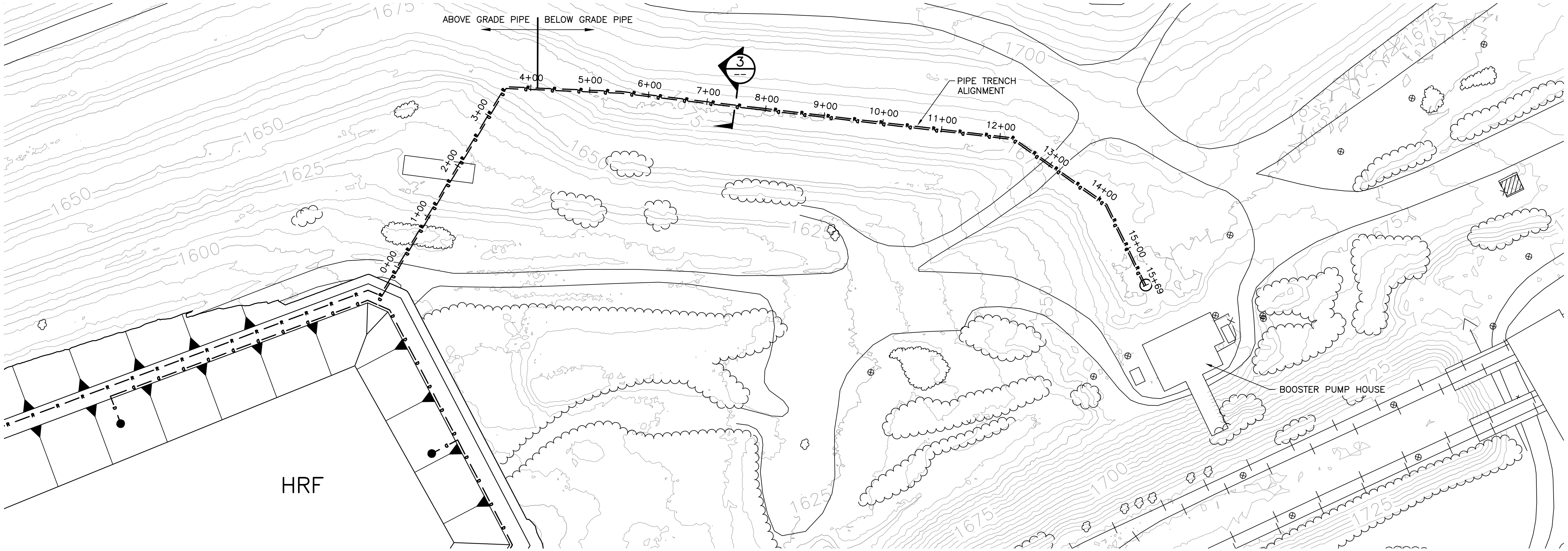
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-016
REV A

INCHES 1 2

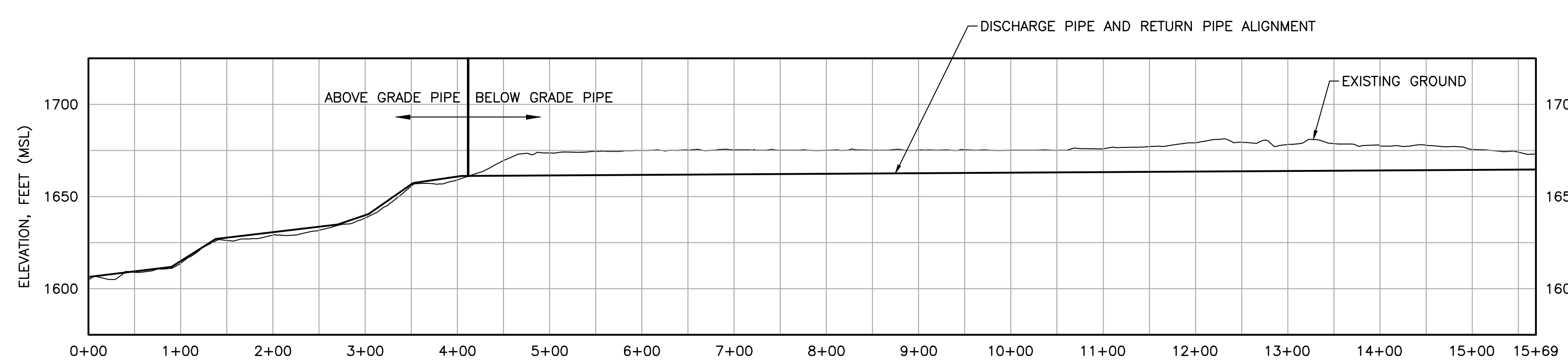


1 PLAN: PIPING LAYOUT

0 100 200 SCALE IN FEET

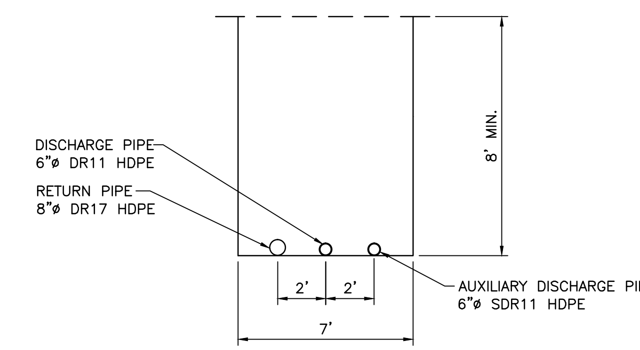
NOTES:

1. PIPE CLEAN-OUT AND PIG LAUNCHING AND RECEIVING ACCESS TO BE PROVIDED IN ABOVE-GRADE PORTIONS OF PIPE.
2. PIPING LAYOUT (PLAN AND PROFILE) IS PRELIMINARY.
3. PIPE SIZES ARE PRELIMINARY.



2 PROFILE: PIPING LAYOUT

0 100 200 HORIZONTAL SCALE IN FEET



3 SECTION: PIPE TRENCH (TYP.)

0 2 4 6 8 SCALE IN FEET

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-017.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:56 PM

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VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

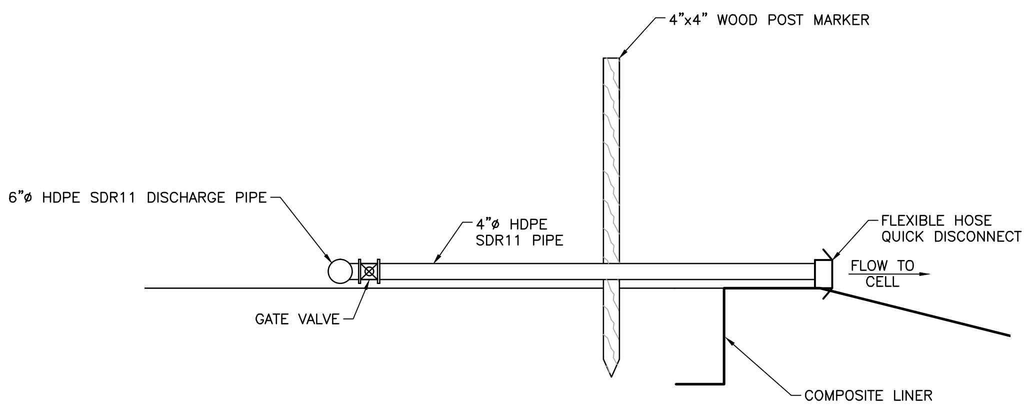
PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
PIPING
PLAN AND PROFILE

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-017
REV A



1 DETAIL: TYPICAL RESIDUE DISCHARGE POINT

0 1 2 3 4
SCALE IN FEET

NOTES:

1. PIPE SIZES ARE PRELIMINARY.

VER NO	DATE	DESCRIPTION
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PIPING DETAILS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

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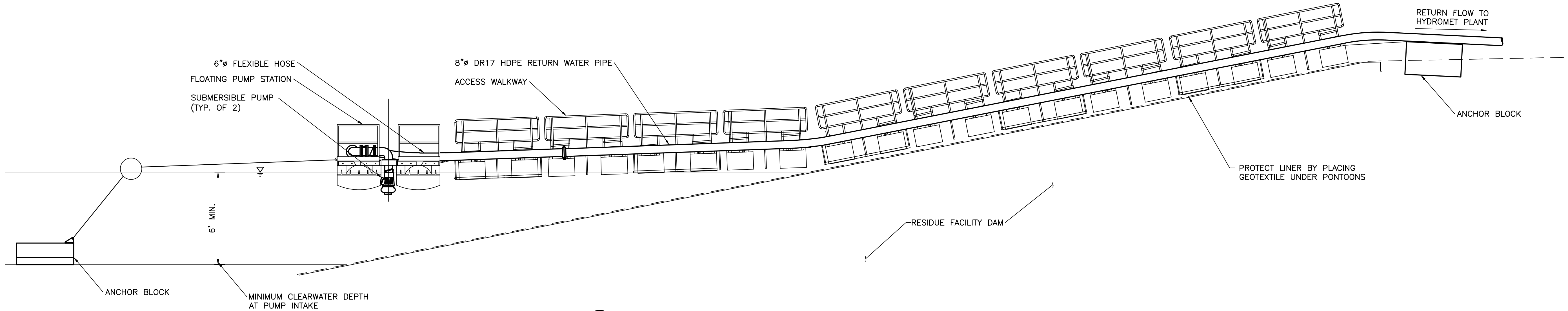
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-018

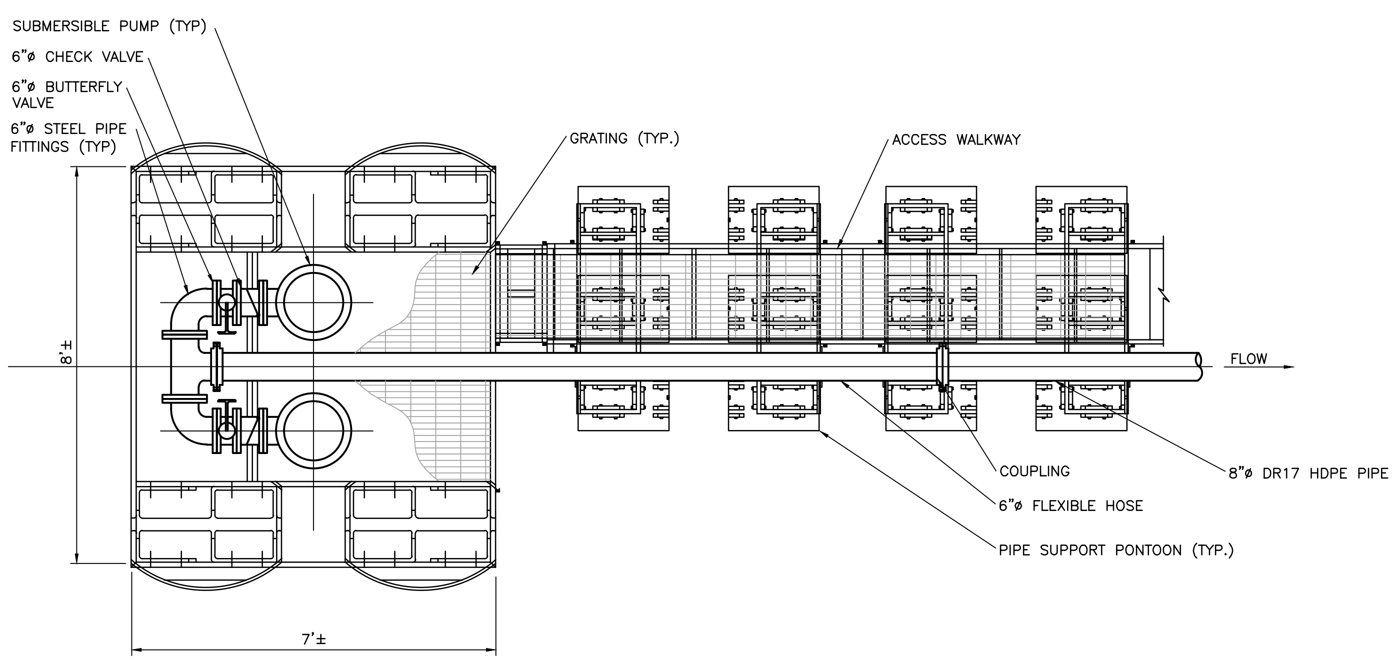
REV A

INCHES 1 2



1 ELEVATION: RETURN WATER PUMP RAFT

0 2 4 6 8
SCALE IN FEET



2 PLAN: RETURN WATER PUMP RAFT

0 1 2 3 4
SCALE IN FEET

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-019.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 6:59 PM

VER NO	DATE	DESCRIPTION
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2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
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HYDROMETALLURGICAL RESIDUE FACILTY
RETURN WATER PUMP RAFT

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POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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MINNEAPOLIS, MN.
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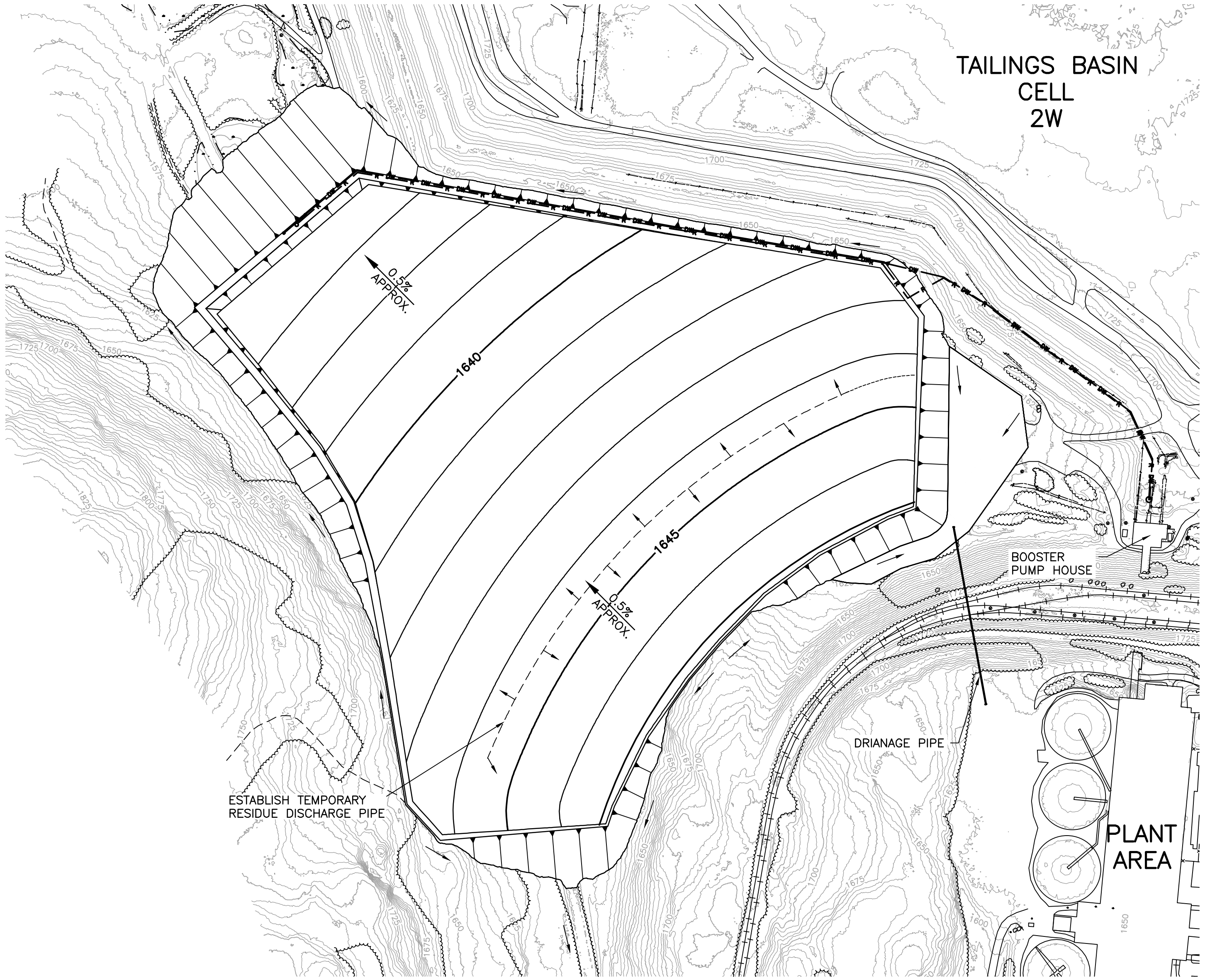
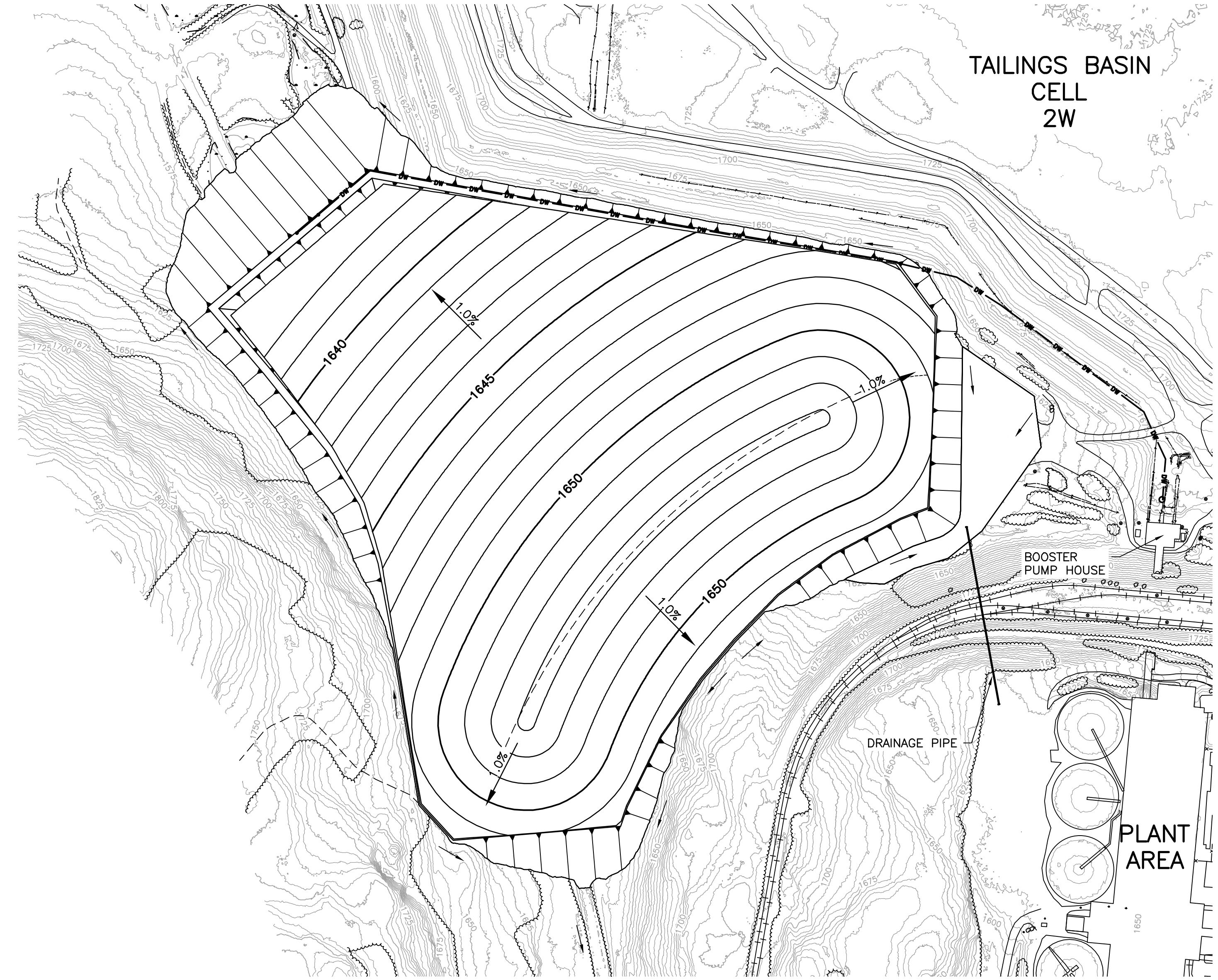
DWG. NO. HRF-019
REV A

INCHES 1 2



1 PLAN: START OF MINE YEAR 20 RESIDUE GRADES

0 300 600 SCALE IN FEET



3 PLAN: END OF MINE YEAR 20 RESIDUE AND TEMPORARY COVER GRADES

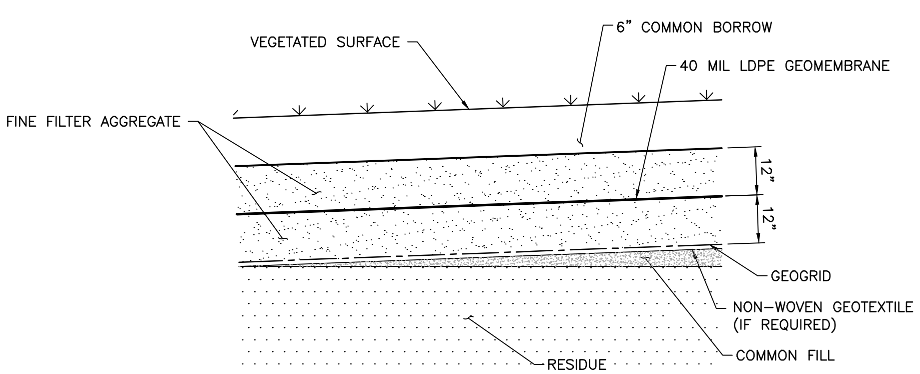
0 300 600 SCALE IN FEET

NOTES:

1. PRIOR TO FINAL CLOSURE PLACE TEMPORARY COVER OVER NEWLY GRADED RESIDUE.

2. ALLOW FOR RESIDUE MATERIAL TO SETTLE PRIOR TO PLACEMENT OF FINAL COVER.

3. COMMON FILL AS NEEDED TO ACHIEVE SLOPES THAT FACILITATE SURFACE WATER RUNOFF.



2 DETAIL: TEMPORARY COVER SYSTEM
NTS

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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SIGNATURE *Thomas J. Radue*
DATE 5/15/17 LICENSE# 20951

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CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
CLOSURE
PREPARATION PLAN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
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MINNEAPOLIS, MN.
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DWG. NO. HRF-020

REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-020.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 7:02 PM

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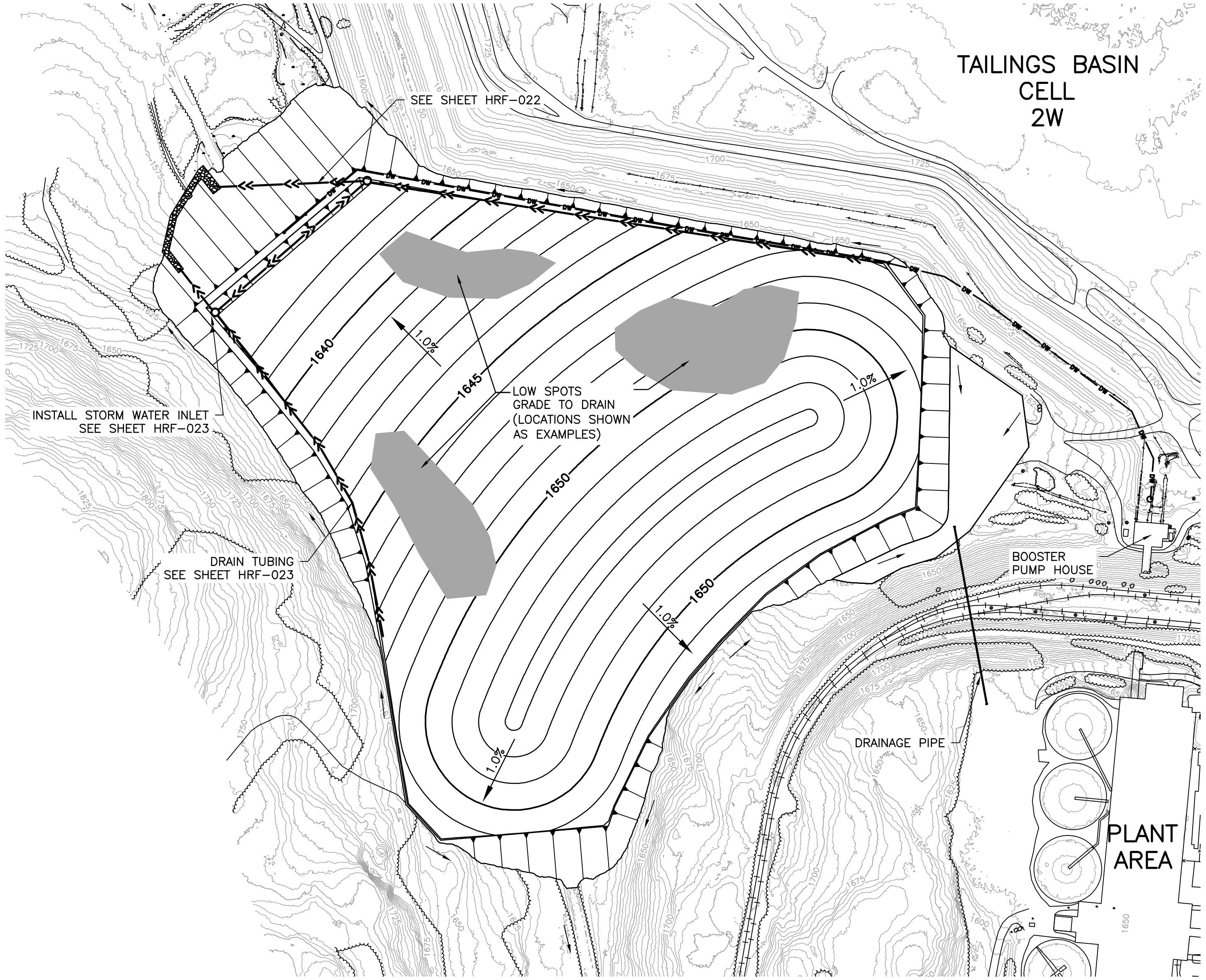
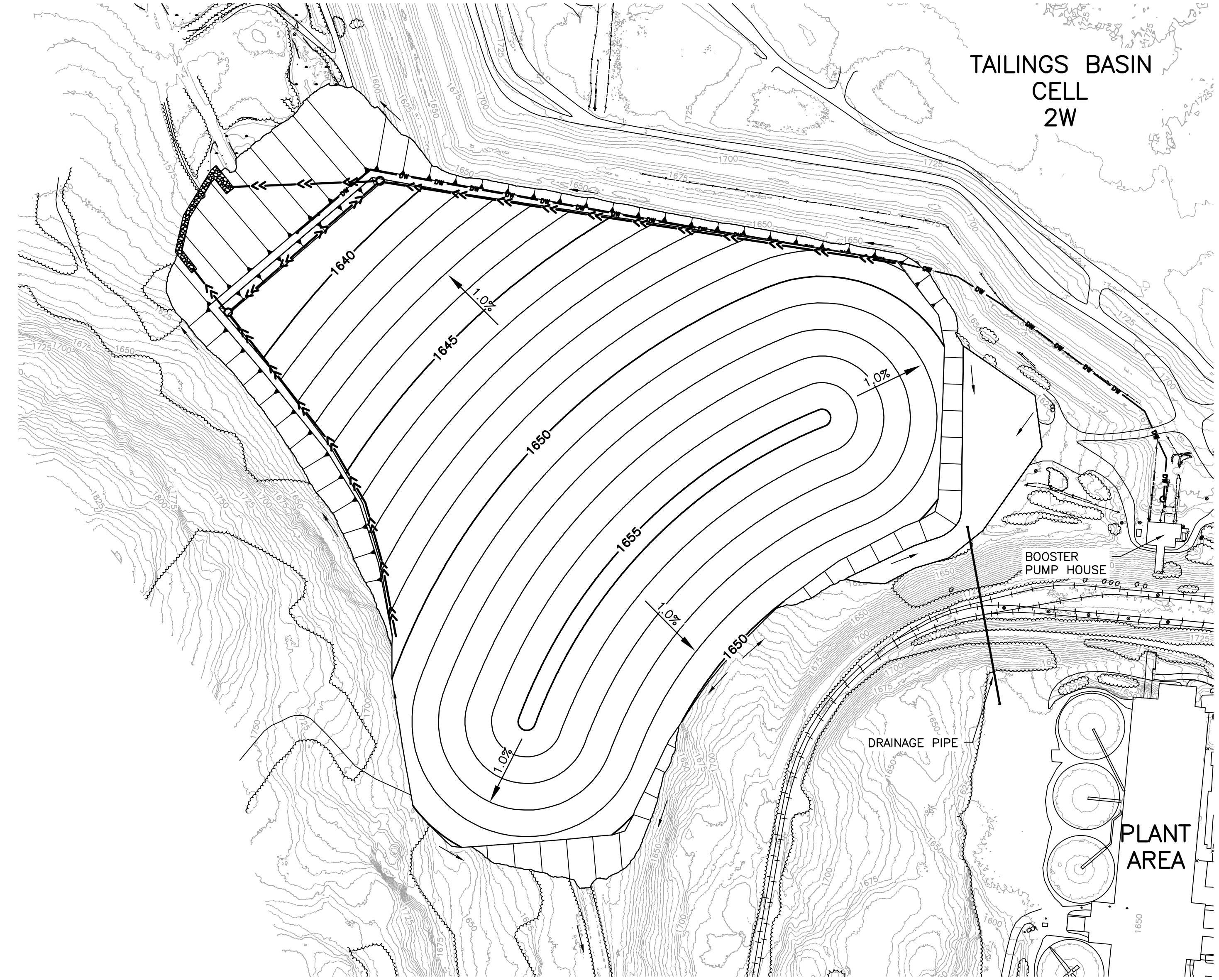


3 PLAN: TEMPORARY COVER REGRADING

0 300 600 SCALE IN FEET



4 PLAN: FINAL COVER GRADES

0 300 600 SCALE IN FEET

NOTES:

1. PRIOR TO FINAL CLOSURE GRADE ANY LOW SPOTS CREATED DURING SETTLEMENT ALLOTMENT TIME.

2. INSTALL DRAIN TUBING AND SURFACE WATER INLETS.

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
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PRINTED NAME THOMAS J. RADUE
SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
TEMPORARY COVER AND
FINAL COVER GRADING

POLYMET MINING

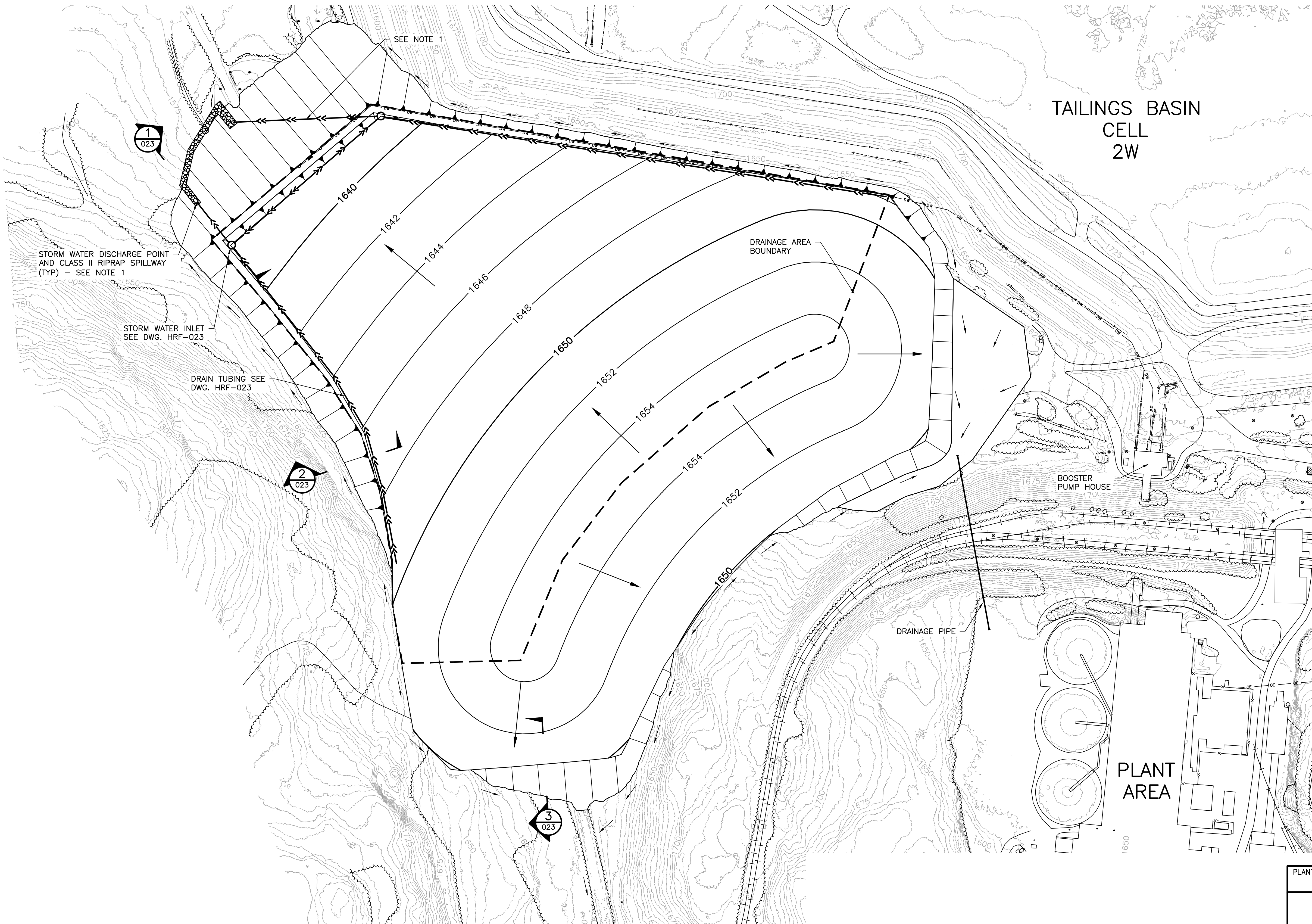
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. HRF-021
REV A

INCHES 1 2



NOTES:

1. FIELD-ALIGN SURFACE WATER DISCHARGE PIPES TO DISCHARGE CLEAN SURFACE RUNOFF TO LOCATION OUTSIDE OF GROUNDWATER CONTAINMENT SYSTEM. SEE FTB SEEPAGE CAPTURE AND STREAM AUGMENTATION SYSTEMS DRAWINGS.

2. EMERGENCY OVERFLOW NOT SHOWN. SEE HRF-023

3. FIELD-FIT TOE-OF-SLOPE DRAINAGE SWALE TO DRAIN STORMWATER RUNOFF AND TO PREVENT PONDING AT TOE OF SLOPE.

1 PLAN: FINAL CLOSURE

0 200 400

SCALE IN FEET

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
3	12/14/12	RESIDUE MANAGEMENT PLAN – VERSION 2 – ATTACHMENT A
4	05/19/15	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS
5	05/15/17	PERMIT APPLICATION UPDATES

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	5	5/15/17
FOR CONSTRUCTION		

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SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
FINAL CLOSURE
GRADING AND DRAINAGE

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
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DWG. NO. HRF-022

REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-022.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 7:07 PM

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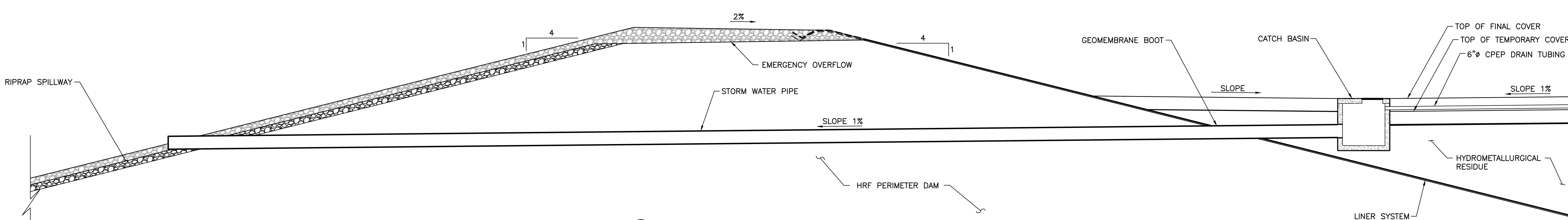
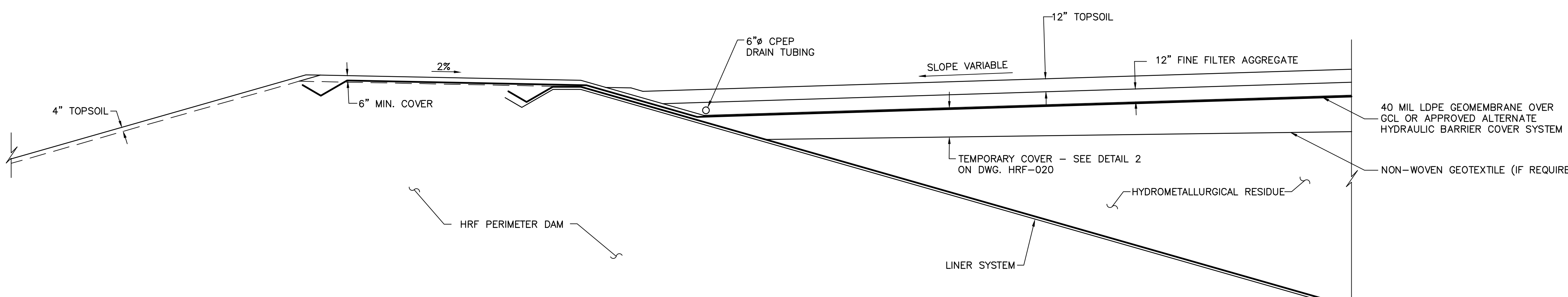


1 – SECTION: STORM WATER INLET
NTS

NOTES:

1. TEMPORARY COVER MATERIALS NOT SHOWN ON THS DRAWING. SEE DETAIL 3 ON DWG. HRF-020.



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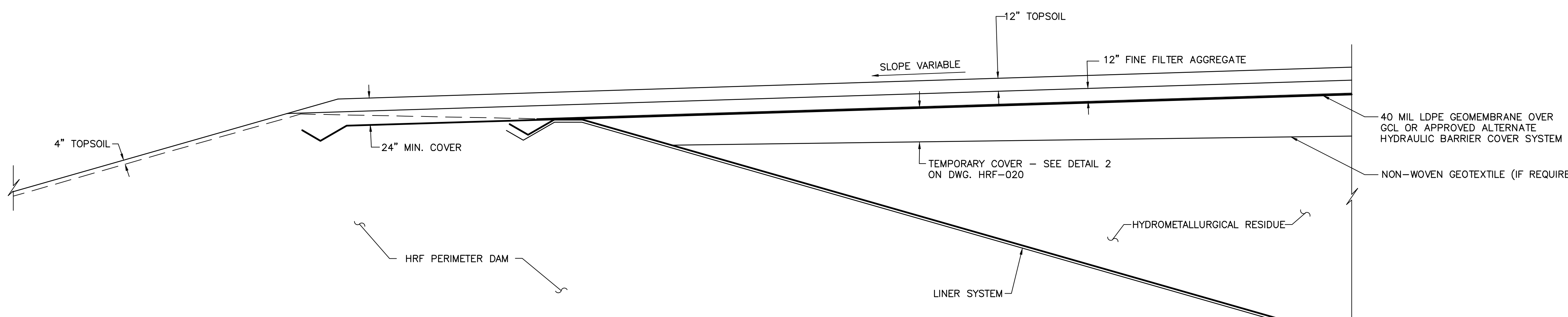
NTS



3 – SECTION: FINAL COVER OVER DAM
NTS

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
CLOSURE
SECTIONS AND DETAILS

VER NO	DATE	DESCRIPTION
1	10/14/11	RESIDUE MANAGEMENT PLAN – VERSION 1 – ATTACHMENT A
2	06/29/12	RESIDUE MANAGEMENT PLAN – VERSION 1 – RESPONSE TO COMMENTS
3	12/14/12	RESIDUE MANAGEMENT PLAN – VERSION 2 – ATTACHMENT A
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ISSUED	VERSION	DATE
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SIGNATURE Thomas J. Radue
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POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
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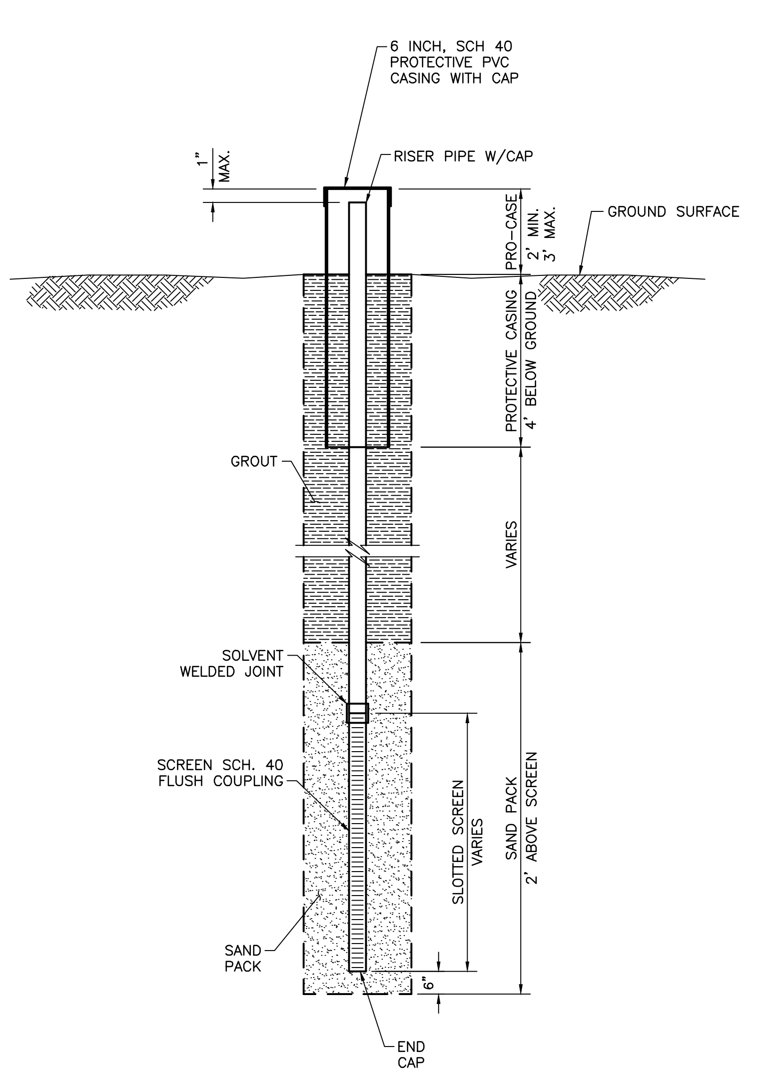
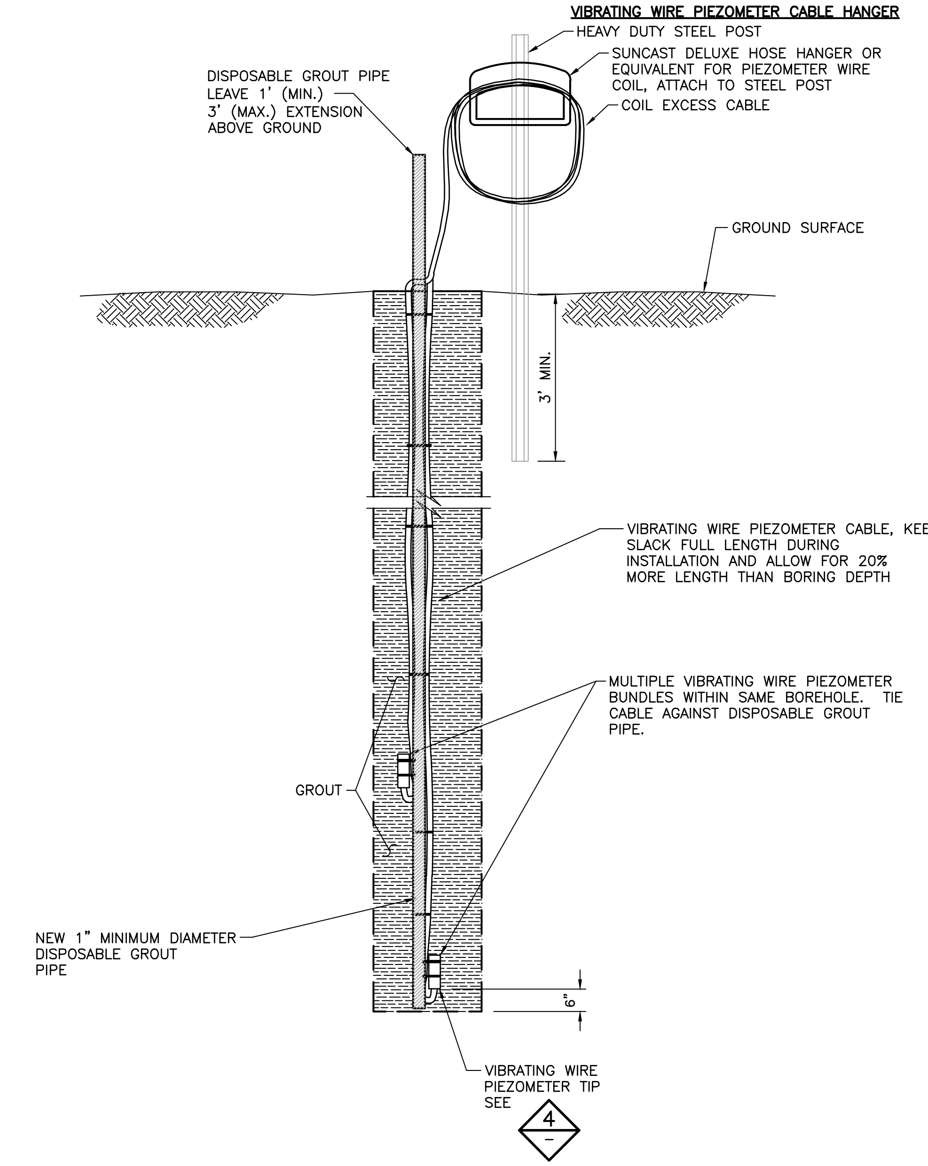
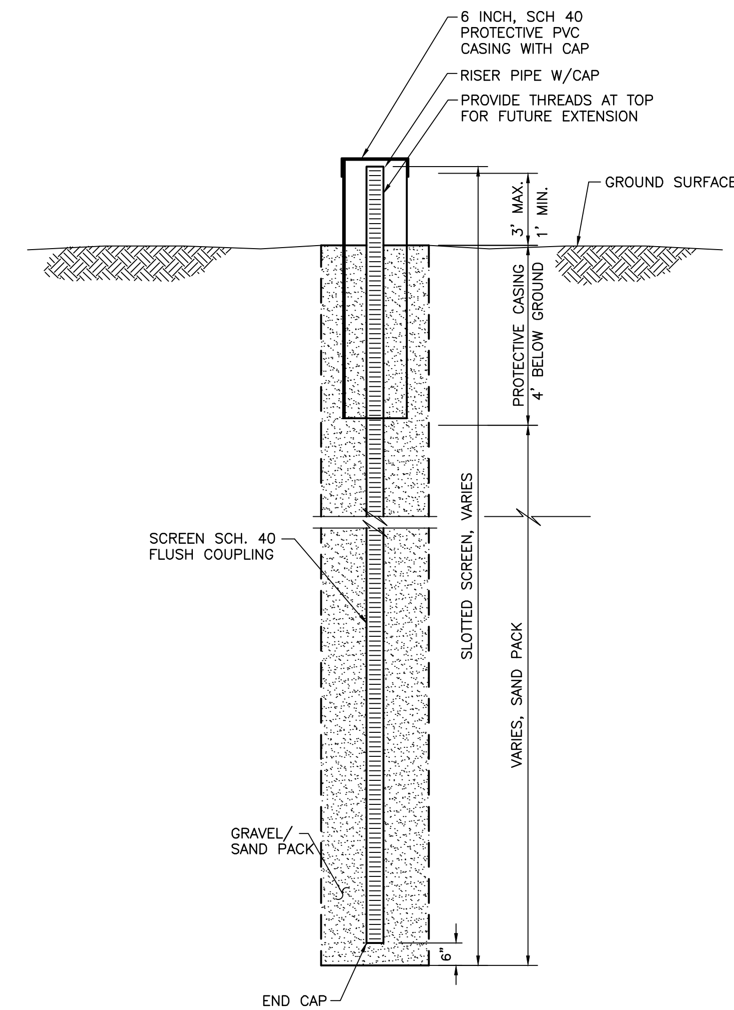
INCHES 1 2







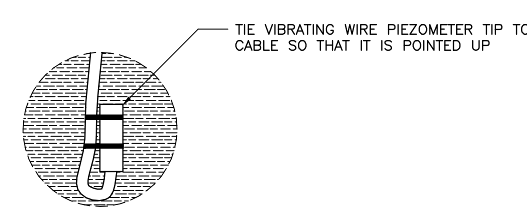
NOTE:

SEE SPECIFICATIONS FOR MONITORING WELLS

1 – DETAIL: TYPICAL (OP) SCREENED PIEZOMETER INSTALLATION
NTS

2 – DETAIL: TYPICAL (VW) VIBRATING WIRE PIEZOMETER INSTALLATION
NTS

3 – DETAIL: TYPICAL (MW) FULLY SCREENED PIEZOMETER INSTALLATION
NTS



4 – DETAIL: TYPICAL VIBRATING WIRE PIEZOMETER TIP
NTS

VER NO	DATE	DESCRIPTION
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2	06/29/12	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 2 – ATTACHMENT
3	12/14/12	FLOTATION TAILINGS MANAGEMENT PLAN – VERSION 3 – ATTACHMENT
4	05/19/15	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS
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ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	5	5/15/17
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SIGNATURE Thomas J. Radue
DATE 5/15/17 LICENSE# 20951

DRAWN: CAD
CHECKED: TJR
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDROMETALLURGICAL RESIDUE FACILTY
GEOTECHNICAL
INSTRUMENTATION DETAILS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
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DWG. NO. HRF-024
REV A

CADD USER: Cristian A. Diaz FILE: K:\DESIGN\23690C29.10\PERMIT_NMT-01-CS-024.DWG PLOT SCALE: 1:2 PLOT DATE: 5/15/2017 7:10 PM

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Attachment B

Residue Testing for RCRA Thresholds

INFORMATION PROVIDED BY POLYMET REGARDING HYDROMETALLURGICAL RESIDUE TESTING FOR RCRA THRESHOLDS
August 2014

In 2005 and 2009, PolyMet conducted hydrometallurgical pilot-plant processing of NorthMet Project flotation concentrates. Recently, PolyMet reviewed the results of those pilot tests to determine whether the hydrometallurgical residue that will be generated by the Project has toxic characteristics that exceed Resource Conservation and Recovery Act (RCRA) hazardous waste thresholds, as specified in 40 C.F.R. § 261.3.[1]

Mining wastes associated with extraction, beneficiation, and processing of ores and minerals are typically excluded from the RCRA definition of hazardous waste by regulatory definition.[2] Despite this exclusion, to further demonstrate the safety of its processes, PolyMet conducted environmental testing to compare the properties of the hydrometallurgical residue with the RCRA hazardous waste thresholds.

Records indicate that 17 residue samples from the 2005 pilot-plant test and one residue sample from the 2009 pilot-plant test were analyzed using the Toxicity Characteristic Leachate Procedure (TCLP) test (EPA1311), which is the analytical test typically used to evaluate solid waste to determine if it has toxicity characteristics that exceed RCRA hazardous waste thresholds. All 18 tests displayed TCLP results below the RCRA hazardous waste thresholds, indicating that for the parameters analyzed (metals), the hydrometallurgical residue is not characteristically hazardous.

The following provides additional detail on the TCLP test procedure and on the collection of the 18 hydrometallurgical residue samples submitted for TCLP testing.

TCLP Test Procedure

RCRA specifies that analytical testing and/or generator knowledge can be used to determine whether a solid waste exhibits characteristics of hazardous waste. PolyMet elected to use analytical testing—the TCLP test—for the eight metals assigned RCRA hazardous waste thresholds in 40 C.F.R. § 261.24 (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). The TCLP is intended to simulate the leaching conditions a waste would be exposed to when placed in a landfill. The solid waste

[1] *See* 40 C.F.R. § 261.3 (2014) (providing the RCRA definition of "hazardous waste" and setting thresholds for particular constituents).
[2] 40 C.F.R. § 261.4(b)(7) (excluding "solid waste from the extraction, beneficiation, and processing of ores and minerals (including coal, phosphate rock, and overburden from the mining of uranium ore)").

sample is placed in an extraction fluid at a ratio of 20 parts extraction fluid to one part waste, and then tumbled for 18 hours. The simulated leachate from the waste is collected and analyzed. The results are then compared to RCRA hazardous waste toxicity limits.

TCLP Test Results

The NorthMet Hydrometallurgical Plant internal processes will produce five types of internal residues from different stages of the hydrometallurgical process. These internal residues will be mixed to generate a “combined residue” that will be placed in the NorthMet Hydrometallurgical Residue Facility.

A total of 17 residue samples generated during the 2005 pilot-plant test were submitted for TCLP testing, including samples of internal residues and samples of the combined residue. Results of TCLP testing on nine residue samples from the 2005 pilot plant are provided in Table 4 of Reference (1) (Attachment 1). Results of TCLP testing on an additional eight residue samples from the 2005 pilot plant are provided on page 2 of Appendix B of Reference (2), (Attachment 2). All 17 residue samples from the 2005 pilot plant displayed TCLP results below RCRA hazardous waste thresholds, indicating that the waste residues are not characteristically hazardous for the parameters analyzed (metals).

A second, limited, hydrometallurgical pilot plant was run in 2009 to resolve outstanding metallurgical questions. Limited concentrate was available, so it was necessary to run part of the pilot plant using batch processing rather than continuous processing. The batch approach was appropriate to answer the metallurgical questions, but produced residue that based on generator knowledge is not expected to be representative of the NorthMet hydrometallurgical residue during operations. Specifically, the batch procedures used in the 2009 pilot plant generated an iron/aluminum residue that tended to be more of a lightweight ferric hydroxide material than the 99% gypsum that was generated from the 2005 continuous pilot plant tests. Based on the above considerations, plans for environmental testing of the 2009 pilot plant residue (other than the autoclave leach residue, which was produced by a continuous process) were discontinued.

Prior to discontinuation of the environmental testing of the 2009 pilot-plant residues, one sample of an internal residue (autoclave leach residue) was subjected to TCLP testing. Results of this testing (Attachment 3) show that the residue from the 2009 pilot-plant test is not characteristically hazardous for the parameters analyzed (metals).

Table 1 summarizes the TCLP test results on hydrometallurgical combined residue, considered to be representative of the residue that will be generated during operations. Comparison with the RCRA hazardous waste thresholds shows that the hydrometallurgical residue does not have toxicity characteristics of a hazardous waste. Full TCLP results on the NorthMet hydrometallurgical residue samples that have been tested are included in Attachments 1, 2, and 3.

Table 1. TCLP test results from NorthMet combined hydrometallurgical residue

Parameter	RCRA hazardous waste threshold[a]	Combined residue[b]	Combined residue[c]
Arsenic, mg/L	5.0	<0.1	<0.001
Barium, mg/L	100.0	<1.0	0.007
Cadmium, mg/L	1.0	<0.01	0.0025
Chromium, mg/L	5.0	0.03	0.022
Lead, mg/L	5.0	<0.05	0.004
Mercury, mg/L	0.2	<0.001	<0.02
Selenium, mg/L	1.0	<0.1	0.002
Silver, mg/L	5.0	<0.01	<0.00025

a. 40 CFR section 261.24
b. Attachment 1
c. Attachment 2

References

1. **Barr Engineering Co.** *Errata 02, Appendix C RS28T, Draft-02, Environmental Sampling and Analysis, Hydrometallurgical Process Liquids and Solids Sampling Results, Pilot Test – NorthMet Deposit, PolyMet Mining Inc., RS32 Part 3.* May 2006.

2. **SRK Consulting.** *RS33/RS65 – Hydrometallurgical Residue Characterization and Water Quality Model – NorthMet Project, Draft-01.* February 2007.

DRAFT

Attachment 1 **Table 4 from Errata 02 RS32 Part 3**

DRAFT

Table 4
TCLP Analytical Data Summary
PolyMet Mining Corporation
(concentrations in ug/L)

Location	**EPA TCLP Regulatory Levels**	**Magnesium Removal Residue -A Copper Sulfate**	**Raffinate Neutralization Residue - A**	**Combined Residue - A**	**Gypsum Neutralization Residue -D Copper Sulfate**	**Gypsum Neutralization Residue -A**	**Iron/Aluminum Removal Residue - D**	**Iron/Aluminum Removal Residue - A Copper Sulfate**	**Leach Residue -A Copper Sulfate**	**Leach Residue -A**
Date	**3/29/1990**	**10/7/2005**	**9/15/2005**	**9/15/2005**	**9/15/2005**	**9/2/2005**	**9/9/2005**	**9/14/2005**	**9/14/2005**	**9/1/2005**
Exceedance Key	**Bold**									
Arsenic, TCLP	5000	<100	<100	<100	<100	<100	<100	<100	<100	<100
Barium, TCLP	100000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000
Cadmium, TCLP	1000	<10	<10	<10	<10	<10	<10	10	<10	30
Chromium, TCLP	5000	<10	<10	30	<10	<10	60	280	<10	30
Lead, TCLP	5000	60	<50	<50	<50	<50	<50	<50	<50	<50
Mercury, TCLP	200	<1.0	<1.0	<1.0	<1.0	5.0	<1.0	<1.0	<1.0	<1.0
Selenium, TCLP	1000	<100	<100	<100	<100	<100	<100	<100	<100	<100
Silver, TCLP	5000	<10	<10	<10	<10	<20	<10	<20	10	<20

DRAFT

Attachment 2 **Page 2 of Appendix B from RS33/RS65**

			Residues							
Procedure	**Parameter**	**Unit**	**Leach, no CuSO4**	**Leach, with CuSO4**	**Gypsum**	**Raffinate Neutralization**	**Fe/Al**	**Mg**	**Combined**	**Combined no Gypsum**
TCLP Leachate Extraction Results	**pH**	**-**	4.74	4.94	4.95	4.96	4.98	9.8	5.23	8.98
	Hardness	**mgCaCO3/L**	1500	1260	1490	1900	1610	3270	2400	3710
	Al	**mg/L**	2.6	0.008	0.22	0.28	1.51	<0.005	0.088	<0.005
	Sb	**mg/L**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	As	**mg/L**	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001
	Ba	**mg/L**	<0.001	0.001	0.001	0.014	0.001	0.004	0.007	0.003
	Be	**mg/L**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bi	**mg/L**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	B	**mg/L**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Cd	**mg/L**	0.021	0.0055	<0.0002	0.0018	0.011	<0.0002	0.0025	<0.0002
	Ca	**mg/L**	451	402	594	754	562	586	733	718
	Cr	**mg/L**	0.031	0.002	0.006	0.007	0.13	0.002	0.022	0.004
	Co	**mg/L**	4.48	0.21	0.14	0.32	3.37	0.001	0.096	0.001
	Cu	**mg/L**	244	5.75	5.28	0.46	46.8	0.018	2.41	0.005
	Fe	**mg/L**	3.9	<0.05	0.42	0.55	0.06	<0.05	0.14	<0.05
	Pb	**mg/L**	0.001	<0.001	0.012	0.34	<0.001	<0.001	0.004	<0.001
	Li	**mg/L**	0.025	0.002	0.001	0.002	0.014	0.008	<0.001	0.002
	Mg	**mg/L**	91	62	2	2.74	50	438	137	464
	Mn	**mg/L**	1.39	0.057	0.029	0.046	0.76	<0.001	0.11	<0.001
	Hg	**ug/L**	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	Mo	**mg/L**	<0.0005	<0.0005	0.0007	0.0006	0.0017	<0.0005	0.0006	0.027
	Ni	**mg/L**	107	4	3.15	6.35	73.4	0.018	3.02	0.093
	P	**mg PO4/L**	<0.15	<0.15	<0.15	1	<0.15	<0.15	<0.15	<0.15
	K	**mg/L**	0.6	2.2	0.5	0.6	0.7	3	1.2	1.7
	Se	**mg/L**	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.033
	Si	**mg SIO2/L**	3.5	4	1.1	1.5	2.7	0.8	14.9	14.1
	Ag	**mg/L**	0.0074	0.0093	<0.00025	<0.00025	0.0015	<0.00025	<0.00025	<0.00025
	Na	**mg/L**	1730	1680	1560	1600	1540	1710	1590	1710
	Sr	**mg/L**	0.29	0.35	0.22	0.46	0.29	0.41	0.34	0.47
	Te	**mg/L**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Tl	**mg/L**	0.0009	<0.0001	0.0002	0.0003	0.0016	<0.0001	0.0003	0.0001
	Th	**mg/L**	0.002	0.0013	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
	Sn	**mg/L**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
	Ti	**mg/L**	0.009	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
	U	**mg/L**	0.0016	<0.0005	<0.0005	<0.0005	0.0069	<0.0005	0.0008	<0.0005
	V	**mg/L**	0.003	0.003	0.003	0.003	0.001	0.003	0.002	0.003
	Zn	**mg/L**	5.49	0.18	0.12	0.25	4.12	<0.005	0.22	<0.005
	Zr	**mg/L**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Notes
#N/A - result checking in progress

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Attachment 3 TCLP Results on 2009 Residue Sample

DRAFT

CLIENT : SRK Consulting
PROJECT : Polymet Hydromet Sample
CEMI Project # : 0518
Test : Toxicity Characteristic Leaching Procedure (EPA Method 1311) at 20:1 Liquid to Solids Ratio
Date : April 7, 2010

2009 Autoclave Leach (Ni Rich Concentrate) EPA 1311

Water Leach	pH	3.25
HCl Leach	pH	-
TCLP	Ext. Fluid	1
Final TCLP	pH	4.93
Aluminum	mg/L	0.073
Antimony	mg/L	0.0005
Arsenic	mg/L	0.0018
Barium	mg/L	0.0289
Beryllium	mg/L	-0.00005
Bismuth	mg/L	-0.00003
Boron	mg/L	-0.3
Cadmium	mg/L	0.00232
Calcium	mg/L	644
Chromium	mg/L	0.0039
Cobalt	mg/L	0.382
Copper	mg/L	1.62
Iron	mg/L	0.018
Lead	mg/L	0.00523
Magnesium	mg/L	2.6
Manganese	mg/L	0.0505
*		
Molybdenum	mg/L	0.0004
Nickel	mg/L	7.75
Phosphorus	mg/L	-0.01
Potassium	mg/L	0.5
Selenium	mg/L	0.0005
Silicon	mg/L	3.29
Silver	mg/L	0.0117
Sodium	mg/L	1400
Strontium	mg/L	1.29
Sulphur	mg/L	618
Thallium	mg/L	0.0004
Tin	mg/L	0.00022
Titanium	mg/L	0.005
Vanadium	mg/L	-0.001
Zinc	mg/L	0.171
Zirconium	mg/L	-0.0005

*** Note: testing was discontinued prior to analysis of mercury in the 2009 TCLP extract.**

Attachment C

TCLP Testing of Residue

INFORMATION PROVIDED BY POLYMET REGARDING
2009 HYDROMETALLURGICAL RESIDUE TESTING
August 2014

Poly Met Mining Inc. (PolyMet) asked Barr Engineering (Barr) to review the NorthMet project files and summarize the Toxicity Characteristic Leachate Procedure (TCLP) testing of hydrometallurgical residue generated during pilot-plant testing in 2009. The objective of the review was to provide further documentation regarding 2009 pilot-plant operations and environmental testing of residues.

Records indicate that one 2009 residue sample (autoclave leach residue) was submitted for TCLP testing (EPA1311), which is the analytical test typically used to evaluate solid waste to determine if the waste has toxic characteristics that exceed Resource Conservation and Recovery Act (RCRA) hazardous waste thresholds, as specified in 40 C.F.R. § 261.3. Results of this testing (Attachment 1) show that the residue from the 2009 pilot-test (as well as the autoclave leach residue from the 2005 test) is not characteristically hazardous for the parameters analyzed (metals).

PolyMet submitted additional detail on the TCLP test procedure and TCLP testing results in a separate submission, *Information Provided by PolyMet Regarding Hydrometallurgical Residue Testing for RCRA Thresholds*. The following paragraphs describe 2009 pilot-plant operations, the characteristics of the residue generated, and project team decisions regarding environmental testing of the residue.

In November, 2009, PolyMet carried out a limited pilot-plant program at SGS Mineral Services in Lakefield Ontario (Reference (1)). The pilot-plant program consisted of continuous PLATSOL^{TM} leaching of a small mass of nickel flotation concentrate, platinum group metals (PGM) precipitation, Copper Enrichment of flotation copper concentrate and residual copper precipitation by sodium hydrosulfide (NaHS). In the pilot plant, residual copper from the copper enrichment was treated with NaHS to scavenge copper. The filtrate from the copper NaHS scavenging circuit was then treated in a series of successive selective batch precipitation tests consisting of iron/aluminum precipitation, 2 stage MHP precipitation and magnesium removal.

Initial plans were to conduct environmental testing on residues from the selective precipitation tests (Attachment 2). The project files indicate, however, that the residues (from iron/aluminum precipitation, MHP precipitation and magnesium removal) were all generated in batch testing mode, using relatively crude methods (large stirred tanks with addition of reagents and aeration), rather than in a continuous pilot-plant circuit that closely matches the full-scale hydrometallurgical process. Batch testing was necessary because this pilot-plant program was limited by feed (concentrate) availability, which resulted in limited solution volumes. While the batch testing approach was adequate to resolve the metallurgical questions being evaluated in the pilot plant, it was recognized that batch testing could alter the physical and chemical characteristics of the residues that were planned to be subjected to environmental testing.

Pilot plant operators noted changes to the physical character of the iron precipitate (the most voluminous residue) in that it tended to be more of a lightweight ferric hydroxide material rather than the 99% gypsum that was generated from a 2005 continuous pilot-plant program. It was subsequently confirmed that the iron content of the iron precipitate would suggest the mineralogical composition of the residue was very likely different than that previously observed under the 2005 continuous processing tests. In addition, higher than expected Nickel and Cobalt losses were attributed to the fact that batch (as opposed to continuous) testing was used in the 2009 pilot plant. Continuous iron/aluminum precipitation would typically lead to lower pay metal losses.

In light of the above considerations, it was determined that the iron/aluminum precipitation, 2-stage MHP precipitation and magnesium removal residues were not representative of the materials that would be generated under continuous pilot-plant tests, and thus not representative of residue that would be generated under full-scale hydrometallurgical treatment of NorthMet nickel concentrates. Based on this determination, plans for environmental testing of the 2009 pilot-plant residue samples were discontinued. Residue samples collected for environmental testing continue to be held in storage at the SGS in Vancouver.

Prior to discontinuation of the environmental testing of the 2009 pilot-plant residues, one sample of autoclave leach residue was subjected to TCLP testing. Attachment 1 presents TCLP results from the 2009 autoclave leach residue, and compares them with TCLP results from the 2005 autoclave leach residue. The results of the TCLP testing are similar for the two samples, however the 2009 sample had a lower copper concentration and a higher nickel concentration than the 2005 sample which was expected because the 2005 feed was a bulk concentrate and the 2009 concentrate was a nickel concentrate. The TCLP results for the residue from the 2009 pilot-plant test showed all parameters were below the RCRA hazardous waste thresholds, indicating that for the parameters analyzed (metals), the autoclave leach residue is not characteristically hazardous.

References

1. **SGS.** *An Investigation into PLATSOL^{TM} Processing of the NorthMet Deposit*, SGS Canada Project 12269-001 – Final Report April 20

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Attachment 1 TCLP Results on 2009 Residue Sample

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CLIENT : **SRK Consulting**
PROJECT : **Polymet Hydromet Sample**
CEMI Project # : **0518**
Test : **Toxicity Characteristic Leaching Procedure (EPA Method 1311) at 20:1 Liquid to Solids Ratio**
Date : **April 7, 2010**

2009 Autoclave Leach (Ni Rich Concentrate) EPA 1311			2005 Autoclave Leach (Bulk Concentrate) EPA 1311				
Water Leach	**pH**	3.25	**Parameter**	**Method**	**Units**		
HCl Leach	**pH**	-	nanopure water volume		mL	2000	
TCLP	**Ext. Fluid**	1	Sample Weight		g	100	
Final TCLP	**pH**	4.93	pH	meter		4.94	
			Dissolved Metals				
			Hardness CaCO3		mg/L	1260	
Aluminum	**mg/L**	0.073	Aluminum Al	ICP-MS	mg/L	0.008	
Antimony	**mg/L**	0.0005	Antimony Sb	ICP-MS	mg/L	< 0.001	
Arsenic	**mg/L**	0.0018	Arsenic As	ICP-MS	mg/L	< 0.001	
Barium	**mg/L**	0.0289	Barium Ba	ICP-MS	mg/L	0.001	
Beryllium	**mg/L**	-0.00005	Beryllium Be	ICP-MS	mg/L	< 0.001	
Bismuth	**mg/L**	-0.00003	Bismuth Bi	ICP-MS	mg/L	< 0.001	
Boron	**mg/L**	-0.3	Boron B	ICP-MS	mg/L	< 0.05	
Cadmium	**mg/L**	0.00232	Cadmium Cd	ICP-MS	mg/L	0.0055	
Calcium	**mg/L**	644	Calcium Ca	ICP-MS	mg/L	402	
Chromium	**mg/L**	0.0039	Chromium Cr	ICP-MS	mg/L	0.002	
Cobalt	**mg/L**	0.382	Cobalt Co	ICP-MS	mg/L	0.21	
Copper	**mg/L**	1.62	Copper Cu	ICP-MS	mg/L	5.75	expected
Iron	**mg/L**	0.018	Iron Fe	ICP-MS	mg/L	< 0.05	
Lead	**mg/L**	0.00523	Lead Pb	ICP-MS	mg/L	< 0.001	
			Lithium Li	ICP-MS	mg/L	0.002	
Magnesium	**mg/L**	2.6	Magnesium M	ICP-MS	mg/L	62	
Manganese	**mg/L**	0.0505	Manganese M	ICP-MS	mg/L	0.057	
*****			Mercury Hg	CVAA	ug/L	< 0.02	
Molybdenum	**mg/L**	0.0004	Molybdenum I	ICP-MS	mg/L	< 0.0005	
Nickel	**mg/L**	7.75	Nickel Ni	ICP-MS	mg/L	4	expected
Phosphorus	**mg/L**	-0.01	Phosphorus P	ICP-MS	mg/L	< 0.15	
Potassium	**mg/L**	0.5	Potassium K	ICP-MS	mg/L	2.2	
Selenium	**mg/L**	0.0005	Selenium Se	ICP-MS	mg/L	0.003	
Silicon	**mg/L**	3.29	Silicon SiO2	ICP-MS	mg/L	4	
Silver	**mg/L**	0.0117	Silver Ag	ICP-MS	mg/L	0.0093	
Sodium	**mg/L**	1400	Sodium Na	ICP-MS	mg/L	1680	
Strontium	**mg/L**	1.29	Strontium Sr	ICP-MS	mg/L	0.35	
Sulphur	**mg/L**	618					
			Tellurium Te	ICP-MS	mg/L	< 0.001	
Thallium	**mg/L**	0.0004	Thallium Tl	ICP-MS	mg/L	< 0.0001	
			Thorium Th	ICP-MS	mg/L	0.0013	
Tin	**mg/L**	0.00022	Tin Sn	ICP-MS	mg/L	< 0.001	
Titanium	**mg/L**	0.005	Titanium Ti	ICP-MS	mg/L	< 0.001	
			Uranium U	ICP-MS	mg/L	< 0.0005	
Vanadium	**mg/L**	-0.001	Vanadium V	ICP-MS	mg/L	0.003	
Zinc	**mg/L**	0.171	Zinc Zn	ICP-MS	mg/L	0.18	
Zirconium	**mg/L**	-0.0005	Zirconium Zr	ICP-MS	mg/L	< 0.01	

*** Note: testing was discontinued prior to analysis of mercury in the 2009 TCLP extract.**

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Attachment 2 Appendix 1 to SGS Proposal #290751

Appendix 1 to SGS Proposal #290751
PMI Waste Characterization Sampling Program

The objective of this appendix is to provide a sampling and shipping procedure to SGS Lakefield Research personnel to assist them in the collection of pilot plant source water, magnesium thickener overflow, residue and product samples produced during the 2009 PolyMet pilot plant run for waste characterization. Samples collected will be shipped from SGS Lakefield Research located in Lakefield Ontario to SRK located in Vancouver, BC (or a directly to a lab designated by SRK.

The samples to be collected, proper preservation techniques and sampling containers are outlined in Table 1 below. All sampling containers used should either be supplied by the environmental analytical laboratory (water and product samples) or collected in new, unused pails for shipment. Barr or SRK personnel will aid in acquiring necessary sample containers if requested by SGS Lakefield Research staff.

In addition to sample collection, it is anticipated that SGS Lakefield Research staff will prepare a final combined residue sample that will be representative of the final residue streams that will be created as part of a full scale facility. This sample will then be shipped as shown in Table 1 and described in Attachment 1 .

Note that all residue samples should be washed prior to sampling to remove residual copper solutions to simulate a full scale operation.

Table 1
Samples, Parameters, Preservatives and Analytical Containers
2009 PolyMet Pilot Plant

Sample	Type	Analytical Parameters	Preservative	Sample Container
Leach Residue	Residue	Total metals, TCLP metals, % solids, humidity cells	Cool to 4-6C upon collection ship on ice	2 gallon pail
Iron Aluminum Residue	Residue	Total metals, TCLP metals, % solids, humidity cells	Cool to 4-6C upon collection ship on ice	2 gallon pail
Magnesium Residue	Residue	Total metals, TCLP metals, % solids, humidity cells	Cool to 4-6C upon collection ship on ice	2 gallon pail
Combined Residue[1]	Residue	Total metals, TCLP metals, % solids, humidity cells	Cool to 4-6C upon collection ship on ice	2 gallon pail
Source Water	Liquid	Low level mercury	HCL, Cool to 4-6C upon collection ship on ice	1 liter plastic container
Magnesium Thickener Overflow[2]	Liquid	Total metals, Sulfur speciation, pH, Total suspended solids (TSS) Humidity cell	Metals – HNO3 Sulfate – cool to 4-6C Sulfide – NaOH, ZN Acetate Sulfite - cool to 4-6C Total sulfur- cool to 4-6C pH- cool to 4-6C TSS – cool to 4-6C Humidity cells – cool to 4-6C	Metals – 500ml plastic Sulfate – 250ml plastic Sulfite – 250ml plastic Total sulfur – 250ml plastic pH-250ml plastic TSS – 1 Liter plastic 5- liter carboy
Mixed Hydroxide Precipitate Product	Product	Total sulfur	Cool to 4-6C upon collection ship on ice	2oz jar - glass
Precious Metals Group Product	Product	Total Sulfur	Cool to 4-6C upon collection ship on ice	2oz jar - glass

[1]Combined residue to be prepared by SGS Lakefield staff using ratios of other residues to make a representative sample of final residue.
[2] Several parameters may be analyzed out of one container so less containers may be required, container size may vary.

Procedure

Liquid Samples:

1. Fit a peristaltic pump with new tubing, and rinse the tubing with deionized water.
2. Using the peristaltic pump, fill the supplied containers as full as possible (minimal headspace) without overflowing.
3. Label container either "source water" or "mg thickener overflow" as appropriate and the collection date.
4. Place in cooler supplied with laboratory sample containers, surround with two 2lb bags of cubed ice (double bagged in Ziploc™ bags) and bubble wrap so there is limited motion of the sample containers in the cooler.
5. Fill out supplied chain-of-custody as described in Attachment 1.
6. Ship overnight ASAP to the address below or other address provided by SRK.

Residue Samples:

1. With a clean scooping utensil (plastic preferred) remove the washed residues from their collection vessels and place in plastic sample container pails. Fill as completely as volume allows.
2. Label container with appropriate residue name.
3. Place in supplied cooler, surround with two 2lb bags of cubed ice (double bagged in Ziploc™ bags) and bubble wrap so there is limited motion of the sample container in the cooler.
4. Fill out supplied chain-of-custody as described in Attachment 1.
5. Ship overnight ASAP to the address below or other address provided by SRK.

Product Samples:

1. With a clean scooping utensil (plastic preferred) remove the final products from their collection vessels and place in glass sample containers. Fill as completely as volume allows (approximately 100grams required).
2. Place in supplied cooler, surround with two 2lb bags of cubed ice (double bagged in Ziploc™ bags) and bubble wrap so there is limited motion of the sample container in the cooler.
3. Label container with appropriate product name.
4. Fill out supplied chain-of-custody as described in Attachment 1.
5. Ship overnight ASAP to the address below or other address provided by SRK.

Ship all collected samples overnight ASAP to:

SRK Consulting
2200-1066 West Hastings Street
Vancouver, British Columbia
Canada
V6E 3X2

If there are questions contact Ward Swanson at Barr Engineering (952) 832-2660.

Attachment 1 - Standard Operating Procedures for Documentation on a Chain-of-Custody

Purpose
To describe how a Chain-of-Custody should be documented properly.

Applicability
These procedures apply any time a Chain-of-Custody is required.

Definitions
Chain-of-Custody: This document shows traceable possession of samples from the time they are obtained until they are introduced as evidence in legal proceedings.

Discussion
The Chain-of-Custody is the most important sampling document, it must be filled out accurately and completely every time.

Responsibilities
The environmental technician(s)/sampling technician(s) are responsible for accurate and complete documentation on the Chain-of-Custody.

Procedure
Writing a Chain-of-Custody
1. The Chain-of-Custody should be completed prior to leaving the sampling location.
2. Complete one Chain-of-Custody or more as needed for each cooler of samples.
3. The Chain-of-Custody form must be completed with the following information:
    a. Project number
    b. Sample identification
    c. Date and time of sample collection
    d. Container type and number
    e. Whether the sample is a grab, composite, or blank sample
    f. Project manager
    g. Project contract
    h. Laboratory
    i. Analysis required
    j. Signature of sampler(s)
    k. Signature of transferee
    l. Date and time of transfer
    m. Method of transport and any shipping numbers
4. The Chain-of-Custody should always accompany the cooler of samples.

Documentation
The Chain-of-Custody form is the documented proof of possession of samples collected. This is documented by samplers collecting the samples and the laboratory receiving the samples.

Attachment D

Liner Leakage Rate Computations

Hydrometallurgical Residue Facility Liner Leakage Calculations

The computation of flow through a composite liner system such as the geomembrane overlying the geosynthetic clay (the lower liner) can be estimated by the following equation for leakage through the area of defects in the geomembrane component of the liner (Reference (4)):

$$Q_{GM} = n\,C\,[\,1 + 0.1(h/t)^{0.95}\,]\,a^{0.1}\,h^{0.9375}\,k^{0.74}$$

where;

Q_{GM}= rate of leakage through the area of the defects in the geomembrane component of the composite liner system (typically in units of gallons per acre per day)

C = a constant related to the quality of the contact between the geomembrane and the underlying clay of the composite liner system

h = hydraulic head above the liner (typically measured in feet)

t = thickness of the soil component of the composite liner system (typically measured in feet)

a = the area of the defect in the geomembrane (typically in terms of square centimeters)

k = hydraulic conductivity of the liner (typically in units of centimeters per second or feet per day)

n = number of defects per unit area under consideration

This basic equation is further modified to compute flow through various shaped defects in composite liner systems as follows:

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 Defects:

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

where:

B = defect length

b = defect width

C_{qo} = contact quality for defect of uniform dimension

C_{qoo} = contact quality for defect of infinite length

n = number of defects per unit area under consideration

Composite Liner System Containment Ability Computations

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 (cm/sec)	Hydraulic Conductivity of Geomembrane Liner Subgrade K_s (m/sec)	Circular Defects Leakage Rate Q_{cir} (gpad)	Square Defects Leakage Rate Q_{sqr} (gpad)	Rectangular Defects Leakage Rate Q_{rec} (gpad)	Average Leakage Rate Q_{avg} (gpad)
Geomembrane/ Geosynthetic Clay (1)	0.21	0.52	1.0	0.30	0.0065	0.01	0.000079	0.01	2	2.5	5.00E-09	5.00E-11	0	0	0	0
	0.21	0.52	20.0	6.10	0.0065	0.01	0.000079	0.01	2	2.5	5.00E-09	5.00E-11	41	41	57	46
	0.21	0.52	40.0	12.19	0.0065	0.01	0.000079	0.01	2	2.5	5.00E-09	5.00E-11	150	150	209	170
	0.21	0.52	60.0	18.29	0.0065	0.01	0.000079	0.01	2	2.5	5.00E-09	5.00E-11	322	322	448	364
	0.21	0.52	80.0	24.38	0.0065	0.01	0.000079	0.01	2	2.5	5.00E-09	5.00E-11	553	553	770	625
Geomembrane/ Geosynthetic Clay (2)	0.21	0.52	1.0	0.30	0.0065	0.01	0.000079	0.01	2	2.5	1.50E-09	1.50E-11	0	0	0	0
	0.21	0.52	20.0	6.10	0.0065	0.01	0.000079	0.01	2	2.5	1.50E-09	1.50E-11	17	17	22	19
	0.21	0.52	40.0	12.19	0.0065	0.01	0.000079	0.01	2	2.5	1.50E-09	1.50E-11	62	62	82	69
	0.21	0.52	60.0	18.29	0.0065	0.01	0.000079	0.01	2	2.5	1.50E-09	1.50E-11	132	132	176	147
	0.21	0.52	80.0	24.38	0.0065	0.01	0.000079	0.01	2	2.5	1.50E-09	1.50E-11	227	227	304	253
Geomembrane/ Geosynthetic Clay (3)	0.21	0.52	1.0	0.30	0.0065	0.01	0.000079	0.01	2	2.5	7.20E-10	7.20E-12	0	0	0	0
	0.21	0.52	20.0	6.10	0.0065	0.01	0.000079	0.01	2	2.5	7.20E-10	7.20E-12	10	10	13	11
	0.21	0.52	40.0	12.19	0.0065	0.01	0.000079	0.01	2	2.5	7.20E-10	7.20E-12	36	36	47	40
	0.21	0.52	60.0	18.29	0.0065	0.01	0.000079	0.01	2	2.5	7.20E-10	7.20E-12	77	77	101	85
	0.21	0.52	80.0	24.38	0.0065	0.01	0.000079	0.01	2	2.5	7.20E-10	7.20E-12	132	132	173	146

(1) Hydraulic conductivity reported by GSE for Bentoliner CAR Geosynthetic Clay Liner and reported by CETCO for Resistex Geosynthetic Clay Liner.
(2) Hydraulic conductivity of 1.5×10^{-9} cm/sec is the CETCO-recommended design value for their polymer-treated GCL when tested with PolyMet synthetic HRF leachate (ref. Geotechnical Data Package – Volume 2 – Version 3 – Attachment F).
(3) Hydraulic conductivity of 7.2×10^{-10} cm/sec is the 176 day test value for GSE polymer-treated GCL when tested with PolyMet synthetic HRF leachate (ref. Geotechnical Data Package – Volume 2 – Version 3 – Attachment F).

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

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

Abreviations:

gpad = gallons/acre/day

cm/sec = centimeters/second

m/sec = meters/second

Attachment E

Polyethylene Geomembrane Chemical Resistance Chart

Attachment E Polyethylene Geomembrane Chemical Resistance Chart

GSE

The Pioneer Of Geosynthetics

S I N C E 1 9 7 2

Technical Note

Chemical Resistance Chart

GSE is the world's leading supplier of high quality, polyethylene geomembranes. GSE polyethylene geomembranes are resistant to a great number and combinations of chemicals. Note that the effect of chemicals on any material is influenced by a number of variable factors such as temperature, concentration, exposed area and duration. Many tests have been performed that use geomembranes and certain specific chemical mixtures. Naturally, however, every mixture of chemicals cannot be tested for, and various criteria may be used to judge performance. Reported performance ratings may not apply to all applications of a given material in the same chemical. Therefore, these ratings are offered as a guide only.

Medium	Concentration	Resistance at: 20° C (68° F)	60° C (140° F)
A			
Acetic acid	100%	S	L
Acetic acid	10%	S	S
Acetic acid anhydride	100%	S	L
Acetone	100%	L	L
Adipic acid	sat. sol.	S	S
Allyl alcohol	96%	S	S
Aluminum chloride	sat. sol.	S	S
Aluminum fluoride	sat. sol.	S	S
Aluminum sulfate	sat. sol.	S	S
Alum	sol.	S	S
Ammonia, aqueous	dil. sol.	S	S
Ammonia, gaseous dry	100%	S	S
Ammonia, liquid	100%	S	S
Ammonium chloride	sat. sol.	S	S
Ammonium fluoride	sol.	S	S
Ammonium nitrate	sat. sol.	S	S
Ammonium sulfate	sat. sol.	S	S
Ammonium sulfide	sol.	S	S
Amyl acetate	100%	S	L
Amyl alcohol	100%	S	L
Aniline	100%	S	L
Antimony trichloride	90%	S	S
Arsenic acid	sat. sol.	S	S
Aqua regia	HCI-HNO3	U	U
B			
Barium carbonate	sat. sol.	S	S
Barium chloride	sat. sol.	S	S
Barium hydroxide	sat. sol.	S	S
Barium sulfate	sat. sol.	S	S
Barium sulfide	sol.	S	S
Benzaldehyde	100%	S	L
Benzene	—	L	L
Benzoic acid	sat. sol.	S	S
Beer	—	S	S
Borax (sodium tetraborate)	sat. sol.	S	S
Boric acid	sat. sol.	S	S
Bromine, gaseous dry	100%	U	U
Bromine, liquid	100%	U	U
Butane, gaseous	100%	S	S
1-Butanol	100%	S	S
Butyric acid	100%	S	L
C			
Calcium carbonate	sat. sol.	S	S
Calcium chlorate	sat. sol.	S	S
Calcium chloride	sat. sol.	S	S
Calcium nitrate	sat. sol.	S	S
Calcium sulfate	sat. sol.	S	S
Calcium sulfide	dil. sol.	L	L
Carbon dioxide, gaseous dry	100%	S	S
Carbon disulfide	100%	L	U
Carbon monoxide	100%	S	S
Chloracetic acid	sol.	S	S
Carbon tetrachloride	100%	L	U
Chlorine, aqueous solution	sat. sol.	L	U
Chlorine, gaseous dry	100%	L	U
Chloroform	100%	U	U
Chromic acid	20%	S	L
Chromic acid	50%	S	L
Citric acid	sat. sol.	S	S

Medium	Concentration	Resistance at: 20° C (68° F)	60° C (140° F)
Copper chloride	sat. sol.	S	S
Copper nitrate	sat. sol.	S	S
Copper sulfate	sat. sol.	S	S
Cresylic acid	sat. sol.	L	—
Cyclohexanol	100%	S	S
Cyclohexanone	100%	S	L
D			
Decahydronaphthalene	100%	S	L
Dextrine	sol.	S	S
Diethyl ether	100%	L	—
Dioctylphthalate	100%	S	L
Dioxane	100%	S	S
E			
Ethanediol	100%	S	S
Ethanol	40%	S	L
Ethyl acetate	100%	S	U
Ethylene trichloride	100%	U	U
F			
Ferric chloride	sat. sol	S	S
Ferric nitrate	sol.	S	S
Ferric sulfate	sat. sol	S	S
Ferrous chloride	sat. sol	S	S
Ferrous sulfate	sat. sol	S	S
Fluorine, gaseous	100%	U	U
Fluorosilicic acid	40%	S	S
Formaldehyde	40%	S	S
Formic acid	50%	S	S
Formic acid	98-100%	S	S
Furfuryl alcohol	100%	S	L
G			
Gasoline	—	S	L
Glacial acetic acid	96%	S	L
Glucose	sat. sol.	S	S
Glycerine	100%	S	S
Glycol	sol.	S	S
H			
Heptane	100%	S	U
Hydrobromic acid	50%	S	S
Hydrobromic acid	100%	S	S
Hydrochloric acid	10%	S	S
Hydrochloric acid	35%	S	S
Hydrocyanic acid	10%	S	S
Hydrofluoric acid	4%	S	S
Hydrofluoric acid	60%	S	L
Hydrogen	100%	S	S
Hydrogen peroxide	30%	S	L
Hydrogen peroxide	90%	S	U
Hydrogen sulfide, gaseous	100%	S	S
Lactic acid	100%	S	S
Lead acetate	sat. sol.	S	—
M			
Magnesium carbonate	sat. sol.	S	S
Magnesium chloride	sat. sol.	S	S
Magnesium hydroxide	sat. sol.	S	S
Magnesium nitrate	sat. sol.	S	S
Maleic acid	sat. sol.	S	S
Mercuric chloride	sat. sol.	S	S
Mercuric cyanide	sat. sol.	S	S
Mercuric nitrate	sol.	S	S

-Continued-

Technical Note

Medium	Concentration	Resistance at: 20° C (68° F)	Resistance at: 60° C (140° F)
Mercury	100%	S	S
Methanol	100%	S	S
Methylene chloride	100%	L	—
Milk	—	S	S
Molasses	—	S	S
N			
Nickel chloride	sat. sol.	S	S
Nickel nitrate	sat. sol.	S	S
Nickel sulfate	sat. sol.	S	S
Nicotinic acid	dil. sol.	S	—
Nitric acid	25%	S	S
Nitric acid	50%	S	U
Nitric acid	75%	U	U
Nitric acid	100%	U	U
O			
Oils and Grease	—	S	L
Oleic acid	100%	S	L
Orthophosphoric acid	50%	S	S
Orthophosphoric acid	95%	S	L
Oxalic acid	sat. sol.	S	S
Oxygen	100%	S	L
Ozone	100%	L	U
P			
Petroleum (kerosene)	—	S	L
Phenol	sol.	S	S
Phosphorus trichloride	100%	S	L
Photographic developer	cust. conc.	S	S
Picric acid	sat. sol.	S	—
Potassium bicarbonate	sat. sol.	S	S
Potassium bisulfide	sol.	S	S
Potassium bromate	sat. sol.	S	S
Potassium bromide	sat. sol.	S	S
Potassium carbonate	sat. sol.	S	S
Potassium chlorate	sat. sol.	S	S
Potassium chloride	sat. sol.	S	S
Potassium chromate	sat. sol.	S	S
Potassium cyanide	sol.	S	S
Potassium dichromate	sat. sol.	S	S
Potassium ferricyanide	sat. sol.	S	S
Potassium ferrocyanide	sat. sol.	S	S
Potassium fluoride	sat. sol.	S	S
Potassium hydroxide	10%	S	S
Potassium hydroxide	sol.	S	S
Potassium hypochlorite	sol.	S	L
Potassium nitrate	sat. sol.	S	S
Potassium orthophosphate	sat. sol.	S	S
Potassium perchlorate	sat. sol.	S	S
Potassium permanganate	20%	S	S
Potassium persulfate	sat. sol.	S	S
Potassium sulfate	sat. sol.	S	S
Potassium sulfite	sol.	S	S
Propionic acid	50%	S	S
Propionic acid	100%	S	L
Pyridine	100%	S	L
Q			
Quinol (Hydroquinone)	sat. sol.	S	S
S			
Salicylic acid	sat. sol.	S	S
Silver acetate	sat. sol.	S	S
Silver cyanide	sat. sol.	S	S
Silver nitrate	sat. sol.	S	S
Sodium benzoate	sat. sol.	S	S
Sodium bicarbonate	sat. sol.	S	S
Sodium biphosphate	sat. sol.	S	S
Sodium bisulfite	sol.	S	S
Sodium bromide	sat. sol.	S	S
Sodium carbonate	sat. sol.	S	S
Sodium chlorate	sat. sol.	S	S
Sodium chloride	sat. sol.	S	S
Sodium cyanide	sat. sol.	S	S
Sodium ferricyanide	sat. sol.	S	S
Sodium ferrocyanide	sat. sol.	S	S
Sodium fluoride	sat. sol.	S	S
Sodium hydroxide	40%	S	S
Sodium hydroxide	sat. sol.	S	S
Sodium hypochlorite	15% active chlorine	S	S
Sodium nitrate	sat. sol.	S	S
Sodium nitrite	sat. sol.	S	S
Sodium orthophosphate	sat. sol.	S	S
Sodium sulfate	sat. sol.	S	S
Sodium sulfide	sat. sol.	S	S
Sulfur dioxide, dry	100%	S	S
Sulfur trioxide	100%	U	U
Sulfuric acid	10%	S	S
Sulfuric acid	50%	S	S
Sulfuric acid	98%	S	U
Sulfuric acid	fuming	U	U
Sulfurous acid	30%	S	S
T			
Tannic acid	sol.	S	S
Tartaric acid	sol.	S	S
Thionyl chloride	100%	L	U
Toluene	100%	L	U
Triethylamine	sol.	S	L
U			
Urea	sol.	S	S
Urine	—	S	S
W			
Water	—	S	S
Wine vinegar	—	S	S
Wines and liquors	—	S	S
X			
Xylenes	100%	L	U
Y			
Yeast	sol.	S	S
Z			
Zinc carbonate	sat. sol.	S	S
Zinc chloride	sat. sol.	S	S
Zinc (II) chloride	sat. sol.	S	S
Zinc (IV) chloride	sat. sol.	S	S
Zinc oxide	sat. sol.	S	S
Zinc sulfate	sat. sol.	S	S

Specific immersion testing should be undertaken to ascertain the suitability of chemicals not listed above with reference to special requirements.

NOTES:

(S) **Satisfactory**: Liner material is resistant to the given reagent at the given concentration and temperature. No mechanical or chemical degradation is observed.

(L) **Limited Application Possible**: Liner material may reflect some attack. Factors such as concentration, pressure and temperature directly affect liner performance against the given media. Application, however, is possible under less severe conditions, e.g. lower concentration, secondary containment, additional liner protections, etc.

(U) **Unsatisfactory:** Liner material is not resistant to the given reagent at the given concentration and temperature. Mechanical and/or chemical degradation is observed.

(–) **Not tested**

sat. sol. = Saturated aqueous solution, prepared at 20°C (68°F)

sol. = aqueous solution with concentration above 10% but below saturation level

dil. sol. = diluted aqueous solution with concentration below 10%

cust. conc. = customary service concentration

Attachment F

Hydraulic Conductivity Tests of Geosynthetic Clay Liners

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 5^{th} 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\letter\08114
Inv # 3384

SUMMARY OF FLEX WALL PERMEABILITY TEST RESULTS
ASTM D-7100

JLT

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

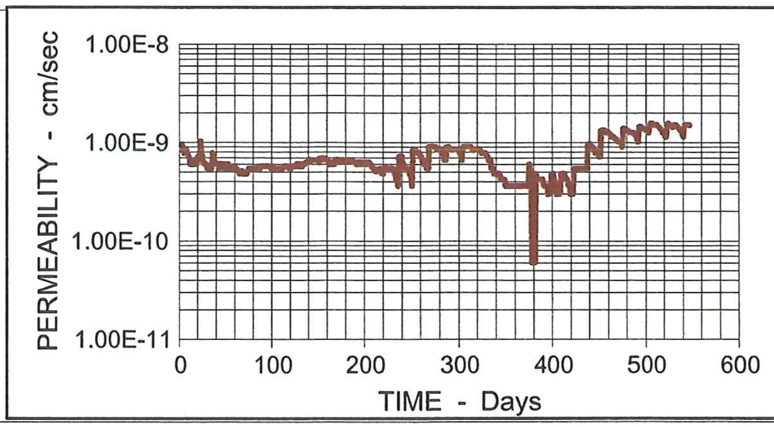
Initial Height (in)	:	0.17	Final Height (in)	:	0.24
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	4.00
Initial Wet Weight (g)	:	51.80	Final Wet Weight (g)	:	86.10
Wet Density (pcf)	:	92.29	Wet Density (pcf)	:	108.66
Moisture Content %	:	23.90	Moisture Content %	:	106.40
Dry Density (pcf)	:	74.49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

Test Parameters

Fluid	:	Syn Leachate	**Average Effective**		
Cell Pressure psi)	:	80.00	**Confining Pressure (psi)**	**:**	4.00
Head Water ›si)	:	77.00	Gradient	:	230.00
Tail Water ›si)	:	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**

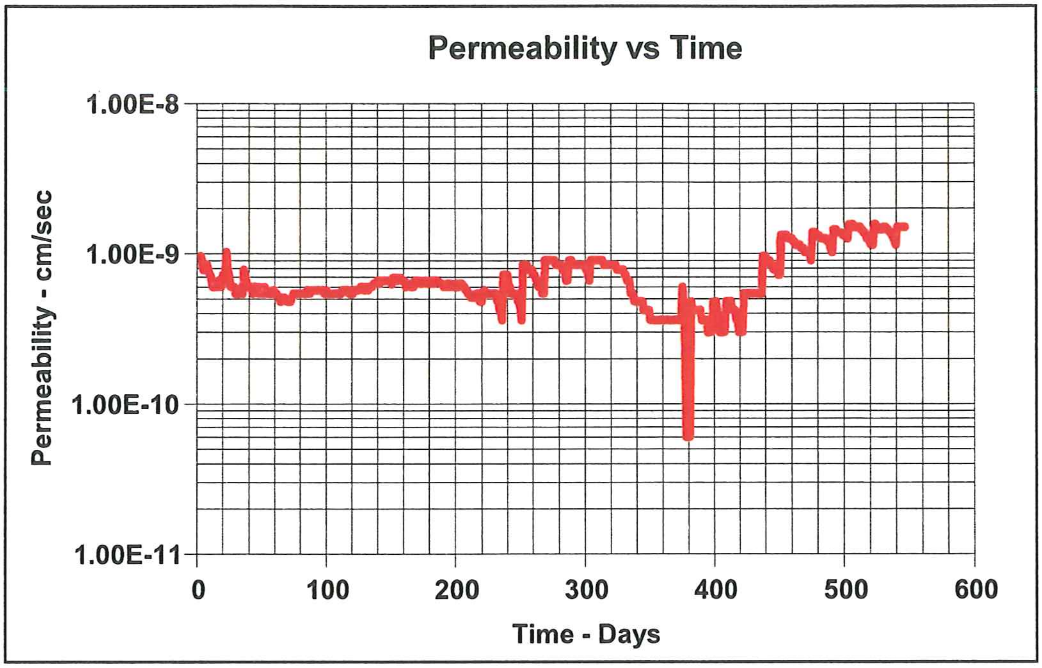
Description : R-101

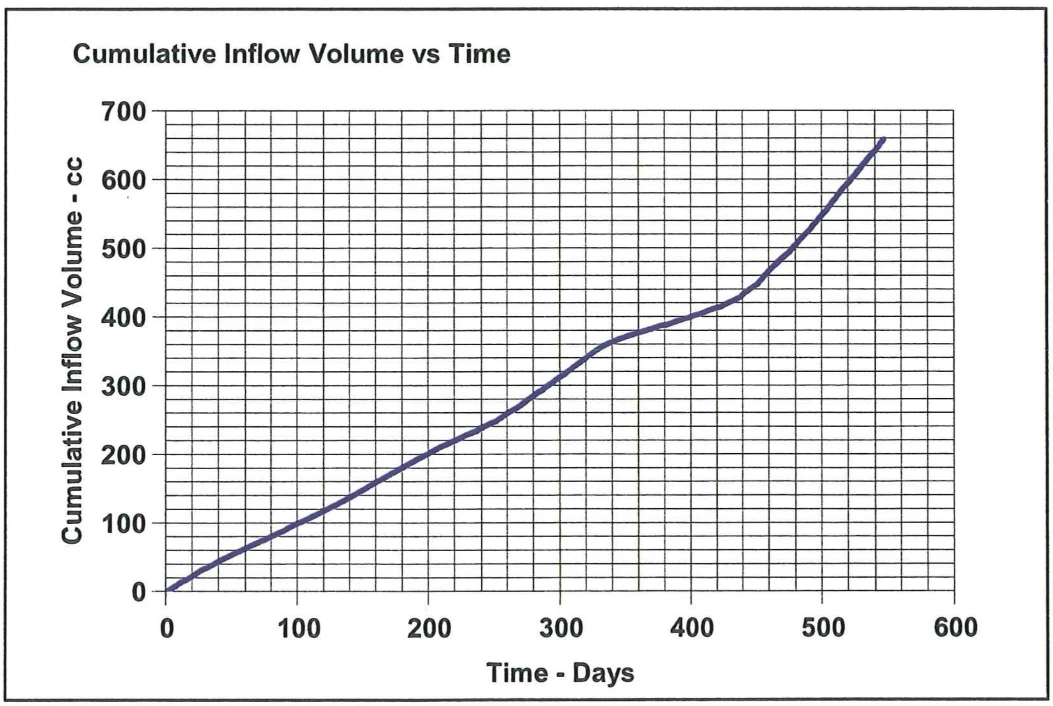
Date : 04-25-08

Estimated Pore Volume : 39 cc

Estimated Inflow Pore Volumes : 16.87

Permeant : Syn Leachate





JLT Laboratories, Inc.

Client :	CETCO	Date :	04-25-08
Project Location :	Barr Engineering	Job No. :	06LG951.01
Description :	R-101	Tested By :	MLB/DB
		Checked By :	JB

Sample ID : R-101

Estimated Poe Volume : 39 cc

Elapsed Time Days	Permeability cm/sec	Inflow cc	Time minutes	Date	Total Cumulative Inflow Volume, cc	Pore Volumes	COMMENTS
1				10/26/2006	0.00	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	38.80	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	1.16	
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= 6.57 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	1446	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	38.65	
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 : 3.78 mS
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	281.65	
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	366.60	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	1438	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	416.80	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	02/17/2008	504.00	437.65	
481	1.32E-009	2.2	1443	02/18/2008	506.20	439.85	
482	1.27E-009	2.1	1437	02/19/2008	508.30	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	03/09/2008	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	
516	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
800.527.9948 www.cetco.com

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.

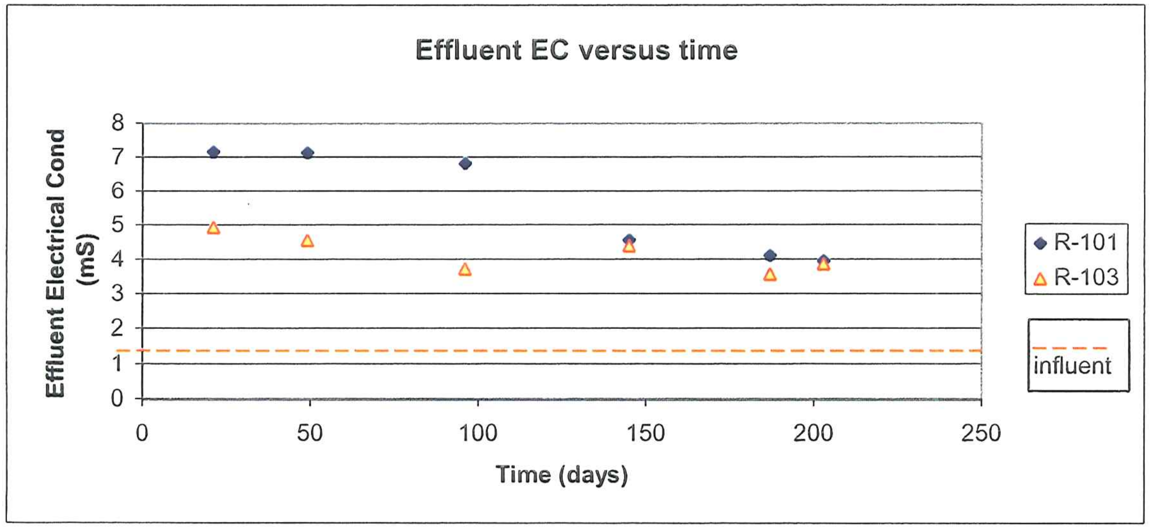
Also attached are the latest influent/effluent electrical conductivity (EC) results for the GCL compatibility testing with samples R-101 and R-103. The R-101 effluent EC has dropped from over 7.0 mS to less than 4.0 mS, but is still higher than the influent EC (1.5 mS). R-101 effluent EC has dropped 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

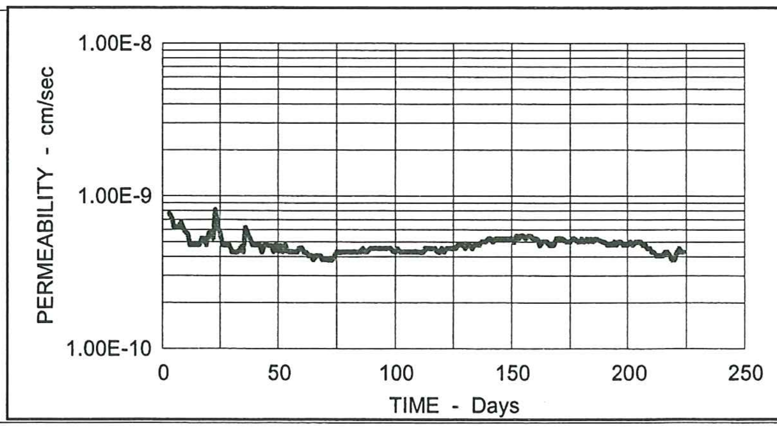
Initial Height (in)	:	0.17	Final Height (in)	:	[redacted]
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	[redacted]
Initial Wet Weight (g)	:	51.80	Final Wet Weight (g)	:	[redacted]
Wet Density (pcf)	:	92.29	Wet Density (pcf)	:	[redacted]
Moisture Content %	:	22.00	Moisture Content %	:	[redacted]
Dry Density (pcf)	:	75.65	Dry Density (pcf)	:	[redacted]
Initial Void Ratio	:	1.2601	Final Void Ratio	:	[redacted]
Saturation , %	:	47.8	Saturation , %	:	[redacted]

Test Parameters

Fluid	:	Syn Leachate	**Effective**		
Cell Pressure psi)	:	80.00	**Confining Pressure (psi)**	**:**	**4**
Head Water psi)	:	77.00	Gradient	:	290.53
Tail Water psi)	:	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**

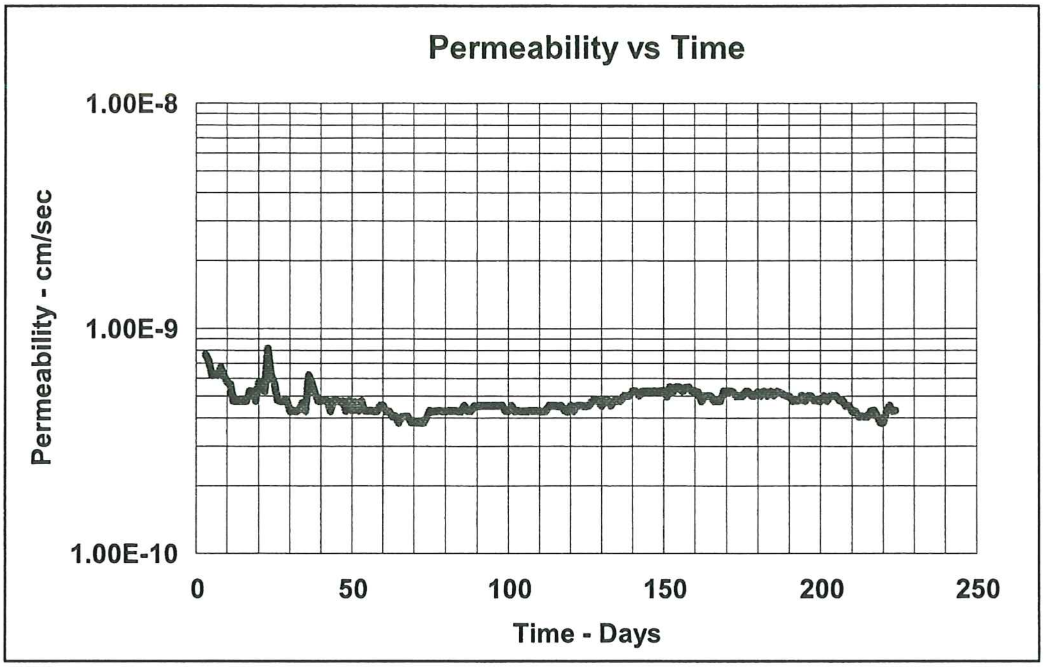
Description : R-101

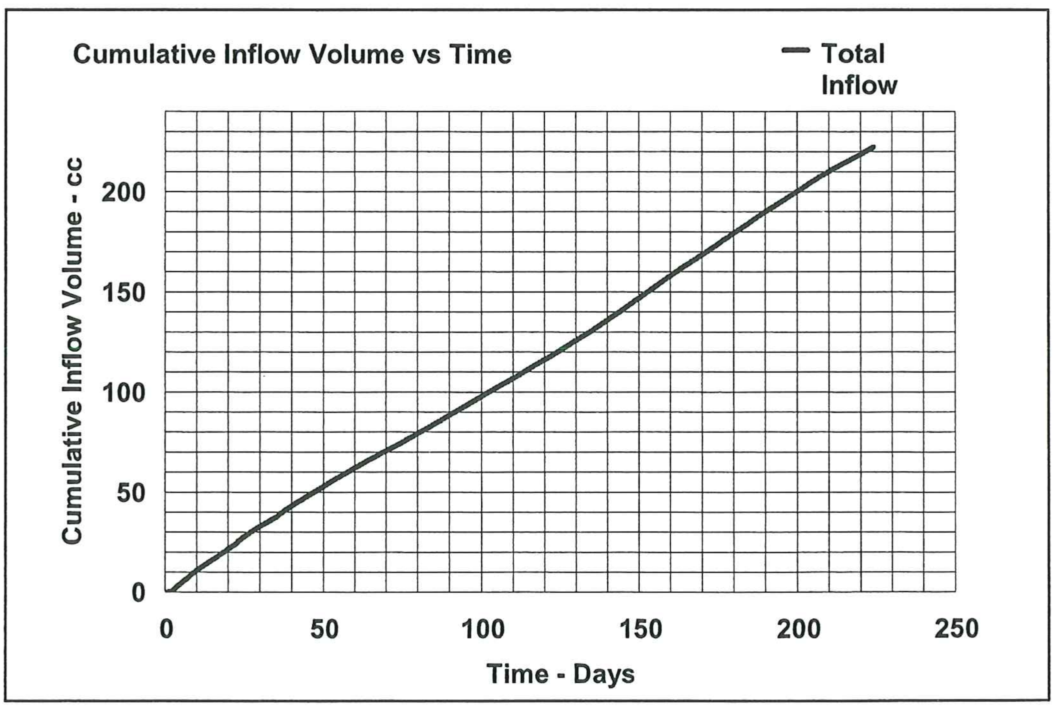
Date : 06-06-07

Estimated Pore Volume : 33 cc

Estimated Inflow Pore Volumes : 4.74

Permeant : Syn Leachate





JLT *Laboratories, Inc.*

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

Date : 06-06-07
Job No. : 06LG951.01
Tested By : MLB/DB
Checked By : JB

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	4.53E-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
106	4.29E-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	4.53E-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	54.76	
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

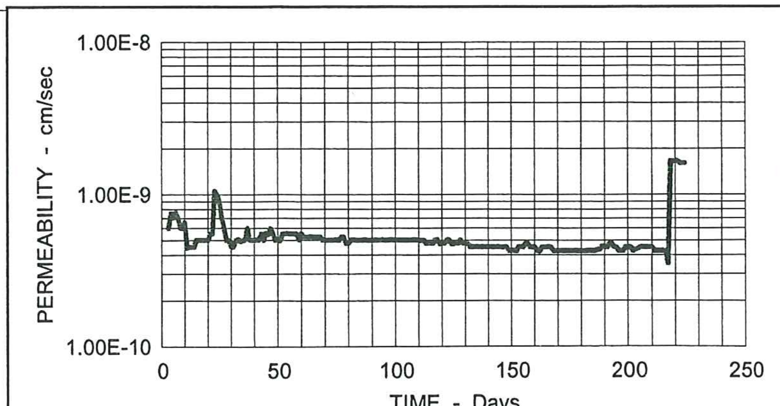
Initial Height (in)	:	0.18	Final Height (in)	:	[redacted]
Initial Diameter (in)	:	4.00	Final Diameter (in)	:	[redacted]
Initial Wet Weight (g)	:	48.10	Final Wet Weight (g)	:	[redacted]
Wet Density (pcf)	:	80.94	Wet Density (pcf)	:	[redacted]
Moisture Content %	:	23.00	Moisture Content %	:	[redacted]
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**

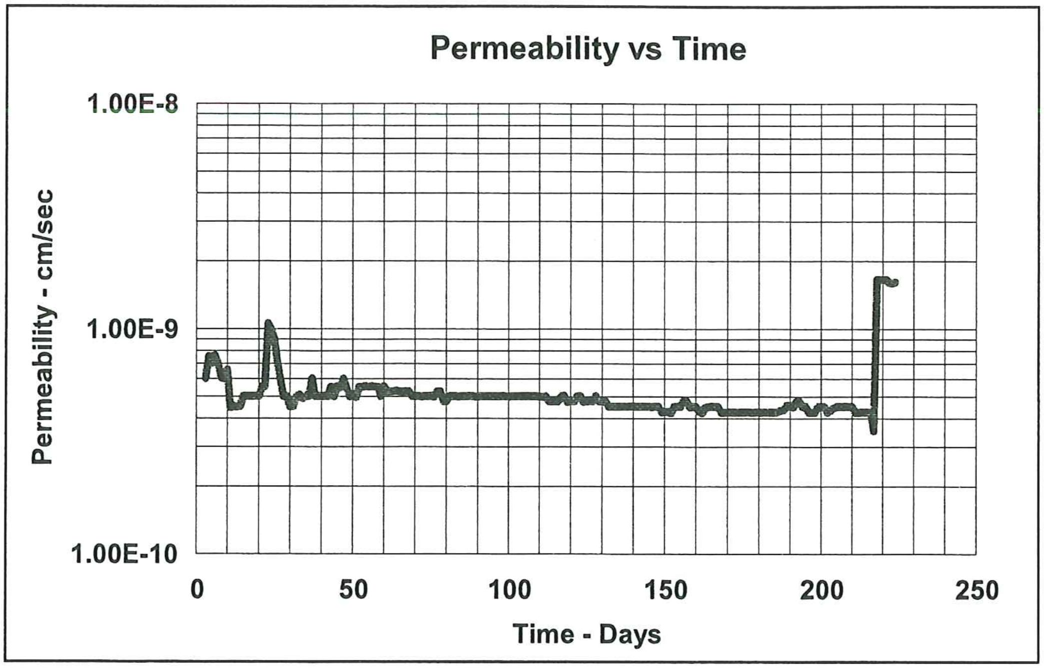
Description : R-103

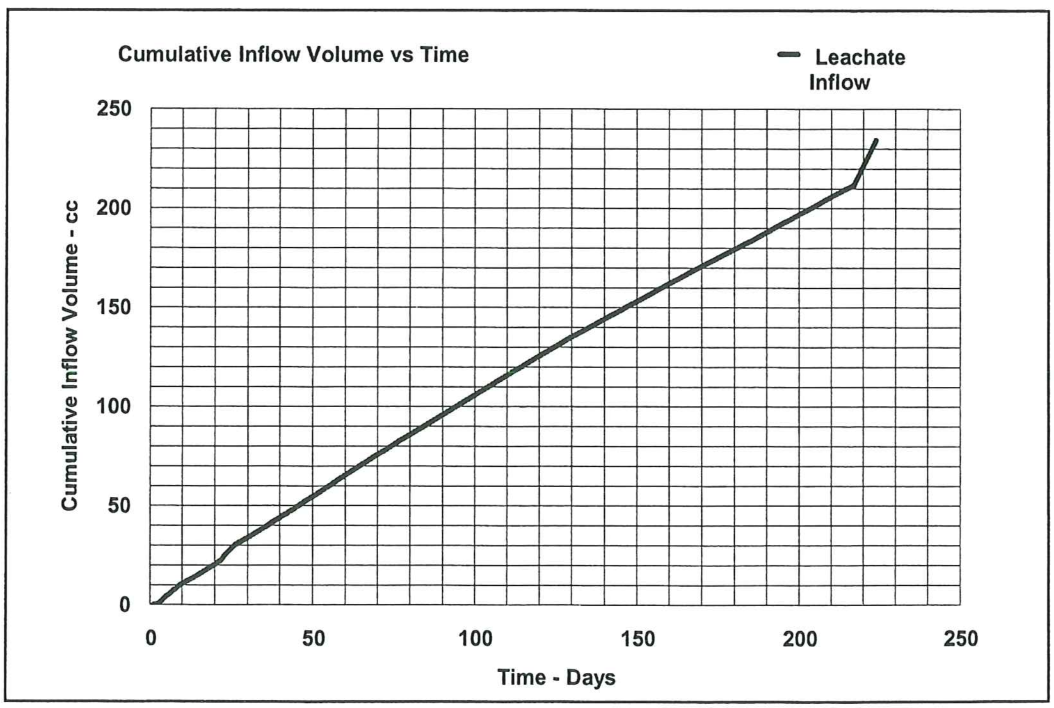
Date : 06-06-07

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	2.81	
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	
87	5.04E-010	1.00	1437	01/20/2007	92.8	2.90	
88	5.04E-010	1.00	1438	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	0.85	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	

Attachment G

Template Construction Specifications

Technical Specifications for Permitting
NorthMet Hydrometallurgical Residue Facility

Polymet Mining Corporation
NorthMet
Hoyt Lakes, MN

Table of Contents

SECTION 01010

SUMMARY OF WORK

PART 1 GENERAL

1.01 SPECIFICATIONS

A. The format of these Specifications is based upon the CSI MASTERFORMAT, however differences in format and subject matter location do exist. These Specifications are written in imperative and streamlined form. This imperative language is directed to the Contractor, unless specifically noted otherwise. It is solely the Contractor’s responsibility to thoroughly read and understand these Specifications and request written clarification of those portions which are unclear.

B. Division of the Work as made in these Specifications is for the purpose of specifying and describing work which is to be completed. There has been no attempt to make a classification according to trade or agreements which may exist between Contractor, Subcontractors, or trade unions or other organizations. Such division and classification of the Work shall be solely the Contractor’s responsibility.

1.02 EXISTING SITE CONDITIONS AND USES

A. The Project Site is located at Poly Met Mining, Inc.’s NorthMet Project near Hoyt Lakes, Minnesota.

B. The Hydrometallurgical Residue Facility (HRF) is located northwest of the plant area and adjacent to the southwest corner of Cell 2W.

1.03 WORK COVERED BY SPECIFICATIONS

A. The overall scope of the Work which is more fully described in these Specifications includes, but is not necessarily limited to, furnishing all labor, tools, equipment, and materials necessary to:

1. Emergency Basin Area Preparation
   a. Remove water from basin area to allow for construction.
   b. Excavate rock and soil, to lines and grades shown in the drawings, in preparation for HRF construction.
   c. Remove railroad lines, structures, and pipelines as shown in drawings or as required to complete the Work.
   d. Remove poles and relocate power line.
   e. Install all necessary erosion control measures.

2. Construct Seepage Collection Drain
   a. Place perforated pipe as shown in the drawings.
   b. Load, haul, and place Granular Drainage Material and Sand Layer to cover the seepage collection drain as shown in the Drawings.

3. Install Header Pipe
   a. Install Header Pipe within Sand Layer as shown in the Drawings.

4. Preload Emergency Basin
   a. Preload area using rock and soil removed during Emergency Basin Excavation.
   b. Place material in lifts as shown in the Drawings.
   c. Remove soil and rock following preload to achieve Liner System subgrade.

5. Construct Perimeter Dam
   a. Use soil and rock removed from the Preload Phase to construct Perimeter Dams.
   b. Excavate, load, haul, place and compact additional Fill Materials needed for Perimeter Dam construction from areas approved by Owner.

6. Construct Liner System
   a. Compact and prepare subgrade.
   b. Furnish and install the Geosynthetic Clay Liner (GCL).
   c. Furnish and install the Lower 60-mil Low Density Polyethylene (LLDPE) Geomembrane.
   d. Furnish and install Middle Geocomposite.
   e. Furnish and install Upper 80-mil LLDPE Geomembrane.

7. Construct Drainage Collection System
   a. Furnish and install Geocomposite.
   b. Place LTVSMC Coarse Tailings over Geocomposite.

8. Construct Leakage Collection Sump and Drainage Collection Sump

   a. Construct Leakage and Drainage Collection Sumps
      i. Construct Sump to lines and grades shown on the Drawings.
      ii. Furnish and install GCL.
      iii. Furnish and install Lower 60-mil LLDPE Geomembrane.
      iv. Furnish and install 60-mil LLDPE or HDPE Rubsheet.
      v. Furnish and install Leakage Collection Piping above 2 inches of aggregate.
      vi. Place Coarse Aggregate over Leakage Collection Piping to lines and grades shown on the Drawings.
      vii. Furnish and install Geocomposite
      viii. Furnish and install Upper 80-mil LLDPE Geomembrane.
      ix. Place 2 feet of LTVSMC Coarse Tailings over final Geocomposite layer.
   b. Construct Leakage and Drainage Collection Sidewall Riser Pipes

9. Install Water Return Pipe and Residue Discharge System
   a. Excavate pipe trench where shown in the Drawings.
   b. Furnish and install Residue Discharge and Water Return Pipes.
   c. Install Residue Discharge Points as shown in the Drawings.

10. Install Floating Pump Station
    a. Furnish and install Water Return Pump Raft according to manufacturer's recommendations.

11. At Closure – Construct Temporary Cover System
    a. Regrade residue surface as shown in the Construction Drawings, using Sand or approved Common Borrow material as necessary to achieve contours as shown; design elevations will be confirmed at time of closure.
    b. Furnish and install Geogrid over residues as shown in the Drawings.
    c. Place Sand or approved Common Borrow over Geogrid as shown in the Drawings.
    d. Place Rooting Zone soils and establish turf as shown in the Drawings or otherwise specified herein.

12. At Closure – Construct Final Cover System
    a. Salvage Rooting Soil from Temporary Cover.
    b. Regrade the Temporary Cover to achieve the contours shown in the Drawings; design elevations will be determined at the time of closure.
    c. Furnish and install 40-mil LLDPE Geomembrane, over GCL, over Temporary Cover System.
    d. Place Topsoil, over Rooting Soil, over Granular Drainage Material, to elevations and thicknesses shown in the Drawings.
    e. Install Drain Tubing, Surface Water Inlet Structures, and Storm Sewer Pipe as shown in the Drawings.
    f. Construct Rip-Rap Spillway where shown in the drawings.

13. Submit construction documentation as specified.

B. It is the intent of these Specifications to cover all aspects of the Project. Should there be some item or items not shown on the Drawings or not described in these Specifications which are required for the Work, those items and the furnishing of all labor, materials, and equipment shall be considered incidental to the Work and no additional compensation will be provided.

C. The Work includes the furnishing of all labor, equipment, tools, machinery, materials, and other items required for the construction of a complete Project as specified and shown on the Drawings. Equipment furnished shall be in safe operating condition and of adequate size, capacity, and condition for the performance of the Work. Contractor shall obtain all measurements necessary for the Work and shall be responsible for establishing all dimensions, levels, and layout of the Work.

D. Contractor shall be solely responsible for the coordination of its activities with regard to the Project and the activities of Subcontractors and Owner.

E. Contractor shall utilize material sources designated by Owner and shall develop necessary access roads for material sources to the Project Site.

F. Contractor shall provide soil testing as required in Section 02220.

1.04 WORK BY OWNER

A. Owner will provide bench mark and site coordinate information necessary for construction of the Work. Once provided, it is Contractors responsibility to protect the bench marks. Contractor shall request benchmark and site coordinate information from Owner a minimum of five days prior to the time when such information is needed.

B. Owner will provide electrical service and connection to the Contractor’s trailer.

1.05 OWNER FURNISHED PRODUCTS

A. Owner will provide borrow sources for the construction of preload and perimeter dams. These are expected to be located in the HRF construction area and in tailings basin cell 2W.

1.06 CONTRACTOR USE OF PREMISES

A. Definition of Project Site: The Project Site is defined as the area within the construction limits shown on the Drawings, plus a nearby material and equipment storage and staging area, the location of which will be designated by Owner. Contractor shall limit operations, including material and equipment storage, to within those boundaries. Any disturbance outside the construction limits shall be fully restored at Contractor's expense in accordance with Laws and Regulations. Contractor shall obtain approval of Owner at all locations where Contractor uses land not included in the construction limits.

B. Hours of Operation: Working hours shall be set by Contractor, subject to approval by Owner.

C. Protection and Repair of Existing Facilities and Utilities: Contractor shall perform operations carefully and in such a manner as to protect existing facilities and utilities. Obstructions not shown on the Drawings may exist and shall be exposed by Contractor without damage. Contractor shall be responsible for damage to existing facilities and utilities resulting from Contractor's operations, and shall repair or replace damaged items to Owner's satisfaction. Groundwater monitoring wells shall be protected during construction unless directed otherwise by Owner.

D. Unfavorable Construction Conditions: When unfavorable weather, soil, drainage, or other unsuitable construction conditions exist, Contractor shall confine operations to work which will not be adversely affected by such conditions. No portion of the Work shall be constructed under conditions which would adversely affect the quality of the Work, unless special means or precautions are taken to perform the Work in a proper, safe and satisfactory manner.

E. Survey Markers: Contractor shall conduct operations so as to preserve bench marks, survey reference points, and stakes existing or established by Owner for the construction. Contractor will be charged the expense of repairing or replacing survey markers and shall be responsible for mistakes or lost time resulting from damage or destruction of survey markers due to Contractor's operations.

PART 2 PRODUCTS [NOT USED]

PART 3 EXECUTION [NOT USED]

END OF SECTION 01010

SECTION 01025

MEASUREMENT AND PAYMENT

PART 1 GENERAL

1.01 GENERAL

A. This Section of the Specifications describes the measurement and payment for the Work as set forth in the Contract Documents.

B. Each lump sum or unit adjustment price stated on the Proposal Form shall constitute full compensation as herein specified for each item of work completed in accordance with the requirements of the Contract Documents.

C. All costs in connection with the Work, including furnishing all materials, machinery, supplies and appurtenances; providing all construction equipment and tools; and performing all necessary labor, coordination, supervision, and management to fully complete the Work shall be included in the unit adjustment or lump sum prices quoted on the Proposal Form. All Work not specifically set forth as a separate bid item herein shall be considered an incidental obligation of the Contractor and all costs in connection therewith shall be included in the amounts and prices submitted on the Proposal Form.

1.02 INTENT OF PROPOSAL FORM ORGANIZATION

A. Payment for all Work shall be in accordance with the terms and conditions set forth elsewhere in the Contract Documents and the Contractor's lump sum and unit adjustment prices set forth in Contractor's conformed Proposal Form. The items set forth in the Proposal Form subdivide the Project for purposes of measurement and payment only, and are intended to represent the entire and complete Project as set forth in the Contract Documents. The items set forth in the Proposal Form shall constitute full compensation to Contractor for providing all material, equipment, labor, and supplies to complete the Work in complete accordance with the Contract Documents.

B. The Bid shall consist of a Lump Sum Price and Unit Adjustment Prices. General descriptions of the Work are provided in Section 01010. The Lump Sum Price shall be full compensation for completion of the Work. Unit Adjustment Prices will be used to adjust the Lump Sum Price based upon Changes to the Contract.

C. Partial progress payments for Work completed under the Lump Sum Bids shall be made as follows:

1. Partial progress payments will be made based upon monthly estimates of percent Project completion and the Schedule of Values.

1.03 LUMP SUM BID

A. The Lump Sum Bid shall constitute full compensation for furnishing all material, equipment, labor, and supplies and performing all operations necessary to complete the Work. The Lump Sum Bid shall constitute full compensation for the entire Project.

B. Quantities will be used as a basis for payment only to the extent of determining percent complete for partial progress payments and to verify that that the Work has been completed to the neat lines shown on the Drawings.

1.04 UNIT ADJUSTMENT PRICES

A. The Unit Adjustment Prices will be used for Change Work under the Lump Sum Price to compensate the Contractor for modifications to the Work covered by Change Orders. The Unit Adjustment Prices will be used as described below.

   1. For soil materials to be incorporated in the Work, the volumes will be determined as constructed in-place based on neat line dimensions.
   2. For soil materials to be placed in temporary stockpile, the volumes will be determined based on surveyed data for the completed stockpile.

B. The Unit Adjustment Price for Rock Excavation shall constitute full compensation for furnishing all material, equipment, labor, and supplies and performing all operations necessary to drill and blast or otherwise excavate virgin rock, load, haul, and stockpile rock at the location designated in the Drawings. **Excavation of virgin rock shall <u>not</u> be included in the Lump Sum Bid. Excavation, loading, transport and placement of previously excavated rock from pre-existing stockpiles shall be included in the Lump Sum Bid.**

C. The Contractor shall measure the volume of the void left by excavation of virgin rock. The volume of the void left by excavation of virgin rock shall be determined from surveys by an independent registered land surveyor licensed in the State of Minnesota and retained by the Contractor. Survey data shall be collected at intervals necessary to compute the rock volume using the average end area method and/or computer earthwork volume programs. Contractor shall supply Owner with the appropriate survey data and quantity calculations.

PART 2 PRODUCTS [NOT USED]

PART 3 EXECUTION [NOT USED]

END OF SECTION 01025

SECTION 01200

MEETINGS

PART 1 GENERAL

1.01 PRECONSTRUCTION CONFERENCE

A. After Owner and Contractor have executed the Agreement, Owner will schedule a preconstruction conference at Project Site that shall be attended by Owner, Contractor, Engineer, Owner's On-site Representative, and others as appropriate. The meeting will be scheduled within twenty-eight (28) calendar days following formal agreement to Contract. The purpose of the meeting will be to ensure that all parties understand their responsibilities and the procedures that will be used to assure efficient completion of the Work.

B. Agenda items may include:

1. Distribution of Plans and Specifications.
2. Designation of responsible personnel for all parties, lines of communication, and lines of authority.
3. Scope of work and the anticipated schedule of operations.
4. Critical work sequencing.
5. Submittal and field test reporting procedures.
6. Record documents and reporting.
7. Project Site safety and security procedures.
8. List of major subcontractors.
9. Procedures for processing change orders.
10. Use of premises including equipment and material storage.
11. Major equipment deliveries.
12. Housekeeping procedures.
13. Other items for consideration during construction activities.

1.02 PROGRESS MEETINGS

A. Weekly progress meetings will be scheduled by the Owner’s On-Site Representative at a regular time mutually agreeable to the Owner, Contractor, and Owner’s On-Site Representative. The Contractor shall attend these meetings and shall coordinate and require the attendance of subcontractors whose work may be in progress at the time or whose presence may be required for any purpose. Scheduling of required attendees shall meet with the approval of the Owner's On-Site Representative.

B. Following each meeting, the Owner’s On-Site Representative will prepare and distribute to Owner and Contractor copies of the minutes of the meeting. These will include a brief summary of the progress of the Work since the previous meeting.

C. The weekly meeting agenda will include:

1. Administrative/Purchasing issues.
2. Technical/Construction issues.
3. Design issues.
4. Schedule/Progress issues.
5. Project Site safety issues.
6. Review status of required submittals

1.03 UNSCHEDULED MEETINGS

A. The Contractor shall attend other unscheduled meetings which may be reasonably requested by Owner's On-Site Representative or Owner to discuss unanticipated changes in the Work or conditions at the Project Site and which must be resolved before progression of work.

1.04 BASIS FOR COMPENSATION

A. The Contractor's cost for work under this Section shall be included in the Lump Sum Bid price and no additional compensation will be provided.

PART 2 PRODUCTS [NOT USED]

PART 3 EXECUTION [NOT USED]

END OF SECTION 01200

SECTION 01300

SUBMITTALS

PART 1 GENERAL

1.01 GENERAL PROCEDURES

A. This Section stipulates the requirements for transmission of submittals from Contractor to Owner's On-Site Representative and actions taken by Owner's On-Site Representative regarding submittals.

B. Submittals shall be identified with the project name, name of submittal, and Specification Section for which the submittal is required.

C. Owner's On-Site Representative will accept submittals only from Contractor. Submittals from subcontractors, vendors, suppliers, or others will be returned without review or action.

D. Owner's On-Site Representative will accept only those submittals required by the Specifications. Unsolicited submittals will be returned without review or action.

E. All engineering data, regardless of origin, shall be stamped with the approval of the Contractor. The Contractor's stamp of approval will be a representation to the Owner and Owner's On-Site Representative that the Contractor has assumed full responsibility for determining and verifying all quantities, dimensions, field construction criteria, materials, catalog numbers, and similar data, and that he has reviewed or coordinated each submittal with the requirements of the Specifications.

F. All engineering data shall be identified by use of the nomenclature established by the Plans and Specifications. Equipment drawings shall have the equipment name and number clearly displayed. Material drawings shall have the structure name and structure number (when applicable) clearly displayed.

1.02 CORRESPONDENCE

A. Correspondence forwarding engineering data shall be addressed to the Owner and Owner's On-site Representative as follows.

To the Owner:
Poly Met Mining Inc.
NorthMet Project
P.O. Box 475; County Road 666
Hoyt Lakes, MN 55750-0475
Attention: **Mr. Jim Tieberg**

To the Owner's On-site Representative:
c/o _________________
Poly Met Mining Inc.
NorthMet Project
P.O. Box 475; County Road 666
Hoyt Lakes, MN 55750-0475
____

Copies to the Owner:
Poly Met Mining Inc.
Attention: **_TBD_______________**
____

Copies to the Project Engineer:
TBD

B. A letter of transmittal shall accompany all submittals of engineering data and shall include a list of the data included in the transmittal. Lists shall include manufacturer's drawing numbers identified with the corresponding project equipment or structure nomenclature as applicable. The letter shall be identified by the project name.

1.03 PROGRESS SCHEDULE

A. Submit an estimated progress schedule and a finalized progress schedule in accordance with the requirements of the General Conditions.

B. Update the schedule on a weekly basis for presentation, discussion, and distribution at the weekly progress meeting.

1.04 SCHEDULE OF VALUES AND PROGRESS PAYMENT SCHEDULE

A. Submit a schedule of values for the Work. The schedule shall be broken out as follows for each Bid Price item and each Unit Adjustment Price item on the Bid Form:

1. Item description.
2. Unit of measure upon which the item is based.
3. Contractor's estimated quantity (number of units upon which the total price for the item is based: for Unit Adjustment Price items, enter 0 for quantity).
4. Total unit price, including materials, equipment, labor, overhead, and profit (for Unit Adjustment Prices, shall be same unit price as on the Bid Form).
5. Extension (total price for the item, calculated by multiplying the number of units by the total unit price).

B. Submit a schedule of anticipated progress payment requests with the schedule of values. The proposed progress payment schedule shall be based on monthly or target-percentage invoicing for Work completed, and shall be closely coordinated with the schedule of values. Resubmit a revised schedule of anticipated progress payment requests whenever the progress schedule is updated or revised. Update the payment schedule each time an actual payment request varies more than 10 percent from the schedule. The progress payment schedule shall take into consideration retainage if applicable.

C. The schedule of values and anticipated progress payment schedule shall be subject to review and approval by Owner. If, in the opinion of Owner, the schedules do not contain sufficient detail or appear to be unbalanced, the Owner may require Contractor to revise and resubmit the schedules and/or provide documentation to justify Contractor's distribution. Contractor shall correct such deficiencies and resubmit the schedules.

1.05 REVIEW OF SUBMITTALS

A. The Owner's On-Site Representative's review of engineering data will cover only general conformity of the data to the Specifications, external connections, and interfaces with equipment and materials furnished under separate specifications. The Owner's On-Site Representative's review does not indicate a thorough review of all dimensions, quantities, and details of the equipment, material, device, or item indicated or the accuracy of the information or documentation submitted; nor shall review or approval by the Owner's On-Site Representative be construed as relieving the Contractor from any and all responsibility for errors or deviations from the requirements of drawings and specifications.

1.06 SUBMITTAL FOR INFORMATION OR DOCUMENTATION

A. Submit 2 copies to Owner's On-Site Representative and 2 copies to Owner.

B. Unless otherwise specified, submittal shall be made at least 1 day before the subject of the submittal is to be incorporated into the Work.

C. Submittal is for the purpose of formal verification that the subject of the submittal conforms to the requirements of the Specifications, for formal documentation of the Work, or both.

D. No action is required by Owner or Owner's On-Site Representative. Owner's On-Site Representative will generally notify Contractor if deficiencies are identified; however Contractor is solely responsible for ensuring that the subject of the submittal conforms to the requirements of the Specifications.

1.07 SUBMITTAL FOR REVIEW

A. Submit 2 copies to the Owner's On-Site Representative.

B. Unless otherwise specified, submittal shall be made at least 10 days before the subject of the submittal is to be incorporated into the Work. Owner's On-Site Representative will respond within 5 days from receipt of submittal.

C. Submittal is for the purpose of providing opportunity to Owner's On-Site Representative for review and comment on the subject of the submittal.

D. Owner's On-Site Representative will respond to the submittal either with a list of comments or indicating no comments.

E. If Owner's On-Site Representative's comments indicate a deficiency with respect to the requirement of the Specifications, Contractor shall amend the submittal and resubmit. Owner's On-Site Representative will again respond to the resubmittal.

F. If Owner's On-Site Representative's comments are in regards to an issue which is based on Contractor's discretion, Contractor shall furnish additional information, provide justification, and otherwise cooperate in addressing and resolving Owner's On-Site Representative's comments.

G. Contractor shall remain solely responsible for ensuring that the subject of the submittal conforms to the requirements of the Specifications.

1.08 RECORD DOCUMENTS

A. Submit record documents prior to Substantial Completion.

B. Record documents shall accurately reflect the as-constructed condition.

1.09 WARRANTY AND GUARANTEE CERTIFICATES

A. Submit warranty and guarantee certificates prior to Substantial Completion.

B. Warrantee and guarantee certificates shall be signed by Contractor, Installer, Manufacturer, and others as required by the Specifications.

1.10 BASIS FOR COMPENSATION

A. The Contractor's cost for work under this Section shall be included in the Bid Price and no additional compensation will be provided.

PART 2 PRODUCTS [NOT USED]

PART 3 EXECUTION [NOT USED]

END OF SECTION 01300

SECTION 01400

QUALITY CONTROL

PART 1 GENERAL

1.01 FIELD QUALITY CONTROL

A. Complete construction quality control for the Work as described in these Specifications, unless specified as the responsibility of the Owner.

B. Retain an independent registered land surveyor licensed in the State of Minnesota for performing quality control on line and grade of the Work. The quality control survey data shall be available for review at all times by Owner or Owner’s On-Site Representative.

C. Retain an independent soil and material testing firm(s) for performing the quality control testing. The quality control data shall be available for review at all times by Owner or Owner’s On-Site Representative.

D. All quality control test results will be used by Owner to demonstrate compliance with project permit requirements. Tests shall be performed and samples shall be collected at random locations such that the test results may be considered representative. Testing shall be performed or samples collected at specific locations determined by Owner’s On-Site Representative, if requested.

E. Owner’s On-Site Representative shall have the authority to direct testing performed by Contractor’s independent soil and material testing firm.

1.02 SUBMITTALS

A. Submit for approval name(s) and qualifications of Contractor’s independent registered land surveyor and Contractor’s independent soil and material testing firm(s).

B. Submit for information on a daily basis, the following information:

1. Survey data for each day that survey work is performed.
2. Soil compaction data for each day that soil compaction data is collected.
3. Other soil and material test data daily as it is available.

C. Submit for documentation a tabulation of all results of survey work performed. This submittal shall be made prior to substantial completion. The tabulation shall be signed by the registered land surveyor. The tabulation shall contain the following information for each survey location:

1. A unique identification number.
2. Coordinates.
3. Elevation of the finished surface of each material (e.g. top of Composite Liner subgrade, top of Fill Material for Perimeter Dam construction, top of Temporary Cover, top of Final Cover Granular Drainage Material, top of Rooting Soil, top of Topsoil; existing surface and finished surface for stockpiles).

D. Submit for documentation the results of all soil compaction testing performed. Test results shall be compiled in a report-format and submitted prior to substantial completion of Work.

1.03 SURVEY VERIFICATION REQUIREMENTS

A. Contractor's independent registered land surveyor shall verify that elevations, grades, slopes, and material thickness constructed by Contractor are within the tolerances specified in Section 02220. Surveying results will be used by Owner to demonstrate compliance with permit requirements. Material thickness shall be determined from the elevation difference between shots taken at the same coordinate location. On slopes, the surveyed vertical thickness shall be adjusted by calculating the thickness perpendicular to the slope for presentation in the submittals. The surveying work shall include determining elevations at specific locations on a matrix of survey points as described below.

1. Perimeter Dams: For elevation, grade, and material thickness verification, survey shots shall be taken on the top of dam fill material. The toe, midpoint, and top of each dam shall be surveyed at 100-foot intervals along the dam alignment.
2. Subgrade: For elevation and grade verification, survey shots shall be taken on the subgrade surface at points shown on the Drawings or to be specified by Owner's On-Site Representative.
3. Header Pipe (if specified/shown on drawings): For elevation and grade verification, survey shots will be taken on the top of pipe elevations at a maximum of 50-foot intervals (lineal) and at all changes in horizontal and vertical alignment.
4. Liner System: For elevation and grade verification, survey shots will be taken on the top of the Liner System subgrade at a maximum of 50-foot grid pattern and at all changes in horizontal and vertical alignment.
5. Water Return and Residue Discharge Pipes: For elevation and grade verification, survey shots shall be taken on the top of pipe elevations at a maximum of 50-foot intervals (lineal) in the areas where pipe has little or no significant change in elevation, and at changes in grade. Coordinate the location of these shots with Owner or Owner's On-Site Representative.

1.04 CONTRACTOR TESTING RESPONSIBILITIES

A. Contractor shall retain an independent testing laboratory(s).

B. Contractor shall be responsible to perform all the testing requirements described in these Technical Specifications unless noted as the responsibility of the Owner.

1.05 OWNER TESTING RESPONSIBILITIES

A. Owner shall be responsible to perform specific testing requirements for the following construction materials:

1. LTVSMC Coarse Tailings – all testing specified in Section 02220
2. Geomembranes – 3rd Party Destructive Testing, see Section 02273
3. Geocomposite Layers – all testing specified in Section 02275
4. Geosynthetic Clay Liner – 3rd Party Testing, see Section 02274

B. Contractor shall provide material samples, and/or coordinate with and provide access to work areas for Owner's On-Site Representative and Owner's independent testing firms for sampling and/or testing.

C. Work failing to meet Specifications shall be repaired at Contractor's expense. Owner will perform additional testing after repairs are completed. The expense of retesting may be charged to Contractor. Contractor may ask to review results of Owner's testing during construction.

1.06 PRESENTATION OF DATA

A. All survey and compaction test data shall be summarized and submitted to Owner or Owner's On-Site Representative on a daily basis. Failure to submit data on a daily basis shall be cause for Owner to suspend Contractor's operations until submittals are made current. Contractor shall not be entitled to additional compensation for any suspension of operations ordered by Owner due to Contractor's failure to submit data on a daily basis.

B. Survey data shall be summarized in a tabular format listing each survey point by unique identification number, coordinate, elevation, difference from previous elevation (material thickness), and required material thickness as appropriate. Required material thickness is measured perpendicular to the slope. Material thickness based upon survey shots at the same coordinate location shall be corrected to the perpendicular-to-slope thickness.

C. Compaction test data shall be summarized in a tabular format listing each compaction test by unique identification number, horizontal coordinate, elevation (within 0.5 foot vertical of actual location), reference proctor, in-place moisture content, dry density, and percent compaction.

1.07 BASIS FOR COMPENSATION

A. The Contractor's cost for work under this Section shall be included in the Lump Sum Bid price and no additional compensation will be provided.

PART 2 PRODUCTS [NOT USED]

PART 3 EXECUTION [NOT USED]

END OF SECTION 01400

SECTION 01510

TEMPORARY UTILITIES

PART 1 GENERAL

1.01 TEMPORARY UTILITIES

A. Water: Potable water is not available at the Project Site. Make all arrangements necessary to provide water for potable consumption. Water used for construction purposes need not be potable but must meet all applicable surface water quality criteria. Non-potable water will be available from an on-site location designated by Owner. The costs of furnishing potable and other water and water usage shall be included in the Bid Price and no additional compensation will be provided.

B. Sanitary Facilities: Contractor shall provide sanitary facilities for use by Contractor's employees, subcontractors, suppliers, Owner's On-Site Representative, Owner and all other persons to be working on the Project Site. Sanitary facilities shall, as a minimum, comply with the requirements of applicable Laws and Regulations for temporary sanitary facilities and shall be emptied and sanitized at the frequency needed to be maintained in a clean and useable condition. Sanitary facilities shall be maintained until Substantial Completion unless earlier removal is approved by Owner or Owner's On-Site Representative. The cost of sanitary facilities shall be included in the Bid Price and no additional compensation will be provided.

C. Electricity: Furnish portable electric power generators necessary for construction of the Work. Should Contractor need electric power service for Contractor's purposes, it shall be the Contractor's responsibility to arrange for and pay for such service. The cost shall be included in the lump sum price and no additional compensation will be provided. Owner will provide access to electric service connection at the location of the Contractor's office location, and provide electric service to the Office Trailer furnished for Owner's On-Site Representative's use.

D. Telephone and Fax: Phone service is not readily available at the Project Site. Cellular phone service may not be available throughout the entire Project Site. Make arrangements for the Contractor's phone and fax service during the Project. The cost of Contractor's telephone service, fax service, and usage, shall be included in the Bid Price and no additional compensation will be provided.

E. Fire Protection: Make all arrangements necessary to ensure that the Project Site and the Work have adequate fire protection services throughout the duration of the Work. Any special fees or charges imposed by governmental units or other organization to provide such services shall be paid by Contractor. The cost of fire protection shall be included in the Bid Price and no additional compensation will be provided.

1.02 OFFICE TRAILER

A. Contractor shall furnish office trailer space for use by Owner and Owner's On-Site Representative. The space for Owner's On-Site Representative shall have a minimum of 120 square feet of floor area, and at minimum be equipped with a desk, a table, and two chairs. The space shall be furnished with electrical service, operable lighting, heat, and air conditioning. This office space may be located in a trailer with other facilities but must be accessible to Owner and Owner's On-Site Representative at all times and must be secured by a separation wall and lockable door. Owner will provide 240 volt, 110 AMP service to the trailer and will make and disconnect electrical service as requested by the Contractor.

1.03 BASIS FOR COMPENSATION

A. The Contractor’s cost for work under this Section shall be included in the Lump Sum Bid and no additional compensation will be provided.

PART 2 PRODUCTS [NOT USED]

PART 3 EXECUTION [NOT USED]

END OF SECTION 01510

SECTION 01560

STORM WATER EROSION PREVENTION AND SEDIMENT AND DUST CONTROL

PART 1 GENERAL

1.01 DESCRIPTION

A. This section covers construction of all stormwater erosion prevention and sediment controls as needed to conduct the Work in accordance with the Technical Specifications, Drawings, Agreement, and in compliance with local, county, state, federal and other jurisdictional rules and regulations.

B. This work consists of: 1) managing storm water runoff and project related water discharges in order to minimize sediment pollution during construction and over the life of the contract and 2) managing the discharges as set forth in any applicable regulatory agency permit. The work includes furnishing, installing, maintaining and utilizing storm water best management practices and any work specified in conjunction therewith as well as removing temporary sediment control devices when no longer necessary.

C. Control dust generation on access roads to the Project Site and within construction limits. Comply with requirements of project-specific Air Quality Management Plans/Fugitive Emissions Control Plans.

1.02 BASIS FOR COMPENSATION

A. The Contractor's cost for work under this Section shall be included in the Bid Price and no additional compensation will be provided.

1.03 REFERENCES

A. Protecting Water Quality in Urban Areas, MPCA 2000.

B. Stormwater Management for Construction Activities, EPA 1992.

C. Developing Pollution Prevention Plans and Best Management Practices, EPA 1992.

D. Erosion Control Handbook, Mn/DOT 2006.

E. Minnesota Stormwater Manual, Version 2, January 2008.

F. Stormwater and Wetlands: Planning Evaluation Guidelines, MPCA 1997.

G. Construction Stormwater Pollution Prevention Plan (SWPPP) – NorthMet Project Plant Site, Barr 2016.

PART 2 PRODUCTS

2.01 MATERIALS

A. Water used for dust control may be obtained from an on-site location designated by Owner.

B. Acceptable temporary erosion control devices include, but are not necessarily limited to, silt fence, straw and hay bales, mulch, geotextiles, and vegetative cover.

2.02 EQUIPMENT

A. Water tank trucks equipped with water cannon capable of delivering water through either front or rear-mounted nozzles. Tank trucks shall be of sufficient size and mobility and carry a sufficient quantity of water to control dust generated by Contractor's activities.

PART 3 EXECUTION

3.01 STORM WATER SEDIMENT AND EROSION CONTROL

A. The Owner is responsible for obtaining the MPCA General Stormwater Construction Permit (MNR 100001) for authorization to discharge storm water associated with the project construction activity under the National Pollutant Discharge Elimination System (NPDES) program and providing a copy of the permit to the Contractor prior to beginning construction activities at the Project site. The Contractor will be required to co-sign the MPCA Stormwater Permit Application and is jointly responsible for compliance with Parts II.B, Part II.C, and Part IV of the MPCA Stormwater Construction Permit (MNR 100001).

B. The Owner is responsible for preparing the Storm Water Pollution Prevention Plan (SWPPP) required under the General Stormwater Construction Permit (MNR 100001) and providing a copy of the SWPPP to the Contractor prior to beginning construction activities at the Project Site.

C. The Owner is responsible for coordinating and obtaining any City, Town, or County permits.

D. The Contractor is responsible for conducting all construction activities in full compliance with the applicable requirements of the MPCA General Stormwater Construction Permit (MNR 100001), the SWPPP and any additional requirements that may be contained in any City, Town or County permits. The Owner will provide the Contractor with copies of all relevant permits and the SWPPP prior to the start of construction activities.

E. The Contractor is responsible for compliance with all requirements specified in Section 3.01 D until construction is complete, and the Project Site has undergone final stabilization. Once the Owner is satisfied that these conditions have been met, the Owner will prepare and submit the Notice of Termination (NOT) to the MPCA.

F. Install erosion control devices and materials at locations as directed by Owner or Owner's On-Site Representative where soil erosion at the Project Site may occur due to Contractor's activities.

G. Install temporary erosion control devices during the progress of the work and maintain them until permanent erosion control (turf establishment, aggregate surfacing, etc.) has been established.

H. Strictly follow all additional requirements of Owner's SWPPP (to be provided by Owner under separate cover).

3.02 EROSION PREVENTION AND SEDIMENT CONTROL

A. The Contractor has responsibility for charge and care of the Project and shall take necessary precautions against injury or damage to the Project by action of the elements. In addition, the Contractor shall take necessary precautions to prevent off site damage resulting from work conducted on the Project or Project related storm water runoff.

B. The Contractor is responsible for preventing or minimizing sediment loss from the Project by directing storm water runoff to constructed ponds and sediment traps as well as installing temporary sediment control devices in drainage locations where runoff can leave the Project limits and/or enter into environmentally sensitive areas. The Contractor shall schedule, construct and/or install temporary sediment control and storm water management measures as required by the Contract and as stated in the permits required for the Project.

C. The Contractor shall install temporary storm water management and sediment control devices in conformity with the details, typical sections, and elevation controls shown in the Drawings. The actual installation location of temporary storm water management and sediment control devices may be adjusted from that indicated in the Plan to better accommodate the actual field conditions and increase the effectiveness of a device.

D. Sediment control measures must be installed down gradient prior to or in conjunction with soil disturbing activities. The Contractor shall schedule, install and maintain temporary sediment control measures as an ongoing effort on a site-by-site basis over the life of the Contract. The Contractor is responsible for minimizing the potential for sedimentation after temporary sediment control devices have been installed by implementing a good quality erosion control program and staging construction as needed.

E. The Contractor shall schedule and phase construction in critical resource areas to the best of his ability in order to minimize the potential of sediment entering into a critical resource. Critical resources include but are not limited to, protected wetlands, surface waters, trout streams, Special Waters, impaired waters, rivers, and endangered species habitat. Measures to minimize sediment potential include practices such as hand clearing and grubbing, limited bare soil exposure time, and immediate final establishment of vegetation.

3.03 FUGITIVE DUST EMMISSIONS CONTROL

A. The Owner is responsible for obtaining air quality permits and preparing and complying with a Fugitive Dust Emissions Control Plan.

B. The Contractor is responsible for complying with the Fugitive Dust Emissions Control Plan. A copy of the Plan will be provided by the Owner.

C. Apply water to roads used by Contractor's equipment as directed by Owner or Owner's On-Site Representative to control dust generated by wind or by Contractor's vehicle traffic.

D. Apply water to ground surfaces within the construction limits as directed by Owner or Owner's On-Site Representative to control dust generated by Contractor's activities at the Project Site.

E. Strictly follow all additional requirements of Owner's Fugitive Emissions Control Plan (to be provided by Owner under separate cover).

END OF SECTION 01560

SECTION 02220

EXCAVATING, BACKFILLING, AND COMPACTING

PART 1 GENERAL

1.01 SECTION INCLUDES

A. All work included in this Section shall be performed in accordance with the following paragraphs, the General Requirements set forth in Division 1 of these Specifications, and the provisions of the other Contract Documents.

B. Work covered by this section includes furnishing all supervision, labor, materials, and equipment required to complete all general or miscellaneous earthwork at the Site to grade and lines shown on the Drawings including, but not limited to:

1. Material source development to obtain construction materials.
2. Excavating, segregating, loading, hauling, and placing or stockpiling existing rock and soil in Emergency Basin Area as specified.
3. Load, haul, and place sand and drainage aggregate for seepage collection drain construction.
4. Excavate, load, haul, and place Fill Material for Perimeter Dam construction.
5. Placement of Rip-Rap at specified locations.
6. Hauling and placing Coarse Aggregate.
7. At Closure placing Temporary and Final Cover.
8. Placement of erosion protection material.
9. Controlling dust within work areas.

1.02 BASIS FOR COMPENSATION

A. Work included under this Section of these Specifications shall be included under the Lump Sum Bid and the Unit Adjustment Price for Rock Excavation

1.03 SUBMITTALS

A. Submit soil testing and survey data as specified in Section 01400.

B. Location of off-site source of materials.

C. Testing of off-site source of materials as per the project Construction Quality Assurance Manual and these Specifications.

D. Name, address, telephone number and contact person of independent soils laboratory.

E. Proposed haul road plan for transportation of all off-site materials to the project site.

F. Provide specified permeability and gradation testing on aggregate and drainage layer materials at least 21 days prior to installation for approval.

G. Fugitive Dust Emissions Control Plan.

1.04 REFERENCES

A. American Society for Testing and Materials, Current Edition, hereafter referred to as ASTM.

B. Minnesota Department of Transportation Standard Specifications for Construction; 2005 Edition.

1.05 SEQUENCING AND SCHEDULING

A. Owner will be evaluating results of the independent registered land surveyor's grade, slope, and material thickness verifications, collecting material samples, and conducting field testing of materials throughout the duration of the Project, as described in Section 01400 of these Specifications. Do not proceed with subsequent operations until Owner or Owner's On-Site Representative has been notified, has been given opportunity to test or review the Contractor's test data, and has informed the Contractor of any test results that have been gathered.

B. The required completion date for the Work as described in these Contract Documents is specified elsewhere in these Contract Documents.

1.06 JOB CONDITIONS

A. It shall be solely the Contractor's responsibility to review available tests and reports, conduct additional tests, and otherwise determine to its own satisfaction the location and nature of all surface and subsurface features and the soil and water conditions that may be encountered. Owner's information on site conditions may be reviewed at Owner's offices as scheduled with Owner.

B. Use of explosives will not be permitted except as pre-approved by Owner.

C. Contractor shall be solely responsible for determining the means and methods for meeting the excavation and compaction requirements unless otherwise specified herein, except that compaction by flooding or puddling or other means that involve saturation or over-wetting the soil will not be permitted.

D. Provide all shoring, bracing, sheet piling, trench boxes, tie backs, and other measures required to perform all Work in accordance with Laws and Regulations. Specifically, all excavations shall conform to the requirements of OSHA set forth in 29 CFR 1926, Subpart P (Occupational Safety and Health Standards-Excavations).

1.07 QUALITY CONTROL

A. Contract with a qualified soils testing firm, subject to approval by Owner, to conduct all sampling and testing of Fill Materials and other soil materials, as specified in these Specifications. The testing laboratory will perform appropriate tests including sieve analysis, standard Proctor moisture-density testing an in-place moisture-density testing, and other tests as needed.

B. Provide testing firm safe access to the Work and materials to be tested, in accordance with the following minimum provisions:

1. All Fill Material used will be assessed on a regular basis by testing firm and Owner or Owner's On-Site Representative. Owner or Owner's On-Site Representative will reject all material which does not conform to the material specifications herein as required for each fill zone. Rejected material placed shall be removed at Contractor's expense.
2. Particle size samples shall be taken of Fill Materials at least twice for each material source and at least once for every 20,000 cubic yards of material placed.

C. Construction Testing: The following testing will be conducted during construction:

1. Perform Standard Proctor moisture-density relationship analyses according to ASTM D 698 for at least two samples for each borrow source location.
2. Conduct soil classification according to ASTM D 2487 for at least two samples for each borrow source location.
3. Perform in-place moisture-density testing according to ASTM D 1556 (sand cone) or ASTM 2922 (nuclear densometer) at least once every lift at a minimum frequency of approximately 500 feet of dam length, and at least once a day when compaction activities are being performed.
4. Report whether each in-place moisture-density test passed or failed. If any test fails, report what actions were taken to correct material compaction, and what additional tests will be submitted demonstrating acceptable (passed) compaction.
5. Only passing tests will be considered in the count of material tests taken, as specified above.

PART 2 PRODUCTS

2.01 GENERAL

A. All Fill Materials shall be free of wood, organic soils, large boulders, topsoil, snow, ice, and other unsuitable materials detrimental to performance of the dam.

2.02 MATERIALS AND MATERIAL SOURCES

A. Fill Material: Materials conforming to the specifications for Fill Materials are located within designated Owner-supplied material sources. These materials include LTVSMC Coarse Tailings, and Common Borrow consisting of blasted bedrock. The general location of material sources shall be designated by Owner and will be shown in the Construction Drawings. All Contractor-supplied materials used must be approved by Owner or Owner's On-Site Representative. If unsuitable Owner supplied materials are encountered, Contractor shall notify Owner and Owner may choose to use the material or direct Contractor to alternate material source sites. The material for use as the dam fill shall consist of inorganic soil classified as a CL, SC, SM, or SP as defined by the Unified Soil Classification System.

B. Granular Drainage Material:
1. 100 percent passing 3/8-inch sieve and maximum 5 percent by weight which passes the #200 Sieve as specified.
2. $k \geq 1 \times 10^{-3}$ cm/sec and $k \geq 1 \times 10^{-2}$ as specified.
3. Rounded to sub-rounded particles per ASTM (when in contact with geomembrane).

C. Coarse Aggregate:
1. Granular material, bank-run sand and bank-run gravel, consisting of rounded durable particles. Crushed aggregate not allowed. Limestone not allowed.

2. Grain size range from maximum diameter of 1-1/2 inches to minimum diameter of 5/8 inch (maximum 5 percent by weight passing #4 sieve).
3. Uniformity Coefficient: Less than 4.
4. Rounded particles per ASTM.

D. Rooting Soil: (TBD)

E. Topsoil: (TBD)

F. Common Borrow: Common Fill on Detail 2/23(TBD)

G. Rip-Rap: Rip-Rap materials used shall be in accordance with Section 3601 of Minnesota Department of Transportation's 2005 Edition of Standard Specifications for Construction.

H. Fine Filter Aggregate

PART 3 EXECUTION

3.01 GENERAL

A. Locate and protect overhead and underground utilities, unless indicated otherwise on the Drawings.

B. Provide temporary controls such as diversions and dewatering equipment to prevent surface runoff from entering excavations and to remove ponded water from excavations. Maintain excavations in a dry and stable condition at all times.

C. Examine the area prior to and while performing earthwork. If unsatisfactory conditions occur during the Work, Contractor shall not proceed with the Work until satisfactory conditions have been established.

D. Determine the location and nature of all surface and subsurface obstacles and the soil and water conditions that will be encountered during construction.

E. Institute and maintain, as directed by Owner, adequate dust control measures such as sprinkling, for all its work areas, haul routes, and parking areas.

3.02 PREPARATION

A. Make arrangements to locate all existing utilities and underground facilities in the areas of the Work. If any are to remain in place, Contractor shall provide adequate means of protection during earthwork operations.

B. Protect structures, fences, utilities, wells, and other facilities from damage caused by settlement, lateral movement, undermining, washout and other hazards created by earthwork operations.

C. Control surface water sufficiently to permit placement of materials in dry conditions.

3.03 EXCAVATION

A. Construct excavations in accordance with applicable Laws and Regulations.

B. Excavate rock and soil in the Emergency Basin Area to the lines, elevations, slopes, and dimensions shown on the Drawings, or as necessary to complete the Work shown on the Drawings.

C. Excavate additional Fill Materials from areas shown in the Construction Drawings as needed to complete the Work shown on the Drawings.

D. Materials excavated for construction that are unsuitable for reuse in the project shall be neatly stockpiled as described in Subpart 3.07.

3.04 MATERIAL PLACEMENT AND COMPACTION

A. Placement of Fill Materials will be performed over the existing ground as shown on the Drawings. Contractor shall keep Owner or Owner's On-Site Representative informed of its operations so that proper inspection and testing can be implemented. No fill material shall be placed on frozen subgrade unless approved by Owner or Owner's On-Site Representative.

B. Finish all areas to the lines and grades shown on the Drawings within the tolerances provided in this Specification and as approved by Owner or Owner's On-Site Representative. All finish grading shall be accomplished using normal mechanical construction equipment. The final constructed dam tops shall be covered and finished with materials shown on the Drawings.

C. Compact the placed Perimeter Dam Fill Materials as shown on the Drawings. All fill shall be compacted in approximately horizontal lifts. Compact each layer to required density for each area classification.

D. Remove and replace fill that is too wet to permit compaction as specified.

E. Compact the material around structures with hand-compaction equipment which is designed for the compaction of backfill. Heavy equipment shall not be utilized for compaction within three (3) feet of structures, or a greater distance if necessitated by equipment or site conditions.

F. Place and compact Fill Materials as specified on the Drawings to an in place density as measured by ASTM D 698.

   1. Perimeter Dams: Uniformly compact the full depth of each lift with a smooth drum or Sheepsfoot vibratory compactor. Lifts shall not exceed 12 inches loose thickness prior to compaction. Compact each lift to at least 95% of standard Proctor maximum dry density. Control moisture as needed to achieve compaction specification.
   2. Pipe Trench Backfill: Place a minimum of 6-inches (unless shown otherwise on Drawings) of Pipe Bedding Material in bottom of trench before laying pipe. Place Coarse Aggregate (unless specified otherwise) on all sides and to depth of 6 inches above pipe. Backfill remainder of trench with Common Borrow or other approved Fill Material in maximum 12-inch loose lifts compacted to at least 95% standard Proctor maximum dry density.

G. Place Coarse Aggregate within the Leakage and Drainage Collection sumps as shown on the Drawings.

H. Place Rip-Rap as shown on the Drawings.

3.05 SITE GRADING

A. Grade intermediate slopes to minimize erosion potential. Maintain temporary erosion controls as necessary to minimize erosion.

B. Smooth-grade finished ground on exterior slopes of berms, along access roads, and other areas disturbed by Contractor's activities, to uniform levels or slopes between points where elevations are shown, or between such points and existing ground.

3.06 DISPOSAL OF EXCAVATED SOIL

A. All excavated materials not incorporated into the construction shall be stockpiled in a location designated by Owner. All stockpiles left in place by Contractor shall be appropriately graded so as to provide proper drainage and left in a neat condition.

3.07 TOLERANCES

A. Construct the excavation and backfill work within the dimensional tolerances given below. Alignment, elevation and thickness tolerances are acceptable deviations from the elevations and material thicknesses shown on the Drawings. No compensation will be made for additional work on materials required by Contractor as a result of construction beyond specified elevations, thicknesses, or grades.

B. Alignment Tolerances:

1. Perimeter Dam Centerline Horizontal Alignment: +/- 0.5 foot.

2. Crest of Slope Alignment Horizontal Alignment:
   a. Interior slope: +/- 0.5 foot.
   b. Exterior slope: +/- 0.5 foot at any location, +/- 0.5 foot average.

3. Toe of Slope Horizontal Alignment:
   a. Interior slope: +/- 0.5 foot.
   b. Exterior slope: +/- 0.5 foot at any location, +/- 0.5 foot average.

C. Elevation Tolerances:
1. Crest of Perimeter Dams: + 0.2 foot, -0.0 foot.
2. Liner System subgrade: +/- 0.2 feet; specified base slopes must be achieved as minimums.

D. Thickness Tolerances

1. Rip-Rap: -0.0 foot, +0.5 foot

2. Coarse Aggregate: -0.0 foot, +0.2 foot

3. Rooting Soil/Topsoil: -0.0 foot, +0.2 foot

3.08 DEBRIS MANAGEMENT

A. Manage debris resulting from the Work or encountered on Site in accordance with applicable Laws and Regulations. Debris may include abandoned electrical cable, abandoned well materials, or other man-made objects.

END OF SECTION 02220

SECTION 02240

DEWATERING AND DIVERSION

PART 1 GENERAL

1.01 DESCRIPTION

A. All work included in this Section shall be done in accordance with the following paragraphs as well as the general requirements as outlined in Division 1 of these Specifications.

B. The work covered by this section of the Specifications consists of furnishing all labor, equipment, and materials, and performing all operations necessary for dewatering the Project Site during construction.

1.02 REFERENCES

A. Protecting Water Quality in Urban Areas, MPCA 2000.

B. Stormwater Management for Construction Activities, EPA 1992.

C. Developing Pollution Prevention Plans and Best Management Practices, EPA 1992.

D. Erosion Control Handbook, Mn/DOT 2006.

E. Minnesota Stormwater Manual, Version 2, January 2008.

F. Stormwater and Wetlands: Planning Evaluation Guidelines, MPCA 1997.

G. Construction Stormwater Pollution Prevention Plan (SWPPP) – NorthMet Project Plant Site, Barr 2016.

1.03 BASIS FOR COMPENSATION

A. Work included under this Section of these Specifications shall be included under the Bid Price.

PART 2 PRODUCTS

2.01 PUMPS

A. Supply and maintain pumps capable of pumping water from excavation areas to permitted discharge locations in the event of heavy rains or runoff so work will not be significantly delayed and water will not saturate the soils.

PART 3 EXECUTION

3.01 GENERAL

A. Furnish and operate temporary controls such as diversions and dewatering equipment to prevent surface water and groundwater from entering and ponding in excavations and to allow construction under dry conditions.

B. Contractor shall be aware that flows will vary in proportion to recent rainfall events, and with rapid and heavy rains, ponded water may accumulate. Contractor shall be responsible for and take measures to protect his personnel, equipment, and supplies from such an event.

C. Discharge water from construction de-watering to an area designated by Owner. Identify conditions requiring water discharge and propose discharge points to Owner. Provide necessary measures to prevent erosion or transportation of sediments at the discharge locations. Remove and dispose of transported sediment.

END OF SECTION 02240

SECTION 02271

RIP RAP

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Work included in this section includes providing the rip-rap and associated materials as shown on the Drawings and specified herein, including ditch check construction as may be required for erosion control but not shown on Drawings.

1.02 BASIS FOR COMPENSATION

A. Compensation for all Work included under this Section shall be included in the Bid Price.

1.03 SUBMITTALS

A. Location of source and type of rip-rap material.

B. Test results.

C. Submit in accordance with Section 01300.

1.04 REFERENCES

A. Minnesota Department of Transportation Standard Specifications for Construction; 2016 Edition.

B. Latest edition of the following American Society for Testing and Materials (ASTM) standards:

1. ASTM D 5519- Standard Test Methods for Particle Size Analysis of Natural and Man-Made Riprap Materials.

1.05 QUALITY CONTROL

A. Contractor is responsible for completion of construction quality control as described below, except where specified as the responsibility of the Owner.

1. Rip-rap Soundness: 1 per source.
2. Particle Size Analysis (ASTM D 5519): 1 per source.

PART 2 PRODUCTS

2.01 MATERIALS

A. Rip-rap shall meet the requirements of MnDOT Construction Standard Specification 2511.2.

B. Filter Material shall meet the requirements of MnDOT Construction Standard Specification 2511.3.

PART 3 EXECUTION

3.01 PREPARATION

A. Grade and dress areas on which rip-rap is to be placed to lines and grades shown on Drawings or as required by Owner's On-Site Representative.

B. Place filter material under rip-rap and cover completely. No filter material shall be exposed along edges or under rip-rap. Place rip-rap so filter material is not damaged.

3.02 INSTALLATION

A. Place rip-rap in areas as shown on Drawings.

B. Place rip-rap for ditch checks as needed for permit compliance and as specified herein.

END OF SECTION 02271

SECTION 02273

GEOMEMBRANES

PART 1: GENERAL

1.01 SUMMARY

A. This specification covers the technical requirements for the Manufacturing and Installation of the geomembrane. All materials shall meet or exceed the requirements of this specification, and all work will be performed in accordance with the procedures provided in these project specifications

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. D 1004 Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
2. D 1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
3. D 1505 Test Method for Density of Plastics by the Density-Gradient Technique.
4. D 1603 Test Method for Carbon Black in Olefin Plastics.
5. D 3895 Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.
6. D 4218 Standard Test Method for Determination of Carbon Black in Polyethylene Compounds.
7. D 4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
8. D 5199 Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
9. D 5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
10. D 5596 Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
11. D 5994 Standard Test Method for Measuring Core Thickness of Textured Geomembranes.
12. D 6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
13. D 6693 Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
14. D 7240 Standard Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test).

B. Geosynthetic Research Institute

1. GRI GM 13 Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.
2. GRI GM 17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

1.03 DEFINITIONS

A. Lot - A quantity of resin (usually the capacity of one rail car) used in the manufacture of geomembranes. Finished rolls shall be identified by a roll number traceable to the resin lot used.

B. Geomembrane Manufacturer (Manufacturer) - The party responsible for manufacturing the geomembrane rolls.

C. Geosynthetic Quality Assurance Laboratory (Testing Laboratory) - Party, independent from the Owner, Owner's On-Site Representative, Manufacturer and Installer, responsible for conducting laboratory tests on samples of geosynthetics obtained at the site or during manufacturing, usually under the direction of the Owner's Representative.

D. Installer - Party responsible for field handling, transporting, storing, deploying, seaming and testing of the geomembrane seams.

E. Panel- Unit area of a geomembrane that will be seamed in the field that is larger than 100 ft^2.

F. Patch - Unit area of a geomembrane that will be seamed in the field that is less than 100 ft^2.

G. Subgrade Surface - Soil layer surface which immediately underlies the geosynthetic material(s).

1.04 SUBMITTALS

A. Furnish the following product data, in writing, to Owner's On-Site Representative prior to installation of the geomembrane material:

1. Resin Data shall include the following.
   a. Certification stating that the resin meets the specification requirements (Table 2.1).

2. Geomembrane Roll
   a. Statement certifying no recycled polymer and no more than 10% rework of the same type of material is added to the resin (product run may be recycled).

B. The Installer shall furnish the following information to the Owner's On-Site Representative and Owner prior to installation:

1. Installation layout drawings.
   a. Must show proposed panel layout including field seams and details.
   b. Must be approved prior to installing the geomembrane.

2. Approved drawings will be for concept only and actual panel placement will be determined by site conditions.
3. Installer's Geosynthetic Field Installation Quality Assurance Plan.

C. The Installer shall, within 15 working days of their final demobilization from the Site, submit the following to the Owner's On-Site Representative:

1. Certificate stating the geomembrane has been installed in accordance with the Contract Documents.
2. Material and installation warranties.

3. As-built drawings showing actual geomembrane placement and seams including typical anchor trench detail.

1.05 QUALIFICATIONS

A. Manufacturer

1. Manufacturer shall have manufactured a minimum of 20,000,000 square feet of polyethylene geomembrane during the last year.
2. Manufacturer shall have a minimum of ten years of continuous experience in the manufacture of low density polyethylene (LLDPE) geomembrane liner.

B. Installer

1. Installation shall be performed by Manufacturer and Owner-approved Installation Company.
2. Installer shall have installed a minimum of 50,000,000 square feet of polyethylene geomembrane for a minimum of 10 completed facilities.
3. Installer shall have worked in a similar capacity on at least 10 projects similar in complexity to the project described in the contract documents.
4. The Installation Supervisor shall have worked in a similar capacity on projects similar in size and complexity to the project described in the Contract Documents.
5. The Installer shall provide a minimum of one Master Seamer for work on the project who has completed a minimum of 1,000,000 square feet of geomembrane seaming work using the type of seaming apparatus proposed for the use on this Project.

1.06 MATERIAL LABELING, DELIVERY, STORAGE AND HANDLING

A. Labeling - Each roll of geomembrane delivered to the site shall be labeled by the Manufacturer. The label will identify:

1. Manufacturer’s name
2. product identification
3. thickness
4. length
5. width
6. roll number

B. Delivery- Rolls of liner shall be prepared to ship by appropriate means to prevent damage to the material and to facilitate off-loading.

C. Storage- The on-site storage location for the geomembrane material, prepared by the Contractor to protect the geomembrane from punctures, abrasions and excessive dirt and moisture, shall have the following characteristics:

1. level (no wooden pallets)
2. smooth
3. dry
4. protected from theft and vandalism
5. adjacent to the area being lined

D. Handling- Materials are to be handled so as to prevent damage.

1.07 WARRANTY

A. Material shall be warranted against Manufacturer's defects for a period of 5 years from the date of geomembrane installation.

B. Installation shall be warranted against defects in workmanship for a period of 1 year from the date of geomembrane completion.

1.08 MEASUREMENT AND PAYMENT

A. Compensation for all Work covered under this Section shall be included in the Lump Sum Contract Price Bid.

B. Partial payments by Owner for Geomembrane Liner are predicated on timely receipt of geomembrane submittals by Contractor.

C. Lump Sum Contract Price Bid shall include any allowances for waste, overlap, and anchoring.

D. Compensation shall include full compensation for furnishing all labor, material, tools, equipment, and incidentals.

PART 2: PRODUCTS

2.01 MATERIALS

A. Raw Materials:

1. LLDPE geomembrane, and extrudate rods used for this project shall be manufactured of new, first quality resins, designed specifically for use in flexible membrane liner installations.
2. LLDPE resin used in manufacturing geomembranes used for this Project shall meet the specifications set forth in the latest revision of the Geosynthetics Research Institute (GRI) for LLDPE.
3. Recycled Polymer shall not be added to the resin. However, the resin may contain polymer reclaimed during the manufacturing process if reclaimed polymer content does not exceed 2 percent by weight.

B. Geomembrane Roll Goods:

1. LLDPE geomembrane sheets used for this project shall meet the requirements set forth in the latest revision set forth by the Geosynthetics Research Institute (GRI) for LLDPE.
2. The geomembranes shall consist of unreinforced low density polyethylene containing at a maximum 3 percent by weight additives, fillers, or extenders.
3. The geomembranes shall be free of holes, blisters, striations, undispersed raw material, and contamination by foreign matter.

C. Extrudate: Resin used in the polyethylene extrudate shall be the same as that used to manufacture the geomembrane sheets. Extrudate rods are to be delivered in original containers with the manufacturer's labeling. Extrudate rods shall be free of dirt, grease, moisture, other contaminants, and shall be free of damage.

D. Neoprene Foam: Closed cell, weatherproof, black neoprene foam with adhesive backing suitable for long-term sun and liquid exposure. Dimensions shall be as specified on the Drawings.

E. Clamped Boots: Boots required to seal the geomembrane to the structures passing through it shall be made of the same materials as the geomembrane. The boots shall be fabricated so that all field assembly, welding, and seam testing can be accomplished using equipment and procedures regularly employed in the field for geomembrane installation. Smooth geomembrane shall be used in all geomembrane boots.

F. Banding Straps: Type 302 stainless steel banding straps or approved equal suitable for use on the pipe diameters shown on the Drawings or encountered in the field. All surfaces of the banding straps shall be machined smooth to prevent tearing or puncturing of the HDPE pipe boots. A sacrificial layer of geomembrane or geotextile shall separate all banding straps from geomembrane boots. Outer lip of boot shall be sealed with silicone sealant as shown on Drawings.

2.02 EQUIPMENT

A. Extruding equipment shall be equipped with a temperature gauge at the barrel and nozzle.

B. Fusion equipment shall be equipped with a temperature gauge capable of continuous monitoring.

C. Provide digital or dial continuous temperature recording instruments, in satisfactory working condition, with each welding unit. Welding equipment shall not be operated without functioning temperature recording instruments for measuring geomembrane sheet temperature.

D. A coupon cutter and a calibrated tensiometer shall be provided for in-field seaming prequalification testing and destructive sample testing.

E. Store, transport, and operate all equipment to avoid damage to geomembranes.

F. Glass top of each vacuum box must be clear and free of scratches for easy reading of pressure gauge. The sealing gasket shall be intact and functioning to form close seals during testing.

G. Owner or Owner’s Representative reserves the right to order the Installer to remove any equipment that in Owner’s or Owner’s Representative’s opinion is not satisfactory. The Installer will remove the equipment promptly from the construction site and replace the unsatisfactory equipment with suitable equipment within 24 hours.

H. An adequate number of welding apparati shall be available to avoid delaying work.

2.03 GEOMEMBRANE INSTALLERS

A. The following geomembrane installers are approved for this Project: Other installers may be acceptable, provided Owner approval is obtained prior Bid submittal.

1. Western Industries (406) 232-1680
   P.O. Box 428 (800) 488-3592
   Miles City, Montana 59301

2. J.C. Ramsdell Enviro Services Inc. (605) 997-3704
   P.O. Box 307 (800) 658-5571
   Flandreau, South Dakota 57028

3. G.S.I. (Geo-Synthetics, Inc.) (877) 950-4474
   428 N. Pewaukee Road
   Waukesha, Wisconsin 53188

2.04 GEOMEMBRANE PROPERTIES

A. Material shall be textured polyethylene geomembrane as shown on the drawings.

B. Resin

1. Resin shall be new, first quality, compounded and manufactured specifically for producing geomembrane.
2. Natural resin (without carbon black) shall meet the following requirements:

Table 2.1: Raw Material Properties

Property	Test Method	LLDPE
Density (g/cm3)	ASTM D 1505	$\geq$0.915
Melt Flow Index (g/10 min)	ASTM D 1238 (190/2.16)	$\leq$1.0
OIT (minutes)	ASTM D 3895 (1 atm/200^{0}C)	$\geq$100

C. Geomembrane Rolls

1. Do not exceed a combined maximum total of 1 percent by weight of additives other than carbon black.
2. Geomembrane shall be free of holes, pinholes as verified by on-line electrical detection, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges.
3. Geomembrane material is to be supplied in roll form. Each roll is to be identified with labels indicating roll number, thickness, length, width and Manufacturer.
4. All liner sheets produced at the factory shall be inspected prior to shipment for compliance with the physical properties specified and be tested by an acceptable method of inspecting for pinholes. If pinholes are located, identified and indicated during manufacturing, these pinholes may be corrected during installation.

D. Textured geomembrane shall meet the requirements shown in Table 2.2.

Table 2.2: Linear Low Density Polyethylene Textured Geomembrane (ref. Drawings for mil Specification)

Tested Property	Test Method	Frequency	Minimum Average Values			
			40 mil	60 mil	80 mil	100 mil
Thickness, mil Lowest individual reading	ASTM D 5199	every roll	40 36	60 54	80 72	100 90
Density, g/cm^3 (max.)	ASTM D 1505	200,000 lbs	0.939	0.939	0.939	0.939
Tensile Properties (each direction) Strength at Break, lb/in-width Elongation at Break, %	ASTM D 6693, Type IV Dumbbell, 2 ipm G.L. 2.0 in	20,000 lbs	 60 250	 90 250	 120 250	 150 250
Tear Resistance, lb	ASTM D 1004	45,000 lbs	22	33	44	55
Puncture Resistance, lb	ASTM D 4833	45,000 lbs	44	66	88	110
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lbs	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lbs	Note(1)	Note(1)	Note(1)	Note(1)
Asperity Height, mil	ASTM D 7466	second roll	18	18	18	18
Oxidative Induction Time, min	ASTM D 3895, 200°C; O_2, 1 atm	200,000 lbs	>100	>100	>100	>100
Typical Roll Dimensions						
Roll Length(2), ft	Double-Sided Textured Single-Sided Textured		700 650	520 420	400 320	330 250
Roll Width(2), ft			22.5	22.5	22.5	22.5
Roll Area, ft^2	Double-Sided Textured Single-Sided Textured		15,750 14,625	11,700 9,450	9,000 7,200	7,425 5,625

NOTES:
- (1)Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- (2)Roll lengths and widths have a tolerance of ±1%.
- *Modified.

E. Smooth geomembrane shall meet the requirements shown in Table 2.3.

Table 2.3: Linear Low Density Polyethylene Smooth Geomembrane (ref. Drawings for mil Specification)

Tested Property	Test Method	Frequency	Minimum Average Value			
			40 mil	60 mil	80 mil	100 mil
Thickness, mil Lowest individual reading	ASTM D 5199	every roll	40 36	60 54	80 72	100 90
Density, g/cm^3 (max.)	ASTM D 1505	200,000 lbs	0.939	0.939	0.939	0.939
Tensile Properties (each direction) Strength at Break, lb/in-width Elongation at Break, %	ASTM D 6693, Type IV Dumbbell, 2 ipm G.L. 2.0 in	20,000 lbs	 152 800	 228 800	 304 800	 380 800
Tear Resistance, lb	ASTM D 1004	45,000 lbs	22	33	44	55
Puncture Resistance, lb	ASTM D 4833	45,000 lbs	56	84	112	140
Carbon Black Content, % (Range)	ASTM D 1603*/4218	20,000 lbs	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	45,000 lbs	Note(1)	Note(1)	Note(1)	Note(1)
Oxidative Induction Time, min	ASTM D 3895, 200°C; O_2, 1 atm	200,000 lbs	>100	>100	>100	>100
Typical Roll Dimensions						
Roll Length(2), ft			870	560	430	340
Roll Width(2), ft			22.5	22.5	22.5	22.5
Roll Area, ft^2			19,575	12,600	9,675	7,650

NOTES:
- (1)Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3.
- (2)Roll lengths and widths have a tolerance of ±1 %.
- GSE UltraFlex is available in rolls weighing approximately 4,000 lb.
- All GSE geomembranes have dimensional stability of ±2% when tested according to ASTM D 1204 and LTB of <-77°C when tested according to ASTM D 746.
- *Modified.

PART 3: EXECUTION

3.01 EXAMINATION

A. Examine and certify in writing acceptability of surface (supporting soil) to receive installation of geomembrane.

B. Submit certification to Owner or Owner's On-Site Representative prior to installing geomembrane.

3.02 EARTHWORK PREPARATION

A. General:

l. After supporting soil is accepted by installer, it is the installer's responsibility to indicate to Owner or Owner's On-Site Representative and to Contractor changes in supporting soil condition that may require repair Work. Maintain prepared soil surface. Damage to subgrade caused by installation shall be repaired at installer's expense.

2. Do not place geomembrane in area softened by precipitation.
3. Do not place geomembrane on slopes greater than 3 horizontal to 1 vertical unless specified otherwise on Contract Drawings.
4. **Do not place geomembrane until subgrade certification survey is completed and approved by Owner's On-Site Representative.**

B. Anchoring System:

1. Excavate anchor trench (if necessary) to lines and grades shown on Drawings, prior to geomembrane placement.
2. Backfilling of Anchor Trench:
   a. Backfill anchor trench as shown on the Drawings and compact to ≥95 percent of Standard Proctor Maximum Dry Density.
   b. Prevent damage to geomembrane when backfilling trenches.

3.03 DEPLOYMENT

A. Assign each panel a simple and logical identifying code. The coding system shall be subject to approval by Owner's On-Site Representative and shall be determined at the job site.

B. Installer shall visually inspect the geomembrane during deployment for imperfections and mark faulty or suspect areas.

C. Deploy geomembrane panels in a manner that will comply with the following guidelines:

1. Geomembranes shall be installed according to site-specific specifications.
2. Unroll geomembrane using methods that will not damage geomembrane and will protect underlying surface from damage (spreader bar, protected equipment bucket).
3. Place ballast (commonly sandbags) on geomembrane which will not damage geomembrane to prevent wind uplift.
4. Personnel walking on geomembrane shall not engage in activities or wear shoes that could damage it. Smoking will not be permitted on the geomembrane.
5. Do not allow heavy vehicular traffic directly on geomembrane. Rubber-tired ATV's and trucks may be acceptable if wheel contact is less than 8 psi and pre-approval is obtained from Owner's Representative.
6. Protect geomembrane in areas of heavy traffic by placing protective cover over the geomembrane.

D. Provide sufficient material (slack) to allow for thermal expansion and contraction of the material.

3.04 FIELD SEAMING

A. Seams shall meet the following requirements:

1. To the maximum extent possible, orient seams parallel to line of slope, i.e., down and not across slope.
2. Minimize number of field seams in corners, odd-shaped geometric locations and outside corners.

3. Slope seams (panels) shall extend a minimum of five-feet beyond the grade break into the flat area.
4. Use a sequential seam numbering system compatible with panel numbering system that is agreeable to the Owner's Representative and Installer.
5. Align seam overlaps consistent with the requirements of the welding equipment being used. A 6-inch overlap is commonly suggested.

B. During Welding Operations

1. Provide at least one Master Seamer who shall provide direct supervision over all other welders.

C. Extrusion Welding

1. Hot-air tack adjacent pieces together using procedures that do not damage the geomembrane.
2. Clean geomembrane surfaces by disc grinder or equivalent.
3. Purge welding apparatus of heat-degraded extrudate before welding.

D. Hot Wedge Welding

1. Welding apparatus shall be a self-propelled device equipped with an electronic controller which displays applicable temperatures.
2. Clean seam area of dust, mud, moisture and debris immediately ahead of hot wedge welder.
3. Protect against moisture build-up between sheets.

E. Trial Welds

1. Perform trial welds on geomembrane samples to verify welding equipment is operating properly.
2. Make trial welds under the same surface and environmental conditions as the production welds, i.e., in contact with subgrade and similar ambient temperature.
3. Minimum of two trial welds per day, per welding apparatus; one made prior to the start of work and one completed at mid shift.
4. Cut four, one-inch wide by six-inch long test strips from the trial weld.
5. Quantitatively test specimens for peel adhesion and for shear strength.
6. Trial weld specimens shall pass when the results shown in the following table for LLDPE are achieved in both peel and shear test.

Table 3.1: Minimum Weld Values for LLDPE Geomembranes

Property	Test Method	30	40	60	80	100
Peel Strength (extrusion), ppi	ASTM D 6392	36	48	72	96	120
Peel Strength (fusion), ppi	ASTM D 6392	38	50	75	100	125
Shear Strength (fusion & ext.), ppi	ASTM D 6392	45	60	90	120	150

a. The break, when peel testing, shall occur in the liner material itself, not through peel separation (FTB).
b. The break shall be a ductile break.

7. Repeat the trial weld, in its entirety, when any of the trial weld samples fail in either peel or shear.
8. No welding equipment or welder shall be allowed to perform production welds until equipment and welders have successfully completed trial weld.

F. Seaming shall not proceed when ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation. Installer shall demonstrate that acceptable seaming can be performed by completing acceptable trial welds.

G. Defects and Repairs

1. Examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.
2. Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations that have been repaired until test results with passing values are available.

3.05 FIELD QUALITY ASSURANCE

A. Manufacturer and Installer shall participate in and conform to all terms and requirements of the Owner's quality assurance program.

B. Quality assurance requirements are as specified in this Section.

C. Field Testing

1. Non-destructive testing may be carried out as the seaming progresses or at completion of all field seaming.
   a. Vacuum Testing
      1) Shall be performed in accordance with ASTM D 5641, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.

   b. Air Pressure Testing
      1) Shall be performed in accordance with ASTM D 5820, Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.

2. Destructive Testing (performed by Installer)
   a. Location and Frequency of Testing
      1) Collect destructive test samples at a frequency of one per every 500 lineal feet of seam length.
      2) Test locations will be determined after seaming.
      3) Exercise Method of Attributes as described by GRI GM-14 (Geosynthetic Research Institute, http://www.geosynthetic-institute.org) to minimize test samples taken.

   b. Sampling Procedures are performed as follows:
      1) Installer shall cut samples at locations designated by the Owner's Representative as the seaming progresses in order to obtain field laboratory test results before the geomembrane is covered.
      2) Installer will number each sample, and the location will be noted on the installation as-built.

3) Samples shall be twelve (12) inches wide by minimal length with the seam centered lengthwise.
4) Cut a 2-inch wide strip from each end of the sample for field-testing.
5) Cut the remaining sample into two parts for distribution as follows:
   a) One portion for Owner's On-Site Representative, 12-inches by 12 inches.
   b) One portion for the Third Party laboratory, 12-inches by 18-inches.
   c) Additional samples may be archived if required.
6) Destructive testing shall be performed in accordance with ASTM D 6392, Standard Test Method for Determining the Integrity of Non-Reinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
7) Installer shall repair all holes in the geomembrane resulting from destructive sampling.
8) Repair and test the continuity of the repair in accordance with these Specifications.

3. Failed Seam Procedures
   a. If the seam fails, Installer shall follow one of two options:
      1) Reconstruct the seam between any two passed test locations.
      2) Trace the weld to intermediate location at least 10 feet minimum or where the seam ends in both directions from the location of the failed test.
   b. The next seam welded using the same welding device is required to obtain an additional sample, i.e., if one side of the seam is less than 10 feet long.
   c. If sample passes, then the seam shall be reconstructed or capped between the test sample locations.
   d. If any sample fails, the process shall be repeated to establish the zone in which the seam shall be reconstructed.

3.06 REPAIR PROCEDURES

A. Remove damaged geomembrane and replace with acceptable geomembrane materials if damage cannot be satisfactorily repaired.

B. Repair any portion of unsatisfactory geomembrane or seam area failing a destructive or non-destructive test.

C. Installer shall be responsible for repair of defective areas.

D. Agreement upon the appropriate repair method shall be decided between Owner's On-Site Representative and Installer by using one of the following repair methods:

   1. Patching- Used to repair large holes, tears, undispersed raw materials and contamination by foreign matter.
   2. Abrading and Re-welding- Used to repair short section of a seam.
   3. Spot Welding- Used to repair pinholes or other minor, localized flaws or where geomembrane thickness has been reduced.
   4. Capping- Used to repair long lengths of failed seams.
   5. Flap Welding- Used to extrusion weld the flap (excess outer portion) of a fusion weld in lieu of a full cap.

6. Remove the unacceptable seam and replace with new material.

E. The following procedures shall be observed when a repair method is used:

1. All geomembrane surfaces shall be clean and dry at the time of repair.
2. Surfaces of the polyethylene that are to be repaired by extrusion welds shall be lightly abraded to assure cleanliness.
3. Extend patches or caps at least 6 inches for extrusion welds and 4 inches for wedge welds beyond the edge of the defect, and around all corners of patch material.

F. Repair Verification

1. Number and log each patch repair (performed by Installer).
2. Non-destructively test each repair using methods specified in this Specification.

G. Daily Installation Information:

1. At the end of each working day, provide a signed detailed report and sketch of Work completed on that day. Report and sketch shall include but not be limited to:
    a. Panel placement.
    b. Trial welds.
    c. Seams.
    d. Seam testing and results.
    e. Destructive testing and results.
    f. Repair locations and log.

2. Owner or Owner's On-Site Representative shall review and sign report acknowledging receipt of report.

H. Complete Installation Information:

1. Installation certification.
2. "As-built" record Drawings showing panel layout including panel dimensions, number, roll number and location of destructive seam samples and repairs.
3. Copy of warranty from manufacturer/fabricator, installer.
4. Submittals required within 15 business days of geomembrane installer demobilization from site.

3.07 GEOMEMBRANE ACCEPTANCE

A. Retain ownership and responsibility for geomembrane until acceptance by Owner. Geomembrane liner accepted by Owner when:
1. Written certification letter, including "as-built" Drawings, signed by Registered Professional Engineer, received by Owner.
2. Installation complete.
3. Documentation of installation completed, including inspection of final report.
4. Verification of adequacy of field seams and repairs, including associated testing, is complete.

END OF SECTION 02273

CERTIFICATE OF ACCEPTANCE OF
GEOMEMBRANE SUBGRADE SURFACE BY INSTALLER

DESCRIPTION OF AREA TO BE CERTIFIED ____

____

INSTALLER	PROJECT
NAME: ______________________________	LOCATION: ___________________________
ADDRESS: ___________________________	PROJECT: ____________________________
____________________________________	____________________________________
AUTHORIZED REPRESENTATIVE: _____________________	OWNER: _____________________________

The undersigned, ______________________________ certifies that he is a representative of (company), duly authorized to execute this certificate, that he visually inspected the subgrade surface described above on __________ (date) and found the surface to be acceptable for installation of the geomembrane.

This certification is based on observations of the surface of the subgrade only. No sub-terrain inspections or tests have been performed and _____________ (company) makes no representations or warranties regarding conditions which may exist below the surface of the subgrade.

DATE: _______________________________

SIGNATURE: ___________________________

NAME: _______________________________

TITLE: _______________________________

CERTIFICATE RECEIVED BY CONTRACTOR:

DATE:_______________________________

COMPANY: ___________________________

SIGNATURE: __________________________

NAME: ______________________________

TITLE: ______________________________

CERTIFICATE RECEIVED BY OWNER:

DATE: _______________________________

COMPANY: ____________________________

SIGNATURE: ___________________________

NAME: _______________________________

TITLE: _______________________________

SECTION 02274

GEOSYNTHETIC CLAY LINER

PART 1: GENERAL

1.01 SUMMARY

A. Work under this section includes the geosynthetic clay liner (GCL) for composite liner.

1.02 DEFINITIONS

A. Geosynthetic Clay Liner (GCL) - A factory manufactured hydraulic barrier consisting of granular sodium bentonite clay, sandwiched between, supported and encapsulated by two geotextiles, held together by needle-punching.

B. Geotextile - A semi-permeable woven or nonwoven fabric used to contain the bentonite used in a GCL.

C. Sodium Bentonite - The high swelling clay component of GCLs consisting primarily of the mineral Montmorillonite.

D. Needle-punching - A GCL manufacturing process whereby boards of barbed needles incorporate the staple fibers from a nonwoven geotextile, through a sodium bentonite clay layer, into the matrix of a second geotextile layer.

E. Thermal Locking - A needle-punching enhancement process utilizing heat to bond the needle-punched fibers and more permanently lock them into the second geotextile to increase the internal shear strength characteristics.

F. Polymer-Treated – Specific GCL type treated with polymers to improve performance in the presence of increased cation concentration.

G. Minimum Average Roll Value (MARV) - The minimum average value of the material in a particular lot calculated as the mean of the tested values minus two standard deviations providing a 95% confidence level.

1.03 REFERENCES

A. Latest edition of the following American Society for Testing and Materials (ASTM) standards:

1. ASTM D 4632, "Standard Test Method for Grab Breaking Load and Elongation of Geotextiles"
2. ASTM D 4643, “Determination of Water (Moisture) Content of Soil by the Microwave Oven Method”
3. ASTM D 5084, “Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter”
4. ASTM D 5261, “Standard Test Method for Measuring Mass Per Unit Area of Geotextiles”
5. ASTM D 5321, “Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method”

6. ASTM D 5887, "Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter"
7. ASTM D 5888, “Standard Guide for Storage and Handling of Geosynthetic Clay Liners”
8. ASTM D 5889, “Standard Practice for Quality Control of Geosynthetic Clay Liners”
9. ASTM D 5890, “Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners”
10. ASTM D 5891, “Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners”

1.04 QUALIFICATIONS

A. The GCL Manufacturer, Installer and Construction Quality Assurance (CQA) inspector shall all be skilled in accordance with the following experience requirements. Any exceptions must be approved by Owner prior to the project bid.

B. GCL Manufacturer - The GCL manufacturer selected for use on this project shall have successfully produced at least 10,000,000 square feet of needle-punched GCL product.

The following GCL suppliers are approved for this project (other suppliers may be acceptable, provided Engineer approval is obtained):

1. CETCO Lining Technologies (800) 527-9948
1500 W. Shure Drive
Arlington Heights, IL 60004

2. G.S.E. Lining Technology (800) 435-2008
19303 Gundle Road
Houston, TX 77073

C. Contractor request for approval of alternate supplier (if any) must be submitted to Owner and Engineer 5 business days prior to Bid opening. Contractor must obtain Owner and Engineer written approval of alternate supplier in order to include alternate in Bid.

D. GCL Installer - The installer shall provide to Owner sufficient evidence of installation experience and competence with the specified geosynthetic materials.

1. GCL Only Installation - The GCL installer shall demonstrate a minimum of 1,000,000 square feet of GCL installation experience, shall provide sufficient evidence of installation experience and competence with other geosynthetics or shall demonstrate an acceptable level of training and supervision will be utilized in order to ensure the quality of the installation.
2. Multi-Component Composite Liner System - The GCL shall be installed by the lining contractor responsible for the installation of the overlying geomembrane liner. The GCL/ geomembrane lining contractor shall demonstrate a minimum of 1,000,000 square feet of successfully completed multi-component composite liner installation experience or shall provide sufficient evidence of the appropriate level of installation experience and competence with other geosynthetics.

1.05 SUBMITTALS

A. Three copies of the project submittals shall be forwarded to Owner or Owner's On-Site Representative as designated below.

B. Information With Bid - The following shall be submitted with the bid:

1. Statement of experience from the proposed GCL Supplier.
2. Statement of experience from the proposed GCL Installer.
3. Project-Specific Polymer-Treated GCL specification.

C. Prior to Installation - The following information shall be supplied to Owner or Owner's Representative for review within 10 business days of the Contract Award to ensure that the materials and parties selected for use on the project meet the requirements of this specification:

1. Samples of GCL proposed for use on the project.
2. Reference list supplied by GCL Manufacturer indicating the appropriate experience level as required by the specification.
3. Reference list supplied by the GCL Installer indicating the appropriate experience level as required by the specification.

D. Prior to Deployment - The following information shall be submitted by the Lining Contractor to Owner or Owner's Representative prior to the deployment of any GCL material to ensure that the materials and subgrade preparation meet the requirements of this specification:

1. GCL Manufacturer's Quality Control Certifications.
2. Certifications of subgrade acceptance for each area covered by GCL, signed by the earthwork Contractor and Owner's Representative.

1.06 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section shall be included in the Lump Sum Contract Price Bid.

B. Partial payments by Owner for Geosynthetic Clay Liner (GCL) are predicated on timely receipt of GCL submittals by Contractor.

C. The Lump Sum Contract Price Bid shall include any allowances for waste, overlap, and anchoring.

PART 2: PRODUCTS

2.01 GCL MATERIALS

A. The GCL product supplied to the project shall be in full accordance with the requirements of this section. The GCL shall be manufactured by mechanically bonding the geotextiles using a needle-punching process to enhance frictional and internal shear strength characteristics.

B. In order to maintain these characteristics, no glues, adhesives or other non-mechanical bonding processes shall be used in lieu of the needle-punch process. Their use to enhance the physical properties of the GCL is not permitted.

C. Description - Acceptable GCL for this project include Resistex ST manufactured by CETCO Lining Technologies and BentoLiner CAR manufactured by G.S.E. Lining Technology, or other Engineer-approved needle-punched GCL which meet the requirements of this specification.

D. The GCL product supplied for this project shall be a polymer-treated GCL manufactured specifically for use in the presence of liquids with elevated cation concentrations.

2.02 GCL MANUFACTURING

A. The GCL supplied in accordance with this project shall be manufactured by needle-punching as described in Section 1.02 - Definitions.

1. The needle-punched GCL shall be thermally locked. The thermal lock process must heat set the nonwoven fibers where they protrude from the second geotextile (woven or nonwoven depending upon product) to more permanently secure the reinforcement in place. Other means may be used to lock the fibers in place if the process demonstrates similar performance to the thermal lock process.
2. To demonstrate the uniformity of the manufacturing process, no delamination of the geotextile components from the bentonite core shall occur when the GCL is exposed to 80 degree tap water for one hour.

2.03 ALTERNATIVE MATERIALS

A. Prior to considering an alternative GCL material, Contractor shall submit certified test results and statements of quality from the proposed GCL supplier to Owner or Owner's Representative, indicating without exception that the proposed GCL meets the requirements of this specification. Submittals shall be delivered to Owner or Owner's Representative a minimum of five business days in advance of the bid.

B. No other manufacturing techniques shall be approved unless it can be suitably demonstrated that the GCL exhibits uniform shear strength characteristics across the entire width of the panel. Isolated sewn or stitched rows do not constitute uniform reinforcement for the purposes of this specification.

2.04 DIMENSIONS

A. The minimum acceptable dimensions for the GCL panels shall be 15 feet wide and 125 feet long. Short rolls (rolls less than 125 feet long) may be supplied, but at a rate not to exceed 5% of the total square footage produced for this project.

B. A minimum overlap guide-line and a construction match-line delineating the overlap zone shall be imprinted with non-toxic ink on both edges of the GCL panel to ensure the accuracy of the seam. The minimum overlap guideline shall indicate where the edge of the panel must be placed in order to achieve a full six inches of bentonite overlap for each panel.

2.05 MANUFACTURING QUALITY CONTROL

A. The GCL shall be tested for compliance with this specification by the test methods and frequencies indicated on the material specification. GCL materials may be tested pre-approved at the manufacturing location.

1. Manufacturer Quality Control Certification - Quality Control certificates shall be issued by the GCL manufacturer to Owner or Owner's On-Site Representative for each delivery of material. The certifications shall be signed by the quality control manager of the GCL manufacturer or other responsible party and shall include the following information:
   a. Shipment Packing List - A list indicating the rolls shipped on a particular truckload.
   b. Bill of Lading - The shipping documents for the truck used for the shipment.
   c. Letter of Certification - The letter indicating the material is in conformance with the physical properties specified.
   d. Physical Properties Sheet - The material specification for the GCL supplied in accordance with this specification.

2. Manufacturer Quality Control Submittal - Quality Control submittals shall be issued by the GCL manufacturer to Owner or Owner's Representative. The submittals shall include the following information:
   a. Bentonite Manufacturer Certification - Bentonite manufacturer quality documentation for the particular lot of clay used in the production of the rolls delivered.
   b. Geotextile Manufacturer Certification - Geotextile manufacturer quality control documentation for the particular lots of geotextiles used in the production of the rolls delivered.
   c. GCL Manufacturer Tracking List - Cross referencing list delineating the corresponding geotextile and bentonite lots for the materials used in the production of the rolls delivered.
   d. Manufacturing Quality Control Data - The manufacturing quality control test data indicating the actual test values obtained when tested at the appropriate frequencies for the properties specified.

2.06 PACKAGING

A. All GCL rolls shall be packaged in moisture resistant plastic sleeves. The cardboard cores shall be sufficiently strong to resist collapse during transit and handling.

B. Prior to shipment, the manufacturer shall label each roll, both on the GCL roll and on the surface of the plastic protective sleeve. Labels shall be resistant to fading and moisture degradation to ensure legibility at the time of the installation. At a minimum the roll labels shall identify the following:

1. Length and width of roll
2. Total weight of roll
3. Type of GCL material
4. Production Lot number and Individual Roll number

2.07 ACCESSORY BENTONITE

A. Any accessory bentonite used for sealing seams, penetrations, or repairs, shall be the same polymer-treated granular bentonite as used in the production of the GCL itself.

PART 3: EXECUTION

3.01 EXECUTION

A. The following installation procedures are as specific as possible while recognizing that the specific requirements of the project may necessitate minor modifications. Significant deviations from these procedures shall be pre-approved by Owner or Owner's Representative or other designated party.

B. Do not install GCL until subgrade certification survey is completed and approved by Owner's On-Site Representative.

3.02 SHIPPING AND HANDLING EQUIPMENT

A. The party responsible for unloading the GCL shall contact the manufacturer prior to shipment to determine the correct unloading methods and equipment if different from the pre-approved and specified methods.

B. GCL must be supported during handling to ensure worker safety and prevent damage to the liner. Under approved circumstances only, shall the rolls be dragged, lifted from one end, lifted with only the forks of a lift truck or pushed to the ground from the delivery vehicle.

C. Owner or Owner's Representative shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the liner material itself. Suitable handling equipment is described below:

1. Spreader Bar Assembly - A spreader bar assembly shall include both a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the GCL core while the spreader bar beam will prevent chains or straps from chafing the roll edges. The cardboard roll supplied with the GCL shall not be used in place of a steel core pipe.
2. Stinger - A stinger is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment. If a stinger is used, it should be fully inserted to its full length into the roll to prevent excessive bending of the roll when lifted.
3. Roller Cradles - Roller cradles consist of two large diameter rollers spaced approximately 3 inches apart, which both support the GCL roll and allow it to freely unroll. The use of roller cradles shall be permitted if the rollers support the entire width of the GCL roll.
4. Straps - Straps may be used to support the ends of spreader bars but are not recommended as the primary support mechanism. As straps may damage the GCL where wrapped around the roll and generally do not provide sufficient uniform support to prevent roll bending or deformation, great care must be exercised when this option is used.

D. GCL Inspection Upon Delivery - Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Repairs to damaged GCL shall be performed in accordance with this specification.

1. Rolls exhibiting damage shall be marked and set aside for closer examination during deployment.
2. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape prior to being placed in storage to prevent moisture damage.
3. GCL rolls delivered to the project site shall be only those indicated on GCL manufacturing quality control certificates.

E. Storage / Stockpiling / Staging

1. Storage of the GCL rolls shall be the responsibility of the installer or other designated party. All GCL rolls shall be stock-piled and maintained dry in a flat location area away from high-traffic areas but sufficiently close to the active work area to minimize handling.
2. For needle-punched GCLs, the presence of free-flowing water within the packaging shall require that roll to be set aside for further examination to ascertain the extent of damage, if any. Free-flowing water within the packaging of unreinforced GCLs shall be cause for rejection of that roll.
3. GCL should be stored no higher than three to four rolls high or limited to the height at which the handling apparatus may be safely handled by installation personnel. Stacks or tiers of rolls should be situated in a manner that prevents sliding or rolling by "choking" the bottom layer of rolls.
4. Rolls shall not be stacked on uneven or discontinuous surfaces in order to prevent bending, deformation, damage to the GCL or cause difficulty inserting the core pipe.
5. An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for GCL material stored outdoors.
6. Bagged bentonite material shall be stored and tarped next to GCL rolls unless other more protective measures are available. Bags shall be stored on pallets or other suitably dry surface which will prevent undue prehydration.

3.03 EXAMINATION

A. The earthen subgrade shall be continuously inspected, approved and certified in writing prior to GCL placement.

B. Submit certification to Owner or Owner's On-Site Representative prior to installing GCL.

3.04 SUBGRADE PREPARATION

A. Earthen Subgrade – The surface (Native subsoil or Controlled Fill) upon which the GCL will be installed shall be inspected by the installer and certified by the earthwork contractor to be in accordance with the following:

1. Finished surface of Earthen Subgrade shall be free of all angular stones, and free of all stones greater than 3/8" protruding from the finished surface.
2. Subgrade surface shall be smooth rolled to achieve a finished surface suitable for placement of GCL.
3. The surfaces to be lined shall be smooth and free of any debris, vegetation, roots, sticks, sharp rocks, or other deleterious materials as well as free of any voids, large cracks or standing water or ice.
4. Directly prior to deployment of the GCL, the subgrade shall be final-graded to fill remaining voids or desiccation cracks, and proof-rolled to eliminate sharp irregularities of abrupt elevation changes. All rocks greater than 3/8" protruding from the finished surface

shall be hand-picked and removed. The surfaces to be lined shall be maintained in this smooth condition.

B. Anchor Trench (if necessary) - An anchor trench shall be excavated by the earthwork contractor or liner installer to the lines and grades shown on the project Drawings.

1. The anchor trench shall be constructed free of sharp edges or corners and maintained in a dry condition. No loose soil shall be permitted beneath the GCL within the trench.
2. The anchor trench shall be inspected as well as approved by Owner or Owner's Representative prior to GCL placement, back-filling and compaction of the anchor key material.

3.05 GCL PLACEMENT

A. GCL Material shall be placed in general accordance with the procedures specified below, or modified to account for site specific conditions.

B. GCL Orientation - In the absence of specific guidelines, GCL panels shall be placed per manufacturer recommendation on slopes to maximize the shear strength characteristics.

C. In base or flat areas, the GCL shall be placed by placing the woven geotextile face of the GCL against the overlying geomembrane.

D. GCL Panel Position - Where possible, all slope panels should be installed parallel to the maximum slope while panels installed in flat areas require no particular orientation.

E. Panel Deployment - GCL materials shall be installed in general accordance with the procedures set forth in this section, subject to site specific conditions which would necessitate modifications.

F. Reinforced GCL shall be used on both slopes as well as the flat areas to ensure the GCL withstands the rigors of the installation and subsequent low load hydration.

G. Deployment should proceed from the highest elevation to the lowest to facilitate drainage in the event of precipitation.

H. The GCL may be deployed on slopes by pulling the material from a suspended roll, or securing a roll end into an anchor trench and unrolling each panel as the handling equipment slowly moves backwards.

I. Deployment on flat areas shall be conducted in the same manner as that for the slopes, however, care should be taken to minimize "dragging" the GCL. Slip-sheet may be used to facilitate positioning of the liner while ensuring the GCL is not damaged from underlying sources.

J. Overlaps shall be a minimum of 6 inches and in no case less than specified on the Drawings, and be free of wrinkles, folds or "fish-mouths".

K. Contractor shall only install as much GCL that can be covered at the end of the day. No GCL shall be left exposed overnight. The exposed edge of the GCL shall be covered by a temporary tarpaulin or other such water resistant sheeting until the next working day.

L. Anchoring- All GCL material installed on slopes shall be anchored to prevent potential GCL panel movement.

1. Standard Anchor - The GCL shall be placed into and across the base of the excavated trench, stopping at the back wall of the excavation.
2. "Run-Out" Anchor - On gentle slopes or locations where it is difficult to create an anchor trench, the GCL may alternatively be anchored by a material run-out past the crest of the slope. The length of the run-out shall be pre-approved by Owner or Owner's Representative prior to the use of this method.

M. Seaming - A 6-inch lap line and a 9-inch match line shall be imprinted on both edges of the upper geotextile component of the GCL to assist in installation overlap quality control. Lines shall be printed as continuous dashes in easily observable non-toxic ink.

1. Overlap seams shall be a minimum of six inches on panel edges and one foot on panel ends.

N. Detailing - Detail work, defined as the sealing of the liner to pipe penetrations, foundation walls, drainage structures, spillways, and other appurtenances, shall be performed as recommended by the GCL Manufacturer.

O. Damage Repair - Prior to cover material placement, damage to the GCL shall be identified and repaired by the installer. Damage is defined as any rips or tears in the geotextiles, delamination of geotextiles or a displaced panel.

1. Rip and Tear Repair (Flat Surfaces) - Rips or tears may be repaired by completely exposing the affected area, removing all foreign objects or soil, and by then placing a patch cut from unused GCL over the damage (damaged material may be left in place), with a minimum overlap of 12 inches on all edges.
   Accessory bentonite should be placed between the patch edges and the repaired material at a rate of a quarter pound per lineal foot of edge spread in a continuous six inch fillet.
2. Rip and Tear Repair (Slopes) - Damaged GCL material on slopes shall be repaired by the same procedures above; however, the edges of the patch should also be adhered to the repaired liner with an adhesive to keep the patch in position during backfill or cover operations.
3. Displaced Panels - Displaced panels shall be adjusted to the correct position and orientation. The adjusted panel shall then be inspected for any geotextile damage or bentonite loss. Damage shall be repaired by the above procedure.
4. Premature Hydration - If the GCL is prematurely hydrated, installer shall notify the QA/QC technician and Owner or Owner's Representative for a site specific determination as to whether the material is acceptable or if alternative measures must be taken to ensure the quality of the design - dependent upon the degree of damage.

3.06 COVER MATERIAL

A. The cover materials (where specified) shall be compatible as well as suitable for use over the GCL, and placed in a manner appropriate to the particular subgrade. Regardless of the cover material, the uncovered edge of GCL panels shall be protected at the end of the working day with a waterproof sheet which is secured adequately with ballast.

B. Geosynthetic Cover - Precautions shall be taken to prevent damage to the GCL by restricting the use of heavy equipment over the liner system.

1. Equipment - Installation of the overlying geosynthetic component can be accomplished through the use of lightweight, rubber-tired equipment such as a 4-wheel all-terrain vehicle (ATV). This vehicle can be driven directly on the GCL, provided the ATV makes no sudden stops, starts, or turns.
2. Placement – Smooth geomembranes may be dragged across the GCL surface with equipment or by hand labor during positioning. Similarly, the geomembrane may be unrolled with the use of low ground pressure equipment.
3. Use of Textured Geomembranes - If a textured geomembrane is placed over the GCL, a slip sheet (such as 20-mil smooth HDPE) shall first be placed over the GCL in order to allow the geomembrane to slide into its proper position. Once the overlying geomembrane is properly positioned, the slip-sheet shall be carefully removed paying close attention to avoiding any movement to the geomembrane.

3.07 WARRANTY

A. GCL material as well as installation warranties provided by the manufacturer and installer shall be made a part of the final submittal documents.

B. The installer of the GCL material shall provide a one year installation workmanship warranty, repairing and or replacing any material not installed in full compliance with the requirements of the specification.

END OF SECTION 02274

SECTION 02275

GEOCOMPOSITE

PART 1: GENERAL

1.01 SUMMARY

A. This specification covers the technical requirements for the manufacturing and installation of the Geocomposite drainage layer (Geocomposite). All materials shall meet or exceed the requirements of this specification, and all work shall be performed in accordance with the procedures provided in these project specifications.

1.02 DEFINITIONS

A. Construction Quality Assurance Consultant (Consultant) – Party, independent from Manufacturer and Installer that is responsible for observing and documenting activities related to quality assurance during the lining system construction.

B. Engineer – The individual or firm responsible for the design and preparation of the project's Drawings and Specifications.

C. Geocomposite Manufacturer (Manufacturer) – The party responsible for manufacturing the geocomposite rolls.

D. Geosynthetic Quality Assurance Laboratory (Testing Laboratory) – Party, independent from the manufacturer, Installer, Owner, and Owner's On-Site Representative, responsible for conducting laboratory tests on samples of geosynthetics obtained at the site or during manufacturing, under the direction of the Engineer.

E. Installer – Party responsible for field handling, transporting, storing, and deploying the geocomposite.

F. Lot – A quantity of resin (typically the capacity of one rail car) used to manufacture polyethylene geocomposite rolls. The finished rolls with be identified by a roll number traceable to the resin lot.

1.03 REFERENCES

A. American Society for Testing and Materials (ASTM)

1. ASTM D 1238-01 Standard Test method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
2. ASTM D 1505-98 Standard Test method for Density of Plastics by the Density-Gradient Technique
3. ASTM D 1603-94 Standard Test Method for Carbon Black in Olefin Plastics
4. ASTM D 4716-00 Standard Test Method for Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
5. ASTM D 5035-95 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)
6. ASTM D 5199-99 Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes

B. Relevant publications from the Environmental Protection Agency (EPA):

1. Daniel, D.E. and R.M. Koerner, (1993) Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities, EPA/600/R-93/182.

1.04 QUALIFICATIONS

A. Manufacturer

1. Geocomposite shall be manufactured by the following:
   a. GSE Environmental
   b. Engineer Approved Equal

2. Manufacturer shall have manufactured a minimum of 10,000,000 square feet of polyethylene geocomposite material during the last year.

B. Installer

1. Installer shall have installed a minimum of 50,000,000 square feet of geocomposite in the last 10 years.
2. Installer shall have worked in a similar capacity on at least 5 projects similar in complexity to the project described in the Contract Documents.
3. The Installation Supervisor shall have worked in a similar capacity on projects similar in size and complexity to the project described in the Contract Documents.

1.05 WARRANTY

A. Material shall be warranted, on a pro-rata basis against defects for a period of 1 year from the date of the geocomposite installation.

B. Installation shall be warranted against defects in workmanship for a period of 1 year from the date of geocomposite completion.

1.06 SUBMITTALS

A. Three copies of the project submittals shall be forwarded to Owner or Owner's On-Site Representative as designated below.

B. Information With Bid - The following shall be submitted with the bid:

1. Statement of experience from the proposed geocomposite Supplier.
2. Statement of experience from the proposed geocomposite Installer, including resume of Installation Supervisor committed to the project.

C. Prior to Installation - The following information shall be supplied to Owner or Owner's Representative for review within 10 business days of the Contract Award to ensure that the materials and parties selected for use on the project meet the requirements of this specification:

1. Samples of geocomposite proposed for use on the project.

2. Reference list supplied by geocomposite Manufacturer indicating the appropriate experience level as required by the specification.
3. Reference list supplied by the geocomposite Installer indicating the appropriate experience level as required by the specification.

D. Prior to Deployment - The following information shall be submitted by the Lining Contractor to Owner or Owner's Representative prior to the deployment of any geocomposite material to ensure that the materials and subgrade preparation meet the requirements of this specification:

1. Geocomposite Manufacturer's Quality Control Certifications.
2. Certifications of subgrade acceptance for each area covered by geocomposite, signed by the earthwork Contractor and Owner's Representative.

1.07 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section shall be included in the Lump Sum Contract Price Bid.

B. Partial payments by Owner for geocomposite are predicated on timely receipt of geocomposite submittals by Contractor.

C. The Lump Sum Contract Price Bid shall include any allowances for waste, overlap, and anchoring.

PART 2: PRODUCTS

2.01 GEOCOMPOSITE MATERIAL LABELING, DELIVERY, STORAGE, AND HANDLING

A. Labeling – each roll of geocomposite delivered to the site shall be labeled by the Manufacturer. The label will identify:

1. Manufacturer's Name
2. Product Identification
3. Length
4. Width
5. Roll Number

B. Delivery – Rolls of geocomposite will be prepared to ship by appropriate means to prevent damage to the material and to facilitate off-loading.

C. Storage – The on-site storage location for the geocomposite, provided by the Contractor to protect the geocomposite from abrasions, excessive dirt, and moisture shall have the following characteristics:

1. Level (no wooden pallets)
2. Smooth
3. Protected from theft and vandalism
4. Adjacent to the area lined

D. Handling

1. The CONTRACTOR and INSTALLER shall handle all geonet in such a manner as to ensure it is not damaged in any way.
2. The INSTALLER shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.

2.02 GEOCOMPOSITE PROPERTIES

A. The geocomposite shall be manufactured by extruding two crossing strands to form a bi-planar drainage net structure.

B. The geocomposite specified shall have properties that meet or exceed the values listed in Table 2.1 below:

Table 2.1: Geocomposite Properties

Property	Test Method	Test Frequency	Value
Transmissivity(1) gal/min/ft (m^2/sec)	ASTM D 4716	1/540,000 ft^2	24.0 (5 x 10^{-3})@25,000 psf
Density g/cm^3	ASTM D 1505	1/50,000 ft^2	0.94
Tensile Strength (MD) lb/in	ASTM D 5035/7179	1/50,000 ft^2	100
Carbon Black Content %	ASTM D 1603(2)/4218	1/50,000 ft^2	2.0
Geocomposite Thickness Mil	ASTM D 5199	1/50,000 ft^2	270

NOTES:
- (1) Gradient of 0.1, normal load of 10,000 psf, water at 70° F, between steel plates for 15 minutes.
- (2) Modified.

Table 2.2: Raw Material Properties

Property	Test Method (1)	Testing Frequencies	Value
Density (g/cm^3)	ASTM D 1505	Once Per Resin Lot	>0.94
Melt Flow Index (g/10 min)	ASTM D 1238	Once Per Resin Lot	$\leq$ 1.0

NOTES:
- (1) Some test procedures have been modified for application to geosynthetics.

2.03 MANUFACTURING QUALITY CONTROL

A. The geocomposite shall be manufactured in accordance with the Manufacturer's Quality Control Plan submitted to and approved by the Engineer.

B. The geocomposite shall be tested according to the test methods and frequencies listed in Table 2.1.

PART 3: EXECUTION

3.01 FAMILIARIZATION

A. Inspection

1. Prior to implementing any of the work in the Section to be lined, the Installer shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where installation of the Section may properly commence without adverse impact.
2. If the Installer has any concerns regarding the installed work of other Sections, Installer shall notify the Project Engineer.

3.02 MATERIAL PLACEMENT

A. The geocomposite roll should be installed in the direction of the slope and in the intended direction of flow unless otherwise specified by the Engineer.

B. If the project contains long, steep slopes, special care should be taken so that only full-length rolls are used at the top of the slope.

C. In the presence of wind, all geocomposites shall be weighted down with sandbags or the equivalent. Such sandbags shall be used during placement and remain until replaced with cover material.

D. If the project includes an anchor trench at the top of the slopes, the geocomposite shall be properly anchored to resist sliding. Anchor trench compacting equipment shall not come into direct contact with the geocomposite.

E. In applying cover material, no equipment can drive directly across the geocomposite. The specified fill material shall be placed and spread utilizing vehicles with a low ground pressure.

F. The cover soil shall be placed on the geocomposite in a manner that prevents damage to the geocomposite. Placement of the cover soil shall proceed immediately following the placement and inspection of the geocomposite.

3.03 SEEMS AND OVERLAPS

A. Each component of the geocomposite shall be secured to the like component at overlaps.

B. Geocomposite Components

1. Adjacent edges of the geotextile along the length of the geocomposite roll shall be overlapped a minimum of 6” or as recommended by the Engineer.
2. The overlapped edges shall be joined by tying to geocomposite structure with cable ties. These ties shall be spaced every 5 feet along the roll length.
3. Geotextile of adjoining rolls across the roll width should be shingled down in the direction of the slope and the accompanying geocomposite joined together with cable ties spaced every foot along the roll width.

4. The geonet component of the geocomposite shall be placed to connect to and discharge into the geonet of the adjacent roll, contained within the geotextile component of the geocomposite above and below, throughout the roll connection area.

3.04 REPAIR

A. Prior to covering the deployed geocomposite, each roll shall be inspected for damage resulting from construction.

B. Any rips, tears or damaged areas on the deployed geocomposite shall be removed and patched. The patch shall be secured to the original geocomposite by tying every 6 inches with the approved tying devices. If the area to be repaired is more than 50 percent of the width of the panel, the damaged area shall be cut out and the two portions of the geocomposite shall be joined in accordance with subsection 3.03.

END OF SECTION 02275

SECTION 02610

PIPES AND FITTINGS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and installing 20" HDPE SDR 11 Leakage Collection and Drainage Collection Pipes.

B. Furnishing and installing 6" HDPE SDR 11 Return Water, Residue Discharge, and Auxiliary Discharge Pipes.

1.02 BASIS FOR COMPENSATION

A. Work included under this Section of these Specifications shall be included under the Lump Sum Price.

1.03 REFERENCES

A. American Association of State Highway and Transportation Officials hereafter referred to as AASHTO.

B. American Society for Testing and Materials, current edition, hereafter referred to as ASTM.

C. American National Standards Institute, current edition, hereafter referred to as ANSI.

PART 2 PRODUCTS

2.01 HIGH-DENSITY POLYETHYLENE PIPE AND FITTINGS

A. HDPE pipe shall be manufactured from materials meeting the requirement of ASTM D 1248 for Type III, Grade P34, Category 5, Class C, and have a PPE rating of PE3408. The pipe produced from this material shall have the dimensions and wall thickness as set forth in ASTM F 714 for the size and Standard Dimension Ration (SDR) shown on the Drawings.

B. HDPE pipe shall be marked at maximum 5 foot intervals with the manufacturer's name or trademark, nominal size and SDR, cell classification, ASTM D 1248, and extrusion date, period of manufacture, or lot number.

C. Polyethylene pipe fittings shall be manufactured from resin having the same classification and properties as the pipe resin, and shall be supplied by the pipe manufacturer. Molded fittings shall be used instead of fabricated fittings, if available. All fittings, bends, and couplings for the HDPE piping shall meet the requirements of this pipe specification and shall have an SDR at or lower than the pipe it is being connected to as shown on the Drawings.

D. Electrofusion fittings (if needed) shall be Central Plastics PE3408 Black 3 Pin 150 Class, or approved equal. Electrofusion fittings shall be sized and installed in accordance with manufacturer recommendations for coupling HDPE pipe of the size and class shown on the Drawings.

2.02 VALVES AND VALVE BOXES

A. Valves for pond return water supply/sump drain line shall be 2 ½” resilient-seated gate valves in conformance with AWWA C509.

B. Valves:
1. Flanged
2. Non-rising stem
3. Grade E bronze components
4. Nitrile rubber O-rings and gaskets

2.03 FLANGES

A. Bolts and Nuts for pipe flanges shall be carbon steel conforming to the requirements of ASTM A307, Grade B. Bolts shall have hex heads to conform to ANSI B18.2.1. Hex nuts conforming to ANSI B18.2.2 shall be used. Bolt and nut threads shall conform to ANSI B1.1. Plain washers shall conform with ANSI B18.22.1.

B. Slip-on metal flanges shall be 150-lb. stainless steel and furnished with full-face rubber gaskets.

C. Flange adapter and slip-on flanges shall be drilled to ANSI 16.1/16.47/16.5 Class 125/150 bolt circles and AWWA C-207 class D (type).

PART 3 EXECUTION

3.01 PIPE TRENCH BACKFILL AND COMPACTION

A. See Specification 02220 for requirements.

3.02 HIGH-DENSITY POLYETHYLENE PIPE

A. GENERAL

1. General steps for butt-fusion joints:
   a. Surfaces of fusion tools, pipe, and fittings shall be free of contaminants prior to use. Pipe ends shall be trimmed as necessary prior to joining.
   b. Heat both pipe ends simultaneously at specified temperature for specified time.
   c. Remove heater and press melted surfaces together to form joint.
   d. Maintain uniform pressure until solidified. Prevent rough handling (testing, stress movements, pulling, or laying) until fully cooled to ambient material temperatures.

2. General steps for electrofusion:
   a. Surfaces of fusion tools, pipe, and fittings shall be free of contaminants prior to use. Pipe ends shall be trimmed as necessary prior to joining.
   b. Follow manufacturer’s recommendations for electrofusion techniques.

B. FUSION UNIT OPERATORS

1. Each operator of fusion units shall demonstrate to Owner's or Owner's Representative's satisfaction that operator is qualified to perform consistently correct fusion joints acceptable to Owner. Contractor shall replace without additional cost to Owner any fusion unit operator to which Owner or Owner's Representative has reasonable objection based on the operator's failure to perform consistently correct fusion joints as recommended by pipe manufacturer or the provision of this Section.

C. PRESSURE TESTING

1. Testing will be done in sections not to exceed 700 feet in length. A final pressure test will be conducted after the pipes have been installed.

2. The contractor will fill the pipelines with water to a pressure of 160 psi for SDR 11 HDPE. The contractor will maintain this pressure in the pipe for a period of one hour.

D. INTERNAL FUSION BEAD REMOVAL

1. The internal fusion bead from each butt weld shall be removed. This equipment is manufactured by R & L manufacturing and distributed by:

   Crookston Welding
   Highway 75 South
   Crookston, MN 56716
   Phone: (218) 281-6911
   Fax: (218) 281-7255

2. Quality control shall be by inspecting the external and extracted internal fusion bead. The internal bead shall also have a smooth root cut of the wall area; this may include wall mass that has been misaligned during fusion process. However any wall mass that is removed should not exceed 1/10th of the wall thickness of the pipe itself.

3.03 FIELD QUALITY CONTROL

A. Pipe and pipe installations will be subject to rejection for any of the following reasons:

1. Failure to conform to the specifications, particularly compaction under and around the pipe.
2. Fractures or cracks passing through pipe wall.
3. Chips or fractures on interior of pipes.
4. Cracks which, in the opinion of Owner or Owner's On-site Representative, may impair strength, durability, or serviceability of pipe.
5. Defects indicating improper proportioning, mixing, or molding.
6. Damaged ends where such damage would prevent making a satisfactory joint.

END OF SECTION 02610

SECTION 15201

PUMPS AND APPURTENANCES

PART 1: GENERAL

1.01 DESCRIPTION

A. All Work included in this Section shall be performed in accordance with the following paragraphs, the General Requirements set forth in these Specifications, and the provisions of the other Contract Documents.

B. Work covered under this Section includes providing all materials, equipment, and labor to perform the required Work, including, but not limited to:

1. Furnishing and installing submersible Leakage pump, valves, piping, and hoses, as required.

2. Furnishing and installing submersible Drainage water pump, valves, piping, and hoses, as required.

1.02 BASIS FOR COMPENSATION

A. Compensation for all Work included under this Section of these Specifications shall be in accordance with the provisions set forth in Section 01025, Measurement and Payment.

B. Furnish and install all equipment required to provide a complete, functioning pumping system as shown on the Drawings.

1.03 REFERENCES

A. American Society for Testing and Materials (ASTM), latest edition:

1. ASTM D3261 - 12 Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

2. ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

3. ASTM F714 Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter

4. ASTM F2164 Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure

1.04 RELATED SECTIONS

A. Section Not Used

1.05 SUBMITTALS

A. Submit for documentation shop drawings, manufacturer's literature, catalog cuts, pump curves and other manufacturers or fabricator's data showing materials, assemblies, and methods for the submersible pump and all appurtenant equipment specified in this Section.

B. Submit product data for all materials specified in this Section to Owner or Owner's On-Site Representative at least two weeks prior to delivery of materials to the Site.

C. If modifications to winch support are required to accommodate the approved winch supplied, submit layout and details of winch support structure construction for approval.

D. Furnish operation and maintenance manual, spare parts list, and assembly drawings for pump and winch.

PART 2: PRODUCTS

2.01 SUBMERSIBLE VERTICAL TURBINE LEACHATE PUMPS

A. Pumps:

1. High Density Polyethylene (HDPE) shrouded vertical well pump.
2. All 304 or higher stainless steel construction for wetted parts, hardware and fittings.
3. Rubber parts: Viton or equal.
4. Integral check valve modified to provide drainage of discharge pipe back to sump upon shut-down.
5. Suitable for use with water contaminated with small amounts of hydrocarbons; suitable for inclined installation in sidewall riser pipe (3H:1V slope) with minimum submergence at the top of the pumping unit as shown in the Drawings.
6. Environmental Pump Solutions Encapsulator Pump Model 300SRPF100-3A, or approved equal.

B. Motors:

1. 10 hp, 460v, 3 Phase.
2. Class1, Division 1 rating for explosive environments.
3. Environmental Pump Solutions Pollution Recovery Motor or approved equal.

C. Motor Lead:

1. Approximately 260 ft., continuous lead without splices between motor and control panel (or junction box for clean water pump).

2. Sized for pump installation as shown on the Drawings.

3. Provide suitable protective sheathing to protect from degradation by exposure to hydrocarbons and ultraviolet light.

4. Confirm final length of cable in field prior to procuring pumping equipment.

D. Minimum operating conditions:

1. Primary Operating Condition: 300 gpm @ 97 ft. TDH

2. Secondary Operating Condition: 350 gpm @ 75 ft. TDH

E. Pump Accessories/Appurtenances:

1. 300 ft. stainless steel pull cable per pump. Confirm length of cable in field prior to installation.

2. Level sensor mounting slot welded to pump assembly.

F. Provide three (3) pumping units total: two (2) leachate pump; one (1) back-up pump. All pumps supplied shall be identical.

2.02 SUBMERSIBLE LEVEL SENSOR – PRESSURE TRANSDUCER

A. Constructed of materials capable of being fully submersed in residue process water and leachate.

B. Wetted materials shall be 316 stainless steel, welded body construction; Viton or similar hydrocarbon resistant wetted rubber parts.

C. Level sensor cable with self-sealing outer jacket which blocks water in the event of damage to the jacket. Vented for barometric pressure compensation; covered vent.

D. Output: 4-20 mA, ±0.1% Full Scale accuracy. Operation range is approximately 1 to 50 psi.

E. Lightning and surge protection.

F. 300 ft. of cable for each of three pumps. Confirm final length of cable in field prior to procuring sensors.

G. Provide three (3) transmitters total. All transmitters supplied shall be identical.

H. Environmental Pump Solutions Miniature Submersible Level Transmitter or approved equal.

2.03 HDPE DISCHARGE PIPE

A. DR 17 HDPE, IPS size, maximum 40-ft sections, dimensions as shown on the Drawings.

B. PE 4710 resin, ASTM D3350, ASTM F714, cell classification 445574C/E; ultraviolet stabilizer.

C. Markings: manufacturer's logo, nominal size and OD base, material code, DR, pressure class, ASTM F714, production date (day, month and year.)

2.04 PUMP DISCHARGE HOSE

A. Two-ply, steel wire reinforced NBR hose with smooth inner wall, high oil resistance, flexible to minus 40 degrees F, minimum 150 psi working pressure, maximum weight 2.5 lb/ft

B. Hose diameter: 4-inch ID. Hose length: >6 ft. estimated for bidding purposes. <u>Confirm final hose length required in field based on actual constructed layout and connecting pipe locations.</u>

C. Flex-Devil by Thermoid/HBD Industries, or approved equal.

2.05 HDPE FITTINGS

A. DR 17 HDPE butt fusion fittings, IPS size, injection molded.

B. PE 4710 resin, ASTM D3350, ASTM D3261, cell classification 445574C/E; ultraviolet stabilizer.

C. Markings: in accordance with ASTM D3261.

2.06 CAMLOCK FITTINGS

A. For HDPE Pipe: Poly-cam Series 641 Camlock/HDPE transition for butt fusion joints, aluminum hard coat camlock, or approved equal.

B. For discharge hose: Aluminum hard coat camlock fittings, hose shank style, compatible with Poly-cam HDPE transition fittings.

C. Provide all standard accessories required for use, including but not limited to oil-resistant gaskets; stainless steel handles, ring pins and pull rings.

2.07 REMOVABLE PIPE INSULATION JACKET

A. Tight-fitting, non-asbestos hydrophobic anti-freeze insulation jacket for use to minus 40 degrees F.

B. Velcro closures with side flaps secured by tie cord, sized for exposed 4-inch hose and 6-inch pipe connection at top of sidewall riser.

C. ThermaXX LLC or equal

2.08 POWER WINCH

A. 230V, 1 phase power winch, portable with plug-in power cord, TEFC UL-listed motor, all components rated for outdoor use.

B. Winch capacity: Minimum 2000 lb. pulling capacity at 3H:1V slope, minimum 300 ft. drum capacity based on cable size provided with pumps. Confirm cable size with pump supplier.

C. Automatic braking system, totally enclosed geartrain, basic Nema 4X two button handheld pendant control.

D. Quick-mount brackets compatible with installation method shown in the Drawings.

E. Confirm power requirements and coordinate with control panel supplier for appropriate power supply to convenience outlet in panel.

2.09 SOURCE QUALITY CONTROL

A. Products supplied as specified under the specific paragraphs of this Section shall be of the same manufacturer and be identical and interchangeable with products of the same specification and size. Products of the same type, but of different diameter or size, shall be supplied by the same manufacturer.

B. Contractor shall be responsible for ensuring that the products meeting the requirements of this Section are supplied. Contractor shall maintain records to establish that products supplied meet or exceed referenced standards as specified in this Section.

PART 3: EXECUTION

3.01 INSPECTION

A. Contractor shall be responsible for all materials required to provide the products as specified and no defective products will be allowed for installation.

3.02 PUMP/DISCHARGE PIPE/TRANSDUCER INSTALLATION

A. Prior to installation in the sidewall riser, fully assemble the pump/pipe assembly at the surface to confirm that all parts are correct and functional. Disconnect pump and pressure test discharge piping using hydrostatic pressure in accordance with ASTM F714. Use test pressure of 50 psi.

B. Install pump and related accessories in strict accordance with the drawings, specifications, manufacturer's recommendations and referenced standards for a complete and operable system.

C. Place transducer in receptacle on pump. Securely tether the transducer cable and the pump motor cable to the discharge pipe with nylon straps a minimum of 20 places on each pipe section after the couplers are in place.

D. Verify the pump location within the sidewall riser/sump with Owner or Owner's On-Site Representative to provide adequate submergence. Keep accurate records of the final total length of the discharge pipe/pump assembly. Place a highly visible permanent mark on the near the upper end of the discharge pipe or coupling and sidewall riser to indicate the correct placement of the pump. Also place marks or words noting that the marked pipe section is the uppermost section to assure that the pump is accurately placed on subsequent installation.

E. Coil excess cable and store inside of sidewall riser pipe for leachate pump. Confirm final storage of excess motor and transducer cable for the clean water pump. Do not cut cables on any pumps or transducers to shorten.

3.03 BURIED HDPE PIPE INSTALLATION

A. Remove all foreign matter and dirt from pipe before installing and keep pipe clean after installation. Blow out piping system with compressed air and flush with clean water at system operating pressure as required to ensure a clean piping system.

B. Joints shall be thermal butt fused in accordance with manufacturer's recommendations by a factory qualified joining technician.

C. Install buried pipe in accordance with manufacturer's recommendations. Do not exceed manufacturer's recommended bending radius.

D. Pressure test buried HDPE pipe from sidewall riser to leachate pond in accordance with ASTM F2164 using hydrostatic pressure using a test pressure of 10 psi. Do not air test.

3.04 WINCH INSTALLATION

A. Install portable winch as directed by Owner's On-Site Representative. Confirm structural frame support configuration with actual winch supplied.

3.05 FIELD QUALITY CONTROL

A. Establish and maintain quality control procedures for work performed under this Section to assure compliance with contract requirements and maintain records of his quality control for all construction operations including, but not limited to, the following:

1. *Materials and products used*
2. *Lines and grades*
3. *Tolerances, test procedures and results*

B. The Drawings indicate certain required pipe sizes and the general arrangement for the major piping and equipment. Field verify locations of all process piping and accessories in the field. In the event it should become necessary to change the location of any of the work due to interference with other work, consult with the Owner and Engineer before making any changes and all such changes shall be made without added cost to the Owner. Under no circumstances shall the pipe sizes indicated on the Drawings be changed without the written approval of the Owner and Engineer.

END OF SECTION 15201

Attachment H

HRF Construction QA/QC Plan

Construction Quality Assurance Manual Template

NorthMet Project
Hydrometallurgical Residue Facility

Prepared for
Poly Met Mining Inc.

July 2016

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Construction Quality Assurance Manual Template

July 2016

Contents

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1.0 Introduction

This manual describes Construction Quality Assurance (CQA) procedures for the installation of the soil and geosynthetic components of liner and cover systems of the Hydrometallurgical Residue Facility (HRF) at the PolyMet Mining Inc. (PolyMet) NorthMet Project (Project) Plant Site. This manual addresses survey, soil, piping, geomembrane, and geosynthetic clay components of the facility leak detection and drainage collection system, liner and cover systems, and is to be used as the basis of the overall CQA program. Requirements presented in this manual will be reconciled with construction plans and specifications once they are finalized. Any material changes made to the CQA procedures outlined herein that may be applied on a project-specific basis (e.g. a particular phase of HRF liner or cover construction) may require permitting agency for review and approval prior to implementation.

The overall goals of this construction quality assurance program are to ensure that proper construction techniques and procedures are used and to verify that the materials and installation techniques used meet the project design and specification requirements. At completion of each phase of HRF liner or cover construction, the CQA program will culminate in a construction documentation report which documents that the grading, liner, cover, and piping systems have been constructed in accordance with design standards and specifications. When any new HRF cell increment is constructed it will be available for use upon permitting agency review and approval of the corresponding construction documentation report or via other means of approval as may be provided by the permitting agency.

Throughout this report, reference is made to PolyMet. Responsibilities of PolyMet as outlined herein may be assigned, at PolyMet's discretion, to an independent engineer or technician to perform the day-to-day on-site construction observation and documentation work for each construction event at the facility. The term "phase" used in this CQA is a generic reference to either construction of a discrete increment of the HRF liner system and/or to construction of a discrete phase or segment of the final cover system.

2.0 Earthwork Construction

Construction quality assurance will be performed by an independent and PolyMet approved materials testing company subcontracted by PolyMet (or by Contractor) as required by the project Contract Documents. If such responsibility is not assigned to Contractor via the Construction Contract Documents/Specifications, PolyMet or their Representative (hereafter referred to singularly as PolyMet) will then perform construction quality assurance on the components of soil construction. Criteria to be used for determination of acceptability of the construction work will be as identified in the project plans and specifications.

Construction Quality Assurance testing will consist of (1) observation of the work, (2) field and laboratory tests, and (3) survey. Field and laboratory tests will be conducted on samples taken from material during the course of the work.

Construction must be performed in accordance with the Storm Water Pollution Prevention Plan (SWPPP) developed by the Engineer for each phase of construction at the facility. It will be the responsibility of PolyMet to observe the Contractor's compliance with the requirements of the SWPPP.

2.1 Observation of the Work

Observation of the construction work by PolyMet will include the following:

- Observation of the thickness of soil lifts as loosely placed and as compacted.
- Observation of the action of the compaction and heavy hauling equipment on the construction surface (sheepsfoot penetration, pumping, cracking, etc.).
- Monitor material test results for pass/fail relative to plan and specification requirements and for proper test distribution and frequency.
- Observation of removal of large stones, roots, and other deleterious material as required.
- Observation that only the appropriate soils are used and that unacceptable materials are rejected at the site.
- Observation that materials used meet the project specifications and have been approved for use by the project engineer.
- Maintenance of a daily field-log of construction activities.
- Maintenance of a photographic record of construction activities.
- Performance of other project administration activities as may be required to confirm Contractor compliance with requirements of the project plans, specifications, contract documents, and CQA plan.

2.2 Laboratory and Field Tests

Table 1 describes laboratory test methods typically utilized to develop data upon which material acceptability evaluations can be based. Table 1 also describes in detail the types and number of tests required for each liner and cover component during construction.

Nuclear density methods will be preferred for density testing due to the ease of testing and the relatively large number of tests which can be run in a given period of time. Questions concerning the accuracy of any single test will be addressed by retesting in the same or nearby location.

Construction quality assurance testing will be conducted on samples taken from the material during the course of construction. Sampling locations will be selected by PolyMet according to the number of required tests. Locations of tests will be documented for report purposes.

A special testing frequency will be used at the discretion of PolyMet when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- soil lift thickness is greater than specified,
- earth fill is at improper and/or variable moisture content,
- rollers are not using optimum ballast,
- dirt-clogged rollers are used to compact the material,
- fill materials differ substantially from those specified, and
- when the degree of compaction is doubtful.

During construction, the frequency of testing may also be increased in the following situations:

- adverse weather conditions,
- breakdown of equipment,
- at the start and finish of grading,
- when material fails to meet specifications, and
- the work area is increased.

2.3 Survey of Earthwork

The survey of specific locations will provide the basis for the construction documentation drawings and provide documentation of liner grade. The survey will be performed by a qualified land surveyor. The major components of the survey will include the following:

- top of HRF liner system subgrade
- base and top of sumps and drains,
- topographic survey of the completed site, perimeter road and ditches,
- top of HRF cover system hydraulic barrier layer subgrade,
- top of cover system drainage layer,
- top of cover soil layer,
- top of finished grade (topsoil layer or other),
- base and top of drains and drainage ways, and
- pipe inverts
- as directed by PolyMet.

Unless specified otherwise, the survey will be conducted on a 50' x 50' grid with survey points at major breaks in slope (i.e., top and toe of slope of berms, trenches, drainage swales, etc.). The grid will be extended vertically to enable calculation of vertical thicknesses of the cover components (granular drainage, cover soil, and topsoil layers).

3.0 Geosynthetic Installation

There are certain aspects of earthwork that directly affect the geosynthetic liner and cover installation. These are the subgrade surface conditions and the overlying backfill.

3.1 Surface Preparation

The subgrade surface for the geosynthetic liner and cover will be observed by PolyMet during smooth drum rolling to detect soft or loose areas.

The Installer shall certify in writing that the surface on which the geosynthetic will be installed is acceptable. The certificate of acceptance shall be given by the Installer to PolyMet prior to commencement of geosynthetic installation in the area under consideration. Commencement of installation without written certification of subgrade acceptance will mean the installer has accepted the subgrade surface.

After the supporting soil has been accepted by the Installer, it shall be the Installer's responsibility to indicate to PolyMet any change in the supporting soil condition that may require repair work.

3.2 GCL Installation

Construction quality assurance will be performed by PolyMet on all components of GCL installation, and as otherwise required by the project plans and specifications. Criteria to be used for determination of acceptability of the installation will be as identified in the project plans and specifications, which shall take precedence, but as may be supplemented below.

3.2.1 Field Observation Requirements

PolyMet shall observe and verify:

- Proper soil subgrade preparation below GCL including smooth uniform grade, remediation of any soft or weak subgrade soils, removal of surface rocks and rocks protruding from the compacted subgrade surface, proper smooth rolling of the subgrade surface, proper line and grade of the subgrade surface, etc.
- Proper unloading, transport, and storage of GCL rolls, including use of spreader bar or other roll carrying apparatus as specified
- Proper GCL type (e.g., reinforced as specified and project-specific bentonite)
- Product uniformity (e.g., uniformity in product thickness, uniformity of reinforcing fibers, undamaged roll edges, etc.)
- Proper handling procedures, proper roll orientation during placement, proper overlap at seams lateral to and longitudinal to roll axis

- Proper protection of GCL from excess moisture during installation, including prevention of contact from rainfall, surface water, and any other water source during installation which may result in hydration of the bentonite, whether or not Contractor is on site at time precipitation or surface water run-on occurs
- Compliance with panel placement and repair procedures
- Protection of GCL during placement of overlying geomembrane, including use of rub sheets between GCL and textured geomembrane, and maintenance of specified alignment and overlap of GCL panels, including proper seam overlap and seam treatment (accessory bentonite if recommended by GCL manufacturer, heat tacking)
- Photo documentation of all GCL installation and overlying geomembrane placement,

As GCL placement is completed and prior to placing overlying materials, PolyMet will indicate to the Installer acceptability of the installation.

3.2.2 Defects and Repairs

All sections of the GCL will be examined by PolyMet. Defects, holes, undispersed raw materials, and any sign of contamination by foreign matter will be identified. Any portion of the geosynthetic clay liner exhibiting a flaw shall be repaired. Repair procedures shall follow the guidelines listed in the specifications. The final decision as to the appropriate repair procedure shall be agreed upon between PolyMet and the Installer.

3.2.3 GCL Acceptance

The GCL shall be accepted by PolyMet when:

- The installation is finished;
- Verification of the adequacy of all repairs is complete; and
- All documentation of installation is completed.

PolyMet will certify that installation has proceeded in accordance with the CQA Manual and Specifications for the project, with any exceptions and their basis noted in the documentation report.

3.3 Geomembrane Installation

Construction quality assurance will be performed by PolyMet on all components of geomembrane installation. Construction quality testing and documentation will be performed by Installer's quality assurance and quality control Representative and verified by PolyMet. Criteria to be used for determination of acceptability of the installation will be as identified in the project plans and specifications, which shall take precedence, and as may be supplemented by requirements listed herein. Table 2 summarizes the geomembrane testing methods, frequencies, and criteria for determining acceptability of the geomembrane installation.

3.3.1 Field Panel Placement

PolyMet and the Installer will agree to an "identification code" for each geomembrane field panel. The number-letter system will be consistent with the proposed panel layout developed by the Installer. PolyMet will maintain a list showing the correspondence between panel numbers and roll numbers.

PolyMet will verify that field panels are installed at the location indicated on the Installer's proposed panel layout plan or with agreed modifications, and will maintain a record drawing of the installed panel layout.

3.3.2 Trial Welds

PolyMet shall observe and verify that trial weld procedures and testing methods are conducted according to the specifications. The following information will be logged:

- date and time of the trial weld completion
- ambient temperature
- apparatus identification
- seaming technician
- barrel temperature for extrusion welding
- preheat temperature or preheat setting for extrusion welding
- wedge temperature for fusion welding
- trial weld number
- pass or fail of the trial weld

3.3.3 Field Seaming

A seam numbering system compatible with the panel numbering system shall be agreed upon between PolyMet and the Installer. Weather conditions such as wind and ambient temperature will be logged for each construction day. At the start of each seam, the seamer shall clearly write the following information on the panel adjacent to each seam:

- Seamer ID;
- Tool No.;
- Time started; and
- Seam No.

3.3.3.1 Seam Preparation

PolyMet shall verify that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;
- seam overlap grinding, if required, is completed according to the Geomembrane Manufacturer's instructions within 1 hour of the seaming operation and done in a way that does not damage the geomembrane; and
- seams are aligned with the fewest possible number of wrinkles and "fishmouths."

3.3.3.2 Extrusion Process

The Installer shall provide PolyMet with certification that the extrudate meets the specifications and is comprised of the same resin type as the geomembrane sheeting.

The following information for each extrusion welded seam will be logged:

- time and date of the beginning of each seam,
- seam number,
- seam length,
- seaming technician, and
- apparatus identification.

3.3.3.3 Fusion Process

The following information will be logged:

- time and date of the beginning of each seam,
- seam number,
- seam length,
- seaming technician, and
- apparatus identification.

3.3.3.4 Nondestructive Seam Testing

The Installer shall nondestructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), or other approved method. The purpose of nondestructive tests is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

The following information will be logged:

- date and time of the completion of the test,

- seam number,
- the general seam location,
- the test crew,
- the air pressure at the beginning and end of the test for double-track fusion,
- the length of time that the air pressure was held for double-track fusion welds, and
- pass or fail result of the test.

3.3.3.5 Destructive Seam Testing

PolyMet will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows:

- A minimum frequency of one test location per 500 feet of seam length. This minimum frequency is to be determined as an average taken throughout the entire area to be covered.
- A maximum frequency will be agreed upon by PolyMet at the start of liner installation and/or preconstruction meeting.
- Test locations will be determined during seaming at PolyMet's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

Installer will not be informed in advance of the locations where the seam samples will be taken.

Samples shall be cut by the Installer as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. PolyMet will observe and verify that testing and sampling procedures are conducted in accordance with the contract documents. This will include:

- observe sample cutting;
- assign a number to each sample and mark it accordingly; and
- record sample location on the panel layout record drawing.

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with approved repair procedures. The continuity of the new seams in the repaired area shall be tested by the Installer as described in the construction specifications or, if not described therein, as described in Section 3.3.3.7.

PolyMet will witness all field tests and mark all samples and portions with the sample number.

3.3.3.6 Independent Geosynthetic Testing Laboratory (applies if specified)

The geosynthetic testing laboratory will be selected by PolyMet. Destructive test samples will be packaged and shipped under the responsibility of PolyMet in a manner which will not damage the test sample. PolyMet will be responsible for storage and archiving the remaining portion of the sample.

Testing will include shear strength and peel adhesion. At least five specimens will be tested for each test method. Specimens will be selected alternately by test from the samples (i.e., peel, shear, peel, shear…).

The geosynthetic testing laboratory will provide test results no more than 48 hours after they receive the samples. PolyMet will review laboratory test results as soon as they become available and inform the Installer of the results.

Alternatively, Installer may select the independent geosynthetic testing laboratory, package and ship samples, and coordinate other aspects of independent geosynthetic testing upon approval of PolyMet. In such case PolyMet shall be copied on all test results immediately upon receipt.

3.3.3.7 Defects and Repairs

All seams and non-seam areas of the geomembrane will be examined by PolyMet. Defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter will be identified. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be broomed or washed by the Installer if the amount of dust or mud inhibits examination.

Any portion of the geomembrane exhibiting a flaw or failing a destructive or nondestructive test shall be repaired. Repair procedures shall follow the guidelines listed in the specifications. The final decision as to the appropriate repair procedure shall be agreed upon between PolyMet and the Installer.

Each repair will be numbered and logged. Each repair shall be nondestructively tested using the methods as appropriate. Repairs which pass the nondestructive test will be taken as an indication of an adequate repair.

Large caps may be of sufficient extent to require destructive test sampling at the discretion of PolyMet. Failed tests indicate that the repair shall be redone and retested until a passing test result is obtained. PolyMet will observe nondestructive testing of repairs; the number of each repair, date, and test outcome will be logged.

When seaming of the geomembrane liner is completed (or when seaming of a large area of the geomembrane liner is completed) and prior to placing overlying materials, PolyMet will observe the geomembrane wrinkles. PolyMet will indicate to the Installer which wrinkles should be cut and reseamed. The seam, thus produced, shall be tested like any other seam.

3.3.3.8 Geomembrane Acceptance

The geomembrane installation shall be accepted by PolyMet when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete; and
- all documentation of installation is completed.

PolyMet will certify that installation has proceeded in accordance with the CQA and Specifications for the project except as noted in the documentation report.

3.4 Backfilling of the Anchor Trench

PolyMet will observe the anchor trench backfilling operation and verify that the geomembrane extends into the horizontal portion of the anchor trench as specified.

4.0 Piping and Pumping Systems

Piping and pumping systems and surface water runoff control systems are an integral component of the HRF construction. The key components of Construction Quality Assurance (CQA) for piping and pumping systems during construction are confirmation of proper equipment and material type, pipe size and grade, survey of piping and structures, observation of installation, and observation of any post-installation performance testing that may be specified.

For buried piping and other systems for which future access is limited, the confirmation of proper material type is critical. In particular, this applies to buried piping systems. PolyMet will document the type of pipe used, the installation procedures, and backfilling techniques.

The critical component of the CQA of piping systems is the vertical and horizontal survey control. Inverts at manholes will be surveyed for elevation with horizontal and vertical components of the manhole documented. Pipe inverts will be surveyed at 25-foot intervals.

Additional CQA requirements for piping include:

- For perforated pipe, proper perforation size, spacing and orientation
- Proper pipe joining procedures
- For perforated pipe, proper pipe orientation in trench with holes facing downward
- Proper pipe bedding and cover
- Photo documentation of pipe installation
- Pipe cleaning after installation

In addition, inverts of drainage swales shall be surveyed at 50-foot intervals.

5.0 Access Road Construction

Verification surveying shall be conducted to verify that road installation and/or restoration is in accordance with the Plans and Specifications. Survey shall be conducted at centerline and both road edges at 100 foot intervals along tangent sections and at 50 foot intervals along curves. Unless required otherwise by the project plans and specifications, grading tolerances shall be as follows:

- Top of subgrade 0 to -0.2 feet
- Top of structural fill 0 to -0.2feet
- Top of Class 5 +0.05 to -0.05 feet

Grades shall be adjusted, as necessary, to meet these tolerances.

Where structural fill used in roadways also constitutes a structural component of the HRF, the fill shall be tested to confirm compliance with density specifications.

6.0 Documentation Report and Drawings

The documentation report is the summary document of the construction activities throughout the project. The construction portion of the report will include description of construction procedures, will include results from field and laboratory tests, and will summarize survey documentation. A summary of the documentation report contents is a follows:

- A comparison of material test results to construction specifications;
- All shop drawings for prefabricated components;
- Photo documentation of all critical aspects of construction;
- Narrative description of all as-built variances from the plans and/or specifications;
- Survey documentation of liner and cover system soils components;
- As-built elevations for all pipe inlets and outlets and fittings;
- Completed manufacturer warranties,
- All physical testing results (field and laboratory); and
- Geomembrane installation information including liner panel layout, sampling locations, and any modifications from original.

The documentation report will be certified by a professional engineer registered in the State of Minnesota.

Tables

Table 1 Soils Quality Assurance Testing Requirements

Subgrade		
Test	**ASTM Method**	**Frequency**
Standard Proctor	D698	Minimum 1
Moisture/Density	D2922 (nuclear) D3017 (nuclear)	1/Acre
USCS Classification	D2487	1/Acre

Buffer Layer Testing (where applicable)		
Test	**ASTM Method**	**Frequency**
Grain Size	D422 and D1140	1 per 2000 cubic yards
Angularity of Sand Grains	per ASTM	

Granular Drainage Layer Testing		
Test	**ASTM Method**	**Frequency**
Grain Size	D422 and D1140	1 per 2000 cubic yards
USCS Classification	D2487	
Angularity of Sand Grains	per ASTM	
Permeability	D2434	1 per 2500 cubic yards (minimum of 2)

Cover Soils Layer Testing		
Test	**ASTM Method**	**Frequency**
Grain Size	D422 and D1140	1 per 2000 cubic yards (minimum of 3)
USCS Classification	D2487	

Topsoil Layer Testing		
Test	**ASTM Method**	**Frequency**
Grain Size	D422 and D1140	1 per 2000 cubic yards (minimum of 3)
USCS Classification	D2487	
USCS Description	D2488	
Nutrient Content & pH	Per Agricultural Soils Testing Laboratory	
Organic Content		
Fertilizer Requirements		

Coarse Aggregate Testing		
Test	**ASTM Method**	**Number of Tests**
Grain Size	D422	1/1000 L.F. of toe drain or drainage swale (minimum of 2)
Angularity of Aggregate	per ASTM	
USCS Classification	D2487	

Notes:

1. Soil testing of subgrade materials placed for final cover construction is not required in areas where total subgrade fill thickness is less than or equal to 6 inches.

Table 2 Geomembrane Quality Assurance Testing Requirements

Geomembrane Testing		
Test	**Reference**	**Frequency**
Material Properties	GRI-GM13 and/or GRI-GM17 as applicable.	By manufacturer Every roll provided
Visual Inspection	—	Entire sheet
Trial Seam Welding	—	Start of seaming process, every 4 hours minimum, each seamer
Non-Destructive Seam Testing	—	All seams/patches
Destructive Seam Strength Test		1 test per 500 L.F. seam minimum

Pass/Fail Criteria – Destructive Samples	
	Smooth and Textured
Peel ASTM D4437	Per Specification
Shear ASTM D4437	Per Specification

Notes:

1. Destructive seam testing for each sample by independent testing laboratory required as noted in this CQA Plan and construction specifications.

2. See construction specifications for additional geomembrane installation and testing requirements.

3. See construction specifications for additional installation and testing requirements for non-geomembrane geosynthetic construction materials.

4. If conflicts exist between the construction specifications and this construction CQA plan, the construction specifications shall take precedence.

5. Subgrade testing shall be as required by the construction specifications. Subgrade testing may be eliminated at PolyMet's or project engineer's discretion provided proof rolling of subgrade is performed in place of density testing of subgrade.

Attachment I

Dam Inspection Form

Attachment I Dam Inspection Form

Facility Inspected:	**Inspection Date:**
Inspection By:	**Weather Conditions:**
Area Inspected:	
General Information	
Current Freeboard:	
Inlet Type: Pipe with Slurry Discharge	**Outlet Type/Level Control:** Floating Discharge

Observed Features	Yes	No	Comments
1.0 (visible part of) Upstream Slope			
1.1 Erosion protection			
1.2 Evidence of erosion			
1.3 Evidence of horizontal or lateral movement			
1.4 Evidence of sloughing			
1.5 Evidence of cracking			
1.6 Mark of high pond level			
1.7 Residue adjacent dam			
1.8 Vegetation condition			
1.9 Slope visually uniform			
1.10 Other unusual conditions			
1.11 Evidence of repairs			
2.0 Crest			
2.1 Breach / wash-out			
2.2 Evidence of horizontal or lateral movement			
2.3 Evidence of settlement			
2.4 Evidence of cracking			
2.5 Shoulder erosion			
2.6 Reduced width			

Observed Features	Yes	No	Comments
2.7 Other unusual conditions			
2.8 Evidence of repairs			
3.0 Downstream Slope			
3.1 Erosion protection			
3.2 Evidence of erosion			
3.3 Evidence of horizontal or lateral movement			
3.4 Evidence of sloughing			
3.5 Evidence of cracking			
3.6 Evidence of leakage			
3.7 Leakage (if any) clear			
3.8 Vegetation condition			
3.9 Slope visually uniform			
3.10 Other unusual conditions			
3.11 Evidence of repairs			
4.0 Downstream Toe			
4.1 Toe drain exists			
4.2 Toe drain working well			
4.3 Toe ditch exits			
4.4 Flow in toe ditch			
4.5 Evidence of leakage			
4.6 Leakage (if any) clear			
4.9 Soft toe condition			
4.10 Evidence of sloughing			
4.11 Evidence of boils			
4.12 Pond at toe of slope			
4.13 Vegetation			
4.14 Evidence of repairs			

Observed Features	Yes	No	Comments
4.15 Other unusual conditions			
5.0 General			
5.1 Embedded/buried structures			
5.2 Pipelines at this embankment			
5.3 Crest accessible by truck			
5.4 Depressions or sinkholes in Residue surface			
5.5 Any unusual conditions			

Notes:

Sketches (if any) Saved At:

Photos Taken: Yes ___ No ___

Photos Saved At:

Attachment J

Dam Stability Instrumentation and Monitoring Plan

Dam Stability Instrumentation and Monitoring Plan

Hydrometallurgical Residue Facility

Prepared for
Poly Met Mining Inc.

BARR

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Dam Stability Instrumentation and Monitoring Plan

Table of Contents

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1.0 Introduction

This attachment describes the plan for stability monitoring of the Hydrometallurgical Residue Facility (HRF) dams at Poly Met Mining Inc.'s (PolyMet's) proposed NorthMet Project (Project). The design and operation of the HRF dams are presented Sections 2 and 5 of the Hydrometallurgical Residue Management Plan (Reference (1)).

Stability monitoring will be required throughout operations, reclamation and initial portions of long-term closure to verify that the HRF dam design constraints are met. Stability monitoring will include installation of piezometers to monitor the piezometric surface in the HRF dams, and installation of inclinometers and survey points to monitor dam movement. Stability monitoring is one component of Dam Safety Inspection (Section 5 of Reference (1)). Other monitoring activities associated with the HRF, which are not described in this plan, include:

- construction monitoring as described in the HRF Template Construction Specifications (Attachment E of Reference (1)),
- pond level and water quality monitoring, as described in Section 5.1.1 of Reference (2),
- Drainage and Leakage Collection System water quantity monitoring, as described in Section 5.1 of Reference (2).

Personnel who will be responsible for HRF management are:

- *Operations Contact* - Beneficiation Division Manager or designee – Responsible for overall HRF design, planning, operations, maintenance, and monitoring, and
- *Design Engineer* (an independent consultant retained specially for dam safety expertise and a Minnesota-registered engineer) – Responsible for performance monitoring data analysis and interpretation, dam safety inspection and reporting assistance, dam raise planning and design assistance, and permitting assistance.

This Instrumentation and Monitoring plan includes:

- Section 2.0 Description of the HRF dam stability monitoring instrumentation, data collection and analysis
- Exhibit A Technical Specifications – Fully Grouted Vibrating Wire Piezometers
- Exhibit B Technical Specifications – Standpipe Piezometers

- Exhibit C Technical Specifications – Inclinometer Installation

This document is intended to evolve through the environmental review, permitting (Minnesota Department of Natural Resources (MDNR) Dam Safety, and MDNR Permit to Mine), and operating and long-term closure phases of the project. It will be reviewed and updated as necessary in conjunction with changes that occur in facility operating and maintenance methods or requirements.

2.0 Stability Monitoring

Stability monitoring of the HRF dams will be carried out during all phases of the Project: construction, operations, reclamation and long-term closure. The HRF dams will be constructed in three phases. During construction of the Phase 2 and Phase 3 dams, piezometers will be installed to monitor pore pressures within the dams and foundation and inclinometers will be installed to monitor potential deformation of the HRF dams. A comprehensive monitoring database will be developed to save and track piezometer and inclinometer data for the dam through-out the 20-year period of construction and operation. Monitoring of the dams will continue in reclamation and long-term closure until MDNR allows reduction or discontinuance.

Stability monitoring will provide data for Dam Safety Inspections (Section 5 of Reference (1)).

2.1 Instrumentation

Instrumentation for stability monitoring of the HRF dams will consist of:

- vibrating wire and standpipe piezometers to monitor the piezometric surface in the dams,
- inclinometers to monitor dam movement during and after construction of the dam, and
- survey measurements to monitor dam movement.

Instrumentation will be installed in two phases. The first phase of instrumentation installation is described in further detail below and will take place during or just after construction of the second lift (Phase 2) of the dam. The second phase of instrumentation installation will take place during or just after construction of the third lift (Phase 3) of the dam. Table 2-1 summarizes the proposed instruments and instrument locations are shown in the Hydrometallurgical Residue Facility Permit Support Drawings (Attachment A of Reference (1)), Drawings HRF-009, HRF-010 and HRF-012.

2.1.1 Piezometer Details

Nested vibrating wire piezometers will be installed in the south and northwest dams of the HRF along the typical cross-sections modeled as a part of the final dam design and optimization process (Reference (3)). The piezometers will be placed to allow for monitoring of pressures within the dam profile. At each piezometer nest locations, the first piezometer will be installed into the native till below the dam. The second piezometer will be placed at an elevation of 10 feet above the native material to monitor for potential leakage through the HRF liner system. The numbers and location of monitoring points recommended at this time are subject to change in number and/or location based on field conditions at the time of installation.

Vibrating wire (VW) piezometers will be installed per requirements of the Template Specifications (Exhibit A) and Installation Diagram (Drawing HRF-024 in Attachment A of Reference (1)). If additional standpipe piezometers are required at a future date, installation will generally follow the configurations shown on Drawing HRF-024 and follow specifications in Exhibit B. The piezometers may be installed in a borehole drilled using the SPT method, providing blow counts on the material during drilling. This data will be compared to previous investigations in the area to confirm design properties.

Monitoring locations will periodically be reviewed and modified as needed through-out the life of the HRF. Monitoring points that become non-functional or that no longer warrant monitoring will be properly abandoned. However, it will be preferable to consistently monitor the same points throughout the life of the HRF.

2.1.2 Inclinometer Details

Standard inclinometers will be installed in pairs to record deformation. Vibrating wire piezometers will be installed to record real-time movement should unanticipated levels of deformation be observed via the standard inclinometers. The VW inclinometers will be installed within the standard inclinometer casing and positioned such that the two inclinometers straddle the point of greatest deflection observed via the standard inclinometer readings. Typical installation details are included on Drawing HRF-024 and template specifications are provided in Exhibit C.

Table 2-1 Proposed Instrumentation for HRF

Name	Instrument	Cross-section	Location
HRF_NWD_20XX_VWP-1a	VW Piezometer	A-A’	Phase 2 Dam Crest
HRF_NWD_20XX_VWP-1b		A-A’	Phase 2 Dam Crest
HRF_SD_20XX_VWP-1a		C-C’	Phase 2 Dam Crest
HRF_SD_20XX_VWP-1b		C-C’	Phase 2 Dam Crest
HRF_NWD_20XX_VWP-2a		A-A’	Phase 3 Dam Crest
HRF_NWD_20XX_VWP-2b		A-A’	Phase 3 Dam Crest
HRF_SD_20XX_VWP-2a		C-C’	Phase 3 Dam Crest
HRF_SD_20XX_VWP-2b		C-C’	Phase 3 Dam Crest
HRF_NWD_20XX_ICL-1	Inclinometer	A-A’	Phase 2 Dam Crest
HRF_SD_20XX_ICL-1		C-C’	Phase 2 Dam Crest
HRF_NWD_20XX_ICL-2		A-A’	Phase 3 Dam Crest
HRF_SD_20XX_ICL-2		C-C’	Phase 3 Dam Crest

2.1.3 Survey Details

A full topographical survey of the HRF dams will be performed after each phase of construction. At least once a year, accurate survey measurements will be taken of previously established points of interest, checking for any sign of horizontal or vertical movement. Reference datum will be selected such that they are on solid ground well beyond the footprint of the dam. Survey frequency will be decreased after HRF closure.

2.2 Data Collection and Analysis

Piezometer, inclinometer and survey readings will be taken at the frequency needed to accommodate real-time adjustment of the construction rate to maintain stability. A Project data network will collect data continuously from VW piezometers and VW inclinometers (if deemed necessary and installed). The continuous readings will be recorded using a datalogger and are recommended to be downloaded monthly or at an increased frequency if the need arises. The frequency of on-going analyses will be re-evaluated as construction and operation progress.

On-going monitoring will be performed by the *Design Engineer* or authorized representative to allow for real time modification of construction, monitoring and operation means and methods as required to maintain dam stability.

Each dam construction event will require specific data collection and analysis. Since the HRF will utilize a double liner system, development of an elevated phreatic surface within the HRF dams is not anticipated. If an elevated phreatic surface does develop and begin to trend upward during operations, additional seepage and stability analyses will be performed to determine what the allowable water levels are within the dams.

The above instrumentation and monitoring plan will be sufficient to identify the onset of a potential instability problem. However, if signs of instability are detected by the daily visual observations that supplement the instrumented monitoring, additional surveillance and remedial measures will be taken to safeguard the stability and integrity of the HRF dams.

3.0 References

1. **Poly Met Mining Inc.** NorthMet Project Residue Management Plan (v3). November 2014.

2. —. NorthMet Project Water Management Plan - Plant (v3). December 2014.

3. —. NorthMet Project Geotechnical Data Package Vol 2 - Hydrometallurgical Residue Facility (v4). October 2014.

Exhibits

Exhibit A

Technical Specifications – Fully Grouted Vibrating Wire Piezometers

TECHNICAL SPECIFICATIONS

SECTION [X]

FULLY GROUTED VIBRATING WIRE PIEZOMETERS

A.1 SCOPE

The work covered under this section of the Specifications consists of furnishing all labor, materials, equipment, and performing all operations necessary to construct and install vibrating wire piezometers using the fully grouted method. The piezometer tips will be provided by the OWNER'S REPRESENTATIVE [or INVESTIGATION CONTRACTOR]. The proposed piezometer locations are shown on the Contract Drawings. A summary is provided in Table A.1.

Table A.1
Vibrating Wire Piezometer Installation Locations

Borehole	Piezometer	Coordinates		Target Depth/ Elevation Layer	Comments
		Northing	Easting		
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
	PZ-XXXX	XXXX	XXXX	XXXX	XXXX

A total of [TBD] vibrating wire piezometers are proposed as shown in Table A.1. [TBD] nested piezometers are proposed in borings (XXXX) and [TBD] nested piezometers are proposed in borings (XXXX). The vibrating wire piezometers will be placed at elevations determined by OWNER'S REPRESENTATIVE.

A typical vibrating wire piezometer is installed using the fully grouted method, which consists of vibrating wire piezometer tip installed in a hole surrounded by bentonite/cement grout in the borehole.

A.2 MATERIALS

A.2.1 Drilling Fluid

Drilling fluid for boreholes used for vibrating wire piezometers shall be drilling mud, a combination of potable water defined as, water which is safe for human consumption, in that it is free from impurities in amounts sufficient to cause disease or harmful physiological effects, and bentonite. Other additives may not be added to maintain a stable hole.

A.2.2 Portland Cement

Portland Cement (Type I) shall meet the requirements of ASTM C-150.

A.2.3 Bentonite

Bentonite shall be finely ground, premium-grade bentonite, equal to Quick Gel manufactured by NL Baroid Industries, Inc. of Houston, Texas. The bentonite shall be free from lumps and objectionable material that would prevent easy mixing into a smooth fluid, free from lumps of unmixed bentonite.

A.2.4 Vibrating Wire Piezometer Tip and Cable

The vibrating wire piezometer shall be a 50[100] psi tip that meets the specifications of the Slope Indicator Company's Model 52611020[52611030] vibrating wire piezometer or approved equal. The cable shall be marked at the factory, at the end where the readout gate is connected, with the following minimum details: length, serial number, and pressure range. These will be supplied by the OWNER'S REPRESENTATIVE [or INVESTIGATION CONTRACTOR].

A.2.5 Grout for Backfill of Vibrating Wire Piezometers

The grout for backfilling the boreholes of the vibrating wire piezometers shall consist of a mixture of Portland Cement (one bag approximately 94 pounds) to 29 gallons of water to approximately 30 pounds of bentonite as needed. Portland Cement and bentonite shall be weighed and amounts recorded for each batch used for backfill. Water and cement shall be mixed first. The bentonite shall be added slowly under high agitation to make grout creamy, yet pumpable. This yields a cement-water-bentonite ratio by weight of 1:2.5:0.3.

INVESTIGATION CONTRACTOR shall provide a scale to weigh out the proportions of this mix, accurate to the nearest pound. Water proportion shall be measured by 5-gallon bucket that is marked at 1-gallon increments. The OWNER'S REPRESENTATIVE shall approve the grout mix before it is placed in the borehole.

A.2.6 Concrete Grout for Protective Casing

The concrete grout shall consist of 1 part potable water, 2 parts Portland cement, and 2 parts clean sand.

A.2.7 Protective Casings

Protective casings shall be embedded into the ground surface and extended over the protruding portions of the piezometer casings. The tops of the protective casings shall extend no more than 4 feet above the ground surface and should be embedded a minimum of 2 feet below ground. The protective casings shall consist of Schedule 40 [PVC / or steel] with caps and be at least 6 inches in diameter. Protective casings will only be installed at locations as directed by OWNER'S REPRESENTATIVE.

A.2.8 Disposable Grout Pipe

The disposable grout pipe shall have a large enough diameter to facilitate grout injection into bottom of borehole while fitting inside hollow-stem auger casing. The disposable grout pipe shall be PVC and will remain in borehole.

A.3 PERFORMANCE

The INVESTIGATION CONTRACTOR shall practice good piezometer/monitoring well construction procedure that conforms to ASTM or other procedures specified in these specifications. If, in the opinion of OWNER'S CLIENT or OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR'S procedure is inadequate to construct a useable piezometer, the INVESTIGATION CONTRACTOR shall change procedures to meet the requirements of these specifications. The piezometers and monitoring wells shall be constructed in the borings specified by OWNER'S CLIENT at the time of drilling.

A.3.1 Piezometer/Monitoring Well Locations

The general locations of the required piezometers are identified in [Exhibit (XX)]. The borings will be staked in the field for INVESTIGATION CONTRACTOR.

A.3.2 Vibrating Wire Piezometer Construction

Each boring shall be advanced to the design depth with a 4¼- inch [or 6¼- inch], minimum inside diameter, hollow-stem auger. The piezometer shall be assembled and installed so that the tip is at the design depth. The porous piezometer filter tip shall be properly saturated before installation into the borehole and set with the tip up and taped to the disposable grout pipe. Final position of the VW piezometer shall be determined in the field by OWNER'S REPRESENTATIVE.

Once the VW tip has been saturated, the INVESTIGATION CONTRACTOR shall assemble the tip, disposable pipe, and cables in a way to prevent the tip from becoming desaturated. If, due to complications during installation, the tip does become desaturated the tip shall be resaturated.

Each VW piezometer tip shall be calibrated by the OWNER'S REPRESENTATIVE prior to installation.

Grout for backfilling the vibrating wire piezometer[s] shall be placed in the borehole by pumping under pressure through the disposable grout pipe (tremie pipe). The hollow-stem auger shall be withdrawn as necessary during the grouting process. The grout pipe shall permanently remain in the boring.

Grout for backfilling the vibrating wire piezometer[s] shall be mixed to a smooth and thick cream-like consistency, to where it is as heavy as it is feasible to pump. The INVESTIGATION CONTRACTOR shall be responsible for supplying a pump that is capable of pumping a heavy slurry mix as previously described for tremie-pipe installation.

a.3.3 Piezometer Protection

The protective casing shall be installed to an approximate depth of 2 feet in the borehole. The exact depth shall be adjusted so that the top of the casing is even with the top of the capped riser pipe. The annulus between the protective casing and the borehole wall shall be filled with concrete grout from the ground surface to a depth of 5 feet. The grout surface outside the casing shall be sloped away from the casing. The annulus between the riser pipe and the protective casing shall be filled with grout to a level no more than 12 inches below the top of riser pipe. Well protection shall only be installed at locations designated by OWNER’S REPRESENTATIVE.

A.3.4 Care and Maintenance of Piezometers

During the course of drilling, the INVESTIGATION CONTRACTOR shall be responsible for the care and maintenance of the piezometers and monitoring wells and shall maintain the site in such a condition and protect the piezometers in such a manner that no undesirable materials are spilled, dripped, or introduced into the borehole by any means.

A.3.5 Borehole Abandonment

If for any reason a borehole or piezometer cannot be completed, the INVESTIGATION CONTRACTOR shall contact OWNER’S REPRESENTATIVE for permission to abandon it. The INVESTIGATION CONTRACTOR shall not abandon any borehole without being directed to do so by the OWNER’S REPRESENTATIVE. Borehole abandonment includes removing all casing, and/or tools from the borehole, sealing the borehole as nearly as possible for its full length with tremied cement grout and restoring the site. If the INVESTIGATION CONTRACTOR abandons a borehole without being directed to do so by OWNER’S REPRESENTATIVE, no payment for work performed on that borehole or piezometer shall be made.

A.4 MEASUREMENT AND PAYMENT

Payment for all materials, equipment, supplies, and labor necessary to perform the work requested under the terms of this Contract will be made according to EXHIBIT C, SCHEDULE OF UNIT PRICES. All functions not specifically covered by a pay item shall be considered incidental to the work performed. Payment shall be made only for those items ordered or approved by OWNER'S REPRESENTITIVE and meeting the contract requirements.

A.4.1 Furnish and Install Vibrating Wire Piezometers

Payment will be made for each vibrating wire tip furnished by the INVESTIGATION CONTRACTOR. Payment for vibrating wire piezometer installation will be measured per foot of grout placed. Payment will be on a unit price basis and will constitute full compensation for all labor, equipment, and grout required for vibrating wire piezometer installation, and all other items and operations required for piezometer construction. Borehole advancement for piezometer installation is not included in payment for payment for piezometer installation but will be paid as described under Borehole Advancement by Hollow-stem Auger in the situations where a piezometer is not installed in an SPT boring.

A.4.2 Furnish and Install Grout Tube

Grout tube payment shall be measured per foot of tube installed. Payment shall be on a unit price and will constitute full compensation for all labor, equipment, and materials required for grout tube installation.

A.4.3 Backfilling Boreholes – Fully Grouted Boreholes

Grouting fully grouted boreholes used for vibrating wire piezometers will be measured for payment by the foot of grout used to backfill the boreholes. Payment will be by the unit price per foot of grout and will constitute full payment for all materials, labor, and equipment required to seal the borehole, and regrade the area. No payment will be made for work performed to abandon a boring or for an equivalent replacement boring when abandonment is necessary because of some fault of the INVESTIGATION CONTRACTOR'S personnel, equipment, procedure, materials, or for boreholes abandoned without specific direction by OWNER'S REPRESENTATIVE to do so. Work performed and accepted by OWNER'S REPRESENTATIVE prior to abandonment will be counted for payment.

Exhibit B

Technical Specifications – Standpipe Piezometers

TECHNICAL SPECIFICATIONS

SECTION [X]

STANDPIPE PIEZOMETERS

B.1 SCOPE

The work covered under this section of the Specifications consists of furnishing all labor, materials, equipment, and performing all operations necessary to construct and install all porous stone tip standpipe [or slotted pipe standpipe] piezometers and perform well development as required within. The proposed piezometer locations are shown on Figure [*Prepared at Time of Installation*] and the approximate length and type are summarized in Table B.1. The actual location will be defined in the field.

Table B.1
Standpipe Piezometer Installation Locations

Borehole	Piezometer	Coordinates		Target Depth/Layer	Comment
		Northing	Easting		
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX
XXX	PZ-XXXX	XXXX	XXXX	XXXX	XXXX

A total of [XXXX] porous stone tip standpipe [or slotted pipe standpipe] piezometers are proposed at [XXXX] of the [XXXX] boreholes. Locations of the piezometers are shown on [the Contract Drawings]. The tip of the porous stone [or slotted section pipe standpipe] piezometers will be located in [XXXX] material. Minor adjustments to the proposed locations and elevations may be made in the field by the OWNER'S REPRESENTATIVE.

A typical porous stone tip standpipe [or slotted pipe standpipe] piezometer, which is installed in a borehole, consists of a filter tip [or slotted pipe] joined to a riser pipe. The porous stone [or slotted pipe] is placed in a sand pack zone and a bentonite pellet seal is placed above the sand pack to isolate the pore pressure at the tip. The annular space between the riser pipe and the borehole is backfilled to the surface with bentonite/cement grout to prevent vertical migration of water. The riser pipe is terminated 3 feet above ground level with a vented cap. At locations indicated by the OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR shall place a coupler at the tip of the riser pipe to allow for future extensions to the riser pipe. The top of the well shall be protected with a metal stick-up protector, cemented in-place at the ground surface.

B.2 REFERENCE STANDARDS

B.2.1 ASTM D-5092 Standard Practice for Design and Installation of Ground Water Monitoring Wells

B.2.2 ASTM C-150 Specifications for Portland Cement

B.3 SUBMITTALS

B.3.1 Concrete sand product sheet.

B.3.2 Porous stone tip manufacturer's certificates.

B.3.3 Sand pack gradation product sheet.

B.3.4 Slotted pipe standpipe manufacturer's certificates.

B.3.5 Bentonite product sheet.

B.3.6 Portland cement product sheet.

B.3.7 Drilling fluid addition product sheet.

B.4 MATERIALS

B.4.1 Drilling Fluid

Drilling fluid for boreholes used for porous stone tip standpipe [or slotted pipe standpipe] piezometers shall be potable water, which is defined as water which is safe for human consumption in that it is free from impurities in amounts sufficient to cause disease or harmful physiological effects. No additives shall be added to water used for the borings to be used as standpipe piezometers.

Drilling fluid for boreholes used for open pipe piezometers shall use a biodegradable additive such as Revert, an organic polymer manufactured by Johnson Screens of St. Paul, Minnesota or approved equal. Bentonite will not be allowed.

If Revert is used, prior to installation of the piezometer; the INVESTIGATION CONTRACTOR shall flush the borehole with "clean" mud to remove any clay or loose material that has been mixed with the mud while advancing the borehole. The clean mud should be as thin as possible, so that placement of backfill material is not obstructed, but that it does not sacrifice the stability of the borehole. After installation of the piezometer, following Section XXXX, the piezometer shall be developed to clear any filter cake from the borehole wall alongside the piezometer. To develop, the INVESTIGATION CONTRACTOR shall create inward flow by removing water from the standpipe, allowing formation water to flow inward and break down the filter cake. Piezometer development shall be continued until a sediment-free piezometer is obtained. After the piezometer is developed, ten well volumes of water shall be removed from the piezometer.

B.4.2 Porous Stone Standpipe Piezometer Tip

The piezometer tip shall consist of a 12-inch porous stone that meets the specifications of the Slope Indicator Company's Standpipe Piezometer Tips, Model 51405102 or approved equal. The piezometer tip shall be joined to the casing by water tight couplings.

B.4.3 Slotted Pipe Standpipe Piezometer Tip

The piezometer tip shall consist of a 4-inch cap that meets the specifications of the Slope Indicator Company's Standpipe Piezometer Tips, Model 51417402 or approved equal. The piezometer tip shall be joined to the casing by water tight couplings.

B.4.4 Sand Pack

The sand pack shall consist of a clean, durable, uniformly graded natural sand meeting the specifications of the #30 sand produced by Red Flint Sand and Gravel, Eau Claire, Wisconsin.

B.4.5 Standpipe Riser Pipe and Fittings

The riser pipe shall be 2-inch inner diameter, schedule 40, PVC pipe. Fittings shall be flush male and female threads and of the same material as the riser pipe as well as water tight. A vented end cap shall be supplied for the top of the riser pipe.

B.4.6 Standpipe Tip to Riser Coupler

The open pipe piezometer porous tip shall be joined to the riser pipe by a coupler that meets the specifications of [the Slope Indicator Company's Pipe Adaptors from 0.75- to 1.25-inch pipe, Model 50712521] or approved equal. The piezometer tip shall be joined to the casing by water tight couplings.

B.4.7 Portland Cement

Portland Cement (Type I) shall meet the requirements of ASTM C-150.

B.4.8 Neat Cement Grout

The neat cement grout shall consist of a mixture of one bag (94 pounds) Portland cement (Type I) to not more than 6 gallons of potable water. Bentonite up to 5 percent by weight of cement may be added. No other admixtures shall be allowed.

B.4.9 Bentonite Pellets

Bentonite pellets shall be organic-free, high-swelling, 100 percent pure bentonite compressed into 3/8-inch-diameter pellets equal to NL Baroid Industries of Houston. The pellets shall be kept dry and transported to the site in such a way as to minimize abrasion. The pellets should be coated so as to minimize bridging during placement.

B.4.10 Concrete Grout for Protective Casing

The concrete grout shall consist of 1 part potable water, 2 parts Portland cement, and 2 parts clean sand.

B.4.11 Stick-up Protective Casings

Protective steel casings shall be embedded into the ground surface and extended over the protruding portions of the piezometer casings. The tops of the protective casings shall extend no more than 3 feet above the ground surface and should be embedded a minimum of 4 feet below ground. The protective casings shall consist of Schedule 40 steel and be at least 4 inches in diameter. The protective casings shall have a locking cover. The exposed portion of the casing shall be painted with a compatible metal corrosion-resistant primer and a red finish coat prior to delivery on-site. The protective casing cap shall be a painted overlapping steel cap of the same quality as the casing and finished with a hasp for attachment to the protective casing. Protective casings will only be installed at locations as directed by the OWNER'S REPRESENTATIVE.

B.4.12 Protective Casing Locks

The OWNER's REPRESENTATIVE will provide locks for protective casings.

B.4.13 Protective Posts

Protective posts shall be 4-inch-diameter, schedule 40, 8 feet in length. Posts shall be filled with concrete. The exposed portion of the posts shall be painted with a compatible metal corrosion-resistant primer and red finish coat prior to delivery on site. Protective posts will only be installed at locations as directed by the OWNER'S REPRESENTATIVE.

B.5 PERFORMANCE

The INVESTIGATION CONTRACTOR shall practice good piezometer construction procedure that conforms to ASTM or other procedures specified in these specifications. If, in the opinion of OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR'S procedure is inadequate to construct a useable piezometer, the INVESTIGATION CONTRACTOR shall change procedures to meet the requirements of these specifications. The piezometers shall be constructed in the borings specified within Table B.1. The Contract Drawings show a diagram of the piezometer installation.

B.5.1 Piezometer Locations

The general locations of the required piezometers are identified in the Contract Drawings. The location will be staked [identified] for the INVESTIGATION CONTRACTOR by the OWNER'S REPRESENTIVE.

B.5.2 Boring Advancement

The INVESTIGATION CONTRACTOR shall employ hollow-stem auger or the approved drilling techniques at all piezometer locations to the required depth of penetration or to depths at which hollow-stem auger advancement ceases to be feasible. The hollow-stem auger shall be equipped with a retractable bottom plug, advanced with the lead auger, and removed prior to each sampling attempt. Auger with 6¼-inch inner diameter shall be used.

If rotary drilling methods are used beyond the ceased advancement of the hollow-stem auger, a minimum 5½-inch diameter hole shall be drilled with a noncoring type roller, fishtail, or other suitable bit.

B.5.3 Standpipe Piezometer Construction

The boring shall be advanced to the design depth with 6¼-inch minimum inside diameter, hollow-stem auger. Bentonite drilling mud shall not be used during boring advance. The piezometer tips and the riser pipe shall be assembled and installed so that the screen is at the design depth and the riser pipe extends 2 to 3 feet above the ground surface. The sand pack shall be installed, as the auger or casing is pulled back, in a manner that shall minimize segregation and ensure the sand pack fills, as nearly as practical, the annular space between the well screen and the borehole wall to a depth of 2 feet above the screen.

A bentonite pellet seal shall be placed above the sand pack to a depth of 4 feet above the top of the piezometer tip. The pellets shall be allowed to swell a minimum of ½ hour under a head of water prior to continuing the installation. Neat cement grout shall be placed above the seal to the ground surface by pumping under pressure through a tremie pipe. After 6 inches of grout have been placed in the borehole, the discharge point of the tremie pipe shall be maintained at 3 inches or more below the grout surface. The hollow-stem auger shall be withdrawn as necessary during the grouting process. Concrete full strength grout should be placed to within 6 feet of the ground surface. The annular space between the riser pipe and the borehole wall above the cement grout shall be filled with concrete. The concrete surface at ground level shall be sloped away from the riser pipe.

B.5.4 Piezometer Alignment and Clearance

Piezometers shall be sufficiently plumb, straight, and free from restrictions to allow a measuring device [¾ inch] in diameter and 12 inches long to pass freely through the full length of the piezometer. The INVESTIGATION CONTRACTOR shall prove the alignment and clearance are adequate prior to acceptance by OWNER'S REPRESENTIVE.

B.5.5 Piezometer Protection

The protective casing shall be installed to an approximate depth of 5 feet in the borehole. The exact depth shall be adjusted so that the top of the casing is even with the top of the capped riser pipe. The annulus between the protective casing and the borehole wall shall be filled with concrete grout from the ground surface to a depth of 6 feet. The grout surface outside the casing shall be sloped away from the casing. The annulus between the riser pipe and the protective casing shall be filled with grout to a level no more than 12 inches below the top of riser pipe. Piezometer protection shall only be installed at locations designated by the OWNER'S REPRESENTATIVE.

B.5.6 Protective Posts

If requested by the OWNER's REPRESENTATIVE, protective posts painted red shall be placed 2 feet from the protective casing in a manner as to protect the piezometer from incoming traffic. The posts shall be set 2 feet into the ground in 12-inch-diameter boreholes. The annulus between the boreholes and the posts and the inside of the posts shall be filled with concrete. Protective posts shall only be installed at locations designated by the OWNER'S REPRESENTATIVE.

B.5.7 Care and Maintenance of Piezometers

During the course of drilling, the INVESTIGATION CONTRACTOR shall be responsible for the care and maintenance of the piezometers and monitoring wells and shall maintain the site in such a condition and protect the piezometers in such a manner that no undesirable materials are spilled, dripped, or introduced into the borehole by any means.

B.5.8 Borehole Abandonment

If for any reason a borehole or piezometer cannot be completed, the INVESTIGATION CONTRACTOR shall contact OWNER'S REPRESENTIVE for permission to abandon it. The INVESTIGATION CONTRACTOR shall not abandon any borehole without being directed to do so. Borehole abandonment includes removing all screens, casing, and/or tools from the borehole, sealing the borehole as nearly as possible for its full length with tremied cement grout, and restoring the site. If the INVESTIGATION CONTRACTOR abandons a borehole without being directed to do so by OWNER, no payment for work performed on that borehole or piezometer shall be made.

B.6 MEASUREMENT AND PAYMENT

Payment for all materials, equipment, supplies, and labor necessary to perform the work requested under the terms of this Contract will be made according to EXHIBIT A, SCHEDULE OF UNIT PRICES. All functions not specifically covered by a pay item shall be considered incidental to the work performed. Payment shall be made only for those items ordered or approved by OWNER and meeting the contract requirements.

B.6.1 Furnish and Install Porous Tip for Standpipe Piezometers

Standpipe piezometer tip payment will be measured per porous [or slotted pipe] tip installed. No more than one tip [or slotted pipe] shall be installed at each piezometer location. Payment shall be on a unit price basis and shall constitute full compensation for all labor, equipment, and materials required for piezometer installation and development including but not limited to the porous tip, [or slotted pipe], casing adapters, development, and all other items and operations required for tip construction.

B.6.2 Furnish and Install Casing for Standpipe Piezometers

Standpipe piezometer payment shall be measured per foot of casing installed. Payment shall be on a unit price basis and shall constitute full compensation for all labor, equipment, and materials including sand pack, bentonite, and grout required for standpipe piezometer installation and development including but not limited to the casing adapters, development, and all other items and operations required for tip construction. Borehole advancement for piezometer installation is not included in payment for piezometer installation and development but shall be paid as described under Borehole Advancement by Hollow-stem Auger.

B.6.3 Setup on a Soil Boring – Piezometer

Payment for setting up on an additional boring at the direction of the OWNER'S REPRESENTATIVE for the purpose of installing a piezometer with hollow-stem auger or water rotary methods will be measured by the boring. Payment will be at the unit price per boring and will constitute full compensation for all labor, equipment, and materials required to move the drill rig and other equipment between borings, to arrange for utility clearance at the boring location, to establish the necessary work zones, and to set up at a boring location in preparation for drilling.

B.6.4 Borehole Advancement

Borehole advancement by [6¼-inch] hollow-stem auger will be measured for payment to the nearest foot from the ground surface to the bottom of the auger. Payment will be by the unit price per foot and will constitute full compensation for all labor, equipment, and materials required to set and remove the auger. [Borehole advancement payment shall include SPT sampling.

B.6.5 Furnish and Install Stick-up Protective Covers

Payment will be made for each casing installation, including the cost of the casing themselves, the concrete, and all labor and materials required to assemble and install the casing.

B.6.6 Furnish and Install Protective Posts

Payment will be made for each post installation, including the cost of the posts themselves, the concrete, and all labor and materials required to assemble and install the posts.

Exhibit C

Technical Specifications – Inclinometer Installation

TECHNICAL SPECIFICATIONS

SECTION [X]

INCLINOMETER INSTALLATION

C.1 SCOPE

The work covered under this section of the Technical Specifications consists of furnishing all labor, materials, equipment, and performing all operations necessary to install inclinometers. The location of inclinometer installations are identified in Table C.1 and are shown in the Contract Drawings.

Table C.1
Inclinometer Installation Locations

Borehole No.	Inclinometer	Coordinates		Anticipated Depth	Comment
		Northing	Easting		
XXX	XXXX	XXXX	XXXX	XXXX	XXXX
XXX	XXXX	XXXX	XXXX	XXXX	XXXX
XXX	XXXX	XXXX	XXXX	XXXX	XXXX
XXX	XXXX	XXXX	XXXX	XXXX	XXXX
XXX	XXXX	XXXX	XXXX	XXXX	XXXX
XXX	XXXX	XXXX	XXXX	XXXX	XXXX

A total of [TBD] inclinometers are proposed at the site, [XXXX] inclinometers at [XXXX], and [XXXX] inclinometers at [XXXX].

A typical inclinometer consists of inclinometer casing installed in a borehole and backfilled to the surface so that the annular space between the casing and the borehole are filled with a cement-bentonite grout. The casing is terminated at the ground level with a protective cap.

C.2 REFERENCE STANDARDS

C.2.1 ASTM C150 Specifications for Portland Cement

C.2.2 ASTM D-6230 Standard Test Method for Monitoring Ground Movement Using Probe-Type Inclinometers

In case of conflict between these Technical Specifications and the above standards, the Technical Specifications will prevail.

C.3 MATERIALS

C.3.1 Drilling Fluid

Drilling fluid shall be drilling mud, a combination of potable water and bentonite. Potable water is defined as water that is safe for human consumption in that it is free from impurities in amounts sufficient to cause disease or harmful physiological effects. Other additives may not be added to maintain a stable hole.

C.3.2 Portland Cement

Portland Cement (Type I) shall meet the requirements of ASTM C-150.

C.3.3 Bentonite

Bentonite shall be finely ground, premium-grade bentonite, equal to Quick Gel manufactured by NL Baroid Industries, Inc. of Houston, Texas or approved equal. The bentonite shall be free from lumps and objectionable material that would prevent easy mixing into a smooth fluid of unmixed bentonite.

C.3.4 Inclinometer Casing

Inclinometer casings shall have an outside diameter of 1.9 inches (48 mm), 2.75 inches (70 mm) or 3.34 inches (85 mm) as specified and be constructed of ABS plastic with a load rating of [TBD] pounds. An example of an acceptable product casing is manufactured by Slope Indicator Company or as approved by the OWNER'S REPRESENTATIVE. Approval of material is required prior to ordering materials.

C.3.5 Inclinometer Protection

Inclinometer protection shall consist of a steel casing that shall be embedded into the ground surface and extended over the protruding portions of the inclinometer casing. The tops of the protective casing shall extend no more than 3 feet above the ground surface and should be embedded a minimum of 4 feet below ground. The protective casing shall consist of Schedule 40 steel and be at least 4 inches in diameter. The protective casing shall have a locking cover. The exposed portion of the casing shall be painted with a compatible metal corrosion-resistant primer and a red finish coat prior to delivery on-site. The protective casing cap shall be a painted overlapping steel cap of the same quality as the casing and finished with a hasp for attachment to the protective casing.

C.3.6 Inclinometer Cement-Bentonite Grout Backfill

The grout for backfilling the inclinometer boreholes shall consist of a mixture of Portland Cement (one bag approximately 94 pounds) to 29 gallons of water to a minimum 30 pounds of Quick Gel bentonite as needed. Water and cement shall be mixed first. The bentonite shall be added slowly under high agitation to make grout creamy, yet pumpable. This yields a cement-water-bentonite ratio by weight of 1:2.5:0.3. Modifications to the cement-bentonite grout mix design including increased water and bentonite or cement should be anticipated in the field in order to accurately represent similar strength as the in-situ soil and prevent segregation of cement. These modifications shall be approved by the OWNER'S REPRESENTATIVE.

C.3.7 Inclinometer Casing Buoyancy – Anchors

The INVESTIGATION CONTRACTOR shall utilize one of the following options for overcoming inclinometer casing buoyancy, “floating,” while placing cement-bentonite grout:

- Casing anchors, such as Durham Geo Slope Indicator Casing Anchors, sized to the appropriate casing diameter, or approved equal.
- Suspend a steel pipe or drill roads inside casing.
- Pre-attach a weight to the bottom of the casing
- Grout the borehole, with casing installed, in stages.

The INVESTIGATION CONTRACTOR shall not apply force to the top of the inclinometer casing to overcome buoyancy.

Barite or any substance considered a contaminant by the EPA is not allowed to be used as a weighted solution inside the inclinometer casing.

C.3.8 Inclinometer Grout Valves

Grout valves (with or without casing anchors) used to provide a means of cement-bentonite grouting the inclinometer casing in narrow annulus space situations shall consist of Durham Geo Slope Indicator Casing Anchors, sized to the appropriate casing diameter, or approved equal.]

C.3.9 Protective Casing Locks

Locks for protective casings will be provided by [OWNER’S REPRESENTATIVE].

C.3.10 Protective Posts

Protective posts shall be [X]-inch diameter, schedule 40, [X] feet in length. Posts shall be filled with concrete. The exposed portion of the posts shall be painted with a compatible metal corrosion-resistant primer and red finish coat prior to delivery on site. Protective posts will only be installed at locations as directed by the OWNER’S REPRESENTATIVE.

C.3.11 Concrete Grout for Protective Casings

The concrete grout for protective casings shall consist of Portland cement (three bags approximately 94 pounds) to 30 gallons of water. This yields a cement-water ratio by weight of 1:1:1.

C.3.12 Telescoping Sections

An example of an acceptable product casing is manufactured by Durham Geo Slope Indicator Company or as approved by the OWNER’S REPRESENTATIVE.

C.4 PERFORMANCE

The INVESTIGATION CONTRACTOR shall practice good drilling procedure that conforms with ASTM or other procedures specified in these Contract Documents. If, in the opinion of OWNER'S REPRESENTATIVE, the INVESTIGATION CONTRACTOR'S procedure is inadequate to obtain samples or install the inclinometer correctly, the INVESTIGATION CONTRACTOR shall change procedures to meet the requirements of these specifications. The inclinometer shall be constructed in the borings specified in Table C.1. The Contract Drawings show a detail of the inclinometer installation.

C.4.1 Inclinometer Location

The locations of the required inclinometers are shown on the Contract Drawings. The locations will be staked/identified for the INVESTIGATION CONTRACTOR by OWNER'S REPRESENTATIVE.

C.4.2 Boring Advancement

The INVESTIGATION CONTRACTOR shall employ hollow-stem auger techniques at the inclinometer locations to depths at which hollow-stem auger advancement ceases to be feasible. The hollow-stem auger shall be equipped with a retractable bottom plug, advanced with the lead auger, and removed prior to each sampling attempt. The diameter of the hollow-stem auger shall be sufficient to accommodate split-barrel samplers, tremie tube for grouting, and inclinometer casings.

In the case that a boring started with hollow-stem auger cannot be completed by the hollow-stem auger method due to heaving sands, extremely hard drilling conditions, cobbles or boulders, bedrock or other conditions that make auger advancement unfeasible, the INVESTIGATION CONTRACTOR shall notify the OWNER'S REPRESENTATIVE and shall extend the boring by mud-rotary methods in the same borehole, leaving the auger in place as a temporary casing until the boring has been completed.

C.4.3 Inclinometer Installation

The inclinometer shall be installed in the borehole and grouted in place with a minimum of [XX] feet within [bedrock] or as directed by the OWNER'S REPRESENTATIVE. A casing anchor and/or grout plug shall be installed on the tip of casing as directed by the OWNER'S REPRESENTATIVE. The inclinometer shall be constructed such that no more than 3 feet and no less than 2 feet stick up above the ground surface. Inclinometer grout shall be placed from the base of the inclinometer to the ground surface by pumping under pressure through a tremie pipe/pipe attached to the grout valve gasket at the tip of the inclinometer casing. After 6 inches of grout have been placed in the borehole, the discharge point of the tremie pipe shall be maintained at 3 inches or more below the grout surface. The hollow-stem auger [borehole casing] shall be withdrawn as necessary during the grouting process. Augers [Casing] shall not be spun upon removal from the ground.

The inclinometer shall be installed so that the difference in alignment of any section is no greater than 3 percent of the depth to that part. If the inclinometer is not installed to meet this tolerance, the INVESTIGATION CONTRACTOR shall abandon the location and install a new inclinometer at a location identified by the OWNER'S REPRESENTATIVE at no additional cost to the OWNER. The verification of verticality shall be made after the grout has set and two datasets are collected.

After installation, the casing groove spiral shall not exceed 1 degree per 10 feet of length; the orientation of the grooves at the top of the casing shall be within 10 degrees of the planned orientation (A-0 grooves in the downhill direction perpendicular to the slope).

C.4.4 Inclinometer Protection

The protective casing shall be installed to an approximate depth of 4 feet in the borehole. The exact depth shall be adjusted so that the top of the casing is even with the top of the inclinometer casing. The annulus between the protective casing and the borehole wall shall be filled with concrete grout from the ground surface to a depth of 5 feet. The concrete grout surface outside the casing shall be sloped away from the casing. The annulus between the inclinometer casing and the protective casing shall be filled with concrete grout to a level no more than 12 inches below the top of inclinometer casing.

C.4.5 Protective Posts

If requested by the OWNER's REPRESENTATIVE, protective posts painted red shall be placed 2 feet from the protective casing in a manner as to protect the inclinometer from incoming traffic. The posts shall be set 2 feet into the ground in 12-inch-diameter boreholes. The annulus between the boreholes and the posts and the inside of the posts shall be filled with concrete. Protective posts shall only be installed at locations designated by the OWNER'S REPRESENTATIVE.

C.4.6 Telescoping Sections

If requested by the OWNER's REPRESENTATIVE, telescoping sections of inclinometer casing shall be utilized at depths determined by the OWNER'S REPRESENTATIVE / as shown in the Contract Drawings (see Drawing [XXXX]).]

C.5 MEASUREMENT AND PAYMENT

Payment for all materials, equipment, supplies, and labor necessary to perform the work requested under the terms of this Contract will be made according to EXHIBIT A, SCHEDULE OF UNIT PRICES. All functions not specifically covered by a pay item will be considered incidental to the work performed. Payment will be made only for those items ordered or approved by OWNER'S REPRESENTATIVE and meeting the contract requirements.

C.5.1 Furnish and Install Inclinometer Casing

Inclinometer casing payment shall be measured per foot of casing installed. Payment shall be on a unit price basis and shall constitute full compensation for all labor, equipment, and materials including grout required for inclinometer installation, and all other items and operations required for inclinometer installation. Borehole advancement with soil sampling for inclinometer installation is not included in payment for inclinometer installation but shall be paid as described under Borehole Advancement and Sampling in Section [XX].

C.5.2 Furnish and Install Protective Casing for Inclinometers

Payment will be made for each casing installation, including the cost of the casing themselves, the concrete, and all labor and materials required to assemble and install the casing.

C.5.3 Furnish and Install Protective Posts

Payment will be made for each post installation, including the cost of the posts themselves, the concrete, and all labor and materials required to assemble and install the posts.

C.5.4 Furnish and Install Casing Anchors

Payment will be made for each casing anchor installation, including the cost of the anchors, and all labor and materials required to assemble and install the anchors.

C.5.5 Furnish and Install Grout Plugs

Payment will be made for each grout plug installation, including the cost of the grout plugs themselves, the concrete, and all labor and materials required to assemble and install the grout plugs.

Attachment K

Contingency Action Plan

POLYMET
MINING

NorthMet Project

Contingency Action Plan
for the Hydrometallurgical Residue Facility

Version 5

Issue Date: May 15, 2017

Table of Contents

1.0 Contingency Action Plan Summary

1.1 Purpose

The purpose of the Hydrometallurgical Residue Facility (HRF) Contingency Action Plan (CAP) is to:

- identify potential facility failure modes that could occur during construction events and during routine operations; conditions that if left undetected and unresolved could instigate instability of facility dams
- proactively identify contingency plans (i.e., operation change, design change if needed) for each potential failure mode, if observed
- identify instrumentation and monitoring that confirms acceptability of construction and operating activities, and proactively alerts construction, operations, and management personnel to facility conditions that if left unresolved could initiate a potential failure mode
- define responsibilities and provide procedures for responding to unexpected and potentially hazardous conditions threatening the integrity and performance of the HRF

This document will evolve throughout the permitting, operating, reclamation, and postclosure maintenance phases of the NorthMet Project (Project). It will be reviewed and updated as necessary in conjunction with changes that occur in facility operating and maintenance methods or requirements. Each revision will be provided to the Department of Natural Resources (DNR) dam safety permitting personnel for informational purposes such that they remain fully informed as plan updates are incorporated. Any plan updates that may affect permit conditions will be discussed with dam safety permitting personnel. A Revision History is included at the end of the document.

This CAP is intended to be a stand-alone guide to initial response to emergency conditions that could potentially develop at the HRF. As with any emergency condition, ongoing real-time decision-making will be required once the situation is assessed. Poly Met Mining, Inc. (PolyMet) will establish and maintain a project-wide emergency action plan (EAP) that should be referenced in the event of other potential conditions such as severe weather (i.e., tornado) or fire that are not a part of this plan and which do not constitute a significant or ongoing threat to the HRF.

1.2 Notification Flowchart

The Notification Flowchart (Large Figure 1) summarizes the sequence of actions required during a situation involving threat of dam failure. Contact lists are provided in Section 3.0. Notification procedures for other hazardous situations are described in Section 0.

1.3 Site Description

The HRF is a lined basin located on PolyMet's NorthMet Plant Site, northwest of the Plant near the southwest corner of the Tailings Basin. The HRF is bounded on the north by the existing Tailings Basin, on the east and south by natural high ground, by a rail embankment on the southeast, and by wetlands and woodland to the west.

Personnel responsible for HRF management are:

- *Operations Contact* - Beneficiation Division Manager or designee – Responsible for overall HRF design, planning, operations, maintenance, and monitoring.

- *Design Engineer* (an independent consultant retained specially for dam safety expertise and a registered engineer) – Responsible for performance monitoring data analysis and interpretation, dam safety inspection and reporting assistance, HRF dam planning and design assistance, and permitting assistance.

1.4 Observational Method

The Observational Method as stated by Peck (1969) in his Rankine Lecture is the method by which the integrity of the HRF dams will be monitored and facility operations and/or design adjusted as needed in response to observations. The steps in the Observational Method and their status as of the writing of this version of the Contingency Action Plan are summarized in Table 1-1.

Table 1-1 Observational Method

Activity	Summary	Status	Related Reference Documents
1. Geotechnical Exploration	Geotechnical exploration sufficient to establish at least the general nature, pattern, and properties of the deposits, but not necessarily in detail.	Complete	Geotechnical Data Package – Volume 2 (Reference (1))
2. Initial Design	Establishment of the design based on a working hypothesis of behavior anticipated under the most probable conditions.	Complete	See Geotechnical Data Package – Volume 2 (Reference (1)) and Residue Management Plan (Reference (2))

Activity	Summary	Status	Related Reference Documents
3. Select Instrument Values to Observe	Selection of instrument values to observe as construction and operations proceed and calculation of the anticipated values on the basis of the working hypothesis. Values to observe will be quantified after installation and baseline monitoring of the new instrumentation listed in the Instrumentation and Monitoring Plan.[(1)](Reference (3))	Partially Complete; framework for values to be observed are reported herein and in the Instrumentation and Monitoring Plan.(Reference (3))	Instrumentation and Monitoring Plan (Reference (3))
4. Calculate Instrument Values to Observe	Calculation of instrument values to observe under the most unfavorable conditions.	To be quantified after installation and baseline monitoring of the new instrumentation listed in the Instrumentation and Monitoring Plan.[(1)](Reference (3))	Instrumentation and Monitoring Plan (Reference (3))
5. Pre-Selection of Course of Action in Response to Observed Instrumentation Values	Selection in advance of a course of action or modification of design for every foreseeable significant deviation of the observational findings from those predicted on the basis of the working hypothesis.	Complete – see subsequent sections of this Contingency Action Plan.	NA
6. Measurement of Values to be Monitored and Evaluation of Actual Conditions	Measurement of values to be monitored and evaluation of actual conditions.	To be initiated following baseline monitoring and initiation of operations.	NA
7. Modification of Design to Suit Actual Conditions	Modification of design to suit actual conditions.	To be implemented as needed during operations.	NA

1) Instrument installation to occur after permitting and HRF dam construction, prior to initiation of operations.

1.5 Supporting Documentation

Geotechnical Data Package – Volume 2 (Reference (1)) presents the findings from site geotechnical explorations and the associated in-field and in-laboratory test data, and the slope stability model outcomes for the most probable geotechnical slope stability conditions and the unfavorable slope conditions evaluated to date.

Design of the HRF as guided by findings presented in the Geotechnical Data Package is presented in the Residue Management Plan (Reference (2)) which provides a full description of the HRF.

The Hydrometallurgical Residue Facility Instrumentation and Monitoring Plan (Reference (3)) presents the plan for instrumentation installation to be completed after permitting and facility construction but prior to initiation of facility operations. Following instrumentation installation, baseline instrument monitoring data will be gathered and, in conjunction with the additional geotechnical data gathered during instrument installation; slope stability models will be updated and typical instrument values at each instrument location will be established for normal and high pond conditions. Threshold values will be documented and the initial actions to be taken in response to data trends toward threshold values will be reviewed and updated as needed (Figure 1-1).

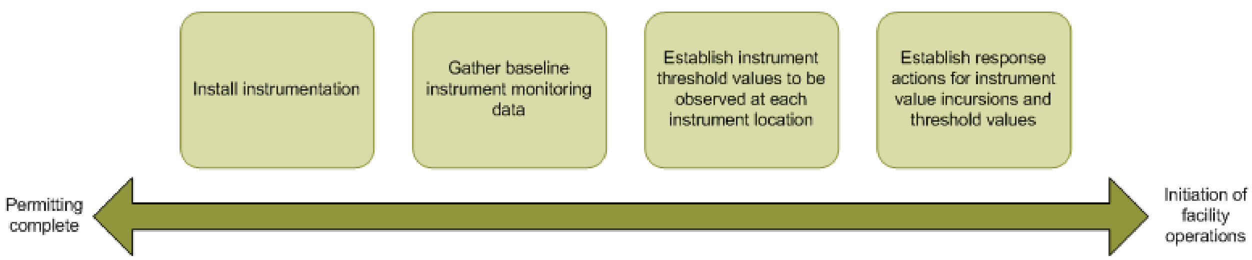

Figure 1-1 Instrumentation Timeline

The details of the instrumentation and monitoring (instrument types, locations, threshold values) will be retained within the Instrumentation and Monitoring Plan, with periodic updates to that plan as needed as instrumentation is installed and/or replaced, and as construction and operations of the HRF proceeds.

1.6 Outline

The outline of this document is:

Section 1.0 Contingency Action Plan Summary.

Section 2.0 Warning signs of unusual, hazardous, or emergency conditions associated with construction and operation of the HRF, and response actions.

Section 3.0 Internal and external emergency notification procedures.

Section 5.0 Emergency Mobilization Procedures.

Section 6.0 Emergency Evacuation Procedures.

2.0 Unusual, Hazardous and/or Emergency Conditions Warning Signs and Response Actions

Unusual, hazardous, and/or emergency conditions warning signs may be visually evident during routine or special residue facility inspections, and/or may be evidenced by changed monitoring values in piezometers, inclinometers, and/or survey monuments. Some unusual conditions may not warrant an emergency response, but require prompt investigation and resolution. Events which may cause unusual, hazardous, and/or emergency conditions may include (but are not limited to):

- Natural weather events, which could impact pond levels or cause erosion, including:
    - high precipitation event
    - significant snowmelt in combination with high precipitation event
- Operational disruptions, which could cause erosion or impact the phreatic surface within the dam, including:
    - an unrepaired pipe break or
    - accidental liner breach
- Construction changes, which could impact the phreatic surface of the dam or create excess pore water pressures within the dam, including:
    - increase in the rate of construction
    - over steepening of dam slopes

Unusual conditions will typically involve an investigation, intensified monitoring, inspecting and/or testing, and defining and implementing possible corrective measures. Some conditions represent a potential emergency if sustained or allowed to progress. In such cases it will be necessary to discuss and define a response plan, at the site, under the direction of the *Operations Contact*, and then to implement the plan. The first actions in the event of any emergency condition are:

- initiate the appropriate chain of communications
- check that all persons who could possibly be affected are safe
- immediately undertake the appropriate response actions

Sections 3, 4 and 5 describe actions to be initiated if an emergency situation occurs. The following sections list potential visual and monitoring instrument warning signs.

2.1 Visual Warning Signs

Large Table 1 provides a listing of visual warning signs and initial response actions for unusual, hazardous, and/or emergency conditions that could develop at the Residue Facility. It is important to note that each condition is unique and that seemingly harmless conditions could quickly progress into something more serious if timely and appropriate action is not taken. To detect visual warning signs, daily and weekly inspections, semi-annual inspections, and inspections after unusual events/observations will be carried out as specified in the Residue Management Plan (Reference (2)).

2.2 Monitoring Instrument Warning Signs

Large Table 2 provides a listing of monitoring instrument warning signs and initial response actions for unusual, hazardous, and/or emergency conditions that could develop at the Residue Facility. As with visual warning signs, it is important to note that each monitoring instrument warning sign condition is unique and that seemingly harmless conditions could quickly progress into something more serious if timely and appropriate action is not taken. Instrumentation data collection will in many cases be automated, allowing for real-time notification of data that is approaching pre-defined threshold values. Instruments that are not automated (e.g., alignment hubs, some inclinometers and some piezometers) will be read at the specified frequency. Further detail is provided in the Instrumentation and Monitoring Plan (Reference (3)).

3.0 Contacts

Emergency contacts are summarized in Table 3-1 through Table 3-3. These tables will be updated prior to initiation of facility operations and on a routine basis as company personnel and responsibilities change.

Table 3-1 NorthMet Residue Facility Structural Integrity Emergency Contact List

Emergency Contact	Name	Mobile	Office
Mining Manager (as alternate to General Manager)	Jim Tieberg	218-248-0952	218-471-2165
Operations Contact (Manager of Operations and Development)	Dave Hughes	TBD	218-471-2158
PolyMet Mining Environmental Compliance Manager	Kevin Pylka	218-750-2054	218-471-2162
Environmental Site Director	Christie Kearney	218-461-7746	218-471-2163
Director of Environmental Permitting and Compliance	Jennifer Saran	651-600-5457	651-389-4108
Design Engineer	Tom Radue	952-240-4051	952-832-2600
Emergency Health and Safety			
Fire/Ambulance/Police – Dependent on Incident Severity	N/A	911	911
Hospital – Grand Itasca Clinic and Hospital	General Number	N/A	218-326-3401
Government Agencies			
Minnesota Duty Officer			800-422-0798
National Response Center			800-424-8802
US EPA Region V			312-353-2318
Minnesota Pollution Control Agency (24 hrs)			612-296-8100 or 612-296-6300
Minnesota Emergency Response Commission			612-643-3000

Table 3-2 City of Hoyt Lakes Emergency Contact List

Title	Name	Phone	Email
Police Chief	Tim Soular	218-225-2000	police@eastrangepd.com
Sergeant	Heather Krueger	218-225-2000	police@eastrangepd.com
911 Emergency Communications	Emergency Non-Emergency	911 218-742-9825	N/A
There are no residents and/or businesses in affected inundation area.			

Table 3-3 St Louis County Emergency Contact List

Title	**Name**	**Phone**	**Email**
Sheriff	Ross Litman	218-726-2340	County_Sheriff@stlouiscountymn.gov
Undersheriff	Dave Philips	218-726-2340	County_Sheriff@stlouiscountymn.gov
911 Emergency Communications	Emergency Non-Emergency	911 218-727-8770	County_Sheriff@stlouiscountymn.gov
Mine Inspector	Steve Manninen	218-742-9840	manninen@stlouiscountymn.gov

4.0 Notification Procedures

The top priority in case of imminent or actual dam failure is to warn and evacuate people, if any, in downstream areas. Large Figure 1 presents the notification procedures for an emergency involving threat of dam failure. Attachment A describes responsible persons and their responsibilities for notification, emergency operations and repairs, and post-emergency action. Section 6.0 describes emergency evacuation procedures.

Emergency notification procedures vary depending on the condition/s existent that prompt the notification and can be divided into three levels:

Level 1 – Condition that does not warrant emergency response but requires prompt investigation and resolution.

Level 2 – Potential emergency if condition is sustained or allowed to progress; requires response plan.

Level 3 – Imminent or actual failure requiring partial or complete evacuation, emergency communications and response actions.

Level 1, Level 2, and Level 3 conditions that could occur at the Residue Facility are listed in Large Table 1 and Large Table 2.

4.1 Internal Notification Procedures

The notification procedures for Level 1 and Level 2 conditions are:

- the person first noticing a Level 1 or Level 2 condition will notify the *Operations Contact* and initiate responses and intensified monitoring

- the *Operations Contact* will notify the *Design Engineer* as appropriate

The notification procedure for Level 3 conditions are:

- the person first noticing a Level 3 condition will notify the General Manager, the *Operations Contact* and initiate responses immediately, and

- The *Operations Contact* will notify the *Design Engineer*.

4.2 External Notification Procedures

No external notification is required for Level 1 or 2 conditions. The notification procedure for a Level 3 condition is as follows:

- If the condition presents the threat of dam failure, the notification procedures shown in Large Figure 1 and the evacuation procedures presented in Section 6.0 will be implemented

- Once Level 3 actions are implemented, but in no case longer than 4 hours after the occurrence, the *Operations Contact* will notify the responsible regulatory personnel at the DNR and/or Minnesota Pollution Control Agency (as appropriate to permit coverage and compliance requirements)

- Notification will occur first via telephone, with follow-up E-mail or other written correspondence to document initial and any follow-up telephone conversations

In the event of an emergency situation resulting from actual or potentially imminent dam failure, the *Operations Contact* will also initiate evacuation procedures as described in Section 6.0.

Copies of this HRF Contingency Action Plan and the plant-wide Emergency Action Plan shall be kept in the office of the *Operations Contact*.

5.0 Emergency Mobilization Procedures

All those involved in response, after first having communicated with the appropriate parties, should consider two types of actions as first steps in the response, with respect to the protection of human life and health, environment and property:

- What can be done to prevent the situation from worsening?
- What can be done to reduce the consequences of the impending or actual failure?

Any such action must be presented to the *Operations Contact* who will decide on its implementation in consultation with the *Design Engineer*. Most obvious mobilization requirements associated with Level 2 and Level 3 conditions are detailed in Table 5-1.

Table 5-1 HRF Mobilization Plan for Level 2 or 3 Situations

Component Failure	Level 2 Condition	Level 3 Condition
Failure of a dam (during construction and/or routine operations).	Planning for mobilization of earthmoving equipment, pumps, and pipelines, as well as lowering of the pond level may be necessary, after all communications are carried out.	Immediate mobilization of earthmoving equipment, pumps, pipelines, power generator(s) available at site locations, and lights, will most likely be necessary. Immediate lowering of the pond level will typically be necessary.
Failure of a pump station.	After the repair work is initiated, plan for mobilization of pumping equipment if the timing for repairs would affect the pumping needs.	Immediate mobilization of pumping equipment and, if required, the availability of a power generator may be necessary.
Failure of a pipeline.	Initiate pipe or pipe section replacement.	Initiate chain of communications after initiating pipe or pipe section replacement.
Localized power failure.	Identify systems affected. Prepare for cessation of residue deposition if power outage exceeds 24 hours.	Identify systems affected. Cease residue deposition if power outage exceeds 24 hours.
Regional power failure.	No action required. HRF operations cease in absence of power.	No action required. HRF operations cease in absence of power.

In conjunction with Level 2 and Level 3 Conditions it will be the responsibility of the *Operations Contact* to compile a list of the specific equipment needs, size/type, source (company, name, contact information), and availability to respond to component failure. The list shall be populated prior to the initiation of facility operations and be reviewed and updated on an annual basis thereafter. This is so that a timely response can be made in the event that emergency mobilization is required. For emergency response equipment that does not have local 24-hour 7-day-per-week availability, provisions shall be made for permanent on-site stationing of the equipment. Primary emergency response equipment will typically consist of on-site earthwork equipment, mobile pumping systems and supplementary piping and power supply, and mobile/emergency lighting carts with power supply.

6.0 Emergency Evacuation Procedures

During operations, personnel will be on-site 24 hours a day, 7 days per week. Personnel will therefore be able to review conditions and monitor for changing conditions. Additionally, monitoring instrumentation is planned to be automated by a remote monitoring system, which includes thresholds and automated alarms if monitored values fall outside of threshold values.

In the event of a failure of the HRF dam, operations personnel on-site at the time of the failure are the only people potentially affected. The Dam Break Analysis (Attachment L of Reference (2)) indicates that a dam break is improbable and that there would be inconsequential impact downstream.

There is some chance that a problem may not be identified, recognized, or responded to in a timely manner. Therefore, any early warning signs will none-the-less be treated with the highest level of priority. If evacuation notices are given for operations personnel, it will be understood that the notice is at minimum due to a prudent level of caution and those potentially affected will be instructed to evacuate without delay. There are no residences and businesses projected to have the potential to be impacted by a dam break at the HRF.

Revision History

Date	Version	Description
10/31/2011	1	Initial release
12/14/2012	2	Content updated to support SDEIS and future DNR Dam Safety Permitting
11/7/2014	3	Retitled Contingency Action Plan and updated Table 2-1 and Table 2-1 Required Action details.
07/11/2016	4	Revisions made to submit for permitting and to include Notification Flowchart (Large Figure 1).
05/15/2017	5	Overall update to make content of Hydrometallurgical Residue Facility CAP parallel content of the Flotation Tailings Basin CAP.

References

1. **Poly Met Mining Inc.** NorthMet Project Geotechnical Data Package Vol 1 - Flotation Tailings Basin (v8). May 2017.
2. **Poly Met Mining, Inc.** NorthMet Project Flotation Tailings Management Plan (v7). May 2017.
3. **Barr Engineering Co.** Tailings Basin Geotechnical Instrumentation and Monitoring Plan. Prepared for Poly Met Mining, Inc. May 2017.

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Large Table 1 Visual Warning Signs

Visual Warning Sign and Typical Location	Corresponding Change in Instrumentation Values (depending on location of movement relative to instrumentation)	Potential/Actual Consequences and Notification Procedures	Required Action
Signs of slowly forming erosion at toe and/or exterior face of slope.	No change in instrumentation values expected.	Potential dam instability and/or eventual dam failure if erosion continues. **Level 1 and Level 2 (see Table Notes)**	1) Discuss findings with the Design Engineer. 2) Be prepared to carry out one or more responses such as: a. Resolve source of erosion. b. Repair erosion area. c. Re-establish vegetation (modify design if recommended by Design Engineer). d. Re-inspect area on weekly basis until area is fully restored.
Soft toe condition or increased seepage at downstream slope or dam toe.	Potential increase in piezometric levels.	Internal erosion or slope slumping and eventual dam failure. **Level 1 and Level 2**	1) Discuss the findings with the Design Engineer. 2) Commission a field investigation program if so recommended. 3) Be prepared to carry out one or more responses including: a. Modification of facility pond operating procedures. b. Placement of graded overburden/buttress. c. Installation of drain system. d. Other design modifications if recommended by Design Engineer.
Cracks developing at dam crest or in slope.	Potential increase in piezometric levels. Potential slope deformation at inclinometers. Potential deflection in alignment monuments.	Deformation of dam structure that may lead to eventual dam failure. **Level 2; potential Level 3**	1) Increase frequency of dam walk-overs to daily until the problem is understood and addressed. 2) Seek advice from the Design Engineer. 3) Monitor crack development for increase in size, spacing, etc. 4) Commission a field investigation if so recommended. 5) Be prepared to carry out one or more responses including: a. Modification of pond and/or facility operating procedures. b. Placement of graded overburden/buttress. c. Temporary cessation of operations. d. Reduction in pond elevation (planned or emergency).
High turbidity in dam seepage flow.	Potential increase in piezometric levels.	Internal erosion and eventual dam failure. **Level 2; potential Level 3**	1) Increase frequency of dam walk-overs to daily until the problem is understood and addressed. 2) Seek advice from the Design Engineer. 3) Take water samples for suspended solids determination if recommended by Design Engineer. 4) Commission a field investigation if so recommended. 5) Be prepared to carry out one or more responses including: a. Modification of pond operating procedures. b. Placement of graded overburden/buttress. c. Installation of drain system. d. Reduction in pond elevation (pumping and/or cessation of tailing discharge).
Pond level close to or approaching overflow level; loss of freeboard.	Potential increase in piezometric levels.	Pond water discharge to environment via emergency overflow. **Level 1**	1) Immediately undertake actions to reduce the pond level (increased pumping to WWTS as necessary). 2) Temporarily terminate residue discharge to pond. 3) Consult with Design Engineer to identify other actions as needed.

Visual Warning Sign and Typical Location	Corresponding Change in Instrumentation Values (depending on location of movement relative to instrumentation)	Potential/Actual Consequences and Notification Procedures	Required Action
Any other change in seepage conditions.	Potential increase in piezometric levels.	Dam stability safety margin affected. **Level 2; potential Level 3**	1) Seek advice from the Design Engineer. 2) Reduction in pond elevation (pumping and/or cessation of residue discharge).
Slumping, sliding or bulging of a dam slope or adjacent ground.	Potential increase in piezometric levels. Potential slope deformation at inclinometers. Potential deflection in alignment monuments.	Catastrophic dam breach resulting in release of water or water and liquefied residue. **Level 2; potential Level 3**	As above (blue shaded box) and: 1) Construct stabilizing berm per direction of the Design Engineer. 2) Initiate geotechnical evaluation per direction of the Design Engineer.
Boils observed downstream of dam.	Potential increase in piezometric levels.	An internal erosion failure possible, with potential breach of the dam. **Level 2; potential Level 3**	As above (blue shaded box) and: 1) Place granular filter buttress over the boils, if approved by the Design Engineer. 2) Initiate geotechnical evaluation per direction of the Design Engineer.
Water vortex within the pool and/or sinkhole on the residue beach.	No change in instrumentation values expected.	An internal erosion failure in progress, with potential breach of the dam. **Level 2; potential Level 3**	As above (blue shaded box) and: 1) Check downstream of the dam area for increased and/or turbid seepage discharge. 2) Place granular filter buttress against any such areas, if approved by the Design Engineer. 3) Initiate geotechnical evaluation per direction of the design engineer.
Severe flood/intense rainstorm or rapid snowmelt resulting in extreme pond level.	Potential increase in piezometric levels.	Overtopping of dam and resulting erosion and over-steepening of the downstream slope, leading to dam failure. **Level 3**	1) Initiate chain of communications and ensure safety of people. 2) Stop discharge into the pond. 3) Lower pond by any practical means approved by the Design Engineer.

Notes for Notification Procedures:

Level 1 – Condition that does not warrant emergency response but requires prompt investigation and resolution.

Level 2 – Potential emergency if condition is sustained or allowed to progress; requires response plan.

Level 3 – Imminent or actual failure requiring partial or complete evacuation, emergency communications and response actions.

Large Table 2 Instrumentation Warning Signs

Instrument Type and Typical Location	Instrumentation Warning Sign	Corresponding Visual Changes (dependent on magnitude of movement)	Potential/Actual Consequences and Notification Procedures	Required Action
Piezometer (single or nested) – Located on Perimeter Dams/Slopes (ref. Instrumentation and Monitoring Plan for Piezometer Names and Locations)	Gradual or Sudden Increase in Water Level in One or More Piezometers, Above Threshold Action Levels (ref. Instrumentation and Monitoring Plan for Piezometer Reading Values – Predicted and Threshold)	1) Soft toe condition or increased seepage at downstream slope or dam toe. 2) Elevated pond level in facility. 3) Increased turbidity in seepage flows. 4) Boils observed downstream of dam.	1) Excessive seepage through dam and potential for dam breach. 2) An internal erosion failure possible, with potential breach of the dam. 3) Catastrophic dam breach resulting in release of water or water and liquefied residue. **Level 1, 2 or 3 (situation dependent)**	1) Check the reading again; confirm instrumentation functionality. 2) Intensify reading frequency to daily. 3) Seek advice from the Design Engineer. 4) Commission a field investigation if so recommended. 5) Be prepared to carry out one or more responses including: a. Check downstream of the dam area for increased and/or turbid seepage discharge. b. Place granular filter buttress against any such areas, if approved by the Design Engineer. c. Initiate geotechnical evaluation per direction of the design engineer. d. Modify pond and/or facility operating procedures. e. Temporary cease operations/stop discharge into the pond. f. Lower pond by any practical means approved by the Design Engineer.
Inclinometer – Located on Perimeter Dams/Slopes (ref. Instrumentation and Monitoring Plan for Inclinometer Names and Locations)	Gradual or Sudden Movement in Horizontal Direction in One or More Inclinometers (ref. Instrumentation and Monitoring Plan for Inclinometer Reading Values – Predicted and Threshold)	1) Cracks developing at dam crest or in slope. 2) Slumping, sliding or bulging of a dam slope or adjacent ground.	1) Deformation of dam structure that may lead to eventual dam failure. 2) Catastrophic dam breach resulting in release of water or water and liquefied residue. **Level 1, 2 or 3 (situation dependent)**	As above (blue shaded box).
Survey Monument – Located on Crest of Perimeter Dams	Gradual or Sudden Movement in Horizontal and/or Vertical Direction in One or More Survey Monuments	1) Cracks developing at dam crest or in slope. 2) Slumping, sliding or bulging of a dam slope or adjacent ground.	1) Deformation of dam structure that may lead to eventual dam failure. 2) Catastrophic dam breach resulting in release of water or water and liquefied residue. **Level 1, 2 or 3 (situation dependent)**	As above (blue shaded box).

Notes for Notification Procedures:

Level 1 – Condition that does not warrant emergency response but requires prompt investigation and resolution.

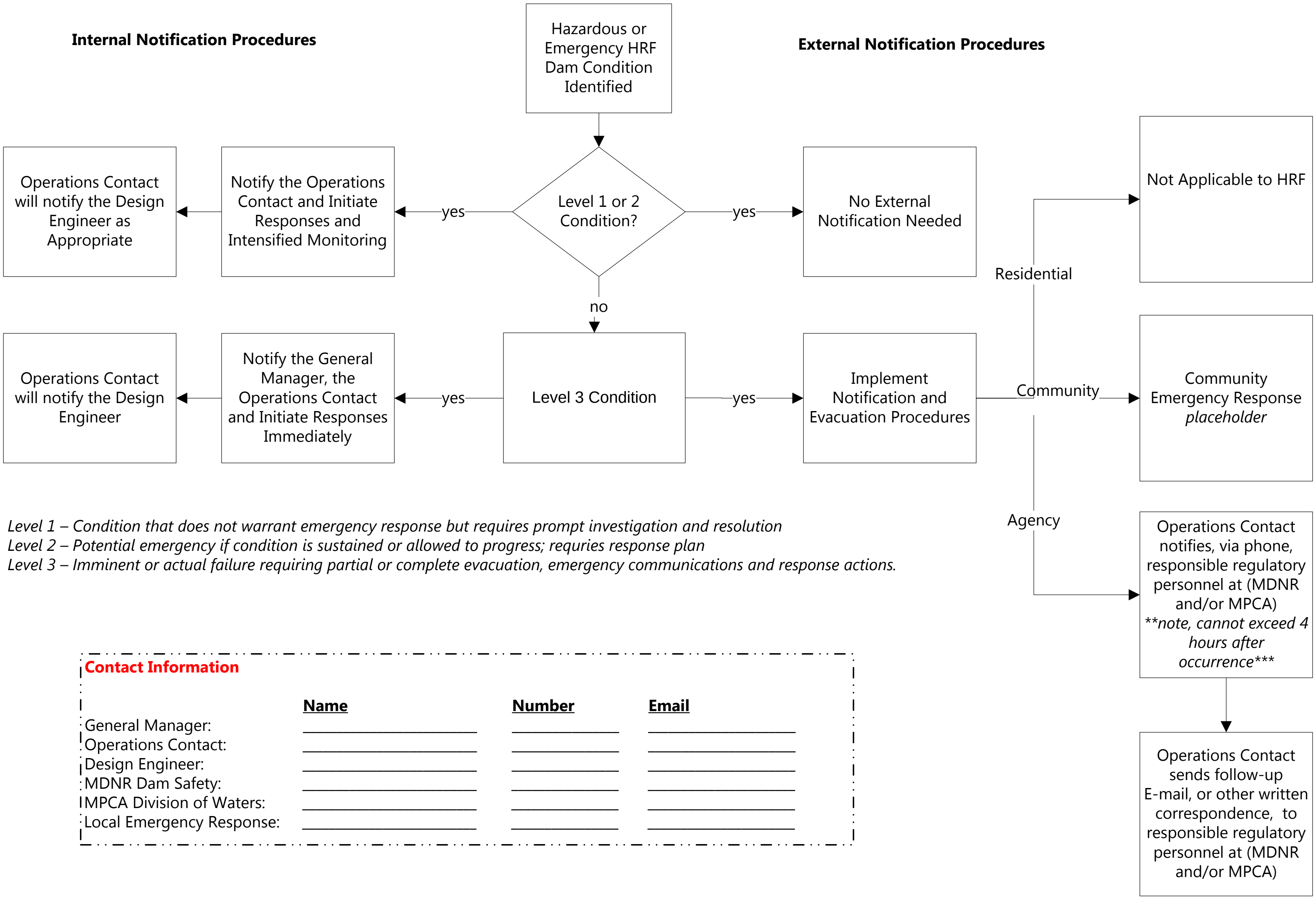
Level 2 – Potential emergency if condition is sustained or allowed to progress; requires response plan.

Level 3 – Imminent or actual failure requiring partial or complete evacuation, emergency communications and response actions.

Large Figures

Internal Notification Procedures

External Notification Procedures



Level 1 – Condition that does not warrant emergency response but requires prompt investigation and resolution
Level 2 – Potential emergency if condition is sustained or allowed to progress; requries response plan
Level 3 – Imminent or actual failure requiring partial or complete evacuation, emergency communications and response actions.

Contact Information

	Name	**Number**	**Email**
General Manager:	____________________	____________	_________________
Operations Contact:	____________________	____________	_________________
Design Engineer:	____________________	____________	_________________
MDNR Dam Safety:	____________________	____________	_________________
MPCA Division of Waters:	____________________	____________	_________________
Local Emergency Response:	____________________	____________	_________________

Large Figure 1 Notification Procedures for an Emergency Involving Threat of HRF Dam Failure

Attachment L

HRF Dam Break Analysis

resourceful. naturally.
engineering and environmental consultants
BARR

Technical Memorandum

To: Poly Met Mining, Inc.
From: Tom Radue, Barr Engineering Co.
Subject: HRF Dam Break Analysis
Date: July 11, 2016
Project: 23690862

Barr Engineering Co. completed a dam break analysis for the Hydrometallurgical Residue Facility (HRF) dams to fulfill dam safety permitting requirements. The HRF dams have been designed to achieve necessary factors of safety (Geotechnical Data Package – Volume II, (Reference (1)), so a dam break is unlikely.

The HRF will be located along the boundary between the Embarrass River watershed and the Partridge River watershed in St. Louis County. The HRF will be three-sided:

- The northern and southwestern dams will be in the Unnamed (Mud Lake) Creek subwatershed of the Embarrass River watershed. The Unnamed (Mud Lake) Creek subwatershed is very sparsely populated. Potential flow paths from the HRF toward Unnamed (Mud Lake) Creek primarily would cross wetland areas interspersed with wooded uplands.
- The southeastern dam will be in the Second Creek subwatershed of the Partridge River watershed. Potential flow paths from the HRF toward Second Creek would be limited by railroad embankments to industrial portions of the PolyMet Plant Site.

Dam break analysis consists of identification of feasible events or a series of events at the HRF that, if not identified and resolved in a timely manner and/or if left unresolved once discovered, could lead to a failure of an HRF dam and the HRF liner system and subsequent release of contained process water or process water and Residue into the environment. For dams associated with liquid containment, such as the HRF dams, failure can be triggered by singular events, or more often, by a series of events. Examples of events that could trigger failure include but are not limited to the following:

- prolonged or massive overtopping of the dam due to uncontrolled discharge into the facility during operations or in combination with inflow from a historic rain event of large magnitude and duration
- uncontrolled or unmitigated seepage through the dam along with internal erosion of the structure of the dam (i.e., migration of soil particles from within the earthen structure of the dam out through the exterior dam face due to particle transport via seepage)
- regional or localized seismic events of sufficient magnitude, acceleration, and duration to damage the foundation or structure of the dam, typically resulting in cracking of the dam or deformation and overtopping
- over–steepening of the dam slopes, resulting in slope instability and failure

- failure of the facility liner system, resulting in uncontrolled seepage and either internal erosion of the dam and/or external sloughing of the dam slope due to saturation of the earthen fill, progressively transitioning to a large scale slope failure
- failure of a nearby piping system resulting in erosion of the body of the dam and potential undermining and failure of the liner system

For a facility with the design characteristics of the HRF it is typical that a chain of events would be required in order to initiate a dam break. Two examples are presented in Table 1.

Table 1 HRF Dam Break Failure Chain Examples

HRF Dam Break	Failure Chain Example 1	Failure Chain Example 2
Event Sequence	1) Facility is operating at the maximum design water elevation	1) A large tear develops through all layers of the double liner system
	2) Return water pipeline becomes inoperable	2) Pond water leaks through the tear and percolates into the HRF dam
	3) Residue transport pipeline discharge to HRF continues	3) The HRF dam structural fill becomes saturated
	4) Historic rain event occurs at the HRF	4) Leakage progresses to the toe of slope and exits with sufficient velocity to cause internal erosion
Failure Mode	Overtopping occurs with overtopping flow concentrated at a single location along the dam crest, eroding a channel through the exterior face of the dam, with erosion progressing back to undercut the liner	Internal erosion evolves to progressive erosion of the dam slope, initiating slope failure and liner failure

Note: The HRF Dam Break failure chains noted above are hypothetical.

Failure chain Example 1 consists of overtopping of the dam; an operations failure concurrent with a historic rain event. It assumes that the return water pipeline is inoperable for an extended period of time and that HRF operations personnel ignore this and the rising water in the facility. This could be accompanied by a significant rainfall that further increases water level and initiates an overtopping event. Such a failure scenario is improbable for the following reasons:

- The facility design and operation accommodates the probable maximum precipitation. Per Hydrometeorological Report number 51 (HMR 51), Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, the 72-hour Probable Maximum Precipitation (PMP) event at the HRF is on the order of 32 inches. The freeboard to be maintained during HRF operations will be a minimum of 36 inches from the top of HRF liner system, with additional freeboard provided by the crest of dam liner system cover materials.

The failure would require prolonged mismanagement on the part of multiple facility operations personnel. This is improbable for the following reasons:

  - Daily HRF inspections and water level monitoring would identify a notable change in the rate of water level rise in the HRF.
  - The water returned to the Hydrometallurgical Plant is put back into the process to facilitate ongoing operations and to minimize water consumption. A long-term shutdown of the water return line would impact plant operations.
- The water is returned to the process to recover the metals in solution and increase metal recovery. A long-term shutdown of the water return line would impact the metal recovery.
- Under routine operating conditions but absent return water, several months would be required to discharge sufficient water into the HRF to initiate overtopping. At the projected HRF inflow rate of 218 gallons/minute, approximately 55 days would be required to raise the pond level a single foot; sufficient time to identify and resolve any operations issues.

Failure chain Example 2 consists of development of a large tear through all layers of the double liner system. For the HRF as proposed, with its relatively flat embankment slopes and intermediate benches to prevent development of strain in the liner system, the most probable initiation point of a tear would be at the base of the facility. This would be the result of large scale localized differential settlement of the HRF foundation materials. Settlement of sufficiently large scale would be required to induce strain in the liner system in excess of the liner system's strain tolerance. Another potential source of tears in the liner system would be from construction activities during initial liner construction. However, both liner tear scenarios are improbable and hence the overall failure scenario is improbable for the following reasons:

- The HRF foundation materials will be pre-loaded to induce settlement and to eliminate the potential for future large scale differential settlement, thereby minimizing strain in the liner system.
- The Linear Low Density Polyethylene (LLDPE) Geomembrane and the Geosynthetic Clay Liner (GCL) hydraulic barriers of the HRF liner system are selected for strain tolerance well in excess of the strain estimated to occur after pre-loading.
- The HRF embankments will be built using compacted structural fill that will not be subject to large scale differential settlement.
- Leak location surveys will be implemented on each geomembrane layer of the HRF liner system following completion of primary construction activities but prior to placing the HRF into service. Leak location surveys are effective at identifying holes in geomembrane liner systems.
- Larger holes and tears are readily detected by visual review of liner quality without the need for leak location surveys.
- Seam strength and integrity testing will be conducted on all seams of geomembrane panels and at geomembrane patch locations during construction.
- The volume of water required to fill all the pores in the embankment is large (millions of gallons) and its loss from the system should be noticed by operations.

- The material proposed to construct the HRF embankments is course, angular material not readily susceptible to piping failures/internal erosion.
- Seepage of significant quantity would be detected in the HRF leakage collection system and/or at the toe of slope of the facility, in the facility groundwater monitoring wells, and/or in the piezometers used for embankment performance monitoring. This data would serve as an early warning that leakage is occurring out of the HRF and mitigative measures could be implemented.

The failure scenarios described previously are two scenarios that, while theoretically possible, have a low probability of occurrence for the reasons summarized above. Further, the HRF dams will be constructed using compacted structural fill overlain by a multi-layer geosynthetic liner system. This type of liner system, when constructed by a qualified contractor using industry-standard quality control techniques, is highly effective at minimizing leakage. Finally, freeboard to be maintained within the HRF will accommodate addition of water and Residue over a period of months prior the threat of overtopping.

Additional hydrologic and hydraulic modeling to detail the extent of inundation from an HRF dam break is not warranted because no plausible HRF dam failure scenarios have been identified.

References

1. **Poly Met Mining Inc.** NorthMet Project Geotechnical Data Package Vol 1 - Flotation Tailings Basin (v8). May 2017.